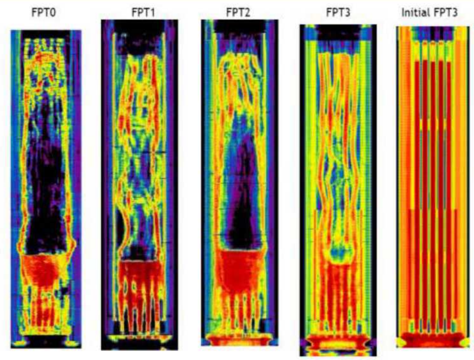
SAND2019-2932C

Exceptional service in the national interest

Sandia National Laboratories

Source: Tokyo Electric Power Company



ONGOING SEVERE ACCIDENT ANALYSIS ACTIVITIES AT SANDIA NATIONAL LABORATORIES

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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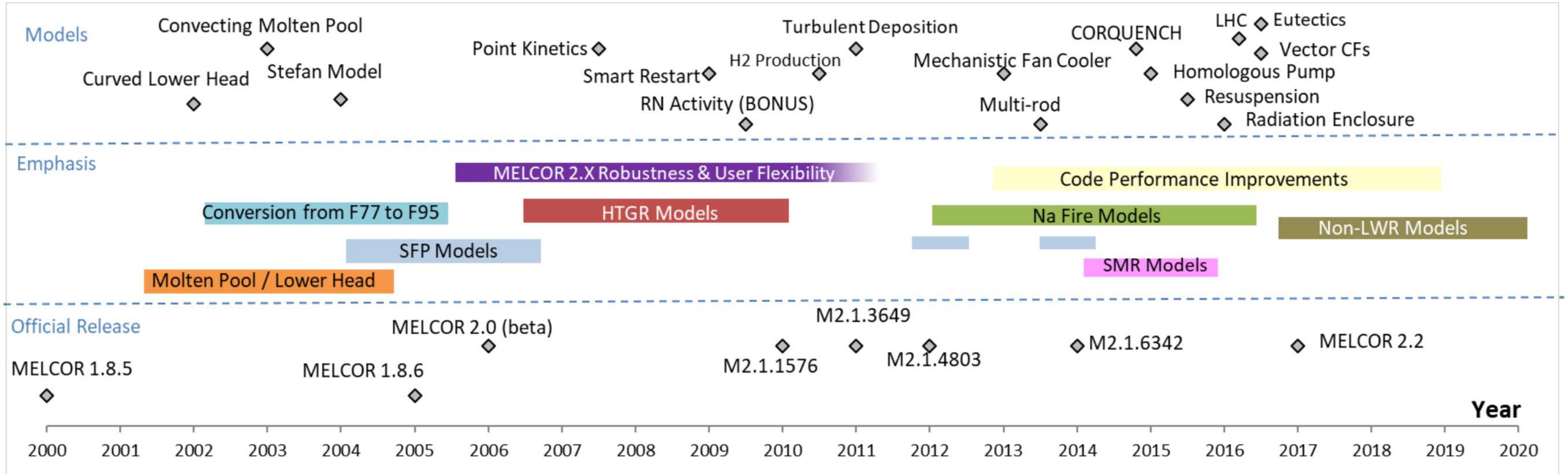
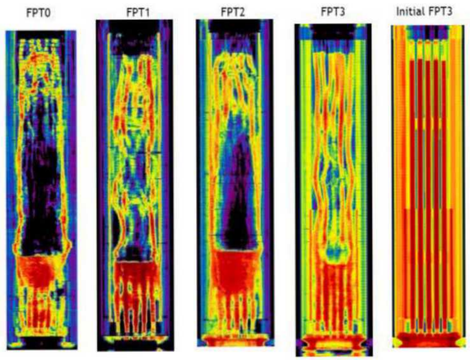
MELCOR Development Activities



- Advanced reactor models
  - Small modular reactor
  - Liquid metal reactors
  - Solid fuel FHRs
  - Liquid fuel MSRs
- Accident tolerant fuel

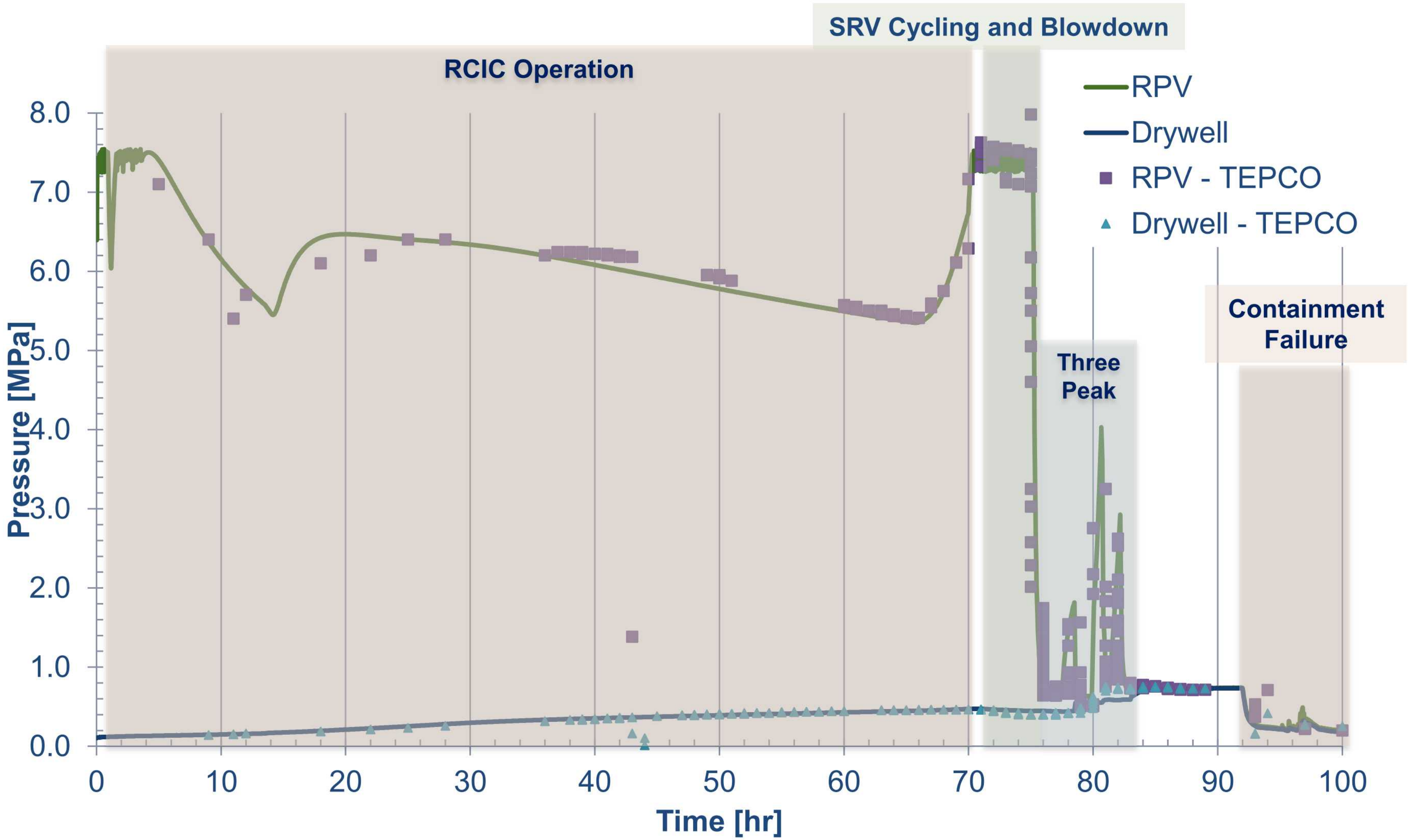


BSAF PHASE II PROJECT

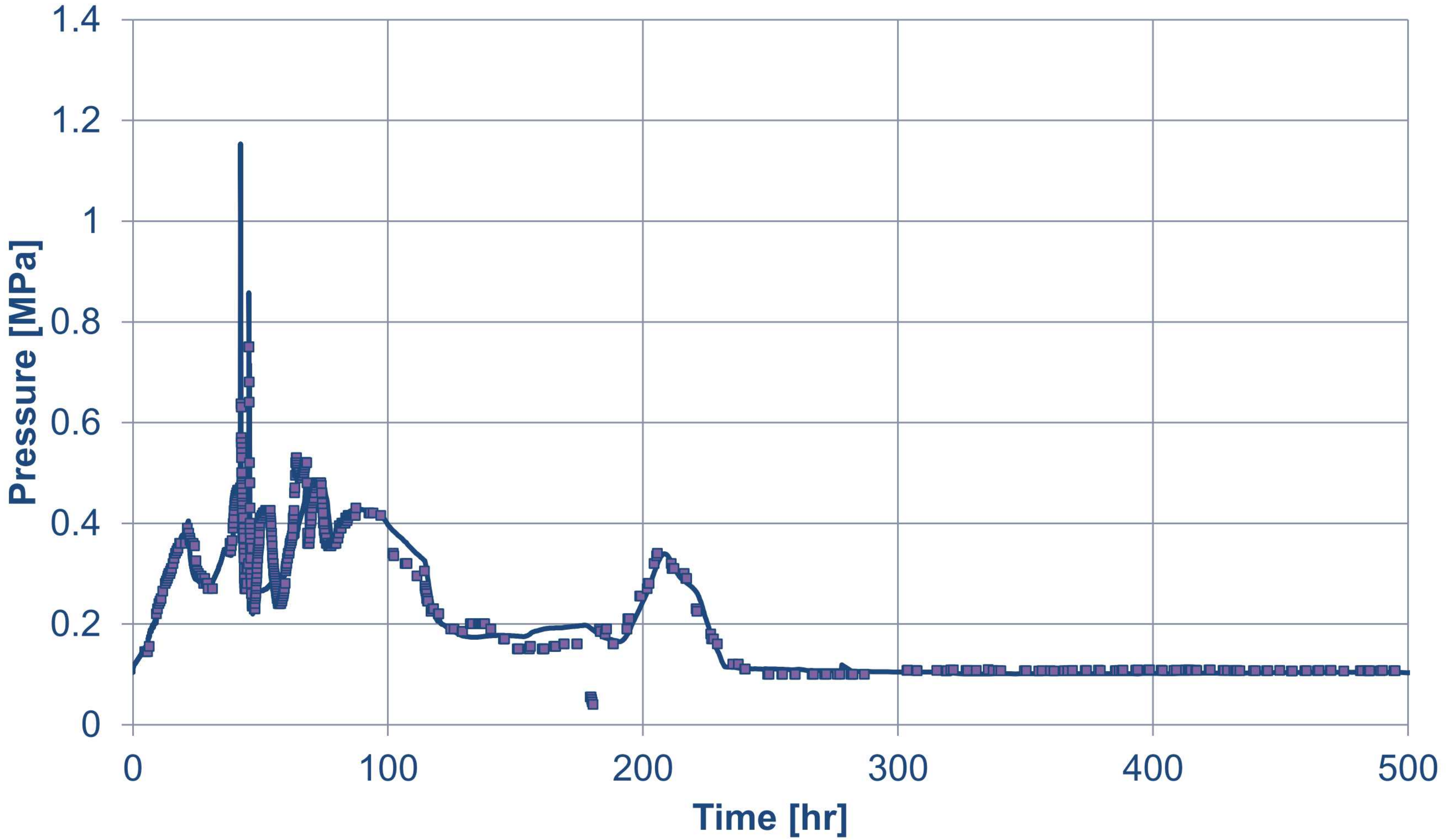
Overview of BSAF Phase II

- Benchmark Study of the Accident at the Fukushima Daiichi Nuclear Power Station (BSAF) Project
  - Completed project
  - Completed final report
- Three separate three week long MELCOR simulations
  - 1F1
  - 1F2
  - 1F3
- Single, combined MACCS simulation of the three MELCOR simulations
  - 2017 WRF Data
  - High-level benchmark of both:
    - Release to the environment from MELCOR
    - Dispersion and subsequent deposition following release

System Pressures – 1F2

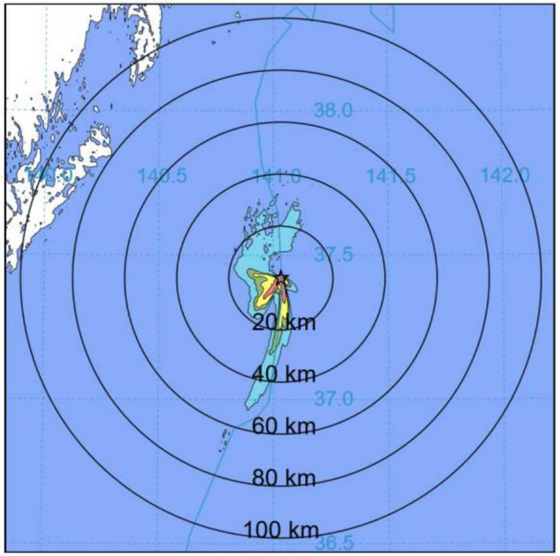


Drywell Pressure – 1F3



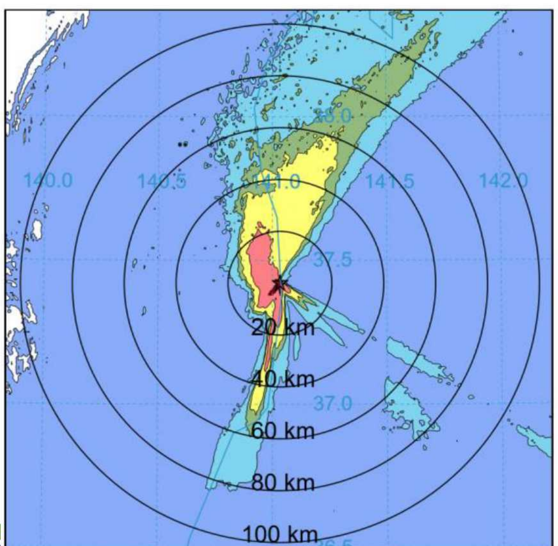
Coupled MELCOR & MACCS Assessment of Fukushima-Daiichi Accidents

1F1

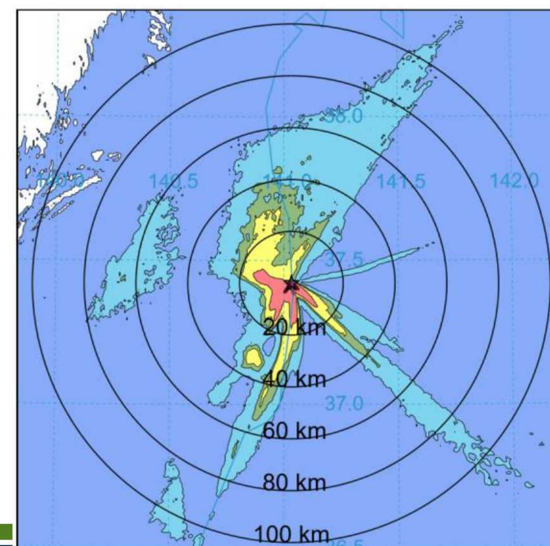


- Evaluate viability of SNL MELCOR source terms by reasonably replicating ground deposition patterns
  - Focus on Cs-137
  - Specific focus on deposition toward the northwest
  - Also focus on overall deposition pattern
- Provide guidance in release timing and magnitude for source term analysts
- Benchmark models against real data
  - HYSPLIT particle tracking model

1F2

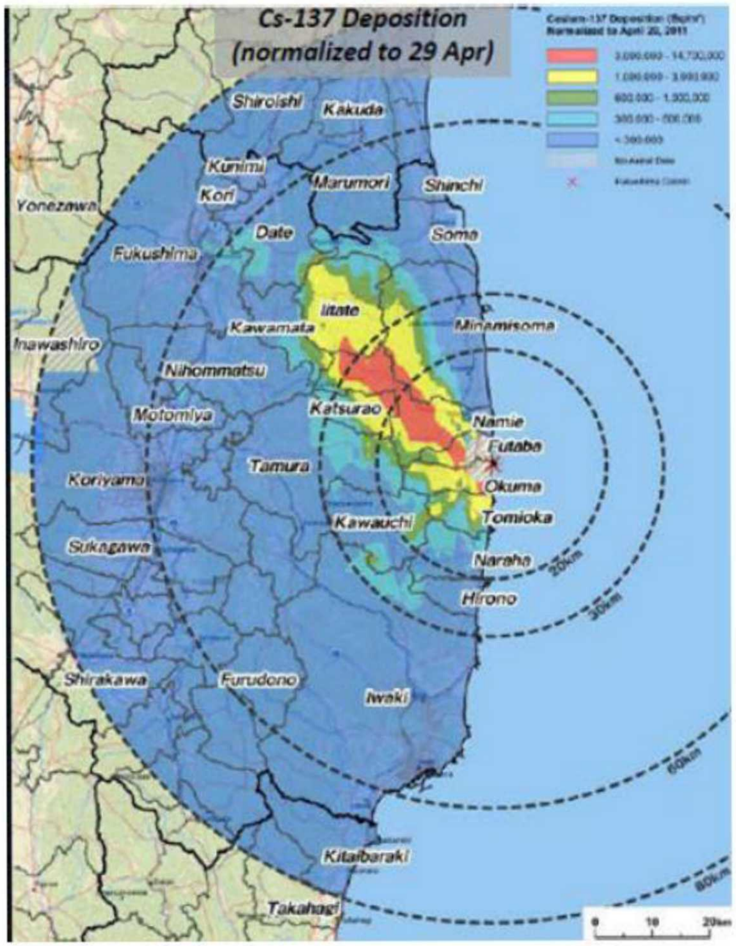


1F3

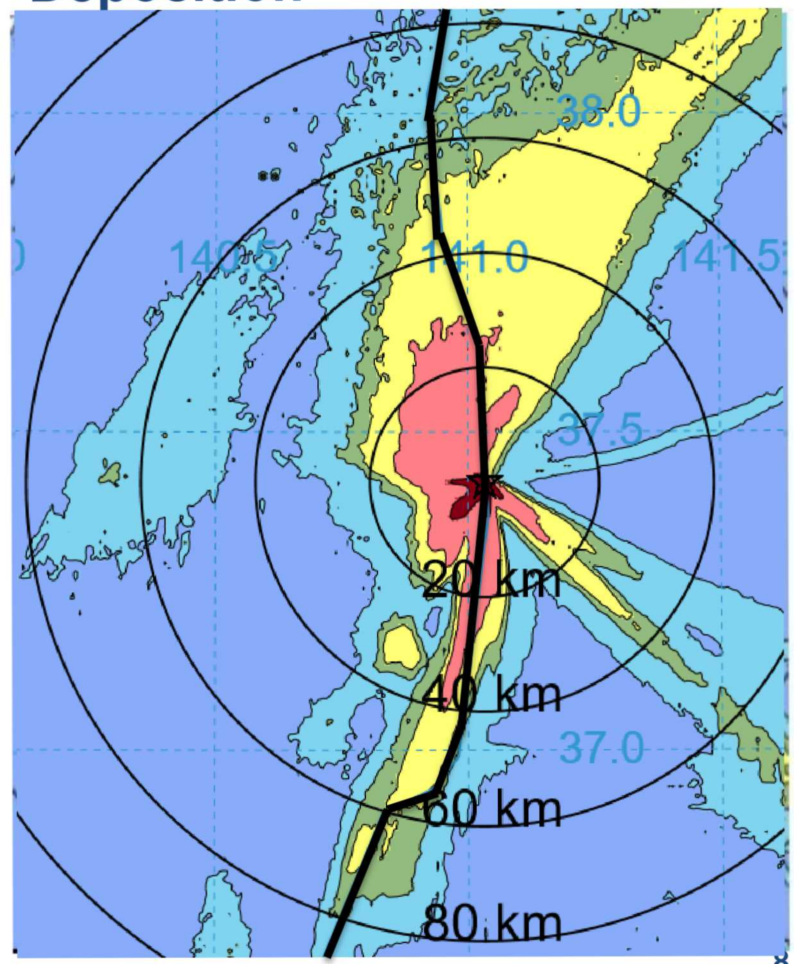


Coupled MELCOR & MACCS Assessment of Fukushima-Daiichi Accidents

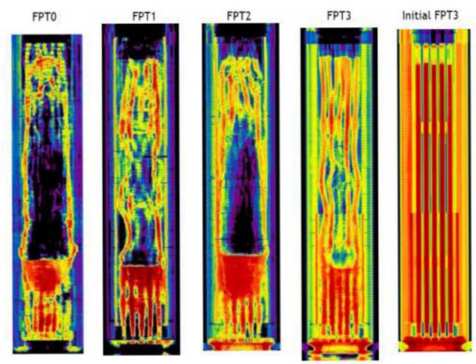
Observed Deposition



MELCOR/MACCS Predicted Deposition



Source: Tokyo Electric Power Company

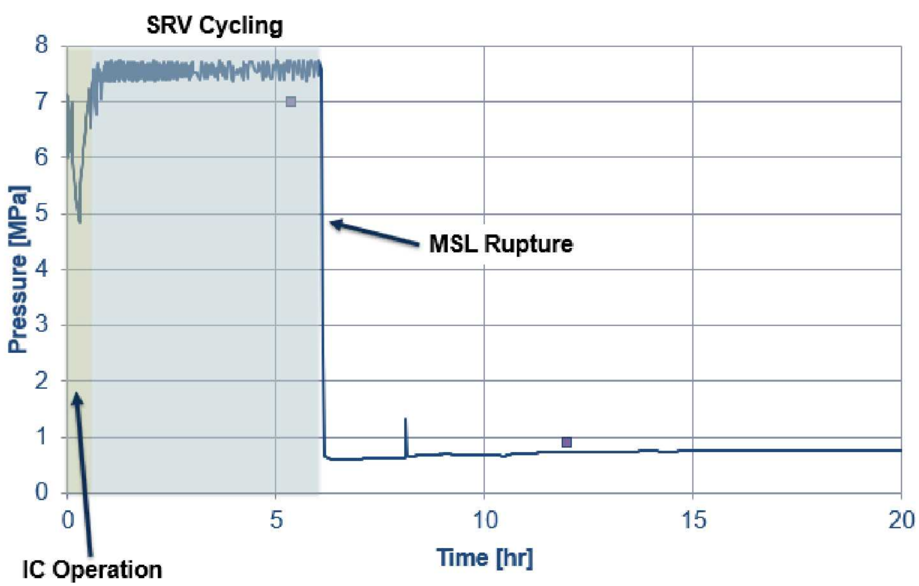


CORIUM CHARACTERIZATION – MINI UA

1F1 Simulation Overview

Plant Conditions

- Deck taken from BSAF Phase II Analysis
- Simulation length – 24 hr



BSAF Phase II RPV Pressure

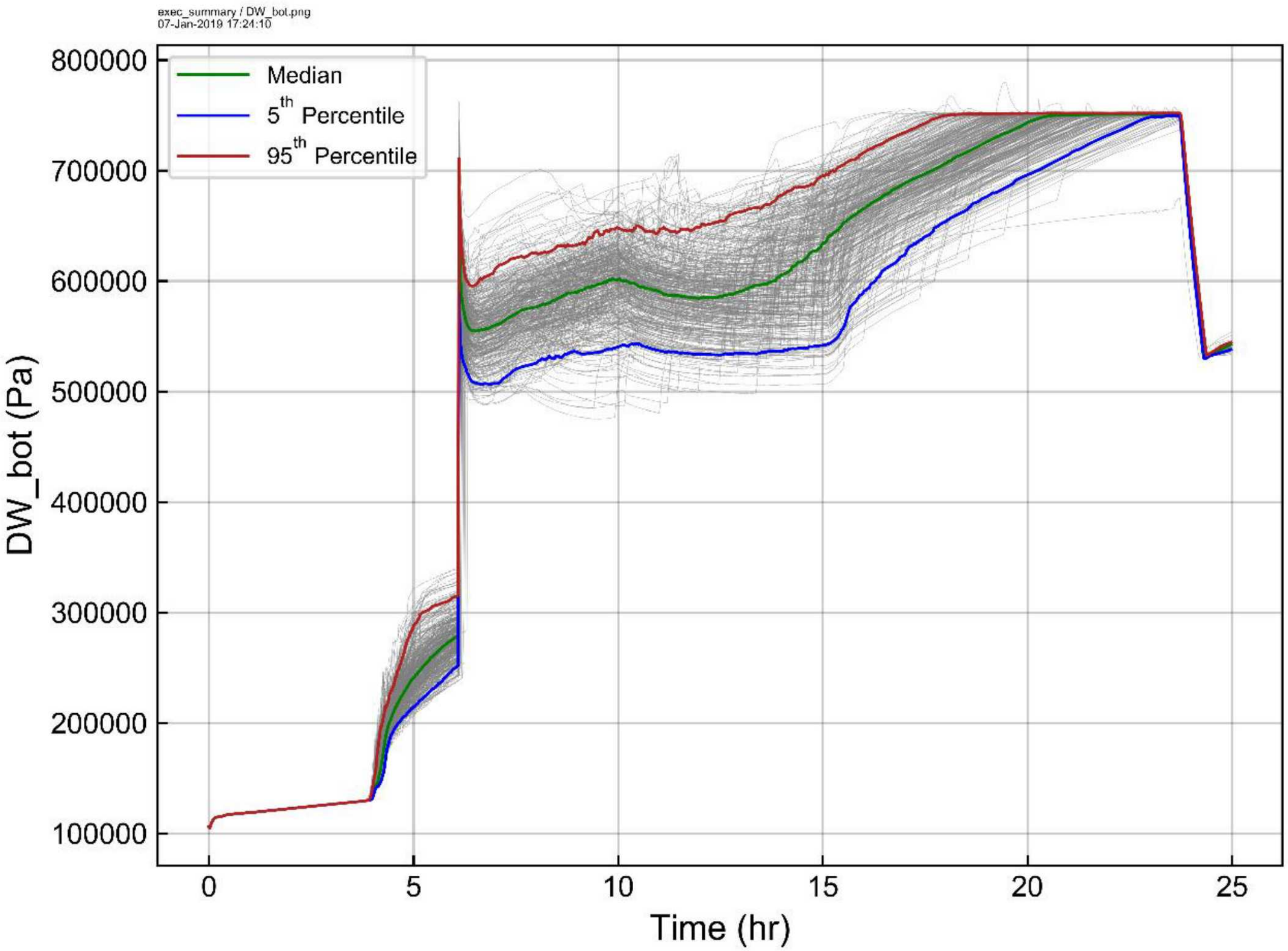
Boundary Conditions

- IC operation
- Allow for MSL rupture, occurs in all cases
- Venting at TEPCO prescribed time
- Explosion @ 24.8 hr
- Minimal injection from 15 onwards
- Control functions and forcing parameters used in BSAF removed

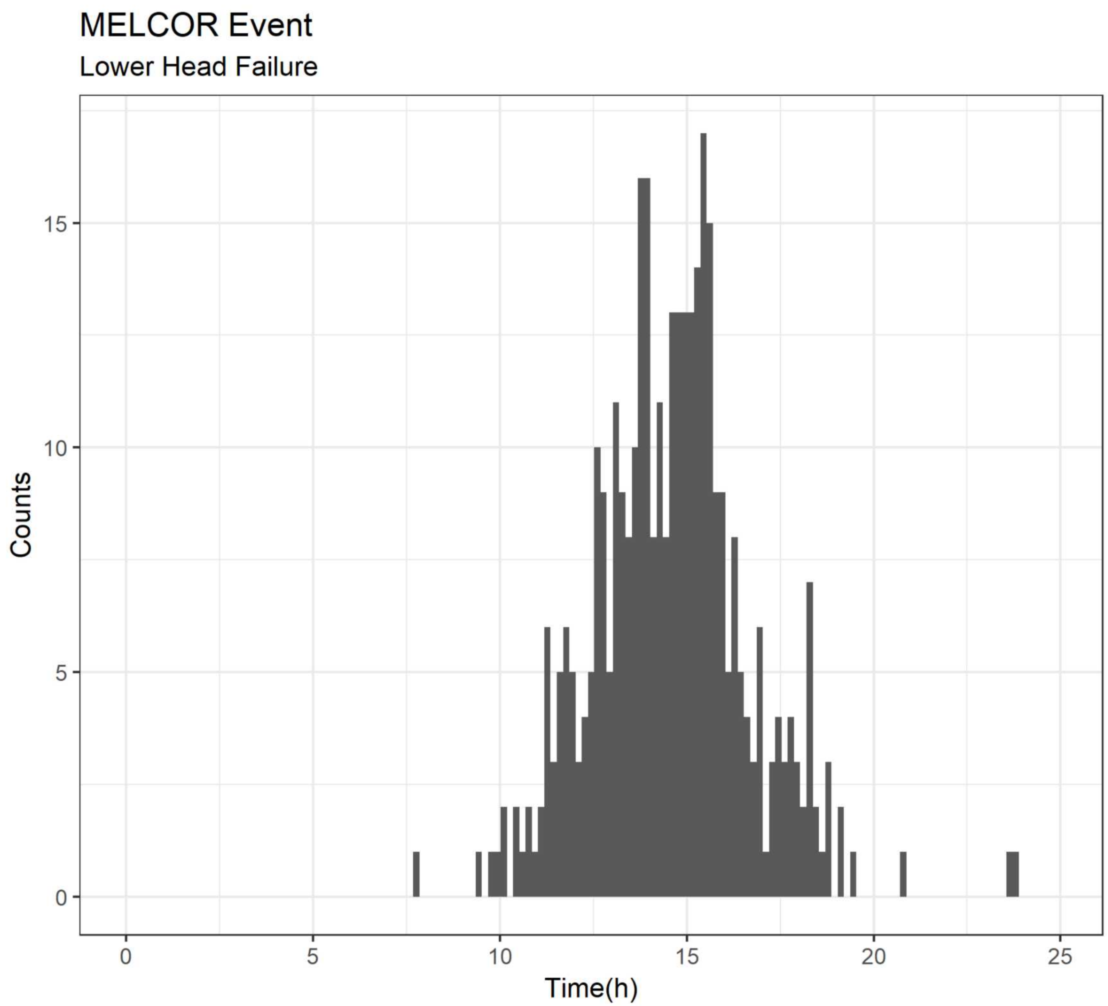
UA Input Parameters

Package	ID	Description	Distribution	Min	Max	Other
COR	1131(2)	Molten Material Holdup Parameters	Scaled Beta	2100	2540	alpha: 3.83, beta: 3
COR	1132(1)	Core Component Failure Parameters	UO2_INT/ZRO2_INT MP_PRC			
COR	1141(2)	Core Melt Breakthrough Candling Parameters	Log Triangle	0.1	2	0.2
COR	1244 (3)	Debris Dryout Heat Flux Correlation: Minimum Debris Porosity	Log Triangle	0.015	1.5	Mode: 0.15
COR	1250 (1)	Conduction Enhancement for Molten Components: Temperature above which enhancement is employed	UO2_INT/ZRO2_INT MP_PRC			
COR	1250 (2)	Conduction Enhancement for Molten Components: Coefficient in enhancement	Log Triangle	0.001	0.1	Mode: 0.01
COR	COR_CCT	Component Critical Minimum Thicknesses	Log Triangle	0.000001	0.0001	Mode: 0.00001
COR	COR_CMT	Candling Secondary Material Transport Parameters	Uniform	0.1	1	-
COR	COR_LP: VFALL	Velocity of falling debris	Log Triangle	0.1	5	Mode: 1.6
MP	UO2_INT: MP_PRC	Material Melting Point	Normal	-	-	Mean: 2479 σ: 83
MP	ZRO2_INT:	Material Melting Point	Normal	-	-	Mean: 2479

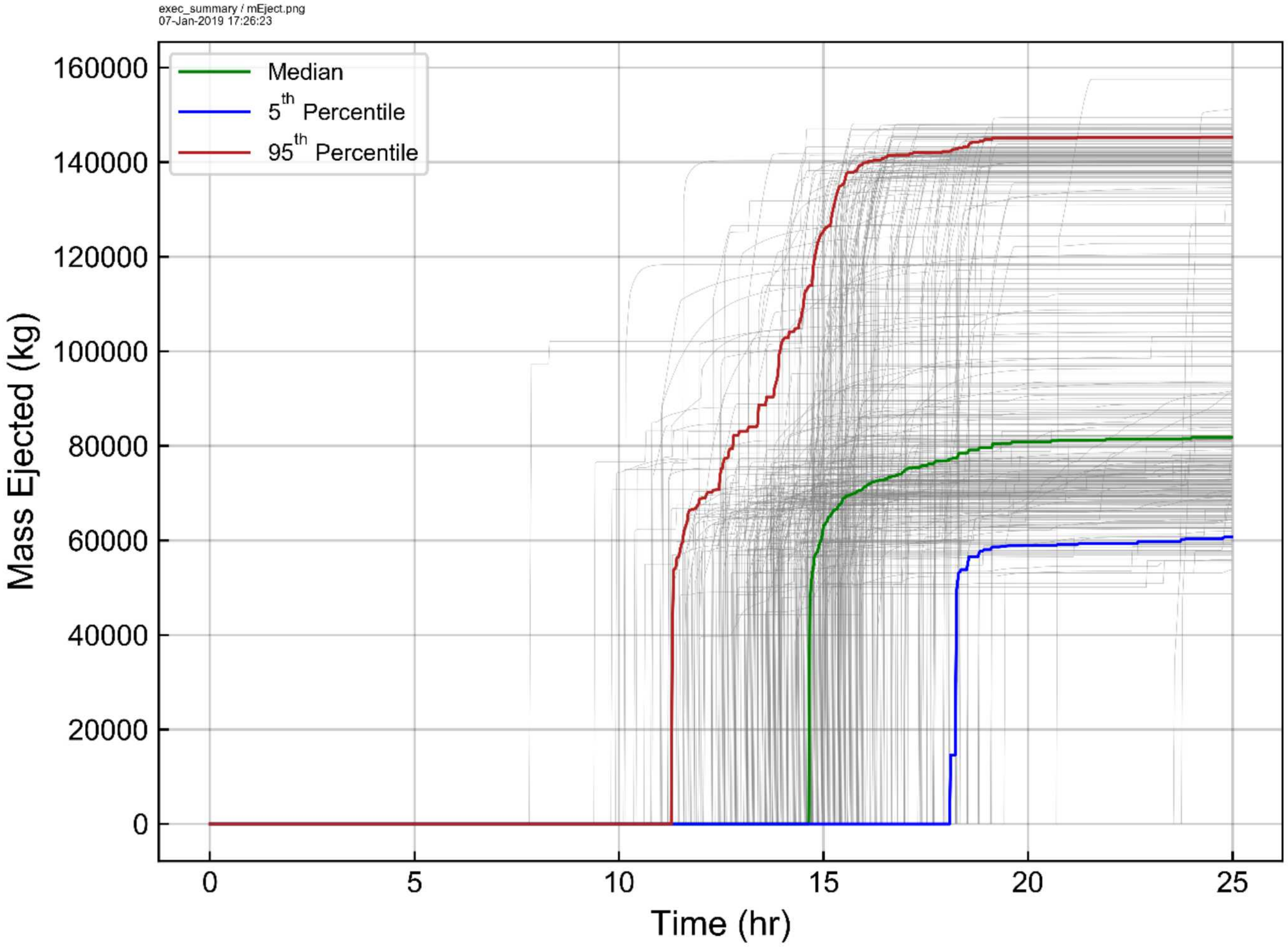
Containment Pressure (DW)



Lower Head Failure

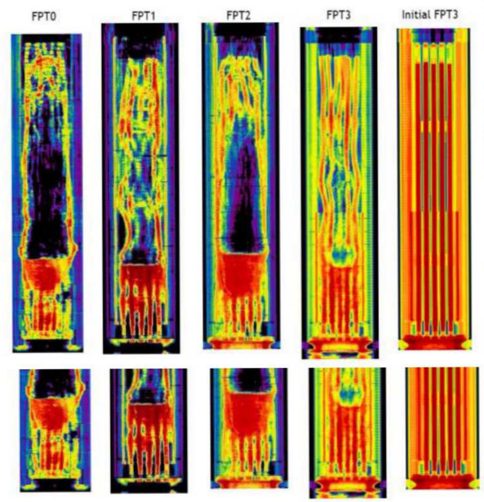


Melt Ejection



Future Plans

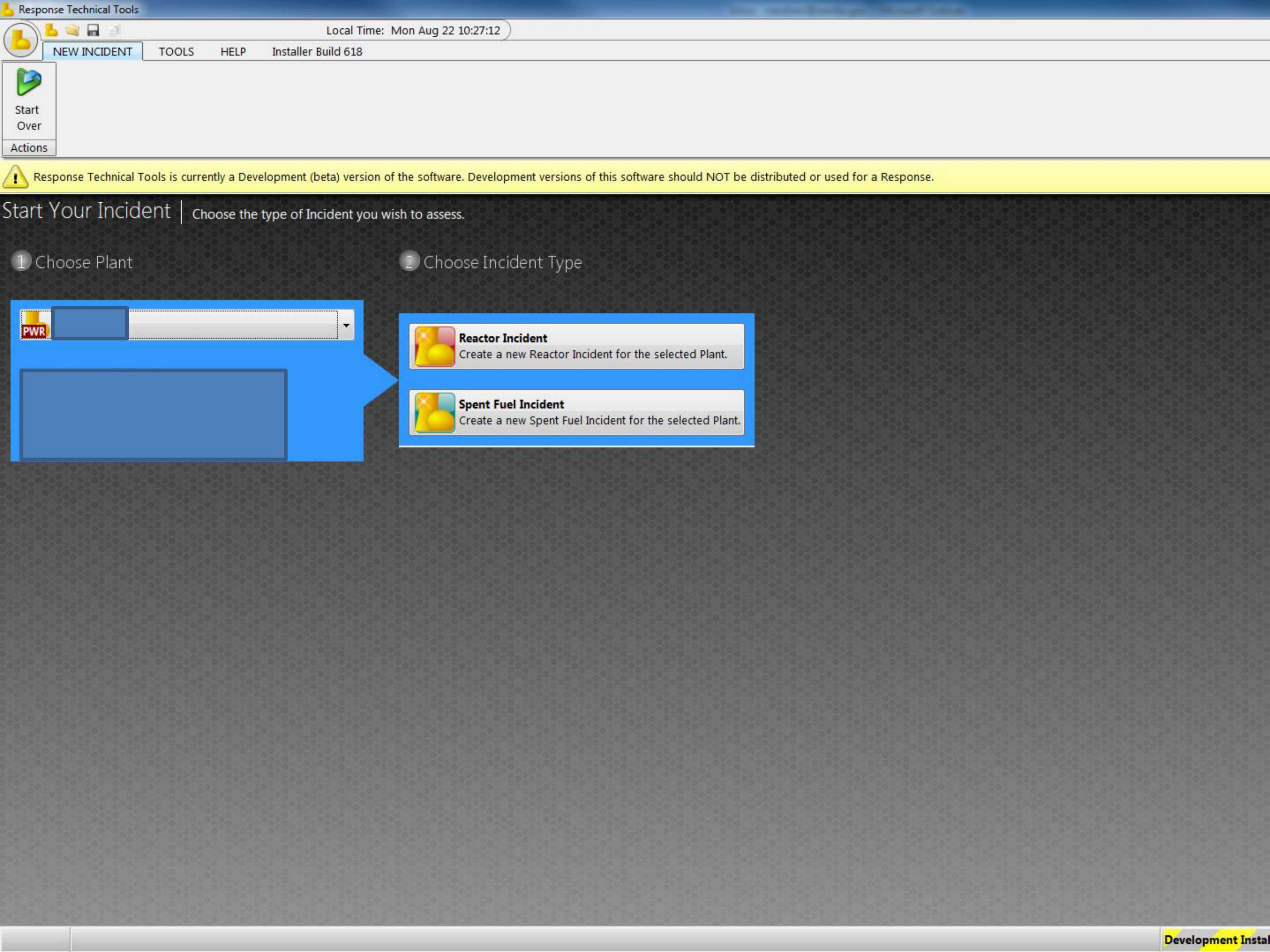
- Expand the number of parameters examined
  - Include boundary conditions
    - Injection
    - Leakages
    - Timings
  - Look at more parameters within the COR package
    - Heat transfer
    - Associated CVH relations (quench, etc.)
- Significantly increase the number of runs
  - 1000s, not 100s for each unit
- Increase the length of the simulation
  - Expand from 24hr to 500 hr

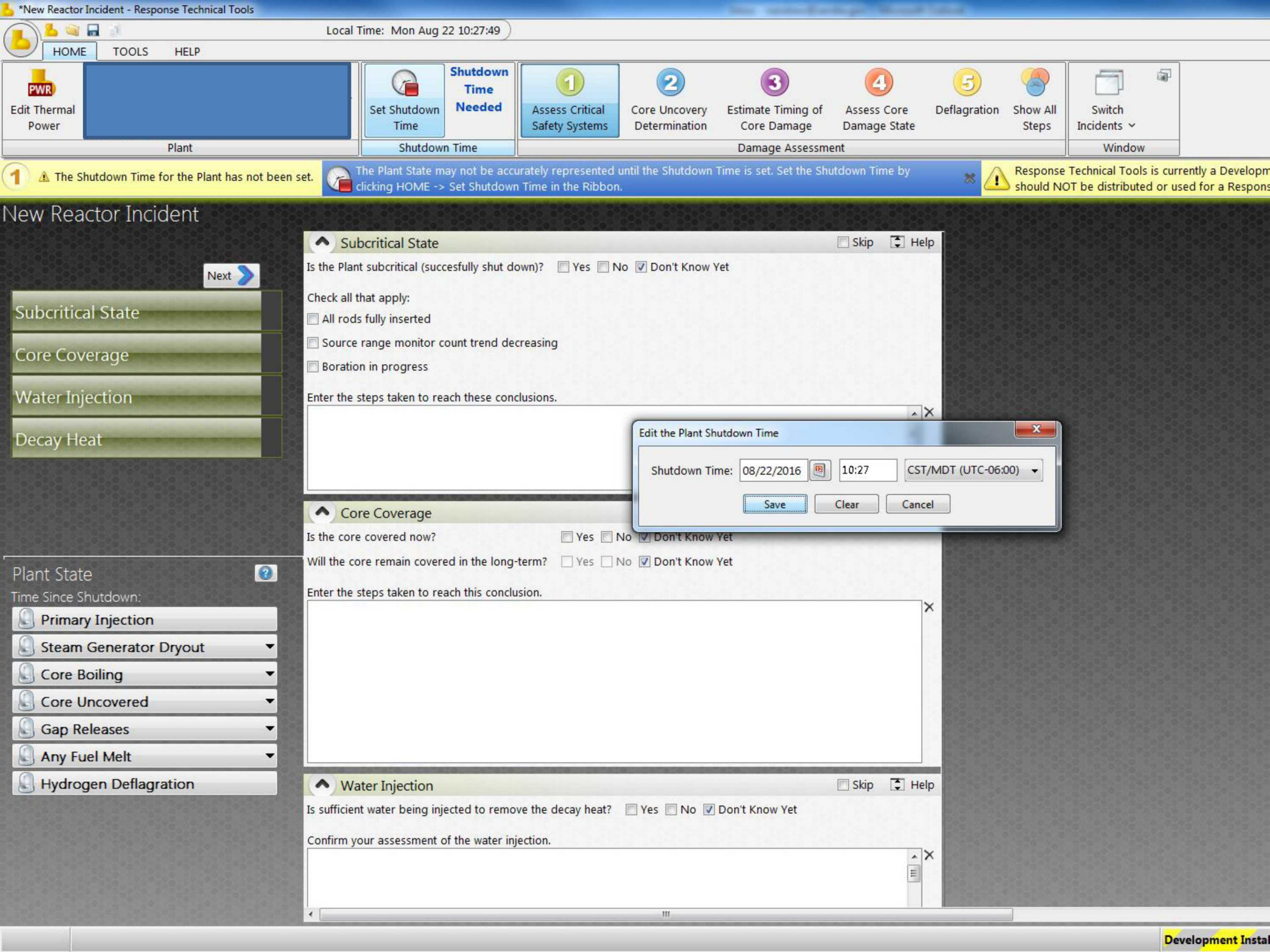


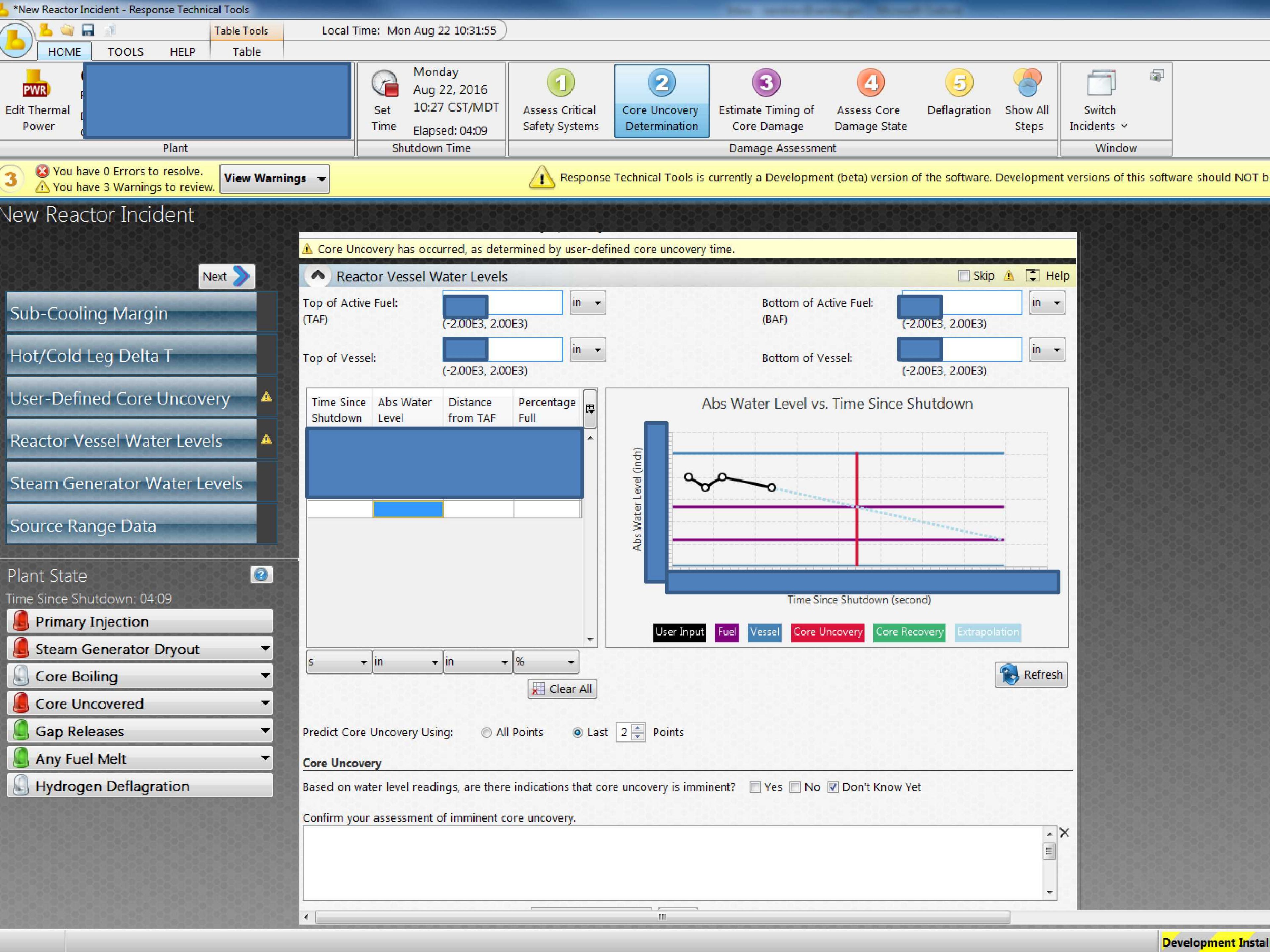
RTT SOFTWARE WALKTHROUGH

Current Status of RTT

- Response Technical Tools
  - Based off of the Response Technical Manual: paper-based response manual for a nuclear incident
  - Inform the NRC as to the status and projected scope of a nuclear incident
  - Based on SNL expertise and NRC experience
- Recent developments
  - Steam generator
  - Interface improvements
  - Modeling core recovery
  - RPV and PCV pressure
- User's Manual
  - SAND2018- 9593


Response Technical Tools
Local Time: Mon Aug 22 10:27:12
NEW INCIDENT
TOOLS
HELP
Installer Build 618
Start Over
Actions
Response Technical Tools is currently a Development (beta) version of the software. Development versions of this software should NOT be distributed or used for a Response.
Start Your Incident
Choose the type of Incident you wish to assess.
1 Choose Plant
2 Choose Incident Type
PWR
Reactor Incident
Create a new Reactor Incident for the selected Plant.
Spent Fuel Incident
Create a new Spent Fuel Incident for the selected Plant.
Development Instal


*New Reactor Incident - Response Technical Tools
Local Time: Mon Aug 22 10:27:49
HOME
TOOLS
HELP
PWR
Edit Thermal Power
Plant
Set Shutdown Time
Shutdown Time Needed
Shutdown Time
Assess Critical Safety Systems
Core Uncovery Determination
Estimate Timing of Core Damage
Assess Core Damage State
Deflagration
Show All Steps
Damage Assessment
Switch Incidents
Window
The Shutdown Time for the Plant has not been set.
The Plant State may not be accurately represented until the Shutdown Time is set. Set the Shutdown Time by clicking HOME -> Set Shutdown Time in the Ribbon.
Response Technical Tools is currently a Developm
should NOT be distributed or used for a Respons
New Reactor Incident
Next
Subcritical State
Core Coverage
Water Injection
Decay Heat
Subcritical State
Skip
Help
Is the Plant subcritical (succesfully shut down)? Yes No Don't Know Yet
Check all that apply:
All rods fully inserted
Source range monitor count trend decreasing
Boration in progress
Enter the steps taken to reach these conclusions.
Edit the Plant Shutdown Time
Shutdown Time: 08/22/2016 10:27 CST/MDT (UTC-06:00)
Save
Clear
Cancel
Core Coverage
Is the core covered now? Yes No Don't Know Yet
Will the core remain covered in the long-term? Yes No Don't Know Yet
Enter the steps taken to reach this conclusion.
Plant State
Time Since Shutdown:
Primary Injection
Steam Generator Dryout
Core Boiling
Core Uncovered
Gap Releases
Any Fuel Melt
Hydrogen Deflagration
Water Injection
Skip
Help
Is sufficient water being injected to remove the decay heat? Yes No Don't Know Yet
Confirm your assessment of the water injection.
Development Instal


*New Reactor Incident - Response Technical Tools
Table Tools
Local Time: Mon Aug 22 10:31:55
HOME
TOOLS
HELP
Table
PWR
Edit Thermal Power
Plant
Set Time
Monday
Aug 22, 2016
10:27 CST/MDT
Elapsed: 04:09
Shutdown Time
Assess Critical Safety Systems
Core Uncovery Determination
Estimate Timing of Core Damage
Assess Core Damage State
Deflagration
Show All Steps
Damage Assessment
Switch Incidents
Window
You have 0 Errors to resolve.
You have 3 Warnings to review.
View Warnings
Response Technical Tools is currently a Development (beta) version of the software. Development versions of this software should NOT b
New Reactor Incident
Next
Sub-Cooling Margin
Hot/Cold Leg Delta T
User-Defined Core Uncovery
Reactor Vessel Water Levels
Steam Generator Water Levels
Source Range Data
Plant State
Time Since Shutdown: 04:09
Primary Injection
Steam Generator Dryout
Core Boiling
Core Uncovered
Gap Releases
Any Fuel Melt
Hydrogen Deflagration
Core Uncovery has occurred, as determined by user-defined core uncovery time.
Reactor Vessel Water Levels
Skip
Help
Top of Active Fuel: (TAF)
(-2.00E3, 2.00E3)
Bottom of Active Fuel: (BAF)
Top of Vessel:
Bottom of Vessel:
in
Time Since Shutdown
Abs Water Level
Distance from TAF
Percentage Full
s
%
Clear All
Abs Water Level vs. Time Since Shutdown
Abs Water Level (inch)
Time Since Shutdown (second)
User Input
Fuel
Vessel
Core Uncovery
Core Recovery
Extrapolation
Refresh
Predict Core Uncovery Using:
All Points
Last 2 Points
Core Uncovery
Based on water level readings, are there indications that core uncovery is imminent?
Yes
No
Don't Know Yet
Confirm your assessment of imminent core uncovery.
Development Instal

*New Reactor Incident - Response Technical Tools

Local Time: Mon Aug 22 10:30:28

HOME | TOOLS | HELP

Edit Thermal Power — Plant

Set Time — Monday Aug 22, 2016 10:27 CST/MDT Elapsed: 02:42 — Shutdown Time

1 Assess Critical Safety Systems | 2 Core Uncovery Determination | 3 Estimate Timing of Core Damage | 4 Assess Core Damage State | 5 Deflagration | Show All Steps — Damage Assessment

Switch Incidents — Window

1 ⚠ *Step 1->Water Injection*: Sufficient water is not being injected to remove decay heat.

⚠ Response Technical Tools is currently a Development (beta) version of the software. Development versions of this software

New Reactor Incident

Next

Core Damage Projections

Estimated Core Damage

Core Damage Projections

Skip Help

Core Uncovery Time (from Step 2): User-Defined Input...

Core Uncovery: 0.02 min Since Shutdown

Core Recovery:

Time Since Core Uncovered: 2.67 min

Rate of Core Temperature Change*: 2.00 °F / s

[0.0, 4.20E3]

Estimated Core Temperature: 9.20E2 °F

*The default Rate of Core Temperature Change is 2 °F/sec, based on the RTM recommendation of 1-2 °F/sec. This value should be used unless a different rate of temperature change is known.

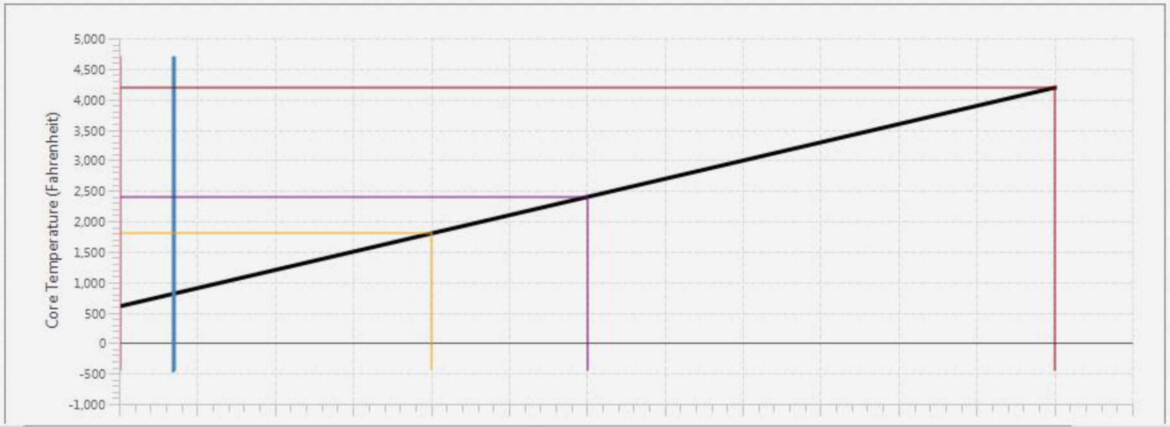
Temperature Thresholds...

Core Damage Projections

Time Until Gap Releases from Fuel: 7.33 min

Time Until Local Fuel Relocation: 12.3 min

Time Until Melt-Through of Vessel: 27.3 min

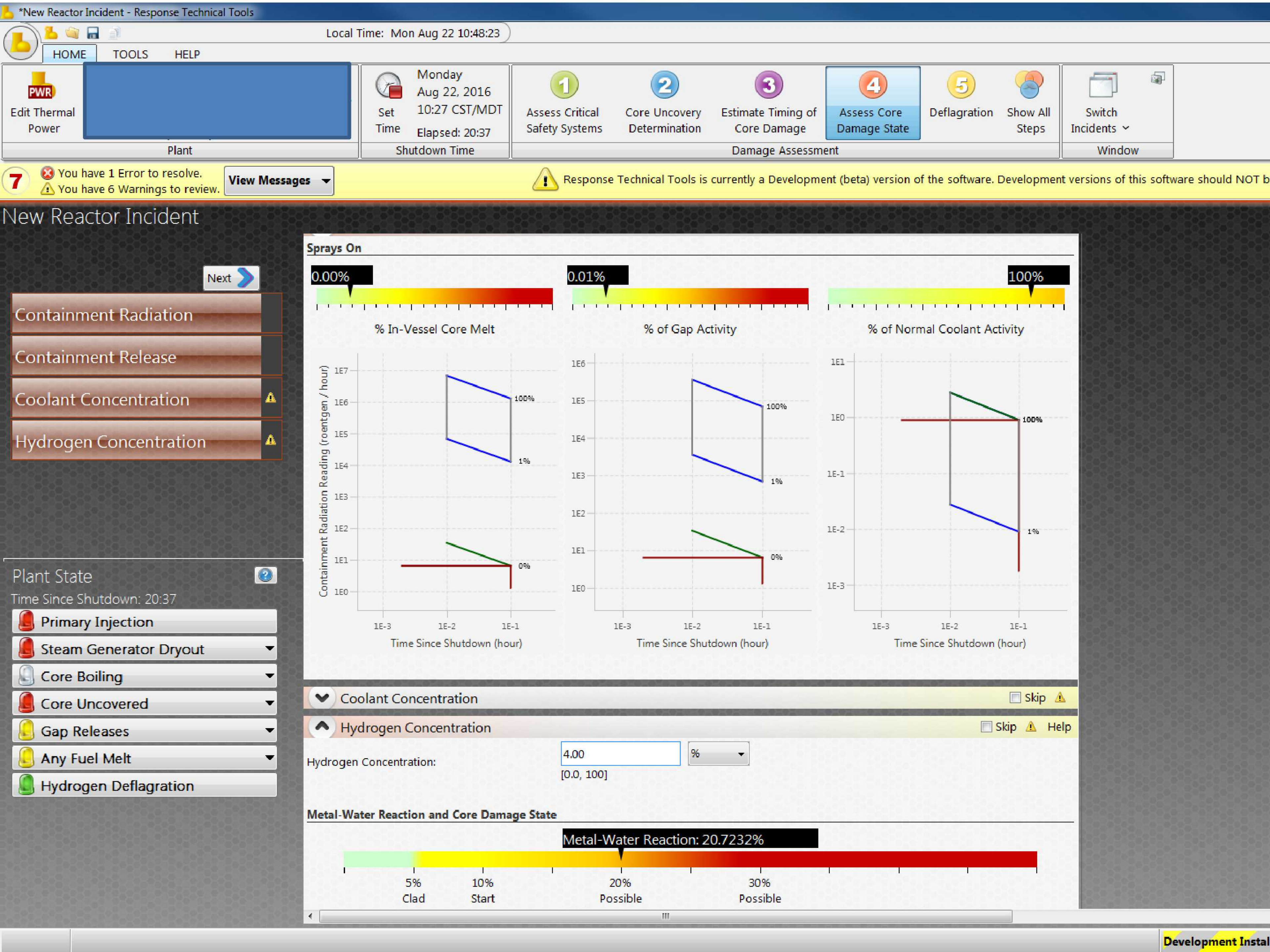


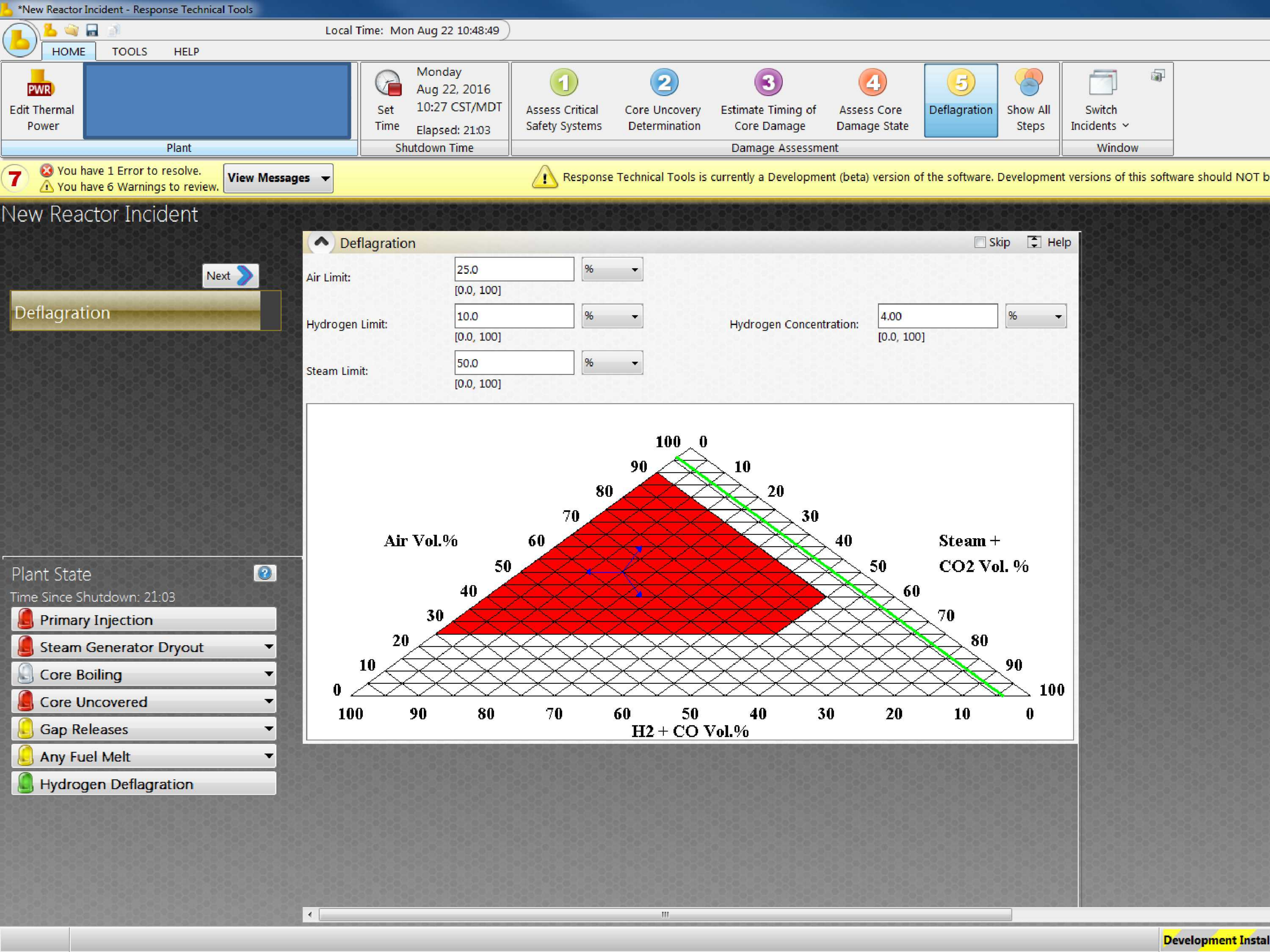
Plant State

Time Since Shutdown: 02:42

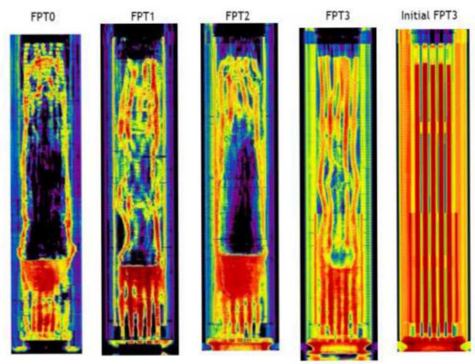
- Primary Injection
- Steam Generator Dryout
- Core Boiling
- Core Uncovered
- Gap Releases
- Any Fuel Melt
- Hydrogen Deflagration

Development Instal


*New Reactor Incident - Response Technical Tools
Local Time: Mon Aug 22 10:48:23
HOME
TOOLS
HELP
PWR
Edit Thermal Power
Plant
Set Time
Monday
Aug 22, 2016
10:27 CST/MDT
Elapsed: 20:37
Shutdown Time
Assess Critical Safety Systems
Core Uncovery Determination
Estimate Timing of Core Damage
Assess Core Damage State
Deflagration
Show All Steps
Damage Assessment
Switch Incidents
Window
You have 1 Error to resolve.
You have 6 Warnings to review.
View Messages
Response Technical Tools is currently a Development (beta) version of the software. Development versions of this software should NOT b
New Reactor Incident
Next
Containment Radiation
Containment Release
Coolant Concentration
Hydrogen Concentration
Plant State
Time Since Shutdown: 20:37
Primary Injection
Steam Generator Dryout
Core Boiling
Core Uncovered
Gap Releases
Any Fuel Melt
Hydrogen Deflagration
Sprays On
0.00%
0.01%
100%
% In-Vessel Core Melt
% of Gap Activity
% of Normal Coolant Activity
Containment Radiation Reading (roentgen / hour)
100%
1%
0%
Time Since Shutdown (hour)
Coolant Concentration
Skip
Hydrogen Concentration
Skip
Help
Hydrogen Concentration:
4.00
%
[0.0, 100]
Metal-Water Reaction and Core Damage State
Metal-Water Reaction: 20.7232%
5% Clad
10% Start
20% Possible
30% Possible
Development Instal


*New Reactor Incident - Response Technical Tools
Local Time: Mon Aug 22 10:48:49
HOME
TOOLS
HELP
Edit Thermal Power
Plant
Set Time
Monday
Aug 22, 2016
10:27 CST/MDT
Elapsed: 21:03
Shutdown Time
Assess Critical Safety Systems
Core Uncovery Determination
Estimate Timing of Core Damage
Assess Core Damage State
Deflagration
Show All Steps
Damage Assessment
Switch Incidents
Window
You have 1 Error to resolve.
You have 6 Warnings to review.
View Messages
Response Technical Tools is currently a Development (beta) version of the software. Development versions of this software should NOT b
New Reactor Incident
Next
Deflagration
Skip
Help
Air Limit:
25.0
%
[0.0, 100]
Hydrogen Limit:
10.0
%
[0.0, 100]
Hydrogen Concentration:
4.00
%
[0.0, 100]
Steam Limit:
50.0
%
[0.0, 100]
Air Vol.%
Steam + CO2 Vol. %
H2 + CO Vol.%
Plant State
Time Since Shutdown: 21:03
Primary Injection
Steam Generator Dryout
Core Boiling
Core Uncovered
Gap Releases
Any Fuel Melt
Hydrogen Deflagration
Development Instal

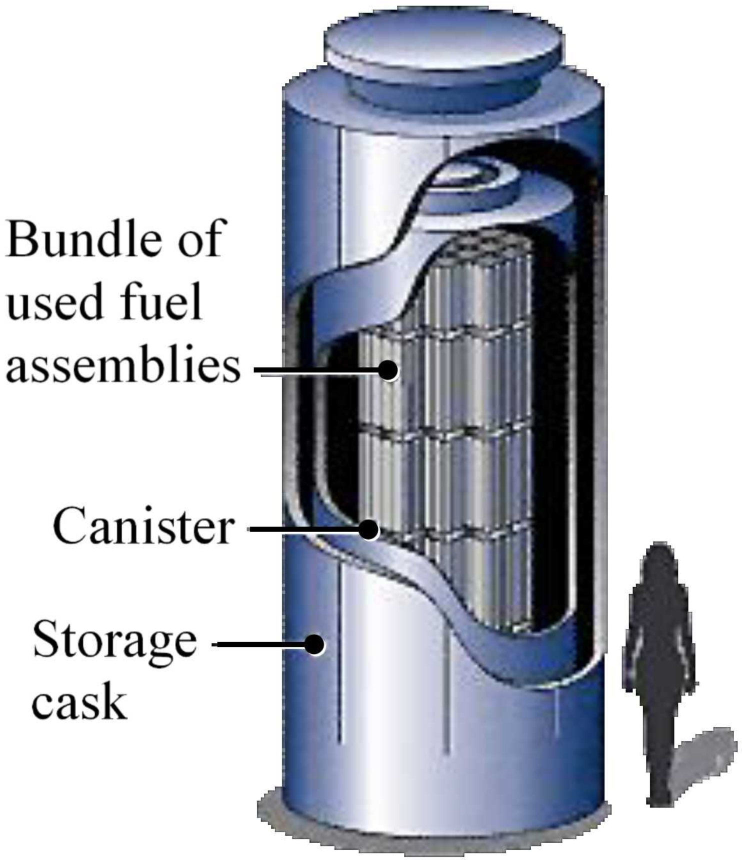
Source: Tokyo Electric Power Company



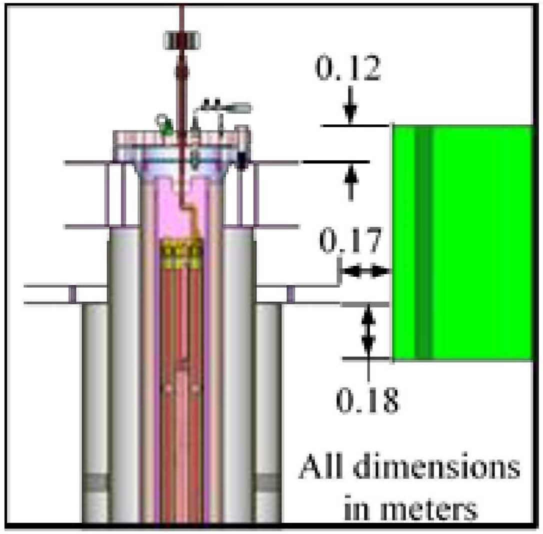
DRY CASK EXAMINATION

Spent Fuel Activities

- SNF under LOCA conditions
- Dry cask storage systems (DCSS)
  - Thermal hydraulic behavior
  - Particulate retention and subsequent stress corrosion cracking
- As more fuel makes its way to DCCS, increased efforts are needed to characterize behavior and potential source terms



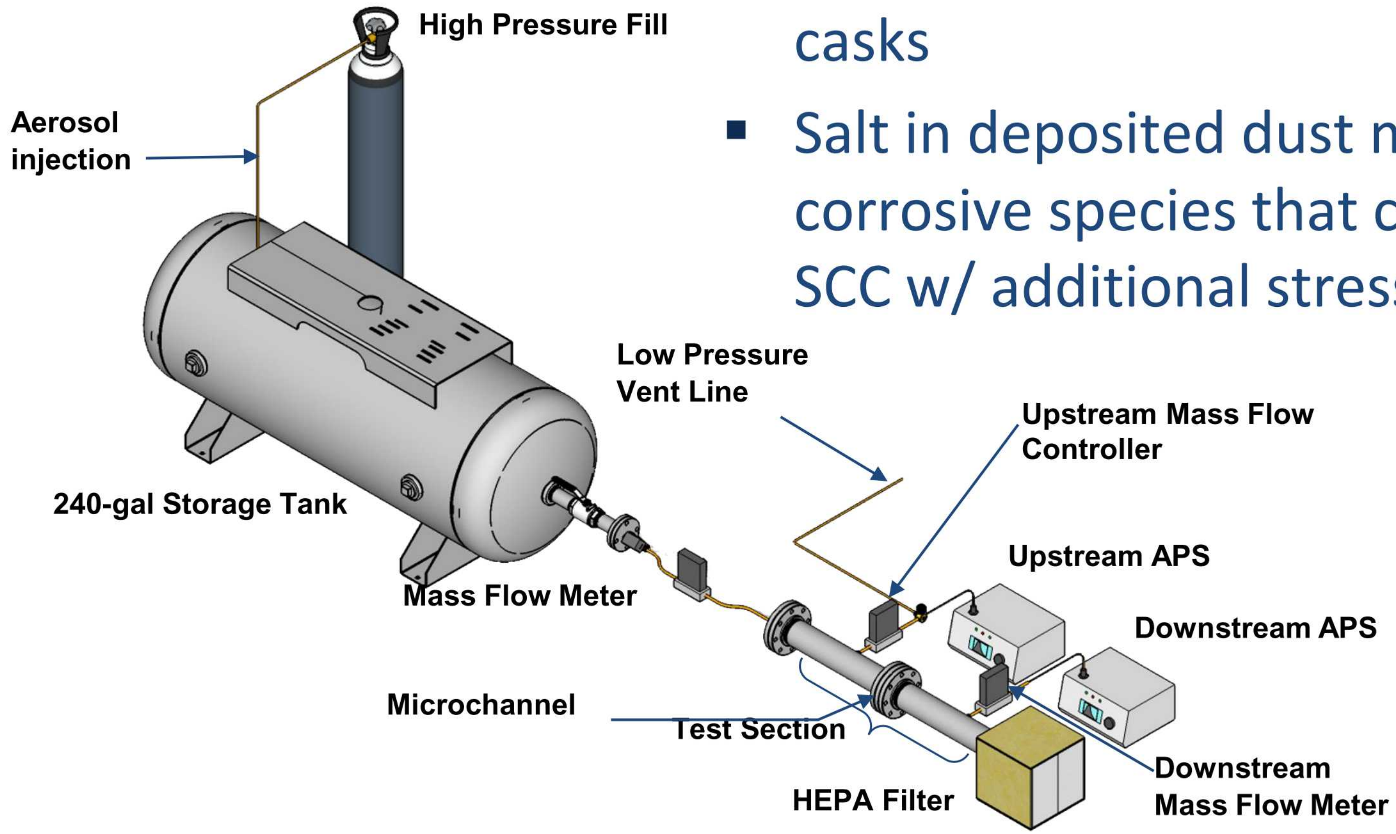
Thermal Hydraulic Behavior



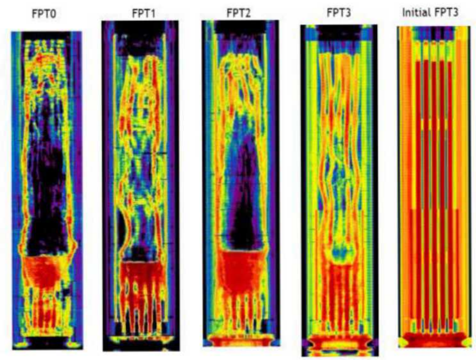
- Incoloy BWR assembly with simulated decay heat load
- Assess peak cladding temperature and airmass flow rate in varying wind and
- Powers and internal pressures ranging from 0.5 to 5.0 kW and 0.3 to 800 kPapressure conditions

Releases through SCC in Casks

- Developing methods for quantifying potential releases through a stress corrosion crack (SCC) that could form in casks
- Salt in deposited dust may contain corrosive species that cause pitting → SCC w/ additional stress on the system



Source: Tokyo Electric Power Company



QUESTIONS AND COMMENTS?