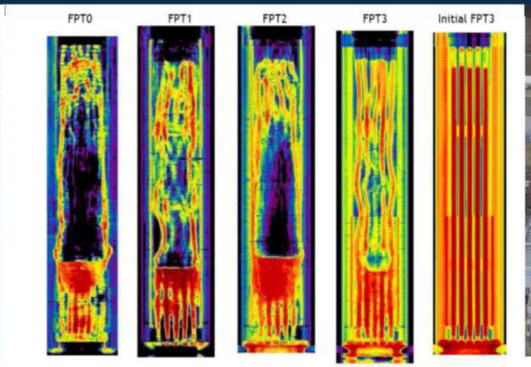
SAND2019-9759C

Source: Tokyo Electric Power Company



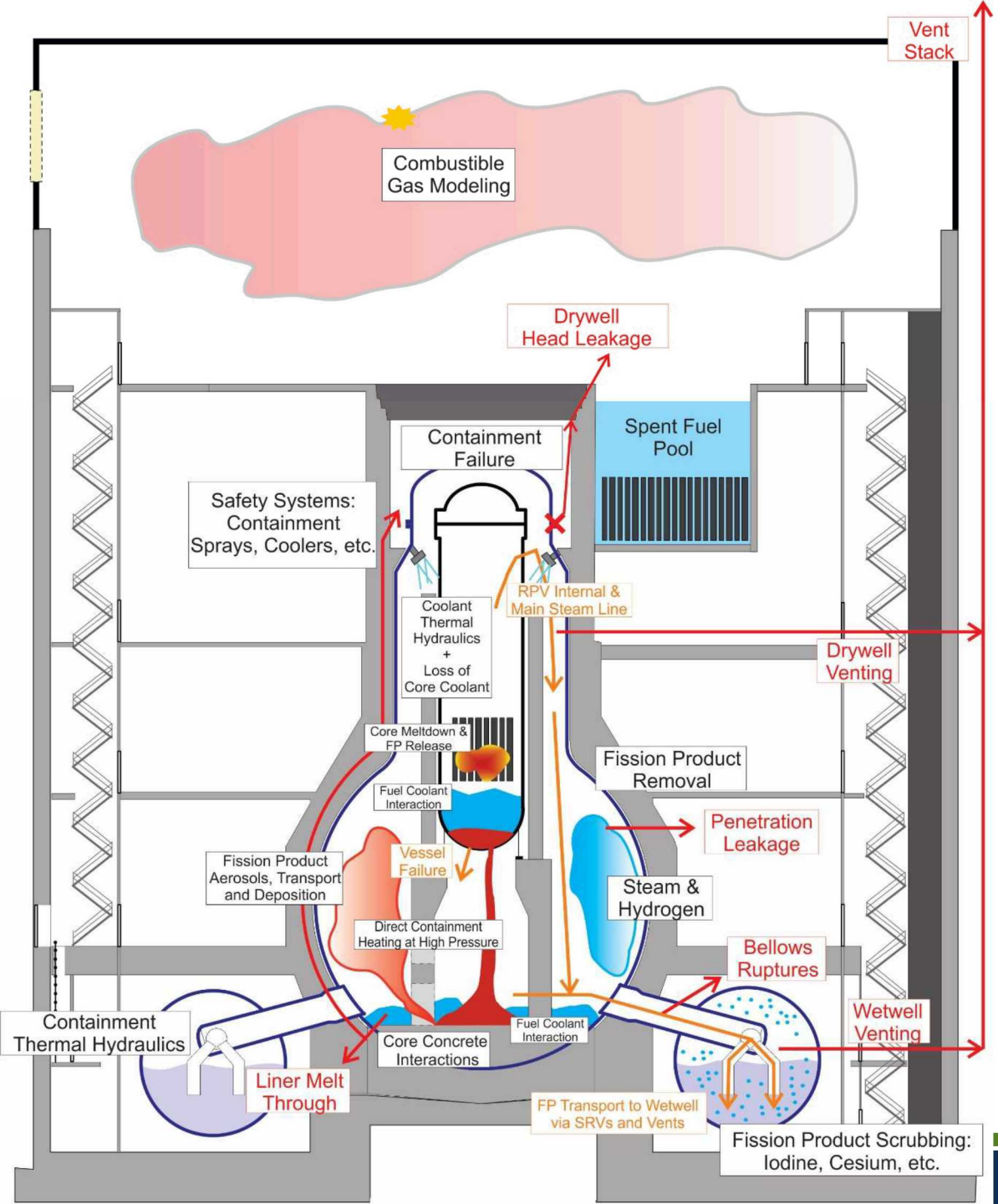
BSAF Phase II Final Results

Nathan Andrews, Troy Haskin, Christopher Faucett,
Randall Gauntt, Nathan Bixler, Dan Clayton

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

Overview of BSAF Phase II

- Benchmark Study of the Accident at the Fukushima Daiichi Nuclear Power Station (BSAF) Project
  - Completed project
  - Currently drafting 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

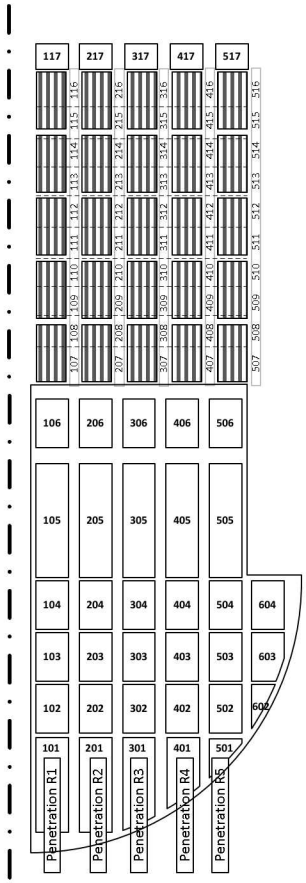


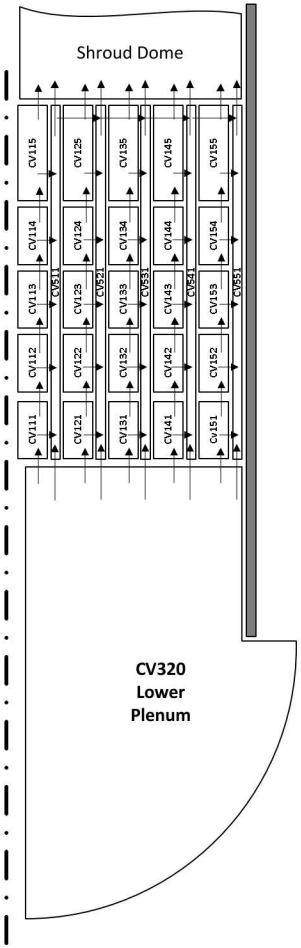
U.S. DEPARTMENT OF ENERGY
Nuclear Energy

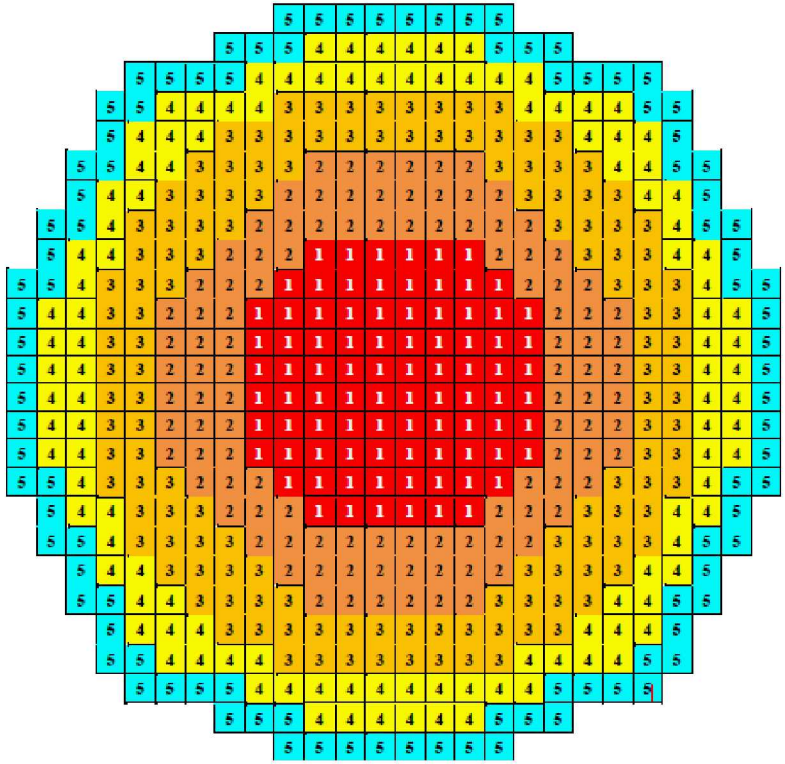
Sandia National Laboratories

- **Reactor, Containment, Building, Venting Systems, Spent Fuel Pools**
- **Core Degradation and Severe Accident Phenomenology**
- **Operator Actions and Decisions**
- **Leakage Pathways and Component Failures**
- **Engineered Safety Features**
- **Fission Product Modeling**
- **Release and Source Terms**

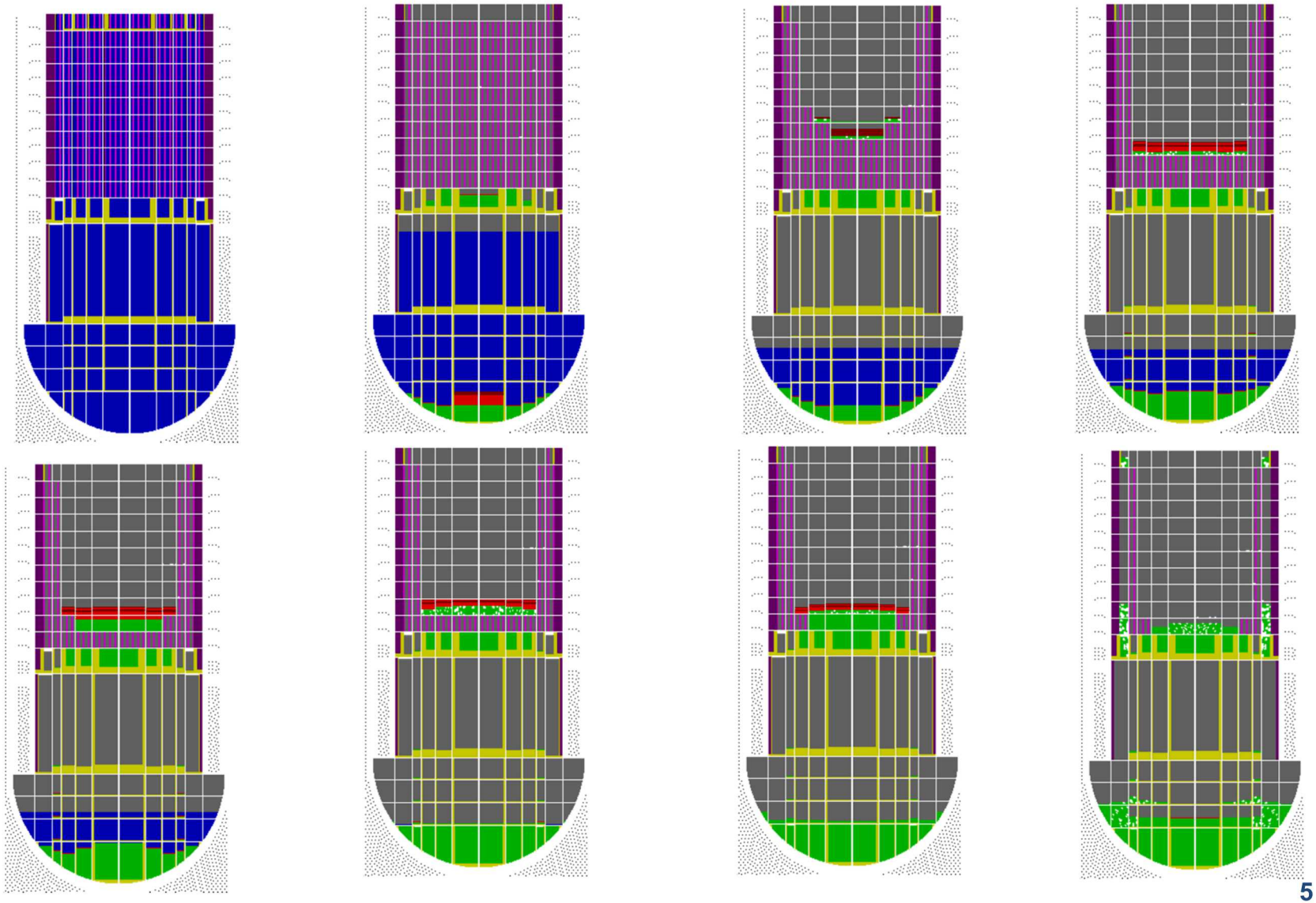
MELCOR Core Abstraction



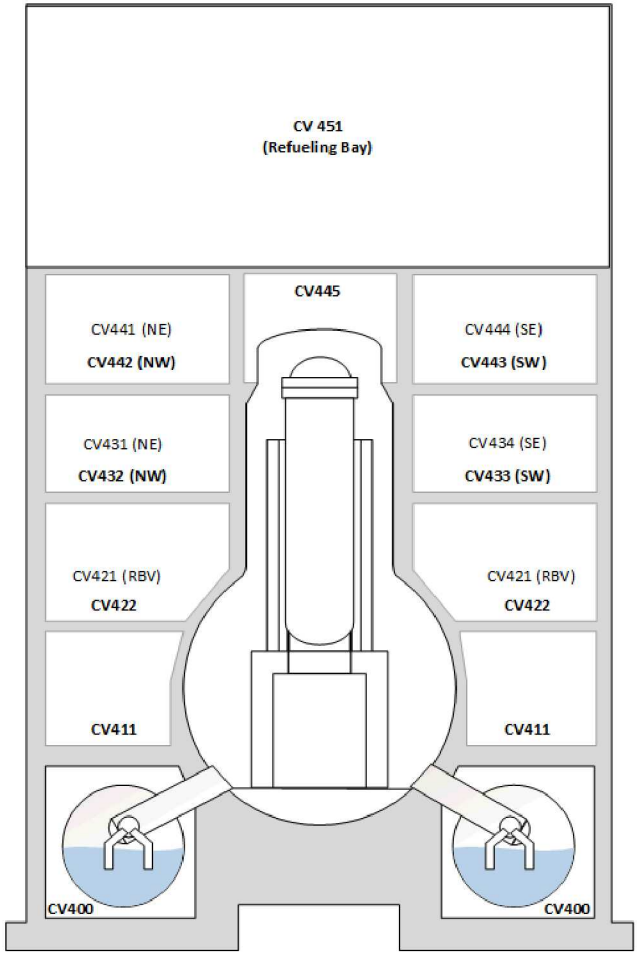


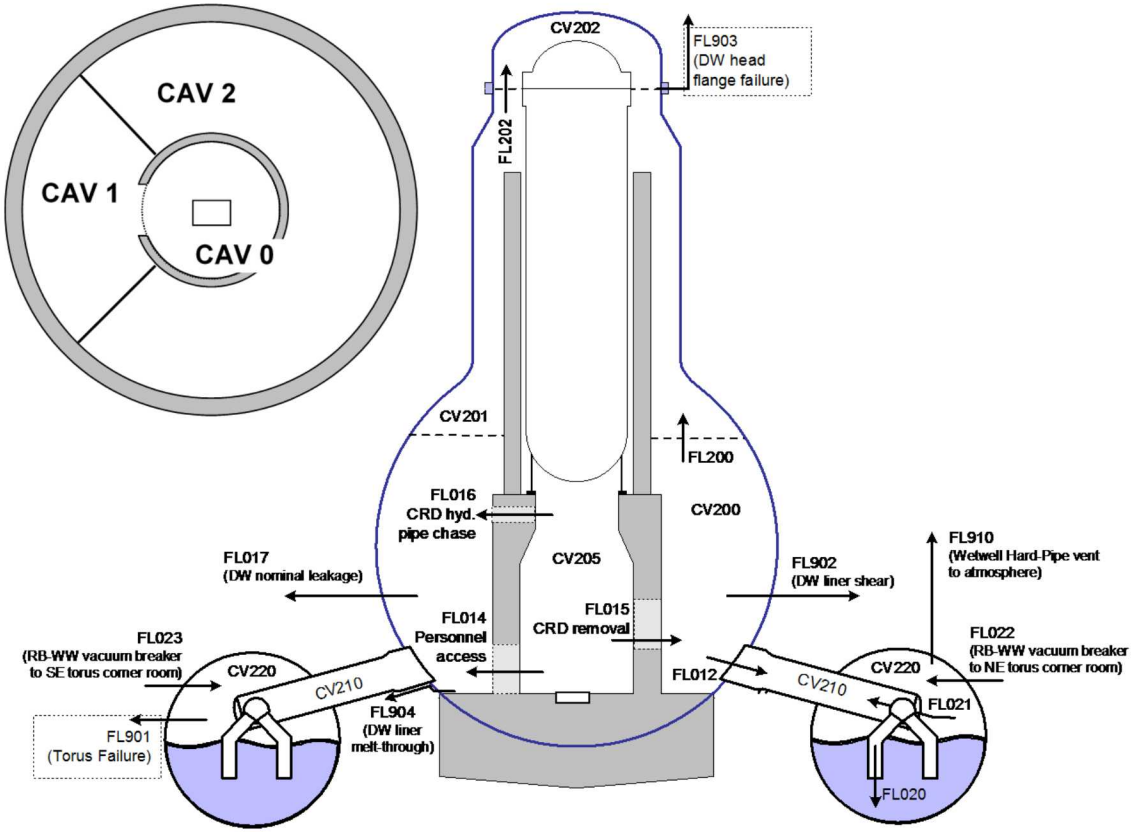


MELCOR Core Degradation Process – 1F1

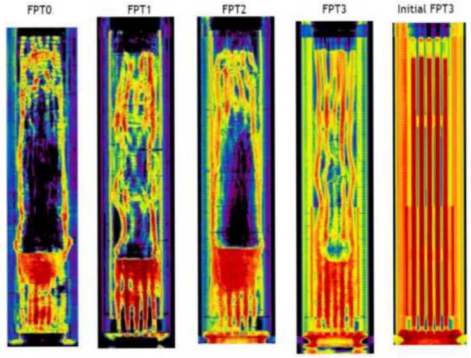


RB & PCV Nodalization





Source: Tokyo Electric Power Company

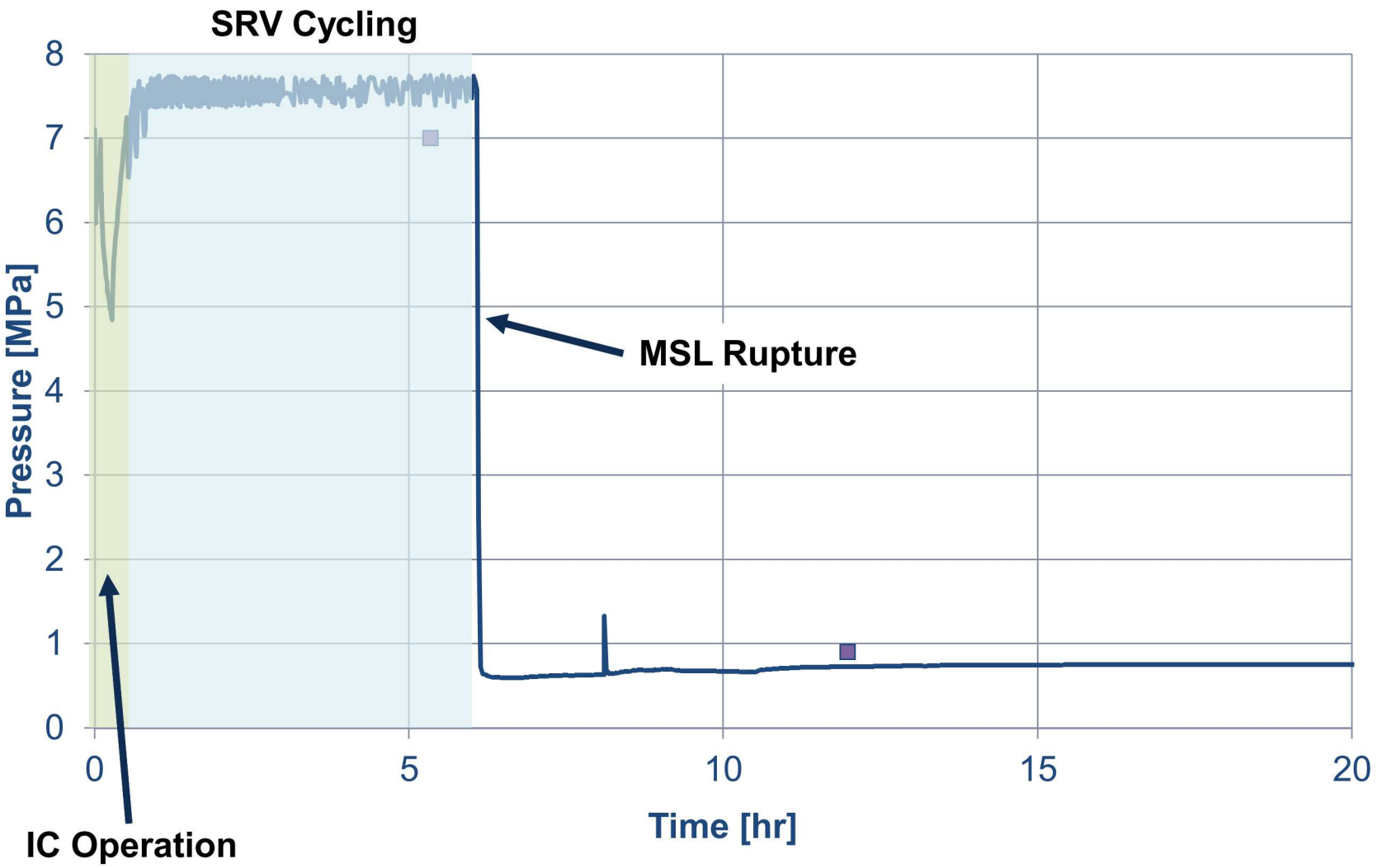


FINAL 1F1 ANALYSES

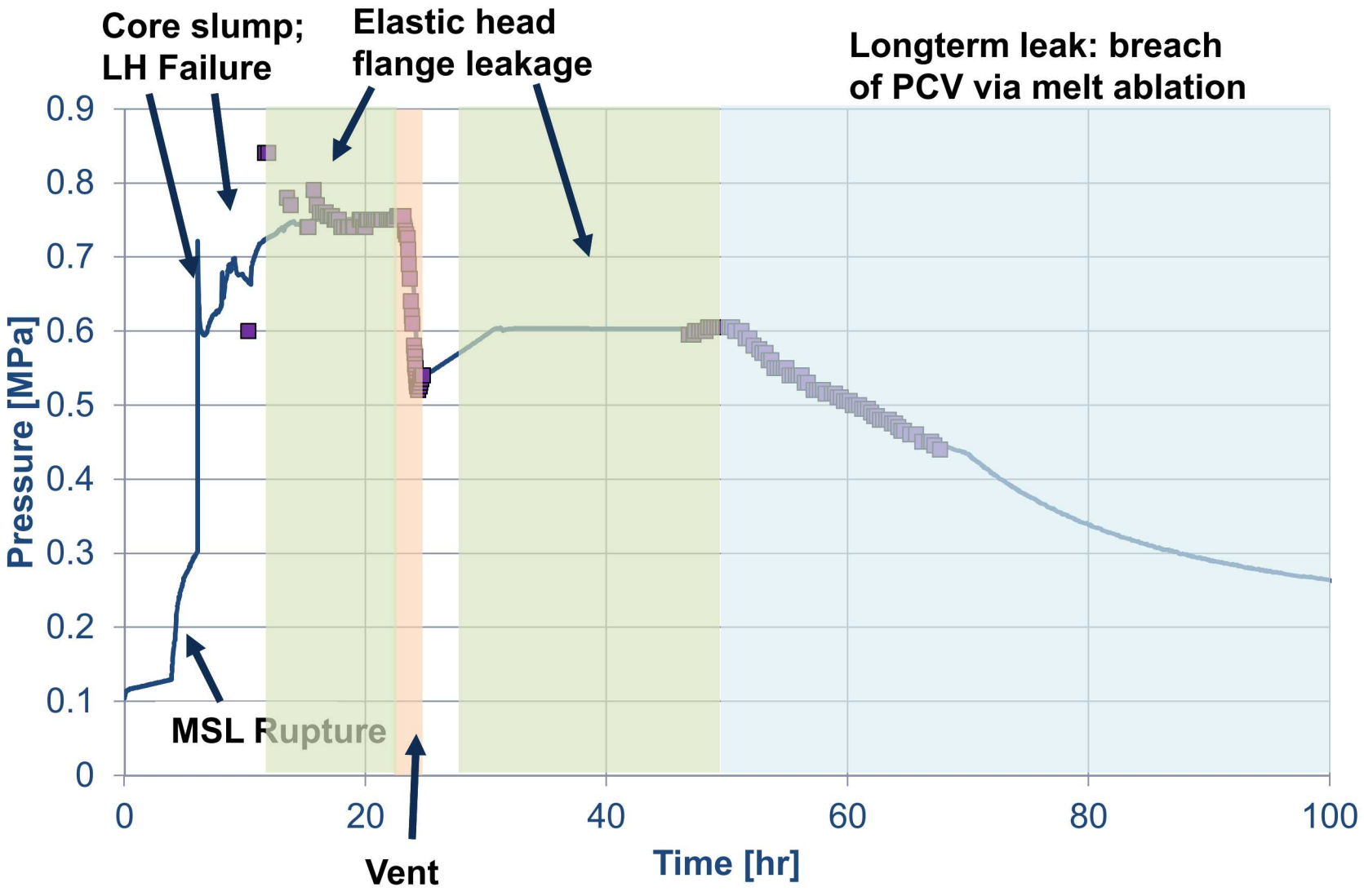
Key Assumptions in 1F1

- Scenario assumptions
  - Main steam line break at 6.1 hours
  - Lower head failure at 10.5 hours
  - Vent at 23.5 hours
  - Explosion at 24.8 hours
- Determination of long-term water injection into containment
  - Monotonically increasing longterm leakage area, approximating liner melt-through
    - Beginning at 50 hours and increasing as indicated by TEPCO provided drywell pressure data
  - Varied alternative water injection rates to match drywell pressure trends when leakage area alone was not sufficient to match pressure

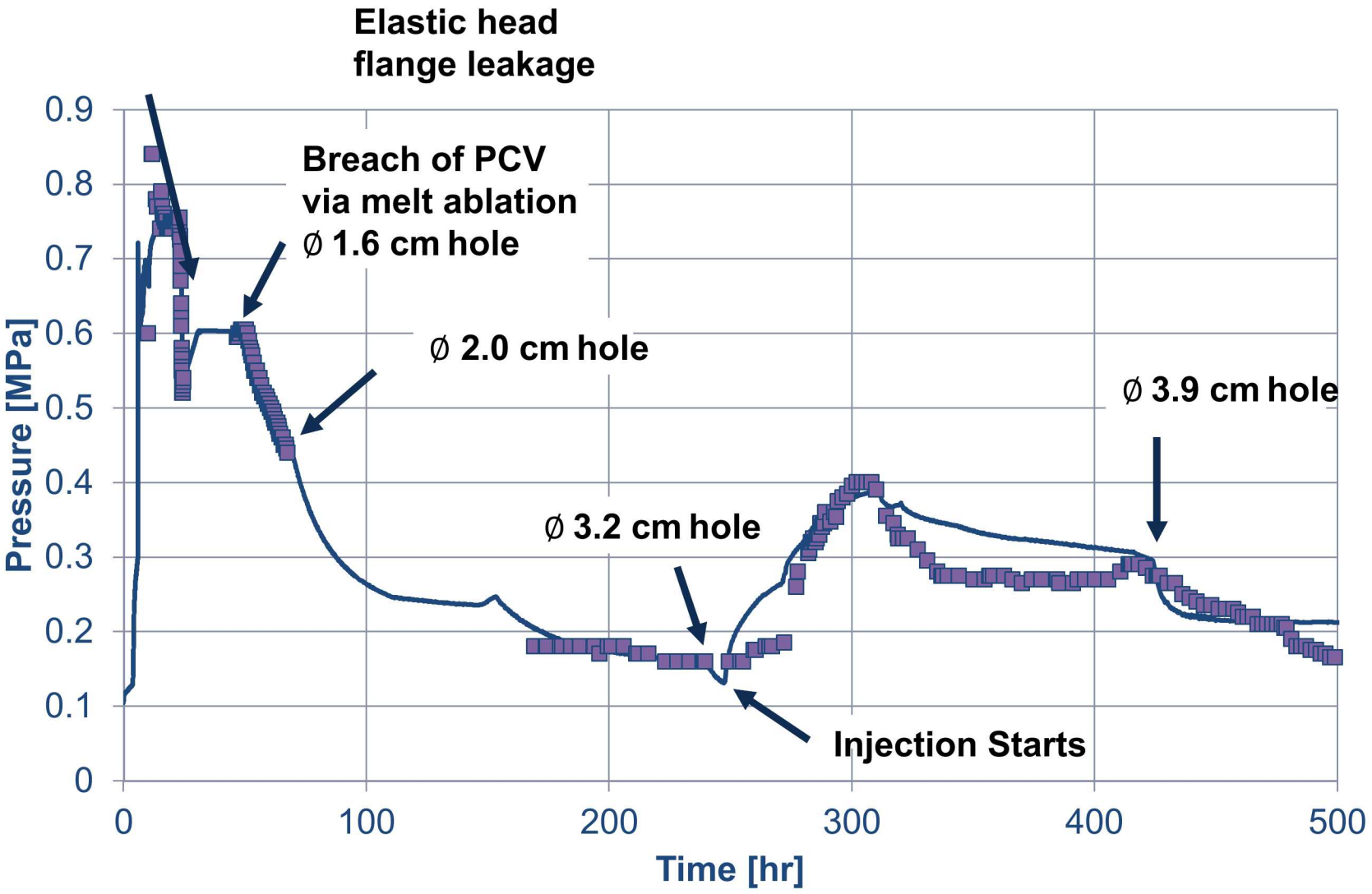
RPV Pressure



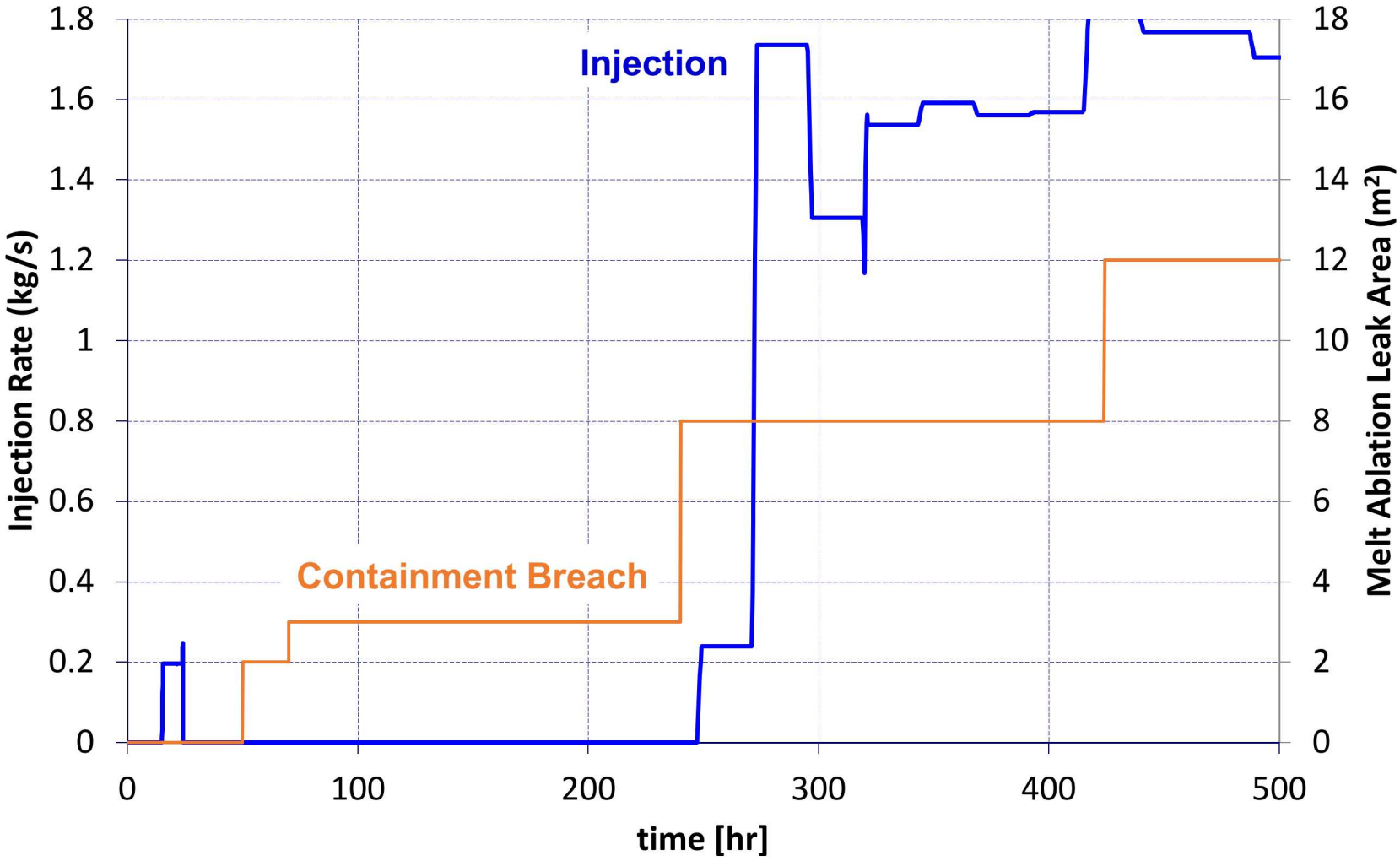
Drywell Pressure



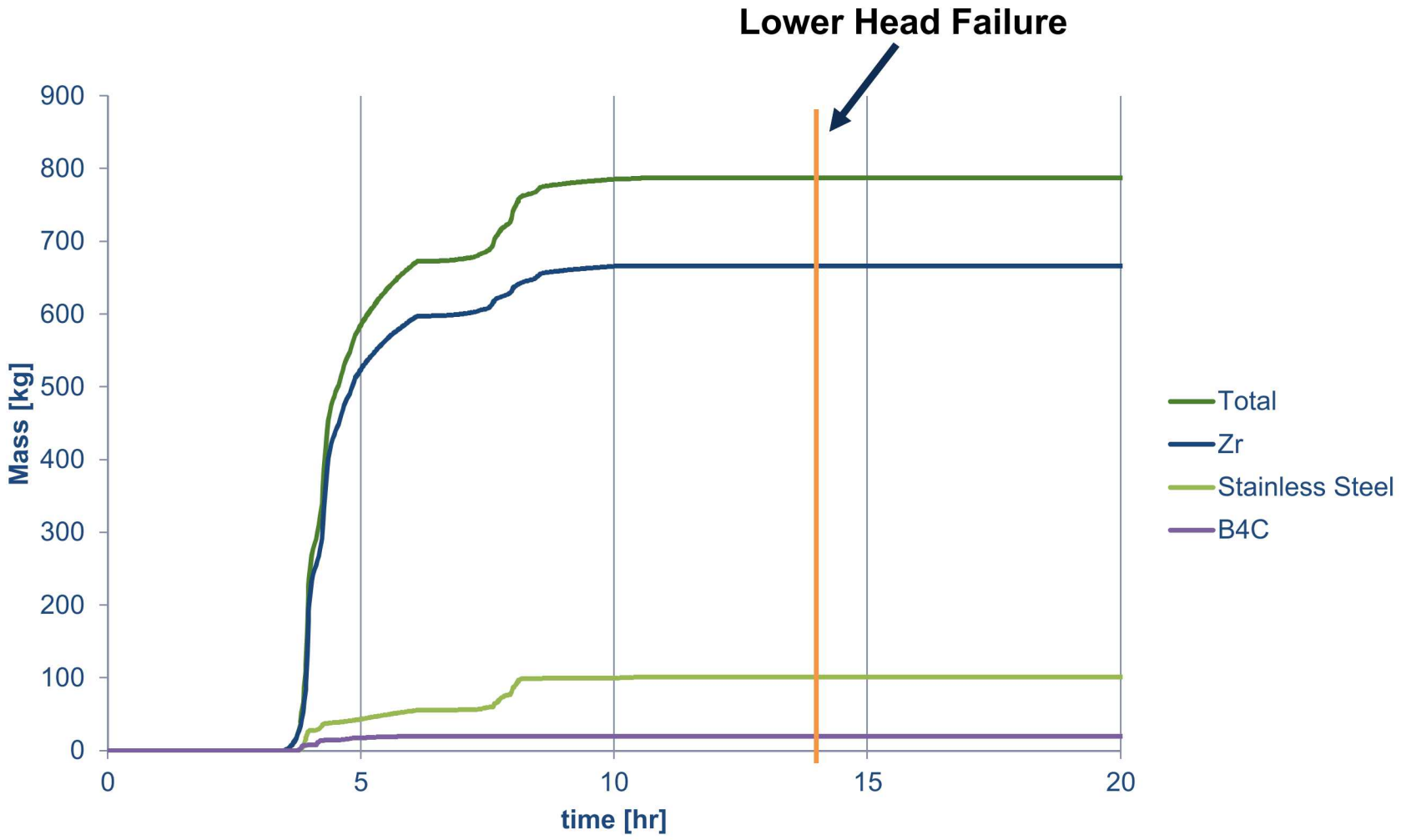
Drywell Pressure



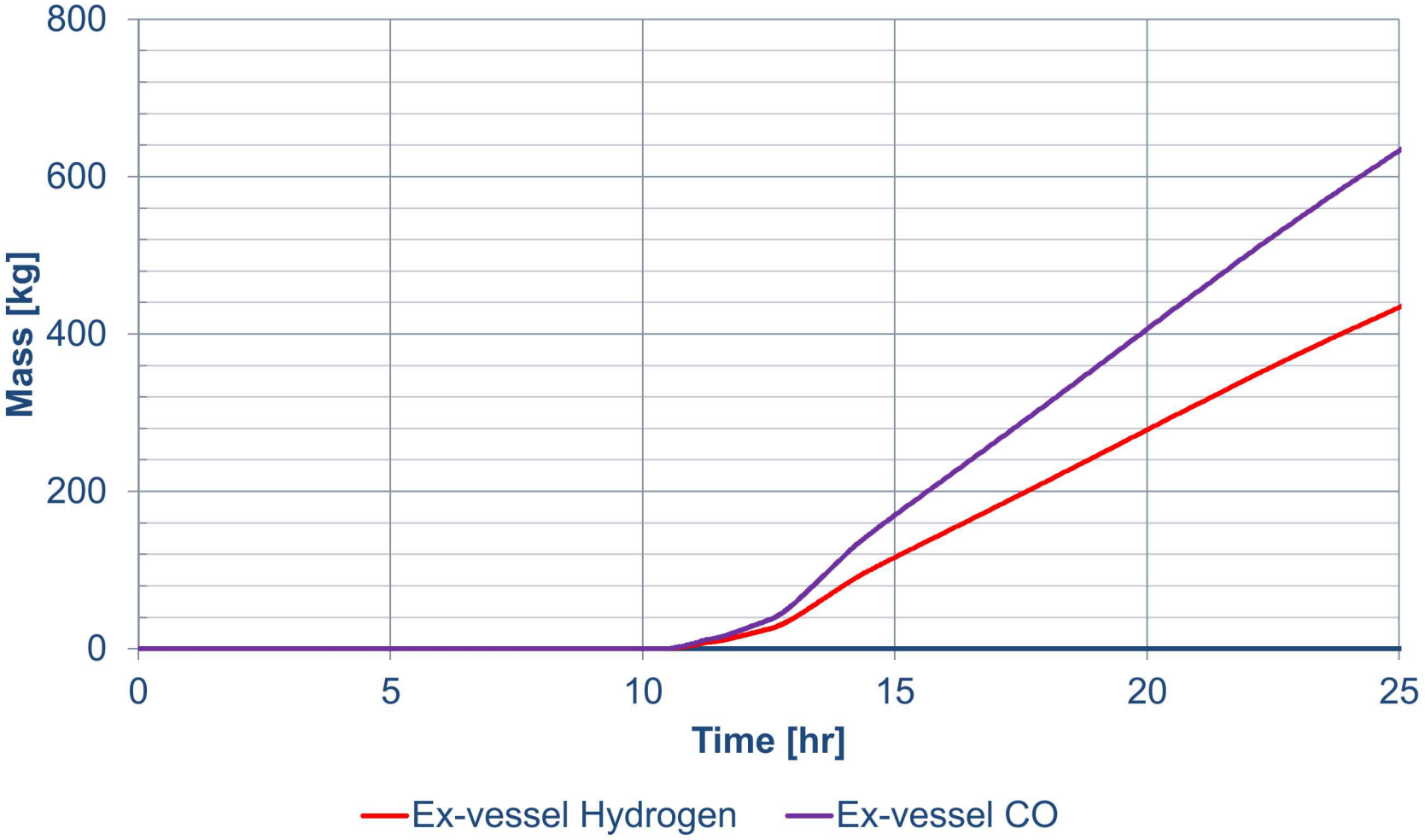
Injection


Injection
Containment Breach
Injection Rate (kg/s)
Melt Ablation Leak Area (m²)
time [hr]
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
0
2
4
6
8
10
12
14
16
18
0
100
200
300
400
500

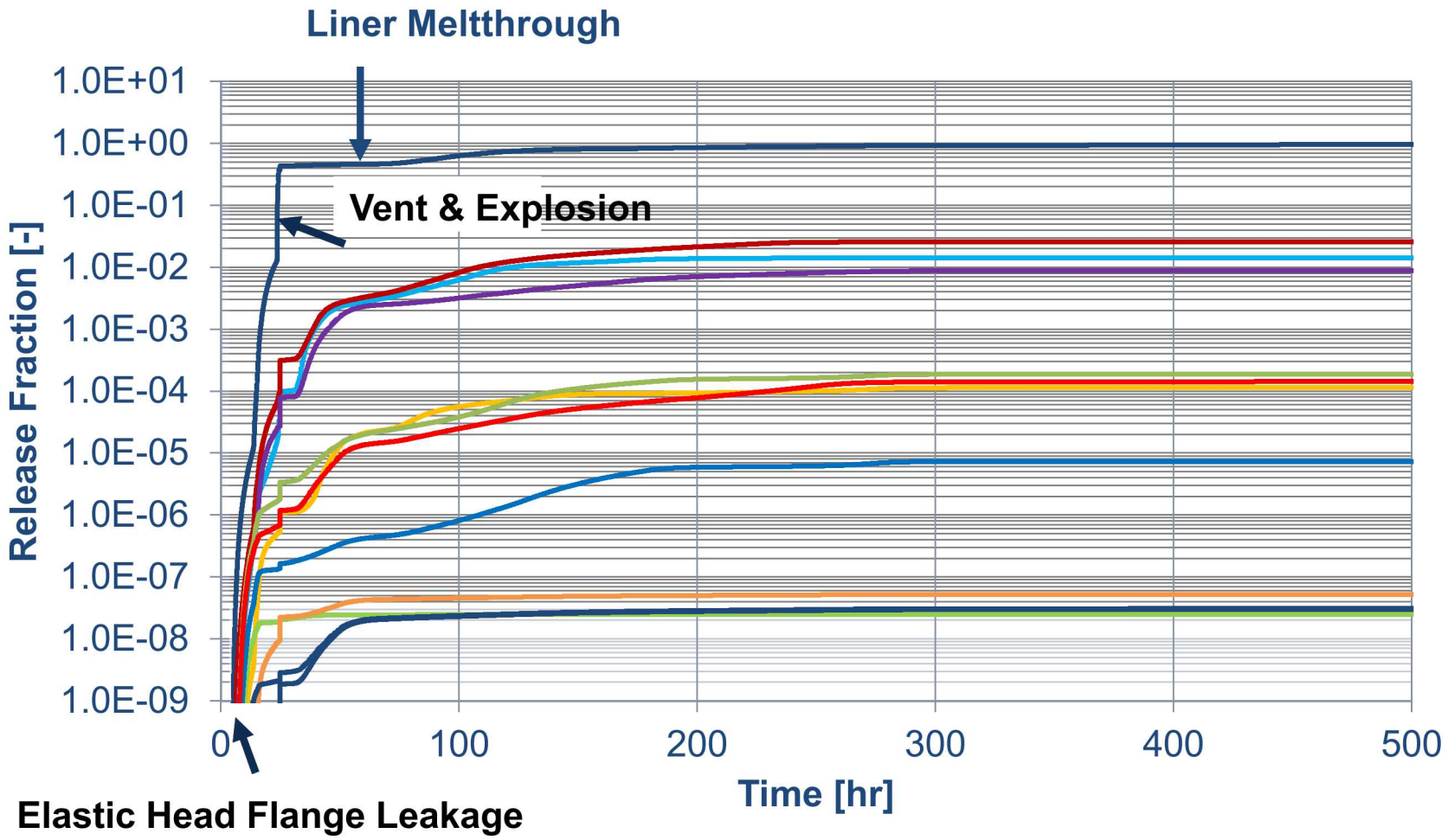
In-Core Hydrogen Generation



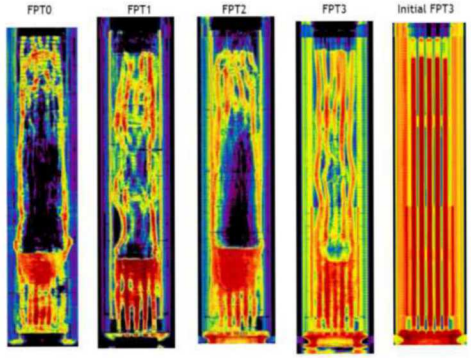
Combustible Gas Generation



RN Release Fractions to Environment



Source: Tokyo Electric Power Company

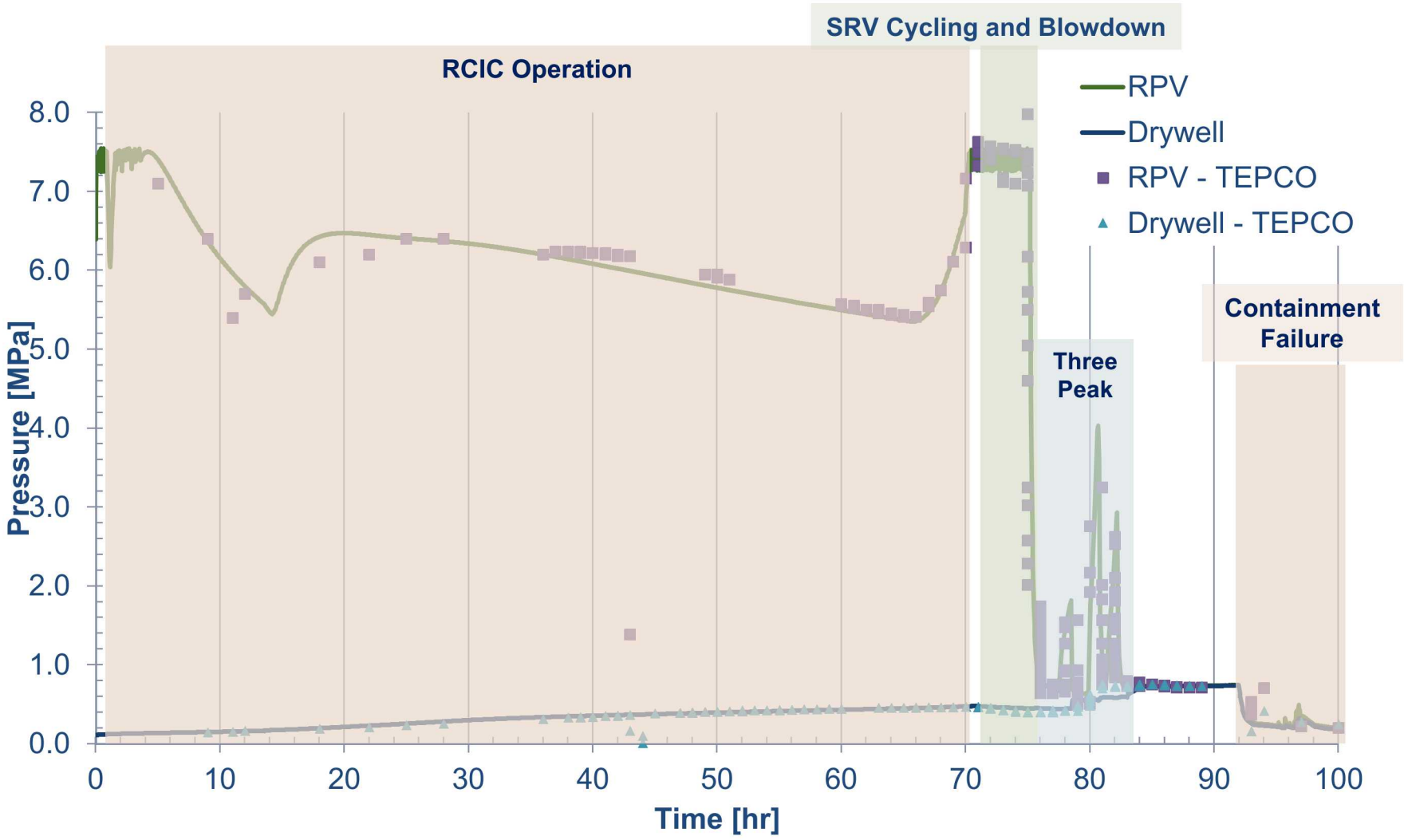


UPDATE OF 1F2 ANALYSES

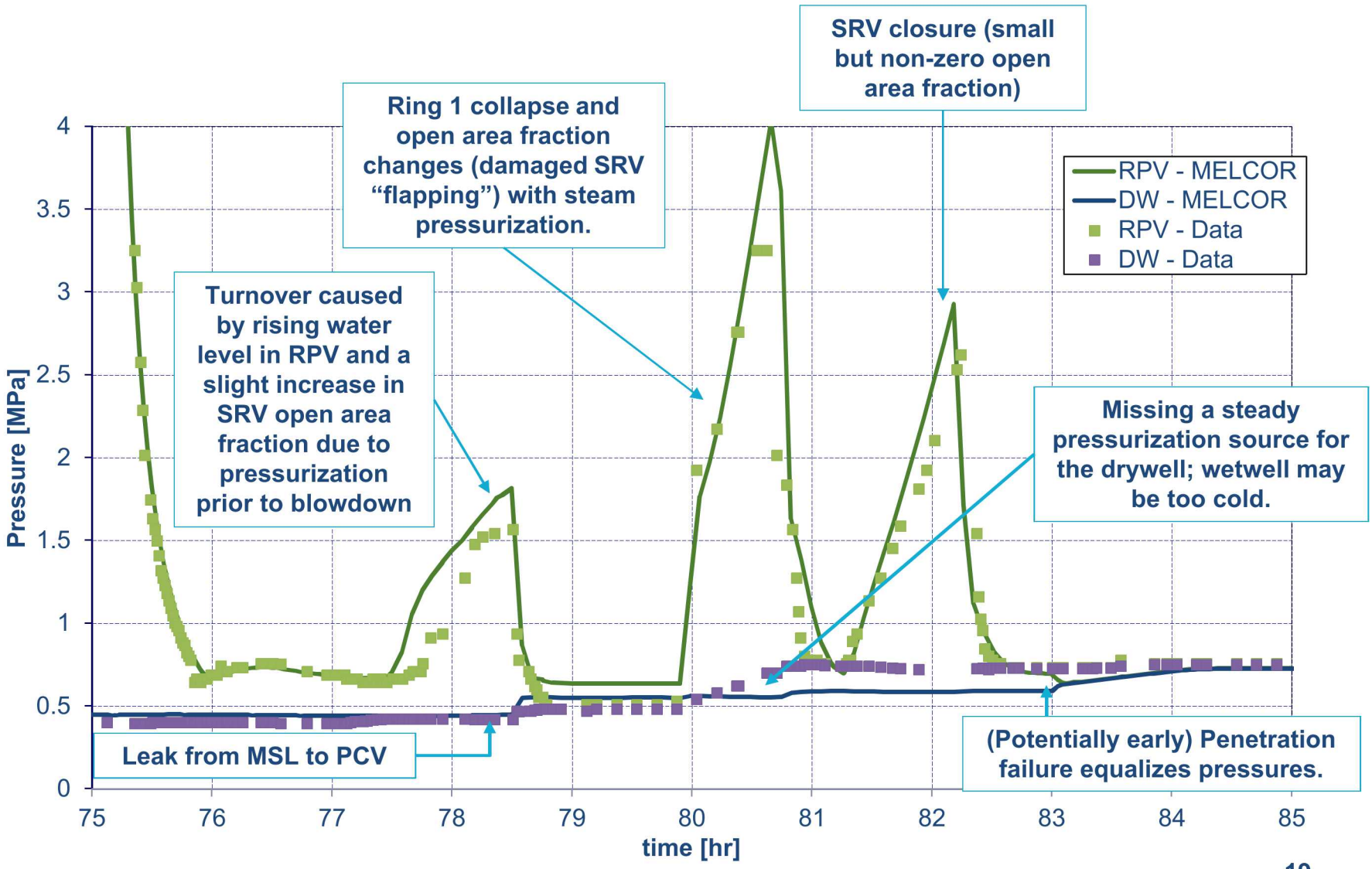
Key Assumptions in 1F2

- Scenario assumptions
  - RCIC operation until 70 hours
  - Fuel failures at 79.9 hours
  - Lower head penetration failure at Ring 4
  - Containment failure at 89.9 hours
- Three-peaks period
  - Insight into core degradation process
  - Complex and requires understanding
    - Core degradation
    - SRV behavior
    - Water level
- Containment failure through a penetration on the 4th ring of the lower head

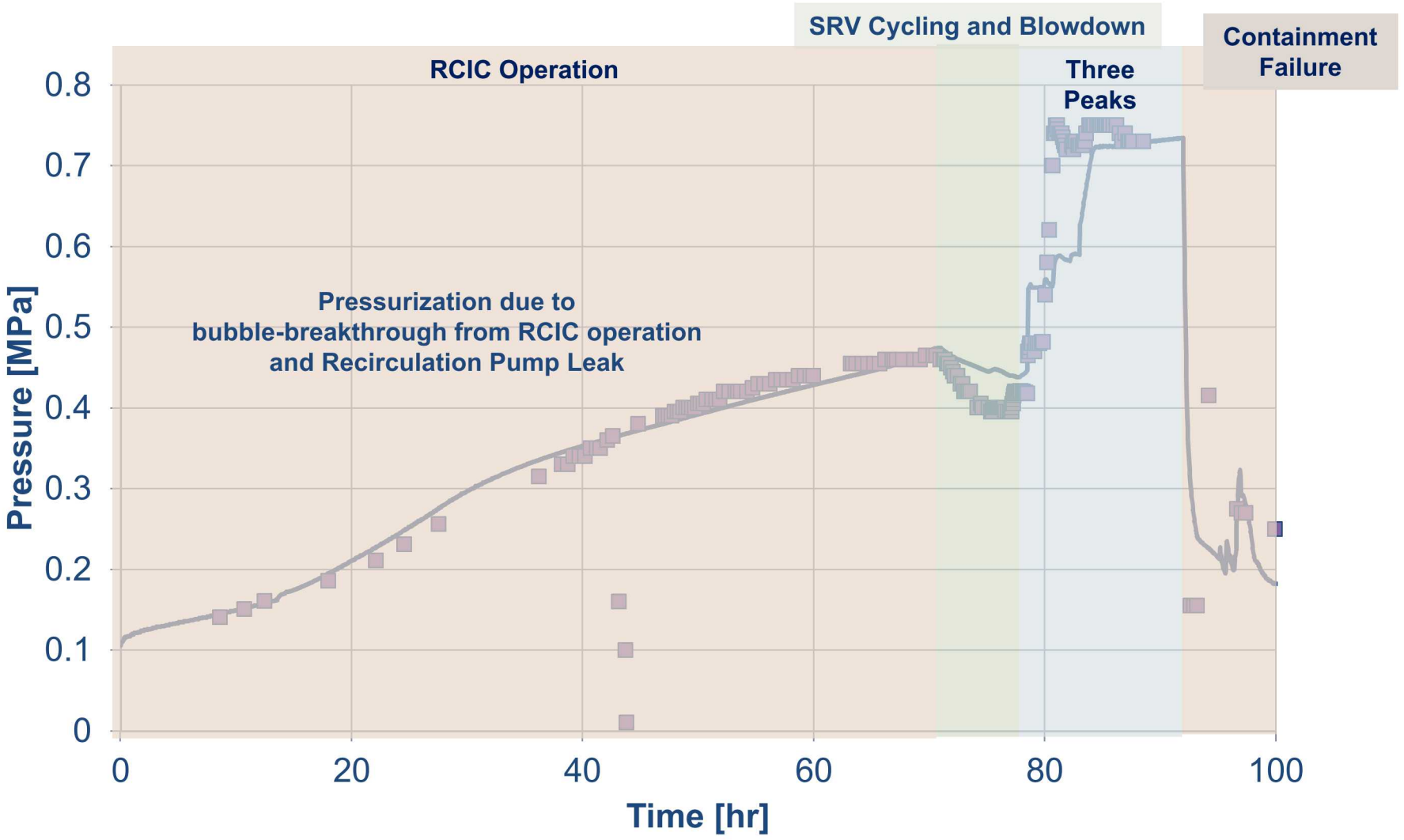
System Pressures



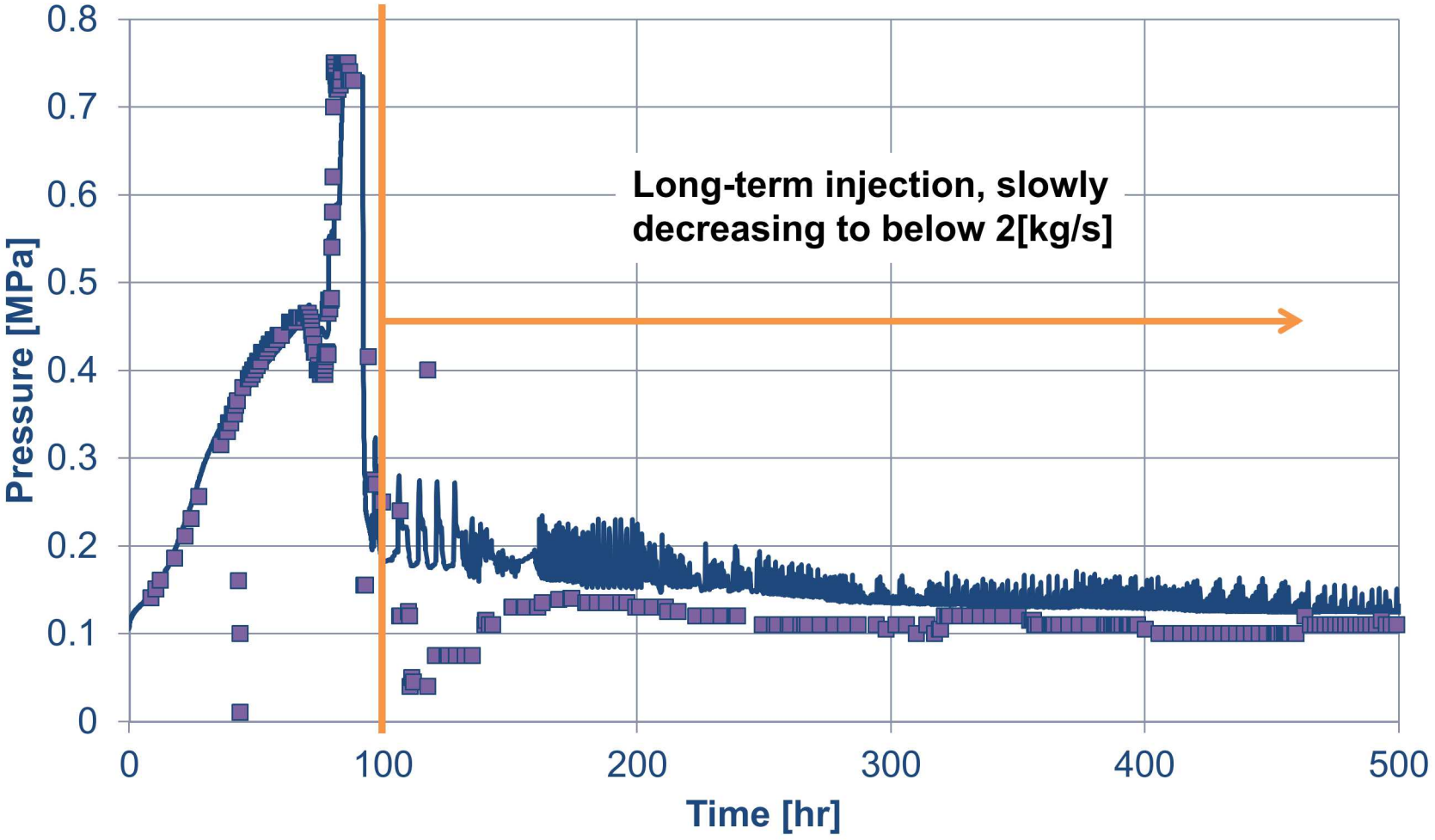
1F2 "Three Peaks" Results



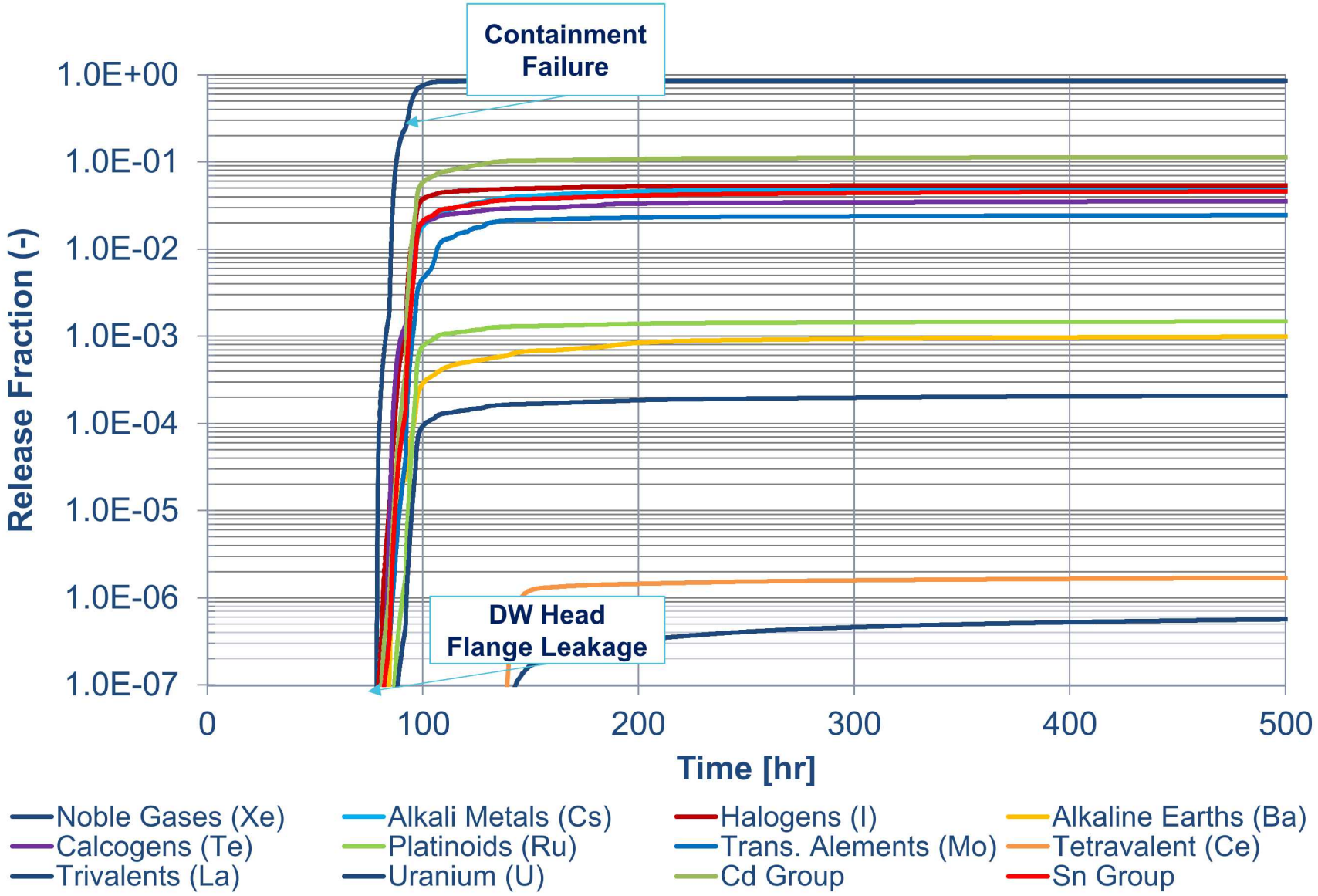
Drywell Pressure



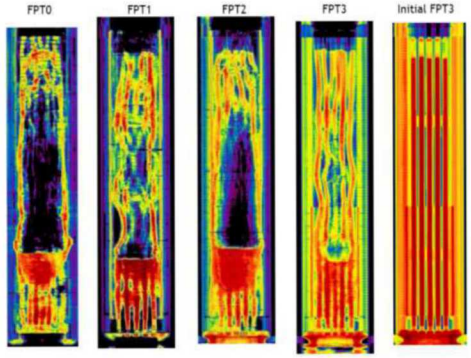
Drywell Pressure



RN Release Fractions to Environment



Source: Tokyo Electric Power Company

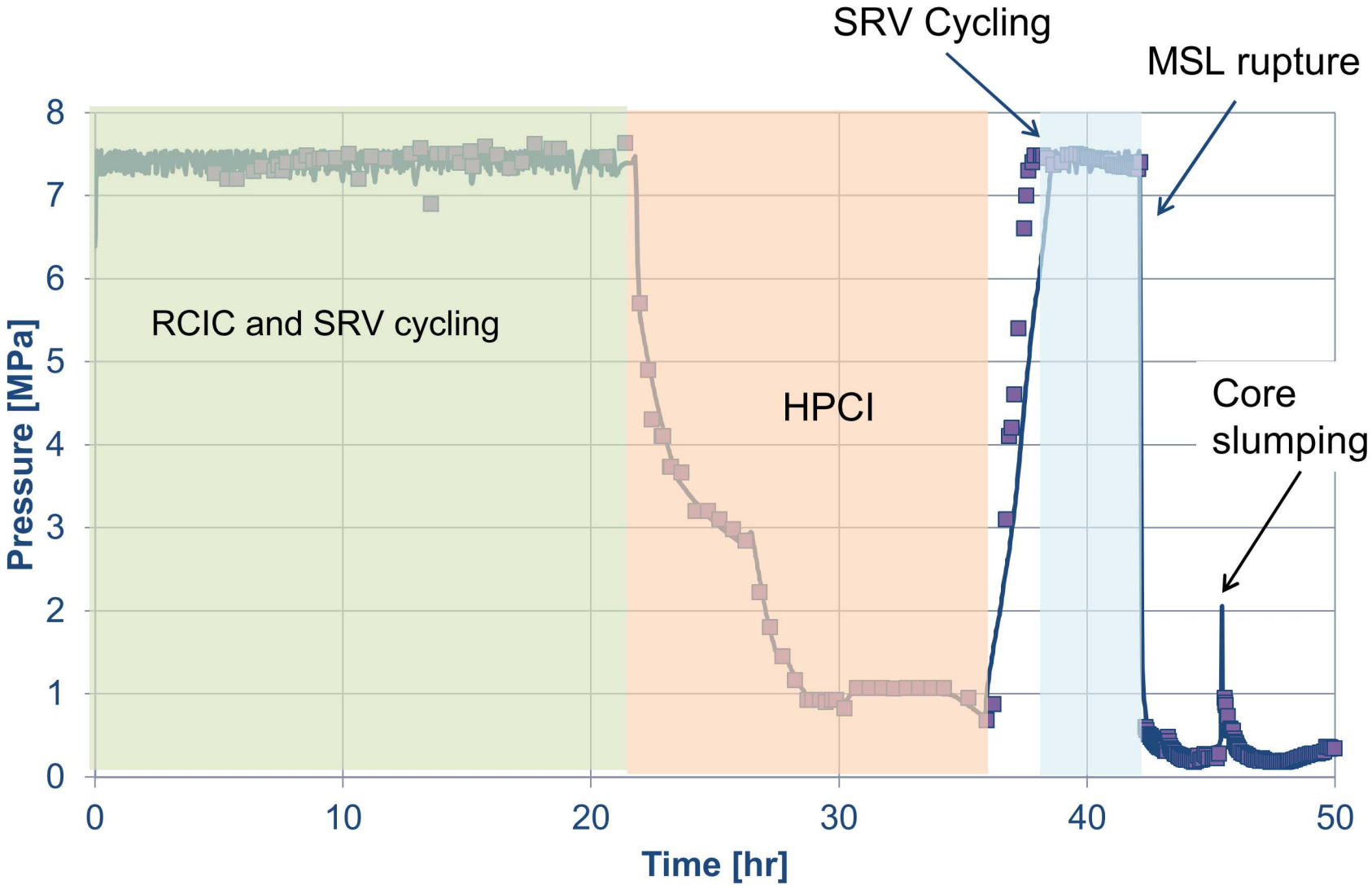


UPDATE OF 1F3 ANALYSES

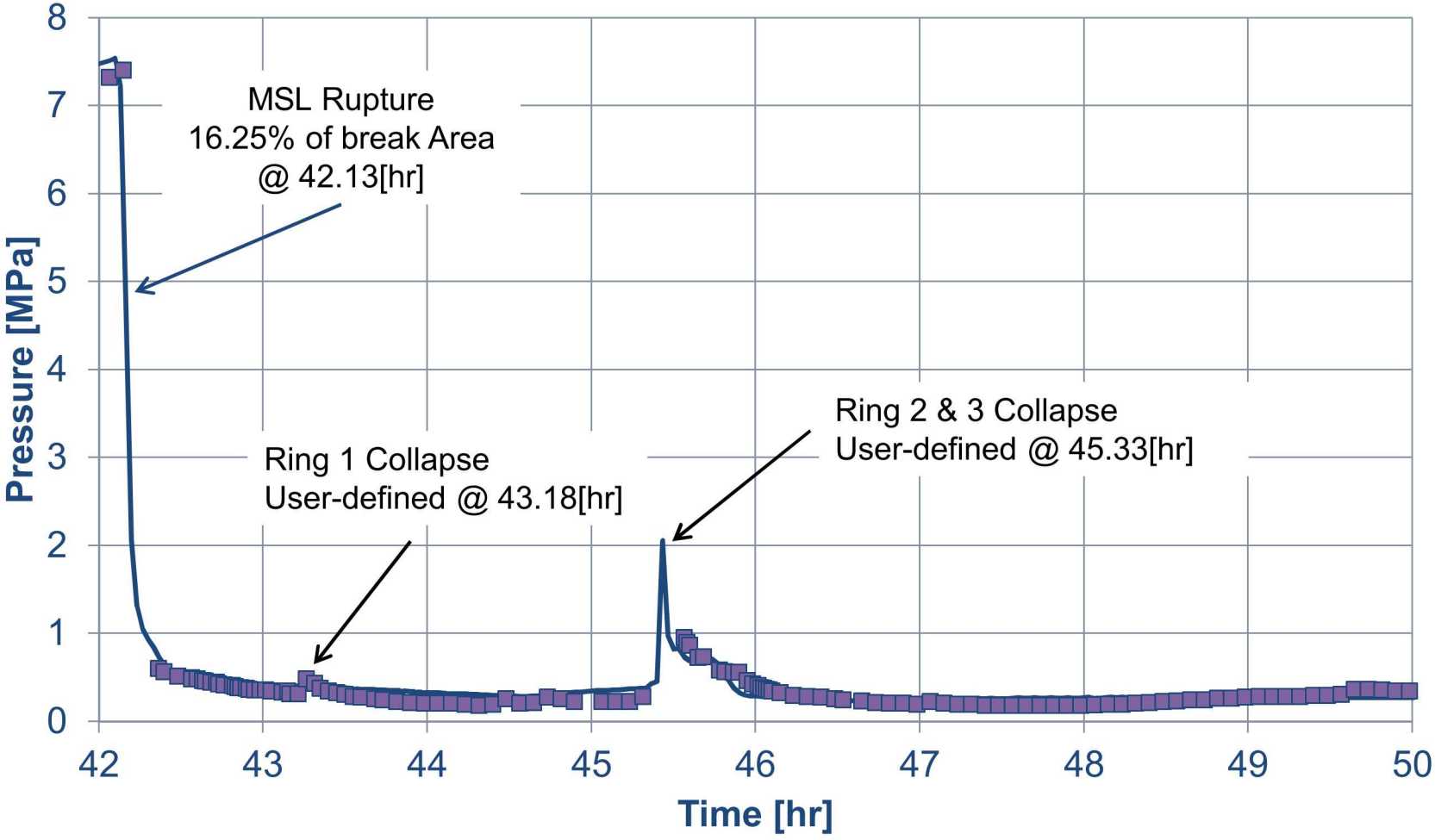
Key Assumptions in 1F3

- Scenario assumptions
  - RCIC operation followed by HPCI operation
  - MSL rupture at 42.1 hours, 16.25% of pipe area
  - Fuel collapse
    - Ring 1: 43.2
    - Ring 2+3: 45.3
  - Containment failure at 58.1 hours
- Determination of long-term water injection into containment
  - Varied alternative water injection rates to match drywell pressure trends
  - Longterm leakage area, approximating progressive degradation, when leakage area alone was not sufficient to match pressure

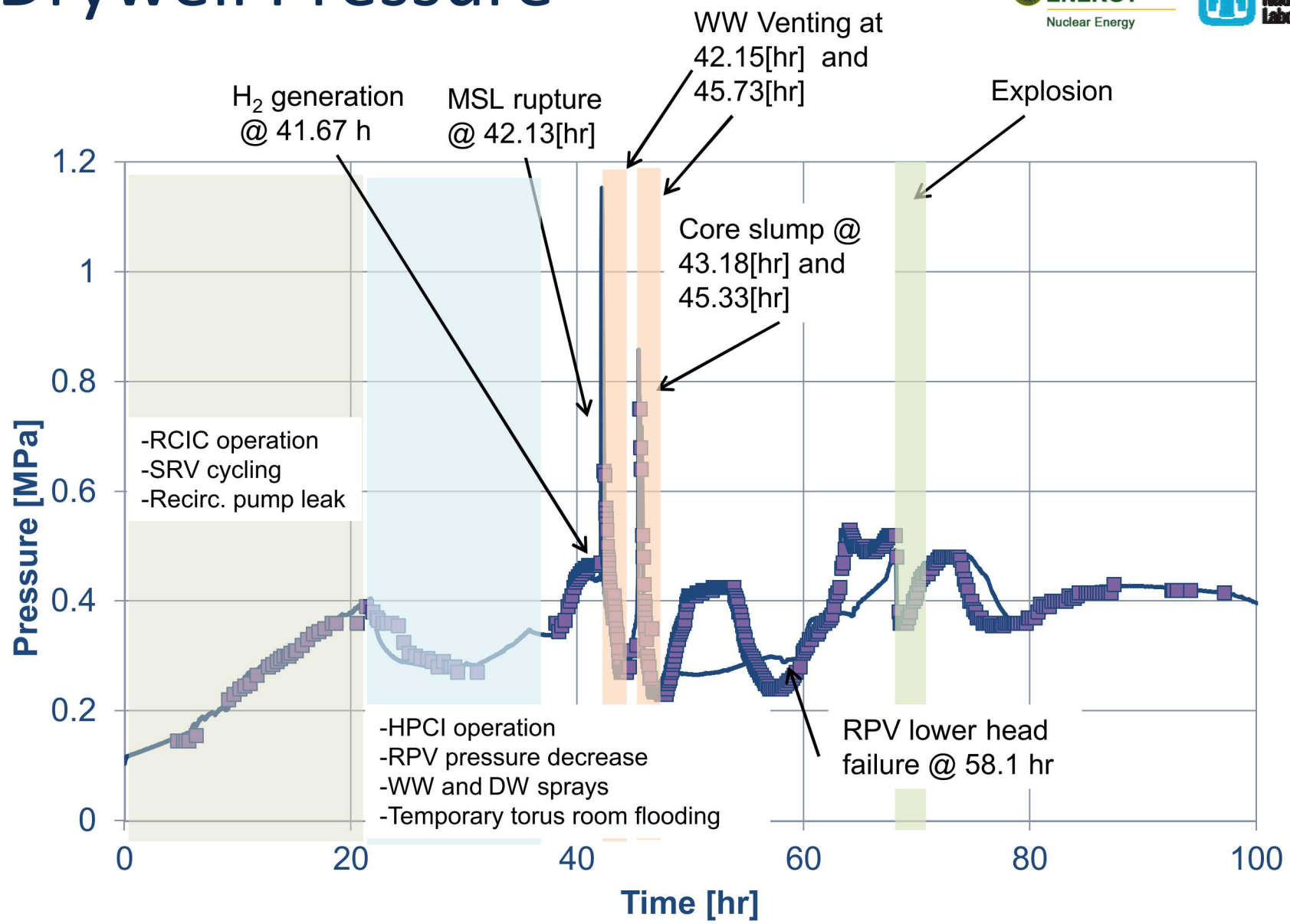
RPV Pressure



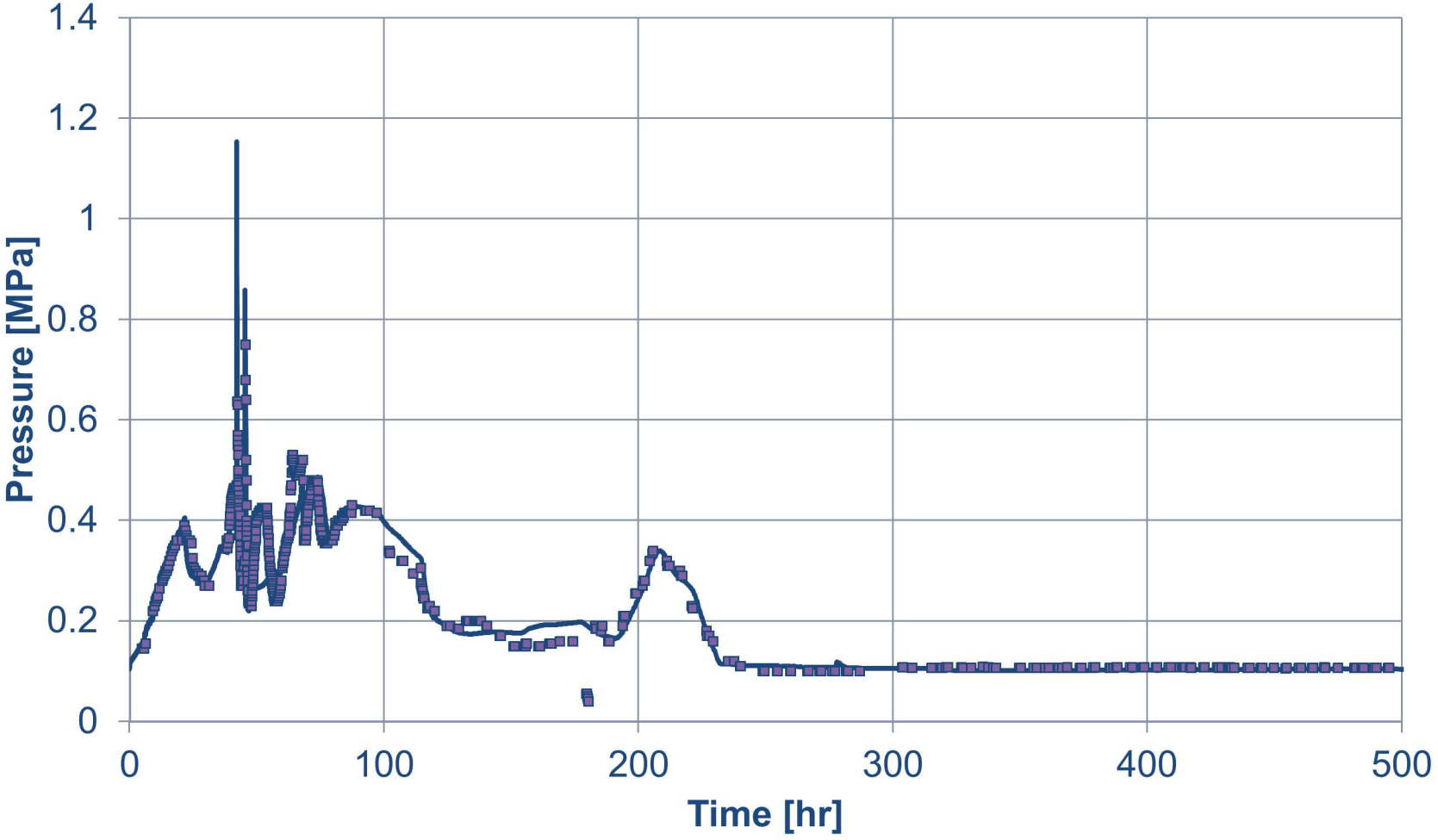
RPV Pressure



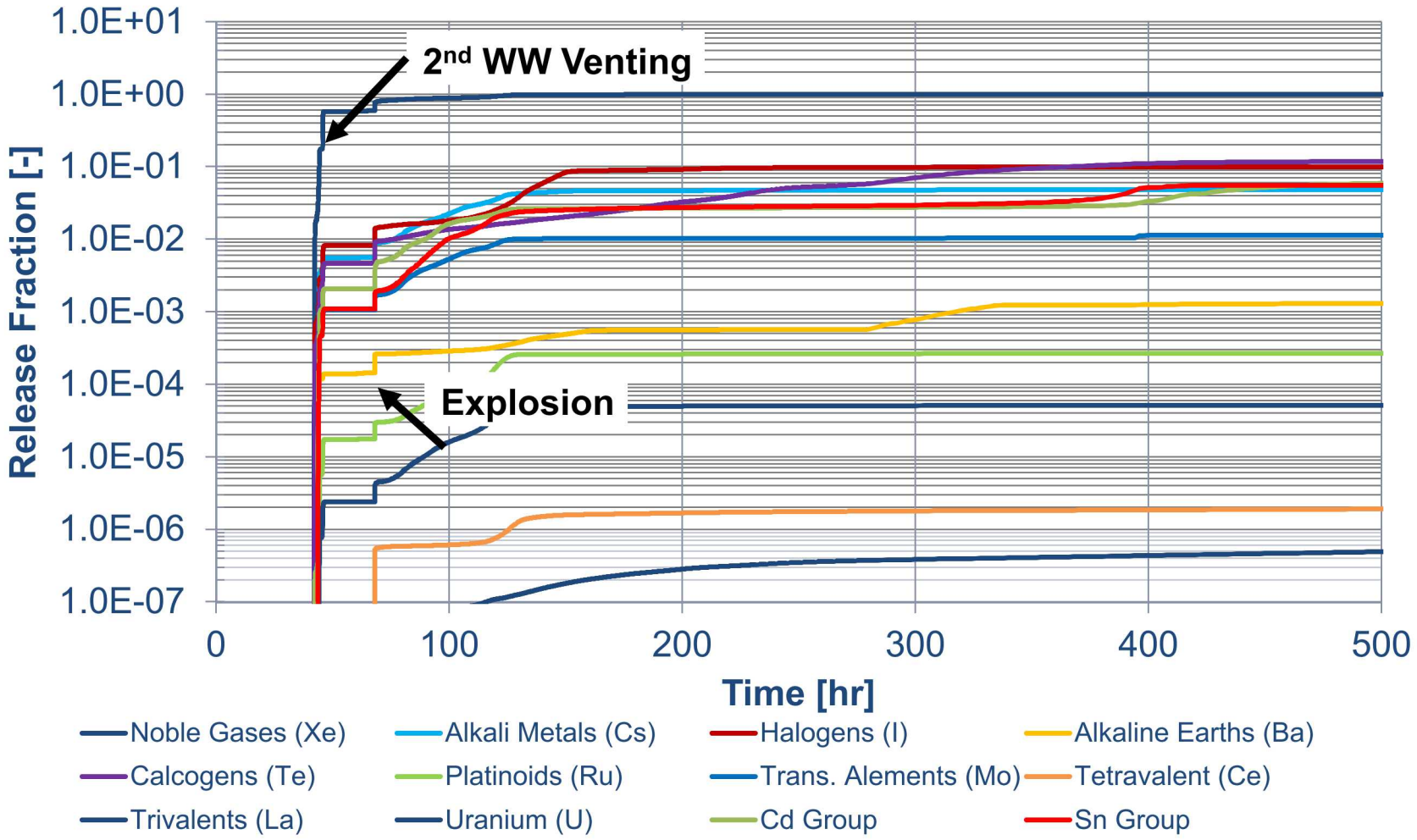
Drywell Pressure



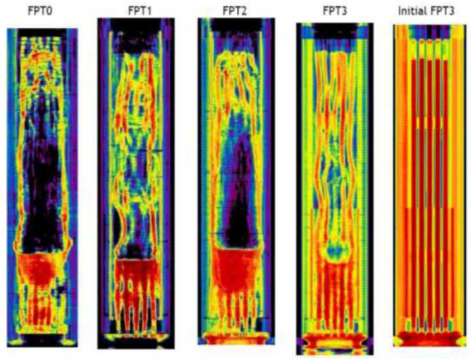
Drywell Pressure



RN Release Fractions to Environment



Source: Tokyo Electric Power Company



Combined 1F Atmospheric Dispersion and Deposition

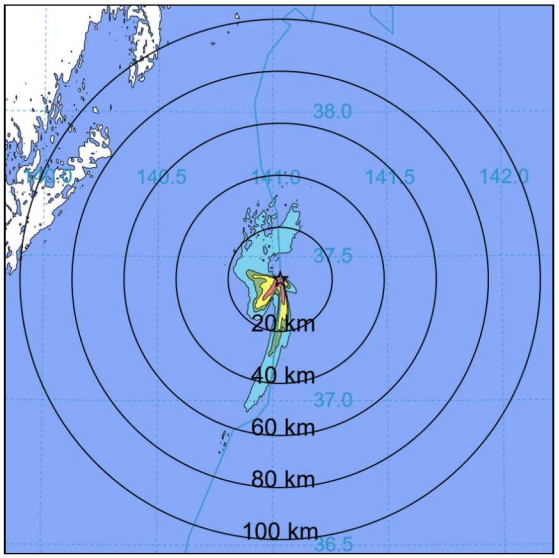
MACCS ANALYSIS

Coupled MELCOR & MACCS Assessment of Fukushima-Daiichi Accidents

U.S. DEPARTMENT OF ENERGY Nuclear Energy

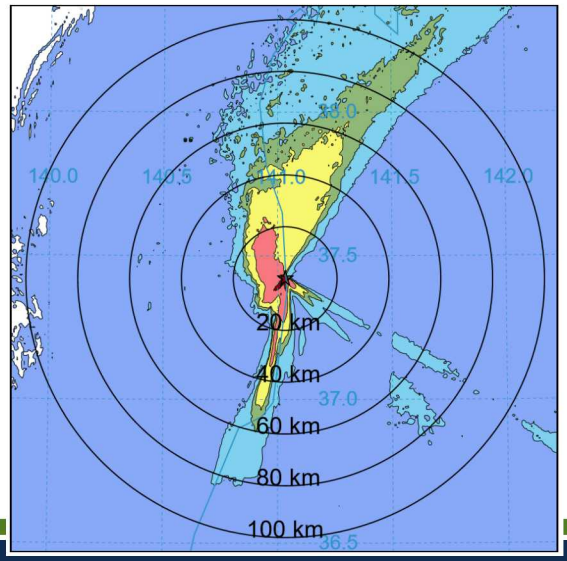
Sandia National Laboratories

1F1

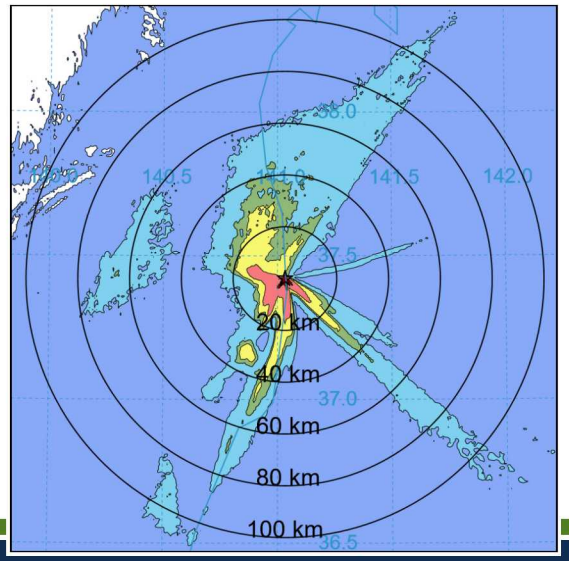


- Evaluate viability of SNL MELCOR source terms by reasonably replicating ground deposition patterns
  - Focus on Cs-137
  - Specific focus on deposition toward the northwest
  - Also focus on overall deposition pattern
- Provide guidance in release timing and magnitude for source term analysts
- Benchmark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

1F2



1F3

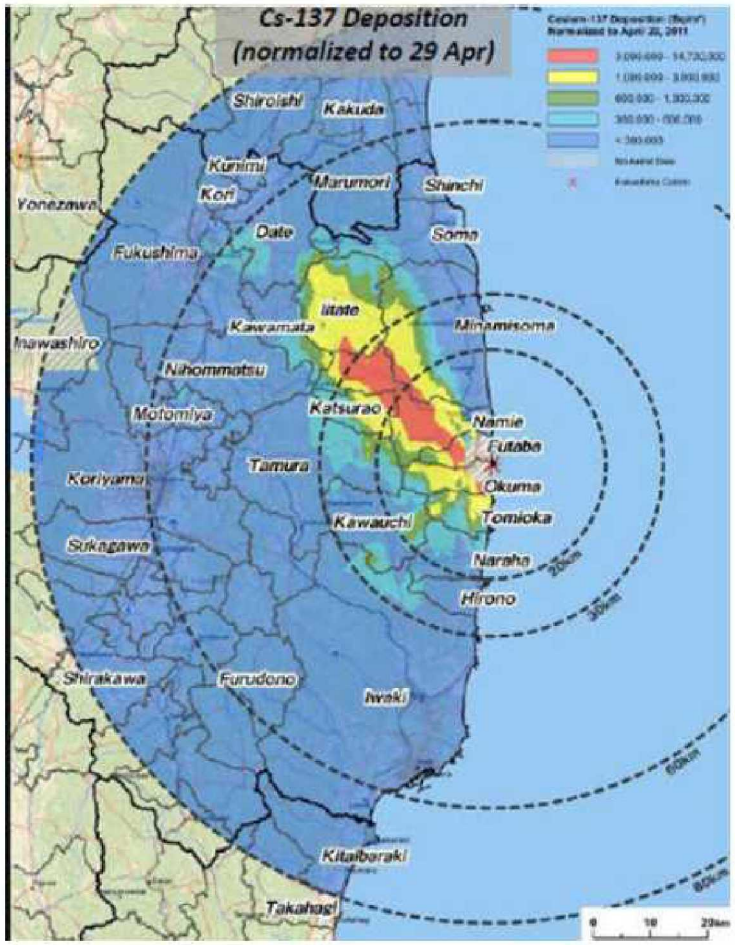


Coupled MELCOR & MACCS Assessment of Fukushima-Daiichi Accidents

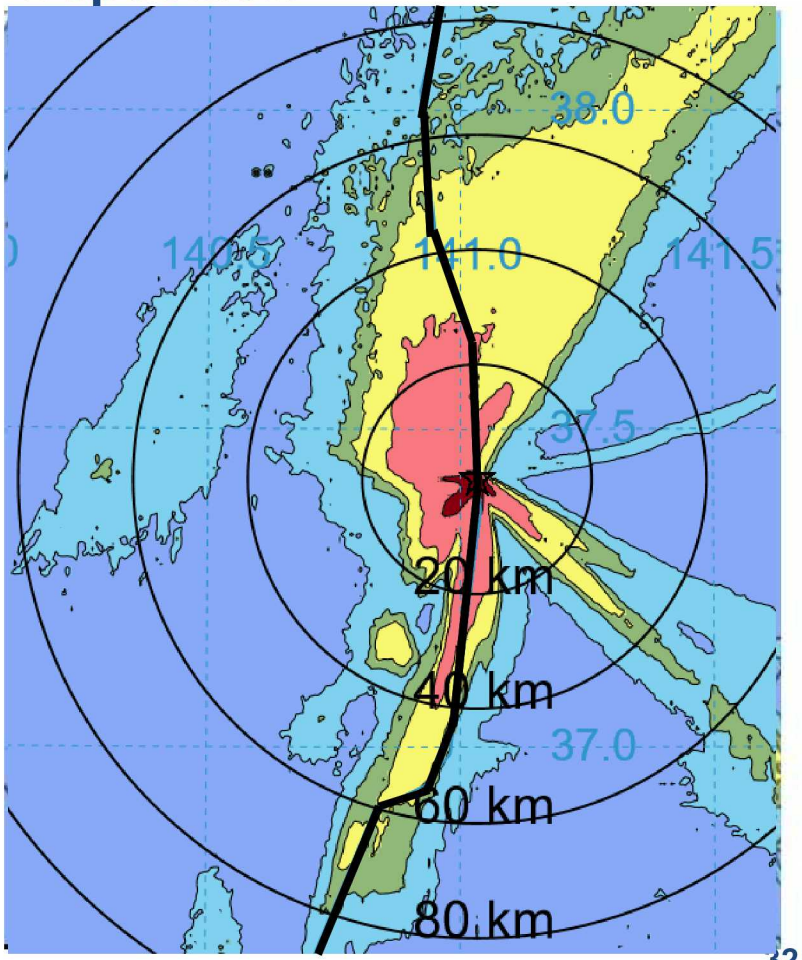
U.S. DEPARTMENT OF ENERGY Nuclear Energy

Sandia National Laboratories

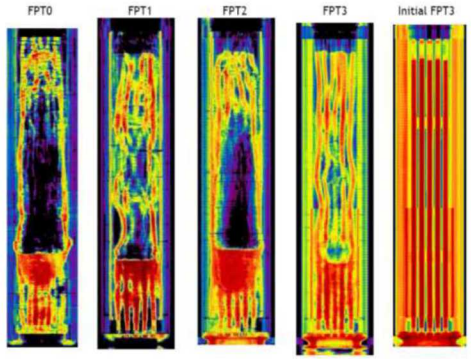
Observed Deposition



MELCOR/MACCS Predicted Deposition



Source: Tokyo Electric Power Company



QUESTIONS AND COMMENTS?

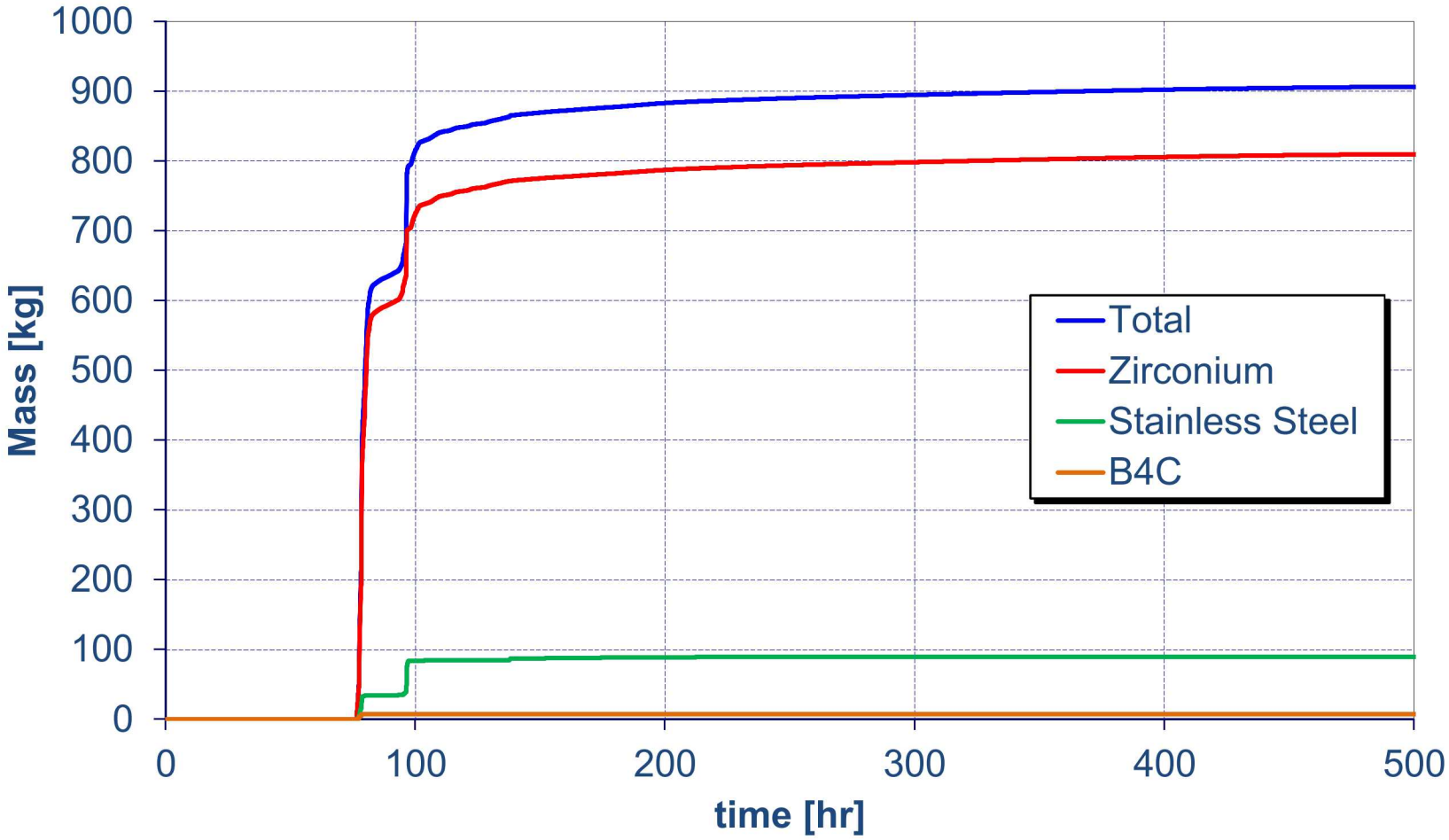
1F2 “Three Peaks” Data

- First Peak
  - Behavior: gradual, continuous RPV pressure increase with an SRV-like decrease coincident with a DW pressure increase
  - Assumed cause: SRV valve closure and re-open
- Second Peak
  - Behavior: sharp 2.7[MPa] spike in RPV pressure in a 10[min] window; a steady (linear) pressurization over 30[min]; rapid decrease in pressure; continuous DW pressure increase over the time
  - Assumed cause: Core collapse with SRV failure-to-close
- Third peak
  - Behavior: gradual, continuous RPV pressure increase with an SRV-like decrease
  - Assumed cause: SRV valve closure and re-open

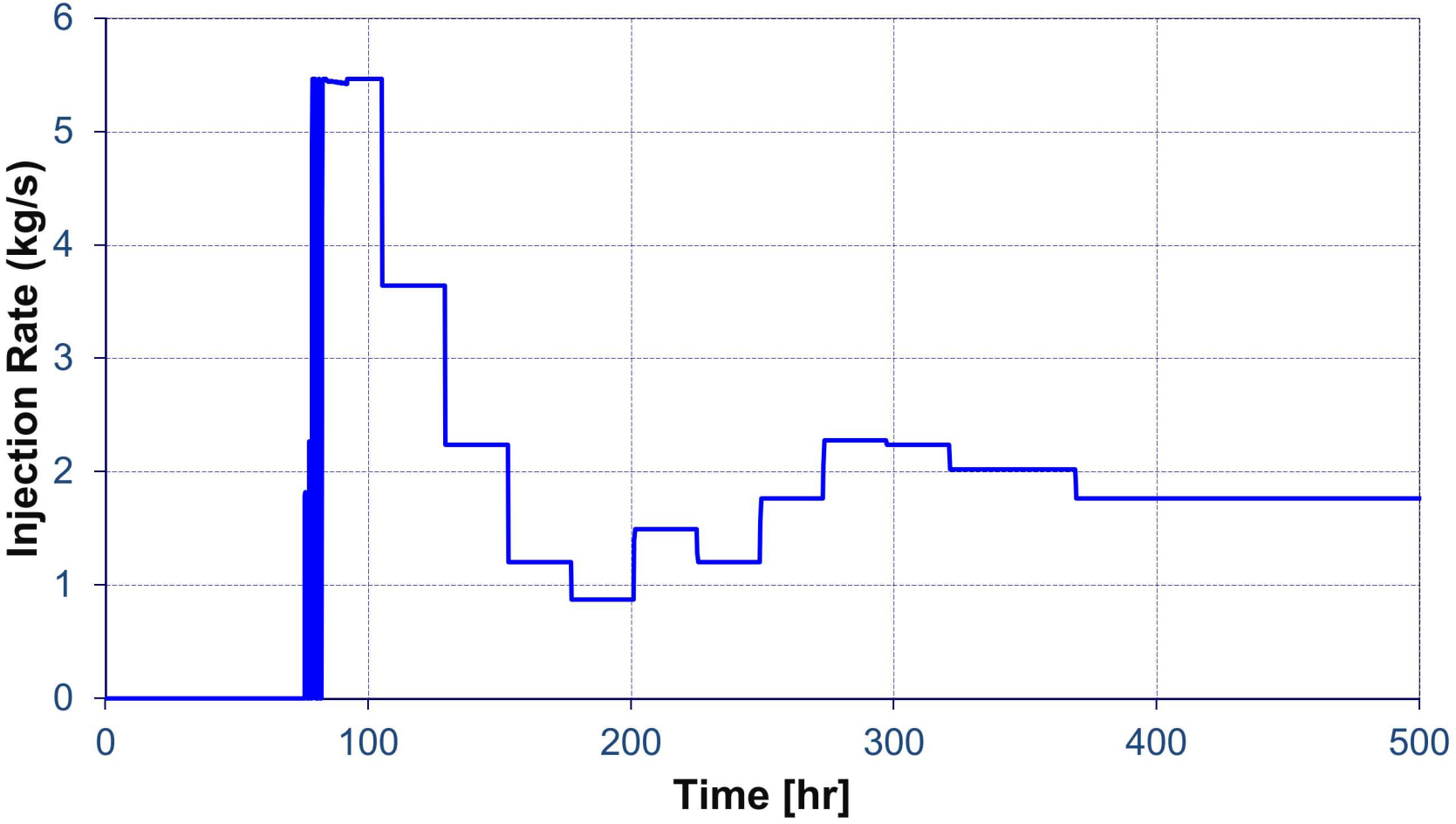
1F2 “Three Peaks” Modelling

- First Peak
  - At 75.98[hr], SRV closes, experiences failure-to-close
    - Varied between 0.008 to 0.05 open fraction prior to full-open
  - At 78.52[hr], full-open actuation (2 SRVs per BSAF event sequence)
- Second Peak
  - At 79.9[hr], Ring 1 collapse for sharp increase in pressure
  - SRV closes, experiences failure-to-close
    - From 80[hr] to 80.71[hr], open fraction varies between 0.0001 and 0.0025
    - Allows steam pressurization without pressure excursion
  - At 80.84[hr], full-open actuation (second SRV assumed 0.5[-] open)
- Third Peak
  - At 81.31[hr], SRV experiences failure-to-close with 0.015 open fraction
  - At 82.24[hr], full-open actuation (1 SRV)

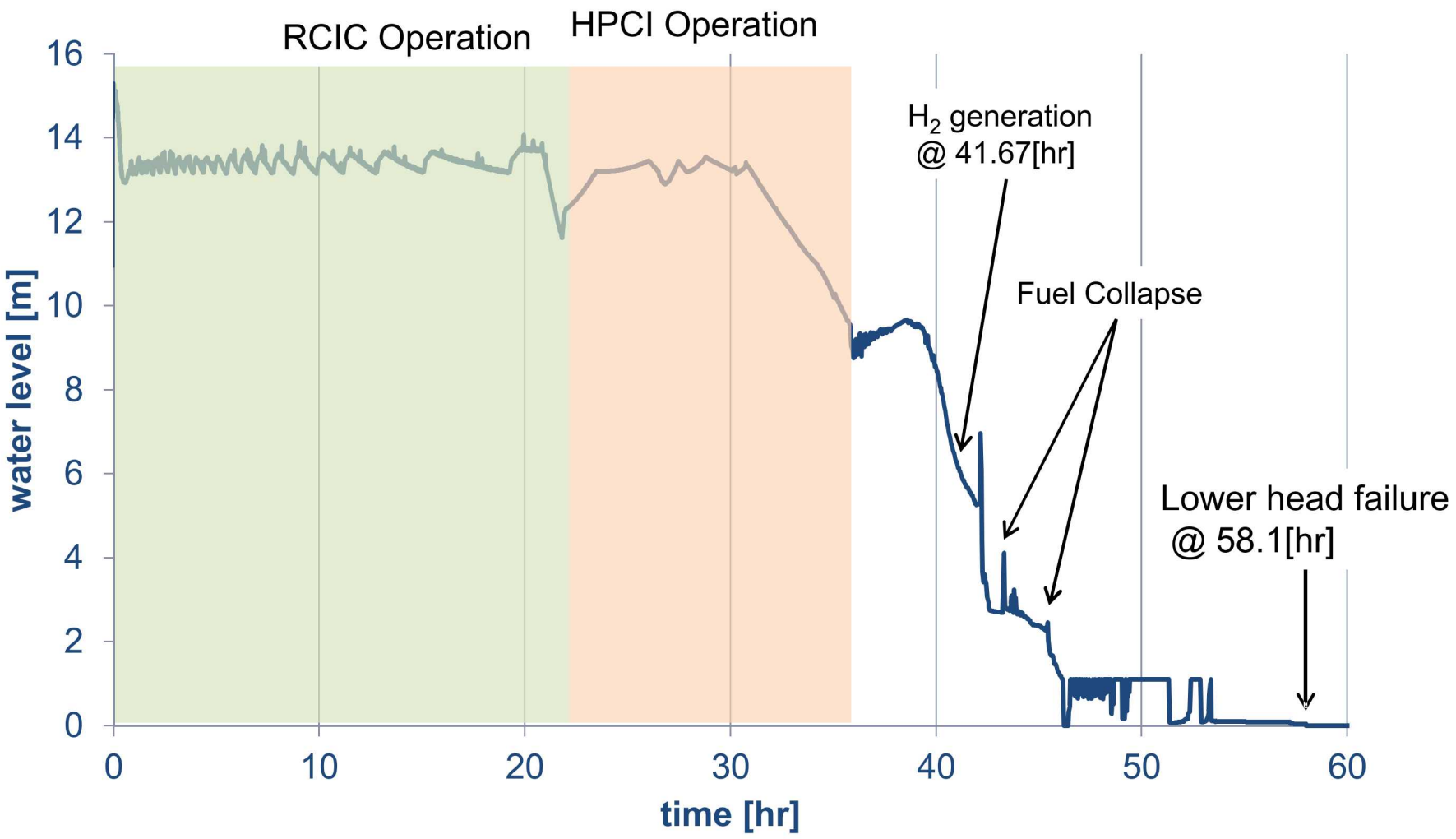
In-Core Hydrogen Generation 1F2



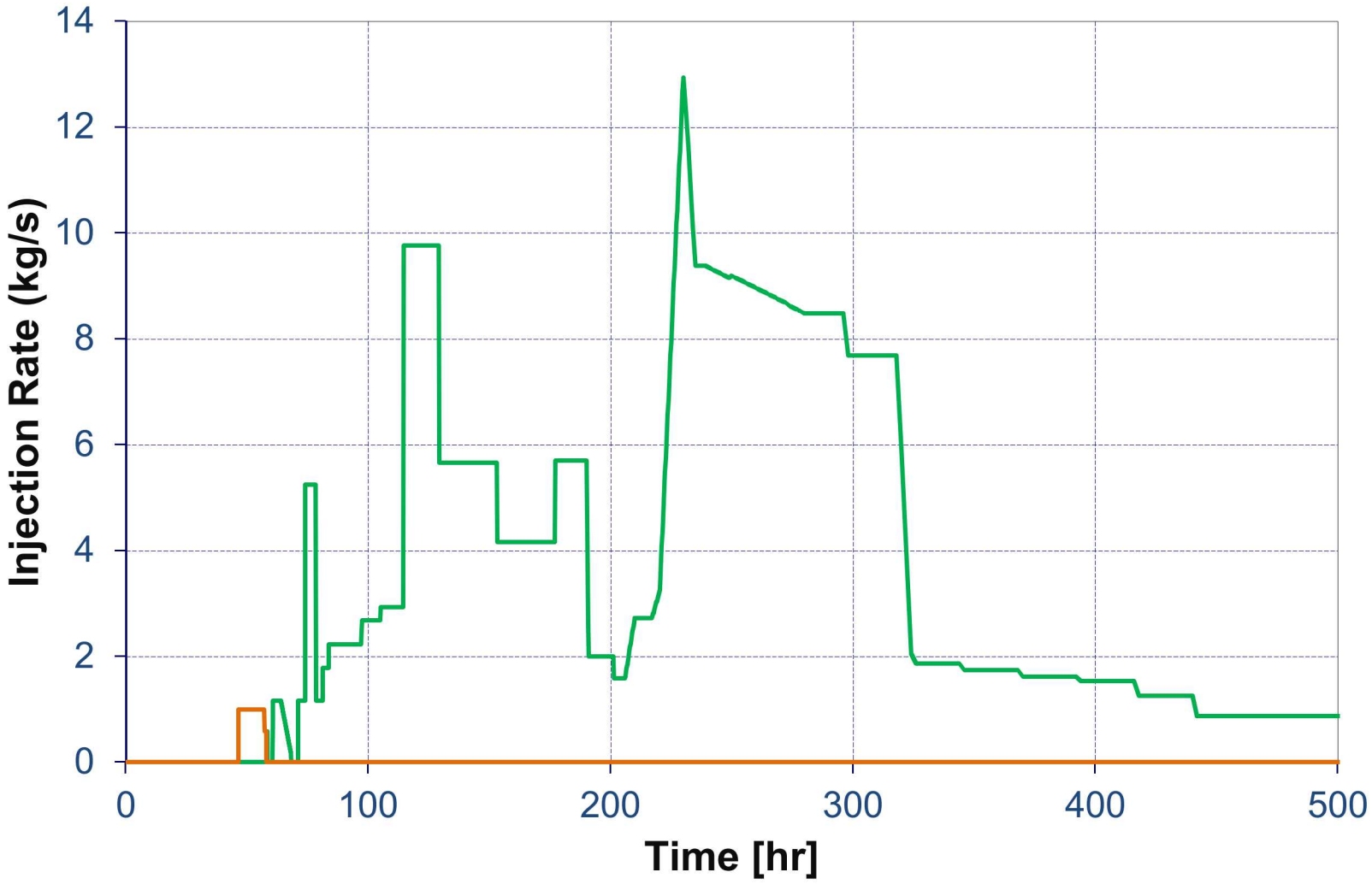
Alternative Water Injection



Core Water Level



Alternative Water Injection



In-Core Hydrogen Generation