NRC A690/52/152 Knowledge Gap Rankings and Research Initiatives

PMs: Samantha Crane and Carol Moyer

TM: Robert Tregoning

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NRC Knowledge Gap Rankings

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- White Paper Knowledge Gaps
- NRC Prioritization
  - Prioritization based on importance for addressing safety and/or regulatory issues.
  - Averaged rankings based on NRC staff and contractor votes.
  - High = 3, Medium = 2, Low = 1
- Ongoing/Planned NRC Research to address each gap

MRP-237 Identified Knowledge Gaps

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1. Lack of crack initiation data on any of the heterogeneously deformed Alloy 690 materials that have shown high susceptibility to crack growth through PWSCC.
2. Incomplete knowledge of the way in which certain Alloy 690 bulk material conditions (particularly unidirectional deformation) can sometimes impair its otherwise excellent resistance to PWSCC crack growth.
3. Possibility of enhanced PWSCC susceptibility in the base material adjacent to welds in thick-walled Alloy 690 as a result of both microstructural changes and the introduction of high residual strains.
4. Uncertainty as to what Alloy 690 material conditions must still be considered potentially relevant to actual plant components (including in localized situations, such as weld heat-affected zones).
5. Controversy as to whether LTCP could be a real degradation mechanism in the field for Alloy 690 and its weld metals, or is just a laboratory phenomenon.
6. Lack of conclusive evidence that weld fabrication defects might not lead to PWSCC susceptibility in Alloys 52(M) and 152.
7. Contradictory laboratory findings as to the possibility of measuring significant PWSCC crack growth rates in Alloys 52(M) and 152.
8. Residual uncertainty as to whether or not weld compositional variations (including dilution effects) and actual welding procedures might affect both PWSCC and LTCP behavior.
9. Absence of detailed information on actual replacement components in the field.
10. No crack growth rate disposition curves as a basis for justifying continued plant operation if service-induced cracks were to be found in Alloys 690/52(M)/152, or if their existence has to be postulated for analysis purposes.

Enhanced PWSCC susceptibility in the base material adjacent to welds in thick-walled Alloy 690.

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- NRC Ranking:
  - 3.0, high
  - Ranking based on CGR testing on HAZ materials not initiation studies
- NRC Ongoing/Planned Research:
  - 690TT HAZ on a 690TT CRDM tube in C-R orientation
  - 690TT HAZ on a 690TT CRDM tube in C-L orientation

Whether weld fabrication defects lead to PWSCC susceptibility in Alloys 52(M) and 152.

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- NRC Ranking:
  - 3.0, high
- NRC Ongoing/Planned Research:
  - none

Whether weld compositional variations (including dilution effects) and actual welding procedures affect both PWSCC and LTCP behavior.

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- NRC Ranking:
  - 3.0, high
- NRC Ongoing/Planned Research:
  - Testing of dilution zone between A52 to 182 weld overlay
  - Planned additional weld overlay/onlay work to determine critical Cr level needed to retard crack growth

Additional Gap: Welding fabrication and repair effects on defect population, residual stress, and cracking susceptibility.

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- NRC Ranking:
  - 3.0, high
- NRC Ongoing/Planned Research:
  - none

How Alloy 690 bulk material conditions (particularly unidirectional deformation) may impair its resistance to PWSCC crack growth.

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- NRC Ranking:
  - 2.86, med to high
- NRC Ongoing/Planned Research:
  - 17% 1D CR S-L orientation A690, SA and TT
  - 30% 1D CR T-L orientation A690, SA and TT
  - 15% and 25% 1D CR S-L orientation A690 plate
  - 20 and 26% 1D CR S-T orientation A690TT plate

Contradictory laboratory findings as to the possibility of measuring significant PWSCC crack growth rates in Alloys 52(M) and 152.

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- NRC Ranking:
  - 2.75, med to high
- NRC Ongoing/Planned Research:
  - Some duplication of tests between the two NRC labs
  - Testing at PNNL and ANL of some highly susceptible materials also tested by GE or Bettis

Which Alloy 690 material conditions must still be considered (including in localized situations, such as weld heat- affected zones).

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- NRC Ranking:
  - 2.57, med to high
- NRC Ongoing/Planned Research:
  - TBD

Whether LTCP could be a real degradation mechanism in the field for Alloy 690 and its weld metals.

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- NRC Ranking:
  - 2.0, med
- NRC Ongoing/Planned Research:
  - Some CGR tests performed at 50C on A152, A690TT, and A690SA

Crack growth rate disposition curves for Alloys 690/52(M)/152.

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- NRC Ranking:
  - 2.0, med
- NRC Ongoing/Planned Research:
  - none

Detailed information on actual replacement components in the field.

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- NRC Ranking:
  - 1.78, low to med
- NRC Ongoing/Planned Research
  - Ongoing monitoring of operational experience as it becomes available

Crack initiation data on any of the heterogeneously deformed Alloy 690 materials that have shown high susceptibility to crack growth through PWSCC.

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- NRC Ranking:
  - 1.5, low to med
- NRC Ongoing/Planned Research
  - None

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Background

Investigation of Stress Corrosion Cracking in Ni-base Alloys - PNNL

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- Determine the Stress Corrosion Cracking (SCC) Crack Growth Rates (CGR) of Nickel-base stainless steel alloys, with emphasis on those alloys with higher Chromium content.
  - Alloy 690
  - Alloy 152, and Alloy 52
- Material Characterization and Analytical Studies of SCC
  - Optical metallography, SEM, and TEM to document the general grain structures, identify precipitates and inclusions, and assess local compositional variations

PNNL: Materials

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Material - Source	Heat No. and Description	Composition wt%
Alloy 690TT - Source A	RE076, CRDM Tube 2146 (1.1" wall)	Ni-29Cr-10.1Fe-0.019C
Alloy 690TT - Source A	RE169 CRDM Tube 2175 (1.0" wall)	Ni-29.4Cr-10.3Fe-0.020C
Alloy 690TT - Source A	RE243 CRDM Tube 2216 (1.0" wall), Tube 2360 (1.4" wall)	Ni-28.9Cr-10.4Fe-0.02C-0.3Mn-0.35 Si-0.14Al-0.23Ti-0.024N-0.0005S-0.008P
Alloy 690TT - Source A	WP016 CRDM Tube 2422 (1.1" wall)	Ni-29.3Cr-10.3Fe-0.020C-0.32Mn-0.28 Si-0.14Al-0.21Ti-0.025N-0.0005S-0.008P
Alloy 690TT - Source A	WP140 CRDM Tube 2502 (1.2" wall)	Ni-29.0Cr-10.4Fe-0.03C-0.3Mn-0.33 Si-0.18Al-0.3Ti, <0.001S
Alloy 690TT - Source A	WP142 CRDM Tube 2541 (1.2" wall)	Ni-29.0Cr-10.5Fe-0.02C-0.3Mn-0.35 Si-0.18Al-0.27Ti-0.037N-0.0006S-0.006P
Alloy 690TT - Source B	NX8625HG21 1.34" Plate	Ni-30Cr-10Fe-0.027C
Alloy 152 – Source B	307380 Mock-up weld for NPP using 304SS plate	Ni-28.7Cr-9.1Fe-0.03C-3.6Mn-0.33 Si-0.15Al-0.12Ti-0.003S
Alloy 52 – Source B	NX2686JK mock-up weld for NPP using 304SS plate	to be measured
Alloy 52 – Source C	Mockup butt weld using alloy 690 plate	to be measured

PNNL: Testing

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Material	Test Description	Status
Alloy 152	PWR Primary Water	Complete 4/07
Alloy 690 CRDM Tube Heat, TT and SA	PWR Primary Water, Heat Treatment effects	Complete 12/07
Alloy 152 – as welded & stress relieved	PWR Primary Water, Temperature effects	Test to 3/08
17% 1D CR S-L Alloy 690 CRDM Heat, TT & SA	PWR Primary Water, Heat Treatment, 1D Rolling effects	Test to 4/08
30% 1D CR T-L Alloy 690 CRDM heat, TT & SA	PWR Primary Water, 1D Rolling effects	Test to 8/08
Alloy 52 mock-up welds (2 sources)	PWR Primary Water, tow weld metals	Plan 3/08-10/08
Two or Three Alloy 690 CRDM Tube Heats	PWR Primary Water, Heat to heat effects	Plan 5/08-12/08
Alloy 52 to Alloy 182 weld and/or overlay	PWR Primary Water, dilution zone effects	Plan 5/08-12/08
15 and 25% 1D CR S-L Alloy 690 Plate	PWR Primary Water, 1D Rolling effects	Plan 11/08-4/09

Cracking of Nickel Alloys and Welds- ANL

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- Provide technical data and analytical methods on the cracking of nickel-alloy components and welds to estimate CGRs in reactor components for regulatory determinations of residual life, inspection intervals, repair criteria, and effective countermeasures for reactor internal components
  - Determine the SCC CGR for Alloys 690, 152 Weld and Alloy 690 HAZ
  - Determine the activation energy for SCC CGR for Alloys 690, 152 Weld and Alloy 690 HAZ
  - Characterize time-and-temperature aging effects at or near the fusion line of Alloy 152 welds on low-alloy pressure vessel steel base metal

ANL: Materials

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- CGR testing of Alloys 690, 152 Weld and 690 HAZ – Alloys
  - Alloy 690 in plate form, including 26% cold rolled
  - 20% cold-rolled Alloy 690 in plate form
  - CRDM Alloy 690TT (2 tubes); 2941-Heat WP142 also used for Alloy 690 HAZ testing
  - Double-J weld mock-up (ANL), currently used in CGR tests, also used for tensile testing vs. temperature
  - Alloy 152 weld on CRDM Alloy 690TT, 2941-Heat WP142
  - Double-V weld mock-up 690/152/LAS, also for aging studies
  - CRDM Alloy 690 tube /152/Alloy 690 plate mock-up

ANL: Testing

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Material	Test 1 Description	Test 2 Description
Alloy 152 mock-up weld on CRDM CR Orientation	PWR Primary Water, Multiple K Test	PWR Primary Water, Multiple Temp Test
Alloy 152 mock-up weld on CRDM LR Orientation	PWR Primary Water, Multiple K Test	PWR Primary Water, Multiple Temp Test
Alloy 152 mock-up weld TS Orientation	PWR Primary Water, Multiple K Test	PWR Primary Water, Multiple Temp Test
Alloy 152 to LAS mock-up weld LS Orientation	PWR Primary Water, Multiple K Test	PWR Primary Water, Multiple Temp Test
Alloy 690TTTT CRDM Tube CR Orientation	PWR Primary Water, Multiple K Test	PWR Primary Water, Multiple Temp Test
Alloy 690TT CRDM Tube LR Orientation	PWR Primary Water, Multiple K Test	PWR Primary Water, Multiple Temp Test
Alloy 690TT HAZ on 690TT CRDM Tube CL Orientation	PWR Primary Water, Multiple K Test	PWR Primary Water, Multiple Temp Test
Alloy 690TT HAZ on 690TT CRDM Tube CR Orientation	PWR Primary Water, Multiple K Test	PWR Primary Water, Multiple Temp Test
26% CR Alloy 690TT Plate ST Orientation	PWR Primary Water, Multiple K Test	PWR Primary Water, Multiple Temp Test
20% CR Alloy 690TT Plate ST Orientation	PWR Primary Water, Multiple K Test	PWR Primary Water, Multiple Temp Test