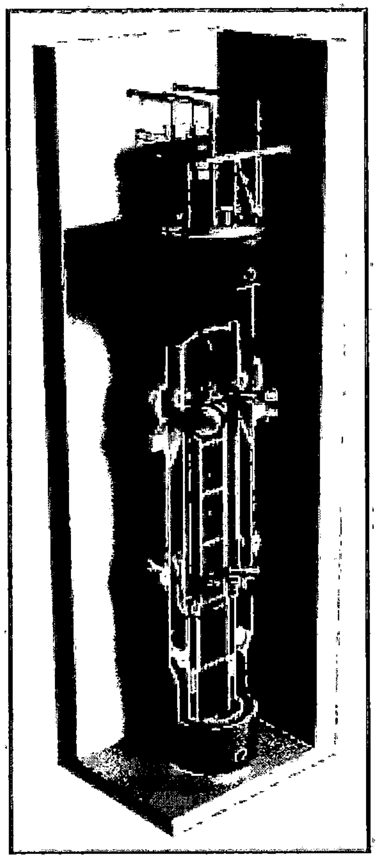
Enclosure:

"ACRS Full Committee Presentation: NuScale Topical Report, Loss-of-Coolant Accident Evaluation Model," PM-0320-69138, Revision 0

NuScale Power, LLC
1100 NE Circle Blvd., Suite 200 Corvallis, Oregon 97330 Office 541.360-0500 Fax 541.207.3928
www.nuscalepower.com

ACRS Full Committee Presentation



NuScale Topical Report

Loss-of-Coolant Accident Evaluation Model

March 5, 2020

PM-0320-69138
Revision: 0

Template #: 0000-21727-F01 R5

Presenters

Matthew Presson
Licensing Project Manager

Dr. Pravin Sawant
Supervisor Code Validation and Methods

Dr. Selim Kuran
Thermal Hydraulic Analyst

Ben Bristol
Supervisor System Thermal Hydraulics

Agenda

- Methodology Overview
  - Background
  - Regulatory Requirements
  - Methodology Roadmap
- NPM Safety Systems Overview
- Element 1: PIRT
- Element 2: Assessment Base
- Element 3: NRELAP5 Evaluation Model
- Element 4: Applicability Evaluation
- Extension of LOCA EM to IORV
- Conclusions

Background

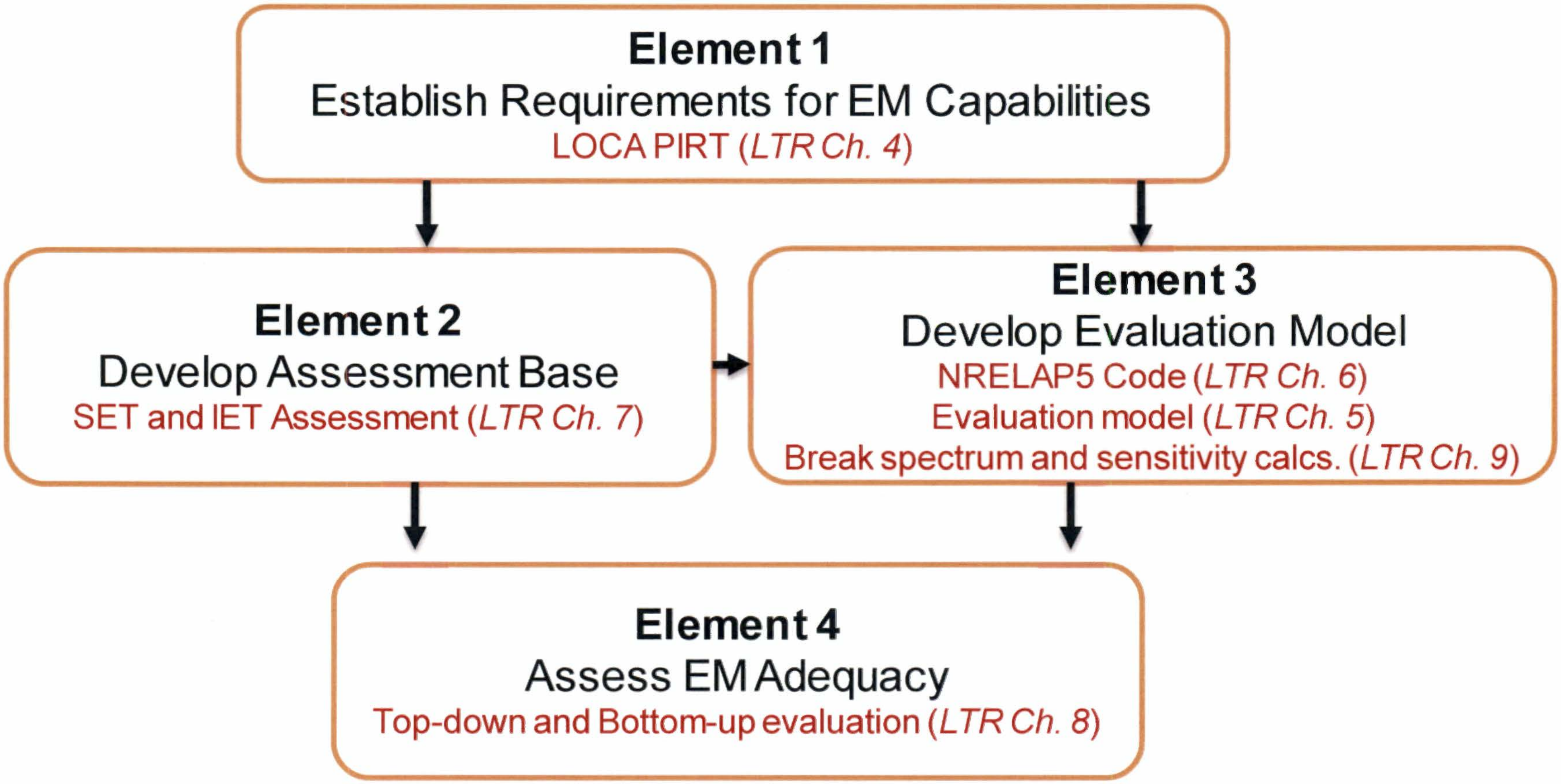
- Unique NPM Design Features
  - Integrated design eliminates piping and limits potential breaks
  - Coolant captured completely in containment, cooled and returned to RPV using a large pool as ultimate heat sink
- Simple LOCA Progression with Well-Known Phenomena
  - Choked/un-choked flow through break and ECCS valves
  - Core decay heat and RCS stored energy release
  - CNV heat transfer to pool (condensation, conduction, convection)
- EM Development Approach
  - Follows Regulatory Guide 1.203 EMDAP (Table 2-1)
  - Compliance with 10 CFR 50.46 and Appendix K requirements (Table 2-2)

Regulatory Requirements

- 10 CFR 50.46 Acceptance Criteria
  - Max. clad temperature < 2200 °F
  - Cladding oxidation > 0.17 times thickness
  - Hydrogen generation < 0.01 times total hydrogen from oxidation of all cladding
  - Core remains amenable to cooling
  - Long-term cooling maintained
- Maximum PCT at steady state, no clad heat up
- Conservative LOCA EM Acceptance Criteria (FOMs)
  - Core remains covered: collapsed level > TAF
  - MCHFR > CHFR Limit (1.29)
  - Containment pressure and temperature below design limit

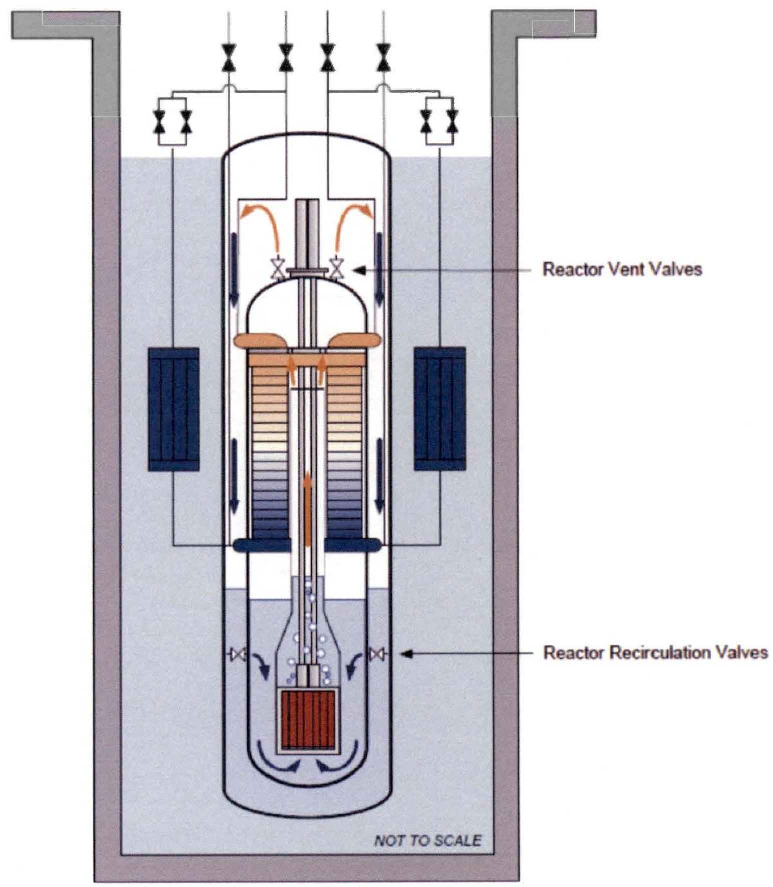
Methodology Roadmap

- 10 CFR 50.46 Appendix K Compliance (Section 2.2.3 of LTR)
- RG 1.203 EMDAP (Section 2.1 of LTR)



NPM Safety Systems

- ECCS
  - Opens a boiling/condensing circulation flow path to transfer decay and residual heat to reactor pool
  - Reactor Recirculation Valves (RRV): 2 valves
  - Reactor Vent Valves (RVV): 3 valves
  - Actuation Signals: High CNV level, 24-hour loss of AC power
  - Fail safe: ECCS trip valves open on loss of DC power
- Inadvertent Actuation Block (IAB)
  - Prevents inadvertent opening of ECCS valves at high RCS pressure
  - Actuation based on differential pressure between RPV and CNV
- Module Protection System (MPS)
  - Reactor scram
  - Steam Generator (SG) and Containment (CNV) Isolation
  - Passive safety system activation (ECCS and DHRS)
- Decay Heat Removal System (DHRS)
  - Passive, boiling-condensation system
  - Removes heat from RCS through SG via two trains
  - Each trains capable of removing 100% decay heat
  - Not credited in LOCA EM



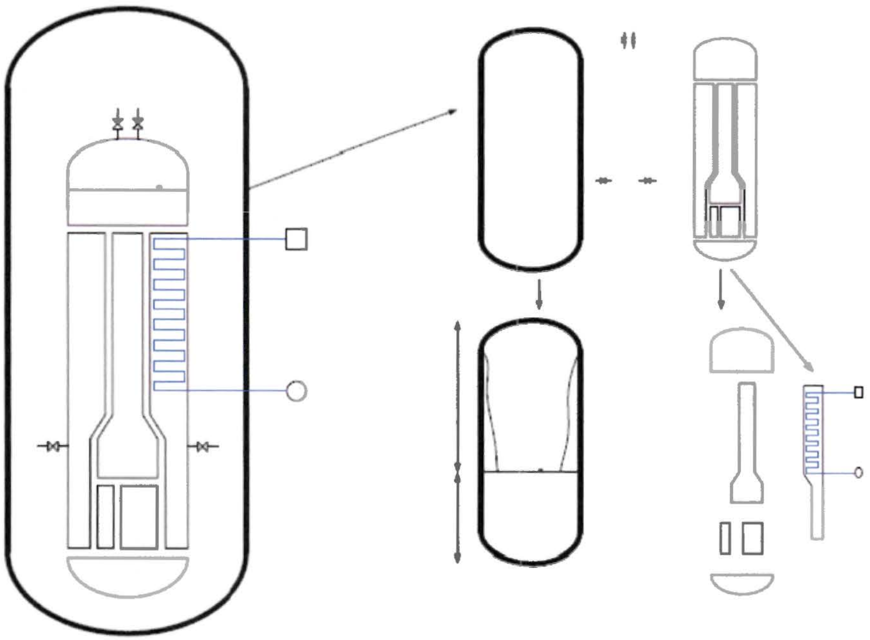
Element 1
PIRT

PIRT Process

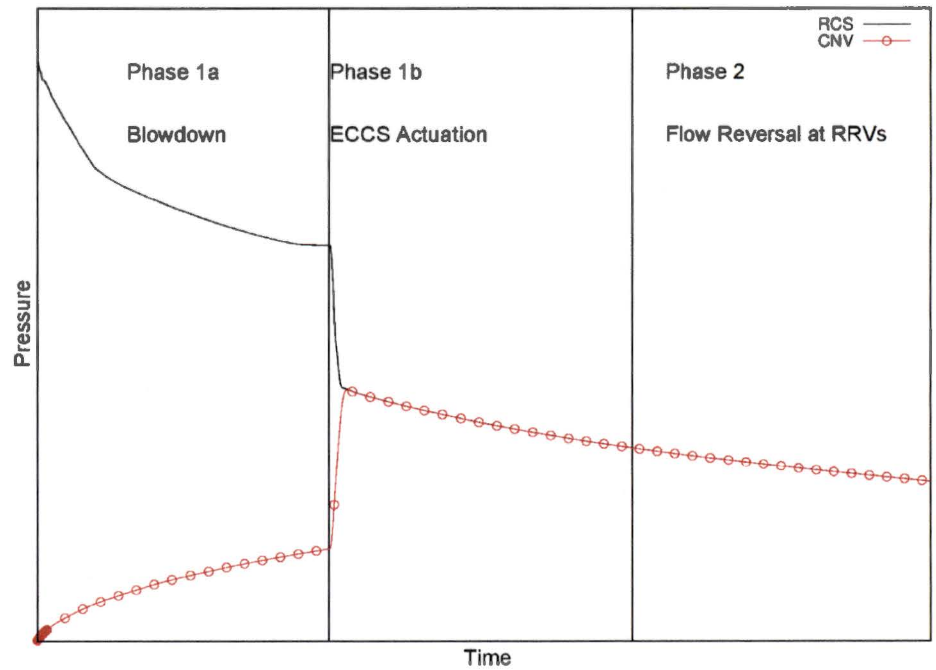
- Assessment of relative importance of phenomena
  - Unique phases
  - Key components
- PIRT panel included recognized experts and NuScale subject matter experts
  - State-of-knowledge, design description, LOCA description, NRELAP5 calculations
- Figures-of-Merit
  - CHF, Collapsed level above top of the active fuel, CNV P & T
- Rankings
  - Importance: High, Low, Medium, Inactive
  - Knowledge: Well known (small uncertainty), Known (moderate uncertainty, partially known (large uncertainty), very limited

Spatial and Temporal Decomposition

- Phenomena identified for Systems, Structure, Components (SSCs) and LOCA phases
  - Phase 1a: Blowdown
  - Phase 1b: ECCS activation (opening)



System/Subsystem/Module decomposition



Distinct phases of a typical NPM LOCA

Element 2
Assessment Base

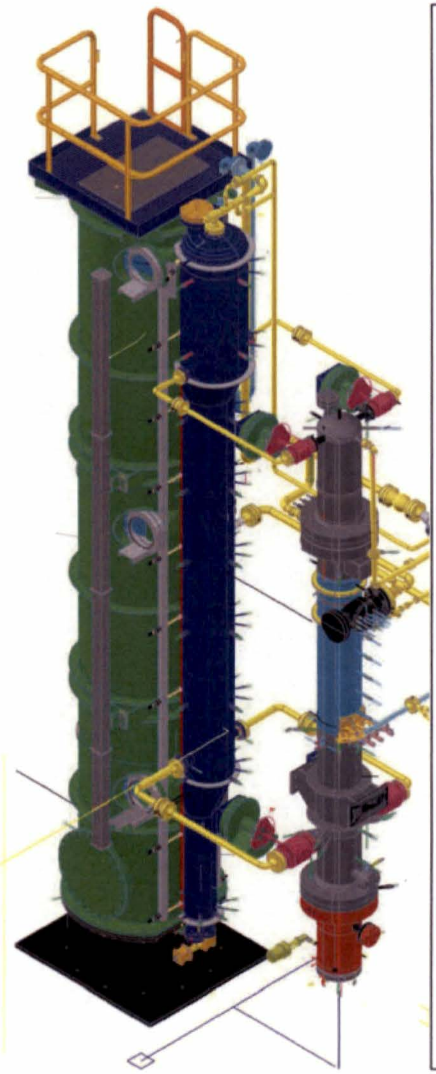
NRELAP5 Code

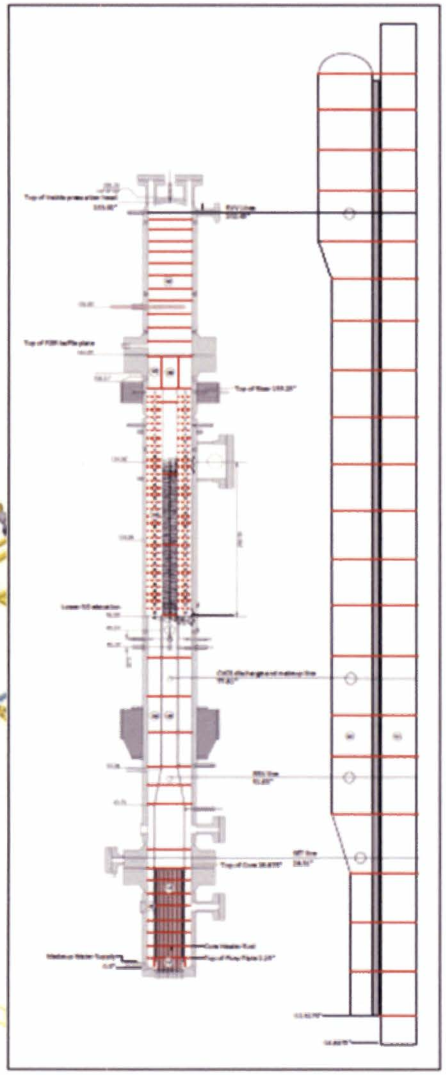
- RELAP5-3D© v4.1.3 used as a baseline code
  - Two-fluid model (thermal and mechanical non-equilibrium) for hydrodynamics with
    - Non-condensable gases with gas phase
    - Semi-implicit scheme for time integration
  - Heat conduction across 1D geometries (slab, cylinder, sphere)
  - Neutron Kinetics with thermal hydraulic feedback
  - Special Process Models
  - Comprehensive control/trip system modeling
- Code configuration control and development consistent with NuScale's NQA-1 2008 / 2009a QA program
- Modifications for NRELAP5:
  - NuScale specific components (e.g., helical coil SG)
  - Regulatory requirements (i.e., Appendix K)
  - Error correction

IET and SET Data

- Extensive database with adequate coverage of all high-ranked phenomena
- Integral effects tests (IET)
  - Six (6) NIST-1 tests
- Separate effects tests (SET)
  - Two (2) NIST-1 SETs
  - Four (4) other NuScale SETs
  - Nine (9) Legacy SETs

NIST-1 Facility





- Primary source of NuScale-Specific IET and SET data
- Design Features
  - Integral Reactor Vessel with electrically heated rod bundle core, helical coil steam generator, and pressurizer
  - Containment with HTP and Cooling Pool
  - DHRS, ECCS, CVCS lines represented
  - ~700 instruments
- Scaling Basis
  - Power/Volume Scaling
  - Reduced height and reduced volume scale
  - Full Pressure and Temperature
  - Same Time Scale (isochronicity)

Element 3
NRELAP5 NPM LOCA

NPM LOCA Model Overview

- Analysis and Justifications
  - NRELAP5 model nodalization and input options
  - Time-step control
  - Initial and boundary condition biases
  - Treatment of setpoints and trips
- LOCA break spectrum
  - Break location and sizes
  - Single failures
  - Power availability
- Methodology sensitivity calculations
  - Required by Appendix K
  - Phenomena-specific
  - To establish conservative biases

Element 4
Applicability Evaluation

Applicability Evaluation

- Evaluated models and correlations (bottom-up)
  - Identified dominant models/correlations for ‘H’ phenomena (Table 8-1 of LTR)
  - Identified key model/correlation parameters and phenomenological domain where models/correlations are used (Tables 8-2 and 8-4)
  - Reviewed models/correlations (Table 8-18 of LTR)
    - Pedigree, Applicability range, Fidelity to SET data, Scalability
- Evaluated integral performance of EM (top-down)
  - Reviewed code governing equations and numerics
  - Evaluated integral performance of code using IET data (Table 8-19 of LTR)
  - Evaluated IET data applicability and NRELAP5 scalability
    - Scaling and distortion analysis
    - Differences and distortions between NPM and NIST can be accounted using NRELAP5

Conclusions

- Number of conservatisms built into the NuScale LOCA EM
  - 10 CFR 50 Appendix K
  - Other methodology conservatisms
- Cycle independent bounding LOCA analysis
- Supported by extensive experiment database, well qualified code, and several sensitivity calculations
- Applicability evaluation consistent with RG 1.203
- CHF not challenged
- Collapsed level in RPV remains above TAF
- No clad or fuel heat-up
- CNV P&T remain below design limits

Appendix B to LOCA LTR

Extension to IORV Event

IORV Background

- LOCA EM Extended to IORV
  - Liquid space (RRV) and steam space (RVV, RSV) discharge
  - Similar transient phenomena and progression
- EM Development Approach
  - Compliance with DSRS for NuScale SMR Design 15.6.6
  - Follows RG 1.203 EMDAP
  - Element 1 (PIRT), Element 2 (Assessment), and Element 4 (Applicability) remains same as LOCA EM
    - Initial LOCA PIRT addressed IORV
  - Element 3 (NRELAP5 Model) unique due to event classification

Differences from LOCA EM

- Minor methodology differences given AOO classification
- Key Acceptance Criteria
  - MCHFR ≥ Limit (≥ 1.13 high flow range, ≥ 1.37 low flow range)
- Conservatisms same as LOCA with exceptions:
  - Fuel properties still biased to maximize stored energy, but additional 15% bias removed
  - Limiting axial power shapes and radial peaking based on subchannel analysis
  - Moody choked flow model for 2-phase flow choking applied to initiating valve
  - Initial conditions biased to minimize MCHFR

Conclusions

- IORV is an extension of LOCA EM given similar transient phenomena and progression
  - PIRT, Assessment, and Applicability same as LOCA
- Minor methodology differences for AOO classification
  - Focused on conservative CHFR evaluation
- MCHFR occurs early in transient, then rapidly rises given increasing flow to power ratio
- Collapsed level in RPV remains above TAF

Acronyms

1-D	one-dimensional
3D	three-dimensional
AC	alternating current
ANS	American Nuclear Society
CCFL	counter current flow limitation
CHF	critical heat flux
CNV	containment vessel
CVCS	chemical and volume control system
DC	direct current
DCA	Design Certification Application
DHRS	decay heat removal system
ECCS	emergency core cooling system
EM	evaluation model
EMDAP	evaluation model development and assessment process
FW	feedwater
FSAR	Final Safety Analysis Report
FOM	figure of merit
HL	hot leg
HP	high pressure
HS	heat sink
HTP	heat transfer plate
H2TS	hierarchical two-tiered scaling
IAB	inadvertent actuation block
IET	integrated effects test
INL	Idaho National Laboratory
KATHY	Karlstein thermal-hydraulic test facility
kW	kilowatt
LOCA	loss-of-coolant accident
LTR	Licensing Topical Report
Max	maximum
MCHFR	minimum critical heat flux ratio
Min	minimum
$Mlb/ft^2 \cdot hr$	pounds mass per square foot per hour
MPS	module protection system
MSIV	main steam isolation valve
NIST-1	NuScale Integral System Test Facility
NPM	NuScale Power Module

Acronyms

P&T	pressure and temperature
PCT	peak cladding temperature
PIRT	phenomena identification and ranking table
psi	pounds per square inch
psia	pounds per square inch absolute
PZR	pressurizer
QA	Quality Assurance
RCS	reactor coolant system
RG	Regulatory Guide
RRV	reactor recirculation valve
RPV	reactor pressure vessel
RVV	reactor vent valve
SG	steam generator
SET	separate effects test
SIET	Società Informazioni Esperienze Termoidrauliche
StDev	standard deviation
TAF	top of active fuel

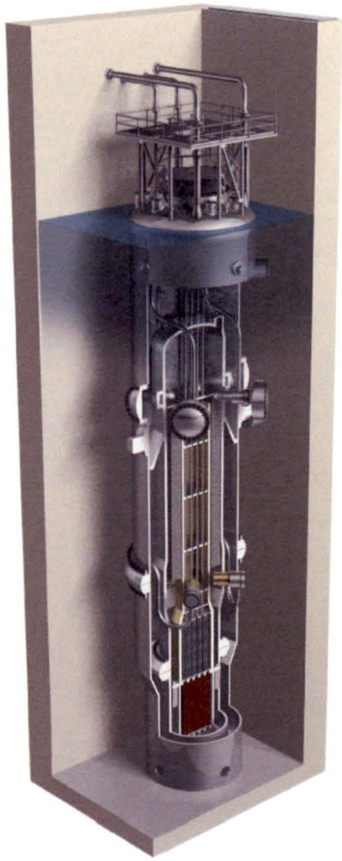
Portland Office
6650 SW Redwood Lane,
Suite 210
Portland, OR 97224
971.371.1592

Corvallis Office
1100 NE Circle Blvd., Suite 200
Corvallis, OR 97330
541.360.0500

Rockville Office
11333 Woodglen Ave., Suite 205
Rockville, MD 20852
301.770.0472

Richland Office
1933 Jadwin Ave., Suite 130
Richland, WA 99354
541.360.0500

Charlotte Office
2815 Coliseum Centre Drive,
Suite 230
Charlotte, NC 28217
980.349.4804



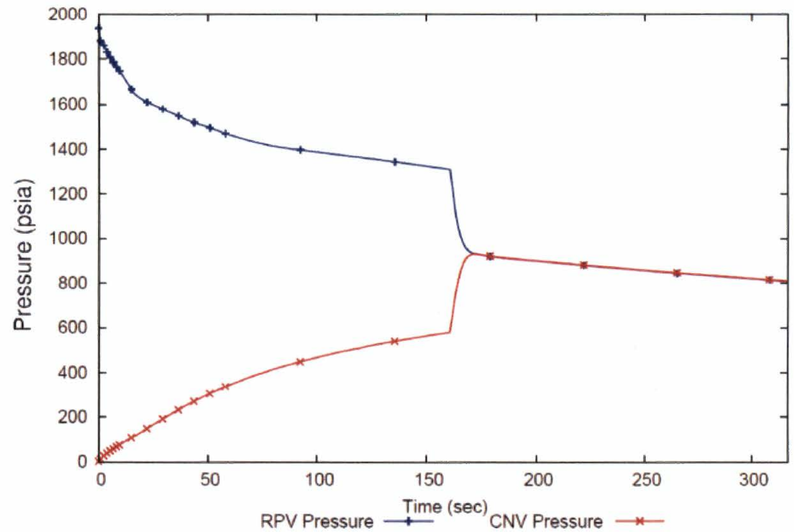
http://www.nuscalepower.com
Twitter: @NuScale_Power

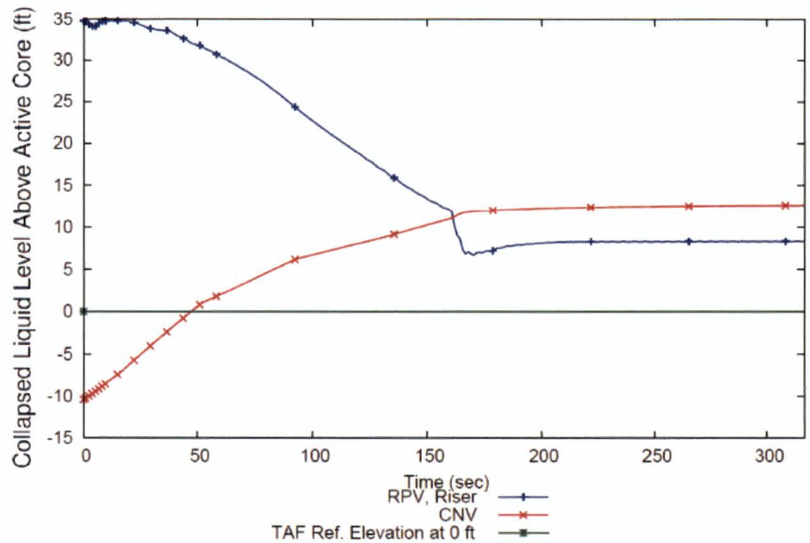
NUSCALE™
Power for all humankind

Backup IORV Slides

RRV Opening Results

Sequence of Events	Time (s)
RRV opens	0
Minimum CHFR occurs	0.5
Containment pressure reaches analytical limit	0.7
Control rods begin to fall	2.7
Peak steam generator pressure is reached	64
Remaining ECCS valves open	161
Minimum collapsed liquid level above the core	170
Peak containment pressure is reached	171
Natural circulation from containment to RPV is established	197





PM-0320-69138
Revision: 0

Template #: 0000-21727-F01 R5

RVV Opening Results

Sequence of Events	Time (s)
RVV opens	0
Containment pressure reaches analytical limit	0.3
Minimum CHFR occurs	0.3
Control rods begin to fall	2.3
Peak steam generator pressure is reached	25
Peak containment pressure is reached	52
Remaining ECCS valves open	3925
Natural circulation from containment to RPV is established	4072
Minimum collapsed liquid level above the core	4192