UNITED STATES
NUCLEAR REGULATORY COMMISSION
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February 24, 2000

MEMORANDUM TO: Stuart A. Richards, Director
Project Directorate IV & Decommissioning
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

FROM: Jack Cushing, Project Manager, Section 2
Project Directorate IV & Decommissioning
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

SUBJECT: SUMMARY OF MEETING WITH THE COMBUSTION ENGINEERING OWNERS GROUP (CEOG) TO DISCUSS EXTENDING THE REACTOR VESSEL INSERVICE INSPECTION INTERVAL(TAC NO. MA8056)

On January 27, 2000, the NRC staff met with representatives of CEOG to discuss the approach to extending the reactor pressure vessel (RPV) inservice inspection (ISI) interval from the current 10 year requirement to 20 years or more using risk informed guidance outlined in Regulatory Guide (RG) 1.174, "An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis." The CEOG is sponsoring the effort with eight (8) utilities that include two (2) non-CE plants. Industry vendors, a utility sponsor and several NRC staff members attended the meeting. Attachment 1 is a list of the meeting participants. Attachment 2 is a copy of the non-proprietary meeting slides.

The presenters at the meeting are listed below.

Presenters

John Ghergurovich	ABB (Task Manager)
Dave Ayres	ABB
Chris Hoffmann	ABB (RPV Materials)
Pete Riccardella	Structural Integrity (SI) (PRA)
Robert Jaquith	ABB (PRA)
Jack Lareau	ABB (ISI Inspection)

Utility

Sherm Shaw — San Onofre Nuclear Generating Sation (SONGS) (Utility Sponsor)

The meeting opened with introductions and an overview of the proposed approach followed by more in-depth technical explanations. The discussion that ensued was a productive give and take about the merits and weaknesses of the approach from both technical and regulatory views.

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After the overview was presented, Sherm Shaw addressed the staff on behalf of the San Onofre Nuclear Generating Sation, as the pilot plant, to express his support for this effort. Sherm Shaw noted that SCE would benefit from a timely successful outcome by applying the methodology to be developed for the elimination of an upcoming RPV inspection in mid-2002.

Early in the meeting, the CEOG noted the success of the recent boiling water reactor vessel inspection program (BWRVIP) and indicated that the proposed effort will use a similar process for approval as outlined in the BWRVIP-05 effort. The CEOG noted that the scope of the methodology for this meeting only addresses the beltline region. However, the ultimate objective of the task is to eventually address the entire inner surface of the RPV typically inspected during a 10-year ISI. The non-beltline inspections will be addressed at the next meeting with the staff. The staff was receptive to the approach presented. However, there were some specific items that the staff noted which require further review and consideration. The major ones are discussed below:

1. ***The staff strongly suggested a parallel pursuit of this topic in the public domain via an ASME Code Case.***

The basis for this is that the staff would rather standardize the process by approving one Code Case and have each licensee follow it. NRC approval of a Code Case would also eliminate the need for relief requests.

2. ***Economic analysis should be performed to determine the saving to the licensees.***

The staff requested a more global assessment of the savings associated with the extension of the inspection interval so the economic benefit can be defined. The reason for this request is to develop a better justification of NRC resources needed to support this effort.

3. ***Transient events to be used in the evaluation need to be reviewed with the staff before developing final results.***

The staff is concerned that the ongoing pressurize thermal shock (PTS) re-evaluation effort may not be completed in time to provide a "final" input to this task. The CEOG noted that the published schedules for these ongoing tasks are not too far off from the proposed schedule for this task and that the proceedings of these meetings were closely followed via participation in these efforts. The NRC staff also specifically noted that the LTOP transient must be one of the "events" to be considered and that less severe but more frequently occurring transients also be investigated.

4. ***Accepted fluence analysis must be used as input to the method.***

The staff noted that each plant pursuing this concept must have an accepted fluence analysis in place in order to be considered.

5. ***Uncertainty in the probabilistic fracture mechanics evaluation (VIPER) output must be quantified.***

The staff noted several times that the probability of failure results that is produced by the VIPER PFM code must also include an uncertainty assessment of the output value. ORNL FAVOR will produce a distribution with a mean probability for vessel failure. Pete Riccardella of SI noted that for the BWRVIP program a bounding (or a large number of iterations) approach was sufficient to address this topic.

6. ***The CEOG intended use of the output of the NDE Expert Panel for defining the flaw distribution and the pressurize thermal shock (PTS) re-evaluation for limiting transient definition is a schedule concern.***

The staff noted that the use of the results from these ongoing industry activities is appropriate but is concerned about the timing of having final information available under the proposed schedule. The CEOG noted that the published schedules for this task are not too far off from the proposed schedule and that the proceedings of these meetings were closely followed via participation in these efforts.

7. ***The staff asked whether the outcome of this work would be applicable to License Renewal.***

The CEOG replied that extending the reactor vessel ISI inspection interval would be applicable to license extension.

Several other points were brought up by the staff during the discussion and are noted below and will be addressed in future meetings/discussions.

8. ***The staff suggested that the methodology be made applicable to all pressurized water reactors (PWR).***

9. ***SCE, the pilot plant, will have to convince the staff that whatever design transients are used are bounded under the on-going PTS re-evaluation.***

10. ***The staff requested that the methodology report include why stress corrosion cracking is not a problem for PWRs.***

11. ***The staff asked if the CEOG was going to follow the new embrittlement correlations.***

12. ***The staff requested that the CEOG address the different fabrication welds in the RPV (Single V vs Double V) would influence flaw distribution.***

13. The staff asked the CEOG to address how the outcome of this work scope would impact the RV internals inspection.

The CEOG is planning to meet again before mid-year to discuss the transients the staff intends to use in the task. At that point, the CEOG will also address the other concerns mentioned above along with the results of some "trial" analyses to see if the staff can better define the outcome of this task.

Project No. 692

Attachments: 1. Meeting Participants
2. ABB/CEOG Slides

cc w/atts: See next page

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LIST OF PARTICIPANTS

MEETING WITH THE CE OWNERS GROUP

PROPOSED RCP SEAL MODEL DEVELOPMENT

January 27, 2000

ABB-CE

Charles Brinkman
Bob Jaquith
David Ayres
John Ghergurovich
Chris Hoffman
Jack Lareau

Structural Integrity

Pete Riccadella
Nathaniel G. Cofie

NUS

Donald Palmrose

SCE/ San Onofre Nuclear Generating Station

Sherm Shaw

NRC

Jack Cushing
Robert Jasinski
Robert Hermann
Bill Bateman
Keith Wichman
Barry Elliot
Sarah Malik
Allen Hiser
Stephen Dinsmore
Debbie Jackson

Attachment 1

CEOG TASK 1133: RVISI Interval Extension Task

1/27/2000 Meeting Agenda, NRC Offices

------------- NON-PROPRIETARY HANDOUT -----------

Attachment 2

Reactor Vessel ISI Interval Extension

CEOG Task 1133

Presentation to NRC Staff, Jan 27, 2000

Extension of Reactor Vessel ISI Interval

- **Presentation Overview**
  - Introduction/Background
  - Project Overview
  - Historical Perspective
  - Technical Basis Development
  - Regulatory Interface
  - Schedule Projection
  - Summary
  - Discussion

Extension of Reactor Vessel ISI Interval

- **Why are we here ? ...**
  - Discuss an approach to justify the extension of the RPV In-Service Inspection(ISI) Interval from the current 10 year requirement to 20 years.
  - We are *not* here to eliminate the inspection content but to demonstrate that by continuing with the same breadth of inspections at a longer interval there is no significant increase in risk of component failure.

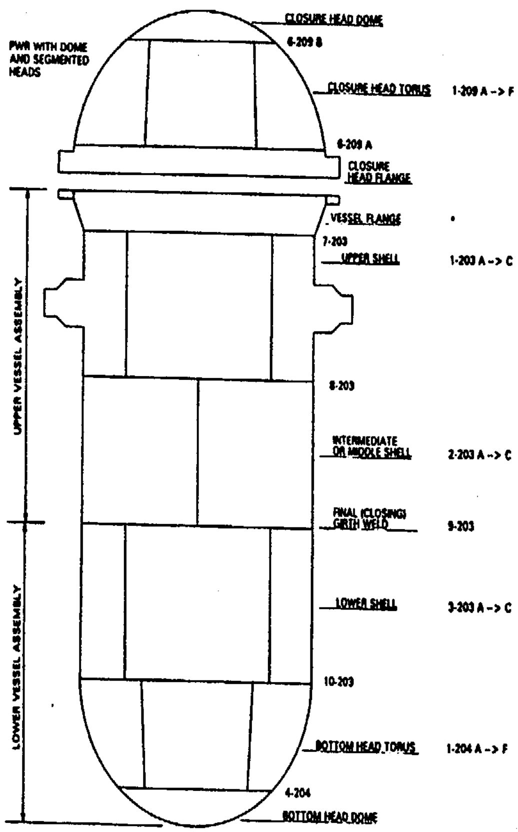
Extension of Reactor Vessel ISI Interval

- **Who is interested ? ...**
  - Sponsored by CEOG ISI Subcommittee
    - APS, BGE, EO, CEC, NU, SCE, ...
    - TU, WCNOC, ...
- **Why ?**
  - Interested in reducing burden on utility operation

Extension of Reactor Vessel ISI Interval

- **What is the scope of applicability ? ...**

FIGURE 1
REACTOR VESSEL WELDS



– Ultimate objective is to address all weld and HAZ regions to be examined during a RPV inspection

- Initial focus is the beltline region

Extension of Reactor Vessel ISI Interval

- **How are we going to do this ?**
  - Execute a broad based Owners Group Program
    - Perform Pilot Plant Analysis which demonstrates that objective can be achieved
    - Formalize approval via a Topical submittal
      - Apply to specific plants to get relief
    - Elicit guidance from regulators
      - Establish Technical level dialogue
- **Proven approach based on successful BWRVIP program**

Extension of Reactor Vessel ISI Interval

- **Program Plan**
  - Phase 1: Conceptual Feasibility Evaluation
  - Phase 2: Technical Feasibility / Pilot Plant Application
    - Develop detailed approach
      - Research available methods
      - Define an appropriate approach
      - Initiate work on a Pilot Plant and discuss w/NRC
  - Phase 3: Technical Application / Topical report
    - Complete work on pilot plant
    - Submit topical for review
  - Phase 4: Licensing
    - Support topical review
  - Phase 5: Plant / Vessel Specific Evaluations
    - Using Topical, apply generic methodology to support individual requests for Exemptions

Extension of Reactor Vessel ISI Interval

- **Phase 1: Conceptual Feasibility Evaluation**

  - Already Completed
  - Overview
    - Survey to obtain plant data on present and planned RPV inspections
      - Cost Benefit Analysis
    - Present concept to NRC, got positive initial feedback
    - Refined direction & scope
      - Reviewed BWRVIP Approach
      - Redefined Technical basis to use Risk Informed Methods
      - Noted successful outcome of BWRVIP Circumferential Weld Exemption

Extension of Reactor Vessel ISI Interval

- **Plant Survey**
  - Economic Survey
    - Dollar savings range $1.1m - $6.1m
    - Man-Rem savings range 0.26 - 1.16 man-rem
  - Cost Benefit
    - Per plant cost for participation is projected to be significantly less than the lowest expected savings.

Extension of Reactor Vessel ISI Interval

- **Phase 2: Technical Feasibility / Pilot Plant Application**
  - *Objective:* Develop, recommend and test a technical approach for determining an appropriate longer inspection interval for the reactor vessel.
    - Focus on evaluating the effect on change in risk associated with extending the ISI interval
  - *Discussion:*
    - Teaming with Structural Integrity Associates (SI)
      - *Key contributor to BWRVIP program*
      - *Modify VIPER Code for PWR vessel flaws*
      - *Fracture mechanics-based flaw growth predictions*
    - Approach based on deterministic and probabilistic fracture mechanics
    - Adapt Risk Informed thinking developed in the piping arena
    - Set up formulation so that change in risk versus inspection interval can be determined.
      - Focus on determining change in Core Damage Frequency (ΔCDF)

Extension of Reactor Vessel ISI Interval

- **History**
  - **1969 CE Presentation to ACRS Materials Committee:**
    - Slow growth of fatigue cracks shows in-service inspection is unnecessary.
    - Also demonstrates: significant conservatism if not considered
    - Result:
      - No change in inspection requirements.
      - No service induced degradation.
      - No Vessel repairs to date as a consequence of inspection.

Problem : No Standard of Risk

Extension of Reactor Vessel ISI Interval

- **History** **(Cont'd)**
  - **1985-7 CE Work on Crack Arrest**
    - Crack arrest demonstrated by analysis and experiment to occur in some PTS transients, thereby demonstrating decreased risk of vessel failure
    - Also demonstrates: significant conservatism if not considered
    - Result:
      - Industry / Regulatory uncertainty about how to do PTS analyses.
      - Revision of criteria now underway.
      - Relevant data has been collected.

Problem : No Standard of Risk

Extension of Reactor Vessel ISI Interval

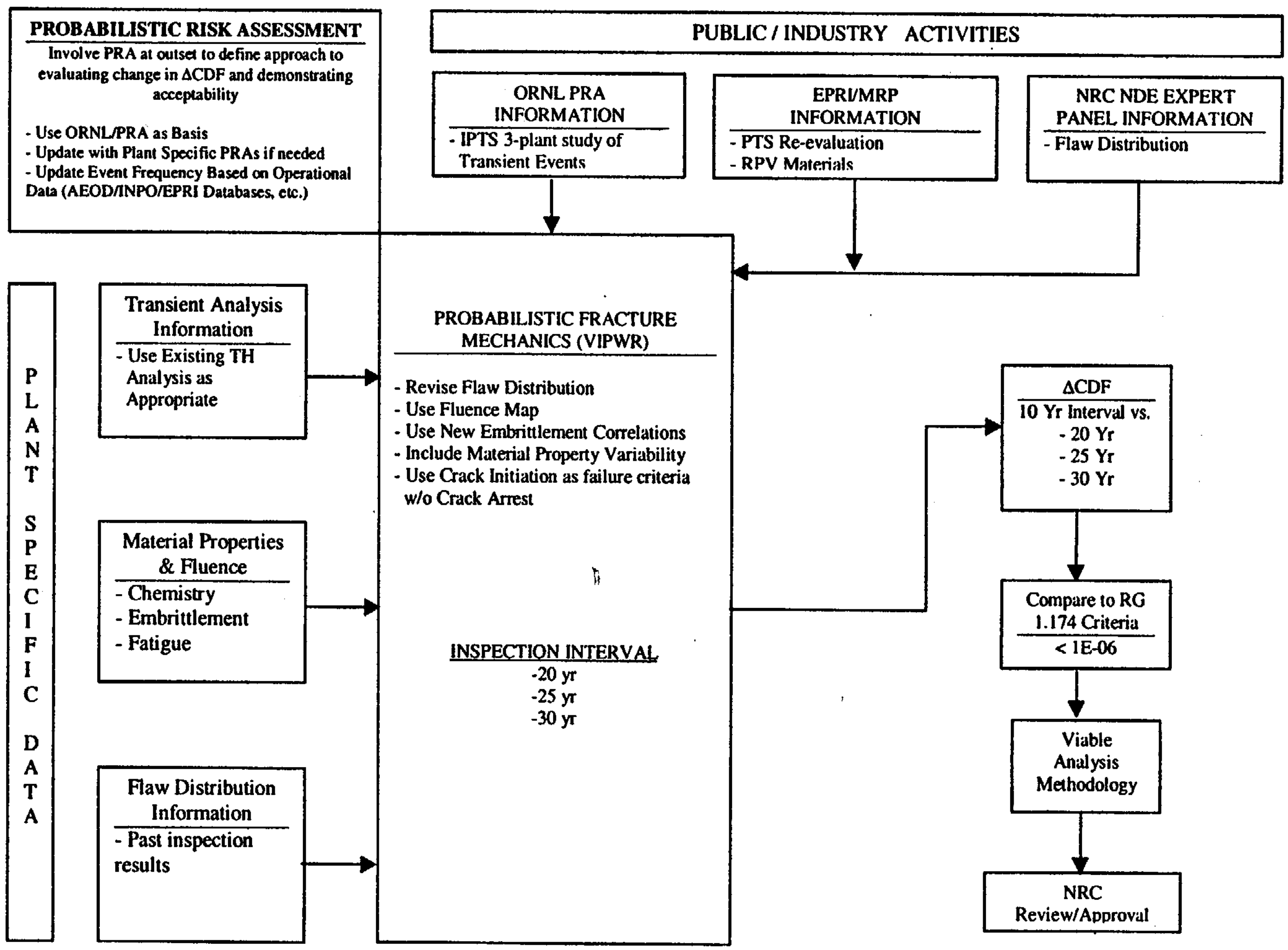
- **History** **(Cont'd)**
  - **2000 ABB/ CE Proposal to Extend Inspection Interval**
    - Very small change in risk of vessel failure if interval is increased
    - Vessel failure conservatively considered to be flaw initiation
    - Will demonstrate: Interval increase satisfies RG 1.174
    - Result:

Now there is a Standard of Risk

- We believe we can be successful

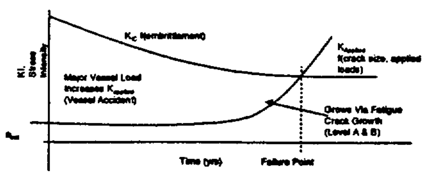
Extension of Reactor Vessel ISI Interval

DEVELOPMENT OF TECHNICAL BASIS FOR EXTENSION OF RPV INSPECTION INTERVAL



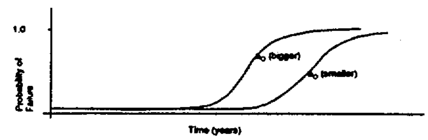
Extension of Reactor Vessel ISI Interval

- **Technical Brief**



Extension of Reactor Vessel ISI Interval

- **Technical Brief** *(Cont'd)*



Extension of Reactor Vessel ISI Interval

- **Technical Discussions**
  - Material Properties / Fatigue
  - Flaw Distribution Approach
  - Risk Informed Approach
  - Design Basis Transient Events
  - Probabilistic Fracture Mechanics

Materials Properties / Fatigue

Chris Hoffmann

RPV Configuration

- **RPV Beltline Dimensions**
  - As-Built Dimensions
  - Weld Locations
  - Cladding Thickness
- **Neutron Fluence Distribution**
  - Axial
  - Azimuthal
- **Definition of Beltline Subregions**

RPV Material Properties

- **Stress Analysis Assumptions**
  - Residual Stress Distribution in Welds (ORNL HSST data)
  - Cladding Stress Free Temperature

RPV Material Properties

- **Beltline Plate Materials**
  - Initial RT_{NDT}
  - Copper & Nickel Content
- **Beltline Weld Materials**
  - Initial RT_{NDT}
  - Copper & Nickel Content

RPV Material Properties

- **Beltline Irradiated Properties**
  - Fluence vs. Time
  - Reg. Guide 1.99 Rev. 2, Position 1.1
    - Shift Prediction
    - Fluence Attenuation
    - Adjusted Reference Temperature
      - ART = f(Time, Depth)
  - SC XI Appendix A K_{Ic} Curve
    - K_{Ic} = f (Time, Depth)

Fatigue Flaw Growth

- **Flaw Growth**
  - Fatigue Crack Propagation
    - SC XI Appendix A Fatigue Crack Growth Curves for RPV Materials
- **Input Parameter Uncertainties**
  - Mechanical Properties
    - Fluence
    - Chemistry
    - Initial RT_{NDT}

Flaw Distribution Approach

John Lareau

Overall Approach

- **Participate in the NRC Expert Elicitation Panel**
- **CE Fabrication Experience**
  - Welding flaws
  - Clad induced flaws
  - Repair welds

Flaw Distribution Task

- **Establish a credible flaw distribution for CE fabricated reactor vessel.**
- **Include flaw location distribution**
  - Depth from clad interface
- **Assess In Process, PSE and ISI methods**
  - ASME Sections III and XI
  - Post Hatch
  - Reg Guide 1.150

In Process NDE

- **Plate Receipt Inspection**
  - 100% UT (0 degree)
  - 100% UT (angle beam) two directions, 3% notch
- **Form and Quench**
  - 100% UT as above
  - 100% MT
  - Repair up to 3/4" depth
  - MT of repair

In Process NDE (cont.)

- **Cut Plate & Weld Prep**
  - MT weld prep
  - Repair
  - MT and UT of repair
- **Weld Long Seams & Machine**
  - 100% MT
  - 100% UT of plate
  - RT of weld

In Process NDE (cont.)

- **Repair RT Indications**
  - Overfill and grind flush
  - MT repair
  - RT repairs > 3/8"
- **Clad**
  - UT for bond
  - PT surface

In Process NDE (cont.)

- **Post Hatch Inspection**
  - 100% UT of welds per ASME XI
- **Reg Guide 1.150**
  - Add near surface UT
  - Qualified in EPRI round robin

Clad Induced Flaws

- **Tricastin**
  - Forged Ring
  - 2 Layer cladding
  - EPRI Report NP-2841, January 1983
    - cold cracking
    - insufficient heat treat

Clad Induced Flaws (cont.)

- **CE Vessels**
  - Plate (A533, A302)
  - Low heat input clad
  - Single layer or double layer with heat treat
  - No detected flaws in PVRUF or Shoreham

Validated PVRUF Flaws – Outside the Near Surface (25mm) Zone

Table 4: Flaws in the Weldment Outside Near-Surface of the PVRUF Vessel

Jan, 2000	<5mm	5-6mm	7-8mm	9-10mm	11-12mm	13-14mm	Total ≥ 5mm
LOF, slag	1400	19	4				23

Table 5: Flaws in Repairs Outside the Near-Surface of the PVRUF Vessel

Jan, 2000	5-6mm	7-8mm	9-10mm	11-12mm	13-14mm	15-16mm	17-18mm	Total ≥ 5mm
LOF	5			1			1	7

Table 6: Flaw in the Base Metal Outside the Near-Surface of the PVRUF Vessel

Jan, 2000	<5mm	5-6mm	7-8mm	8-9mm	9-10mm	10-11mm	Total ≥ 3mm
Laminations			1				1
Indications	365	10	1				11

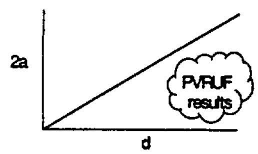
Validated PVRUF Flaws – Inner 25mm

Table 1: Flaw in the Weldment of the Inner 25mm of the PVRUF Vessel								
Jan, 2000	<3mm	3mm	4mm	5mm	6mm	7mm	8mm	Total ≥ 3mm
Crack, LOF	193	7	2	2				11

Table 2: Flaws in the Cladding of the Inner 25mm of the PVRUF Vessel								
Jan, 2000	<3mm	3mm	4mm	5mm	6mm	7mm	8mm	Total ≥ 3mm
LOF, slag	1148	3	1					4

Table 3: Flaws in the Base Metal of the Inner 25mm of the PVRUF Vessel								
Jan, 2000	<3mm	3mm	4mm	5mm	6mm	7mm	8mm	Total ≥ 3mm
Indications	180	10	3					13

Flaw Distribution



2a: throughwall flaw projection
d: ligament to surface

Flaw Distribution (cont.)

- **Present Position**
  - Size Distribution
    - Based on PVRUF
    - Compare with PRODIGAL
  - Location Distribution
    - Distribute through "most" of the volume
    - Limit surface flaws based on NDE
  - Weld Repair Flaws are Subsurface

Risk Informed Approach

Bob Jaquith

Basis for Change

- **Historically PRAs assume RPV failure frequency ~ 1.0E-7 per year (WASH-1400)**
- **Technology and experience now available to confidently assess PTS failure risk**
- **Expect to show that PTS contribution to RPV failure is small fraction of assumed RPV failure frequency**
- **Any increase in RPV failure frequency due to changes in inspection interval expected to be negligible**

Regulatory Basis

- **Change to Inspection Interval will be based on demonstrating adherence to RG 1.174**
- **RG 1.174 - An Approach for Using PRA In Risk-Informed Decisions On Plant-Specific Changes to the Licensing Basis**
  - Show Substantial Benefit from Change
  - Show small increase in Risk
    - ICCDP < 1.0E-6
    - ICLERP < 1.0E-7

Limits on Increase in Risk

- **ICCDP < 1.0E-6**
  - PSAs assume RPV failure leads to core melt with P=1
    - Therefore, the increased Probability of RPV failure is equal to the ICCDP.
- **ICLERP < 1.0E-7**
  - Since RPV failure may have no correlation to containment reliability, the LERP increase should be directly proportional to the CDF increase (plant specific)
  - Expected RPVfailures not expected to create new missile challenges to containment integrity. Since core not damaged prior to RPV failure, DCH not present.
  - Consequently, LERP impact is small (<.01) based mainly on probability of loss of containment isolation.

Bounding Event Sequences Selected to Establish Conditional Impact of Severe Challenges

- ORNL PRA for Calvert Cliffs will be basis for transient selection
- Provides limiting set of challenges to RV
- Provides inputs to VIPER analysis
- Risk = Sum of: Sequence Frequency X Conditional RPV Failure Probability
  - NUREG/CR-4022 Pressurized Thermal Shock Evaluation of the Calvert Cliffs Unit 1 Nuclear Power Plant, by ORNL, Sept 1985

ORNL Evaluation of Calvert Cliffs

- Best Estimate Frequency of RPV Through-Wall crack is 7.0E-08 per reactor year (at 32 EFPY)
- Small Break LOCA (with low decay heat) is most significant contributor to PTS risk.
- Uncertainty in flaw density in the RPV was the major contributor to uncertainty in risk

ORNL Evaluation vs. the Current Program

- Even the ORNL results may support RPV inspection interval extension (may meet RG 1.174 criteria)
- However, we expect reduced uncertainty and increased margins based on new information:
  - More favorable flaw distribution
  - Lower conditional failure probabilities (from VIPER)
  - Lower initiating event frequencies (NUREG/CR 5750, Feb. 1999, INEEL)

Overview of Transient Analyses

- Select based on ORNL results
  - Other events may be added as necessary based on downstream results
- Use existing analyses
  - Base on ORNL results
  - Modify for pilot plant (SONGS)
  - Verify results with CENTS as appropriate
  - Input to VIPER analysis

Sequence of Concern

- Cooldown and Depressurization due to initiating event
- Repressurization Due to
  - HPSI
  - Charging
  - Swell

ORNL Event Selection

- 0.1 m^2 MSLB Upstream of MSIVs
  - From HZP* with loss of RCPs
  - From full power with LOAC
  - From HZP* with 4 pumps operating
- Double-ended MSLB Upstream of MSIVs
  - From HZP* with Continued AFW flow to ruptured SG
  - From HZP* with two stuck-open MSIVs

* Frequency of HZP events will be weighted based on average time in that mode

ORNL Event Selection

- Small SLB Downstream of MSIVs
  - From full power
  - From full power with one stuck-open MSIV
- Runaway feedwater
  - Max MFW flow to two SGs at full power
  - Max MFW flow to one SG at full power
  - Max AFW flow to two SGs at full power

ORNL Event Selection

- Small Break LOCA
  - 0.002 m^2 hot-leg break from full power
  - Stuck-open PORV with stuck-open ADV from full power

ORNL Common Assumptions

- RCP off 30 seconds after SIAS
- Operator fails to turn off charging pumps
- Operator fails to control re-pressurization
- Operator fails to maintain level in intact steam generator
- Operator Fails to respond to high SG alarms

Estimate Risk and Change in Risk

- Estimate the Occurrence Frequency for each of the 12 ORNL dominant events.
- Determine temperature/pressure inputs to VIPER for each event
- From VIPER determine Conditional RV failure probability
- Calculate the difference in RV failure frequency for different inspection intervals
- Estimate bounding ICCDP values

Extension of PWR Reactor Vessel ISI Intervals - PFM Methodology

Peter C. Riccardella

Structural Integrity Associates, Inc.

Overview

- General approach will be to build upon methodology developed for BWR Vessel Inspection Evaluation (VIPER, BWRVIP-05)
  - Retain agreed upon major assumptions
  - Adapt methodology, as appropriate, for applicability to PWR vessels (VIPWR)
- Overall goal will be to determine permissible increase in inspection intervals consistent with RG 1.174 Guidelines
- Analysis will consider probabilities of vessel failure with current 10 year inspection intervals versus with various proposed alternatives (20 years, 25 years, . . .)

Review of BWR Shell Weld Inspection Study (BWRVIP-05)

Previous Requirements (ASME Code and 10CFR50.55a)

- Inspect "Essentially 100%" of axial and circumferential RPV shell welds
- Same for BWRs and PWRs

BWRVIP Alternative - Currently Accepted

- Inspect "Essentially 100%" of axial welds
- No Circumferential weld inspections
- Inspection interval unchanged (10 years)

Note: "Essentially 100%" defined as at least 90% of each weld

BWRVIP-05 Chronology

- Development of VIPER Methodology (1994 & 1995)
- BWRVIP-05 Report Submitted (Sept. 1995)
- NRC RAIs and Responses (June 1996 - Jan. 1998)
- NRC Safety Evaluation (July, 1998) and Generic Letter 98-05 (Nov. 1998) Granting Relief from Circumferential Weld Inspections
- Additional RAIs and Responses on Axial Weld Issue (Dec. 1998 - April 1999)
- Axial Weld Issue Resolved (Fall 1999)

By incorporating lessons learned and retaining agreed-upon assumptions from BWR effort, hopefully PWR process will be streamlined !

Overview of VIPER Methodology

PROPRIETARY

Review of Key Inputs for VIPWR

- Flaw Distribution
- Fluence Distribution
- Operational Transients
- Crack Propagation
- Clad Residual Stress
- Effectiveness of Inspection (POD)

Key Assumptions - Flaw Distribution

PROPRIETARY

Comparison of BWRVIP and NRR Flaw Size Distributions

PROPRIETARY

Key Assumptions - Fluence Distribution

- **Original Analyses Based on Single Peak Fluence Level throughout Vessel**
- **Final Analyses of Axial Welds used Plant-Specific Axial and Circumferential Fluence Distributions**

BWR Vessel Axial Weld Fluence Profile

PROPRIETARY

BWR Vessel Axial Weld Distributed Fluence Results

PROPRIETARY

Limiting Operational Transient

PROPRIETARY

Other Key Assumptions

- Crack Propagation (FCG versus SCCG)
- Cladding Residual Stress
  - **Treated as a distributed variable**
  - **Indexed to clad temperature during transient**
- Effectiveness of Inspection (POD)

Cladding Residual Stress Data

PROPRIETARY

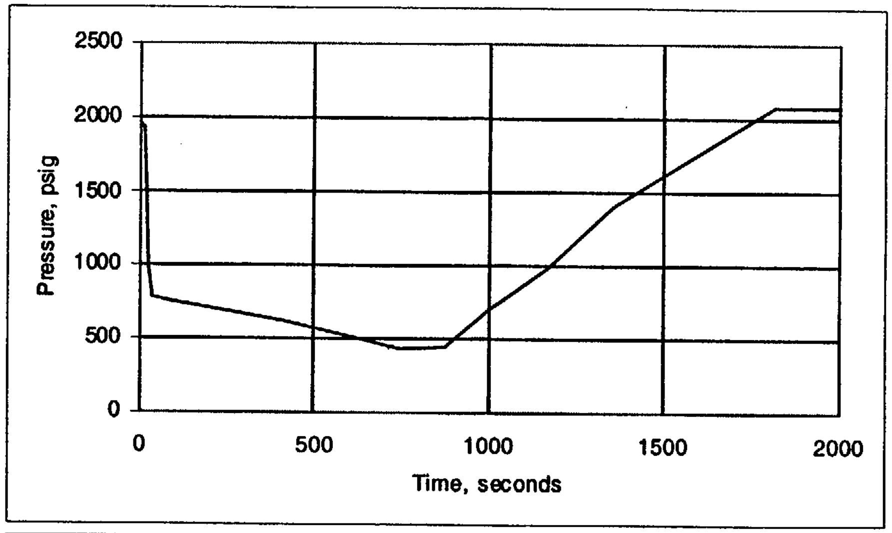
Cladding Residual Stress Temperature Dependence

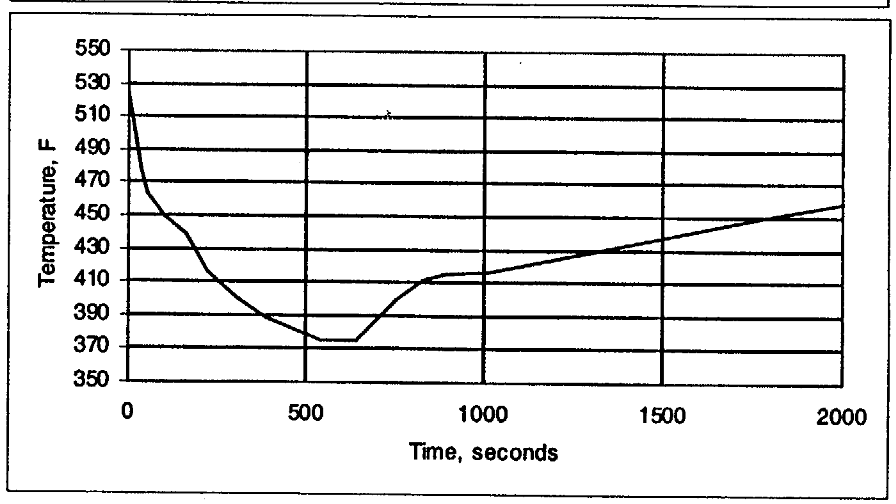
PROPRIETARY

Modifications Required to Adapt VIPER to PWRs (VIPWR)

- PTS versus LTOP is challenging event to vessel
- Consider both $K_{deepest\ point}$ and $K_{surface}$ (clad-base metal interface) in fracture calculations
- Fatigue Crack Growth rather than Stress Corrosion Cracking is primary crack growth mechanism

Typical PTS Event
(Steam Line Break)



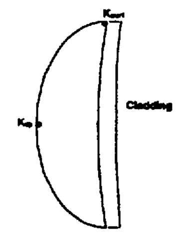


Proposed PTS Algorithm for VIPWR

- **Pre-determine Transient Stress and Temperature Profile following PTS event:**
  $T(x,\tau) = A(\tau)\exp(B(\tau)x)$
  $\sigma(x,\tau) = C_0(\tau)+C_1(\tau)x+C_2(\tau)x^2+C_3(\tau)x^3$
- **To simulate PTS event, loop from $\tau = 0$ to τ = end of PTS transient, checking K vs. K_{Ic} at each time step**
  - K = f (C_is, crack depth, clad stress)
  - K_{Ic} = f (Fluence, Cu, Ni, Initial RTNDT, and Temperature @ applicable crack depth)

PTS Vessel Failure Criteria

- **Check K vs. K_{Ic} at deepest point of crack (K_{dp}) and at clad-base metal interface (K_{surf})**
- **If K_{dp} exceeds K_{Ic} vessel is considered to have failed**
- **If K_{surf} exceeds K_{Ic}, flaw grows in length, and then must check K_{dp} for infinitely long crack**



Monte Carlo Simulation Process

1. **Start iteration - select random variables to determine initial flaw sizes and material properties**
2. **Grow cracks using fatigue cycles for each year of plant operation**
3. **Simulate PTS events each year**
   - apply PTS failure criteria to all flaws (current sizes)
   - if any flaw fails, record a failure in appropriate year
   - continue process <u>with all flaws</u> each year until scheduled inspection
4. **Inspect vessel at scheduled inspection interval**
   - screen out flaws that would be repaired as a result of inspection (based on selected POD curve and Section XI flaw evaluation criteria)
5. **Repeat steps 2 - 4 for all inspection intervals until end-of-life** (including license extension period where applicable)
6. **Probability of failure per year = maximum number of failures in any year divided by total number of iterations**

Regulatory Interface

Phil Richardson
Charlie Brinkman

Regulatory Interface for CEOG RV ISI

- Maintain open lines of communication
  - **Frequent dialog between ABB and NRC**
    - **Jack Cushing, NRC Project Manager for CEOG**
    - **Phil Richardson, ABB Licensing Project Manager**
    - **Charlie Brinkman, Director, ABB Washington Operations, available as necessary**

Regulatory Interface for CEOG RV ISI

- Together, we will facilitate the interface between ABB and the NRC Staff
  - **Eliminate surprises**
  - **Determine and define the real issues**
  - **Determine the success path(s)**
  - **Keep the task focused**
  - **Conclude each meeting, call, video conference, etc. with an action plan**

Regulatory Interface for CEOG RV ISI

- CEOG will monitor industry activities
  - Changes in NEI Active Issues
    - RPV Integrity
    - Risk-informed ISI
  - Related submittals
  - Related regulatory issues
- Feedback changes and lessons learned into CEOG program

Regulatory Interface for CEOG RV ISI

- Success Factors
  - Proposed approach developed in accordance with NRC recommendations
    - August '98 meeting
  - Regulatory support for risk-informed activities
    - Current guidance exists, RG 1.174
  - No known regulatory roadblock to licensability

Extension of Reactor Vessel ISI Interval

- Schedule
  - Phase 2: Technical Feasibility / Pilot Plant Application
    - Complete Modifications to the VIPER Code and perform Initial Bounding Analyses and meet to discuss results in about 20 weeks *(Mid-Year, June/July 2000)*
  - Phase 3: Technical Application / Topical report
    - Subsequent Topical Submittal to follow in about 8-10 weeks *(This Fall)*
  - Phase 4: Licensing
    - Review of Pilot Plant Submittal *(Early Spring 2001)*
  - Phase 5: Plant / Vessel Specific Evaluations
    - Per individual plant needs

Extension of Reactor Vessel ISI Interval

- Recent Industry Activities
  - EPRI MRP Program
    - NRC/ORNL PTS Re-evaluation
  - NDE Expert Panel
  - ASME
    - RV Inner Radius Inspection
- Interest Outside CEOG has been solicited
  - Received Positive feedback .... (Non-CEOG)
    - Duke Power, Texas Utility, Southern Nuclear, American Electric Power, Wolf Creek
  - Have suggested that it be brought to other owner groups
  - Try to blend it in to existing industry programs

Extension of Reactor Vessel ISI Interval

- In Summary
  - Background/Historical Perspective
  - Technical Discussions
    - Material Properties / Fatigue
    - Flaw Distribution Approach
    - Risk Informed Approach
    - Design Basis Transient Events
    - Probabilistic Fracture Mechanics
  - Industry Activities

Extension of Reactor Vessel ISI Interval

- Discussion / Q&A
  - This project requires NRC support
  - Feedback
    - Discuss approach

February 24, 2000

The CEOG is planning to meet again before mid-year to discuss the transients the staff intends to use in the task. At that point, the CEOG will also address the other concerns mentioned above along with the results of some "trial" analyses to see if the staff can better define the outcome of this task.

Project No. 692

Attachments: 1. Meeting Participants
2. ABB/CEOG Slides

cc w/atts: See next page

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