WESTINGHOUSE OWNERS GROUP

Redefinition of the Licensing Basis
Large Break LOCA
Probabilistic Risk Assessment Overview

November 2000

Risk Assessment Discussion

- Structural Reliability Background
- Estimation of Large Break LOCA initiating event frequencies based on pipe size
- Estimation of conditional core damage probability given a LOCA

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Estimation of Large Break LOCA Initiating Event Frequencies Based on Pipe Size

- Use of risk-informed inservice inspection piping failure probabilities for all piping that could result in a large break LOCA
  - Information collected from seven Westinghouse plants
  - Probabilistic fracture mechanics software (approved by NRC through SER) used to estimate failure probabilities by line size
  - Failure probabilities without ISI but with credit for leak detection used for this program
  - Failure probabilities based on disabling leak rate equivalent to LBLOCA
    - Generally defined as greater than 6" in diameter and make up capacity of 5000 gpm (based on NUREG-4550 definitions)
    - Failure probabilities based on 5000 gpm leak size

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Structural Reliability Background

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Structural Reliability and Risk Assessment (SRRA)

- Deterministic model of failure (e.g., fracture mechanics)
- Consideration of uncertainties in input parameters (e.g., flaw size, stress, material properties, etc.)
- Monte-Carlo simulation is used to generate probability of failure
- Compatible with known experience/ benchmarked
- Differences in failure probabilities based on:
  - Geometry - Loading
  - Environment - Material properties
  - Aging effects - Effectiveness of ISI
  - Corrective actions

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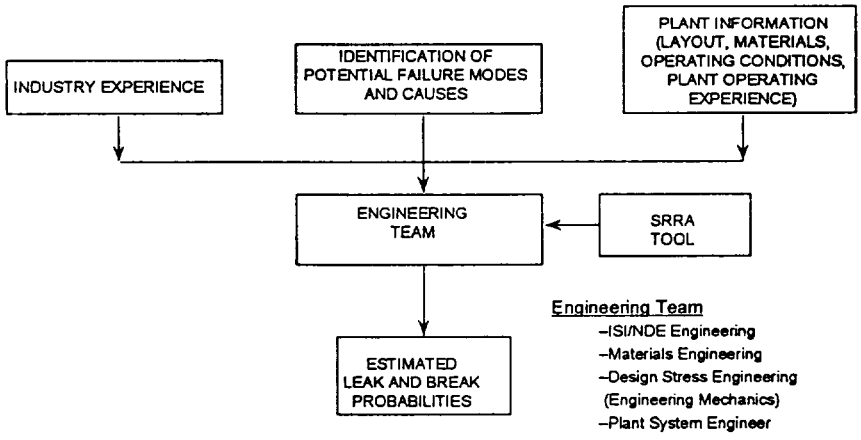
SRRA Failure Probability Assessment Process



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Required SRRA Information

- Thermal-Fluid Systems Analysis
  - potential sources and locations of thermal striping or stratification
  - areas of high flow velocity or turning losses for vibrations/wastage
  - stagnant flow zones and coolant chemistry for wastage/corrosion
  - location of high transient pressures or loads (e.g., water hammer)
  - steady-state and transient temperatures and gradients
- Piping Integrity and Materials Analysis
  - location of discontinuities, like snubbers, anchors, and dissimilar metal joints for high operating or cyclic stresses
  - areas of high thermal stress (low cycle fatigue)
  - locations with high transient loads (seismic)
  - material locations for stress corrosion and other potential degradation mechanisms from prior failure analyses

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More SRRA Information

- Inservice Inspection
  - locations with poor preservice inspection (undetected flaws)
  - inspection locations now required by ASME Section XI
  - history of any indications in this or similar configurations
  - results of applicable Section XI flaw evaluations
  - accuracy of potential inservice inspection
- Operations and Maintenance
  - any problems observed during fabrication, installation or hot functional testing of system
  - any observed failures or areas of high vibrations
  - history of snubber retesting or other support problems
  - previous plant-specific ISI experience and maintenance problems including leaks or repairs, problems with valves, bellows, etc.
  - industry experience (considered and evaluated for applicability)

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SRRA Input Parameters

Input Parameter Description
Type of Piping Material
Crack inspection Interval (optional)
Crack inspection Accuracy (optional)
Temperature at Pipe Weld
Nominal Pipe Size
Thickness to O.D. Ratio
Normal Operating Pressure
Residual Stress Level
Initial Flaw Conditions
DeadWeight & Thermal Stress Level
Stress Corrosion Potential
Material Wastage Potential
Vibratory Stress Range
Fatigue Stress Range
Low Cycle Fatigue Frequency
Design Limiting Stress (LL/Break Only)
System Disabling Leak (Large Leak Only)

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Standard SRRA Uncertainties

Parameter	Distribution	Basis for Uncertainty
PIPE-DIA	Normal	Tolerance = $\pm 2\sigma$ for ASTM A-106, A-355 & A-376
WALL/DIA	Normal	12% = $\pm 2\sigma$ for ASTM A-106, A-355 & A-376
SRESIDUAL	Log-Normal	2σ factor = 2 for benchmarking with IGSCC leak data
INT%DEPTH	Log-Normal	Calculated using latest models for flaw depth distribution
L/D-RATIO	Log-Normal	pc-PRAISE FCG example used a 1σ factor of 1.3077
HOURS/CY	Log-Normal	$\pm 3\sigma$ range based upon a capacity factor from 70 to 100%
PRESSURE	Log-Normal	3σ value = 10% of median value
STRESS-SS	Log-Normal	3σ factor = 2 by engineering judgement
SSC-COEFF	Log-Normal	$\pm 2\sigma$ range = 31.6 factor in NUREG-0313, Rev. 2
ECW-RATE	Log-Normal	Consistent with 99.5% bound (2.575σ) factor of 9.24 for data on wall thinning in EPRI NP-6066
STRESS-FT	Log-Normal	Upper 99% bound is a factor of 2
STRESS-ST	Log-Normal	2σ factor = 2 by engineering judgement
FCG-COEFF	Log-Normal	Consistent with 90% bound (1.282σ) factor of 3.83 in pc-PRAISE
LIMIT-PBS	Normal	Statistical fit of weld data in EPRI NP-4768
STRESS-DL	Log-Normal	2σ factor = 2 by engineering judgement

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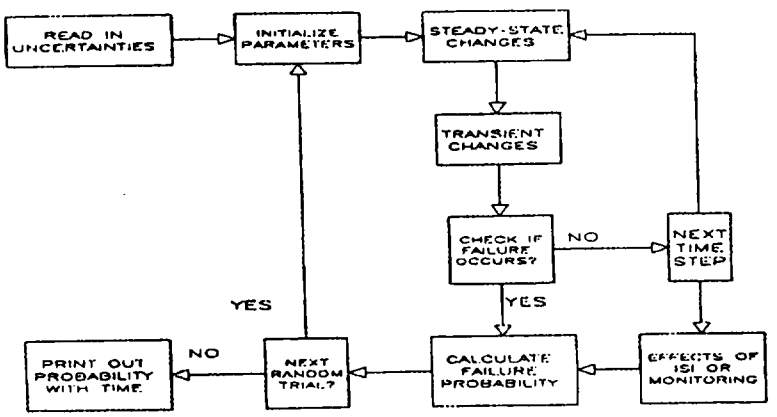
SRRA Program Flow Chart



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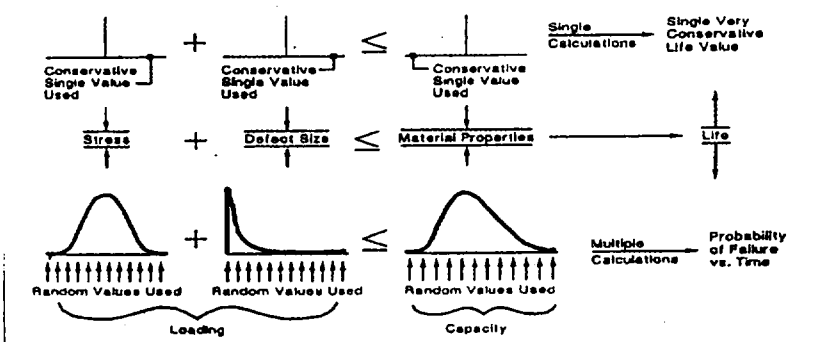
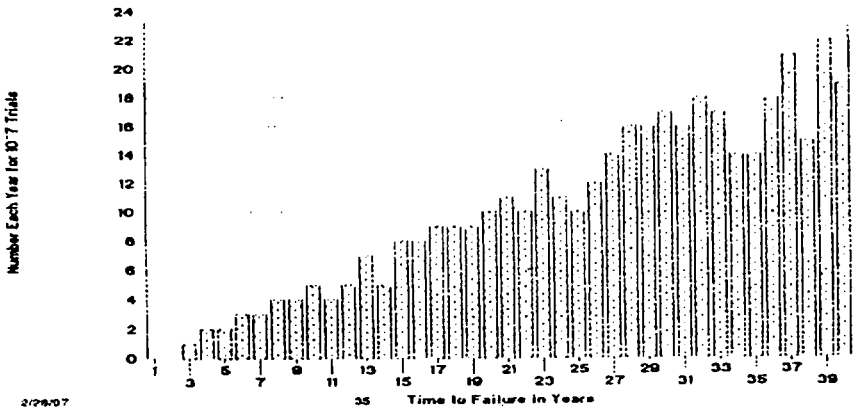
Monte-Carlo Simulation



SRRA Failure Histogram



Verification of SRRA Probabilities

- Simple Hand Calculations
- @Risk Importance Sampling Check
- Comparison With Data
  - PWR Wear vs. ASME Requirements
  - BWR Stress Corrosion Cracking
- pc-PRAISE Benchmarking Study

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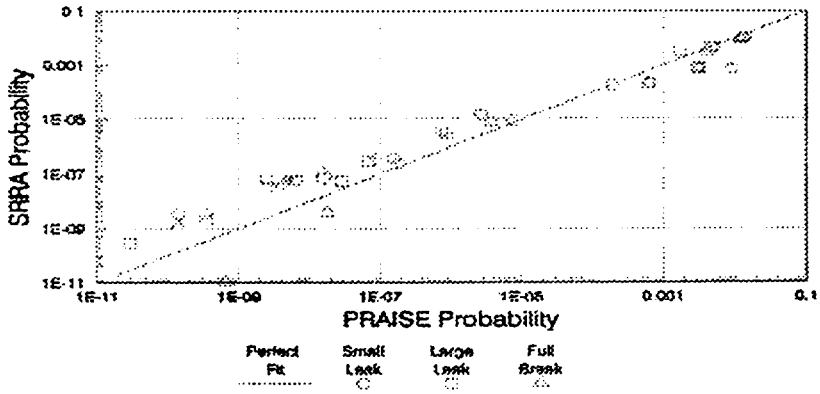
Results of SRRA Benchmarking Study



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RI-ISI SRRA References

- WCAP-14572, Revision 1-NP-A, *WOG Application of Risk Informed Methods to Piping Inservice Inspection Topical Report, including* Supplement 1 (*Structural Reliability and Risk Assessment Model),* February 1999
- SRRA models and software extensively reviewed and accepted by NRC (12/98 SER)

Calculation of Initiating Event Frequencies

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Calculation of Initiating Event Frequencies

- Failure probabilities from structural reliability/risk assessment based on 40 year life
- To estimate initiating event frequency, the failure probability is divided by 40 years
- Data collected and analyzed by line size and plant
- Point estimate and expected values (through uncertainty analysis) determined based on data

Uncertainty Analysis Approach

- Described and approved in WCAP-14572, Revision 1-NP-A
- Distributions on failure probabilities/ frequencies were assigned distributions around each "point estimate" such that the median of the log-normal distribution is equal to the point estimate.
- The "spread" of the distribution about the median is determined by the standard deviation. To estimate the spread or variability of the lognormal distribution, factors of 5, 10 and 20 were used for this analysis. These factors were used to estimate the 95th-% tile of the distribution, i.e., the 95th-% tile was set equal to the selected factor times the initial point estimate (median).
- If the point estimate was less than 1E-04, a factor of 20 was used. If the point estimate was greater than or equal to 1E-02, a factor of 5 was used. Otherwise, a factor of 10 was used.

Uncertainty Analysis

- The given point estimates were taken as the median of the lognormal distribution, i.e., there is a 50% chance that the actual failure rate will be higher and a 50% chance that it will be lower.
- Interpreting them as medians is a conservative assumption from the perspective of risk since, in a right skewed probability distribution such as the lognormal, the mean is greater than the median, i.e., we are assuming that, on average, the actual value will be greater than the point estimate.

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Estimated WOG LOCA Initiating Event Frequencies by Line Size (Point Estimate)

Line Size	Average Frequency (Point Estimate)	% of Total
6"	1.50E-05	N/A
8"	1.76E-07	5.9%
10"	1.76E-06	59.2%
12"	4.59E-07	15.5%
14"	8.27E-08	2.8%
27.5"	4.94E-08	1.7%
29"	3.52E-08	1.2%
31"	3.67E-08	1.2%
32"	2.46E-07	8.3%
34"	8.03E-08	2.7%
36"	4.42E-08	1.5%
Total without 6" lines included	2.97E-06	

DEGB frequencies would be much lower

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Estimated WOG LOCA Initiating Event Frequencies by Line Size (Mean based on Uncertainty Calculations)

Line Size	Average Frequency (Mean)	% of Total
6"	5.48E-05	
8"	9.29E-07	5.9%
10"	9.33E-06	59.6%
12"	2.39E-06	15.3%
14"	4.30E-07	2.7%
27.5"	2.62E-07	1.7%
29"	1.86E-07	1.2%
31"	1.93E-07	1.2%
32"	1.28E-06	8.2%
34"	4.19E-07	2.7%
36"	2.31E-07	1.5%
Total without 6" lines included	1.57E-05	

DEGB frequencies would be much lower

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Estimated LOCA Initiating Event Frequencies for Representative Plant (Full Break - DEGB)

Representative Four Loop WOG Plant DEGB Frequencies		
Line Size	Full Break (Point Estimate)	Full Break (Mean)
6"	2.84E-12	1.52E-11
10"	5.84E-13	3.04E-12
14"	6.95E-13	3.67E-12
27.5"	7.66E-15	4.00E-14
29"	6.36E-14	3.32E-13
31"	1.19E-16	6.20E-16

Supports industry & NRC conclusions of full break DEGBs less than 1E-10/year

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Summary of Initiating Event Frequencies by Line Size and Number of Loops

WOG Plants Summary		
	Point Estimate	Mean (Distribution)
3 Loop 6"	2.45E-05	8.09E-05
3 Loop Total > 6"	2.02E-06	1.06E-05
4 Loop 6"	5.49E-06	2.88E-05
4 Loop Total > 6"	2.38E-06	1.26E-05

- Very little difference between results for WOG 3 and 4 loop plants for greater than 6" cases
- Results expected to represent all WOG plants
- NRC August 2000 Option 3 Framework
  - Infrequent initiators $\leq$ 1E-02/year
  - Rare initiators $\leq$ 1E-05/year
- LBLOCA defined as infrequent initiator (page 3-4 of Framework)

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Estimation of Conditional Core Damage Probability Given a LOCA

- For WOG plant current PRA studies
  - LBLOCA initiating event frequencies are assumed to be on the order of 1E-04/year used in WOG plant PRAs
  - LBLOCA CDF frequencies are assumed to be on the order of 1E-06/year in WOG plant PRAs
  - LBLOCA CDF contribution to total plant CDF is less than 15% (most less than 10%) for WOG plant PRAs
- With LBLOCA frequencies presented on previous slides, the LBLOCA contribution to total CDF would be even less (on the order of 1E-07/year)

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Estimation of Conditional Core Damage Probability Given a LOCA

- For WOG Plant current PRA studies
  - Average Conditional CDF for 35 WOG Plants is on the order of 1.0E-02 (point estimate) for LOCAs greater than 6"
  - For the seven WOG plants used in this evaluation, average conditional CDF is 1.6E-02 for LOCAs greater than 6"

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Average CDF by Line Size

Line Size	Average LOCA Frequency (Point Estimate)	Average Conditional CDF (Point Estimate)	Average CDF	Average LOCA Frequency (Mean)	CDF Estimate
6"	1.50E-05	1.60E-02	2.40E-07	5.48E-05	8.77E-07
Total > 6"	2.97E-06	1.60E-02	4.75E-08	1.57E-05	**2.51E-07**

- Average LERF would be expected to be 1-2 orders of magnitude less than average CDF
- NRC August 2000 Option 3 Framework
  - Core Damage Frequency ≤ 1E-04/year
  - Conditional LERP < 1E-01
- WOG plant LBLOCA CDF is significantly less than 1E-04/year (on the order of 3E-07/year)

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Summary

- Failure probabilities for pipe leaks large enough to initiate a LBLOCA (5000 gpm) estimated using SRRA Models and Software (previously reviewed and approved by the NRC)
- Uncertainty analysis on point estimates used to estimate mean values of LBLOCA frequency by pipe size
- Results show:
  - Initiating Event Frequency (5000 gpm): ~ 1E-05/year
  - DEGB Initiating Event Frequency significantly <1E-10/year
  - Total mean core damage frequency (>6") more than two orders of magnitude lower (~3E-07/year) than August 2000 Quantitative Guidelines for Risk-Informed Changes to Regulatory Requirements (≤ 1E-04/year)
- Redefinition of LBLOCA is acceptable