Peach Bottom – Timing and Criteria for RCS Failure

- **Background:**
  - Multiple natural mechanisms for early RCS failure are represented in the Peach Bottom MELCOR model
    - Stochastic failure of a cycling SRV to re-close
    - Thermal seizure of an SRV in the open position
    - Steam line or nozzle creep rupture
  - SOARCA baseline calculations – SRV thermal failure was the 'lead' or first mechanism to occur
  - Peer reviewers seemed to generally agree with our approach, but questioned the <u>sensitivity</u> of the results to this modeling

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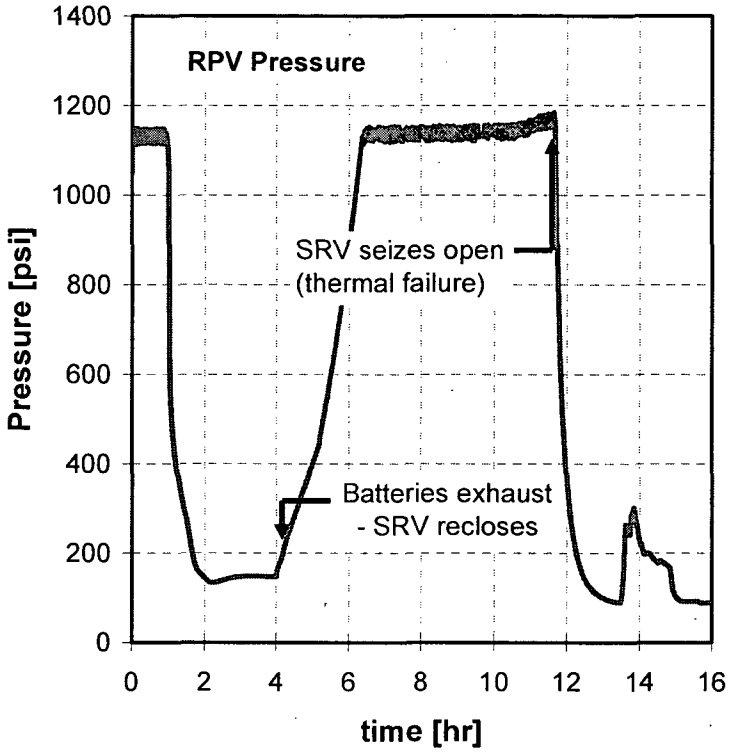
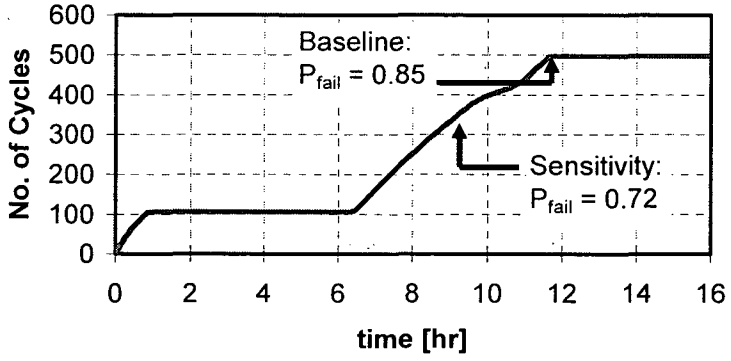
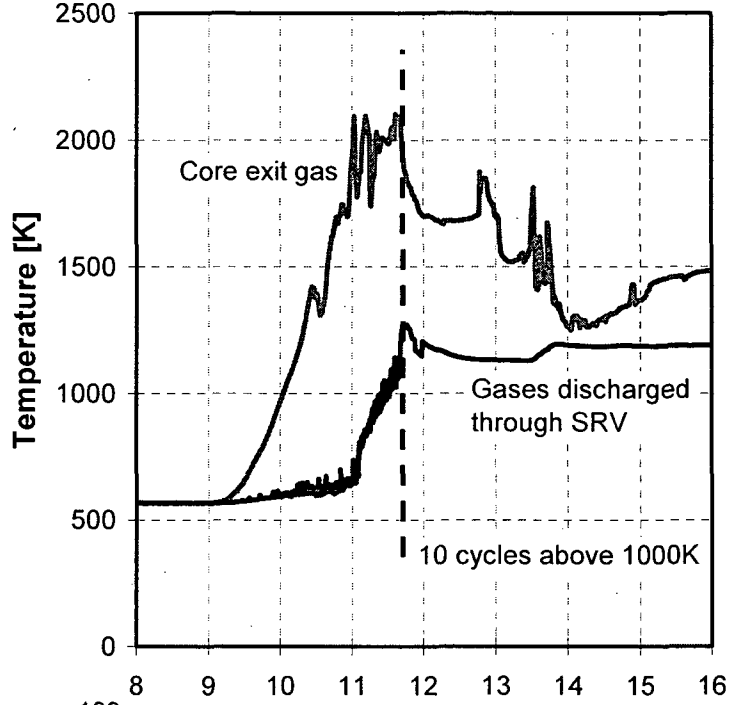
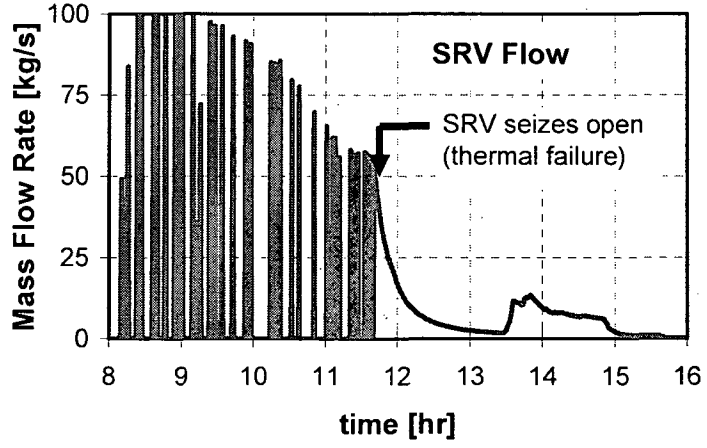
Stochastic vs Thermal SRV Failure in Baseline LTSBO





Stochastic

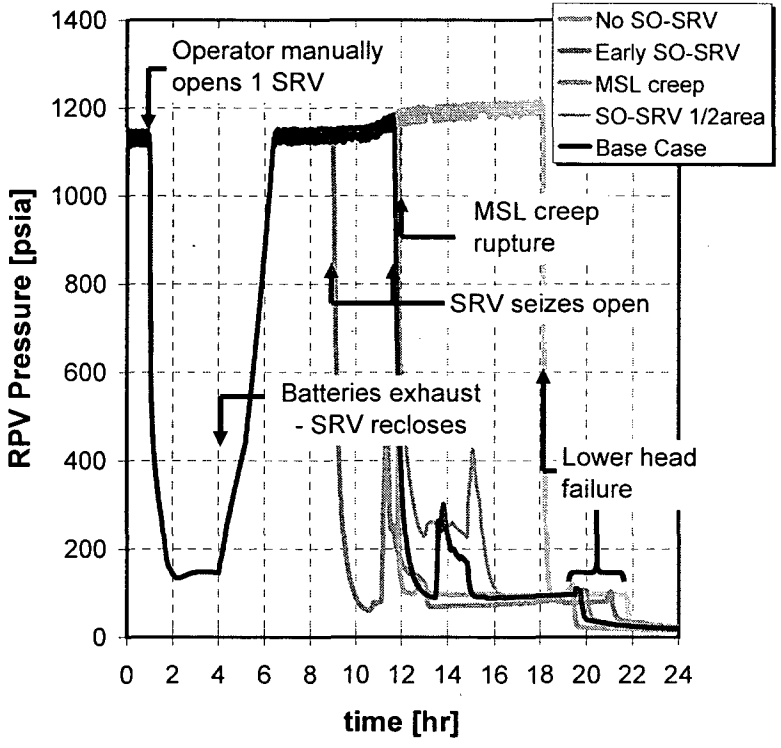


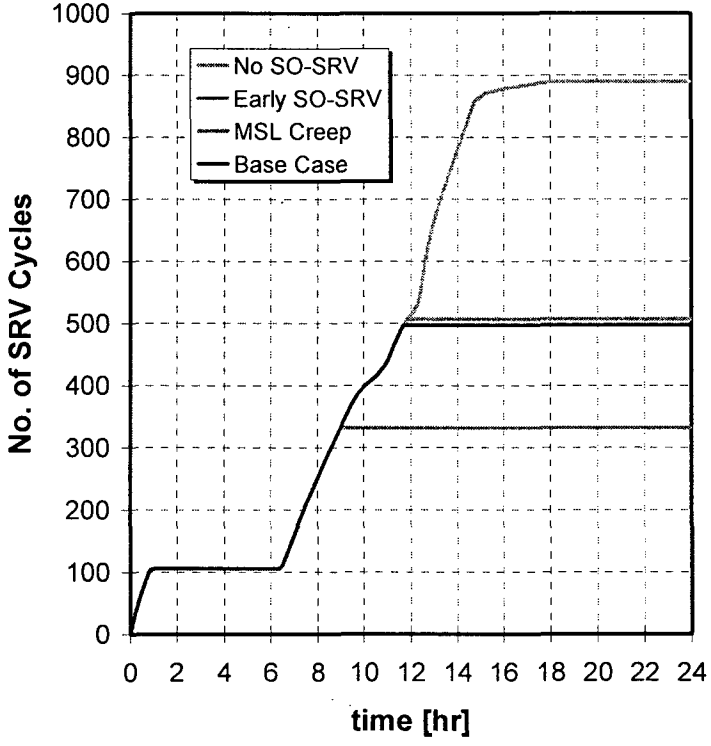


Thermal

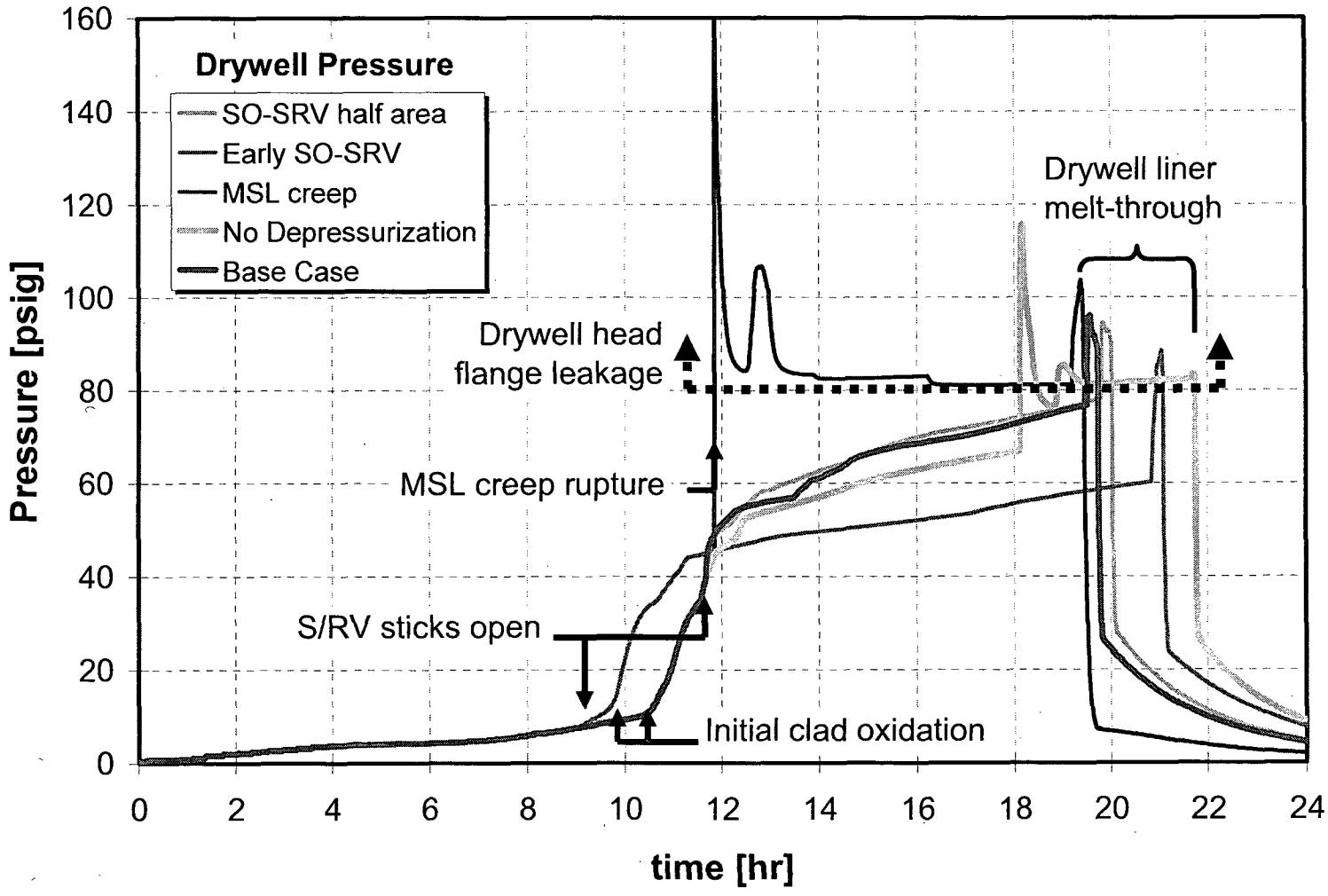
Sensitivity Calculations for Peer Review

- **Thermal seizure in half-open position.**
  - Work continues to explain long-term Cs release for this case
- **Earlier (stochastic) failure to reclose (level @ TAF)**
  - Failure at ~70% confidence level
- **No SRV failure to reclose, main steam line (MSL) creep rupture**
  - Represents lower likelihood case
- **No depressurization (ignores predicted SRV seizure or creep rupture)**
  - Not judged a credible case, but examined in response to peer review request

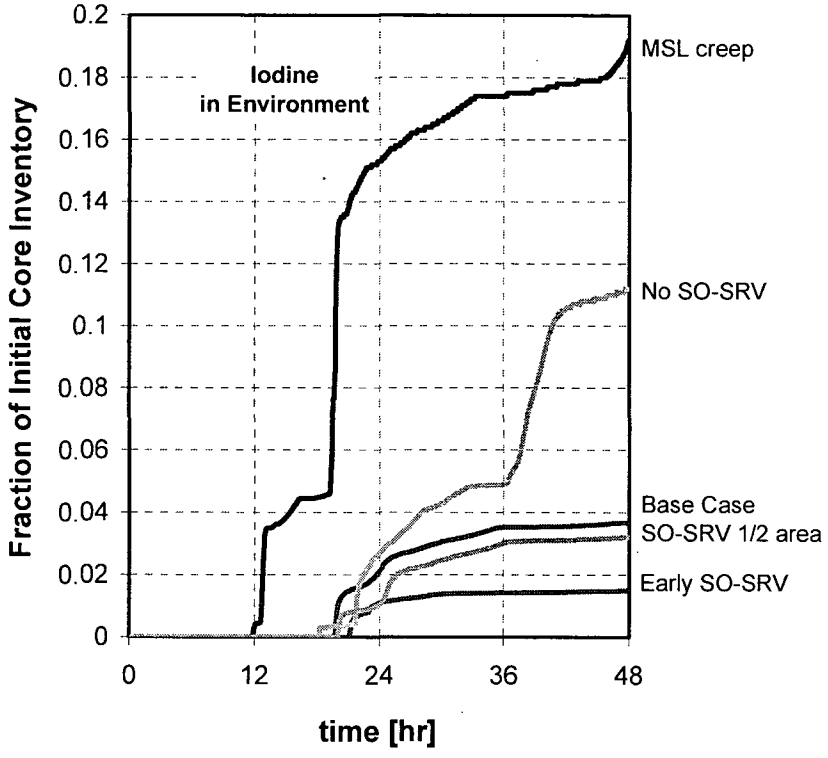


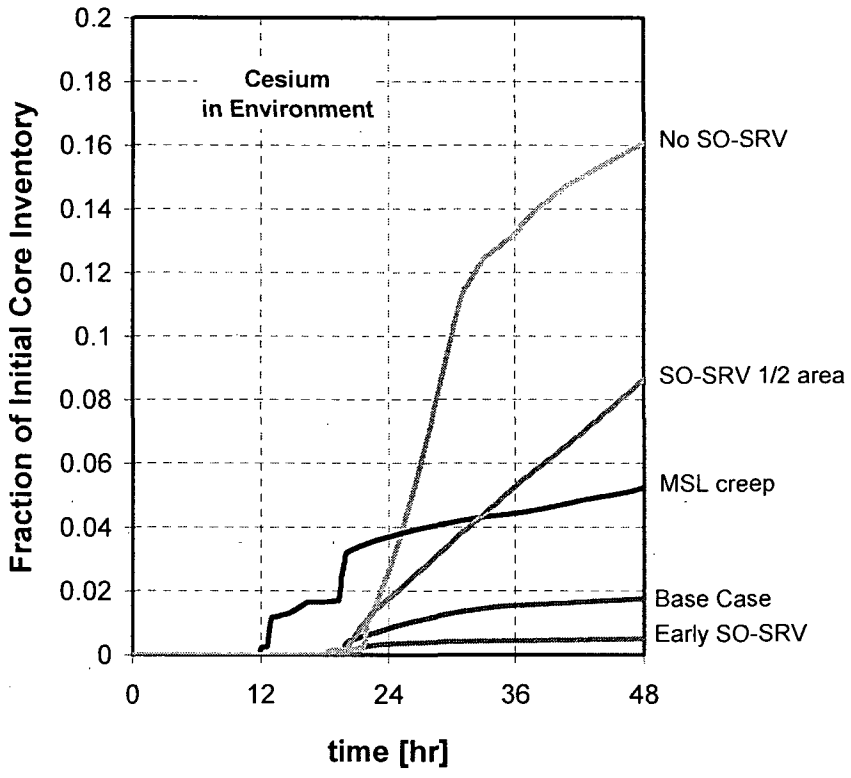


Impact of MSL Creep Rupture vs. SRV Seizure on Containment Pressure



Effects of SRV Failure Criteria on Environmental Source Term



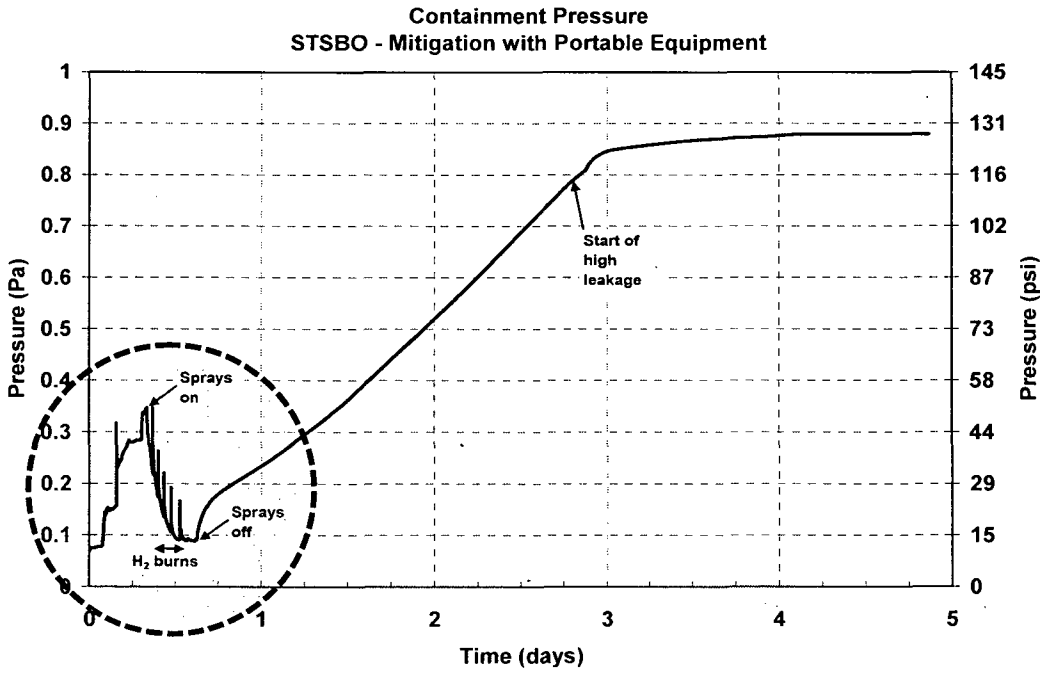


Status

- Additional information provided by peer reviewer at 3rd peer review meeting suggests that a purely stochastic SRV failure may be less likely
  - However, early SRV failure may be more likely due to combination of large number of lifts and modest heating above design
- Examination of material properties suggests SRV thermal failure modeling approach (fails after 10 lifts after reaching 1000K) is not best estimate
  - Valve may be weaker thermally than currently modeled
    - Examination of valve material properties indicates dramatic decrease in spring constant with temperature well below 1000K
  - Considering side calculations (ABACUS) using MELCOR thermal hydraulic predictions to develop more realistic estimate of time of SRV thermal failure, and feed that back into MELCOR

Surry – Uncertainties in Hydrogen Combustion in the Mitigated STSBO

- Long-standing issue (SAMGs) – containment spray recovery following core damage and potentially high hydrogen concentrations
  - SOARCA mitigated STSBO sequence assumes emergency containment spray established after 8 hrs
    - Large seismic event slows mitigation efforts
  - Uncertainties in the timing and severity of the hydrogen combustion

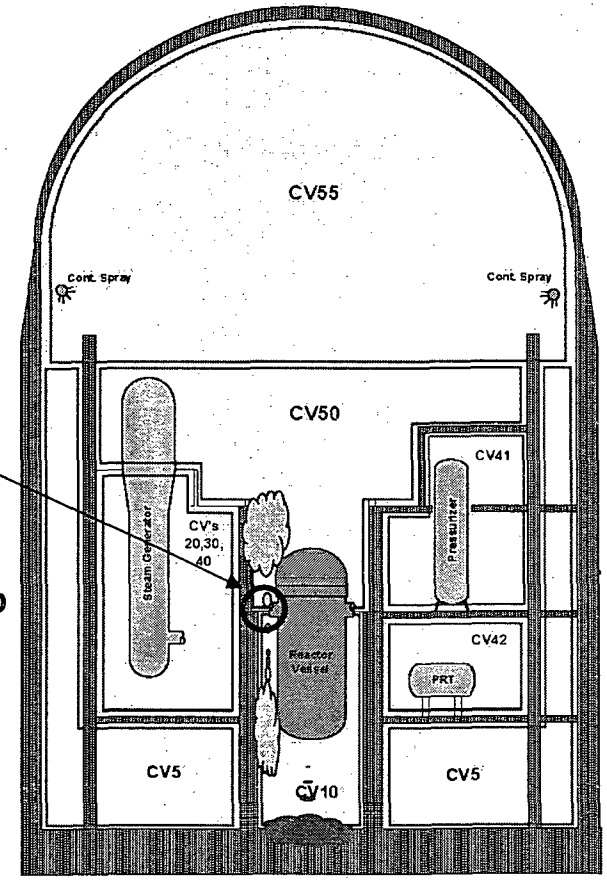


Investigating Uncertainties in Hydrogen Combustion

- Element of investigation
  - Assessed potential and consequences of high temperature auto or jet ignition at hot leg rupture and vessel failure
  - Performed sensitivity studies using MELCOR to investigate the consequences of delayed combustion
  - Hand calculations
    - Maximum deflagration pressure (AICC)
    - Detonation pressure (CJ)

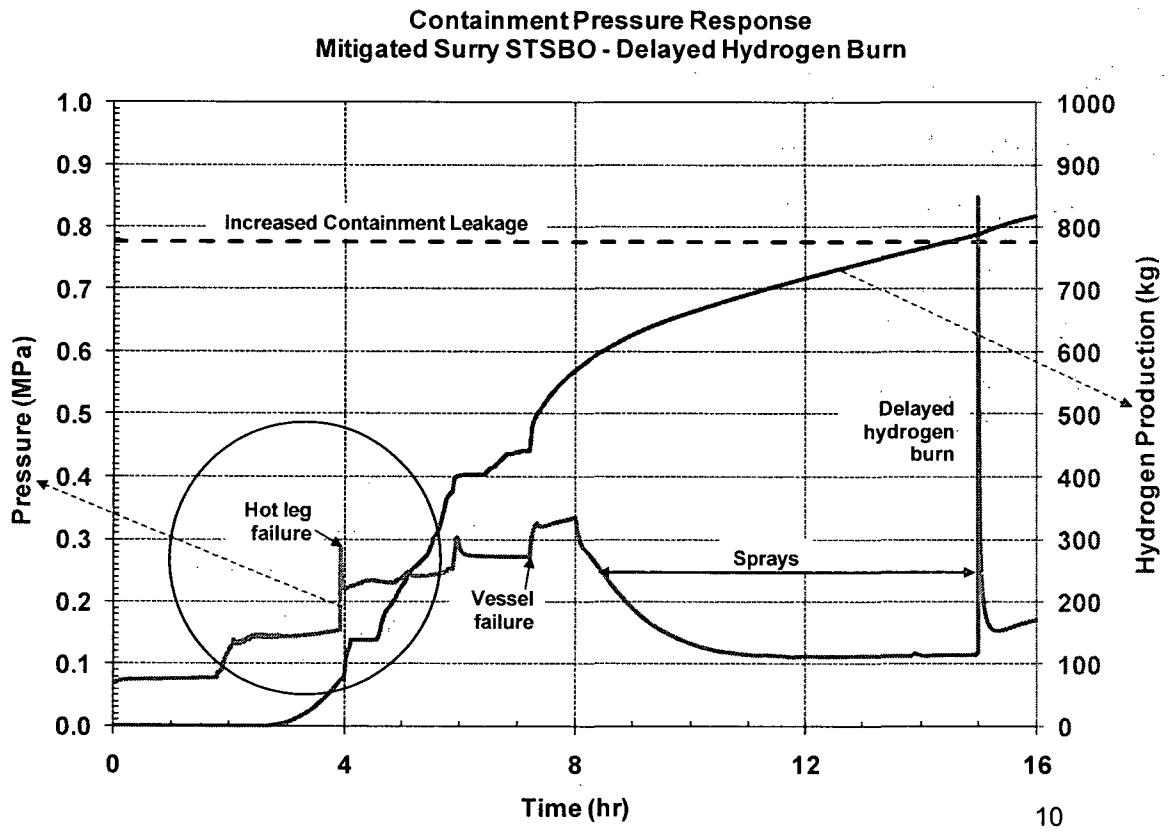
Analysis of Auto and Jet Ignition

- Two time frames examined
  - Hot leg creep rupture (high temperature, hydrogen rich gas jet)
  - Vessel failure (high temperature core debris)
- Hot leg creep rupture findings
  - Jet combustion is likely with minor pressurization
  - High temperature jet at ~1300 K
    - $\chi_{h2,\ jet} \geq 0.20$, $\chi_{o2} \geq 0.10$, and $0.35 \leq \chi_{h2o} \leq 0.50$
    - Blowdown done in minutes
    - Containment is steam inerted after accumulators dump ($\chi_{h2o} \geq 0.65$)



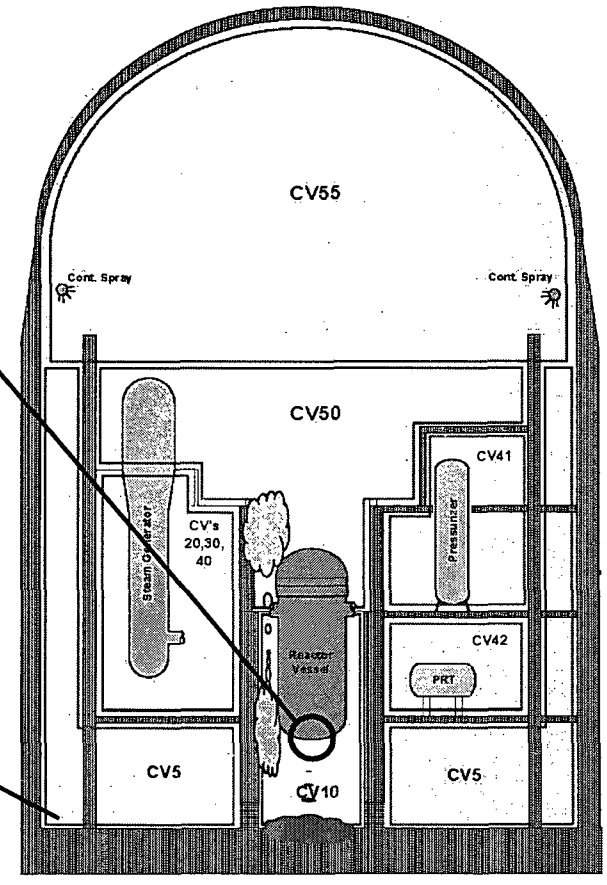
Analysis of Auto and Jet Ignition

- Hot leg creep rupture findings (cont)
  - Occurs after only 140 kg in-vessel hydrogen production
    - ~140 kg (~70 kg created during the blowdown)
  - Conclusions
    - "Small" burn likely
    - No risk of increased containment leakage
    - Burn would terminate when accumulator water cools the jet and steam inerts the containment



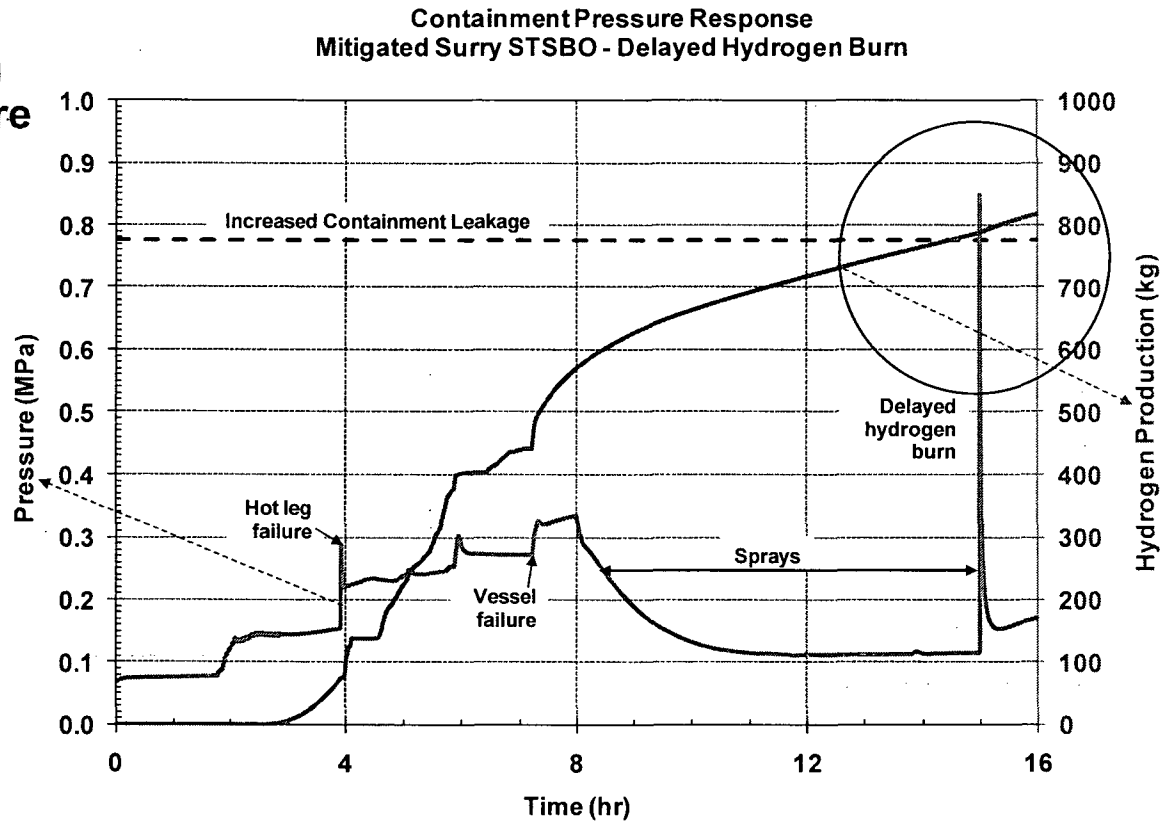
Analysis of Auto and Jet Ignition

- **Vessel failure findings**
  - High temperature ignition source
    - Debris is >1700 K
  - Auto combustion is unlikely
    - Locally and globally steam inerted (>65%)
    - Earlier spray operation would reduce steam concentration and make auto combustion more likely
  - Water covers the debris
    - Water sources
      - Seal leakage
      - PRT rupture
      - Condensation
    - Water boils to keep the cavity (and containment) highly steam inerted



Analysis of Delayed Ignition

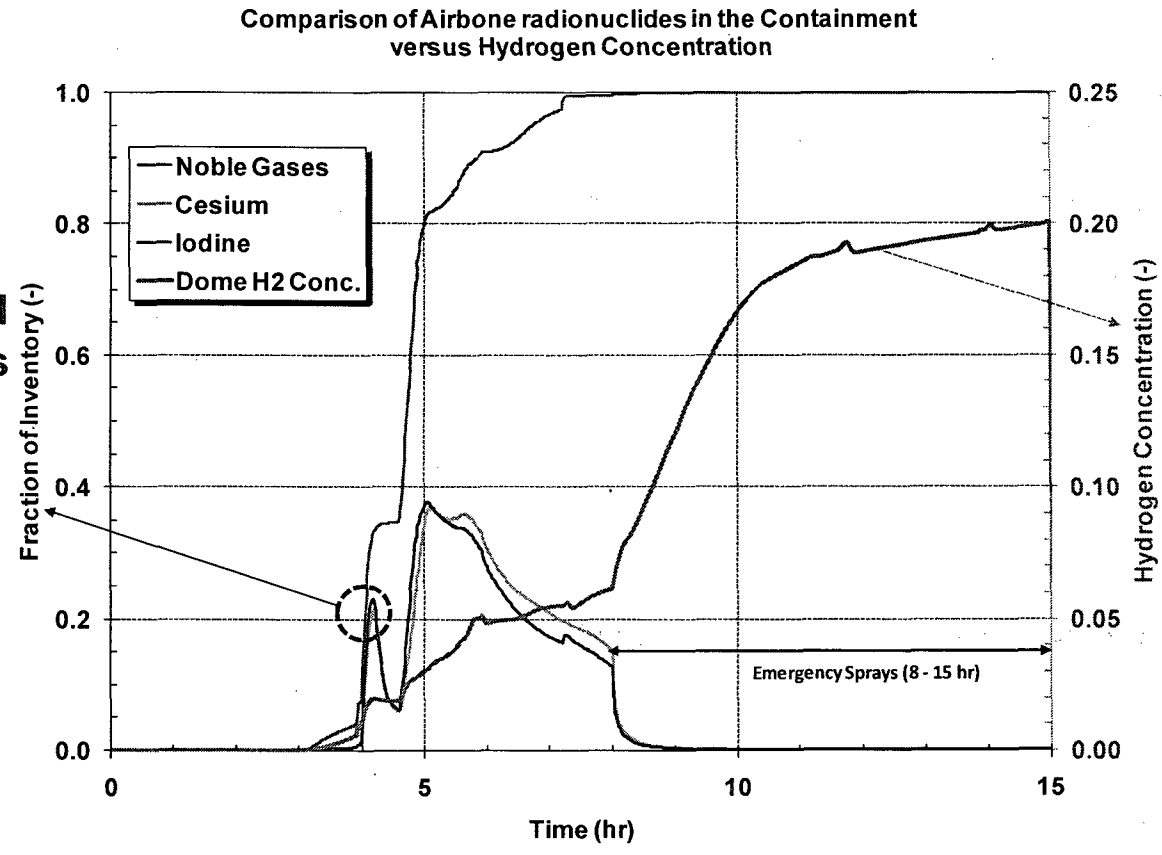
- MELCOR sensitivity study on delayed ignition
- Assumptions
  - Ignored beneficial ignition at hot leg and vessel failure
  - Delayed ignition until containment spray termination (15 hours)
  - Ignited all CVs simultaneously
    - $\chi_{H2} \sim 0.20$
    - $\chi_{CO} \sim 0.15$
- Results
  - Potential for increased containment leakage
    - Predicted failure area of _____ square inches
  - Burn is oxygen limited (incomplete combustion)



Analysis of Delayed Ignition

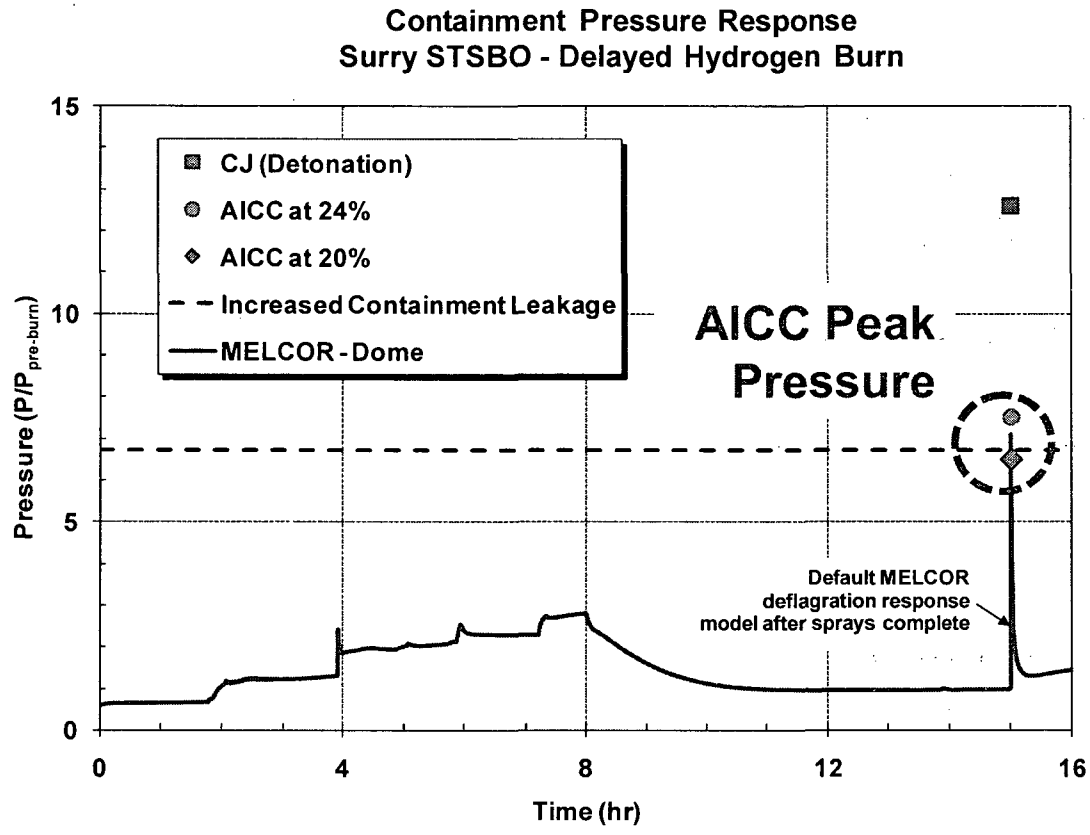
- **Results**
  - Airborne aerosol fission product concentration is negligible after ~1 hour
  - Additional fission product release due to increased containment leakage would consist only of noble gases
  - Base case judged as reasonable
    - Bounding cases do not increase the source term
    - Bounding cases require many conservative and some non-physical assumptions

Sprays create combustible conditions but also knockdown airborne fission products



Analysis of Bounding Combustion

- **Conservative methods**
  - Adiabatic, isochoric, complete combustion (AICC)
    - No heat transfer
    - $\chi_{H2} \sim 0.20$
    - $\chi_{CO} \sim 0.15$
- **Results**
  - Potential for increased containment leakage
    - Just H_2, AICC at 20%
    - CO + H_2, AICC at 24%
      - $\chi_{O2} \sim 0.12$
  - Conservatism
    - No heat transfer



Status

- Results indicate that containment not likely to be deinerted at the same time there are significant fission products airborne
  - Planning additional sensitivity calculations to confirm
  - Vary spray start time (6 hours, 12 hours)
  - Vary ignition time
- Current sensitivities for delayed ignition do not take credit for burn when hot leg ruptures
  - Plan to credit in any additional calculations
- Issue of whether operators would turn on sprays if suspected there was very high concentration of H_2 and CO
  - Highlight issue when requesting Surry perform fact check in April