Safety Analyses on a Safety Valve Stuck-Open for the HANARO fuel test loop

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1. Introduction

A fuel test loop (FTL) for irradiation tests is under development at the HANARO. The construction of the FTL was completed at the beginning of 2007 and integral performance tests have been carried out. The safety of the FTL including the PWR test fuels which will be installed should be verified for design basis accidents and anticipated operational occurrences (AOOs).

This paper deals with the thermal-hydraulic transient analyses and the prediction for a departure from a nucleate boiling ratio (DNBR) during a safety valve stuck-open for the HANARO fuel test loop, which is one of the AOOs.

2. Analysis Methods

2.1 Design Features of the Fuel Test Loop

The FTL consists of an in-pile test section (IPS) and an out-pile system (OPS). The IPS is located at the IR1 hole of the HANARO core and the test fuels are installed in the IPS. The OPS is categorized into the main cooling water system (MCWS), the emergency cooling water system (ECWS), and so on. The MCWS controls the pressure, temperature, flow rate and chemical properties of the main cooling water during a normal operation. The ECWS supplies emergency cooling water to the IPS during an emergency.

The safety control system of the FTL is classified into the HANARO protection system and the FTL protection system. The HANARO protection system provides a fast scram from the high flow, low flow, high pressure, low pressure and high temperature set-points of the main cooling water. The FTL protection system isolates the IPS from the OPS and injects the emergency cooling water into the IPS from the high flow, low-low flow, low-low pressure, and high-high temperature set-points of the main cooling water.

2.2 Thermal-Hydraulic Modeling

Multi-dimensional Analysis of Reactor Safety (MARS) computer code was used for the thermal-hydraulic transient analyses and the DNBR prediction during the AOOs [1-3].

The MCWS including the IPS and the ECWS were modeled. The other systems connected to the MCWS are not included in the MARS modeling.

The test fuel zone was modeled with a pipe with 14 sub-volumes. The IPS vessel, flow divider, and fuel transport leg were modeled as heat structure components because of the generated gamma heat due to a neutron irradiation. The gamma heat was modeled as a heat source. The test fuels were modeled as heat structure components with 14 axial nodes and 11 radial meshes respectively. Figure 1 shows the linear heat rates used for the thermal-hydraulic analyses for the AOOs. The maximum linear heat rate studied in this work is 369.6W/cm. The cladding diameters of the test fuels are 9.5mm respectively and the pitch is 13.8mm.

105% of the normal operation power and a normal coolant temperature plus 6℃ were used for all the analyses.

3. Results

Anticipated operational occurrences considered as the FTL design bases are as follows:

- inadvertent closure of the loop isolation valves,
- safety valve stuck-open,
- loss of main cooling water flow,
- loss of class IV power, and
- loss of main cooler feed water.

The present study only deals with the safety valve stuck-open. This anticipated operational occurrence is assumed to occur due to some mechanical problems of the safety valves.

The critical heat flux (CHF) correlations of the MARS code are not adequate to predict the DNBR for the test fuels of the FTL because of geometric differences. It is well known that a CHF is highly dependent on the geometric features of a boiling surface. Therefore a series of CHF experiment was performed at the same geometry of the test fuels and the flow path of the IPS. As a result of the experiment a correction function for the 1986 AECL Look-UP Table was developed [4]. The newly developed CHF was used for the DNBR prediction for the AOO.

When a safety valve is opened and then not closed due to some mechanical problems, the HANARO is tripped by a low pressure signal and the FTL protection system is actuated by a low-low pressure signal. The actuation of the FTL protection system means that the IPS is isolated by the closure of loop isolation valves and that the emergency cooling water is injected into the IPS, in which test fuels are placed.

Figure 2 shows the DNBRs for the safety valve stuck-open. The legends in Figure 2 indicate the lower and upper limits of the analysis range for the flow rate and pressure. The DNBRs decrease to a minimum level and then increase. The decrease of the DNBRs is because of the decrease of the pressure and flow rate. The increase of the DNBRs after a minimum value is because of an increase of the flow rate due to an emergency cooling water injection and because of a decrease of fission power due to the HANARO trip. The minimum DNBR is predicted as 2.53, which meets the design limit, 1.39, of the DNBR for the FTL.

It is indicated that the safety control system of the FTL functions adequately and that the emergency cooling water system has sufficient cooling capabilities for the AOO during the early cooling stages. The MARS also predicts that the maximum peak pressure of the IPS is lower than the 110% of the design pressure.

4. Summary

Thermal-hydraulic transient analyses have been carried out for a safety valve stuck-open for the HANARO fuel test loop. The DNBRs have also been calculated.

From the present analyses of the test fuels, the results are summarized as follows:

1) The HANARO fuel test loop has sufficient emergency cooling capabilities,
2) The minimum DNBR is greater than the design limit DNBR,
3) The maximum peak pressure of the IPS is lower than the 110% of the design pressure.

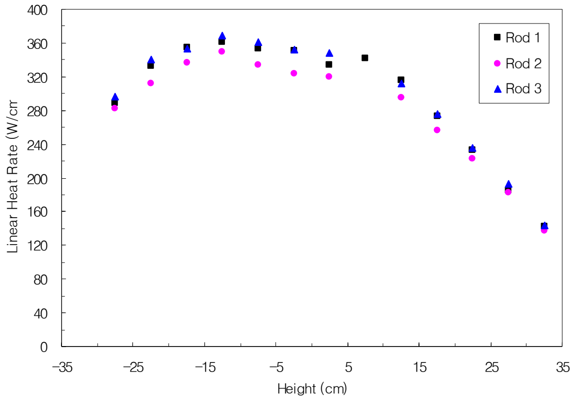

Fig.1. Linear heat rates for the PWR test fuels.

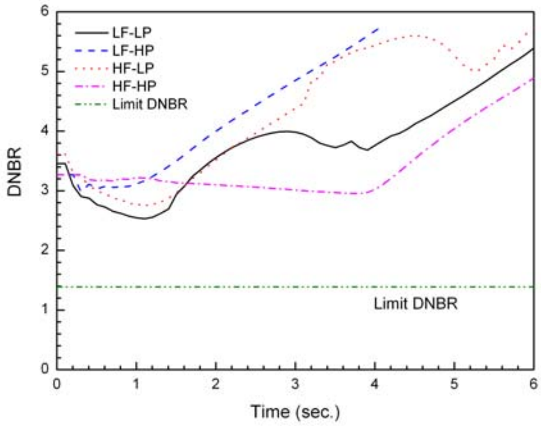

Fig.2. DNBRs for a Safety Valve Stuck-Open.

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