GE Nuclear Energy

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For your records, enclosed are non-proprietary versions of the presentations made by GE Nuclear Energy to the NRC on June 30, 2000.

Regards,

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GE Nuclear Energy

Overview of 1999/2000 Shroud Support Cracking in Tsuruga 1

Tom Caine, GENE
June 30, 2000

Key Topics

- Plant History
- Background on Cracking Discovery
- Crack Location/Description
- Crack Disposition

General Information about Tsuruga Unit-1

- **Plant Type:** Three Loop BWR-2
- **Commercial Operation:** Mar. 14, 1970
- **Electrical Output:** 357 MWe
- **Current Outage:**
  - 26th R/M Outage started 8/20/1999
  - Main Task of Outage: Replacement of Major Internals, e.g Shroud, Core Plate, Top Guide.
  - Planned Duration of Outage: ~9 months
  - Current Estimated Outage Duration ~????

Background on Cracking Discovery

- Upper Shroud Support was cut just below the circumferential weld and removed.
- Cut edge of Lower Shroud Support was machined flat to install the new Upper Shroud Support.
- After machining, inspection of the machined surface was performed(VT). 9 indications were found (12/9/99).
- Shroud Support to RPV weld (H9) was also inspected(VT) and approximately 80 fine crack indications were found.
- Initial observations were reported to MITI and press(12/10/99) and complete examination of the shroud support commenced.

Examination Results

PT Examinations plus some metallurgical replicas completed by 12/22/99. Results were:

- 19 indications were found on ID of Lower Shroud Support(Alloy 600):
  - Maximum length 93mm
  - 11 developed along vertical welds
  - 8 on the base plate.
  - 1 indication on OD apparently penetrated from ID.
- Approximately 60 indications were found on ID of Upper Shroud Support.
  - All on or near the circumferential weld.
  - 4 of them apparently went to Lower Shroud Support across the weld.
  - 2 indications on OD apparently penetrated from ID.

Examination Results (cont'd)

- There were approximately 230 indications found on H9 weld.
  - All on ID side.
  - No indications on OD side(upper side) of weld
  - No indications on the surface of stainless steel cladding.

- Based on replica analysis, cracking was characterized as intergranular/interdendritic.

Crack Evaluation

- Crack samples were taken from Upper Shroud Support and Lower Shroud Support for metallurgical analysis.
  - A total of 17 replica samples were taken. 14 were analyzed. All indicated interdendritic/intergranular cracking.
  - A total of 13 crack samples were taken for metallurgical analysis including SEM of fracture surface. 9 were evaluated. Cracking in all cases was interdendritic/intergranular.
  - Exploratory excavation at 5 locations was attempted. Maximum depth was 34mm. None of the 5 reached low alloy steel.

Crack Disposition

- A total of 300 cracks were detected by VT and PT. Most exhibited axial cracking in the weld.
  - Maximum crack depth on vertical weld was 20mm
  - maximum crack depth of base metal was 18mm.
  - Base metal cracks associated with temporary attachment welds
- H9 weld:
  - All 228 cracks removed by grinding. There was no crack propagation into the low alloy steel, but 46 cracks were ground to the LAS interface.
  - The maximum depth was 44 mm.
  - Excavation work resulted in penetrating holes to OD surface at 6 locations.
- Most of lower shroud support will be removed.

Root Cause Evaluation

- Microscopy
  - Intergranular/interdendritic cracking; no indication of fatigue.
  - Initiation was in Alloy 182 with propagation into Alloy 600.
  - Oxide film evaluation showed propagation from ID to OD and from weld metal to base metal.
  - Hardness normal
- Chemical analysis matched CMTRs
- Similar Experience- NMP1(1995) and Monticello(2000)
- Fabrication History
  - Temporary attachments to inside of lower shroud support
  - PWHT performed after shroud support installation
  - Hydrotest to 1.5 operating pressure

Root Cause(cont.)

- Plant Operation
  - Normal water chemistry from startup to 1997.
  - Low level HWC from 1997 to 1999.
- Stress Analysis and Mockup
  - Extensive analysis performed by FEM and Mockup
  - Results correlated with observed cracking pattern, i.e. tensile stresses higher on ID and in hoop direction.

Root Cause Conclusion:
Cracking a combination of susceptible material(Alloy 182), environment(NWC), and residual stresses from fabrication.

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NobleChem™ Update

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Structural Assessment & Mitigation
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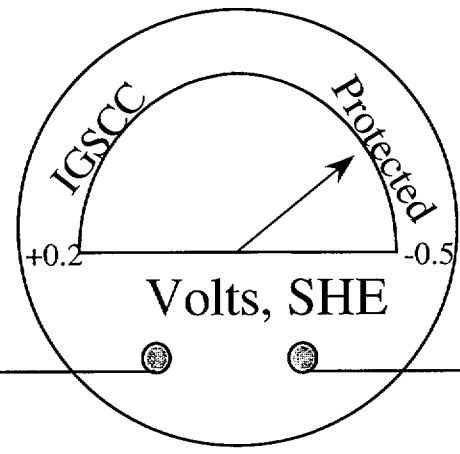
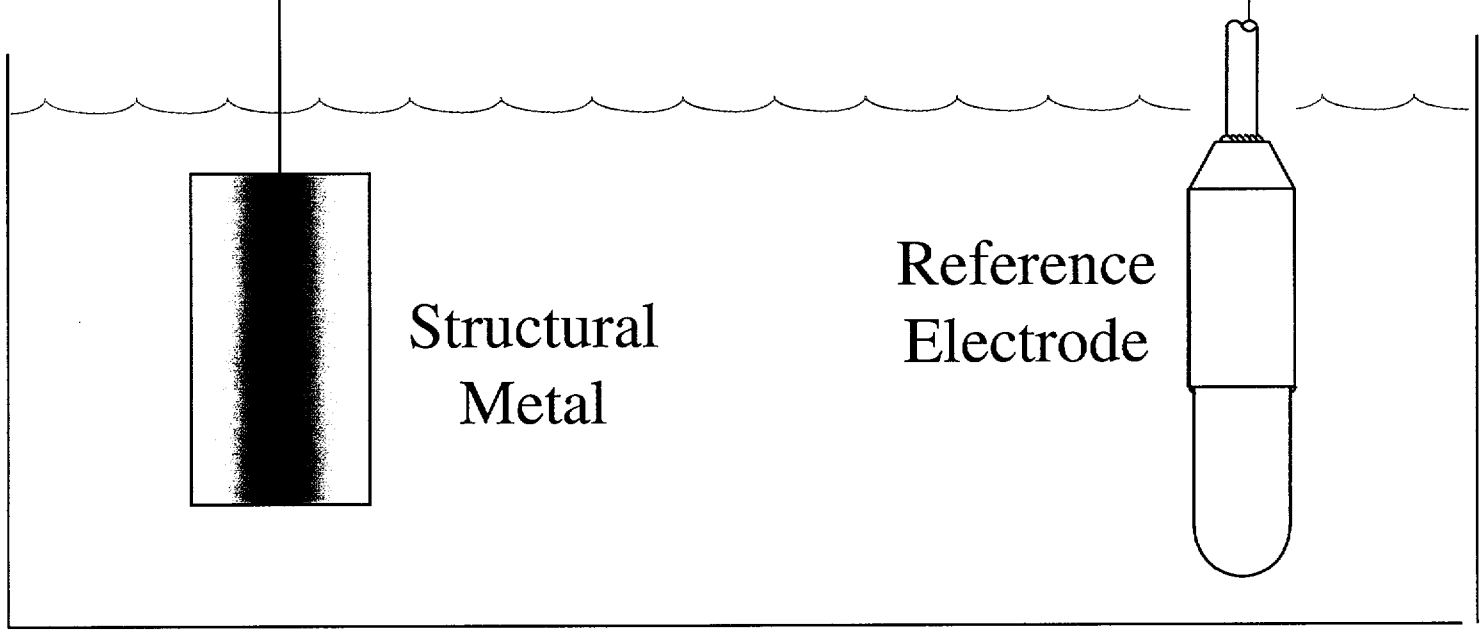
Electrochemical Corrosion Potential

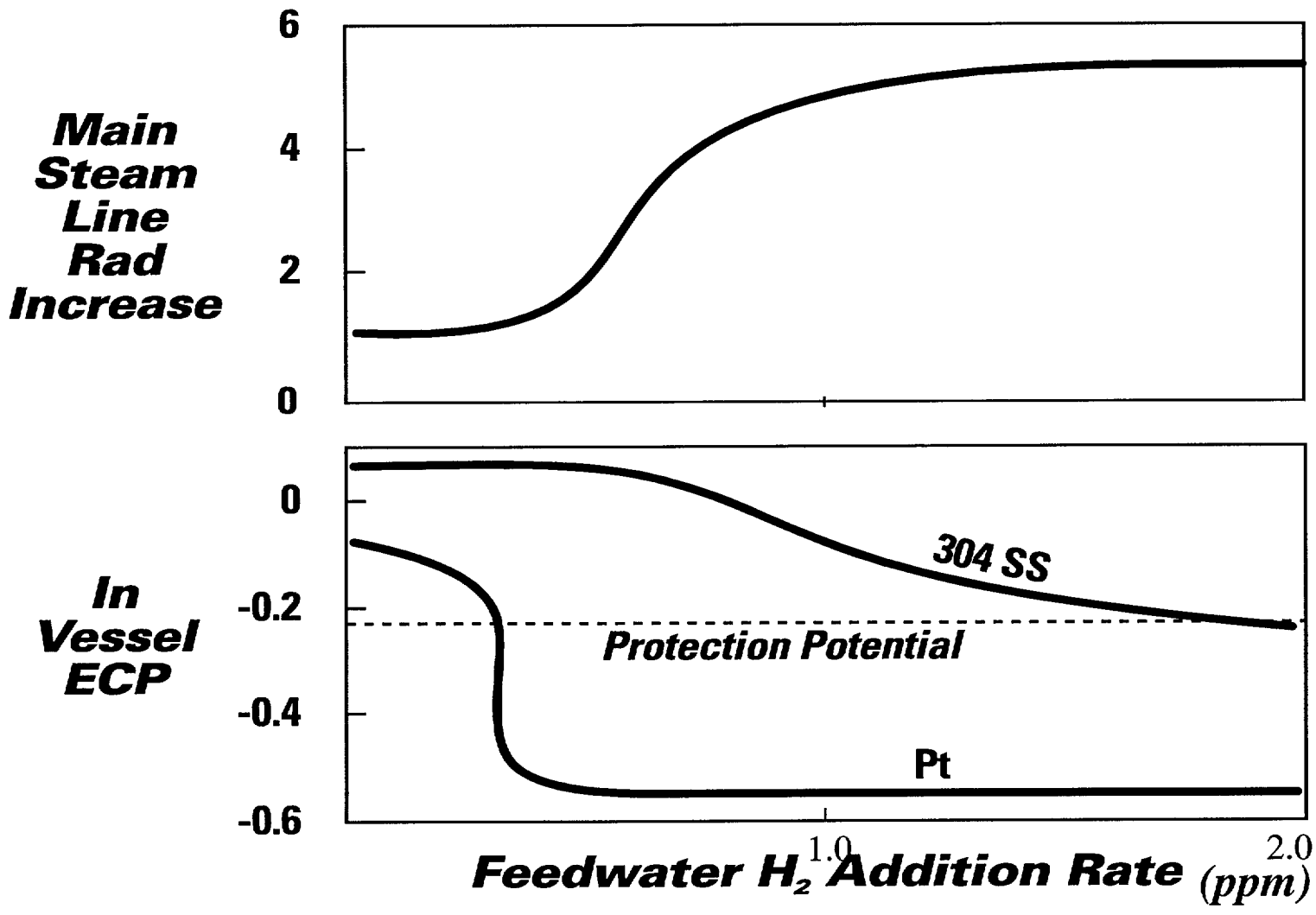
SHE = Standard Hydrogen Electrode Scale



E < -0.230 V,SHE

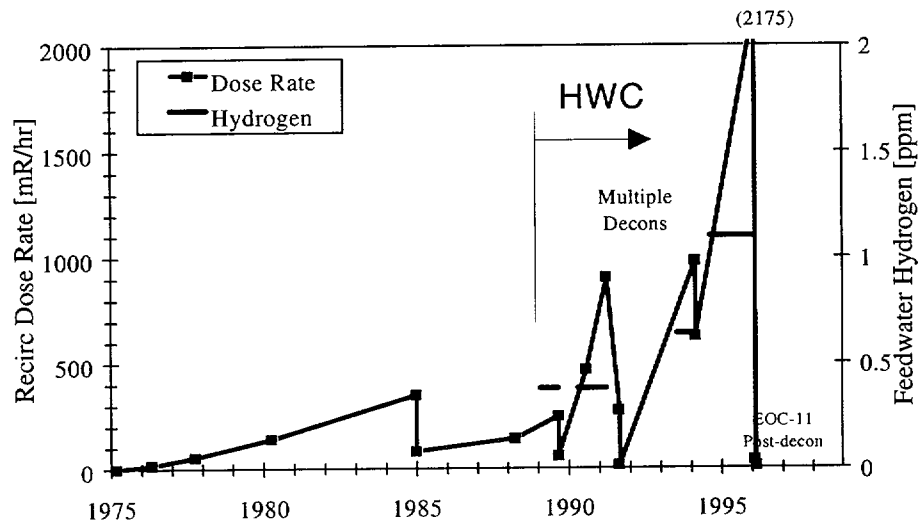


Basis for Noble Metal Technology

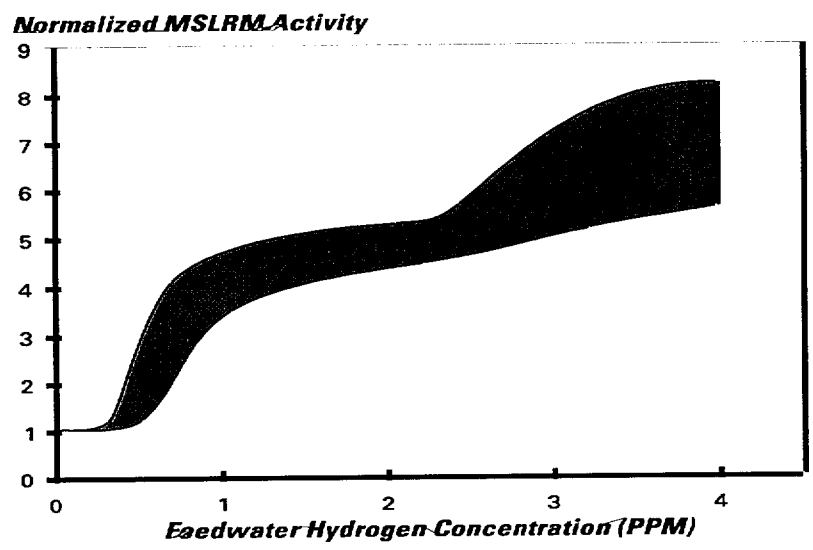


Hydrogen Water Chemistry...can be a headache!

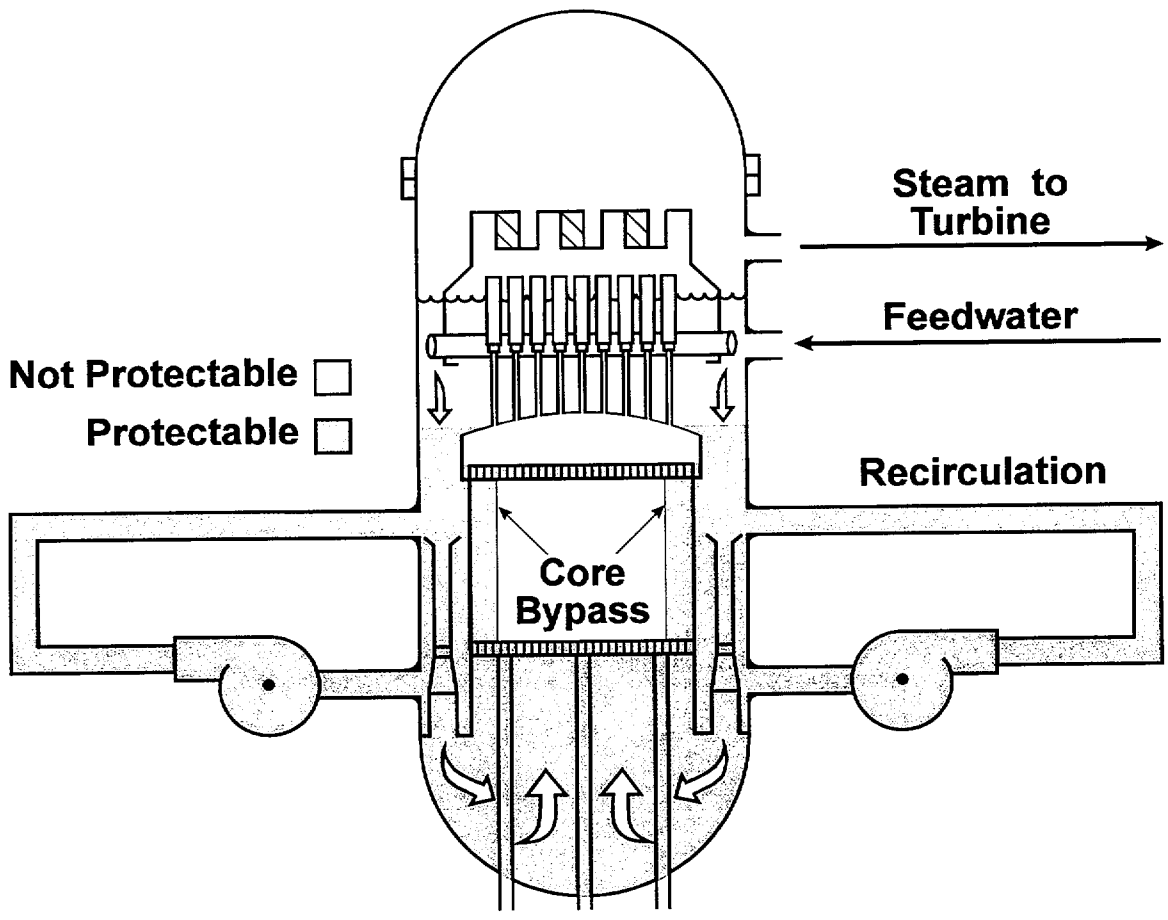
Can increase shut down dose rates



Can cause increased operating dose rates



Regions Protected by Noble Metal Technology



NobleChem™ Applications Summary

NobleChem™ Application Status

Plants applied
Duane Arnold (1996)
Peach Bottom 2 (1998)
Hatch 1 (1999)
Quad Cities 1 (1999)
Dresden 2 (1999)
Peach Bottom 3 (1999)
Duane Arnold -reapply (1999)
LaSalle 1 (1999)
FitzPatrick (1999)
Quad Cities 2 (2000)
Hatch 2 (2000)
Cooper (2000)
Limerick 1 (2000)
Browns Ferry 3 (2000)
Nine Mile Point 1 (2000)

NobleChem Application Roadmap

- Complete all paper work...the hard part!
  - Plant specific walkdown/assessment
  - Plant specific safety analysis
  - Application procedures
- Perform NobleChem Application
  - Install temporary injection/sampling skids
  - Bring reactor to application temperature
  - Inject Pt and Rh chemicals for 48 hours
  - Monitor chemistry and deposition
- Pack up and ship equipment
- Perform Benchmark Testing and Monitor Durability

Application/Demobilization Performed in < 5 days

NobleChem Process Improvements

- Deposition loading controlled by Pt and Rh mass injection
- Uniform coverage controlled by temperature
- "Real Time" deposition monitoring done during NobleChem application to assure total Pt and Rh deposition target is met
- Computer model utilizing actual plant deposition during injection to monitor and predict process expectations
- Defined decision points to allow adjustments to be made if deposition kinetics are affected by plant unique influences

Reactor Temperature Control During NobleChem Application

Shutdown Cooling Mode

Residual heat removal system balances core decay heat

Steaming Mode

Temperature is maintained by holding reactor pressure at saturation temperature for the chosen temperature via steam vent control

Post NobleChem Operating Experience

Post NobleChem™ Conductivity Increase

- Post NobleChem conductivity increase occurs only when hydrogen injection is initiated

- Conductivity increase is 100% due to increase of soluble iron (and associated hydroxyl ion) in reactor water
  - Source is the temporary release of soluble iron during the conversion of hematite (Fe_2O_3) to the spinel form (Fe_3O_4)

- Magnitude and duration is dependent on prior water chemistry history…plants operating previously with zinc and moderate hydrogen injection will see less of an effect

Occurrence of Conductivity Increase is Positive Conformation of NobleChem Effectiveness

Post NobleChem™ Main Steam Radiation Increase

- Magnitude and duration of temporary increase appears to be a function of total noble metal injected
- Increase can occur even without hydrogen injection
- Root cause thought to be related to presence of noble metal in two-phase region of fuel
- Controlling total mass of noble metal injected limits/eliminates increase

Main Steam Radiation Increase is Temporary and Minor Compared to Moderate HWC Increases

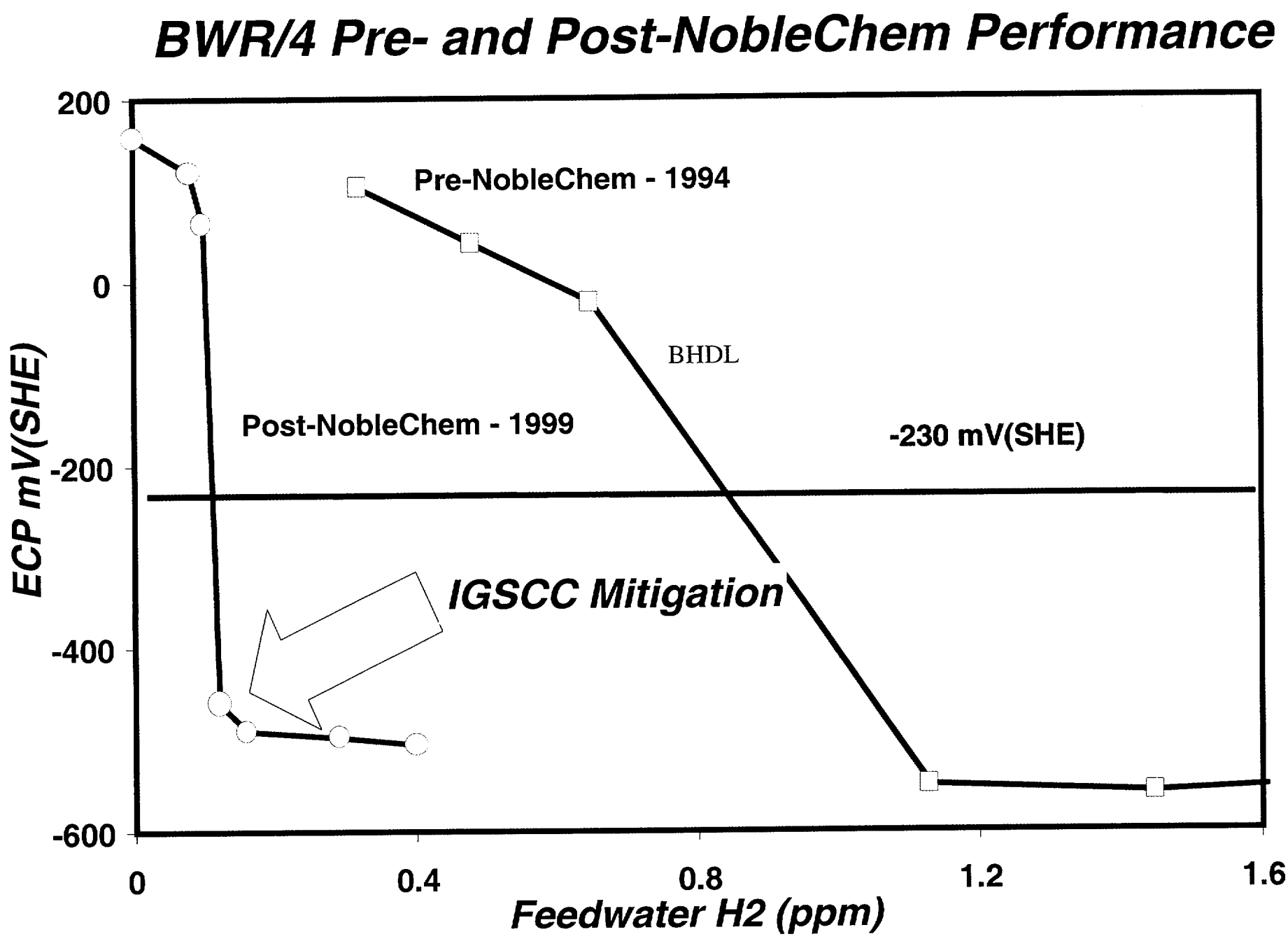
Shutdown Dose Rates After DZO/NobleChem

- DAEC Shutdown Dose Rate Lowest among BWRs
- Experience Based on Mid-Cycle Drywell Entries:
  - Two BWR/4's Piping Dose Rates Down by 50 %
  - One BWR/4 Piping Dose Rates Down by 67 %
- Plant Data Confirms Lab Results

DZO/NobleChem Lowers Piping and Drywell Dose Rates

NobleChem™ Performance

- NobleChem™/HWC performance dependent on presence of noble metal and >stoichometric H_2
  - Results quite repeatable among BWRs
  - Low H_2 requirements allow mitigation with negligible operating dose increases
    - Greater acceptance by utilities
    - Improved HWC injection availability


BWR/4 Pre- and Post-NobleChem Performance
200
0
-200
-400
-600
ECP mV(SHE)
Pre-NobleChem - 1994
BHDL
Post-NobleChem - 1999
-230 mV(SHE)
IGSCC Mitigation
0
0.4
0.8
1.2
1.6
Feedwater H2 (ppm)

Summary

NobleChem™ with Low HWC :

- Application process is optimized
- Post-application startup chemistry changes observed are manageable
- SCC of piping and internals is mitigated
- Low operating dose rates achieved
- Low shut down dose rates seen
- No impact on fuel
- Response to low HWC repeatable among BWRS