LOCA Initiating Event Frequencies and Uncertainties Status Report

Risk Informed GSI-191 Resolution

Monday, August 22, 2011

8:00 am - 5:00 p.m EDT

Public Meeting with STP Nuclear Operating Company

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SCANDPOWER Risk Management

Discussion Topics

- Current Status
- Refinements of Approach for Conditional Rupture Probabilities
- Preliminary Results
- Independent Review by Ali Mosleh
- Issues to Complete

LOCA Frequencies Objectives

- Incorporate insights from previous work on LOCA frequencies
- Characterize LOCA initiating events and their frequencies with respect to:
  - Specific components, materials, dimensions
  - Specific locations
  - Range of break sizes
  - Damage / Degradation mechanisms and mitigation effectiveness
  - Other break characteristics, e.g. speed
- Quantify both aleatory and epistemic uncertainties; augment with sensitivity studies
- Support interfaces with other parts of the GSI-191 evaluation
  - LOCA initiating event frequencies for PRA modeling
  - Break characterization for evaluation of debris formation
- Participate in NRC workshops

Current Status

- Defined homogenous pipe failure rate categories
- Refined method for deriving conditional rupture probabilities vs. break size
- Obtained preliminary results for each pipe category
- Obtained preliminary results for total LOCA frequencies from pipe failures
- Independent reviews by MIT and Ali Mosleh in progress

Homogeneous Pipe Failure Rate Cases

Calc. Case No.	Description	Weld Type	Applicable Damage / Degradation Mechanism	Nominal Pipe Size [inch]	Comment
1	RCS Hot Leg excl. S/G Inlet	B-J	TF, D&C	29	Location of design basis LOCA; B-F weld has higher failure rate but inside Rx cavity
		B-J	D&C		
		B-F	PWSCC, D&C		
2	RCS Cold Leg; different FR basis but same CRP basis as for Hot Leg	B-J	D&C	27.5", 31"	S/G outlet welds excluded from this case
		B-F	PWSCC, D&C		
3	RCS Hot Leg S/G Inlet'S/G Inlet	B-F	D&C	27.5	Includes S/G inlet nozzle-to-safe-end weld to resolve much higher incidence rate at Japanese plants following S/G replament. Applicability to U.S. plants being investigated
4	Prz-Surge Line	B-J	TF, D&C	16	Includes branch connection (BC) nozzle welds, nozzle to pipe, pipe to pipe, and pipe to Pressurizer inlet safe end
		B-J (BC)	TF, D&C		
		B-F	PWSCC, D&C		
5	Pressurizer Medium Bore Piping	B-J	D&C	4", 6"	Pressurizer spray (4"), PORV and SRV welds (6")
		B-J (BC)	TF, D&C		
		B-F	PWSCC, TF, D&C		
		B-F	PWSCC, D&C		
		B-F	Weld Overlay		
6	Class 1 Small Bore Piping	B-J	D&C, TGSCC, VF	ø ≤ 2"	Challenging to establish weld population data - significant plamt-to-plant variability. Important to distinguish between socket weld and non-socket weld populations.
7	Class 1 Medium Bore Safety Injection and RHR Piping	B-J	D&C	4" ≤ ø ≤ 10"	Welds in Class 1 piping and branch connections for HPI/LPI/RHR systems; large weld population
		B-J	TF, D&C		
		B-J	IGSCC, D&C		
		B-J	IGSCC, TF, D&C		
8	Class 1 Medium Bore CVC Piping	B-J	TF, D&C	2" ≤ ø ≤ 4"	CVC System including RCP seal injection line (injection/return)
		B-J	D&C		
		B-J	VF, D&C		
		B-J (BC)	TF, D&C		

Step by Step Procedure

1. Determination of weld types (i)
2. Perform data query for failure counts (n)
3. Estimate component exposure (T) and uncertainty
4. Develop component failure rate prior distributions for each DM
5. Perform Bayes’ update for each exposure case (combination of weld count and DM susceptibility)
6. Apply posterior weighting to combine results for different hypothesis yield conditional failure rate distributions; compute unconditional failure rates for locations with uncertain DM status
7. Develop conditional probability of rupture size given failure probabilities for each weld type and associated epistemic uncertainties
8. Combine the results of Step 6 and Step 7 by Monte Carlo in Eq. (1) for component LOCA frequencies and total LOCA frequencies for each component
9. Apply Markov Model to specialize rupture frequencies for differences in integrity management
10. For intermediate LOCA categories and break sizes, interpolate the results of Step 10 via log-log linear interpolation
11. Calculate total LOCA frequencies from all components and reconcile differences with earlier LOCA frequency estimates

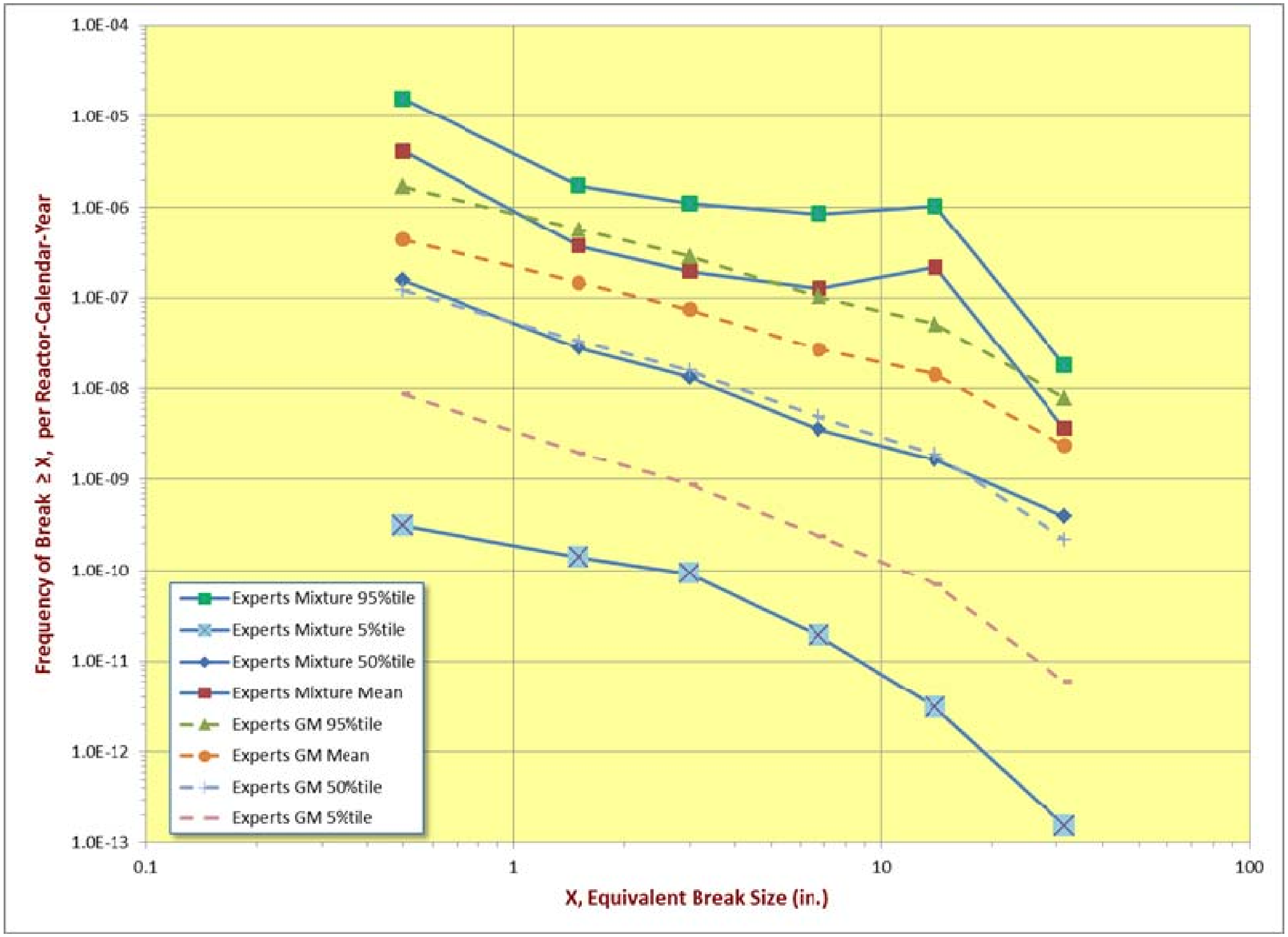
Step 7 Conditional Probability of Pipe Rupture

- Step 7.1 Benchmark of Lydell's Base Case LOCA frequencies for PWR hot leg, surge line, and HPI line
- Step 7.2 Compare results of individual expert elicitation LOCA Frequencies from NUREG-1829 to base case
- Step 7.3 Set Target LOCA frequencies that encompass elicitation results (method revised since July meeting)
- Step 7.4 Derive conditional rupture probability distributions that when combined with Lydell failure rate estimates match the target LOCA frequencies
- Step 7.5 Perform Bayes' updates that incorporate evidence on pipe failures without LOCAs

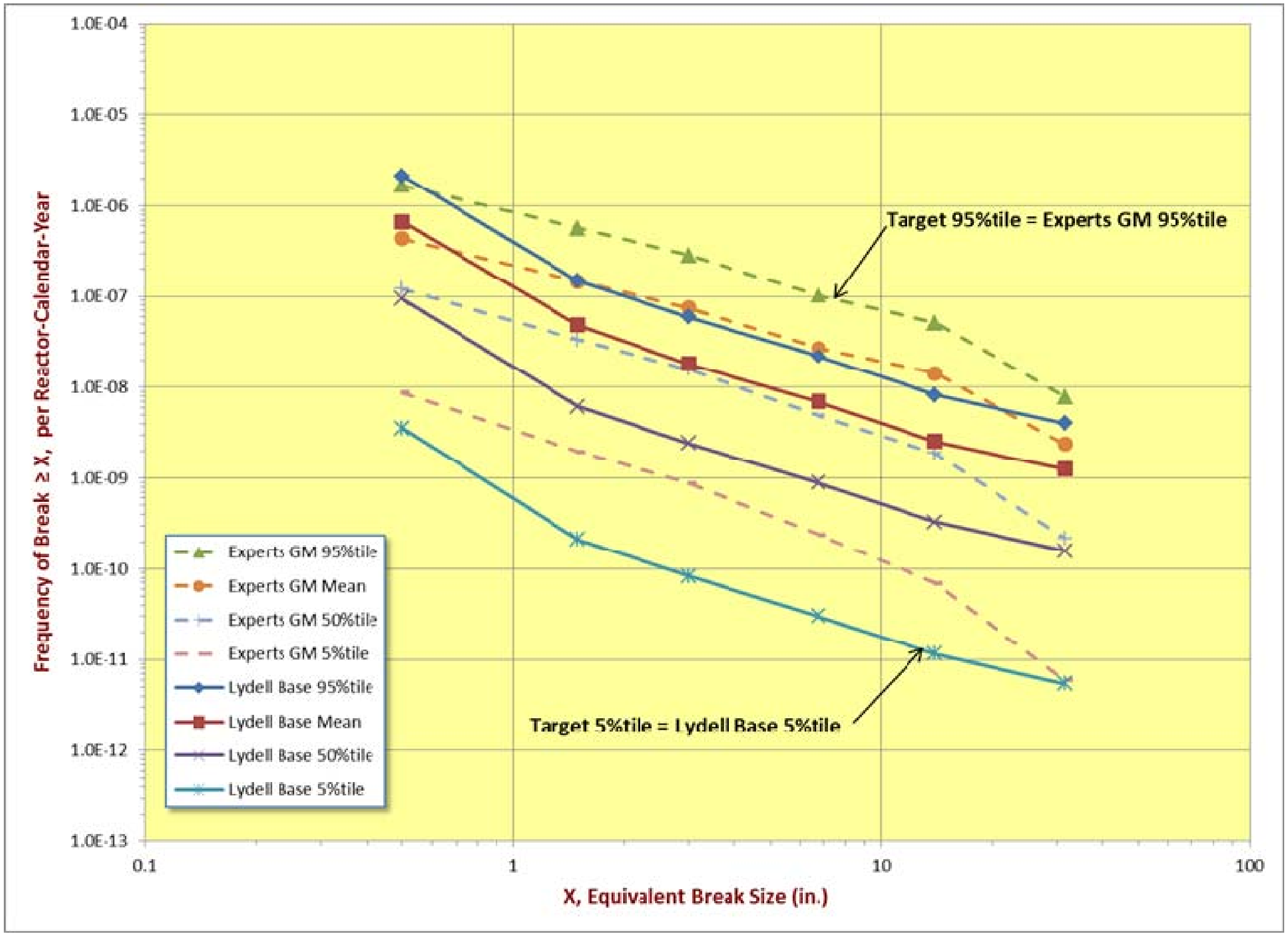
Selection of Target LOCA Frequencies

- Used expert distributions from NUREG-1829
  - Input from 9 experts for component level LOCA frequencies at different plant ages; using data for 40 years
  - Bengt Lydell base case results in Appendix D
- Evaluated alternative approaches to aggregating into composite distributions for different components
  - Mixture distribution of NUREG-1829 data - rejected
  - Geometric mean distribution of NUREG-1829 data
    - Geometric means of 50th percentiles and range factors - accepted
    - Geometric means of input 5%tiles and 95%tiles - rejected
  - Hybrid of geometric means and Lydell base
    - Use of worst case 5$^{\%}$ tiles and 95%tiles (Method described in July meeting)
    - Mixture distribution of geometric mean and Lydell (Method recommended by Dr. Mosleh)
- Performing sensitivity studies on alternative models

Comparison of Geometric Mean and Mixture Distributions from NUREG-1829 Data



Use of Worst-Case Percentiles from NUREG-1829 GM and Lydell Base Case



Selected Approach for Target LOCA Frequencies

- Probabilistic mixture of two models
  - Model 1 Geometric mean of 9 expert distributions
    - Develop 40 year composite distribution of 9 experts using geometric mean method
    - Combined lognormal distribution for Current day and 40yr multipliers for each expert preserving median and range factors
    - Developed composite distribution based on geometric means of each experts medians and range factors
  - Model 2 Bengt Lydell Base Case analysis
  - Results of Models 1 and 2 combined giving equal weight to each yielding a mixture distribution of the two models
  - This method produces somewhat greater uncertainties than using Model 1 by itself

Comparison of Hybrid Methods

STP Hot Leg Target LOCA Model - Worst Case 5%tile and 95%tile						
LOCA Cat.	**Break Size**	**Mean**	**5%tile**	**50%tile**	**95%tile**	**RF**
1	0.5	5.79E-07	3.55E-09	8.72E-08	2.14E-06	24.6
2	1.5	1.95E-07	2.10E-10	1.09E-08	5.68E-07	52.0
3	3	1.05E-07	8.33E-11	4.89E-09	2.87E-07	58.7
4	6.76	3.75E-08	3.03E-11	1.77E-09	1.03E-07	58.3
5	14	2.02E-08	1.16E-11	7.75E-10	5.17E-08	66.8
6	31.5	2.41E-09	5.44E-12	2.08E-10	7.94E-09	38.2
STP Hot Leg Target LOCA Model - Probabilistic Mixture						
1	0.5	5.08E-07	5.30E-09	1.05E-07	1.91E-06	19.0
2	1.5	9.32E-08	3.91E-10	1.46E-08	3.68E-07	30.7
3	3	4.54E-08	1.60E-10	6.39E-09	1.76E-07	33.1
4	6.76	1.64E-08	5.73E-11	2.05E-09	6.32E-08	33.2
5	14	8.37E-09	2.03E-11	7.64E-10	2.92E-08	37.9
6	31.5	1.80E-09	5.85E-12	1.80E-10	5.83E-09	31.6

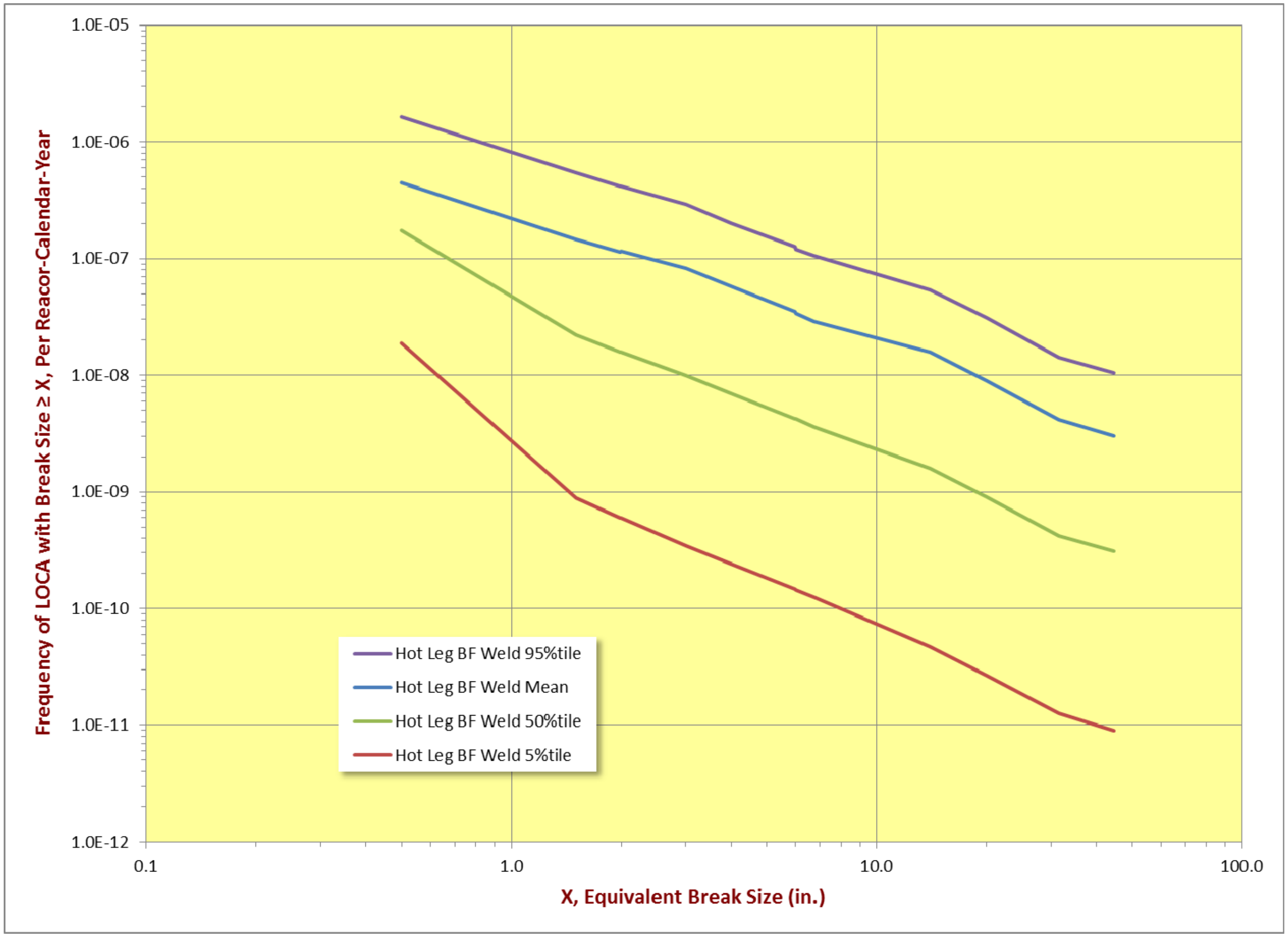
Preliminary Results

- Results shown here use worst case percentile method for combining the NUREG-1829 GM and Lydell base case distributions
- Some modest reductions in means and range factors expected from incorporation of mixture method
- Current results only address LOCAs caused by pipe failures
- Non-pipe contributions to be considered in 2012

Example Results – Hot Leg B-F Weld at RPV Nozzle

BF Weld		Mean	5%tile	50%tile	95%tile	RF
Failure Rate		2.72E-04	1.04E-04	2.32E-04	5.77E-04	2.4
Cumulative LOCA Frequencies Vs. Break Size (in.)	0.5	4.42E-07	1.89E-08	1.74E-07	1.63E-06	9.3
	1.5	1.46E-07	8.90E-10	2.22E-08	5.45E-07	24.7
	1.99	1.13E-07	5.98E-10	1.57E-08	4.14E-07	26.3
	2.0	1.15E-07	5.96E-10	1.58E-08	4.19E-07	26.5
	3.0	8.21E-08	3.44E-10	9.92E-09	2.89E-07	29.0
	4.0	5.81E-08	2.42E-10	7.00E-09	2.02E-07	28.9
	5.99	3.49E-08	1.45E-10	4.22E-09	1.25E-07	29.3
	6.0	3.41E-08	1.43E-10	4.24E-09	1.20E-07	29.0
	6.8	2.89E-08	1.25E-10	3.60E-09	1.05E-07	29.0
	14.0	1.57E-08	4.67E-11	1.57E-09	5.41E-08	34.0
	20.0	8.93E-09	2.65E-11	8.93E-10	3.07E-08	34.0
	31.5	4.15E-09	1.26E-11	4.21E-10	1.42E-08	33.7
	44.5	3.02E-09	8.95E-12	3.12E-10	1.04E-08	34.2

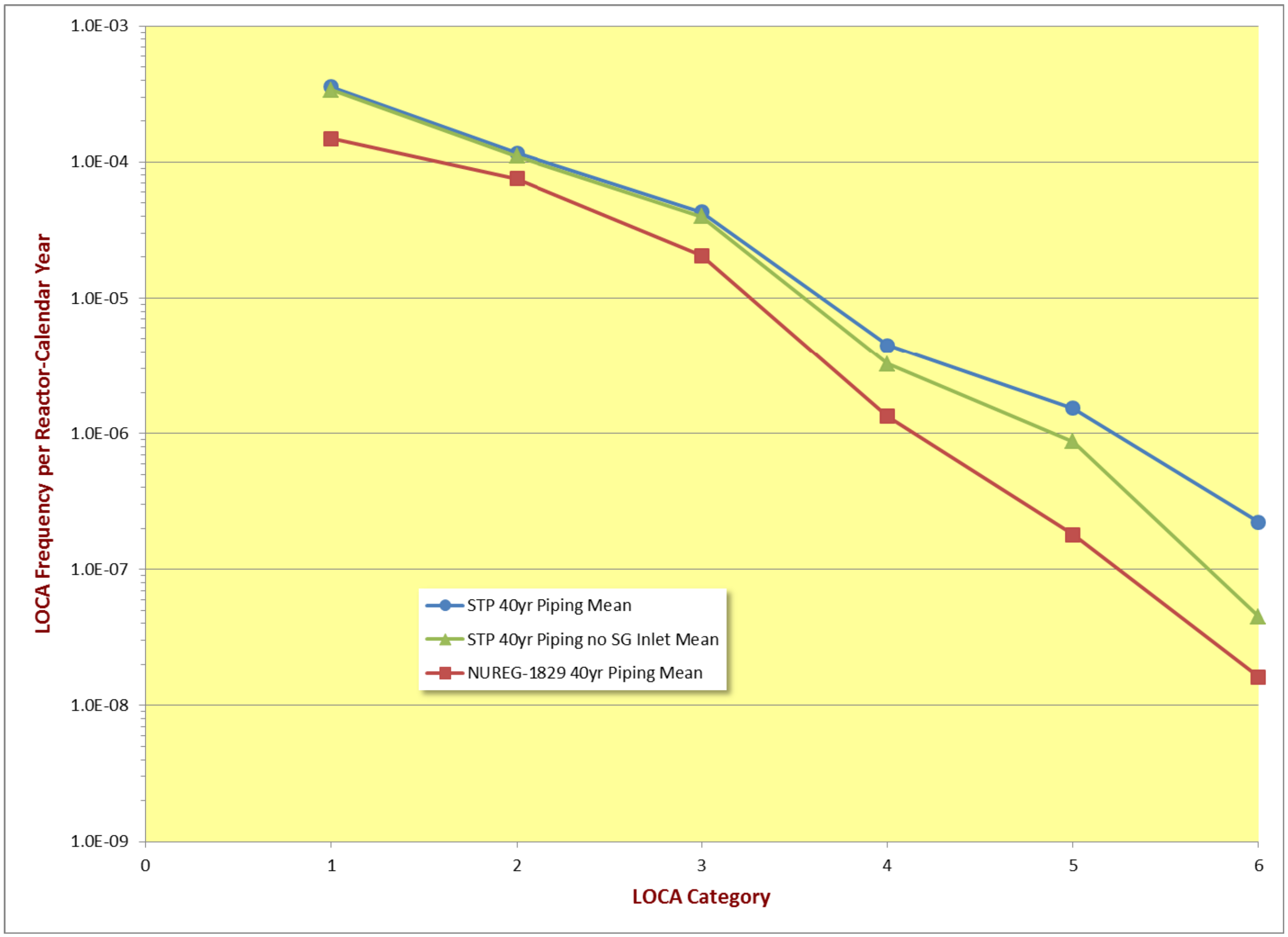
Example Results – Hot Leg B-F Weld at RPV Nozzle



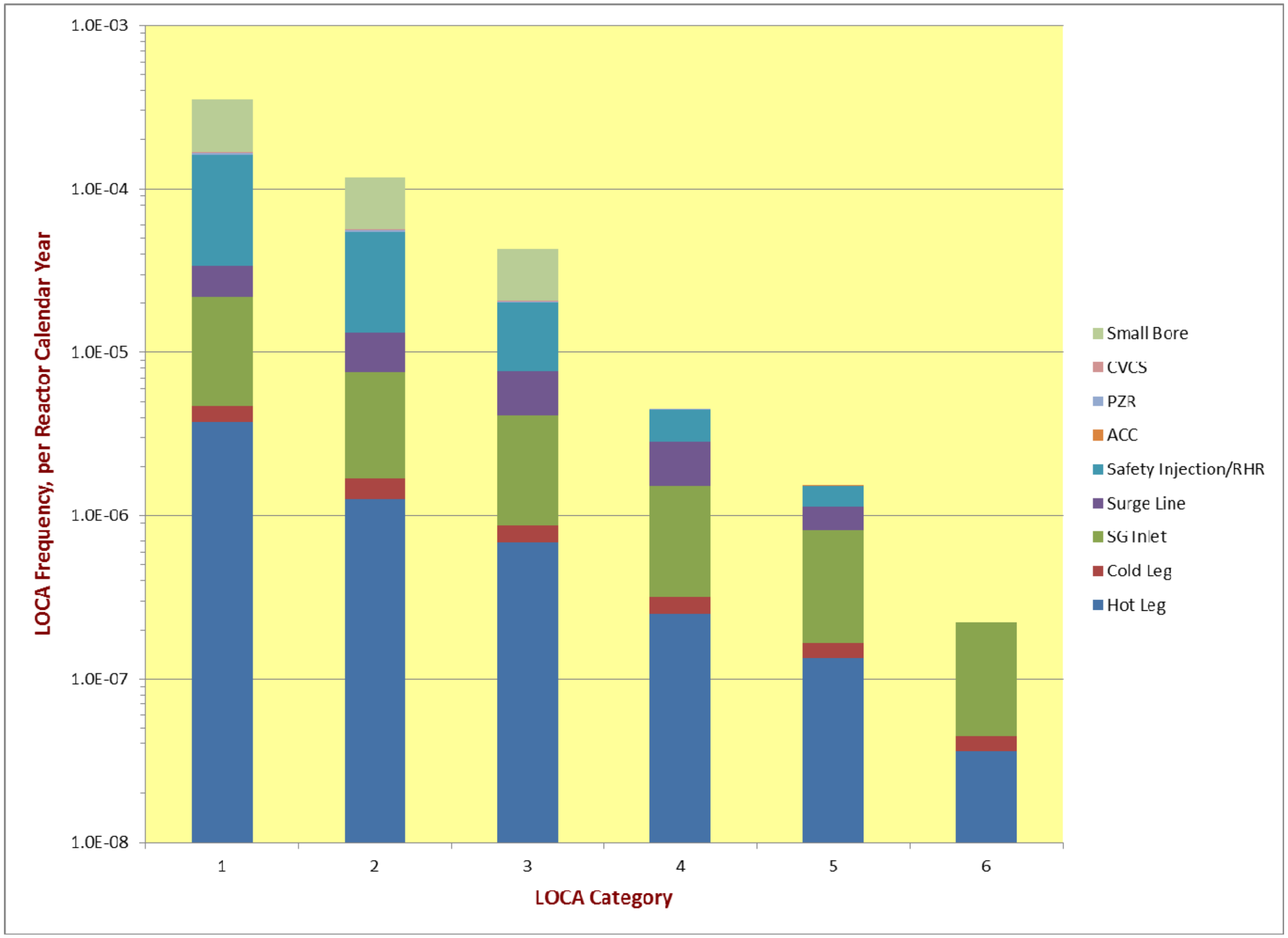
Preliminary Results for Initiating Event Frequencies from Pipe Breaks

Initiating Event	Break Size	Mean	5%tile	50%tile	95%tile	RF
SLOCA	.5 to 2"	2.68E-04	4.44E-05	1.75E-04	7.85E-04	4.2
MLOCA	2" to 6"	6.69E-05	2.94E-06	2.53E-05	2.44E-04	9.1
LLOCA	> 6"	3.34E-06	3.49E-08	6.37E-07	1.23E-05	18.8

Preliminary Results for Total LOCA Frequency from Pipes



Preliminary Results – System Contributions to LOCA Frequency



Major Tasks to Complete

- Provide input to CASAGRANDE with appropriate conditional probabilities vs. break size given the initiating event
  - Conditional probability that the break occurs in each location
  - Conditional probability that the break is in different size at each location
- Provide input to RISKMAN on the initiating event frequencies and uncertainties
- Finalize the draft report and submit for NRC review meeting in mid-September