# BWROG ECCS Suction Strainers Risk-Informed Solutions Committee – Phase III NRC Meeting

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# Project Phase III Overview

Tasks for the Phase III Risk-Informed Evaluation

- Calculate strainer failure probabilities using CASA-Grande
- Calculate LOCA Initiating Event Frequencies
- Evaluate LOCA Accident Sequence Logic
- Perform Thermal-Hydraulic Calculations
- Perform Human Reliability Analysis
- Quantify Results
- Document Phase III Evaluations

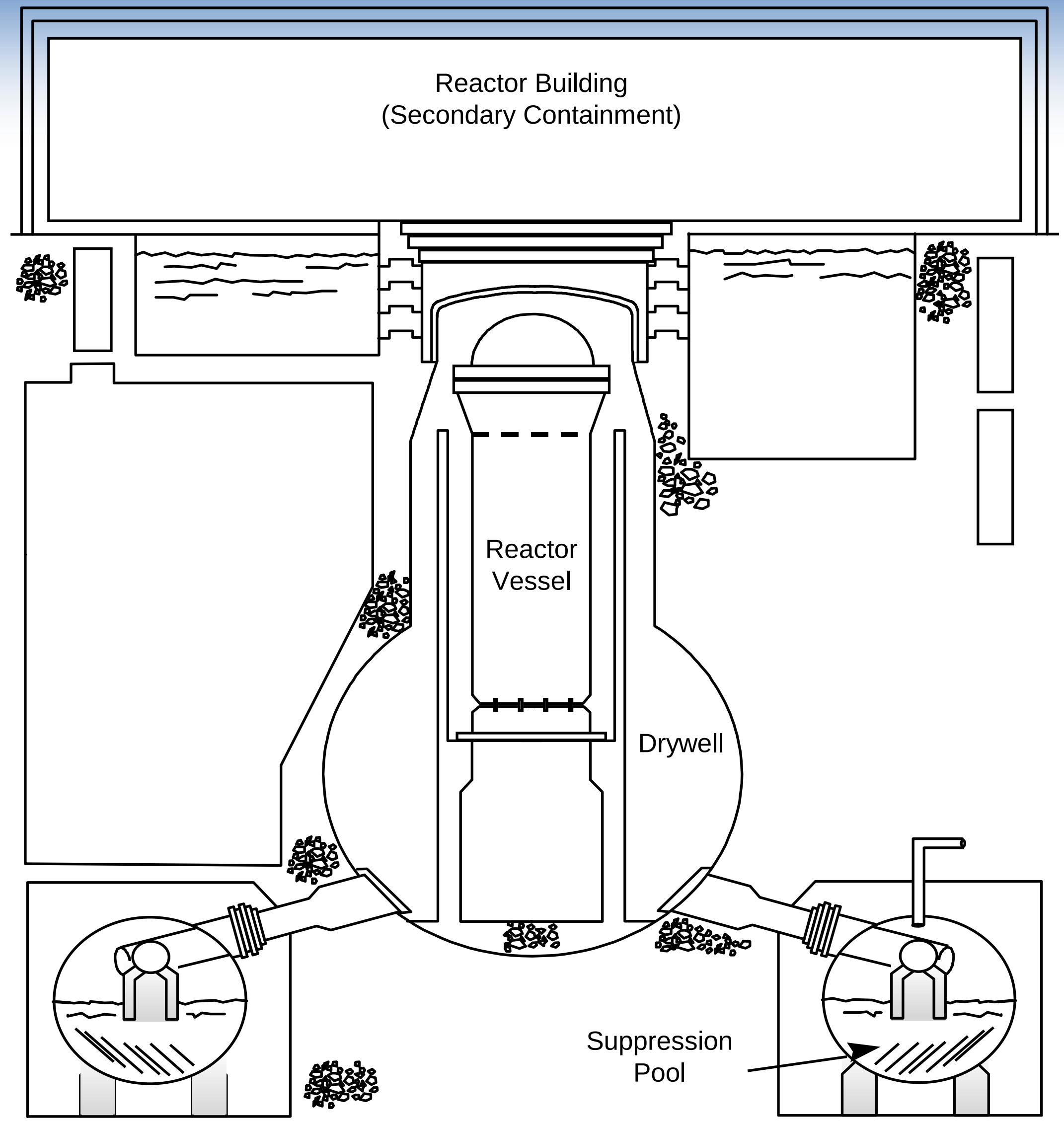
# Project Phase III Overview (cont.)

| | Phase II Pilot Plant | Phase III Pilot Plant |
|---|---|---|
| **Reactor / Containment Type** | BWR/4 Mark I (See Figure 1) | BWR/5 Mark II (See Figure 2) |
| **ECCS Summary** | • 1 turbine-driven High Pressure Coolant Injection (HPCI) pump (assume minimal credit for pilot project because HPCI suction strainer not upgraded)<br>• 4 Residual Heat Removal (RHR) pumps. 2 RHR pumps per division.<br>• 2 Low Pressure Core Spray pumps<br>• 4 RHR and 2 CS pumps supported by 4 ECCS suction strainers. 1 suction strainer for each division of RHR and CS (typical configuration for many BWR/4 Mark I plants). | • 1 motor-driven High Pressure Core Spray (HPCS) pump. Capable of high volume RPV makeup when the RPV is at high or low pressure.<br>• 3 RHR pumps<br>• 1 Low Pressure Core Spray pump<br>• Each of 5 ECCS pumps supported by a single, separate suction strainer (typical configuration for BWR/5 Mark II plants) |

# Project Phase III Overview (cont.)

**Figure 1**

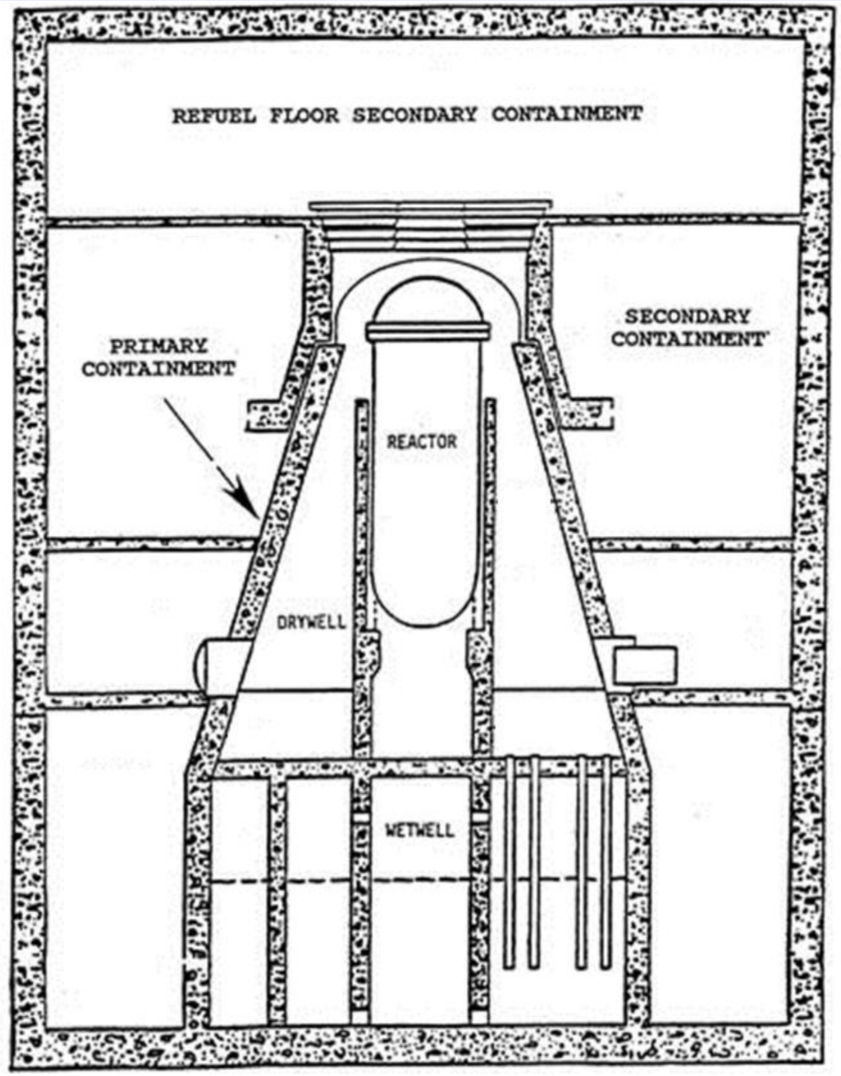
**Typical Mark I Containment Simplified Diagram**



# Project Phase III Overview (cont.)

**Figure 2**

**Typical Mark II Containment Simplified Diagram**



# Project Phase III Overview (cont.)

- CASA Grande model results used as input to PRA model for ECCS suction strainer common cause failure probabilities and failure timings
  - Used similar assumptions as Phase II project
  - Maintain consistency with the URG and design basis calculations
  - Sensitivities to address Grobe Letter potential issues

# Project Phase III Overview (cont.)

- MAAP thermal-hydraulic calculations performed to verify success criteria and identify accident sequence timings (i.e., to support human reliability analysis)
- PRA accident sequence and systems logic based on Phase III Pilot plant specific PRA model. Minor changes required to address enhancements consistent with Phase II Pilot PRA model (i.e., add event tree nodes for ECCS suction strainer failure)

# Project Phase III Overview (cont.)

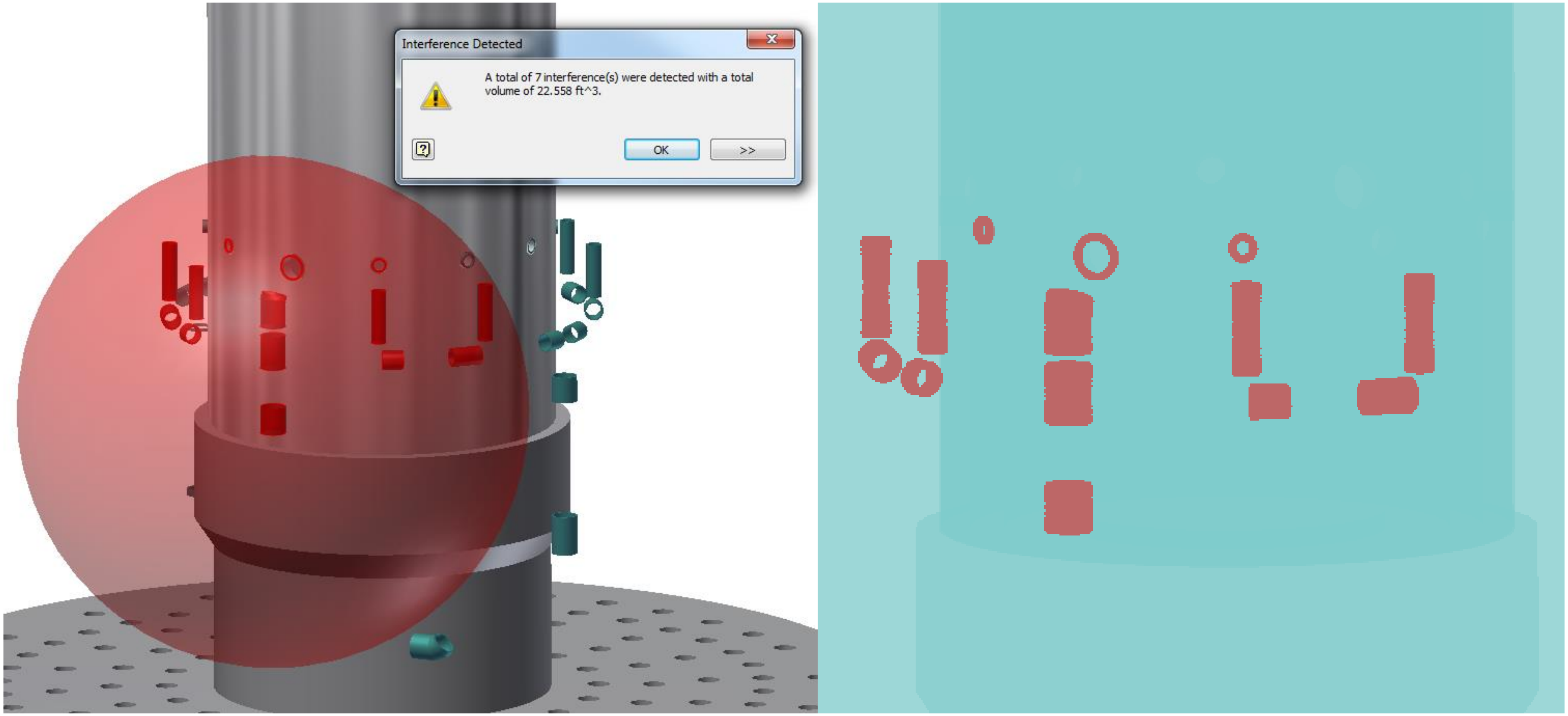
- Sensitivity cases were developed to evaluate quantitative impact of individual ECCS SS potential issues or PRA modeling issues (i.e., credit for operator actions). An additional sensitivity case is used to account for multiple issues and to evaluate potential synergistic impacts

# Phase III Baseline

- The goal of the baseline model is to quantify risk of the pilot plant using CASA Grande and the PRA model to analyze the risk associated with pilot plant specific design inputs and industry standard assumptions
- Modifications to these baseline model assumptions are used to quantify changes to risk associated with the potential issues outlined in Grobe Letter
- These modifications will be implemented in a series of sensitivity cases

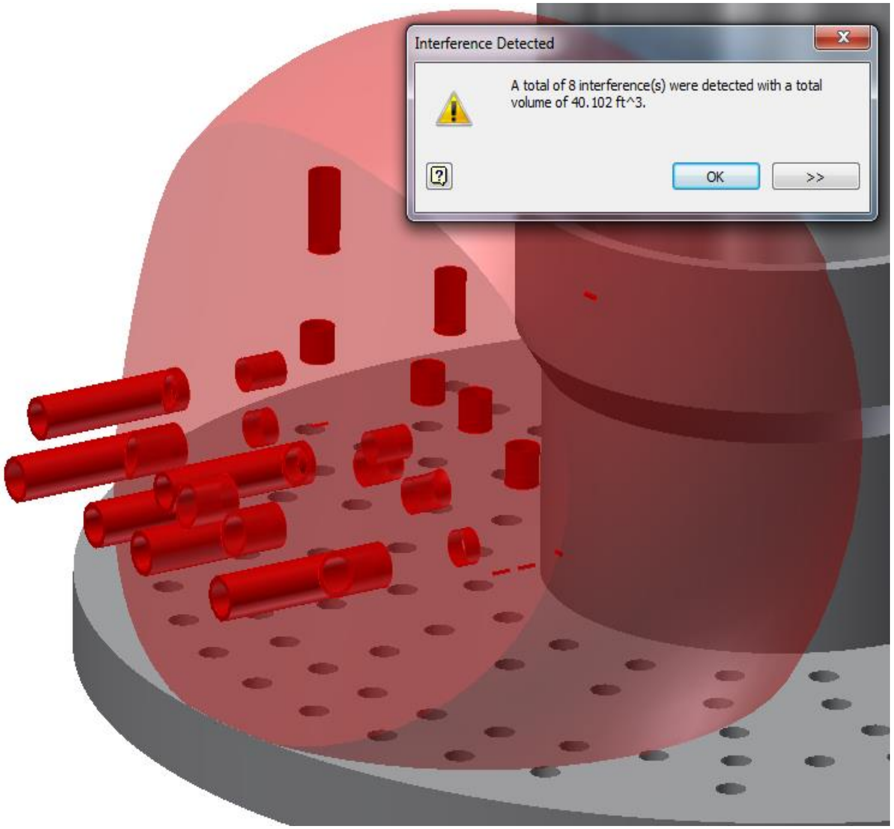
# Baseline Model

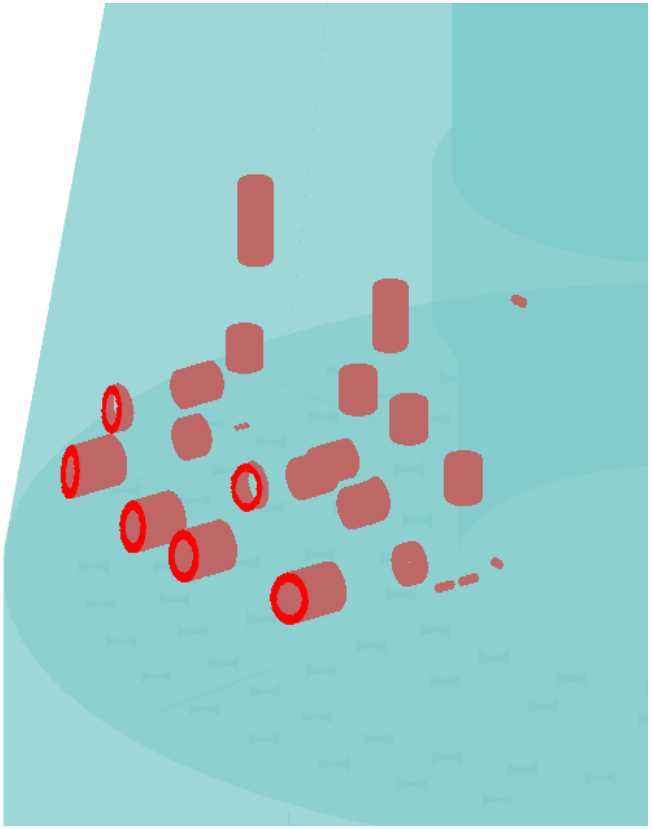
| | CASA Grande ($ft^3$) | CAD Model ($ft^3$) | % Difference |
|---|---|---|---|
| Temp-Mat (High) | 22.437 | 22.558 | -0.54% |
| Temp-Mat (Low) | -- | -- | -- |



# Baseline Model

| | CASA Grande ($ft^3$) | CAD Model ($ft^3$) | % Difference |
|---|---|---|---|
| Min-K (High) | 41.348 | 40.102 | 3.11% |
| Min-K (Low) | 0.157 | 0.158 | -0.83% |



# Modeling Techniques

During the modeling process several modeling techniques and assumptions were implemented with a conservative bias to provide reliability in the results and to negate any uncertainties not explicitly modeled

Conservatisms were implemented up to the point at which results were no longer meaningful for risk analysis

Baseline strainer failure criteria will be used as an example

# Strainer Failure Criteria

Conservatism:

- A break scenario is a “strainer failure scenario” if *any operating* strainer exceeds a failure threshold for debris
  - No partial credit is given for remaining operable strainers or for degraded performance

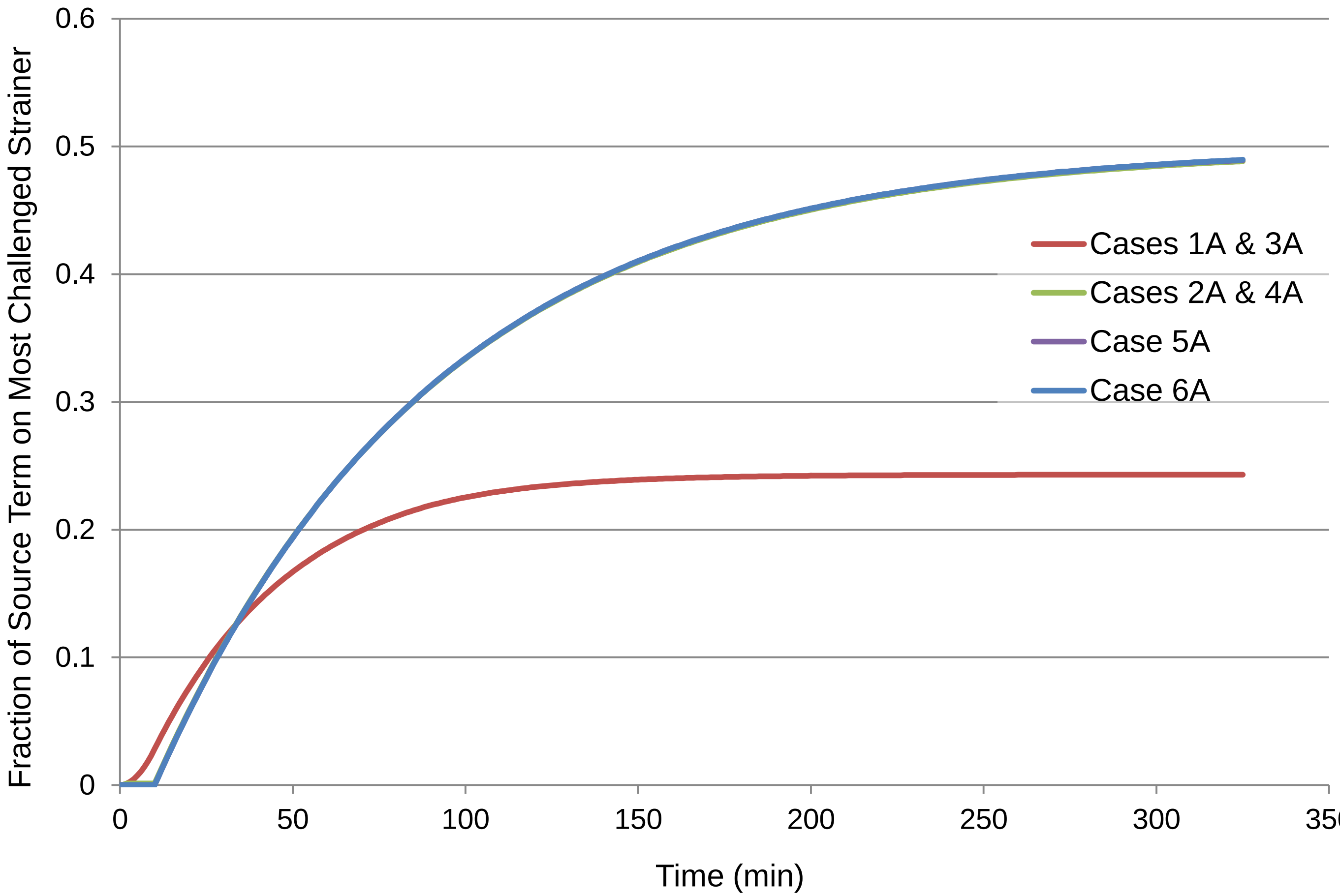
Methodology Note:

- Inactive strainers result in large debris loads on active strainers
- Many scenarios model ECCS pumps as idle or ECCS strainers as inactive

# Strainer Failure Criteria

| | | | Strainer 1 | Strainer 2 | Strainer 3 | Strainer 4 | Strainer 5 |
|---|---|---|---|---|---|---|---|
| | | | RHR A | RHR B | RHR C (LPCI Only) | LPCS | HPCS |
| T-H Cases 1A & 3A | Flow (gpm) | 0-80 min | 6660 | 6660 | 6660 | 6590 | 0 |
| | | >80 min | 6660 | 6660 | 6660 | 6590 | 6250 |
| | Debris Fraction | 48 hours | 0.24302 | 0.24302 | 0.24302 | 0.24046 | 0.03048 |
| T-H Cases 2A & 4A | Flow (gpm) | 0-2 min | 6660 | 6660 | 6660 | 6590 | 0 |
| | | 2-10 min | 0 | 0 | 0 | 0 | 0 |
| | | >10 min | 6660 | 6660 | 0 | 0 | 0 |
| | Debris Fraction | 48 hours | 0.49880 | 0.49880 | 0.00121 | 0.00119 | 0 |
| T-H Case 5A | Flow (gpm) | 0-10 min | 0 | 0 | 0 | 0 | 0 |
| | | 10-270 min | 6660 | 6660 | 0 | 0 | 0 |
| | | >270 min | 6660 | 6660 | 0 | 0 | 1400 |
| | Debris Fraction | 48 hours | 0.49804 | 0.49804 | 0 | 0 | 0.00392 |
| T-H Case 6A | Flow (gpm) | 0-10 min | 0 | 0 | 0 | 0 | 0 |
| | | >10 min | 6660 | 6660 | 0 | 0 | 0 |
| | Debris Fraction | 48 hours | 0.50000 | 0.50000 | 0 | 0 | 0 |

# Strainer Failure Criteria



# Strainer Failure Criteria

A CASA Grande break scenario is counted as failure if the amount of debris transported to *any* operating strainer exceeds test data. This methodology is termed, “Probability of Exceeding a Tested Threshold – PETT.”

Worked well for fiber dominated Phase II Pilot using limits of GE correlation

# Challenge for Phase III

DBA strainer qualification for the Phase III Pilot Plant tested a specific debris combination consisting of Min-K, zinc, rust flakes, paint chips (epoxy coatings), and corrosion products (sludge).

CASA Grande analyzes a spectrum of scenarios with unique debris compositions that don't match the DBA test

# Debris Equivalence

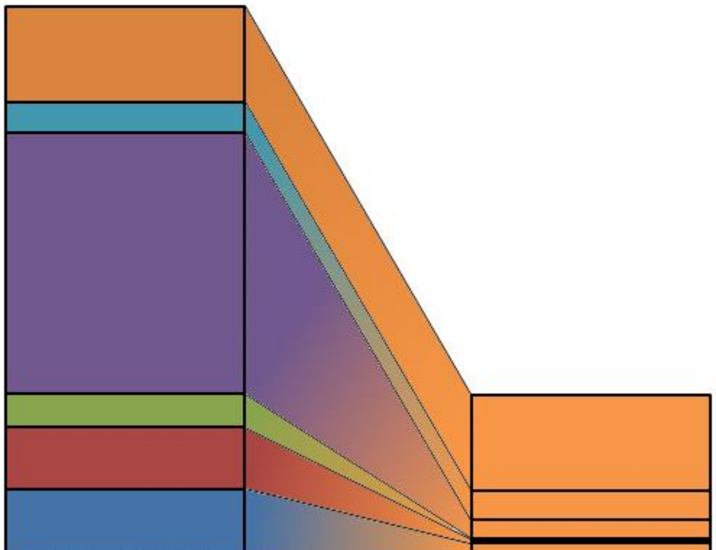
Thresholds for debris failure were calculated using URG "bump-up" factors to convert tested scenario debris into equivalent amounts of calculated Min-K debris

All Tempmat, Min-K, and equivalent Min-K debris from a break scenario are totaled and compared to the equivalent design basis loading of debris (consisting of Min-K and converted mixed particulate)

Debris equivalence prevents 100% failure because the ECCS was qualified with 3 of 5 strainers operating, while the plant response to some break scenarios utilizes only 2 strainers.

# DBA Strainer Loading

Debris equivalence accounts for the head loss *effects* of each debris type in the DBA test to form a single debris-type failure threshold.



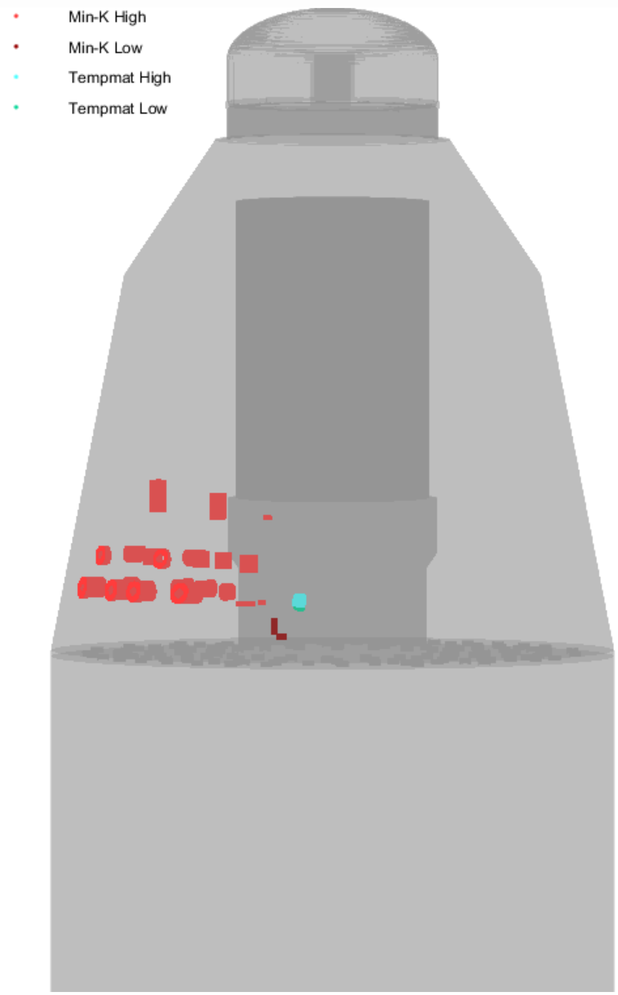
| | Stainer Qualification Debris Mixture (lbm of component) | Equivalent Min-K Debris Loading (lbm of Min-K) |
|---|---|---|
| Min-K Particulate | 51.1 | 51.1 |
| Min-K Fiber | 16.1 | 16.1 |
| Zinc | 140 | 9.47 |
| Rust Flakes | 17.7 | 0.73 |
| Paint Chips | 33 | 1.88 |
| Corrosion Products | 34 | 5.25 |
| Total | 291.9 | 84.53 |

} Effective Min-K bump-Up, 17.33 lbm

Each ECCS suction strainer is expected to successfully operate up to 84.53 lbm of Min-K equivalent debris. Any quantity of equivalent debris larger than this on any strainer is counted as a failure in CASA Grande for that break scenario.

# Example Break Scenario

To illustrate the PETT implementation, consider an example break scenario:

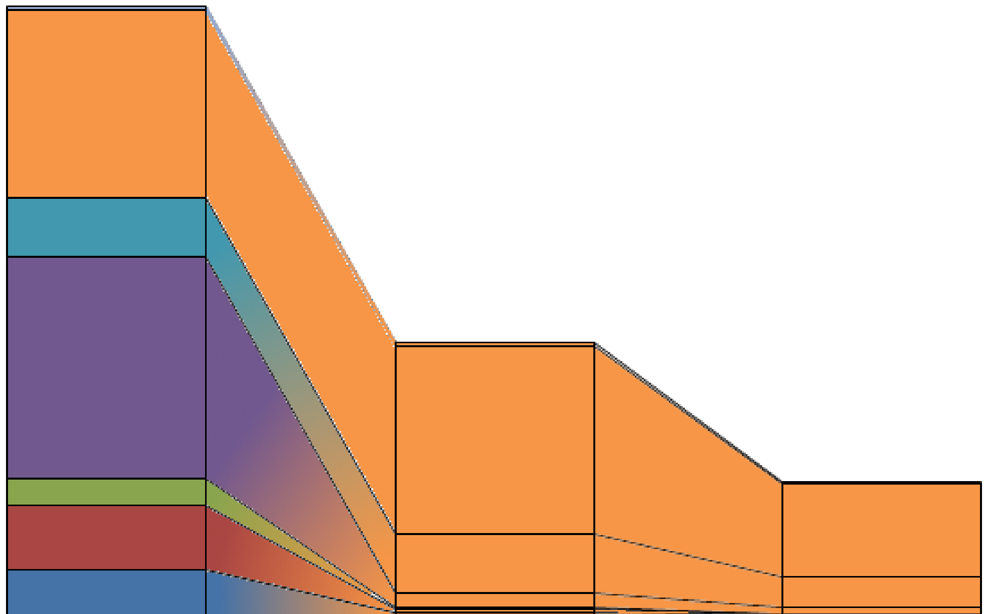



## Transported Debris

| | Debris Name | Debris Mass Transported to Pool [lbm] |
|---|---|---|
| Break ZOI - Dependent | Min-K – High | 460.45 |
| | Min-K – Low | 1.24 |
| | Tempmat – High | 2.28 |
| | Tempmat – Low | 4.57 |
| Fixed Quantity | Sludge/Dust/Dirt | 96.0 |
| | Rust Flakes | 50.1 |
| | Epoxy Paint Chips | 120.2 |
| | Zinc (IOZ) | 412.0 |
| Total | - | 520.1553 |

# Example Break Scenario (cont.)

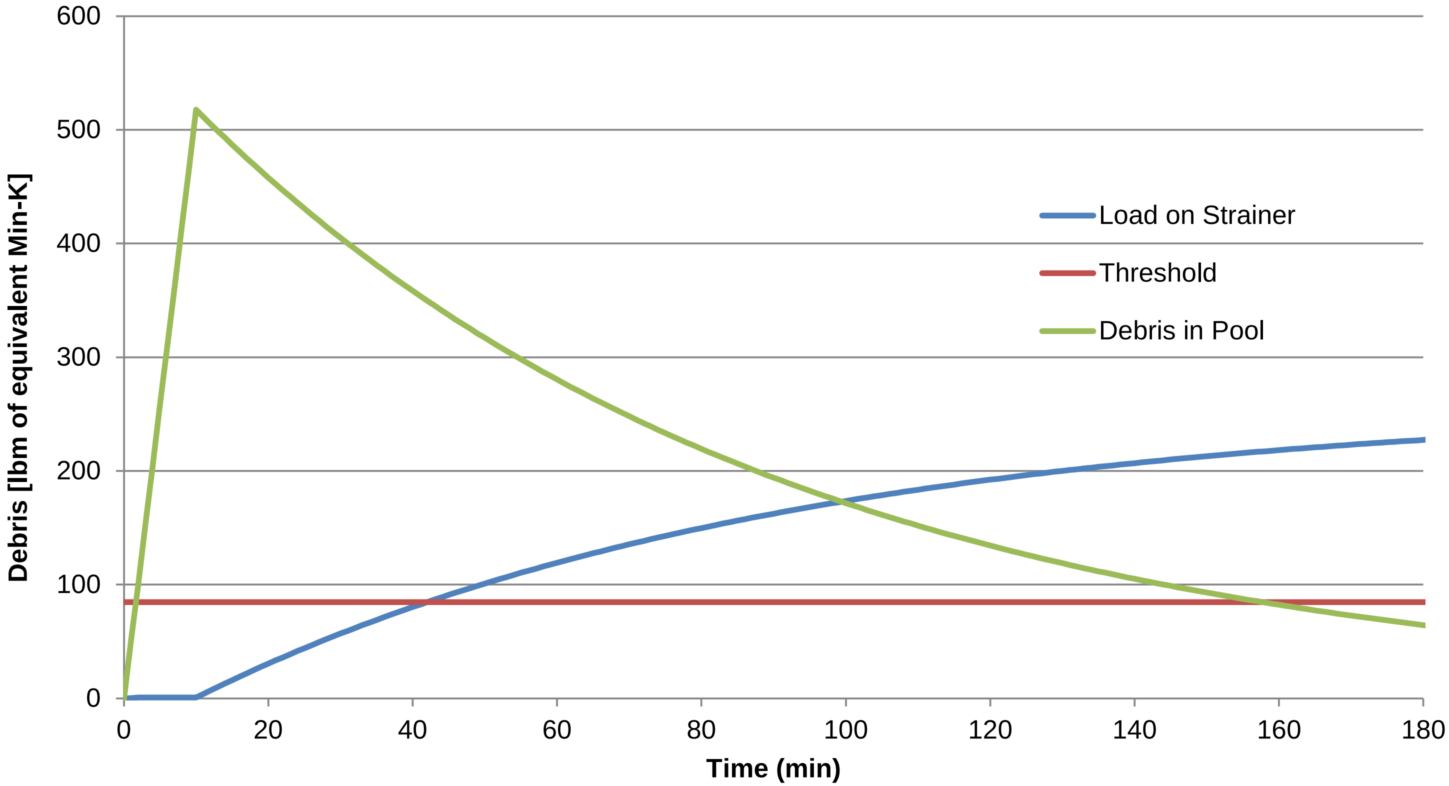
- Bounding strainer load totals 259.45 lbm of equivalent Min-K, but PETT threshold is 84.53 lbm for a single strainer, so this scenario is counted as a failure in CASA Grande



| | Debris Transported to Pool (lbm of component) | Min-K Equivalent Debris Transported to Pool (lbm of Min-K) | Min-K Equivalent Debris on Bounding Strainer at 48 Hours (lbm of Min-K) |
|---|---|---|---|
| Tempmat | 6.85 | 6.85 | 3.42 |
| Min-K Particulate | 350.88 | 350.88 | 175.02 |
| Min-K Fiber | 110.81 | 110.81 | 55.27 |
| Zinc | 412 | 27.87 | 13.90 |
| Rust Flakes | 50.1 | 2.06 | 1.03 |
| Paint Chips | 120.2 | 6.86 | 3.42 |
| Corrosion Products | 96 | 14.82 | 7.39 |
| Total | 1146.84 | 520.15 | 259.45 |

# Example Break Scenario (cont.)

The bounding strainer fails at 41.95 minutes for this example, when the load on the bounding strainer exceeds the PETT threshold



# Baseline Initiating Event Frequency Distribution Techniques

The baseline model was analyzed using three options for weighting each postulated break relative to the other breaks in that LOCA category (i.e. small, medium, and large break and above and below TAF)

- The 3B000 case uses the mean initiating event frequency taken from NUREG-1829 guidance for each postulated break size
- The 3B000-L case samples lognormal initiating event frequencies for each postulated break size. This case helps to quantify the effects of correlated sampling between CASA Grande and the PRA
- The 3B000-B case uses the mean initiating event frequency taken from system-dependent distributions to analyze the effects of system-weighted (i.e. “bottom-up”) initiating event frequencies on the results

# Sensitivity Overview

- All NRC Grobe Letter potential issues except 1) chemical effects, 2) in-core debris accumulation, 3) downstream effects on components, and 4) coatings assessment have been investigated using parameter variations
- Appropriate parameter variations have been performed for each of the potential issues
  - The most influential plant parameters affecting each issue has be identified
  - The individual risk contribution of each potential issue has be quantified
  - The aggregate risk contribution of selected potential issues has be quantified

# NRC ECCS Suction Strainer Issues

| ECCS Suction Strainer Potential Issues of Concern | Explicitly Evaluated in CASA Grande Sensitivity Cases? |
|---|---|
| 1. Downstream Effects (Components & Systems) | No |
| 2. Downstream Effects (Fuel / In-vessel) | Out of Scope |
| 3. Debris Head Loss Correlations | Yes |
| 4. Chemical Effects | Out of Scope |
| 5. Coatings Assessments | No |
| 6. Latent Debris | Yes |

| ECCS Suction Strainer Potential Issues of Concern | Explicitly Evaluated in CASA Grande Sensitivity Cases? |
|---|---|
| 7. Zone of Influence (ZOI) Adjustment for Air Jet Testing (AJT) | Yes |
| 8. Coatings Zone of Influence (ZOI) | Yes |
| 9. Debris Transport and Erosion | Yes |
| 10. Debris Characteristics | Yes |
| 11. Near Field Effect / Scaling | No |
| 12. Spherical Zone of Influence (ZOI) | Yes |

# ECCS Suction Strainer Potential Issues Sensitivity Analysis

Issues 1, 5, and 11 will not be explicitly addressed through sensitivity cases

- Issue No. 1 : DSE-C is intended to be resolved through appropriate application of WCAP-16406-P
- Issue No. 5: Coatings Assessment is a BWROG programmatic survey response and does not require a RI resolution at this time
- Issue No. 11: Near Field Effects and Scaling is incorporated into the Issue No. 3: Head Loss Correlation sensitivities (similar to Issue No. 10)

Other ECCS suction strainer issues will be addressed through candidate sensitivity cases

# Phase III Sensitivity Cases

| Case Tag | Issue # | Brief Description |
|---|---|---|
| 3S001 | M | Transport Time |
| 3S002 | M | Cumulative Effects |
| 3S003-A | M | HPCS Out of Service |
| 3S003-B | M | RHR Out of Service |
| 3S003-C | M | HPCS and RHR Out of Service |
| 3S301-A | 3 | Head Loss Calculated using the NUREG/CR-6224 Correlation |
| 3S301-B | 3,10 | Head Loss Calculated using the NUREG/CR-6224 Correlation with Alternative Min-K Parameters |
| 3S302 | 3,10 | Threshold Fiber Bed Failure Criteria (in addition to PETT limits) |
| 3S605 | 6 | 5% of Drywell Inventory as Fiber |
| 3S610 | 6 | 10% of Drywell Inventory as Fiber |
| 3S615 | 6 | 15% of Drywell Inventory as Fiber |
| 3S700 | 7 | 10% Increase in ZOI Radius |
| 3S800 | 8 | Break Dependent Coatings |
| 3S900 | 9 | Additional Debris Erosion |

# ECCS Suction Strainer Potential Issues Sensitivity Analysis (cont.)

## Issue 3: Debris Head Loss Correlations

NRC staff has commented that head loss correlations for BWR strainer sizing may not have adequately bounded debris beds with microporous insulation or the thin bed condition

Sensitivity Case 3S301-B:

- NUREG/CR-6224 head loss correlation has been run as a deviation from the baseline. This correlation treats the effects of microporous insulation and thin bed condition differently than the PETT baseline method (which is not a head loss correlation)

# ECCS Suction Strainer Potential Issues Sensitivity Analysis (cont.)

## Issue 3: Debris Head Loss Correlations (cont.)

Sensitivity Case 3S302:

- A second sensitivity case treats all debris beds that exceed a minimum fiber debris threshold are treated as strainer failures
- This treatment eliminates the uncertainty related to the selected head loss correlation and the modeled debris characteristics (Issue 10)

# ECCS Suction Strainer Potential Issues Sensitivity Analysis (cont.)

## Issue 6: Latent Debris

The issue is that accounting for latent debris as only particulate may be non-conservative for low fiber plants

Sensitivity Cases 3S605, 3S610, 3S615:

- These sensitivity cases modify the latent drywell dust/dirt/sludge debris source term to account for 5%, 10%, and 15% latent fiber by weight, respectively

# ECCS Suction Strainer Potential Issues Sensitivity Analysis (cont.)

## Issue 7: ZOI Adjustment for Air Jet Testing

Current closure letter has addressed this issue in combination with Issue 12 for problematic debris sources

Sensitivity Case 3S700:

- This sensitivity case increases the ZOI radius size by 10%, resulting in a 33.1% increase in volume (ignoring shadowing effects) to create additional debris outside the baseline ZOI

# ECCS Suction Strainer Potential Issues Sensitivity Analysis (cont.)

## Issue 8: Coatings ZOI

The concern is that the generic baseline value of qualified coatings may be non-conservative when considering plant specific, location dependent ZOI analyses

Sensitivity Case 3S800:

- This sensitivity case uses the CASA-CAD geometry and ZOIs to account for qualified coatings debris generation at each break location in containment

# ECCS Suction Strainer Potential Issues Sensitivity Analysis (cont.)

Issue 9: Debris Transport & Erosion

The staff has suggested the development of transport fractions, including erosion and suppression pool settling, may be potentially non-conservative

Sensitivity Case 3S900:

- This sensitivity case considers additional erosion of Tempmat debris by modifying the Tempmat transport fractions. Specifically this sensitivity will increase the percentage of erosion from 6.25% in the baseline to 25%
- The baseline model already assumes 100% transport of all Min-K within the break ZOI, so this insulation type is unaffected by this sensitivity case

# ECCS Suction Strainer Potential Issues Sensitivity Analysis (cont.)

## Issue 10: Debris Characteristics

Blockage potential of problematic materials such as microporous insulation may not have been treated conservatively

Since this issue pertains primarily to the head loss (blockage) potential, it is included in Issue 3 Head Loss Correlation sensitivities

# ECCS Suction Strainer Potential Issues Sensitivity Analysis (cont.)

## Methodological Sensitivity Cases

Sensitivity Case 3S001: Transport Time

- This sensitivity case transports all debris to the suppression pool in the first CASA Grande time step (1 minute) instead of the baseline assumption of constant transport over 10 minutes

# ECCS Suction Strainer Potential Issues Sensitivity Analysis (cont.)

## Methodological Sensitivity Cases (cont.)

Sensitivity Case 3S002: Cumulative Effects

- This case examined the cumulative effects of combining the assumptions of the Phase III Pilot’s dominant sensitivity cases:
  - 3S615: 15% of drywell debris as fibrous
  - 3S700: 10% increase in insulation ZOI radius
  - 3S800: ZOI coatings generation
  - 3S900: Additional Debris Erosion

# ECCS Suction Strainer Potential Issues Sensitivity Analysis (cont.)

## Methodological Sensitivity Cases (cont.)

Sensitivity Cases 3S003-A, 3S003-B, 3S003-C:

ECCS Pumps Out-of-Service

- These cases will investigate the effects of modeling ECCS pump(s) as out-of-service on the ECCS strainer failure probabilities
- These cases are integrated into the plant PRA model with the baseline case to estimate core damage frequency
- The modeled pump failures include:
  - HPCS since loss of CST injection will likely increase ΔCDF
  - RHR since loss of this suppression pool injection path has the greatest impact on CASA Grande calculated strainer failure probabilities
  - Both HPCS and RHR pumps out-of-service

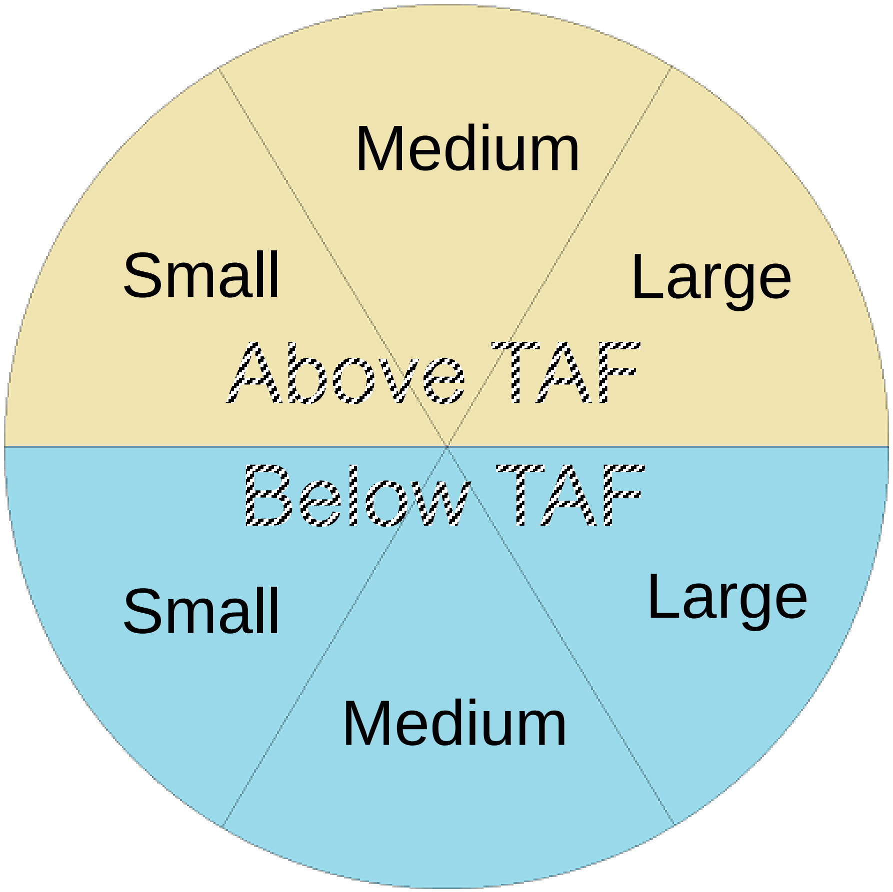
# PRA Inputs – CASA Grande Results

- Conditional failure probabilities and minimum time to failure from CASA Grande will be used as input to the PRA model
- Conditional failure probabilities will be processed through the PRA to determine $\Delta$CDF

# PRA Inputs – CASA Grande Results (cont.)

- CASA Grande provides necessary inputs into PRA for the spectrum of LOCA scenarios

- Six CASA Grande simulations will be run for the baseline and each sensitivity



# Calculate LOCA Initiating Event Frequencies

| LOCA Initiating Event | Size Diam. (in.) | Location | IE Frequency (based on NUREG-1829) |
|---|---|---|---|
| Small LOCA in RCIC Line (above TAF) | <2” | RCIC | 1.5E-06 |
| Other Small LOCA (above TAF)[(1)] | <2” | Steamline | 9.4E-05 |
| Small LOCA below TAF | <2” | Recirc | 4.2E-04 |
| **Total Small LOCA Frequency** | | | **5.2E-04** |
| Medium LOCA in RCIC Line (above TAF) | 2”-6” | RCIC | 6.0E-07 |
| Medium LOCA in CS Line (above TAF) | 2”-6” | CS | 3.5E-06 |
| Medium LOCA in HPCS Line (above TAF) | 2”-6” | HPCS | 3.5E-06 |
| Medium LOCA in LPCI Line (above TAF)[(1)] | 2”-6” | LPCI | 9.1E-06 |
| Other Medium LOCA (above TAF) | 2”-6” | Steamline | 1.1E-05 |
| Medium LOCA below TAF | 2”-6” | Recirc | 9.5E-05 |
| **Total Medium LOCA Frequency** | | | **1.2E-04** |

# Calculate LOCA Initiating Event Frequencies

| LOCA Initiating Event | Size Diam. (in.) | Location | IE Frequency (based on NUREG-1829) |
|---|---|---|---|
| Large LOCA in CS Line (Above TAF) | >6" | CS | 2.0E-07 |
| Large LOCA in HPCS Line (Above TAF) | >6" | HPCS | 2.0E-07 |
| Large LOCA in LPCI Line (Above TAF)(1) | >6" | LPCI | 8.6E-07 |
| Other Large LOCA above TAF | >6" | Main Steam | 1.6E-06 |
| Large LOCA below TAF | >6" | Recirc | 4.5E-06 |
| **Total Large LOCA Frequency** | | | **7.3E-06** |

(1) For the Phase II study, LOCAs in the LPCI line were categorized as LOCAs below TAF because LPCI injects into the recirculation discharge line for a BWR/4. For the Phase III study, LOCAs in the LPCI line are categorized as LOCAs above TAF because LPCI injects into the RPV shroud for a BWR/5.

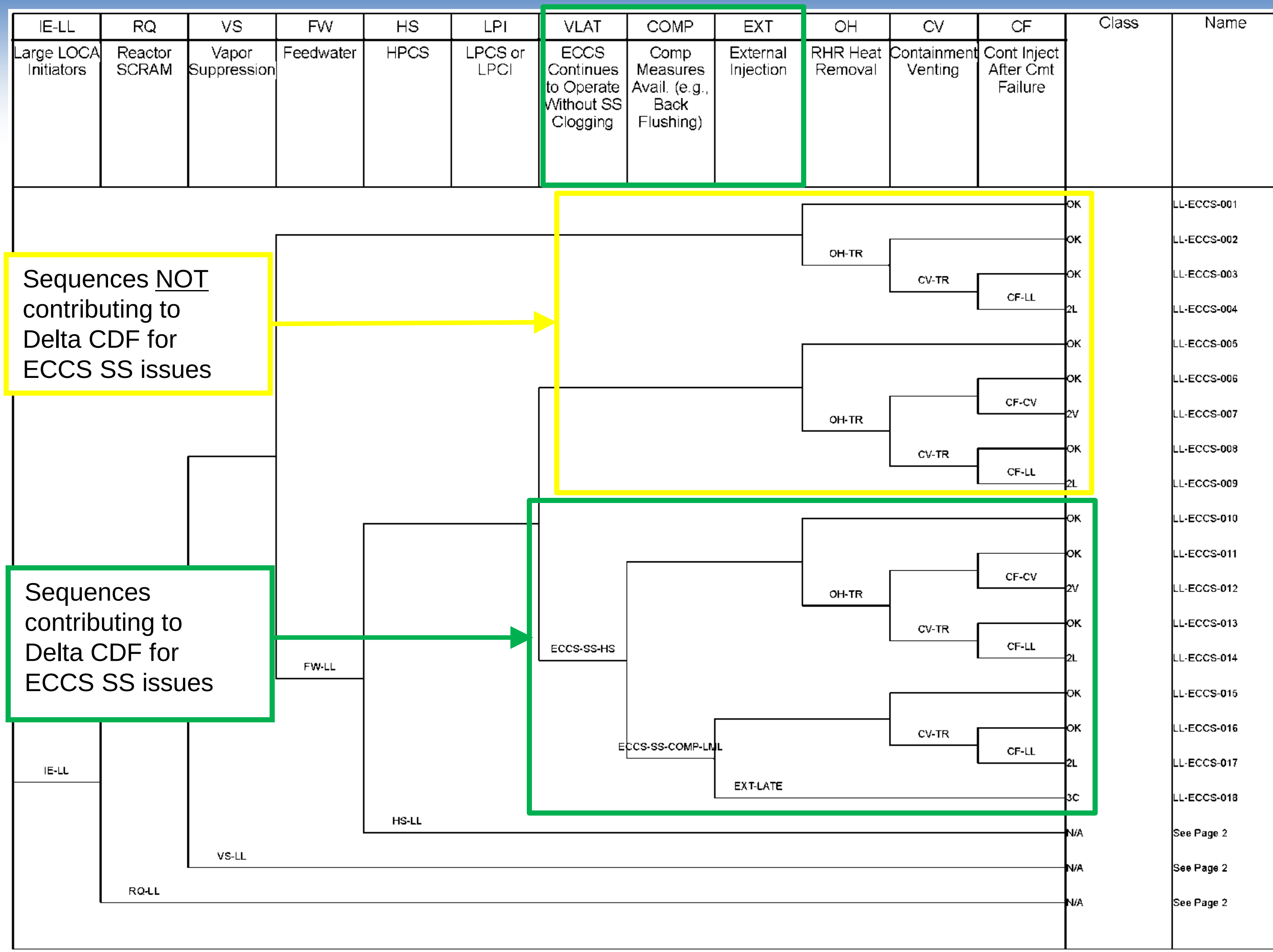
# Event Tree Logic Model

The following three (3) event trees are used to support the ECCS suction strainer risk evaluation

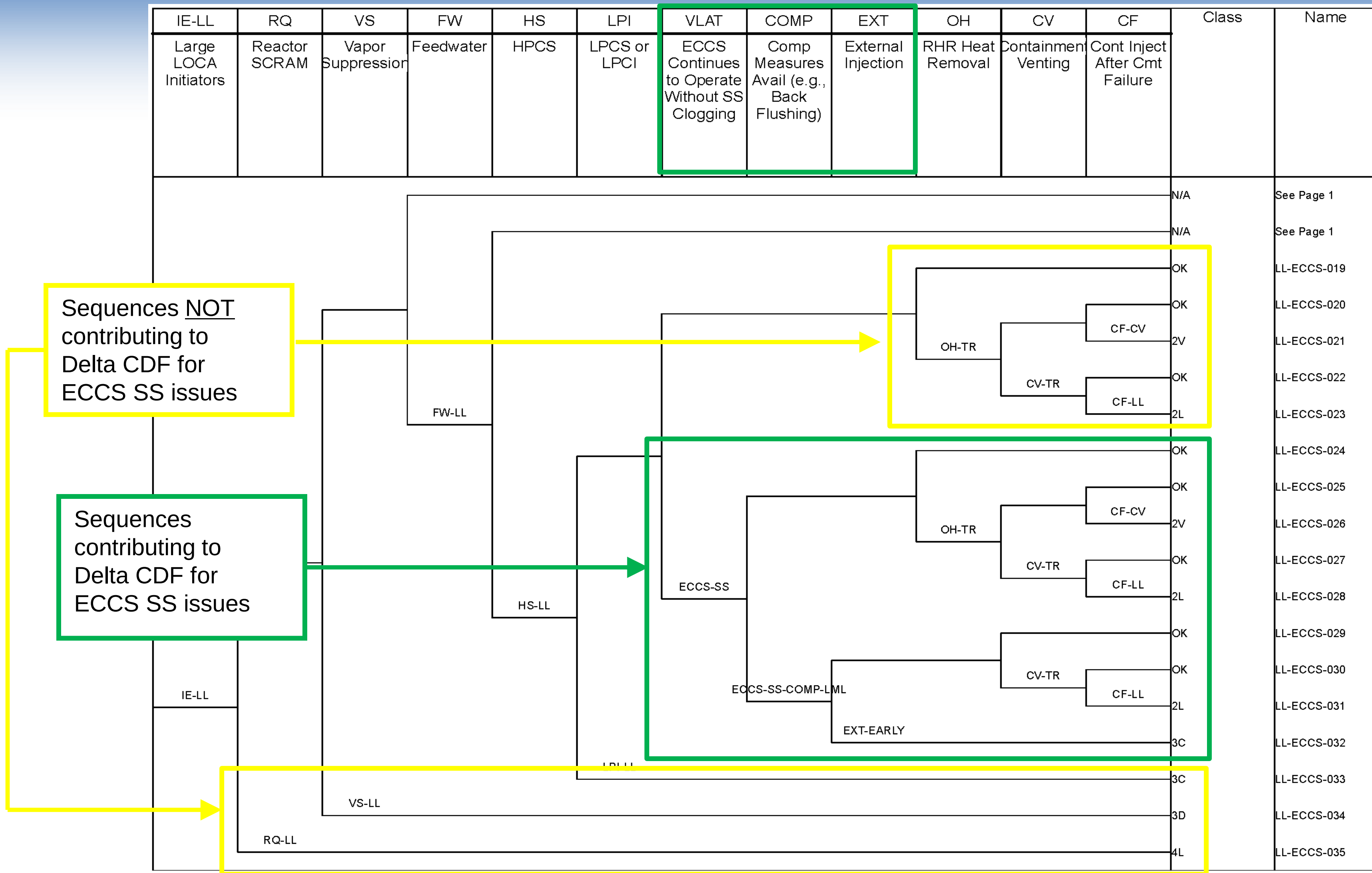
- Large LOCA (above and below TAF)
- Medium LOCA (above and below TAF)
- Small LOCA (above and below TAF)

Note: The PRA model used for the Phase II risk study evaluated above and below TAF LOCAs in separate events trees (i.e., 6 total event trees); PRA modeling preference does not impact the quantitative evaluation

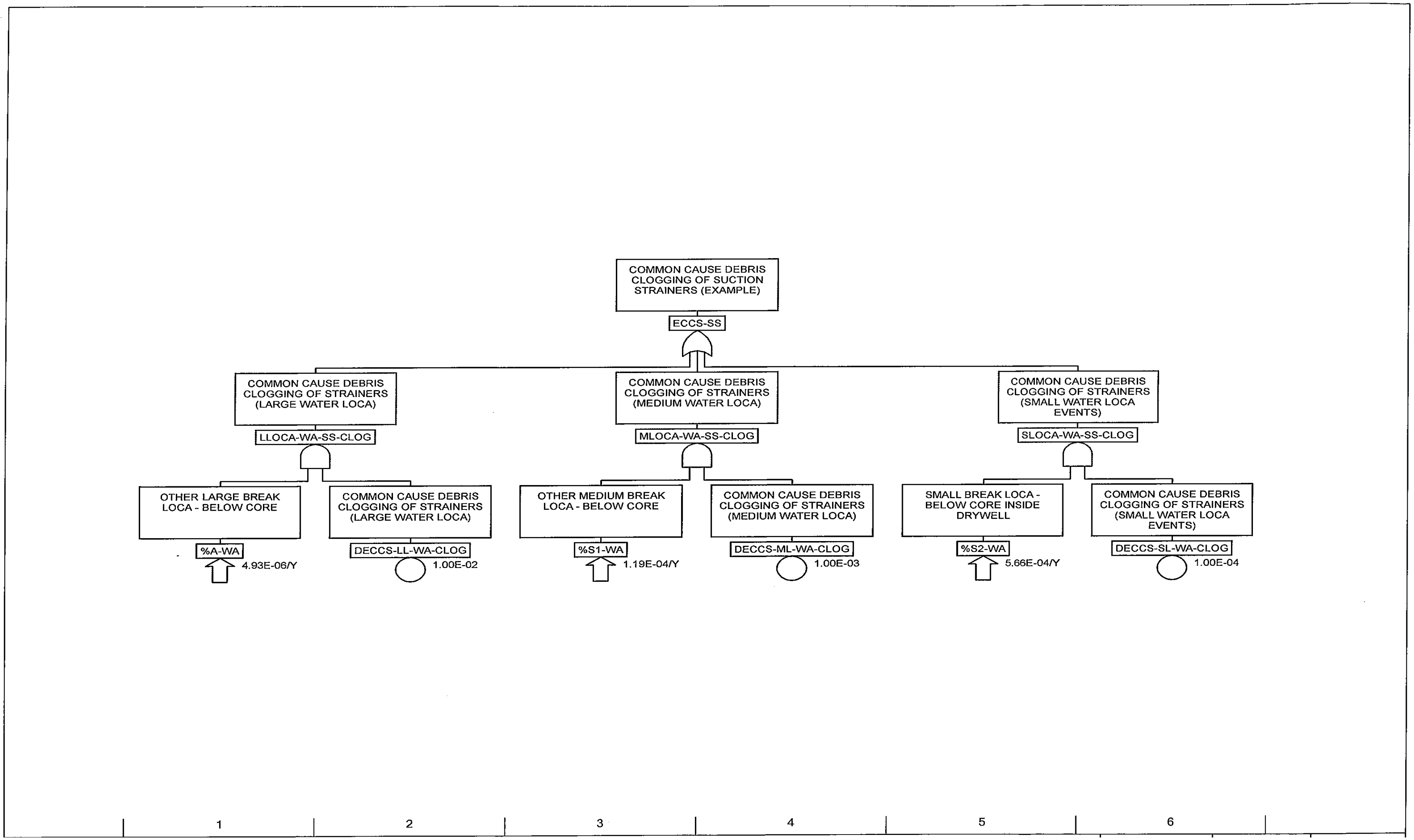
# Large LOCA Event Tree (Page 1)



# Large LOCA Event Tree (Page 2)



# Example Fault Tree Logic to Model Debris Clogging of ECCS Suction



# System Fault Tree Logic

- VLAT Node (ECCS Continues to Successfully Operate Without Suction Strainer Clogging) – Added to model ECCS suction strainer failure for the range of LOCA scenarios (size and location)
- COMP Node (Compensatory Measures Successful) – This node considers operator actions to mitigate suction strainer clogging. Potential for limited credit for this node because back flush not proceduralized at Phase III pilot plant

# Perform Thermal-Hydraulics Analyses

- MAAP thermal-hydraulic runs will be performed for a variety of LOCA sizes, locations, and scenarios:
  - Verify event tree success criteria and accident timings to support human reliability analysis
- Example Large Water LOCA cases identified the following:
  - With no injection, core damage occurs in approximately 6 minutes
  - With 4 minutes of injection from 1 LPCI pump and long term makeup from CRD at 100 gpm, core damage delayed until approximately 33 minutes
  - Credit for limited high volume makeup may sufficiently delay core damage to support credit for operator mitigation actions
  - Compared to Phase II thermal hydraulic results, higher power core for Phase III plant results in much less delay for core damage

# Perform Thermal-Hydraulics Analyses (cont.)

| MAAP Scenario | Time to Core Damage: Phase II Pilot Plant (BWR/4) | Time to Core Damage: Phase III Pilot Plant (BWR/5) |
|---|---|---|
| Large water LOCA in recirculation suction line - No RPV injection | 6 min. | 6 min. |
| Large water LOCA in recirculation suction line - CRD at 100 gpm and 1 LPCI pump for 4 minutes | 63 min. | 33 min.(1) |
| Large water LOCA in recirculation suction line - HPCS pump with suction from CST. CST inventory sufficient for approximately 80 minutes of HPCS makeup to RPV. CRD at 100 gpm | N/A | 2.1 hrs. |
| Large steam LOCA in main steam line - No RPV injection | 34 min. | 18 min. |
| Large steam LOCA in main steam line - CRD at 100 gpm and 1 LPCI pump for 4 minutes | No Core Damage | 1.6 hrs.(1) |
| Large steam LOCA in main steam line - HPCS pump with suction from CST. CST inventory sufficient for greater than 36 hours of HPCS makeup to RPV | N/A | No Core Damage |

(1) The identified time to core damage would only apply for scenarios where HPCS is probabilistically unavailable (i.e., pump fails to start, system unavailable due to maintenance)

# Perform Human Reliability Analyses

Perform human reliability analysis (HRA):

- Review available procedures
- Interview operations personnel (i.e., discuss available cues to support diagnosis, training and operating experience for ECCS suction strainer clogging events, time to implement specific actions)
- Calculate Human Error Probabilities (HEPs)

Operator actions to be investigated:

- Align alternate external RPV makeup (i.e., credit as a sensitivity case to mitigate ECCS suction strainer failure)
- Potential alternate mitigation actions (i.e., manage flow though individual suction strainers)
  - No procedure for ECCS suction strainer back wash at Phase III pilot plant

# Quantify Results

- CASA Grande will be used to provide the basis for the ECCS suction strainer clogging failure probabilities and failure timings
- Regulatory Guide 1.174 specifies that a risk-informed approach provides valuable insights and guidance for use in interactions between the NRC and licensees
- The ECCS suction strainer assessment aligns with RG 1.174 guidance

# Quantify Results (cont.)

- High volume RPV makeup from motor-driven HPCS provides additional defense-in-depth and potential risk benefit for all LOCA scenarios
    - Delay or avoid core damage due to initial pump suction from CST and not suppression pool.

# CASA Results Input to Phase III PRA

| CASA Grande Quantification Case Tag | Failure Probs - LOCAs Above TAF | | | Failure Probs - LOCAs Below TAF | | |
|---|---|---|---|---|---|---|
| | Small | Medium | Large | Small | Medium | Large |
| 3B000 (Baseline) | 0.0000 | 0.0000 | 0.0637 | 0.0000 | 0.0000 | 0.0000 |
| 3B000-L (Lognormal) | 0.0000 | 0.0000 | 0.0433 | 0.0000 | 0.0000 | 0.0000 |
| 3B000-B (Bottom-Up) | 0.0000 | 0.0000 | 0.0574 | 0.0000 | 0.0000 | 0.0000 |
| 3S001 (Transport Time) | 0.0000 | 0.0000 | 0.0637 | 0.0000 | 0.0000 | 0.0000 |
| 3S002 (Cumulative Effects) | 0.0000 | 0.0000 | 0.1004 | 0.0000 | 0.0000 | 0.0039 |
| 3S003-A (HPCS OOS) | 0.0000 | 0.0000 | 0.0637 | 0.0000 | 0.0000 | 0.0000 |
| 3S003-B (RHR OOS) | 0.0000 | 0.0000 | 0.0637 | 0.0000 | 0.0000 | 0.0000 |
| 3S003-C (HPCS & RHR OOS) | 0.0000 | 0.0000 | 0.0637 | 0.0000 | 0.0000 | 0.0000 |
| 3S301-A (6224-A) | (under development) | | | | | |
| 3S301-B (6224-B) | 0.0000 | 0.0000 | 0.0175 | 0.0000 | 0.0000 | 0.0025 |
| 3S302 (Fiber Bed Limit) | (under development) | | | | | |
| 3S605 (5% Latent Fiber) | 0.0000 | 0.0000 | 0.0653 | 0.0000 | 0.0000 | 0.0000 |
| 3S610 (10% Latent Fiber) | 0.0000 | 0.0000 | 0.0685 | 0.0000 | 0.0000 | 0.0000 |
| 3S615 (15% Latent Fiber) | 0.0000 | 0.0000 | 0.0722 | 0.0000 | 0.0000 | 0.0000 |
| 3S700 (10% ZOI Increase) | 0.0000 | 0.0000 | 0.0897 | 0.0000 | 0.0000 | 0.0026 |
| 3S800 (Coatings ZOI) | 0.0000 | 0.0000 | 0.0618 | 0.0000 | 0.0000 | 0.0000 |
| 3S900 (Increased Erosion) | 0.0000 | 0.0000 | 0.0870 | 0.0000 | 0.0000 | 0.0000 |

# CASA Results Input to Phase III PRA

| CASA Grande Quantification Case Tag | Minimum Time to Failure - LOCAs Above TAF | | | Minimum Time to Failure - LOCAs Below TAF | | |
|---|---|---|---|---|---|---|
| | Small | Medium | Large | Small | Medium | Large |
| 3B000 (Baseline) | N/A | N/A | 41.37 | N/A | N/A | N/A |
| 3B000-L (Lognormal) | N/A | N/A | 41.37 | N/A | N/A | N/A |
| 3B000-B (Bottom-Up) | N/A | N/A | 41.37 | N/A | N/A | N/A |
| 3S001 (Transport Time) | N/A | N/A | 40.69 | N/A | N/A | N/A |
| 3S002 (Cumulative Effects) | N/A | N/A | 39.51 | N/A | N/A | 47.54 |
| 3S003-A (HPCS OOS) | N/A | N/A | 41.37 | N/A | N/A | N/A |
| 3S003-B (RHR OOS) | N/A | N/A | 41.32 | N/A | N/A | N/A |
| 3S003-C (HPCS & RHR OOS) | N/A | N/A | 41.32 | N/A | N/A | N/A |
| 3S301-A (6224-A) | (under development) | | | | | |
| 3S301-B (6224-B) | N/A | N/A | 1684.00 | N/A | N/A | 80.40 |
| 3S302 (Fiber Bed Limit) | (under development) | | | | | |
| 3S605 (5% Latent Fiber) | N/A | N/A | 41.22 | N/A | N/A | N/A |
| 3S610 (10% Latent Fiber) | N/A | N/A | 41.08 | N/A | N/A | N/A |
| 3S615 (15% Latent Fiber) | N/A | N/A | 40.93 | N/A | N/A | N/A |
| 3S700 (10% ZOI Increase) | N/A | N/A | 40.75 | N/A | N/A | 48.96 |
| 3S800 (Coatings ZOI) | N/A | N/A | 41.46 | N/A | N/A | N/A |
| 3S900 (Increased Erosion) | N/A | N/A | 40.88 | N/A | N/A | N/A |

# Phase III PRA Outputs (DRAFT)

| Quantification Description | ΔCDF (/Yr) (No Credit for Op Actions) | ΔCDF (/Yr) (Credit for Op Actions) |
|---|---|---|
| Baseline (3B000) | 6.6E-10 | 3.9E-10 |
| CASA Grande Lognormal Initiating Event Frequencies (3B000-L) | 4.5E-10 | 2.6E-10 |
| System Bottom-Up Initiating Event Frequencies (3B000-B) | 6.0E-10 | 3.5E-10 |
| Transport Time (3S001) | 6.6E-10 | 3.9E-10 |
| Cumulative Effects (3S002) | 1.9E-08 | 2.8E-09 |
| One Pump Out-of-Service – HPCS (3S003-A) | 6.6E-10 | 3.9E-10 |
| One Pump Out-of-Service – RHR (3S003-B) | 6.6E-10 | 3.9E-10 |
| Two Pumps Out-of-Service – HPCS & RHR (3S003-C) | 6.6E-10 | 3.9E-10 |
| NUREG/CR-6224 Head Loss – A (3S301-A) | (under development) | (under development) |
| NUREG/CR-6224 Head Loss – B (3S301-B) | 1.2E-08 | 1.5E-09 |
| Threshold Bed Failure (3S302) | (under development) | (under development) |
| 5% of Latent Inventory Fiber (3S605) | 6.8E-10 | 4.0E-10 |
| 10% of Latent Inventory Fiber (3S610) | 7.1E-10 | 4.2E-10 |
| 15% of Latent Inventory Fiber (3S615) | 7.5E-10 | 4.5E-10 |
| 10% ZOI Increase (3S700) | 1.3E-8 | 2.0E-9 |
| Break Dependent Qualified Coatings (3S800) | 6.4E-10 | 3.8E-10 |
| Debris Erosion (3S900) | 9.1E-10 | 5.4E-10 |