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November 17, 1982
IPN-82-74

Director of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Attention: Mr. Darrell G. Eisenhut, Director
Division of Licensing

Subject: Indian Point 3 Nuclear Power Plant
Docket No. 50-286
Girth Weld Repair Program

Dear Sir:

By letter dated October 25, 1982 (IPN-82-71) the Authority provided you with our responses to your September 24, 1982 request for information concerning the Indian Point 3 girth weld repair program.

The Authority provides in Enclosure 1 to Attachment A to this letter, the nine metallurgical reports referenced in the Authority's aforementioned October 25, 1982 letter. In addition, Attachment A provides a summary of each metallurgical report.

The Authority concludes that the attached reports support the hypothesis that the cracking is associated with nucleation sites which were mild corrosion pits in a highly stressed weld. The evidence suggests that this condition may be attributable to a less than adequate heat treatment when the vessel was manufactured. The cracks propagated under the normal cyclic loads in the presence of the high residual stress. The process was enhanced by the presence of corrosion mechanisms.

Should you or your staff have any questions, please contact Mr. P. Kokolakis of my staff.

Very truly yours,

G. M. Wilverding

for J. P. Bayne
Executive Vice President
Nuclear Generation

A001
Limited Dist

Att.
cc: attached

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cc: Resident Inspector's Office
Indian Point Unit 3
U. S. Nuclear Regulatory Commission
P. O. Box 38
Buchanan, New York 10511

ATTACHMENT A

GIRTH WELD REPAIR -
METALLURGICAL ANALYSES SUMMARY

POWER AUTHORITY OF THE STATE OF NEW YORK
INDIAN POINT 3 NUCLEAR POWER PLANT
DOCKET NO. 50-286
NOVEMBER 17, 1982

ATTACHMENT A

GIRTH WELD REPAIR -
METALLURGICAL ANALYSES SUMMARY

The following reports are summarized:

1. *LP Report No. M6820 - Charpy Impact Testing

2. LP Report No. M6850 - Charpy Impact Tests Weld Plate Coupon 3/16" Diameter E7018 Electrodes

3. LP Report No. M6855C - Weld Metal Charpy V-Notch Tests

4. LP Report No. M6855C-1 - Weld Procedure Qualifications SMAW WPS3A, SGT 4

5. LP Report No. M6855C-2 - Weld Coupon Heat - Affect Zone Hardness Survey

6. LP Report No. M6855C-3 - Weld Procedure Heat - Affected Zone Microstructure and Hardness Survey

7. LP Report No. 7154 - Circumferential Weld Boat Sample from Steam Generator #32 (contains report M6785 - Filings from Steam Generator #32)

8. +GE Report No. CI - 1052 - Examination of a Boat Sample Supplied by GE, I&SE Nuclear Plant Services

9. LP Report No. 7164 - Metallurgical Examination of Shell Girth Weld Coupon from Steam Generator #32.

* LP (Lucius Pitkin, Inc.)

\+ GE (General Electric Co.)

1. Report No. M6820 - Section C and D test results are for the SA302 Grade B plates used in the welding procedure qualification. The plates meet the specification requirements of 50,000 psi yield strength, 80-100,000 psi ultimate tensile strength and 30 ft.-lbs. absorbed energy at +10F.

2. Report No. M6850 - These test results supplement the Category I mill certs for the E 7018 electrodes used for welding procedure qualification WPS-3A.

3. Report No. M6855C - These test results supplement the category I mill certs for E 8018 C-3 electrodes used for welding procedure qualification WPS-3B.

4. Report No. M6855C-1 - These test results comprise the qualification of welding procedure WPS-3A utilizing E 7018 electrodes, no preheat, and 1150F ±25F post weld heat treatment. The impact test results for 1200F post weld heat treatment were unsatisfactory and this heat treatment is not recommended.

5. Report No. M6855C-2 - This report is of tests performed on the welding procedure qualification test for WPS-3B which cracked during welding. The failure is attributed to insufficient preheat, bead size and bead placement sequence. However, the coupon was used to ascertain the response of an SA302 Grade B place/E8018C-3 electrode weldment to various heat treatments. The weldment, representative of the actual Vessel ID, is heat treated for 30 hrs. at 800F, 900F, 1000F, 1100F and 1200F. The test results establish that the hardness of the heat affected zone does not change appreciably until 1100F is attained.

6. Report No. M6855C-3 - This report supplements the data in reports M6855C-1 and M6855C-2 by determination of the microstructure of the heat affected zone and the microhardness of the base metal, weld and heat affected zone of SA302B/E8018-C3 and SA302B/E7018 weldment coupons. The as welded SA302B heat affected zone microstructure is established as lightly tempered martensite. At 1150 and 1210F the microstructure is tempered martensite.

The results of the reports thus far qualify WPS#3A for the repair of the steam generator girth weld defects and establish the relationship that the hardness and lightly tempered martensitic structure of the as welded heat affected zone representative of the vessels does not undergo an appreciable change until temperatures over 1100F are reached at which time the microstructure is tempered martensite.

7. Report No. 7154 - This metallurgical analysis of a boat sample from steam generator #32 identifies the cracking mechanism as transgranular and characteristic of low-cycle (thermally induced stress) corrosion fatigue cracking. The cracks appear to have initiated from pits on the inner surface and to have propagated transgranularly through the weld and base metal.

   Additional data obtained shows by chemical analysis that the base material and weld metal are as specified, the general microstructure of the weld metal consists of ferrite and pearlite and the general microstructure of the base metal consists of uniformly tempered bainite.

8. Report No. CI-1052 - This metallurgical analysis was performed on the same boat sample as a supplement to report No. 7154. The analysis concludes however, that a fatigue mechanism is unlikely, contrary to the Report No. 7154 and must be, by process of elimination, stress corrosion cracking.

These observations, however, are based on analysis of secondary cracks only. The conclusion that the cracking mechanism may be stress corrosion cracking is based on examination of only one crack. The Authority believes that other evidence supports the cracking mechanism stated in the summary on page 4.

The report does state that the secondary cracks were transgranular, propogated by a stress-environment interaction, oxide filled and associated with a high hardness heat affected zone. This data supports Report No. 7154.

9. Report No. 7164 - This metallurgical analysis was performed on a 6" diameter full-section thickness specimen from the girth weld area of steam generator #32. The analysis concludes that:

   - the cracking initiated from the inner surface and is associated with fine pits.

   - the mode of cracking is transgranular and characteristic of corrosion enhanced progressive cracking; i.e., corrosion fatigue.

   - the rate of crack propagation is significantly influenced by the environment.

   - the corrosion mechanism is associated with a high oxygen environment.

   - the material toughness is very high and will satisfy a leak-before-break criterion.

   - the material shows inordinately high hardness (Rockwell C39 to 41), a lightly tempered martensitic microstructure and a crack which changed direction from a horizontal to a vertically oriented direction. This evidence, when coupled with the crack extension difficulties encountered with one of the J-integral specimens, is supportive of the theory that the stress relief was inadequate and that high residual stresses exist in the vessel in this area which contains a major weld repair.

   - Samples from the vessel specimen heat treated at 1000F showed significant changes in microstructure and hardness similar to results obtained in Reports No. M6855C-2 and M6855C-3 indicating that these areas were not subjected to temperatures above 1000F.

   - the cracking is attributed to high residual tensile stresses and normal cyclic service stresses aggravated by a small amount of pitting corrosion. The contribution of residual stresses in crack nucleation cannot be quantified but fatigue crack growth rate is enhanced by corrosion when cyclic stresses are high and frequency of loading is low.

These results are in close agreement with references 1 and 2.

In addition to the above nine documents, etching tests were performed on cracks outside the general weld area. All the cracks examined have been determined to be associated with a weld repair.

SUMMARY

The Authority concludes that the attached reports support the hypothesis that the cracking is associated with nucleation sites which were mild corrosion pits in a highly stressed weld. The evidence suggests that this condition may be attributable to a less than adequate heat treatment when the vessel was manufactured. The cracks propagated under the normal cyclic loads in the presence of the high residual stress. The process was enhanced by the presence of corrosion mechanisms.

A repair program consisting of crack removal and repair of resultant cavities by welding utilizing E7018 electrode without a preheat and employing an 1150F $\pm$ 25F post weld heat treatment will repair the defects and return the vessel to an acceptable condition.

References:

1) Pendleton, R. L.; and Skogseth, J.; Corrosion Fatigue.

2) Vyas, B; Czajkowski, C. J.; and Weeks, J. R.; Metallurgical Examination of Cracked Feedwater Pipes From Nine Pressurized Water Reactors, Nuclear Technology, Vo. 55, November 1981.

ENCLOSURE 1

GIRTH WELD REPAIR -
METALLURGICAL REPORTS

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