The Materials Initiative

NEI 03-08 Overview

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Overview

- Primary system materials integrity is vital to plant performance and reliability
- Reactor components operate in a harsh environment - high temperatures, cyclic stress, vibration, intense neutron fields, etc.
- Numerous materials and alloys exist in a plant's systems and the aging of these materials is complex and not always fully understood
- Routine surveillances, ISI, and replacements can mitigate some of these factors; however, some failures can be expected
- Challenge: To find the next material vulnerability and to address it before any failures occur

Background - Operating Experience through 2002

- Reactor Internals components:
  - Core shrouds
  - Core spray piping
  - Jet pump beams
  - Jet pump inlet piping
  - Top guides
  - Steam dryers
  - BWR fuel support castings
  - PWR baffle bolts and split pins
- Pressure boundary items:
  - BWR recirculation piping
  - BWR CRD stub tubes
  - Pressurizer heater sleeves
  - Primary system full penetration butt welds
  - PWR reactor vessel bottom mounted nozzles
  - PWR CRDM head penetrations

Forcing Function

- BWRs had programs dealing with IGSCC
  - Piping covered by GL 88-01 and then BWRVIP-75
  - Reactor internals managed by BWRVIP program
- A series of <u>events in PWRs</u> motivated industry executives to take broad generic action
  - Indian Point steam generator tube
  - V.C. Summer dissimilar metal weld leak
  - Multiple PWR head penetration leaks
  - Davis-Besse head wastage

Indian Point

- February 2000:
  SG tube leak
  - Hidden by noise in NDE signal

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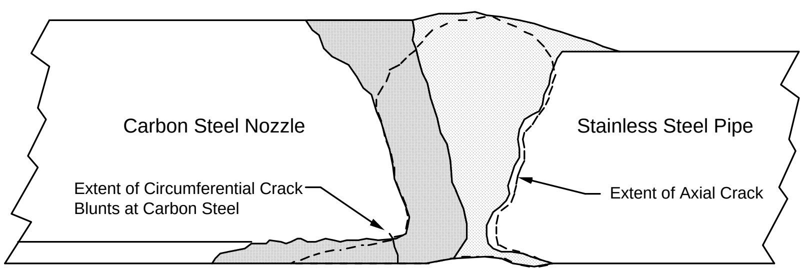
V. C. Summer

- Crack in RCS hot leg, Fall 2000
  - A Hot Leg Nozzle to Pipe Weld



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PWR RPV Heads

Leaking PWR CRDM Head Penetrations

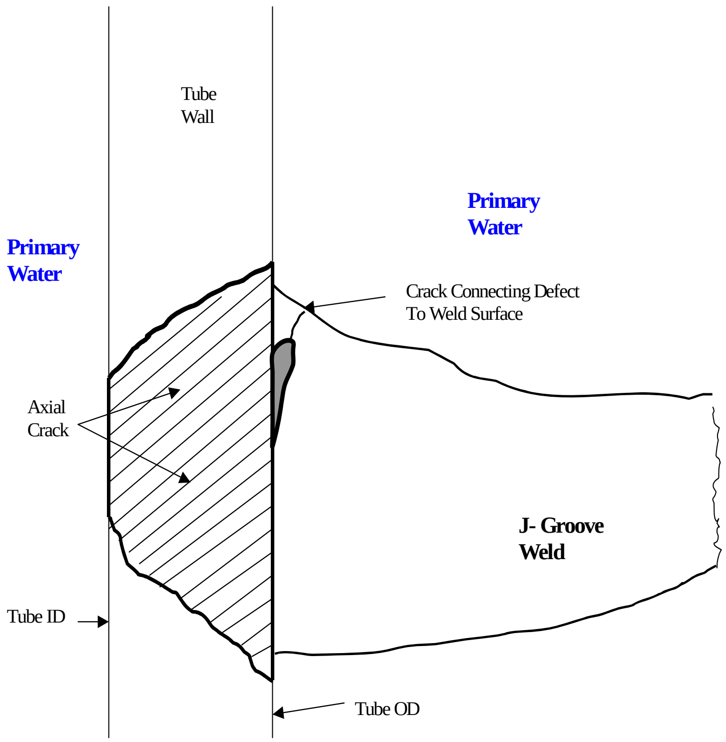
Davis-Besse

March 2002

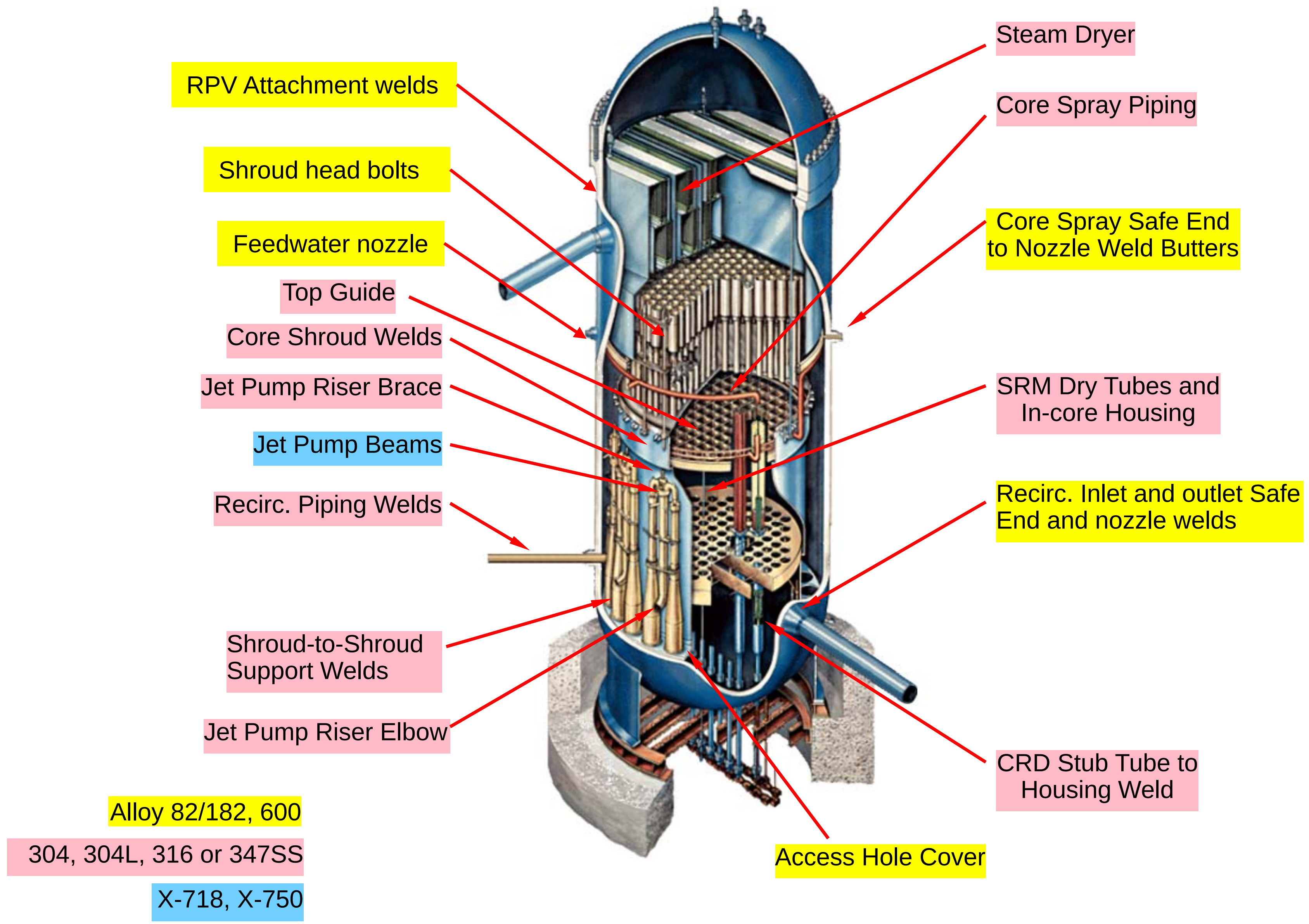
– CRDM penetration and head wastage

South Texas Project

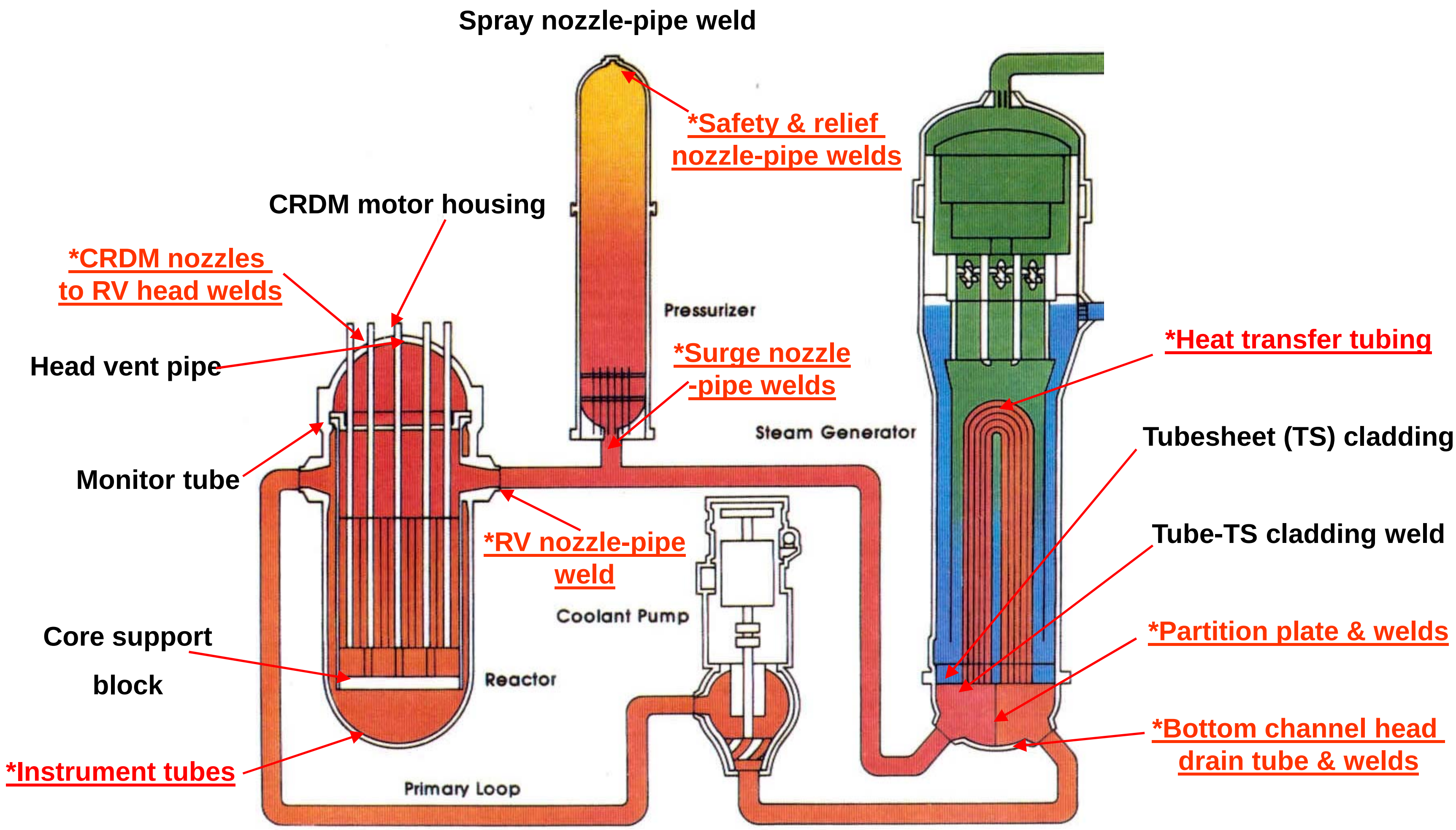
- April 2003
  – Bottom mounted instrument penetrations



BWR Affected Components



PWR PWSCC Potential Impact



* Represents locations that have experienced cracking and or leakage are highlighted in red.

Impact of Unexpected Operating Experience (OE)

- Unanticipated Impacts
  – Events costly and impact reliability, safety, and performance
    - Davis-Besse – more than $500M
    - Unplanned head replacement ~ $60M to $100M and up
    - Unanticipated RPV penetration repairs ~$65M
    - Lost generation ~$1 million/day replacement power
    - Increased dose exposure
  – Increased regulatory involvement and oversight
  – Quality of life of utility work force
- Something had to be done

The issues and expectation

- What will fail next?
- When will it fail?
- Are replacement materials susceptible?

Industry must anticipate and stay ahead of these problems

1st Step - Self-Assessment

- In August 2002 NEI Executive Committee directed industry to:
  - Get in front of material issues
  - Perform assessment of materials programs to identify strengths, weaknesses, and make recommendations
  - Scope
    - Primary pressure boundary components in BWRs and PWRs
    - Material issues related to nuclear fuels
    - NDE
    - Chemistry/corrosion control programs
- A Materials Assessment Working Group (MAWG) was formed with representatives from all industry groups dealing with materials issues

MAWG Issue Statement

The corrosion of the base metal in the Davis-Besse reactor pressure vessel head, increased occurrences of control rod drive mechanism nozzle cracking in pressurized water reactors (PWRs), and the V. C. Summer hot leg dissimilar metal weld defect represent issues that have threatened nuclear plant asset value and raised questions regarding the ability of the industry to detect degraded conditions in reactor coolant system components and piping. Other plant events over the last three years involving steam generator tubes, boiling water reactor (BWR) vessel internals and other pressure boundary, vessel internals, and fuel materials suggest that the nuclear industry has not been able to consistently anticipate and manage materials problems as well as it could. These events also suggest the need for better integration of existing PWR and BWR materials programs, as well as underlying technical support programs in the areas of plant chemistry, NDE, cracking/corrosion research, etc. Lessons from programs that are working well need to be transferred. Finally, the industry must continue to monitor and manage the impacts of materials issues prevention and mitigation strategies on fuel reliability and performance.

Key Conclusions from MAWG Assessment

- Industry lacked a unified strategic focus and direction
- Limited coordination of industry efforts on materials issues
- Budget and funding challenges
- Unable to enforce and to verify implementation of industry guidance
- Oversight of industry materials efforts was inconsistent
- Industry participation in materials issue programs lacking
- Implementation of materials tools inconsistent

- <u>Recommendation</u>: Define an NSIAC Initiative to address materials aging management

What is a NSIAC Initiative?

- Formal agreement among the utility Chief Nuclear Officers (CNOs) that form the Nuclear Strategic Issues Advisory Committee (NSIAC) to follow a defined policy
- Requires 80% vote of the NSIAC for approval
- Binding industry commitment at CNO level for full implementation
  - Not a formal regulatory commitment
  - Provides regulatory credibility
  - Deviation process involves an informal regulatory commitment

Industry Materials Initiative

- Unanimous NSIAC approval May 2003
- Initiative provides for:
  - Two oversight groups for materials issues
    - MEOG – Materials Executive Oversight Group
    - MTAG – Materials Technical Advisory Group
  - Proactive management of materials aging
  - Integration and coordination of industry work on materials issues
  - Funding provision for high priority, emergent and long term issues
  - Consistent and timely implementation of guidelines
  - Oversight of industry material activities
  - Treated as if it were a regulatory commitment

NEI 03-08 – Guideline for the Management of Materials Issues

- Documents the Materials Initiative
- Defines scope of the Initiative
- Establishes policy
- Identifies Issue Programs within scope
- Defines roles, and responsibilities
  - MTAG and MEOG
  - Issue Programs (IPs)
  - Utilities
- Current version is Revision 2, effective January 1, 2010

- Note: Initial version of NEI 03-08 had 10 strategic elements for IPs. It recommended the BWRVIP as the program be used as a model for 8 of the 10 elements

Materials Initiative

- The objective of this Initiative is to assure safe, reliable and efficient operation of the U.S. nuclear power plants in the management of materials issues.
- Each licensee will endorse, support and meet the intent of NEI 03-08, Guideline for the Management of Materials Issues. This initiative is effective January 2, 2004.
- The purpose of this Initiative is to:
  - provide a consistent management process
  - provide for prioritization of materials issues
  - provide for proactive approaches
  - provide for integrated and coordinated approaches to materials issues
- Utility actions required by this Initiative include:
  - commitment of executive leadership and technical personnel
  - commitment of funds for materials issues within the scope of this Initiative
  - commitment to implement applicable guidance documents
  - provide for oversight of implementation

Materials Management Policy

- Initiative Policy Statement
  - "… the industry will ensure that its management of materials degradation and aging is ***forward-looking and coordinated*** to the maximum extent practical. Additionally, the industry will ***continue to*** rapidly identify, react and ***effectively respond to emerging issues***. The associated work will be managed to emphasize safety and operational risk significance as the first priority, appropriately balancing long term aging management and cost as additional considerations. To that end, as issues are identified and as work is planned, the groups involved in funding, managing and providing program oversight will ensure that the ***safety and operational risk significance of each issue is fully established prior to final disposition***."

NEI 03-08 Scope and Issue Programs

- Scope
  - Reactor internals
  - Primary system pressure boundary components
  - Related NDE, chemistry and corrosion controls
  - Other as directed by NSIAC
- Issue Programs (IPs)
  - EPRI
    - BWRVIP
    - Materials Reliability Project (MRP)
    - Steam Generator Management Program (SGMP)
    - Nondestructive Examination (NDE)
    - Primary Systems Corrosion Research (PSCR)
    - Water Chemistry Control (WCC)
  - PWR Owners Group Materials Subcommittee (MSC)

NEI 03-08 Expectations for Owners

- Utility responsibilities (shall)
  - Maintain a RCS Materials Degradation Management Program
  - Implement "Mandatory" and "Needed" IP guidance (see next slide)
  - Participate in IPs
  - Apply appropriate focus on materials issues
  - Communicate materials OE

NEI 03-08 Implementation Requirements

- NEI 03-08 guidance is classified as follows:
  - "Mandatory" - to be implemented at all plants where applicable
  - "Needed" – to be implemented whenever possible, but alternative approaches are acceptable
  - "Good Practice" – implementation is expected to provide significant operational and reliability benefits, but the extent of use is at the discretion of the individual plant or utility
- In practice, "Mandatory" and "Needed" guidance is <u>required</u> unless a formal deviation disposition is processed (similar to a ASME Code Relief Request). The only difference for a deviation from "Mandatory" guidance versus one from "Needed" guidance is that deviating from "Mandatory" guidance requires independent 3rd party approval.
- Guidelines typically include an "Implementation" paragraph and/or the transmittal letters outline the NEI 03-08 implementation requirements of the report.

NEI 03-08 Expectations for Issue Programs

- Materials IP responsibilities
  - Identifying, prioritizing, and resolving issues
  - Communicating
  - Managing regulatory interface
  - Developing guidance
  - Reviewing deviations
  - Self assessments and performance metrics
  - Process for addressing emergent materials issues

Implementation Issues

Questions Affecting Industry Implementation 2003

- What groups are involved?
- What should we do?
- What do we know?
- What are the threats?
- How do we rank issues?
- Who should do the work?
- How much will we spend and on what will we spend it?
- How do we monitor progress?

Integrated Materials Issues Strategic Plan

- Provides **Systematic Approach to Managing Materials Issues**
  - Identify vulnerabilities
  - Assess condition (inspect & evaluate)
  - Mitigate degradation initiation and propagation mechanism
  - Repair or replace as required
- **Approach Used:**
  - **Degradation Matrix and Issue Management Tables**
    - Degradation Matrix and Issues Management Tables to be maintained as living documents

Industry Materials Degradation and Issue Management Table Approach

MDM

- Develop a fundamental understanding of the degradation phenomena/mechanisms

IMTs

- Perform operability and safety assessments
- Develop Inspection and evaluation guideline
- Evaluate available mitigation options
- Develop repair & replace options
- Monitor and assess plant operation experience
- Obtain regulatory acceptance

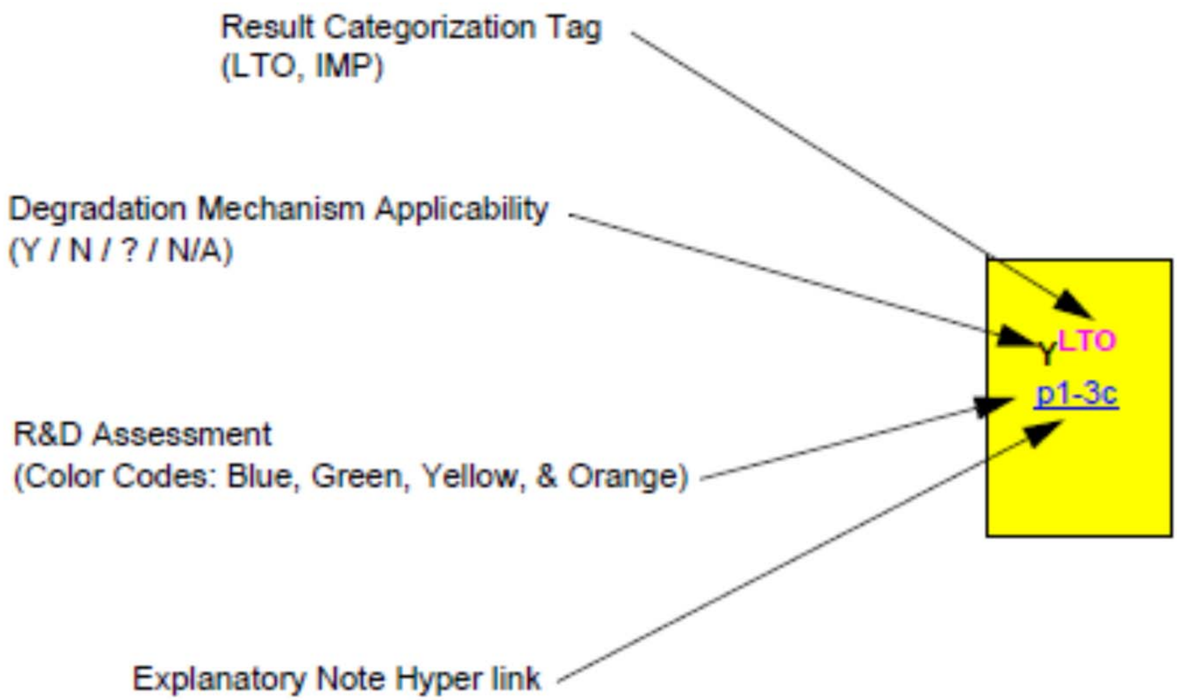
Materials Degradation Matrix (MDM) and Issue Management Tables (IMT) are effective materials aging management tools in support of industry's Materials Degradation and Issue Management Initiative

The Materials Degradation Matrix

Materials Degradation Matrix (MDM)

- MDM provides a comprehensive listing of potential degradation mechanisms for existing LWR primary system components
- Assesses the extent to which applicable degradation mechanisms are understood
- Evaluates the state of industry knowledge worldwide associated with mitigation of applicable degradation mechanisms
- Documents the results of an expert elicitation process
- Proactively identifies potential challenges to avoid surprises
- Identified Strategic Long Term Operation (LTO) Issues in Materials Degradation
- Current Revision 3, 2013 (EPRI document **3002000628**)

Color Chart Presentation of MDM Results



Blue	lack of data to establish degradation applicability
Green	well characterized, little or no additional research is needed
Yellow	ongoing R&D efforts to resolve uncertainties in near-term time frame
Orange	insufficient R&D to resolve uncertainties in a near-term time frame

MDM Results – BWR Pressure Boundary

Table 4-1: BWR Primary Pressure Boundary

MATERIAL	DEGRADATION MODE													
	Corrosion				Wear	SCC		Fatigue		Reduction in Fract Properties		Irradiation Effects		
	Wstg	Pitting	FAC	Foul	Wear	IG/TG	IA	HC	EAF	Th	Env	Emb	VS	IC / SR
C&LAS: Base Metal & HAZ	N	N	Y b1-3a	N	N	Y b1-6a	?[LTO] b1-7a	Y[IMP] b1-8a	Y[LTO] b1-9a	N	Y b1-11a	Y[LTO] b1-12a	N/A	N
C&LAS: Welds	N	N	Y b1-3b	N	N	Y b1-6b	?[LTO] b1-7b	Y[IMP] b1-8b	Y[LTO] b1-9b	N	Y b1-11b	Y[LTO] b1-12b	N/A	N
SS: 300 Series SS Base Metal & HAZ	N	N	N	N	N	Y b1-6c	N	Y[IMP] b1-8c	Y[LTO] b1-9c	N	Y b1-11c	N	N/A	N
SS: 300 Series Welds & Clad	N	N	N	N	N	Y b1-6d	N	Y[IMP] b1-8d	Y[LTO] b1-9d	Y b1-10d	Y b1-11d	Y b1-12d	N/A	N
Cast Austenitic Stainless Steel	N	N	N	N	N	Y b1-6e	N	N	Y[LTO] b1-9e	Y b1-10e	Y b1-11e	N	N/A	N
Ni-Alloy: A600 Base Metal & HAZ	N	N	N	N	N	Y[LTO] b1-6f	N	N	Y[LTO] b1-9f	N	Y b1-11f	N	N/A	N
Ni-Alloy: A182 Welds & Clad	N	N	N	N	N	Y[LTO] b1-6g	N	N	Y[LTO] b1-9g	N	Y b1-11g	N	N/A	N
Ni-Alloy: A82 Welds & Clad	N	N	N	N	N	Y[LTO] b1-6h	N	N	Y[LTO] b1-9h	N	Y b1-11h	N	N/A	N
Ni-Alloy: A52/152 Welds & Clad	N	N	N	N	N	N	N	N	Y[LTO] b1-9i	N	Y b1-11i	N	N/A	N

MDM Results---- BWR Reactor Internals

Table 4-2: BWR Reactor Vessel Internals

MATERIAL	DEGRADATION MODE													
	Corrosion				Wear	SCC		Fatigue		Reduction in Fract Properties		Irradiation Effects		
	Wstg	Pitting	FAC	Foul	Wear	IG/TG	IA	HC	EAF	Th	Env	Emb	VS	IC / SR
STRUCTURAL COMPONENTS & WELDS														
SS: 300 Series Base Metal & HAZ	N	N	N	Y b2-4a	Y [IMP] b2-5a	Y b2-6a	Y [LTO] b2-7a	Y [IMP] b2-8a	Y [LTO] b2-9a	N	Y b2-11a	Y b2-12a	N	Y b2-14a
SS: Welds & Clad	N	N	N	Y b2-4b	Y [IMP] b2-5b	Y b2-6b	Y [LTO] b2-7b	Y [IMP] b2-8b	Y [LTO] b2-9b	Y b2-10b	Y b2-11b	Y b2-12b	N	Y b2-14b
Cast Austenitic Stainless Steel	N	N	N	N	N	Y b2-6c	Y [LTO] b2-7c	Y [IMP] b2-8c	Y [LTO] b2-9c	Y [IMP] b2-10c	Y b2-11c	Y [LTO] b2-12c	N	N
Ni-Alloy: A600 Base Metal & HAZ	N	N	N	N	N	Y [LTO] b2-6d	N	Y [IMP] b2-8d	Y [LTO] b2-9d	N	Y b2-11d	N	N	N
Ni-Alloy: A182 Welds & Clad	N	N	N	N	N	Y [LTO] b2-6e	N [LTO] b2-7e	Y [IMP] b2-8e	Y [LTO] b2-9e	N	Y b2-11e	N	N	N
Ni-Alloy: A82 Welds & Clad	N	N	N	N	N	Y [LTO] b2-6f	N [LTO] b2-7f	Y [IMP] b2-8f	Y [LTO] b2-9f	N	Y b2-11f	N	N	N
FASTENERS & HARDWARE														
SS: 300 Series	N	N	N	N	N	Y b2-6g	Y b2-7g	Y [IMP] b2-8g	Y [LTO] b2-9g	N	Y b2-11g	Y b2-12g	N	Y [IMP] b2-14g
SS: XM-19	N	N	N	N	N	Y b2-6h	Y [LTO] b2-7h	Y [IMP] b2-8h	Y [LTO] b2-9h	N	Y b2-11h	Y [LTO] b2-12h	N	Y [LTO] b2-14h
Ni-Alloy: X-750	N	N	N	N	N	Y b2-6i	Y [LTO] b2-7i	Y [IMP] b2-8i	Y [LTO] b2-9i	N	Y b2-11i	Y [LTO] b2-12i	N	Y [LTO] b2-14i

MDM Results – PWR Pressure Boundary

Table 3-1: PWR Primary Pressure Boundary (1)

	DEGRADATION MODE													
	Corrosion				Wear	SCC		Fatigue		Reduction in Fract Properties		Irradiation Effects		
MATERIAL	Wstg.	Pitting	FAC	Foul	Wear	IG/TG	IA	HC	EAF	Th	Env	Emb	VS	IC / SR
C&LAS: Base Metal & HAZ	Y p1-1a	N	N	N	N	Y p1-6a	? p1-7a	N	Y^{LTO} p1-9a	? p1-10a	Y p1-11a	Y^{LTO} p1-12a	N	N
C&LAS: Welds	Y p1-1b	N	N	N	N	Y p1-6b	? p1-7b	N	Y^{LTO} p1-9b	? p1-10b	Y p1-11b	Y^{LTO} p1-12b	N	N
SS: 300 Series SS Base Metal & HAZ	N	Y p1-2c	N	N	N	Y p1-6c	N	Y^{IMP} p1-8c	Y^{LTO} p1-9c	N	Y p1-11c	N	N	N
SS: 300 Series SS Welds & Clad	N	Y p1-2d	N	N	N	Y p1-6d	N	Y^{IMP} p1-8d	Y^{LTO} p1-9d	Y p1-10d	Y p1-11d	Y p1-12d	N	N
Cast Austenitic Stainless Steel	N	N	N	N	N	Y p1-6e	N	Y^{IMP} p1-8e	Y^{LTO} p1-9e	Y^{LTO} p1-10e	Y p1-11e	N	N	N
Ni-Alloy: A600 Base Metal & HAZ	N	N	N	N	N	Y^{LTO} p1-6f	N	N	Y^{LTO} p1-9f	N	Y p1-11f	N	N	N
Ni-Alloy: A690 Base Metal & HAZ	N	N	N	N	N	Y p1-6g	N	N	Y^{LTO} p1-9g	Y p1-10g	Y p1-11g	N	N	N
Ni-Alloy: A82/182 Welds & Clad	N	N	N	N	N	Y^{LTO} p1-6h	N	N	Y^{LTO} p1-9h	N	Y p1-11h	N	N	N
Ni-Alloy: A52/152 Welds & Clad	N	N	N	N	N	Y p1-6i	N	N	Y^{LTO} p1-9i	Y p1-10i	Y p1-11i	N	N	N

(1) The scope of Table 3-1 includes the reactor vessel, pressurizer, steam generator channel head, tubesheet surfaces exposed to primary water, divider plate, and the primary piping system.

MDM Results – PWR Reactor Internals

Table 3-2: PWR Reactor Vessel Internals

MATERIAL	DEGRADATION MODE													
	Corrosion				Wear	SCC		Fatigue		Reduction in Fract Properties		Irradiation Effects		
	Wstg	Pitting	FAC	Foul	Wear	IG/TG	IA	HC	EAF	Th	Env	Emb	VS	IC / SR
STRUCTURAL COMPONENTS & WELDS														
SS: 300 Series Base Metal & HAZ	N	N	N	N	Y[IMP] p2-5a	Y p2-6a	Y[LTO] p2-7a	Y p2-8a	Y[LTO] p2-9a	N	Y p2-11a	Y p2-12a	Y[LTO] p2-13a	Y p2-14a
SS: 300 Series Welds & Clad	N	N	N	N	N	Y p2-6b	Y[LTO] p2-7b	Y p2-8b	Y[LTO] p2-9b	Y p2-10b	Y p2-11b	Y p2-12b	Y[LTO] p2-13b	Y p2-14b
Cast Austenitic Stainless Steel	N	N	N	N	N	Y p2-6c	?[LTO] p2-7c	Y p2-8c	Y[LTO] p2-9c	Y p2-10c	Y p2-11c	Y[LTO] p2-12c	N	N
Ni-Alloy: A600 Base Metal	N	N	N	N	Y[IMP] p2-5d	Y[LTO] p2-6d	N	Y p2-8d	Y[LTO] p2-9d	N	Y p2-11d	N	N	N
FASTENERS & HARDWARE														
SS: 300 Series (304, 347, 316CW)	N	N	N	N	N	Y p2-6e	Y[LTO] p2-7e	Y p2-8e	Y[LTO] p2-9e	N	Y p2-11e	Y p2-12e	Y[LTO] p2-13e	Y[LTO] p2-14e
SS: A-286 Precip. Hardened SS	N	N	N	N	Y p2-5f	Y p2-6f	Y[LTO] p2-7f	Y p2-8f	Y[LTO] p2-9f	N	Y p2-11f	Y[LTO] p2-12f	N	Y[LTO] p2-14f
SS: Martensitic (Tp. 403, 410, 431, 17-4PH, 15-5PH)	N	N	N	N	Y p2-5g	Y p2-6g	N	Y p2-8g	Y[LTO] p2-9g	Y p2-10g	Y p2-11g	N	N	N
Ni-Alloy: X-750	N	N	N	N	Y p2-5h	Y p2-6h	Y[LTO] p2-7h	Y p2-8h	Y[LTO] p2-9h	N	Y p2-11h	Y[LTO] p2-12h	N	N

MDM Results - Steam Generator Tubes

Table 3-3: PWR Steam Generator Tubing, Tube Plugs & Tubesheet Welds

MATERIAL	DEGRADATION MODE										
	Corrosion				Wear	SCC		Fatigue		Reduction in Fract Properties	
	Wstg	Pitting	FAC	Foul	Wear	OD	ID	HC	EAF	Th	Env
TUBES											
Ni-Alloy: 600TT	Y p3-1a	N	N	Y p3-4a	Y p3-5a	Y LTO p3-6a	Y LTO p3-7a	Y p3-8a	Y p3-9a	N	N p3-11a
Ni-Alloy: 690TT	Y p3-1b	N	N	Y p3-4b	Y p3-5b	Y p3-6b	N	Y p3-8b	Y p3-9b	Y p3-10b	Y p3-11b
SS: Alloy 800	Y p3-1c	Y p3-2a	N	Y p3-4c	Y p3-5c	Y p3-6c	N	Y p3-8c	Y p3-9c	N	N
TUBE PLUGS & TUBESHEET WELDS											
Ni-Alloy: Tube Plugs	N	N	N	N	N	N	Y p3-7d	N	Y p3-9d	N	Y p3-11d
Ni-Alloy: Alloy 52 / 82 Welds	N	N	N	N	N	N	Y p3-7e	N	Y p3-9e	N	Y p3-11e

The Issue Management Tables

Example IMT – BWR Reactor Pressure Vessel

Table A-1 Reactor Pressure Vessel (Continued)

Components & ID No.	Material	Degradation Mechanisms	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
1.3-5 Feedwater Nozzle Safe Ends	Ni-Alloy *(Some safe ends - A600 with A82/ A182 welds)*	SCC: IG/TG Fat: LC-Env BiFP: Env Ext: Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225 **HWC Technology** BWRVIP-62R1 BWRVIP-156 BWRVIP-159 BWRVIP-219 BWRVIP-245 BWRVIP-248 **Oper. Changes** GE-NE-523-A71-0594 *(Low Flow Controller Oper.)* **Stress Improvement** BWRVIP-61 *(Weld Overlay, IHSI, MSIP)*	**ASME Sect. XI** IWA-4000 **Weld Overlay** CC-N-504-2 *(Vendor Controlled)*	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A)* **IGSCC** Generic Letter 88-01 BWRVIP-75-A BWRVIP-222 **LC-Env Fatigue** 1022873 *Break Loc. Postulation* 1022876 *Stress-Based Mon.* 1024995 *EAF Screening* 1025823 *EAF Calc Guidance* NUREG-1801-X.M1 NUREG-6260 NUREG-6909 **HC Thermal Fatigue** NUREG-0619 GE-NE-523-A71-0594	B-DM-03 B-DM-06 B-DM-09 B-AS-07 B-AS-27
1.3-6 Core Spray Nozzles	C&LAS *(SA-508, Cl 2)*	SCC: IG/TG Fat: LC-Env BiFP: Env Ext: Pitting	A	**Water Chemistry** BWRVIP-190 BWRVIP-225	**ASME Sect. XI** IWA-4000	**ASME Sect. XI** IWB-2500-1 *(BWRVIP-74-A)* **LC-Env Fatigue** 1022873 *Break Loc. Postulation* 1022876 *Stress-Based Mon.* 1024995 *EAF Screening* 1025823 *EAF Calc Guidance* NUREG-1801-X.M1 NUREG-6260 NUREG-6909	B-DM-06 B-DM-07 B-AS-07

Example Gap Description – BWR

B-DM-06 - Environmental Effects on Fracture Resistance **Issue:** Recent testing indicates that primary systems materials can have lower fracture resistance (J-R tearing resistance) when tested in coolant than when tested in air. Although there is an increasing body of data that can be used to quantify the effect, the factors influencing this phenomenon and the potential operational significance of this effect for BWR primary systems materials remain incompletely understood. **Description:** Although there is consensus that the observed effect is a hydrogen-induced phenomenon, there are insufficient data to quantitatively predict the effects for all of the relevant materials and service conditions. Hydrogen fugacity in the environment, the diffusivity of hydrogen within the metal, and the interaction of hydrogen with other parameters (e.g., temperature and mechanical loading rate) all remain poorly understood. Since any effect of hydrogen will increase with increasing yield strength, a more significant effect likely exists for irradiated materials and higher strength materials (e.g. cold-worked or precipitation hardened stainless steels). Synergisms with SCC, and corrosion fatigue must also be considered. Until an improved understanding of this phenomenon is achieved, this gap is applied to all IMT component line items associated with these materials and environmental conditions. Closure of this gap involves further characterization of this environmental fracture issue to fully disposition this effect as non-relevant or to fully evaluate any consequences on reactor operation. [*NOTE: With regard to observations of rapid fracture occurring under rising K conditions, similar testing in air concluded that plastic instability resulting from mechanical overload conditions was the primary factor in the observations. No evidence of an effect of environmental was observed. This new data eliminates "rapid fracture" as a significant concern and reduces the overall level of concern associated with this gap.*] **References:** MDM (Notes b1-11a-i and Appendix A Section 6.2) MRP-209, 1020957, MRP-293	**Priority:** R3(2013) Medium R2(2010): High R1(2008): Medium **Status:** Open **Responsibility:** BWRVIP: Assessment Other: PSCR Program **LTO Impact:** None

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Example IMT – PWR Reactor Pressure Vessel

Table A-1 Reactor Pressure Vessel (Continued)

Component & ID No.	Material	Degradation Mechanism	Conseq. of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps
1.2-2 Outlet Nozzles	LAS-SS Clad *(SA-336 or A/SA-508 Cl 2 or 3)*	Fat: LC-Env RiFP: Th, Env IE: Emb Ext: Wstg Pitting	B, E, G	**Water Chemistry - Primary** EPRI 1014986	**ASME Sect. XI** IWA-4000	**Inservice Inspection** 10 CFR 50.55a ASME Sect XI, IWB-2500-1 WCAP-16168-NP-A **Boric Acid Corrosion Cont.** WCAP-15988-NP *BAC Prog.* NRC GL 88-05 **LC-Env Fatigue** MRP-148R1 *Fatigue Management* MRP-149 *Lic. Basis Mon.* MRP-47 *Fatigue Env. Effects* 1022873 *Break Loc. Postulation* 1022876 *Stress-Based Mon.* NUREG-1801, X.M1 *Fat. Mon.* NUREG/CR-6260 NUREG/CR-6909	P-DM-09 P-DM-10 P-AS-02 P-AS-28

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Example Gap Description - PWR

Table 3-3 Assessment Gaps (Continued)

R&D Gap Description	Results Data
P-AS-28 - Neutron Embrittlement of Nozzle Forgings and Upper Shell Course **Issue:** Some RPV upper shell course plates, nozzle forgings, and associated weld materials will become limiting during initial license renewal periods. The number of limiting "extended beltline" welds and forging will likely increase when considering LTO. **Description:** Implementation of material chemistry controls on base metal and weld impurity content (primarily Copper) results in smaller reductions in fracture toughness for these materials than for materials with uncontrolled material chemistries. Additionally, NRC now interprets any component subject to fluence exceeding 10^{17} n/cm^2 (E > 1 MeV) to be subject to reactor integrity regulations, effective "extending" the beltline. Plates and nozzle forgings located outside of the traditional beltline region exposed to neutron fluence in excess of 10^{17} n/cm^2 (E > 1 MeV) can quickly become limiting because chemistry was not controlled. Additionally, in many cases copper content was not reported in the CMTRs and must be assumed to be at the upper allowable limit per the material specification. The effects of this are exacerbated by the fact that some forgings do not have reported values of Initial RT_{NDT}, which in turn requires an often-conservative bounding assumption to be made. Thus, a high assumed Initial RT_{NDT} plus a significant irradiated shift (because of assumed upper limit copper) can result in these "extended beltline" materials becoming the limiting vessel materials for plant pressure-temperature curves once higher fluences are reached. In addressing a similar issue, the BWRVIP determined that while there are specified limits on the range of nickel, manganese, and sulfur, there were no controls on copper content in nozzle forgings. In fact, most foundries did not measure copper in the ladle or in the check analysis. As a result, limited data are available for copper content in SA508-2 forgings. The BWRVIP work goes on to identify "best estimate" values for copper, nickel, manganese, and phosphorus for use in lieu of "worst case" values. Resolution of this gap involves similar investigation for PWR vessels to address both 60-year and 80-year operation. Although the effort may not necessarily be limited to statistical evaluation, as was the case for BWRVIP. **References:** Vogtle Electric Generating Plant License Renewal Application (Section 4.2) BWRVIP-173-A	**Status:** Open **Priority:** R3 (2013): High R2 (2010): Medium R1 (2008): Medium **Responsibility:** MRP PWROG **LTO Impact:** Direct

Available at http://epri.com

- EPRI Materials Degradation Matrix, Revision 3 (EPRI Report 3002000628)

- BWR and PWR Issue Management Tables have been updated to reflect MDM extension to 80 years
  - BWR-167NP, Rev. 3 (EPRI Report 3002000690)
  - MRP-205, Rev. 2 (EPRI Report # 1021024)

Current Status

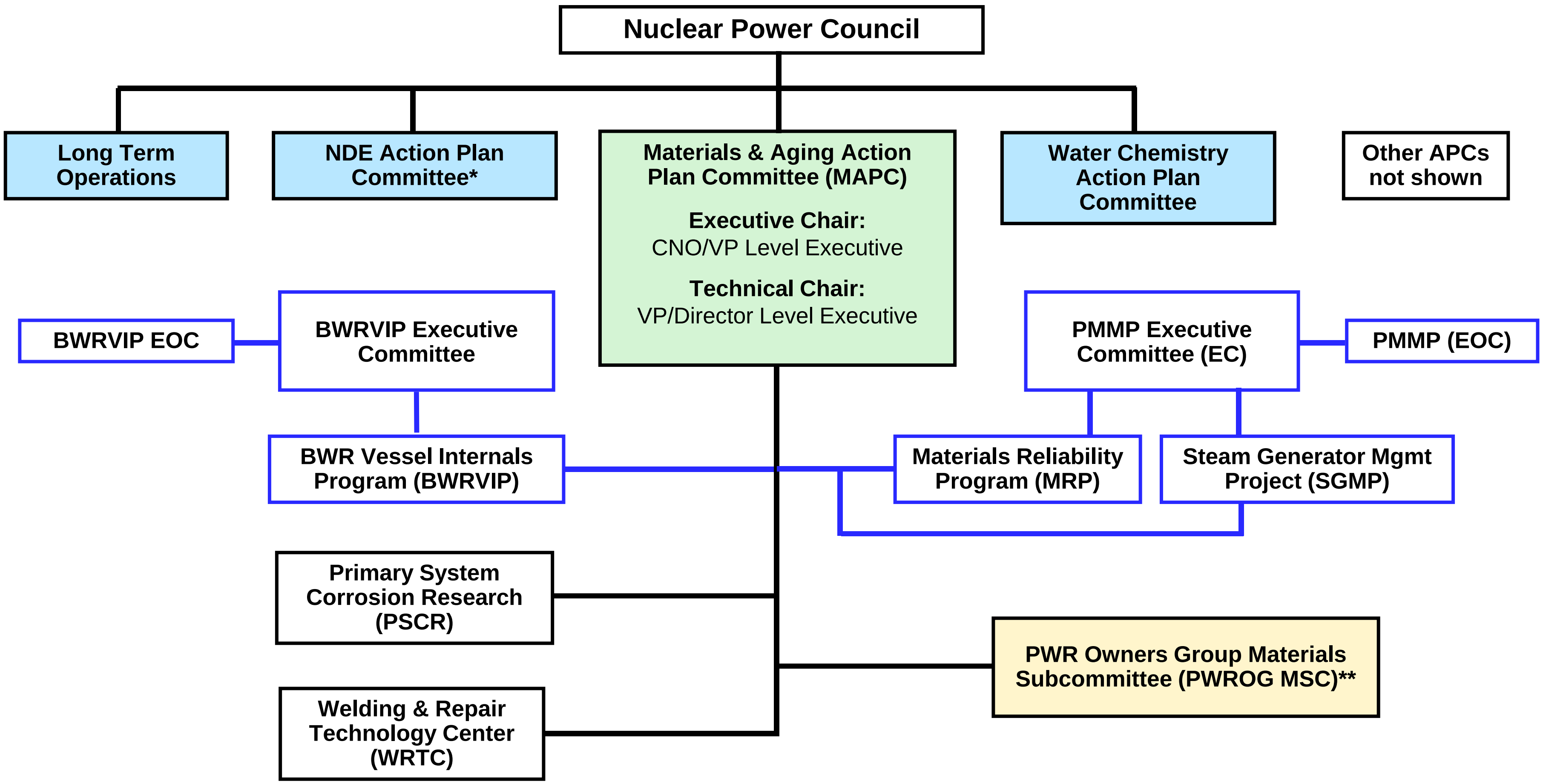
2008 Assessment

- Industry performed an assessment of NEI 03-08 effectiveness
- Key conclusions:
  - Overall success in achieving the Initiative’s objectives
  - Broad commitment to the Policy and desired behavior is being obtained
  - Overall guidance is being implemented and programs are being supported
  - Continue management attention to the use of deviations
  - Highest priority issues being addressed by IPs, but improvements could be obtained by prioritizing across IP boundaries
  - Roles of MEOG, MTAG, and APWGs should be revisited

2008 Assessment Impact

- MEOG and MTAG will be sunset
- EPRI Materials Action Plan Committee (MAPC) to provide strategic direction for materials issues including:
  - EPRI materials IPs: BWRVIP, MRP, SGMP, PSCR, WCC, NDE
  - PWROG MSC
- NDE APC would be separate but coordinate with MAPC
- BWRVIP and PWR executive committees report to MAPC for strategic coordination
- MAPC members to include:
  - CNO as chair to coordinate with NSIAC
  - Executive and Technical chairs of the IPs
  - At-large members for fleet representation
  - INPO and NEI representatives
- Implement January 1, 2010

Materials Organizational Structure



**NDE APC coordinates with Materials APC and PWR Owners Group*
***Materials Subcommittee has a representative on Materials APC*

Initiative Accomplishments

- Integrated industry strategic plan for materials
- Achieved a high level of industry integration, coordination, alignment, and communication on material issues
- Established a process for prioritizing projects, budgets, and planning
- Predictable funding for materials R&D
- Engaged INPO as an active participant
- Defined expectations and protocols for industry actions upon discovery of an emergent issue
- Established consistent process for deviations and communication with NRC
- Executive level interactions between industry and senior NRC management
- Successful at closing materials issues and gaps
- Fewer unexpected materials related transients

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