UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO EXTENSION OF THE SCHEDULE FOR

REINSPECTING CORE SHROUD VERTICAL WELDS

NIAGARA MOHAWK POWER CORPORATION

NINE MILE POINT NUCLEAR STATION, UNIT 1

DOCKET NO. 50-220

1.0 INTRODUCTION

1.1 PURPOSE

This safety evaluation (SE) addresses a request submitted by Niagara Mohawk Power Corporation (NMPC and the licensee) to extend the reinspection interval for the core shroud vertical welds at Nine Mile Point Nuclear Station, Unit 1 (NMP1), from 10,600 hours of hot operation to 14,500 hours of hot operation. The purpose of this review is to determine whether or not the stress intensity factor (K)-independent crack growth rate of 2.2×10^{-5} inch/hour given in Boiling Water Reactor Vessels and Internals Project document BWRVIP-14, "Evaluation of Crack Growth in BWR Stainless Steel RPV Internals," can be applied to the crack growth evaluation of the NMP1 core shroud vertical welds to support the extension of the reinspection interval..

1.2 BACKGROUND

NMP1 operating cycle 13, the current cycle, began in late April 1997 following completion of refueling outage 14. Operating cycle 12 began in April 1995 and ended in March 1997.

During the 1995 refueling outage (RFO-13) for NMP1, NMPC performed preemptive repair of the core shroud by installing four core shroud stabilizer assemblies ("tie rods") to ensure the structural integrity of the core shroud with respect to the function of the circumferential welds that experienced cracks in some boiling-water reactors (BWRs). The repair was considered as an alternative to an American Society of Mechanical Engineers Boiler and Pressure Vessel (ASME Code) repair pursuant to 10 CFR 50.55a(a)(3)(i) and was approved by NRC in an SE dated March 31, 1995.

During the 1997 refueling outage (RFO-14), NMPC performed core shroud inspection in accordance with BWRVIP-07, "Guidelines for Reinspection of BWR Core Shrouds," dated February 1996, and found cracking in the vertical welds. NMPC also found that tie rod nuts had lost some preload and that the lower wedge retainer clips on three of four shroud stabilizer assemblies had experienced damage, including one that had actually broken off. NMPC modified the lower wedge retainer clip design and took additional actions to restore the stabilizer assemblies to the intended function previously approved by the NRC staff. The repair modification was considered as an alternate repair under the ASME Code Section XI definition of repair or replacement pursuant to 10 CFR 50.55a(a)(3)(i) and was approved by the NRC staff in a letter dated May 8, 1997. In addition, NMPC proposed that reinspection of the shroud vertical welds be performed after 10,600 hours of hot operation. This interval, 10,600 hours of hot operation, was based upon a fracture mechanics analysis of the most limiting case of vertical weld V-9. The allowable flaw size for weld V-9 was determined by using the conservative linear elastic fracture mechanics (LEFM) analysis. Based on the allowable flaw size, the limiting interval, 10,600 hours of hot operation, was calculated by using the bounding crack growth rate of 5×10^{-5} inch/hour. By letter dated April 8, 1997, NMPC stated that additional analyses were planned, and would be submitted to the NRC staff, to justify extension of the reinspection interval for the shroud vertical welds.

NMPC performed metallurgical testing of two boat samples taken from vertical welds V-9 and V-10 of the core shroud. These two vertical welds join the two plates forming the central-mid-cylinder shell course. This cylinder is located between horizontal welds H-4 and H-5 and is approximately at the core mid-plane. Boat sample V-10 was removed from the outside diameter (OD) surface of the shroud and is about 57.5 inches below horizontal weld H-4. Boat sample V-9 was removed from the inside diameter (ID) surface of the shroud (different plate) and is about 25 inches below weld H-4. Boat Sample V-10 contains cracks initiated from the OD surface. However, boat sample V-9 contains no crack. The purpose of testing the boat samples is to identify the cracking mechanism. The testing performed included metallographic examination for microstructure features, cracking morphologies and patterns, fractography, chemical analyses, microhardness testing, sensitization evaluation by optical metallography and electrochemical potentiokinetic reactivation (EPR) measurements, tensile tests and measurements of neutron fluence with energies above 1 MeV.

The testing and analyses results reported in NMPC's letters dated September 30, 1997, and January 30, February 27, September 21 and October 22, 1998, show that the characteristics of the observed cracking are consistent with the features of intergranular stress corrosion cracking (IGSCC). Further, the estimated fluence at the remaining uncracked ligaments is expected to be less than 5×10^{20} n/cm^2 at the end of operating cycle 13.

By letter dated February 27, 1998, NMPC submitted a request to extend the reinspection interval for the core shroud vertical welds from 10,600 to 14500 hours of hot operation. The justification in the request is based upon the results of metallurgical evaluation of the boat samples, fluence measurements and calculations, and reassessment of crack growth for welds V-9 and V-10 with the application of a K-independent crack growth rate of 2.2×10^{-5} inch/hour. The NRC staff evaluates the applicability of the K-independent crack growth rate of 2.2×10^{-5} inch/hour to NMP1 in the following section.

2.0 EVALUATION.

NMPC has performed extensive metallurgical testing on the two boat samples taken from NMP1 core shroud vertical welds V-9 and V-10. Sample V-9 was taken from the ID surface of vertical weld V-9 and did not contain any crack. Sample V-10 was taken from the OD surface of vertical weld V-10 and contained some cracks. The key testing results from cracking morphologies, material sensitization, tensile testing and fluence measurements are summarized below:

(I) Cracking Morphologies

- All primary and secondary cracking is intergranular in nature.
- All cracks are filled with oxides including areas near the crack tip, indicating that the

cracking is moving very slowly to allow the oxidation process to catch up with the cracking.

- The crack initiation at boat sample V-10 appears to be promoted by the surface cold work. A surface cold work layer with a depth about 6 to 7 miles was identified by microhardness testing and the appearance of slip lines in the microstructure. The depth of the surface cold work layer on boat sample V-9 which does not contain any crack is much shallower (about 2 miles).

- The observed cracking at boat sample V-10 appears to be confined to the areas of the heat affected zone (HAZ)

(ii) Material Sensitization

- Classical weld sensitization was observed by optical metallography in the HAZ of boat sample V-10. The weld sensitization was not evident in the base material, away from the HAZ zones.

- The results of EPR measurements of both samples indicate moderate sensitization consistent with weld sensitization. The degree of sensitization reported for sample V-10 (6-15 coulombs/cm^2) is larger than measured for sample V-9 (2-5 coulombs/cm^2).

(iii) Tensile Testing

- The yield strength for samples V-9 and V-10 as tested at 550 ^{0}F is reported to be about 48.1 ksi and 51.0 ksi, respectively.

- The ultimate strength for samples V-9 and V-10 as tested at 550 ^{0}F is reported to be about 69.75 ksi and 74.9 ksi, respectively.

- The elongation and reduction in area for samples V-9 and V-10 as tested at 550 ^{0}F are reported to be about 24.7% and 28.3% (sample V-9), and 26.7% and 16% (sample V-10), respectively.

(iv) Fluence Measurements

- The fluence levels at the shroud ID surface and mid-wall as measured on the sample V-9 are reported to be 3.068 x 10^{20} n/cm^2 and 2.273 x10^{20} n/cm^2, respectively.

- The fluence level at the shroud OD surface and mid-wall as measured on the sample V-10 are reported to be 1.113 x 10^{20} n/cm^2 and 1.541 x 10^{20} n/cm^2, respectively.

- The neutron flux calculations have shown that the fluence on the ID surface of sample V-9 bounds the maximum fluence at the remaining ligaments for both the V-9 and V-10 welds.

Based upon the results of the metallurgical evaluation of the boat samples and the reported fluence measurements, NMPC concluded that the features of cracking in the shroud vertical welds are consistent with the cracking mechanism of IGSCC observed in other BWR components.

NMPC compared the microstructural features of the cracks in sample V-10 to that from a boat sample taken from the shroud of a foreign plant. The foreign boat sample did not show significant weld sensitization (grain boundary carbide precipitation) or microstructure evidence of surface cold work. In the cracked region of the foreign boat sample, the fluence is estimated to be about 8×10^{20} n/cm^2 (E>1 MeV), and the cracking mechanism was determined to be irradiation assisted stress corrosion cracking (IASCC), which exhibits the microstructural features of (1) significant grain encirclement and grain fallout and (2) significant crack branching, including the areas at the crack tip. Based upon this comparison, NMPC concludes that the primary cracking mechanism in the vertical welds at NMP1 was not due to IASCC because the key microstructural features for IASCC, as shown in the foreign boat sample, are not observed in the boat sample V-10. Further, the reported NMP1 fluence is considerably less than the foreign plant fluence.

The NRC staff agrees with NMPC's conclusion that the cracking of shroud vertical welds is not IASCC because all the features observed on the boat samples support the cracking mechanism of IGSCC and the NMP1 fluence is considerably less.

The major effects of irradiation on the austenitic stainless steel is to increase the sensitization and hardening (yield strength) of the base material (outside of the weld HAZ). From the sensitization study of the boat samples V-9 and V-10, there is no evidence of significant sensitization in the base material. However, hardening of the stainless steel material is evident from the tensile testing of the miniature tensile specimens made from the NMP1 boat samples. Based on General Electric's (GE's) testing results of irradiated stainless steel, the degree of hardening (yield strength) shown in boat samples V-9 and V-10 is consistent with the material irradiated to a fluence range of 1×10^{20} to 3×10^{20} n/cm^2 (E>1 MeV). As discussed in the NRC staff's SE dated June 8, 1998 for BWRVIP-14, if the fluence does not exceed the threshold value of 5×10^{20} n/cm^2 (E>1 MeV), the effect of irradiation on the properties of austenitic stainless steel material is expected to be small. Therefore, the NRC staff concludes that the contribution of irradiation to the cracking of shroud vertical welds V-9 and V-10 will not be significant, because the measured fluence at various locations of the boat samples is below the threshold value of 5×10^{20} n/cm^2 (E>1 MeV).

NMPC has performed neutron flux calculations, including an uncertainty analysis, for vertical welds V-9 and V-10. The results of the calculations show that the estimated fluence at the remaining ligament of welds V-9 and V-10 will be below 5×10^{20} n/cm^2 at the end of cycle 13 (i.e., at the end of the 14,500 hours of hot operation). The NRC staff has reviewed NMPC's neutron flux calculations and has determined that the methodologies used by NMPC are acceptable. The NRC staff's determination is, in part, based upon the consideration that the calculated fluences at the boat sample locations are about 16% higher than the measured fluences, which represents additional margin relative to the calculated fluence. The NRC staff's evaluation of NMPC's measured and calculated fluence values for the NMP1 shroud is presented in Appendices A and B of this SE, respectively.

NMPC justified its request to extend the reinspection interval of the shroud vertical welds from 10,600 to 14,500 hot operating hours by using a reduced bounding crack growth rate of 2.2×10^{-5} inch/hour based on GE's PLEDGE model and the approaches given in BWRVIP-14. The reinspection interval of 10,600 hours was calculated by using a bounding crack growth rate of 5.5×10^{-5} inch/hour for the cracking of a ligament of 0.53 inches. The results of NMPC's revised fracture mechanics analysis have shown that the cracking of an additional ligament of 0.53 inches would also be acceptable because it will not impact the structural integrity of the limiting vertical weld. NMPC performed the crack growth evaluation using GE's PLEDGE model to confirm that the use of the reduced bounding crack growth rate of 2.2×10^{-5} inch/hour is conservative. Based on the PLEDGE model, the anticipated crack growth rate at vertical welds V-9 and V-10 locations is estimated to be about 4.2×10^{-6} inch/hour. However, the NRC staff has not completed the review of the PLEDGE model. Therefore, the use of the PLEDGE model to assess the crack growth for the NMP1 core shroud was not considered as a part of this NRC staff SE.

BWRVIP-14 provides a methodology for assessment of crack growth in BWR stainless steel shrouds and other stainless steel internals components. Three approaches based upon a data base correlation model are described in the report. The NRC staff's SE dated June 8, 1998, approved the three approaches for the evaluation of crack growth given in BWRVIP-14. One of the approaches--the use of the K-independent crack growth rate of 2.2×10^{-5} inch/hour--is referenced in NMPC's crack growth assessment to support its request of extending the reinspection interval. However, to allow its application, certain limiting conditions must be satisfied. The conditions set forth in the NRC staff's SE for BWRVIP-14 are summarized below:

(1) The cracking mechanism must be IGSCC rather than IASCC.

(2) The neutron fluence should not exceed 5×10^{20} n/cm^2 (E>1 MeV).

(3) The approaches given in BWRVIP-14 apply only to the weld joints with simple geometry such as the double-V shroud welds (cylinder-to-cylinder horizontal welds and plate-to-plate vertical welds). As discussed in BWRVIP-14 and the NRC staff's associated SE, the profile of the through-wall residual stresses of these weld joints is well characterized by measurements and analysis with tensile stresses on the outside surfaces and compressive stresses in the midwall.

(4) Residual stresses resulting from weld repair and other factors must be considered.

(5) The plant is operated in accordance with Electric Power Research Institute (EPRI) BWR water chemistry guidelines.

(6) The maximum stress intensity factor (K) resulting from the applied and residual stresses should be less than 25 ksi(inch)^{½}.

The staff finds that the above stated conditions are satisfied for NMP1 core shroud vertical welds V-9 and V-10. The bases for complying with these conditions are discussed below:

(1) The results of the metallurgical testing of the boat samples as discussed above have shown that the primary cracking mechanism in the vertical welds is IGSCC and not IASCC.

(2) The results of NMPC's neutron flux calculations show that the fluences at the remaining ligament of vertical welds V-9 and V-10 will not exceed 5×10^{20} n/cm^2 at the end of cycle 13 (after hot operation of 14,500 hours).

(3) The weld joints of vertical welds V-9 and V-10 are plate-to-plate double-V welds with simple weld geometry. The weld residual stress profile for those welds, as characterized by NMPC's analysis, is similar to that given in BWRVIP-14.

(4) NMPC has reviewed the fabrication records for the shroud vertical welds and did not find any record of weld repair.

(5) NMPC is committed to operate NMP1 in accordance with the water chemistry guidelines in EPRI technical report TR-103515, "BWR Water Chemistry guidelines-1966 Revision," as stated in NMPC's letter dated April 30, 1997. This commitment is also stated in NMP1 Technical Specification (TS) Bases 3.2.3 and 4.2.3 as revised by license amendment No.163 dated September 18,1998. NRC inspectors have audited NMPC's monitoring of NMP1 operating chemistry and their findings confirm NMPC's statement that NMP1 operating chemistry has been, and is being, maintained well within the EPRI guidelines.

(6) Based on NMPC's fracture mechanics analysis of shroud vertical welds, the maximum K in the remaining ligament of vertical welds V-9 and V-10 will not exceed 25 $ksi(in)^{1/2}$.

The NRC staff finds that additional structural margins exist in the shroud vertical welds after an extended period of 14,500 hours of hot operation for the reasons given below:

(1) To provide additional support for its request to extend the reinspection interval to 14,500 hours, NMPC performed supplemental fracture mechanics analyses of the NMP1 core shroud vertical welds as discussed in NMPC's letter dated April 30, 1998. The supplemental analyses revised several overly conservative assumptions that had been made in NMPC's earlier assessment of structural integrity. Because of these overly conservative assumptions, NMP1 was limited to 10,600 hours of hot operation before reinspecting the vertical welds. The revised assumptions in the analyses consisted of (1) revising the level of cracking in the vertical welds of V-9 and V-10 by using a through-wall crack instead of the part through-wall crack or (2) considering the ultrasonic testing (UT) data for both the H-4 and H-5 horizontal welds instead of assuming these welds to be completely cracked through-wall. The results of the revised analyses show that NMP1 can be safely operated for at least 14,500 hours, using the bounding crack growth rate of 5×10^{-5} inch/hour for crack growth calculations. As discussed in item (3) below, the anticipated crack growth rate in the vertical welds is much slower than the bounding crack growth rate of 5×10^{-5} inch/hour. Therefore, additional structural margin exists for the vertical welds.

(2) The results of NMPC's fracture mechanics analysis show that, during operating cycle 13, a ligament of 0.53 inch can be cracked without impacting the structural integrity of the limiting vertical weld. Therefore, for 14,500 hours of hot operation in cycle 13, the allowable maximum crack growth rate was calculated to be 3.6×10^{-5} inch/hour. Since the allowable crack growth rate is higher than the assumed crack growth rate of 2.2×10^{-5} inch/hour in the crack growth calculation, additional structural margin exists for the limiting shroud vertical weld because an additional uncracked ligament beyond the minimum required by the ASME Code will be available at the end of cycle 13.

(3) Based on the data base correlation model in BWRVIP-14, the crack growth rate is defined as a function of electro-chemical potential (ECP), conductivity, temperature, and K. The approach of using the K-independent crack growth rate of 2.2×10^{-5} inch/hour is determined from the model based on the conditions of ECP at 200 mV-SHE, conductivity at 0.1 µmho/cm, temperature at 288 ^{0}C, and K at 25 $ksi(in)^{1/2}$. NMPC reported that in the current cycle, NMP1 has been operating with very good water chemistry. The average conductivity since April 1998 is well below 0.1 µmho/cm. The NRC staff finds that, based on the

correlation model in BWRVIP-14, the corresponding crack growth rate is estimated to be about 1 x 10^{-5} inch/hour when the conductivity is improved to 0.1 μmho/cm from 0.15 μmho/cm and all other conditions pertaining to the K-independent crack growth rate of 2.2 x 10^{-5} inch/hour remain the same. Since the anticipated crack growth rate is smaller than the rate assumed, an additional structural margin exists to the limiting shroud vertical weld because an additional uncracked ligament beyond that required by the ASME Code will be available in the vertical welds at the end of operating cycle 13.

Based on the above discussion, the NRC staff has determined that the use of the K-independent crack growth rate of 2.2 x 10^{-5} inch/hour for the crack growth evaluation in the shroud vertical welds is acceptable because all the limiting conditions set forth in the NRC staff's SE for BWRVIP-14 are satisfied.

3.0 CONCLUSION

Based on a review of the results of the metallurgical testing of the two vertical weld boat samples, as well as the fluence measurements and neutron flux calculations, the NRC staff has determined that the use of a K-independent crack growth rate of 2.2 x 10^{-5} inch/hour given in BWRVIP-14 for the calculations of crack growth in shroud vertical welds is acceptable because all the conditions stipulated in the NRC staff's SE regarding the use of this approach in BWRVIP-14 are met. Therefore, the NRC staff concludes that reasonable assurance exists that NMP1 can be safely operated with the current operating cycle extended to 14,500 hours before reinspection of the vertical welds because the structural integrity of the core shroud vertical welds will be maintained with the ASME Code required safety margin. Thus, the NRC staff concludes that a mid-cycle reinspection of the shroud vertical welds at 10,600 hours of hot operation is not necessary, since performing a mid-cycle reinspection would result in hardship without a compensating increase in the level of quality and safety.

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APPENDIX A

NRC STAFF EVALUATION OF

MEASURED FLUENCE VALUES AT THE CORE SHROUD

NINE MILE POINT NUCLEAR STATION, UNIT 1

In letters dated January 30 and February 27, 1998, and in other correspondence, Niagara Mohawk Power Corporation (NMPC and the licensee) submitted information in support of its request that the NRC consent to extending the schedule for reinspection of shroud vertical welds at Nine Mile Point Nuclear Station, Unit 1 (NMP1) from 10,600 hot operating hours to 14,500 hot operating hours. The request for consent is based, in part, upon an assessment of the intergranular stress corrosion cracking (IGSCC) of the shroud. Exposure of the shroud to fast neutron fluence is one of the factors contributing to IGSCC because such exposure can increase the material embrittlement. In this appendix, the NRC staff evaluates the proposed values of the measured fluence, and its associated uncertainty estimates, for application to the estimate of the shroud IGSCC.

EVALUATION

NMPC's justification for extending the inspection interval is based, in part, upon the results of shroud metallurgical ("boat") sample dosimetry measurements for the fast neutron fluence and subsequent evaluation of the material embrittlement. The sample measurement was performed for NMPC by Framatome Technologies Incorporated (FTI) and their report was forwarded by NMPC's January 30, 1998 letter.

At the end of NMP1 operating cycle 12, two boat samples were extracted from the shroud--one from the inside surface of vertical weld V-9 at a position 26.4 inches above fuel midplane, and the second from the outside surface of V-10 at a position 8.3 inches below fuel midplane. Dosimeters were cut from the boat samples and measured. The results of the dosimeter activation measurement, along with weight and isotopic composition information and the reactor operating history, allowed the estimation of the shroud fluence at the sampling points and the associated uncertainty.

The procedure followed was to cut three dosimeters from each boat sample, corresponding to different depths of the shroud thickness. The dosimeters were dissolved in an acidic solution and the elemental weight fractions in the solute were determined. Given the isotopic composition, the isotopic weight fractions were determined. The Fe-54(n,p)Mn-54, Ni-58(n,p)Co-58 and Co-59(n,γ)Co-60 reactions were used as dosimeters. However, the Cobalt reaction does not have a meaningful response in the energy range of interest ($E > 1.0$ MeV), and was, therefore, ignored. A total of 24 activation readings (i.e., 2 samples x 2 dosimeters x 3 positions x 2 measurements) were taken. The activation readings were converted to fast neutron flux using (1) a calculated spectrum for the sampling locations, and (2) the reactor irradiation history (operating history). Finally, from the flux, the fluence is estimated from the reactor operating history.

Due to the limited number of readings, several consistency and reliability checks were performed. These included comparison with calculated values, fast flux decay vs distance, and Fe/Ni reading consistency. The results showed excellent consistentency and were within their uncertainty limits. There was no measurable bias.

A number of potential sources of uncertainty were identified and quantified. Elements of the FTI generic methodology were used and their applicability for NMP1 was justified. The numerical values of the uncertainties are reasonable. The accuracy requirements for the intended application is relatively small. Thus, considering the consistency of the readings, the reasonable agreement with calculated values, and the requirements of the proposed application, the NRC staff finds the proposed values to be acceptable.

CONCLUSION

On the basis of its review of information submitted by NMPC in letters dated January 30 and February 27, 1998, the NRC staff finds the proposed values for measured fast neutron fluence to be acceptable considering the limited number of dosimet adings, the related consistency and reliability checks, and the values of the associated uncertainty.

APPENDIX B

NRC STAFF EVALUATION

OF CALCULATED FLUENCE VALUES AT THE CORE SHROUD

NINE MILE POINT NUCLEAR STATION, UNIT NO. 1

By letter dated October 22, 1998, Niagara Mohawk Power Corporation (NMPC and the licensee) submitted information regarding an evaluation of the fast neutron fluence to the core shroud at Nine Mile Point Nuclear Station, Unit No. 1 (NMP1) and requested that the NRC staff approve the estimated values. The purposes of NMPC's evaluation are to: (1) substantiate the measured values, (2) estimate the specific fluence at the end of the current operating cycle at the shroud welds, and (3) establish that the uncertainty in the proposed fluence determination is within 20% (1σ). The evaluation supplements the information derived from the metallurgical ("boat") samples extracted from vertical shroud welds V-9 and V-10 and measured as dosimeters. The results of these measurements have been reviewed and approved by the NRC staff. The fluence values derived from the boat sample measured activity are compared to the corresponding calculated values.

METHODOLOGY

During operating cycle 12 (and cycle 11), NMP1 operated with a new control rod pattern that changed the void fraction distribution of the core to which the dosimeters were exposed. This new void distribution differed from those used in previous dosimetry calculations such as in the analyses of the surveillance capsules located at 30-degrees, 300-degrees, and 210-degrees which were analyzed based upon mid-cycle 7 neutron transport data including void distribution. For the boat samples, NMPC sought to closely evaluate the performance of iron (Fe) and nickel (Ni) dosimeters due to their short half lives with respect to the duration of the cycle. For this reason, the cycle time was divided into five time segments, each with a separate void fraction distribution. The void fraction was estimated from the control rod pattern in the corresponding time interval and was provided in 24 axial nodes.

The DORT code (see Radiation Safety Information Computational Center (RSICC) Computer code collection, CCC-543, "TORT-DORT-PC, Two and Three-Dimensional Discrete Ordinates Transport Version 2.7.3," dated March 1996, available from the RSICC, Oak Ridge National Laboratory, Oak Ridge, TN) was employed for the transport (and spectrum) calculations with the BUGLE-96 library of 47 energy groups, an ENDF/B-VI based data set (see RSICC Data Library Collection, DLC-185, "BUGLE-96, Coupled 47 Neutron, 20 Gamma Ray Group Cross Section Library Derived from ENDF/B-VI for Light Water Reactor Shielding and Pressure Vessel Dosimetry Applications," dated March 1996, available from the RSICC, Oak Ridge National Laboratory, Oak Ridge, TN). The analyses employed the synthesis method using the (r,θ), (r,z) and (r) fluxes to obtain a three-dimensional representation of the fluxes (and fluence) for NMP1 operating cycle 12. For the interpretation of the dosimetry, a calculated spectrum was evaluated in the position of the boat samples and the 210-degree surveillance capsule. The scattering anisotropy was treated with a P_3 expansion of the scattering cross section and the angular discretization was modeled with a S_8 order of angular quadrature. NMPC stated that the calculational procedure complies with appropriate standards of the American Society for Testing and Materials (ASTM) and NRC requirements/ guidance (e.g., draft Regulatory Guide-1053, "Calculational and Dosimetry Methods for Determining Pressure Vessel Neutron Fluence," issued for comment June 1996).

The boat sample dosimetry measurements and fluence evaluations were performed for NMPC by Framatome Technologies Incorporated (FTI). To convert the dosimeter exposure to fluence, FTI used previously estimated spectra by Battelle for NMP1 operating cycle 7 which were estimated in connection with the evaluation of the 300-degree surveillance capsule (see FTI Document 86-1266298-00, "Fluence Analysis Report for Boat Samples, Nine Mile Point 1," forwarded under NMPC cover letter dated January 30, 1998). In May 1998, evaluation of the 210-degree surveillance capsule, which had been removed at the end of NMP1 operating cycle 12 (see MPM Technologies Inc. document MPM-998676, "Nine Mile Point Unit 1 Shroud Transport Analysis," forwarded under NMPC cover letter dated September 21, 1998) was completed. For the mid-cycle 7 spectra and analysis, both the boat sample and the 210-degree capsule dosimetry measurements indicated an inconsistency between the copper (Cu), Fe and Ni dosimeter reactions.

NMPC performed analyses to quantify the impact of the NMP1 operating cycle 12 void distribution upon the dosimeter response. Improvements were derived from a five step representation of the void fractions in cycle 12. Comparison of the measured and calculated fluxes indicated reasonable agreement, with the calculated values being higher for the boat sample dosimetry and lower for the 210-degree capsule. Therefore, NMPC proposed to use the calculated values for the purposes of this application. The NRC staff finds the calculational methodology acceptable because it complies with the practices and recommendations in Draft Regulatory Guide 1053. In addition, the results are conservative with respect to the shroud dosimetry measurements, which are more relevant to the shroud fluence.

DOSIMETRY RESULTS

The calculated V-9 and V-10 weld fluence values 14,500 hours after the end of NMP1 operating cycle 12 (i.e., at the projected end of cycle 13), are shown in Figure 1 of this appendix. This can be directly compared to the crack depth profile of both welds as measured at the end of cycle 12, shown in Figure 2 of this appendix. The NRC staff notes that the maximum fluence value occurs at the 27.00 inch elevation above the fuel midplane and is 4.32×10^{20} n/cm^2 (E > 1.0 MeV, see Table A-12 of Report MPM-108679, "Final Report, Nine Mile Point Unit 1 Shroud Neutron Transport and Uncertainty Analysis," forwarded by NMPC cover letter dated October 22, 1998). The V-9 and V-10 welds are azimuthally symmetric with respect to the peak shroud fluence location which is 4.39×10^{20} n/cm^2 (E > 1.0 MeV, see Table A-16 of the same report, at 19.34 degrees on the azimuth). The NRC staff also notes that the maximum crack depth in the V-9 weld coincides with the maximum fluence location, but this is not the case for the V-10 weld.

CONCLUSION

On the basis of its review of NMPC's submittals regarding the NMP1 shroud fluence evaluation, the NRC staff finds that: (1) the proposed calculated fluence values substantiate the shroud measured values, because they are within the estimated uncertainty limits, (2) the proposed fluence values for the critical shroud welds, V-9 and V-10, are acceptable because they were determined using an acceptable calculational method, and (3) the estimated uncertainty of the calculation is within the NRC staff's recommended uncertainty limits of 20%. Therefore, the NRC staff concludes that the proposed shroud fluence values are acceptable.

Shroud Fluence on V9 and V10

(From Table A-12)

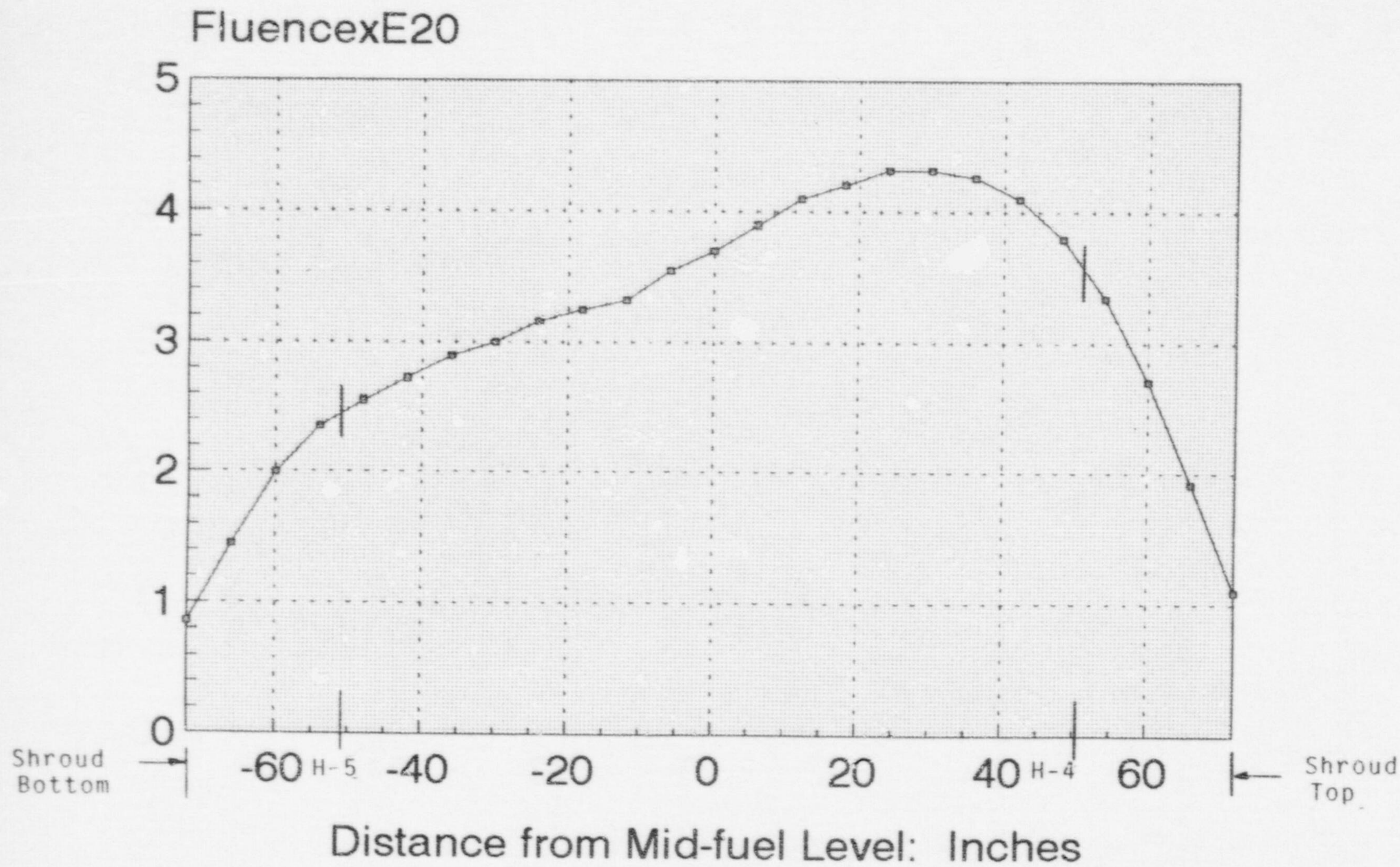
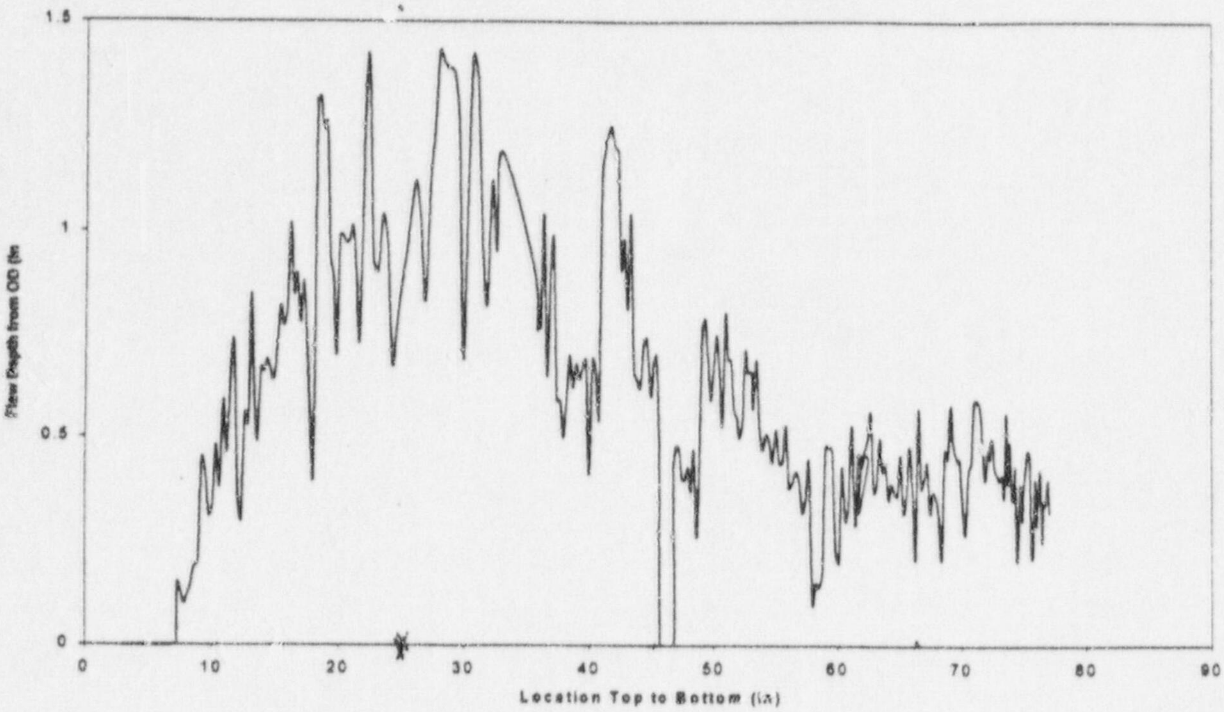
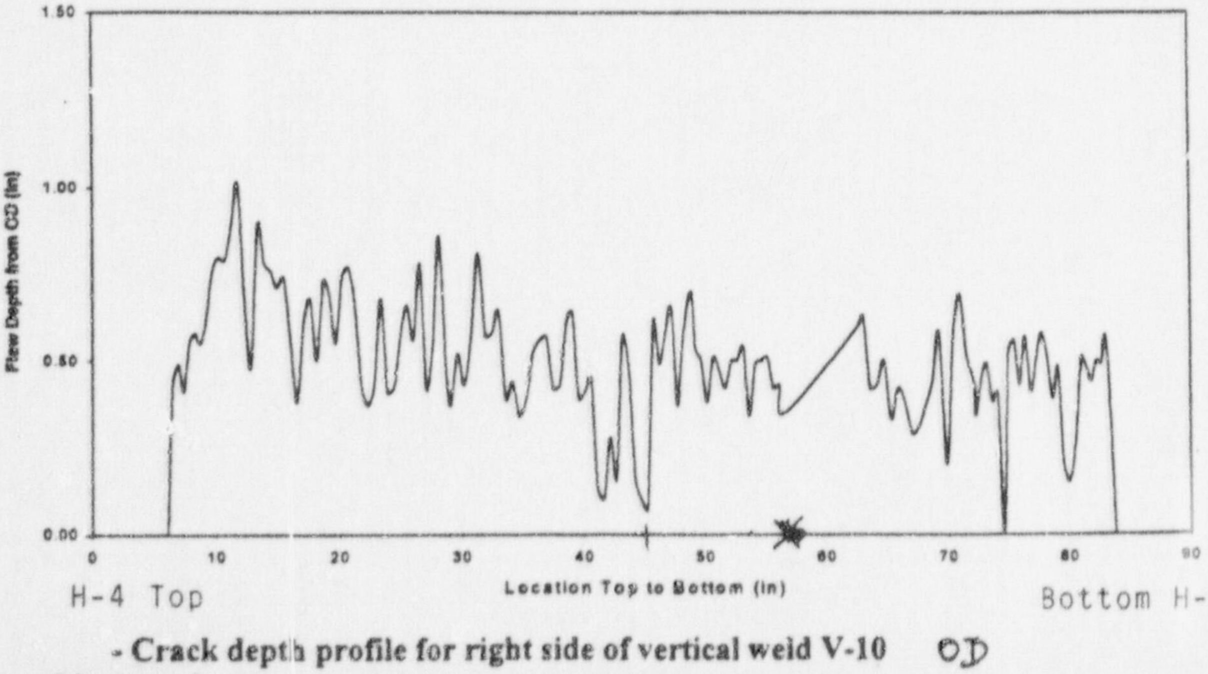


Figure 1



- Crack depth profile for left side of vertical weld V-9 OD

Altran Corporation
Technical Report 97181-TR-02
Revision 0



- Crack depth profile for right side of vertical weld V-10 OD

Figure 2