BACKGROUND/HISTORY OF RISK-INFORMED INSERVICE INSPECTION ACTIVITIES

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TECRO-AIT JSC Meeting on Civil Nuclear Cooperation
November 4-6, 2003
Taichung, Taiwan

BACKGROUND

- **In 1996, the PRA Implementation Plan established plans for the development of a General RG and SRP and four application specific RGs and SRPs:**

  Technical Specifications
  ISI
  IST
  Graded QA

OBJECTIVE

- Objectives of ISI Program is to identify degraded conditions that are precursors to pipe failures.
- Regulatory requirements for ISI are specified in 10 CFR 50.55a(g).
- 10 CFR 50.55a(g) references ASME Code Section XI for ISI requirements.
- 10 CFR 50.55a(a)(3)(i) provides for authorization of alternative ISI programs by Director of NRR.
- Relief request required for staff review and approval.

CURRENT STATUS

- **Risk-Informed Inservice Inspection (RI-ISI) has been one of the most successful risk-informed initiatives.**

- **Number of Units (of 103) expected to implement RI-ISI programs: 99**

- **Number of Units That Have Submitted RI-ISI Programs: 68**
  Based on EPRI Methodology: 49
  Based on WOG Methodology: 19

  Number of Plants Approved by NRC: 62
  Number of Plants Currently under Review: 6

<u>RI-ISI GUIDANCE</u>

- **Approved well defined generic methodologies via Topical Reports (WOG and EPRI):**
  - ➔ **SER for WOG Topical Report issued in December 1998.**
  - ➔ **SER for EPRI Topical Report issued in October 1999.**

- **The WOG and EPRI methodlogies are generally simiar but use diferent techniques at different stages**

- **Issued Regulatory Guidance:**

  - ➔ **RI-ISI Regulatory Guide 1.178, Sep. 1998 (Up-dated Sep. 2003)** ***"An Approach For Plant-Specific Risk-Informed Decisionmaking Inservice Inspection of Piping"*****.**

  - ➔ **Standard Review Plan Section 3.9.8, Sep. 1998 (Up-dated Sep. 2003)** ***"Standard Review Plan for the Trial Use For the Review of Risk-Informed Inservice Inspection of Piping".***

UNDERLYING ASSUMPTIONS

- **U.S. plants are designed and constructed to the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (BPV) Code.**

- **The Code inservice inspection requirements did not consider risk insights. Inspection resources should be focused in those areas which are most safety and risk significant.**

- **Volumetric examinations of welds is capable of reducing the likelihood that the weld will eventually fail.**

- **Welds exposed to a degradation mechanism are more likely to fail than welds exposed to no degradation mechanism.**

RI-ISI PROCESS OVERVIEW

Divide Systems into Piping Segments

Segments are primarily defined as lengths of piping that, when failed anywhere along the pipe, have the same consequence. There is no need to look at every weld when every failure has the same consequence.

Evaluate Consequences of Each Segment's Failure

Consequences are normally evaluated using techniques that are used in PRA flooding analysis. Conditional core damage and large early release probabilities (CCDP and CLERP) estimated given the segment failure.

Determine Failure Potential of Each Segment

Failure potential is based on the degradation mechanisms present and the degree that the mechanism manifests itself. During the determination of the risk significance the benefits of current ASME weld inspections are not include because the goal is to identify locations were inspection is most needed.

Categorize Risk Significance of Each Segment

Risk is a combination of consequence and failure potential. The highest risk significant segments are inspected, the lowest are not. Relocating inspection from low to high risk locations provides the risk benefit that allows a reduction in the total number of inspections.

Select Welds and Elements for Inspection

Individual welds with each segment are considered to identify those that would be most advantageous to inspect (generally welds with the greatest degree of degradation mechanism are selected)

Assess Impact on CDF and LERF

The change in risk expected from changing the locations inspected under ASME to RI-ISI is estimated to provide assurance that the new locations selected compensate for the reduced number of locations. The benefit of weld inspection on failure frequency is included in the failure frequency estimates.

WOG METHODOLOGY

Fracture mechanics modeling used to simulate flaw growth over operating life based on input parameters representing weld geometry, material properties, and operating environment (degradation mechanisms). All degradation mechanisms in segment applied to a "worst case" weld and that weld failure probability used to represent entire segment.

Monte Carlo sampling from input parameter distributions used to simulate many operating lives and count the number of times the initial flaw grows to failure. Yields probability of failure by end of operating life.

Fracture mechanics result are highly dependent on selected initial properties and less on operating cycles so a linear annual frequency can be assumed for risk estimates.

Quantitative frequency and consequences combined for each segment and summed to get total risk and risk reduction worth for each segment (RRW- normalized fractional contribution to risk)

Segments are placed in High Safety Significant category based on RRW exceeding 1.005. The High Safety significant segments are further categorized into two groups (Regions 1 and 2) based on the expected failure frequency.

Region 1 welds have high Safety Significant and High Failure Frequency. All Welds in Region 1 that are exposed to a degradation mechanism are selected for inspection. Statistical selection of number of welds to inspect for remaining welds that are not exposed to a degradation mechanism (normally defaults to one weld inspection per segment).

Region 2 welds have High Safety significance but Low Failure Frequency. Statistical selection of number of welds to inspect (normally defaults to one weld inspection per segment).

Change in risk estimates uses fracture mechanics frequency estimates combined with CCDP and CLERP estimates.

WOG RISK MATRIX

<table>
<tr><th></th><th>Low
Safety
Significant
RRW < 1.005</th><th>High
Safety
Significant
RRW > 1.005</th></tr>
<tr><td rowspan="2">High
Failure
Importance
$P_{Large\ Leak} > 10^{-4}$</td><td rowspan="2">3

Owner Defined
Program</td><td>1(A)
Susceptible Locations
(100%)</td></tr>
<tr><td>1(B)
Statistical Inspection
Location Selection
Process</td></tr>
<tr><td>Low
Failure
Importance</td><td>4
Only System Pressure
Test & Visual
Examination</td><td>2
Statistical Inspection
Location Selection
Process</td></tr>
</table>

EPRI METHODOLOGY

Presence of degradation mechanism used to place each segemnt in High, Medium, or Low failure Potential Category.

Estimated conditional consequence of failure used to place each segment into in High, Medium, or low Consequence Category.

Piping segments Risk Category based on combining High, Medium, and Low Failure Potential Category with High, Medium, and Low Consequences Category.

Different combinations of failure potential and consequences result in High, Medium, or Low risk significance.

A percentage of welds (emphasizing those exposed to a degradation mechanism) are selected - 25 % of welds in High risk segments, 10% in Medium risk segments.

Change in risk estimates uses degradation specific weld failure frequencies developed by EPRI from worldwide observed events

EPRI RISK MATRIX

	CONSEQUENCE CATEGORY CCDP and CLERP Potential			
FAILURE POTENTIAL CATEGORY	**NONE**	**LOW** **CCDP < 1E-6**	**MEDIUM**	**HIGH** **CCDP>1E-4**
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)

REVIEW OBSERVATIONS AND CONTINUING ACTIVITIES

- **PRA Quality - September 2003 Version of RG and SRP includes guidance on submitting industry PRA quality peer review results.**

- **Start of ISI Program - When changing to a RI-ISI program within the 10 year interval, the Code minimum and maximum percentages of examination per period still apply to RI-ISI.**

- **Additional Examinations - The number of additional elements to be examined equals the number of elements with the same postulated failure mode originally scheduled for examination in the fuel cycle.**

- **Updates to RI-ISI Programs (slide 9)**

- **Application to BER Piping (slide 10)**

UPDATES TO RI-ISI PROGRAMS

- **RI-ISI programs should be living programs and should be changed if needed to reflect new relevant information such as:**
  - **major updates to plant PRA models**
  - **new trends in service experience with piping systems at the plant and across the industry**
  - **new information on element accessibility**

- **At a minimum, risk ranking should be reviewed and adjusted on an ASME-period basis.**

- **RI-ISI programs should be updated and submitted to NRC:**
  - **at the end of the 10-year ISI interval**
  - **prior to the end of the 10-year interval if there is a deviation from the RI-ISI methodology described in the initial submittal, or if industry experience determines that there is a need for significant revision to the program**

APPLICATION TO BER PIPING

- Modification of inspections within the break exclusion region (BER) not permitted in the original EPRI and WOG RI-ISI methodologies.

- Both EPRI and WOG have developed methodologies to apply RI-ISI methodology to piping within the BER.

    SER on EPRI submittal completed in June 2002

    WOG Submittal currently under review

- When BER program is in FSAR, the extension of RI-ISI methodology to BER piping may be done via the 10 CFR 50.59 process

LONG-TERM ACTIVITIES

- **Update RG 1.178 and SRP 3.9.8 to incorporate lessons learned.**

- **Staff is working with ASME to develop acceptable Code Cases and an Appendix for RI-ISI applications.**

  - ➔ **Code Case N-560 (Class 1, EPRI Method).**
  - ➔ **Code Case N-577 (Class 1, 2, 3, WOG Method).**
  - ➔ **Code Case N-578 (Class 1, 2, 3, EPRI Method).**
  - ➔ **Appendix X (Class 1, 2, 3, WOG and EPRI Methods).**

- **Endorsement of Code Cases in RG 1.147, with limitations and conditions where appropriate.**

- **Anticipate that Code Cases will be incorporated into the ASME Code.**

- **Eventual rulemaking to incorporate by reference the ASME Code with limitations, if necessary.**

COMPARISON OF ASME XI AND RI-ISI

ITEM	ASME XI	RI-ISI
Applicability	As defined in the appropriate ASME XI	Currently applicable to piping only
Percentage of examinations for Class 1 piping	Category BF Welds: 100% Category BJ Welds: 25%	As Defined in the Approved RI-ISI Program for the Plant
Percentage of examinations for Class 2 piping	Categories C-F-1, C-F-2 Welds: 7.5%	As Defined in the Approved RI-ISI Program for the Plant
Examination locations	Terminal ends, locations of high stresses and fatigue usage factors, etc	As defined in the approved RI-ISI program for the plant

Item	ASME XI	RI-ISI
Examination method	As defined in the appropriate ASME XI table, usually depends on pipe size and weld type	As defined in the applicable approved topical report, usually depends on degradation mechanism
Examination volume	As defined in the appropriate ASME XI Table	As defined in the applicable approved topical report, depends on degradation mechanism and usually more volume than ASME XI
Examination Frequency	10 Year inspection interval defined in ASME XI	Same as ASME XI

Item	ASME XI	RI-ISI
Definition of inspection periods	Three periods as defined in ASME Xi	Same as ASME XI
Minimum examinations during inspection periods	16%, 50%, and 100% at the end of three periods	Same as ASME XI
Examination acceptance standards	Defined in ASME XI	Same as ASME XI
Flaw evaluation standards	Defined in ASME XI	Same as ASME XI