COMMISSION BRIEFING SLIDES/EXHIBITS

BRIEFING ON PLANT AGING

AND MATERIALS DEGRADATION

NOVEMBER 8, 2004

Management Of Materials Issues

Chris Crane

President & Chief Nuclear Officer, Exelon Nuclear

NEI

Materials Initiative

- Coordinates over $59.5M in industry sponsored materials research & development
- Prioritization, management and resolution of current and future issues
- Accountability to assure plant safety and reliability

NEI

Management of Materials Issues

- Background
- Industry Initiative
- Strategic Plan
- Deliverables
- Accomplishments
- Expectations
- Regulatory Process

NEI

Background

- NEI Executive Committee Resolution
  - Fully support industrywide effort to improve management of materials issue
- Self-Assessment of Materials Programs
  - Driven by recent plant events
  - Develop a more proactive process

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Backround

- **Self-Assessment**
  - **Identify barriers or gaps in current materials programs**
  - **Integrate industry programs**
    - **SG Management (SGMP)**
    - **PWR Materials Reliability (MRP)**
    - **BWR Vessel & Internals (BWR VIP)**
    - **Fuel Reliability Program (FRP)**
    - **Chemistry, Corrosion and NDE**
    - **NSSS Owners Groups**

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Background

- **Self-Assessment Conclusions**
  - **Limited coordination of industry efforts on materials issues**
  - **Limited ability to enforce implementation of industry guidance**
  - **No verification of implementation**
  - **Inadequate participation and support of Issue Programs (IP)**
  - **NSIAC Initiative warranted**

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Background

- Self-Assessment Recommendations
  - Create executive-level and technical oversight groups
  - Establish policy on the management of materials issues
  - Use the NEI Initiative Process
  - Expand INPO's role
  - Enhance communications
  - Define regulatory interface

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Materials Initiative

- The objective is to assure safe, reliable and efficient operation of 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 was effective January 2, 2004.

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Materials Initiative

- Purpose is to provide
  - Consistent management process
  - Prioritization of materials issues
  - Proactive, integrated and coordinated approaches
  - Oversight of implementation

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Materials Initiative

- Required actions
  - Commitment of Executive leadership and technical personnel
  - Commitment of funds for materials issues within scope
  - Commitment to implement applicable guidance documents

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Materials Initiative

- Approved by NSIAC in May 2003
- Each licensee will meet the intent of NEI 03-08, Guideline for the Management of Materials Issues
- Initiative effective January 2, 2004
  - Includes $12M for 2004-2005 to fund high priority materials issues in addition to the $47.5M currently budgeted by Issue Programs for 2005

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NEI 03-08 Guideline

- Establishes two standing committees
  - Executive Oversight
  - Technical Advisory
- Establishes policy
- Defines roles, responsibilities and expectations
- Provides for an integrated approach

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Policy Commitment

- **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***."

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Materials Issue Programs Governed by the Initiative

- **EPRI**
  - **BWRVIP**
  - **MRP**
  - **SGMP**
  - **Fuel Reliability Program (as impacted by materials management strategies)**
  - **Corrosion Research**
  - **Chemistry Control**
  - **NDE**

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Materials Issue Programs Governed by the Initiative

- NSSS Owners Group Subcommittees
  - Materials
  - Chemistry
  - RPV
  - NDE
  - Steam Generators

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Strategic Plan

- Comprehensive, integrated view of materials issues
- Framework for planning, coordinating and directing efforts
- Contains elements for an effective management program

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Strategic Plan

- Defines high priority materials issues and short and long term technical gaps
- Used as industry guidance for prioritizing materials issues
- Revision 0 Issued in March
- Revision 1 planned for Early 2005
  - Degradation Matrix and Issue Management Table

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DEGRADATION MATRIX

- Lists all materials within scope of the Materials Initiative
- Identifies potential degradation mechanisms for applicable materials
- Information obtained from materials experts, laboratory R&D, and operating experience

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Issue Management Tables

- Addresses significance of material degradation on applicable materials
- Defines where materials are used and consequences of failure
- Identifies existing programs/guidance available for effective management
  - Assessment, inspection/evaluation, mitigation, repair/replacement

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Deliverables - Implementation Protocol

- General guidance for implementation of IP work products
- Mandatory, Needed & Good Practice implementation categories defined
- Deviations from Mandatory & Needed action will be tracked in Corrective Action Program
- Executive concurrence required for
  - Mandatory & Needed elements
  - Deviations from Mandatory and Needed

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Deliverables - Emergent Issue Protocol

- Oversight and Coordination
  - MTAG phone call when emergent issue occurs
  - Lead and support roles defined and communicated
  - IP will lead technical resolution and NRC interface strategy
  - Keep MTAG informed of status and NRC interactions
  - MTAG / MEOG support if needed

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Deliverables

- SG Management
  - License Change Package
- MRP Inspection and Evaluation Guidelines
  - RPV head and bottom mounted instrument nozzles
  - Primary system butt welds
- WOG
  - Pressurizer heater sleeves
  - Boric Acid Corrosion Control Guidelines

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Deliverables

- BWR VIP
  - Steam Dryers
- Fuel Reliability
  - AOA Guideline Revision 1
- Performance Metrics
- Overall coordination with ASME

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Proposed Performance Metrics

- Unexpected materials related NRC generic correspondence
- New materials degradation operating experience
- Lost capacity or unplanned/extended outages due to materials issues
- INPO materials program related AFIs
- Corrective action program effectiveness
- Issue Program products related to Strategic Plan technical gaps

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Materials Initiative Funding

- 20 projects approved for $9.2 million
  - 7 NDE projects for $3M
  - 5 MRP projects for $2.4M
  - 3 BWRVIP projects for $1M
  - 2 Corrosion Research projects for $600K
  - 1 Fuels Reliability project for $1.2M
  - 1 SGMP project for $615K
  - 1 Chemistry Control project for $350K

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Accomplishments

- NEI Initiative
  - NEI 03-08
- Strategic Plan
- Protocols
- Funded projects

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Future Activities

- Complete the Issue Management Tables and revision 1 of the Strategic Plan
- Develop industry performance metrics and self assessment guidance
- Monthly MTAG phone calls – materials issue oversight & coordination
- Quarterly meetings with the NRC
- Complete self assessment and report results

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Expectations for Industry

- Adopt a proactive approach to materials issues
  - Communication of OE with IP / NEI
- Develop an integrated materials plan that reflects industry's Strategic Plan priorities
- Be prepared to fully implement applicable IP recommendations
- Support materials IPs and their need for technical and leadership personnel
- Support funding to address materials issues
- Self assessment of activities

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Changes to Expect

- Industry guidance from IPs will have mandatory and needed actions
- Improved communications on materials issues and related interactions with the NRC
- Improved integration/coordination among IPs
- Improved industry performance relative to materials degradation
- Successful transition to a proactive approach for materials issues

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Regulatory Process

- Implementation of mandatory and needed actions that fall within the scope of 10 CFR 50
  - Primary system components
  - Subject to NRC inspection
- Performance-based approach
- Areas of Concern
  - Unnecessary duplication
  - Diversion of resources

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Conclusion

- Actions Taken by Industry
  - Proactive, integrated and coordinated
  - Focus to assure plant safety and reliability
  - Continuous improvement and feedback

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Additional Background

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ACRONYMS

AFI – Area For Improvement
AOA – Axial Offset Anomaly
ASME - American Society of Mechanical Engineers
BWR – Boiling Water Reactor
BWR VIP – Boiling Water Reactor Vessel & Internals Program
CFR – Code of Federal Regulations
EPRI – Electric Power Research Institute
FRP – Fuel Reliability Program
INPO – Institute of Nuclear Power Operations
IP – Issue Program
NDE – Nondestructive Examination

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ACRONYMS

NEI - Nuclear Energy Institute
NSIAC – Nuclear Strategic Issues Advisory Committee
NSSS – Nuclear Steam Supply System
MEOG – Materials Executive Oversight Group
MRP - Materials Reliability Program
MTAG – Materials Technical Advisory Group
OE – Operating Experience
R&D – Research and Development
RPV - Reactor Pressure Vessel
SG – Steam Generator
SGMP – Steam Generator Management Program
WOG - Westinghouse Owners Group

NEI

Materials Executive Oversight Group (MEOG)

- Chris Crane (*Chairman*) - Exelon
- Jim Levine (*Vice-Chairman*) - APS
- Garry Randolph – AmerenUE
- Joe Sheppard – STP
- Bryce Shriver – PPL
- Art Stall – FPL
- Gary Taylor – Entergy
- David Mauldin – APS
- Rodney Webring – Energy Northwest
- Jim Klapproth - GE
- Nick Liparulo – West.
- Gary Mignogna – AREVA
- Mark Reddemann – INPO
- Dave Modeen – EPRI
- Alex Marion - NEI

NEI

Materials Technical Advisory Group (MTAG)

- Chairman – David Mauldin – APS
- Vice Chairman – Bill Eaton - Entergy
- BWRVIP/BWROG – Robin Dyle - SNOC
- MRP – Mike Robinson - Duke
- SGMP – Forrest Hundley – SNOC
- FRP – Charles Turk – Entergy
- WOG/CEOG – Greg Gerzen – Exelon
- BWOG – Dave Whitaker - Duke
- EPRI NDE – Mike Turnbow – TVA
- EPRI Chem – John Wilson – Exelon
- EPRI Corrosion – Craig Harrington – TXU
- At Large Members
  - Joe Donahue – Progress Energy
  - Dennis Weakland – FENOC
  - Bob Hardies – Constellation
  - Ralph Phelps – OPPD
- MTAG Support
  - EPRI – Chuck Welty
  - INPO – Steve Johnson
  - NEI – Jim Riley

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Degradation Matrix

-

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Issue Management Table

- Draft example of [illegible] component evaluation

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Materials Degradation Matrix

Level 1

PWR						BWR		
PWR Reactor Pressure Vessel	PWR Pressurizer	PWR SG Shell	PWR Reactor Internals	PWR Piping	PWR SG Tubes & Internals	BWR Pressure Vessel	BWR Reactor Internals	BWR Piping

Level 2

PWR Component	Material	SCC SCC					Corrosion/Wear C & W				Fatigue Fat.			Reduction in Toughness RiT					
														Aging	Irradiation				
	[1]Subdivision→	IG	IA	TG	LTCP	PW	Wstg	Pit	Wear	FAC	HC	LC/Th	Env	Th	Emb	VS	SR	Th_n	Fl
PWR Pressurizer (Including Shell, Surge and Spray Nozzles, Heater Sleeves and Sheaths, Instrument Penetrations)	C&LAS	? e002	N	? e002	N	? e003	Y e004	N	N	Y e005	N	Y e006	Y e007	Y e008	N/A	N/A	N/A	N/A	N/A
	C&LAS Welds	? e002	N	? e002	N	? e003	Y e004	N	N	Y e005	N	Y e006	Y e007	Y e008	N/A	N/A	N/A	N/A	N/A
	Wrought SS	? e012	N	? e012	? e013	? e012	N	N	N	N	N	Y e014	Y e015	N	N/A	N/A	N/A	N/A	N/A
	SS Welds & Clad	Y e016	? e017	Y e018	? e013	? e019	N	N	? e020	N	N	? e014	Y e015	Y e022	N/A	N/A	N/A	N/A	N/A
	Wrought Ni Alloys	N	N	N	? e023	Y e023	N	N	N	N	Y e014	Y e014	Y e015	N	N/A	N/A	N/A	N/A	N/A
	Ni-base Welds & Clad	N	? e024	N	Y e023	Y e025	N	N	N	N	N	Y e014	Y e015	N	N/A	N/A	N/A	N/A	N/A

Level 3

e030	Corrosion-assisted fatigue is a known phenomenon on secondary side (e.g., in the vicinity of girth welds in steam generator shells and in the region of feedwater nozzles) and is not like environmental fatigue described in other areas of this DM. Environmental fatigue research relevant to this specific phenomenon is not ongoing within MRP Fatigue ITG, and is a potential gap.

EPRI

C01

Materials Degradation Matrix

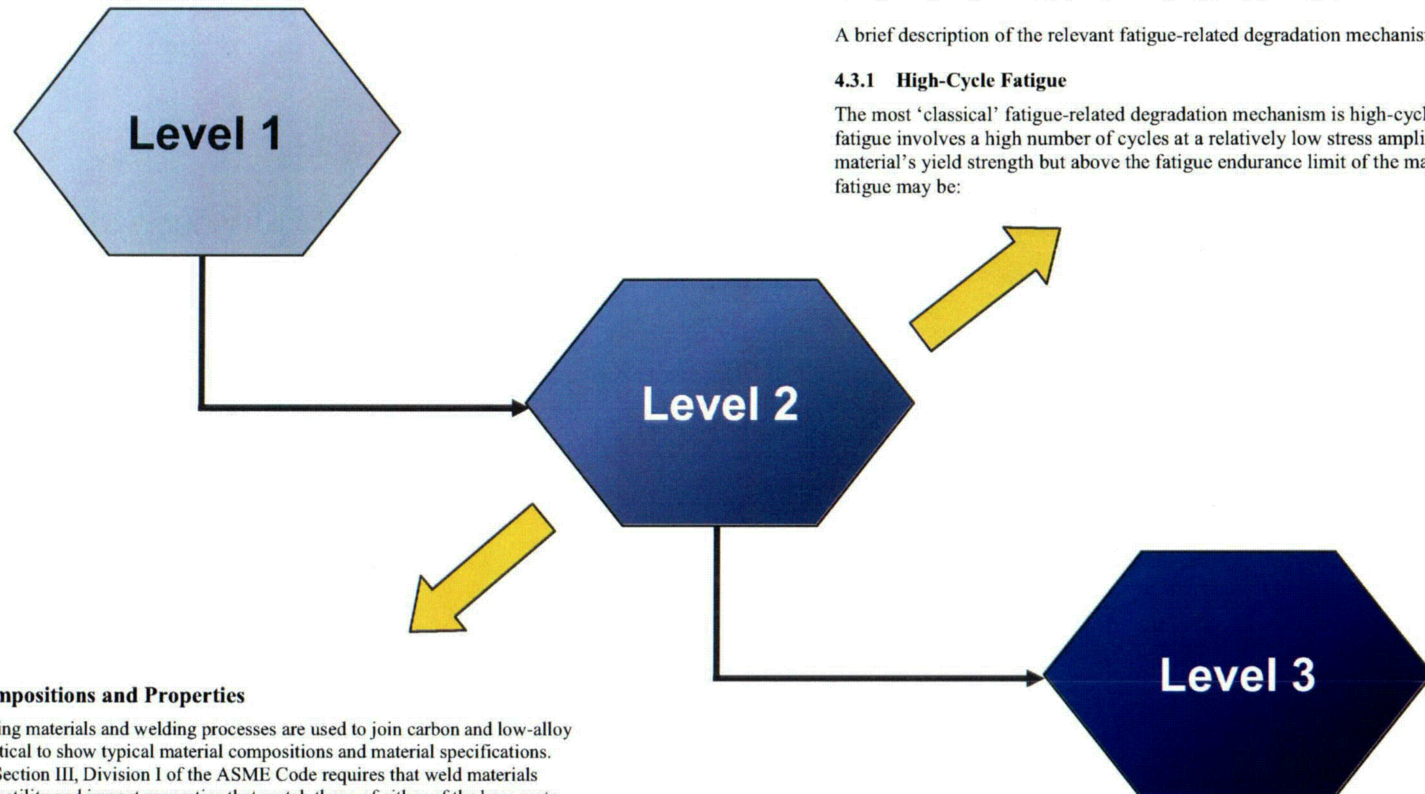
4.3 Fatigue Degradation Mechanisms and Mitigation Options

Fatigue is the structural deterioration that can occur as the result of repeated stress/strain cycles caused by fluctuating loads or temperatures. After repeated cyclic loading, if sufficient localized micro-structural damage has been accumulated, crack initiation can occur at the most highly affected locations. Subsequent cyclic loading and/or thermal stress can cause crack growth.

A brief description of the relevant fatigue-related degradation mechanisms is provided below.

4.3.1 High-Cycle Fatigue

The most 'classical' fatigue-related degradation mechanism is high-cycle (HC) fatigue. HC fatigue involves a high number of cycles at a relatively low stress amplitude (typically below the material's yield strength but above the fatigue endurance limit of the material). High cycle fatigue may be:



3.2 Material Compositions and Properties

A large variety of welding materials and welding processes are used to join carbon and low-alloy steels, and it is not practical to show typical material compositions and material specifications. Section NB-2431.1 of Section III, Division I of the ASME Code requires that weld materials have tensile strength, ductility and impact properties that match those of either of the base materials being welded, as demonstrated by tests using the selected weld material and the same or similar base materials. Section NB-2432.2 of Section III, Division I of the ASME Code requires that the chemical composition of the welding material be in accordance with an appropriate ASME Code welding specification (in Section II.C of the Code), but leaves the choice of the specific material up to the manufacturer.

The most common weld processes used to join carbon steel and LAS parts include submerged arc welding, shielded metal arc welding (SMAW), and gas tungsten arc welding (GTAW). Post-weld heat treatment is generally required per ASME Code rules after welding of the carbon and low-alloy steels used for reactor coolant system service.

EPRI

C02

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Draft BWR Issue Management Table

Equipment	Material	Failure Mechanism	Consequences of Failure	Mitigation	Repair / Replace	I & E Guidance	Gaps	Priority & Basis	Responsible Program(s)
BWR Recirculation piping	SS (lc and hc), Inconel welds	SCC, fatigue	Leakage, forced outage	Yes, chemical and stress improvement	Yes, replace pipe or weld overlay	Yes, BWRVIP-75		Low – solution available	BWRVIP, WCC
BWR Vessel	Cs/las, ss clad, welds	IGSCC, IASCC, TGSCC, FIV, Th & Env Fatigue, Emb, Th aging, Fluence	LOCA – loss of asset	Yes – HWC, NMCA	Yes – nozzle repair	Yes – covers embrittlement and weld degradation		Low – solution available	BWRVIP
BWR Internals	Ss, cass, cs, welds, Inc	IASCC, IGSCC, FIV, Wear, EF, Emb, Fluence – R&D needed	Core configuration	Yes – some, work needed	Yes – shroud and top-guide, costly – work needed	Yes (interim) – 13 BWRVIP I&E Guidelines – work needed		High – existing and potential unresolved issues	BWRVIP, WCC, FRP, Corrosion Research
Core Shroud	Stainless Steel	IGSCC, IASCC, Reduction in Toughness	This is a function of location. Vertical weld flaws have minor significance unless the intersecting circumferential weld is flawed through-wall. Very flaw	Hydrogen Water Chemistry at moderate levels can protect the shroud at lower levels and some benefit is available at higher levels in some plants. When augmented with Noble Metals, more shroud protect is	The repairs to date have been mechanical clamps that replace some or all of the circumferential welds. This is accomplished by developing high compressive loads on the shroud which	BWRVIP has developed a series of inspection guides that have been combined into one overall document (BWRVIP-76). This	Fracture toughness decrease with increasing fluence and there is limited data to help the industry understand long	High priority items for the shroud still exist. Initially was the number one priority. With programs in place for inspection, the needs for	BWRVIP with the Assessment Committee leading

			tolerant for circumferential flaws. Significance of circumferential weld flaws is based on location of the weld. Limiting accident scenario is main steam line break coupled with an earth quake. Even then, shroud circumferential welds were shown to perform adequately with 90% through wall flaw, 360° in circumference. It is worth noting that should a flaw develop for the full circumference, the shroud would lift enough to "burp" itself	possible due to the need for les hydrogen due the to the catalyst effect of the noble metals. Plant-specific assessments are needed to determine the exact level of protection. Other methods of protection are being investigated/considered such as water jet peening etc.	negates the need for the circumferential welds. This provides significant redundancy since no circumferential welds to date have come near a 360 degree through-wall flaw. Repair by welding is very limited in prospect due to difficulty in welding on highly irradiated stainless steels.	document includes inspection criteria for circumferential and vertical welds, and support ring welds, The criteria also address both repaired and unrepaired shrouds including repair hardware. The evaluation criteria exist for all locations and is based on long standing ASME criteria including safety factors. Evaluation methods also account for the changes in crack	term issues. Work is underway to develop additional data prior to the shrouds reaching fluence levels of concern. Similarly, work is underway to properly understand and characterize crack growth behavior in highly irradiated stainless steels.	the shroud are reduced.	

			and provide operators with an indication of a problem and allow safe shutdown.			growth rate and fracture toughness a irradiation damage increases. The methods also allow for crack growth to be adjusted based on water chemistry, residual stresses, changing K values, etc.			

PLANT AGING AND MATERIALS DEGRADATION ISSUES

Jim Dyer, Director NRR
Dr. Carl Paperiello, Director RES
November 8, 2004

Acronyms

- **ASME:** American Society of Mechanical Engineers
- **BWR:** Boiling-water reactor
- **CCDF:** Conditional core damage frequency
- **IASCC:** Irradiation-assisted stress-corrosion cracking
- **IGSCC:** Intergranular stress-corrosion cracking
- **ISI:** Inservice inspection
- **NRR:** Office of Nuclear Reactor Regulation
- **PIRT:** Phenomena identification and ranking table
- **PWR:** Pressurized-water reactor
- **PWSCC:** Primary water stress-corrosion cracking
- **RCS:** Reactor coolant system
- **RES:** Office of Nuclear Regulatory Research
- **RPV:** Reactor pressure vessel

Regulatory Overview

- Regulatory framework
- Historical issues with materials degradation
- Current challenges
- Future goals

Regulatory Framework

- Regulations
  - ASME Code requirements for design and inspection
- Technical Specifications
  - Leakage monitoring
- Bulletins and Orders – short term, emergent issues

Regulatory Framework (continued)

- Integration of Research for degradation management programs
- Industry actions and initiatives

Regulatory Framework (continued)

- Regulatory Oversight
  - Baseline ISI
  - Temporary Instructions
  - Follow up interactions with licensees
  - Reactor Oversight Process indicators and findings

Historical Issues With Materials Degradation

- Radiation embrittlement of RPVs
- IGSCC in BWR piping
- BWR internals cracking
- Steam generator tube degradation
- PWSCC in PWRs
- Boric acid corrosion
- IASCC in PWRs
- Vibratory fatigue
- Thermal fatigue
- Erosion/corrosion

Current Challenges

- PWSCC of penetration nozzles in reactor and other vessels, nozzle welds
  - Addressed through Bulletins and Order
- PWSCC in dissimilar metal butt welds of RCS piping
  - Regulatory action being considered

Current Challenges (continued)

- Extended power uprate adverse flow effects
  - Steam dryer cracking
  - Feedwater probe failure
  - Staff monitoring industry actions

Current Challenges (continued)

- Steam generator degradation
  - Active NRC oversight
  - Implementing new regulatory framework through technical specifications

Future Goals

- Return to more stable regulation
- Increase reliance on industry
- Proactive oversight
- Operating experience monitoring
- Independent NRC research

Proactive Materials Degradation Assessment

- Research input into regulatory activities
- Approach
- Short-term program
- Longer term program
- Implementation schedule
- Utilization of results

Research Input Into Regulatory Activities

- Environmentally assisted cracking
  - BWR pipe cracking
  - Internals cracking
- Steam generator integrity
- Nondestructive Examination
- Pressure vessel integrity

Approach

- Some of the materials degradation in nuclear power plant components experienced in the past has surprised both NRC and industry
- NRC & industry pursuing proactive approach to materials degradation

Approach (Continued)

- **Identify components of interest to ensure reliability**
- **Coordinate research for effective implementation of proactive materials degradation management**

Approach (Continued)

- **Activities to identify components**
  - **Information on degradation that has been experienced – short-term results**
  - **Phenomena identification and ranking table (PIRT) for potential future degradation – longer term results**

Short-term Program

- Identified components that have already experienced degradation
- Evaluating inspection and leak monitoring techniques and requirements
- Provide input to conditional core damage frequency (CCDF)
- Probabilities of failure for probabilistic risk assessments

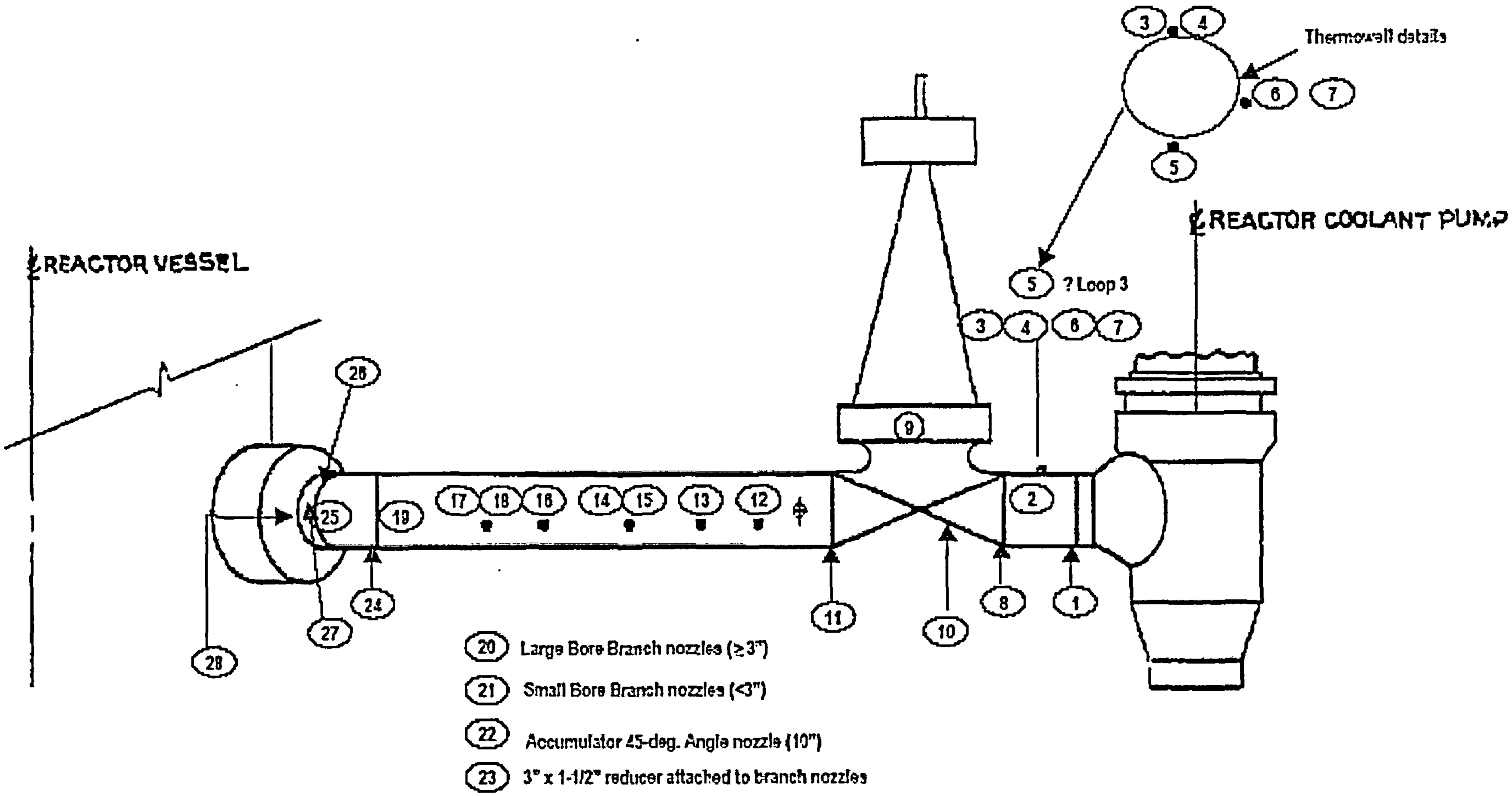
Longer Term Program

- PIRT process
  - Expert elicitation
- International in scope
- Bounded – important plant systems being addressed

Longer Term Program (Continued)

- Background information provided to expert panel members
  - Component's environment and operational experience
- Experts identify and rate degradation mechanisms, assess knowledge levels, and provide bases for decisions

GROUP 1: RCS Cold Leg Piping
(Covers worksheets RCS-CL – 1 thru 28)



Implementation Schedule

- First two PIRT meetings on PWR reactor coolant system and emergency core cooling system completed
  - Potential future degradation being identified
- Six more meetings to complete PWR and BWR evaluations
- PWR report – June 2005
- BWR report – December 2005

Utilization of Results

- Lists of components susceptible to future degradation, bases for calls, and knowledge levels
- Input to cooperative integrated research programs
- Technical basis for effective proactive materials degradation management by NRC and industry