NRC Audit of NARWHAL Software

Additional Information to Address NRC Staff Questions Raised During Audit

August 11, 2016

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Outline

- Audit Summary
- Additional Information on NRC Staff Technical Questions
  - Strainer flashing failures
  - Fiber quantity required to filter particulate
  - Insulation size distribution methodology
  - Break size and orientation increments
  - LOCA frequency allocation methodology
  - DEGB-only vs. continuum break model
  - Analysis of breaks past first isolation valve
  - Random pump failure timing
  - Risk-contribution from secondary side breaks

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Audit Summary

- NRC audit conducted May 17-19, 2016 at ENERCON office in Albuquerque, NM
- Purpose of the audit was to review NARWHAL and BADGER software design and functionality in the context of how the software will be used
  - ENERCON presented industry methodology for non-pilot plants to implement a risk-informed approach
  - Vogtle-specific models were used as an example
- NRC staff provided favorable feedback on the NARWHAL software
  - Transparent
  - Good QA documentation
  - Liked being able to view time-dependent results
- Overall, the audit was very helpful for exchanging ideas and identifying areas of potential concern
- NRC staff identified several areas where relatively minor methodology changes would make submittals easier to approve

Audit Summary

- Risk quantification using threshold break frequency
  - Threshold break methodology requires less work
    - Don’t need to allocate LOCA frequencies to individual welds
    - Don’t need to plug NARWHAL results into PRA model to calculate ΔCDF
  - Threshold break methodology results in a significantly higher risk calculation
    - Almost all breaks at the threshold break size would not fail (very low conditional failure probability at this size)
    - Many of the larger breaks (including some DEGBs on primary loop pipes) would not fail
- Risk quantification using GSI-191 CFPs in PRA model
  - NRC staff is very comfortable with the overall methodology of calculating GSI-191 CFPs and entering these values in PRA model to quantify risk

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Audit Summary

- "Deterministically resolved" breaks
  - Idea behind RoverD methodology is that breaks can be evaluated deterministically and the ones that do not fail are "deterministically resolved"
    - Appears to indicate that deterministic rules should be followed (i.e., evaluate worst single failure with bounding design basis inputs)
    - Once the bounding deterministic evaluation has been completed, it shouldn't be necessary to evaluate other equipment configurations
  - NRC's position is that the term "deterministic" simply means that a given set of inputs are used to calculate a given set of outputs
    - Single failure criterion isn't applicable to a risk-informed evaluation
    - Even if a given break passes under one equipment configuration (i.e., a single pump failure), it still needs to be evaluated under other equipment configurations
    - There is not a single critical break size at each weld, and the results of analyzing multiple equipment configurations must be rolled together to calculate the overall risk

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Audit Summary

- Evaluation of various equipment configurations
  - The probability of random (non-GSI-191 related) failures should be accounted for each equipment configuration analyzed
  - Risk quantification can be done outside of PRA, but still requires PRA input for the equipment failure probabilities

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Audit Summary

- Uncertainty quantification methodology
  - Statistical sampling approach
    - Consistent with NUREG-1855 and straightforward for NRC PRA reviewers to accept
    - Requires development of probability distributions for GSI-191 input parameters, which could be difficult for NRC GSI-191 reviewers to accept
  - Sensitivity analysis approach
    - A less orthodox approach, but would be straightforward for both NRC PRA and GSI-191 reviewers to accept as long as the worst case scenario is not in Region 1 or close to the Region 1 boundary
  - Qualitative evaluation of uncertainties
    - May be acceptable, but approach has not been fully defined

Audit Summary

- Safety margin (SM) and defense-in-depth (DID)
  - SM was defined as, "How confident are we that a success is a success?"
    - In other words, safety margin is built in conservatisms that increase confidence that sequences that go to success remain in success (and why some that are assumed to fail might actually succeed)
  - DID was defined as, "What if we're wrong about a successful end state, and it turns out to actually be a failure?"
    - In other words, DID / mitigative strategies are items that address protection of public from radiation due to sequences that go to failure (containment integrity, emergency plan, operator actions in EOP's not credited, use of FLEX not credited, etc.)
  - These definitions are important since it helps define how the content should be split between the SM and DID sections
  - RG 1.229 has reporting requirements related to decreases in SM and DID
    - Most plant modifications or operability issues would not affect DID
    - Very important to <u>not</u> list all areas of conservatism as SM, or else every plant modification and operability issue could trigger reporting
- Submittal needs to identify models that couldn't change without NRC approval

Strainer Flashing Failures

- Flashing (boiling) in strainer
  - When the sump temperature is at or above 212 °F and accident pressure is not credited, flashing will occur when strainer head loss exceeds strainer submergence
  - Most conservative approach is to use submergence at the top of the strainer
  - NARWHAL Version 1.0 used submergence at strainer midpoint to calculate flashing failures
  - NARWHAL Version 2.0 allows user to specify
    - Reference elevation for calculating degasification and flashing
    - Accident pressure credited for degasification and flashing (not used for NPSH)

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Strainer Flashing White Paper Summary

- A plant-specific analysis should be performed to determine two-phase flow regime in strainer
  - Non-transportable: Vapor would accumulate at top of strainer and would not challenge ECCS operation
    - Most plants expected to fall in this regime
    - As vapor accumulates in strainer, pressure increases due to the downward movement of the air/water interface until flashing ceases (i.e., it is self-limiting)
    - Using the strainer midpoint elevation to calculate flashing failures is reasonably conservative
  - Bubbly flow: Steam can transport as bubbly flow in the liquid
    - A few plants may fall in this regime
    - A straightforward plant-specific analysis can be used to show that the bubbles would collapse well before reaching the ECCS pumps
  - Annular flow: Steam can transport through a cylindrical vapor channel with a liquid film around the surface of the pipe
    - Not expected that any plants will fall in this regime
    - Due to the complexity of the analysis, any plants that do fall in this regime should conservatively use the top of the strainer to calculate flashing failures

Particulate Filtration

- Preliminary Vogtle NARWHAL model assumed particulate would be filtered when fiber bed exceeds 1/16” fiber equivalent
- Although there would be clean screen area with low head losses at this point, some particulate would be captured along with the initial fiber
- Rather than justifying the fiber thickness required to filter particulate, the Vogtle head loss model will be modified to incorporate the measured head loss for a small quantity of fiber and large quantity of particulate

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Insulation Size Distribution Methodology

- Insulation debris size distribution centroid methodology
  - Generic ENERCON calculation (GSI191-CALC-001) provides methodology for calculating debris size distribution as a function of the average distance of insulation in the ZOI from the break (i.e., the centroid distance) based on the methodology recommended in NEI 04-07 Volume 2
  - NRC staff questioned whether the fraction of fine debris should be higher than 20% for centroids very close to the break (i.e., within 2D)
  - ENERCON revised the generic calculation to provide stronger justification

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Insulation Size Distribution Methodology

- By definition, if a break has a 2D centroid, the insulation inside the ZOI must be very close to the break and the quantity of debris must be relatively small (i.e., most of the ZOI generates no debris)
  - To theoretically maximize the quantity of debris that could be generated with a 2D centroid, all insulation would have to fall within a 2.5D sphere
  - A 2.5D sphere has 0.32% of the total volume of a 17D sphere (i.e., a much lower potential for generating large quantities of debris)
- A typical 4 Loop Westinghouse plant with low density fiberglass insulation was used to evaluate the range of centroids for over 28,000 breaks spanning a wide range of conditions
  - Most breaks (approximately 18,000) had a centroid between 8D and 11D
  - Approximately 2,000 breaks (ranging from ½” to 2”) had a centroid of 0D because the debris quantity was 0 ft^3
  - Remaining 43 breaks with a centroid between 0D and 2D generated a debris quantity of less than 10 ft^3 (less than the quantity typically assumed for latent fiber debris)
- Changing the assumption of the fraction of fines generated by breaks with centroids between 0D and 2D would have a negligible effect on the overall risk quantification since the debris quantities generated are so small

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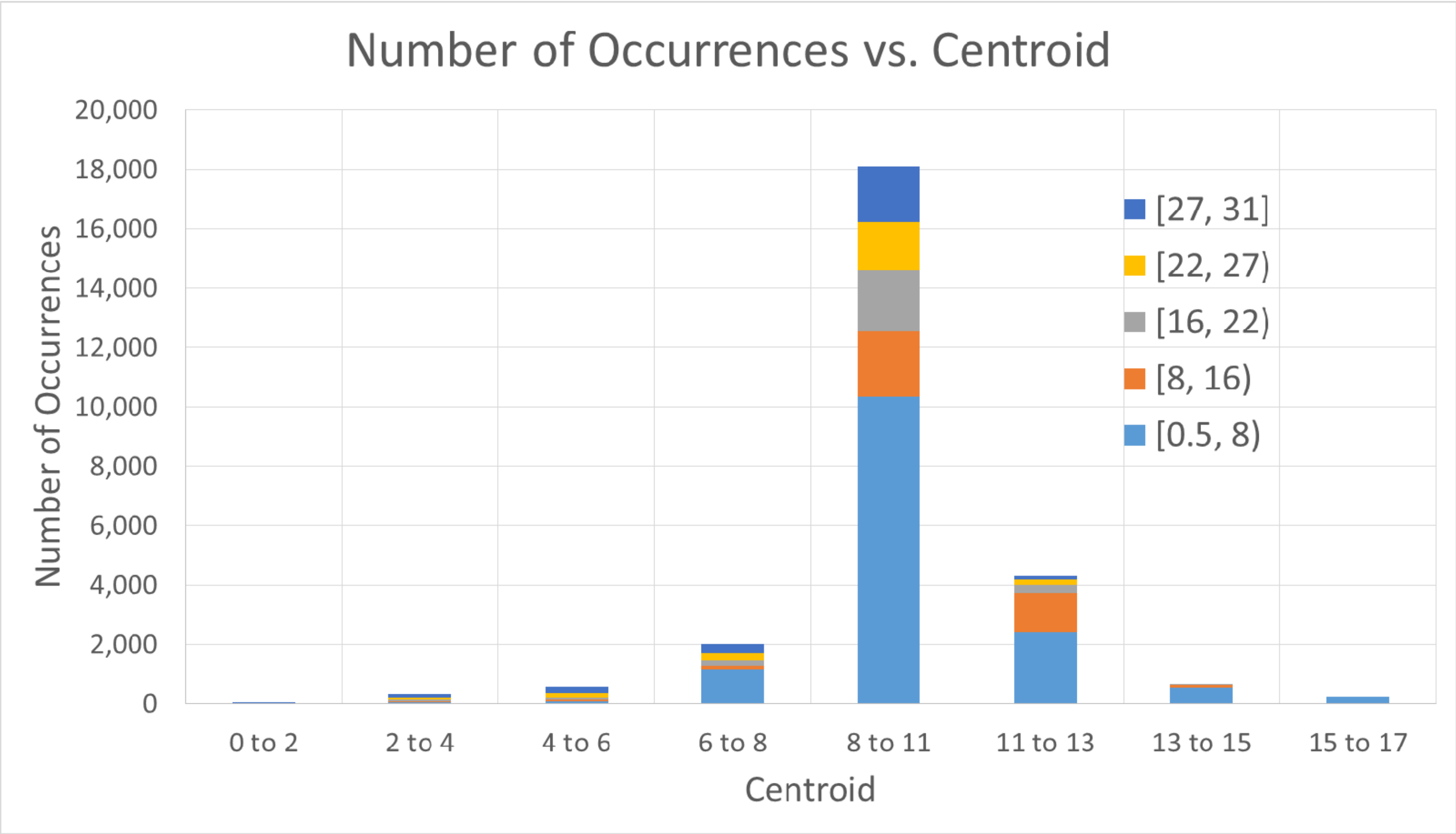
Range of Centroid Distances for Breaks Evaluated



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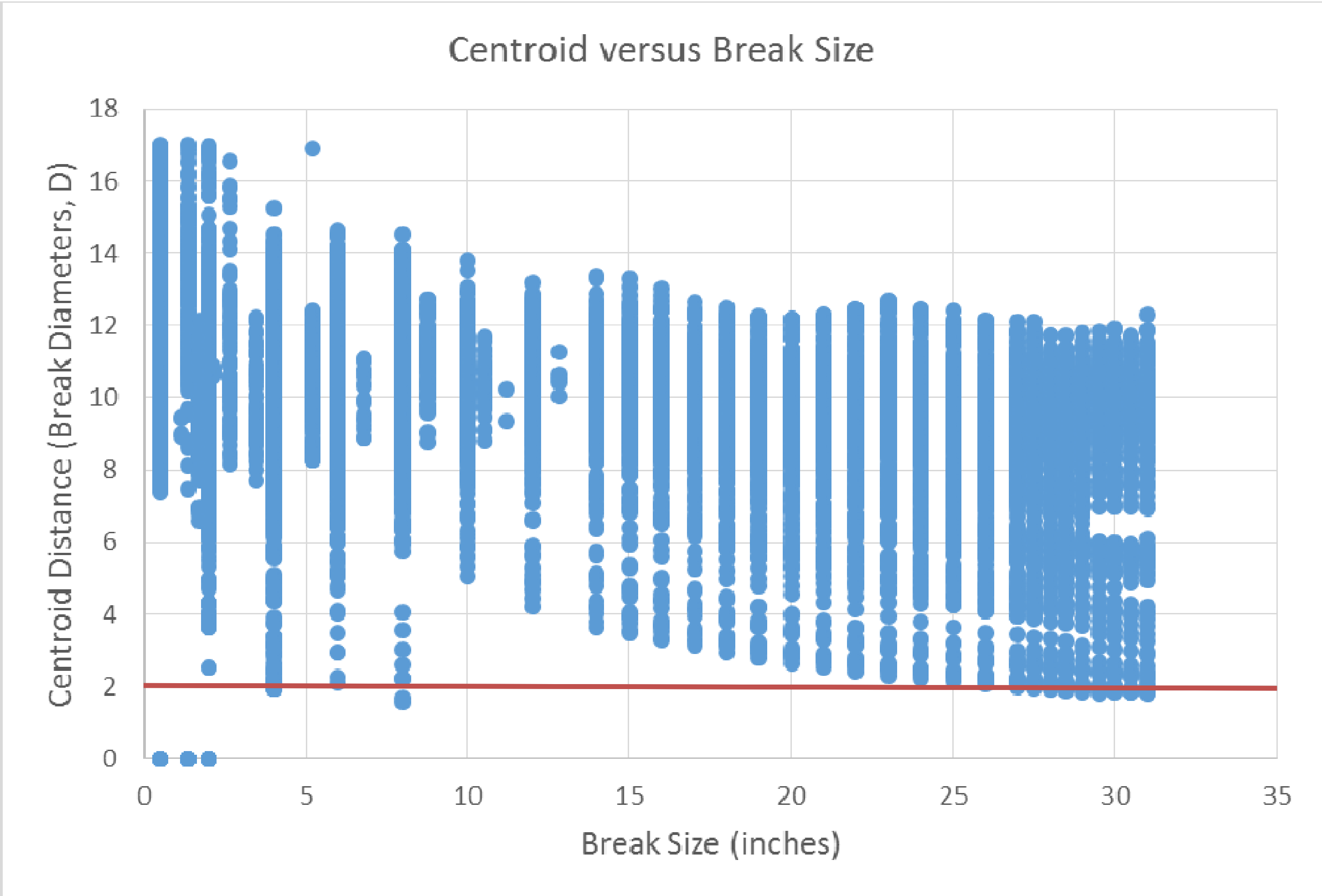
Centroid Distances for Various Break Sizes



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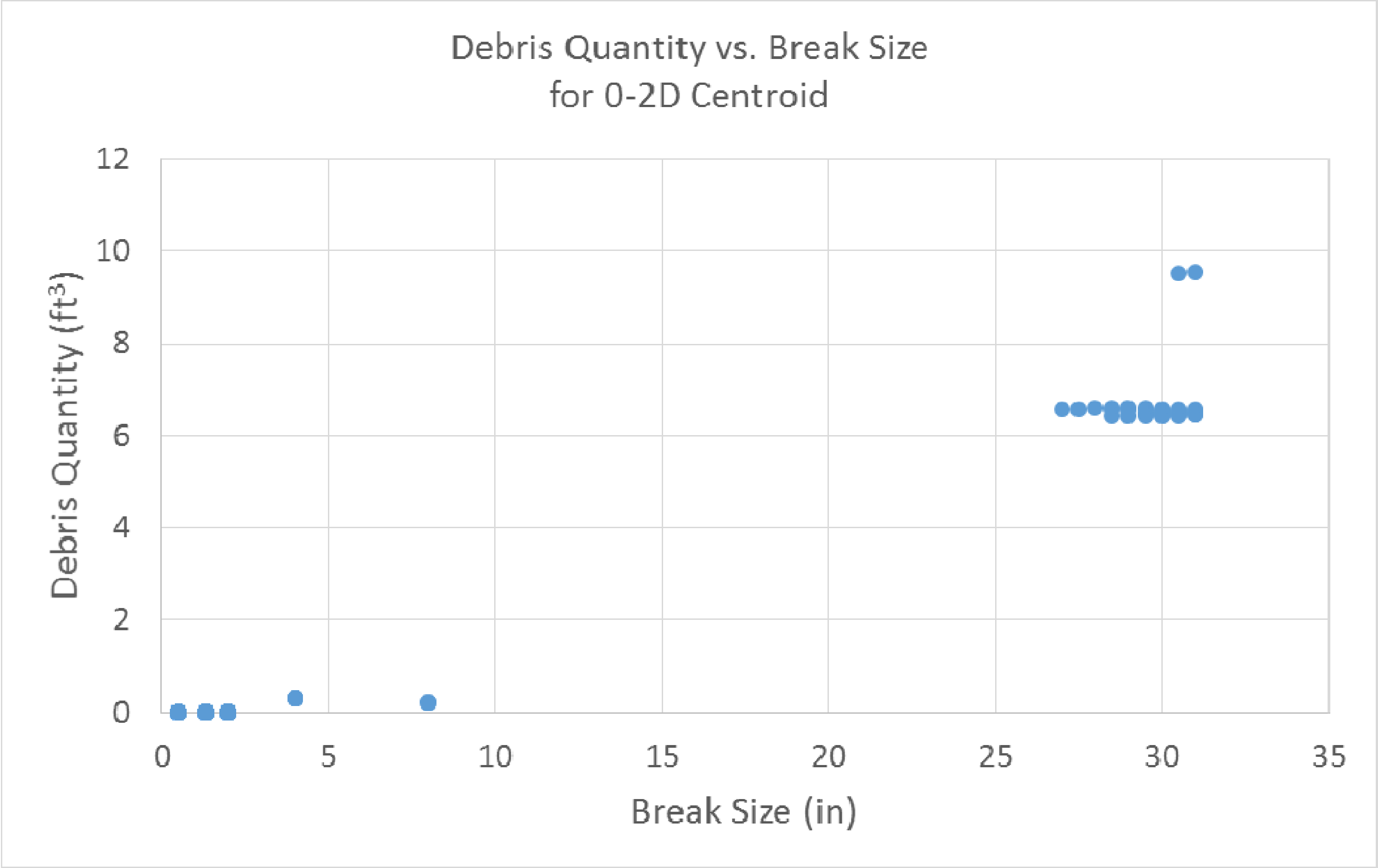
Debris Quantities for Breaks with Centroids from 0D to 2D



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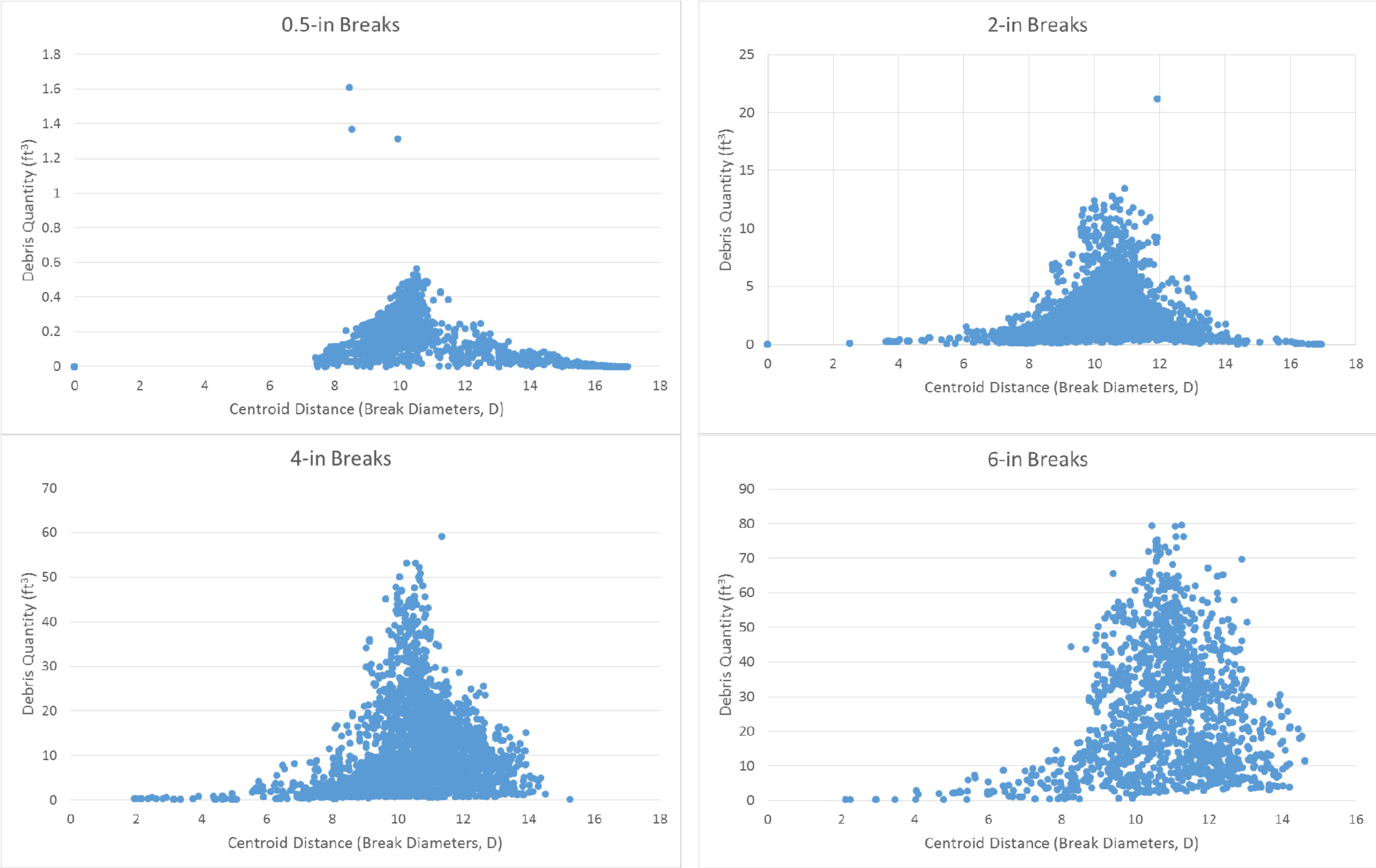
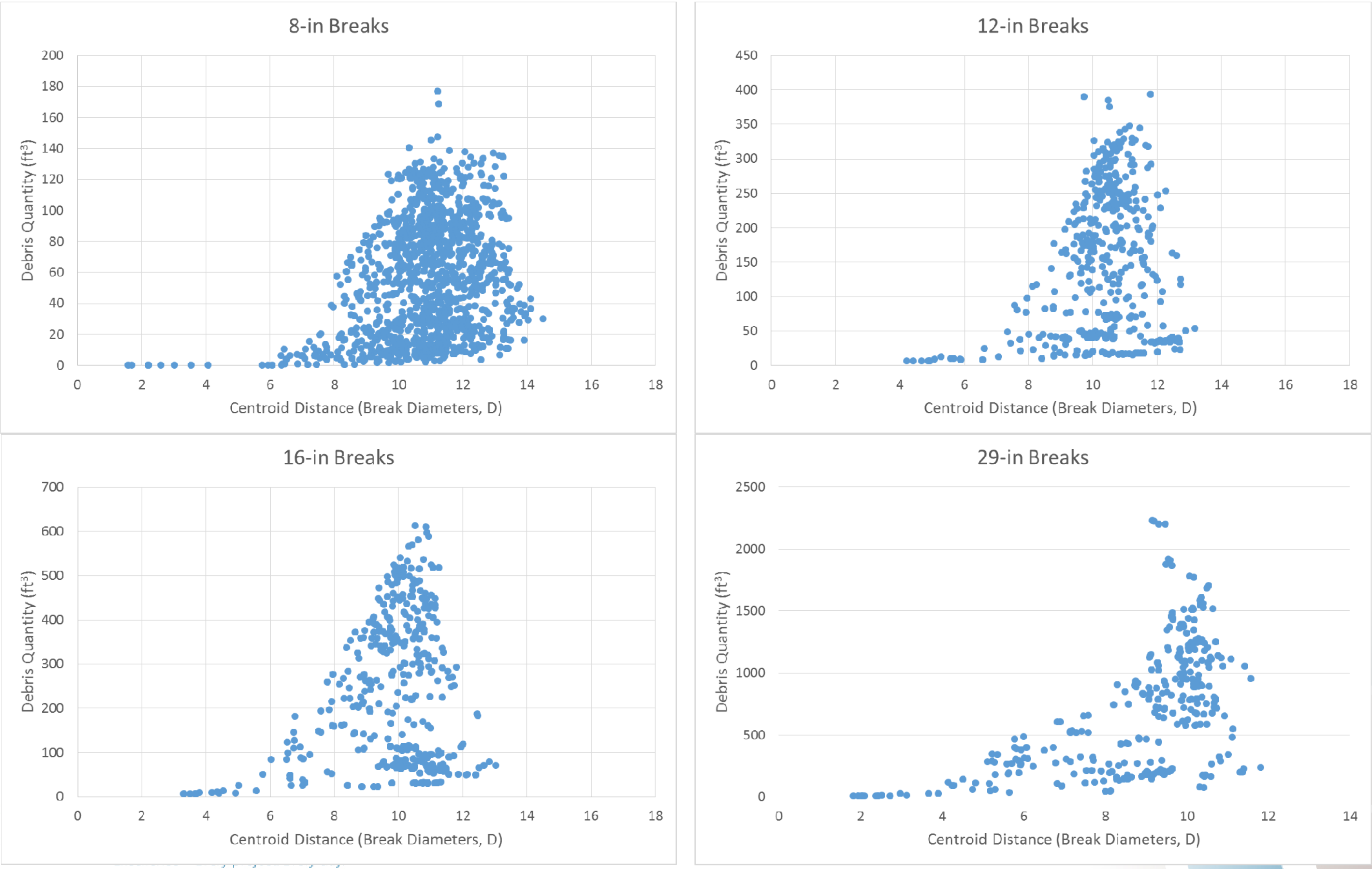
Debris Quantity vs. Centroid Distance



Debris Quantity vs. Centroid Distance



Break Size and Orientation Increments

- Due to the effect on ΔCDF seen in the STP RoverD methodology from minor variations in break size and orientation, the NRC staff questioned whether 45° orientation increments and ½” to 3” size increments provide sufficient resolution to find failures that have a significant impact on risk
- This concern has a different impact on the non-pilot plants depending on whether risk is quantified using the PRA model with conditional failure probabilities (CFPs) or the threshold break approach
- ENERCON prepared a generic white paper (using example 4 Loop plant results) to address this issue

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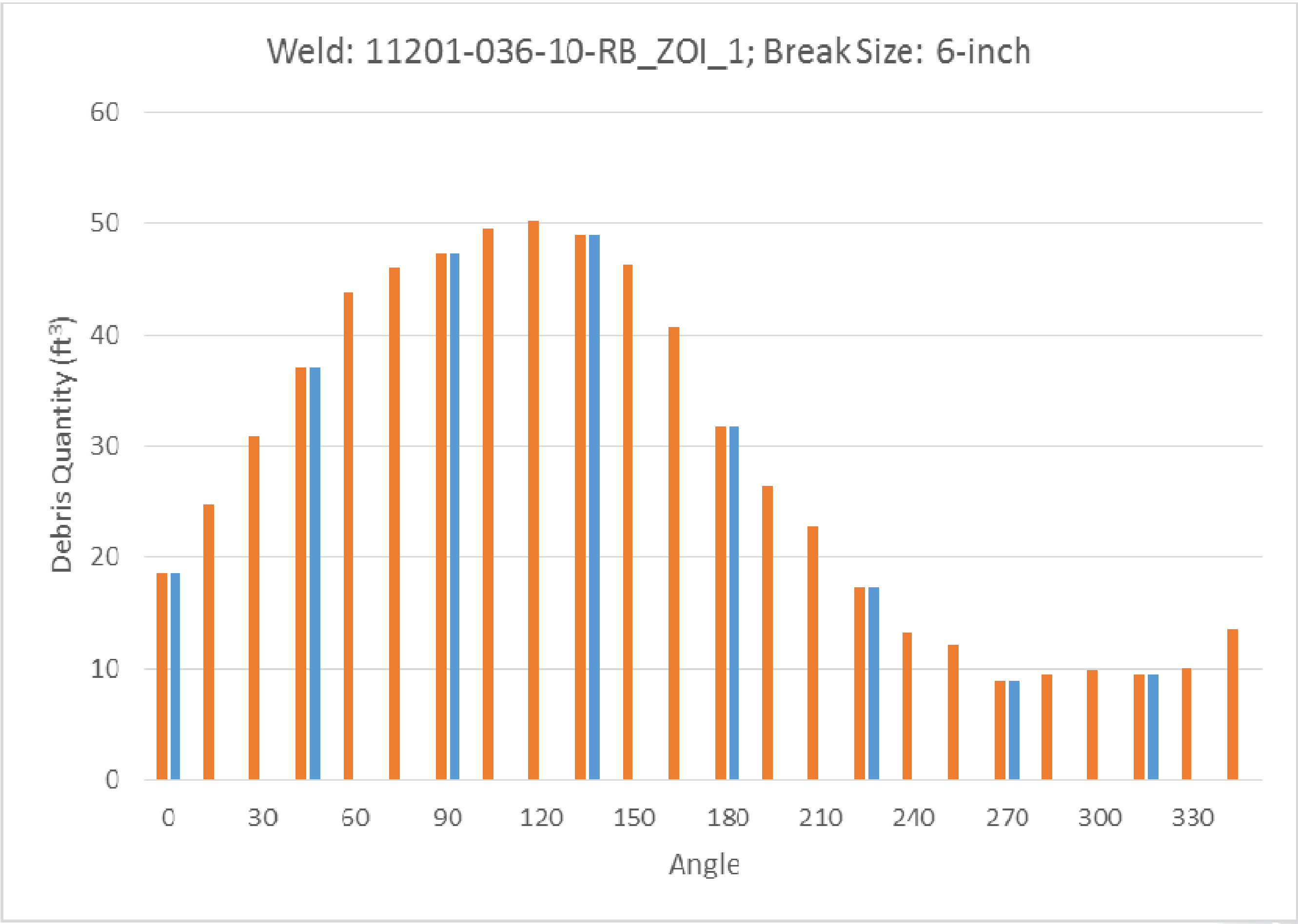
Typical Results of Refined BADGER Analysis



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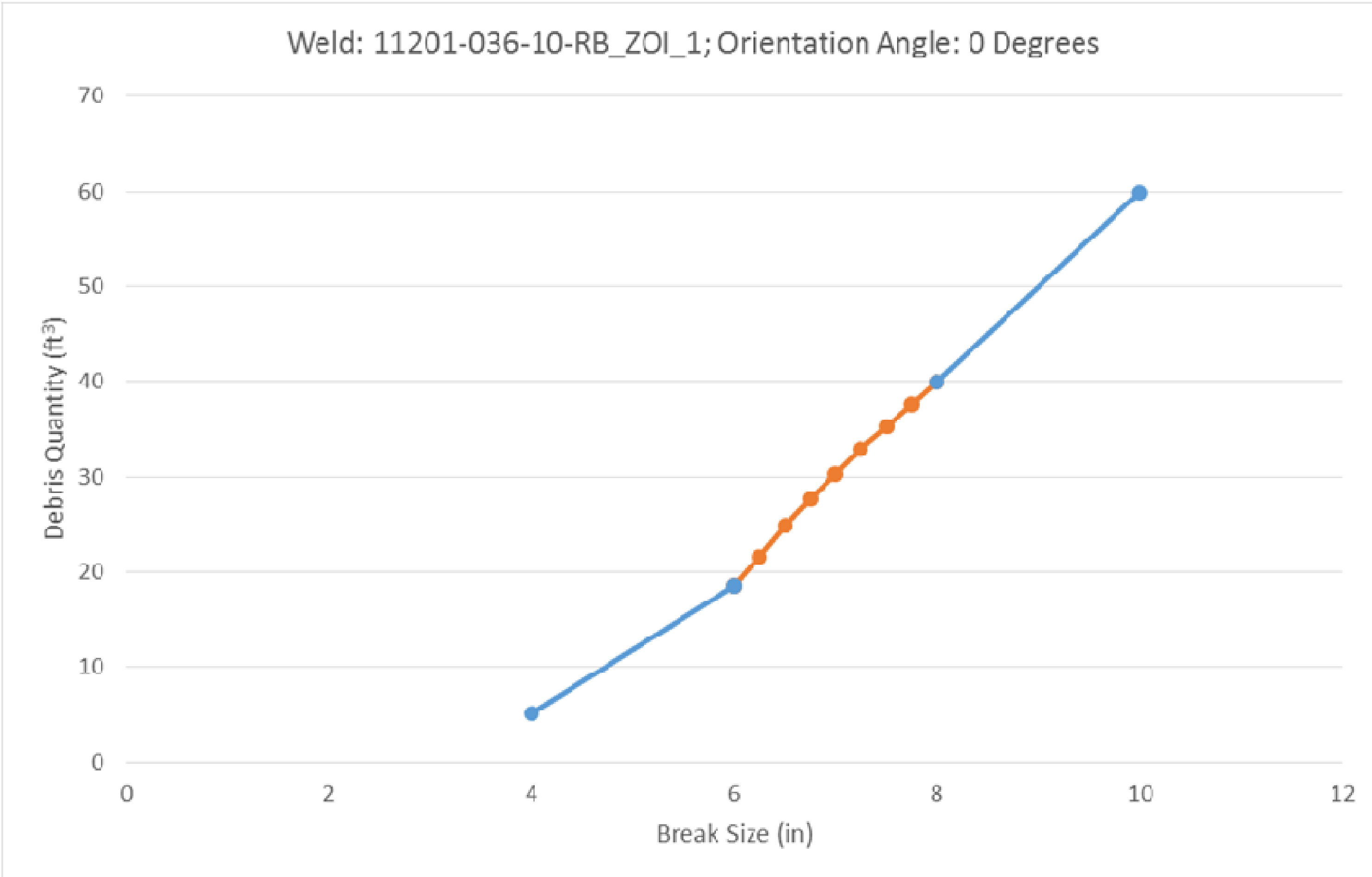

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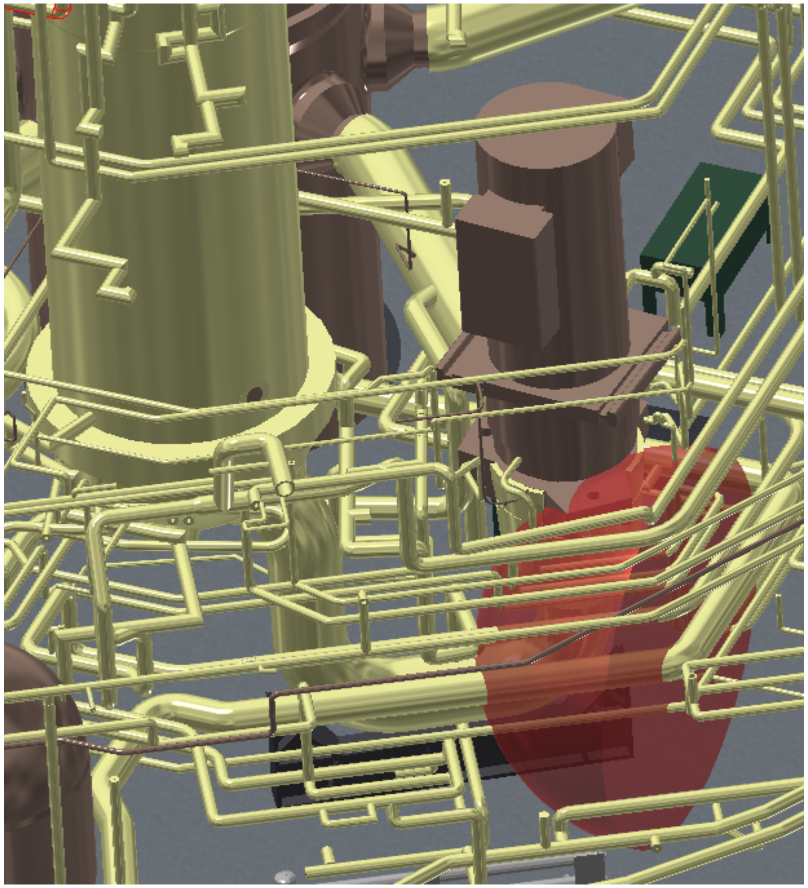

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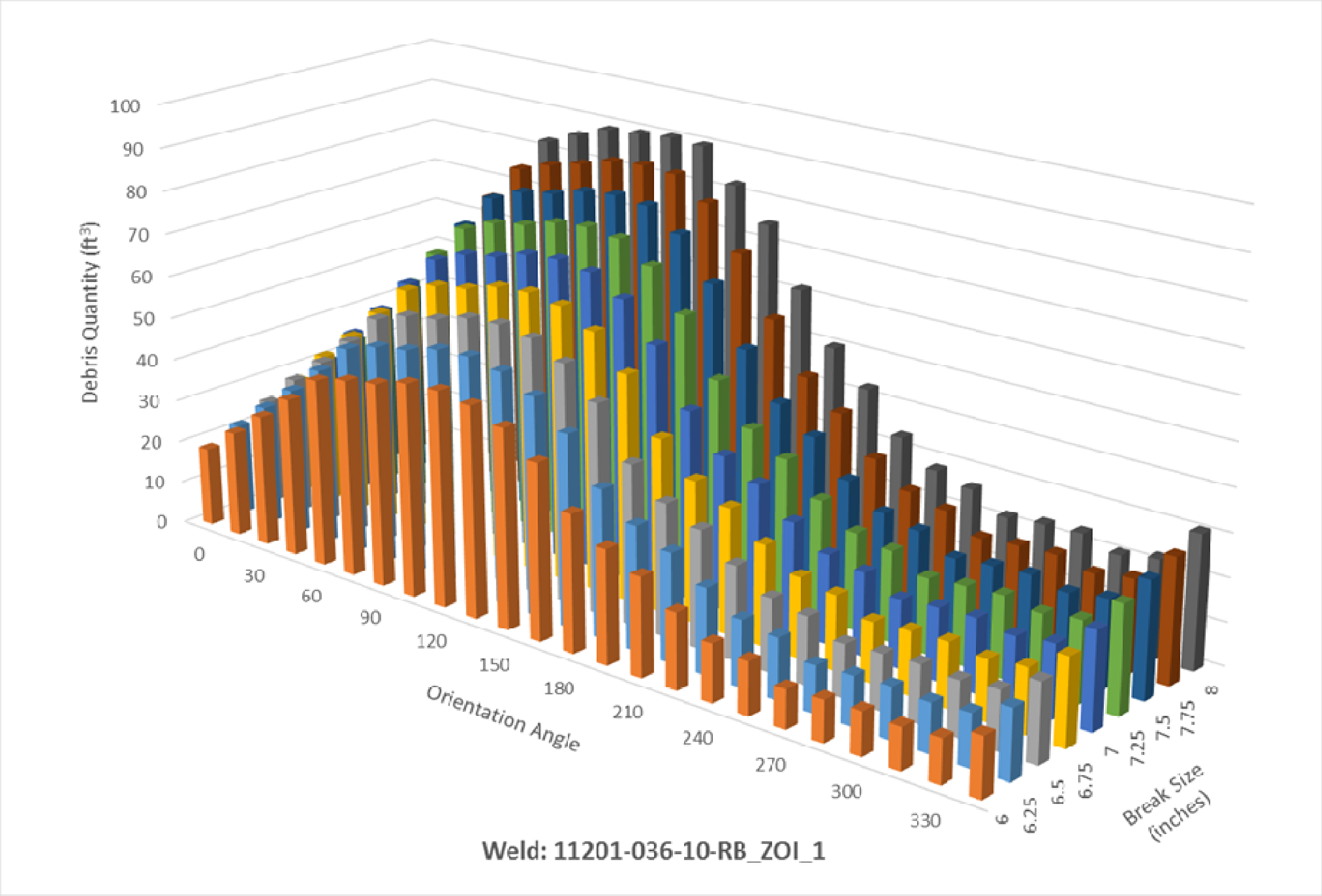

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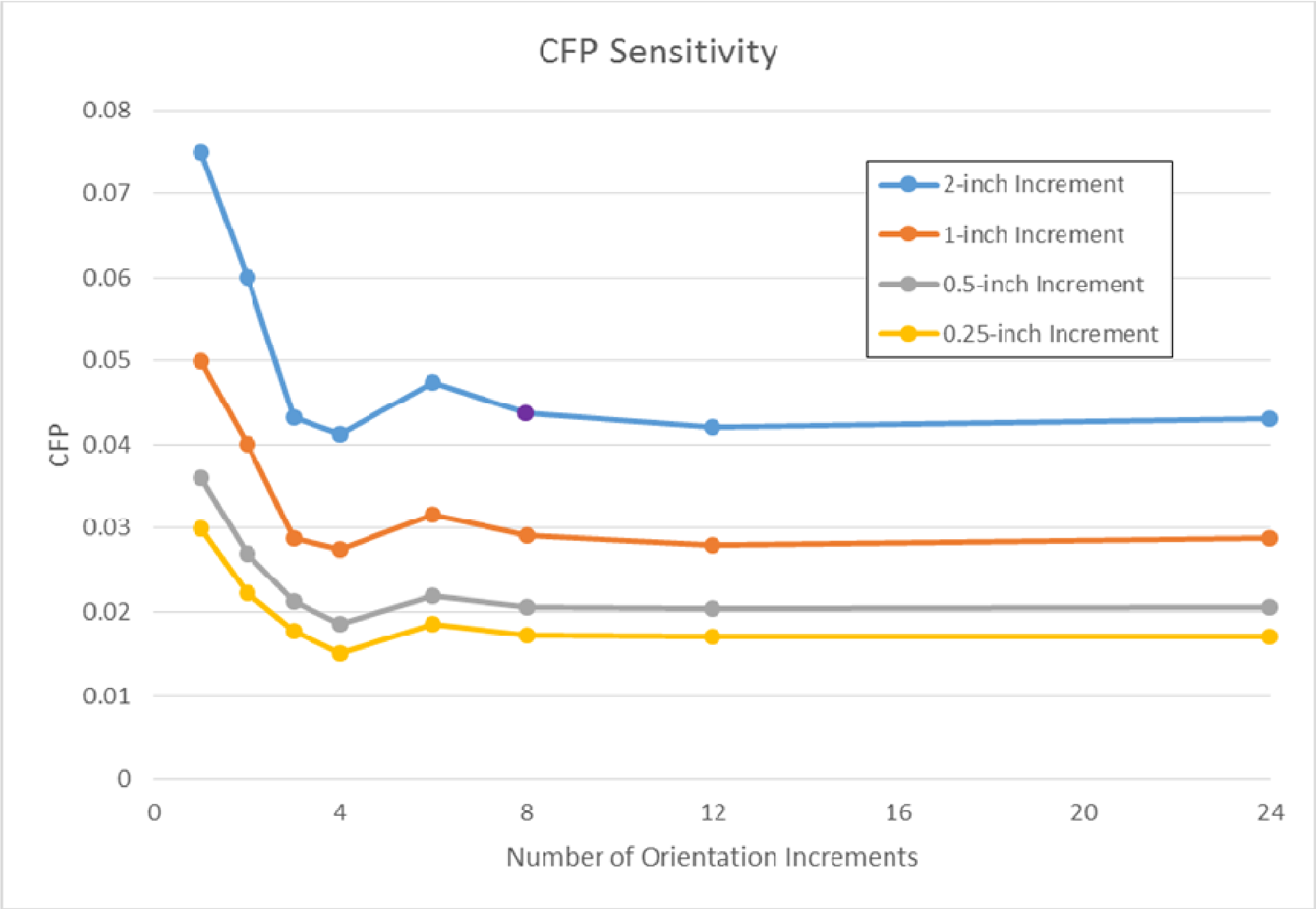
CFP Sensitivity to Size and Orientation Increments



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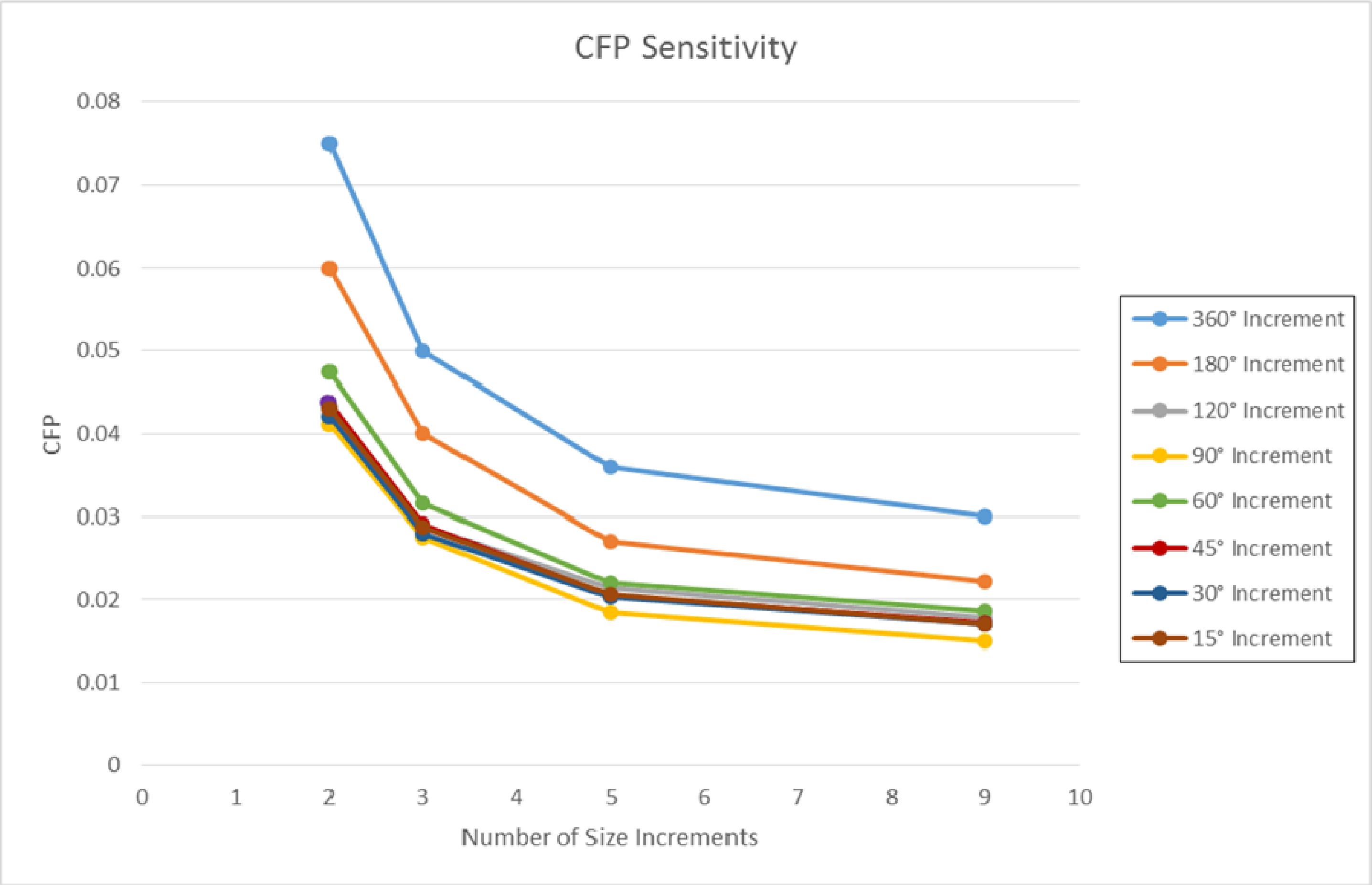

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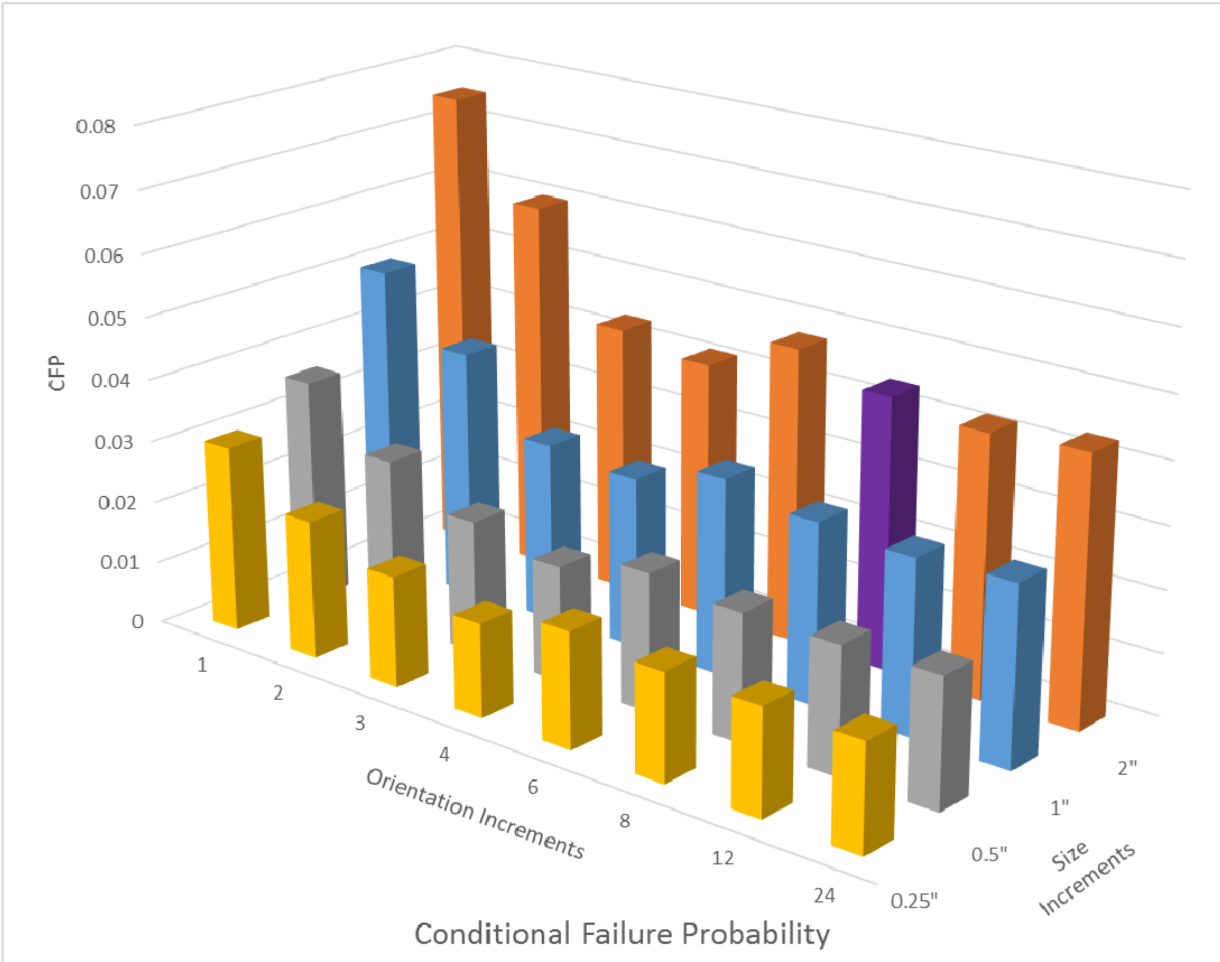

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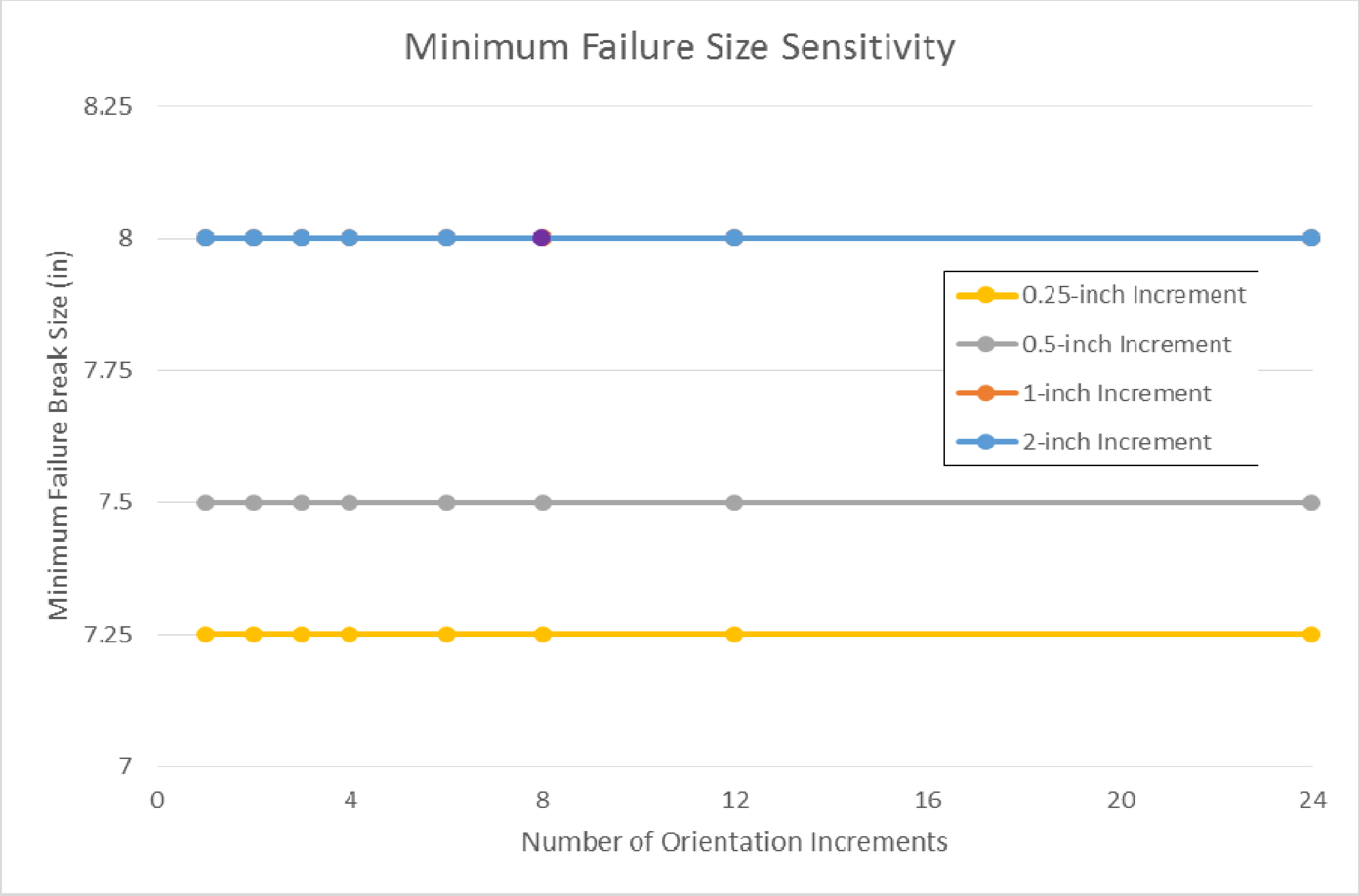
Smallest Failure Sensitivity to Size and Orientation Increments



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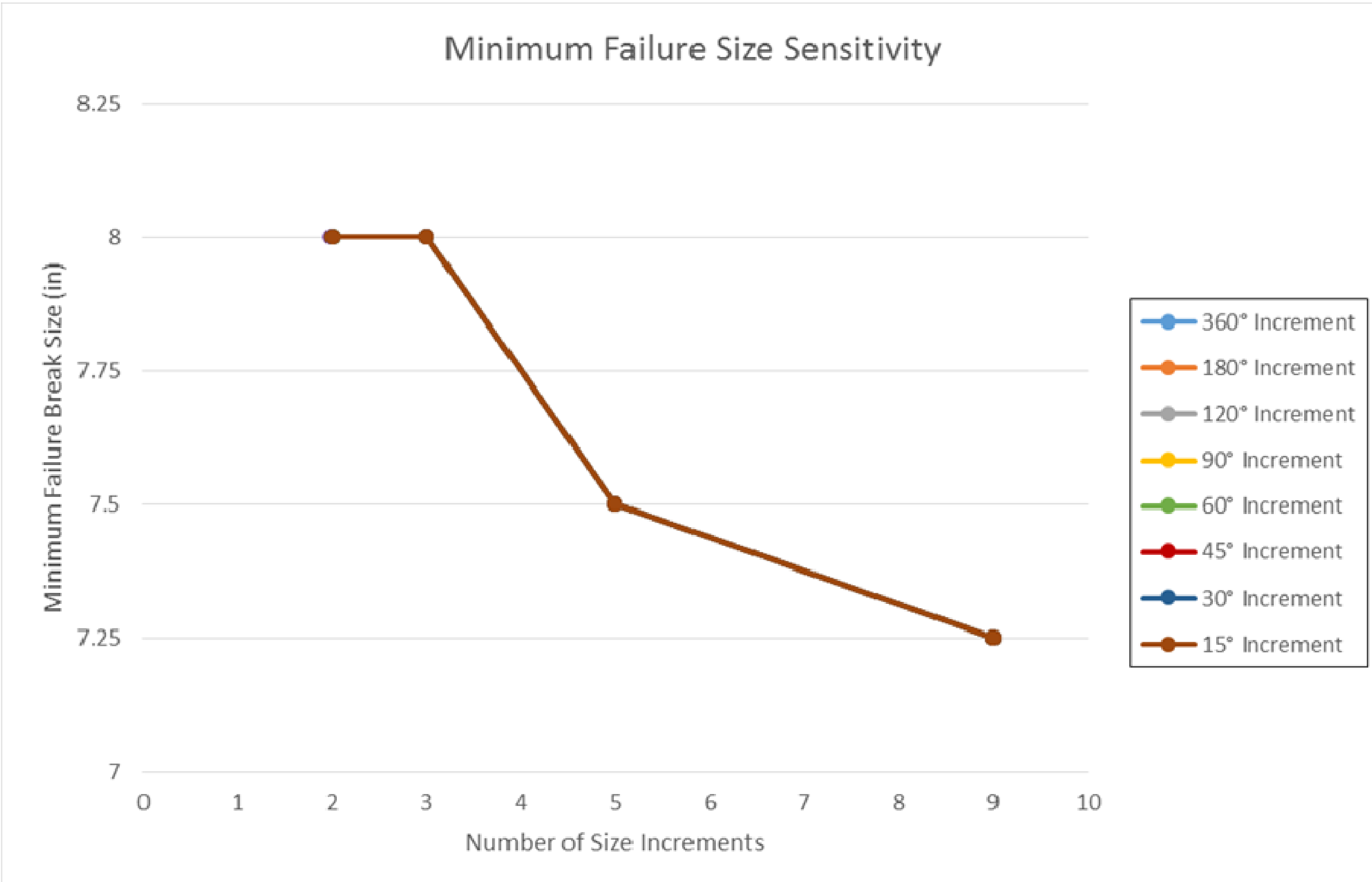

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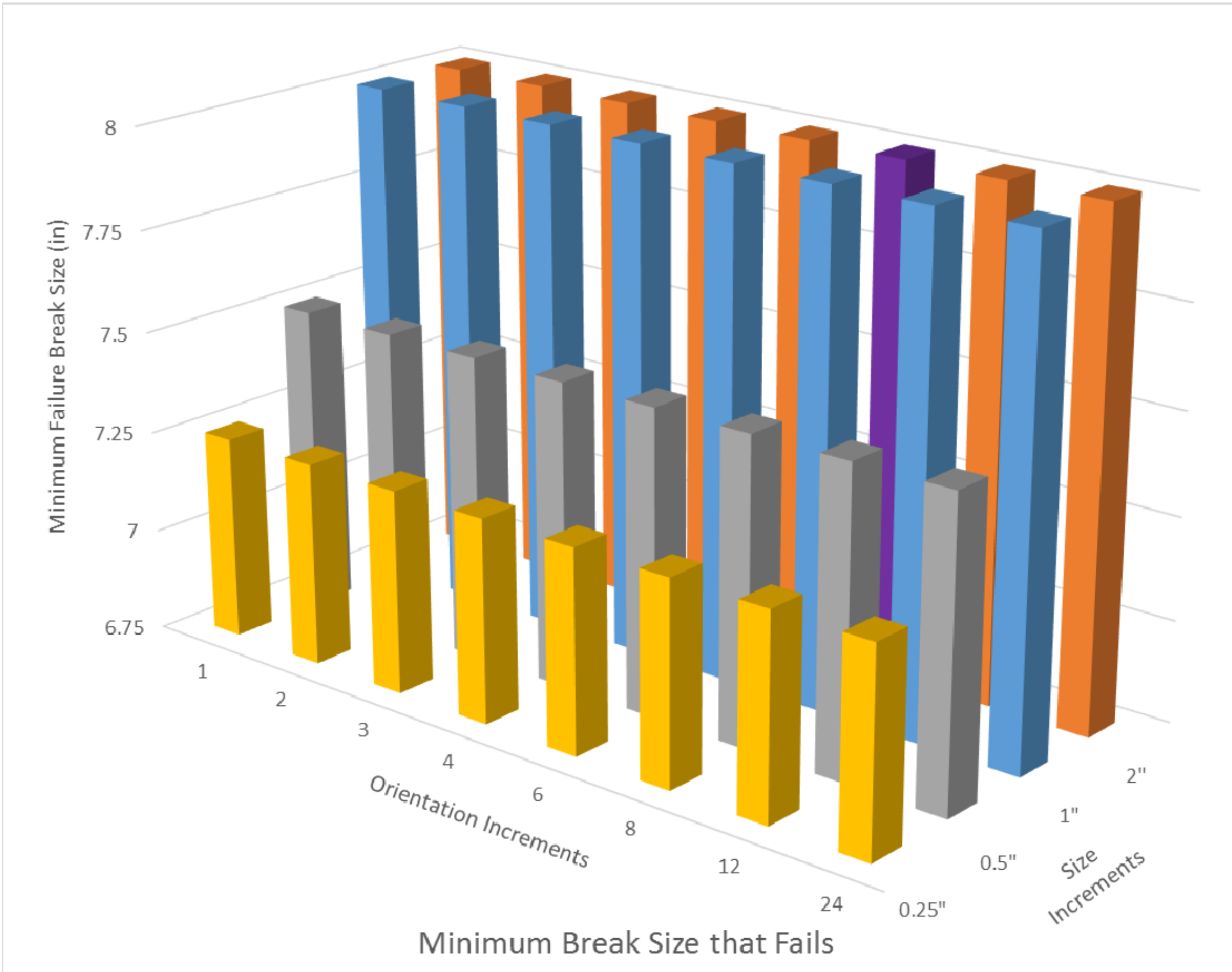

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Conclusions of Size and Orientation Sensitivity Evaluation

- CFP values do not change significantly with more resolution on break orientations and sizes
- Plants using the threshold break approach have two options
  - Use the next smaller break size (i.e., if a 14” break is the smallest one that fails and all 12” breaks pass, set the threshold break size at 12 inches)
  - Run BADGER using more resolution on size and orientation for the smallest breaks that fail to justify an intermediate value for the threshold break size (e.g., 13.6 inches)

LOCA Frequency Allocation Methodology

- NRC staff identified several relatively minor issues related to LOCA frequencies, which in general only apply to the plants using the CFP/PRA risk quantification methodology
  - Need to use log/linear interpolation (NARWHAL Version 1.0 had log/log and linear/linear)
  - Avoid extrapolation beyond 31" exceedance frequencies provided in NUREG-1829
  - Methodology to account for DEGB frequencies ($\sqrt{2} \times D_{pipe}$) is not clear
  - Pure top-down LOCA frequency methodology isn't preferred, but RG 1.229 may provide a hybrid type method based on ranking of Class 1 welds as high/medium/low likelihood as a function of degradation mechanisms
- NARWHAL Version 2.0 PRA package includes hybrid LOCA frequency methodology consistent with NRC-described RG 1.229 content that is under consideration
- ENERCON revised generic LOCA frequency methodology (GSI191-CALC-006) to modify methodology for extrapolation of frequency for very large breaks and include additional description for treatment of DEGB frequencies

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CFP Methodology

- Overall plant-wide LOCA frequencies must be allocated to individual welds and break sizes using an acceptable allocation methodology
- GSI-191 failures (strainer, pump, and and/or core failures due to the effects of debris) must be evaluated for each break
- PRA model categories (e.g., large breaks) could be broken up into size ranges where breaks within a given size range are assumed to have an equal probability (every size range must include breaks)
- CFP for a PRA category is calculated based on the combined CFPs for each size range along with the corresponding LOCA frequency weight associated with each category
- CFP values can then be used with the plant PRA model to calculate the risk associated with GSI-191

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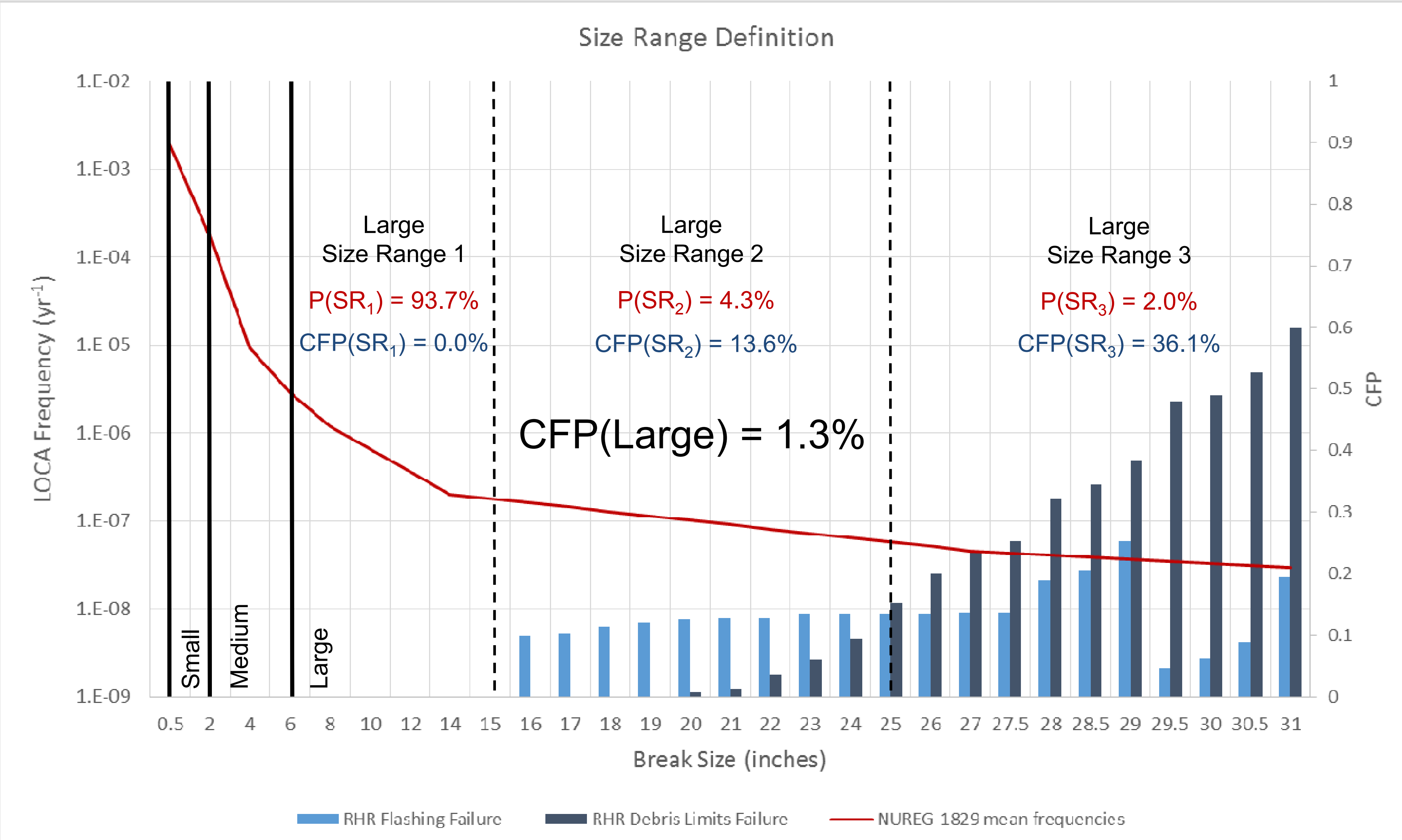
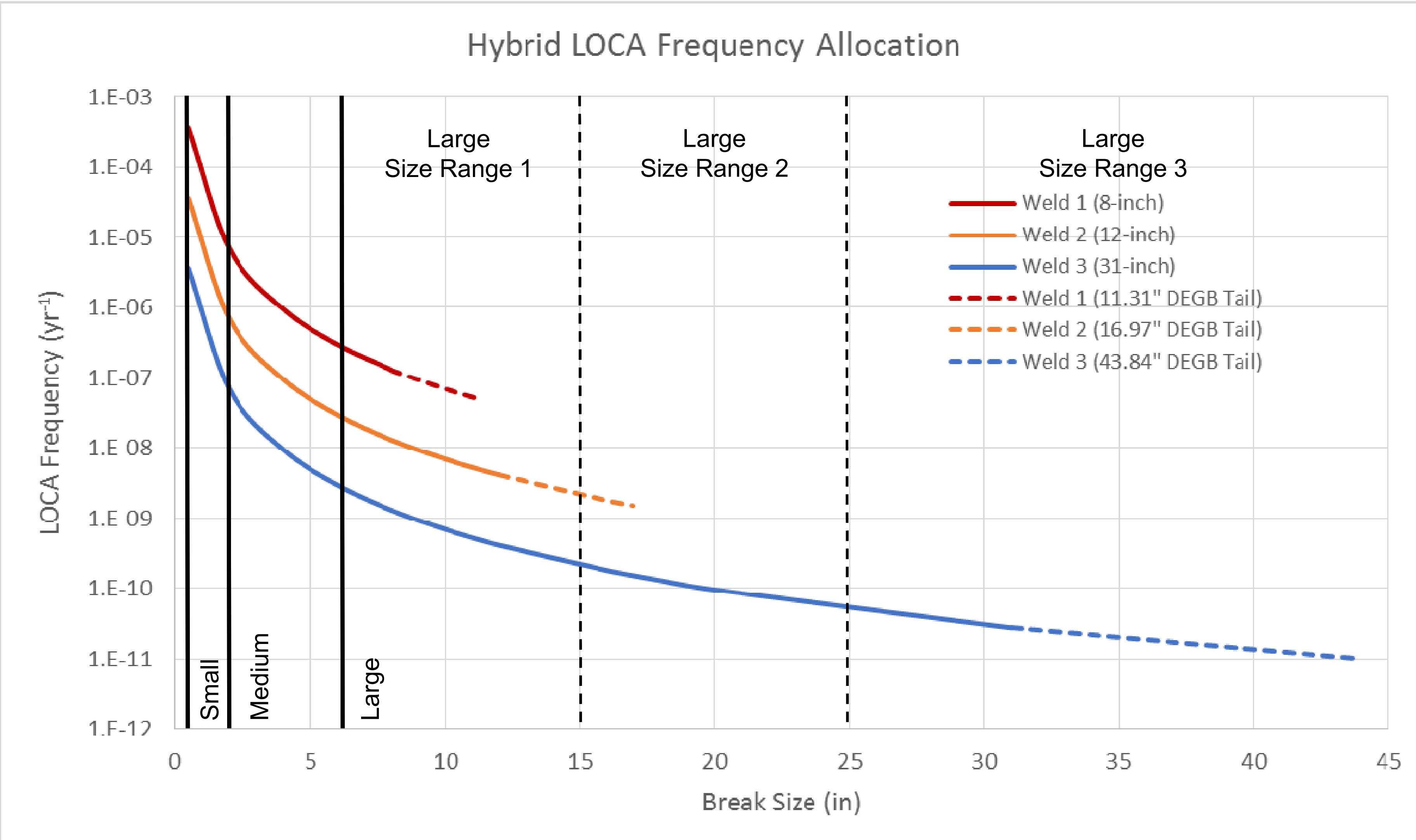
Size Range Methodology



Hybrid LOCA Frequency Methodology

- Simple example with 3 welds
  - Weld 1 (Significant degradation mechanisms)
    - 8-inch diameter
    - 11.3” DEGB equivalent diameter
    - High failure probability (10x frequency multiplier)
  - Weld 2 (Some degradation mechanisms)
    - 12-inch diameter
    - 17.0” DEGB equivalent diameter
    - Medium failure probability (1x frequency multiplier)
  - Weld 3 (Only design and construction defects)
    - 31-inch diameter
    - 43.8” DEGB equivalent diameter
    - Low failure probability (0.1x frequency multiplier)

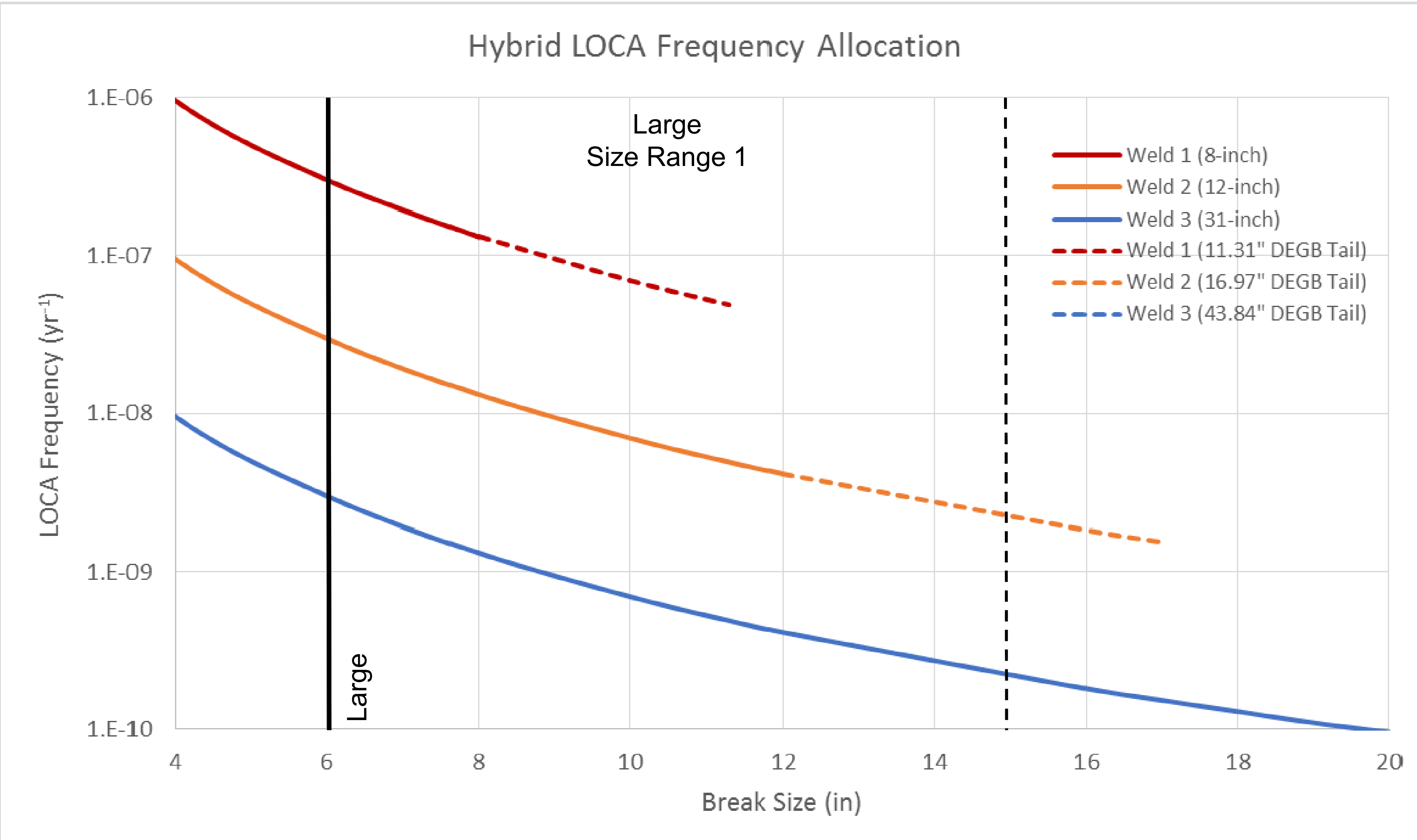
Example Weld Frequencies



Treatment of DEGB Tail

- Breaks larger than pipe diameter assumed to fail as DEGB (spherical ZOI)
- Equivalent break diameter for a DEGB is $\sqrt{2}$ times pipe diameter (2x flow area has $\sqrt{2}$x equivalent break diameter)
- Actual break size is somewhere between pipe diameter and DEGB equivalent diameter
  - A DEGB on a 12-inch pipe could be referred to as a 17-inch break (i.e., equivalent to a 17-inch partial break on another pipe)
  - Conservative option is to refer to a DEGB on a 12-inch pipe as a 12-inch break (ZOI for a 12-inch DEGB is twice the volume of a 12-inch partial break)
- Since DEGBs represent a range of break sizes between the pipe diameter and the DEGB equivalent diameter, the frequency "tail" should not be neglected

Treatment of DEGB Tails



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Weld Frequency Contribution

- Breaks of any size on a given weld are assumed to have equal probability within a size range (e.g., Large Size Range 1)
- Probability contribution for a given weld is the exceedance frequency at the low end of the size range minus the frequency at:
  – The high end of the size range if the pipe diameter is larger than the size range
  – The DEGB equivalent diameter frequency if the pipe diameter is within the size range

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Example Weld Contributions

- Frequencies in 6”-15” size range
  - $F_{Weld1} = F_{6”} - F_{11.3”} = 3.0E\text{-}7 - 4.9E\text{-}8 = 2.5E\text{-}7$
  - $F_{Weld2} = F_{6”} - F_{17.0”} = 3.0E\text{-}8 - 1.5E\text{-}9 = 2.9E\text{-}8$
  - $F_{Weld3} = F_{6”} - F_{15”} = 3.0E\text{-}9 - 2.2E\text{-}10 = 2.8E\text{-}9$
  - $F_{Total} = F_{Weld1} + F_{Weld2} + F_{Weld3} = 2.8E\text{-}7$
- Relative probability weight for each weld in 6”-15” size range
  - $P_{Weld1} = 89\%$
  - $P_{Weld2} = 10\%$
  - $P_{Weld3} = 1\%$

LOCA Frequency Extrapolation

- NUREG-1829 only provides exceedance frequencies up to 31-inch break sizes
  - CE plants have 42-inch hot leg pipes
  - DEGB equivalent diameters for Westinghouse plant primary loop pipe breaks are larger than 31 inches
- Treatment of larger breaks using size range methodology
  - Assuming 31-inch exceedance frequency for all larger break sizes is actually non-conservative when applying the size range methodology
    - $F_{\text{size Range 3}} = F_{25"} – F_{43.8"} = 5.7E\text{-}08 – 2.9E\text{-}08 = \mathbf{2.8E\text{-}08}$
  - Logarithmic extrapolation could be performed, but the results are questionable
    - $F_{\text{size Range 3}} = F_{25"} – F_{43.8"} = 5.7E\text{-}08 – 1.0E\text{-}08 = \mathbf{4.7E\text{-}08}$
  - Conservative option is to use zero frequency for size range endpoints larger than 31 inches
    - $F_{\text{size Range 3}} = F_{25"} – F_{43.8"} = 5.7E\text{-}08 – 0.0 = \mathbf{5.7E\text{-}08}$

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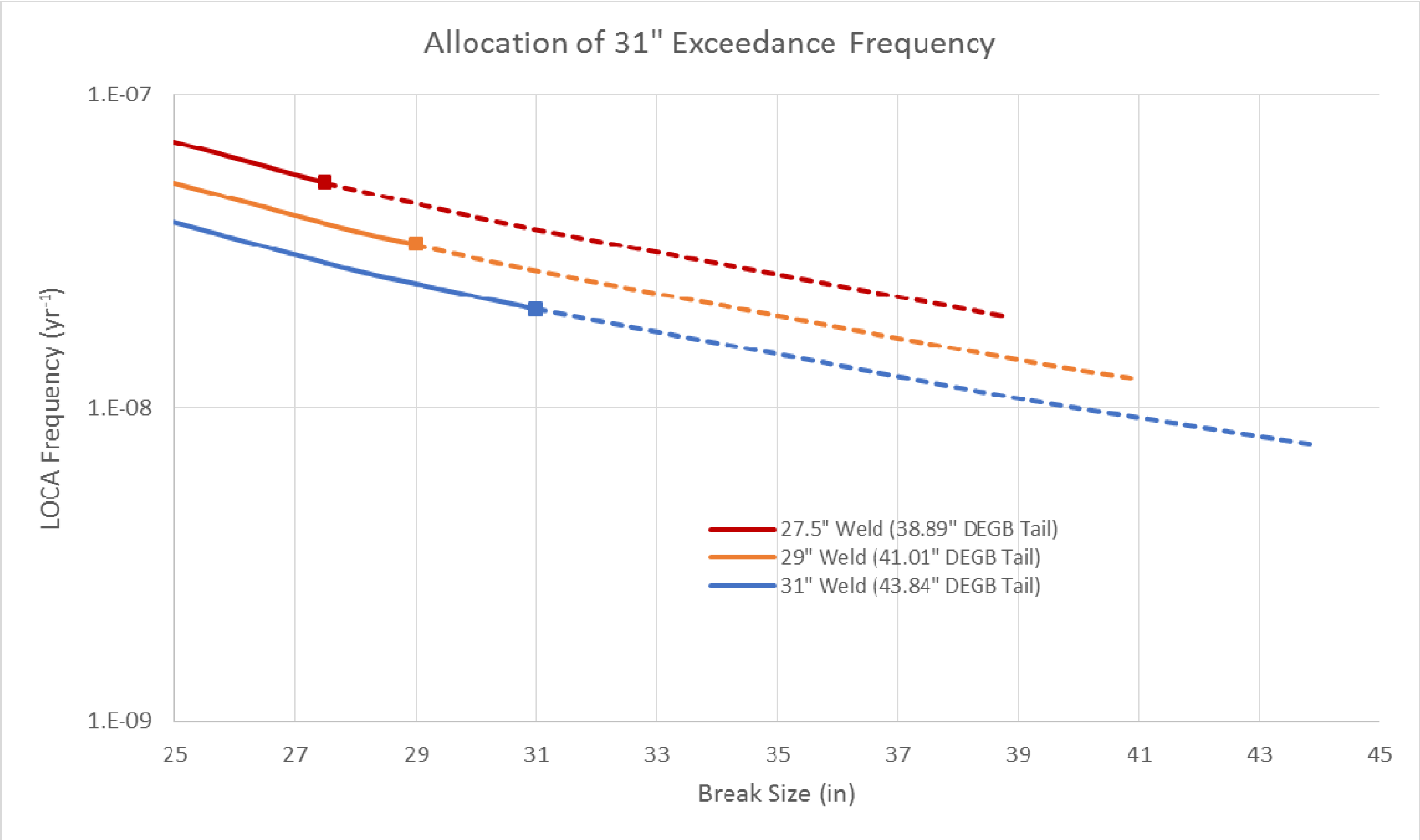
Primary Loop Pipe Exceedance Frequencies



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Continuum vs. DEGB-Only Model

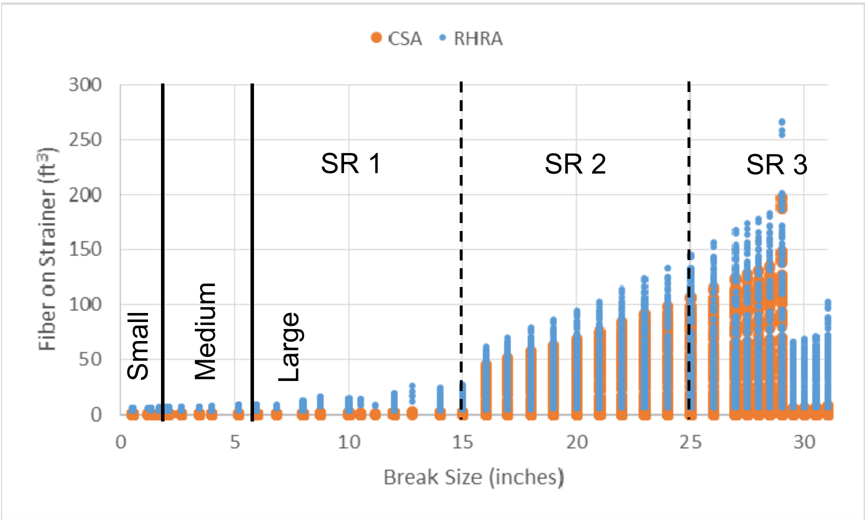
- NUREG-1829 includes a statement that a break of a given size is more likely to result from a complete rupture of a small pipe than a partial rupture of a larger pipe
- Statement has been interpreted to mean that partial breaks are not possible (i.e., all partial breaks would proceed to full DEGBs)
- NRC staff clarified that partial breaks are possible, but may or may not have a negligible probability
- Licensees should evaluate both extremes
  - Continuum break model where a small break on a large pipe is assumed to have the same frequency as a complete rupture on a small pipe with an equivalent break size
  - DEGB only model where partial breaks are assumed to have negligible frequency and frequency is only allocated to DEGBs
- DEGB-only model would result in a threshold break ≥ continuum break model

DEGB-Only Evaluation using CFP Approach

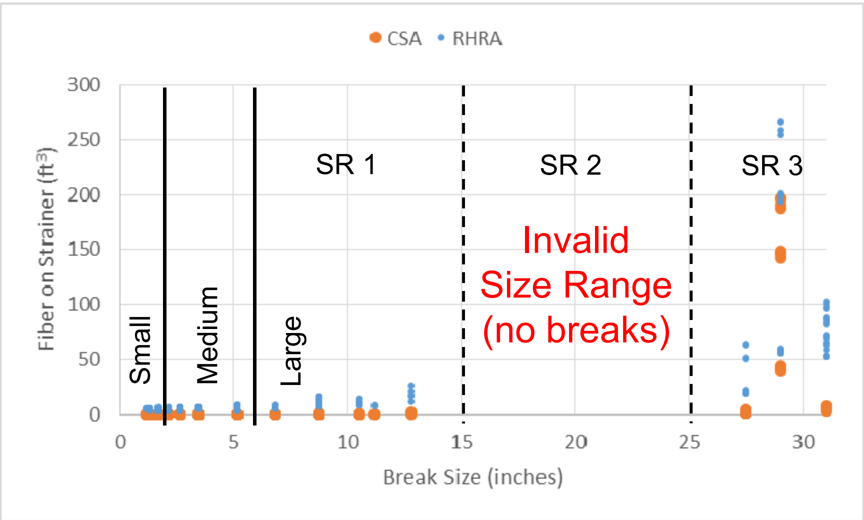
- CFP values can be calculated for continuum break model and DEGB-only model using CFP methodology described previously
  - Large gap in possible DEGB sizes between 12-14” surge line and 27.5”+ primary loop piping
  - Must use a different set of size ranges for DEGB-only model and continuum break model
- Risk quantification for DEGB-only model can be significantly skewed depending on how size ranges are defined
  - Specifying boundary just below primary loop piping diameter places all of the intermediate break frequency on smaller surge line welds that are less likely to fail (biases ΔCDF low)
  - Specifying boundary just above surge line break diameter places all of the intermediate break frequency on larger primary loop piping welds that are more likely to fail (biases ΔCDF high)
  - Using the midpoint between the DEGB sizes provides an unbiased estimate of ΔCDF for the DEGB-only model
- Vogtle analysis shows that continuum break model and DEGB-only model produce similar results

Continuum vs. DEGB-only Comparison of Fiber on Strainer

Continuum Break Model



DEGB-Only Model



Fiber on Strainer

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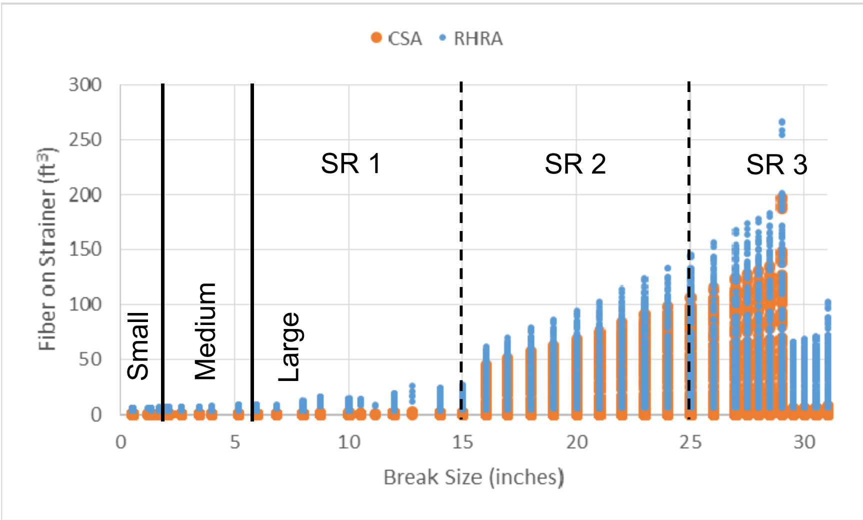
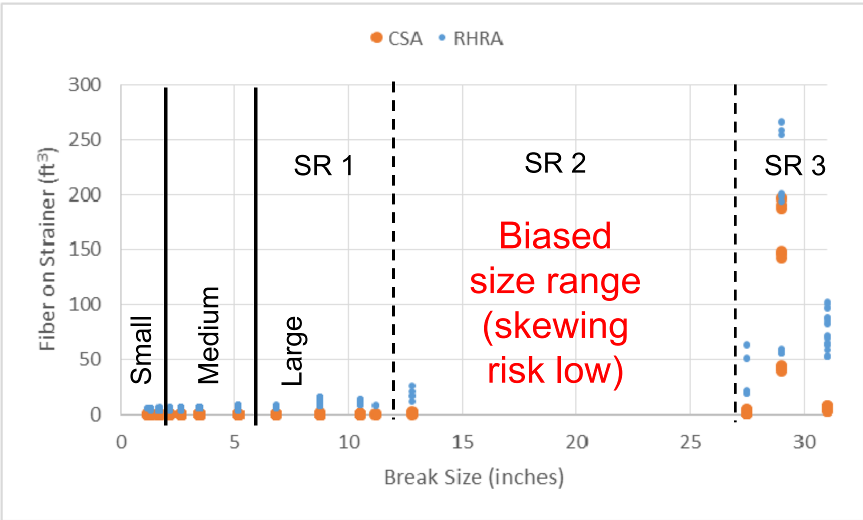
Continuum vs. DEGB-only Comparison of Fiber on Strainer

Continuum Break Model



DEGB-Only Model



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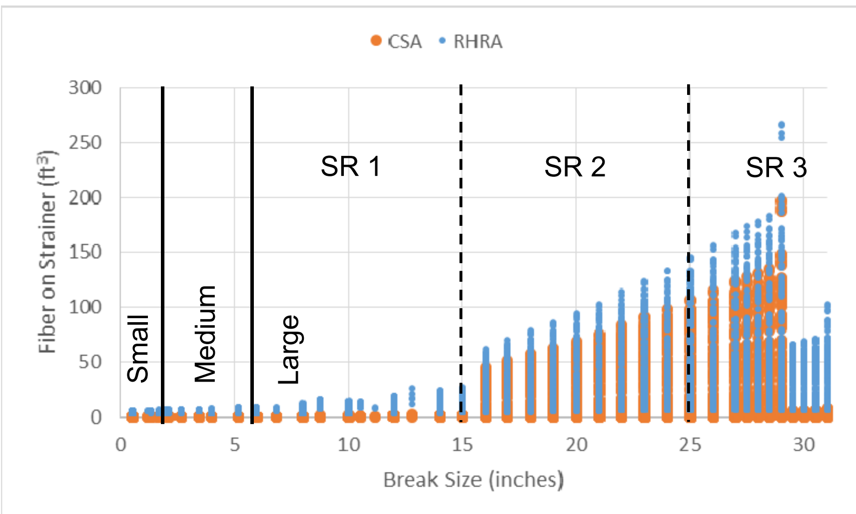
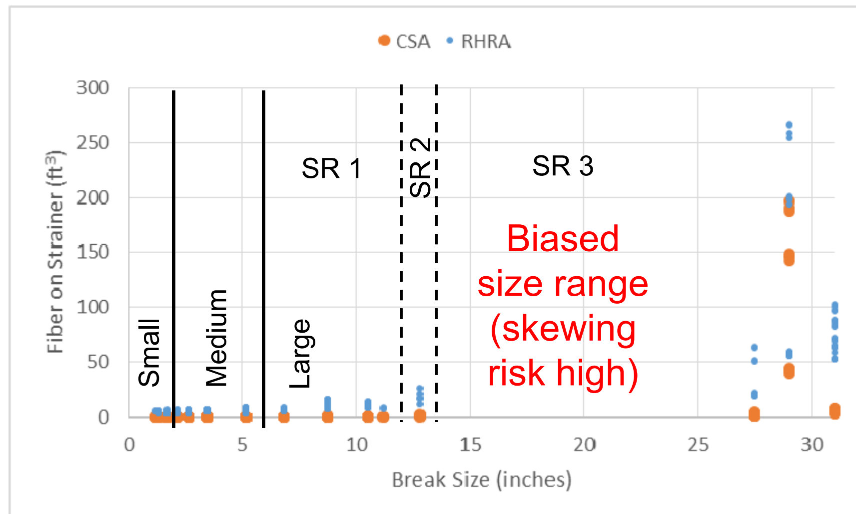
Continuum vs. DEGB-only Comparison of Fiber on Strainer

Continuum Break Model



DEGB-Only Model



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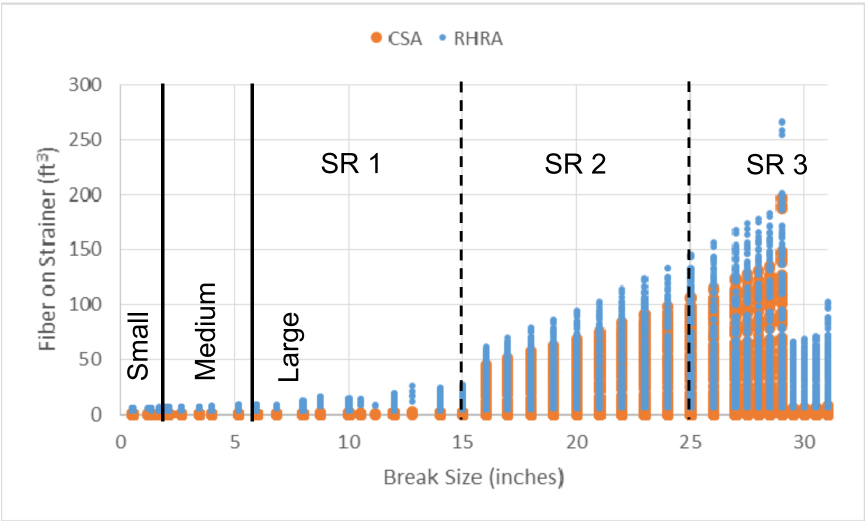
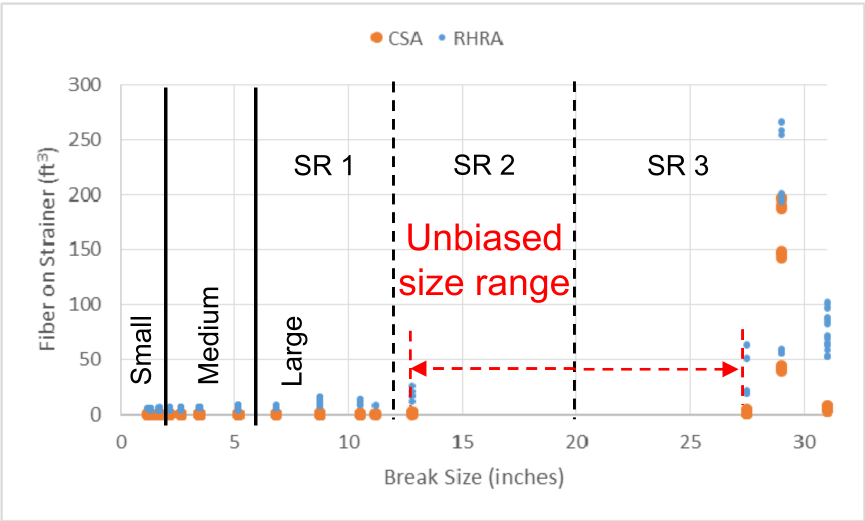


DEGB-Only Model



Fiber on Strainer

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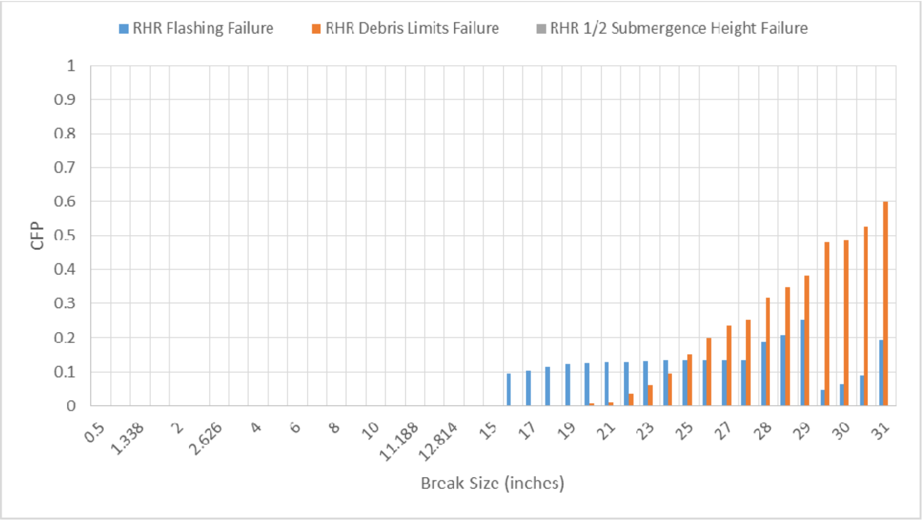
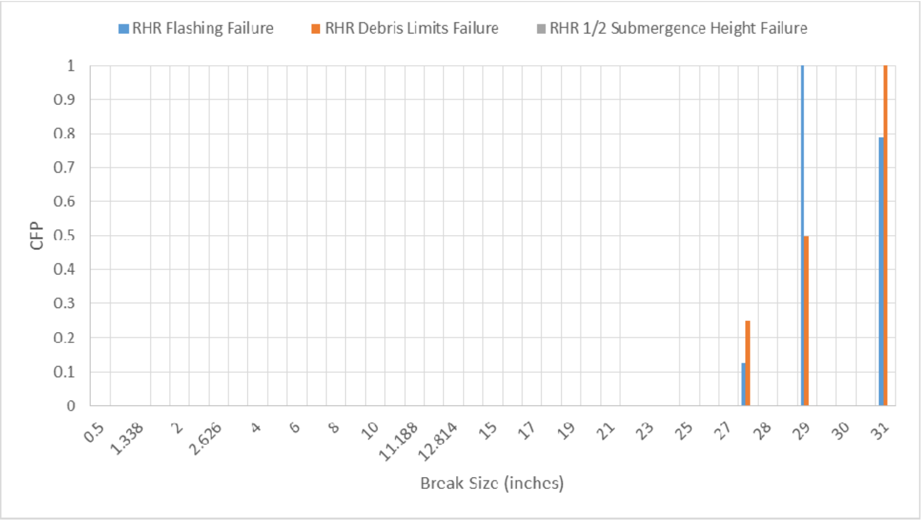
Continuum vs. DEGB-only Comparison of CFP Values

Continuum Break Model



DEGB-Only Model



Conditional Failure Probabilities

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Continuum vs. DEGB-only Comparison of ΔCDF

Case	PRA Category	Continuum CFP	DEGB (Bias Max) CFP	DEGB (Bias Min) CFP	DEGB (Unbiased) CFP
Two ECCS/CS Trains	Small	0	0	0	0
	Medium	0	0	0	0
	Large	0.0118	0.0780	0.0101	0.0243
Single ECCS/CS Train	Small	0	0	0	0
	Medium	0	0	0	0
	Large	0.0353	0.0816	0.0145	0.0286

$$\Delta CDF_{continuum} = 5.2 \cdot 10^{-6} \cdot (0.91 \cdot 0.0118 + 0.09 \cdot 0.0353) = 7.2 \cdot 10^{-8}$$

$$\Delta CDF_{DEGB\ (unbiased)} = 5.2 \cdot 10^{-6} \cdot (0.91 \cdot 0.0243 + 0.09 \cdot 0.0286) = 1.3 \cdot 10^{-7}$$

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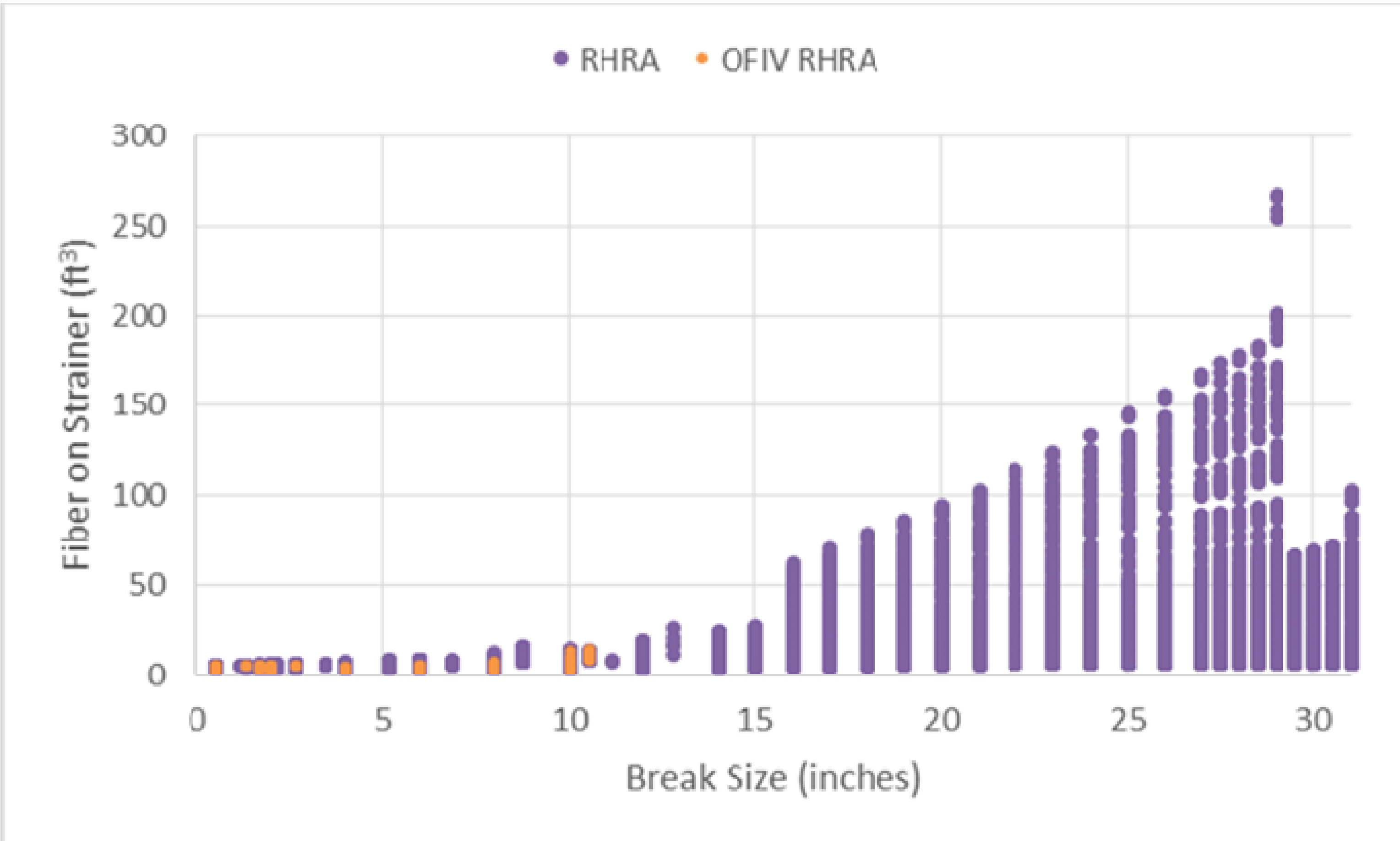
Breaks Past First Isolation Valve

- NUREG-1829 does not include isolable breaks
- A break outside the first isolation valve (OFIV) could occur, but would require valve failure to result in an unisolable LOCA
- Qualitative analysis should be performed to determine whether OFIV breaks would result in significantly worse debris generation and/or transport compared to similar size breaks inside first isolation valve
  - If not, these breaks can be concluded to have a negligible effect on risk due to the low probability of valve failure
  - If so, it may be necessary to evaluate these breaks quantitatively
    - Frequency based on similar welds inside the first isolation valve
    - Valve failure probability based on PRA data (~10^{-3} or less)
    - GSI-191 failure probability based on NARWHAL analysis
- Vogtle analysis showed no significant difference in similar size breaks inside and outside first isolation valve (and no failures for any OFIV breaks)

OFIV Break Comparison of Fiber Accumulation on Strainer



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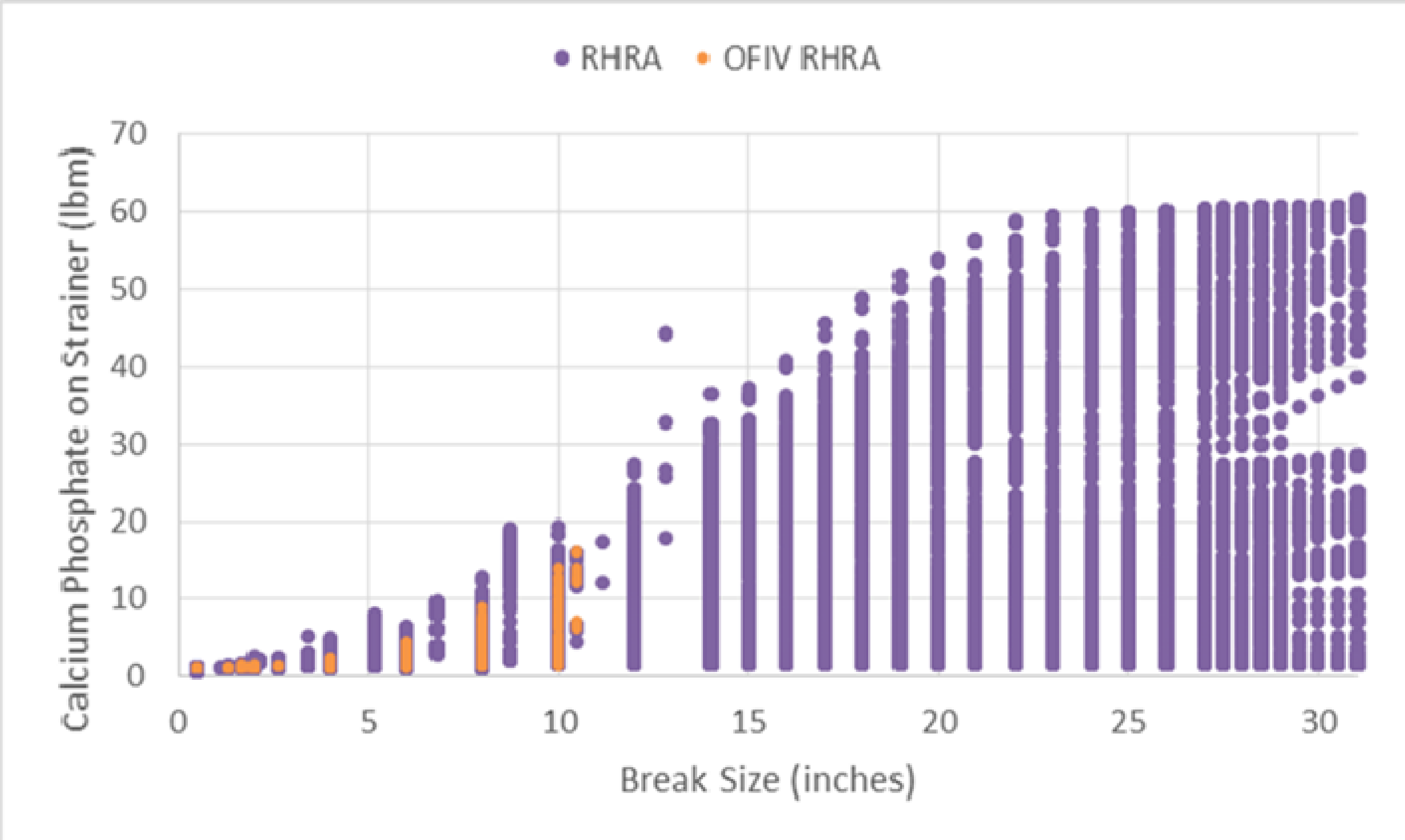
OFIV Break Comparison of Calcium Phosphate Accumulation on Strainer



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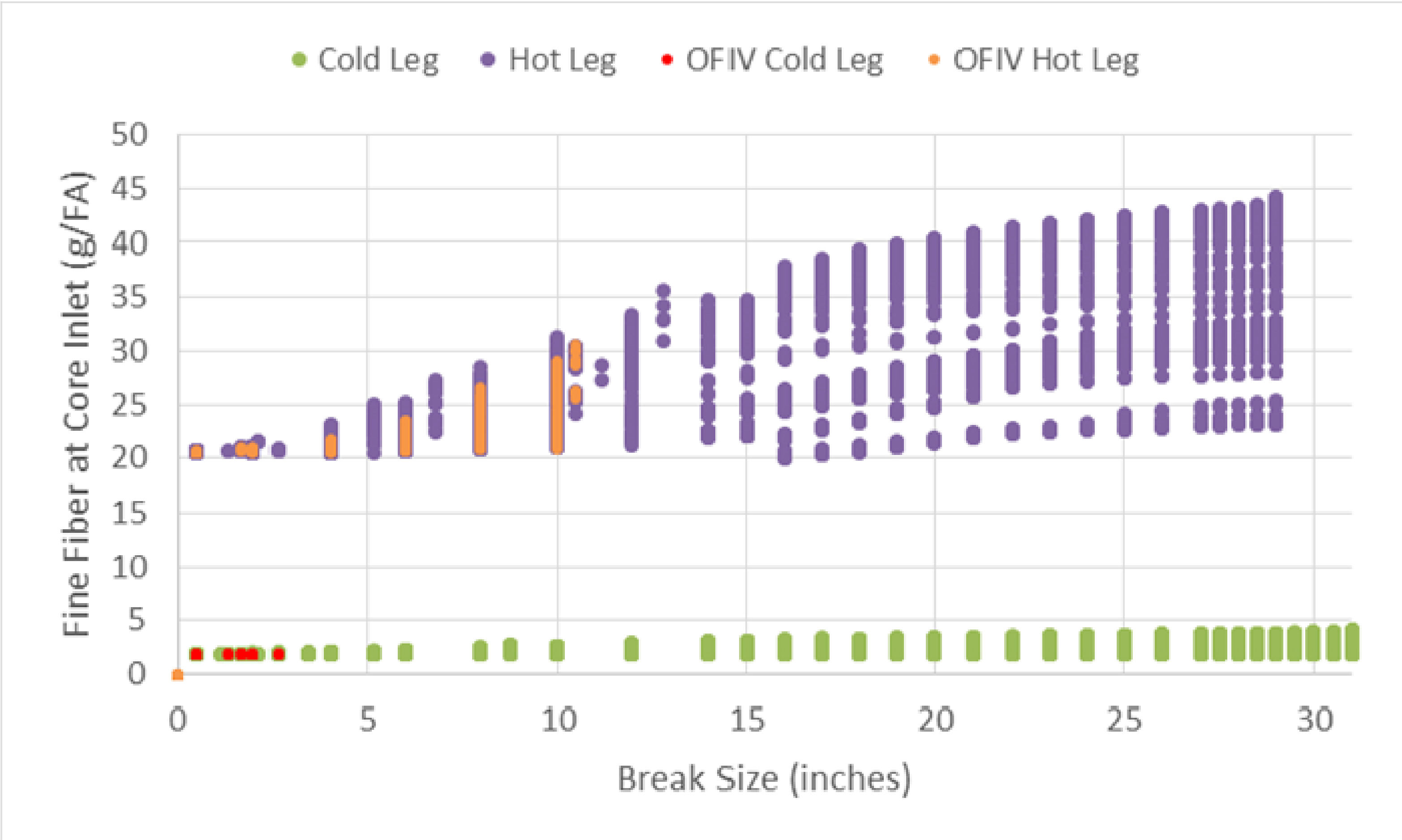
OFIV Break Comparison of Fiber Accumulation at Core Inlet



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Timing for Random Pump Failures

- Random equipment failures unrelated to GSI-191 include pump failure to start (FTS) and failure to run (FTR)
- In a PRA model, FTS and FTR are assumed to happen at the start of the event, which is how these failures have been treated for risk-informed GSI-191 evaluations
- NRC staff questioned whether the FTR timing could impact the GSI-191 risk quantification
- For Vogtle, failure of the CS or RHR pumps at the start of recirculation would result in higher GSI-191 CFPs compared to failure at the start of the event or failure later in the event
- Each licensee will need to evaluate potential time-dependent failures (unrelated to GSI-191) and justify assumptions

Random Equipment Failures

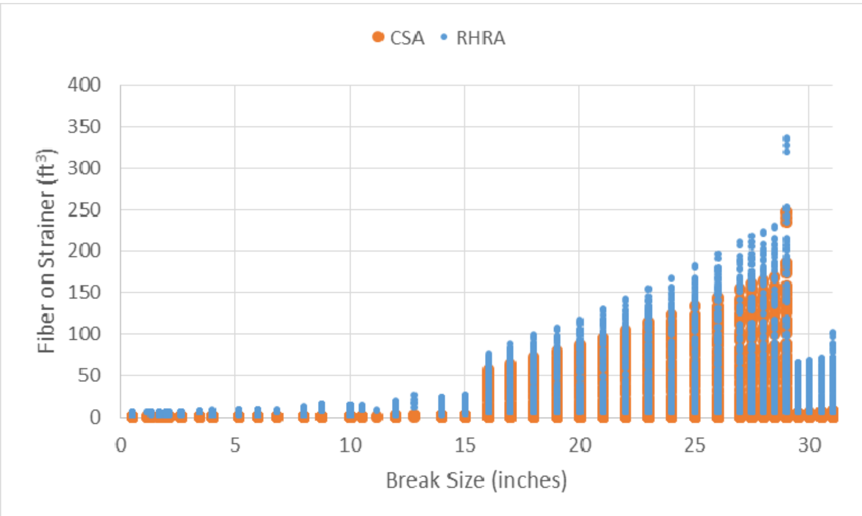
- For Vogtle, the important combination of pump failures includes RHR and CS pumps
  - No pump failures
  - Single RHR pump failure
  - Single CS pump failure
  - Single RHR pump and single CS pump failures
  - Two CS pump failures
  - Single RHR and two CS pump failures
- Failures of SI and charging pumps are bounded by failures of RHR pumps based on Vogtle-specific models and assumptions

CS and RHR Train Failure Probabilities

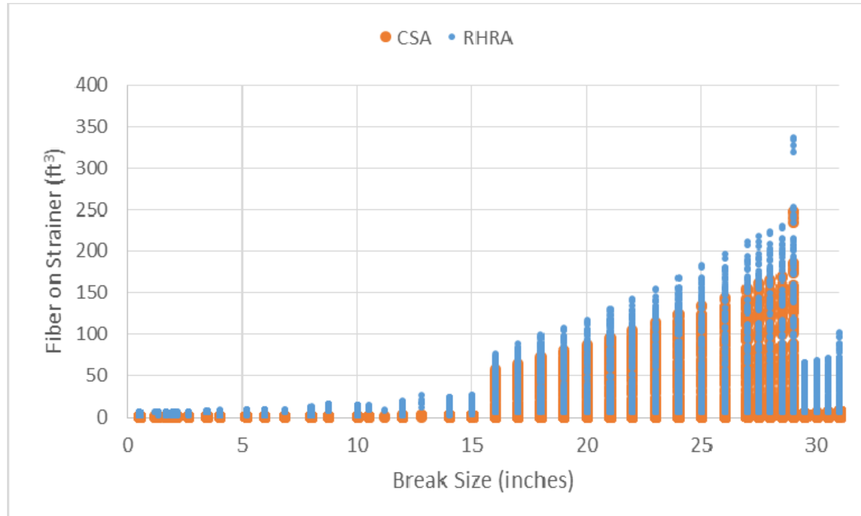
Failure	Probability	Percent Contribution
1 CS Train FTS – RWST Injection	3.7E-3	65%
1 CS Train FTS – Sump Recirculation	1.1E-3	19%
1 CS Train FTR – First hour	1.9E-4	3%
1 CS Train FTR – Next 23 hours	6.6E-4	12%
Total 1 CS Train	**5.67E-3**	**99%**
2 CS Trains FTS – RWST Injection	8.5E-5	0.2%
2 CS Trains FTS – Sump Recirculation	5.17E-2	99.6%
2 CS Trains FTR – First hour	1.3E-5	0.0%
2 CS Trains FTR – Next 23 hours	1.3E-4	0.3%
Total 2 CS Train	**5.19E-2**	**99.9%**
1 RHR Train FTS – RWST Injection	4.9E-3	70%
1 RHR Train FTS – Sump Recirculation	1.1E-3	16%
1 RHR Train FTR – First hour	1.7E-4	2%
1 RHR Train FTR – Next 23 hours	7.6E-4	11%
Total 1 RHR Train	**6.98E-3**	**99%**

Comparison of Failure Timing for CS Pump B

CSB Failure at Start of Event



CSB Failure at Start of Recirculation



Fiber on Strainer

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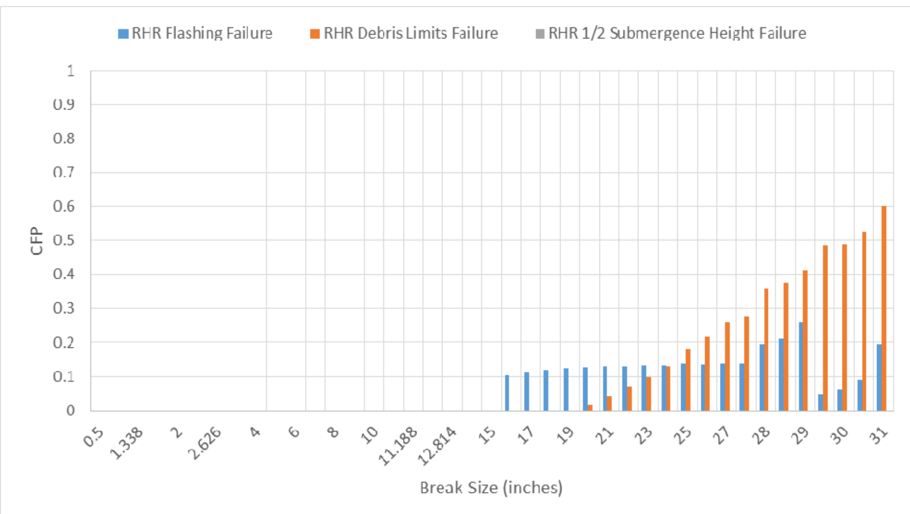
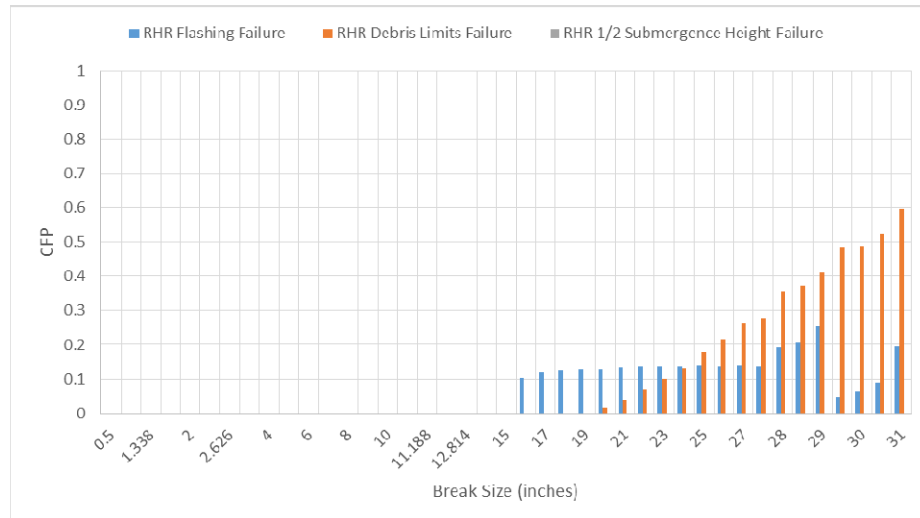
Comparison of Failure Timing for CS Pump B

CSB Failure at Start of Event



CSB Failure at Start of Recirculation



Conditional Failure Probabilities

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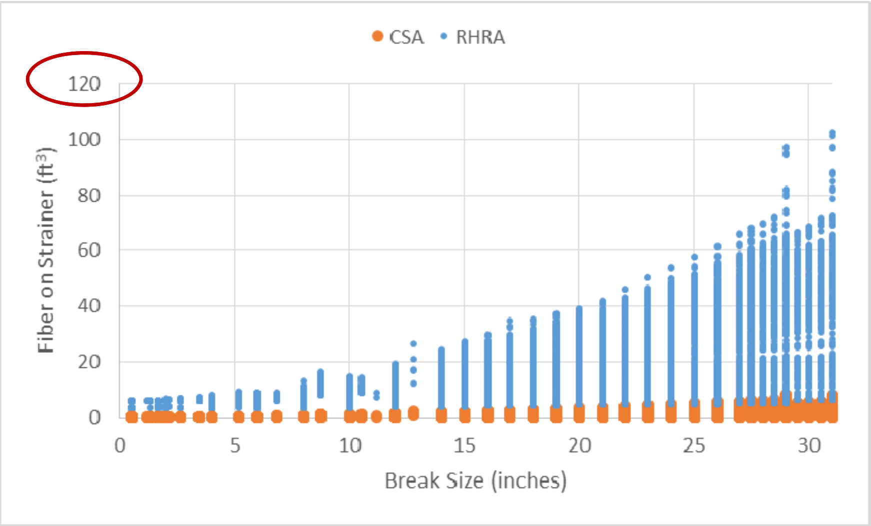
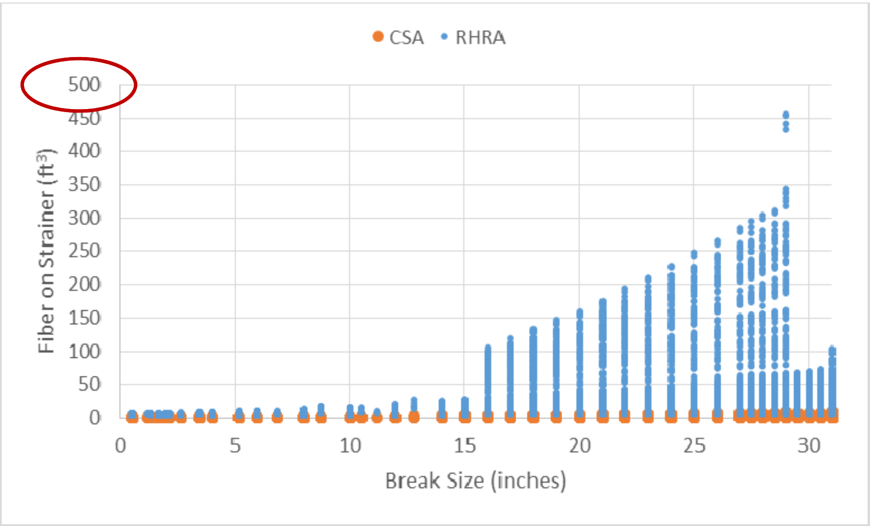
Comparison of Failure Timing for Both CS Pumps

All CS Failure at Start of Event



All CS Failure at Start of Recirculation



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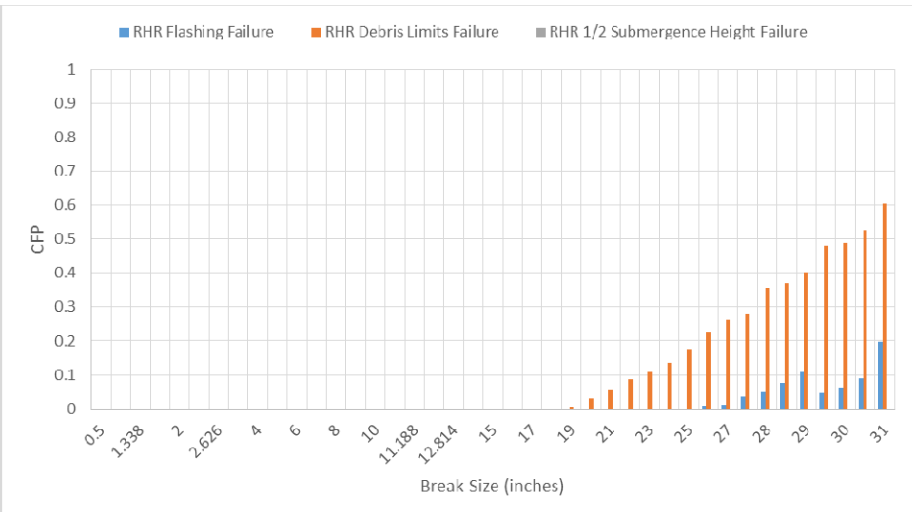
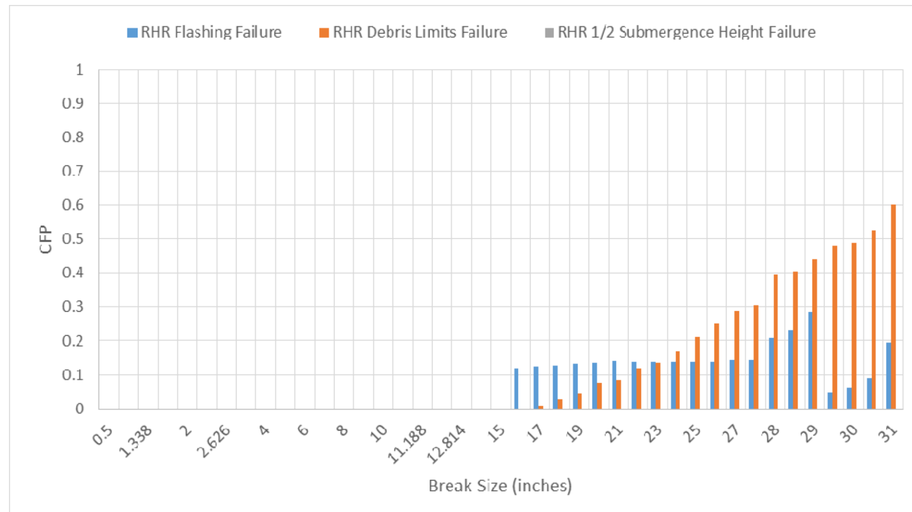
Comparison of Failure Timing for Both CS Pumps

All CS Failure at Start of Event



All CS Failure at Start of Recirculation



Conditional Failure Probabilities

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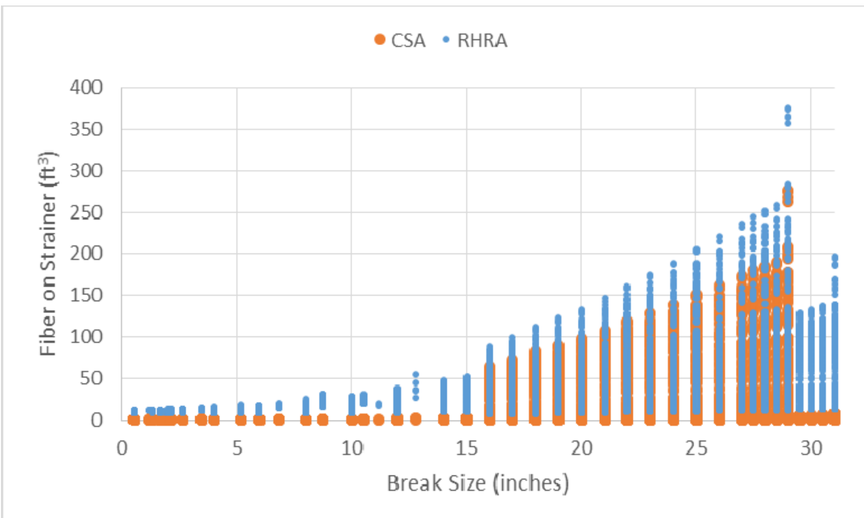
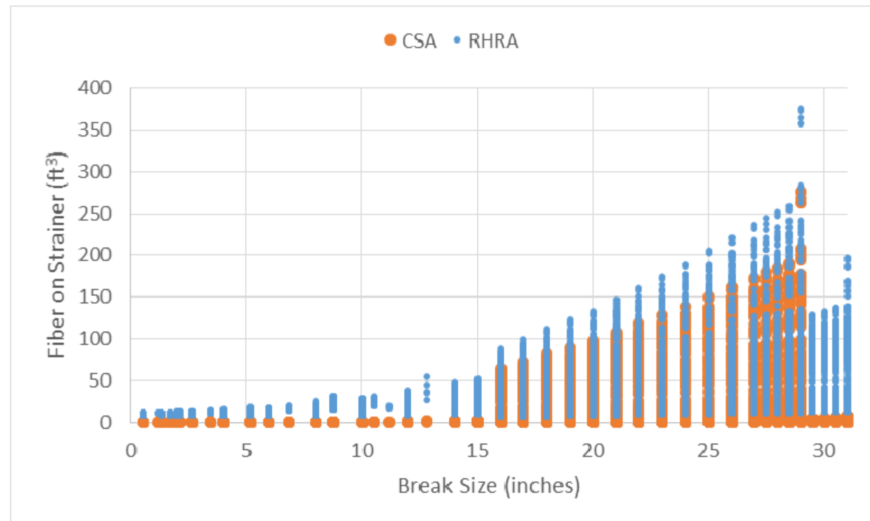
Comparison of Failure Timing for RHR Pump B

RHRB Failure at Start of Event



RHRB Failure at Start of Recirculation



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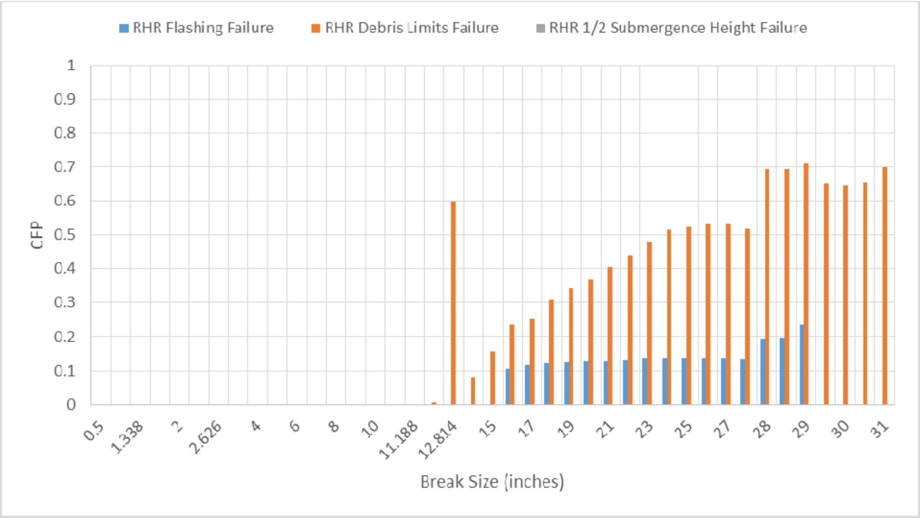
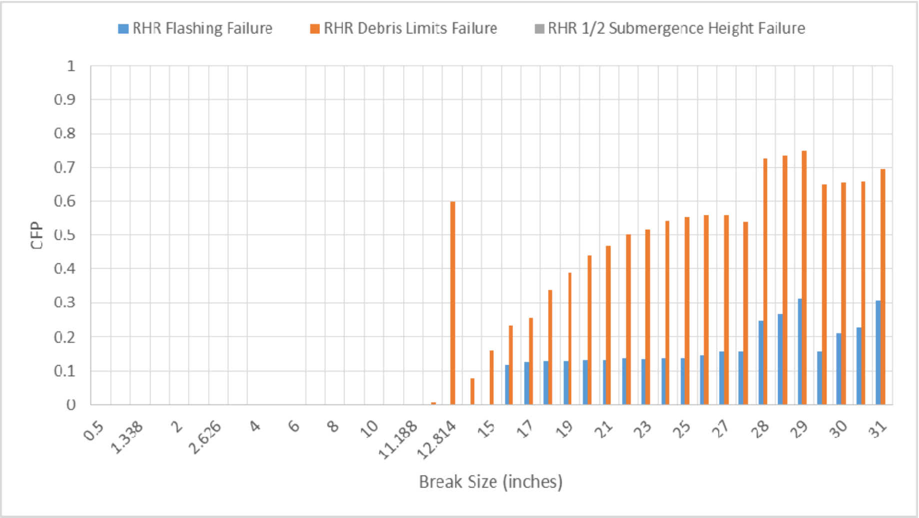
Comparison of Failure Timing for RHR Pump B

RHRB Failure at Start of Event



RHRB Failure at Start of Recirculation



Conditional Failure Probabilities

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Comparison of Failure Timing for ΔCDF

Case	PRA Category	Failure at Start of Injection	Failure at Start of Recirculation	Difference
Single CS Pump Failure	Small	0	0	0%
	Medium	0	0	0%
	Large	0.0120	0.0122	1.7%
Two CS Pump Failures	Small	0	0	0%
	Medium	0	0	0%
	Large	0.0069	0.0126	82.6%
Single RHR Pump Failure	Small	0	0	0%
	Medium	0	0	0%
	Large	0.0330	0.0351	6.4%

$$\Delta CDF_{Failure@t=0} = 5.2 \cdot 10^{-6} \cdot (0.91 \cdot 0.0118 + 0.01 \cdot 0.0120 + 0.06 \cdot 0.0069 + 0.02 \cdot 0.0330) = 6.20 \cdot 10^{-8}$$

$$\Delta CDF_{Failure@Recirc} = 5.2 \cdot 10^{-6} \cdot (0.91 \cdot 0.0118 + 0.01 \cdot 0.0122 + 0.06 \cdot 0.0126 + 0.02 \cdot 0.0351) = 6.41 \cdot 10^{-8}$$

Risk Contribution from Secondary Side Breaks

- Secondary side breaks may require ECCS recirculation under certain circumstances (e.g., feed and bleed)
- Assuming all secondary side breaks that require ECCS recirculation will result in strainer failure increases ΔCDF by 2.9E-7
  - Small value (within RG 1.174 Region III)
  - Large enough to significantly skew the overall GSI-191 ΔCDF
- Approximately 80% of frequency for secondary side breaks is from feedwater lines
- Lower pressure/temperature in secondary side piping results in smaller ZOIs
- ECCS flow rates would be significantly lower, which would reduce debris transport and strainer head loss for any debris that does transport
- Additional analysis is expected to show that no feedwater line breaks would fail and it is possible that no mainsteam line breaks would fail

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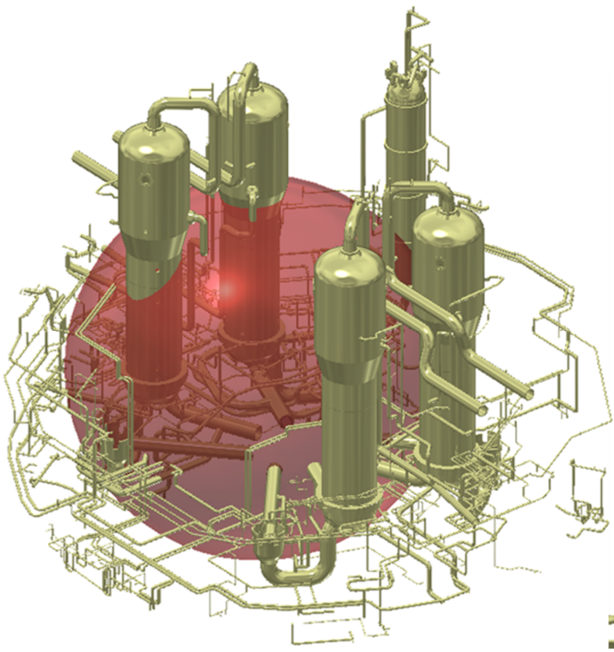
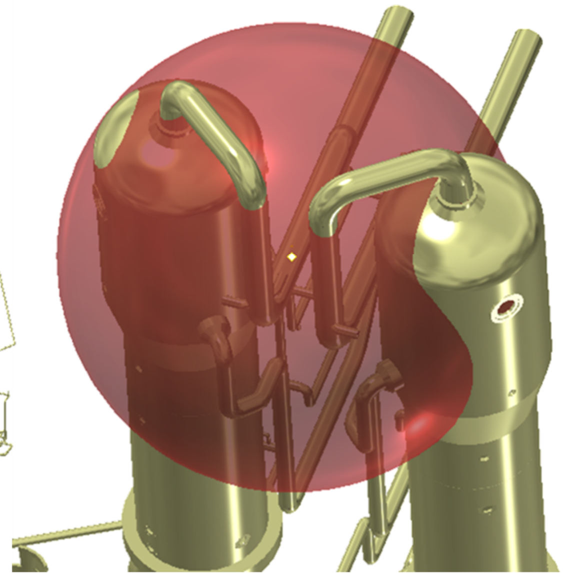
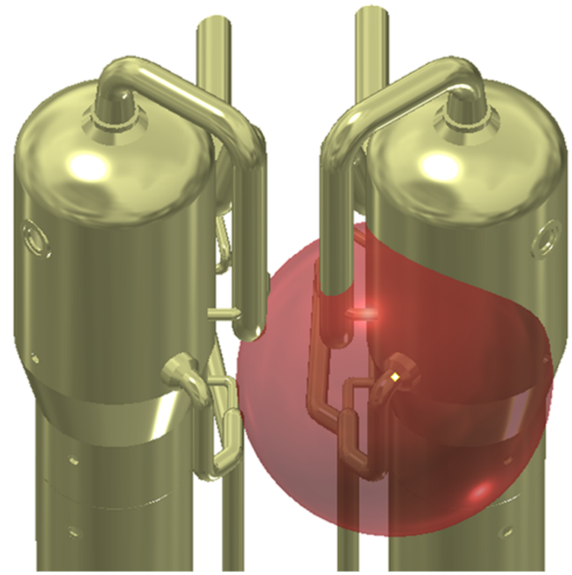
Debris Generation Evaluation



Bounding RCS Break
(29” DEGB with 17D ZOI)
2,235 ft^3 fiber debris



Bounding MSL Break
(26” DEGB with 10.6D ZOI)
1,156 ft^3 fiber debris



Bounding FWL Break
(16” DEGB with 11.3D ZOI)
221 ft^3 fiber debris

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Summary

- NRC audit was very helpful in identifying potential issues prior to submitting LARs
- Resolution of generic strainer flashing issue
  - NARWHAL modified to provide user flexibility
  - Additional (relatively minor) plant-specific analysis required to justify using midpoint strainer elevation to calculate flashing failures
- Resolution of Vogtle strainer particulate filtration issue
  - Vogtle NARWHAL model modified to use head loss test data directly for low fiber quantities
- Resolution of generic insulation size distribution methodology issue
  - Breaks with small centroids produce a negligible quantity of debris and revising the fraction of fines for these breaks would not significant affect risk quantifications

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Summary

- Resolution of generic break size and orientation increment issue
  - Refining size and orientation increments has very little impact on ΔCDF calculated using CFP approach (no change necessary for these licensees)
  - Refining size increments can significantly change ΔCDF calculated using threshold break approach
    - Largest break size that *does not* fail can be conservatively used as the threshold break size
    - To refine the threshold break size, additional size and orientation analysis can be performed for the specific break locations and sizes where the smallest failures are observed
- Resolution of generic LOCA frequency allocation methodology issues
  - NARWHAL modified to include log/linear interpolation
  - Methodology revised to avoid extrapolating 31” exceedance frequencies provided in NUREG-1829
  - Additional explanation provided for DEGB frequencies ($\sqrt{2} \times D_{pipe}$)
  - NARWHAL modified to include a hybrid type method based on ranking of Class 1 welds as high/medium/low likelihood as a function of degradation mechanisms

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Summary

- Resolution of Vogtle DEGB-only vs. continuum break model issue
  - Risk calculated with DEGB-only model is not significantly different from continuum break model
  - Continuum break model will be used for base case risk quantification and DEGB-only model will be included as a sensitivity in the Vogtle LAR
- Resolution of Vogtle breaks past first isolation valve issue
  - No need to quantitatively address breaks past first isolation valve unless there are unique debris generation/transport issues that would result in much higher GSI-191 CFPs for these breaks
- Resolution of Vogtle random pump failure timing issue
  - Random pump failures at the start of recirculation are generally worse than random failures at the start of the event or later in the event
  - Risk quantification will use conservative failure time since the impact on the results is minor
- Resolution of Vogtle secondary side break issue
  - Preliminary evaluation shows that most secondary side breaks will not result in strainer failure

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