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Comparison of auxiliary Feedwater and EDRS Operation during Natural Circulation of MRX

Jae Hak Kim and Goon Cherl Park

Seoul National University
Department of Nuclear Engineering
San 56-1 Shillim-dong, Kwanak-gu
Seoul, Korea 151-742

Abstract

The MRX is an integral type ship reactor with 100 MWt power, which is designed by Japan Atomic Energy Research Institute. It is characterized by integral type PWR, in-vessel type control rod drive mechanism, water-filled containment vessel and passive decay heat removal system. Marine reactor should have high passive safety. Therefore, in this study, we simulated the loss of flow accident to verify the passive decay heat removal by natural circulation using RETRAN-03 code. auxiliary feed water systems are used for decay heat removal mechanism and results are compared with the loss of flow accident analysis using emergency decay heat removal system by JAERI. Results are very similar to case of EDRS 1 loop operation in JAERI analysis and decay heat is successfully removed by natural circulation.

I. Introduction

The MRX is an integral type ship reactor with 100 MWt power, which is designed by Japan Atomic Energy Research Institute. It is characterized by integral type PWR, in-vessel type control rod drive mechanism, water-filled containment vessel and passive decay heat removal system. A marine reactor should be operated and managed even in the case of accidents and be highly automated since they are placed in narrow spaces and operated far from land and in severe sea environment. Therefore, passive safety system is very important for marine reactor. There are two kinds of passive safety functions in MRX. The one is passively maintaining core flooding function in the event of LOCA and the other is passive decay heat removal function after reactor shutdown. In this study we focused on the passive decay heat removal by natural circulation during loss of flow accident(LOFA). JAERI already have performed loss of flow accidents with emergency decay heat removal system(EDRS). They simulated loss of flow accidents for two cases with RELAP5/Mod2. The case 1 is EDRS operation after its setpoint of 310℃ at core exit temperature is reached. In this case, any reactor systems such as auxiliary feed water or EDRS are not working until EDRS setpoints are reached. And the case 2 is EDRS operation right after the reactor shutdown. Because we don't have detailed EDRS data, we used auxiliary feed water as a decay heat removal mechanism. At first, for the case 1, we calculated the loss of flow accident until the EDRS setpoints are reached for the comparison of natural circulation phenomena with JAERI analysis. For the case 2, we used auxiliary feed water as a decay heat removal mechanism. In this paper we compared the natural circulation phenomena between EDRS and auxiliary feed water operation and also verified that RETRAN-03 can simulate the physical phenomena in helically coiled S/G tubes very well.

Reactor type	Integral type PWR
Power(MWt)	100
Fuel	Zry-clad UO_2 fuel rod
Primary pressure(MPa)	12
Steam generator	Once-through helical coil
Tube material	Incoloy 800
Reactor vessel Inner dia./Height(m)	3.7/9.3
Reactor containment Inner dia./Height(m)	7.3/13.0
Coolant inventory(t) Mass flow rate(kg/s)	41/1250

Table 1 MRX basic design parameter

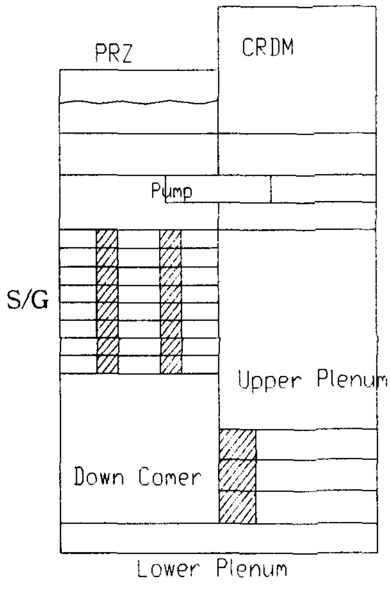

Fig. 1 RETRAN-03 Nodalization

II. RETRAN-03 Nodalization

Core regions divided into 3 volumes and for the simulation of helically coiled S/G tubes, S/G primary and secondary sides are divided into 8 volumes respectively. Major design parameters and RETRAN-03 nodalization model are shown in table 1 and figure 1 respectively.

III. LOFA Analysis without EDRS and auxiliary Feed Water System operation

EDRS is a *natural circulation loop which removes decay heat from core to containment* water. During normal operation EDRS is not working because it can derive unnecessary containment water pressure and temperature rise. Therefore its operation setpoints are core outlet temperature is over 310 ℃ or the core pressure is less than 9 MPa. Because we don't have actual EDRS data, we analyzed LOFA accidents until the EDRS setpoints are reached to verify our RETRAN-03 inputs and investigate the natural circulation phenomena of MRX reactor without any operations during LOFA accidents. Relief valves and safety valves are opened at 12.6 MPa and 13.7 MPa respectively according to the pressurizer pressure difference signal.
As shown in figure 2, primary system pressure reached relief valve setpoint of 12.6 MPa at 455 sec and increased to safety valve setpoints of 13.7 MPa at 900 sec after shutdown. Also, primary system pressure does not exceed its design value of 13.7 MPa by the control of relief and safety valves. Core outlet temperature is decreased slightly to 5 ℃ right after the shutdown and increases gradually to 310 ℃ about 2409 sec. Comparing with the JAERI results in figure 3, relief valve, safety valve, and EDRS setpoints are almost consistent and primary side temperatures show good agreements in their trends and absolute values. Therefore we conclude that we made same analysis conditions for *RETRAN-03* simulation as *JAERI loss of flow accidents analysis using* RELAP5/Mod2.

IV. LOFA Analysis with auxiliary Feed Water Operation

In this case, pump is tripped at 10 sec, and a reactor tripped by the scram signal of low flow of 80% core flow rate. Feed water is stopped with the pump trip signal and

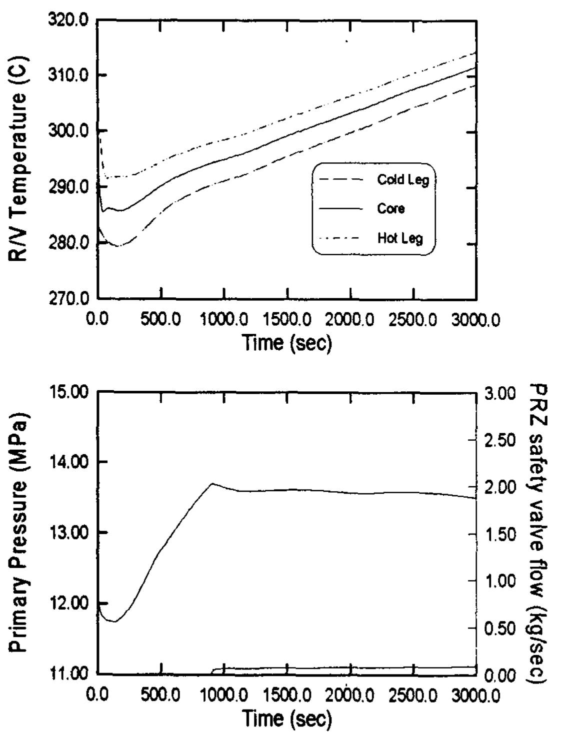

Fig. 2 RETRAN-03 results(CASE I)

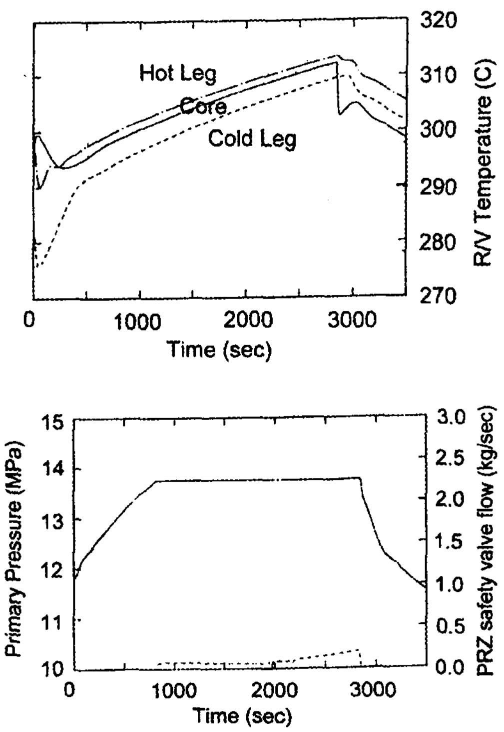

Fig. 3 JAERI results with EDRS Operation (CASE I)

auxiliary feedwater is actuated instantaneously with the reactor trip signal.

Core flow is decreased very rapidly by the pump trip and scram signal of low flow is occurred after 1 sec. Pressurizer liquid level increases very slighty after the pump trip but starts decreasing after 30 sec and dried out after 2300 sec after the reactor scram. Pressurizer pressure decreases continuously without increase after the trip because the reactor scram is occurred very quickly after the pump trip and auxillary feed water is inserted instantaneously. Figure 2 shows the general trend of primary system calculated by RETRAN-03 and figure 3 shows the results of JAERI analysis with EDRS 1 loop operation instead of auxillary feed water. There are some discrepancies in temperature difference between hot and cold leg and pressurizer liquid level decreasing rate, but overall trend such as flow rate variation and temperature values are very similar after 2000 sec after scram. Therefore, it can be said that auxiliary feedwater system has almost same heat removal capability as the 1 loop of the emergency decay heat removal system.

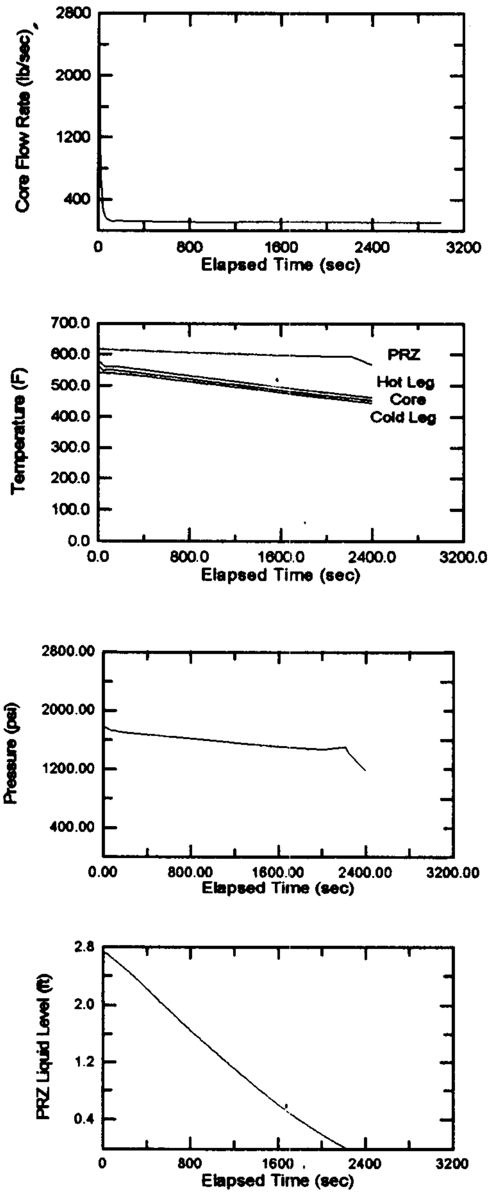

Fig. 4 RETRAN-03 Results with AFW (CASE II)

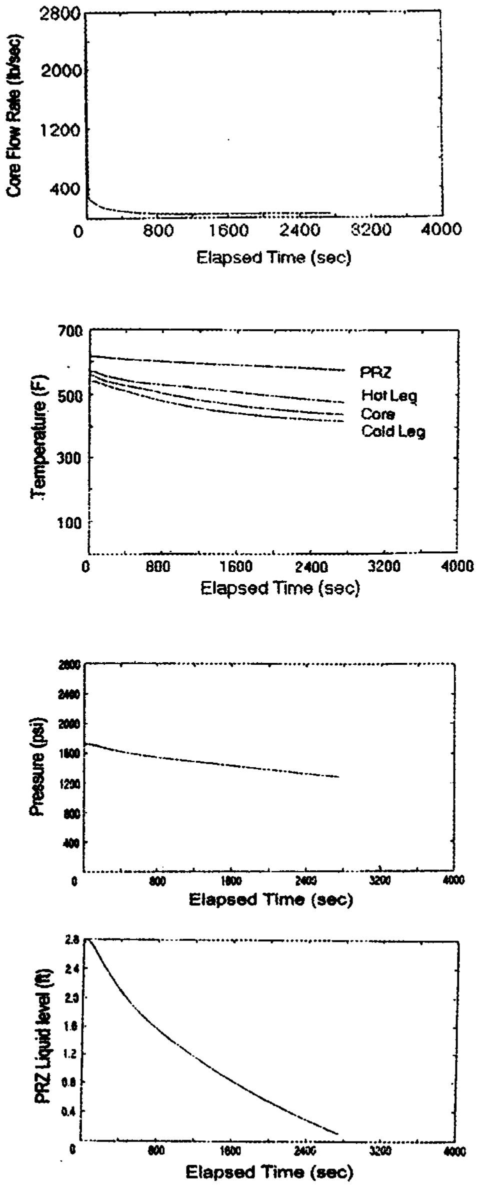

Fig. 5 JAERI results with EDRS operation (CASE II)

V. Conclusions

We analyzed the loss of flow accidents of MRX reactor with auxiliary feedwater operation and the results show similar trends to the EDRS 1 loop operation in JAERI analysis. EDRS is designed to remove decay heat passively by natural circulation even in the case of auxiliary feedwater malfunction in LOCA or LOFA accidents. But to prevent the unnecessary increase of containment water pressure and temperature increase, it's better to use auxiliary feedwater system instead of EDRS. And it can be concluded that auxiliary feed water can remove core decay heat successfully before the EDRS operation setpoints are reached.

Acknowledgment

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