HIGH FLUX ISOTOPE REACTOR COLD SOURCE SAFETY ANALYSIS

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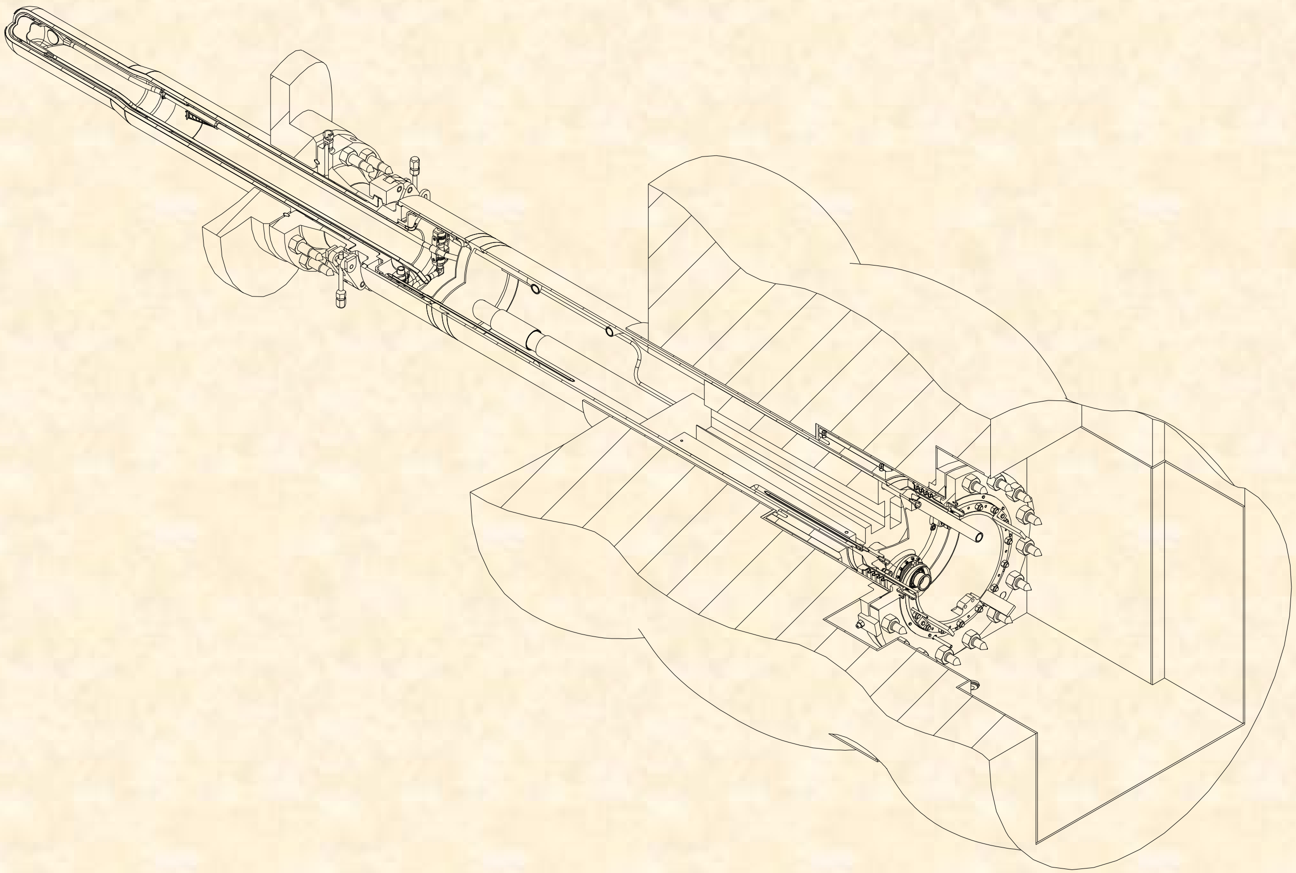
Presentation Outline

- HFIR Cold Source Description
- Safety Analysis Background
- Moderator Volume Analysis Overview
- Hydrogen Explosion Analysis Approach
- Hydrogen System Transient Analyses
- Conclusions

HFIR Cold Source Description

- Existing 4-in. beam tube enlarged and backfitted with 18K hydrogen cold source
- Proximity to core involves high heat load and long horizontal run for hydrogen tubes
- Resultant design is highly active
  - Force-cooled hydrogen loop with decay heat removal requirements
  - Supercritical conditions
  - Reactor scrams and He flooding

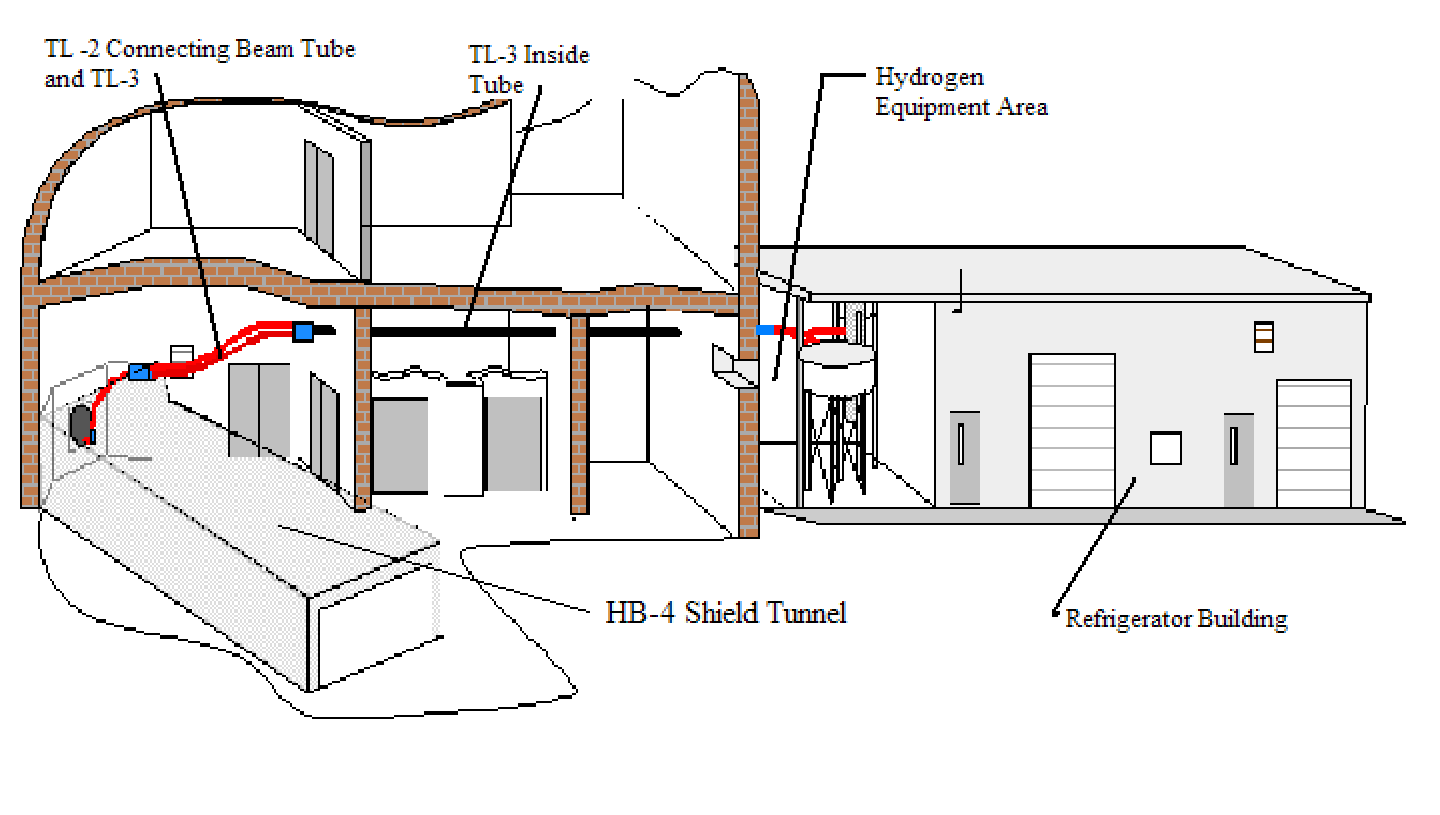
HB-4 Beam Tube and Cold Source



HFIR Cold Source Description (Cont'd)

- **Proximity to reactor safety equipment presents numerous hazards**
- **Resultant design uses location and multiple containment boundaries for safety**
  - **Passive lines through reactor building**
  - **Cooling equipment and instrumentation just outside reactor building in hydrogen equipment area (HEA)**
  - **Pressurization equipment and relief points remote from HEA**

Transfer Line Route From HB-4 to HEA



Transfer Line Areas of Interest

Storage Tank Areas of Interest

Safety Analysis Background

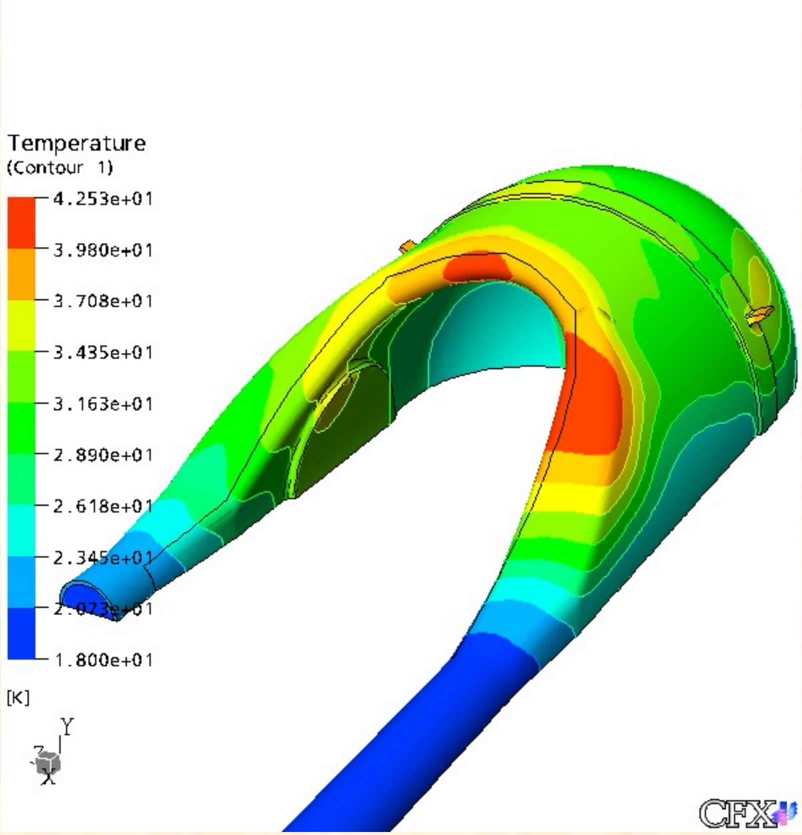
- Documented safety analysis (DSA) for the HFIR cold source follows DOE Std. 3009 in graded fashion
- Two-phase approach to safety analysis
  - Phase 1 to support helium- and hydrogen-system testing with heater power + helium testing with reactor power
  - Phase 2 to support final hydrogen system testing with reactor power, followed by full power operation

Safety Analysis Background

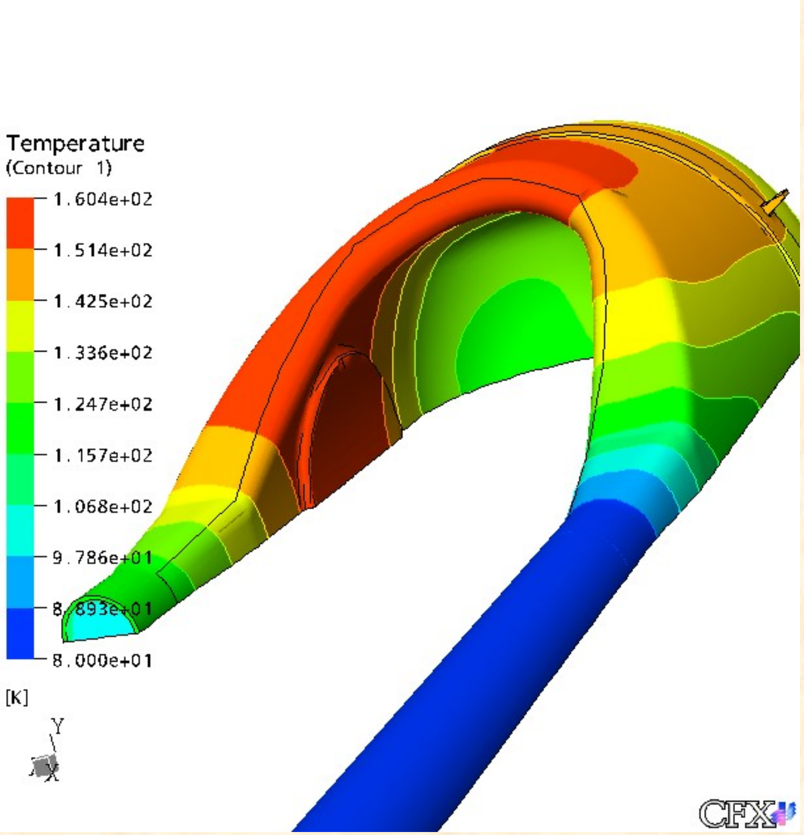
- Safety analysis addresses moderator volume integrity
  - Detailed thermal analysis
  - Stress analysis
- Safety analysis addresses hydrogen release consequences
  - Explosion
  - Cryogenic effects
- Safety analysis addresses overall system transient performance

Moderator Volume Steady-State Wall Temperature Estimates

Production Mode



Standby Mode



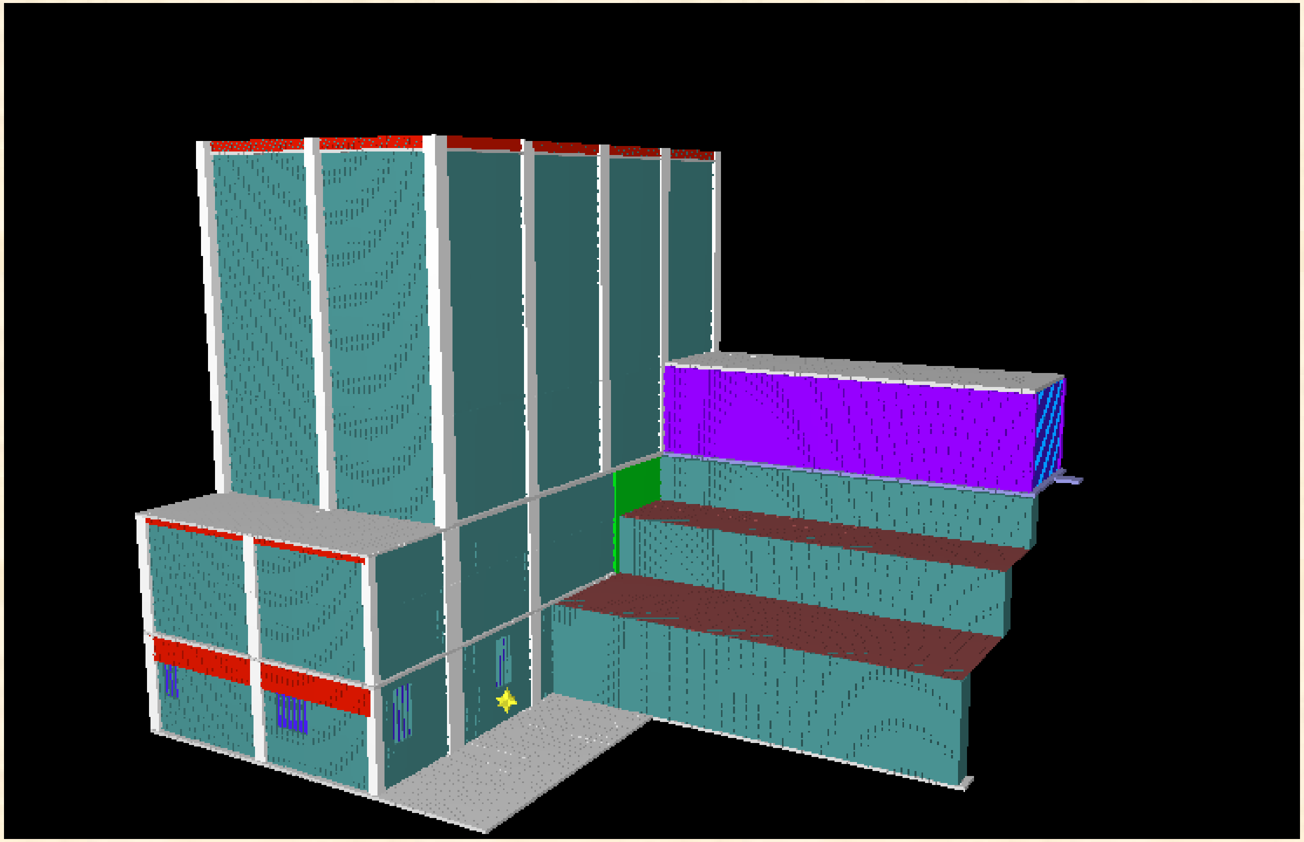
Detailed 3D CFD Models of the Moderator Vessel Compare Well

	Production Mode		Standby Mode	
Variables	FLUENT SKE/RNG	CFX KE/SSG	FLUENT SKE/RNG	CFX KE/SSG
Inlet Temperature (K)	18	18	80	80
Outlet Temperature (K)	22.6/22.6	19.8/22.2	99.25/99.3	99.2/102.7
Heat Load (W)	2998/3008	2859	2470/2468	N/A
Maximum Wall Surface Temperature (K)	43.6/44.3	38.9/44.2	165/164	151/160
Pressure drop (Pa)	2187/2027	2017/2185	650/638	860/924

Explosion Hazards Evaluated Based on Distance From Reactor Core

- Detailed beam tube detonation analysis using CTH code to show primary coolant pressure boundary segmented from hydrogen hazard
- TNT equivalence and strong deflagration models used to estimate consequences to nearby reactor equipment
- Key internal and external explosions considered
  - Hydrogen storage tank
  - Transfer line
  - HEA
  - Transfer line inside building
  - Beam room alcove

External Explosion Hazards Evaluated Using BLAST/FX Code — Developed by Northrop Grumman Mission Systems



System Transient Analyses With ATHENA Code

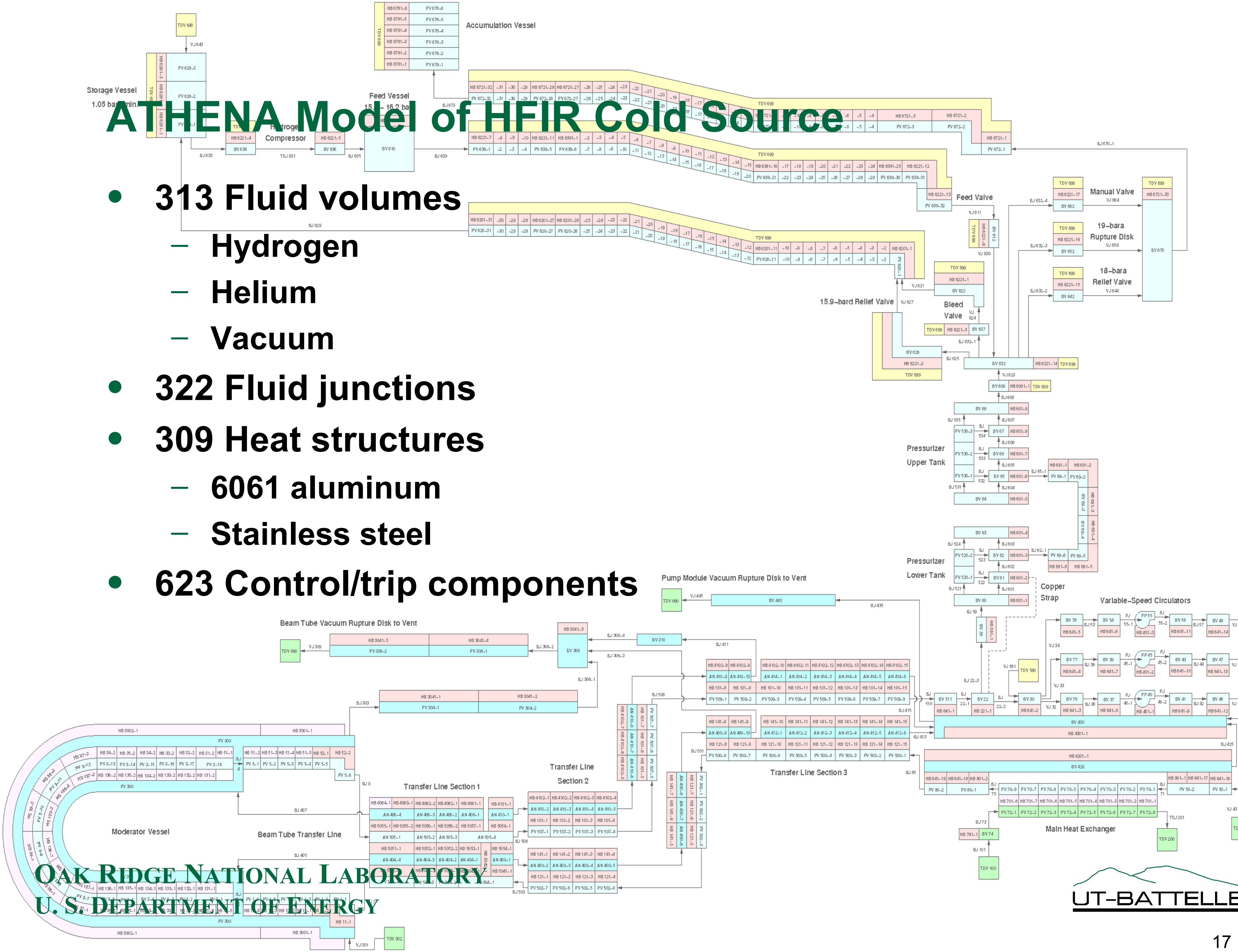
- "Advanced Thermal-Hydraulic Energy Network Analyzer"
- Extension of RELAP5 code, developed by Idaho National Laboratory for modeling water-reactor coolant systems
  - Includes properties for non-water working fluids, including cryogenic hydrogen and helium
- Performs transient, 1-D simulations of 2-phase fluid flow and heat transfer with adjacent structures
  - Solves mass, momentum, and energy equations for both liquid and vapor phases
  - Solves conduction equations (including internal heating) for structures
  - Includes full range of surface heat transfer correlations
  - Includes engineering models for pipe junctions, valves, pumps, control system logic, etc.

ATHENA Analyses (cont.)

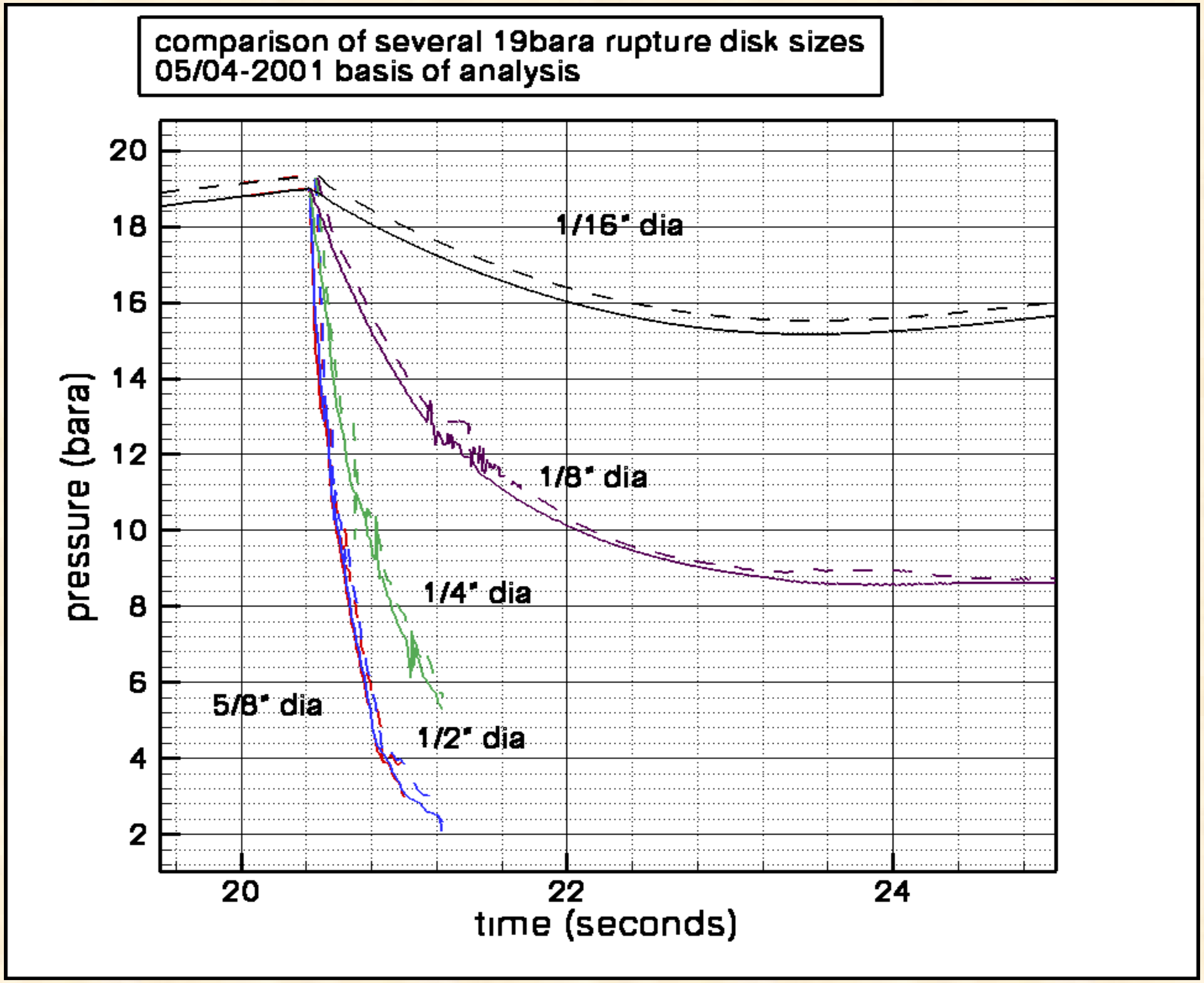
- User specifies dimensions and operating conditions in an input file based upon generic building-block approach
  - Define fluid volume dimensions
  - Define connections between fluid volumes
  - Define solid structure dimensions and heat transfer with adjacent fluid volumes
  - Define control system logic
  - Define initial and operating conditions
- Applications include all categories of transients
  - Increase/decrease in inventory
  - Increase/decrease in heat addition
  - Increase/decrease in flow
  - Operational and accident sequences modeled

ATHENA Model of HFIR Cold Source

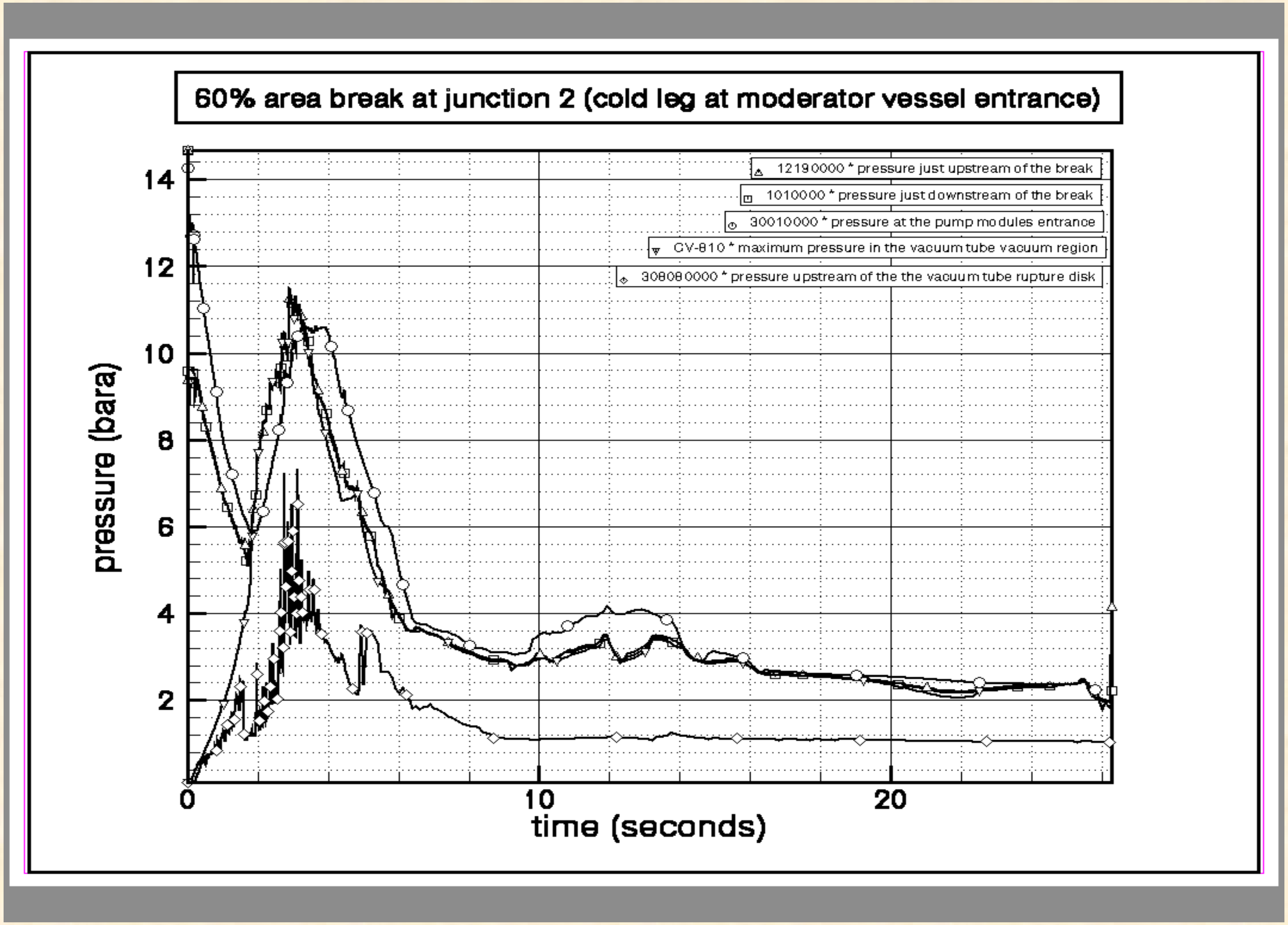
- **313 Fluid volumes**
  - Hydrogen
  - Helium
  - Vacuum
- **322 Fluid junctions**
- **309 Heat structures**
  - 6061 aluminum
  - Stainless steel
- **623 Control/trip components**



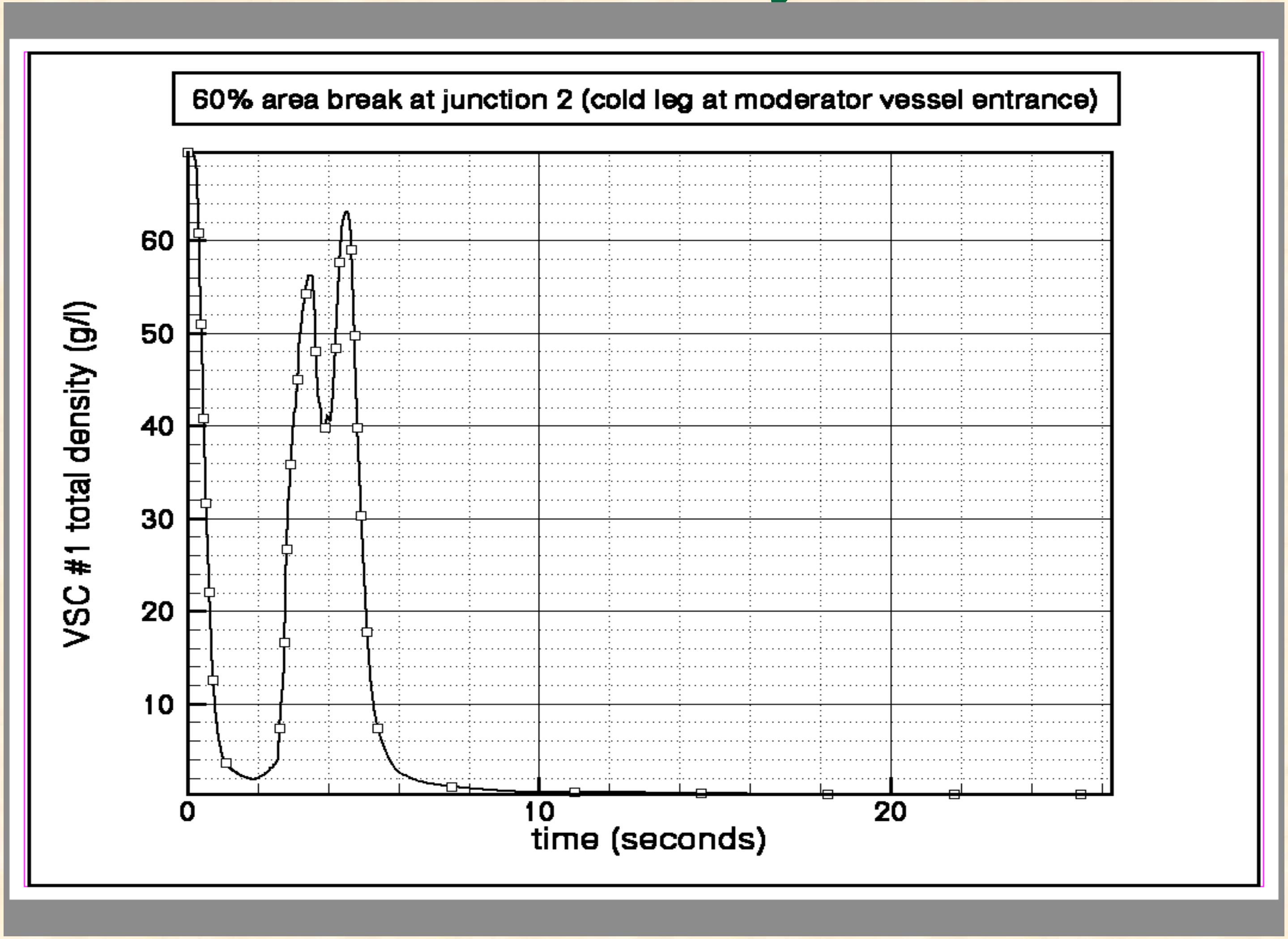
ATHENA-Typical Loss of Inventory: Rupture Disk Sizing (Two-phase Event)



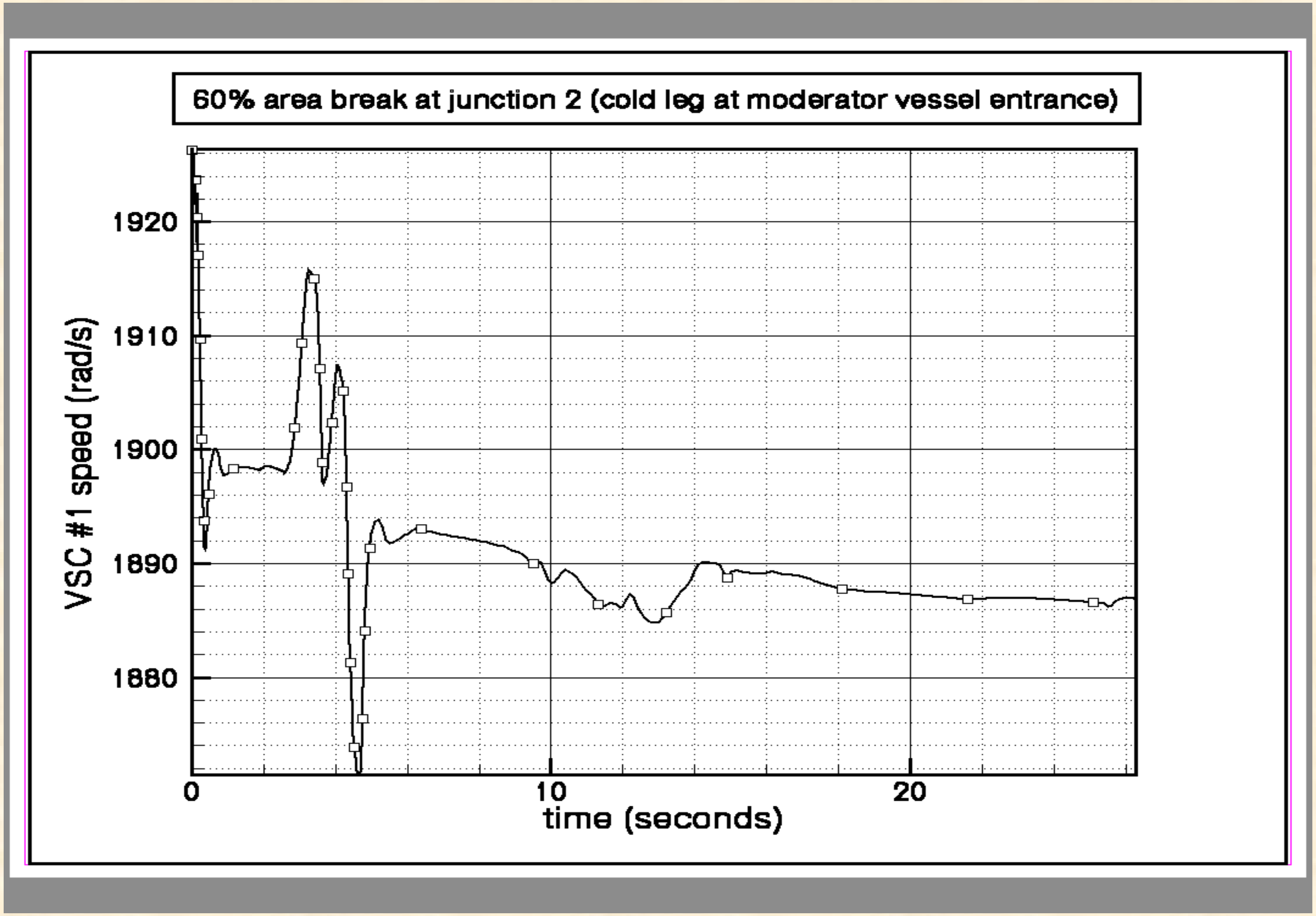
ATHENA-Typical LOCA Event: Hydrogen Flow Into the Vacuum Tube-Pressure



ATHENA-Typical LOCA Event: hydrogen flow into the vacuum tube-density



ATHENA-Typical LOCA Event: Hydrogen Flow Into The Vacuum Tube-pump Speed



Conclusions

- Systematic and comprehensive identification of hazards completed and safety analysis underway
- Analysis of key hazards performed in detail and many difficult analysis problems addressed