AREVA's Activities Related to VHTR Thermal-Hydraulic Analysis Using RELAP5-3D

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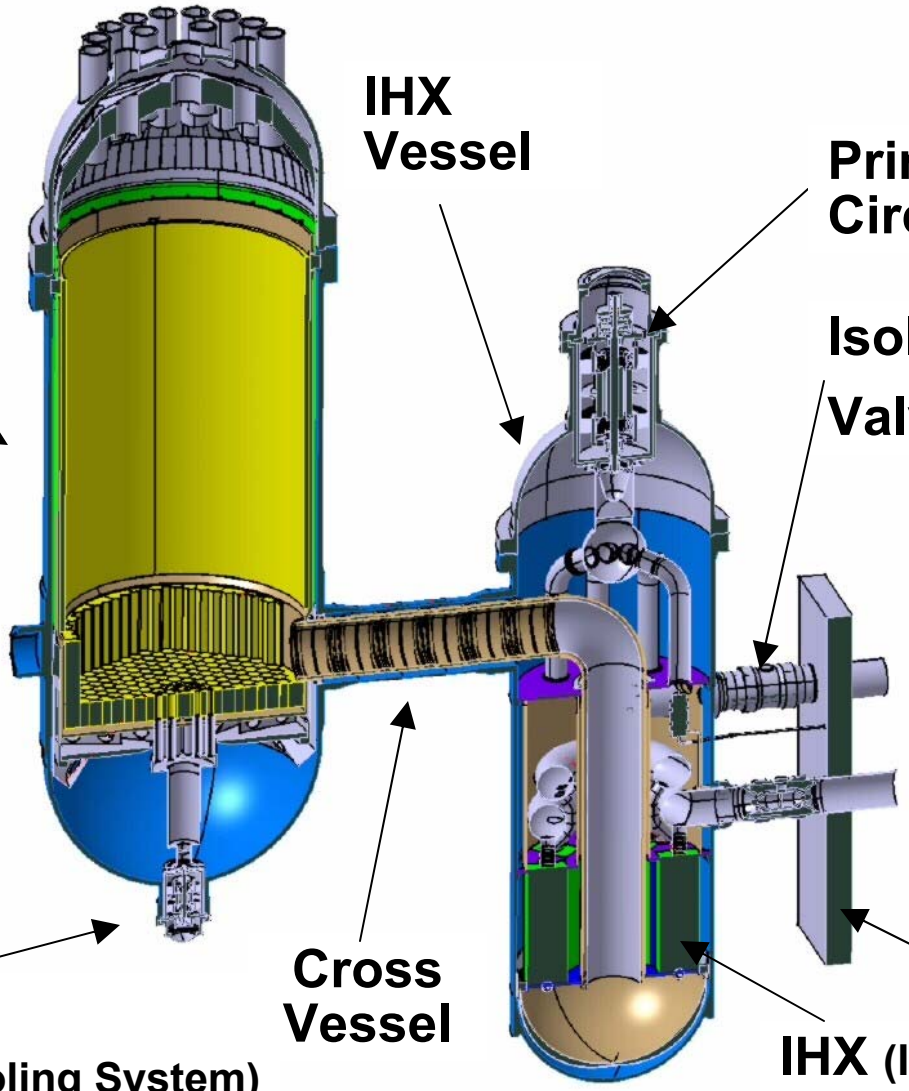
Introduction & Objectives

- ***Tasks:***
  - ***Evaluate RELAP5-3D for VHTR Analyses***
  - ***Provide backup/validation tool for MANTA***
- ***Pursuing CSAU-like methodology approach***
  - ***Develop analysis-based PIRTs (informal).***
    - or from Wilson, et. al., NED, 1992.
  - ***Confirm adequate models and modelling necessary to capture dominant TH phenomena***
  - ***Identify models/methods necessary to complete RELAP5-3D as a sufficient tool to VHTR analysis***

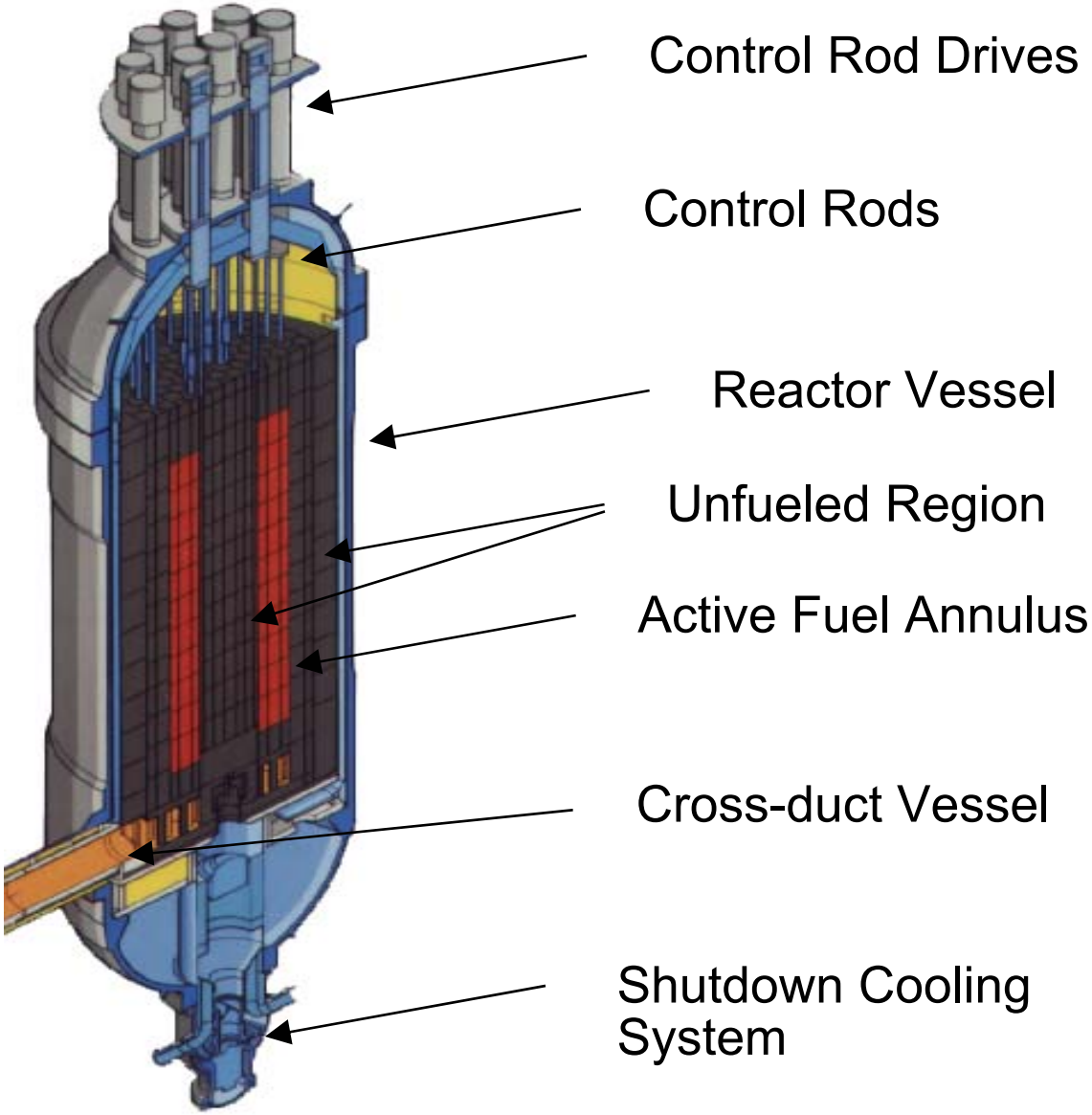
Design Description

- **Prismatic core**
  - **Graphic moderator**
  - **Stacked fuel/graphic compact (no metal)**
  - **Low Power Density**
  - **1000 C outlet temperature (600 C core delta)**
- **Indirect cycle**
  - **Brayton cycle**
  - **Cogeneration for hydrogen production**

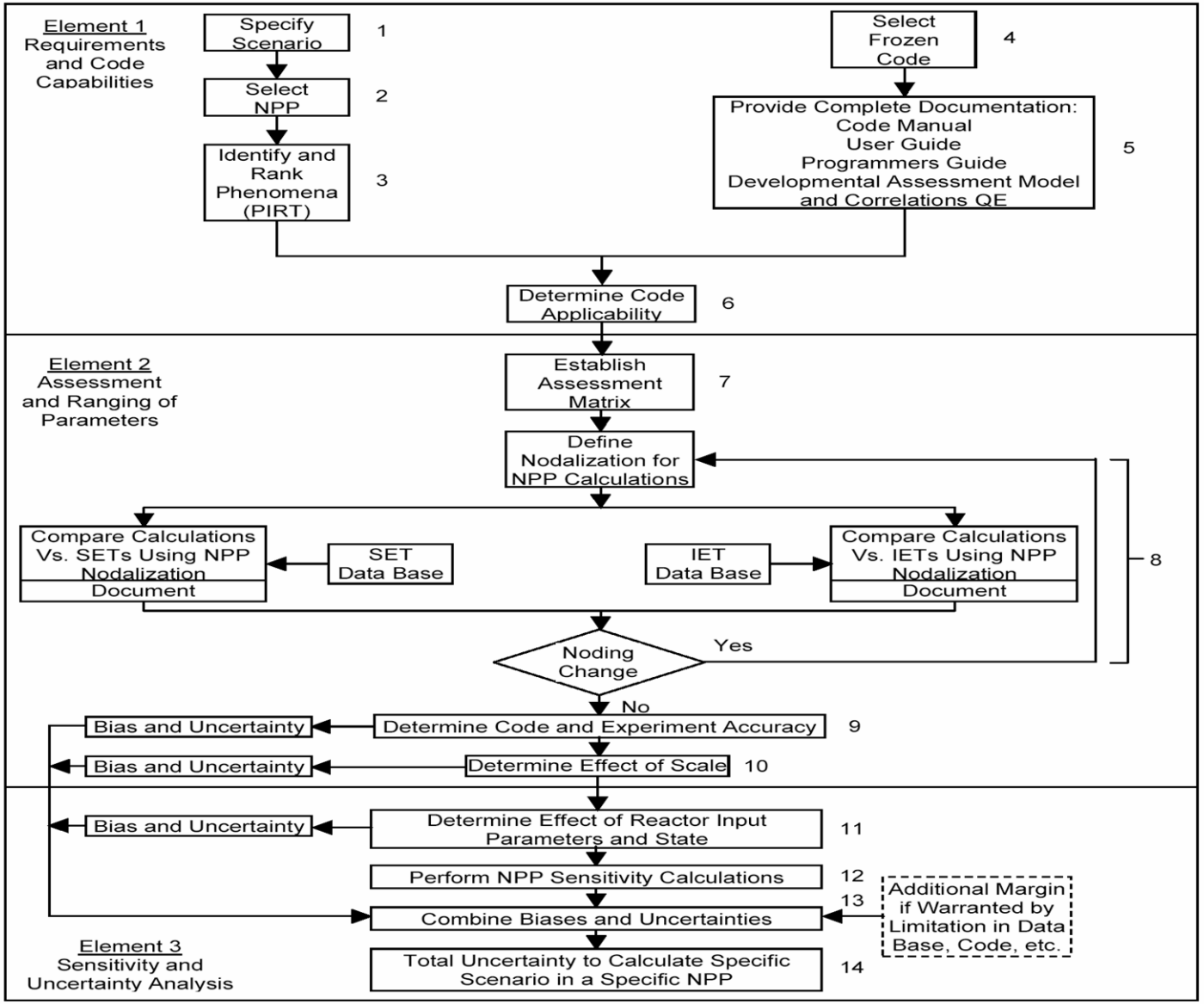
Design Schematic - Pressure Vessels



Design Schematic - RV Internals



CSAU Methodology



Code Selection

- *AREVA is considering*
  - *MANTA - internally developed*
  - *RELAP5-3D - INEL developed*
  - *Others….*

PIRT Development

- Identify processes and phenomena which occur in the system
  - Rank relative to importance for safety, investment or normal operation
    - Fuel temperature (< ~1600 C) & vessel integrity (pressure)
    - Component temperature and pressure response considered for selection of design materials
    - Control system, system optimization, RPS setpoints, etc.

Description of Phenomena

- Power
  - Neutronics
  - Decay heat
  - Distribution
  - Gamma heating
- Fluid flow
  - Distribution
  - Multi-dimensional
  - Multi-constituent
  - Compressible fluid properties
  - Pump/Circulator/Turbo Machinary Characteristics
- Heat Transfer
  - Stored energy
  - Gap conductance
  - Conduction
  - Natural convection
  - Forced convection
  - Radiation
- Others
  - Contaminants/Water Ingress (Corrison/Oxidation)
  - Control systems

PIRT Example: Loss of Load (Key Measures: Core and IHX Temps)

Component	Phenomena	Reactor Trip	Circulator Trip	Load change	Loss of Load
Core	Neutronics	NLMH	NLMH	NLMH	NLMH
Core	Decay Heat	NLMH	NLMH	NLMH	NLMH
Core	3D Power Distribution	NLMH	NLMH	NLMH	NLMH
Core	3D Flow	NLMH	NLMH	NLMH	NLMH
Core	Gamma heating	NLMH	NLMH	NLMH	NLMH
Core	Stored Energy	NLMH	NLMH	NLMH	NLMH
Reflector	Conduction	NLMH	NLMH	NLMH	NLMH
Reflector	Radiation	NLMH	NLMH	NLMH	NLMH

Code Applicability

- Determine whether or not RELAP5-3D able to address scenario of interest
  - Compare the documented models and code numerics against the PIRT table.

Phenomena	Code A	Code B	Code C	Code D
Neutronics	Yes	Yes	No	Yes
Decay Heat	Yes	TBD	Yes	TBD
3D Power Distribution	Yes	Yes	TBD	No
3D Flow	Yes	TBD	No	No
Gamma heating	Yes	Yes	Yes	TBD
Stored Energy	Yes	TBD	TBD	Yes
Conduction	Yes	Yes	No	Yes
Radiation	Yes	TBD	Yes	TBD

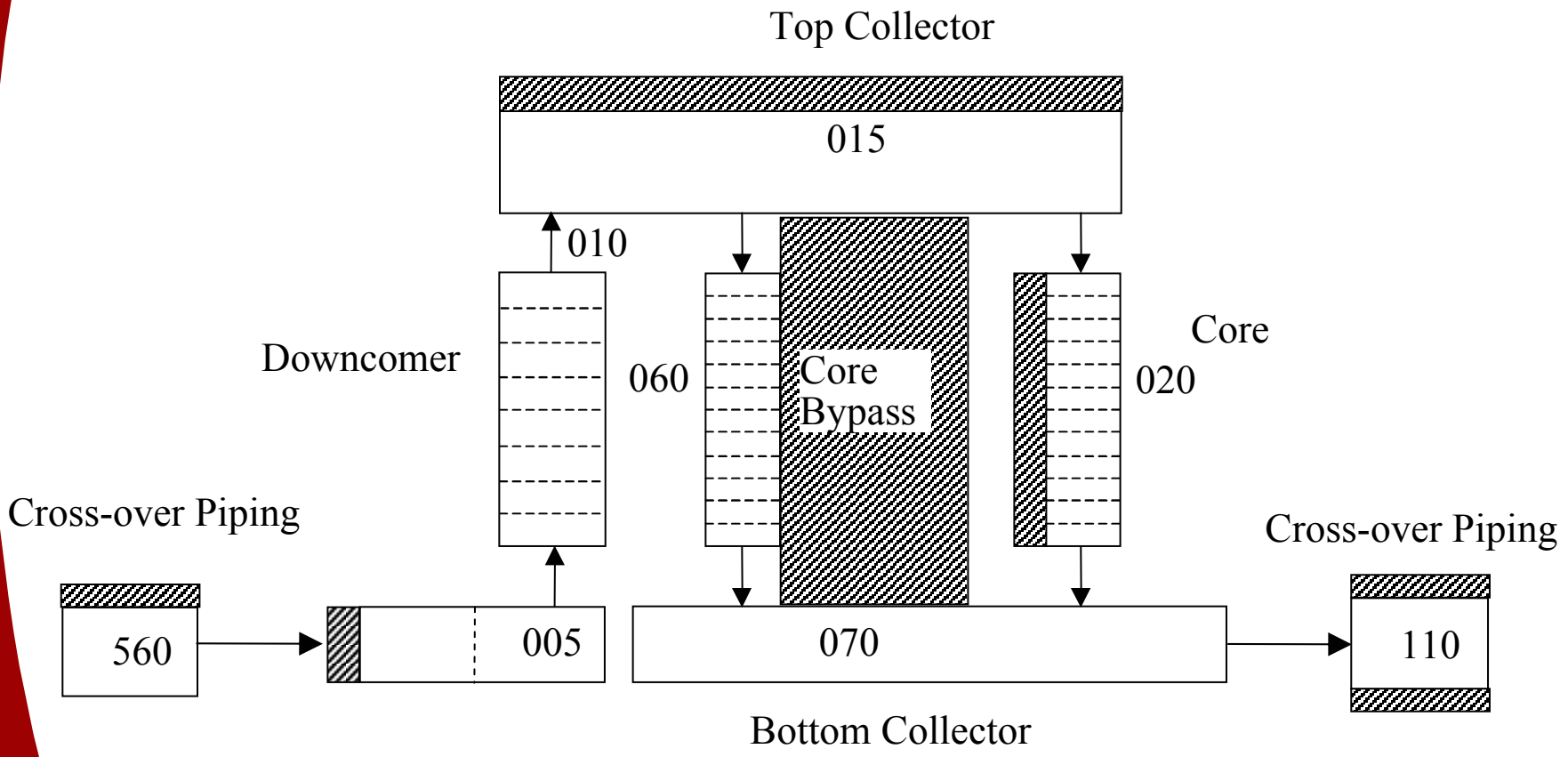
Establishment of Assessment Matrix

- Code assessment shows the capability and accuracy of the codes to predict the actual phenomena
- Integral Test Programs
  - EVO (Germany)
  - HTTR (Japan)
  - Fort Saint Vrain
  - PBMR Micromodel
- Separate Effects
  - Internal component testing
  - Space/Fusion Rx R&D ????

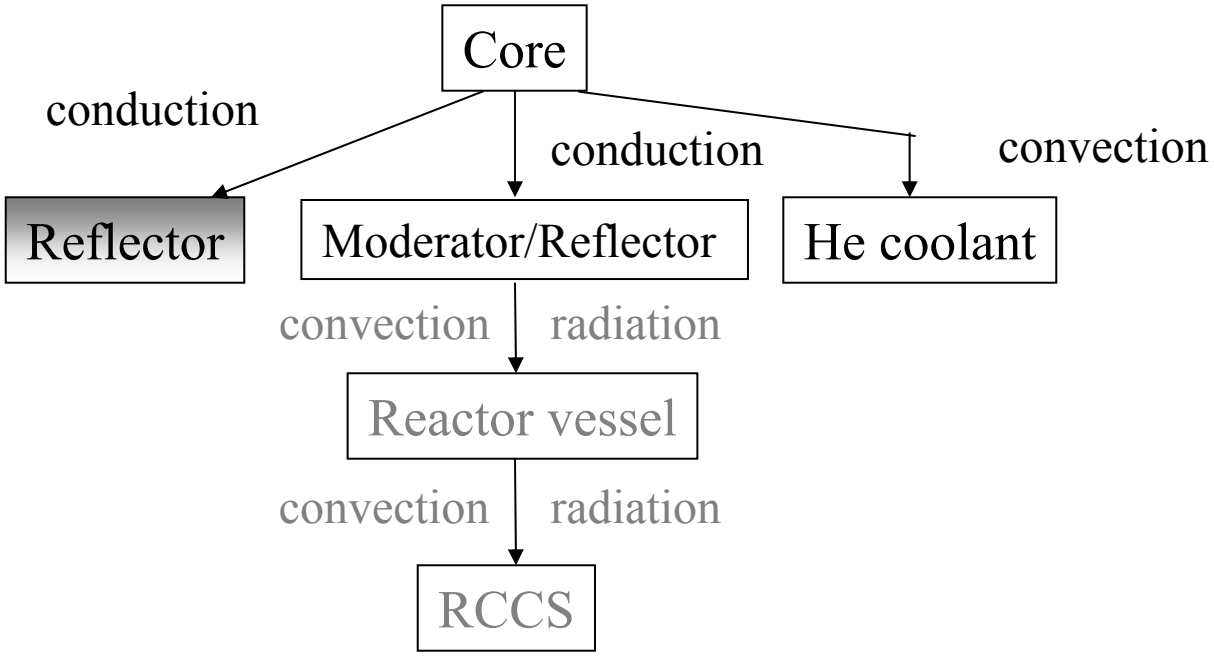
Model Development

- *Follow CSAU step 8*
  - *Primary Circuit only for most studies*
  - *Secondary and Tertiary loops later in 2004*
  - *Main objectives*
    - *Support NPP characteristics*
    - *Preserve dominant phenomena*
    - *Minimize code uncertainty*

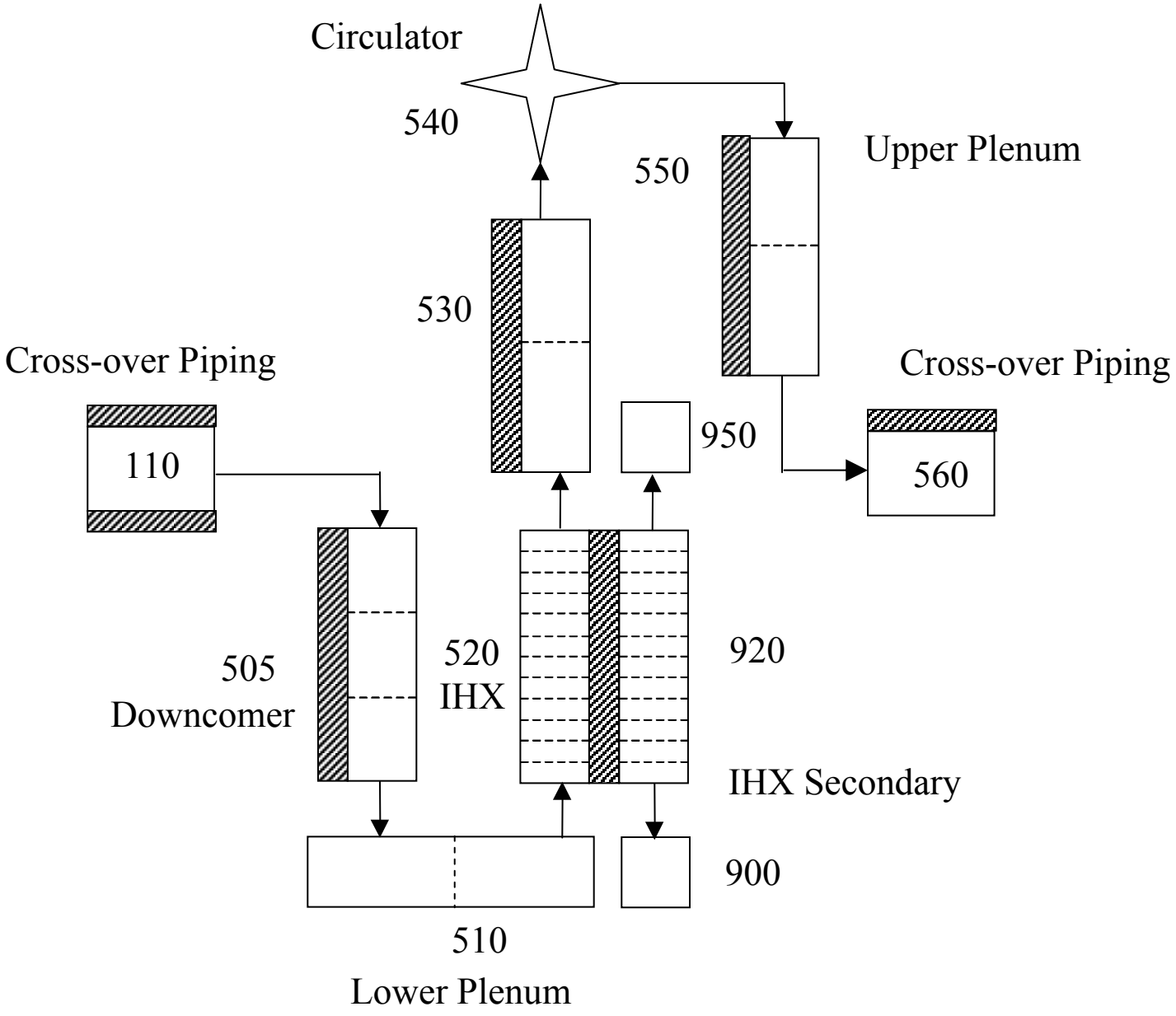
VHTR Vessel Hydraulic Nodalization



Heat Transfer Modeling for Short-term transients



VHTR IHX Nodalization



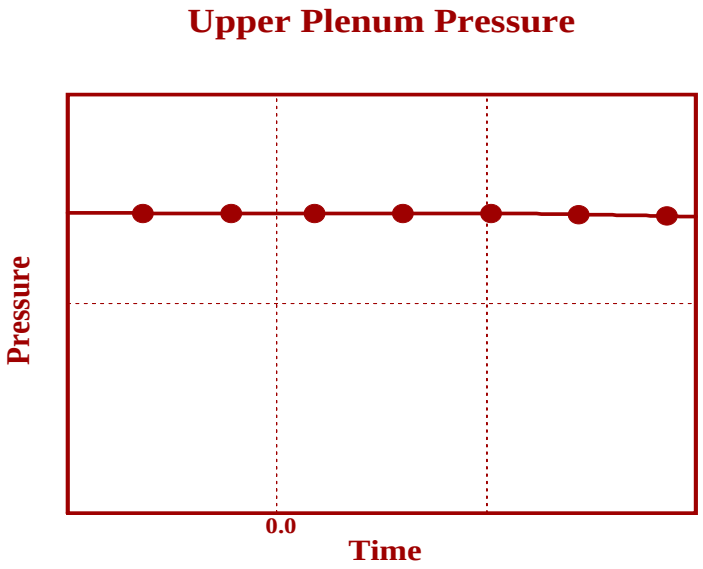
Scoping Studies

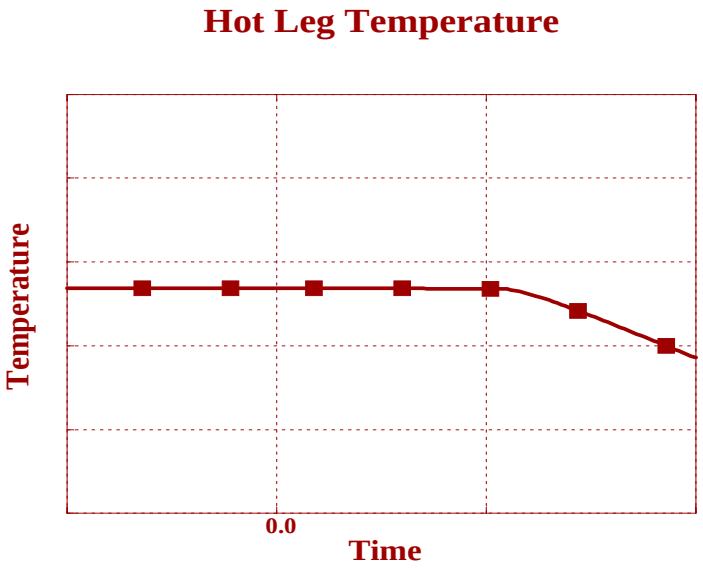
- ***Currently for model shakedown activities***
  - ***Steady-state***
  - ***Null Transient/Reactor Trip***
  - ***Circulator Trip (Loss of Flow)***
  - ***Load Follow/Reactor Trip***
  - ***Loss of Load***
- ***Benchmark vs. MANTA***
- ***Perturbation studies***
  - ***PIRT studies***
  - ***Process studies***

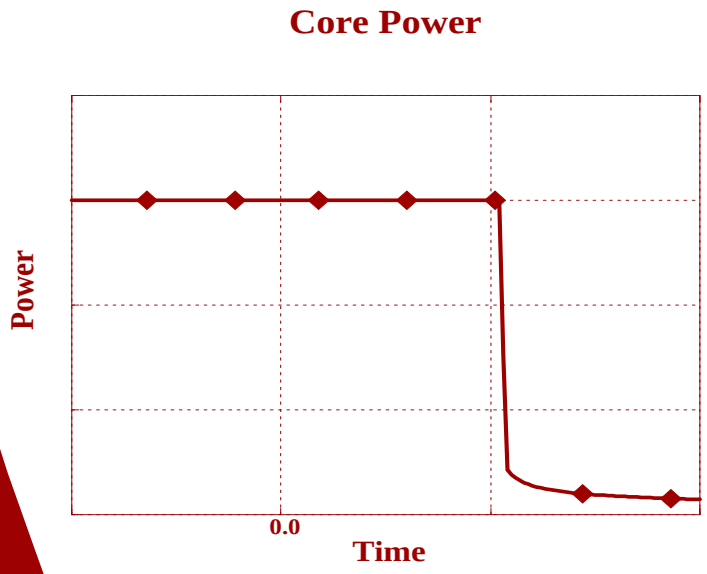
Steady-state

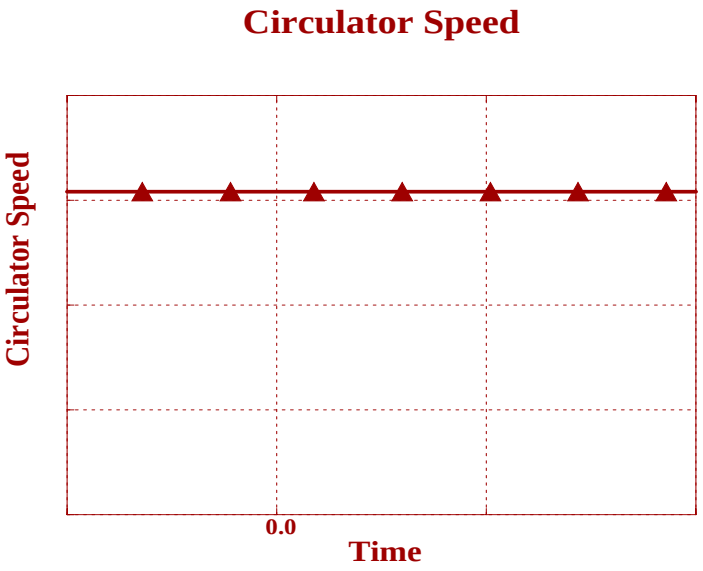
Parameter	Target	RELAP5
Power (MW)	600	600
Rx Outlet Temp (°C)	1000	994
Rx Inlet Temp (°C)	400	394
Primary Flow Rate (kg/s)	192	193.6
Primary Pressure (MPa)	5	5.02
Max Fuel Temp.	1300	1475
IHX Sec. Inlet Temp (°C)	342	342
IHX Sec. Outlet Temp (°C)	950	944

Null Transient/Reactor Trip

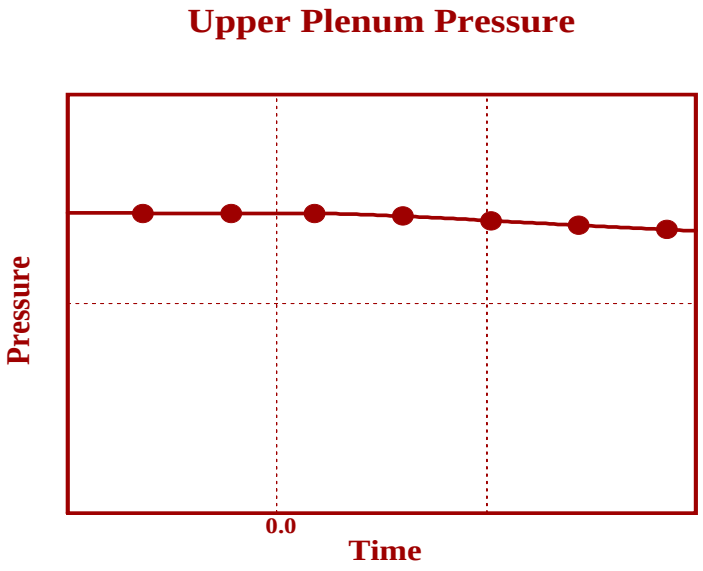


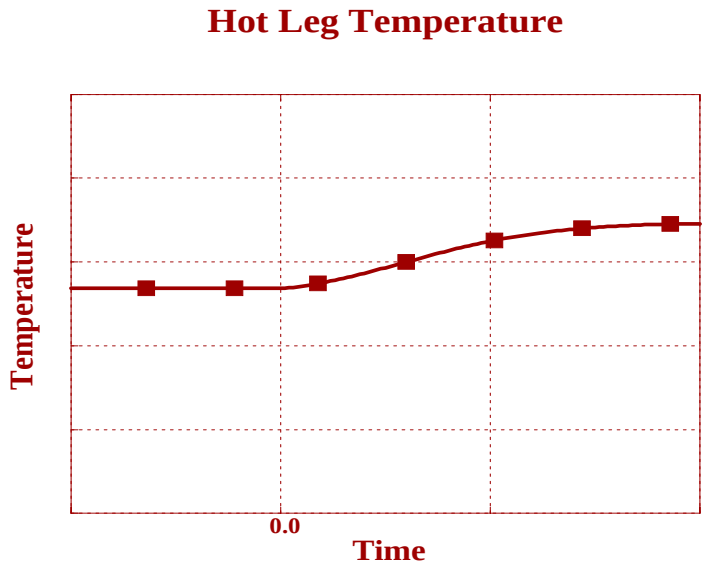


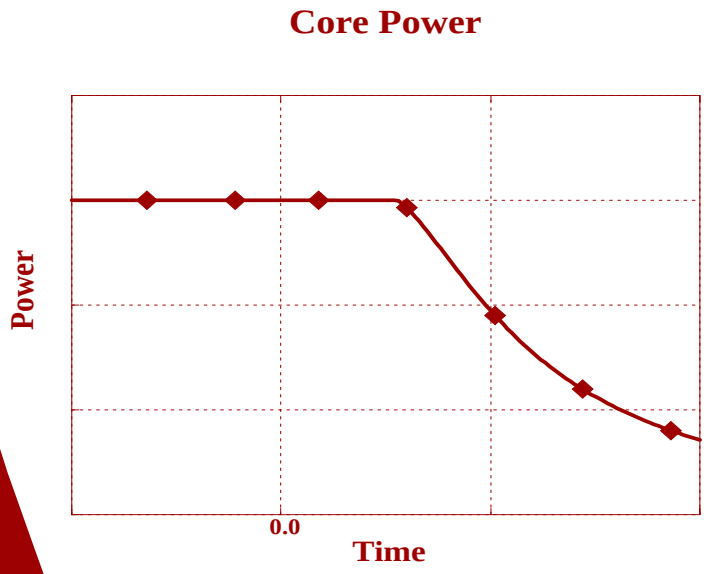


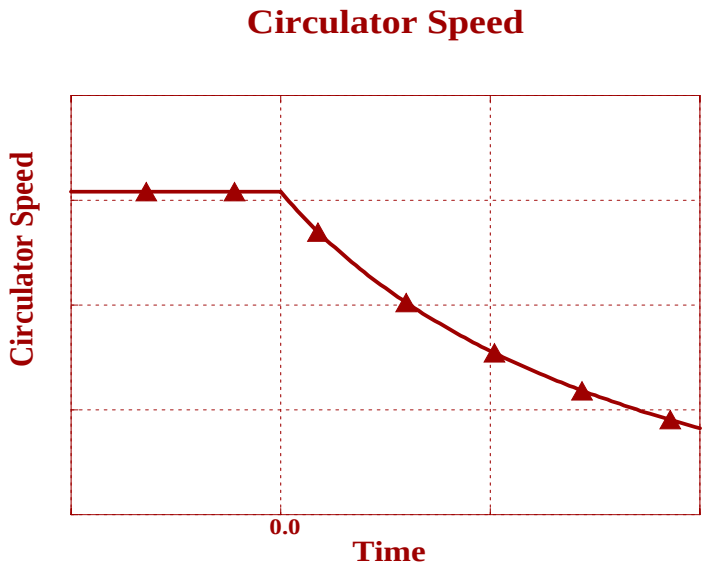


Circulator Trip

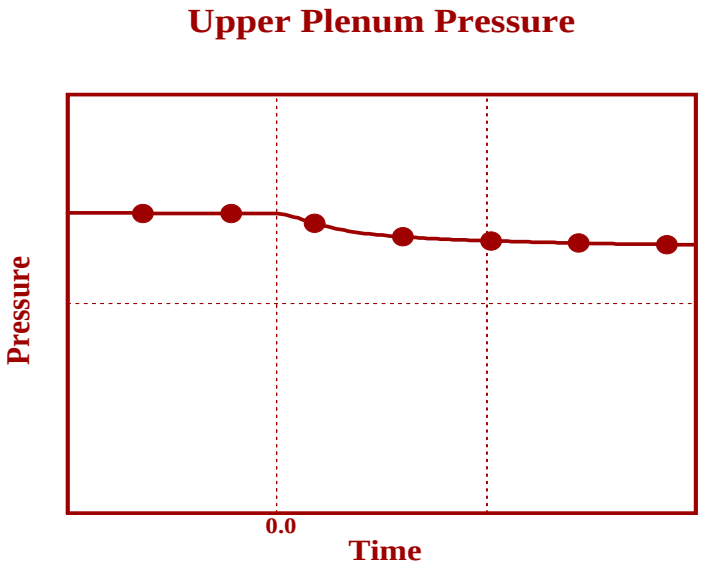


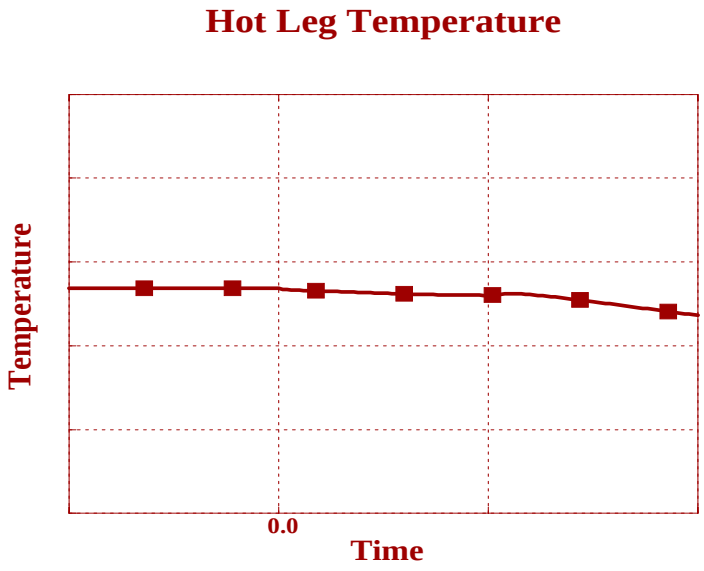


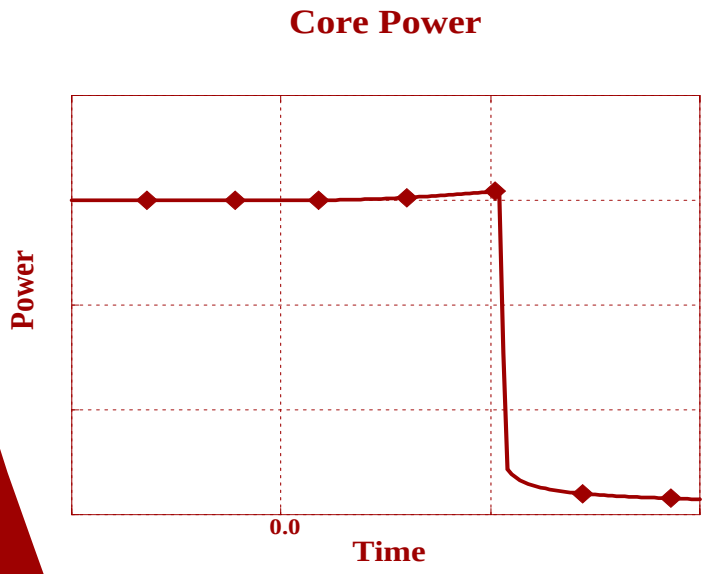


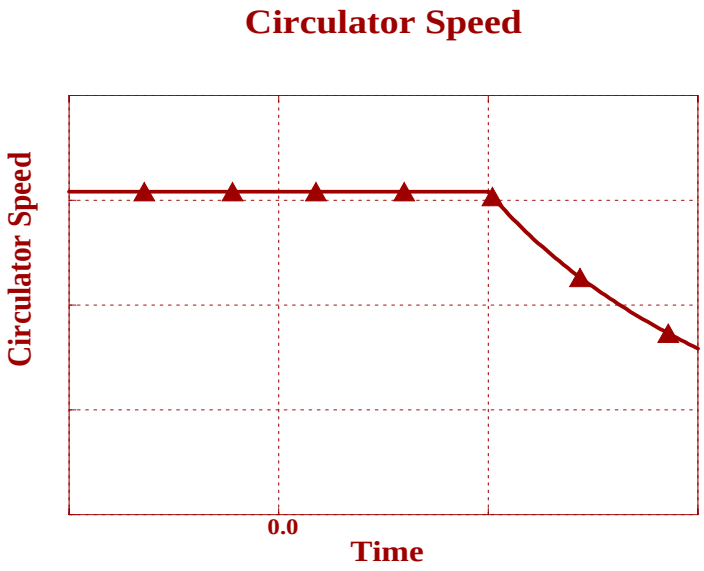


Load Follow/Reactor Trip

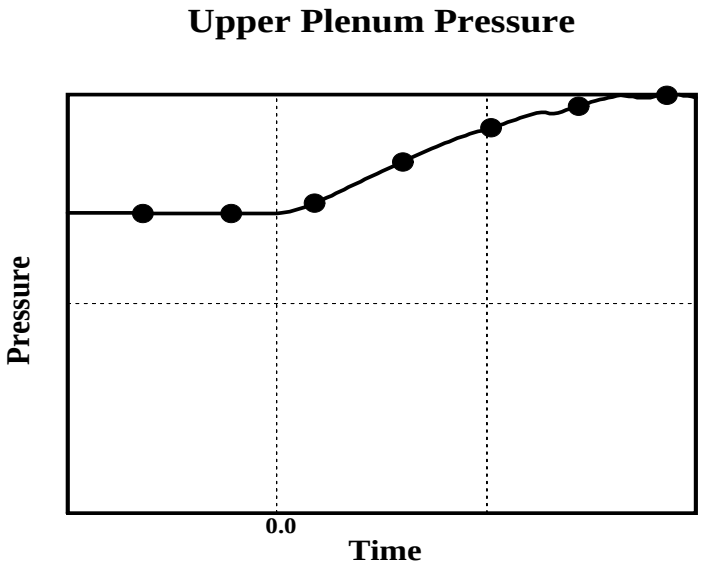


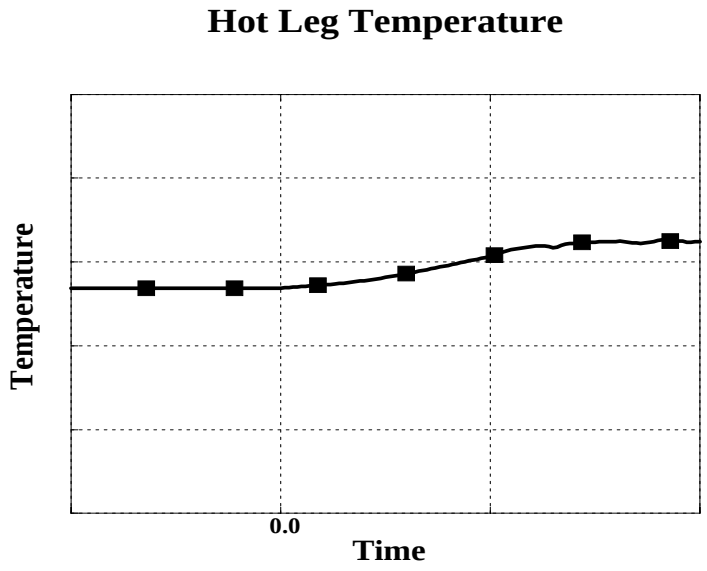


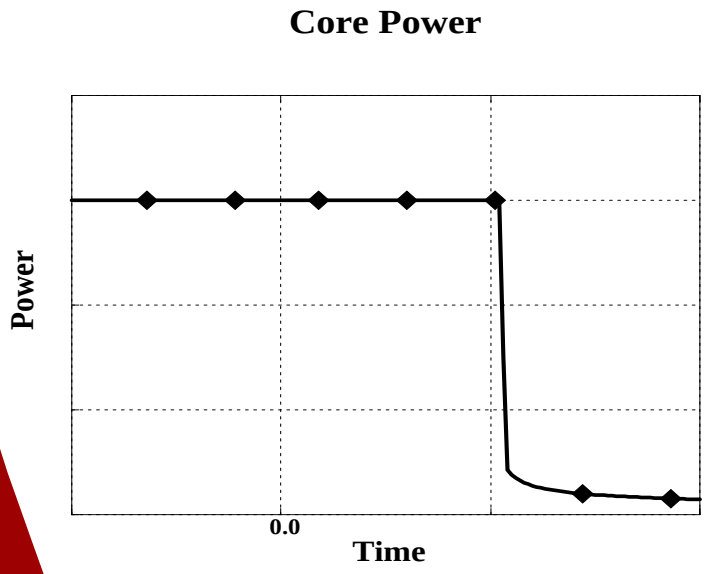


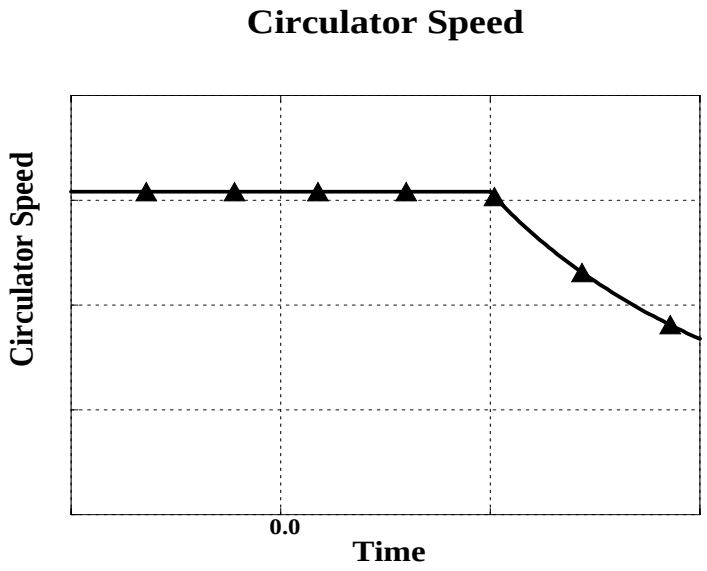


Loss of Load


Upper Plenum Pressure
Pressure
0.0
Time


Hot Leg Temperature
Temperature
0.0
Time


Core Power
Power
0.0
Time


Circulator Speed
Circulator Speed
0.0
Time

Current Status

- **Progress to date**
  - **A Scoping primary circuit modelled with helium coolant (based on both AREVA & GA design docs)**
  - **Point kinetics core model**
  - **Steady-state conditions established**
  - **Transient focus on short-term events**

Schedule

- **2004 Goals:**
  - **Complete RELAP5-3D model (w/ secondary/tertiary loops)**
  - **Analyze a suite of short-term events**
  - **Support MANTA development activities as needed**
    - **Establish PIRTs for a set of small and long-term transients**
    - **Others?**
  - **Identify Code Deficiencies/Recommend Solutions**
- **2005 Goals**
  - **Gas Reactor assessments vs. Tests**
  - **PIRT parameters uncertainty range sensitivity studies**
  - **Conduction Cooldown ???**