SAND2018-0298PE

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Sandia National Laboratories

BSAF Phase II Final Results

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Update of 1F1 Analyses

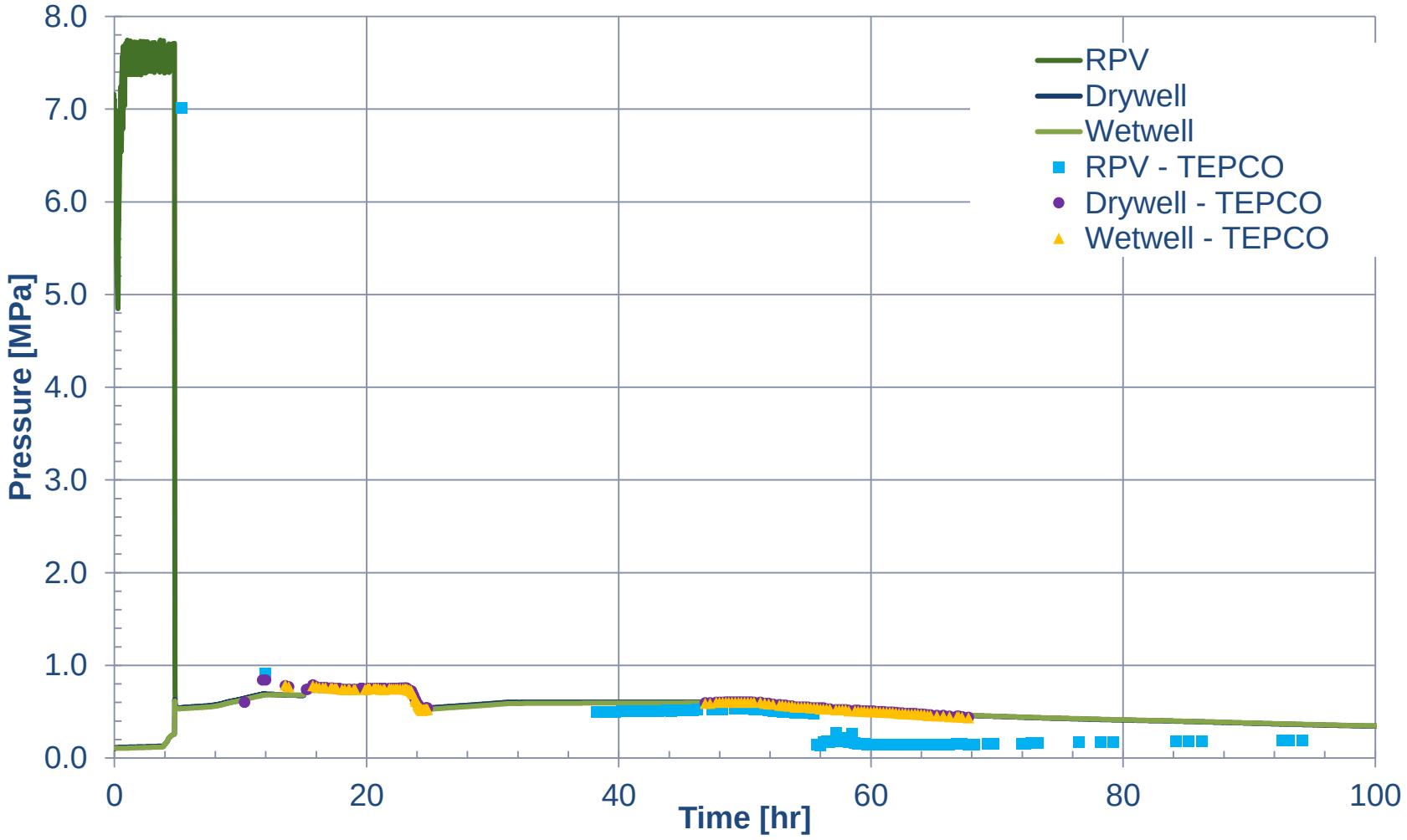
Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

Progress in Modeling 1F1

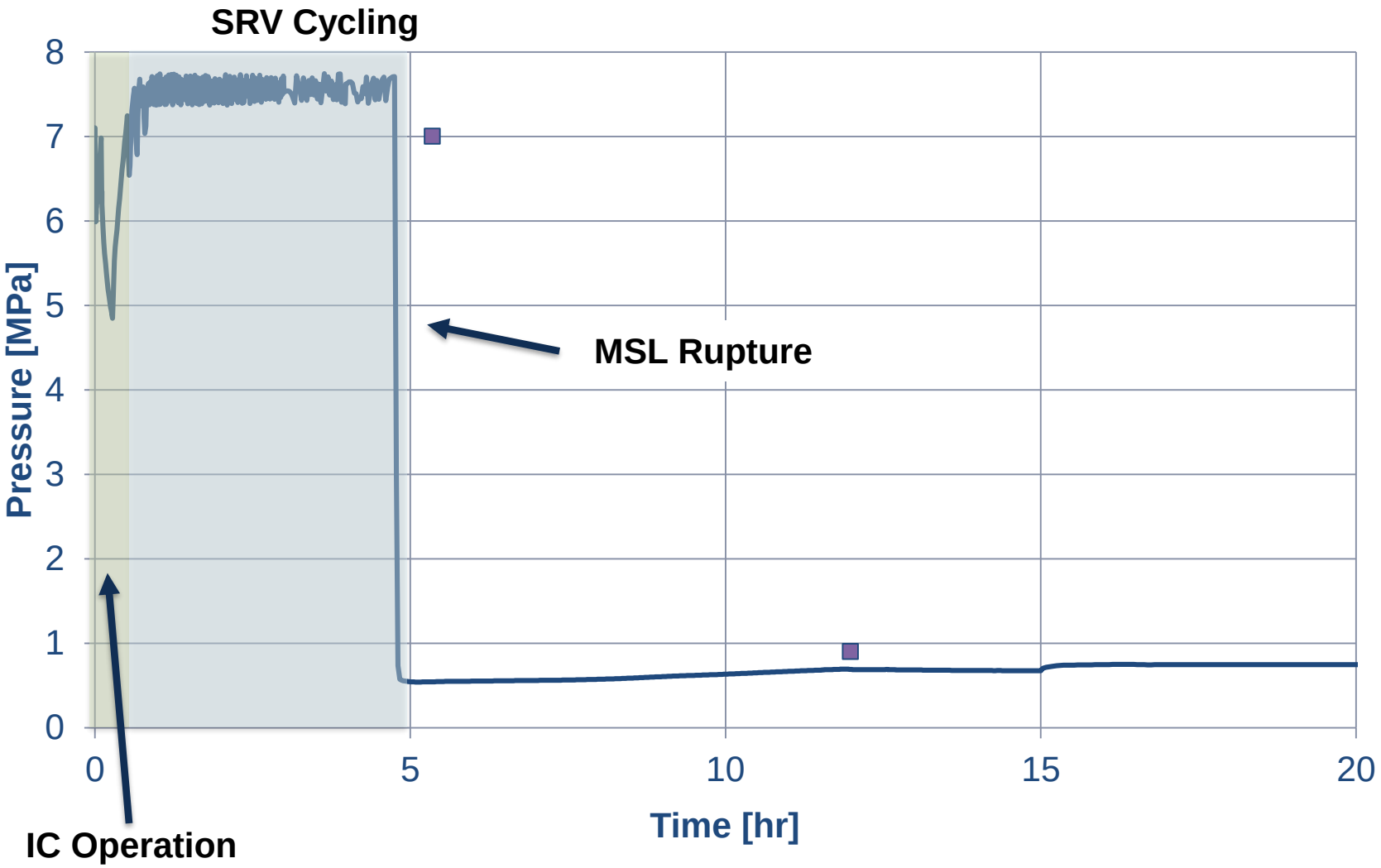
- Forensic approach
- Examination of long-term water injection into containment
  - Fixed longterm leakage area
  - Varied alternative water injection rates to match drywell pressure trends
  - Minimal through three weeks
- Liner melt-through
  - MELCOR predicts near the drop in containment pressure at 50 hours

PRESSURE TRENDS

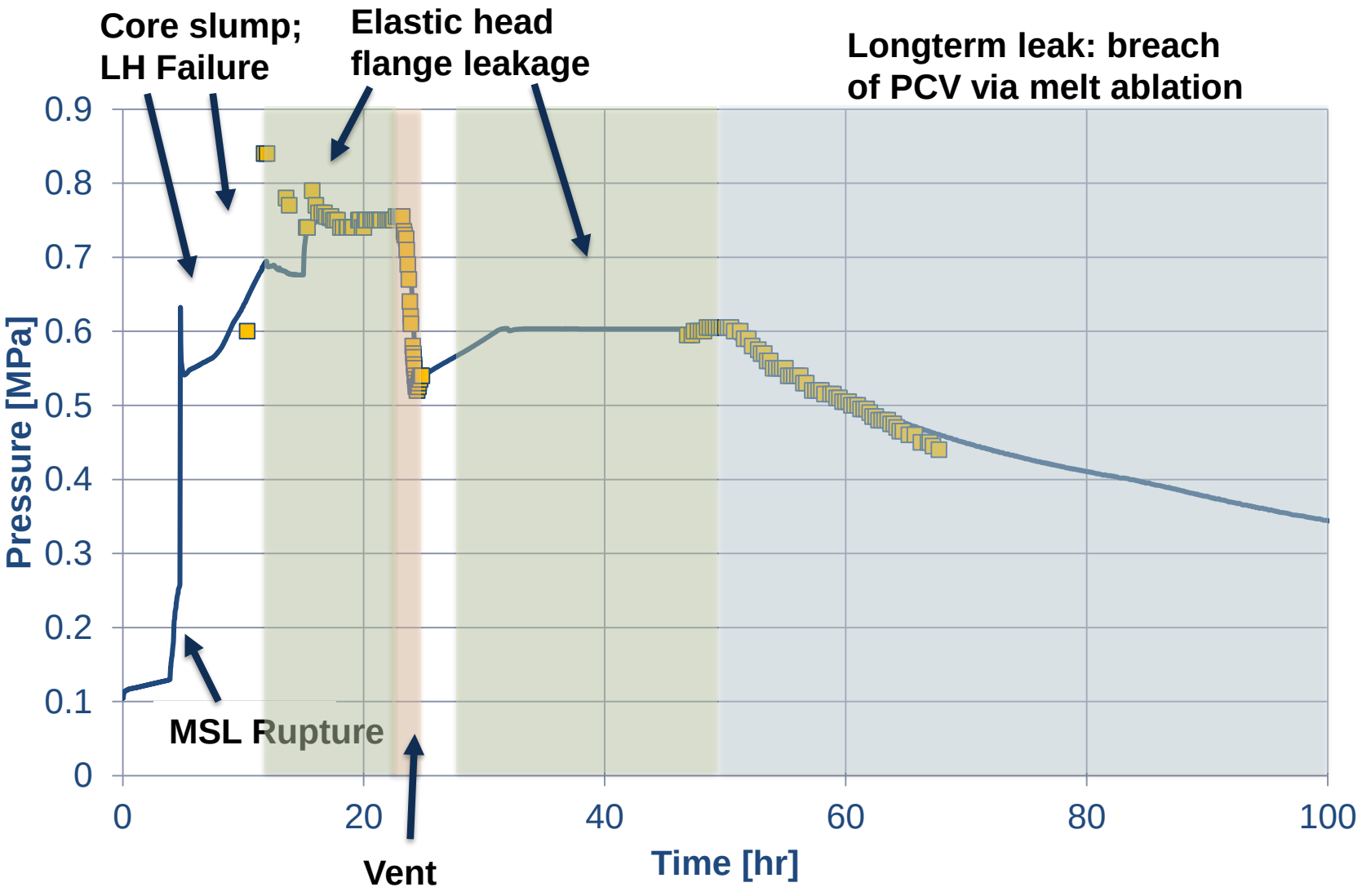
System Pressures



RPV Pressure

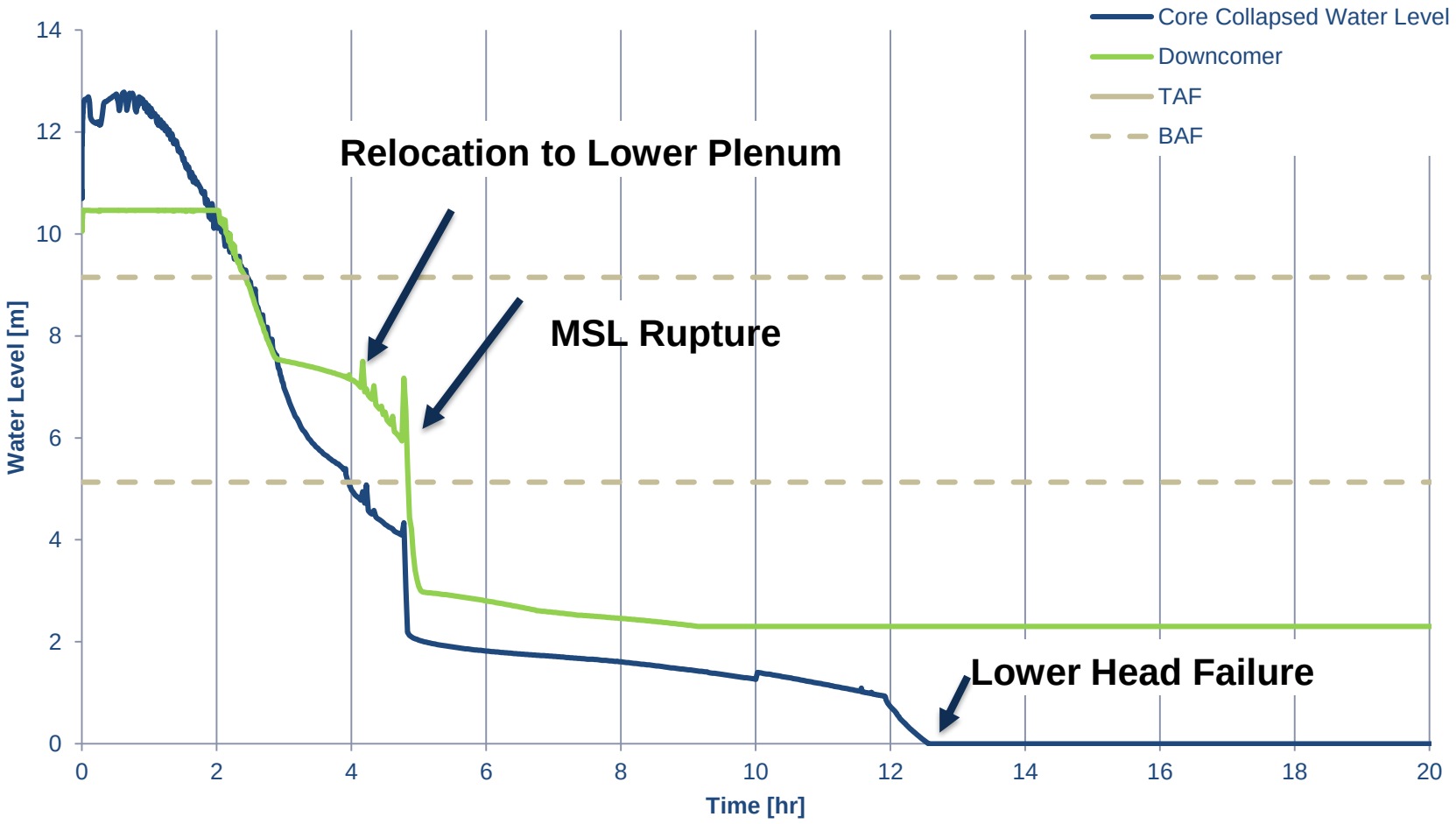


Drywell Pressure



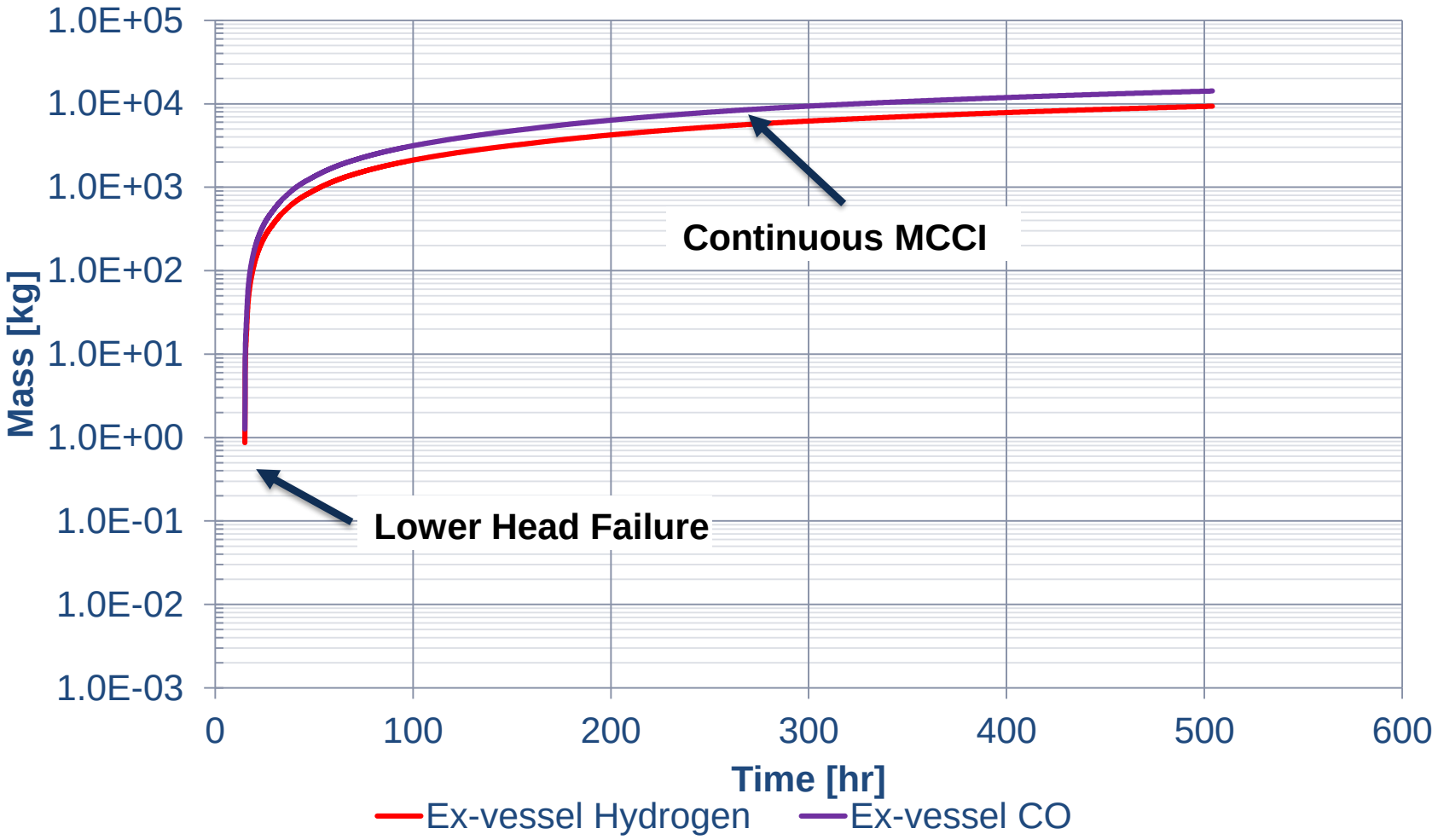
INJECTION AND RPV WATER LEVEL

Core Water Level



RELEASE FRACTIONS AND MCCI

Combustible Gas Generation



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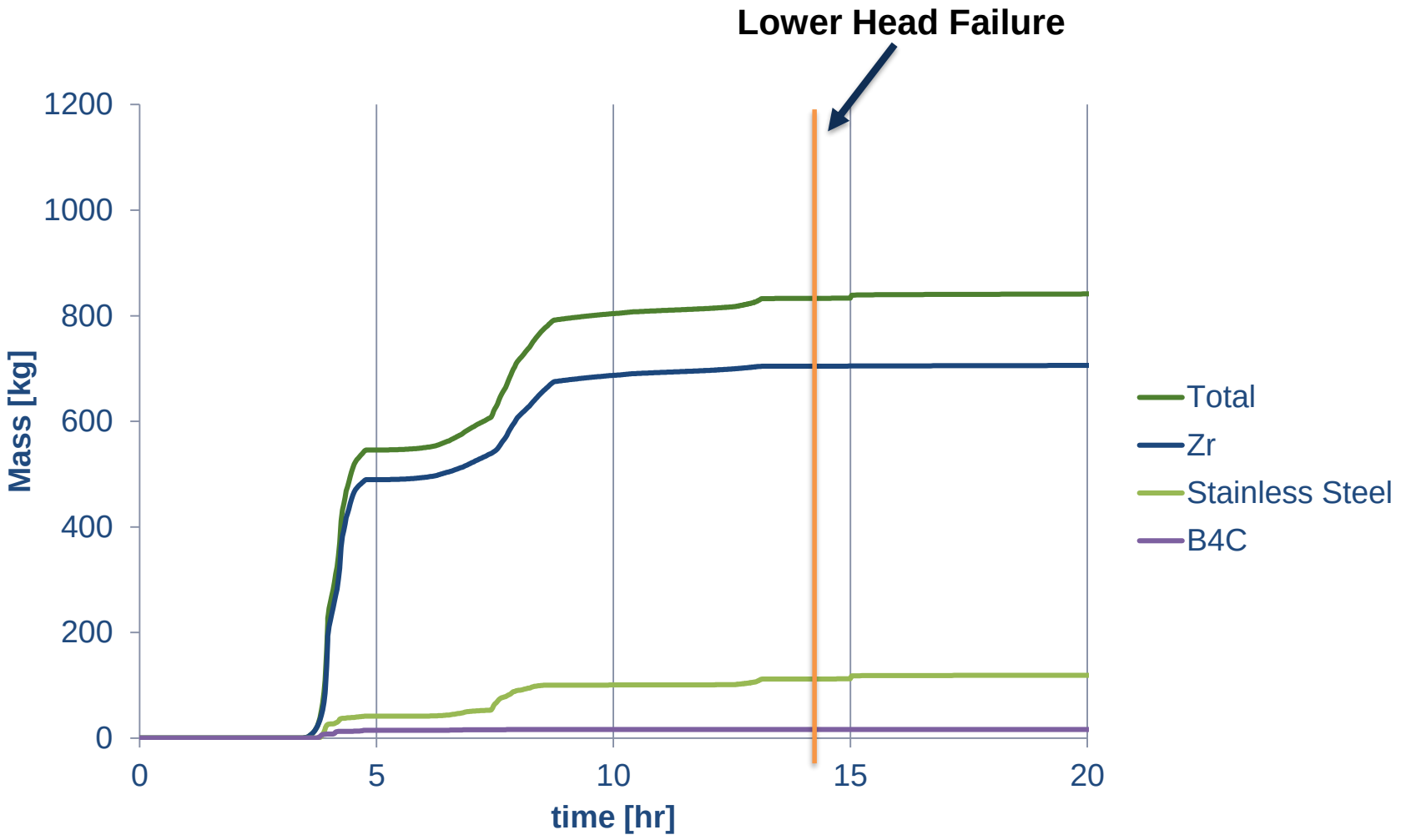
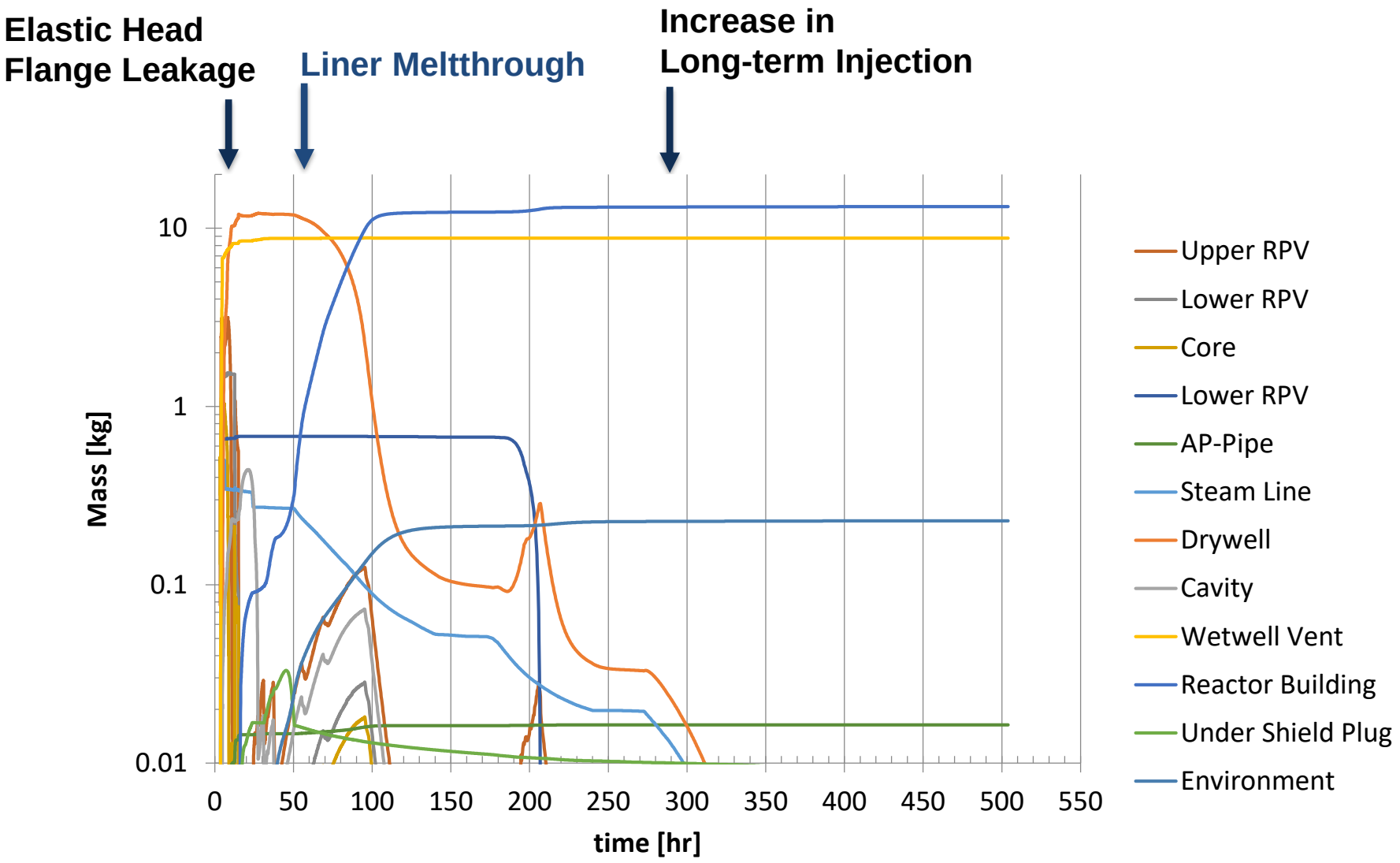


Plant-Wide CsI Distribution



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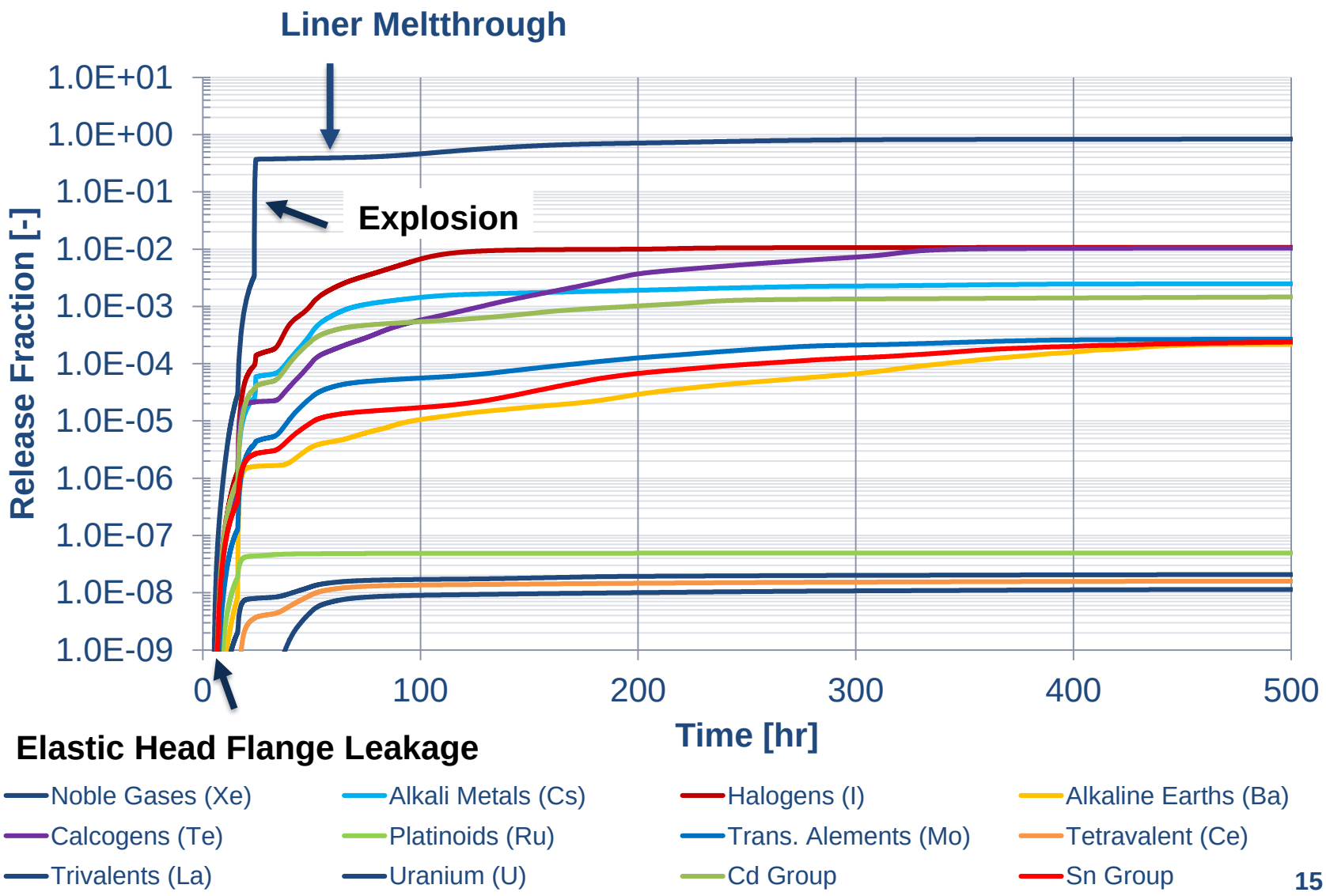

Update of 1F2 Analyses

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Progress in Modeling 1F2

- Forensic approach
- Model developments
  - Implementation of improved RCIC model
  - Torus room flooding
  - Modeling “three peaks”
  - Containment “pop” prior to large NW release
- Long term injection

MODEL UPDATES

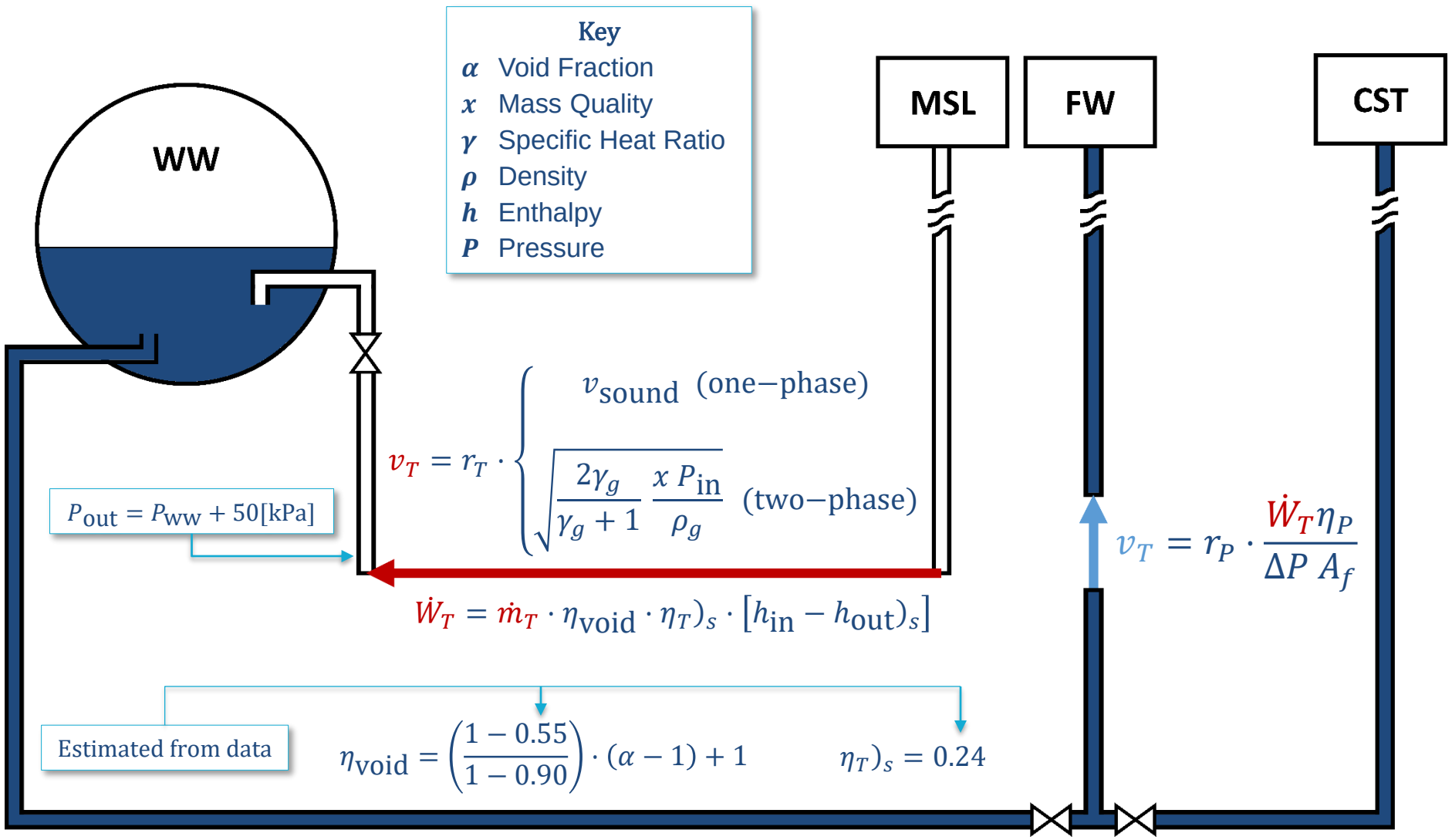
1F2 RCIC Model

- Specified velocities for both turbine and pump
  - Assumption: turbine flow always choked
    - One-phase: sonic velocity
    - Two-phase: Homogeneous Frozen Choked Flow
  - Turbine work drives pump velocity
  - Model constants r_T and r_P adjust velocities to rated conditions.
- Turbine work is a thermodynamic calculation
  - Isoentropic efficiency $\eta_T)_s$ estimated from data
  - Outlet pressure set at 50 kPa above wetwell liquid surface pressure
  - Void efficiency η_{void}
    - Linearly degrades output work with a slope estimated from data
    - bounded between 10% and 100%.
  - Flow area switches from a restricted value to a full-open value (estimated from rated conditions) at loss of on-site power.

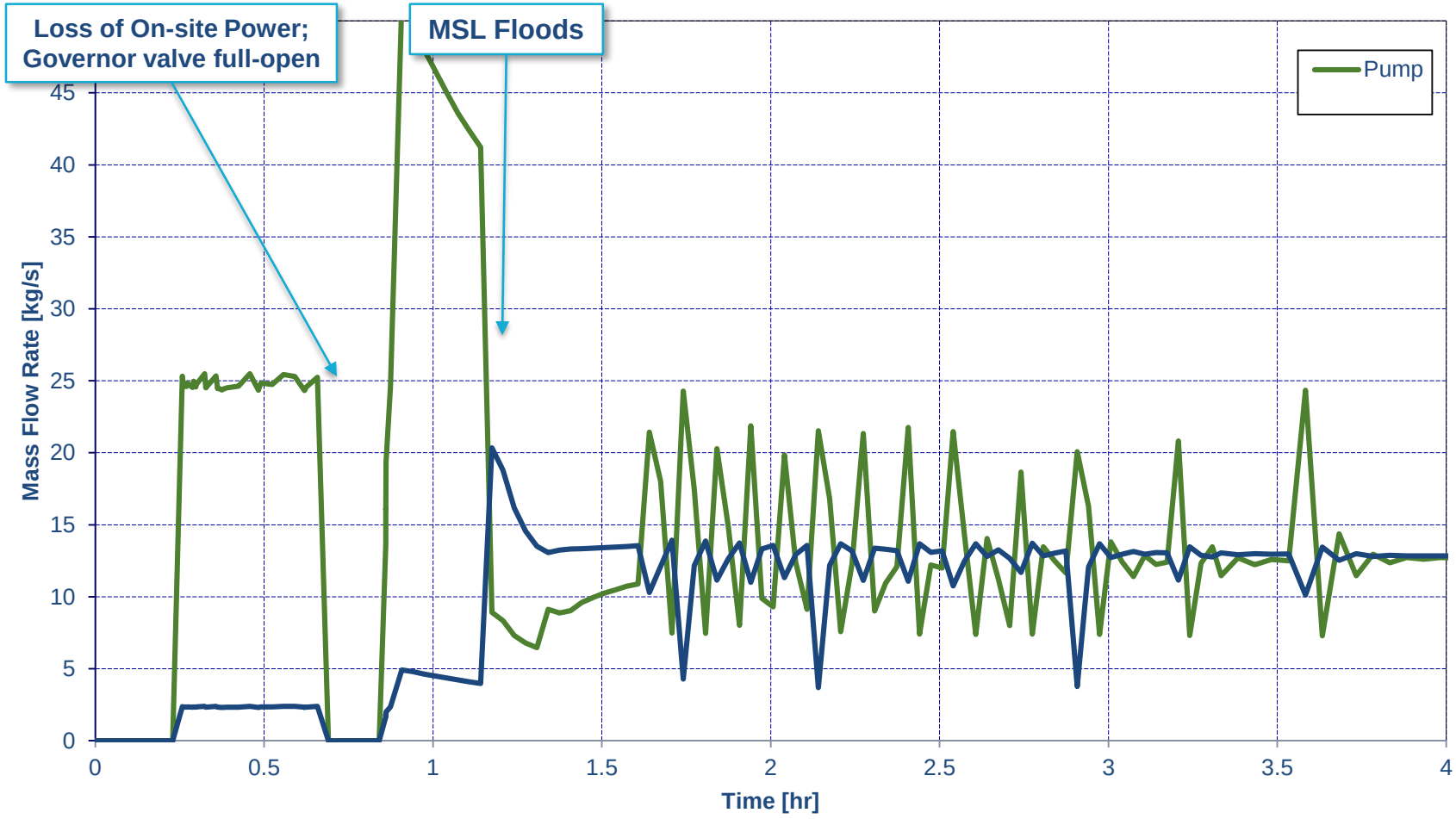
1F2 Torus Room Flooding

- Torus room flooding
  - Important for long-term cooling of reactor via the RCIC system
  - Greatly influenced by CST-to-WW switchover.
- Flooding amount unknown
- Parametric study
  - Flood amount expressed as percentage of torus room filled
  - Varied and compared to data
  - 30% gives good agreement
- Begun flooding at time of tsunami for duration of 1 hour to maximum level

1F2 RCIC Model



1F2 RCIC Operation



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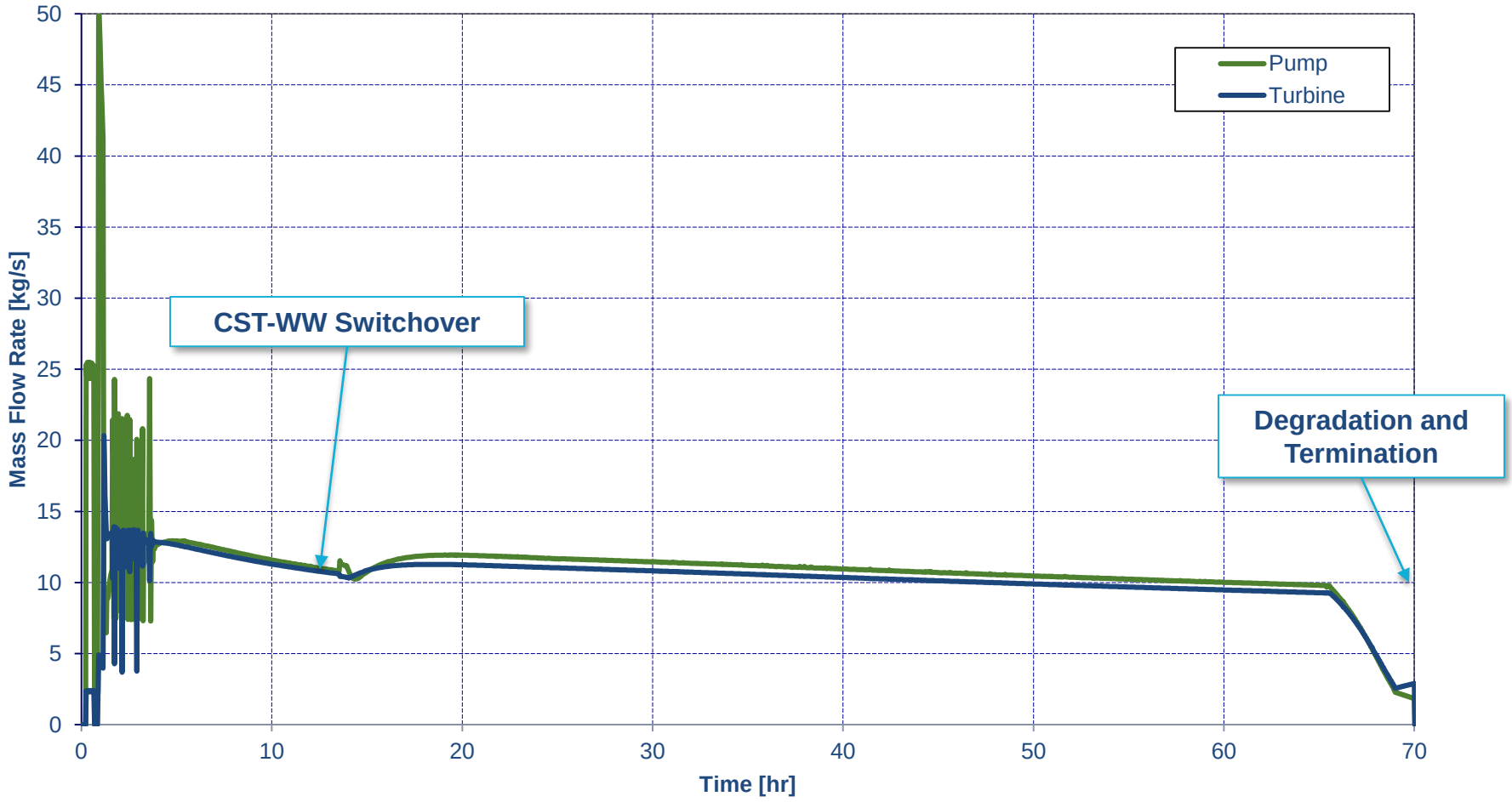


1F2 Water Injection

- Rate
  - Modelled as a constant rate for a given day
  - Per-day rate taken as 30% of daily integral total provided by TEPCO
  - As high as 6.5[kg/s] on Day 4; asymptotes to 0.60[kg/s] in late-time
- Assumed timing
  - Start 75.7[hr] after SCRAM (half an hour after manual blowdown)
  - Loss of injection at 76.5[hr] for 34 [min] (from TEPCO)
  - Resumption and continuous injection at 77.1[hr]
- Pressure considerations
  - No injection allowed if RPV pressure above 1[MPa]
  - Full injection at or below 0.6[MPa]

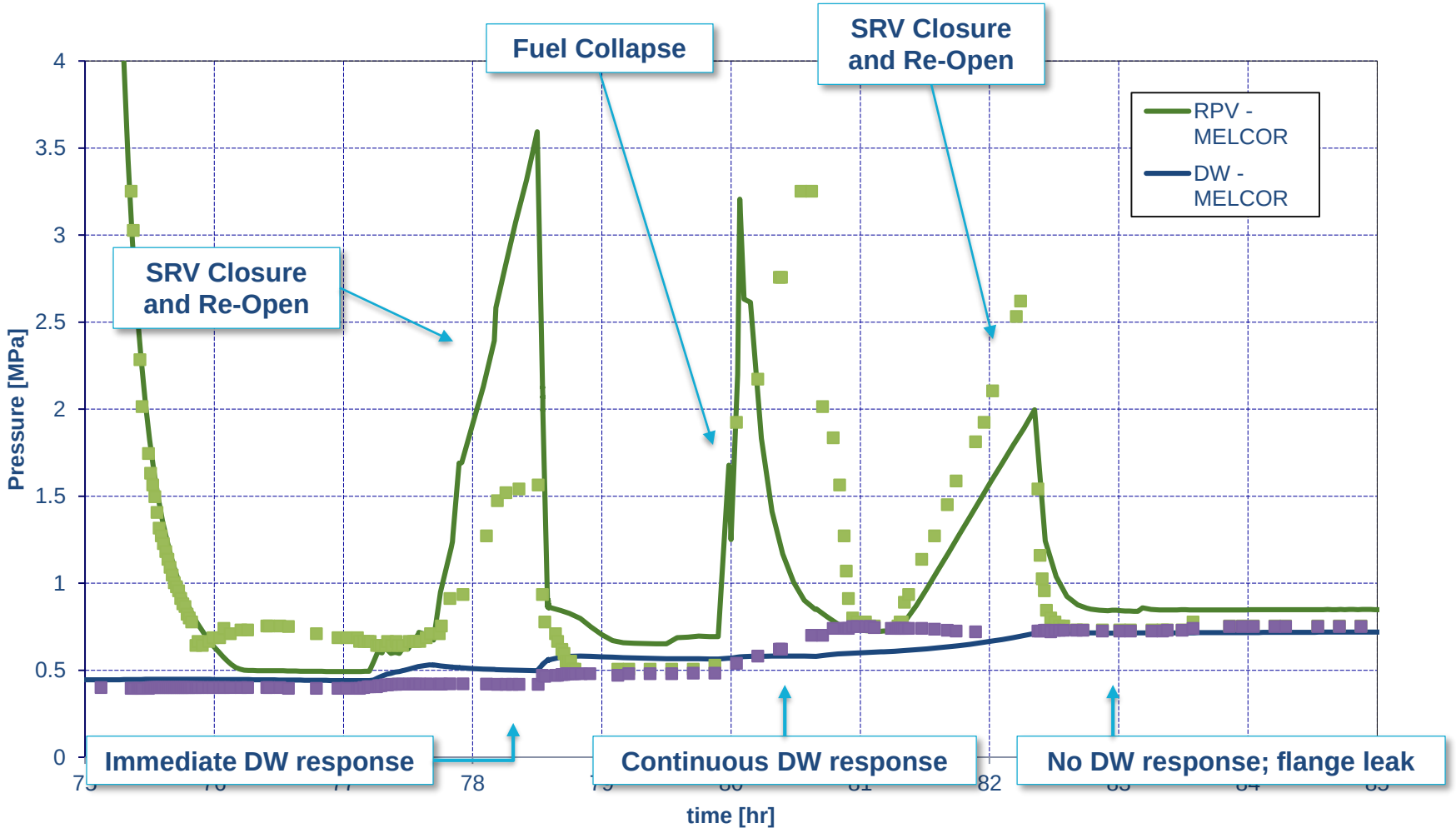
1F2 “Three Peaks” Data

- 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 over 40[min] with a rapid decrease and continuous DW pressure increase over the time
  - Assumed cause: Core collapse
    - Default MELCOR degradation agrees with a support plate failure in Ring 1 at 79.9[hr]
- 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
  - Blowdown SRV closes at 77.7[hr]
  - Blowdown SRV reopened at 78.5[hr]
- Second Peak
  - Collapse Rings 1-4 to meet the pressure spike magnitude and approximately match the pressurization rate for the Third Peak
  - Timings:
    - Ring 1: 79.90[hr]
    - Ring 2: 80.05[hr]
    - Ring 3: 80.10[hr]
    - Ring 4: 80.15[hr]
- Third Peak
  - Blowdown SRV closes at 81.3[hr]
  - Blowdown SRV reopened at 82.4[hr]

1F2 “Three Peaks” Results



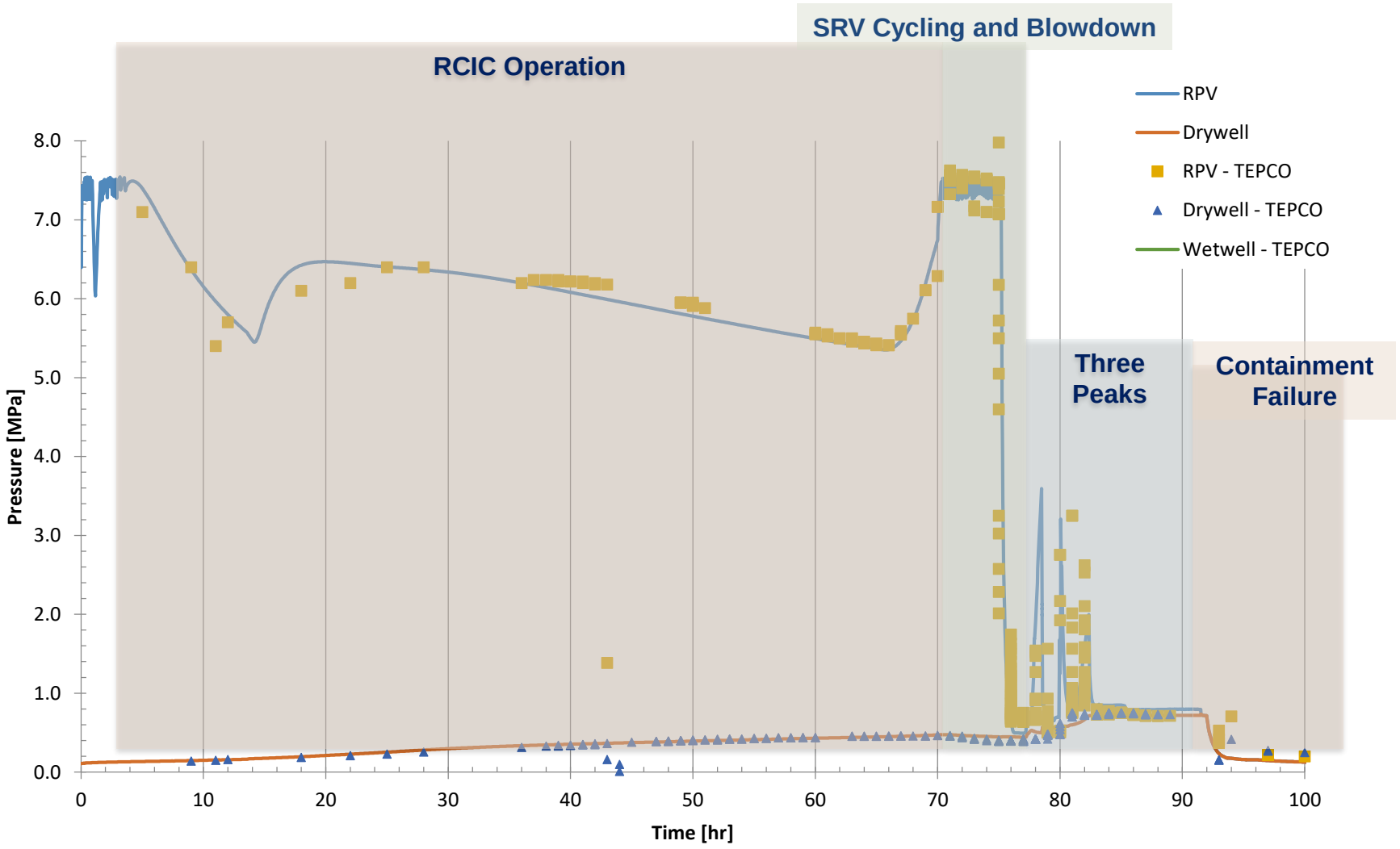
Lower Head Failure

- A side penetration was modelled at a user-specified time
  - In Ring 5, Axial Level 1 at 91.5[hr]
  - Insufficient molten material was unable to be formed for mass relocation through the penetration
- Extra held-up mass and decay heat, which actually relocated ex-vessel in reality, led to a lower head yield and complete debris relocation to the cavity at 92.4[hr]

- Efforts to improve the lower head modelling
  - Force retention of debris with water coverage: Release fractions are about half of the above, full-relocation model.
  - Various paths being explored to improve penetration modelling and perform partial relocation.

PRESSURE TRENDS

System Pressures



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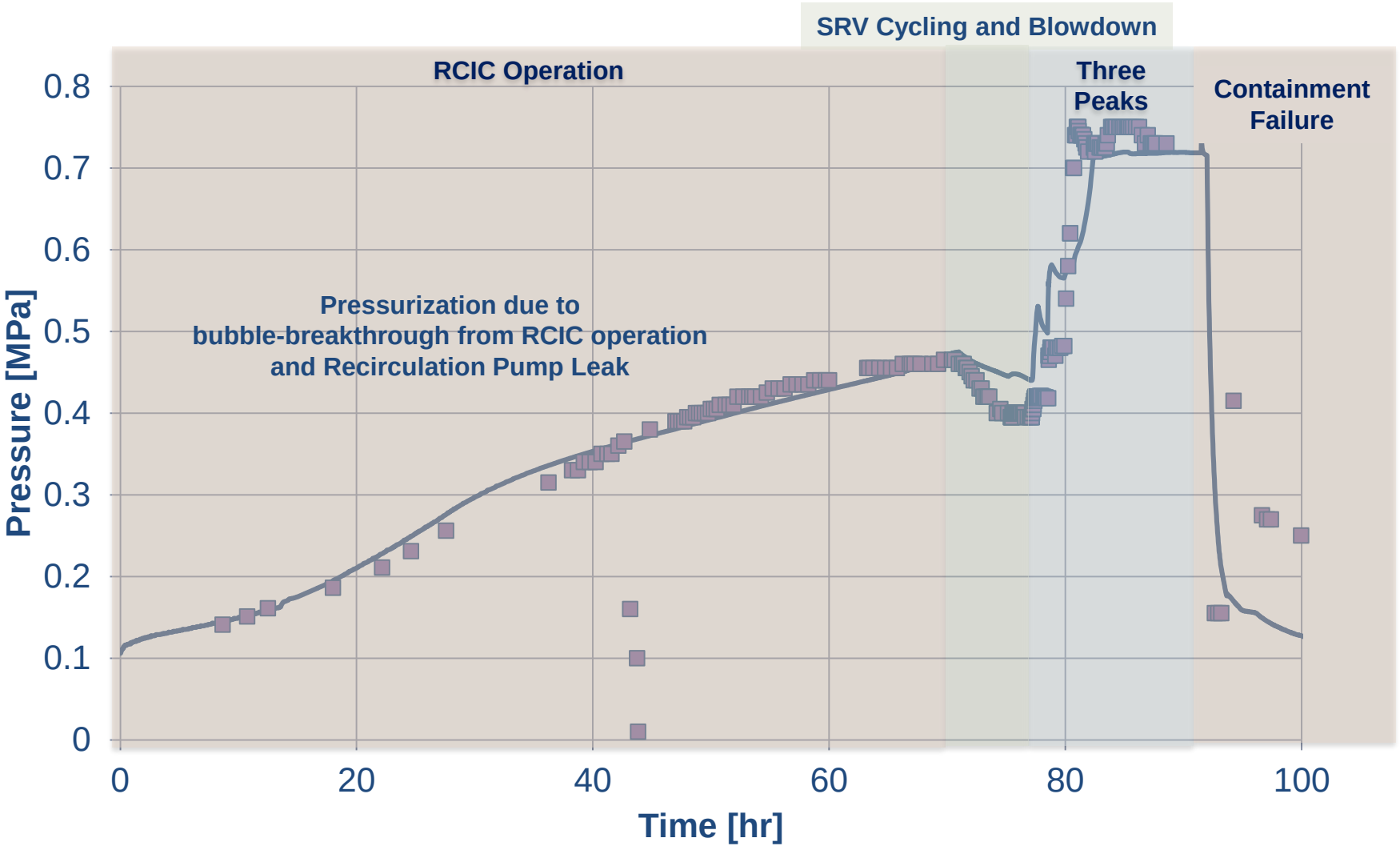

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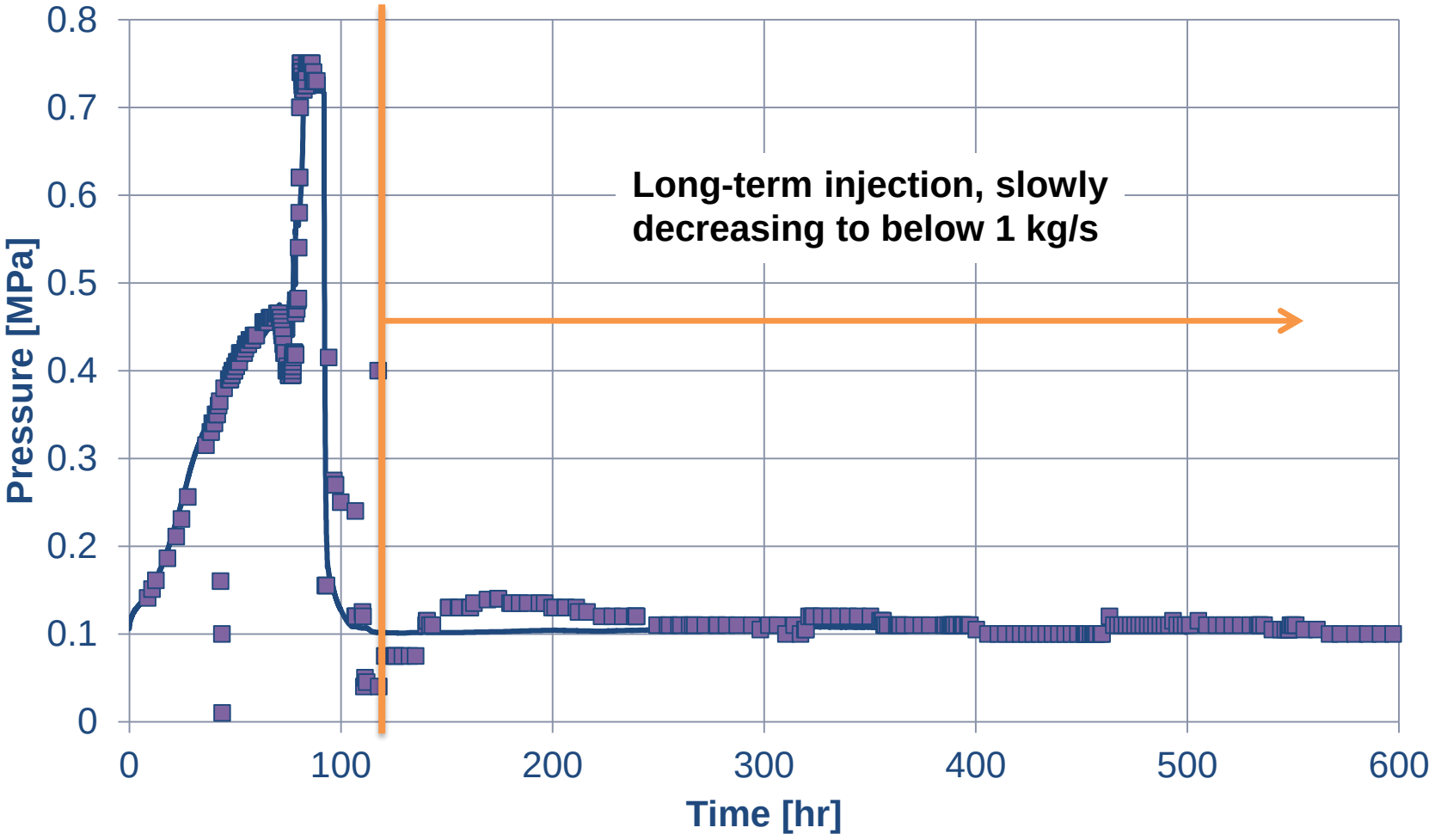
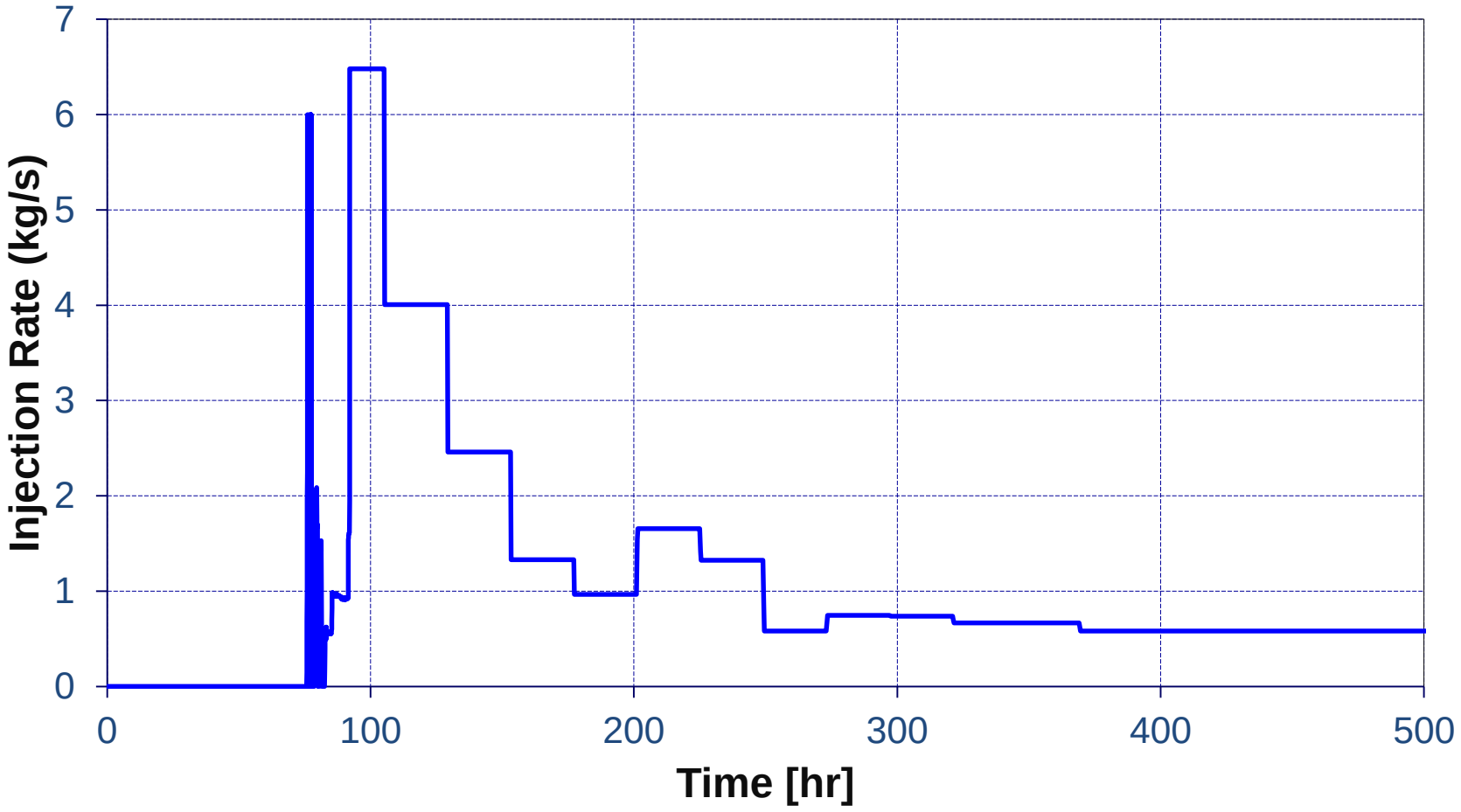


INJECTION AND RPV WATER LEVEL

Alternative Water Injection



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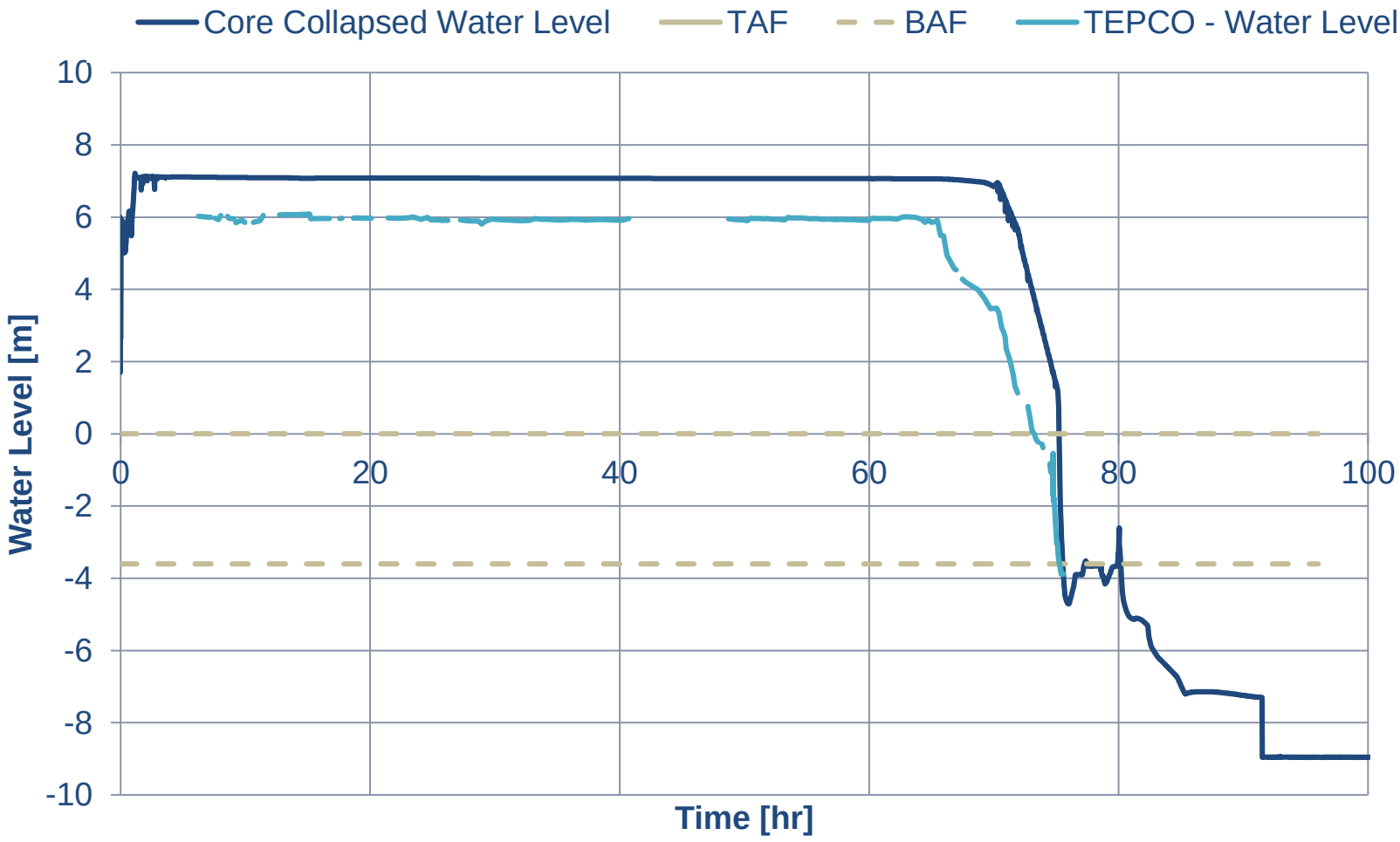

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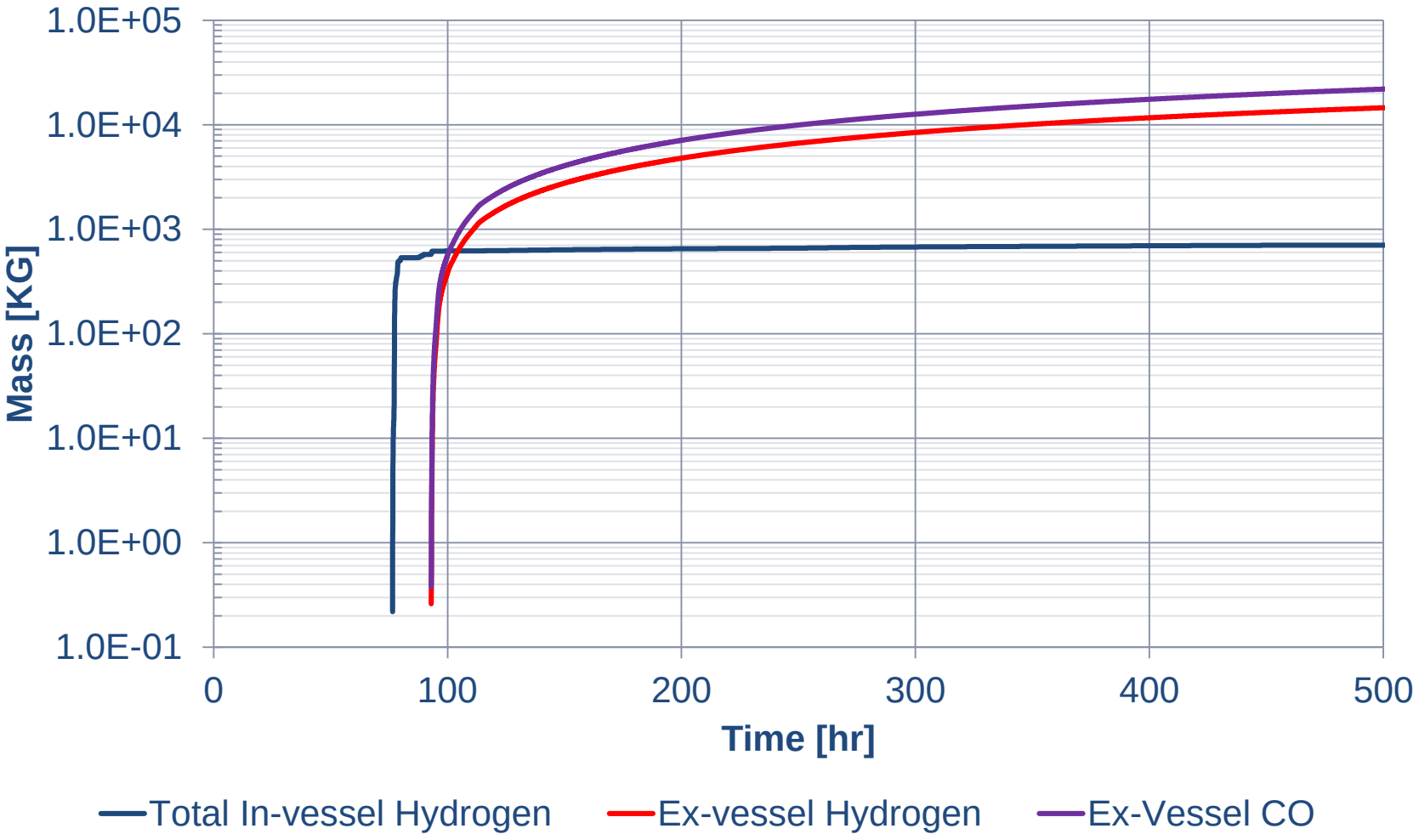

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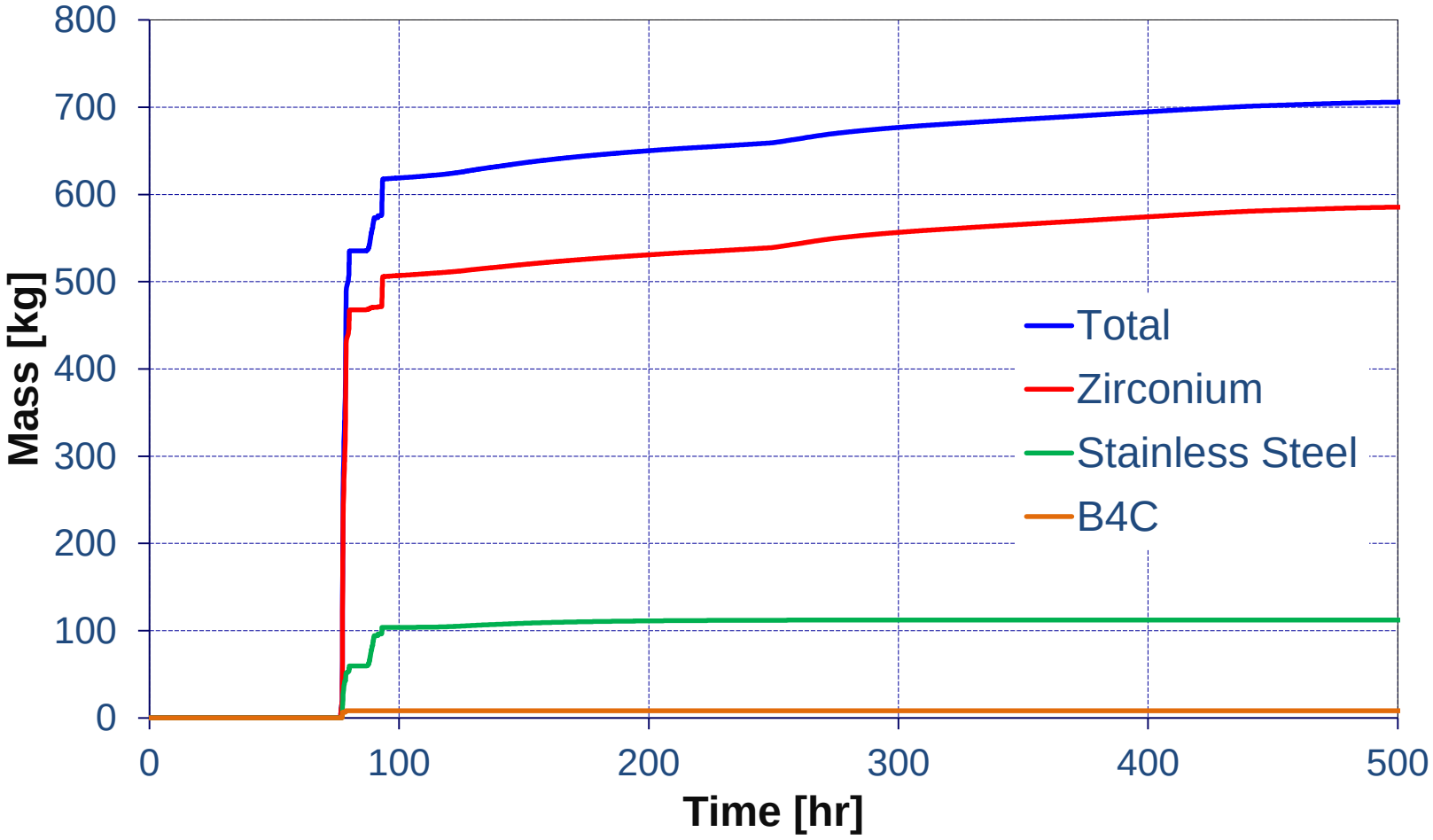

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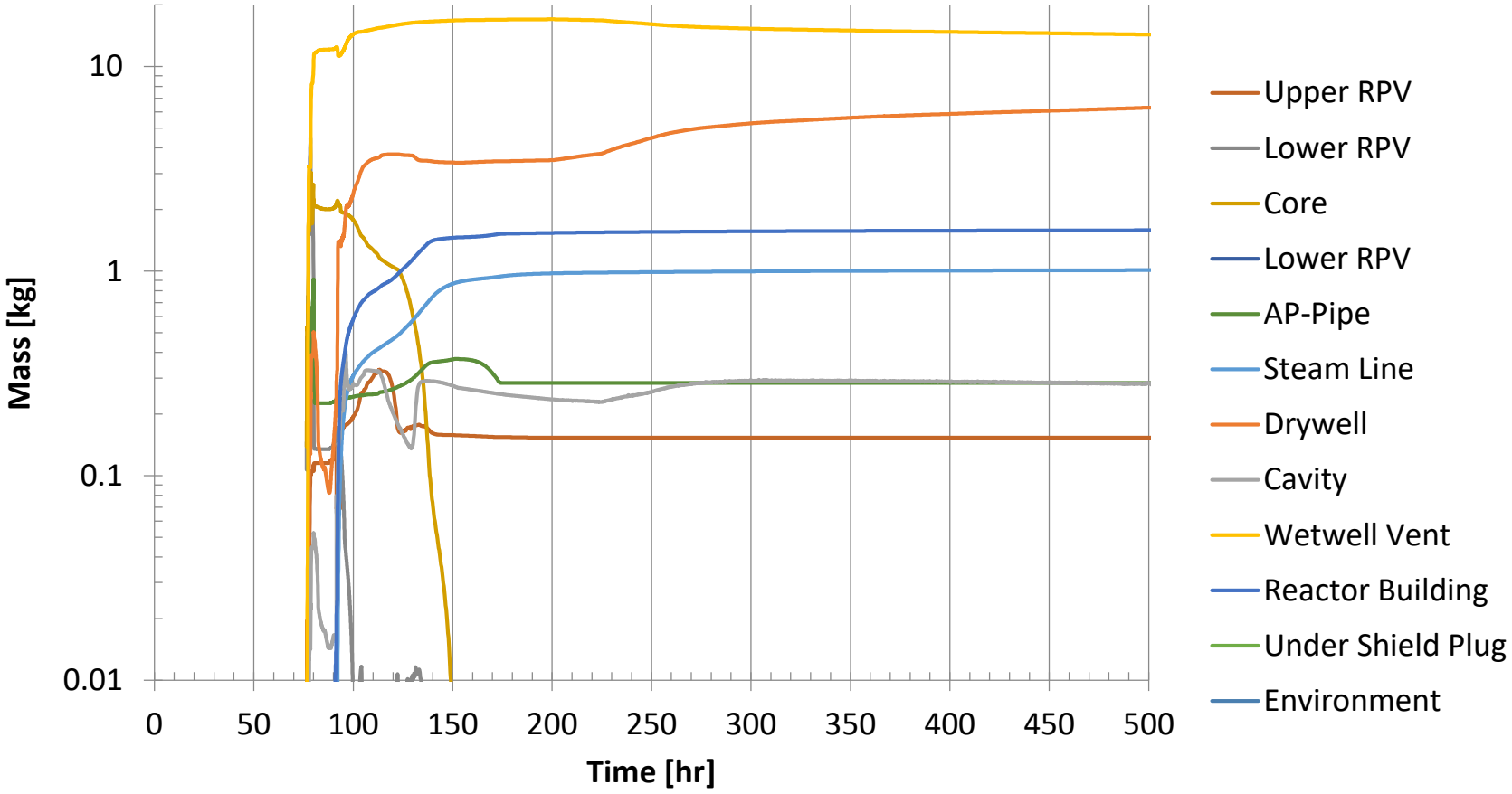

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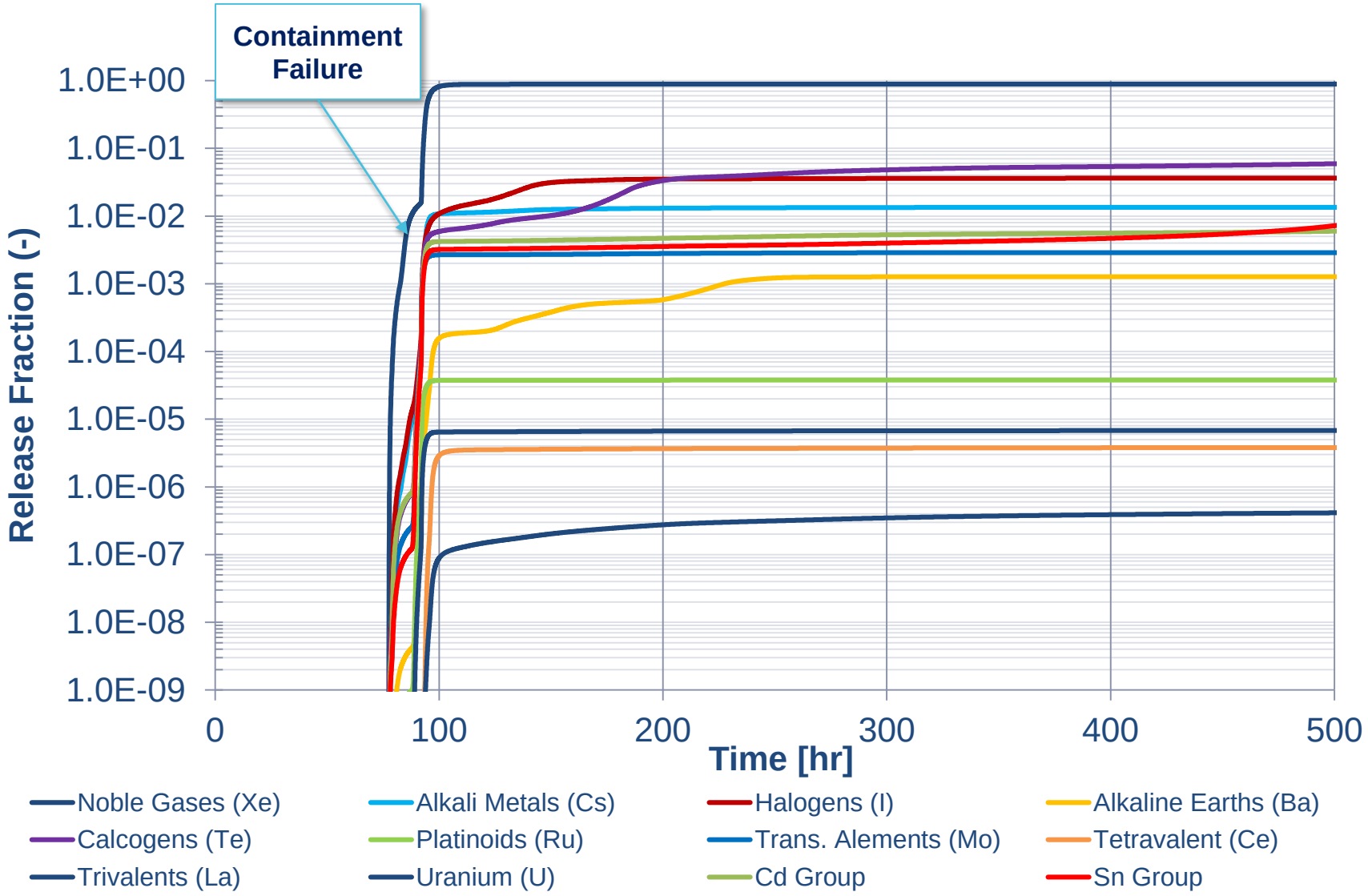

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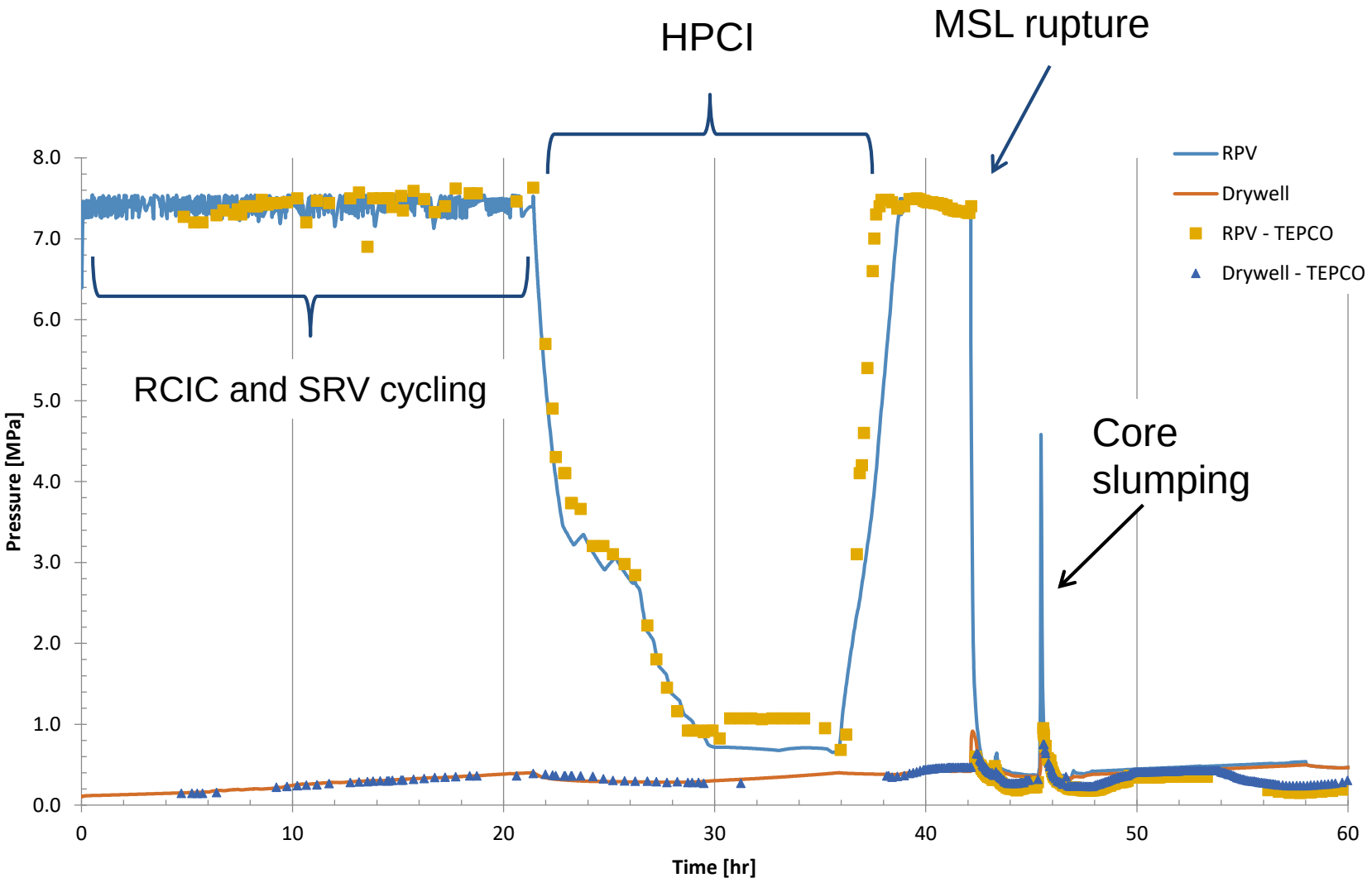
Progress in Modeling 1F3

- Forensic approach
  - Marching forward from 125 hours by varying injection rates and containment leakage to follow data and better predict the source term
- Model developments
  - Examined melt ablation and liner melt through
- Long term injection
  - Minimal injection after 180 hours
  - Failure of core rings late in time
  - Significant late stainless steel hydrogen generation

PRESSURE TRENDS

System Pressures



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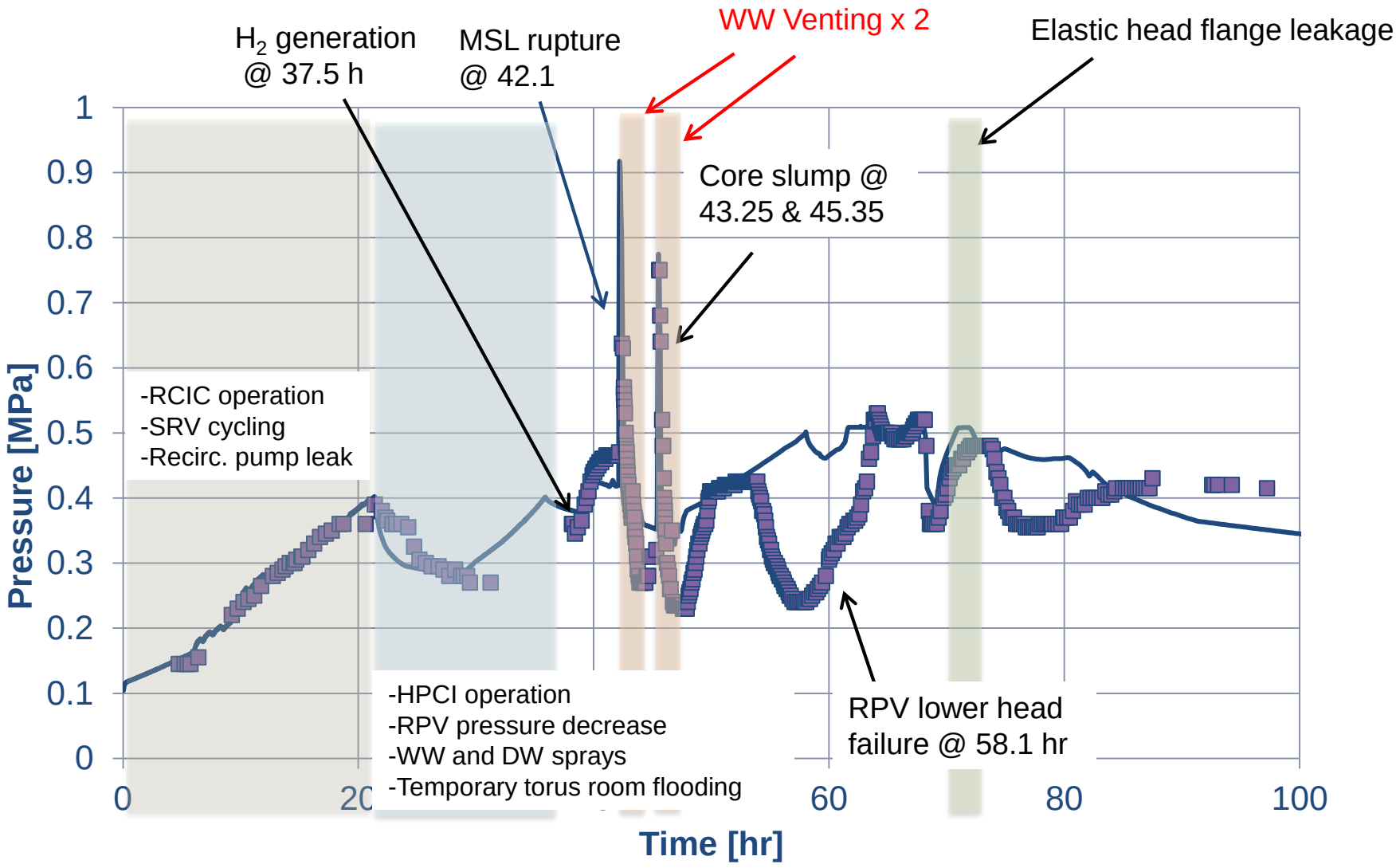
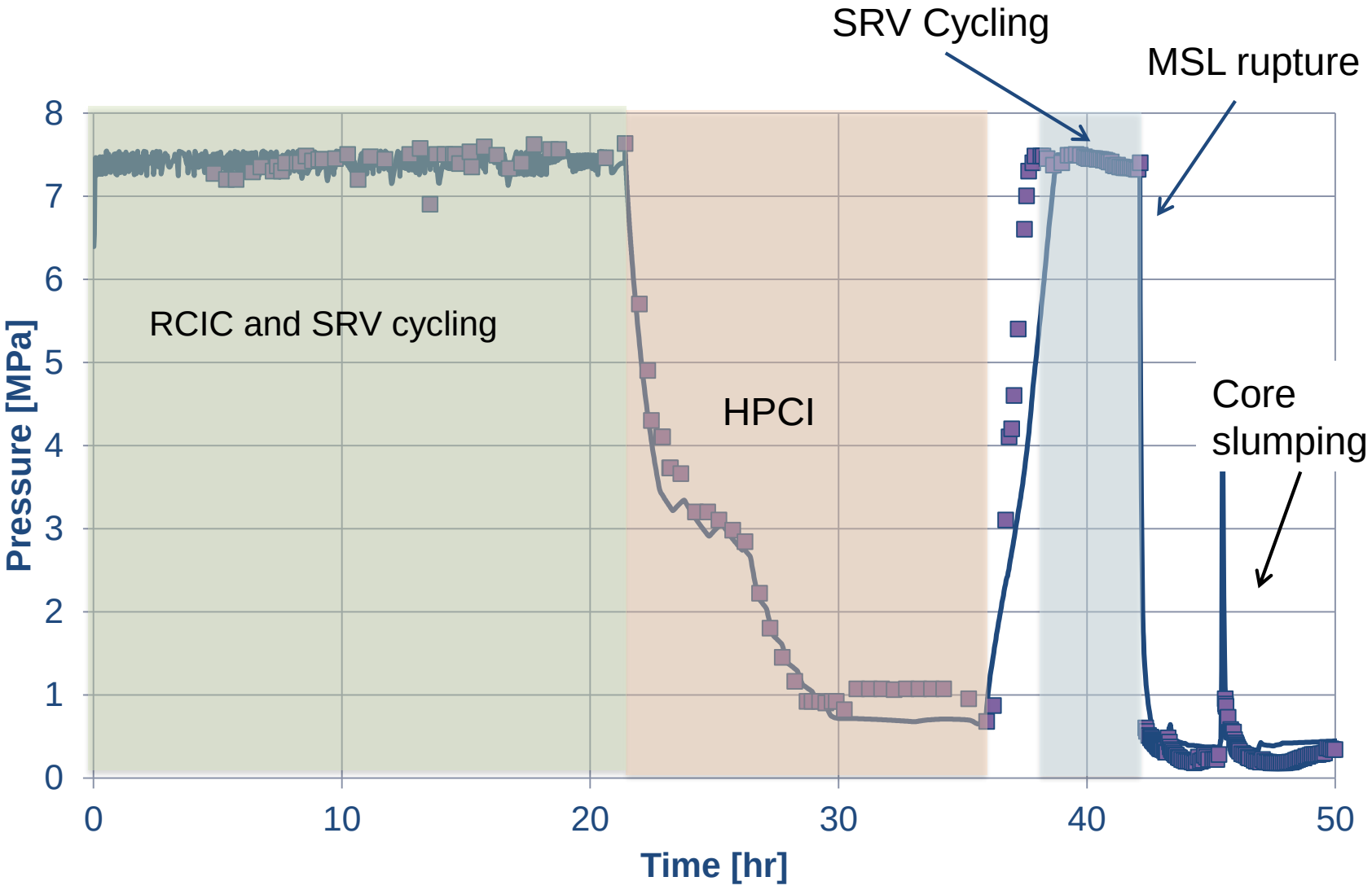


RPV Pressure



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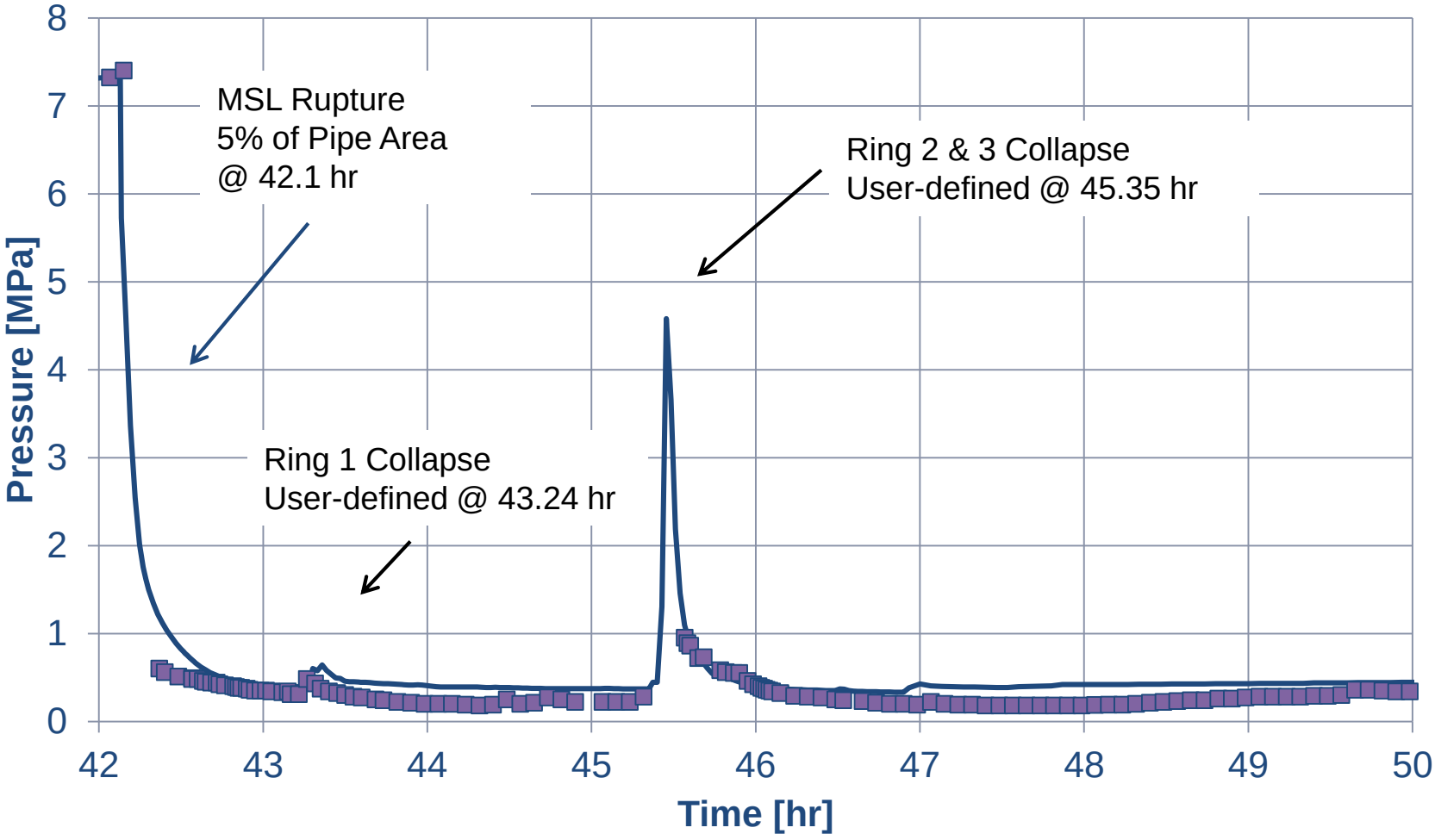

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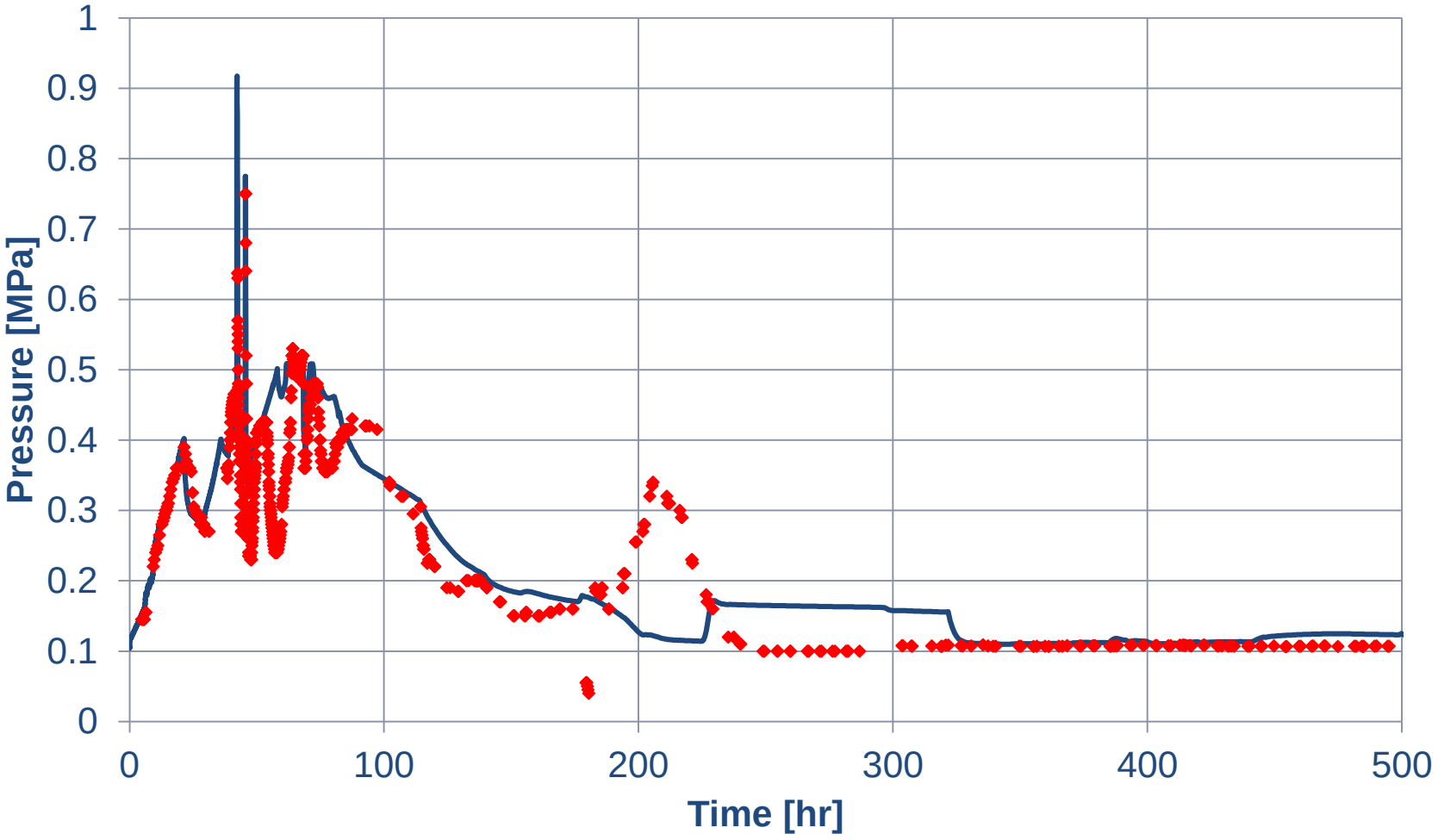

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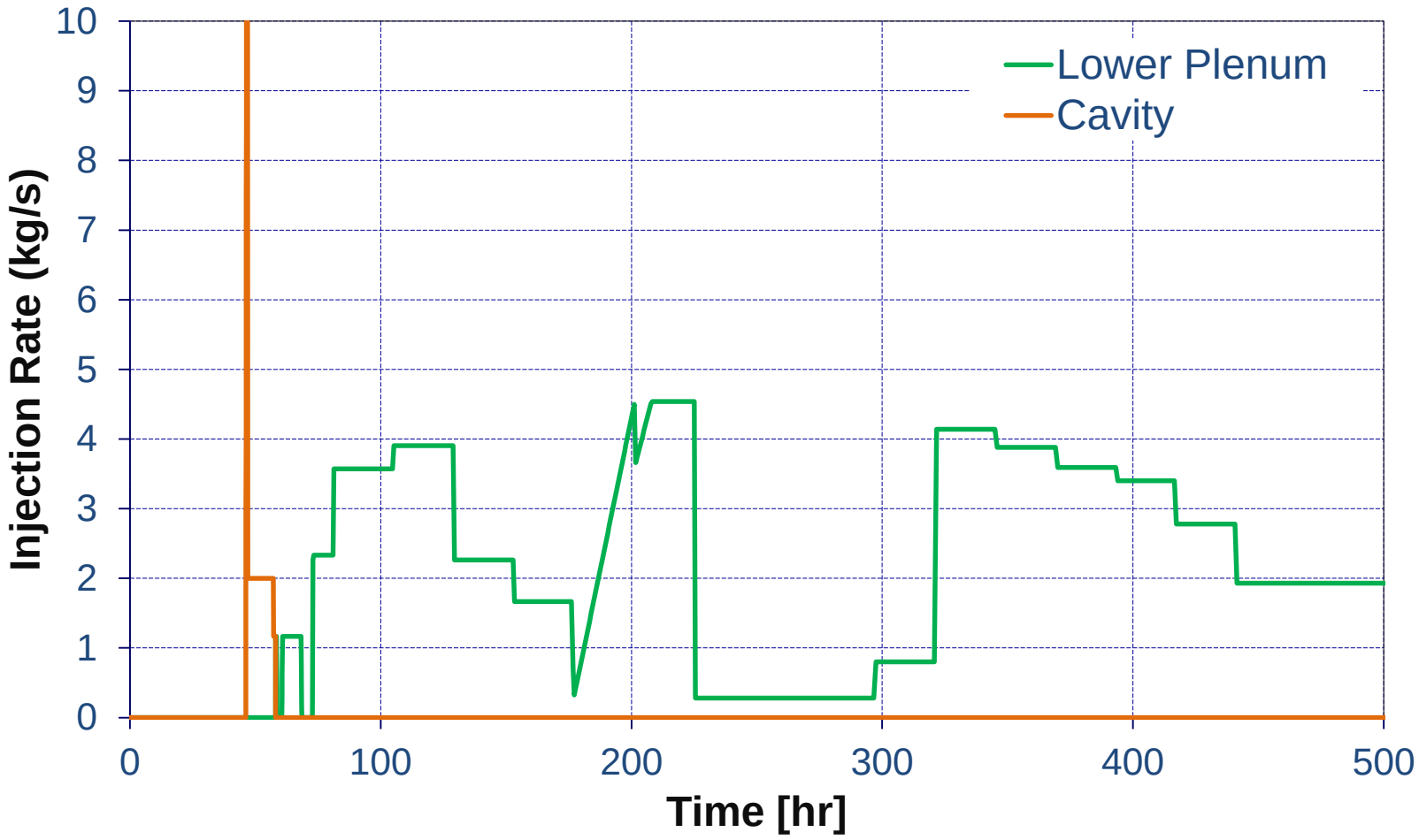

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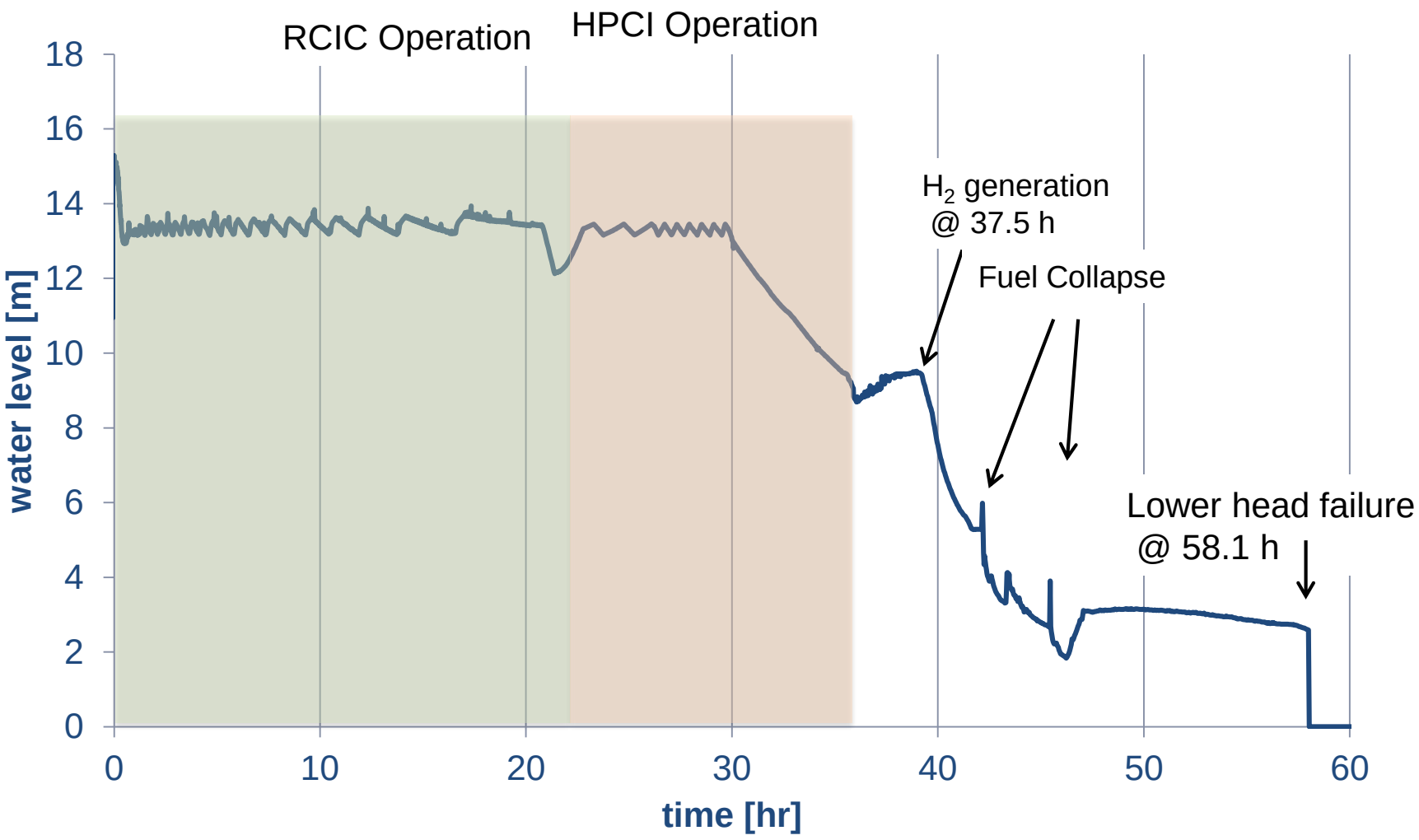

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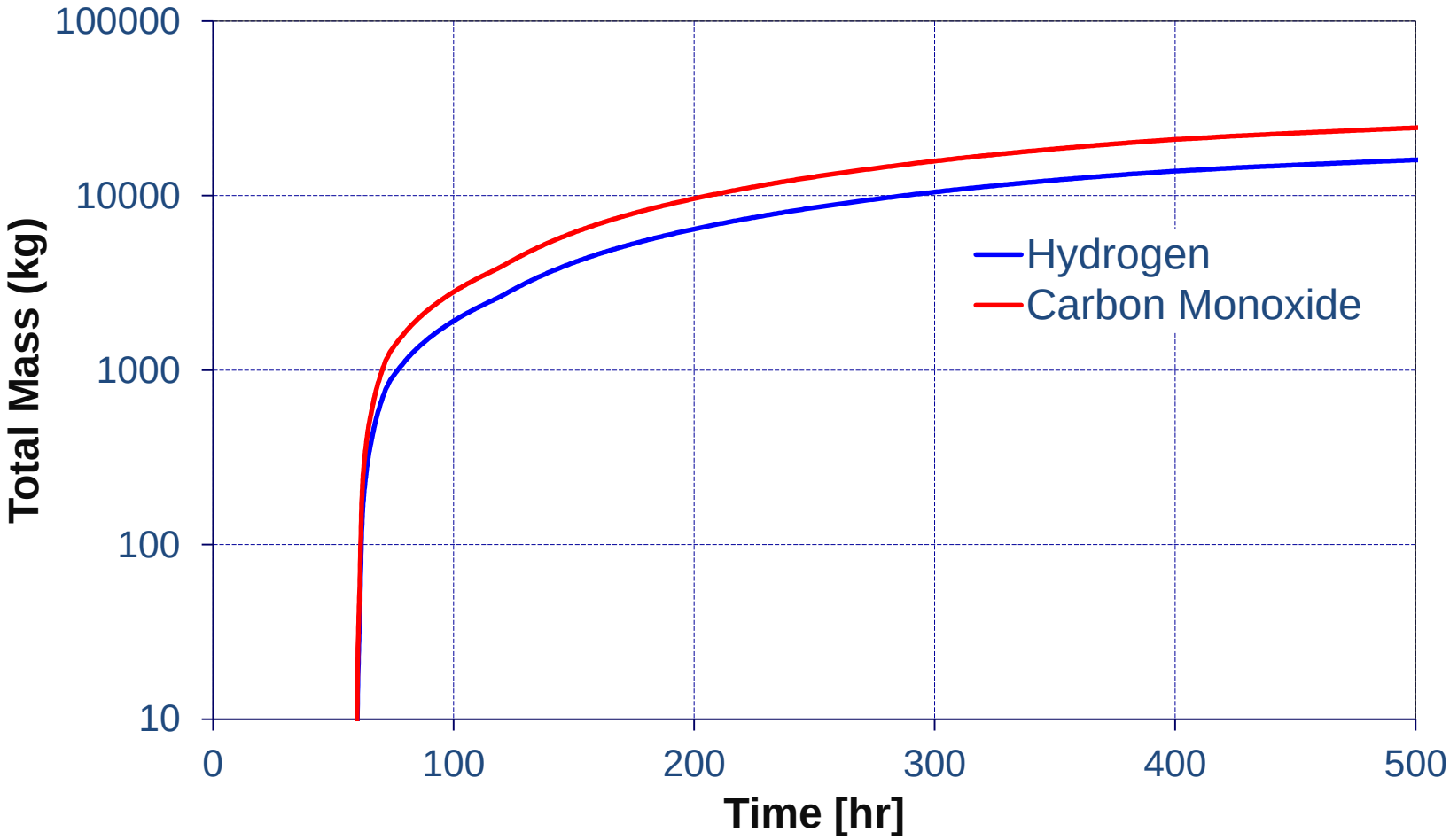

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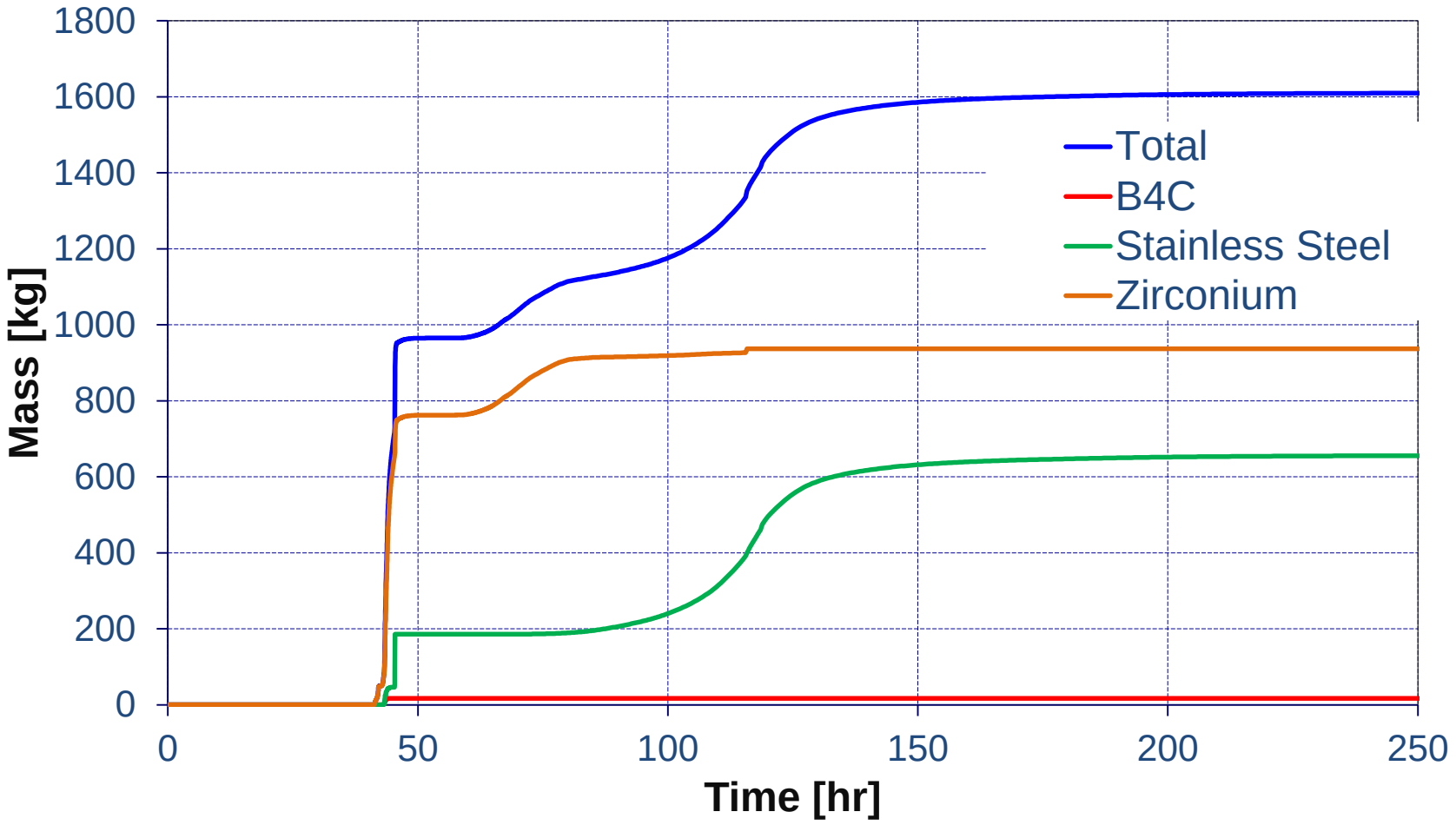

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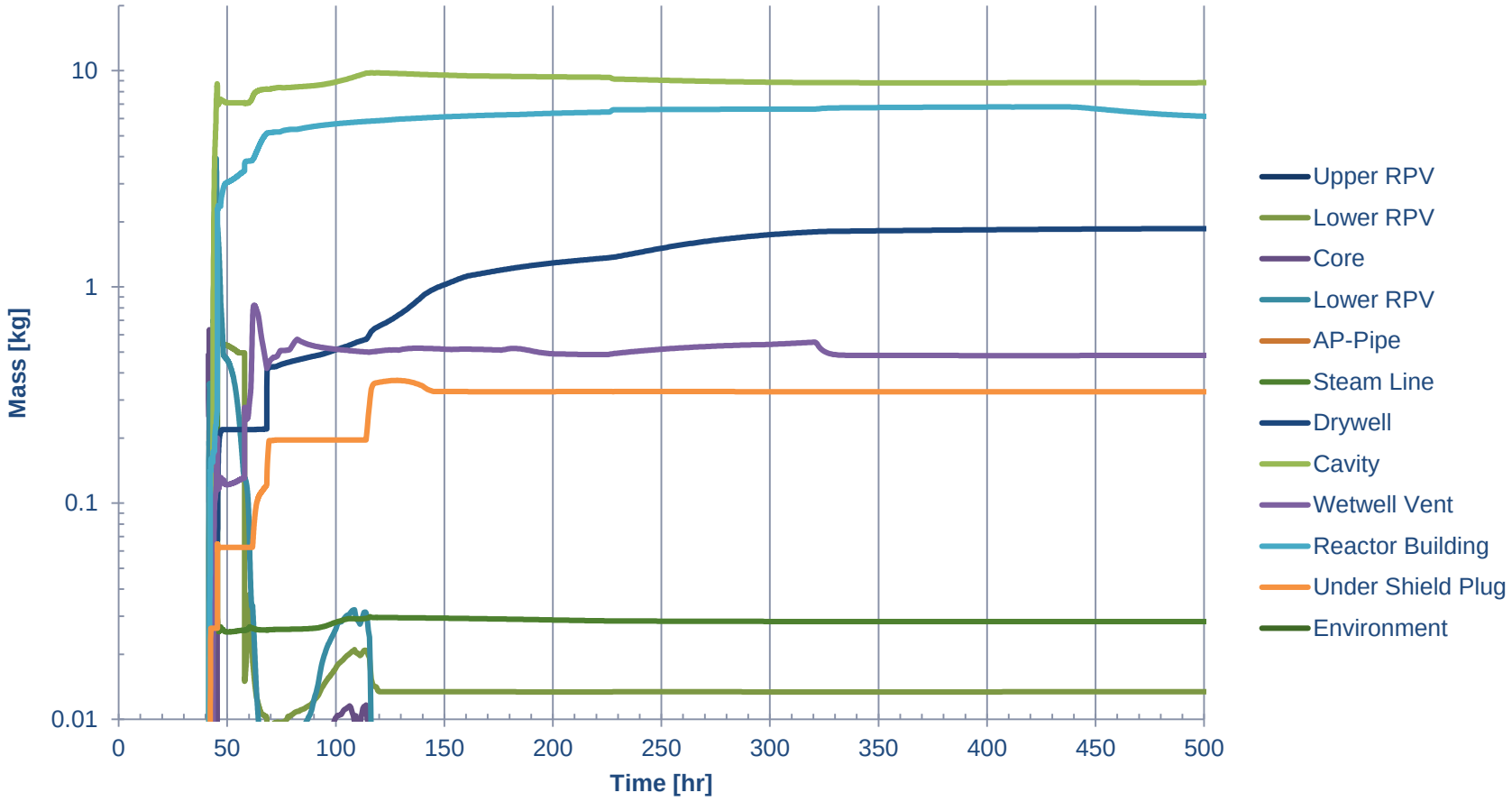

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