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U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

Quad Cities Nuclear Power Station, Unit 2
Facility Operating License Nos. DPR-30
NRC Docket No. 50-265

Subject: Supplemental Information Supporting Request for Approval of Pipe Flaw Evaluation on QCNPS Unit 2

Reference: (1) Letter from Keith R. Jury (Exelon Generation Company, LLC) to U. S. NRC, "Request for Approval of Pipe Flaw Evaluation," dated February 22, 2002

(2) Letter from Keith R. Jury (Exelon Generation Company, LLC) to U. S. NRC, "Additional Information Supporting Request for Approval of Pipe Flaw Evaluation," dated February 26, 2002

With Reference 1, Exelon Generation Company (EGC), LLC, requested approval for a piping flaw evaluation for a weld in the Reactor Recirculation System piping at Quad Cities Nuclear Power Station (QCNPS), Unit 2. In that request, EGC proposed to accept the flaw as-is without repair. The flaw did not meet the acceptance standards of American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (B&PV) Code Section XI, 1989 edition, for continued operation without evaluation. Subsequent discussions with the NRC resulted in additional information being requested to complete the review (Reference 2).

In a March 1, 2002, telephone discussion between EGC and the NRC, Mr. F. Lyon of the NRC provided verbal approval of the flaw evaluation to support start up QCNPS Unit 2. During this discussion additional clarifying information was requested. The attachment to this letter provides the requested information.

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Should you have any questions related to this letter, please contact Mr. Patrick R. Simpson at (630) 657-2823.

Respectfully,

Terrence W. Simpkin
for Keith R. Jury
Director – Licensing
Mid-West Regional Operating Group

Attachment 1: Additional Information Supporting Request for Approval of Pipe Flaw Evaluation

Attachment 2: Review of Resistance of BWR Recirculation System Cast Valve Quad Cities Nuclear Power Station Unit 2

cc: Regional Administrator – NRC Region III
NRC Senior Resident Inspector – Quad Cities Nuclear Power Station
Office of Nuclear Facility Safety – Illinois Department of Nuclear Safety

Attachment - 1
Additional Information Supporting Request for Approval of Pipe Flaw Evaluation

RAI Question 1) What is the critical flaw length and depth? *Additional supporting information requested.*

Response:

a) The critical flaw depth for a 360 degree flaw is 1.15 inches.
b) The critical flaw length for a through-wall crack is 41.56 inches.

These values were obtained with a safety factor of 1.0.

RAI question 2.1 Provide an expanded technical justification for the use of a K value of 21 ksi-in (-.5) in crack growth calculations for the relevant crack depth range; also provide evidence (preferably measured residual stress data) showing that the residual stress distribution of NUREG-0313 is more conservative than that of a Induction Heating Stress Improvement (IHSI) treated piping in your crack growth calculations. *Additional supporting information requested concerning the 1 inch.*

Response:

For crack depth less than 1 inch, the bounding K-value is expected to be maintained below 21 ksi-in. This is consistent with the value specified in NUREG-0313, Revision 2.

RAI Question 2.2: Provide an expanded discussion as to how the licensee is following the as-revised guidance of BWRVIP-14, particularly, in meeting the required conditions in conductivity and K value. *Additional information requested a) verify that the Electro-chemical potential (ECP) measurement location provides a representative water sample in relation to the crack location b) provide coupon test results to support their confidence in durability of NobleChem during the upcoming operating cycle c) and document the molar ratio of 4:1 of dissolved hydrogen in feedwater.*

Response:

a) The ECP is measured hourly at the Autoclave system. The ECP probes are in the Reactor Water Clean-up (RWCU) system, located prior to the first heat exchanger from the reactor, per General Electric (GE) recommendation. The ECP has averaged approximately -490 mV - Standard Hydrogen Electrode (SHE) on both units, well below the HWC specification of -230 mV. In accordance with GE Proprietary Information document titled "Noble Chem Application Considerations at Quad Cities Unit 2", the RWCU piping flange monitoring location was determined to be adequate for Noble Chem monitoring. After installation, the sample was confirmed by GE to be representative of the entire system from flow velocity and temperature data provided from the site. Based on the GE Radiolysis Model Analysis estimates, flow at the RWCU piping flange monitoring location is more oxidizing than that of the Recirculation flow because it is a combination of the recirculation and bottom head flow. Therefore, the ECP measurements at the RWCU piping flange monitoring location are comparable or possibly conservative relative to that of the recirculation piping conditions.

b) Several tubing pieces were extracted from the noble metal durability monitoring system at Quad Cities Unit 2 and analyzed for noble metal deposition. The results show about a 35% decrease in the noble metal deposition over the 18 months of plant operation represented by the tubing data. Based on an exponential extrapolation of the data trend to the March 2004 outage, the noble metal deposition at that time is expected to be 0.5 micrograms per square centimeter or more, which is significantly above the threshold recommended for reapplication of noble metal. GE typically recommends a reapplication of noble metal when the durability monitor deposition approaches 0.1 micrograms per square centimeter.

If additional information is required, a GE-proprietary report can be submitted under GE affidavit.

c) The GE Radiolysis Model Analysis estimates a 4:1 molar ratio of hydrogen to oxidant is achieved for the reactor internals at 0.4 ppm dissolved hydrogen in reactor feedwater. Benchmark testing was performed on both units. After reviewing the data, GE recommended that the dissolved hydrogen in reactor feedwater be maintained at 0.30 to 0.35 ppm in feedwater at Quad Cities Unit 2 Station. Currently, the hydrogen flowrate of 11 SCFM provides 0.35 ppm dissolved hydrogen in reactor feedwater. The GE Radiolysis Model Analysis applicable to Quad Cities Unit 2 estimates a 6:1 molar ratio of hydrogen to oxidant is achieved for the recirculation system at 0.35 ppm dissolved hydrogen in the reactor feedwater.

Question;

The weld was at the junction of pipe to valve body. UT was done of the piping, but not of the valve. *Additional information requested: verify that the valve body composition is resistant to IGSCC.*

Response:

Verification of the resistance of the valve body composition to IGSCC is provided in Attachment 2, "Review of Resistance of BWR Recirculation System Cast Valve Quad Cities Unit 2 Nuclear Power Station Unit 2."

ATTACHMENT 2
Review of Resistance of BWR Recirculation System Cast Valve
Quad Cities Nuclear Power Station Unit 2

Overview

The purpose of this report is to review current understandings concerning the performance of large cast stainless steel valves and pump housings in operating BWRs. This information can aid the Quad Cities Unit 2 Nuclear Power Station in its assessment of the risk that any castings in its plants have intergranular stress corrosion cracking (IGSCC) present that has any engineering significance.

The key factors that will be presented to support this assessment will include the overall characteristics of stainless steel castings in their installed condition, the laboratory and field experience in assessing the susceptibility of cast material to IGSCC, and the understanding regarding the effectiveness of the hydrogen water chemistry (HWC and Noble-Chem) at Quad Cities Unit 2 in mitigating IGSCC. Based on these factors, with particular emphasis on the excellent history of IGSCC resistance in the CF8 and CF8M type material, inspection of the casting Heat Affected Zones (HAZs) is unnecessary. Furthermore, the ASME code recognizes the difficulty of volumetric inspection of castings and is in the process of eliminating UT requirements for cast components. This is also supported by the lack of a qualified inspection technique for detection of IGSCC in austenitic cast stainless steel. The nuclear power generation industry through the Electric Power Research Institute (EPRI) recognizes that UT of castings is not meaningful.

Even if cracking is present it would be small and localized and any further initiation or crack propagation will continue to be mitigated by the hydrogen water chemistry (HWC) operating environment at the plant. In addition, Quad Cities Unit 2 Unit 2 has also implemented NobleChem which will enhance the benefits of HWC and virtually eliminate IGSCC growth or future initiation.

Background

The performance of cast austenitic stainless steel has been excellent throughout the history of operation of BWRs. CF8 and CF8M cast duplex microstructures have been used for all of the valve bodies and pump housings in the primary recirculation piping. These components have been free of any environmental cracking in the GE BWRs. Review of GE records confirms that there has been no IGSCC reported in BWR casting material.

At the time that the valves were ordered for Quad Cities Unit 2, the industry practice did not specify the carbon content. The material was ordered to the ASTM specifications for the CF8 product form. The maximum carbon per the ASTM specification is 0.08%. GE obtained the certified material records for the 02BD-F9 valve body from the QA records. The material compositions for the suction and discharge valves are being provided in a separate document. It is seen that the maximum carbon content is 0.06%. The measured range of delta ferrite for the valve side of the 02BD-F9 weld location has been in the range of 10-15 FN. As discussed later, this is judged to be high enough to assure that IGSCC will not occur.

(1) United States field cracking experience: welds and castings

Both high carbon and low carbon austenitic stainless steel weld metals and castings have exhibited excellent resistance to IGSCC over the history of operating BWRs. The largest information base is for Type 308 and Type 308L welds that were used for the majority of the recirculation piping welds as well as for the reactor internals fabrication. The volumetric (ultrasonic), surface (penetrant tests) and visual inspections (VT-2) that are part of standard outages have revealed very few incidences of weld metal cracking in these components. In that the operating BWRs were constructed beginning in the 1960's when there were no specific ferrite and carbon controls for the weld metal, this provides strong evidence of the robustness of the duplex weld metals against Stress Corrosion Cracking (SCC). The few instances where cracking has occurred, metallurgical examinations have verified that the ferrite levels are extremely low and the characteristics of the duplex microstructure are gone and the weld metal has the microstructure of purely austenitic material. This provides strong field evidence of IGSCC resistance in duplex materials (welds and castings) even without stringent ferrite requirements.

Visual inspections of the pressure vessel cladding have also added confirmation to the high resistance of weld metal to SCC with no instances observed. This weld metal has been post weld heat treated leading to reduction in ferrite level as well as aiding the kinetics for any carbide precipitation and the concurrent chromium depletion. Likewise, no cracking of weld buildup pads for attachments has been reported, even though for many BWRs these pads are Type 308 and furnace sensitized.

For austenitic stainless steel castings, there have been no reported field instances of stress corrosion for US plants except where there was carburization attributable to the mold material or due to the hardfacing process. This is to be expected due to the inherent resistance of the duplex microstructure and the structural margin leading to lower stresses. As will be discussed in later sections, the number of inspections for components in operation is limited due to the difficulty in performing UT inspections. However, those inspections have not revealed any cracking.

(2) Laboratory data on IGSCC Susceptibility and Behavior of Castings and Weld Materials

At GE, as well as at other laboratories, many studies have also been conducted to evaluate the resistance of weld metal as well as duplex castings. The largest and most thorough studies were pipe test studies conducted to reproduce field pipe cracking as well as to qualify improved piping materials as replacements. In each of the over 70 tests conducted, there were generally 12 circumferential welds made using Type 308 weld metal that was procured with a composition that would produce 5% to 8% ferrite in the as-deposited condition. None of these welds exhibited any cracking even though the testing conditions were severe and the deposited ferrite was expected to range from approximately 3% to over 8%.

Several other laboratory studies have been performed to evaluate the resistance of weld metal to crack initiation. These studies include slow strain rate tests (SSRT), constant load (CL) tests, creviced bent beam (CBB) tests as well as standard ASTM A262, practice E corrosion tests. Most of the weld metal specimens were given a post weld heat treatment at 621°C for 24 to 40 hours. This treatment would promote carbide precipitation leading to sensitization. The heat treatment also reduced the ferrite levels from those achieved in the original deposition. Early CL studies verified that weld metal having ferrite levels from 1% to 11% and carbon levels up to 0.07% did not crack at stresses up to the material's yield strength.

Finally, there is also laboratory data on the crack growth rate behavior for duplex materials. This data was developed as part of the Large Diameter Pipe program to understand the resistance and rates for IGSCC cracks that might have initiated and grown into the weld metal. At the low carbon and moderate ferrite levels (8% to 11%), cracking is arrested after limited penetration. At higher carbon (typical of Type 308) and lower ferrite levels, 1.9 to 3.3%, the initiated cracks did continue to grow. However, the rates measured were slower than sensitized stainless steel and on the order of 3×10^{-6} in/hr under slow cyclic loading. This information is very consistent with data from the Swedish experience to be discussed later. It is clear that the nature of the duplex microstructure lends overall added resistance to IGSCC.

It is noted that the great majority of the data has been developed based on Type CF3/CF8 casting materials. The CMTR records for the Quad Cities Unit 2 2 valve bodies indicate that the material is Type CF8M. The basic difference between CF3/CF8 and CF8M is the presence of molybdenum. IGSCC resistance for duplex austenitic castings, however, is not directly dependent on the chemical composition. The key factors in IGSCC resistance of austenitic stainless steel castings are carbon content and ferrite. This relationship between the materials is analogous to the relationship between Types 304 and 316 materials (the wrought versions of CF8 and CF8M). Therefore, the IGSCC data for Type CF3/CF8 is considered applicable to Type CF8M materials, and can be used to predict IGSCC behavior.

(3) Pipe Replacement experience

The pipe replacement activities in the 1980's provided an opportunity to evaluate cast hardware that had been in service since the beginning of operation. In all cases it was both desirable and necessary to continue to re-use the pumps and valves along with the replacement pipe. In order to prepare the castings, the original heat affected zones were refurbished prior to joining to the new piping. GE as part of its installation instructions required that the weld prep and refurbished counterbores be penetrant examined consistent with the ASME Code. These practices were followed at the several plants which included Peach Bottom Units 2 and 3 and Pilgrim where GE was responsible for the actual installation and at Vermont Yankee and Hatch Units where GE developed the installation procedures. No evidence of cracking was found at any of these plants in the cast material. Based on current understanding of IGSCC initiation, the prior time of operation would have provided adequate time for crack initiation if there were any regions of susceptibility or regions of manufacturing induced defects that became open to the ID surface.

This adds confidence that the population of castings installed in GE plants were exhibiting IGSCC resistant characteristics over the full range of carbon and ferrite levels.

The only Exelon plant to replace piping was Dresden Unit 3. The valves and pump housings were also reused and went through similar preparation and penetrant inspection. There were no instances of IGSCC even though the plant had been operating for over 10 years. The valve and pump housings were made in the same time frame as those for the Quad Cities Units.

(4) Overview of Valve and Pump Housing Visual Inspections

As part of ASME requirements, valves and pump housings that are accessible due to maintenance need to be given a VT-3 inspection. While the number of inspections performed is far less than those required for piping welds, the fleet as a whole has inspected a reasonable number of components. In the US, there is no current knowledge of any significant findings. In many ways, this also supports the resistance of the overall population of large cast components.

Specifically, at Exelon plants, Code requires VT-3 inspection of one valve or pump in each category (which is defined by design, type, or function, etc.) once every 10-year interval if and only if the valve or pump is scheduled for maintenance. For valves, no IGSCC has been identified at Exelon plants. Quad Cities, Dresden, and LaSalle Nuclear Power Plants at one time or another have disassembled recirculation pumps and performed VT-3 on the interior surface, and again no IGSCC was identified. In addition, VT-2 inspections are performed and no leakage from cast components has been observed.

(5) Review of Valve and Pump Housing cracking at OKG

While the casting performance in the US has been very good, in 1995 cracking was discovered in some valve and pump housings in Sweden associated with the Oskarshamn 1. These inspections were performed in conjunction with an extensive outage associated with the plant's shroud replacement project, the FENIX effort.

During this inspection, ID cracks were found in eight valve bodies with minor cracks found in three pump housings. The valves were all of a European niobium stabilized stainless steel. These components were manufactured in the late 1960s or early 1970s and had been in service for approximately 25 years. The cracking could be seen visually. Assessments were made to assess the probable cause for cracking. The majority of cracks were attributed to hot cracking/reheat cracking defects that occurred during original manufacture. This was determined to be the most probable cause of cracking. This was confirmed by evaluation of the outside surfaces of the castings that contained similar cracking patterns. The evaluation did find cracking associated with ferrite/austenite interfaces as well as low ferrite regions where the cracking was found in purely austenite regions which had evidence of chromium depletion. All of the cracks contained heavy oxide. Therefore, it was hard to rule out that crack extension had not taken place during operation. However, any crack growth would have been at a very slow rate. The cracking was removed by EDM and structural analyses established a large amount of margin. Even though cracking was found, the behavior was not inconsistent with the significant experience and lab understanding that establishes the high IGSCC resistance of austenitic castings used in the US BWR fleet.

(6) Quad Cities Unit 2 Casting Assessments

The castings at Quad Cities Unit 2 have undergone limited assessments. Recent efforts were also made to assess the valve ferrite levels by performing field measurements on the exterior of the castings. The measured ferrite level ranged from 10 to15 FN. Given the field performance, these castings appear typical of those at the plants that performed piping replacements and who found no indications of IGSCC during those activities such as Peach bottom Units 2 and 3. Figure 4 from Ref. 1 shows GE data from IGSCC tests on castings with different carbon content and ferrite numbers. It is seen that for the measured ferrite value of 15 FN, the threshold carbon content for IGSCC is 0.08%. That is, IGSCC is not expected for carbon content less than 0.08%. For the lower range of 10FN, the corresponding limit is 0.06%. Since the upper bound carbon content for the valve in question is 0.06%, the ferrite range of 10-15 FN is sufficiently high to assure that IGSCC will not occur. As discussed in the next section, the presence of NobleChem will further reduce the likelihood of IGSCC.

(7) Impact of Operating Environment at Quad Cities Unit 2

The final factor is the plant's efforts to maintain an environment that minimizes the risk of IGSCC. The water chemistry that has been present over the last several cycles at the Quad Cities Unit 2 Unit 2 has included hydrogen injection. In particular, the last cycle is a good measure of the water chemistry quality that will be present in the upcoming cycle with significant mitigation enhancement after Noble-Chem injection. The key parameters are the conductivity as well as the specific anionic species in the coolant. The average conductivity over the last cycle, which is the most representative of the future operational levels for Unit 2, was less than 0.1 μS/cm). The yearly chloride and sulfate levels have also been very low. Hydrogen was injected for over 90% of the time. With Noble-Chem, the ECP levels would be easily reduced below –230 mV SHE.

Therefore, the past and future operating environment, will limit the potential for any further degradation in the castings if it were to have been present due to localized regions without any ferrite.

Summary

In summary, the field and laboratory experience provides strong evidence that the valve material on one side of weld 02BD-F9 will not experience IGSCC. For castings, there has been an absence of reported cases of IGSCC in the Type CF8 and CF8M austenitic cast stainless steel. Secondly, there is also cumulative information gained through many pipe replacement inspections and routine valve body inspections that also confirm the resistance to IGSCC. Finally, from the IGSCC correlation of Ref 1, IGSCC would not occur for carbon levels up to 0.06% for the range of 10-15 FN measured for the valve. Since the certified material composition records confirm that the carbon content is 0.06% or less, it can be concluded that IGSCC of the valve side of weld 02BD-F9 is extremely unlikely.

Reference

1. Hughes, NR, Clarke WL, and Delwiche DE, "Intergranular Stress Corrosion Cracking Resistance of Austenitic Stainless Steel Castings," *Stainless Steel Castings, ASTM ST+P 756,* VG Behal and AS Melilli, Eds., American Society for Testing and Materials 1982, pp 26-47

ATTACHMENT 2
Review of Resistance of BWR Recirculation System Cast Valve
Quad Cities Nuclear Power Station Unit 2

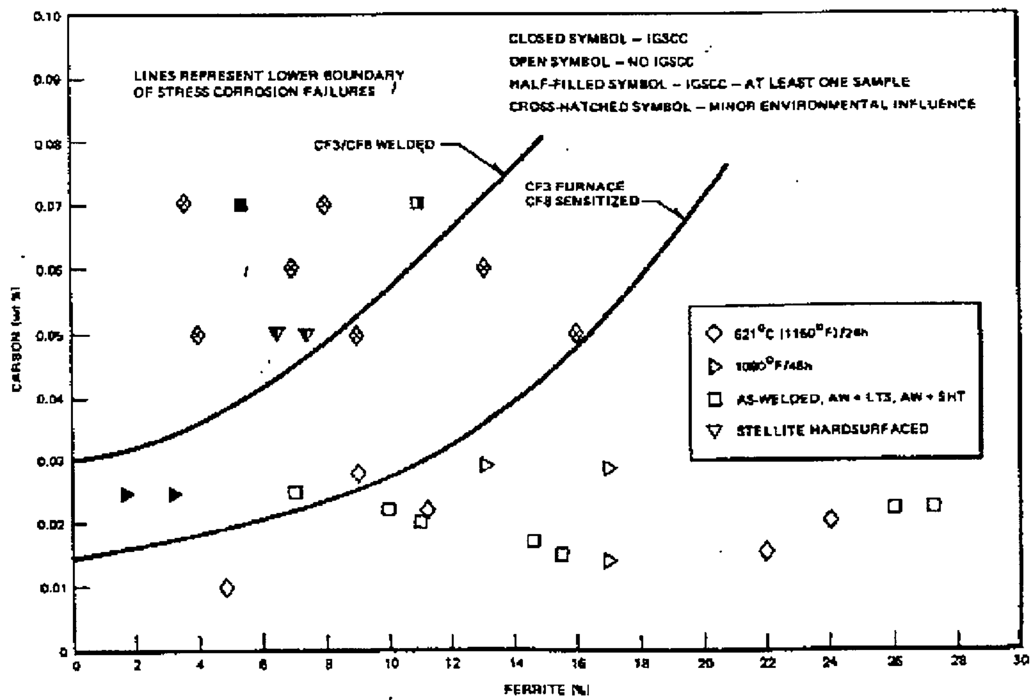

FIG. 4—*IGSCC resistance may be predicted by the combined influence of carbon content and percent ferrite.*