Overview of Thermal Hydraulics Capabilities

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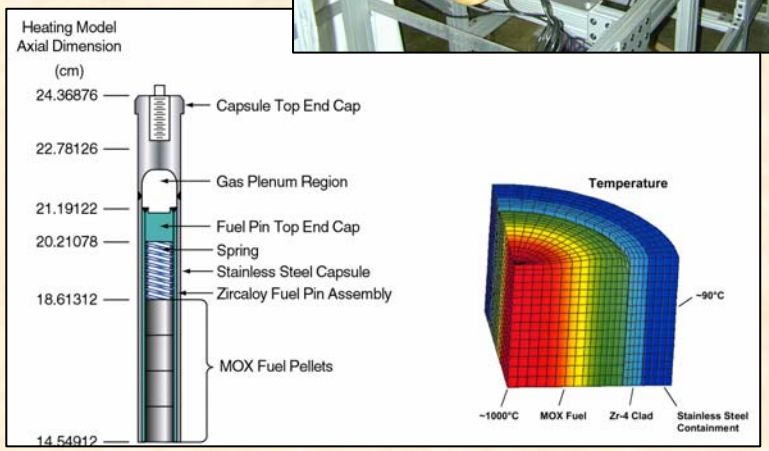
10/2006

Thermal Hydraulics and Irradiation Engineering - NSTD

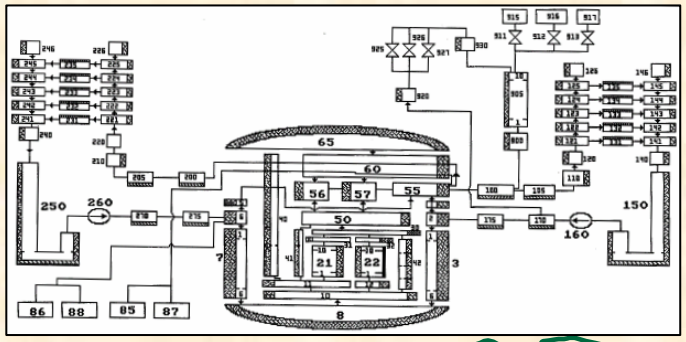
Heat Transfer, Fluid Flow & Reactor Safety Analysis

- Single and two-phase flow and heat transfer
- Computational fluid dynamics
- Transient thermal hydraulics
- Nuclear fuel behavior
- Severe accident analysis
- Explosion and aerosol transport analysis
- Support for experimental design

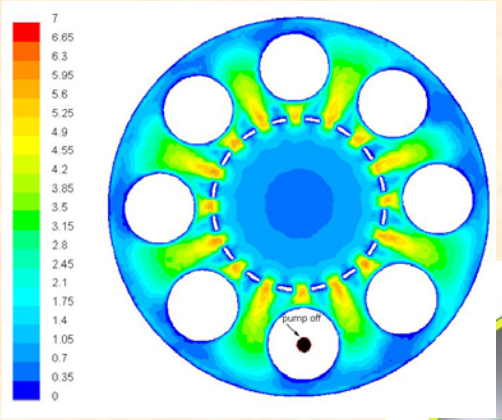


Thermal, Fluid & Irradiation Experimentation

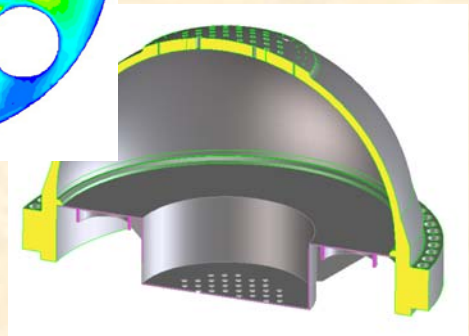
- Heat transfer measurements
- Fluid flow characterization
- Two-phase flow
- Materials irradiation in HFIR, ATR (INEEL), etc.



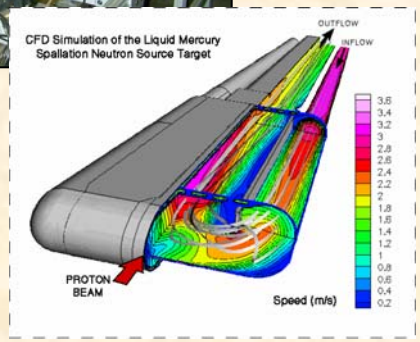
Computational Fluid Dynamics Combined with Benchmark Experiments - Used Extensively For System Design



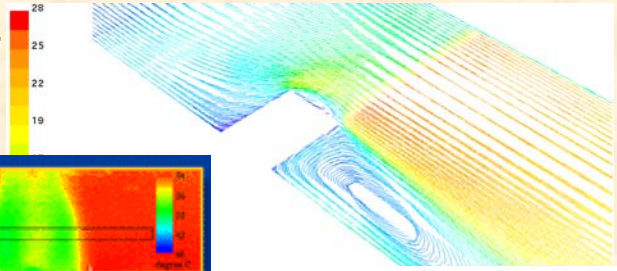
IRIS Pressurizer

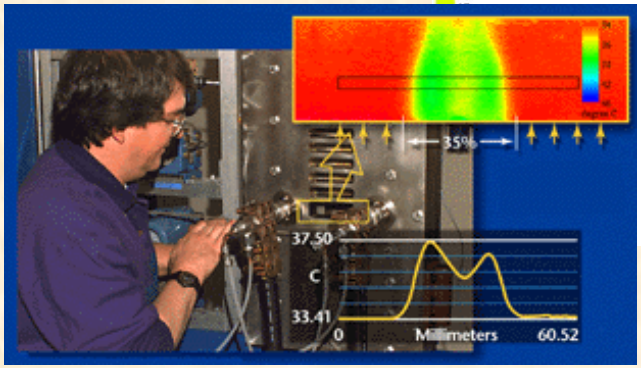


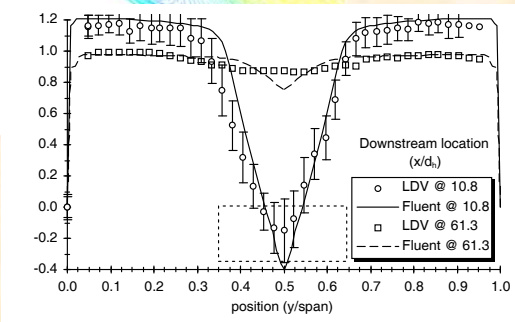
SNS Target



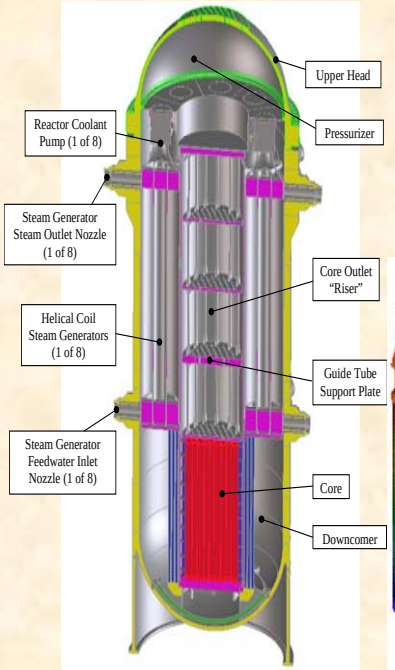
Flow Blockage
At Inlet to Rectangular
Flow Channel



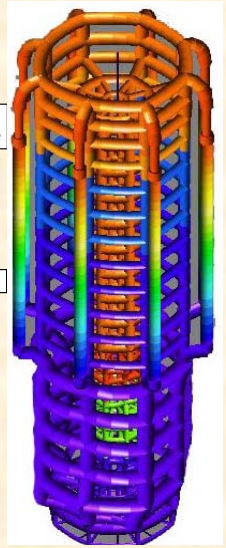


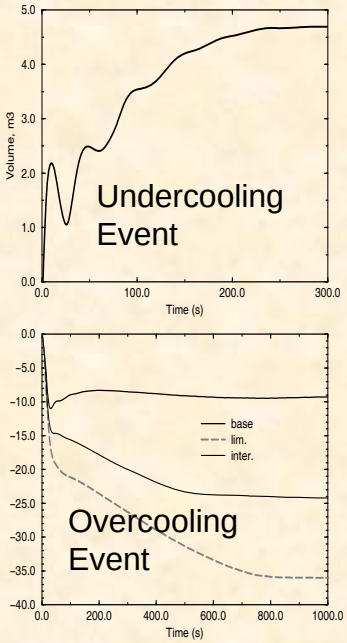


RELAP3.3, RELAP-3D, ATHENA, and TRACE Are Used to Perform Transient System Analysis

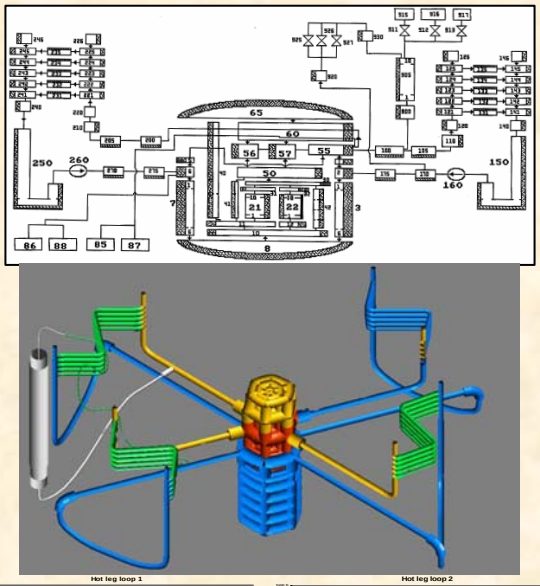


IRIS Transient Response





Kozloudy NPP, VVER-1000 Benchmark



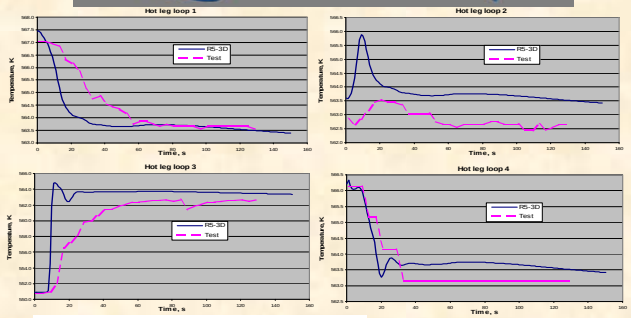


Fig. 3 Hot leg temperature prediction

SIMULATION OF VVER-1000 CT2 COOLANT MIXING TEST

- **SG #1 isolated**
- **Small power change with no practical effect on temperatures**
- **Temperatures at two locations (core exit and at the loops) are measured**
- **Loop 1 flow rotation is observed**

Double click box to play movie →

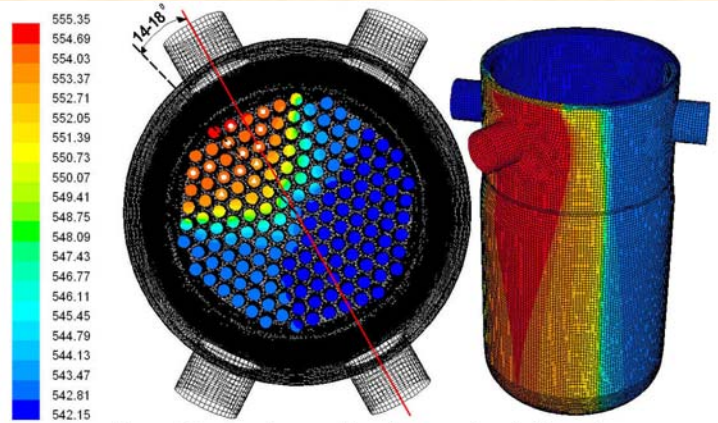


Figure 4 Temperature profiles at core exit and side wall

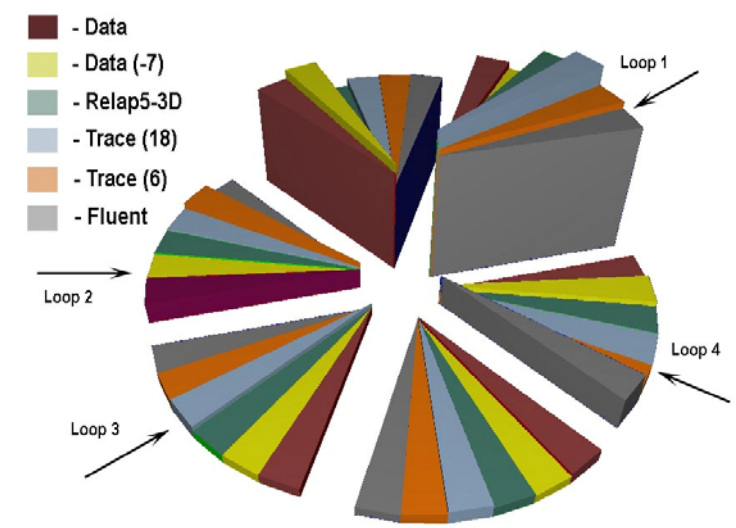
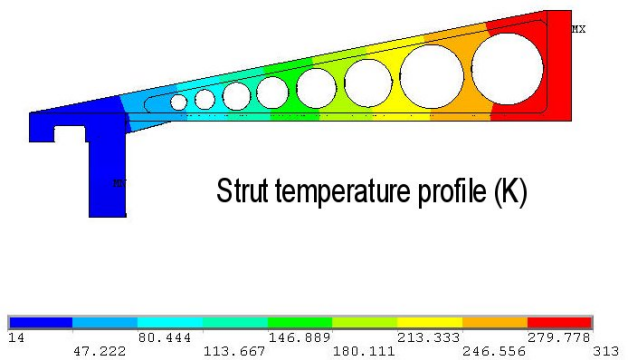
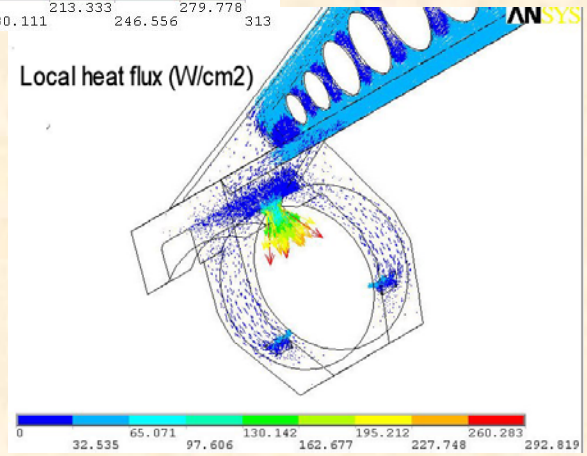


Figure 5 Mean segment temperatures at core exit

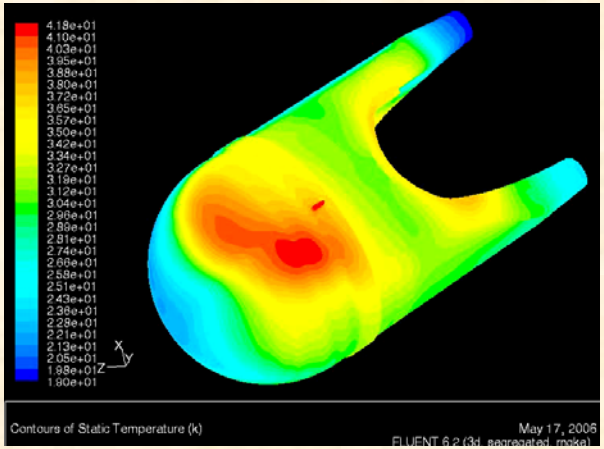
Thermal and Fluid Analysis Have Been Used to Support the HFIR Liquid Hydrogen Cold Source

Hydrogen Circuit Heat Loss Calculations Included ANSYS Results Initiated via Pro-E Drawings

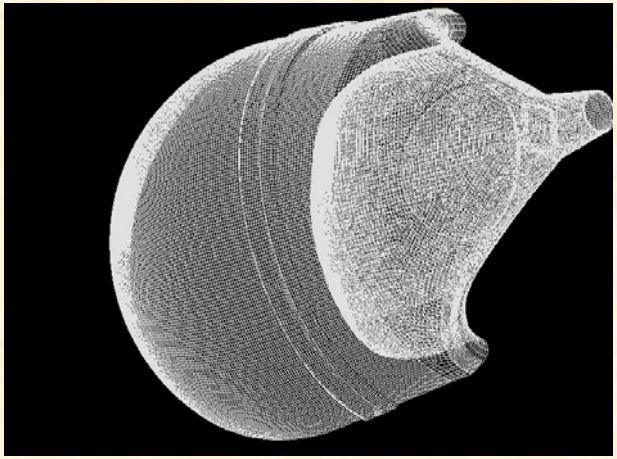




FLUENT CFD Analysis Was Used to Evaluate Moderator Heat Transfer



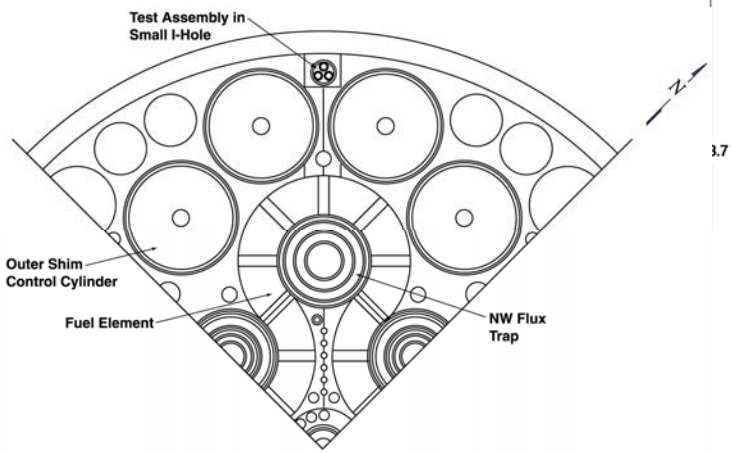
Double click picture to play movie



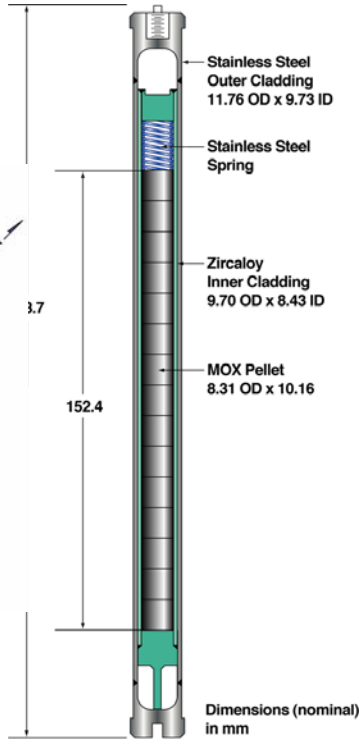
MOX Fuel Performance Experimental and Analytical Assessment – Irradiation to 50Mwd/Mt

- DOE project managed by ORNL
- Experiment Designed at ORNL
- Fuel Irradiated at ATR
- PIE, data interpretation and performance analysis performed at ORNL
- MOX performance model developed

ATR core and capsule Irradiation location

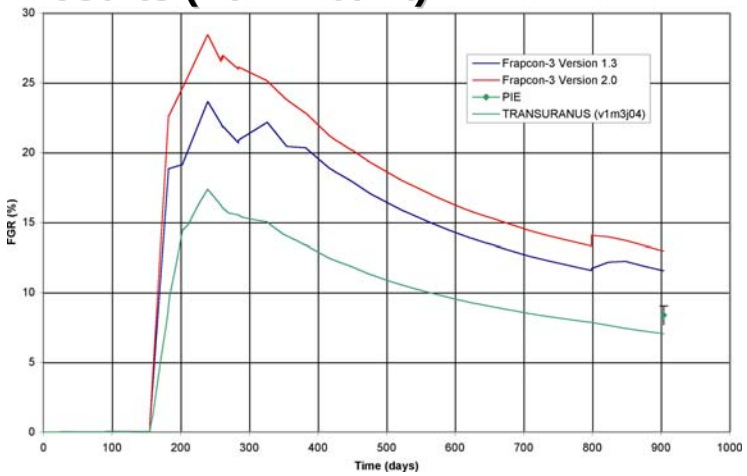


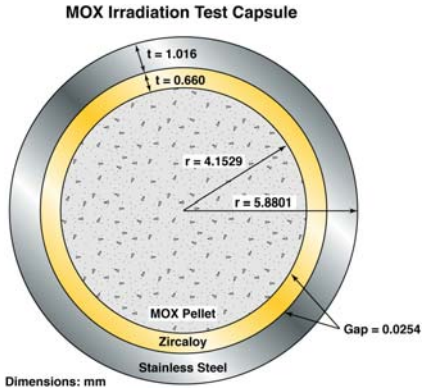
MOX capsule design



Irradiated fuel cross section

Code predictions compared to PIE results (40 Mwd/Mt)





Advanced CAD and Thermal Modeling Tools Used for Experiment Design

- **Pro/Engineering CAD software used to develop 3-D models**
- **ANSYS multi-physics analysis code used for thermal design**

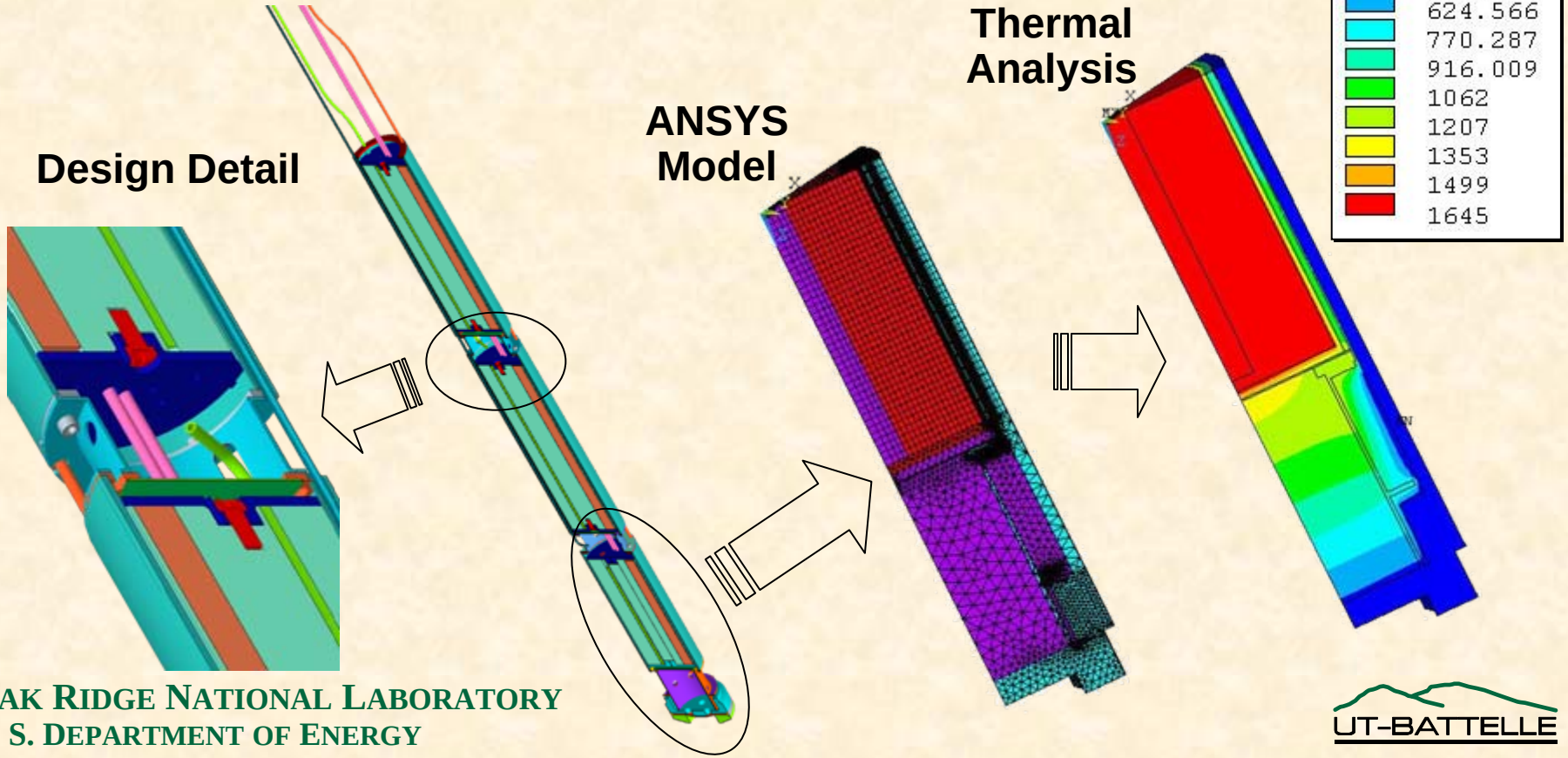
Pro E Drawing

ANSYS Thermal Analysis

Design Detail

ANSYS Model

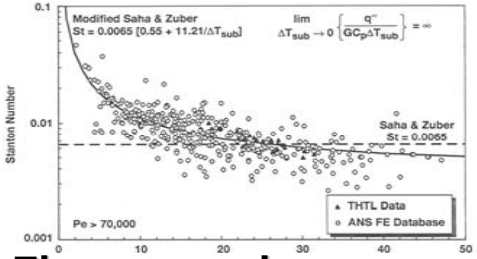
Thermal Analysis



Benchmark Experiments Performed to:

- Characterize thermal and fluid behavior
- Develop correlations and validate codes

Advanced Neutron Source Flow Excursion Experiments

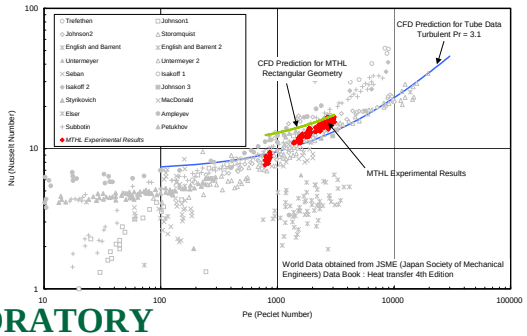


Flow excursion correlation development

SNS Mercury and Water loops

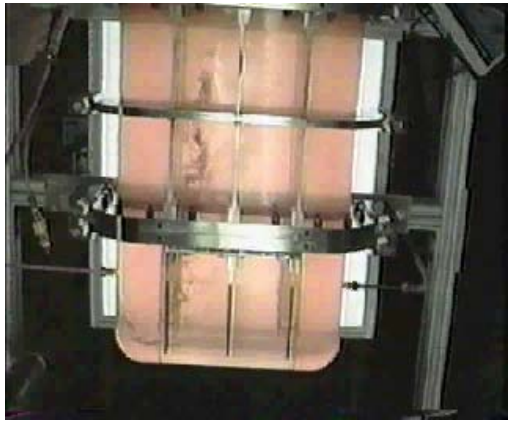
Hg heat transfer loop

Mercury Heat Transfer



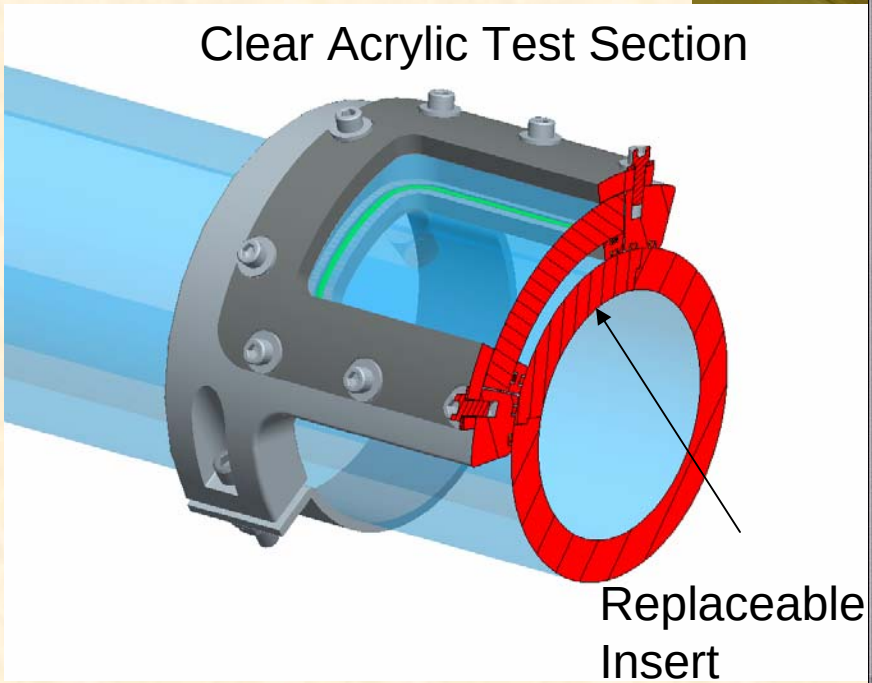
Full scale Hg target test facility

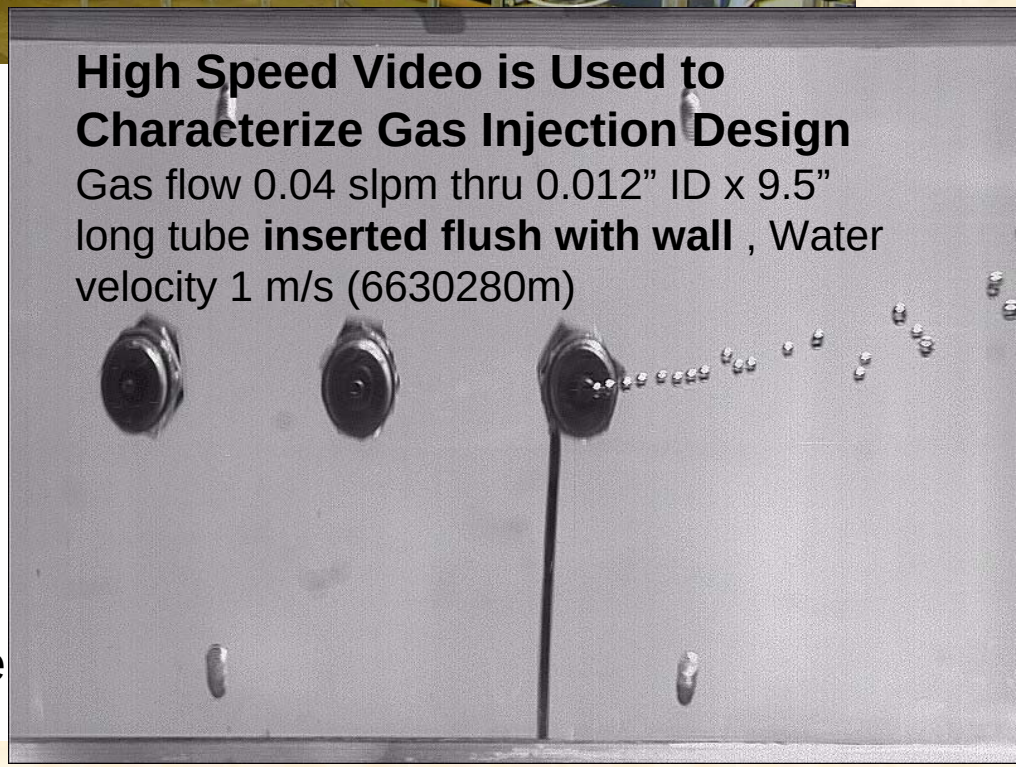
Target flow simulated using water



CFD Predicted and Experimental Streamlines

Water Test Loop Used for Gas Layer Development Studies in Support of SNS Liquid Mercury Target Upgrade Program





Experience Exists with a Wide Range of T/H Analysis Codes

- **Transient Analysis Codes**
  - RELAP5 3.2, 3.3
    - VVER-1000 safety analysis
    - HFIR irradiation experiments
  - RELAP5 3-D
    - VVER-1000 (coupled with 3-D NESTLE)
    - IRIS design
  - ATHENA (code development)
    - Supercritical hydrogen
    - Liquid metals
    - Molten Salt
  - TRACE
    - Initial testing (coupled with PARCS)
- **Computational Fluid Dynamics**
  - Fluent
    - IRIS pressurizer/pump performance
    - VVER-1000 mixing benchmark
    - HFIR flow blockage
  - CFX
    - Spallation Neutron Source mercury target
- **Fuel Performance**
  - FRAPCON
  - FRAPTRAN
  - TRANSURANUS
    - MOX fuel performance prediction and benchmark
- **ANSYS**
  - Irradiation experiment thermal design
- **MELCOR**
  - BWR code development and analysis
- **CTH** (hydrocode – blast effects)
- **etc.**