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GAMMA+ code validation for EBR-II SHRT-17

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1. Introduction

The Experimental Breeder Reactor II (EBR-II) plant is located in Idaho and was designed and operated by Argonne National Laboratory (ANL) for the U.S. Department of Energy [1]. The Shutdown Heat Removal Test (SHRT) program was carried out in EBR-II between 1984 and 1986. The objectives of this program were to support U.S. LMR plant design and provide test data for validation of computer codes for design. This experiment demonstrates passive reactor shutdown and decay heat removal in response to protected transients. Described in this paper is GAMMA+ validation results with the EBR-II SHRT-17 experimental data.

2. Experiment Description

EBR-II consists of a reactor, primary heat transfer system, and intermediate heat transfer system. The primary tank in EBR-II is illustrated in Fig. 1 below. Two primary pumps take sodium from this pool and provide sodium to the two inlet plena for the core. Hot sodium exits the subassemblies into a common upper plenum where it mixes before passing through the outlet pipe into the IHX. The pipe feeding sodium to the IHX is referred to as the 'Z-pipe' [2].

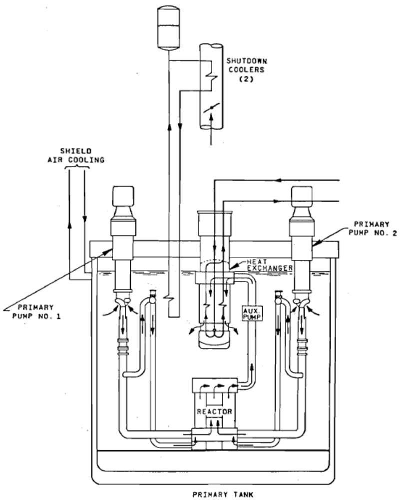

Fig. 1. EBR-Ⅱ Primary Tank Sodium Flow Paths

A full power loss-of-flow test in the SHRT series demonstrates the effectiveness of natural circulation in the EBR-Ⅱ reactor. To initiate the SHRT-17 test, both primary coolant pumps and the intermediate-loop pump are tripped to simulate a protected loss-of-flow accident beginning from full power and flow conditions. The reduction in coolant flow rate causes reactor temperatures to rise temporarily to high, but acceptable levels as the reactor safely cooled itself down by natural circulation [3].

3. Computer Code Analysis

The GAMMA+ code is a system code to predict thermo-hydraulic and chemical reaction phenomena expected to occur during thermo-fluid transients. The GAMMA+ version has been further updated from the original GAMMA code, by implementing additional features for applying to the VHTR design and safety analyses.

Fig. 3 shows the nodalization of the EBR-II for GAMMA+. The primary sodium tank pool and both of primary pumps are modeled from the fluid block (FB) 300 to 360. The core part is simulated with 10 sub-channels, including driver fuel, partial driver fuel, control rods and safety rods, internal reflector, hot driver, K-Steel, XX-09, XX-10, uranium blanket, and external reflector, and sub-channels are modeled from FB 370 to 450. Z-pipe connecting the IHX shell side inlet and the core upper plenum outlet is modeled with FB 460. The inlet to the IHX tube side used a flow boundary condition, and the outlet is modeled as a pressure boundary condition.

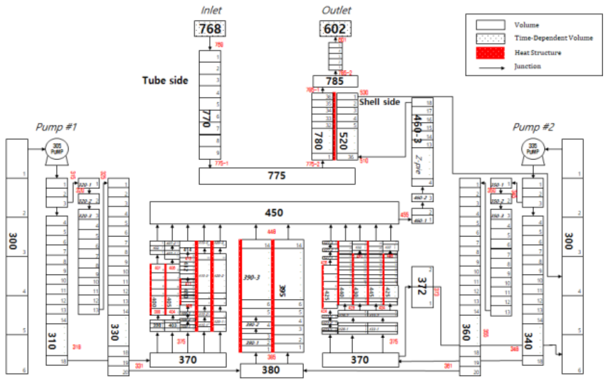

Fig. 3. Nodalization of the EBR-II in GAMMA+ analysis

4. Computer Code Analysis

In order to perform GAMMA+ code validation, the analysis result of the GAMMA+ code and the EBR-II SHRT-17 experiment result has been compared. For the SHRT transients, two instrumented subassemblies were inserted into core positions normally reserved for control rods. These two subassemblies were identified as XX09 and XX10 and were specifically designed with a variety of instrumentation to provide data for benchmark validation purposes. XX09 was a fueled subassembly that contained 59 fuel pins; in over one third of these pins, the standard spacer wires were replaced with spacer wire thermocouples that collectively recorded temperatures at four axial locations. XX10 was a non-fueled subassembly consisting of 18 pins, each wrapped with spacer wire thermocouples that collectively measured temperatures at four axial locations [4].

Simulation results for temperatures in XX09 and XX09 are illustrated in Fig. 4 and 5, respectively. Subchannel modelling was not used, so no radial temperature variation was calculated. In XX-09 OTC temperature comparison (Fig 4), GAMMA+ predicts sharper peak (813K) than the experiment, however, the sodium saturation temperature is around 1088K, so there is more than a 200K margin to boiling for the coolant. Some bends can be observed around the 40 and 200 seconds but it is hard to quantify thermal impact during this transition. In XX-10 OTC temperature comparison (Fig 4), which is different location, GAMMA+ shows almost the same peak temperature (765K) with the experiment and it is naturally cooled down. During the earlier part of the transient, more than 20K temperature deviation can be noticed, however, it seems temperature fluctuation due to balancing mass flow rate among neighbor channels. It is way below the temperature peak. Therefore, it is hard to trigger safety concerns at this moment. In general, the simulation results demonstrate well the inherent safety characteristics of the EBR-II reactor during this protected loss of flow transient.

5. Conclusions

In order to perform GAMMA+ code verification, the analysis result of the GAMMA+ code and the EBR-II SHRT-17 experiment result are compared. Key parameter of this verification is temperature at each thermocouple and its transient shows reasonably good agreement with each other. Other parameters, such as mass flow rate and various temperature points of the system will be comprehensively covered in dedicated analysis report.

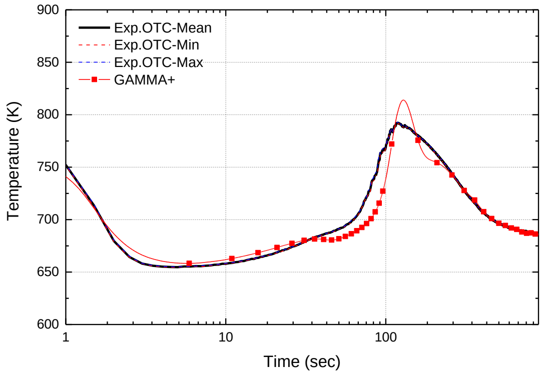

Fig. 4. XX-09 OTC Temperature comparison

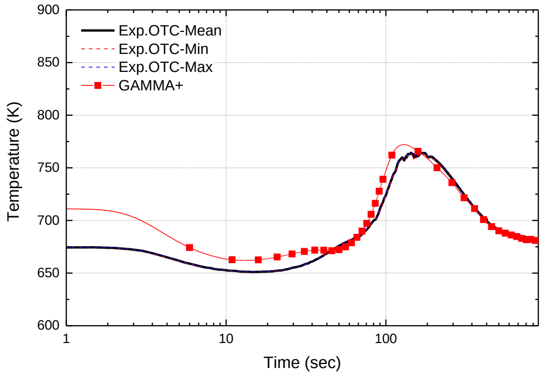

Fig. 5. XX-10 OTC Temperature comparison

6. Acknowledgement

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