H.B. Robinson / Shearon Harris Thermal-Hydraulic Transient Analysis Methodology

June 2015

NRC Offices

Presentation Outline

- Update on Proposed Submittals
- Licensing Approach
- Background on DPC-NE-3000-PA
- RETRAN-3D Code and Application
- Overview of RETRAN-3D Plant Models
- RETRAN-3D Input Model Validation
- Expanded VIPRE-01 Model
- Conclusion

Methods Reports

	MNS/CNS	ONS	Proposed RNP/HNP	Target Submittal Date
Physics Codes / Models	DPC-NE-1005 CASMO-4/SIMULATE-3	DPC-NE-1006 CASMO-4/SIMULATE-3	DPC-NE-1008 CASMO-5/SIMULATE-3	July 2015
Physics Applications Power Distribution Monitoring	DPC-NE-2011	NFS-1001 DPC-NE-1002	DPC-NE-2011 revision	December 2015
Physics Applications Reload Design	DPC-NF-2010	NFS-1001 DPC-NE-1002	DPC-NF-2010 revision	December 2015
NSSS Codes / Models	DPC-NE-3000 RETRAN-02	DPC-NE-3000 RETRAN-3D	DPC-NE-3008 RETRAN-3D	August 2015
Subchannel T/H Methods	DPC-NE-3000 DPC-NE-2004 VIPRE-01	DPC-NE-3000 DPC-NE-2003 VIPRE-01	DPC-NE-3008 DPC-NE-2005 (Appendix) VIPRE-01	August 2015
SCD Methodology	DPC-NE-2005	DPC-NE-2005	DPC-NE-2005 revision	**March 5, 2015**
Transient Analysis	DPC-NE-3001 DPC-NE-3002 SIMULATE-3K (REA)	DPC-NE-3005 SIMULATE-3K (REA)	DPC-NE-3009 SIMULATE-3K (REA)	December 2015
Fuel Performance	DPC-NE-2008 (TACO-3) DPC-NE-2009 (PAD 4.0)	DPC-NE-2008 (TACO-3 and GDTACO)	N/A - TS changes only COPERNIC-2	December 2015

Licensing Approach

- DPC-NE-3008-P describes the RETRAN and VIPRE base analysis models (similar to DPC-NE-3000-PA)
- Extends the Duke methodology to the Harris and Robinson Nuclear Plants
- System response uses the RETRAN-3D computer code in RETRAN-02 Mode
  - Minor modeling enhancements implemented
- DNBR analysis will use the VIPRE models described in DPC-NE-2005-P (submitted to the NRC 3/15)
- Extended VIPRE models described in the report

Licensing Approach (cont.)

- LAR submittals
  - Methodology report
  - Tech Spec 5.6.5 and 6.9.1.6 changes
  - COLR/Tech Spec changes as required

- UFSAR changes
  - Implemented via 10 CFR 50.59 following methodology report approval with first in-house reload analysis

Schedule

- Support the reload licensing analysis for Harris Cycle 22 and Robinson Cycle 32
  - H1EOC21 (4/18)
  - R2EOC31 (9/18)
- Reload Analyses Start:
  - HNP (December 2016)
  - RNP (Spring 2017)
- Review requested by end of 2016

Background on DPC-NE-3000-PA

Revision	SER Date	Relevant Portions
0	1991	Describes the transient analysis simulation models and validation analyses for McGuire and Catawba using RETRAN-02 and VIPRE-01
0a	1994	Adds Oconee transient analysis simulation models and validation analyses using RETRAN-02 and VIPRE-01
1	1995	Replacement SGs for McGuire and Catawba; incorporates improvements such as non-equilibrium bubble rise model
2	1998	
3	2003	Oconee SG replacement; received approval to use RETRAN-3D in a mode that essentially defaults to RETRAN-02
4a	2008	Includes an expanded Oconee VIPRE-01 methodology (Appendix E)
5a	2012	SER for implementation of Gadolinia as an integral burnable absorber

DPC-NE-3008-P

- DPC-NE-3008-P applies DPC-NE-3000-PA to the Harris and Robinson Nuclear Plants (HNP and RNP)
- Describes the transient analysis simulation models and validation analyses for HNP and RNP
  - W 3-Loop design (models are similar to McGuire/Catawba)
  - Use RETRAN-3D in a mode that essentially defaults to RETRAN-02 (similar to Oconee)
- Describes each RETRAN plant model and validates the RETRAN models against selected events from Chapter 15 of each plant's FSAR
- Describes an expanded VIPRE-01 methodology

Why Upgrade to RETRAN-3D for HNP/RNP?

- RETRAN-3D has many new and enhanced capabilities relative to RETRAN-02
  - e.g., 3-D kinetics, implicit numerical scheme, improved heat transfer correlation package
  - Most of the RETRAN-02 features are retained as options
  - Approved by the NRC in 2001 with 45 limitations and conditions of use
- Previously approved for Oconee
- Subsequent updates to RETRAN-3D add new features and correct errors

DPC-NE-3008-P: RETRAN-3D Approach

- Like Oconee, use RETRAN-3D in a mode that essentially defaults to RETRAN-02
  - For example, use the algebraic slip equation based on the drift flux model of Chexal-Lellouche in the SG tube bundle region
- Other model improvements related to, for example,
  - Enthalpy transport
  - Accumulator modeling

Overview of RETRAN-3D Plant Models

- Following slides show layout of RETRAN-3D volumes and junctions for primary and secondary systems
- Level of modeling detail similar to that used for McGuire and Catawba Nuclear Stations
  - See DPC-NE-3000-PA Figures 3.2-1 to 3.2-3
- Plant-specific models reflect design features, modeling improvements, etc.
  - Two improvements selected for discussion today
  - Final modeling to be described in DPC-NE-3008-P

Primary System (HNP)

[ ]

Secondary System (HNP)

[ ]

Loop Modeling

- Single RETRAN-3D model developed for each plant
- Each model has three reactor coolant loops, steam generators and steam lines (to common header)
- Simplifies maintenance of plant models

Steam Generator Boiler Region

Model Validation

- <u>Goal:</u>
  - Demonstrate the ability to appropriately model key phenomena for a range of transient responses
- <u>Method:</u>
  - Conduct code-to-code benchmarks using selected transients from HNP and RNP Chapter 15 AOR
    - McGuire/Catawba and Oconee used plant transient data
- <u>Philosophy:</u>
  - Match key analysis inputs and modeling assumptions
  - Compare important trends and behaviors

Scope of Model Validation Cases

Scope of Validation Cases		Plant/Event Evaluated	
		Harris	Robinson
15.1	Increase in Heat Removal by the Secondary System	Increase in Feedwater Flow	
15.2	Decrease in Heat Removal by the Secondary System	Turbine Trip Feedwater Line Break	Loss of Feedwater
15.3	Decrease in RCS Flow Rate	Loss of Flow	Locked Rotor
15.4	Reactivity and Power Distribution Anomalies		Uncontrolled Bank Withdrawal at Power

15.2 Turbine Trip (HNP) Transient Overview and Summary

- Classified as ANS Condition II event (fault of moderate frequency)
- Analyzed for two main purposes
  - Verify primary/secondary relief capability
  - Protect Specified Acceptable Fuel Design Limits (SAFDLs)
- Assumptions designed for conservative prediction
  - Example: No credit for direct reactor trip on turbine trip

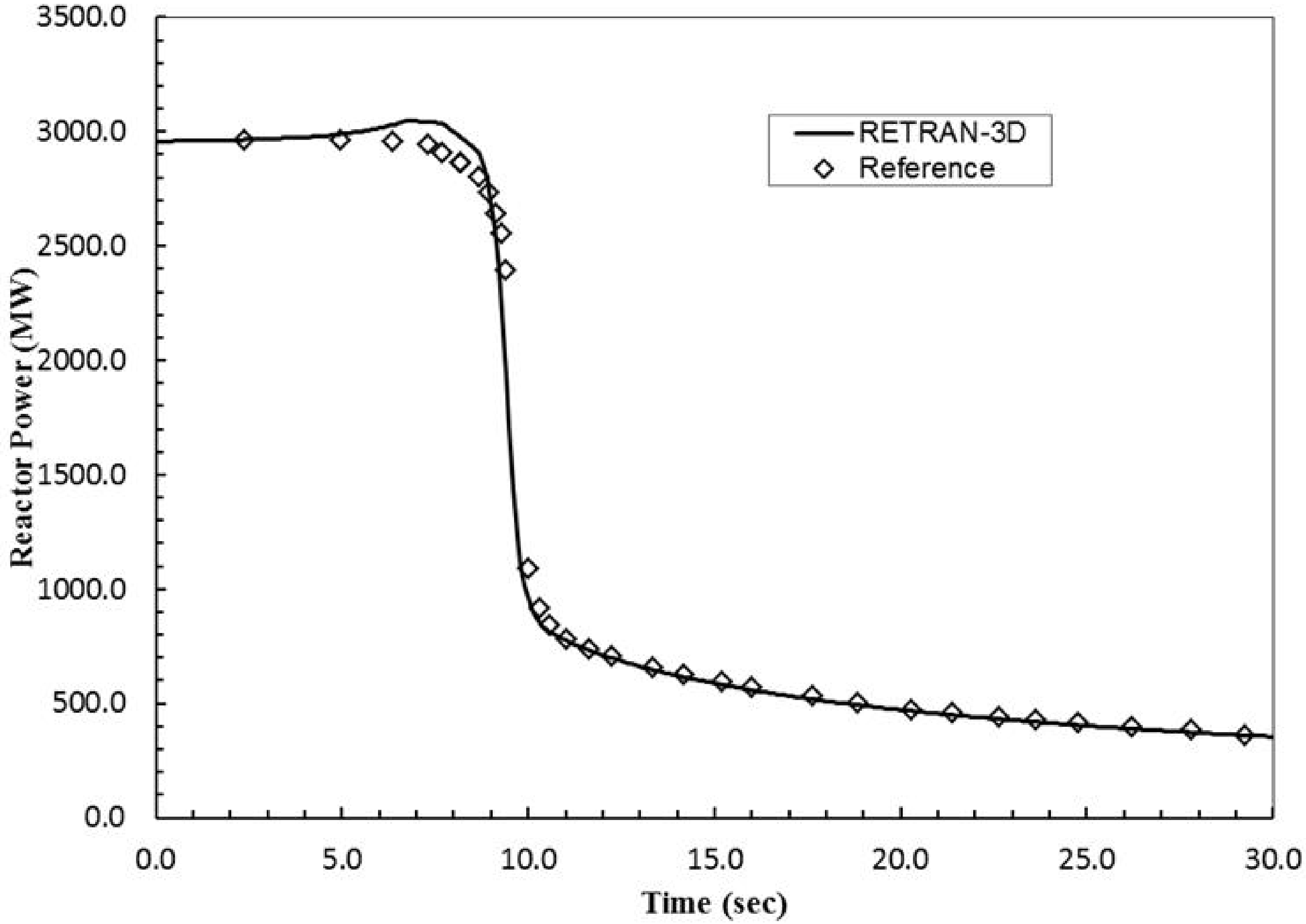
15.2 Turbine Trip (HNP) Transient Overview and Summary

- Benchmark calculations completed for two cases from FSAR §15.2.3
  - Primary and secondary over-pressurization
- Used to evaluate model performance for decrease in secondary heat removal
  - Match key analysis inputs and modeling assumptions
- Following slides compare sequence of events and transient response for each case

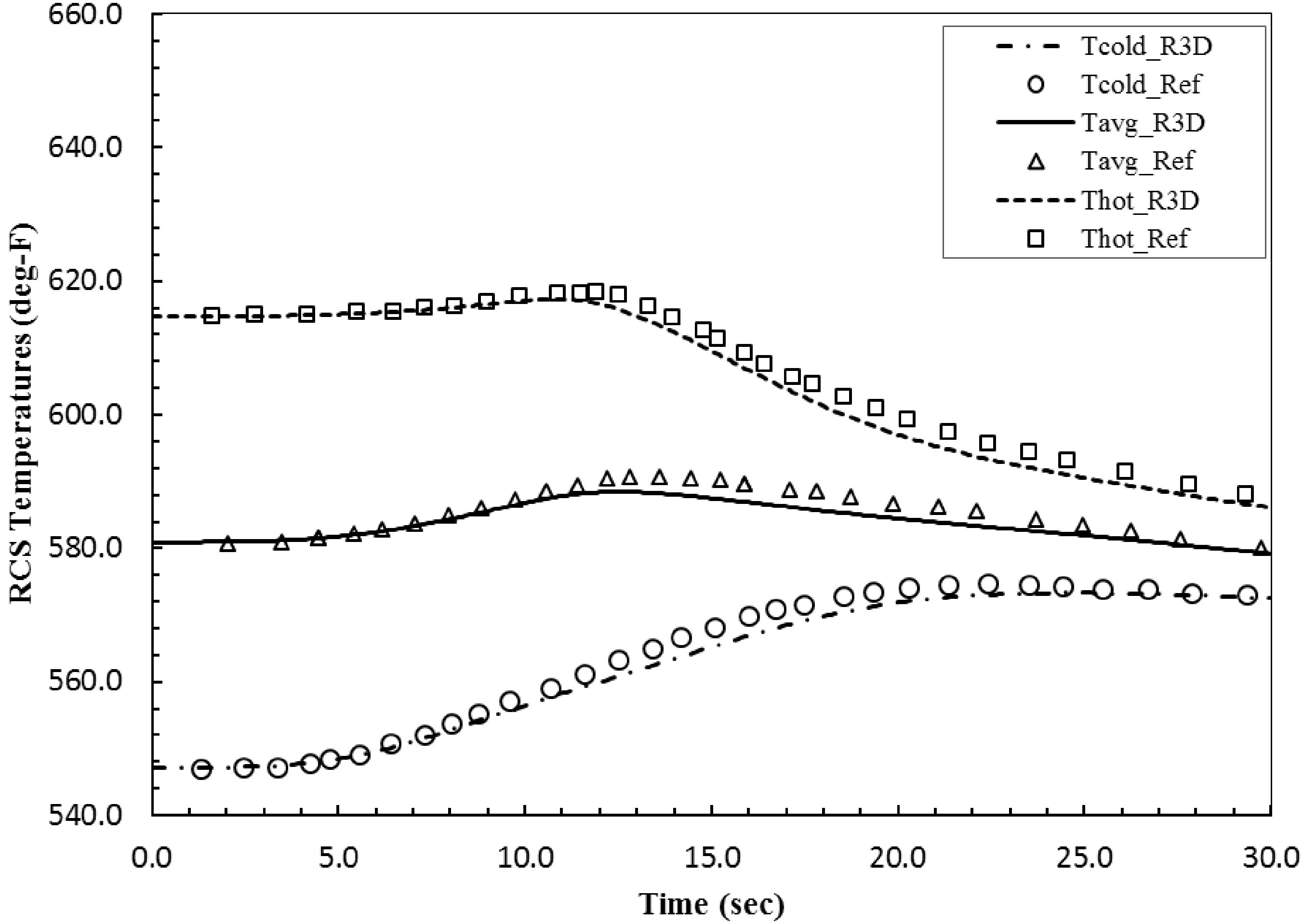
15.2 Turbine Trip (HNP)
Primary Over-Pressurization Sequence of Events

Event	Event Time, s	
	AOR	RETRAN-3D
Turbine Trip	0.0	0.01
Reactor Trip Signal – High Pressure	5.03	4.74
Scram Initiation	7.04	6.74
Peak Primary Side Pressure	7.8	7.7 (2742.7 psia)
SG 1st bank MSSVs open	8.4	8.7
SG 2nd bank MSSVs open	9.3	10.4
SG 3rd bank MSSVs open	10.8	11.7
SG 4th bank MSSVs open	---	---
SG 5th bank MSSVs open	---	---

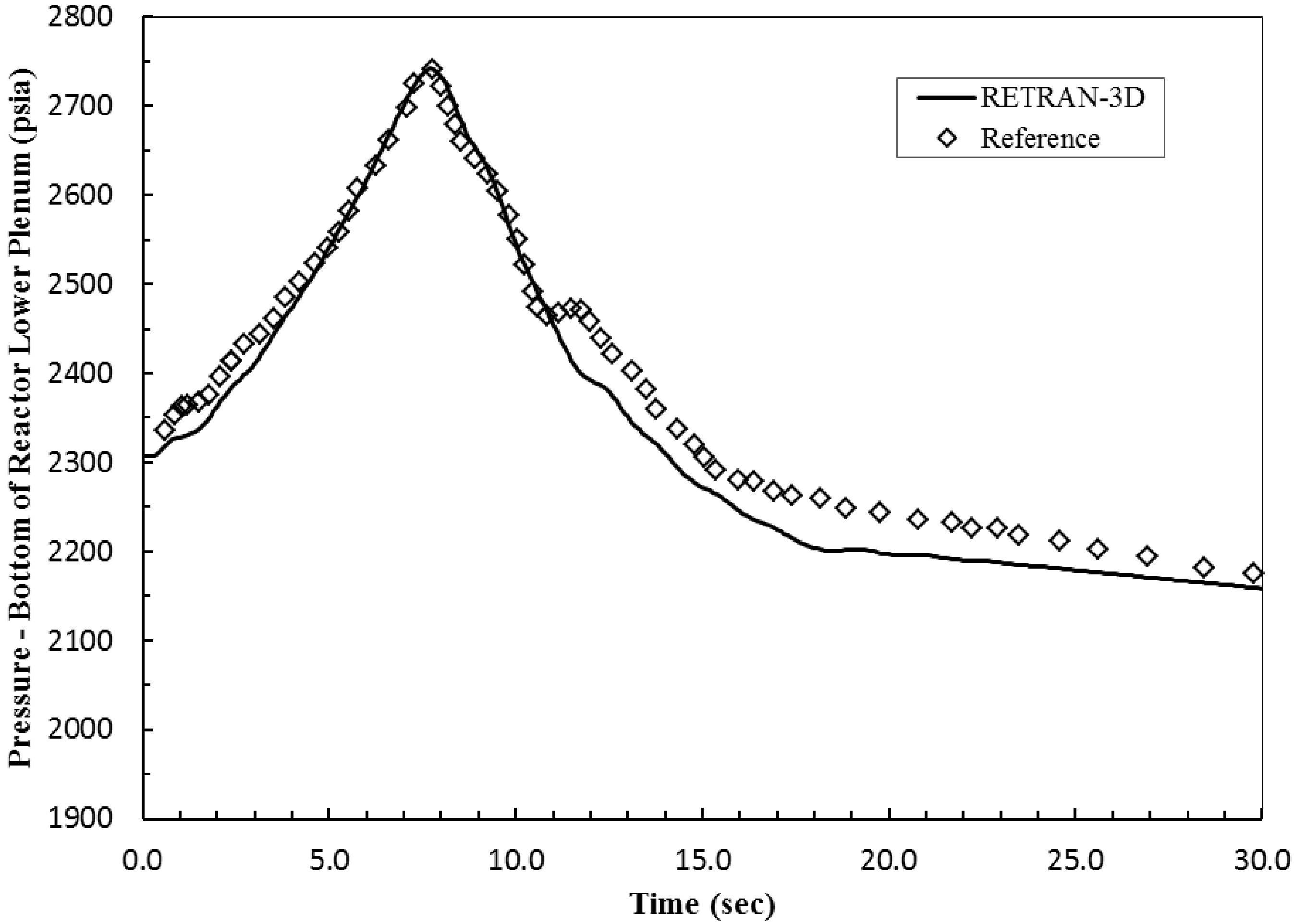
HNP Turbine Trip – Primary Over-Pressurization Reactor Power



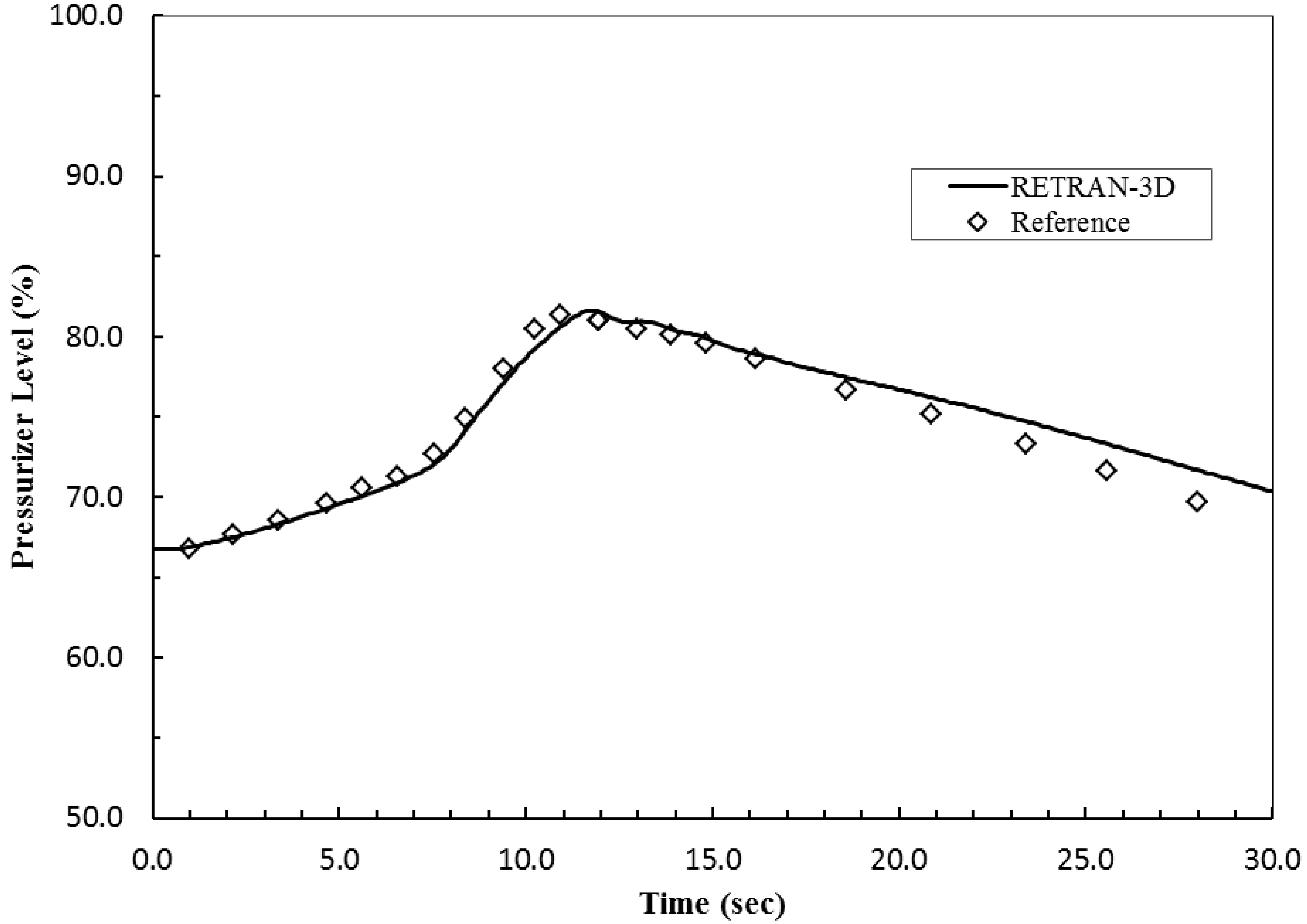
HNP Turbine Trip – Primary Over-Pressurization Average Temperature



HNP Turbine Trip – Primary Over-Pressurization Pressure at Bottom of Core Lower Plenum



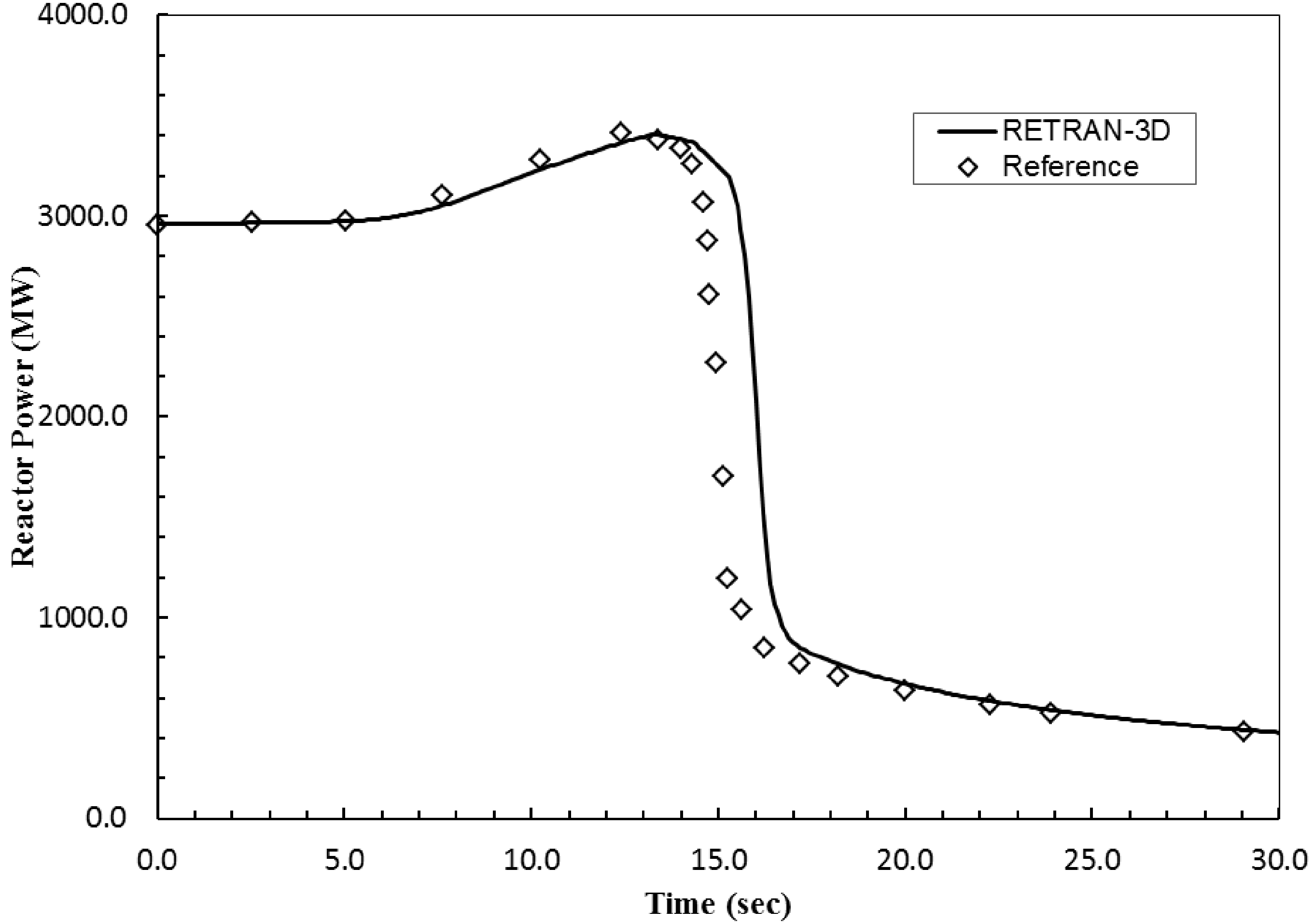
HNP Turbine Trip – Primary Over-Pressurization Pressurizer Level



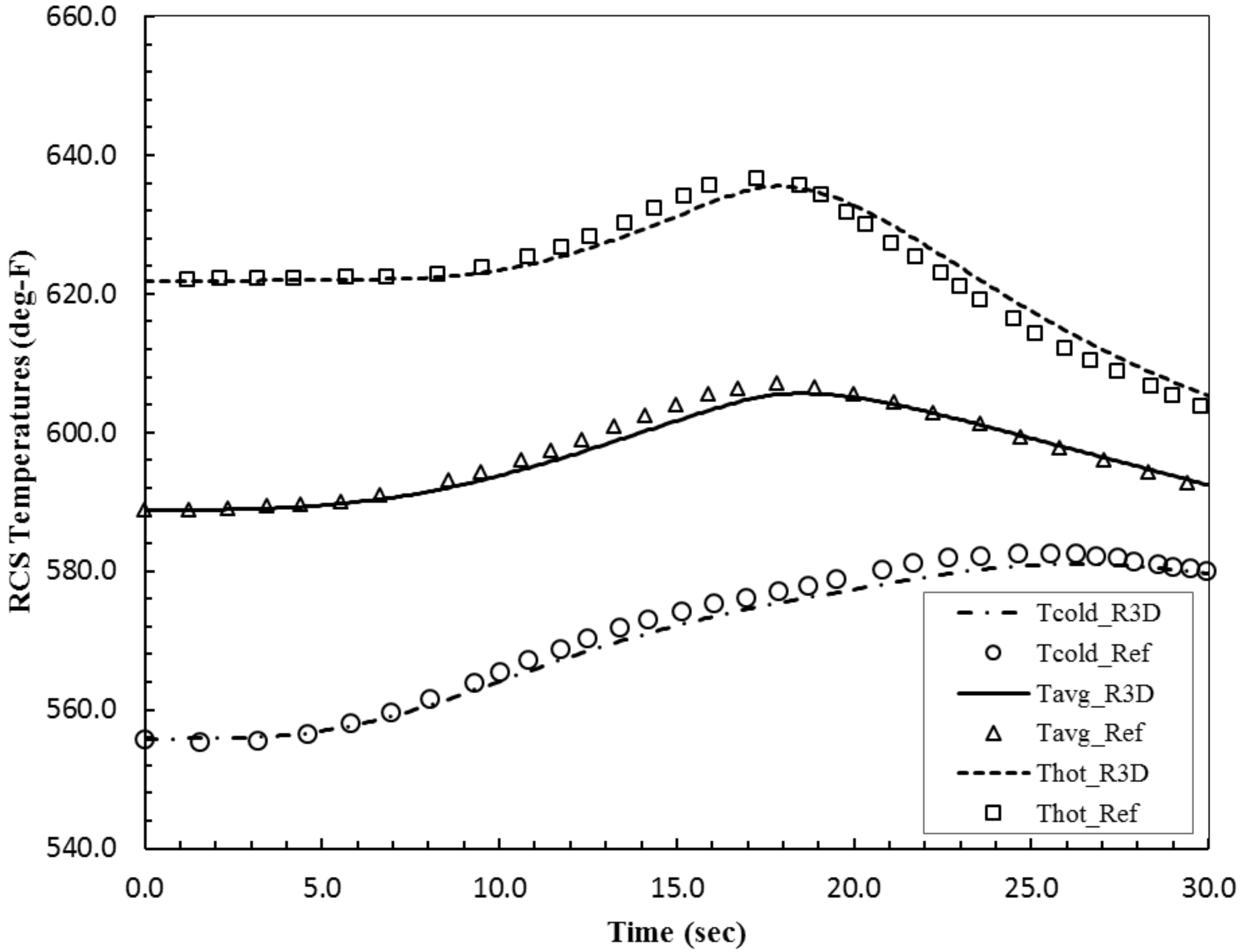
15.2 Turbine Trip (HNP) Secondary Over-Pressurization Sequence of Events

Event	Event Time, s	
	AOR	RETRAN-3D
Turbine Trip	0.0	0.01
Pressurizer spray on	1.0	0.9
Pressurizer compensated PORV open	1.2	1.2
Pressurizer uncompensated PORV open	4.3	4.0
SG 1st bank MSSVs open	5.4	5.3
SG 2nd bank MSSVs open	6.5	5.9
SG 3rd bank MSSVs open	7.9	7.0
SG 4th bank MSSVs open	10.1	9.7
OTΔT trip signal	11.16	12.06
Reactor scram	12.41	13.32
SG 5th bank MSSVs open	13.2	13.8
Peak pressurizer level	16.2	17.7 (98.7%)
Peak secondary side pressure	18.9	19.3 (1296.5 psia)

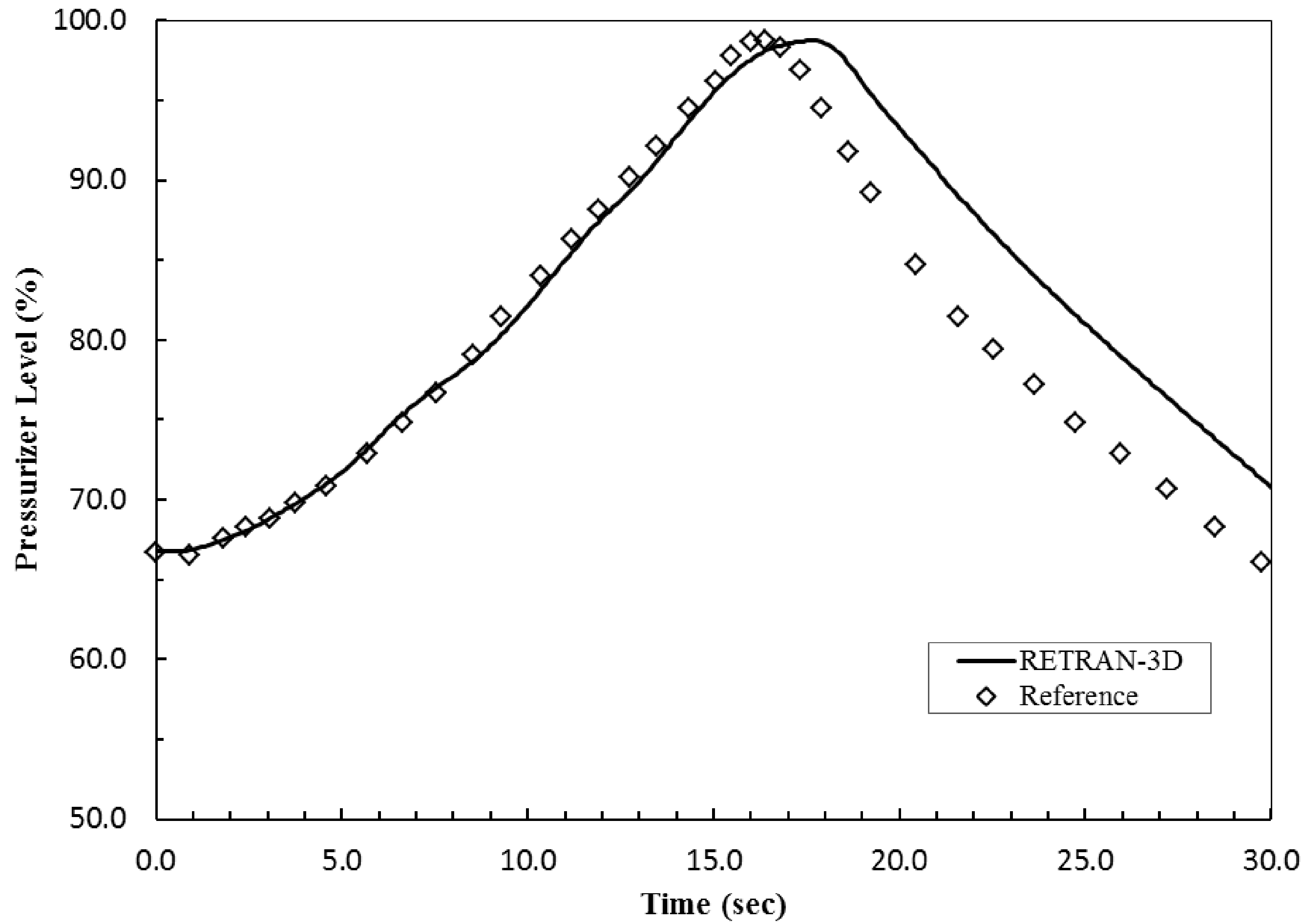
HNP Turbine Trip – Secondary Over-Pressurization Reactor Power



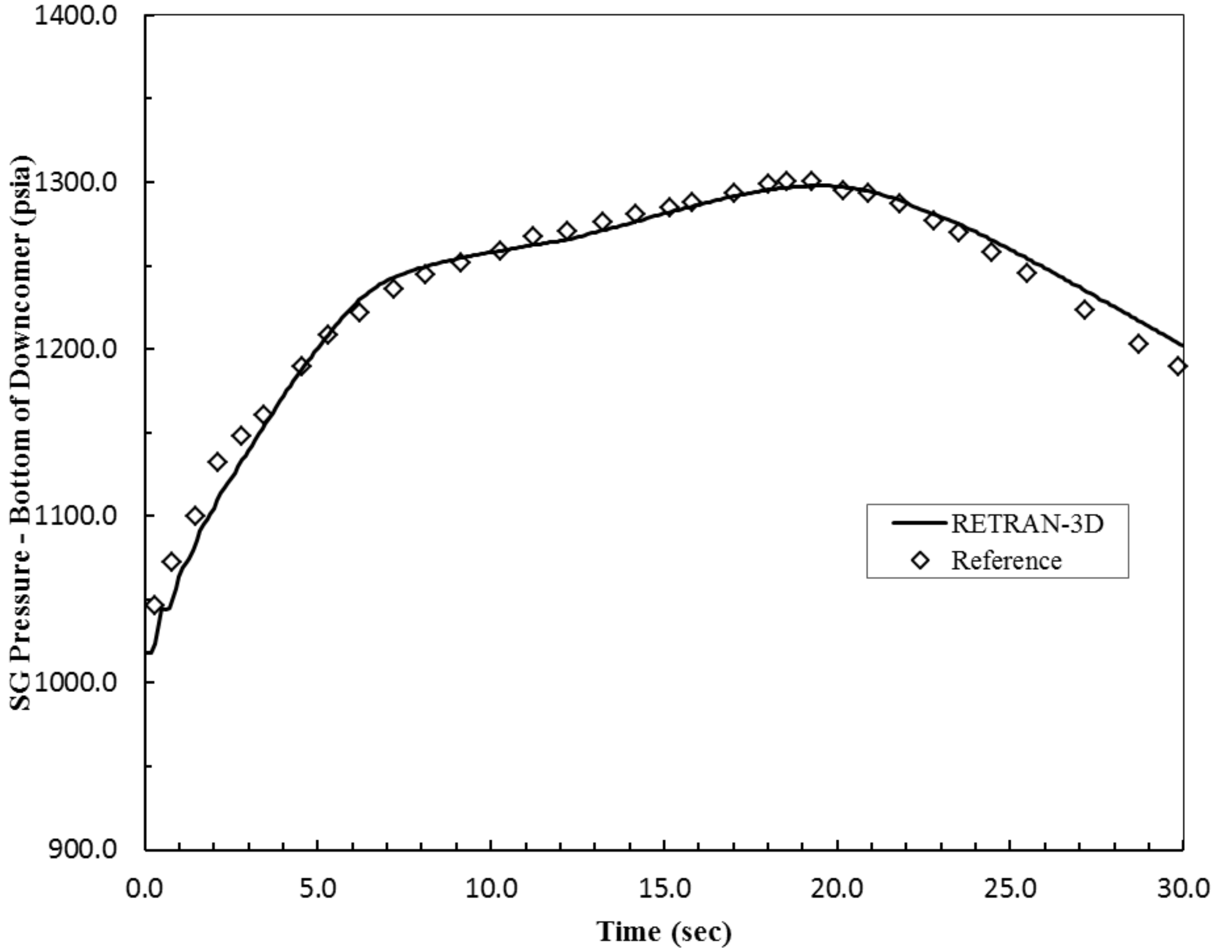
HNP Turbine Trip – Secondary Over-Pressurization Average Temperature



HNP Turbine Trip – Secondary Over-Pressurization Pressurizer Level



HNP Turbine Trip – Secondary Over-Pressurization Pressure at Bottom of SG Downcomer



15.3 Locked Rotor (RNP) Transient Overview and Summary

- Classified as ANS Condition IV event (limiting fault)
- Analyzed for two main purposes
  - Verify primary/secondary relief capability
  - Protect Specified Acceptable Fuel Design Limits (SAFDLs)
    - DNB event
- Assumptions designed for conservative prediction
  - Heaters disabled

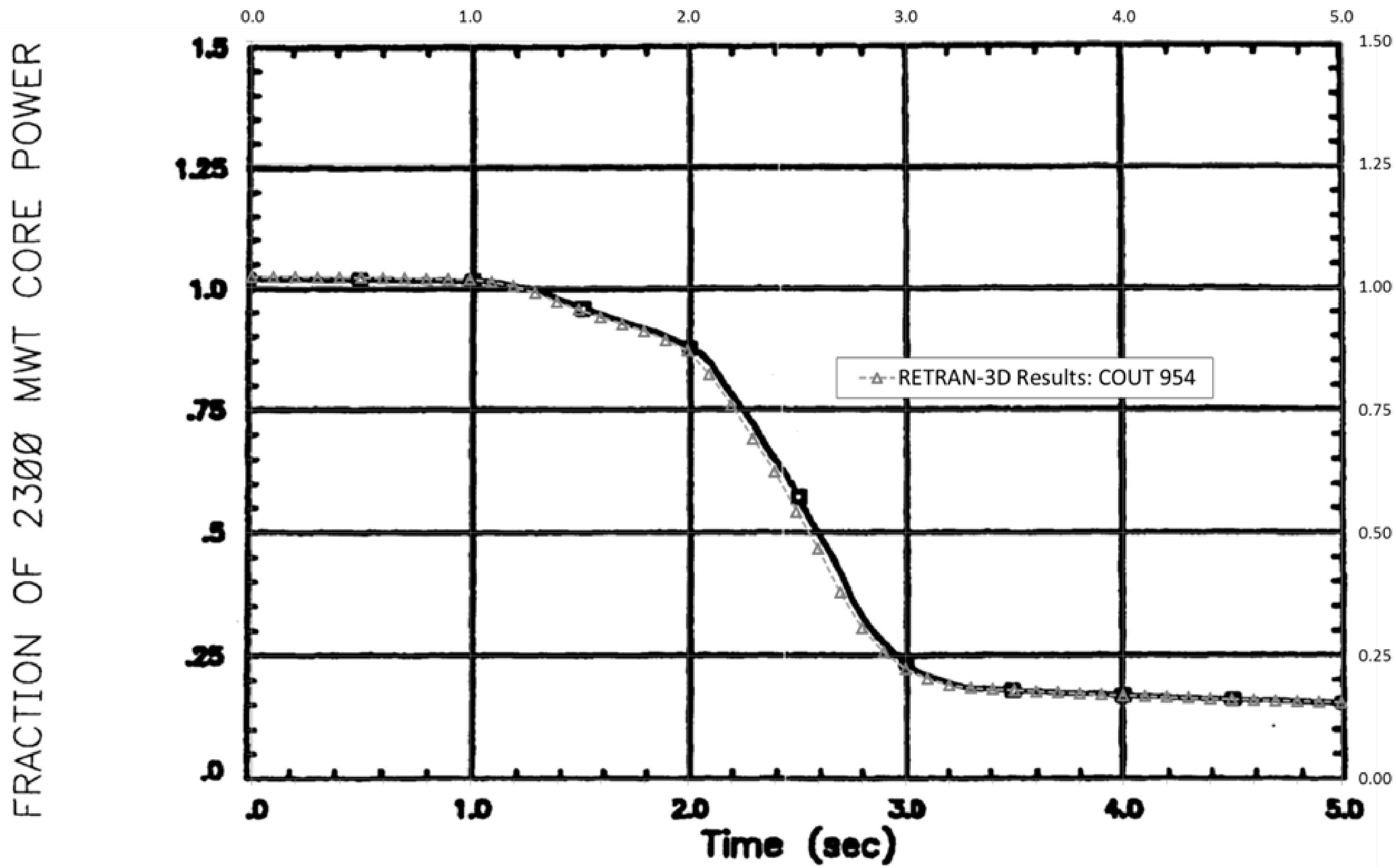
15.3 Locked Rotor (RNP) Transient Overview and Summary

- Benchmark calculations completed for a case from FSAR §15.3.2
  - DNB
- Instantaneous seizure of one RCP (speed to zero)
- Reactor Protection System:
  - Low RCS flow reactor trip
- Used to evaluate model performance for decrease in RCS flow rate
  - Match key analysis inputs and modeling assumptions

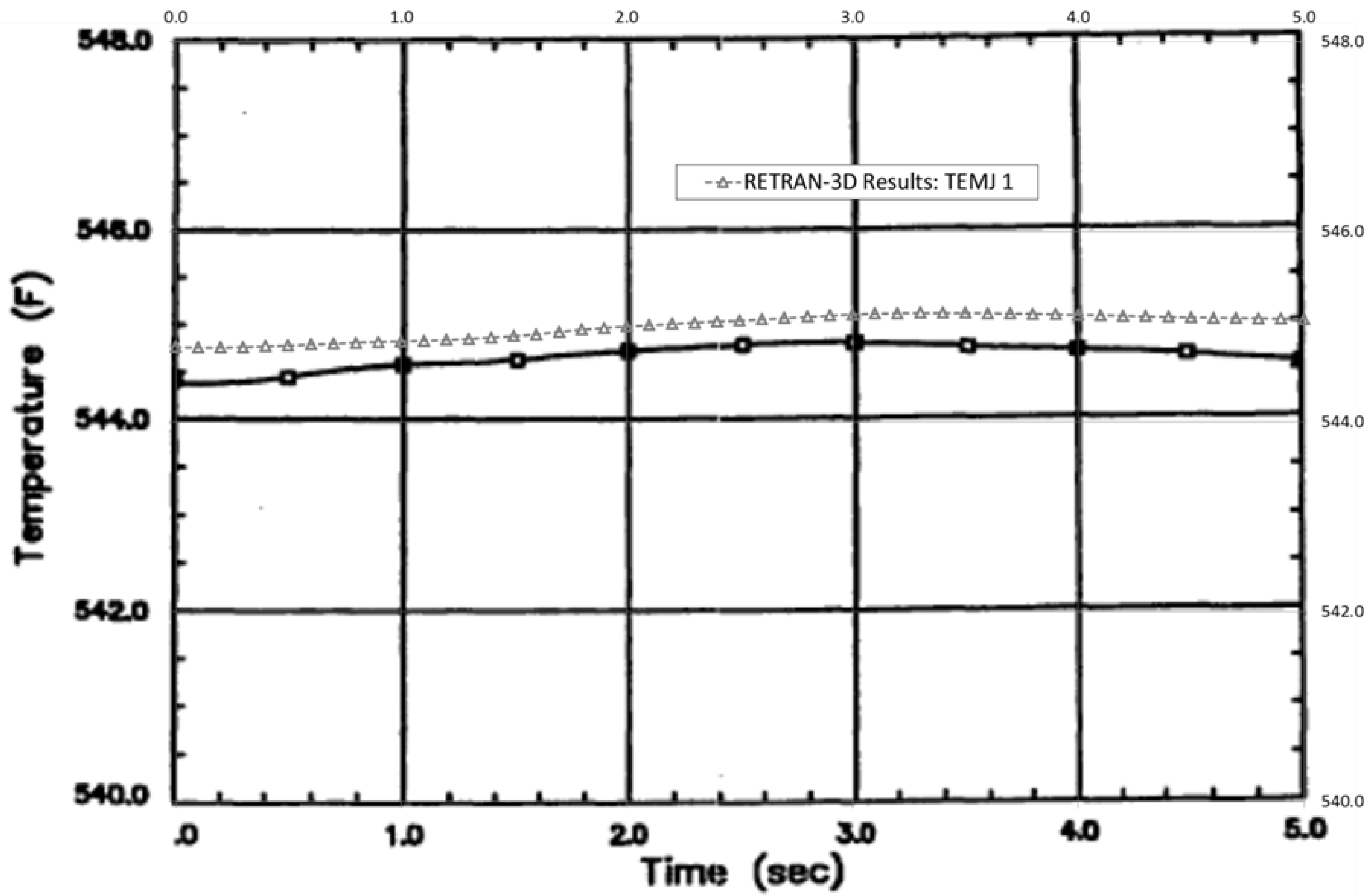
15.3 Locked Rotor (RNP) Sequence of Events

Event	Event Time, s	
	AOR	RETRAN-3D
Single Primary Pump Seizes	0	0
Low RCS Flow Trip Signal	0.075	0.038
Scram	1.075	1.04
Turbine Trip	1.10	1.04
Trip of Unaffected Pumps	1.10	1.04
Affected-loop Flow Reversed	1.50	1.7
Minimum DNBR Occurred	2.25	2.55

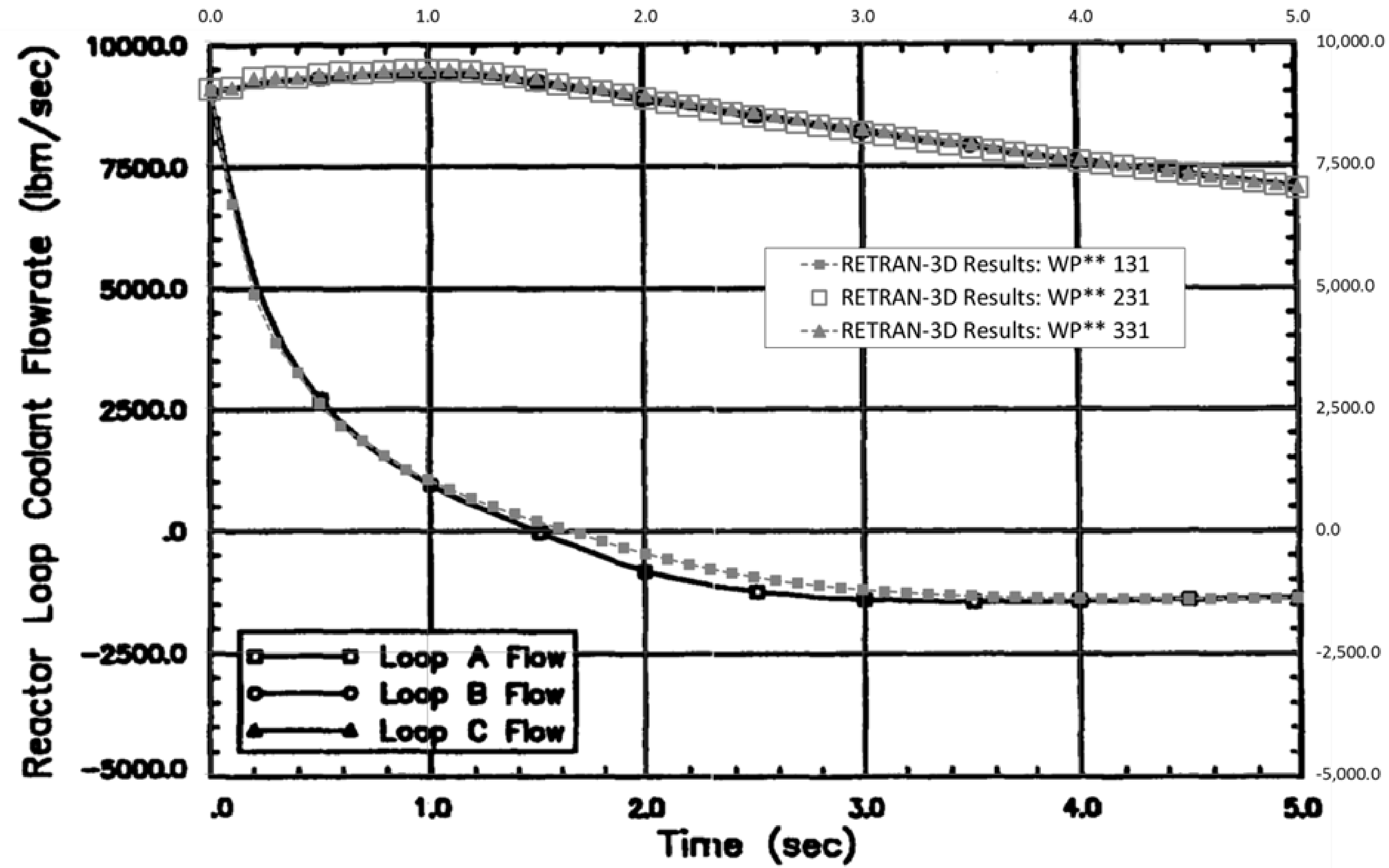
RNP – Locked Rotor
Normalized Reactor Power



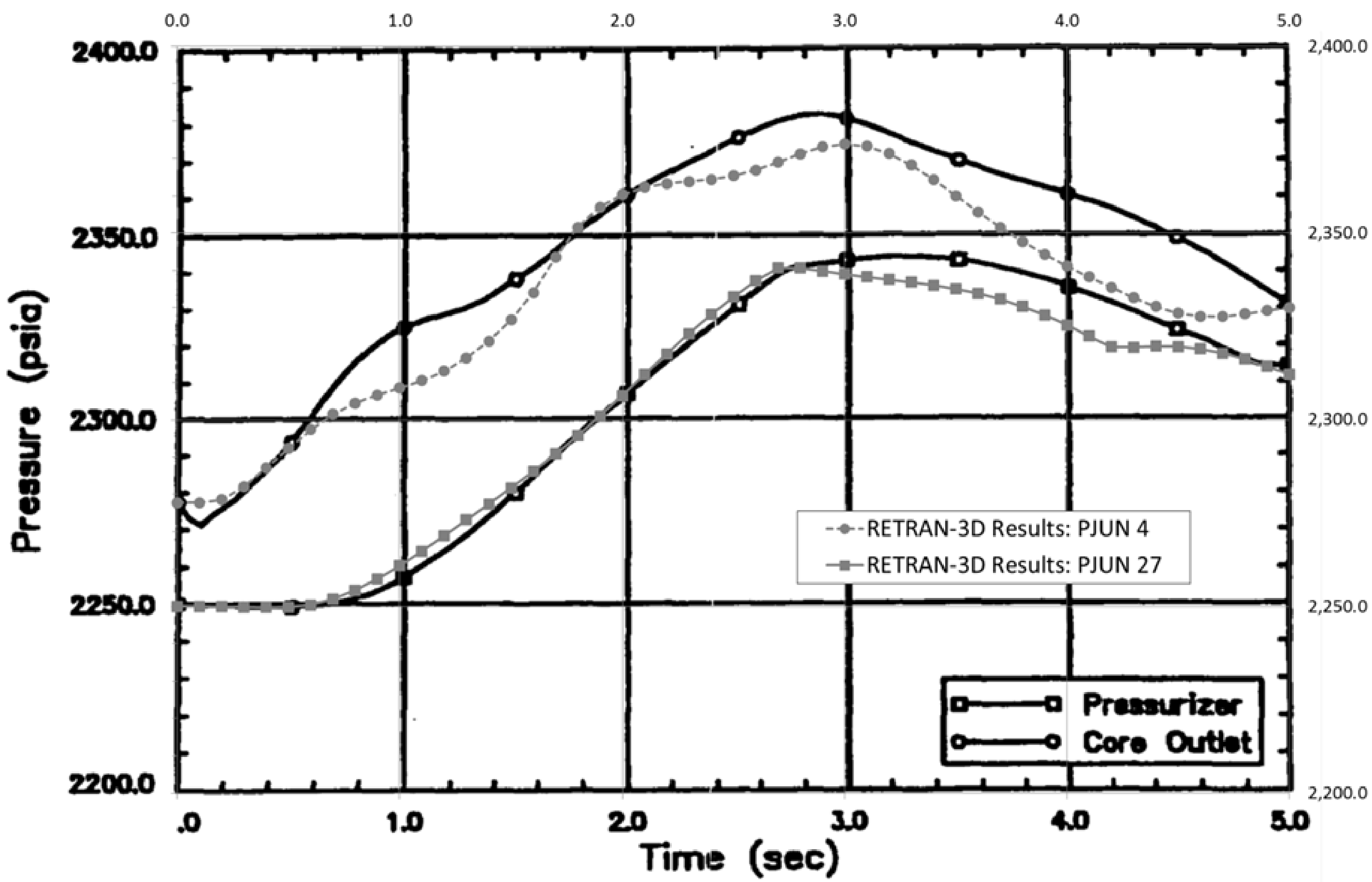
RNP – Locked Rotor
Core Inlet Temperature



RNP – Locked Rotor
RCS Loop Mass Flow Rate



RNP – Locked Rotor
Primary Pressure



Expanded VIPRE-01 Model

<u>Background</u>

- The RNP and HNP expanded VIPRE-01 models are based on their respective 14-channel VIPRE-01 models
- The RNP and HNP 14-channel VIPRE-01 models have been developed and submitted to the NRC for review and approval in DPC-NE-2005-P
  - Applicable to the AREVA Advanced W HTP fuel type
  - Based on the NRC-approved ONS 14-channel VIPRE-01 model documented in DPC-NE-3000-PA
- The 14-channel model will primarily be used for the following applications:
  - Determination of steady-state and transient MDNBR for UFSAR Chapter 15 events
  - Maximum Allowable Radial Peaking (MARP) calculations
  - Statistical Core Design (SCD) analyses

Expanded VIPRE-01 Model

Background (cont.)

- Key characteristics of the 14-channel VIPRE-01 model:
  - Simulates limited fuel pin detail in the interior of the hot fuel assembly
  - Uses a conservative center-peaked and flat radial pin power distribution
  - Computationally efficient
  - Conservative MDNBR results
- Limitations of VIPRE-01 14-channel model:
  - Limited to specific applications where the pin peaking is located in the interior of the hot fuel assembly
  - Not suitable for mixed-core applications

Expanded VIPRE-01 Model

Model Description

- To address the limitations of the 14-channel models, the following expanded VIPRE-01 models are developed:
  - [ ] model for RNP, and
  - [ ] model for HNP
- Key Characteristics of the expanded models:
  - [ ]
  - [ ]
  - Surrounding the above pin-wise detail are lumped fuel assemblies of assemblies adjacent to the hot assembly and a lumped core representing the rest of the fuel assemblies
  - VIPRE-01 code options (e.g., flow, heat transfer and CHF correlations, turbulent mixing parameters, code solution scheme and convergence criteria, …) selected are identical to the 14-channel model

Expanded VIPRE-01 Model

<u>Applications of the Expanded Model</u>

- Supplement the existing smaller VIPRE-01 models
- Quantify mixed-core effects
- Quantify the effects of fuel assembly gap changes (specifically if the pin peaking is occurring at or near the fuel assembly gap)
- Recover DNB margin by implementing actual pin-wise power distribution from CASMO/SIMULATE core design codes

Conclusion

- RETRAN Base Models developed for Harris and Robinson
- Benchmark analysis against current FSAR analysis demonstrates the ability to model key phenomena
- Computer codes and analysis approach build upon previous Duke Energy experience
  - With minor enhancements
- Extended VIPRE-01 model provides capability to address a wider range of conditions