EPRI

# MRP/NRC Senior Management Meeting

Materials Reliability Program

**Jack Bailey, TVA**
**Chairman, MRP Senior Representatives**

**Mike Short, Southern California Edison**
**Chairman, MRP Integration & Implementation Group**

**Mike Robinson, Duke Energy**
**Chairman, MRP Fatigue Issue Task Group**

**February 16, 2001, Washington, D.C.**

Materials Reliability Program

1

EPRI

## Meeting Objectives

- **MRP Overview**
- **MRP Status and Schedule**
- **RCS Hot Leg Cracking Issue**
- **Concerns and Issues - NRC/Industry**

Materials Reliability Program

2



Attachment 3

EPRI

## MRP Objectives

Provide a single utility-directed oversight structure to proactively address and resolve, on a consistent industry-wide basis, PWR material-related issues.

The specific objectives are to:

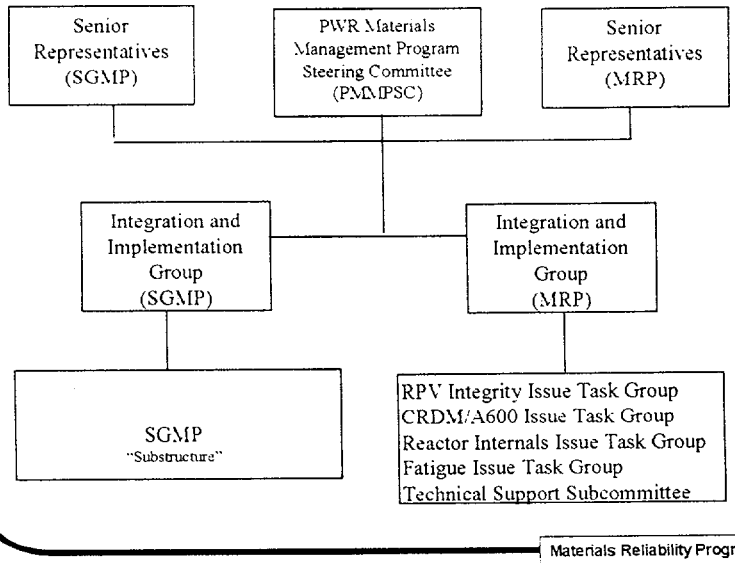
- **Resolve existing and emerging PWR materials performance, reliability, operational and regulatory issues**
- **With the direct involvement of NEI, serve as the industry focal point for PWR materials related regulatory issues**
- **Integrate NSSS OG activities with MRP**

Materials Reliability Program

3

EPRI

## MRP Structure




Materials Reliability Program

4

EPRI

## PWR Materials Management Program Steering Committee (PMMPSC)

J. Woodard, SNOC *(Chairman)*

J. Bailey, TVA
J. Baumstark, ConEd
William H. Bohlke, Exelon
D. Christian, Dominion Generation
T. Cloninger, South Texas Project
Joe Donahue, CP&L/FPC
J. Holden, Florida Power Corp.

Michael Tuckman, Duke Energy *(Co-Chairman)*

C. Hutchinson, Entergy
R. Mecredy, RG&E
T. Mitchell, INPO
A. Marion, NEI
L. Womack II, PG&E

Materials Reliability Program

5

EPRI

## Benefits

- Improved Nuclear Safety & Reliability
- Focus on Issue Closure
  - Consistent Industry Approach and Methods
  - Efficient Regulatory Processes
- Industry Focal Point for Issue Resolution
- Integrated Industry Understanding
- Effective Use of Resources
- License Renewal Support

Materials Reliability Program

6

EPRI

## MRP Issue Task Groups Status

| | |
|---|---|
| – CRDM/Alloy 600 ITG | Larry Matthews, SNOC |
| – Fatigue ITG | Mike Robinson, DEC |
| – RPV Integrity ITG | Bob Hardies, BG&E |
| – RPV Internals ITG | Jeff Gilreath, DEC |

Materials Reliability Program

7

EPRI

## Fatigue Issue Task Group

Goals

1. Provide a consistent set of guidelines for addressing piping thermal fatigue issues (non-design basis thermal cycling/stratification) in small bore Class 1 piping attached to but unisolable from the RCS

2. Provide license renewal applicants with acceptable methods for the management of reactor water environmental effects on the fatigue life of metal components

Materials Reliability Program

8

EPRI

# Fatigue Issue Task Group

Status

- Interim Thermal Fatigue Management Guidelines Issued
- Guidelines for Addressing Fatigue Environmental Effects developed and submitted for NRC Staff review
- 4 Meetings with NRC Staff on the Project
  - 1/12/00 Provide status on thermal fatigue project
  - 11/28/00 Review fatigue environmental effects project plan
  - 11/29/00 Provide status on thermal fatigue project
  - 1/31/01 Resolve Staff comments on Fatigue Environmental Effects Guidelines
- NRC Staff participation in project meetings
- Joint sponsorship of First International Fatigue Conference

Materials Reliability Program

9

EPRI

# Fatigue Issue Task Group

Thermal Fatigue Key Deliverables

| | |
|---|---|
| • Thermal Fatigue Operating Experience | Complete |
| • Thermal Fatigue Mitigation Guidelines | Complete |
| • Thermal Fatigue Inspection Technology | Complete |
| • Interim Thermal Fatigue Management Guidelines | Complete |
| • Plant specific Training Workshops | On-going |
| • Thermal Fatigue Monitoring Guidelines | 3rd Qtr. 2001 |
| • Thermal Fatigue Screening Guidelines | 2nd Qtr. 2002 |
| • Final Thermal Fatigue Management Guidelines | 4th Qtr. 2002 |

Materials Reliability Program

10

EPRI

# Fatigue Issue Task Group

Fatigue Environmental Effects Key Deliverables

- **Fatigue Environmental Effects Guidelines, Rev 0** — **2nd Qtr. 2001**
  - Need NRC review and acceptance
  - Need credit for conservatism in existing fatigue design basis for moderate environmental effects (Z Factor)
- **Fatigue Environmental Effects Data Review** — **3rd Qtr. 2001**
- **Fatigue Environmental Effects Tests** — **2th Qtr. 2003**
- **Fatigue Environmental Effects Guidelines, Rev 1** — **4th Qtr. 2003**

Materials Reliability Program

11

EPRI

# Reactor Pressure Vessel Integrity

Goal: To resolve reactor pressure vessel integrity challenges to plant operations by 2004

Materials Reliability Program

12

EPRI

## Reactor Pressure Vessel Integrity Issue Task Group

Key Program Areas in 2000

- Re-evaluation of PTS screening criteria
  - joint effort with NRC
- Master Curve Approach (MCA) for RPV integrity assessment
- Support activities
  - RPVDATA: RPV material property database
  - P-T limit curve software
  - Codes and Standards development - ASME and ASTM

Materials Reliability Program

13

EPRI

## Reactor Pressure Vessel Integrity Issue Task Group – 2000 Status

PTS Re-Evaluation Effort

- Coordinated utility plant-specific participation
  - Beaver Valley, Calvert Cliffs, Oconee, Palisades
- Expert participation in PRA, PFM, TH, subgroup activities
  - Developed methodology to evaluate uncertainty in $K_{IC}/K_{IR}$ and $RT_{NDT}$
  - Participated in NRC expert elicitation for flaw distribution development
  - Independent review/analysis of proposed embrittlement correlation
  - Determination of future possible FAVOR modifications (sensitivity studies on various inputs, Master Curve, etc.)
  - Development of RELAP input for Beaver Valley
  - Initiated independent evaluation of LERF considerations

Materials Reliability Program

14

EPRI

## Reactor Pressure Vessel Integrity Issue Task Group – 2000 Status

Master Curve Approach (MCA)

- Supported resolution of technical issues for MCA application to RPV integrity assessment
  - Continued development of physical basis for MCA for application to irradiated materials
  - Developed validation of MCA (as outlined in ASME Code Case) for RPV integrity assessment
  - Participated in IAEA Coordinated Research Program (CRP)
- Supported Plant-Specific Application of MCA
  - Provided independent review for Kewaunee Master Curve submittal supported generic issue resolution

Materials Reliability Program

15

EPRI

## Reactor Pressure Vessel Integrity Issue Task Group – 2000 Accomplishments

- Technical Reports/Software
  - Review of Phosphorus Segregation and Intergranular Embrittlement in Reactor Pressure Vessel Steels
  - RPVDATA: Reactor Vessel Materials Database
  - PT Calculator for Windows
  - Validation of Master Curve Fracture Toughness Methodology for RPV Integrity Assessment
- Progress/Letter Reports
  - Establishing a Physical Basis for the Master Curve
  - The Effect of Dynamic Strain Aging on Transition Region Fracture Toughness
  - $K_{IC}/K_{IA}$ Uncertainty Characterization
  - Independent statistical/mechanistic review of proposed embrittlement correlation models

Materials Reliability Program

16

EPRI

## Reactor Pressure Vessel Integrity Issue Task Group – 2001 Activities

PTS Re-Evaluation Effort

- Continue expert participation on PRA, TH, PFM subgroups and provide necessary technical support
- Initiate V&V efforts on FAVOR code
- Independent review of TH and PRA analyses
- Support embrittlement correlation input for PFM analysis
  - Support resolution of application issues – attenuation, flux effect, P, etc.
  - Finalize independent mechanistic/statistical recommendations
- Support evaluation of LERF impact on PTS Risk

Materials Reliability Program

17

EPRI

## Reactor Pressure Vessel Integrity Issue Task Group – 2001 Activities

Master Curve Approach

- Support Beaver Valley MCA application
- Continue participation in IAEA CRP
  - Resolve MCA application issues
  - Begin development of RPV integrity assessment guidelines
- Complete and document Master Curve physical basis
- Support ongoing ASME/ASTM activities regarding MCA application and operating plant criteria

Materials Reliability Program

18

EPRI

## Reactor Internals Issue Task Group

Goal: To proactively manage RPV internals aging issues

Materials Reliability Program

19

EPRI

Reactor Internals Issue Task Group

Objectives:

- **Serve as the industry lead for resolution of reactor internals material degradation issues**
  - Implement programs to identify and evaluate potential aging effects
  - Conduct research, gather OE, and inspection results on the effects of aging mechanisms on reactor internals, potential to occur, and consequences
  - Serve as focal point for communication with the NRC on aging issues for reactor internals components
  - Support development of effective strategies for long term aging management of internals components (life extension)

Materials Reliability Program

20

EPRI

## Reactor Internals Issue Task Group
## 2000 Key Deliverables

2000 Products

- **JOBB – CD Version of EDF Inspection and Materials R&D Reports**
- **Interim Report on Hot Cell Testing of Lead Plants Bolts**
- **Inspection and Replacement of Baffle to Former Bolts at Point Beach-2 and Ginna**
- **EPRI Baffle Bolt Project Summary**

Materials Reliability Program

21

EPRI

## Reactor Internals Issue Task Group
## 2001 Key Deliverables

- Technical Basis Document for Evaluation of Void Swelling and Stress Relaxation in PWR Internals Due to Irradiation
- Final Report on Hot Cell Material Testing of Baffle/Former Bolts Removed from Two Lead Plants
- White Paper on Irradiation Embrittlement
- JOBB: 2001 EDF Inspection and Materials R&D
- Strategy and program assessment by third party to identify enhancements or program needs
- US PWR materials irradiated in Boris 60 reactor

Materials Reliability Program

22

EPRI

## Reactor Internals ITG Meetings with NRC in 2000

- NRC Visiting Westinghouse Hot Cell -- March 22, 2000
  - Hot cell facilities tour
  - Hot cell testing of extracted bolts from Westinghouse plants
- NRC, WOG, BWOG and MRP meeting at NRC -- April 18, 2000
  - PWR MRP Reactor Internals ITG/JoBB Program and Status
  - WOG Baffle Barrel Bolting Program status and lead plant results
  - WOG Generic Technical Report on Aging Management of Reactor Internals

Materials Reliability Program

23

EPRI

## Concluding Remarks

Materials Reliability Program

24

EPRI

# Industry Response
# Alloy 82/182 Weld Cracking

## NRC Briefing – February 16, 2001

**Materials Reliability Program**
**Alloy 600 Issue Task Group (ITG)**

Larry Mathews, SNC, Chairman
Al McIlree, EPRI Project Manager

MRP- A600 ITG

1

EPRI

## Background

- There have been two recent through-wall cracks in Alloy 82/182 welds in domestic PWR plants
  - A short through-wall axial crack in a hot leg nozzle safe end weld at VC Summer
  - An axial-radial crack through a CRDM nozzle J-groove weld at Oconee 1
- Both cracks were found by visual detection of boric acid crystals

MRP- A600 ITG

2



Attachment 4

EPRI

## Background (cont.)

- Both of the leaks have been repaired
  - A 12" long section of the VC Summer hot leg pipe containing the leaking weld was replaced with a new section of stainless steel pipe with Alloy 52/152 weld metal
  - The cracked portion of the Oconee 1 CRDM nozzle weld was ground out and weld repaired with Alloy 152 weld metal

MRP- A600 ITG

3

EPRI

## NRC Questions Regarding Summer Crack

- Are inspection techniques other than UT appropriate
- Qualification of alternative techniques
- What qualified UT techniques are used by industry
- Capabilities of UT techniques for "Summer-type" flaws
- Applicability/benefit of enhancing leakage detection capabilities
- Scope of the problem, ie. where are the Alloy 82/182 welds and what are safety consequences, if any, of cracks
- Impact on leak before break (LBB)
- Impact on inspection intervals

MRP- A600 ITG

4

EPRI

## Industry Response to Generic Implications

- MRP A600 ITG has taken the lead in developing the industry plan
  - VC Summer event Oct, 2000
  - Root Cause information early Dec, 2000
  - IIG Recommended Industry Program mid Dec.
- Executive approval early Jan, 2001
  - Developed organization
  - Developed detailed plan and budget
- ITG organized 1/19/01 to address key focus areas
  - Assessment Committee
  - Inspection Committee
  - Repair/Mitigation Committee

MRP- A600 ITG

5

EPRI

## Industry Response to Generic Implications

- I/25/01 Meeting with NRC
  - Outline approach
  - Solicit feedback
- 2/1/01 Initial meetings of Inspection and Assessment Committees
  - develop plan, schedule, and budget

MRP- A600 ITG

6

EPRI

# MRP Status
# February 16, 2001

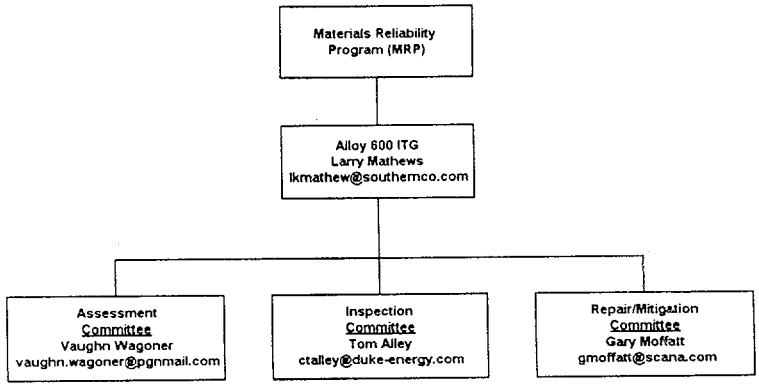
- The industry plan includes:
  - Short term assessment to demonstrate that continued operation with Alloy 82/182 welds is acceptable, by late March.
  - Interim inspection guidance for near term outage plants ASAP
  - Longer term assessment of all Alloy 82/182 applications in PWR primary systems
  - Review and improvement of inspection technology
  - Review of repair/mitigation methods and improvement if necessary
- Endorsement of plan by Senior Representatives is anticipated at their meeting on 03/09/01



MRP- A600 ITG

EPRI

# MRP/ITG Organization

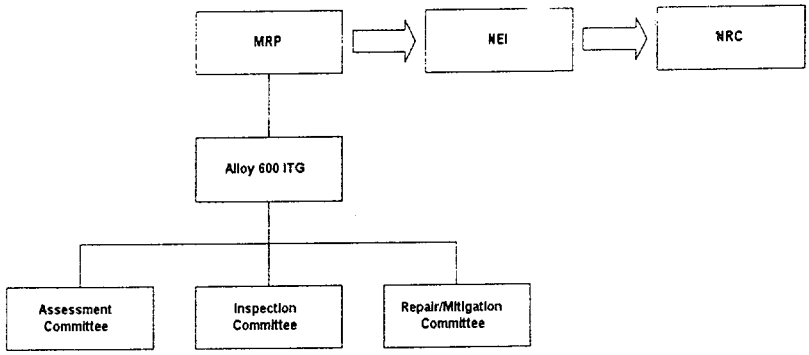





MRP- A600 ITG

EPRI

## Coordination of Overall Effort




MRP- A600 ITG

9

EPRI

## Assessment Committee Activities

- **Short Term Safety Assessment**
  - **Identify area likely to be most susceptible**
    - » Evaluate size, temperature, and weld materials
    - » W and CE – likely to be hot leg pipe welds
    - » B&W – likely to be CRDM nozzle welds
  - **Demonstrate that most cracks will be axial, or axial-radial in case of CRDM nozzle welds**
    - » Domestic and international experience with similar welds
    - » Finite element stress analysis including welding residual and operating stresses

MRP- A600 ITG

10

EPRI

## Assessment Committee Activities (cont.)

- **Short term Safety Assessment (cont'd)**
  - **Demonstrate large tolerance for axial flaws**
    - » Stress analyses indicate preference for axial cracking
    - » Flaw limited to axial length of pipe weld
    - » Flaw limited to J-groove and nozzle thickness for CRDM welds
    - » Limit load and fracture mechanics analyses will show large margin
  - **Demonstrate large tolerance for circumferential flaws**
    - » Leakage will be detected from partial-arc flaws while there is still large margin on limit load

MRP- A600 ITG

11

EPRI

## Weld Assessment Technical Approach (cont.)

- **Short term Safety Assessment (cont'd)**
  - **Pipe weld failures are covered by Defense-in-Depth (pipe failure has been analyzed in the SARs)**
  - **Visual inspections for boric acid have been effective in identifying leaks well before any structural margins are affected**

MRP- A600 ITG

12

EPRI

## Weld Assessment Technical Approach (cont.)

- Longer Term Action
  - Complete scope definition
  - Evaluate generic applicability
    - » Finite element analyses, including operating and residual stresses
  - Assess safety significance
  - Prioritize locations based on safety significance, NDE capabilities, and actual experiences
  - Determine inspection requirements
  - Develop consistent flaw evaluation guidelines
  - Assess research needs and oversee tasks
    - » Coordination with ongoing CGR work



MRP- A600 ITG

EPRI

## Inspection Committee Activities

- Short Term Inspection Guidance
  - Develop consistent inspection approach
    - » ID UT still considered best available technique
    - » Considered adequate for upcoming spring outages
    - » Demonstrations on EPRI mockup
  - Enhanced awareness of inspectors to signal anomalies
  - Review previous inspection data for geometry, signal quality, etc.
  - Review fabrication records for geometry, repair history, etc.
  - Enhanced sensitivity for boric acid walkdown
    - » Visual inspections are effective
  - Enhanced awareness of Operations/Chemistry personnel during operation



MRP- A600 ITG

EPRI

## Inspection Committee Activities (cont'd)

- Longer Term Actions
  - Evaluate need for alternate/new techniques
    - » Evolving Vendor capabilities
    - » International capabilities
    - » Geometry concerns
  - Evaluate Spring Inspection results/feedback to Fall plants
  - Define additional mockup needs
  - Work with vendors on delivery systems
  - Coordination of demonstrations with current App. VIII actions
  - Provide training/expert help to utilities
  - Evaluate impact on Risk Informed ISI



MRP- A600 ITG

EPRI

## Repair/Mitigation Committee

- Need for repair/mitigation improvements depends on Assessment and Inspection Committee findings
- Prioritize from repair/mitigation/inspection perspective
  - Likelihood/consequence of failure
  - Implementation difficulty
  - Cost and dose
  - Material availability
- Create a repair/mitigation matrix
  - Assess existing technology
  - Qualification and demonstration
  - Code and regulatory compliance/involvement



MRP- A600 ITG

EPRI

## Schedule

- Technical working meeting with NRC in March
  - Describe detailed approach
  - Discuss preliminary findings
  - Solicit feedback
  - Arrange NRC visit to NDE Center
- Short term Assessment/Inspection effort completed in March
  - Safety Assessment of Alloy 82/182 welds
  - Inspection guidance for Spring 2001 outages
- Longer Term
  - Assessment/Inspection effort complete in June
    - » Evaluation of Spring 2001 inspections
    - » Assessment of all Alloy 82/182 welds
  - Assessment of all Alloy 600 applications, inspection and repair/mitigation technology, research efforts

MRP- A600 ITG

17

EPRI

## CONCLUSIONS

- MRP A600 ITG has taken the lead in developing the industry plan
- Not a near term safety issue
  - Visual inspections for boric acid are effective
  - Pipe weld failures are covered by Defense-in-Depth (pipe failure has been analyzed in the SARs)
  - Short term assessment to demonstrate that continued operation with Alloy 82/182 welds is acceptable, by late March
- Interim inspection guidance for near term outage plants ASAP
- Longer term assessment of all Alloy 600 and Alloy 82/182 applications in PWR primary systems, including inspection, repair, and mitigation
- Will continue to keep NRC informed

MRP- A600 ITG

18

EPRI

# Status of RV Head Penetration Program

## NRC Briefing – February 16, 2001

**Materials Reliability Program**
**Alloy 600 Issue Task Group (ITG)**

**Larry Mathews, SNC, Chairman**
**Al McIlree, EPRI Project Manager**

MRP- A600 ITG

1

EPRI

# Status of RV Head Penetration Program

- Update on the CRDM/ Alloy 600 Issue Task Group (ITG) activities provided to Mr. Strosnider in Nov. letter
  - The letter reported on four active tasks;
    - » PWSCC Mitigation Testing
    - » Survey of domestic PWSCC experience, excluding SG tubing
    - » PWSCC Inspection and Evaluation Guidelines for RV Head Penetration Nozzles
    - » EDF Crack Growth Results for Alloy 182 Weld Metal

MRP- A600 ITG

2



Attachment 5

EPRI

## Status of RV Head Penetration Program (continued)

- The November letter also reported on published EPRI reports on six completed tasks;
  - » Proceedings of a fifth EPRI Workshop on Alloy 600 PWSCC
  - » Crack Initiation Testing of Alloy 600 RVH Materials ranking heats by microstructure.
  - » Crack Growth Rates of Alloy 600 RVH Materials ranking heats by microstructure
  - » Crack Growth Rates of EDF Alloy 600 CRDM Nozzles
  - » Crack Growth Rates of Alloy 182 Weld Metal
  - » Development of Predictive PWSCC Model as a module for EPRI CHECWORKS

MRP- A600 ITG

3

EPRI

## Status of RV Head Penetration Program (continued)

- For the Four Active Tasks, the current year plans are:
  - » PWSCC Mitigation Testing: Specimens undergoing lab examination now. Results published by mid year.
  - » Survey of Domestic PWSCC Experience: Will be updated to include all Alloy 600 and 82/182 weld metals. Published report planned for mid year.
  - » PWSCC Inspection and Evaluation Guidelines: Will available by the end of this year.
  - » EDF Crack Growth testing of Alloy 182 Weld Metal: Published by mid 2002.

MRP- A600 ITG

4

EPRI

# Status of RV Head Penetration Program (continued)

- Highlights of the six completed tasks;
  - » Proceedings of Fifth EPRI Workshop on Alloy 600 PWSCC
    - Domestic and international industries
    - Recent industry experiences
    - New developments in inspection, repair and remedial measures, crack initiation and growth testing and modeling, and strategic planning.
  - » Crack Initiation Testing of Alloy 600 RVH Materials ranking heats by microstructure.
    - 10 Alloy 600 and one Alloy 690 heats tested
      - 750 hrs. in doped steam environment
    - Alloy 690 did not crack
    - Alloy 600 materials
      - Higher grain boundary carbide (GBC) coverage and relatively large grain size showed lower susceptibility to SCC.

MRP- A600 ITG

5

EPRI

# Status of RV Head Penetration Program (continued)

- Highlights of the six completed tasks (continued);
  - » Crack Growth Rates of Alloy 600 RVH Materials ranking heats by microstructure.
    - Simulated primary water environment, 290°-330°C
    - Results consistent with the Scott correlation
      - Enhanced growth rates two heats with low GBC.
  - » Crack Growth Rates of EDF Alloy 600 CRDM Nozzles
    - EDF measured growth rates of CRDM nozzle service cracks.
    - 180 cracks monitored via successive UT inspections
    - Maximum growth rate of 0.46 micron/hr
    - Average growth rate of 0.12 micron/hr
    - Crack growth experience generally consistent with domestic crack growth laboratory testing.

MRP- A600 ITG

6

EPRI

# Status of RV Head Penetration Program (continued)

- Highlights of the six completed tasks (continued);
  - » Crack Growth Rates of Alloy 182 Weld Metal
    - 17 specimens from three heats
    - Crack growth in all specimens was interdendritic.
    - Crack fronts uneven on all specimens and non-planar in some
    - Effects of temperature and stress intensity factor similar to Alloy 600
    - Crack growth rates up to 5 times higher than Alloy 600
    - Crack growth parallel to weld dendrites 5 to 10 times higher than around dendrites.
  - » Development of Predictive PWSCC Model as a module for EPRI CHECWORKS
    - EPRI model incorporated into the CHECWORKS software suite
    - Allows plants to evaluate inspection and repair strategies
      - Based on crack probability and costs

MRP- A600 ITG

7