Operating Past 60: Applications to Inconel 600/690 Management Programs

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Background

- Ni-based alloys have extensive service history in US and World nuclear plants
  - not all of it positive
  - US industry continues to operate a extensive materials degradation program to address Alloy 600 and 182/82 weld material degradation
  - International programs for materials testing and replacements also continue to be implemented
- Materials include:
  - A600 base metal, 182/82 weld metal, A690 BM, 152/52 WM, A800 extruded tube
  - Precipitation hardened alloys
    - X-718, X-750 with various temper treatments
- Replacements for Alloy 600 include A690 material and weld metal, or changing design using stainless steel

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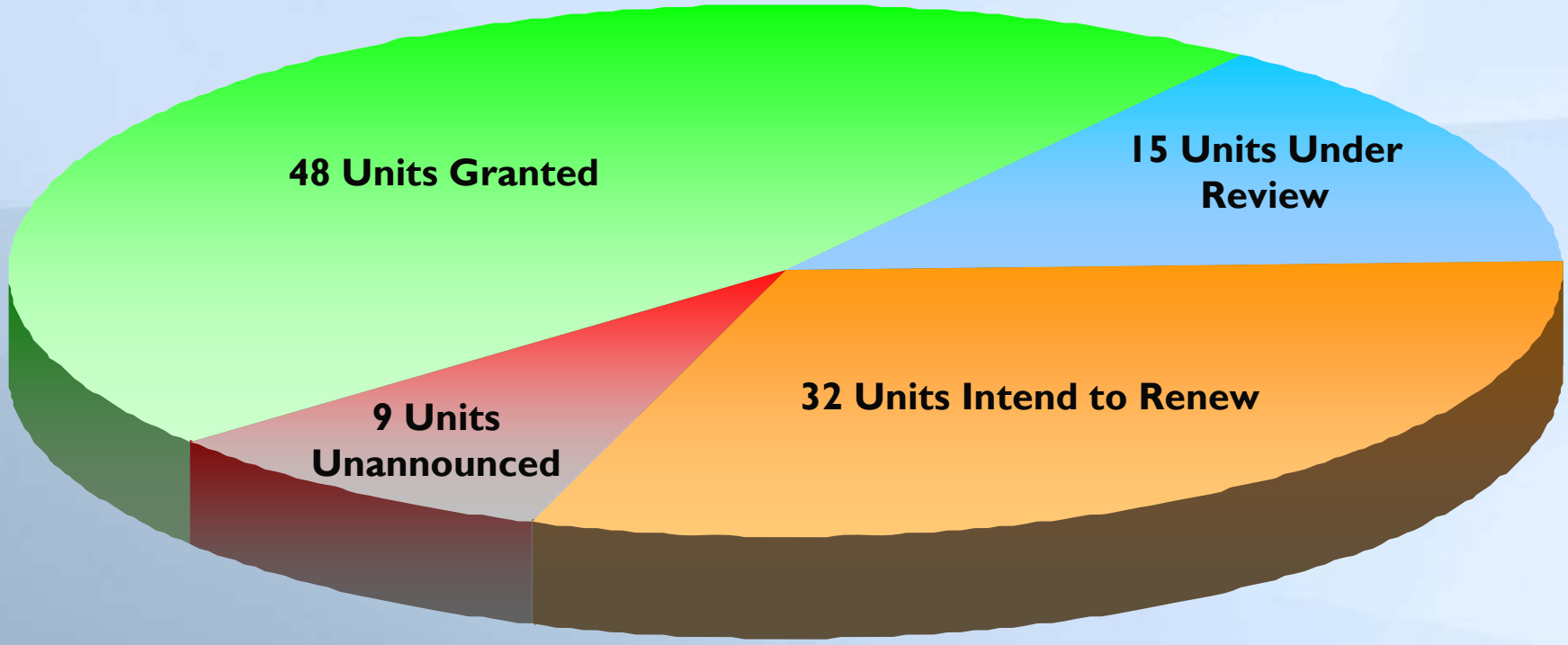
Current Applications for License Renewal for 60 year License

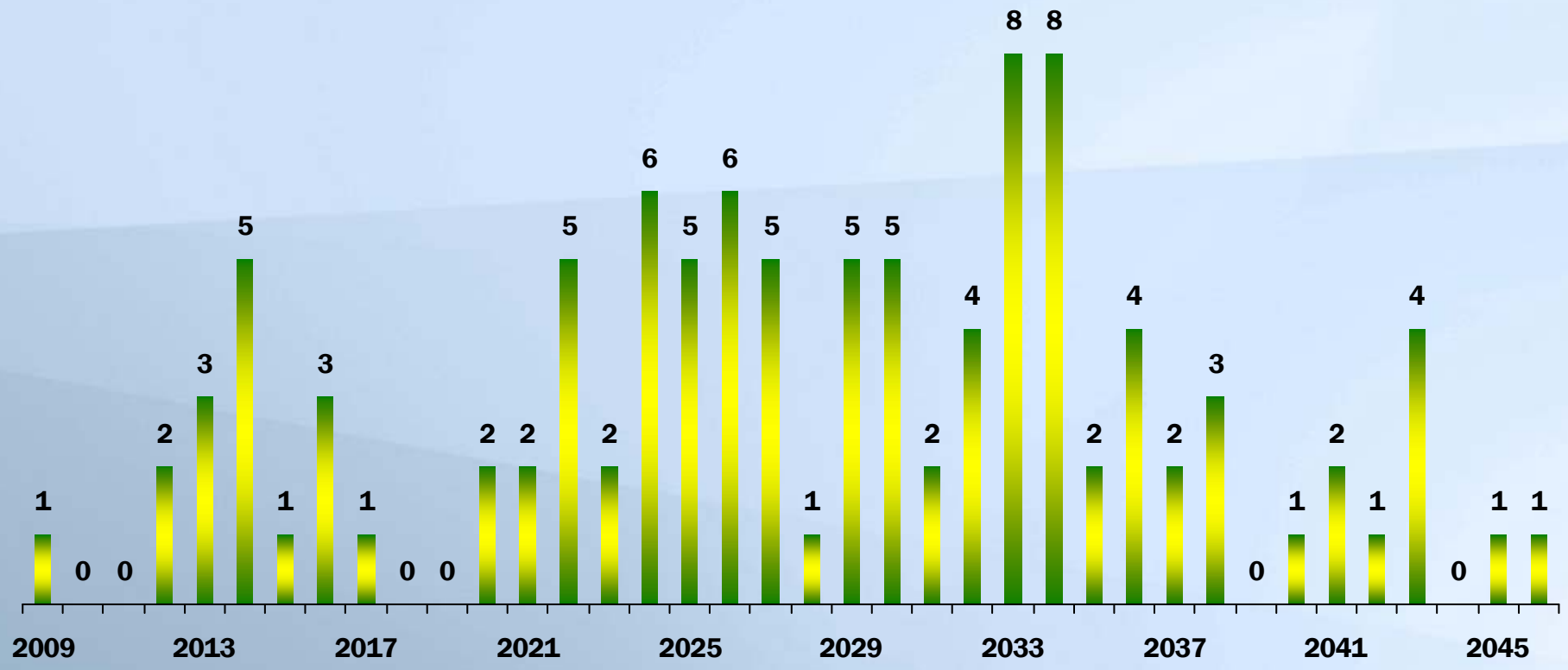


Source: Nuclear Regulatory Commission

Updated: 1/08

U.S. Nuclear Plant License Expirations

2009-2046



Source: Nuclear Regulatory Commission
Updated: 1/07

Materials Reliability

- Continues to be a top issue for the US nuclear industry
- Pressure boundary material must be
  - Suitable for intended service environment
  - Meet high quality standards
  - Predictable behavior
  - Installed per design requirements
  - Inspectable
  - Replaceable

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Current Ni Based Alloy Failures

- Internals components
  - Jet Pump Beams
  - BWR Steam Dryers
  - PWR Split Pins
- Pressure boundary items
  - CRDM head penetrations
  - BMI penetrations
  - Hot leg instrument taps
  - Full penetration butt welds
  - Pressurizer heater sleeves
  - BWR recirculation piping
- Steam generators
  - Tubing
  - Welds

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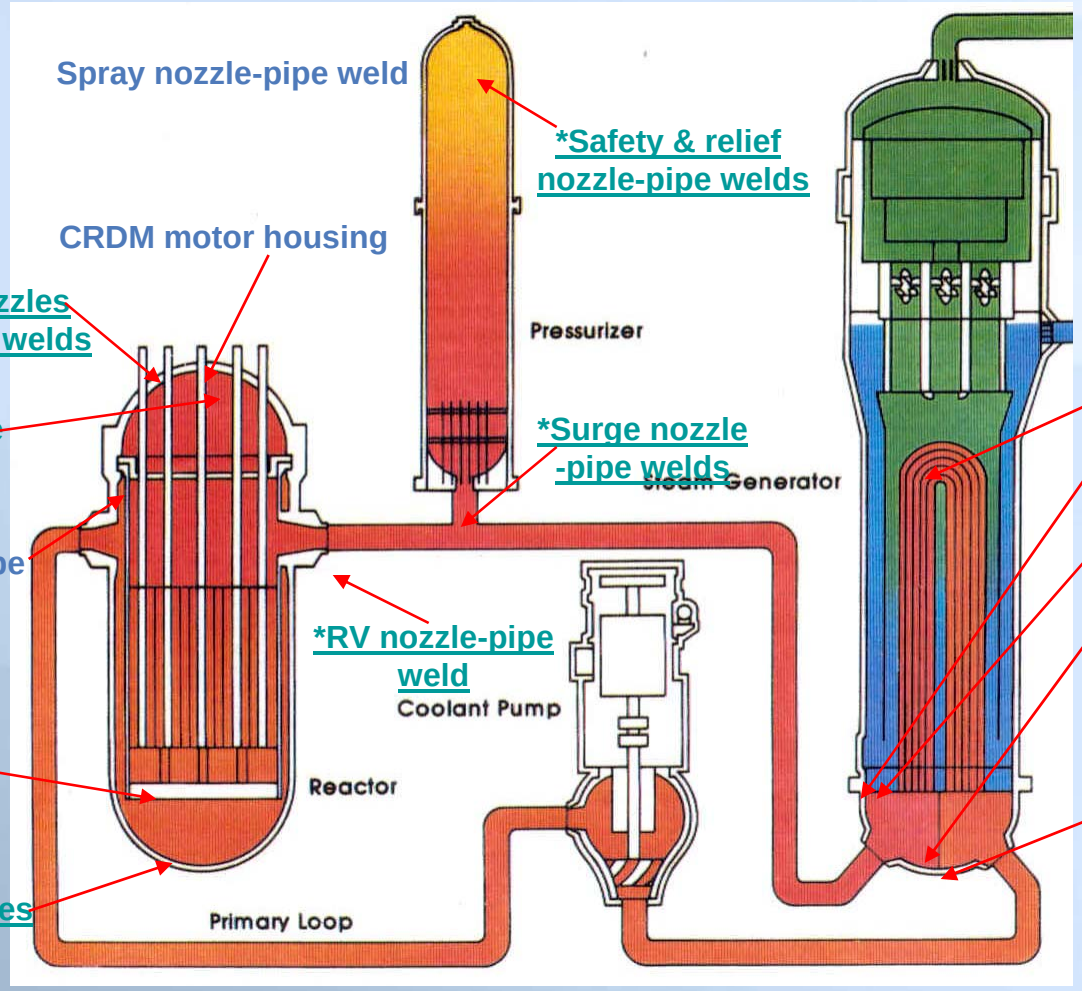
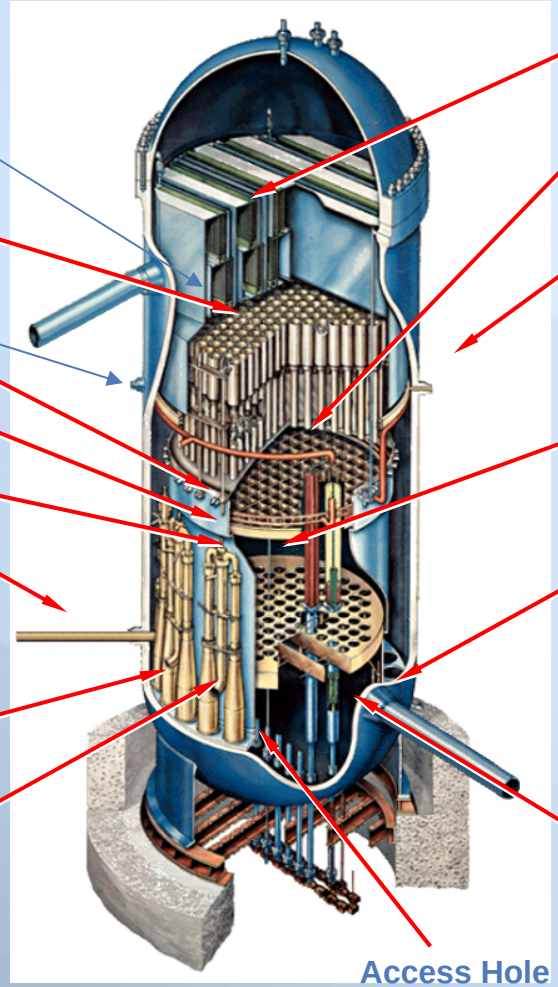
PWR Alloy 600 PWSCC Impacts



- Represents locations that have experienced cracking and or leakage at other PWRs are highlighted in red.
- Replacement or Repairs with A690 noted in Green

BWR Internal Components



Shroud head bolts

Top Guide

Feedwater nozzle weld butters

Core Shroud Welds

Jet Pump Riser Brace

Jet Pump Beams

Recirc. Inlet and outlet Nozzle to safe end weld butters

Shroud-to-Shroud Support Welds

Jet Pump Riser Elbow

Steam Dryer

Core Spray Piping

Core Spray Safe End to Nozzle Weld Butters

SRM Dry Tubes and In-core Housing

Recirc. Inlet Safe End and nozzle welds

CRD Stub Tube to Housing Weld

Access Hole Cover and shroud support shelf

A600/182

304, 304L

316L,

Or 347

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Alloy 600 Continuing Focus Areas

- Hot Leg applications
- Cold leg applications
- Lower temperature applications
- Low temperature crack growth
- Steam generator alloy 600 thermally treated tubing

A690 Focus Areas

- Significant improvement over A600
- No instances of field PWSCC reported to date
- Extremely low crack growth rates, if any, identified under severe test conditions
- Need to continue to search out material vulnerability
  - Water chemistry changes
  - Repair configurations
- Translate data into improved inspection requirements

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Strategic Direction to Address Materials

- May 2003 industry Chief Nuclear Officers unanimously approved the "Industry Initiative on Management of Materials Issues"
- Initiated NEI 03-08 Guideline for the Management of Materials issues
- Forward-looking and coordinated
- Identifies, reacts and effectively responds to Alloy 600 emerging issues
- Emphasizes safety and operational risk significance
- Balances long-term aging management and cost

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Strategic Direction to Address Materials

- Issued "Integrated Materials Issues Strategic Plan"
- Materials Degradation Matrix (MDM), issued 2004
- Issue Management Tables
  - IMT assesses the consequences of failure
  - Identifies gaps in inspection, mitigation, repair, and replacement guidance
  - Gap priorities used to establish IP project plans for 2007 and beyond.

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Programs Addressing Alloy 600 Degradation Management

- Materials Reliability Project
- PWR Owners Group
- BWR VIP
- Steam Generator Management Group
- Water Chemistry Control
- EPRI Corrosion Research
- ASME Codes and Standards
- EPRI NDE Center
- NRC Research and Regulation

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Degradation Matrix

- Identify materials used for major passive components/systems within Materials Initiative scope
- Obtain inputs from experts, laboratory R&D, industry operating experience
  - Identify potential degradation mechanisms
  - Determine material applicability
  - Define areas of uncertainty
- Identify and characterize issues that pose potential threats
  - Green - Adequately addressed, programs managing issues
  - Yellow - Work in progress that will develop tools to manage issues
  - Red - No program to address, insufficient work in progress to address vulnerability
  - Blue – Unknown applicability

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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*				
	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.

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Maintaining the Priority of the Materials Initiative Philosophy

- Maintain momentum for the Materials Initiative
- Continue to focus on the future
- Continue to share operating experience
- Team with Naval Reactors, Bettis, etc to support US plant research

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Conclusions

- Control surprises by known mechanisms
- Detect degradation as soon as possible
- Mitigate or replace prior to onset of impact
- Plan for contingencies
- Outline the decision process
- Communicate effectively with NRC
- Communicate with the industry

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Questions or Comments

- Thanks to DOE/NRC for Sponsoring and Organizing this Conference

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