

# **PWSCC Crack Growth Rate (CGR) Expert Panel**

*Status Update*

**Materials Reliability Program**

**Industry-NRC Materials R&D Update  
Meeting**

June 2-4, 2015

Rockville, MD



# Introduction

- An international PWSCC Expert Panel has been organized by EPRI to support development of equations for predicting the CGR due to PWSCC of Ni-based alloys
- A significant portion of the available crack growth rate data was produced by national laboratories under sponsorship of the U.S. NRC, and NRC staff input has been considered in planning for this Expert Panel effort
- The Expert Panel effort is currently scheduled through 2016, with subgroups for Data Evaluation and Application experts
- Results from research will be used to:
  - Inform regulatory consideration of inspection relief
  - Develop guidelines for material procurement to maximize PWSCC resistance
  - Qualify new weld metal formulations with regard to PWSCC resistance
  - Incorporate flaw disposition curves for base and weld metals into codes and standards for use in flaw evaluations

# NRC Participation

- NRC participation in the Expert Panel is governed by an addendum to the Memorandum of Understanding between EPRI and the NRC Office of Nuclear Regulatory Research (RES).
- NRC contractors from DOE national laboratories are members of the Data Evaluation subgroup and RES staff are observers for Expert Panel meetings.
- NRC contractors may review the data using their experience with CGR testing.
- NRC must independently assess the applicability of the data for plant component integrity analyses, so engagement with the Applications subgroup is anticipated to be more limited.
- NRC participation does not imply that staff will endorse the Expert Panel conclusions. Topical Reports or other work products that will support licensing actions are subject to further review.

# Plan

## ▪ Objectives

- Produce equations for predicting the PWSCC crack growth rates in Alloys 690, 52, and 152
- If warranted, revise the CGR disposition curves in MRP-55 and MRP-115 for Alloys 600 and 82/182, respectively, to consider the data that have become available since original publication

## ▪ Scope

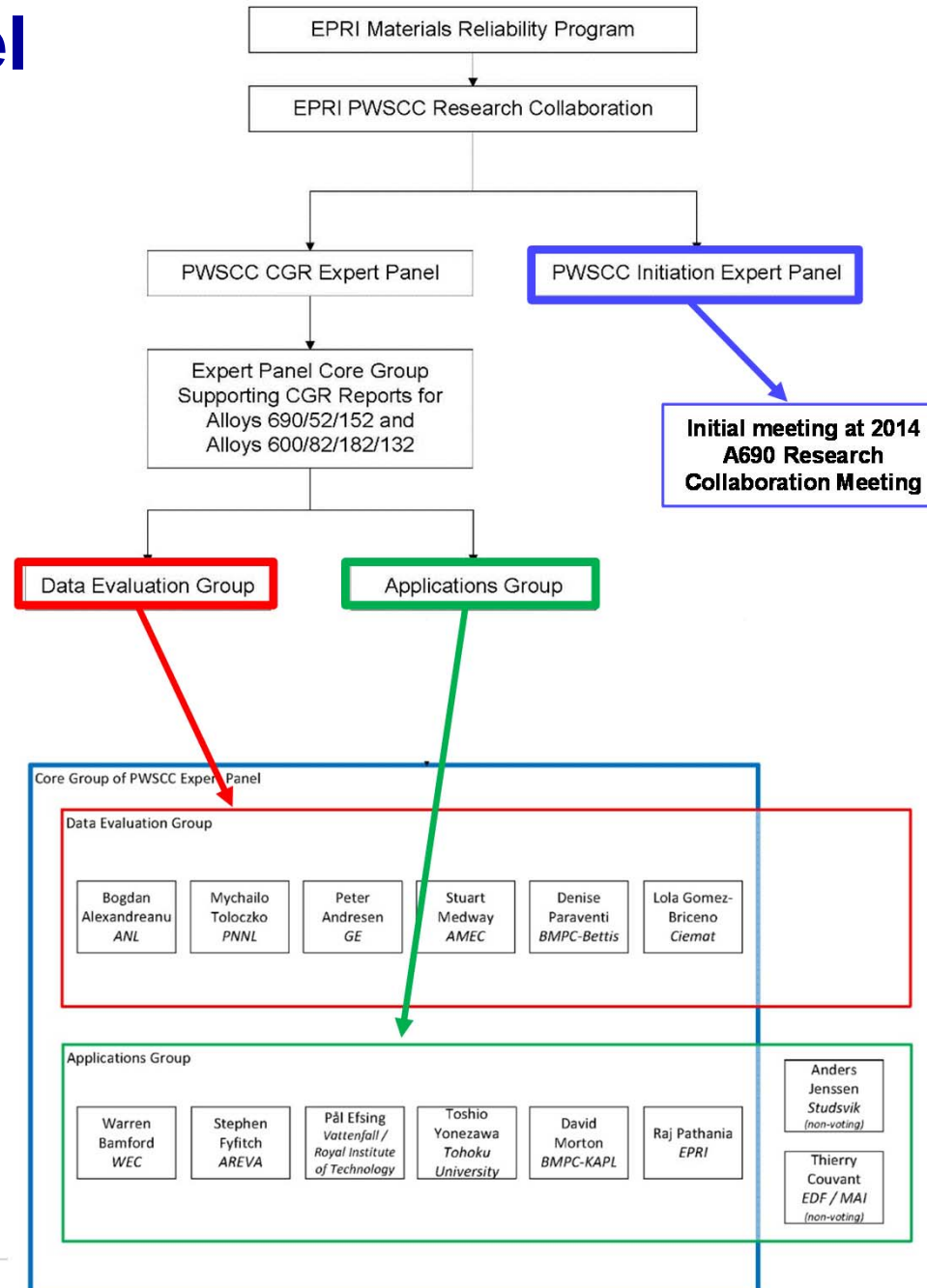
- Data Evaluation Group
  - Develop, assess, and score database
  - Develop position on dilution zone and weld interface testing
  - Interact with Applications Group on database and tests
  - Report on original data, scored data, and methodology/process
- Applications Group
  - Review database, including with regard to plant applicability
  - Interact with Data Evaluation Group on database and tests
  - Develop and apply statistical process to scored database
  - Report on equations for predicting crack growth rate and methodology/process

## ▪ Deliverables

- Reviewed and scored databases
- Revised MRP-55 and MRP-115 disposition curves for A600/82/182/132, as warranted
- Crack growth disposition curves for A690/52/152

# Expert Panel

## - Organization



# PWSCC CGRs for Alloys 690/52/152

*Data Evaluation Group*

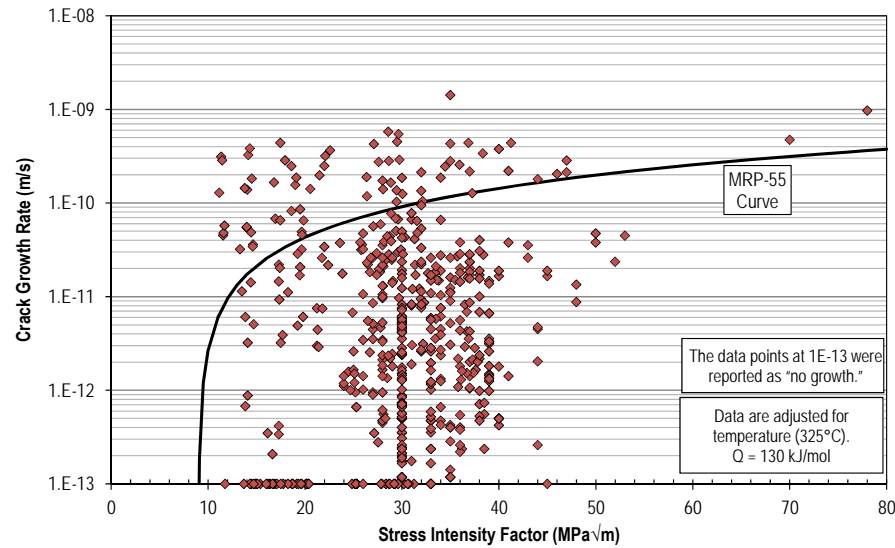
## ■ Data Collection

- The testing laboratories have provided crack growth rate testing information for over 700 data points
- A wide variety of material conditions and environments have been tested and are being evaluated
- Supplementary information, such as crack length vs. time plots and fractography, have been collected for most specimens when available
- The CGR database and supplementary information were provided to the Data Evaluation Group in preparation for scoring the data

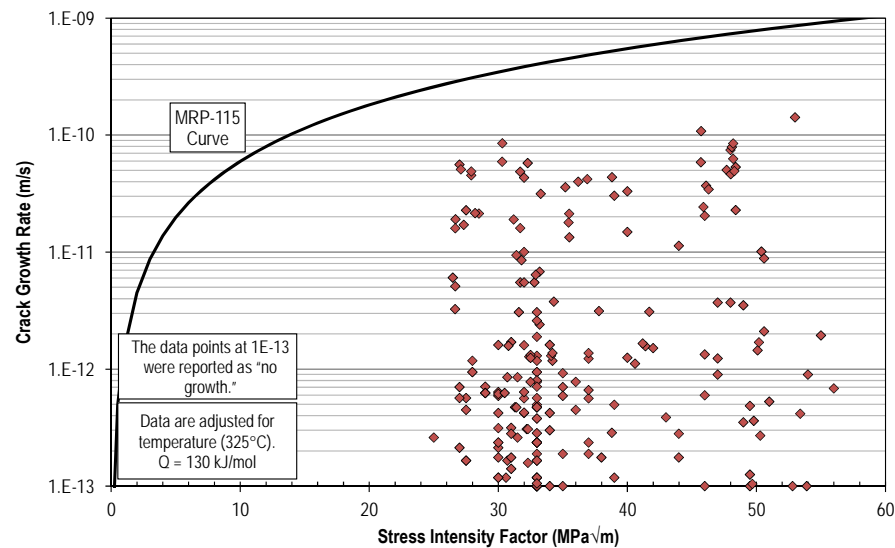
# PWSCC CGRs for Alloys 690/52/152

Data Evaluation Group

Alloy 690: 7 laboratories, 500+ data points



Alloy 52/152: 6 laboratories, 200+ data points



These plots show all data prior to screening.

# PWSCC CGRs for Alloys 690/52/152

## *Data Evaluation Group*

### ■ Scoring Administrative Approach

- The Data Evaluation group is now scoring the CGR data quality from a testing perspective, without consideration of the relevance of the data to particular plant applications
- The data are scored from 1 (relatively high reliability) to 5 (relatively low reliability) by each expert on both confidence in the test and confidence in the reported CGR value, the former of which is then averaged to determine an aggregate score
- An aggregate score of 3 has been used in previous modeling efforts (e.g., IASCC) as a cutoff for the data to be used in the development of the disposition curves, and it is reasonable to use this threshold for PWSCC also
- The effect of choosing cutoffs other than 3 on the results and conclusions will be investigated



# PWSCC CGRs for Alloys 690/52/152

## *Data Evaluation Group*

### ■ Key Issues to Consider When Assessing Data

- The data must be as complete as possible to ensure the correct scores are given; i.e., it is undesirable to score incomplete tests or specimens for which more information is available but has not yet been provided
- “No growth” data is reported as 1E-10 mm/s, which was determined by the experts to be a reasonable value below the detection limit of direct current potential drop (DCPD)
- All complete constant load (CL) / constant K (CK) data should be reported and scored for all specimens
- Data with partial periodic unloading (PPU) is under consideration as input to scoring subsequent CL/CK data.
- The more complex situation for weld interface data (including for weld dilution zones) will be considered after scoring of data for base metal and bulk weld metal. Additional research is ongoing.
- Due to the particular PWSCC test behavior and challenges of high-Cr materials, the experts identified attributes to consider when scoring the data, but they decided not to develop prescriptive scoring criteria, akin to those used for Alloys 600/82/182/132

# PWSCC CGRs for Alloys 690/52/152

*Data Evaluation Group*

## ■ Attributes to Be Considered When Scoring Data

- Fractography
  - Crack front engagement
  - Crack front straightness
  - Intergranular (IG) morphology
  - Off-plane cracking
- Consistency of PWSCC behavior throughout test
- Cyclic CGR response
- IG transitioning
- Loading conditions and control
- CGR estimation from data
- Full specimen test record availability
- Crack extension
- Test duration
- Stability of test conditions
- Post-test correction
- Hardness / yield strength data

# PWSCC CGRs for Alloys 690/52/152

## *Data Evaluation Group*

### ■ Scoring Progress

- An initial subset of 36 data points, spanning various conditions of Alloy 690, Alloy 690 heat affected zone (HAZ), and Alloy 52/152, were selected for the Data Evaluation Group to score
- The scores for each of the 36 data points were discussed at an early-May meeting, along with the approach to this phase of scoring
- The experts came to good agreement on scores for much of the data, and there is reasonable agreement on the key aspects to be considered in the scoring process
- Subsequent to the May meeting, another subset of ~75 data points was provided for the next round of scoring by June 12 conference call, with the remainder of the database to follow
- Conference calls and in-person meetings will support the Data Evaluation Group through the scoring process, such as to discuss complex data points and the various approaches to scoring the data
- Key remaining tasks after scoring:
  - Develop position on existing CGR data for weld metal interfaces
  - Document work and positions in report

# PWSCC CGRs for Alloys 690/52/152

## *Applications Group*

- The Applications Group will review the compiled data, including the materials database on the specimens used for CGR testing:
  - Heat/weld number, post-supplier processing information, material properties, etc.
- Attributes to be reviewed include:
  - Relevance of test materials and post-supplier processing to plant components
  - Specimen orientations included in database and orientations relevant to plant component geometries
  - Effects of added deformation
- Once the CGR database has been scored by the Data Evaluation experts, the Applications experts will develop and apply a statistical process to the scored database to produce disposition equations for Alloys 690/52/152
- This methodology, the positions developed, and the statistical results will be documented in the final report

# PWSCC CGRs for Alloys 600/82/182/132

## *Status and Next Steps*

- Laboratory CGR data generated since MRP-55 and MRP-115 were published in 2002 and 2004, respectively, have been collected and assessed using the original screening and statistical methods
- The newer data are generally consistent with the original data, both in terms of mean behavior and data scatter
- Therefore, the current plan is to concentrate efforts of the experts on reviewing the test data and developing technical positions on the following four issues which were not explicitly evaluated in MRP-55 and MRP-115:
  - Low stress intensity factor (K) for Alloys 600 and 82/182/132
    - $K < 15$  to  $20 \text{ MPa}\sqrt{\text{m}}$
  - Alloy 600 HAZ
  - Cold-worked Alloy 600
  - Effect of post-weld heat treatment of adjacent carbon or low-alloy steel on Alloys 600/82/182/132

# Current Schedule

- Kickoff Meeting – Data Evaluation and Applications Groups  
(July 2014)
- Collection of data and supplementary information  
(through May 2015)
- Meeting of the Data Evaluation Group to discuss the initial scoring of a subset of Alloy 690/52/152 data  
(May 5-6, 2015)
- Joint Meeting of the Data Evaluation and Applications Groups  
(July 14-15, 2015)
- Review and scoring of data for Alloys 690/52/152  
(Spring – Fall 2015)
- Statistical assessment of scored data for Alloys 690/52/152  
(Fall 2015 – Spring 2016)
- Writing of CGR report  
(Spring – Fall 2016)
- Publication of final report by EPRI  
(End of 2016)

# Plans for July 14-15 Experts Meeting

- Meeting of Data Evaluation Experts
  - Continue scoring data points for test quality
  - Set plan for scoring remaining data
- Meeting of Applications Experts
  - Relevance of test conditions and specimen orientations to plant applications for Alloys 690/52/152
  - Initial options for statistical treatment of lab data for Alloys 690/52/152
  - Statistical assessments already completed of new data for Alloys 600/82/182/132
- Joint Meeting
  - Approach to scoring lab data by Data Evaluation experts
  - Relevance of specimen orientations to plant applications
  - White paper on Alloy 52/152 weld interfaces in PWR plant applications
  - Planned expert review of particular issues for crack growth rate data for Alloys 600/82/182/132



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