Southern Nuclear

NRC Public Meeting
Vogtle GSI-191 Resolution Plan and Current Status

November 29, 2016

Agenda

8:00 - Introductions and Opening Remarks
8:15 - Overall Schedule for Implementation
8:30 - Specific Technical Topics

- Hybrid LOCA frequency methodology sensitivity
- Credit for containment accident pressure
- Fiber quantity required for chemical head loss
- Partially submerged breaks

9:45 - Break
10:00 - SNC Submittal Table of Contents Overview
10:15 - Overview of Risk Quantification and Results

- PRA model/interface description
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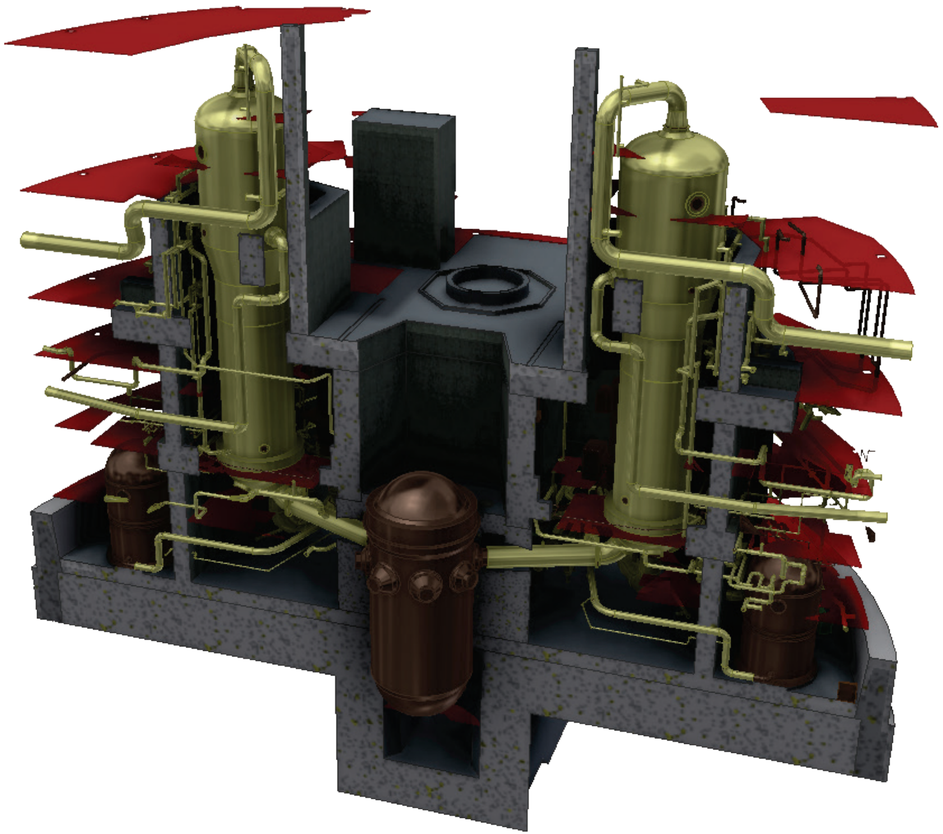
11:15 - Safety Margin vs. Operating Margin
11:30 - Method for Evaluating Plant Modifications
11:45 - Conclusions and Closing Remarks

Purpose of Meeting

- Obtain staff feedback on methods SNC is using to address specific technical issues (follow-up from earlier discussions)
- Provide preliminary information on layout and content of Vogtle license amendment request (SNC Submittal) submittal to help staff know what to expect and identify potential gaps
- Discuss timing of submittal relative to WCAP-17788 and South Texas Project (STP) risk-informed GSI-191 pilot project approvals

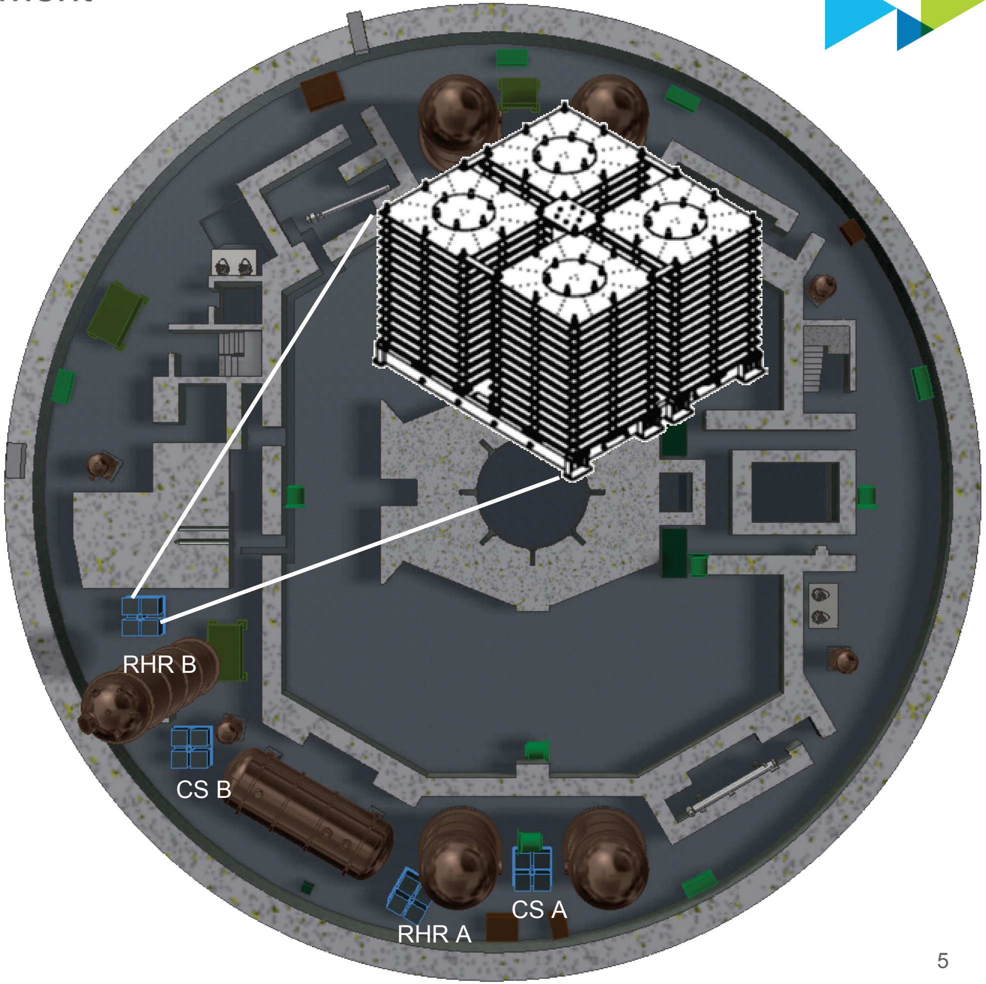
Background Information – Vogtle Plant Layout

- Westinghouse 4-loop PWR (3,626 MWt per unit)
- Large dry containment
- Two redundant ECCS and CS trains
  - Each train has an RHR pump, a high head pump, an intermediate head SI pump, and a CS pump
  - SI and high head pumps piggyback off of the RHR pump discharge during recirculation.
- Maximum design flow rates:
  - RHR 3,700 gpm/pump
  - CS 2,600 gpm/pump
- Two independent and redundant containment air cooling trains



Background Information – Strainer arrangement

- Two RHR and CS pumps each with their own strainer
- Each GE strainer is similar with four stacks of disks
  - RHR strainer (current): 18-disk tall, 765 ft^2, 4.9 ft tall
  - RHR strainer (modified): 16-disk tall, 677.6 ft^2, 4.4 ft tall
  - CS strainer: 14-disk tall, 590 ft^2, 4 ft tall
  - Perforated plate with 3/32” diameter holes



Background Information – Plant Response to LOCAs

- Plant response includes the following general actions:
  - Accumulators inject (breaks larger than 2 inches)
  - ECCS injection is initiated from the RWST to the cold legs via RHR, SI, and High Head pumps
  - Containment spray is initiated from the RWST via CS pumps
  - **Realignment of RHR pumps to cold leg recirculation begins at RWST low-low alarm**
  - CS pumps switched to recirculation at RWST empty alarm
  - CS pumps secured no earlier than 1.5 hours after start of recirculation, and probably before 6 hours depending on pressure and dose rate
  - RHR pumps switched to hot leg recirculation at 7.5 hours

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Schedule Update – Original Milestones Identified in May 2013 Letter

Milestone	Expected Completion Date	Current Status
Develop containment CAD model to include pipe welds	Complete	Complete
Conduct meeting with NRC	3rd Quarter 2013	Complete
Modify probabilistic risk assessment (PRA) to include Strainer and Core Blockage events	4th Quarter 2013	Complete
Perform Chemical Effects testing	1st Quarter 2014	Complete
Perform thermal and hydraulic modeling of RCS, Core, and Containment conditions	1st Quarter 2014	Complete
Perform Strainer Head Loss and Bypass testing to establish correlation for range of break sizes	2nd Quarter 2014	Complete[1]
Assemble base inputs for CASA Grande	2nd Quarter 2014	Complete[2]
Evaluate Boric Acid Precipitation impacts	3rd Quarter 2015	Complete[3]
Finalize inputs to CASA Grande	3rd Quarter 2015	Complete[2]
Complete Sensitivity Analyses in/for CASA Grande	4th Quarter 2015	Complete[2]
Integrate CASA Grande results into PRA to determine ΔCDF and ΔLERF	1st Quarter 2016	Complete[2]
Licensing Submittal for VEGP	To be established through discussions with NRC – tentatively September 2016	Projected 1st Quarter 2017[4]

[1] Using 2009 Vogtle test results for strainer head loss.
[2] Using NARWHAL instead of CASA Grande.
[3] Using PWROG WCAP-17788.
[4] Prior to SE on STP Pilot Project or SE on WCAP-17788.

Schedule Update

Milestone	Expected Completion Date
Draft of Full Submittal	11/11/2016 (actual)
SNC Review Process Complete	February 2017
Issue Vogtle Submittal to NRC *Includes Containment Sump TS similar to Traveler being developed by PWROG	March 2017
NRC Issues STP SE	April 2017[1]
NRC Acceptance Review	June 2017
NRC Issues WCAP-17788 SE[2]	Fall 2017[1]
NRC SE with LAR Approval	June 2018
Vogtle Unit 1 Outage – RHR Strainer Modifications	Fall 2018
Vogtle Unit 2 Outage – RHR Strainer Modifications	Spring 2019

[1] Estimated.
[2] WCAP-17788 is referenced in Vogtle submittal.
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Hybrid LOCA Frequency Methodology Sensitivity

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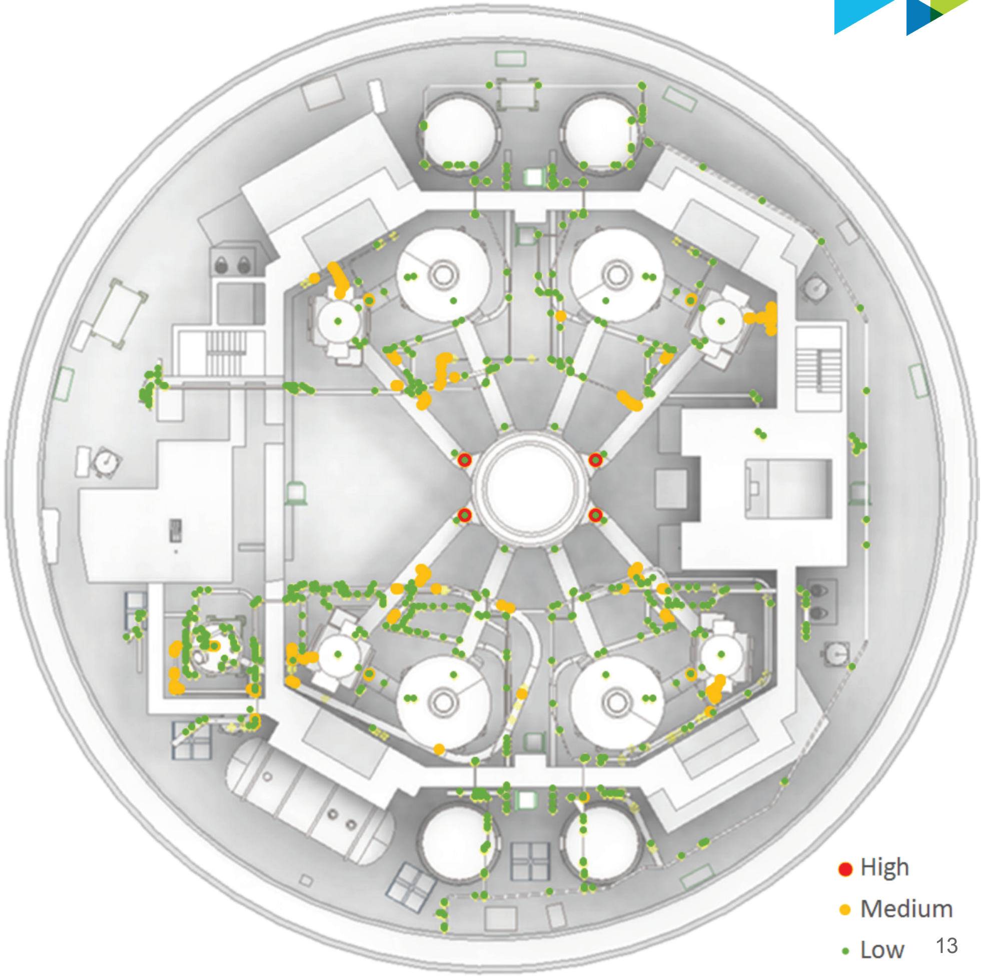
- Using top-down methodology for risk quantification (base case for GSI-191)
- Using hybrid methodology sensitivity (three cases) to quantify uncertainty associated with top-down methodology
- Analyzed welds within Class 1 pressure boundary
- Degradation mechanisms (DMs) for each weld determined based on ISI program
  - Design and construction (D&C) defects (applies to all welds)
  - Thermal fatigue (TF)
  - Vibration fatigue (VF)
  - Intergranular stress corrosion cracking (IGSCC)
  - Primary water stress corrosion cracking (PWSCC) (most welds exposed to PWSCC at Vogtle have been mitigated)

Hybrid LOCA Frequency Methodology Sensitivity

- Each weld ranked as high, medium, or low failure probability based on DM
  - D&C only exposure classified as low rupture probability
  - PWSCC exposure classified as high rupture probability
  - Exposure to any other DM (TF, VF, or IGSCC) classified as medium rupture probability
- Probability weights assigned with a difference of two orders of magnitude to maximize effects of sensitivity analysis
  - High = probability weight of 10,000
  - Medium = probability weight of 100
  - Low = probability weight of 1



Hybrid LOCA Frequency Methodology Sensitivity

- Three sensitivities cases evaluated
  - Sensitivity 1 used weighting described on previous slide
  - Sensitivity 2 assumed high rupture probability welds are no more likely than medium rupture probability welds
  - Sensitivity 3 assumed high and medium rupture probability welds are no more likely than low rupture probability welds (i.e., all welds treated equally, which is equivalent to the top-down approach)
- Results from the three sensitivity cases are dependent on which weld category has the most GSI-191 failures

Hybrid LOCA Frequency Methodology Sensitivity

Equipment Configuration	Base Case	Sensitivity 1	Sensitivity 2	Sensitivity 3
LBLOCA CFP (No pump failures)	0.0117	1.64E-05	0.00145	0.0117
LBLOCA CFP (2 CS pump failures)	0.0177	2.47E-05	0.00219	0.0177
LBLOCA CFP (1 train failure)	0.0673	4.95E-04	0.0141	0.0673
ΔCDF	**2.44E-08**	**4.83E-11**	**3.22E-09**	**2.44E-08**

Results show:

- Low rupture probability welds have highest GSI-191 failure probability
- High rupture probability welds have lowest GSI-191 failure probability
- Top-down approach is conservative for Vogtle

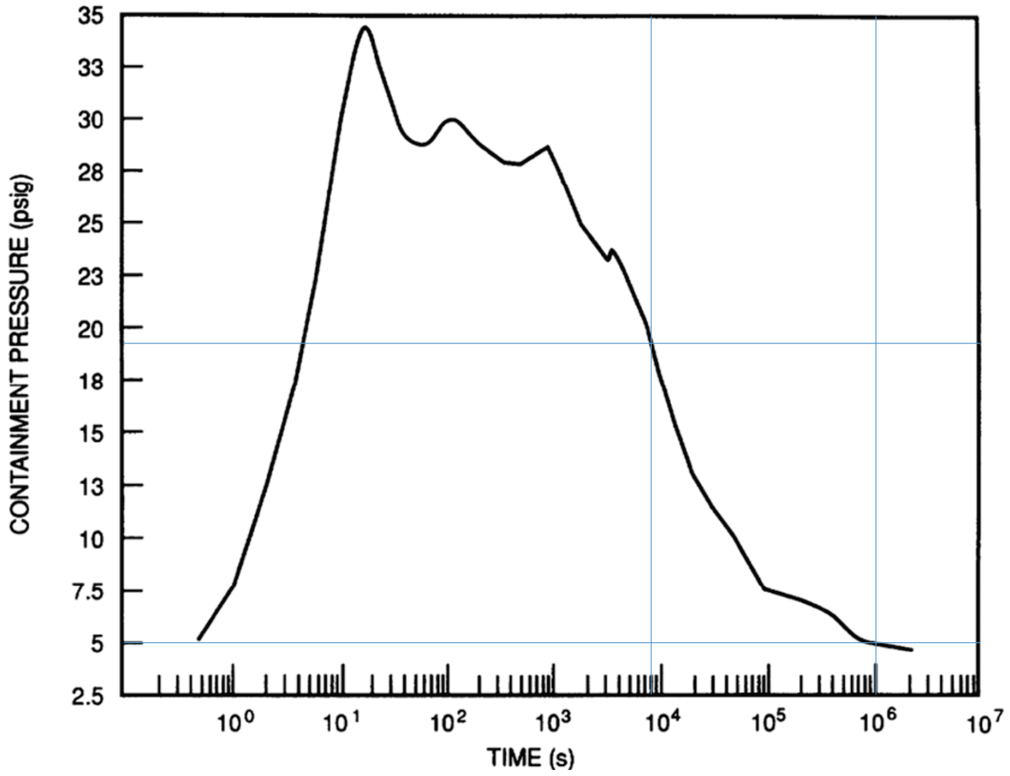
Credit for Containment Accident Pressure

Credit for Containment Accident Pressure

- No accident pressure credited for pump NPSH margin
  - Assuming vapor pressure when sump temperature above 210.96 °F
  - Assuming -0.3 psig (TS minimum) when sump temperature below 210.96 °F
- Accident pressure is credited for degasification and flashing
  - 2.5 psi credited to limit degasification
  - Approximately 3.5 psi credited to prevent flashing failures

Credit for Containment Accident Pressure

- Pool temperature near or above 210.96 °F for approximately first 120 minutes
- Containment pressure above 19 psig for first 133 minutes (8,000 seconds)
- Containment pressure above 5 psig for first 11.5 days (10^6 seconds)
- Never drops below 4.5 psig within 30-day mission time

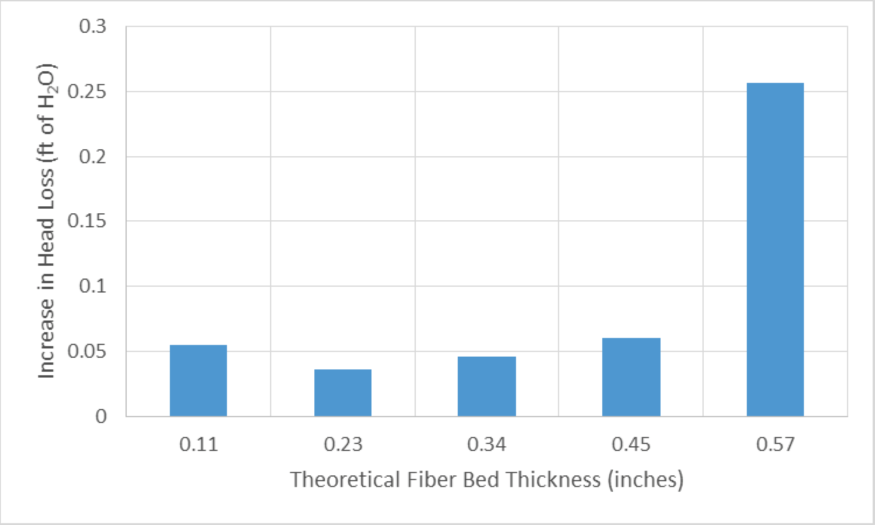


Containment pressure with maximum safety injection

Fiber Quantity Required for Chemical Head Loss

Fiber Quantity Required for Chemical Head Loss

- Chemical head loss not applied until a filtering fiber bed accumulates over entire strainer
- Test results show that this filtering fiber bed is greater than 0.45 inches
- Maximum head loss for each type of precipitate applied with fiber bed >0.45 inches and any chemical precipitate
  - Calcium phosphate starts precipitating immediately for all breaks
  - Sodium aluminum silicate (SAS) precipitates no later than 24 hours for all breaks
- Head loss extrapolation is based on test results for chemical head loss and is therefore only applied if criteria for applying chemical head loss are met



Fiber Quantity Required for Chemical Head Loss

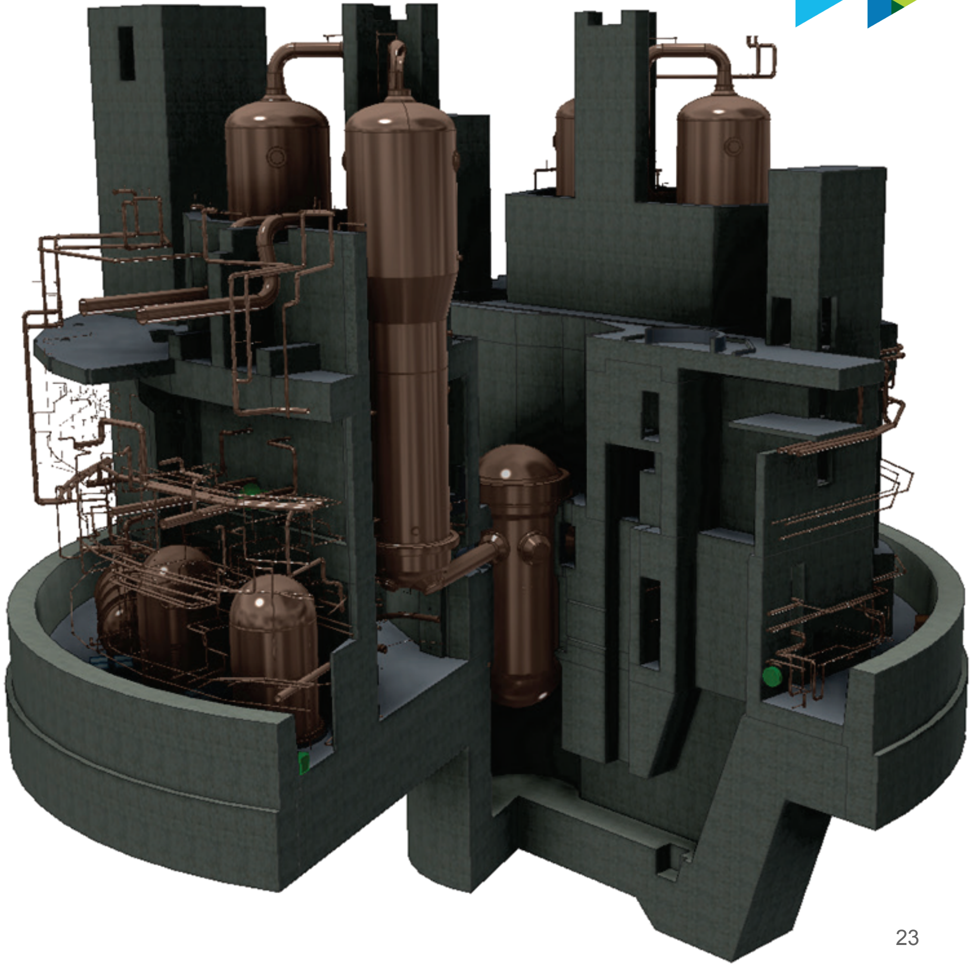
Debris	Fiber[1]	Calcium Phosphate	SAS	Head Loss Contribution
Conventional Debris	≤3.1 ft^3	N/A	N/A	0.625 ft
	>3.1 ft^3	N/A	N/A	5.46 ft
Calcium Phosphate Debris	≤2.483 ft^3	≥0 lb_m	N/A	0 ft
	>2.483 ft^3	0 lb_m	N/A	0 ft
		>0 lb_m	N/A	1.11 ft
Sodium Aluminum Silicate Debris	≤2.483 ft^3	N/A	≥0 lb_m	0 ft
	>2.483 ft^3	N/A	0 lb_m	0 ft
		N/A	>0 lb_m	5.24 ft
Extrapolation Constant	≤2.483 ft^3	≥0 lb_m	N/A	0 ft
	>2.483 ft^3	≥0 lb_m	N/A	3.89 ft
Maximum Total	>3.1 ft^3	>0 lb_m	>0 lb_m	15.7 ft

[1] Fiber debris quantities and headloss at test conditions and scale with 65.57 ft^2 test strainer.

Partially Submerged Breaks

Partially Submerged Breaks

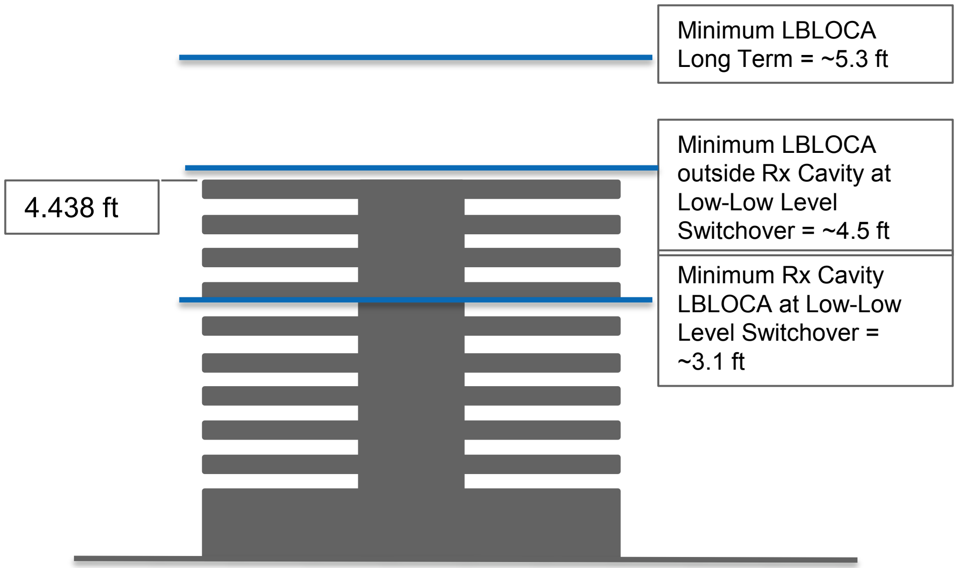
- With plant modifications to refueling water storage tank (RWST) switchover procedure and RHR strainer height, all breaks will have a fully submerged strainer when RWST injection is complete
- Valve to RHR strainers is automatically opened at low-low level alarm (valve to RWST closed at empty level alarm)
- CS pumps switched over to recirculation at empty level alarm
- Strainers are fully submerged when flow through RHR strainers begins for all breaks with the exception of large reactor cavity breaks with high pressure that initiate containment sprays
- Strainers are fully submerged for all breaks by the time the RWST reaches the empty level



- Limited scenarios where RHR strainers partially submerged
  - Large breaks in Rx cavity that initiate CS
  - Strainers fully submerged approximately 6-11 minutes after flow through RHR strainers begins
  - Pool level ≥ 5 ft when RHR and CS pump suction from RWST is isolated

Modified RHR Strainer

All heights are measured from floor



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SNC Submittal Table of Contents Overview

- Enclosure 1
  - Provides a **high level overview** of all enclosures
  - Organized with same layout as draft RG 1.229 Section C
- Enclosure 2
  - Provides a detailed description of plant-specific GSI-191 models (including proprietary information and affidavits for withholding proprietary information)
  - Organized in accordance with the content guideline for **GL 2004-02 responses**
  - Includes responses to previous Vogtle GSI-191 RAIs
  - Primarily intended for NRC reviewers with expertise in GSI-191
- Enclosure 3
  - Description of **risk quantification** using NARWHAL and the Vogtle GSI-191 PRA model
  - Organized with same layout as draft RG 1.229 Appendix A
  - Describes how all of the individual parts are combined to quantify risk
  - Primarily intended for NRC reviewers with expertise in PRA

SNC Submittal Table of Contents Overview

- Enclosure 4
  - Provides a summary of **defense-in-depth and safety margin**
  - Shows that health and safety of the public are not adversely affected by potential debris-related failures
- Enclosure 5
  - Provides a **request for exemptions** to specific requirements in 10 CFR 50.46(a)(1), General Design Criterion (GDC) 35, GDC 38, and GDC 41 to allow Vogtle to use a risk-informed approach
- Enclosure 6
  - Provides a license amendment request (**LAR**) requesting approval to change Vogtle’s licensing basis to support risk-informed resolution of GSI-191
  - Includes FSAR markup
  - Includes TS changes
    - **RWST water level surveillance (reduces minimum water level by 2% for 7 days)**
    - **Containment Sump (allows 90 days to evaluate discovered conditions)**
- Enclosure 7
  - Duplicate of Enclosure 2 with **proprietary information redacted** for public release

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PRA Model/Interface Description

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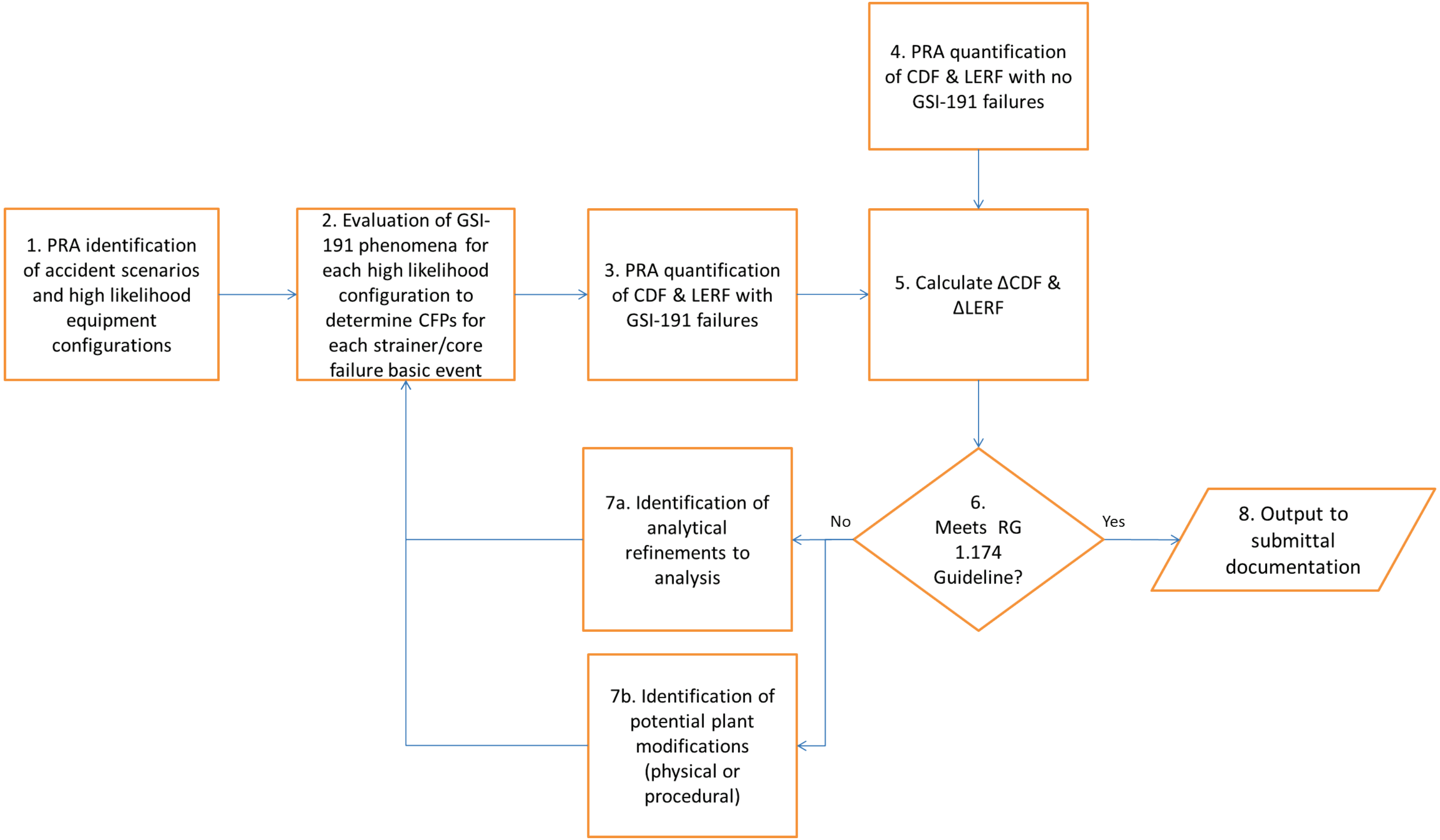
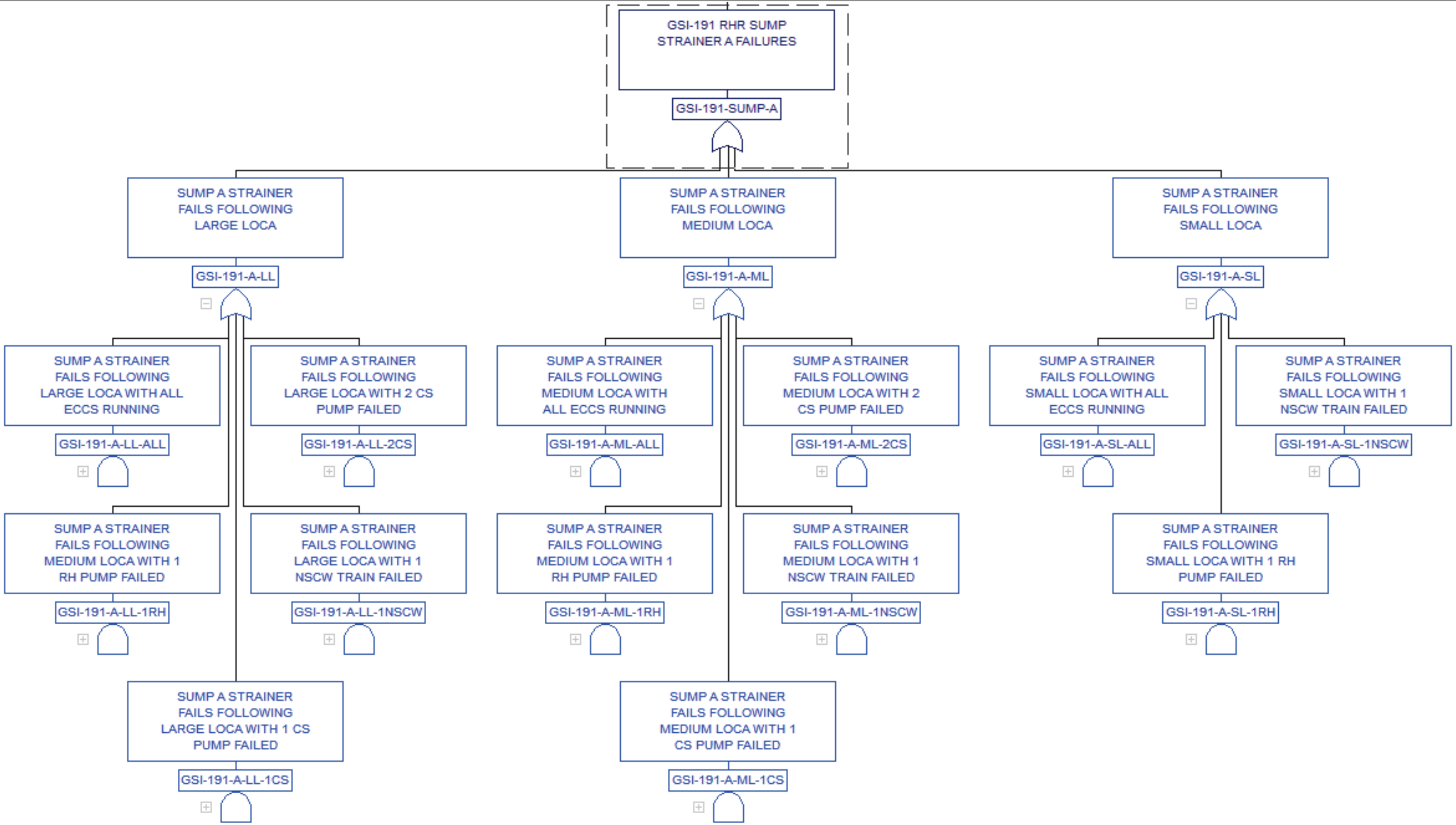
- Current Vogtle model of record for internal events modified for GSI-191 evaluation (GSI-191 PRA model)
- GSI-191 conditional failure probabilities calculated using NARWHAL software for each equipment configuration
- NARWHAL results entered in GSI-191 PRA model to calculate ΔCDF and ΔLERF

PRA Model/Interface Description



PRA Model/Interface Description – PRA Model Changes



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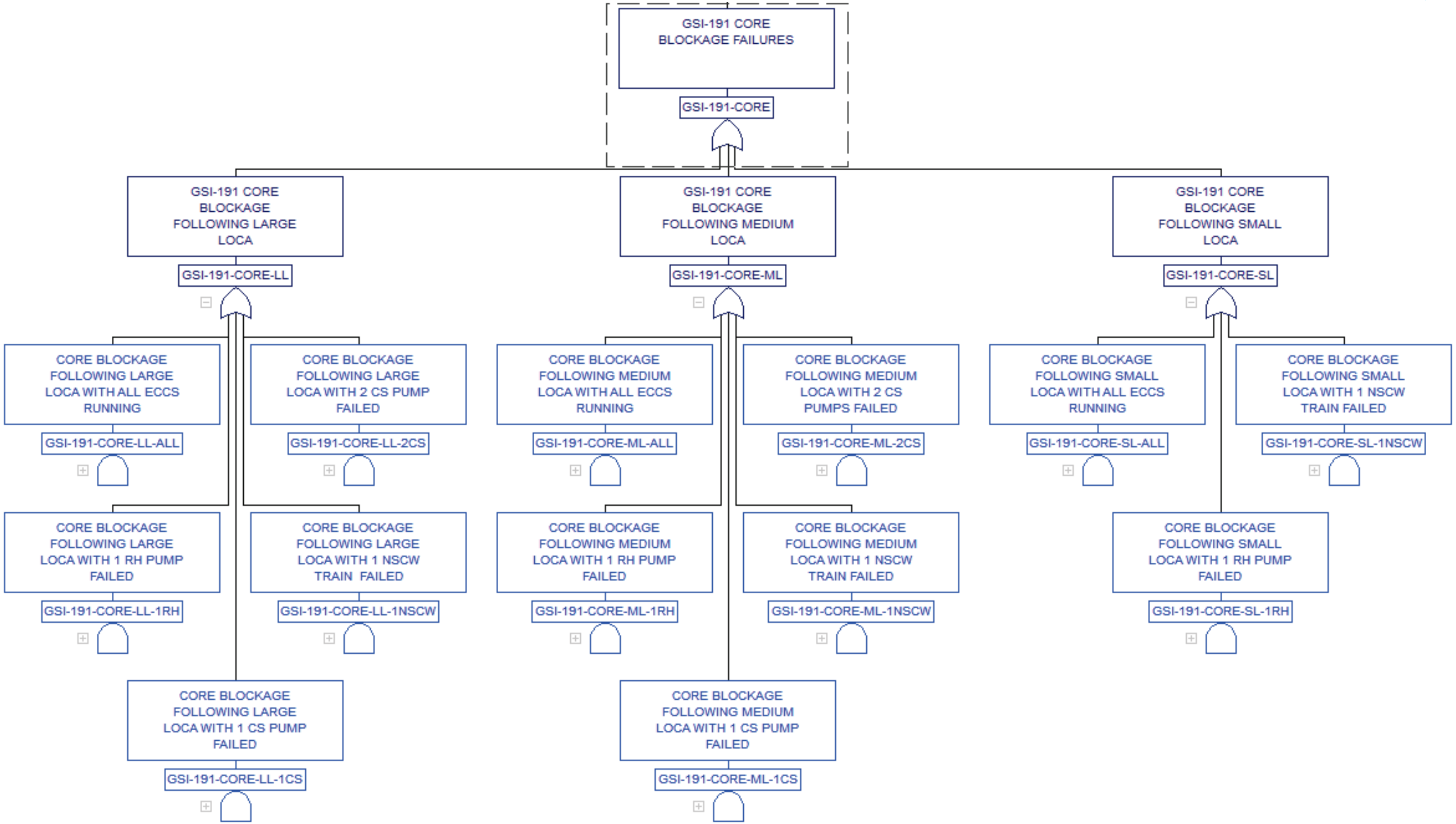
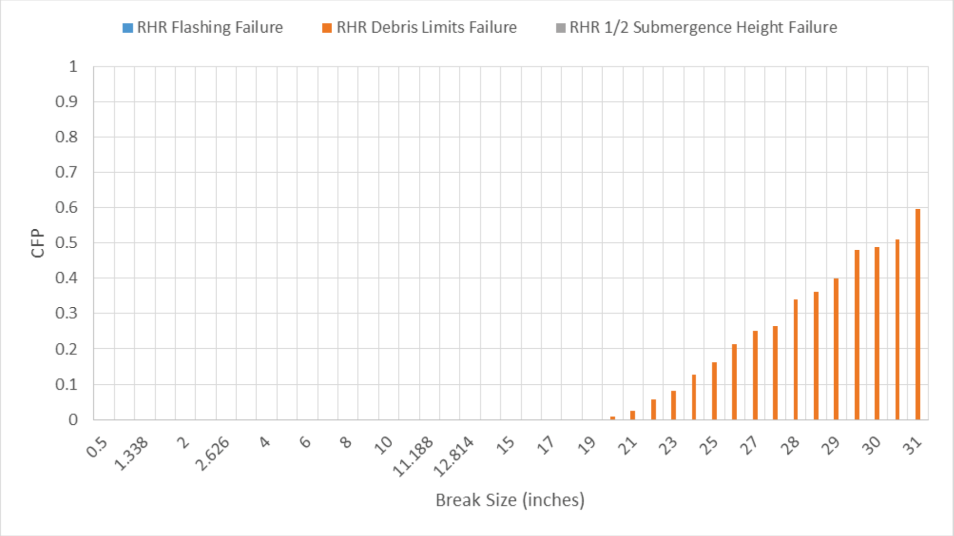


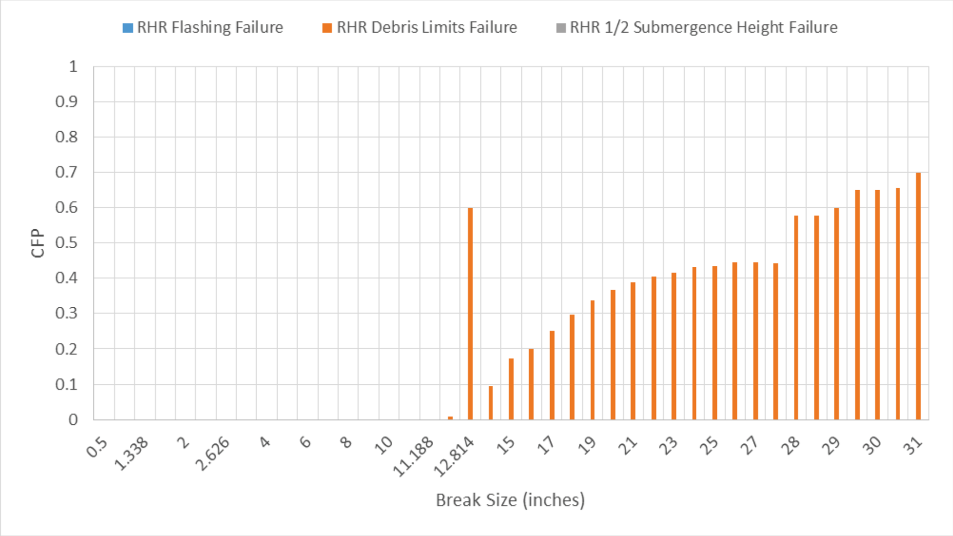
Risk Quantification Results

Risk Quantification Results

- Breaks postulated at all Class 1 ISI welds inside first isolation valve
- Over 27,000 breaks evaluated including ½-inch breaks up to DEGBs on every weld
- Smallest break size that fails is a 20-inch partial break when all equipment is available and a 12-inch partial break for any equipment configuration (single train failure)
- 36 welds had at least one break assigned to failure when all equipment was available (48 welds for single train operation)
- Failure mode was due to an RHR strainer debris limit (fiber and/or chemical precipitate)
- No core failures were predicted

Risk Quantification Results

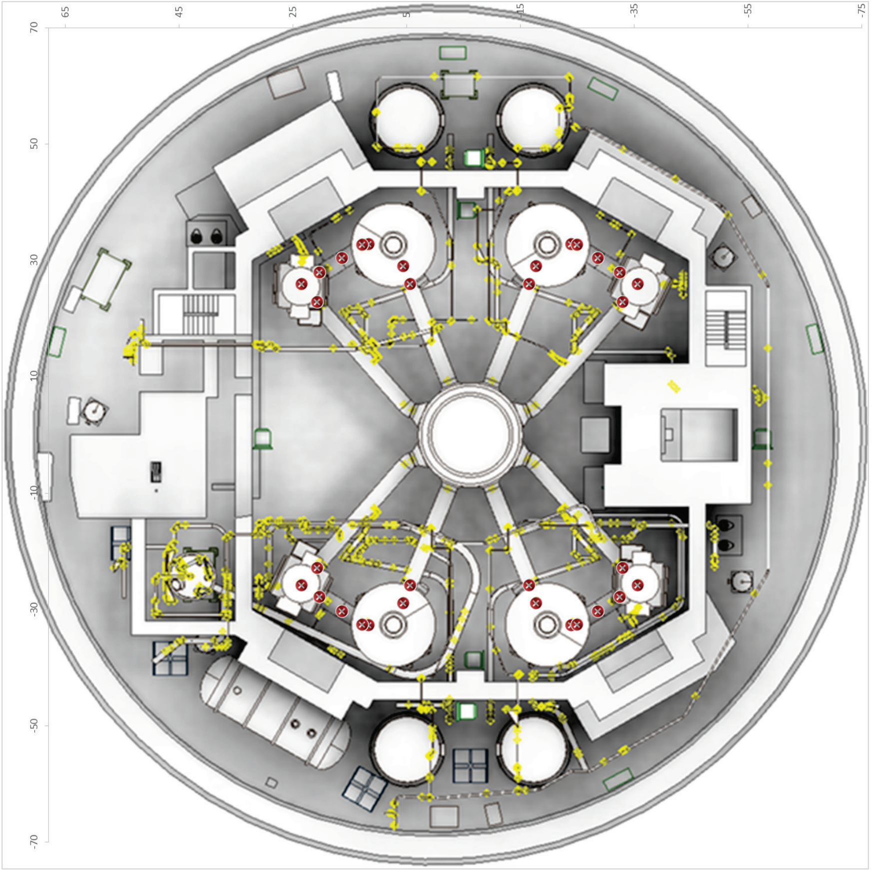




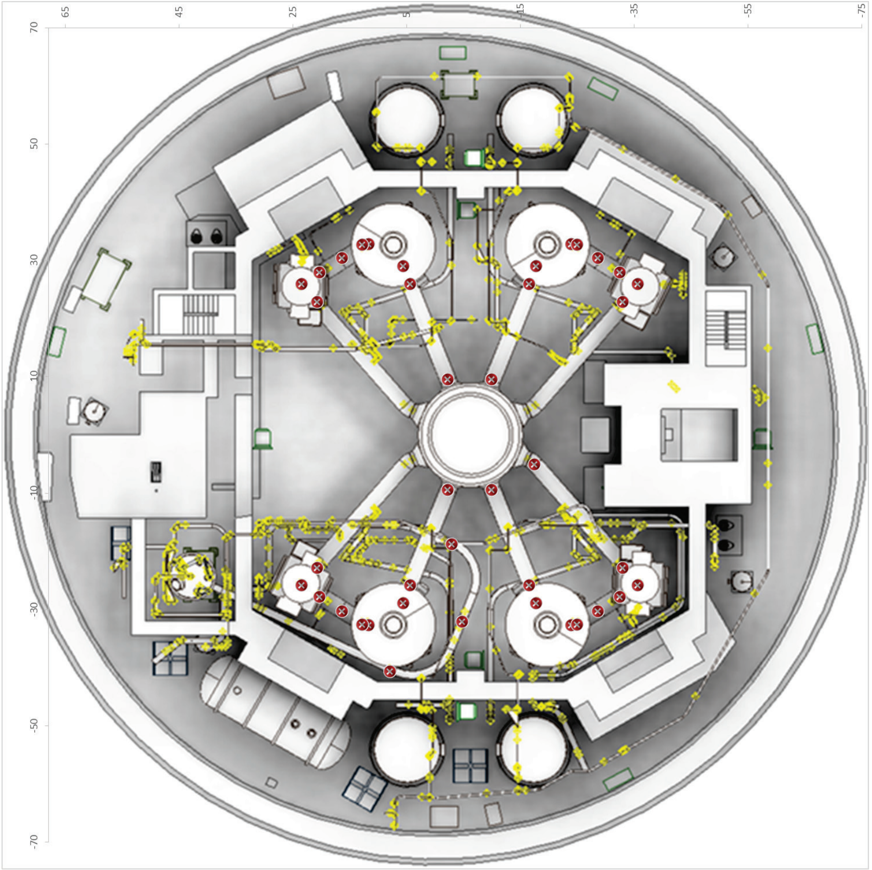
Break sizes with failures (all equipment available)

Break sizes with failures (single train failure)

Risk Quantification Results



36 welds with failures (all equipment available)



48 welds with failures (single train failure)

Risk Quantification Results

Conditional failure probabilities (CFPs) for Pipe break large LOCA initiating event scenarios

Equipment Configuration	Core	Strainer A and B	Strainer A Only	Strainer B Only
No Equipment Failure	0	0.0117	0	0
RHR Pump B Failure	0	N/A	0.0615	N/A
Charging Pump B Failure	0	0.0117	0	0
SI Pump B Failure	0	0.0117	0	0
Train B (ECCS and CS) Failure	0	N/A	0.0673	N/A
CS Pump B Failure	0	0.0139	0	0
Both CS Pumps Failure	0	0.0177	0	0

Risk Quantification Results - Secondary Side Breaks

- Secondary side breaks inside containment (SSBI) were evaluated in a manner similar to primary side breaks with the following exceptions:
  - Breaks evaluated in approximately 5 ft intervals on main steam and feedwater piping
  - All breaks assumed to be DEGBs
  - Smaller ZOI sizes due to reduced pressure and temperature
  - Lower emergency core cooling system (ECCS) flow rate
  - Containment spray assumed to initiate for all breaks
- PRA model accounts for SSBI initiating event frequency and low probability failure sequences that would lead to ECCS recirculation (e.g., failure to terminate safety injection or a stuck open PORV)

Risk Quantification Results - Secondary Side Breaks

CFPs for SSBI - feedwater line break initiating events

Equipment Configuration	Core	Strainer A and B	Strainer A Only	Strainer B Only
No Equipment Failure	0	0	0	0
Charging Pump B Failure	0	N/A	0	N/A
CS Pump B Failure	0	0	0	0
Both CS Pumps Failure	0	0	0	0

Risk Quantification Results - Secondary Side Breaks

CFPs for SSBI - main steam line break initiating events

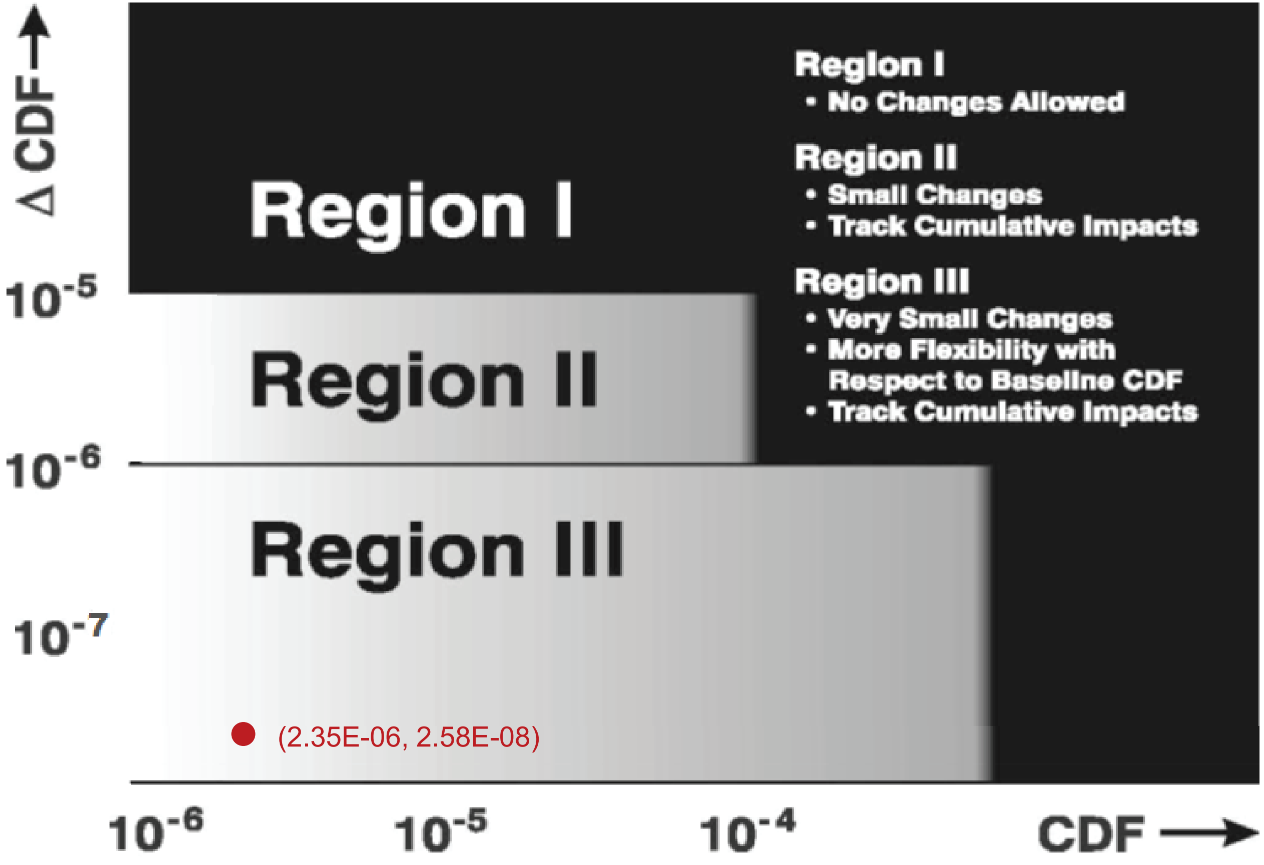
Equipment Configuration	Core	Strainer A and B	Strainer A Only	Strainer B Only
No Equipment Failure	0	0	0	0
Charging Pump B Failure	0	N/A	0	N/A
CS Pump B Failure	0	0	0	0
Both CS Pumps Failure	0	0.475	0	0

Risk Quantification Results

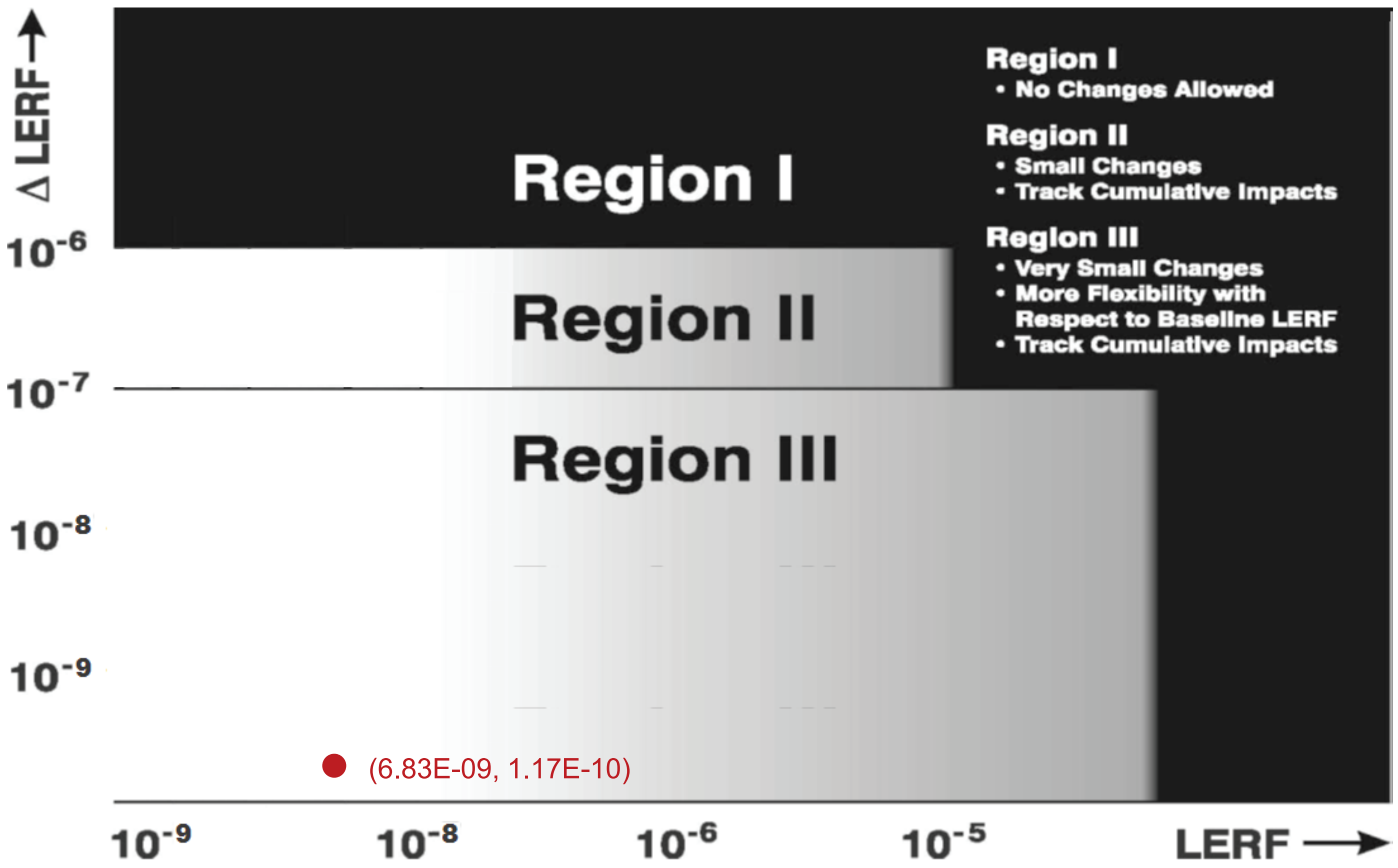
- Baseline risk from GSI-191 PRA model
  - CDF = 2.35E-06/reactor-year
  - LERF = 6.83E-09/reactor-year

Equipment Configuration	ΔCDF (ry^{-1})	ΔLERF (ry^{-1})
Risk increase from GSI-191 failures for high-likelihood LOCA configurations	2.30E-08	3.06E-11
Bounding risk increase from GSI-191 failures for unlikely LOCA configurations	1.40E-09	4.06E-12
Risk increase from GSI-191 failures for SSBIs	1.39E-09	8.25E-11
Total risk increase associated with GSI-191	**2.58E-08**	**1.17E-10**

Risk Quantification Results



RISK Quantification Results

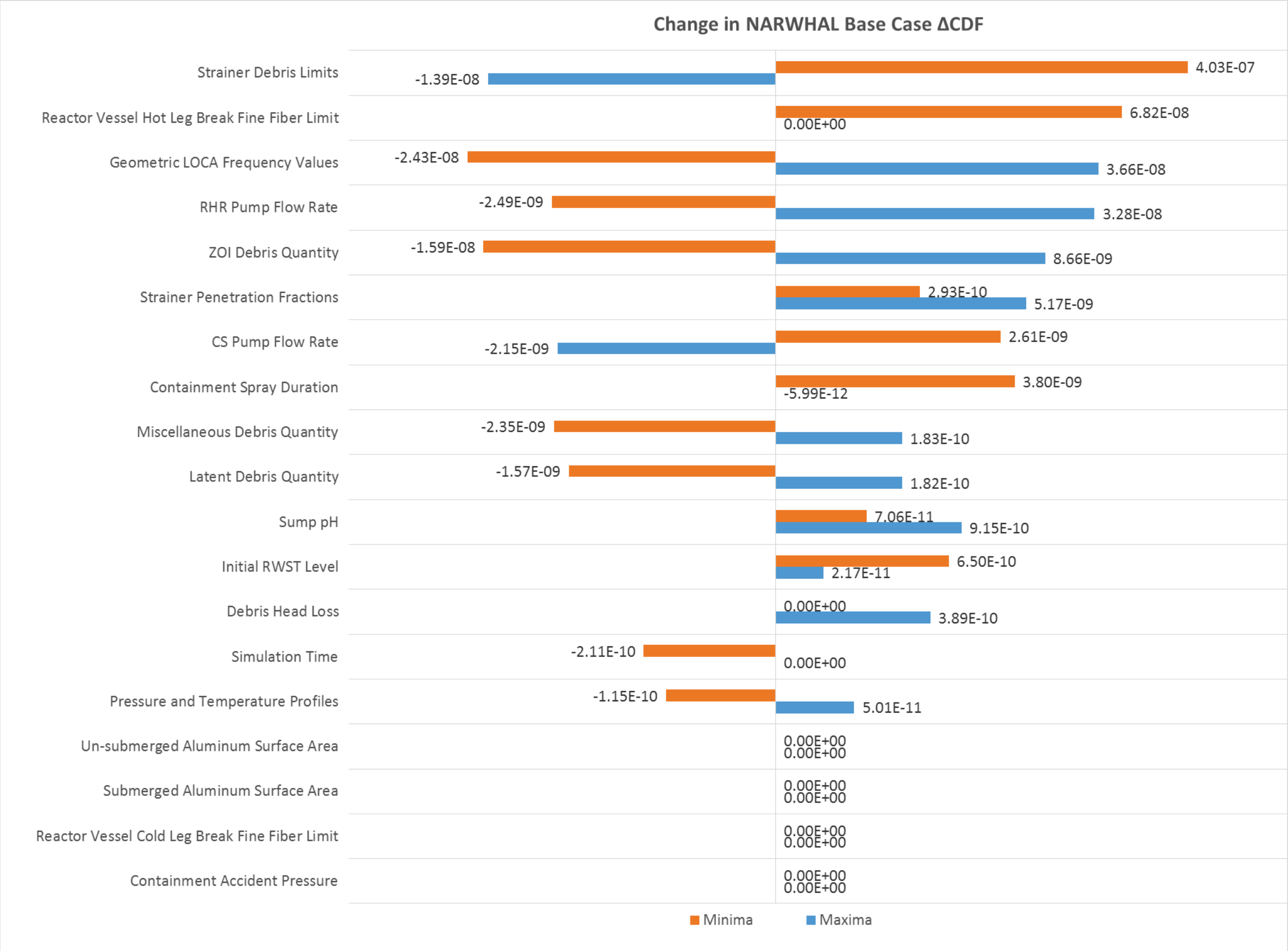


Sensitivity Analysis Results

Sensitivity Analysis Results

- Varied one parameter at a time
- Consistent methodology used to select minimum and maximum values for each parameter
  - Nominal defined as value used in base case NARWHAL model
  - If nominal value was skewed in conservative direction, minimum [maximum] value was assumed to be 10% lower [higher] than the nominal value
  - For all other cases, the minimum and maximum values were determined by the available information (design limits preferentially used if available, or minimum/maximum values from analytical ranges)
  - If no information was available for the range of a given input, then the minimum [maximum] value was assumed to be 25% lower [higher] than the nominal value
- Results were used to rank the sensitivity for each input parameter using a tornado diagram

Sensitivity Analysis Results



Uncertainty Quantification Results

Uncertainty quantification Results

- Uncertainty quantification includes parametric uncertainty and model uncertainty
- Parametric uncertainty addressed in a bounding manner by simultaneously varying all parameters in the conservative direction (multiple simulations run to determine worst case conditions for both the strainers and the core)
- Model uncertainty addressed by postulating alternate models for each model where no consensus exists

Uncertainty Quantification results

Strainer Failure Cases (2x2 Matrix)

- Water volume
  - Min (equivalent to base case)
  - Max (~500,000 lb_m additional water)
- Max RHR flow rate (4,500 gpm)
- Min CS flow rate (1,950 gpm)
- CS duration
  - Min (120 minutes)
  - Max (30 days)
- Min Penetration (0%)
- Max LOCA frequency (95th percentile)

Core Failure Cases (2x2 Matrix)

- Water volume
  - Min (equivalent to base case)
  - Max (~500,000 lb_m additional water)
- RHR flow rate
  - Min (2,775 gpm)
  - Max (4,500 gpm)
- Min CS flow rate (1,950 gpm)
- Max hot leg switchover (HLSO) time (563 minutes)
- Min CS duration (120 minutes)
- Max LOCA frequency (95th percentile)

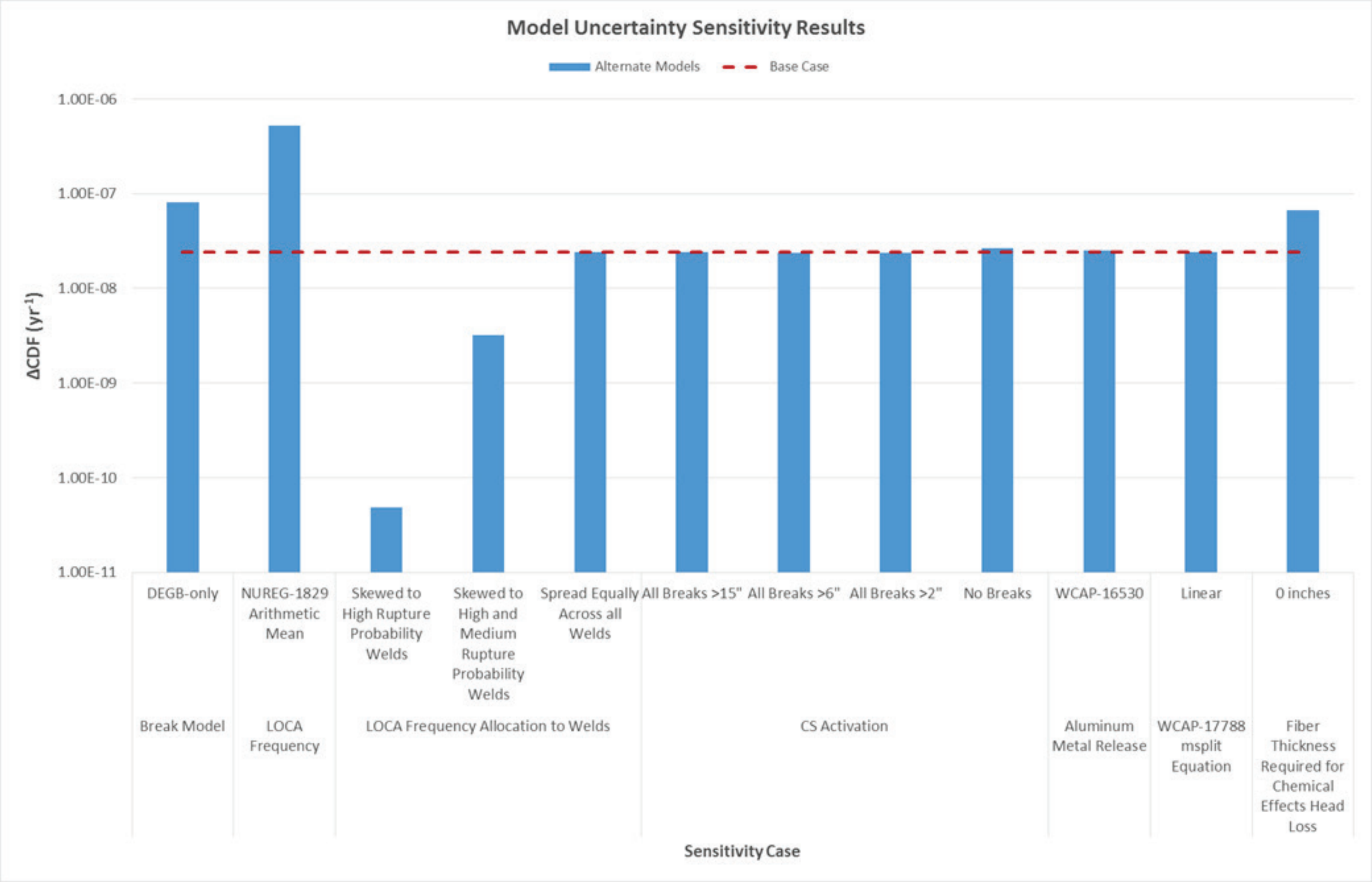
Uncertainty Quantification results

Sensitivity Case	Description	ΔCDF
Strainer Case 1	Min water volume and min CS duration	1.21E-07
Strainer Case 2	Min water volume and max CS duration	1.21E-07
Strainer Case 3	Max water volume and min CS duration	1.16E-07
Strainer Case 4	Max water volume and max CS duration	1.16E-07
Core Case 1	Min water volume and min RHR flow rate	6.95E-08
Core Case 2	Min water volume and max RHR flow rate	1.14E-07
Core Case 3	Max water volume and min RHR flow rate	7.06E-08
Core Case 4	Max water volume and max RHR flow rate	1.09E-07

Uncertainty Quantification results

- The following model comparisons were evaluated to quantify uncertainty
  - Break model (continuum vs. DEGB-only)
  - LOCA frequencies (geometric mean vs. arithmetic mean)
  - LOCA frequency allocation (top-down vs. hybrid)
  - CS actuation (hot leg breaks larger than 15 inches vs. multiple options including no breaks and all breaks larger than 2 inches)
  - Aluminum metal release equation (UNM vs. WCAP-16530)
  - WCAP-17788 m_{split} equation (logarithmic fit vs. linear fit)
  - Fiber bed thickness required for chemical head loss (0.45 inches vs. 0 inches)

Uncertainty Quantification results



Risk Results Summary

Results Summary

- ΔCDF and ΔLERF are both well below the RG 1.174 Region III thresholds for defining the effects of debris as very low risk
- Sensitivity analysis showed that the results are most sensitive to the following top five parameters (in order of importance):
  - Strainer debris limits
  - Reactor vessel hot leg break fiber limit
  - LOCA frequency values
  - RHR pump flow rate
  - ZOI debris quantity
- Uncertainty quantification showed that there is high confidence that the risk is very low
  - Parametric evaluation showed that even with the worst case values for each input parameter, risk is still in Region III
  - Model uncertainty quantification showed that even with alternative models, risk is still in Region III

Agenda

8:00 - Introductions and Opening Remarks
8:15 - Overall Schedule for Implementation
8:30 - Specific Technical Topics

- Hybrid LOCA frequency methodology sensitivity
- Credit for containment accident pressure
- Fiber quantity required for chemical head loss
- Partially submerged breaks

9:45 - Break
10:00 - SNC Submittal Table of Contents Overview
10:15 - Overview of Risk Quantification and Results

- PRA model/interface description
- Risk quantification, sensitivity, and uncertainty quantification results

11:15 - Safety Margin vs. Operating Margin
11:30 - Method for Evaluating Plant Modifications
11:45 - Conclusions and Closing Remarks

Safety Margin Vs. Operating Margin

- Safety margin is defined as the response to the question, “What aspects of the analysis increase confidence that a declared success is a success?”
- Numerous conservatisms are used throughout the risk-informed GSI-191 evaluation
- Some conservatisms are used for operating margin to allow for future design changes, etc.
- Some conservatisms are used for safety margin to provide confidence that the risk is not underestimated
- Safety margin built in throughout analysis (see backup slides)

Operating Margin Examples

Item	Actual Value	Value Used	Operating Margin
Unqualified epoxy coatings	2,700.6 lb_m	2,729 lb_m	28.4 lb_m
Unqualified alkyd coatings	30.6 lb_m	59 lb_m	28.4 lb_m
Unqualified IOZ coatings	27.6 lb_m	56 lb_m	28.4 lb_m
Latent debris	60 lb_m	200 lb_m	140 lb_m
Miscellaneous debris	4 ft^2	50 ft^2	46 ft^2
Unsubmerged aluminum metal	741.3 ft^2	926.6 ft^2	185.3 ft^2
Submerged aluminum metal	278.7 ft^2	348.4 ft^2	69.7 ft^2

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Method for Evaluating Plant Modifications

- Plant modifications that affect GSI-191 inputs will be evaluated as part of the modification process (including 50.59 screening)
  - If modification does not exceed operating margin values (i.e., input values used in NARWHAL base case), modification is acceptable
  - If modification does exceed operating margin values, GSI-191 risk will be re-quantified by running NARWHAL with new input values and calculating ΔCDF and ΔLERF using GSI-191 PRA model
    - If risk result is within NRC-approved limits (e.g., RG 1.174 Region III) and there is no reduction in safety margin or defense-in-depth, modification is acceptable (i.e., the change does not result in a "more than minimal" accident consequence)
    - If risk result exceeds NRC-approved limits and/or the modification affects safety margin or defense-in-depth, modification can only be made with a new license amendment
- Modifications that are acceptable without a license amendment will be documented and subject to the normal review process by NRC inspectors

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Schedule Update

Milestone	Expected Completion Date
Draft of Full Submittal	11/11/2016 (actual)
SNC Review Process Complete	February 2017
Issue Submittal to NRC	March 2017
NRC Issues STP SE	April 2017[1]
NRC Acceptance Review	June 2017
NRC Issues WCAP-17788 SE[2]	Fall 2017[1]
NRC SE with LAR Approval	June 2018
Vogtle Unit 1 Outage – RHR Strainer Modifications	Fall 2018
Vogtle Unit 2 Outage – RHR Strainer Modifications	Spring 2019

[1] Estimated.
[2] WCAP-17788 is referenced in Vogtle submittal.

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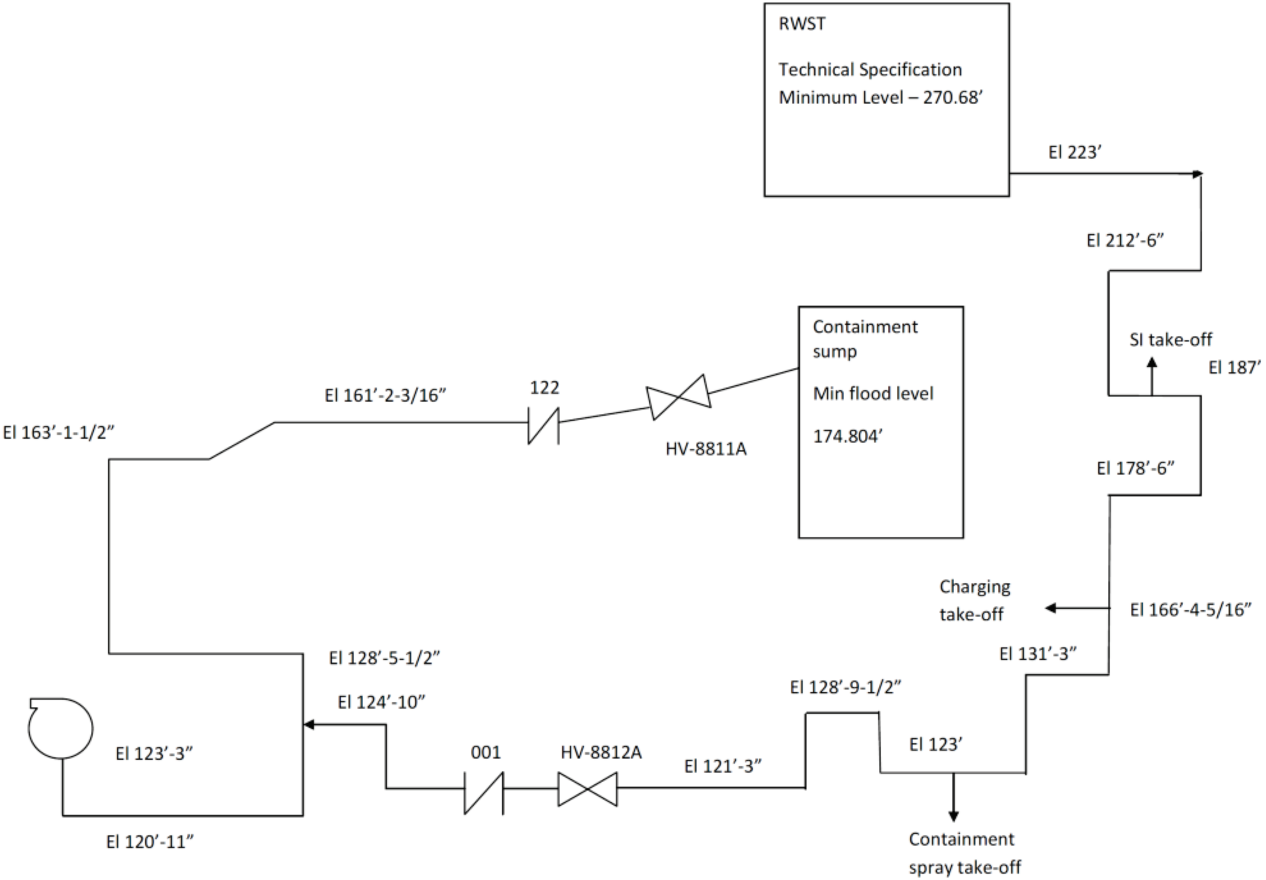
Purpose of Meeting

- Obtain staff feedback on methods SNC is using to address specific technical issues (follow-up from earlier discussions)
- Provide preliminary information on layout and content of Vogtle license amendment request (LAR) submittal to help staff know what to expect and identify potential gaps
- Discuss timing of submittal relative to WCAP-17788 and South Texas Project (STP) risk-informed GSI-191 pilot project approvals

Southern Nuclear

Backup Slides

RHR Pump Suction Flow Path Elevations

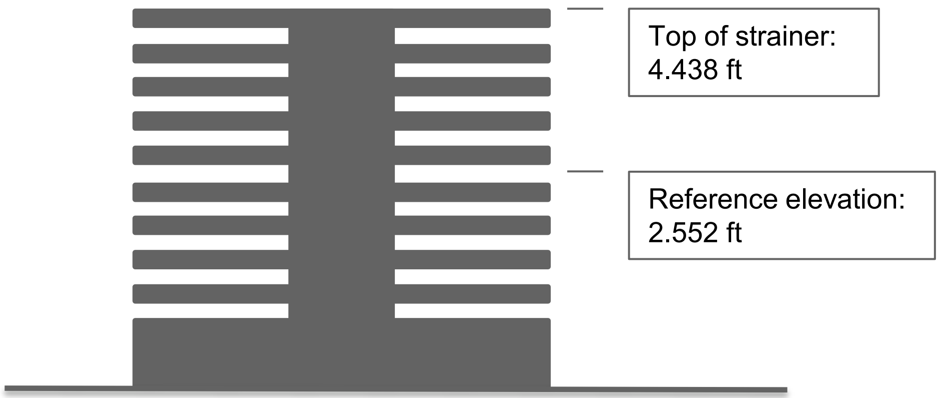


Credit for Containment Accident Pressure

- NARWHAL calculates flashing and degasification at a specific reference elevation (specified at strainer midpoint for Vogtle)
  - Gives average degasification assuming uniform flow across strainer height
  - Difference in hydrostatic head from top of strainer ~1 psi
  - 2.5 psi accident pressure credited gives total of ~3.5 psi credited for flashing at top of strainer

Modified RHR Strainer

All heights are measured from floor



Safety Margin

- All frequency associated with secondary side breaks is allocated to DEGBs
- Random pump failures are assumed to occur at switchover to recirculation
- Initial containment pressure is at technical specification (TS) minimum of -0.3 psig
- No credit taken for containment accident pressure in NPSH calculations and minimal credit taken for degasification and flashing calculations
- Design basis containment and sump temperature profiles used for all break sizes
- Large break flow rate used for all break sizes to calculate strainer head loss and NPSH margin
- With the exception of shadowing by concrete walls, no credit was taken for structures or restraints that would limit the quantity of debris generated within a break ZOI

Safety Margin

- 100% failure of unqualified coatings for all breaks
- Unqualified epoxy fails as 100% particulate
- Unqualified coatings fail at the start of the accident
- Maximum pH for chemical release and minimum pH for solubility
- No aluminum remains in solution after the solubility limit has been reached or 24 hours (whichever comes first)
- All insulation debris is assumed to be in the sump for the chemical release calculation
- Fine debris has a high condensate washdown fraction (10%) when sprays are not initiated
- Fine debris has a high spray washdown fraction (100%) when sprays are initiated
- Fine debris has a high recirculation transport fraction (100%) for all breaks
- Small and large pieces of fiberglass transport at the incipient tumbling velocity for the respective debris sizes

Safety Margin

- Small and large pieces of fiberglass debris have a high containment pool erosion fraction (10%)
- A strainer is assumed to fail any time the accumulated debris quantities exceed the tested debris quantities
- Miscellaneous debris (e.g., tags or labels) all transports to the strainers prior to any other debris and reduces the effective strainer area
- Debris head loss was conservatively calculated using a rule-based approach (i.e., if the accumulation of a given debris type exceeds a certain threshold, a bounding head loss is automatically applied)
- Strainer head loss testing was conservatively performed using a strainer module with fewer disks and scaled up to the full height strainers based on the area ratios
- Calcium phosphate head loss was applied for all breaks that generate and transport a sufficient quantity of fiber debris
- The chemical head loss was extrapolated to 30 days and the extrapolation constant was applied 450 minutes after the start of the event

Safety Margin

- Strainer failure is assumed in all cases where the head loss meets or exceeds the structural margin of the strainer
- All gas voids formed by degasification were assumed to transport to the pumps
- Pump NPSH required was adjusted for gas voids based on very conservative guidance
- The fiber penetration correlation ignores effects of fiber and particulate interactions and accumulation of pieces of fiberglass
- Maximum boil-off flow rate with additional 20% margin used to calculate debris accumulation on core inlet for cold leg breaks
- Fiber limits associated with core blockage and boron precipitation are based on bounding tests and analyses

Safety Margin – Example with Detailed Description

Topic	Conservatism Credited as Safety Margin	Realistic Conditions	Impact on Evaluation
Scenario Frequency	All frequency associated with secondary side breaks is allocated to DEGBs	Smaller breaks on main steam and feedwater piping are much more likely than DEGBs, and would generate significantly lower debris quantities	Overall likelihood of failure is over-predicted for secondary side breaks
Scenario Frequency	Random pump failures are assumed to occur at switchover to recirculation	Random pump failures can occur at the beginning of the event, at the start of recirculation or any time during the event	Failures at the start of the event would delay switchover to recirculation, failures later in the event would result in distribution of debris across more strainers
Thermal-Hydraulics	Initial containment pressure is at technical specification (TS) minimum of -0.3 psig	Containment pressure would be above TS minimum	NPSH margin is under-predicted and degasification and flashing are over-predicted
Thermal-Hydraulics	No credit taken for containment accident pressure in NPSH calculations and minimal credit taken for degasification and flashing calculations	The post-LOCA containment pressure would be significantly higher than the saturation pressure	NPSH margin is under-predicted and degasification and flashing are over-predicted