Towards Standard Methodology in the Safety Analysis of Research Reactors

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Content

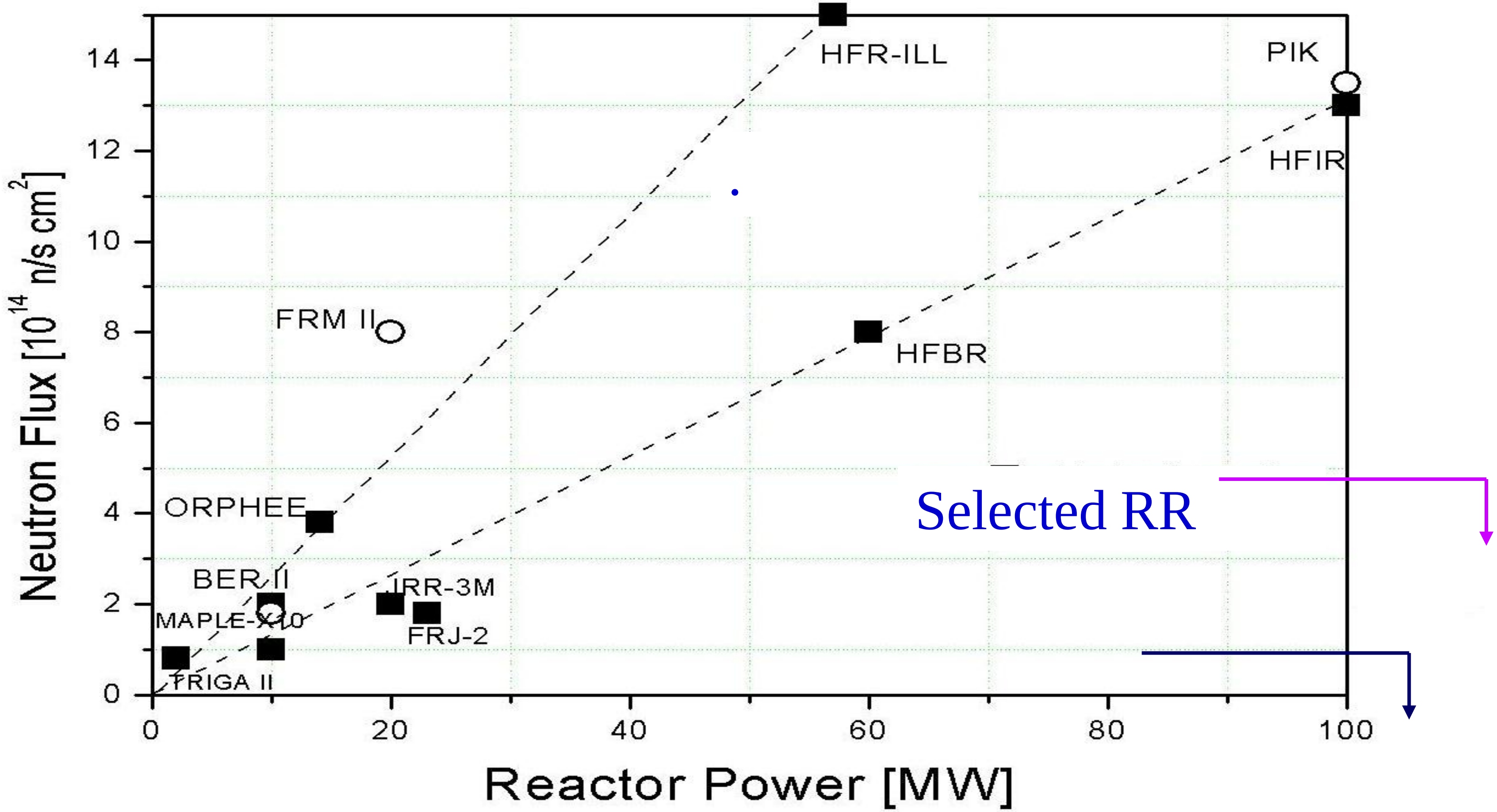
- Background;
- Safety Analysis Scheme of RR;
- Qualification of Safety Analysis Codes;
- Examples: Application on Selected RR;
- Role of IAEA in Adopting a Safety Analysis Codes;
- Conclusion.

Classification of Research Reactors

There is a wide spectrum of RR types:

- Low to medium flux reactors: $\phi < 10^{14} cm^{-2} \cdot s$
- High flux reactors: $10^{14} cm^{-2} \cdot s \leq \phi < 5 \cdot 10^{14} cm^{-2} \cdot s$
- Highest flux reactors: $\phi \geq 5 \cdot 10^{14} cm^{-2} \cdot s$

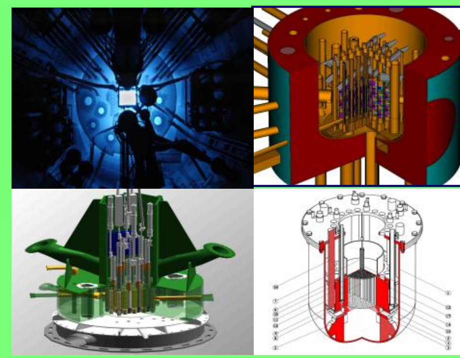
Various RR and FE Types



Neutron flux vs. reactor power for various research reactor types

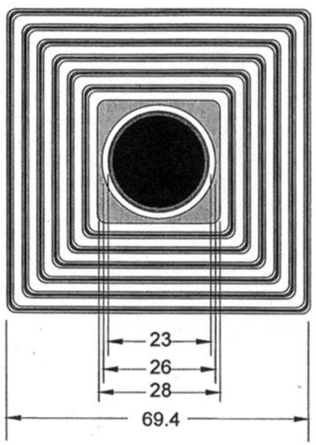
Specific Features of RR

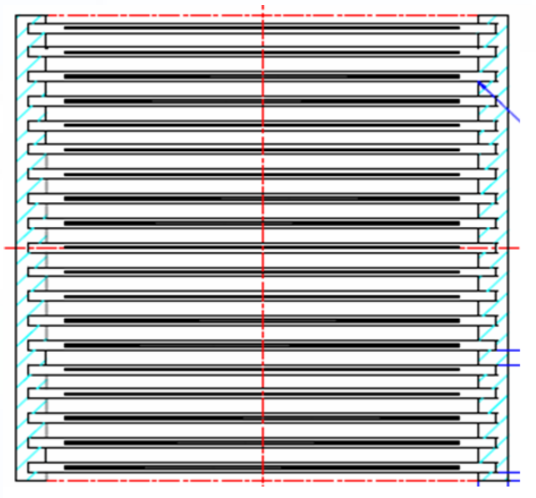
- Low hazard potential
- High power density
- Compact core design
- Small fission product inventory
- High heat flux
- Short FE cycle length
- Low system pressure
- Low fuel melting point
- Fast transient behavior

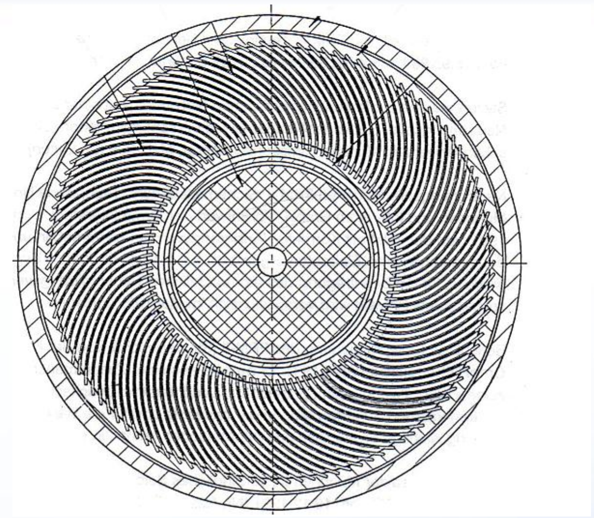


Wide spectrum of RR types

Various FE Types







Involutes Fuel Plates

Scope of RR Safety Analysis

- Analysis of event sequences and evaluation of PIEs consequences,
- and comparison of the achieved analysis results with design limits and radiological acceptance criteria.

General Aspects of RR

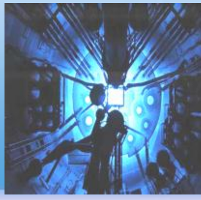
- Despite the difference between RR and power reactors, the safety objective is the same;
- Variety of RR has limited the effort to establish detailed standard approach and the development of comprehensive Safety Analysis Codes for RR.

Safety Aspects of RR

Safety Limits:

- **Sub-cooled boiling (ONB, OSV);**
- **Thermal hydraulic instability (OFI),**
- **Parallel channel instability,**
- **DNB (saturated or subcooled).**

Safety Aspects of RR
(Some PIE)



- **RIA, LOFA, LOCA;**
- **Loss of elect. power**
- **Internal and external events,**
- **Human errors, etc..**

Approach for Comprehensive Safety Analysis

Specification of core, FE and loops geometry

Core specification

Neutronic Analysis:
Criticality and burn-up
(MCNP, CITATION, …)

Key dynamic parameters:
Φ, φ, β, α, Λ

TH Analysis:
SS, Transients
(RELAP, ATHLET, MERSAT, CATHARE, PARET, CATENA)

Distribution of
T, v, p, ε

Safety analysis of DBA:
RIA, LOFA, LOCA, ATWS
(TH Codes +3D-Kinetic)

Safety limits and margins:
DNBR, OFI

Design&
Safety Analysis

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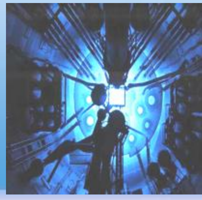
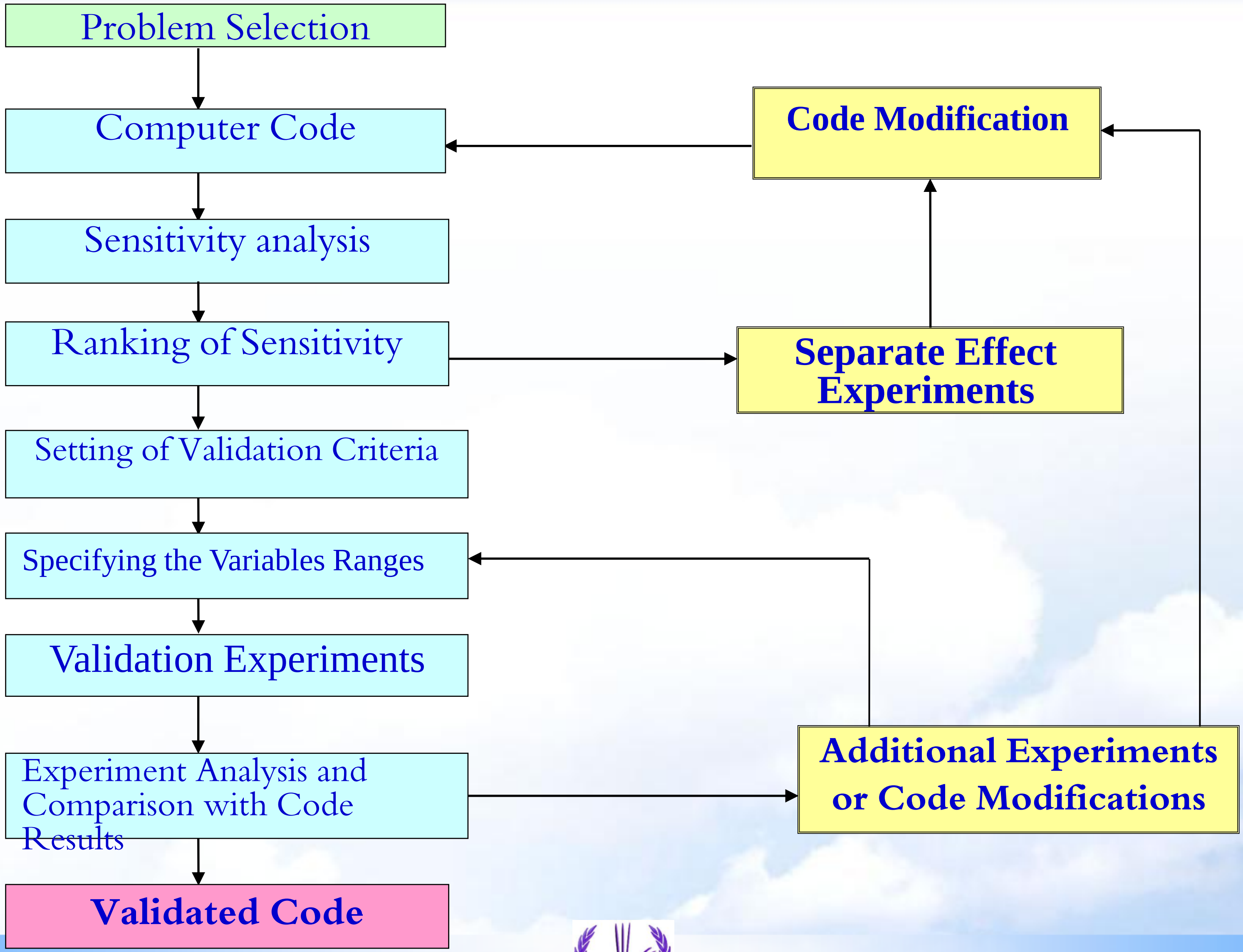
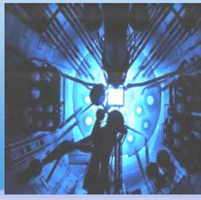
Verification and Validation Procedure





Validation Matrix
(single &integral effect test)



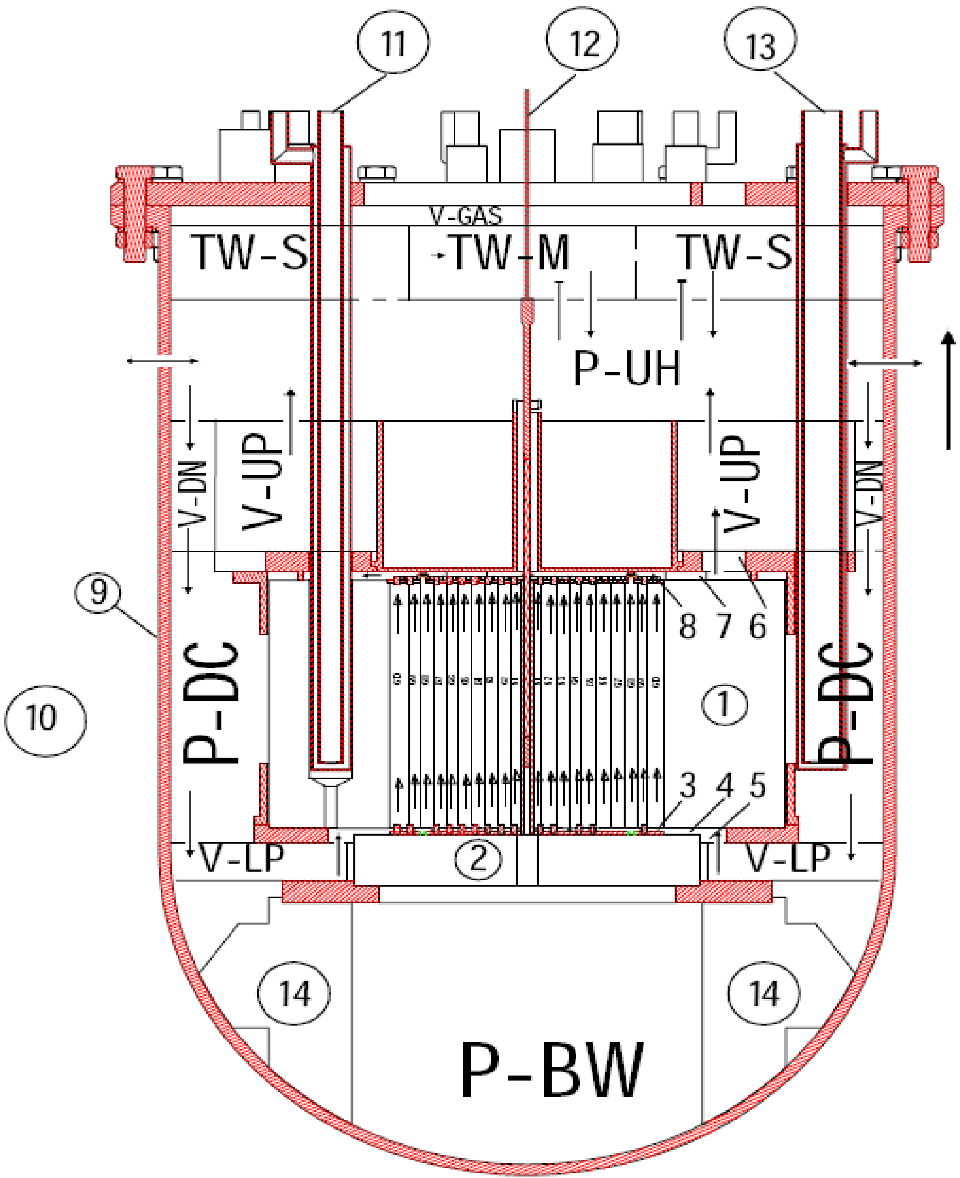
		Physical Phenomena						
		ONB, OSV	OFI & PCI	DNB & Transition Boiling	Fuel Melting	Flow Reversal	Natural Circulation	Reactivity Feedback & 3D Effects
Experiments	Axial Void Distribution	A		P				
	Static Instability Experiments	A	P					
	Parallel Channel Instability	P	A	P	P			
	RIA				P			A
	LOFA		P	A	P	P	P	P
	LOCA			A	A			P
	Loss of Heat Sink				P		A	P
	Two Phase Heat Transfer	A		A			P	

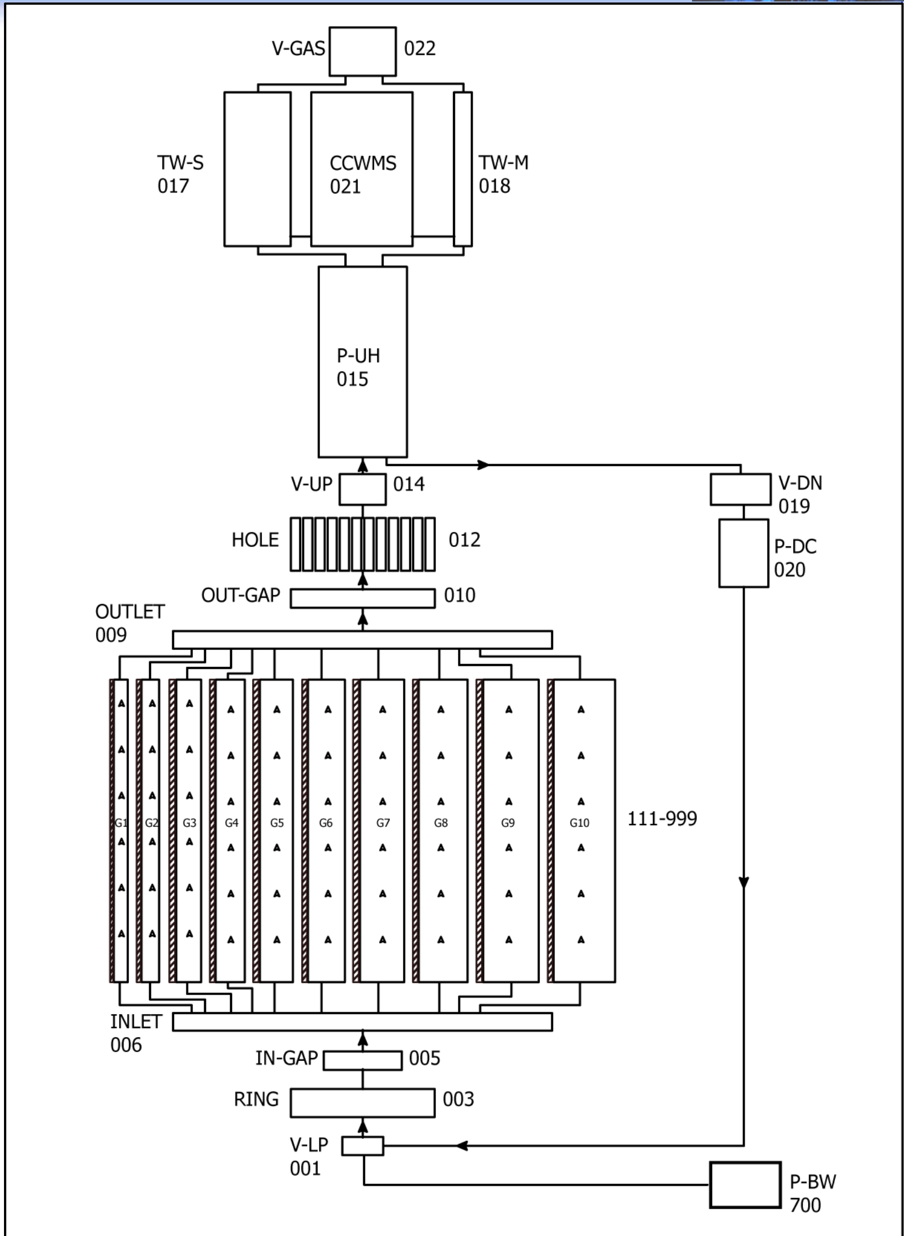
Covering range of the experiment regarding the physical phenomenon:
A: Appropriate for code validation, P: Partially appropriate for code validation

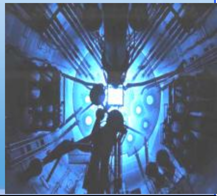
Selected Examples:

- MNSR, IAEA-10 MW, FRJ-2, FRM-2
- ETRR2, RSG-GAS, IEA-R1, MNR, SPERT-IV

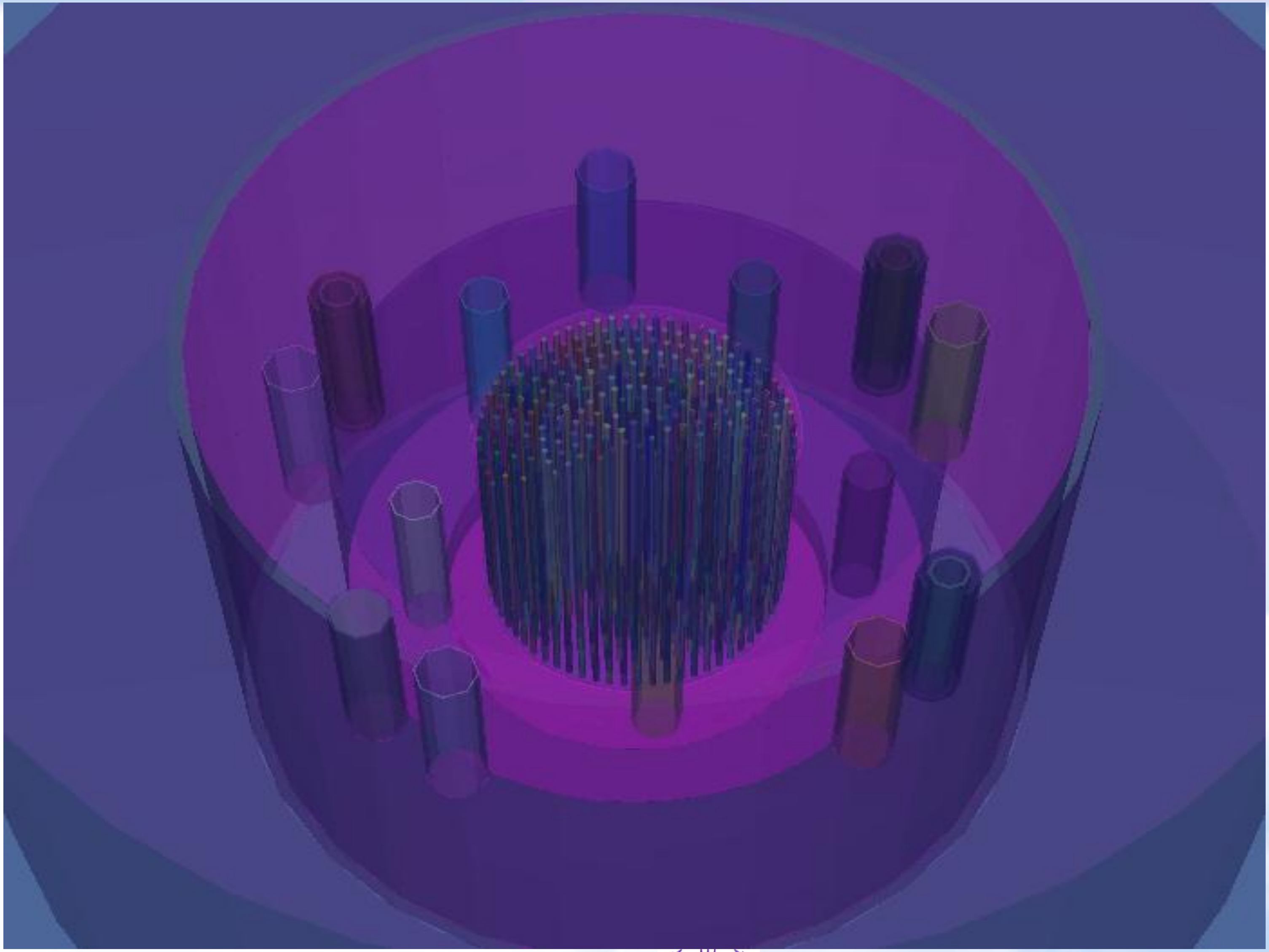
MSNR Models (MERSAT, ATHLET, RELAP)







MCNP 3-D Model of MNSR



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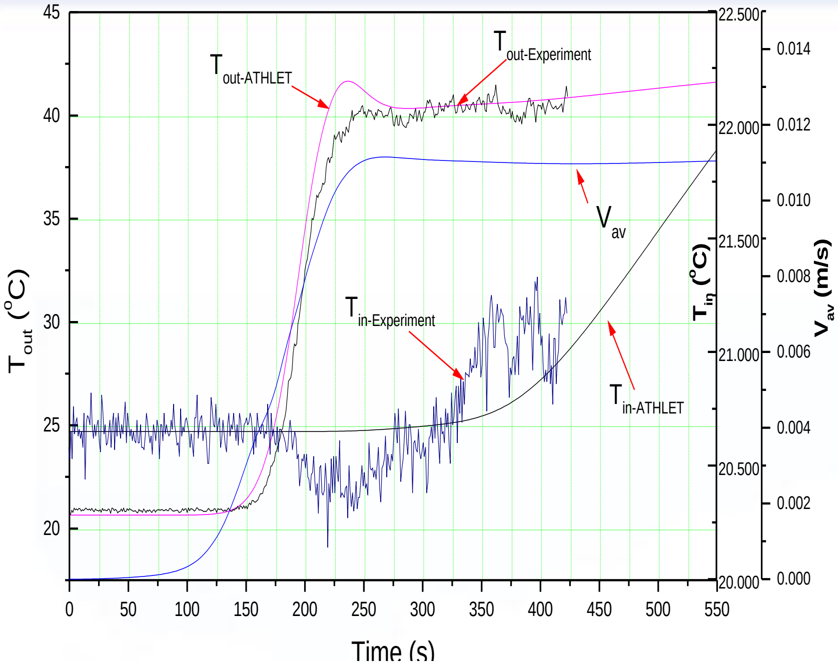
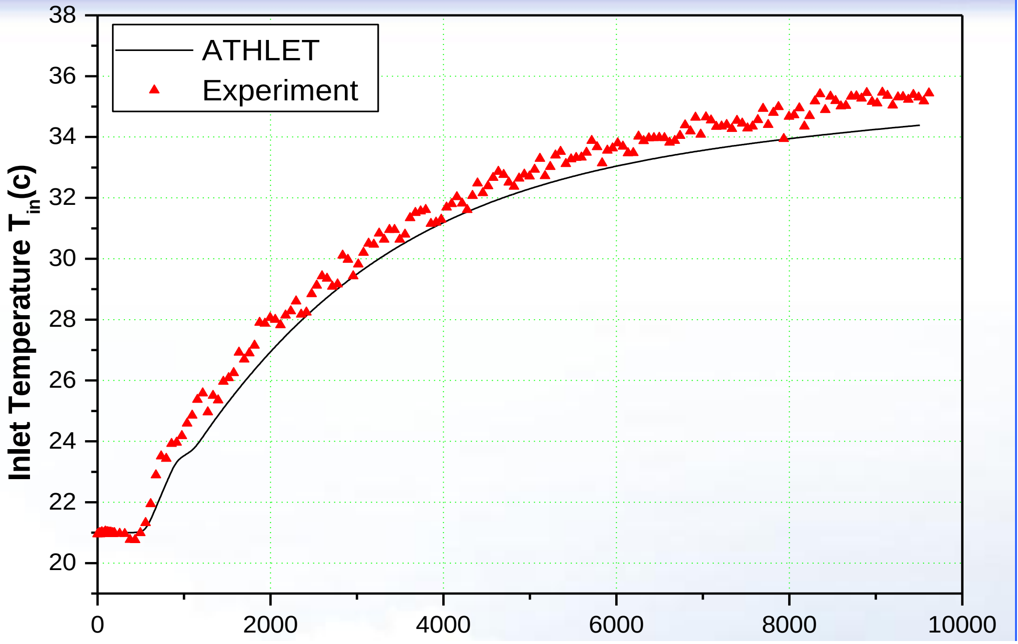
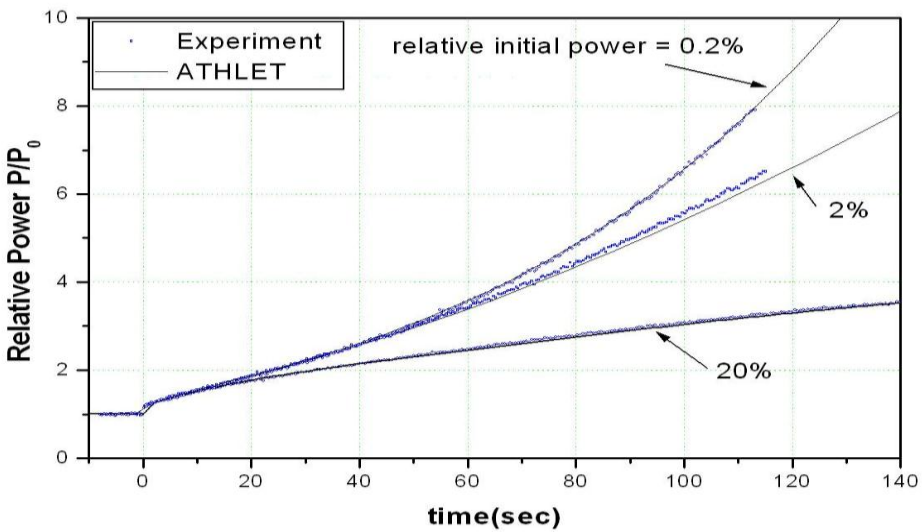
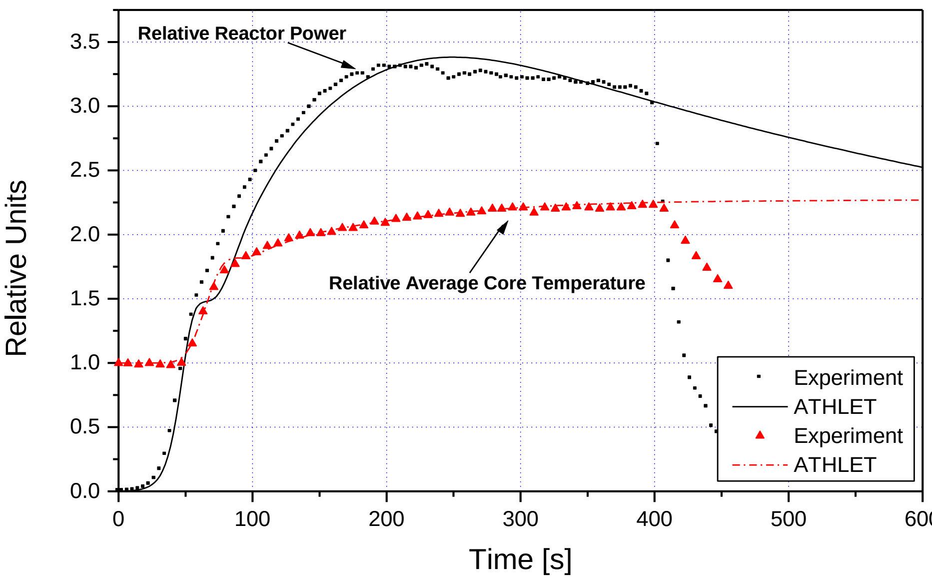
TH Experiments and Validation Results

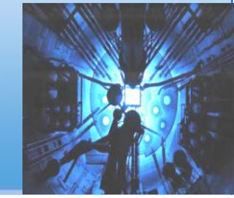




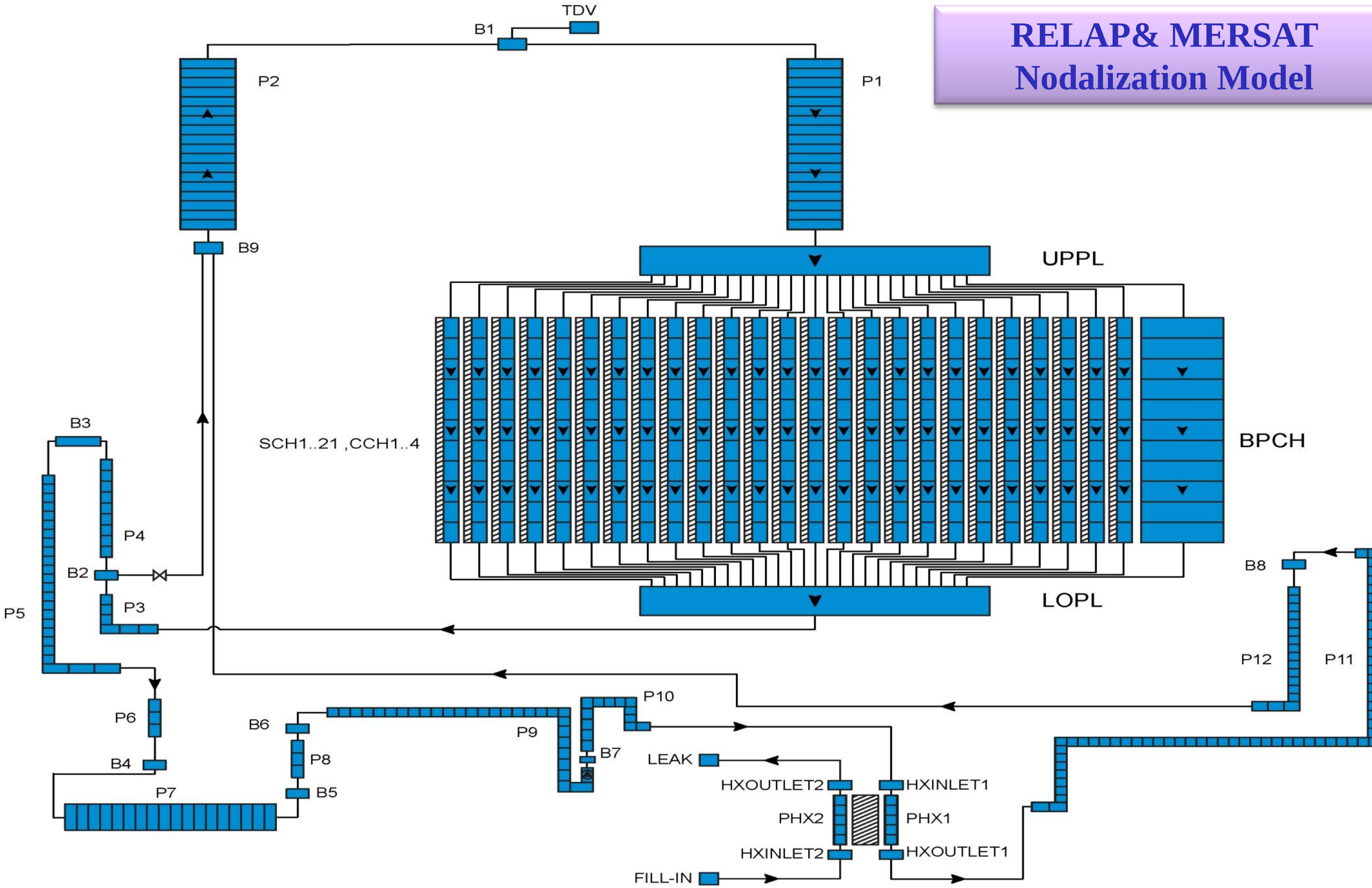




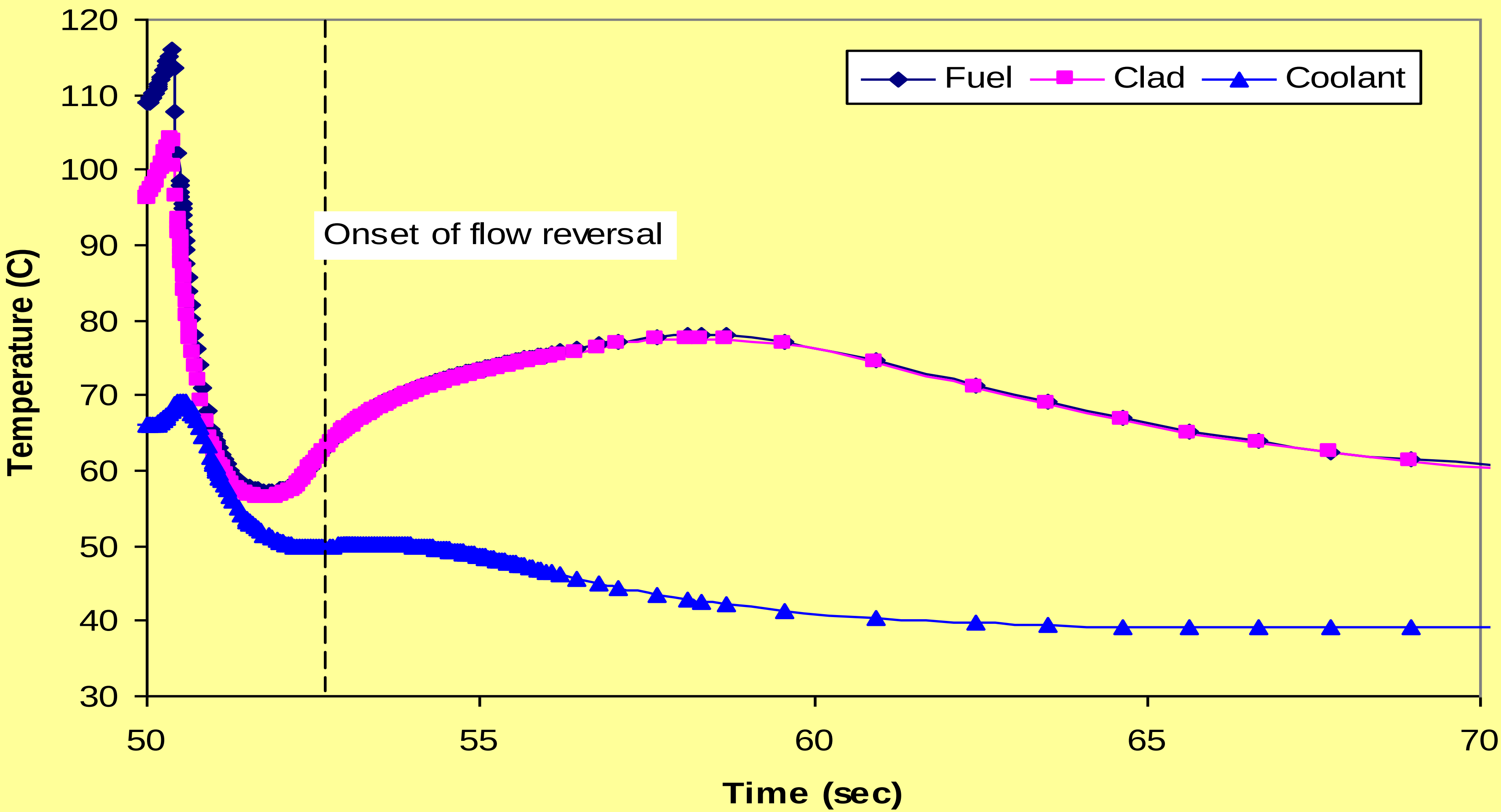
LOFA and RIA Analysis of IAEA-RR (10 MW)



RELAP& MERSAT Nodalization Model

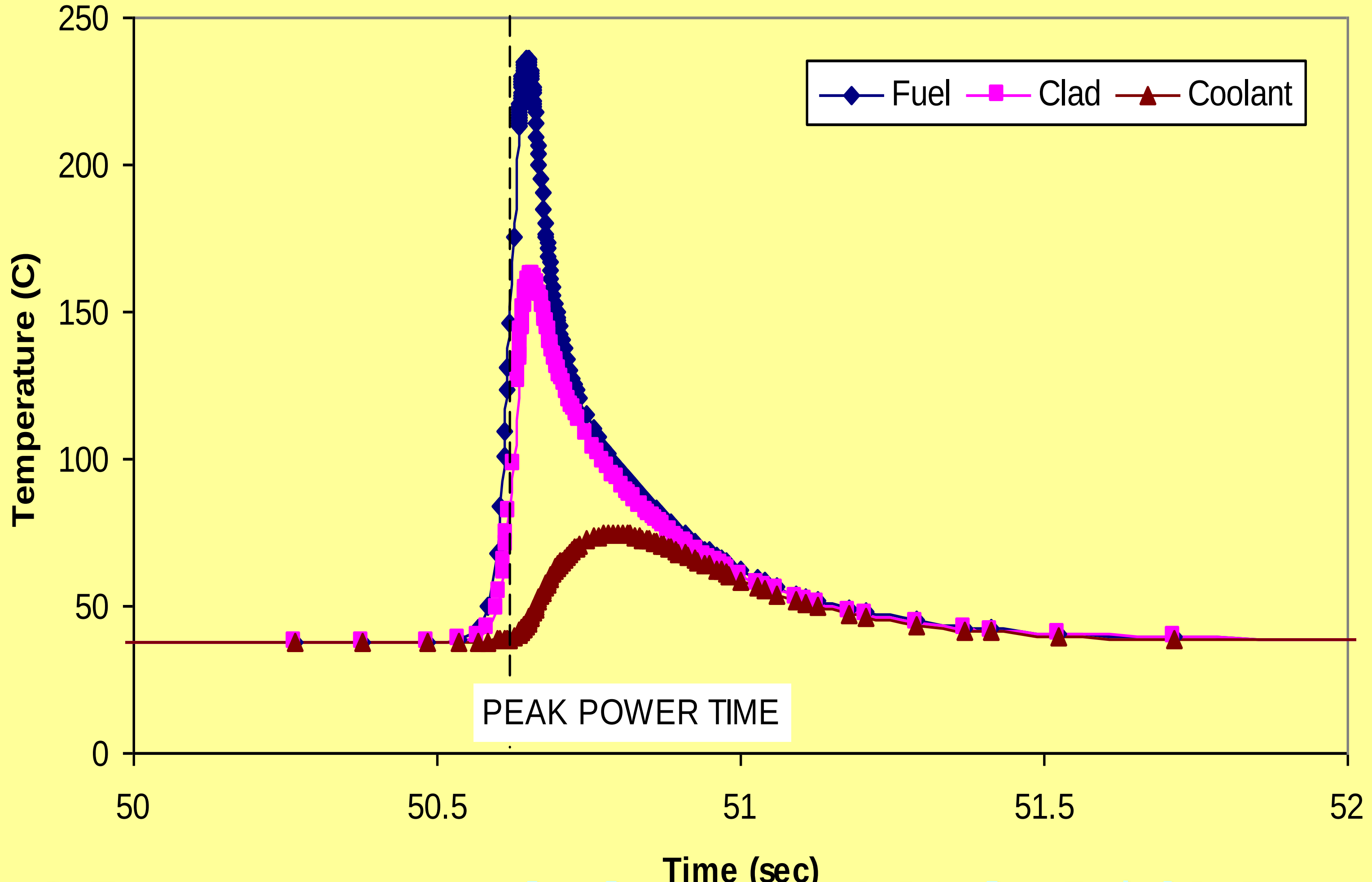


LOFA Analysis of IAEA-RR



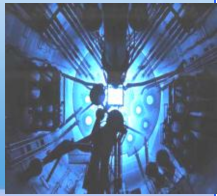
HC Temperatures during LOFA.

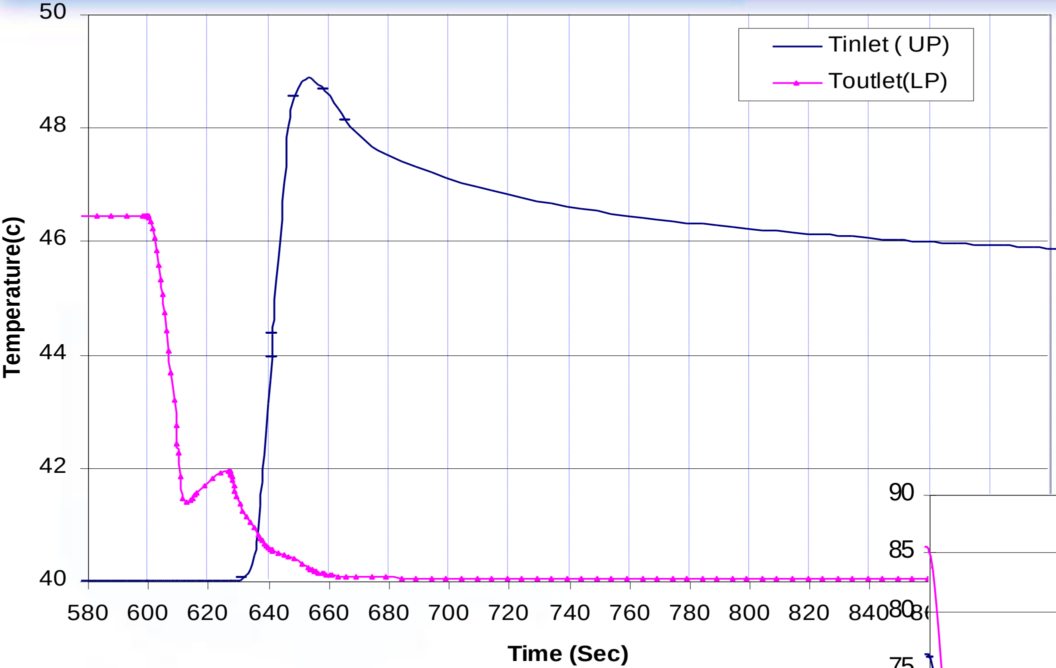
RIA Analysis of IAEA-RR



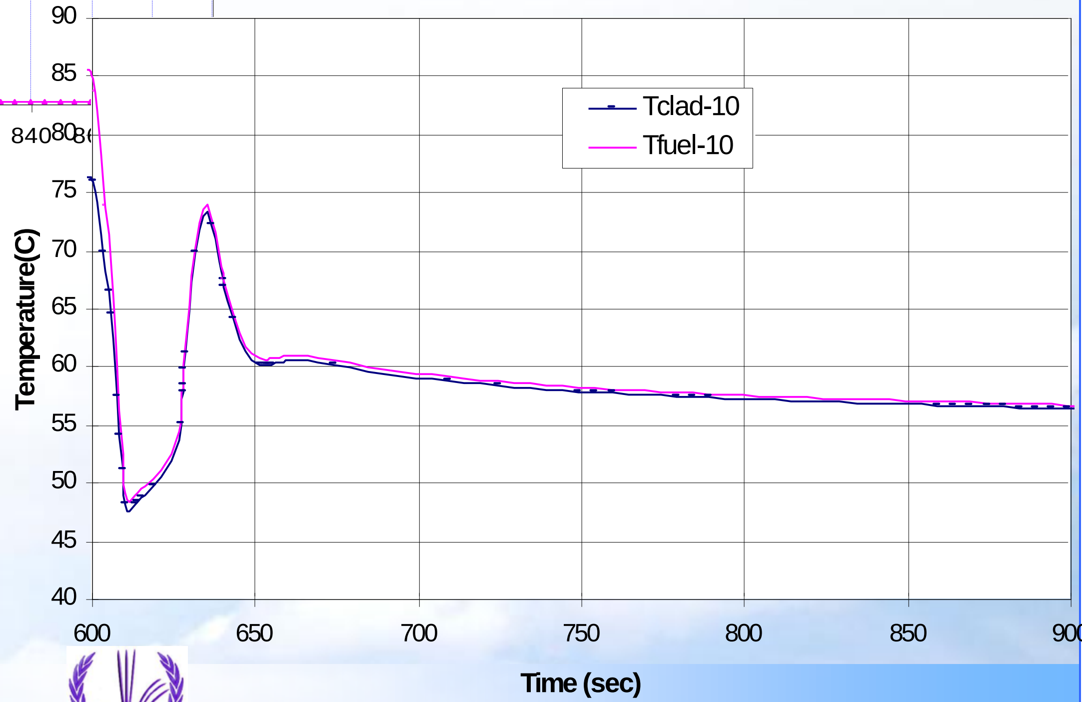
HC Temperatures during Fast RIA (1.5 $/0.5 sec)

LOFA Simulation of IEA-R1



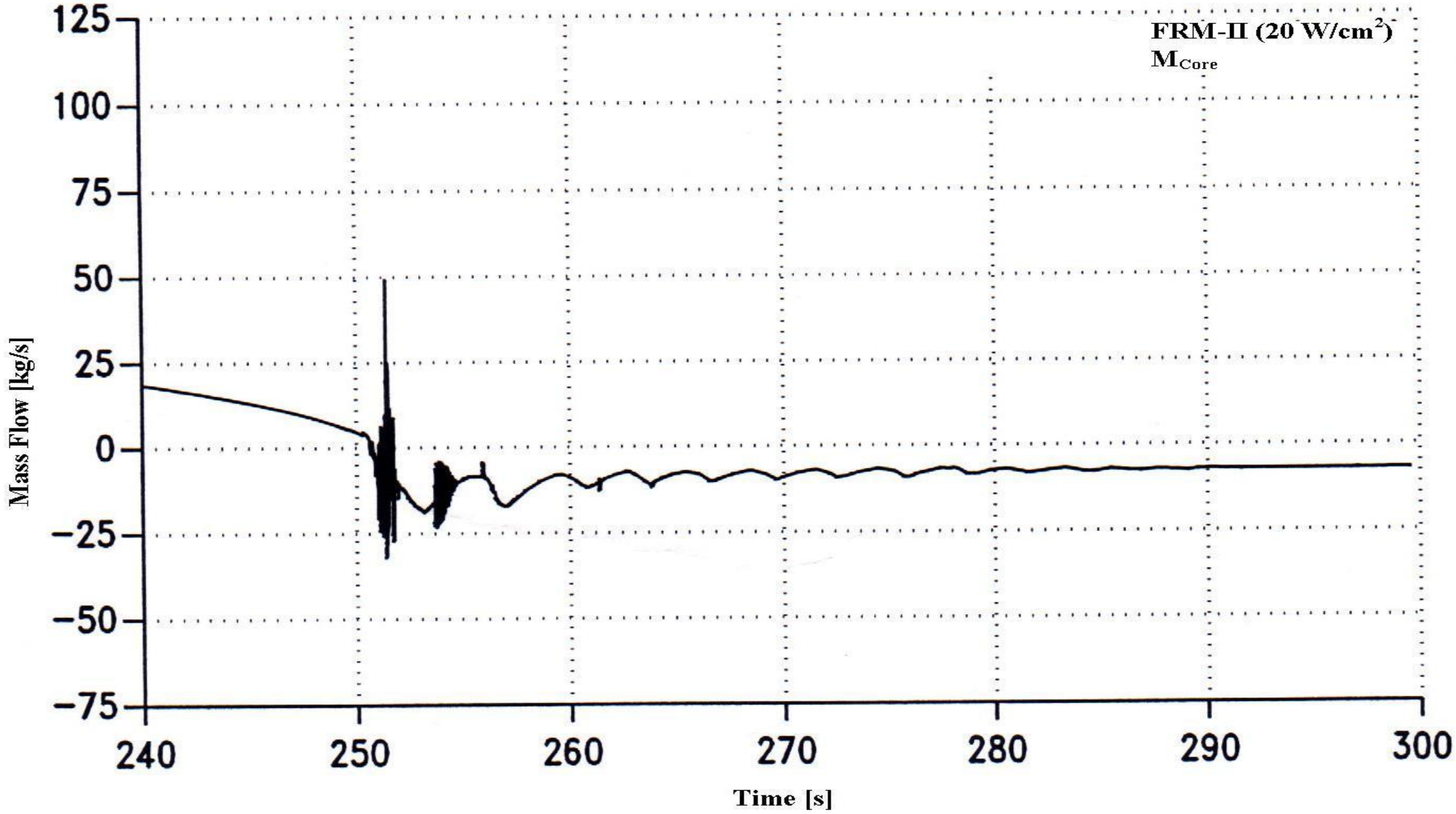


Core inlet and outlet coolant temperatures during the LOFA



Flow Reversal

(ATHLT Application)



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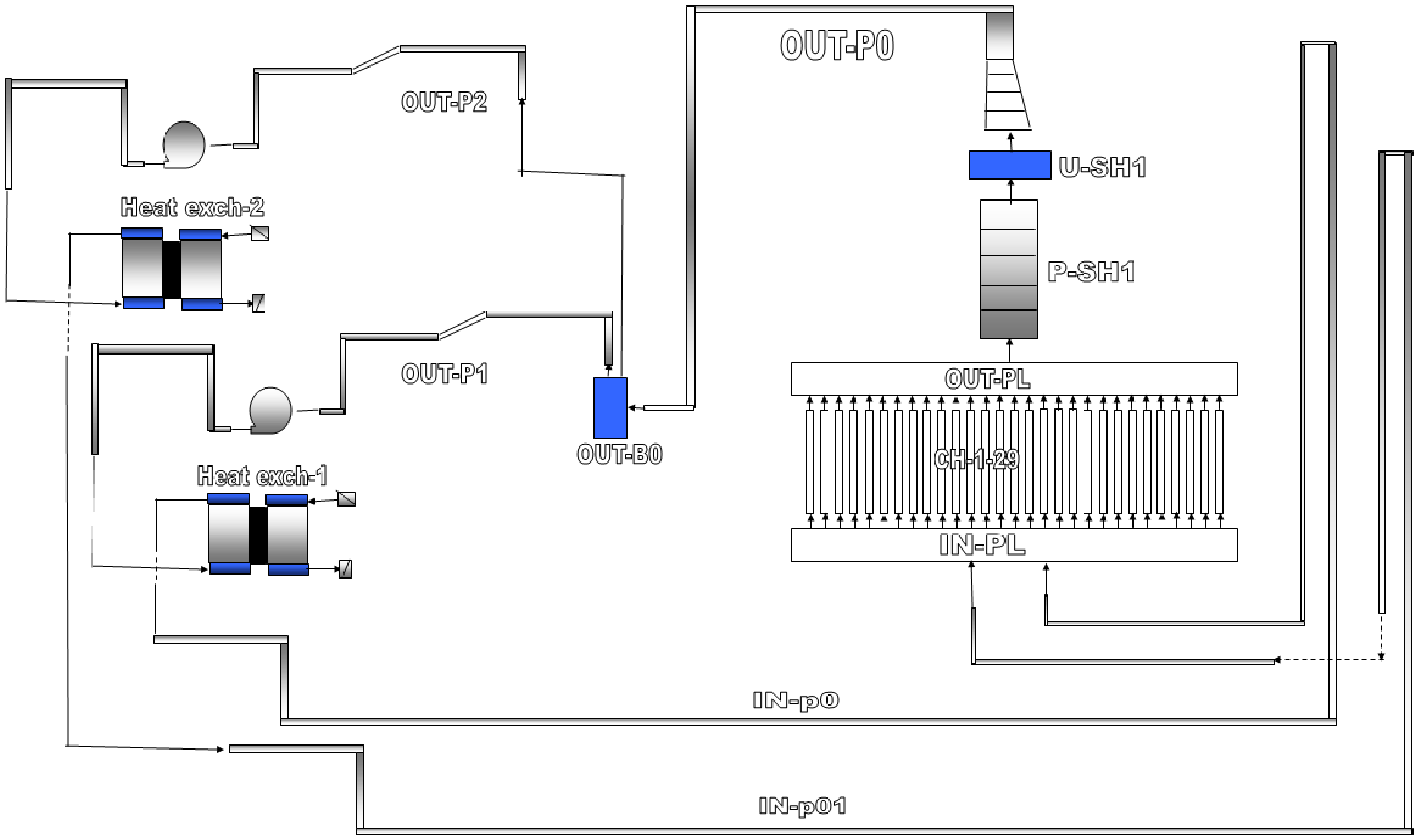
ETRR2 Reactor

MERSAT Nodalization Model



On going IAEA’s-CRP1496 on:
“Innovative Methods in Research Reactor Analysis”

Scope of the Project:

Assessment and qualification of selected computational codes for the application in neutronic, thermal hydraulic and safety analysis of research reactors

Conclusion

- **The performance of standard safety analysis for RR require the establishment of qualified deterministic safety analysis code (TH-system code& 3-D Neutronic)**
- **IAEA could start an initiative to set up such SAC !**

Proposal for possible working program

Development Phase:

- **Establishing a technical working group to initiate the development program (adopting modular structure),**
- **Utilizing the experience in restructuring the advanced codes like RELAP, ATHLET, CATHARE,…with emphasis on 3DN**

Conclusion

Testing and Verification:

- IAEA's WG and selected teams in MS,

Validation:

- Establishing a robust validation matrix using RR data base,
- Distribution to MS for initial test to receive feedbacks and recommendations,
- Establishing and freezing the first version: accumulating user recommendations for periodical updating,

Conclusion

This effort could support the standardization of SA of RR resulting in:

- **Improve the performance and utilization of RR especially in developing countries,**
- **Enhance the safety culture in MS by exchange of experiences in RR safety analysis,**
- **Open possibility to simulate combined event sequences (lesson learned from F-D accident).**