January 16, 2002

Mr. John T. Conway
Site Vice President
Nine Mile Point Nuclear Station, LLC
P.O. Box 63
Lycoming, NY 13093

SUBJECT: NINE MILE POINT NUCLEAR STATION, UNIT NO. 2 (NMP2) - REINSPECTION PLAN FOR CORE SHROUD WELD H4 (TAC NO. MB2797)

Dear Mr. Conway:

By letter dated October 30, 2000, the NRC staff conveyed its review results of NMP2's Refueling Outage 7 (RFO7) core shroud ultrasonic reexamination, concluding then that it can be operated without repairing weld H4 for one fuel cycle. By letter dated September 14, 2001, Niagara Mohawk Power Corporation (NMPC) submitted its reevaluation of core shroud weld H4, taking into account benefits from the implementation of noble metal chemistry application and hydrogen water chemistry. NMPC demonstrated through an analytical flaw evaluation, using modified crack growth rates, that NMP2 can be operated without repair of weld H4 for two fuel cycles of operation after RFO7 (i.e., without reinspection during RFO8).

On November 7, 2001, NMPC's ownership interest and operating license in NMP2 were transferred to Nine Mile Point Nuclear Station, LLC (NMPNS), thus allowing NMPNS to possess, use and operate NMP2. By letter dated November 20, 2001, NMPNS requested that the NRC continue to review and act on all requests previously submitted by NMPC before the transfer, and to consider such requests as if they had been originally submitted by NMPNS. Accordingly, the staff continued its review of the subject submittal.

The NRC staff completed its review of the subject submittal and found that the flaw evaluation meets the intent of the rules in Section XI of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code). Since the safety factors associated with the detected cracks are greater than 2.77 specified in the ASME Code, the NRC staff concludes that NMP2 can be operated without repair of weld H4 for two fuel cycles after RFO7. The staff's review results are set forth in the enclosed safety evaluation.

Sincerely,
/RA/

Peter S. Tam, Senior Project Manager, Section I
Project Directorate I
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket No. 50-410

Enclosure: Safety Evaluation

cc w/encl: See next page

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Docket No. 50-410
Enclosure: Safety Evaluation
cc w/encl: See next page
ACCESSION NUMBER: **ML020100071**

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DATED: January 16, 2002

NINE MILE POINT UNIT 2 - REINSPECTION PLAN FOR CORE SHROUD WELD H4

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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

REEVALUATION OF CORE SHROUD WELD H4

NINE MILE POINT NUCLEAR STATION, LLC

NINE MILE POINT NUCLEAR STATION, UNIT 2 (NMP2)

DOCKET NO. 50-410

1.0 INTRODUCTION

By letter dated October 30, 2000, the NRC staff conveyed to Niagara Mohawk Power Corporation (NMPC) its review results of core shroud ultrasonic reexamination performed during NMP2's Refueling Outage 7 (RFO7). The NRC staff concluded then that the unit can be operated without repairing weld H4 for one fuel cycle based on a bounding crack growth rate (CGR) of $5x10^{-5}$ inch/hour. By letter dated September 14, 2001, NMPC submitted its reevaluation of core shroud weld H4, taking into account benefits from the implementation of noble metal chemistry application (NMCA) and hydrogen water chemistry (HWC). NMPC intended to demonstrate, through a revised analytical flaw evaluation using modified assumptions on crack geometry and modified CGRs, that NMP2 could be operated without repair of weld H4 for two fuel cycles of operation after RFO7 (i.e., without reinspection during RFO8).

On November 7, 2001, NMPC's ownership interest and operating license in NMP2 were transferred to Nine Mile Point Nuclear Station, LLC (NMPNS), thus allowing NMPNS to possess, use and operate NMP2. By letter dated November 20, 2001, NMPNS requested that the NRC continue to review and act on all requests previously submitted by NMPC before the transfer, and to consider such requests as if they had been originally submitted by NMPNS. Accordingly, the staff continued its review of the subject submittal.

2.0 EVALUATION

2.1 Licensee's Evaluation

2.1.1 Crack Growth Rate

The licensee used a CGR of $2.2x10^{-5}$ inch/hour for Cycle 8 to reflect water chemisty with a conductivity of $\leq$ 0.15 µS/cm and an electrochemical potential of +200 mV. Since NMCA and hydrogen injection were implemented at NMP2 during fuel Cycle 8, the licensee used a reduced CGR of $1.1x10^{-5}$ inch/hour for Cycle 9, as permitted by an NRC safety evaluation (SE) dated December 3, 1999 (see Reference 3). For the length direction, however, the licensee used the bounding CGR of $5.0x10^{-5}$ inch/hour for both cycles.

In the subsequent flaw evaluation for weld H4, the licensee employed its "distributed ligament length (DLL) flaw evaluation methodology (BWRVIP-20)" to conduct the evaluation. The DLL

methodology is capable of analyzing a core shroud weld with multiple flaws using either the limit load or the linear elastic fracture mechanics (LEFM) analysis. Since the predicted fluence at the end of Cycle 9 for weld H4 exceeds the LEFM threshold fluence of 3.0×10^{20} n/cm^2 as specified in Topical Report BWRVIP-01, Revision 1 (dated March 1995, and also referred to as GENE-523-113-0894, Rev. 1, “BWR Core Shroud Inspection and Evaluation Guidelines”; approved by the NRC staff on June 16, 1995), the licensee has performed both limit load and LEFM evaluations for weld H4.

2.1.2 Flaw Evaluation - Limit Load Analysis

In its limit load analysis, the licensee assumed through-wall flaws for regions where the inside diameter (ID) surface fluence at the end of Cycle 9 exceeds 3.0×10^{20} n/cm^2. The initial crack depth in all other regions with detected cracks or regions with uninspected cracks was assumed to be the maximum detected flaw depth of 0.78 inch. Using this initial crack depth and the above-mentioned CGRs for Cycle 8 and Cycle 9 for 16,000 hours each, the licensee estimated that the final crack depth is 1.42 inches at the end of Cycle 9. This estimate included a ultrasonic testing (UT) uncertainty of 0.108 inch. The final crack lengths between flaws were calculated internally by the DLL program in a similar manner. The results indicated that the safety factor at the most limiting location of weld H4 is 4.98 based on a stress intensity, S_m, of 14.4 ksi and primary membrane and bending stresses of 0.328 ksi and 1.19 ksi for the normal and upset loading condition. Since the calculated safety factor is greater than the Code-specified safety factor of 2.77, the licensee concludes that the structural margin requirements at weld H4 are satisfied through the end of Cycle 9.

2.1.3 Flaw Evaluation - LEFM

In the LEFM analysis, the licensee assumed essentially the same multiple crack geometry that was used in the limit load analysis except that the through-wall regions now correspond to locations with ID surface fluence at the end of Cycle 9 exceeding 5.0×10^{20} n/cm^2. The final crack geometry was developed using the same crack growth approach as described in Section 2.1.2 above. The licensee’s LEFM methodology was based on a fracture mechanics model of multiple flaws with uniform depth, which is consistent with that in a previous submittal dated July 9, 1998, for the evaluation of the core shroud examination results of RFO6. The LEFM results indicated that the calculated safety factor was 3.05 for a K_{Ic} value of 150 ksi(in)$^{1/2}$, exceeding the Code-specified value of 2.77. Based on the results from the limit load and the LEFM analyses, the licensee concludes that weld H4 meets the structural margin requirements for continued operation after RFO7 for two fuel cycles. To demonstrate that weld H4 has more margin than that was indicated by the LEFM results, the licensee performed an additional analysis based on elastic-plastic fracture mechanics (EPFM), and found that the corresponding safety factor for EPFM was 4.0.

2.1.4 Neutron Fluence

(See NRC staff’s evaluation in Section 2.2.4)

2.2 NRC Staff's Evaluation

2.2.1 Crack Growth Rate

The licensee's CGR of $2.2x10^{-5}$ inch/hour for Cycle 8, reflecting water chemistry with a conductivity of $\leq$ 0.15 µS/cm and an electrochemical potential of +200 mV, and CGR of $1.1x10^{-5}$ inch/hour for Cycle 9, reflecting the implementation of NMCA and hydrogen injection, are acceptable because they are in accordance with the staff's SE on Topical Report BWRVIP-14 (see Reference 3). According to this SE, the above-mentioned CGRs are only applicable to components which had experienced fluences less than $5.0x10^{20}$ n/cm^2. The licensee simplified the weld H4 crack geometries for the limit load and LEFM analyses so that these CGRs could be applied. For the length direction, it is conservative to use the bounding CGR of $5.0x10^{-5}$ inch/hour for both cycles.

In order to use the reduced bounding crack growth rates for flaw evaluation, certain conditions must be met. To use the CGR of 2.2 x 10^{-5} inch/hour, the necessary conditions are specified in BWRVIP-14 and the staff's SE (Reference 3). The use of a CGR of 1.1 x 10^{-5} inch/hour is allowed when an effective HWC or NMCA program is maintained. The criteria for an effective HWC or NMCA program are identified in Open Item 3.2 of the staff's SE dated January 30, 2001 (Reference 4). The staff's conclusion is based on the assumption that these conditions or criteria are met, especially that the measurements would indicate that the electrochemical potential at the weld H4 location is below -230 mV, or the hydrogen vs. oxygen molar ratio is 4:1 and above.

2.2.2 Flaw Evaluation - Limit Load Analysis

By assuming through-wall flaws for regions where the ID surface fluence of weld H4 at the end of Cycle 9 exceeds $3.0x10^{20}$ n/cm^2, the licensee's approach satisfied not only the fluence condition for using the reduced CGRs, but also the condition for employing the limit load analysis to assess the structural integrity weld H4. Further, the licensee's approach of considering the uninspected regions as flaws of the maximum detected flaw depth is appropriate. The staff's SE dated August 20, 2001 (see Reference 5) accepted this approach for plants with normal water chemistry. Although Topical Report BWRVIP-63 only discussed axial welds, the staff determined that this approach applies to circumferential welds also, because the technical basis for the staff's prior approval for the axial welds is independent of the crack orientation, and the stresses due to pressure are much less for the circumferential welds. The rest of the licensee's limit load analysis is similar to that in the previous submittal and is similarly acceptable. Since the calculated safety factor is greater than the Code-specified safety factor of 2.77, the staff agrees with the licensee's conclusion that the structural margin requirements at weld H4 are satisfied through the end of Cycle 9.

2.2.3 Flaw Evaluation - LEFM

In the LEFM analysis, the licensee assumed essentially the same multiple crack geometry that was used in the limit load analysis except that the through-wall regions now correspond to locations with ID surface fluence at the end of Cycle 9 exceeding $5.0x10^{20}$ n/cm^2. By assuming through-wall flaws for regions where the ID surface fluence of weld H4 at the end of Cycle 9 exceeds $5.0x10^{20}$ n/cm^2, the licensee's approach satisfied the fluence condition for using the reduced CGRs. It should be mentioned that this assumed geometry contains regions of

fluences (at the end of Cycle 9) greater than $3.0x10^{20}$ n/cm^2, and, therefore, triggered the licensee to perform an evaluation using LEFM. The licensee's LEFM methodology has already been reviewed and accepted by the staff as indicated in the SE dated October 30, 2000. Since the current LEFM results indicated that the calculated safety factor of 3.05 exceeds the Code-specified value of 2.77, the staff concludes that weld H4 meets the structural margin requirements for continued operation of NMP2 after refueling outages for two fuel cycles. The licensee's EPFM results, which show additional margin, are another positive factor to the staff's determination.

2.2.4 Neutron Fluence

The structural strength of the remaining ligament in weld H4 is a function of neutron fluence. The staff reviewed the acceptability of the azimuthal variation of the proposed fluence value as measured in the 3-degree surveillance capsule and calculated in Reference 7.

Two types of dosimeters were used by the licensee: Fe-54 (n, p) Mn-54 and Cu-63 (n, a) Co-60. In addition, for verification, a scrapping from a Charpy test bar was also used. The samples were weighed, counted and handled in a standard manner. The licensee's transport calculation used the DORT Code (Reference 8) and the BUGLE-96 cross section library (Reference 9). Neutron scattering was treated with a P_3 approximation and angular discretization was modeled with an S_8 approximation.

(R, θ) and (r, z) calculations were performed for an eighth geometry which included the 3-degree capsule and the jet-pump and pump risers in the downcomer. The calculation extended through the vessel thickness to the reactor cavity. The water void fraction was input in segments as a function of (r, θ, z). The Code, the cross sections, the approximations and the number of mesh points satisfy the guidance in Regulatory Guide (RG) 1.190. The results of the calculation for the capsule center flux (E > 1.0 MeV) is $2.7x10^8$ n/cm^2 s. This value compared favorably with similar calculations performed by others.

The licensee's dosimeter results appear inconsistent (Reference 7 states that the position of the dosimeters within the capsule was uncertain). Assumptions of the possible locations yield calculated/experimental activation values within and outside the 20 percent value stated in RG 1.190. To obtain more information, a scrapping was obtained from a Charpy sample, but the axial location of the Charpy sample and the location of the scrapping was also uncertain. While the mean values are within reasonable limits of each other, the uncertainty in the location of the dosimeters, the scrapping, and the Charpy sample makes it difficult to establish the value of the uncertainty derived from the measured dosimetry. For the purposes of the crack growth rate, the licensee states that a 2σ uncertainty is added to the calculated fluence value for the end of Cycle 9. In addition, the Cycle 7 contribution to the fluence was calculated for a cycle length of 664.3 effective full-power days (EFPDs) while the actual run was about 545 EFPD.

Comparing the fluence conservatism with the addition of the 2σ (about 32%) and the Cycle 7 short run to the results of the dosimetry, the staff concludes that the values of the azimuthal fluence distribution used for the core shroud weld H4 structural analysis are conservative and, thus, are acceptable.

3.0 CONCLUSION

The NRC staff has completed its review and found that the licensee's flaw evaluation meets the intent of the rules in Section XI of the ASME Code. Since the safety factors associated with the detected cracks are greater than 2.77 specified in the ASME Code, the staff concludes that NMP2 can be operated without repair of the H4 weld for two fuel cycles after RFO7. The staff's conclusion is based on the assumption that the conditions or criteria mentioned in Section 2.2.1 are met, especially that the measurements would indicate that the electrochemical potential at the weld H4 location is below -230 mV, or the hydrogen vs. oxygen molar ratio is 4:1 and above.

4.0 REFERENCES

1. Letter from R. B. Abbott of NMPC to NRC, "Reinspection Plan for the Core Shroud Weld H4," dated September 14, 2001.

2. Letter from P. Tam of NRC to J. H. Mueller of NMPC, "Nine Mile Point Nuclear Station Unit No. 2 - Safety Evaluation of Core Shroud Inspection Results (TAC No. MA9057)," dated October 30, 2000.

3. TR-105873, "BWR Vessel and Internals Project, Evaluation of Crack Growth in BWR Stainless Steel Internals (BWRVIP-14)," issued by Electric Power Research Institute (EPRI), March 1996. (NRC staff safety evaluation dated December 3, 1999).

4. TR-108705, "BWR Vessel and Internals Project, Technical Basis for Inspection Relief for BWR Internal Components with Hydrogen Injection (BWRVIP-62)," issued by EPRI, December 1998. (NRC staff safety evaluation dated January 30, 2001).

5. TR-131170, "BWR Vessel and Internal Project, Shroud Vertical Weld Inspection and Evaluation Guidelines (BWRVIP-63)," issued by EPRI, June 1999. (NRC staff safety evaluation dated, August 20, 2001).

6. TR-114232 "BWR Core Shroud Inspection and Flaw Evaluation Guidelines," issued by EPRI, November 1999.

7. Letter from R. B. Abbott of NMPC to NRC, dated March 8, 2001, transmitting Topical Report MPM-1200676 "Nine Mile Point Unit 2, 3-Degree Surveillance Capsule Report" MPM Technologies, Inc., dated December 2000.

8. TORT-DORT-PC, "Two- and Three-Dimensional Discrete Ordinates Transport Version 2.7.3, " Radiation Safety Information Computation Center, Computer Code Collection CCC-543, Oak Ridge National Laboratory, Oak Ridge TN, June 1996.

9. BUGLE-96, "Coupled 47 Neutron, 20 Gamma Ray Group Cross Section Library Derived from ENDF/B-VI for LWR shielding and Pressure Vessel Dosimetry Applications," Radiation Safety Information Computation Center, DLC-185, Oak Ridge National Laboratory, Oak Ridge TN, March 1996.

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