



**Industry and NRC Coordination Meeting on PWR and  
BWR Materials Issues**

**OD-Initiated SCC of Stainless Steel (PA-MS-C-0474)**

Maurice (Mo) Dingler - PWROG Vice Chairman, WCNOG

May 25-26, 2010

PWR Owners Group  
Industry and NRC Coordination Meeting  
on PWR and BWR Materials Issues  
**OD-Initiated SCC of Stainless Steel**

*PWROG MSC SCC of SS Strategic Plan:*

- Guidance document for PWROG program addressing issues related to SCC (ID and OD-initiated) of stainless steel in PWR internal and external environments
- Consideration of OD-initiated SCC was recently added

PWR Owners Group  
Industry and NRC Coordination Meeting  
on PWR and BWR Materials Issues  
**OD-Initiated SCC of Stainless Steel**

*Goals of the MSC Stainless Steel Strategic Plan:*

- Develop PWROG/EPRI MRP multi-phase programs to understand the PWR conditions that are required to cause SCC of stainless steel and to develop the I&E guidance required to manage the SCC of stainless steel issue
  - EPRI MRP test program currently underway
    - Program currently focused on ID-initiated SCC, but may be expanded to OD-initiated SCC if available literature does not thoroughly cover the factors involved (stress, environment, material)
  - PWROG program to develop I&E guidelines (proposed)
    - Program would consider ID and OD-initiated SCC

PWR Owners Group  
Industry and NRC Coordination Meeting  
on PWR and BWR Materials Issues  
**OD-Initiated SCC of Stainless Steel**

*Goals of the MSC Stainless Steel Strategic Plan (Cont.):*

- Target: 2011-2012
  - Document current understanding of the internal and external PWR conditions which are required to cause SCC (ID and OD-initiated) of stainless steel
    - Phase 1 of stainless steel I&E Guidelines program (proposed)
  - Review PWR Primary Water Chemistry Guidelines for any modifications
- Target: 2013-2015
  - Complete I&E Guidelines under the NEI-03-08 protocol
  - Issue is being managed by the entire PWR fleet
  - Minimize any unplanned outages or extension of planned outages in PWR fleet because of the SCC (ID and OD-initiated) of stainless and issue

PWR Owners Group  
Industry and NRC Coordination Meeting  
on PWR and BWR Materials Issues  
**OD-Initiated SCC of Stainless Steel**

- PWROG OD-initiated SCC of SS White Paper
  - Developed by PWROG in response to the recent OE at Callaway, Wolf Creek and San Onofre
  - Purpose
    - Evaluate a cross-section of observed occurrences of OD-initiated SCC of SS piping components in the PWR industry
    - Make a preliminary assessment of the issue

**PWR Owners Group**  
**Industry and NRC Coordination Meeting**  
**on PWR and BWR Materials Issues**  
**OD-Initiated SCC of Stainless Steel**

<b>Component</b>	<b>Nominal Size</b>	<b>Temperature</b>	<b>Contaminant</b>	<b>Stress Source</b>	<b>Service Life/Found</b>
PZR Aux Spray Line	2" Sch. 160	550°F in use and 80-110°F not	Chlorides (crevice)	Pitting and 2250 psi pressurized pipe	24 years /2008
PZR Aux Spray Line	2" Sch. 160	550°F in use and 80-110°F not	Chlorides (crevice)	Pitting and 2250 psi pressurized pipe	24 years /2008
ECCS suction piping	24" Sch. 10	Ambient (marine atmosphere)	Chlorides (marine environment)	Residual stress in weld HAZ	25 years /2009
Alternate boration gravity feed to charging line	6" Sch. 10	Ambient (marine atmosphere)	Chlorides (marine environment)	Residual stress in weld HAZ	25 years /2009
ECCS mini flow return to RWST	Not available	Ambient (marine atmosphere)	Chlorides (marine environment)	Residual stress in weld HAZ	25 years /2009
Inlet piping to residual heat removal pump relief valve	Not available	Not available	Chlorides (non standard insulation)	Residual stress in weld HAZ	7 years /1997
CVCS standby charging pipe	Not available	120-212°F During start up	Chlorides (Vinyl chloride tape)	Pitting and pressurized pipe	23 years /2000
CVCS BA transfer line	1" Sch. 40	175-185°F Normal operation	Chlorides (alternate wet/dry)	Not available	3 years /1986
CVCS BA transfer line	¾"-3" Sch. 40	180°F (1 <sup>st</sup> 19 years) and 130°F (4 years)	Chlorides (alternate wet/dry)	Residual stress in weld HAZ	23 years /1995
ECCS suction piping	24" Sch. 10	Ambient (marine atmosphere)	Chlorides (marine environment)	Residual stress in field weld HAZ	16 years /1993
RCS instrument tubing	3/8" tubing	Not available	Chlorides (historic spills or leaks)	Residual stress in weld HAZ	29 years /2006
CRD hydraulic system piping	Not available	125°F	Chlorides (historical spill)	Pitting and 1300 psi pressurized pipe	8 years /1994
CRD hydraulic system piping	Not available	125°F	Chlorides (leaking seawater pipe)	Pitting and 1300 psi pressurized pipe	26 years /2002
Lower head safety injection piping in the valve pit	10" Sch. 40S	Not available	Chlorides (leaking ground water)	Residual stress in weld HAZ	27 years /2005

PWR Owners Group  
Industry and NRC Coordination Meeting  
on PWR and BWR Materials Issues  
**OD-Initiated SCC of Stainless Steel**

- Operating Experience
  - Considered 14 occurrences of ODSCC of SS at PWRs & BWRs
  - 10 occurred indoors in a controlled environment
    - 9 TGSCC and 1 IGSCC
  - 4 occurred in marine atmospheric conditions
    - All TGSCC
  - All observed SCC was in Type 304 SS (carbon likely >0.03 wt%)
  - Pipe thickness varied

No.	Pipe Schedule
3	10
3	40
2	160
6	Not reported

PWR Owners Group  
Industry and NRC Coordination Meeting  
on PWR and BWR Materials Issues  
**OD-Initiated SCC of Stainless Steel**

- Operating Experience (Indoors)
  - Environment
    - Aerated water
      - Moisture in air or water leaking on to affected pipe
    - Pipe temperature typically 120-212°F
    - Chlorides
      - Contamination event (VC tape, spills, leaking raw water)
      - Mechanism that concentrates trace chlorides over time
        - » Crevices, heat tracing, alternate wetted/dried
  - Stress
    - Residual stress due to welding
    - Stress concentration in pits coupled with operational stresses
  - Material
    - Type 304 SS susceptible to pitting corrosion
    - Sensitization played a role in at least one case



PWR Owners Group  
Industry and NRC Coordination Meeting  
on PWR and BWR Materials Issues  
**OD-Initiated SCC of Stainless Steel**

- Operating Experience (Marine Atmosphere)
  - Environment
    - Ambient temperature
    - Chlorides from salt water atmosphere
  - Stress
    - Residual stress due to welding and/or cold work
  - Material
    - Sensitized Type 304 SS
      - Sensitization is not required if the material is heavily cold worked

PWR Owners Group  
Industry and NRC Coordination Meeting  
on PWR and BWR Materials Issues  
**OD-Initiated SCC of Stainless Steel**

- Evaluation
  - Crack growth generally slow
    - Temperature
      - SCC crack growth increases with increasing temperature
      - ODSCC CGR limited by pipe surface temperature
    - Stress
      - Welding residual stress variable through thickness causing crack growth to slow
      - Operational stresses typically low relative to residual stresses
  - High fracture toughness
    - Type 304 SS is inherently ductile at all relevant temperatures
  - Crack Tightness
    - Leakage detectable long before critical flaw size reached

PWR Owners Group  
Industry and NRC Coordination Meeting  
on PWR and BWR Materials Issues  
**OD-Initiated SCC of Stainless Steel**

- Existing Inspection Requirements
  - GL 88-05
    - Walk down inspections of carbon & LAS piping
    - Indirect inspection of SS piping
  - ASME Section XI
    - Pressure Test
      - VT-2 of Class 1, 2 and 3
    - Welds
      - Surface & volumetric examination of Class 1 & 2
    - Welded attachments
      - Surface examination of Class 1 and 2
      - VT-1 of Class 3

PWR Owners Group  
Industry and NRC Coordination Meeting  
on PWR and BWR Materials Issues  
**OD-Initiated SCC of Stainless Steel**

- Status
  - Experience has demonstrated that GL 88-05 and ASME Section XI inspections, along with other plant activities, to be effective in identifying OD-initiated cracks or associated leaks long before critical flaw size is reached
    - Existing inspection requirements are adequate for addressing ODSCC of stainless steel in the near term
  - PWROG program to develop SS I&E guidelines
    - Program is currently in the approval process cycle
    - If approved, multi-year program would begin in 2010
    - Program would consider ID and OD-initiated SCC of SS
    - EPRI MRP SCC of SS test program would be utilized