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SUBJECT: Submits fracture mechanics evaluation of indication found in reactor pressure vessel high pressure core spray nozzle safe end to safe end extention weld KC-32,per TS 4.0.5.f & Generic Ltr 88-01.

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December 28, 1990
NMP2L 1270

U. S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, D. C. 20555

Re: Nine Mile Point Unit 2
Docket No. 50-410
NPF-69

Gentlemen:

In accordance with the requirements of Technical Specification 4.0.5.f and the guidance of Generic Letter 88-01, Niagara Mohawk is submitting, for your review, a fracture mechanics evaluation of an indication found in the reactor pressure vessel high pressure core spray nozzle safe end to safe end extension weld KC-32. To support our schedule for resumption of operation, Niagara Mohawk requests Staff approval of this evaluation by January 13, 1991. This weld had been previously classified as a Category D weld in Niagara Mohawk's Generic Letter 88-01 submittal, dated November 20, 1990. As shown in Attachment A, "Fracture Mechanics Evaluation," the probable cause for the flaw was solidification shrinkage (hot) cracking occurring during the fabrication process. However, due to the presence of Inconel 182, which is susceptible to Intergranular Stress Corrosion Cracking, the flaw has been evaluated and categorized per the guidance of Generic Letter 88-01.

Attachment A demonstrates the acceptability of this weld for continued service without repairs based on a fracture mechanics evaluation. The fracture mechanics evaluation was performed in accordance with American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section XI, Winter 1986 Addendum, and Generic Letter 88-01 guidance. Niagara Mohawk has also performed a Mechanical Stress Improvement Process on the weld to mitigate crack growth. The resulting stress in the weld is described in Attachment B. As also described in the attachment, the ultrasonic response to the defect increased following the Stress Improvement.

Section XI, Article IWB-2430(a), requires an expanded sample when examinations reveal indications that exceed Code allowable. There are a total of seven welds of the same type as KC-32, and IWB-2430(a) requires two additional examinations based on the initial sampling plan contained in Niagara Mohawk's Inservice Inspection Program. Niagara Mohawk has examined all seven welds during the current refueling outage, thereby exceeding the requirements of IWB-2430(a). No additional indications were found.

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Since the evaluation in Attachment A demonstrates the acceptability of limited additional service with the flaw in its present condition, this weld will be reclassified as Category F in accordance with Generic Letter 88-01. Category E would normally apply since the potential for crack growth has been mitigated by Mechanical Stress Improvement, however the crack size exceeded the recommendations of Generic Letter 88-01 for use of Stress Improvement. This indication will be re-examined during each subsequent refueling outage in accordance with the guidance of Generic Letter 88-01. Further evaluations and/or repairs will be performed concurrent with those examinations.

Very truly yours,

NIAGARA MOHAWK POWER CORPORATION

C. D. Terry
Vice President
Nuclear Engineering

TF/kms

Attachments

xc: Regional Administrator, Region I
Mr. W. A. Cook, Senior Resident Inspector
Mr. R. A. Capra, Project Directorate No. I-1, NRR
Mr. D. S. Brinkman, Project Manager, NRR
Records Management

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ATTACHMENT A

FRACTURE MECHANICS EVALUATION

During the October 1990 in-service inspection of Unit 2, an indication was found in the 10" reactor pressure vessel high pressure core spray nozzle safe end to safe end extension weld KC-32. The initial ultrasonic examination of the weld indicated a flaw depth of 0.15 inches (17.6% of the wall thickness) and a length of 1.9 inches (6.3% Circumferential). Weld KC-32 was performed during fabrication to avoid a dissimilar field weld. The weld consists of an Alloy 82 consumable insert and an Alloy 82 root pass, with the remainder being Alloy 182. The indication was found upstream of the safe end to safe end extension weld on the inside surface. The indication exhibited the characteristics of intergranular cracking, which could be attributed either to stress corrosion or to hot cracking (hot cracking would occur during fabrication or repair).

In order to evaluate the cause of the indication, manufacturing, fabrication and other associated documentation was reviewed. One item of significance was noted. During fabrication of the weld, but before installation of the safe-end, fabrication defects were found near the weld outside diameter extending intermittently 360 degrees around the circumference. The fabrication defect was repaired, examination was repeated, and the fabrication defect was recorded as being acceptably repaired. Based on the review, the probable cause of the indication was hot cracking during the fabrication process. This conclusion is based on the following:

1. A combination of three adverse welding conditions was present (i.e., a potentially high dilution welding process, an estimated high carbon content in the diluted weld root and a welding procedure which allowed a high heat input initial insert fusion pass and subsequent passes) which make this type of weld sensitive to hot cracking to a higher than normal level.

2. The indication had a depth of 0.35 inches in one operating cycle. Crack initiation in Alloy 182 welds and butters typically occurs after approximately six years of service, unless the weld has been exposed to unusually severe water chemistry conditions. Records show very good water chemistry for Unit 2.

3. The indication is primarily in Alloy 82 consumable insert/root pass. Generic Letter 88-01 identifies Alloy 82 as resistant to stress corrosion cracking and according to General Electric there have been no reported incidences of cracking in Alloy 82 weld material at BWR plants. Also, the weld has no Alloy 182 butter where initiation could occur.

4. The entire weld assembly underwent Post Weld Heat Treatment (PWHT) after fabrication repair was completed. Therefore, any residual stresses that occurred from the original welding and repair were likely reduced.

Since the indication was found after an unusually short period of operation, in material that is not known to be susceptible to stress corrosion cracking, and the typically high weld residual stresses were reduced by PWHT, it is reasonable to conclude that this crack was initiated by a mechanism other than stress corrosion (i.e., hot cracking). However, once there is a crack, subsequent growth by stress corrosion cracking in the Alloy 182 material cannot be precluded.

The 1990 examination used more advanced techniques (i.e., use of both shear and longitudinal waves and use of Smart automated equipment) than that performed earlier. Detection of small and tight indications would not be expected using only shear waves, as was done during the shop and the pre-service inspections. Even though the indication is now detectable using both shear waves and refracted longitudinal waves, it could have been missed during previous examinations. Therefore, it is quite conceivable that this indication existed during fabrication and was too small or tight to be detected by the procedures in use. The indication could have opened up and/or grown during plant operation to a point where it is now detectable with the shear waves.

Stress improvement utilizing a Mechanical Stress Improvement Process (MSIP) was performed on the weld after the flaw was discovered. Subsequent ultrasonic examination (UT) showed the actual size of the flaw was 41% of the wall thickness and that it extended around 11.3% of the weld circumference. A fracture mechanics evaluation was performed in accordance with ASME Section XI Winter 1986 Addendum and Generic Letter 88-01 guidance. The evaluation used the methodology described in NUREG-0313, Rev. 2, "Technical Report on Material Selection and Processing Guidelines for BWR Coolant Pressure Boundary Piping." Figure 2 in NUREG-0313 provides the Staff's recommended correlation for crack growth rate as a function of applied stress intensity factor, "K."

The stress intensity factor for the subject crack was calculated based on stresses resulting from all primary loads (including seismic) as determined in accordance with ASME Section III, Subsection NB, and as described in Updated Safety Analysis Report Section 3.9A. A predicted growth rate corresponding to the stress intensity factor was then determined from Figure 2 of NUREG-0313. Utilizing an initial flaw size of 0.35 inches (41% through wall depth), a crack growth evaluation yielded a growth in the crack depth from 41% to 59% of the wall after one cycle (12000 hours) of operation.

This predicted crack size after one cycle was compared to a failure assessment diagram developed in accordance with Section XI, C-3320. The failure assessment diagram defines the combination of crack depth and length at which failure occurs based on net section collapse criterion. The diagram utilized a safety factor of 2.77 for normal operating conditions and a factor of 1.39 for emergency and faulted conditions. The predicted crack size after one cycle falls within the acceptance region of the failure assessment diagram. The predicted crack depth of 59% (0.59t) at the end of the next operating cycle also falls within the 0.60t requirement for Shielded Metal Arc Welds contained in ASME Section XI, Appendix C, Paragraph C-3320(d), Winter 86 Addenda.

ATTACHMENT B

MECHANICAL STRESS IMPROVEMENT PROCESS

During the October 1990 in-service inspection of Unit 2, a flaw was found in the 10" reactor pressure vessel high pressure core spray nozzle safe end to safe end extension weld KC-32. The probable cause for the crack is a mechanism other than stress corrosion (i.e., hot cracking). However, once there is a crack, subsequent growth by stress corrosion cracking in the Alloy 182 material cannot be precluded. Therefore, a fracture mechanics evaluation was performed to demonstrate the acceptability of the weld for continued service. In addition, Mechanical Stress Improvement Process (MSIP) was employed to put the weldment into compression and arrest further crack growth. MSIP removes residual tension occurring in weldment for as-welded conditions and generates high axial and hoop compressive stresses in the weld, the Heat-Affected Zone and adjacent material.

In general terms, MSIP consists of squeezing a piping component plastically near a weld. The application of MSIP involves the use of hydraulically actuated tools that produce a slight permanent contraction of the pipe on one side of the weld. The squeezing is continued until sufficient plastic deformation occurs so that the harmful tensile residual stresses along the inside surface of the pipe at the weld are replaced by compressive residual stresses. MSIP imposes compressive strains and does not include severe thermal gradients. The performance of MSIP is verified by measuring the pipe circumference before and after application of the process. MSIP is accepted by Revision 2 of NUREG-0313 as a Stress Improvement process for mitigation of Intergranular Stress Corrosion Cracking in BWR plants.

NUREG-0313 endorses the use of stress improvement for cracks with a depth of 30% or less of the wall thickness and a length of less than 10% of the circumference. The original ultrasonic test (UT) results indicated that the crack in Weld KC-32 met the requirements of the NUREG for MSIP: 17.6% of the wall thickness and 6.3% of the circumference. However, ultrasonic response to the defect increased following MSIP. The results of the UT examination conducted after MSIP revealed that the flaw was larger than originally estimated: 41% of the wall thickness and 11.3% of the circumference. It is highly unlikely that the existing defect was extended during the application of MSIP. The process never produces tensile strain in the region where the defect is located and the compressive strain that region did see was very small. In addition, ultrasonic evidence for greater length and possibly depth existed during the original inspection, but signals were too weak to be accurately resolved. It is, therefore, reasoned that the increase in UT response after the

application of MSIP is the effect of an increased ultrasonic reflectivity from the features of the welding solidification defect. This conclusion has been reviewed and concurred with by SMC O'Donnel Inc., the MSIP vendor, and personnel from the EPRI Nondestructive Examination Center.

While the crack does exceed the recommended size for application of MSIP, EPRI laboratory testing has shown that MSIP is effective in arresting crack growth on cracks that extend up to 50% through the pipe wall.

MSIP was analytically simulated by performing a nonlinear computer analysis on a finite model of the assembly. This provided a model of the resulting redistribution of the residual stresses and the pattern of stress after normal operating loads were included. The process was modeled using a detailed axisymmetric finite element model of the nozzle, liner, safe-end, extension piece and connecting piping. The model simulated residual stresses representative of the welding process and stresses due to MSIP and normal operating loads. The model utilized the indicated depth of 41% of the wall thickness. Further, in the axisymmetric model such a crack is assumed to exist around the full circumference of the assembly. The analysis considered a 0.788% residual contraction in the extension piece, which was based on field measurements after the MSIP was completed.

The analytical residual stress patterns show that MSIP was successful in converting tensile stresses along the inside surface of the piping to compressive stresses. The results show that significant axial compression, extending well beyond the depth of the detected indication, has been induced by MSIP and that the compressive state of stress is maintained at the indication location even after operating loads are included. Under these conditions, the crack is stabilized such that it will be resistant to further extension due to the IGSCC mechanism.