NERS 551
Nuclear Reactor Kinetics

4-8-2011

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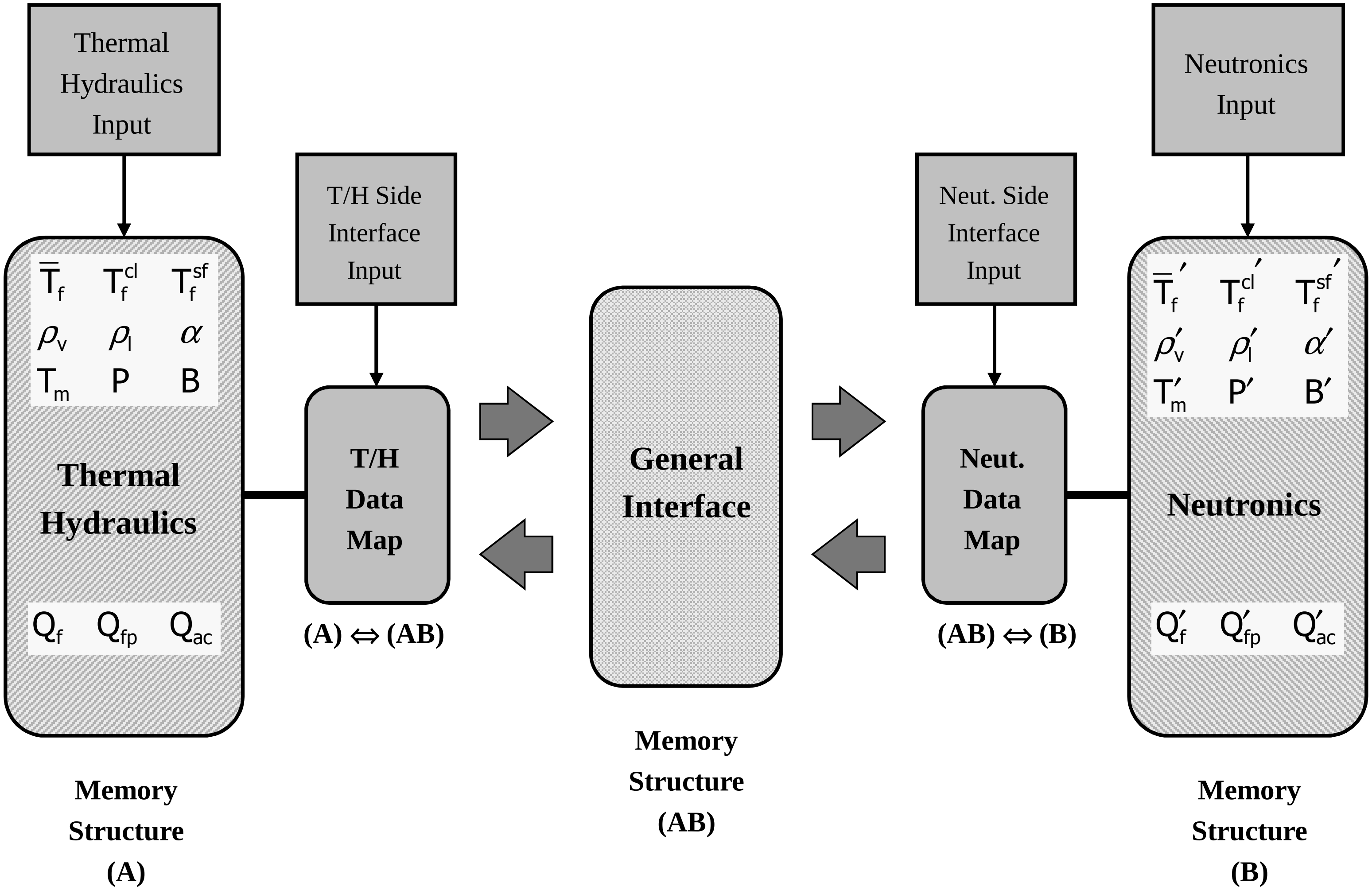
Outline for Today's Class

- Neutronic/Fluid Coupling
- Data transfer and Mapping
- Notes on PVM
- Coupled calculation procedure
- MSLB

Neutronic/Thermal-Hydraulic Code Coupling



Calculation Control

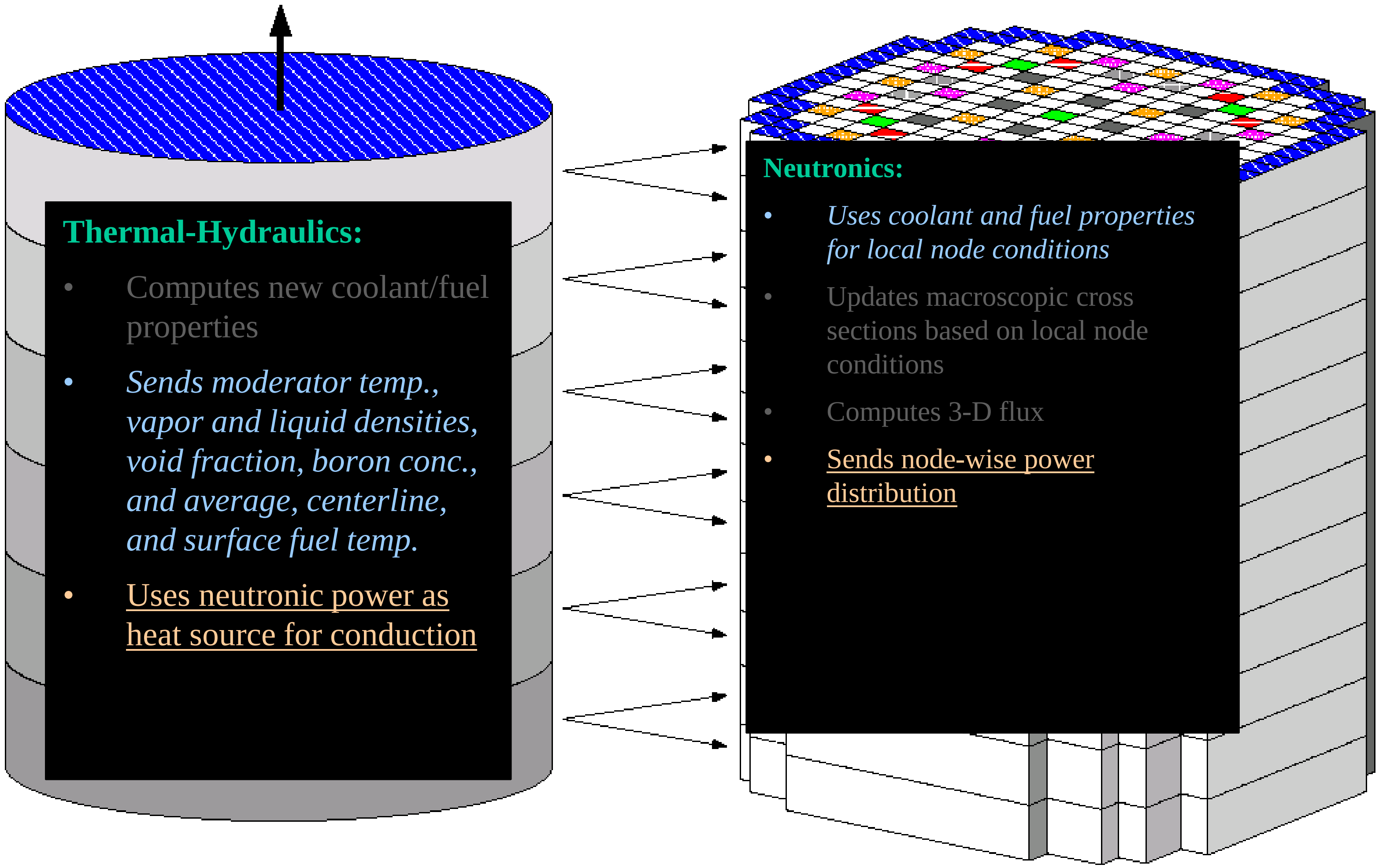
Initialization

T/H-Specific Data Map Routine (THDMR)		General Interface (GI)		Neutronics-Specific Data Map Routine (NDMR)
recv GI ID	←	broadcast GI ID	→	*recv* GI ID
send T/H ID	→	*recv* T/H ID		
		recv Neut. ID	←	*send* Neut. ID
		recv **Neut. Buffer**	←	***send*** **Neut. Buffer**
recv **Neut. Buffer**	←	***send*** **Neut. Buffer**		
send **T/H Buffer**	→	***recv*** **T/H Buffer**		
		send **T/H Buffer**	→	***recv*** **T/H Buffer**
		recv 2 perm. matrices	←	*send* 2 perm. matrices

Calculation Control

	THDMR		GI		NDMR
T/H-to-Neutronics Mapping	***send*** **T/H Buffer**	→	***recv*** **T/H Buffer**		
	send **unpermuted T/H Vector**	→	***recv*** **unpermuted T/H Vector**		
			< Permute Vector >		
			send **T/H Buffer**	→	***recv*** **T/H Buffer**
			send **permuted T/H Vector**	→	***recv*** **permuted T/H Vector**
Neutronics-to-T/H Mapping			***recv*** **Neut. Buffer**	←	***send*** **Neut. Buffer**
			recv **unpermuted Neut. Vector**	←	***send*** **unpermuted Neut. Vector**
			< Permute Vector >		
	recv **Neut. Buffer**	←	***send*** **Neut. Buffer**		
	recv **permuted Neut. Vector**	←	***send*** **permuted Neut. Vector**		

Spatial Coupling



General Idea of Spatial Mapping

- Mapping determines
  - where to deposit NK node power in the T/H node
    - Part of NK power goes to TH cell for direct moderator heating
    - Part of NK power goes to HS cell for fuel heat source
  - where to deposit TH cell properties in NK code
    - T/H and HS sends temperatures/densities feedback to NK node
- Weight specifies the fraction of the total neutronic power generated in a particular node that is deposited into its associated TH and HS cell
- Weights are geometric volume fractions determined by what fraction of neutronic node lies in the volume of corresponding TH and HS cell

Important notes on mapping

- Sum of weights for each neutronic node MUST sum up to 1.0
- All neutronic nodes have to be mapped somewhere in the T/H code
- Mapping non-conforming meshes is possible, but makes mapping difficult, for example very coarse T/H mesh to very fine neutronic mesh

Reflector mapping

- Radial reflector:
  - additional heat structure with no power mapped to the TH (bypass) channel should be used
- Axial reflector
  - Heat structures should have additional axial elevation, but the upper and lower ones will have no power (representing axial reflector for mapping)
  - TH-channels should also have additional axial elevations but only from 2 to N-1 represents the active core

MAPTAB format: RELAP5

- NRC didn't want to include it in the manual, so the only guide is from sample problems
- RELAP5 MAPTAB format is much easier than TRACE

```
%DOPL
   same as TRACE
%TRIP
   same as TRACE
%TABLE1
   pipe_cell_number  PARCS_node   weight
%TABLE2
   hs_cell_number             PARCS_node   weight
```

Coupled calculation procedure

- 3-step procedure
  - 1. Steady-state **stand-alone** T/H calculation
  - 2. Steady-state **coupled** TH-NK calculation
  - 3. Transient **coupled** TH-NK calculation
  - Reason: develop flow and good initial guess for fuel and moderator temperature before starting coupled calculation
- 2-step procedure
  - 1. Steady-state **coupled** TH-NK calculation
  - 2. Transient **coupled** TH-NK calculation
  - Reason: “easy” problems can be coupled even with bad initial guess

Notes on PVM

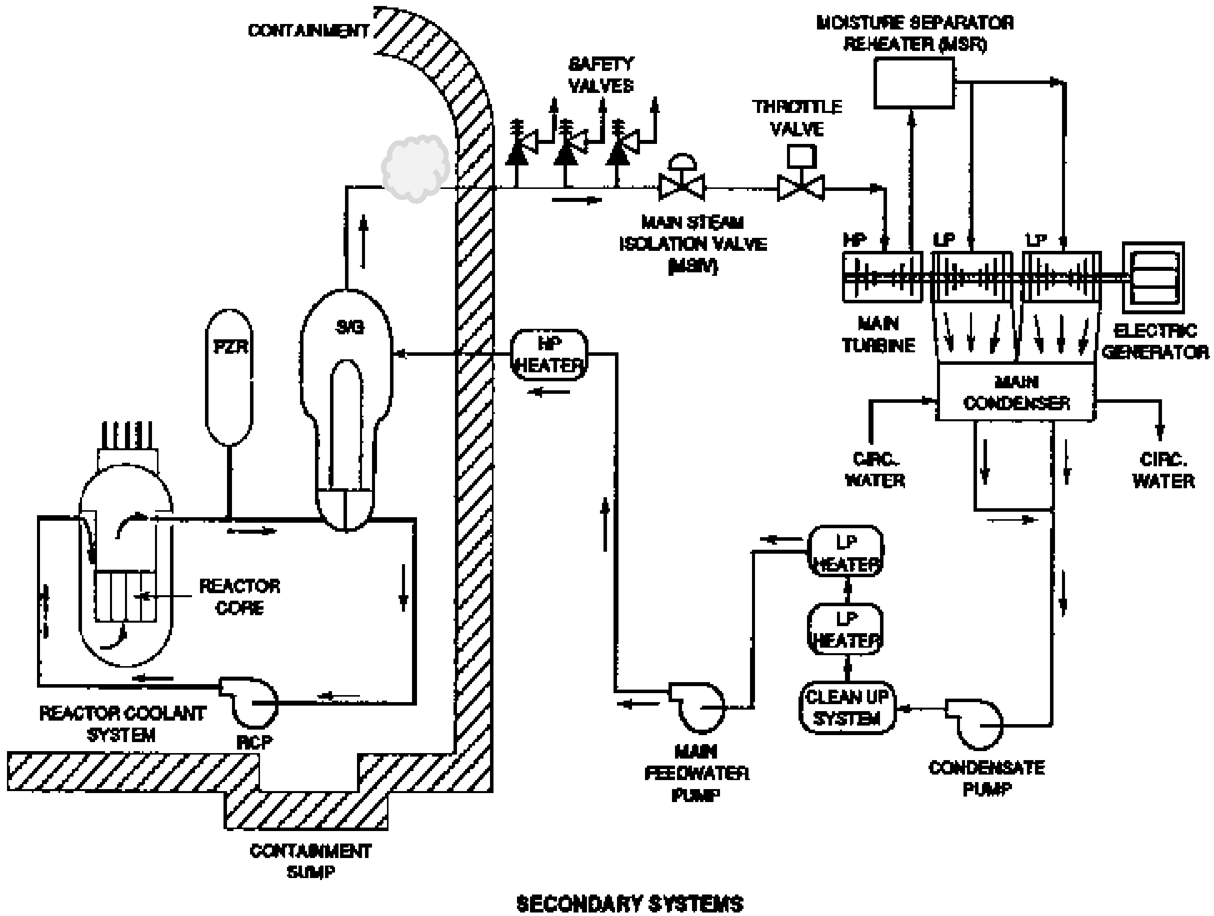
- PVM is necessary to compile PARCS
  - Even the most recent integrated TRACE/PARCS requires PVM for compilation, but NOT for execution
  - This "feature" will be fixed in the future
- PVM 3.4.3 or newer should be used
- PVM will not work properly under Windows if default temporary directory is used!
  - Use simple path for PVM temporary directory, for example:
    - C:\temp
    - C:\tmp
  - And make sure this directories exist!
- PVM can be run as "PVM Console" or "PVM Daemon", I recommend running it as "PVM Console" as it is easer to monitor PVM status
- PVM Console has to be shut down with "halt" command, otherwise, follow procedure below to fix PVM problems
- If you get PVM errors during coupled run, do following:
  - Reboot computer
  - Go to PVM's temporary directory (C:\temp or C:\tmp)
    - Exact path is set by PVM_TMP environment variable
  - Remove "pvmd.*" and "pvml.*" files
  - Reboot computer
  - Start "PVM Console"

OECD/NEA MSLB Benchmark

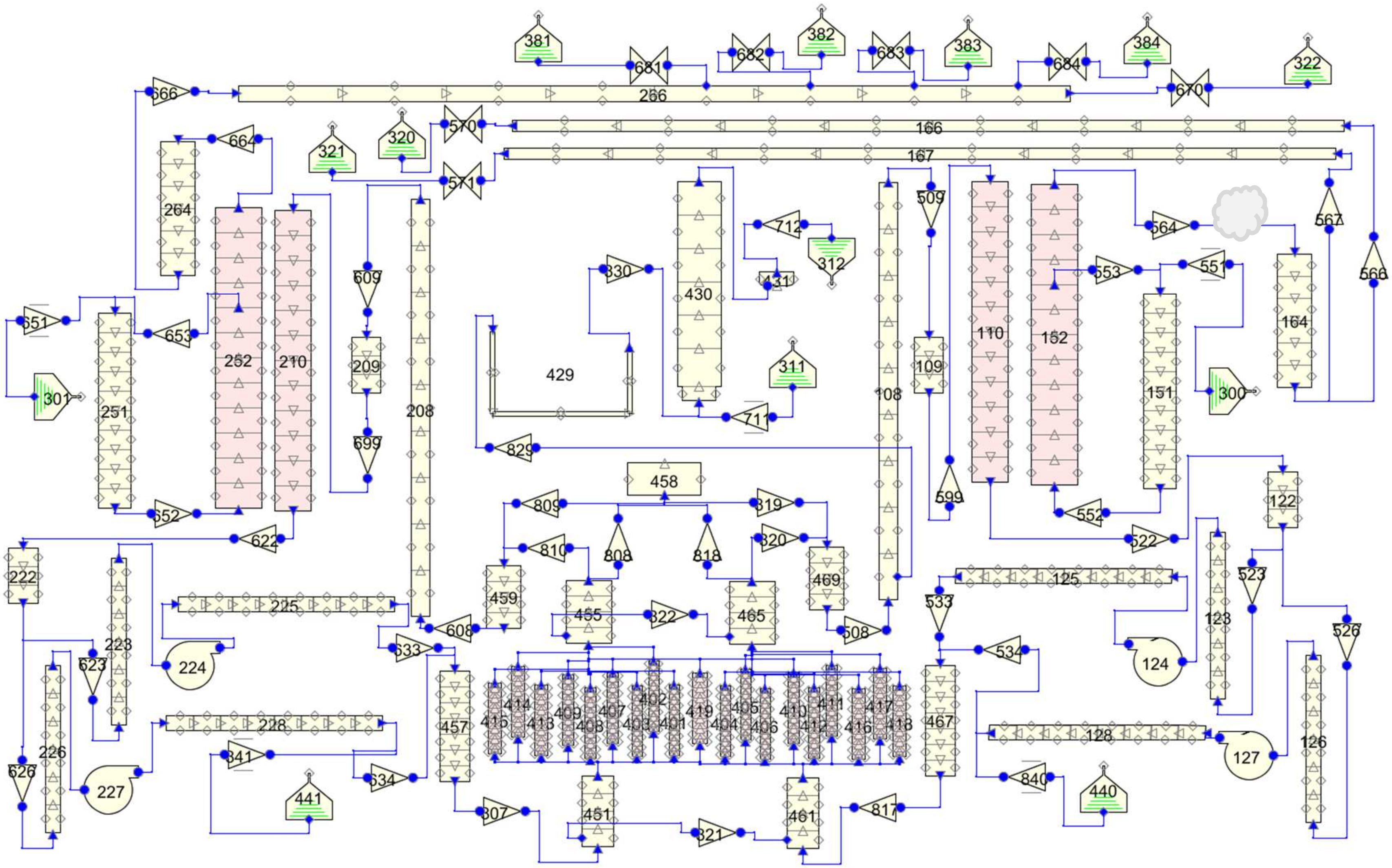
- Based on B&W TMI1 reactor in Pennsylvania, a PWR
- Accident Scenario
  - Break of a Main Steam Line in a Secondary Loop
  - Sudden (Secondary Side) Pressure Decrease in Steam Generator
  - Enhanced Heat Removal from Primary to Secondary
    - *Coolant Temperature Reduction in Core Inlet (One Side Only)*
    - Positive Reactivity Feedback / Core Power Increase
    - *High Flux* (114%) *Trip Set Point / Reactor Scram / Highest Worth Rod Stuck*
    - Continuous Coolant Overcooling and Positive Reactivity Insertion
- Distorted Radial Power Distribution Over Time
  - *Over-Cooling in One Side of Core*
  - *Mainly Due to the Stuck Rod Assumption*
  - Requires 3D Kinetics

Nuclear Reactor Transient Analysis: Main Steam Line Break

PWR Plant Schematic



RELAP Model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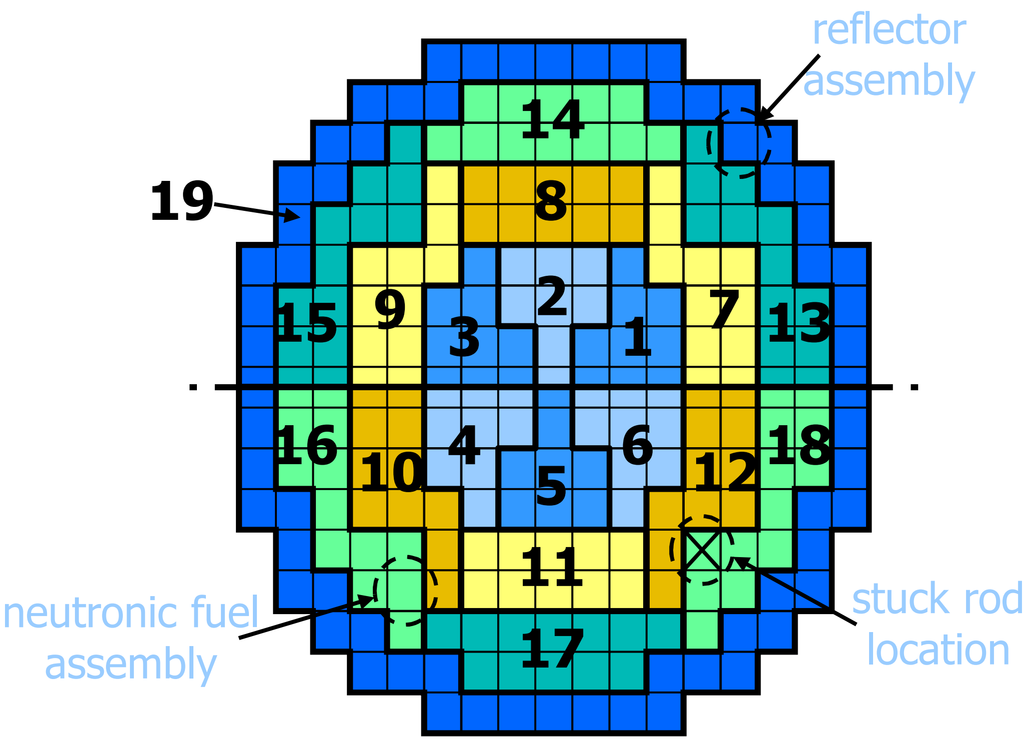
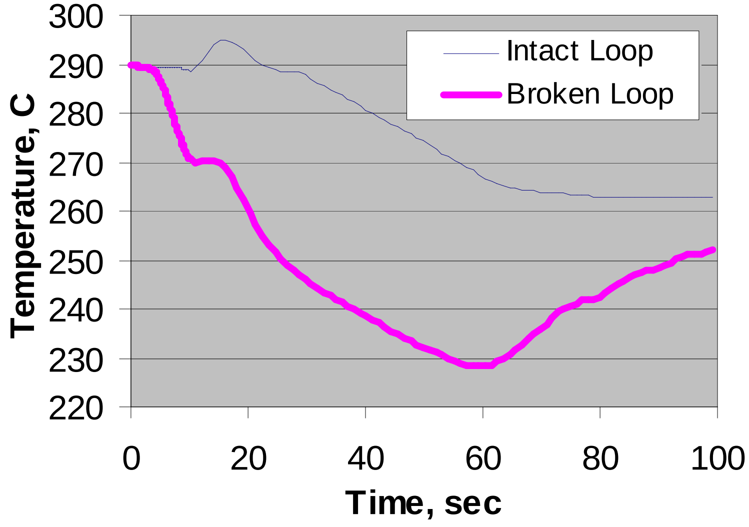
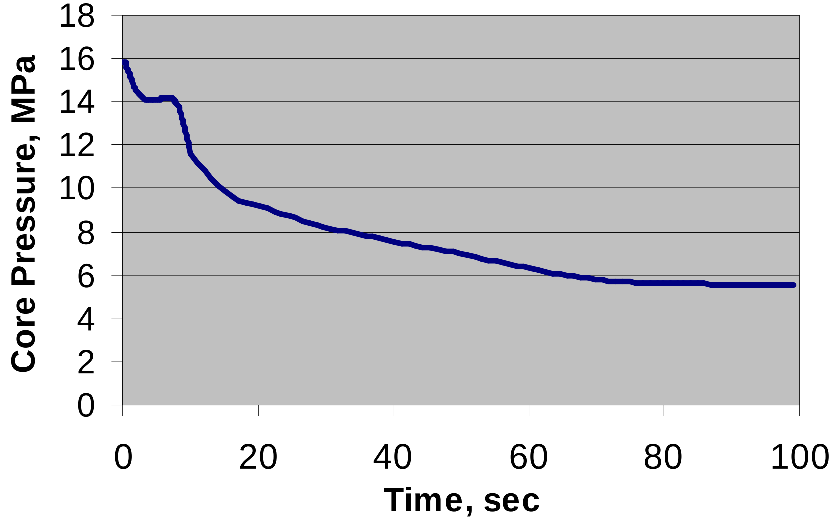
Neutronics Model and Mapping

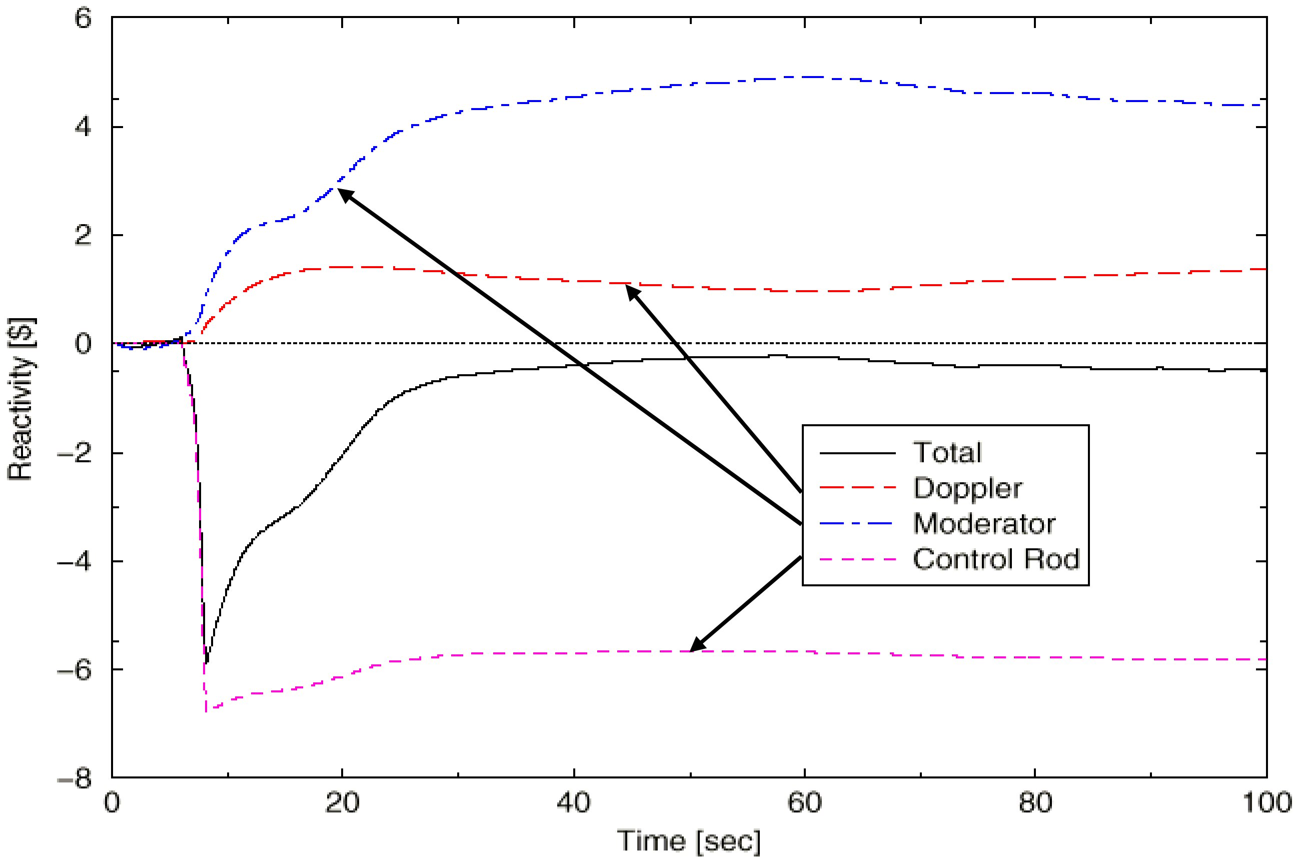


OECD/NEA MSLB Benchmark: Temperature and Pressure



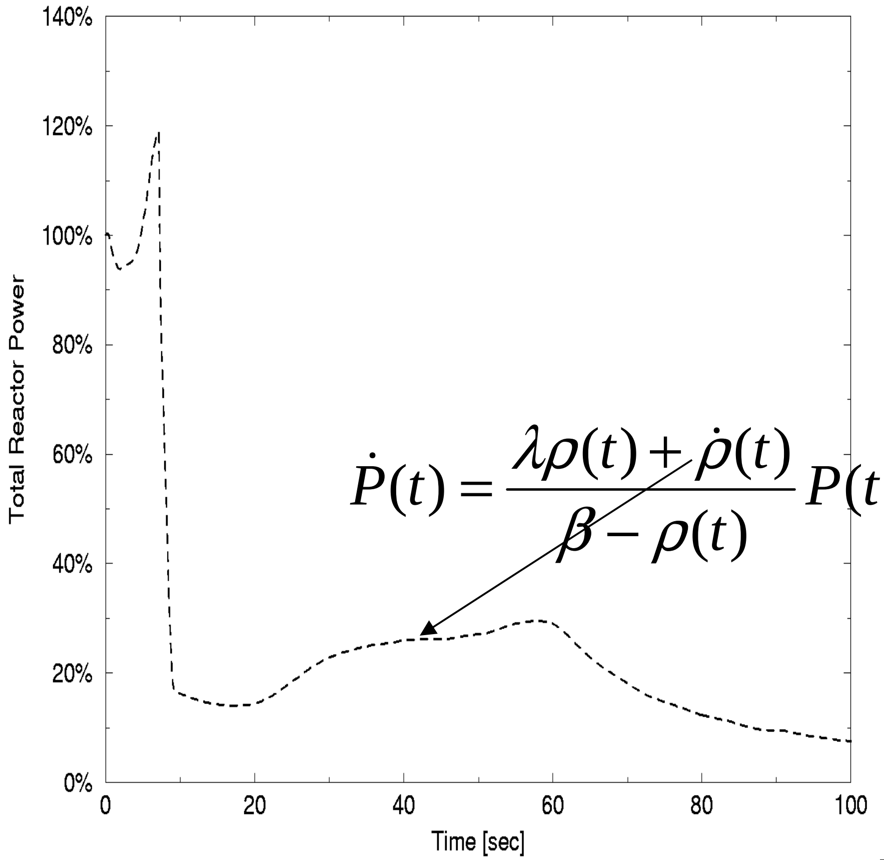


OECD/NEA MSLB Benchmark: Reactivity

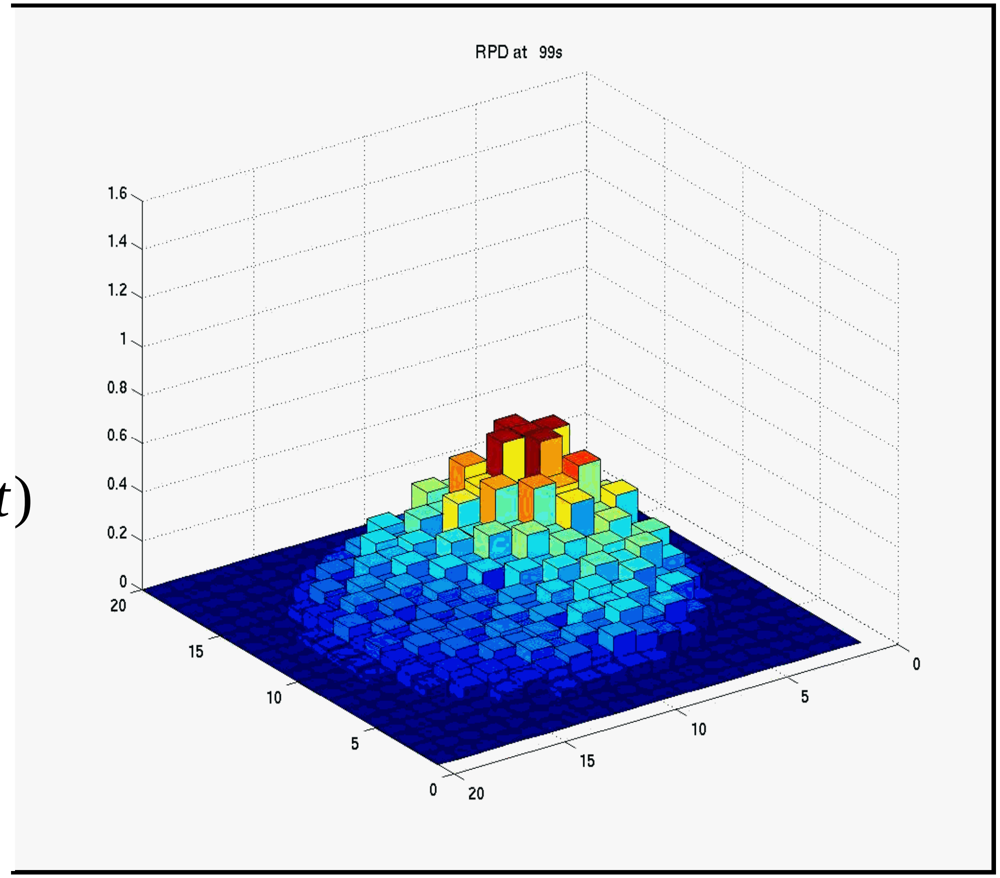


MSLB Transient Analysis

- Radial Power Evolution

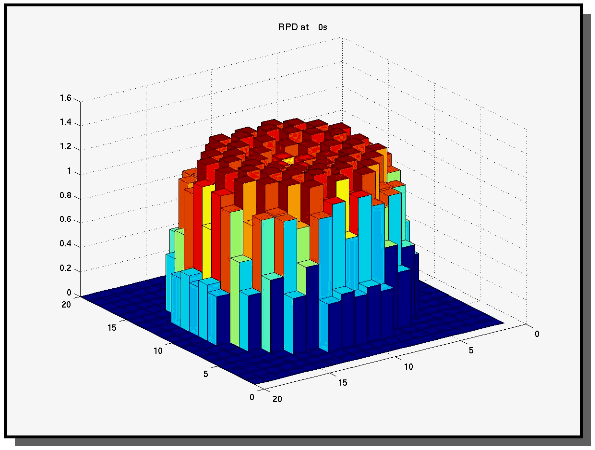


$$\dot{P}(t) = \frac{\lambda\rho(t) + \dot{\rho}(t)}{\beta - \rho(t)} P(t)$$

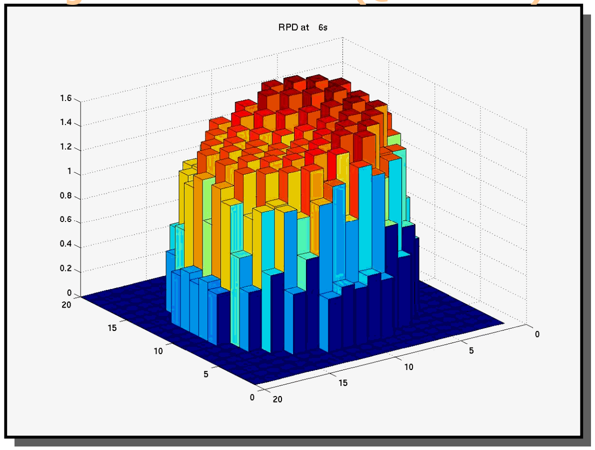


OECD/NEA MSLB Benchmark: Radial Power

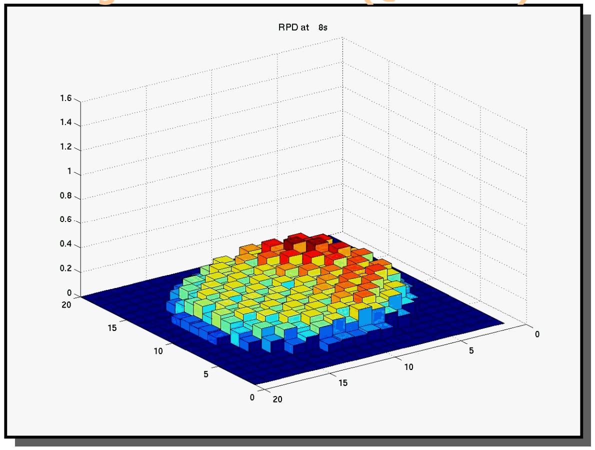
Initial HFP State



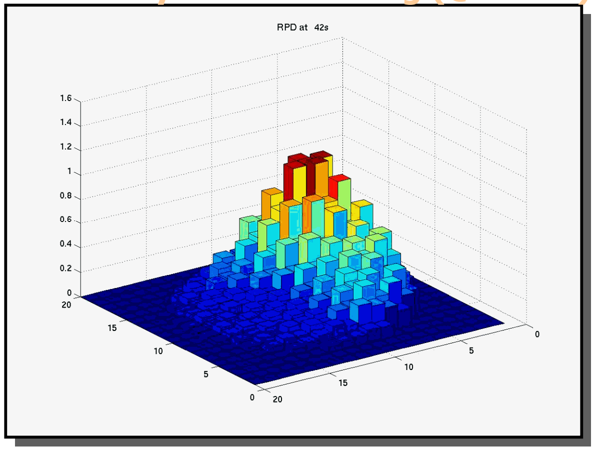
Right Before Scram (@6.03 sec)



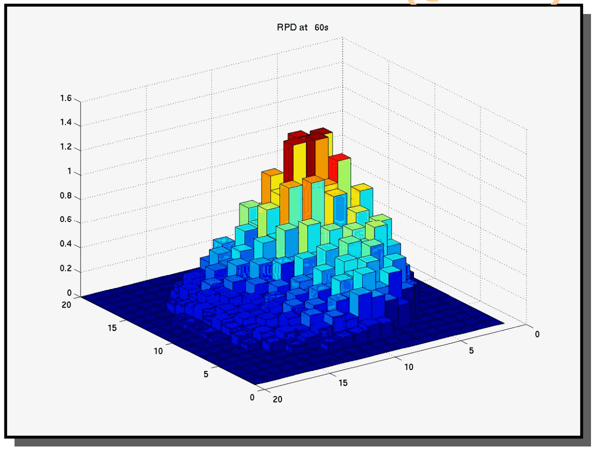
Right After Scram (@8.3 sec)



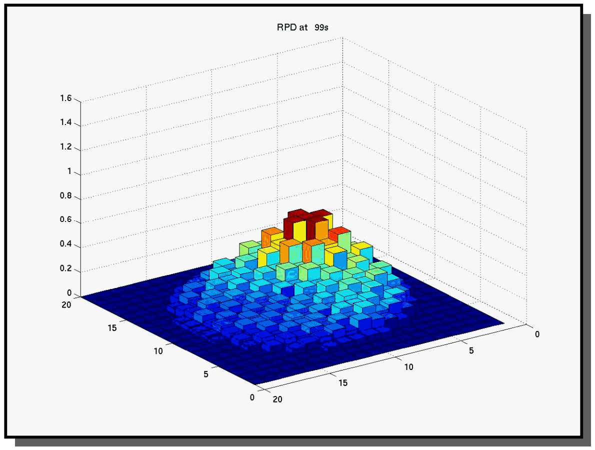
Max. Assy Power Peaking (@42 sec)



Max. Return to Power (@60 sec)

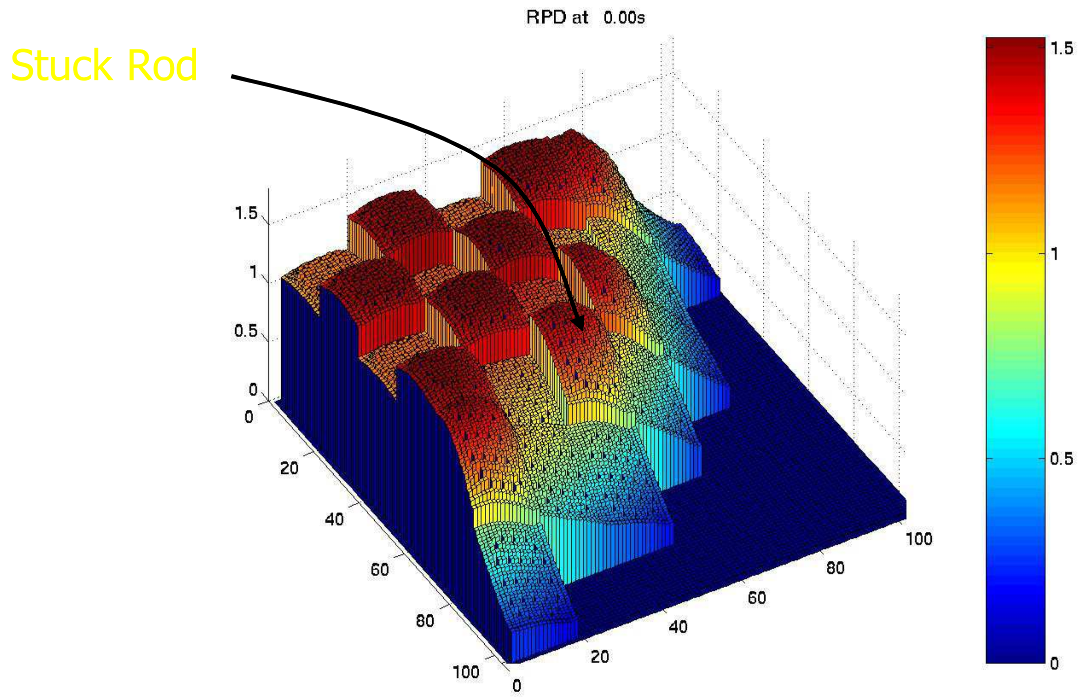


End of Transient



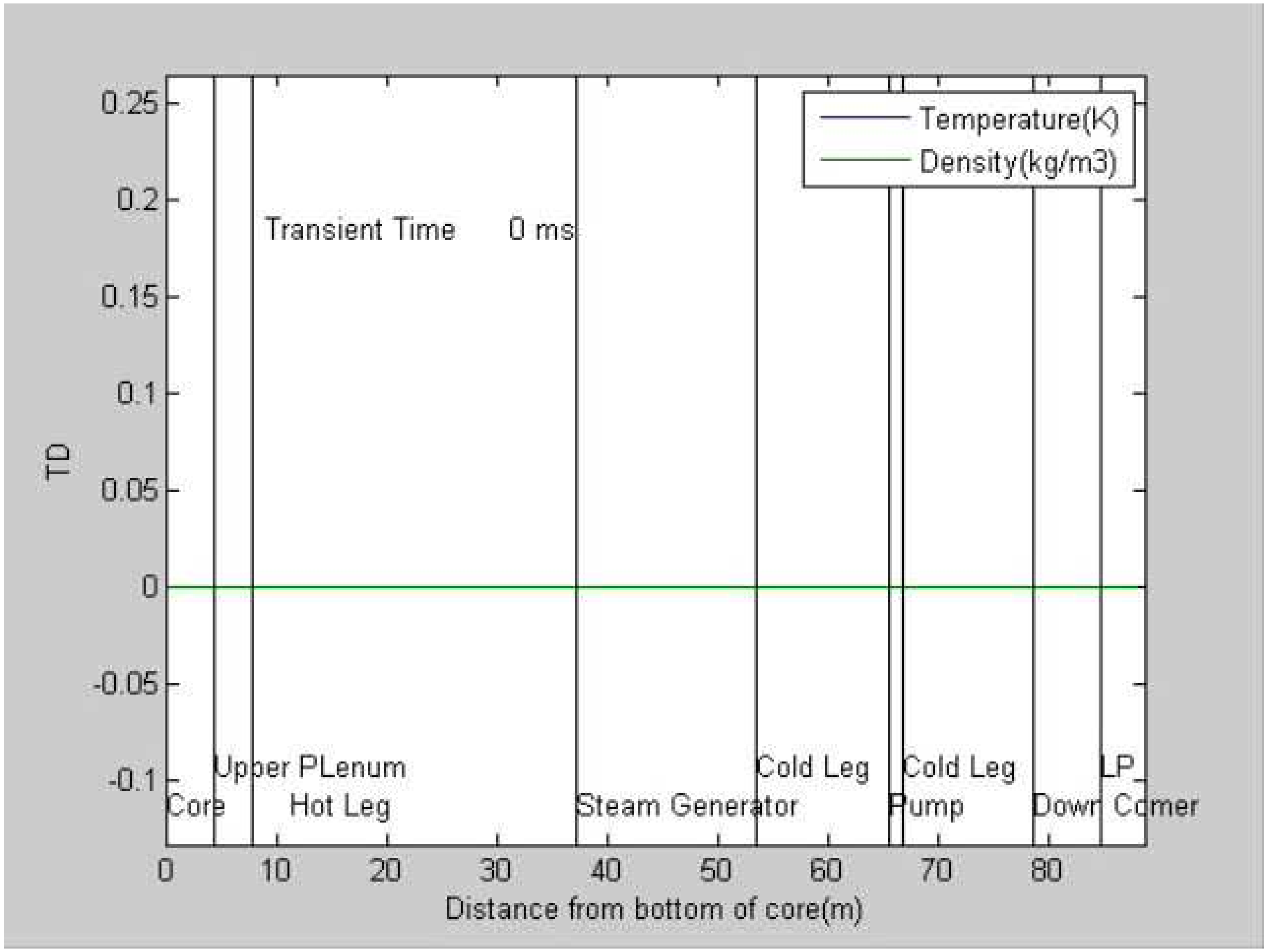
OECD/NEA MSLB Benchmark: Pin Power

- Pin Power in Vicinity of Stuck Rod



OECD/NEA MSLB Benchmark:

- Temperature and Density Change in Primary Loop



OECD/NEA MSLB Benchmark:

- Pressure Change in Primary Loop