Constellation

Revisiting High Energy Line Break Location Methodology

January 11, 2023

Agenda

Time	Topic	Speaker
1:00 PM	Introductions/Opening Remarks	NRC/NEI/EPRI/Industry Management
1:10 PM	Risk Informed HELB Presentation	Industry/EPRI
2:00 PM	NRC Research Activities related to HELB	NRC Research
2:45 PM	Discussion	All
3:00 PM	Break	All
3:45 PM	Brainstorming Session – Risk Informing HELB	All
4:30 PM	Opportunity for Public Comment	Members of the Public
4:40 PM	Action Items/Closing Remarks	NRC/NEI/EPRI/Industry Management
4:50 PM	Meeting Adjourn	

Constellation

Background on Current Requirements for Identifying HELB Locations

- As a result of industry ongoing activities (e.g. power uprates, license renewal, subsequent license renewal), a number of deterministic requirements are being challenged as to their efficiency in maintaining and improving plant safety while providing flexibility in plant operations and resource allocation.
- As an example, for a couple of operating sites, attempting a MUR uprate identified the potential for a system to be re-classified from a moderate energy system to a high energy system due to increases in the subject system's operating temperature and pressure after MUR
- Having to meet current deterministic HELB requirements would entail significant plant reanalysis and substantial plant modification
- Discussions with the New Build fleet have also identified these deterministic HELB requirements contributing to capital cost and engineering difficulties

Regulatory Application

- As a result of power up-rates, temperatures and/or pressures can increase in certain piping systems resulting in the system qualifying as HELB scope (e.g., SRP Chapter 3.6)
- Since this piping has not been evaluated per these references, the objective of this report is to evaluate such piping to determine whether risk-informed approaches can be adapted to this piping and what changes to the methodologies or design might be appropriate for such piping.
- Intend to apply to the non-safety related main steam cross-around piping from the high-pressure turbine to the moisture separators, and from the moisture separators to the low-pressure turbines.

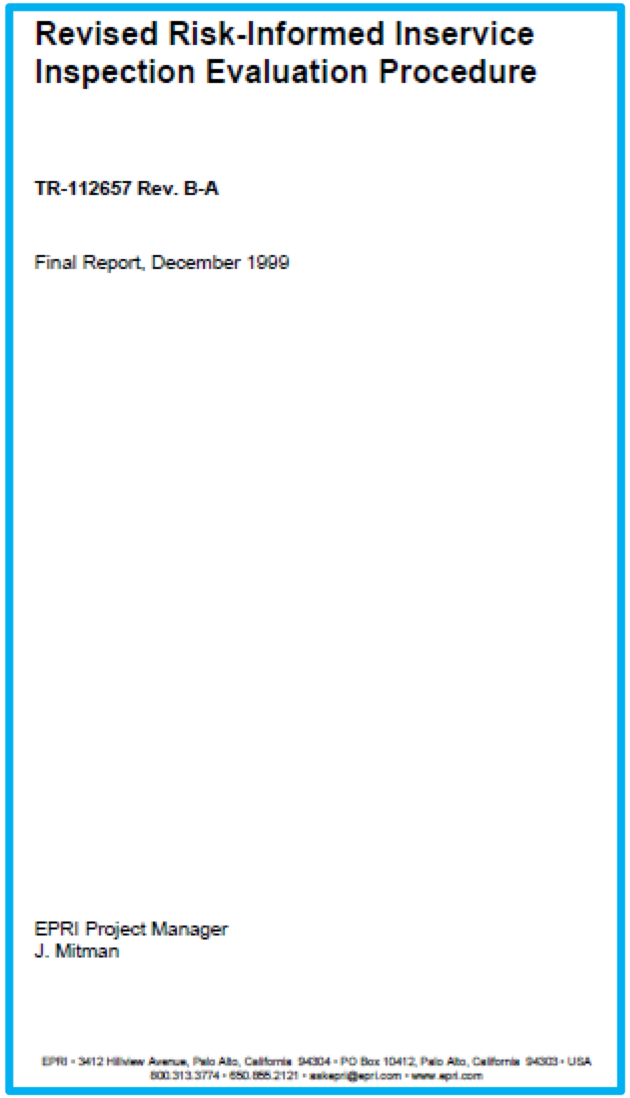
- Planned topical report submittal including pilot results

RI-ISI Methodology Overview

- Background
- Scope
- Consequence of failure
- Failure potential
- Risk Ranking
- Inspection Element Section
- Change in Risk Assessment

RI-ISI Methodology Overview

- EPRI TR-112657, Rev B-A is the foundational RI-ISI methodology
  - Codified in ASME Section XI, Appendix R, Supplement 2
  - Endorsed in 10CFR50.55a
  - ~ 60 US applications (BWRs and PWRs)
  - Applied / adapted for use in seven other countries, including CANDU nuclear and conventional systems
  - Applied / adapted to other components and programs including RI-repair/replacement, 10CFR50.69
  - Adapted to addressed break exclusion region (BER) NDE requirements
  - Streamlined RI-ISI (N716-1 endorsed in RG1.147)
  - Consistent with RG 1.178


Revised Risk-Informed Inservice Inspection Evaluation Procedure

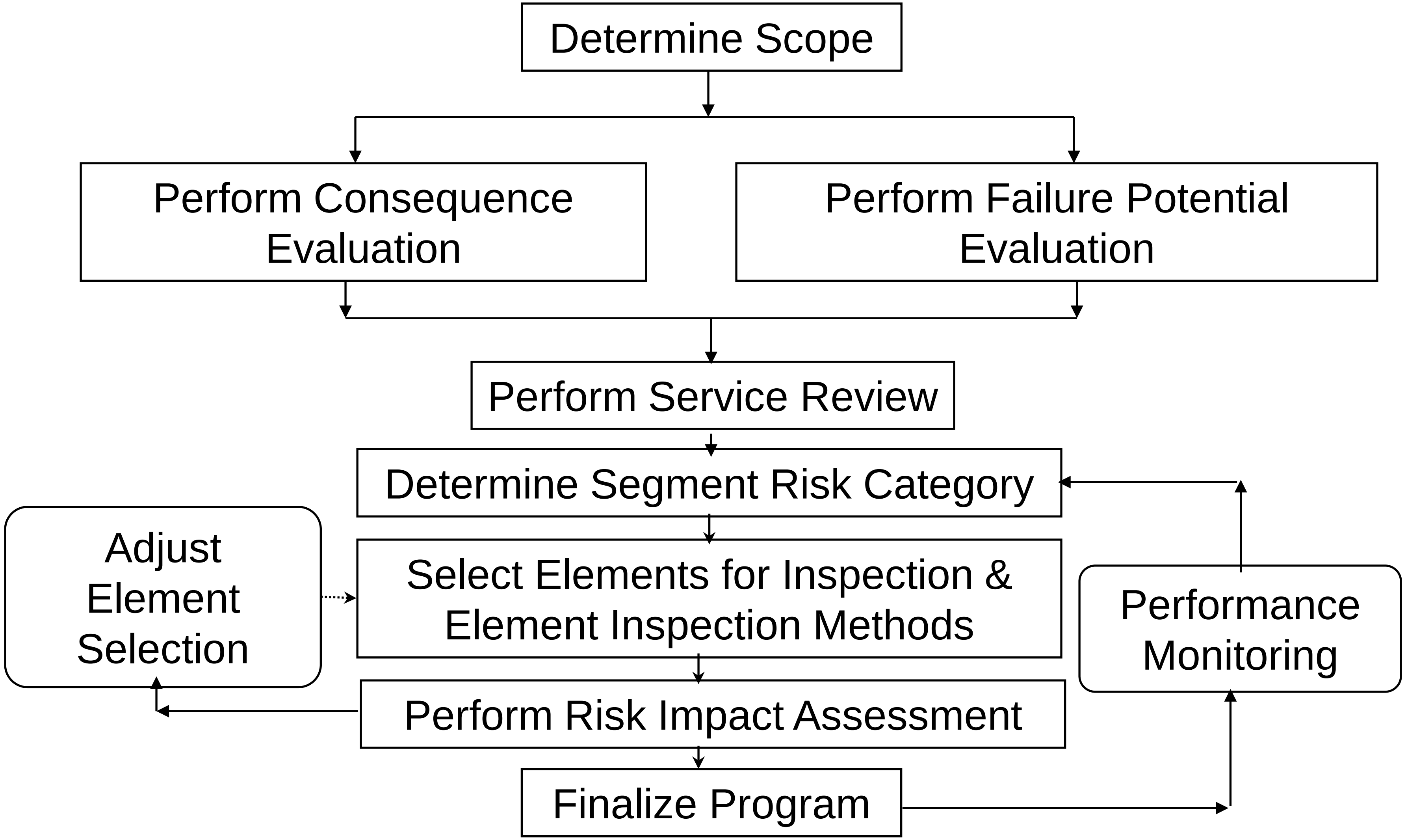
TR-112657 Rev. B-A

Final Report, December 1999

EPRI Project Manager
J. Mitman

EPRI • 3412 Hillview Avenue, Palo Alto, California 94304 • PO Box 10412, Palo Alto, California 94303 • USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com

RI-ISI Process Overview



RI-ISI Risk Ranking and Inspection Population

Consequence Evaluation

Failure Potential Assessment *(Degradation Mechanism)*

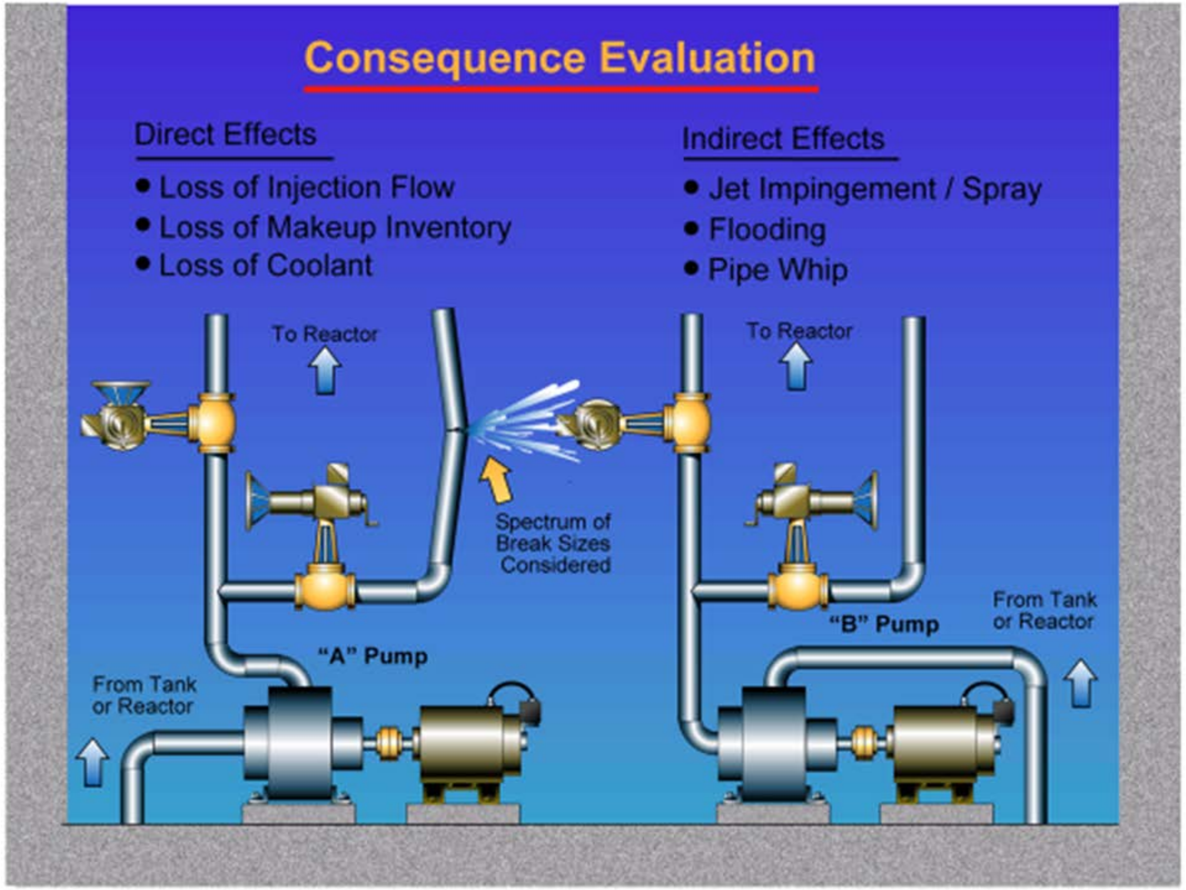
DEGRADATION CATEGORY Pipe Rupture Potential	CONSEQUENCE CATEGORY CCDP and CLERP Potential: NONE	LOW	MEDIUM	HIGH
HIGH	LOW (Cat. 7)	MEDIUM (Cat. 5)	HIGH (Cat. 3)	HIGH (Cat. 1)
MEDIUM	LOW (Cat. 7)	LOW (Cat. 6)	MEDIUM (Cat. 5)	HIGH (Cat. 2)
LOW	LOW (Cat. 7)	LOW (Cat. 7)	LOW (Cat. 6)	MEDIUM (Cat. 4)

RI-ISI Methodology Overview

- Scope
  - Can be applied to a single system or multiple systems
  - Can be applied to a single class (e.g. Class 1 only) or multiple classes (e.g. Class 1 and 2)
  - Can be applied to safety related systems and non safety related systems
  - Can be applied to portions of a system (e.g. that portion subject to NDE)

Consequence Evaluation

- **Parameters:**
  - Break size (small, large, worst case)
  - Isolability of the break (success, failure & reliability)
  - Direct effects (flow diversion)
  - Indirect effects (spatial, loss of inventory)
  - Containment performance
  - Recovery



The goal of the consequence evaluation is to assigned a consequence rank (High, Medium or Low) to the piping segment under evaluation.

Consequence Ranking

Table 3-1 from TR-112657

Consequence Category	Corresponding CCDP Range	Corresponding CLERP Range
High	CCDP > 1E-4	CLERP > 1E-5
Medium	1E-6 < CCDP ≤ 1E-4	1E-7 < CLERP ≤ 1E-5
Low	CCDP ≤ 1E-6	CLERP ≤ 1E-7

Consequence Evaluation

Failure Potential Assessment *(Degradation Mechanism)*

DEGRADATION CATEGORY Pipe Rupture Potential	CONSEQUENCE CATEGORY CCDP and CLERP Potential: NONE	LOW	MEDIUM	HIGH
HIGH	LOW (Cat. 7)	MEDIUM (Cat. 5)	HIGH (Cat. 3)	HIGH (Cat. 1)
MEDIUM	LOW (Cat. 7)	LOW (Cat. 6)	MEDIUM (Cat. 5)	HIGH (Cat. 2)
LOW	LOW (Cat. 7)	LOW (Cat. 7)	LOW (Cat. 6)	MEDIUM (Cat. 4)

This criteria is used by RI-ISI, RI-RRA and 10CFR50.69 pressure boundary categorization processes

Initiating Event Impact Group (PWR example)

Table 3-4 from TR-112657

Design Basis Initiating Event Category	Initiating Event	Initiating Event Frequency (1/Yr.)	CDF due to Initiating Event (1/yr.)	Corresponding CCDP	Consequence Category
II	Reactor Trip	2	1E-6	5E-7	LOW
	Turbine Trip	1	1E-6	1E-6	LOW
	Loss of PCS	3E-1	9E-7	3E-6	MEDIUM
III	Loss of SW Train	8E-2	2E-6	3E-5	MEDIUM
	LOSP	5E-2	2E-6	4E-5	MEDIUM
IV	SLB	1E-3	1E-9	1E-6	MEDIUM
	Small LOCA	5E-3	2E-6	4E-4	HIGH
	Medium LOCA	1E-3	2E-6	2E-3	HIGH
	Large LOCA	1E-4	1.5E-6	1.5E-2	HIGH

EPRI

RI-ISI Risk Ranking and Inspection Population

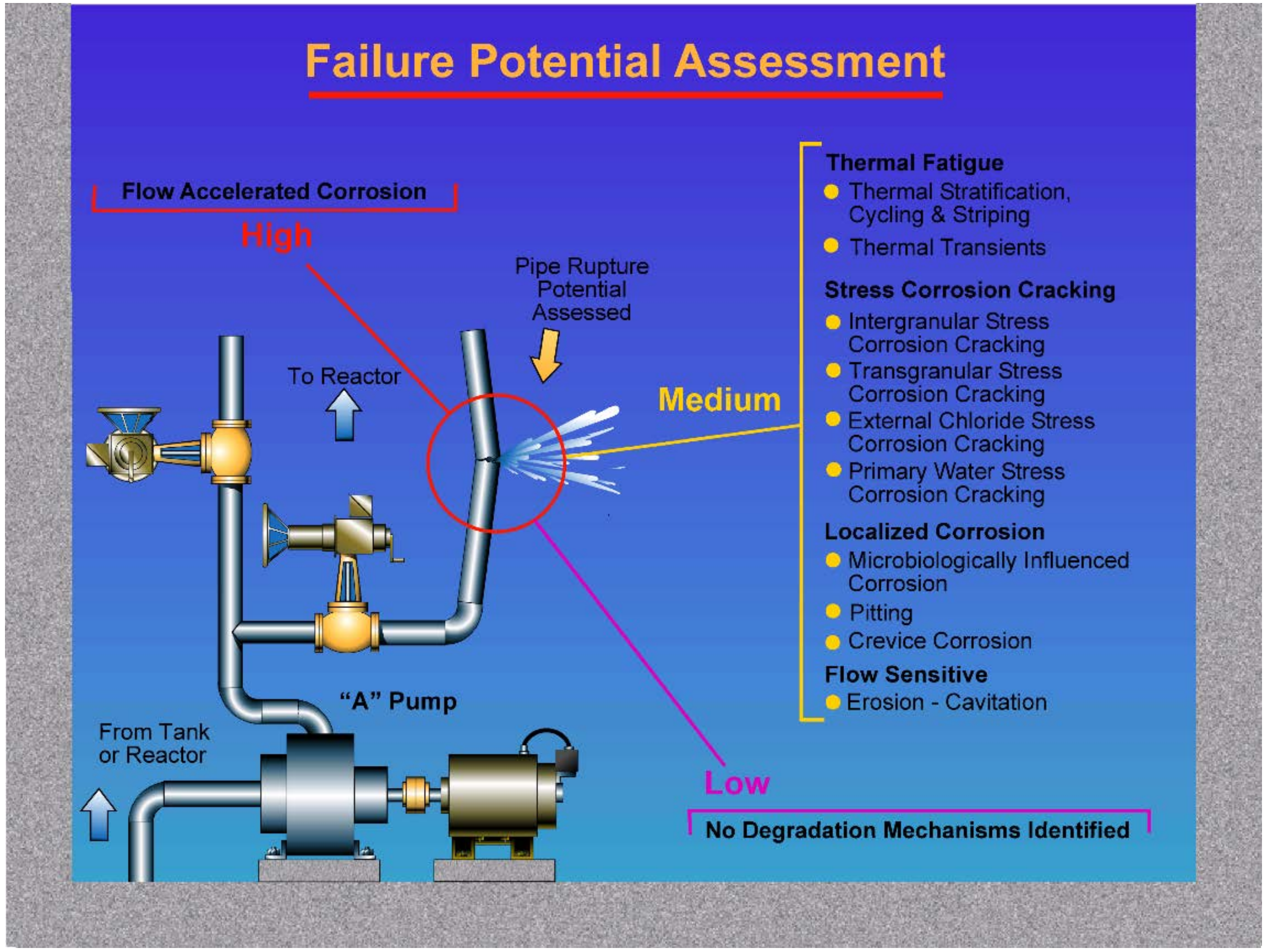
Consequence Evaluation

Failure Potential Assessment ***(Degradation Mechanism)***

DEGRADATION CATEGORY Pipe Rupture Potential		CONSEQUENCE CATEGORY CCDP and CLERP Potential			
		NONE	**LOW**	**MEDIUM**	**HIGH**
	HIGH	LOW (Cat. 7)	MEDIUM (Cat. 5)	HIGH (Cat. 3)	HIGH (Cat. 1)
	MEDIUM	LOW (Cat. 7)	LOW (Cat. 6)	MEDIUM (Cat. 5)	HIGH (Cat. 2)
	LOW	LOW (Cat. 7)	LOW (Cat. 7)	LOW (Cat. 6)	MEDIUM (Cat. 4)

Degradation Assessment

- Component pressure boundary assessed based on degradation mechanisms:
  - Component-based degradation tables developed
  - Detailed and prescriptive susceptibility threshold criteria established via an extensive literature search including plant specific, EPRI, and other industry databases



The goal of the degradation mechanism evaluation is to assigned a failure potential rank (High, Medium or Low) to the piping segment under evaluation.

Degradation Mechanism Category

Large Pipe Break Potential	Leak Conditions	Degradation Mechanism
HIGH	Large	Flow Accelerated Corrosion (FAC)
MEDIUM	Small	Thermal Fatigue Stress Corrosion Cracking (IGSCC, TGSCC,PWSCC, ECSCC) Localized Corrosion (MIC, Pitting, Crevice Corrosion) Erosion/Cavitation
LOW	None	No Degradation Mechanisms

Degradation Mechanism Evaluation - Example

DM Assessment Worksheet Scope	Line #1RRA0045-12" and Line #RRA0011-12" in the vicinity of mixing tee and downstream runs					
No.	**Attributes to be Considered**	**Yes**	**No**	**N/C**	**N/A**	**Remarks**
TASCS-1	nps > 1 inch (DN25), and	☒	☐	☐	☐	TASCS-1: Pipe is 12" (323.9mm)
TASCS-2	pipe segment has a slope < 45° from horizontal (includes elbow or tee into a vertical pipe), and	☒	☐	☐	☐	TASCS-2: horizontal and vertical runs
TASCS-3-1	potential exists for low flow in a pipe section connected to a component allowing mixing of hot and cold fluids, or	☒	☐	☐	☐	TASCS-3-1: Warmer bypass flow around the RRA heat exchangers meets colder water exiting the heat exchangers at the mixing tee.
TASCS-3-2	potential exists for leakage flow past a valve (i.e., in-leakage, out-leakage, cross-leakage) allowing mixing of hot and cold fluids, or	☐	☒	☐	☐	TASCS-3-2: Per XXXX, *RRA-RCP isolation valve leakage test: During the startup of the reactor, when the RRA system is isolated, the RRA inlet valve is periodically tested to ensure the tightness of the RCP/RRA interface.*
TASCS-3-3	potential exists for convection heating in dead-ended pipe sections connected to a source of hot fluid, or	☐	☒	☐	☐	TASCS-3-3: Per XXXY: design modifications have been implemented to eliminate this concern.
TASCS-3-4	potential exists for two phase (steam / water) flow, or	☐	☒	☐	☐	TASCS-3-4 and 3-5: Not applicable to due to configuration.
TASCS-3-5	potential exists for turbulent penetration into a relatively colder branch pipe connected to header piping containing hot fluid with turbulent flow, and	☐	☒	☐	☐	
TASCS-4	calculated or measured ΔT > 50°F (28°C), and	☐	☐	☒	☐	TASCS-4 & TASCS-5: Based on operating experience and industry evaluations, this location is potentially susceptible to thermal fatigue.
TASCS-5	Richardson number > 4.0	☐	☐	☒	☐	
In conclusion, the TASCS degradation mechanism does affect the piping regions described above.						

Degradation Mechanism Evaluation –cont.

DM No.	DM Attributes	Susceptible Regions	DM References
TASCS-1	nps > 1 inch (DN25), and	nozzles, branch pipe connections, safe ends, welds, heat affected zones, base metal, and regions of stress concentration	– GE-NE-523-A71-0594-A, Revision 1, Alternate BWR Feedwater Nozzle Inspection Requirements – NUREG-0619, BWR Feedwater Nozzle and Control Rod Drive Return Line Nozzle Cracking, November 1980 – NRC Information Notice 93-20, Thermal Fatigue Cracking of Feedwater Piping to Steam Generators, March 24, 1993 – IE Bulletin 79-13, Cracking in Feedwater System Piping, June 25, 1979 – Information Notice No. 91-28, Cracking in Feedwater Piping Systems, April 15, 1991 – NUREG/CR-5285, Closeout of IE Bulletin 79-13: Cracking in Feedwater System Piping, March 1991 – NRC Bulletin 88-08, Thermal Stresses in Piping Connected to Reactor Coolant Systems, June 22, 1988 – NRC Bulletin 88-11, Pressurizer Surge Line Thermal Stratification, December 20, 1988 – EPRI TR-103581, Thermal Stratification, Cycling, and Striping – EPRI TR-104534, Fatigue Management Handbook – EPRI TR-1001006, Operating Experience Regarding Thermal Fatigue of Unisolable Piping Connected to PWR Reactor Coolant Systems
TASCS-2	pipe segment has a slope < 45° from horizontal (includes elbow or tee into a vertical pipe), and		
TASCS-3-1	potential exists for low flow in a pipe section connected to a component allowing mixing of hot and cold fluids, or		
TASCS-3-2	potential exists for leakage flow past a valve (i.e., in-leakage, out-leakage, cross-leakage) allowing mixing of hot and cold fluids, or		
TASCS-3-3	potential exists for convection heating in dead-ended pipe sections connected to a source of hot fluid, or		
TASCS-3-4	potential exists for two phase (steam / water) flow, or		
TASCS-3-5	potential exists for turbulent penetration into a relatively colder branch pipe connected to header piping containing hot fluid with turbulent flow, and		
TASCS-4	calculated or measured ΔT > 50°F (28°C), and		
TASCS-5	Richardson number > 4.0		
TT-1-1	operating temperature > 270°F (130°C) for stainless steel, or		
TT-1-2	operating temperature > 220°F (105°C) for carbon steel, and		
	potential for relatively rapid temperature changes including		
TT-2-1	cold fluid injection into hot pipe segment, or		
TT-2-2	hot fluid injection into cold pipe segment, and		
TT-3-1	|ΔT| > 200°F (110°C) for stainless steel, or		
TT-3-2	|ΔT| > 150°F (83°C) for carbon steel, or		
TT-3-3	|ΔT| > ΔT allowable (applicable to both stainless and carbon)		

Degradation Mechanism Evaluation – cont.

Basis for the DM, the DM Attributes and Susceptible Regions – Alternating stresses caused by thermal cycling of a component results in accumulated fatigue usage and can lead to crack initiation and growth.

Austenitic and carbon steel piping segments with operating temperatures less than 270 and 220°F, respectively, are not susceptible to degradation by thermal fatigue. Piping segments having operating temperatures greater than these values should be evaluated for the potential for degradation from thermal transients and thermal stratification, cycling, and striping as indicated in the following:

TT – Areas considered susceptible to Thermal Transient (TT) fatigue include pipe segments where there is relatively rapid cold (hot) water injection with delta temperature greater than 150°F for carbon steel pipe and 200°F for austenitic steel pipe. When these temperature changes are exceeded, additional evaluations can be performed to determine if delta temperature is greater than delta temperature allowable. Procedures in EPRI TR-104534, Vols. 1-4, "Fatigue Management Handbook" can be used to determine delta temperature allowable.

TASCS – Areas where there can be leakage past valves separating hot and cold fluids and regions where there might be intermittent mixing of hot and cold fluids caused by fluid injection are considered to be susceptible to degradation from Thermal Stratification, Cycling and Striping (TASCS) fatigue. Exceptions are for pipe segments where the pipe diameter is 1 inch or less, or the slope of the segment is 45° or more from the horizontal. When these criteria are exceeded, additional evaluations can be performed to determine if the maximum delta temperature is greater than 50°F or the Richardson number is greater than 4.0. Refer to EPRI TR-104534, for procedures to compute the Richardson number.

Additional Analysis Tools – Analysis tools for thermal fatigue that have emerged based on additional industry experience gained since the development of the EPRI RI-ISI methodology (TR-112657 Revision B-A) that can be used to support the DM evaluation include the following:

– MRP-235, Revision 3, Fatigue Management Handbook
– MRP-146, Revision 2, Management of Thermal Fatigue in Normally Stagnant Non-Isolable Reactor Coolant System Branch Lines
– MRP-192, Revision 3, Assessment of Residual Heat Removal Mixing Tee Thermal Fatigue in PWR Plants
– BWRVIP-196, Revision 1, Assessment of Mixing Tee Thermal Fatigue Susceptibility in BWR Plant
– MRP-433, PWR Residual Heat Removal Mixing Tee Thermal Fatigue Guidance Update: Current Experience, Selection of Modeling Tools, Input Data Identification, and Planned Approach
– MRP-445, Thermal Fatigue Mitigation Concepts Revealed During International Benchmarking – Recommendations for EPRI Guidance
– MRP-468, Thermal Fatigue Operating Experience Database Expansion and Evaluation
– MRP-29, Revision 1, Mitigation of Thermal Fatigue in Piping Connected to PWR Reactor Coolant Systems
– MRP-459, Influence of Flexible Power Operations on Thermal Fatigue

RI-ISI Risk Ranking and Inspection Population

Consequence Evaluation

Failure Potential Assessment ***(Degradation Mechanism)***

		CONSEQUENCE CATEGORY CCDP and CLERP Potential			
		NONE	LOW	MEDIUM	HIGH
DEGRADATION CATEGORY Pipe Rupture Potential	HIGH	LOW (Cat. 7)	MEDIUM (Cat. 5)	HIGH (Cat. 3)	HIGH (Cat. 1)
	MEDIUM	LOW (Cat. 7)	LOW (Cat. 6)	MEDIUM (Cat. 5)	HIGH (Cat. 2)
	LOW	LOW (Cat. 7)	LOW (Cat. 7)	LOW (Cat. 6)	MEDIUM (Cat. 4)

RI-ISI Risk Ranking and Inspection Population

- Class 1, 2, 3 and/or NNS systems
  - 25 percent of high risk region (CAT1, 2 & 3)
  - 10 percent of medium risk region (CAT4 & 5)
  - augmented exams may be credited (e.g. IGSCC)
  - Class 1 minimum trigger

- RI-HELB perspective

Risk-informed (RI) New Break Locations: Overview

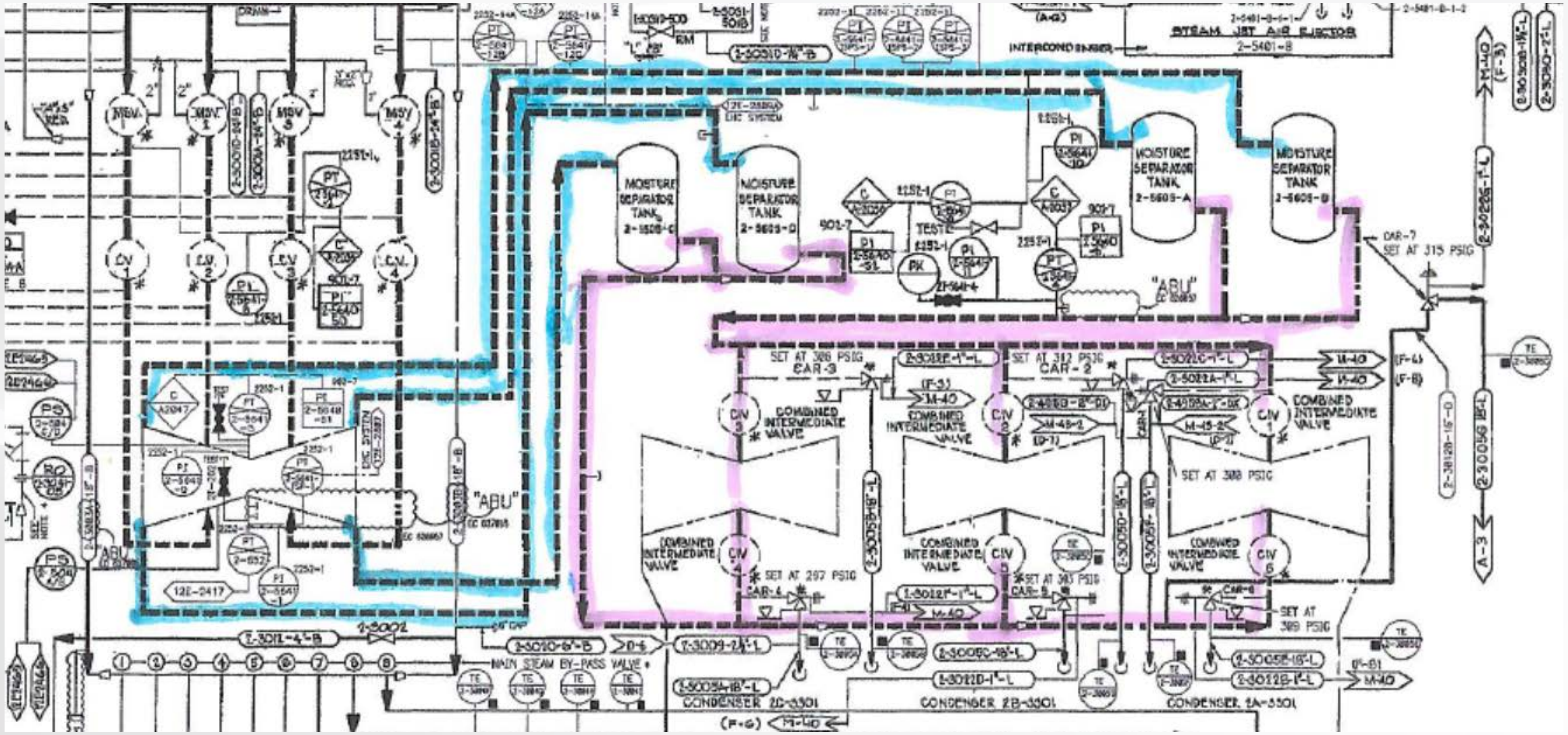
- Pilot Plant Scope
- Design, FSAR, & PRA Review (RI-ISI)
- Consequence of failure (RI-BER)
- Failure potential (Degradation Potential)
- Risk Ranking & Inspection Element Section
- Change in Risk Assessment

RI - New Break Locations: Overview

- EPRI Report 1006937-A [RI-BER]
- Adapted from EPRI TR-112657, Rev B-A [RI-ISI]
- RI-BER includes the following additional evaluations
  - Containment Isolation Valves Impact
  - Containment Penetrations Impact
  - Unrestrained Pipe Whip Impacts (Criterion 3 through 5)
  - Jet Impingement Impact
  - Other Spatial Impacts
  - Spatial Propagation

RI - New Break Locations: Pilot Plant Scope

- Non-safety related main steam cross-around piping from the high-pressure turbine to the moisture separators, and from the moisture separators to the low-pressure turbines



Constellation

RI - New Break Locations: Design, FSAR & PRA Review

- Cross-around piping scope is inside turbine pipeway/cavity
- Main Steam Piping is also located in same area (equalizing header, turbine stop & control valves etc.)
- Main Steam pressure and temperature much higher than cross-around
- Main Steam HELB analysis per 1972 AEC Letter to envelope the cross-around piping scope
- Based on PRA, a medium consequence (loss of main condenser) [RI-ISI]
- RI-BER Consequence evaluation considered next

Constellation

RI - New Break Locations: Consequence Evaluation

- Plant Walkdown Required to Assess Spatial Impacts
- Criterion 1 and 2: Cross-around scope far removed from containment isolation valves and penetrations
- Criterion 3-6 (Pipe Whip and Jet impingement):
  - At least one pair of turbine stop & control valves assumed to fail because of proximity
  - Loss of main condenser due to MSIV closure or loss of EHC, etc.
  - Structural impact bounded by main steam and walkdown confirmation
- Criterion 7 (other Spatial Impacts): flooding not a concern, but two MCCs outside turbine cavity doors assumed to fail due to door missile or steam impact (Walkdown)
- Criterion 8 (Spatial Propagation): steam propagates up to the turbine building ceiling where there is no PRA equipment. There is also blowout panels on the upper floor (Walkdown)

Constellation

RI - New Break Locations: Consequence Evaluation Results

- Several PRA Calculations performed assuming loss of main condenser, failure of a turbine stop & control valve pair (MSIV isolation is required), failure or two MCCs identified during walkdown and other impacts to model both large and small breaks, MSIV isolation etc.

- Medium Consequence (CCDP<1E-4 and CLERP<1E-5)

Constellation

RI - New Break Locations: Degradation Mechanism Assessment

- No Degradation Mechanism identified from the evaluation
- All piping and components are therefore assigned a low failure potential rank

Consequence Evaluation

Failure Potential Assessment ***(Degradation Mechanism)***

DEGRADATION CATEGORY Pipe Rupture Potential	CONSEQUENCE CATEGORY CCDP and CLERP Potential: NONE	LOW	MEDIUM	HIGH
HIGH	LOW (Cat. 7)	MEDIUM (Cat. 5)	HIGH (Cat. 3)	HIGH (Cat. 1)
MEDIUM	LOW (Cat. 7)	LOW (Cat. 6)	MEDIUM (Cat. 5)	HIGH (Cat. 2)
LOW	LOW (Cat. 7)	LOW (Cat. 7)	LOW (Cat. 6)	MEDIUM (Cat. 4)

Constellation

RI - New Break Locations: Risk Ranking & Inspection Population

- RI-ISI Perspective
  - Risk Category 6 (Low Risk) based on Medium Consequence and Low failure Potential Rank
  - Risk Category 6 requires no inspections

RI - New Break Locations: Change in Risk Assessment

Consequence Evaluation

Failure Potential Assessment *(Degradation Mechanism)*

DEGRADATION CATEGORY Pipe Rupture Potential	CONSEQUENCE CATEGORY CCDP and CLERP Potential: NONE	LOW	MEDIUM	HIGH
HIGH	LOW (Cat. 7)	MEDIUM (Cat. 5)	HIGH (Cat. 3)	HIGH (Cat. 1)
MEDIUM	LOW (Cat. 7)	LOW (Cat. 6)	MEDIUM (Cat. 5)	HIGH (Cat. 2)
LOW	LOW (Cat. 7)	LOW (Cat. 7)	LOW (Cat. 6)	MEDIUM (Cat. 4)

Based on Methodologies risk impact is not required for risk category 6 because even if welds were being removed from inspection the increase risk would be very low

Since no inspections are required and no inspections were being conducted, the change in risk is zero

Agenda

Time	Topic	Speaker
1:00 PM	Introductions/Opening Remarks	NRC/NEI/EPRI/Industry Management
1:10 PM	Risk Informed HELB Presentation	Industry/EPRI
2:00 PM	NRC Research Activities related to HELB	NRC Research
2:45 PM	Discussion	All
3:00 PM	Break	All
3:45 PM	Brainstorming Session – Risk Informing HELB	All
4:30 PM	Opportunity for Public Comment	Members of the Public
4:40 PM	Action Items/Closing Remarks	NRC/NEI/EPRI/Industry Management
4:50 PM	Meeting Adjourn	

Brainstorming Topics

- **Goals**
  - Reach understanding/alignment on NRC/Industry approaches
  - Identify potential uses of risk informed HELB

- **Benefits:**
  - Focus resources on risk/safety significant SSCs

- **Potential Paths Forward**
  - Scope of effort (e.g., safety and/or non-safety related piping)
  - Form of endorsement (e.g., topical report versus plant specific approval)
  - Leverage both industry and NRC research
  - Schedule

Constellation