Preliminary Safety Analysis of Design Basis Events for TRU Burner Reactor

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1. Introduction

KAERI is developing an advanced sodium-cooled fast reactor for a TRU (Transuranic waste) burning with a power of 3800 MWt. The TRU burner reactor consists of the PHTS (Primary Heat Transport System), the six IHTS (Intermediate Heat Transport System), and the six DHRS (Decay Heat Removal System). The reactor has negative reactivity feedbacks except density reactivity during the plant operation time. Also, it has passive safety system to prevent the loss of power in operation time by utilizing a natural circulation in DHRS.

In this study, a preliminary safety analysis of representative design basis events (DBEs) for TRU burner reactor is implemented using MARS-LMR code. Representative DBEs is selected to transient over power (TOP), loss of flow (LOF), and loss of heat sink (LOHS).

2. Safety Analysis Methodology

Fig. 1 shows the safety analysis nodalization for the TRU burner reactor. The core is modeled by five parallel flow channels such as the hottest inner driver fuel assembly, the hottest outer driver fuel assembly, the rest of driver fuel assemblies, non-fuel assemblies, and leakage flow. The PHTS is placed in a large pool, which is divided into hot pool and cold pool zones. The six sodium-to-sodium DHXs (Decay Heat eXchangers) and three pumps are located in the cold pool, whereas six IHXs (Intermediate Heat eXchagers) are located in the hot pool to transfer the reactor generated heat from the PHTS to the SG (Steam Generators). Table 1 shows Plant Protection System.

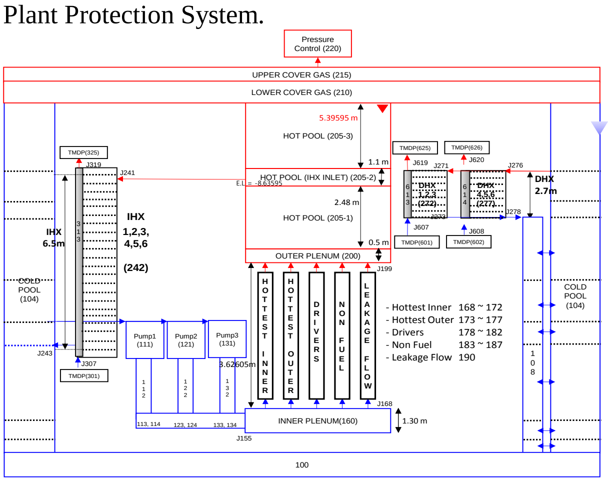

Fig. 1. Nodalization of TRU Burner Reactor

Table 1: Plant Protection System

Trip Parameters		Setpoint	Signal Delay time [sec]	Action
RPS	Overpower	110 %	0.05	Reactor Trip
	High Neutron Flux Change	7 %/min	0.05	Reactor Trip
	High Power to PHTS Flow Rates Ratio	110 %	0.8	Reactor Trip
	High Core Inlet Temperature	Nominal+15˚C	6	Reactor Trip
	High Fuel Assembly Outlet Temperature	Nominal+15˚C	6	Reactor Trip
ESFAS	High Core Inlet Temperature	Nominal+15˚C	6	DHRS Actuation
	High Fuel Assembly Outlet Temperature	Nominal+15˚C	6	DHRS Actuation

3. Safety Analysis Results

Table 2 describes the steady state comparison of the design value and the calculated value with a MARS-LMR code on each parameter. Based on the steady state results of Table 2, a preliminary safety analysis has been carried out using MARS-LMR code for TOP, LOF, and LOHS for the TRU burner reactor. In the safety analysis, nominal operating condition, which is 100 % of power condition, ANS-79 decay power model, 20.1 seconds delay in opening of AHX and FHX dampers, and loss of off-site power (LOOP) is taken into account. The PHTS, the IHTS, and the feedwater pumps trip are stopped by the LOOP assumption. The PHTS pump inertia is selected to provide 8 seconds of flow coast down halving time. Two PDHRS and two ADHRS are available in accordance with a single failure criterion and maintenance. The safety acceptance criteria of DBA is based in the integrity of reactor core. Thus, sodium coolant temperature should be under boiling temperature (about 900 ℃) enough.

Table 2: Steady State Comparison of Design Value and Calculated Value with MARS-LMR Code

Parameters	Design	MARS-LMR
Power (MWt)	3800	3800
Flowrate in a Core (kg/s)	19786	19899
Core Outlet Temperature (℃)	510.0	509.8
Core Inlet Temperature (℃)	360.0	359.6
Inner Peak Fuel Assembly Coolant Temperature (℃)	541.9	540.8
Outer Peak Fuel Assembly Coolant Temperature (℃)	542.9	543.1
Cover Gas Pressure (Pa)	150000	154083
Inlet Plenum Pressure (Pa)	676738	660056

3.1 Transient Over Power

Table 3 shows the sequence of TOP. Fig. 2 ~ 6 shows the core power, core mass flowrate, core inlet and outlet plenum coolant temperature, peak fuel assembly coolant temperature, and DHRS heat removal rate for TOP respectively. DHRS heat removal rate exceeds the decay heat generation rate, and reactor cool down.

Table 3: Sequence of TOP

Event (TOP)	Time, Setpoint
Reactivity Insertion Starts	0.0 sec
The RPS on high neutron flux change rate trip reaches the trip setpoint	7.84 sec, 7 %/min
Insertion of control assemblies occurs	8.44 sec
The ESFAS on high fuel assembly outlet temperature trip reaches the trip setpoint	32.0 sec, nominal + 15 ℃
DHRS damper actuation occurs	53.1 sec
DHRS blower actuation occurs	58.1 sec

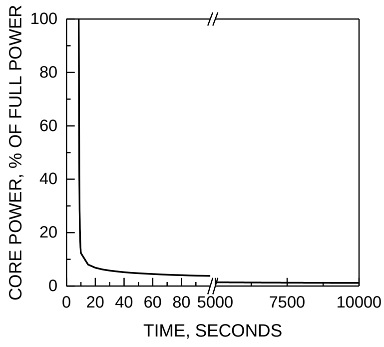

Fig. 2. Core Power of TOP

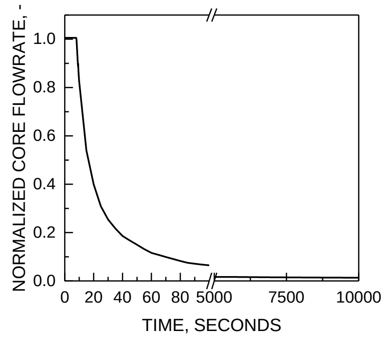

Fig. 3. Core Mass Flowrate of TOP

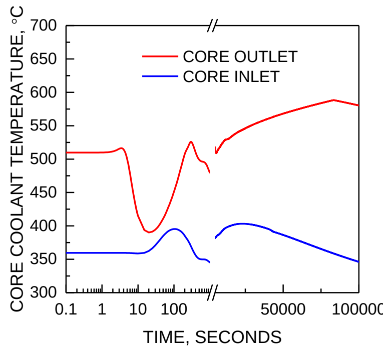

Fig. 4. Core Inlet/Outlet Plenum Coolant Temperature of TOP

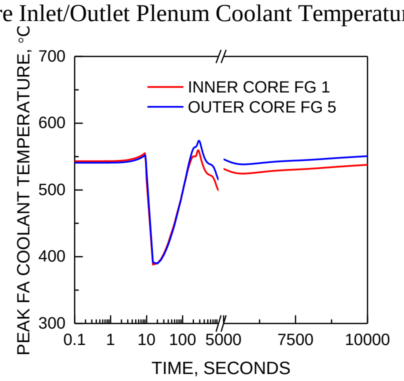

Fig. 5. Peak Fuel Assembly Coolant Temperature of TOP

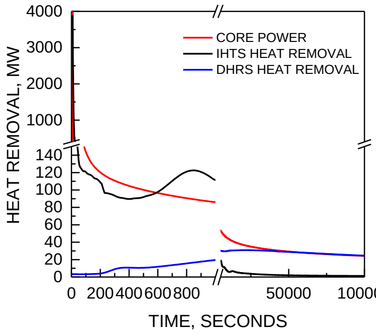

Fig. 6.DHRS Heat Removal Rate of TOP

3.2 Loss Of Flow

Table 4 shows the sequence of LOF. Fig. 7 ~ 11 shows the core power, core mass flowrate, core inlet and outlet plenum coolant temperature, peak fuel assembly coolant temperature, and DHRS heat removal rate for LOF, respectively. DHRS heat removal rate exceeds the decay heat generation rate, and reactor cool down.

Table 4: Sequence of LOF

Event (LOF)	Time, Setpoint
Three PHTS pumps stop	0.0 sec
The RPS on high power to PHTS flow ratio trip reaches the trip setpoint	0.82 sec, 110 %
Insertion of control assemblies occurs	2.17 sec
The ESFAS on high fuel assembly outlet temperature trip reaches the trip setpoint	2.37 sec, nominal + 15 ℃
DHRS damper actuation occurs	23.47 sec
DHRS blower actuation occurs	28.47 sec

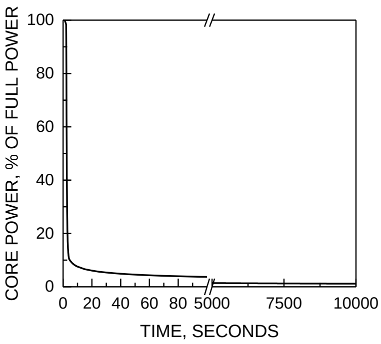

Fig. 7. Core Power of LOF

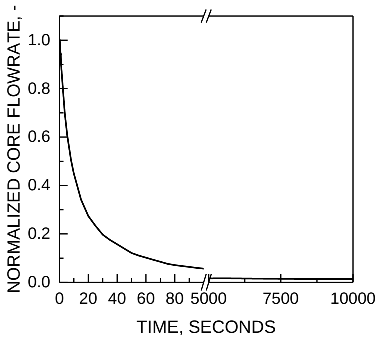

Fig. 8. Core Mass Flowrate of LOF

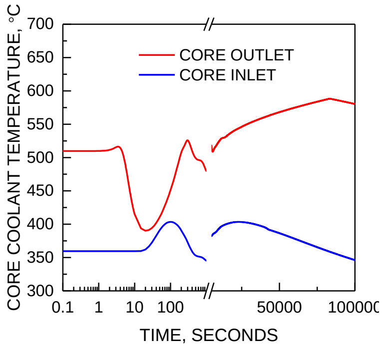

Fig. 9. Core Inlet/Outlet Plenum Coolant Temperature of LOF

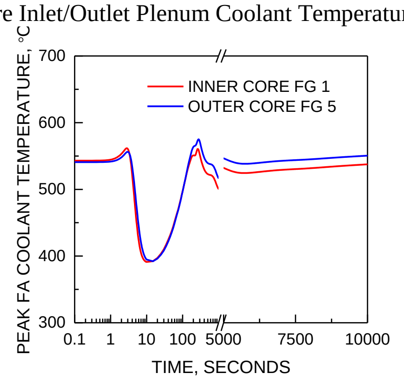

Fig. 10. Peak Fuel Assembly Coolant Temperature of LOF

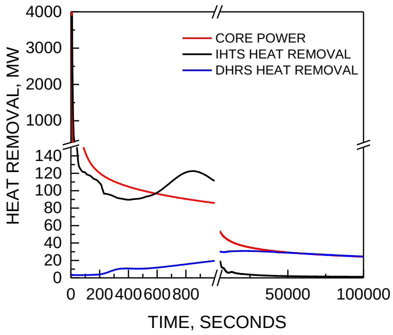

Fig. 11.DHRS Heat Removal Rate of LOF

3.3 Loss Of Heat Sink

Table 5 shows the sequence of LOHS. Fig. 12 ~ 16 shows the core power, core mass flowrate, core inlet and outlet plenum coolant temperature, peak fuel assembly coolant temperature, and DHRS heat removal rate for LOHS, respectively. DHRS heat removal rate exceeds the decay heat generation rate, and reactor cool down.

Table 5: Sequence of LOHS

Event (LOHS)	Time, Setpoint
Single feedwater pump seizure occurs	0.0 sec
High core inlet temperature reaches reactor tip setpoint	58.4 sec, nominal + 15 ℃
Insertion of control assemblies occurs	64.9 sec
DHRS damper actuation occurs	79.5 sec
DHRS blower actuation occurs	84.5 sec

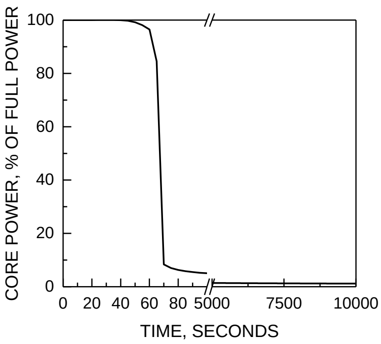

Fig. 12. Core Power of LOHS

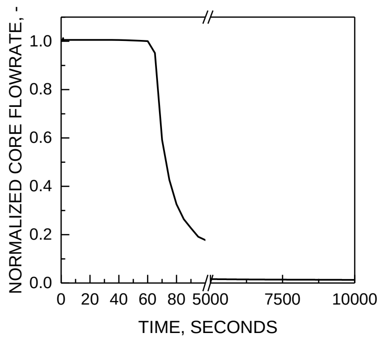

Fig. 13. Core Mass Flowrate of LOHS

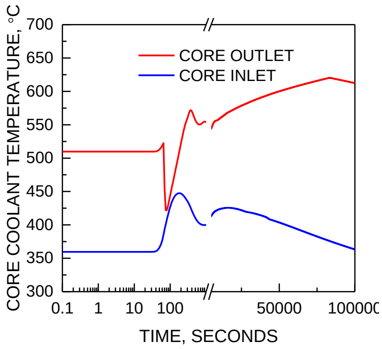

Fig. 14. Core Inlet/Outlet Plenum Coolant Temperature of LOHS

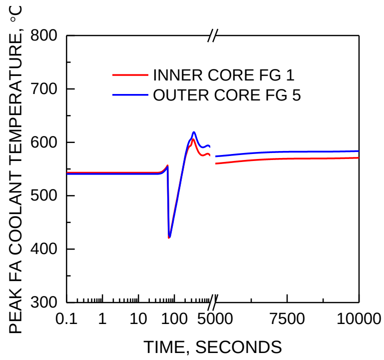

Fig. 15. Peak Fuel Assembly Coolant Temperature of LOHS

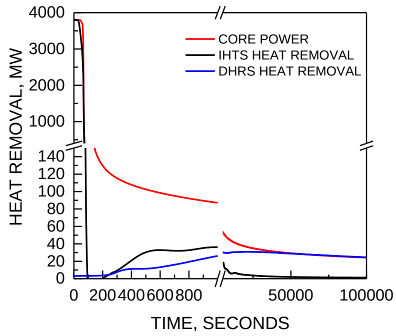

Fig. 16.DHRS Heat Removal Rate of LOHS

4. Conclusions

A preliminary safety analysis of representative DBEs using MARS-LMR code has been carried out for the TRU burner reactor. The reactor during DBEs is immediately tripped by PPS, and safely cool down without coolant boiling.

ACKNOWLEDGEMENTS

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