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Analyses of Loss-of-Coolant Accidents for the HANARO Fuel Test Loop Based on the Evaluation Method

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1. Introduction

A fuel test loop is under development at the HANARO (High-flux Advanced Neutron Application Reactor). It is an experimental facility for fuel irradiation tests. The fuel test loop has been designed to be able to provide experimental conditions similar to the normal operation pressure and temperature of commercial nuclear power plants.

Emergency cooling water system has been designed to mitigate the postulated loss-of-coolant accidents of the fuel test loop. The performance of the emergency cooling water system has been predicted by using MARS code. This paper deals with the analyses of the postulated loss-of-coolant accidents based on the evaluation models as described in the KINS/GT-N007-1 [1].

2. Analysis Methods

2.1 Modeling of the Fuel Test Loop

All the equipment such as the pump, the heat exchanger, the heater, the tanks, and the valves for the main cooling water system and the emergency cooling water system were modeled with the MARS code.

A part of the in-pile test section where the test fuels were placed was modeled with a pipe with 14 sub-volumes. The test fuels were modeled as a heat structure component with 14 axial nodes and 11 radial meshes. Three fuel pins considered in the present analyses are a PWR fuel type. The length and diameter of the fuel pins are 700mm and 9.5mm respectively. The maximum linear heat rate is 45.68kW/m. The inner and outer vessels, flow divider, and fuel transport legs of the in-pile test section were also modeled as heat structure components because of the gamma heat generation. The normal design-operation conditions of the fuel test loop are assumed as the initial conditions for the loss-of-coolant accidents.

The fuel test loop has two safety-related control systems. One is the reactor (HANARO) protection system, which provides a fast scram from the trip parameters such as a high flow, low flow, high pressure, low pressure and a high temperature of the main cooling water. The other is the emergency shutdown system of the fuel test loop, which isolates the in-pile test section from the out-pile system and injects emergency cooling water into the in-pile test section from the trip parameters such as a high flow, low-low flow, low-low pressure, and a high-high temperature of the main cooling water. The safety-related control systems were implemented in the MARS modeling [2].

2.2 Evaluation Models

The MARS (Multi-dimensional Analysis of Reactor Safety) code, which was developed and verified by KAERI, is a realistic system transient analysis code for water-cooled reactors. This code is a unified version of the 1 D reactor system analysis code, RELAP5/MOD3, and the 3D reactor vessel analysis code, COBRA-TF. Although the MARS code has been basically developed based on a realistic model, a few evaluation models are also implemented [3, 4, 5, 6].

In this work the analyses used the Moody model for predicting the discharge rates from broken pipes and the Baker-Just model for predicting the water-metal reactions of fuel claddings [7]. These are the evaluation models that shall be used for the performance analyses of the emergency cooling water system for the loss-of-coolant accidents.

KINS/GT-N007-1 states that conservative heat transfer coefficients shall be used to predict the peak cladding temperatures. However the realistic correlations of the heat transfer coefficients are implemented in the MARS code. Therefore multipliers for the correlations of the heat transfer coefficients are used so that the peak cladding temperatures are predicted conservatively.

2.3 Modeling of Breaks

In the analyses of the postulated loss-of-coolant accidents, a spectrum of possible pipe breaks shall be considered. In this work the analyses included instantaneous double-ended guillotine breaks ranging in cross-sectional area up to and including that of the largest pipe in the main cooling water system. The analyses also included the effects of longitudinal splits in the largest pipes, with a split area equal to the cross-sectional area of a pipe. Four discharge coefficients were investigated for the analyses of double-ended guillotine breaks including the range from 0.6 to 1.0.

3. Results

The analyses of the loss-of-coolant accidents due to double-ended guillotine breaks indicate that the maximum peak cladding temperature is predicted for the cold-leg break in the Room 1 as shown in Figure 1. All the equipment of the main cooling water system and the emergency cooling water system are located in Room 1. The maximum peak cladding temperature is approximately 1234K (961°C) and less than the design limit of fuel cladding temperature for PWRs. After the peak cladding temperatures rapidly reach the maximum values for each discharge coefficient, they decrease monotonically.

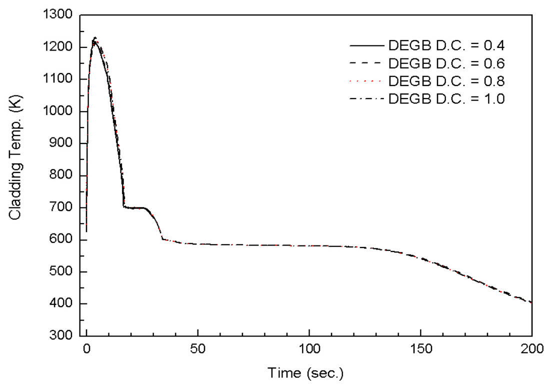

Fig. 1. PCT for the Double-Ended Guillotine Breaks of Pipes

In case of the longitudinal splits of the pipes the maximum peak cladding temperature is found for the cold-leg break in the HANARO pool as shown in Figure 2. The peak cladding temperatures are significantly dependent on the break areas of the pipe. The critical break area that the maximum peak cladding temperature is calculated is the 14 percents of the pipe's cross-sectional area.

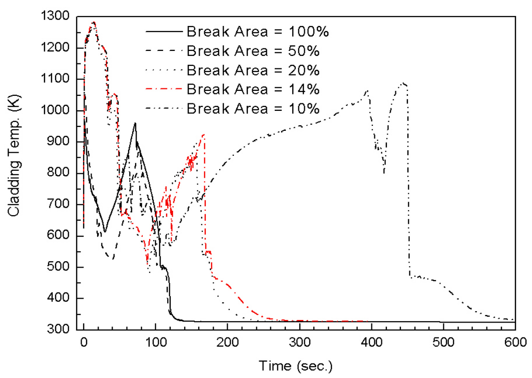

Fig. 2. PCT for the Longitudinal Splits of Pipes

The maximum peak cladding temperature is approximately 1286K (1013°C) and less than the design limit of fuel cladding temperature for PWRs. No ruptures of the fuel cladding are predicted. The hydrogen generation and the cladding oxidation are negligible when compared with the design limits of PWR fuels.

4. Conclusion

The analyses of the postulated loss-of-coolant accidents due to double-ended guillotine breaks and longitudinal splits of pipes have been carried out based on the evaluation method as described in the KINS/GT-N007-1. As a result of the analyses it is ensured that the emergency cooling water system of the HANARO fuel test loop has an appropriate cooling performance for the fuels investigated in the present study to mitigate the loss-of-coolant accidents at an early stage.

Acknowledgements

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