Preparation of MARS-LMR Best-Estimate Input for Evaluating the Applicability of Safety Analysis Methodology based on BEPU Technique

Doo-hyuk Kang [a*], Seok-ju Kang [a], Jae-seung Suh[a], Sung-won Bae [b]
[a]*System Engineering & Technology Co., Ltd., Room 302, 105, Sinildong-ro, Daedeok-gu, Daejeon, Korea*
[b]*Korea Atomic Energy Research Institute, 989-111, Daedeok-daero, Yuseong-gu, Daejeon, Korea*
[*]*Corresponding author: dhkang@s2ntech.com*

1. Introduction

The DEC(Design Extended Condition) accidents of the SFR(Sodium-cooled Fast Reactor) have not been validated sufficiently for the best-estimate safety analysis in comparison to the pressurized water reactor. Also, the parameters dominating the uncertainty quantification were different with the parameters of the PWR. There is a need to re-establish the methodology at the level of PIRT development for the applicability of an analysis of the uncertainty quantification. Besides, we need to develop the input deck for the MARS-LMR best-estimate safety analysis in order to assess the applicability of safety analysis methodology based on BEPU technique and show the completion of the input deck throughout the results of preliminary computation.

The objective of this study is to develop the MARS-LMR best-estimate input of the EBR-II nuclear power plant for evaluating the applicability of safety analysis methodology based on BEPU technique for DEC. This code is developed to simulate the sodium thermal-hydraulic and neutronic behavior such as reactivity feedbacks for liquid metal cooled fast reactor [1]. A preliminary analysis of the SHRT-45R test was performed using the MARS-LMR code to understand the general behavior of EBR-II SHRT-45R test.

2. Methods and Results

2.1 Introduction of EBR-II

Argonne National Laboratory's (ANL) Experimental Breeder Reactor II (EBR-II) was a liquid metal reactor (LMR) with a sodium-bonded metallic fuel core that contributed very favorably to the reactor's negative reactivity feedback. On June 20, 1984, a severe loss-of flow test in the Shutdown Heat Removal Test (SHRT) series demonstrated the effectiveness of natural circulation in the EBR-II reactor. This test was SHRT-17 and at the beginning of the test the primary pumps were tripped at the same time as a full control rod insertion. On April 3, 1986, a severe unprotected loss-of-flow test demonstrated the effectiveness of passive feedback in the EBR-II reactor. This test, SHRT-45R, was very similar to SHRT-17 except that during the test the plant protection system (PPS) was disabled to prevent it from initiating a control rod scram. Both tests began from full reactor power and were initiated when both primary coolant pumps and the intermediate loop pump were simultaneously tripped to simulate a loss-of-flow accident (LOF). In the case of SHRT-45R, the loss of forced coolant flow caused reactor temperatures to rise temporarily to a high, but acceptable, level as the reactor safely shut itself down due to total negative reactivity feedback. The SHRT-45R test demonstrated that an EBR-II type Sodium-Cooled Fast Reactor (SFR) plant could be designed such that natural phenomena (e.g., thermal expansion of reactor materials), in addition to electromechanical systems (e.g., control rod drives), are effective in protecting the reactor against the potentially adverse consequences of unprotected accidents [2].

2.2 Plant Overview

The primary tank in EBR-II is illustrated in Figure 1 below. All major primary system components were submerged in the primary tank, which contained approximately 340 m^3 of liquid sodium at 371°C. Two primary pumps drew sodium from this pool and provided sodium to the two inlet plena for the core.

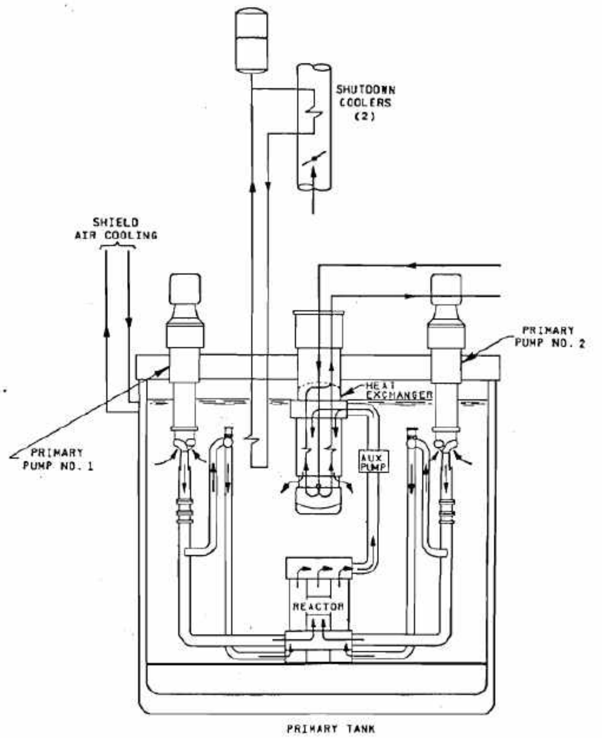

Fig. 1. EBR-II Primary Tank Sodium Flow Paths [2]

Subassemblies in the inner core and extended core regions received sodium from the high-pressure inlet plenum, accounting for approximately 85% of the total primary flow. The blanket and reflector subassemblies in the outer blanket region received sodium from the low-pressure inlet plenum.

Hot sodium exited the subassemblies into a common upper plenum where it mixed before passing through the outlet pipe into the intermediate heat exchanger (IHX). The pipe feeding sodium to the IHX is referred to as the Z-pipe. Sodium then exited the IHX back into the primary sodium tank before entering the primary sodium pumps again.

The fuel assembly of the core region in the reactor vessel accommodated 637 hexagonal subassemblies. The subassemblies were segregated into three regions: core, inner blanket (IB) and outer blanket (OB). Figure 2 illustrates the subassembly arrangement of the reactor and the subassembly identification convention.

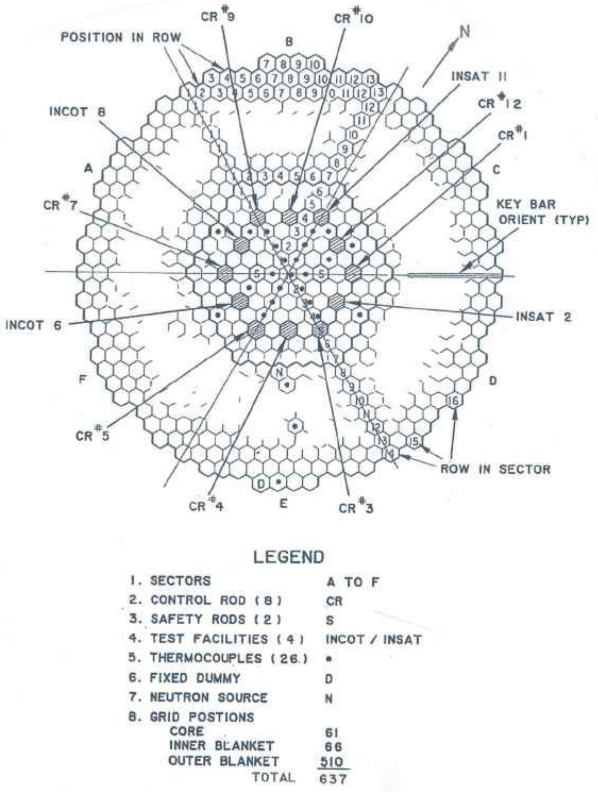

Fig. 2. EBR-II Core Layout [2]

2.3 Initial Conditions of EBR-II SHRT-45R

Table 1 summarizes the initial conditions and transient initiators for the SHRT-45R test.

Table 1. SHRT-45R Test Description

Initial Power	60.0 MW
Initial Primary Coolant Flow	481.02 kg/s
Initial Intermediate Coolant Flow	303.47 kg/s
Initial Core Inlet Temperature	343.78 ℃
Primary and Intermediate Pump Coastdown Conditions	-Power removed -Flow coastdown controlled -Approximately 95 seconds before pump stop
Control Rods	Insertion disabled
Auxiliary EM Pump Conditions	On battery

2.4 Preparation of MARS-LMR Input for EBR-II

The input deck of the SHRT-45R test of EBR-II for MARS-LMR best-estimate code for evaluating the applicability of safety analysis methodology based on BEPU technique for DEC has been prepared using the steady-state MARS-LMR input deck provided by KAERI.

Figure 3 shows the MARS-LMR nodalization scheme for the EBR-II plant, which includes all of the primary systems, fuel assemblies, two primary pumps and intermediate heat exchanger [2].

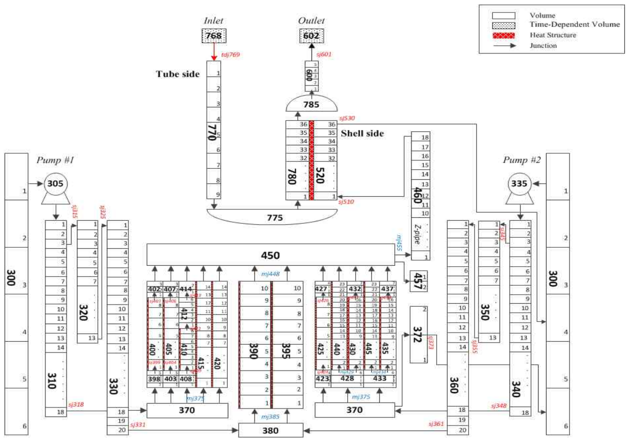

Fig. 3. MARS-LMR nodalization for the EBR-II

Table 2 summarizes the power and the flow rate of the sodium in core subassemblies for the SHRT-45R test.

Position	Power (MWth)	Sodium flow (kg/s)
Outer reflector	0.855	11.56
Uranium blanket	4.529	65.51
Driver subassemblies	44.321	299.34
Partial driver subassemblies	4.560	42.61
Control and safety subassemblies	4.352	34.76
K-type steel subassemblies.	0.088	4.11
Inner reflector	0.293	5.77

Hot driver subassemblies	0.588	3.39
XX-09	0.396	2.57
XX-10	0.017	0.36
Total	60.0	469.98

3. Conclusions

The MARS-LMR best-estimate input of the EBR-II was prepared for evaluating the applicability of safety analysis methodology based on BEPU technique for DEC under support from the KAERI. Also, a preliminary analysis of the SHRT-45R test was performed using the MARS-LMR code to understand the general behavior of EBR-II SHRT-45R test.

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