Investigation of Stress Corrosion Cracking in Nickel-Base Alloys

Steve Bruemmer and Mychailo Toloczko
Pacific Northwest National Laboratory

NRC Project N6007 Kick-Off Meeting
Richland, Washington

May 3, 2005

Research Supported by
U.S. Nuclear Regulatory Commission

Kick-Off Meeting Agenda

1. **NRC Introduction & Meeting Purpose:** *M. Srinivasan*
2. **Overview of PNNL Research Project:** *S. Bruemmer*
3. **Review of SCC Crack-Growth Test Systems:** *M. Toloczko*
4. **Test Plans and Initial Results:** *S. Bruemmer, M. Toloczko*
5. **Discussion of Programmatic Challenges:** *S. Bruemmer*
6. **Opportunity for Public Questions/Comments**
7. **Crack and Crack-Tip Observations on Alloy 600 and Alloy 182 CRDM Components:** *S. Bruemmer*

Agenda

2. Overview of PNNL Research Project

- ***Objectives, Scope & Research Team***
- **Task Structure, Major Activities & Milestones**
- **Reporting & Meetings**

Project Objective & Scope

Conduct SCC crack-growth-rate (CGR) testing of Ni-base stainless alloys focused on alloy 690 and its weld metals alloy 152 and 52. State-of-the-art test systems will be constructed to allow experimentation under simulated and/or accelerated (e.g., increased temperature, more aggressive environments, increased load range or load interaction effects) PWR and BWR conditions. Direct current electric potential drop methods will be used to acquire crack extension data and reference electrodes will be used to monitor corrosion potential. Initial tests will be performed on alloy 600/182 and stainless steels as part of round-robin collaborations to assess and demonstrate PNNL capabilities to obtain high-quality CGR data in relevant LWR environments.

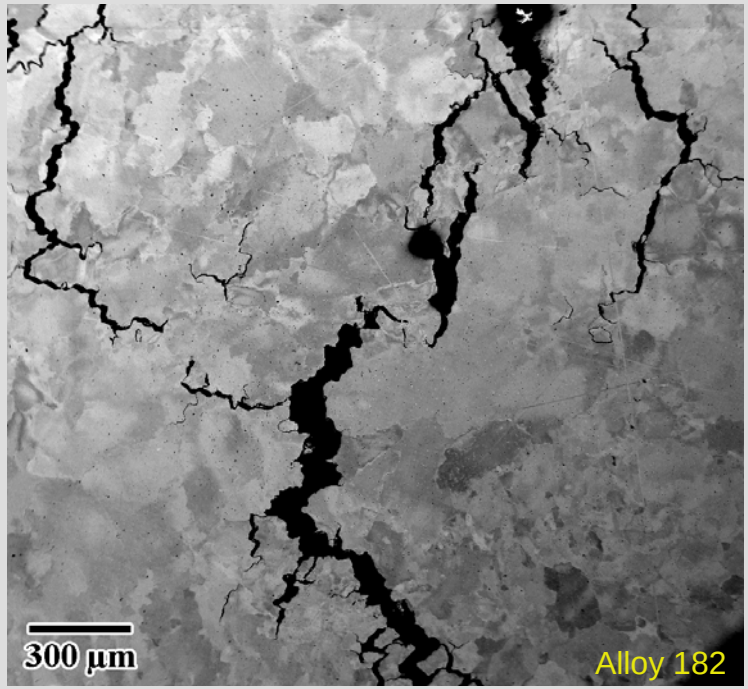
Background

IGSCC of thick-section, Ni-base stainless alloys has become a significant issue in PWRs. Alloy 600 and its weld metals (alloy 182 and 82) have experienced cracking in service highlighted by RPV and pressurizer nozzle safe end welds, CRDM and BMI nozzle J-groove welds.

Many unanswered questions concerning behavior of current alloys and limited quantitative SCC crack-growth data for replacement materials, alloy 690 and its weld metals (alloys 152 and 52).

Alloy 600/182 Background

- Service SCC shows incubation times between 1 and 30 years
- SCC is strongly temperature dependent
- Significant heat-to-heat variability
- Important materials variables:
  - bulk composition (carbon)
  - forging/rolling operation temperatures
  - yield strength after hot working
  - microstructure & carbide distribution
  - surface cold work
  - welding & repair welding parameters, fabrication defects, solidification segregation/precipitation, hot cracking



Alloy 690/152/52 Background

- Clearly much more SCC-resistant alloys than alloy 600/182 in PWR primary water
- Service experience excellent
  - ~15 years for steam generators (A690)
  - ~10 years welded components
- Specific Potential Issues
  - limited quantitative assessment of SCC crack-growth rates for alloy 690
  - limited testing of alloy 152/52 welds
  - low-temperature crack propagation
  - limited evaluation of bulk composition, thermomechanical processing and microstructure on SCC resistance

Research Team

- Project Manager & Technical Lead: *Steve Bruemmer*
- Test System Design/Construction: *Mychailo Toloczko*, *John Keaveney*
  Consultants: *Peter Andresen, Greg Catlin, GEG*
- SCC Crack-Growth Testing: *Mychailo Toloczko*, *John Keaveney*
  Consultants: *Peter Andresen, GEG*, *Peter Scott, Framatome*
- Materials & Characterization: *Lee Fetrow, John Vetrano*, *Larry Thomas*

General Electric Global Research

- World leader for quantitative SCC crack-growth-rate testing of LWR materials and they have led key international round-robin test programs.
- 25 years of development and test system evolution, unmatched experience with ECP control and DCPD, unique control and data acquisition software.
- Pioneered ultra-high-purity, make-up water system (outlet resistivity better than 15 Mohm-cm) for BWR applications and for isolation of impurity effects
- Recent PWR experience (290-360°C, B/Li water) evaluating Ni-base alloys and stainless steels
- Peter Andresen and his team have advised in the construction of SCC crack-growth systems for many laboratories over the last 10 years.

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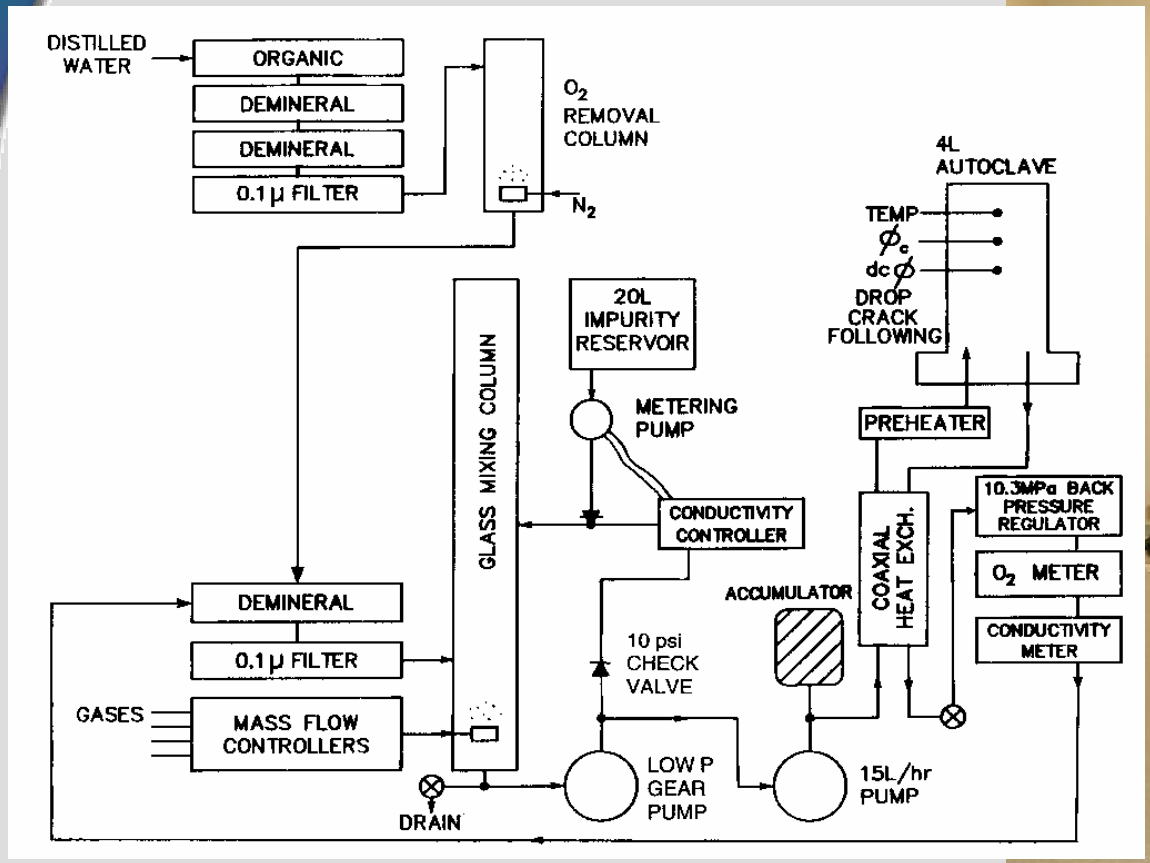
Tasks & Key Milestones

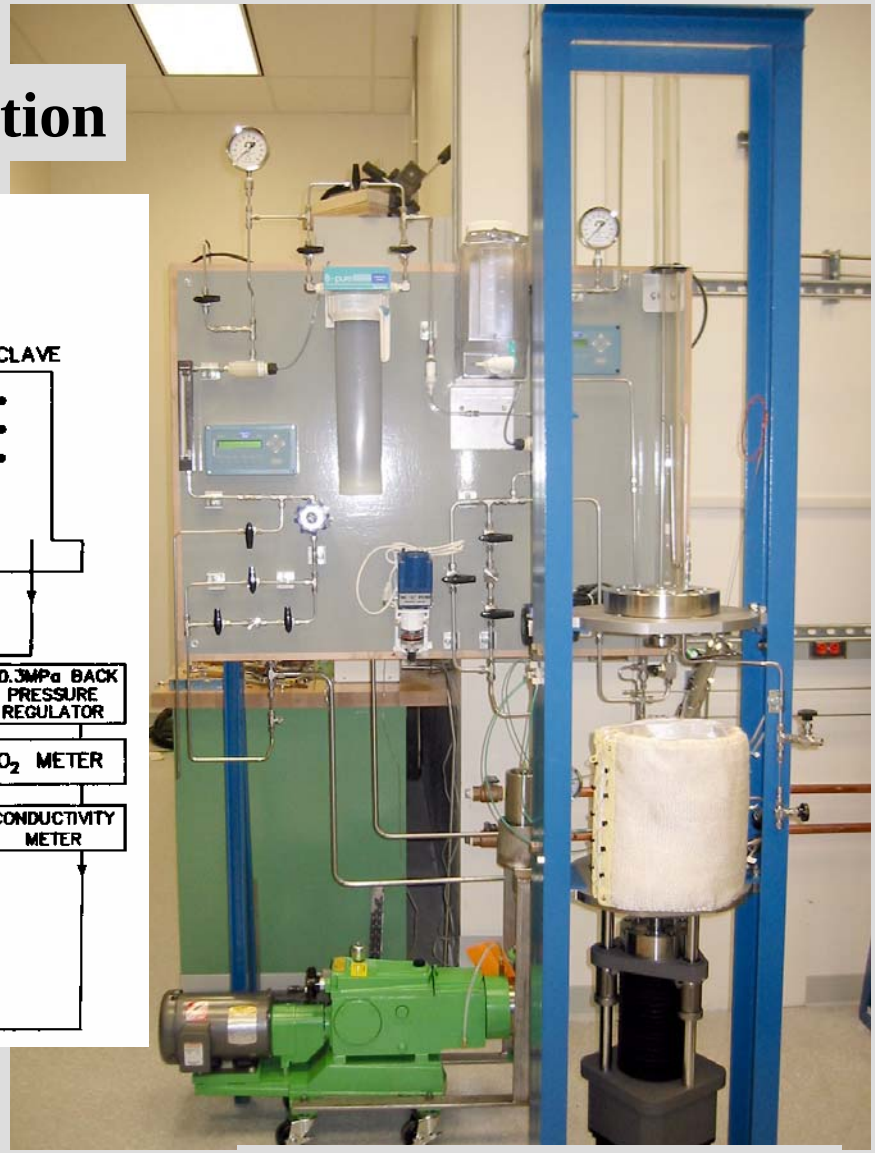
1. Test System Construction
   a) System Design & Order Components — Sept 2004
   b) System #1 Completion/Set-up — Feb 2005
   c) System #2 Completion/Set-up — June 2005
   d) System #3 Completion/Set-up — Apr 2006

2. System Testing & Demonstration
   a) System #1 Conditioning — May 2005
   b) System #2 Conditioning — Sept 2005
   c) Complete Demonstration Tests — Apr 2006
   d) System #3 Conditioning — Aug 2006

Test System Design/Construction



Initial Design Based on GE Approach



PNNL CGR System #1

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   d) System #3 Completion/Set-up — Apr 2006

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Test System #1 Conditioning & Initial Testing

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1. Test System Construction
   a) System Design & Order Components — Sept 2004
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Tasks & Key Milestones

3. SCC Crack-Growth Testing
   a) Initiate Key Alloy 600/182/82 Tests — Sept 2005
   b) Initiate Key Alloy 690/152/52 Tests — April 2006
   c) Complete Key Alloy 600/182/82 Tests — Dec 2006
   d) Complete Key Alloy 690/152/52 Tests — Aug 2008

4. Materials & SCC Characterizations
   a) Microstructure Alloy 600/182/82 — Mar 2006
   b) SCC Crack Tips Alloy 600/182/82 — Sept 2007
   c) Microstructure Alloy 690/152/52 — Sept 2007
   d) SCC Crack Tips Alloy 690/152/52 — Aug 2008

Alloy 600/182/82 Issues

- Limited fundamental understanding of SCC in primary water
- Significant heat-to-heat variability
- Important materials variables:
  - processing, fabrication & heat treatments impacting yield strength, microstructure & carbide distribution
  - welding & repair welding impacting yield strength & microstructure
  - heat-affected zone susceptibility?
- Important environmental variables:
  - temperature
  - impurities (S?)

Alloy 690/152/52 Issues

- Clearly much more SCC-resistant alloys than alloy 600/182 in PWR primary water
- Service experience excellent
- Specific Potential Issues
  - limited quantitative assessment of SCC crack-growth rates for alloy 690
  - limited evaluation of bulk composition, thermomechanical processing and microstructure on SCC resistance
  - limited testing of alloy 152/52 welds
  - heat-affected zone susceptibility?
  - low-temperature crack propagation
  - weld hot cracking

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Tasks & Key Milestones

5. Program Management, Reporting & Meetings

a)	Attend ITG Expert and PRP Meetings	2005 - 2008
b)	Attend ICG-EAC Meetings	2005 - 2008
	Organize U.S. ICG-EAC Meeting	May 2006
c)	Participate in Nucl Safety Research Conf	2006 - 2008
d)	Interim Report Alloy 600/182/82	Jan 2007
e)	Interim Report Alloy 690/152/52	Aug 2008

ICG-EAC 2006

Planned Date and Location

May 14-19, 2006

Charleston, South Carolina USA

Hosts

Nuclear Regulatory Commission
EPRI, General Electric, PNNL, +

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