Development of PIRTs for SPACE code extension to Application into Research Reactors

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1. Introduction

The applicability of the SPACE code, licensed to use for analyzing the nuclear safety of the nuclear power plants in Korea under high pressure and high temperature, needs to be extended to cover the operational ranges of the research reactors (RRs) such as the HANARO, the KJRR, the JRTR, and research reactors to be potentially designed in the future.

The thermal hydraulic phenomena within the research reactors are identified and the ranking tables are prepared to cover the initiating events up to beyond design basis accidents. Multi-dimensional physics is also included for the use in the future.

Proposed were the RRs PIRTs, which will be the bases for the requirements for the code extension and the V&V.

2. PIRT methodology and Development process

The methodology and development process for PIRT are based on the references [1~7].

3. Scenario-specific PIRT

Scenario-specific PIRTs were developed for the JRTR[8-11], KJRR[12-15] and the HANARO[16-19].

A specific PIRT for excess reactivity insertion is only presented in this paper.

3.1 Definition of Events

The events imply that power excursion occur due to various reasons: positive reactivity inserts all of a sudden, power increases, temperature of fuel and core increases.

3.2 Scenario

- Positive reactivity inserted
- Core power increases
- Protection system initiated by power or rate of power depending on amount of the inserted reactivity
- Rods dropped
- Forced or natural circulation cools the core

The reference reactor was the KJRR-specific.

3.3 Experiments

IAEA benchmarks and UMLRR can be used as a reference to compare the core transient during reactivity insertion.

3.4 Acceptance Criteria

For all operational states except for the limiting accident of the research reactors, no fuel failure, expressed as DNBR, is allowed.

3.5 T/H phenomena

The identified phenomena are as given in the follows table.

System/Structure	Component	Phenomena
Reactor Structure Assembly	Core (fuel)	Core power
		Asymmetric power
		Reactivity feedback (MTC/FTC)
		Fuel heat transfer
		Decay heat
	Core (fluid)	Voiding (weak subcooled boiling)
		Single phase forced convection
		Wall heat transfer
Primary Piping	pipes	Single phase forced convection
Reactor Pool	Pool	Single phase forced convection
		Flow mixing
		Evaporation
Secondary Cooling System	Heat Exchanger	Wall heat transfer
Confinement	Confinement wall	Wall heat transfer
		Condensation
		Two phase natural circulation
	Confinement Safety Valves	Discharge flow
Confinement Cooling	Cooler	Cooling

4.6 Rankings

The ranked phenomena are as given in the follows table. (Editing problems. During review, a table will be given)

3.6 SPACE improvements

The SPACE code is required to improve the performance for analyzing multi-dimensional physics coupled thermal-hydraulics issues in order to get more thermal margin for non-symmetric reactivity insertion transients.

4. Experimental DB and Matrices for V&V

5.1 Experimental DB [20~33]

T/H model	Experiments	Remarks
1. Pressure Drop	1.1 CNNC experiments	
	1.2 KAERI DP Test of single channel	
	1.3 KAERI DP Test of a Fuel Assembly	
	1.4 KAERI DP Test of a Probe Fuel	
2. Single-Phase Convective heat transfer	2.1 CNNC experiments	
	2.2 KAERI experiments	
	2.3 JRR-3 experiments	
	2.4 ETRR-2 experiments	
3. CHF correlations	3.1 Kaminaga correlations	
	3.2 Mirshark correlations	
	3.3 CNPRI correlations	
4. OFI correlation	4.1 Whittle and Forgan correlation	
	4.2 THTL experiments	
	4.3 CNNC experiments	
5. OSV correlation	5.1 Saha-Zuber correlation	
	5.2 CNNC experiments	
6. ONB correlation	6.1 Bergles-Rohsenow correlation	
	6.2 CNNC experiments	
	6.3 Tanaka experiments	
7. Subcooled boiling	7.1 Bibeau experiments	Annular tube
	7.2 Zeitoun experiments	Annular tube
	7.3 Evangelisti experiments	Annular tube
	7.4 Dimmick experiments	
	7.5 Model development	
8. Pipe break flow / siphon break	8.1 POSTECH experiments	
	8.2 Idaho University experiments	
	8.3 Handong University experiments	
9. UMRR reactivity insertion transient	9.1 UMLRR reactivity insertion transients	
	9.2 SPERT experiments	
	9.3 PARET and RELAP code	Code to Code comp.
10. Natural Convection	10.1 IEA-R1 Loss of flow tests	
	10.2 ANL Experiments	10.2a, 10.2b: rectangle 10.2c, 10.2d: pipe

5.2 Matrices for V&V

		UMRR RII, SPERT test	IAEA benchmark RIA	CNNC experiments	TRIGA mark II
Phenomena versus test type					
	●: occurring				
	◐: partially occuring				
	-: not occurring				
Facility versus phenomenon					
	●: suitable for code assessment				
	◐: limited suitability				
	-: not suitable				
Phenomena	중성자 출력	●	●	-	-
	중성자 비대칭 출력	-	-	-	-
	붕괴열	●	●	-	-
	핵연료(핀 봉, 판형) 열전달	-	-	●	-
	반응도 궤환 효과	-	-	-	-
	제어봉 자기력 감쇠	-	-	-	-
	제어봉 자유낙하	-	-	-	-
	노심 압력강하/차압	-	-	●	-
	이상유동 (비응축가스)	-	-	-	-
	이상유동 열전달	-	-	-	-
	단상자연순환	-	-	-	-
	수조 자연순환(다차원)	-	-	-	◐
	수조 수위 감소	-	-	-	-
	플랩밸브 개방	-	-	-	-
	사이폰 현상	-	-	-	-

	PCS(1 차측) 펌프 관성서행	-	-	-	-
	PCS(1 차측) 열교환기 열전달	-	-	-	-
	냉각재 유출 유량	-	-	-	-
	감쇄탱크(Decay Tk) 성층화	-	-	-	-
	SRHRS 펌프 기동	-	-	-	-
	SRHRS 펌프 관성서행	-	-	-	-
	노심 유동 역전	-	-	-	-

6. Conclusions

A licensed system code, dedicated to research reactors under low temperature and low pressure, is under development based on the SPACE code, licensed as a domestic thermo-hydraulic system code for nuclear power plants under high temperature and high pressure in Korea.

Phenomena Identification and Ranking Tables for the research reactors were developed by considering the characteristics of the research reactors such as the HARARO, JRTR, KJRR, and potentially expected research reactors.

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