Mr. J. H. Swailes March 3, 2000
Vice President of Nuclear Energy
Nebraska Public Power District
P. O. Box 98
Brownville, NE 68321

SUBJECT: COOPER NUCLEAR STATION: EVALUATION OF THE REVISED FRACTURE MECHANICS METHODOLOGY AS APPLIED TO CORE SPRAY PIPING WELD FLAWS AND INSPECTION OF REACTOR VESSEL INTERNAL CORE SPRAY PIPING (TAC NO. MA4201)

Dear Mr. Swailes:

By letter dated November 6, 1998, Nebraska Public Power District (NPPD) reported the results of the examination of two flaw indications found in the core spray piping welds A1 and A21. These indications were found originally by ultrasonic testing examination in 1995 and were reexamined during refueling outage 18 which concluded in December 1998. The letter requested (1) Nuclear Regulatory Commission (NRC) concurrence that Cooper Nuclear Station (CNS) can be safely operated for fuel cycle 19 and (2) NRC review and approval of a revised fracture mechanics evaluation as presented in attachment 3 to the November 6, 1998, letter. Approval of the former request was necessary prior to startup for cycle 18 and approval of the latter was requested for fuel cycles 20 and 21.

With regard to the first request, NPPD presented information that the measured and projected flaw sizes were well within the maximum flaw length permitted by the 1995 fracture mechanics evaluation methodology (the approved fracture mechanics methodology at the time of the request). The staff concurred that CNS could be safely operated during cycle 19 in a safety evaluation dated November 23, 1998.

With regard to the second request, the staff has reviewed NPPD's submittal dated November 6, 1998, and has concluded that the revised fracture mechanics methodology meets the rules of the American Society of Mechanical Engineers Code (see enclosed safety evaluation). Specifically, the revised stresses for the allowable flaw length calculation are derived from the most recent information, but the methodology for calculating the predicted flaw length remains the same. The acceptance of the operating basis earthquake and the safe shutdown earthquake loads which caused major reduction in the input stresses was determined by the staff. Therefore, the staff concludes that NPPD can use the revised fracture mechanics methodology in future flaw evaluations.

In addition, the staff has reviewed NPPD's evaluation of the predicted flaw size as compared to the allowable flaw size using the new methodology. NPPD stated that with the new allowable flaw size, even with the conservative assumption of crack growth rate, at least three additional operating cycles (including cycle 19) are expected before the integrity of the weld reaches the analyzed limits. Based on its review, the staff concludes that the critical weld should remain acceptable up to at least refueling outage 21, unless future inspections show a dramatically increased growth rate. Future inspections should be performed in accordance with the staff's safety evaluation dated December 2, 1999, for "BWR Core Spray Internals and Flaw Evaluation Guidelines (BWRVIP-18)," dated July 1996.

The staff's safety evaluation is enclosed.

Sincerely,

/RA/

Lawrence J. Burkhart, Project Manager, Section 1
Project Directorate IV & Decommissioning
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket No. 50-298

Enclosure: Safety Evaluation

cc w/encl: See next page

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Cooper Nuclear Station

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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

EVALUATION OF THE REVISED FRACTURE MECHANICS METHODOLOGY

FOR CORE SPRAY WELD FLAWS AND

INSPECTION OF REACTOR VESSEL INTERNAL CORE SPRAY PIPING

NEBRASKA PUBLIC POWER DISTRICT

COOPER NUCLEAR STATION

DOCKET NO. 50-298

1.0 INTRODUCTION

By letter dated November 6, 1998 (Ref. 1), Nebraska Public Power District (NPPD) submitted a flaw evaluation related to the flaw indications found in the core spray piping welds A1 and A21 at Cooper Nuclear Station (CNS). These indications were found originally by ultrasonic examination in 1995, and were reexamined during the 1998 outage. The submittal was intended to demonstrate that the plant can be operated without repair for an additional fuel cycle. This application was approved by the staff, and the safety evaluation was issued on November 23, 1998. In the 1998 submittal the licensee also enclosed as Attachment 3, a revised fracture mechanics methodology to be used in future evaluations of these core spray piping weld indications. Based on the results of this revised methodology, NPPD also requested review and approval of information contained in its November 6, 1998, letter that stated that CNS could be operated for another two cycles (cycles 20 and 21) without any repair or replacement of the core spray piping.

2.0 BACKGROUND

By letter dated November 27, 1996 (Ref. 2), NPPD notified the NRC that the inservice inspection of the core spray spargers and piping would be performed in accordance with the Boiling Water Reactor Vessel and Internal Project Guidelines, BWRVIP-18 (Ref. 3). In a follow-up letter of May 7, 1997 (Ref. 4), NPPD reported the results of the inspection performed during the 1997 refueling outage. NPPD stated that the previously identified indications on the collar to shroud weld did not show any significant growth over the cycle. Based on these inspection results, NPPD received permission from the NRC, in the letter of May 9, 1997 (Ref. 5), to operate for one more cycle (Cycle 18) before reinspecting these indications.

The two Loop A collar to shroud welds, A1 and A21, discussed in the above May 7, 1997, letter, (Ref. 4) were inspected during the 1998 refueling outage using similar UT examination as employed in the 1997 outage. The flaw indication in Weld A21 did not exhibit any signs of growth and was measured at 5.6 inches. Weld A1 exhibited indication growth of 0.4 inch in overall length with a recorded size of 9.5 inches. This is well within the allowable flaw size of 11.7 inches. A summary of the inspection results reported in 1995, 1997, and 1998, and the maximum-allowable flaw sizes, based on analysis, is provided in Table 1 of Attachment 2 to the licensee's November 6, 1998, submittal (Ref. 1).

NPPD's request to operate for one additional cycle (Cycle 19) without repairing the subject indication is based on (1) adequate structural integrity margin, (2) acceptable loose parts evaluation, (3) adequate core spray flow, and (4) monitoring industry developments for improved examination techniques and repair technologies.

In addition to the above request, NPPD also requested the NRC to approve a revised fracture mechanics evaluation (Ref. 1) for continued operation through Cycles 20 and 21. This request was raised as a result of the licensee's recent review of the 1995 fracture mechanics evaluation. NPPD has identified some conservatism in the earlier calculation of seismic induced loadings. As such, NPPD has subsequently revised the fracture mechanics evaluation to reflect the recent findings. Attachment 3 to Reference 1 provides such revised evaluation for the subject indications.

3.0 EVALUATION

3.1 Acceptability of Revised Fracture Mechanics Methodology

In the revised fracture mechanics analysis, NPPD still employed the limit load analysis in Appendix C and the acceptance criteria specified in IWB-3640 of the American Society of Mechanical Engineers (ASME) Code to conduct the flaw evaluation. Nonetheless, all input stresses used in the formulas based on limit load analysis have been revised. The largest change in the input stresses was caused by the significant reduction of operating-basis-earthquake (OBE) and seismic safe-shutdown-earthquake (SSE) loads. The revised OBE and SSE loads were derived from the OBE and SSE response spectra documented in a General Electric (GE) report, GE-NE-B13-01805-122 (Ref. 6).

In addition to the 85-percent reduction in OBE and SSE stresses, there is an 8.5-percent increase in the membrane stress due to pressure. The pressure increase was from the evaluation of the head pressure resulting from the maximum possible core spray system flow that was determined by calculation as described in Attachment 3 to NPPD's submittal dated November 6, 1998. To calculate the primary membrane stress (P_m) and the primary bending stress (P_b), the licensee used the equations of the 1998 evaluation as a basis, and applied a factor of 0.15 to the stress components due to OBE and SSE and a factor of 1.085 to the stress component due to pressure. This was performed for all loading conditions (normal, upset, emergency, and faulted). Further, because the weld was fabricated by the gas tungsten-arc welding process, the licensee did not consider the expansion stress (P_e) that was included in the original fracture mechanics analysis. Substituting P_m and P_b values into the limit load equations, NPPD has calculated the allowable flaw length for each loading condition, and determined that the limiting allowable flaw length is 13.3 inches for the upset condition.

NPPD calculated the predicted flaw length by adding the flaw growth for a specified number of fuel cycles to the initial flaw length. NPPD used the proximity rule of the ASME Code and determined that the three flaws in weld A1 should be treated as a single flaw of 9.5 inches. NPPD then used the bounding crack growth rate of $5X10^{-5}$ inch/hour and estimated the flaw growth to be 1.2 inches for one fuel cycle. The predicted flaw length would be 9.5 + 1.2N inches, where N is the number of fuel cycles in the period of evaluation.

The staff accepted NPPD's evaluation methodology because (1) the revised OBE and SSE loads have been evaluated by NRC staff, (2) the revised higher pressure (an increase of 8.5 percent) is more conservative, (3) the removal of the expansion stress is in accordance with the ASME Code, and (4) the use of the bounding crack growth rate of $5X10^{-5}$ inch/hour is conservative. Hence, the staff determined that any future flaw evaluation for a period of operation should be acceptable as long as the predicted crack length at the end of the evaluated period is less than the allowable crack length.

NPPD reported the results of the second reexamination conducted in the 1998 outage as 5.6 inches (zero growth) for the flaw in weld A21 and 9.5 inches (0.4-inch growth) for the flaw in weld A1. This is an indication that the growth is much less than the 1.2 inches per cycle based on the bounding growth rate.

3.2 Acceptability of Inspection of Reactor Vessel Internal Core Spray Piping for Fuel Cycles 20 and 21

As stated in Section 2.0, Weld A21 has one indication with a length of 5.6 inches, and as shown in the above-mentioned Table 1, the indication has not exhibited any signs of growth. The indication in Weld A1 shows an approximately 0.4 inch of growth in the 1998 inspection, with an overall length of 9.5 inches. The apparent growth rate of 0.4 inch per 18-month cycle is significantly less than the bounding rate of 1.2 inches/cycle (Ref. 3) assumed in NPPD's previous analyses submitted on November 22, 1995 (Ref. 7) and December 18, 1995 (Ref. 8).

NPPD noted that a lower than actual system pressure was incorrectly used in the 1995 analysis. Correctly applying the actual system pressure would decrease the allowable flaw size from the original 11.8 inches to 11.7 inches. This change is inconsequential and does not affect the overall conclusions of the 1995 fracture mechanics evaluations. The staff agreed with the NPPD's assertion (in a separate review) that the allowable flaw size of 11.7 inches will not be exceeded during an additional cycle (Cycle 19) of operation because (1) the measured crack growth rate is significantly less than the bounding crack growth rate used in the fracture mechanics analysis, and (2) the flaw sizes, which are currently measured as 9.5 and 5.6 inches, respectively, for Weld A1 and Weld A21, will remain within the allowable size for an additional cycle even if based on a bounding growth rate of 1.2 inches/cycle (Ref. 3). This is acceptable to the staff.

In order to demonstrate the existence of additional structural margin, the licensee has developed a revised fracture mechanics analysis, as provided in Attachment 3 to Reference 1, which incorporates the new flaw length and CNS-specific seismic criteria. The staff has reviewed the licensee's engineering evaluation on the conservatism involved in the existing critical flaw size calculations of core spray piping. The purpose of the licensee's engineering evaluation is to revise the existing critical flaw size calculations for Welds A1 and A21 of the subject piping. The conservatism arises because of the use of assumed peak seismic accelerations, instead of calculated accelerations from Cooper in-vessel response spectra.

The existing core spray piping flaw calculation was performed by GE in 1995 before NPPD requested that GE develop in-vessel seismic response spectra. In that early report, the horizontal seismic accelerations were conservatively assumed to be 5.0g for the OBE and 10.0g for the SSE. The corresponding vertical seismic accelerations were assumed to be 1.0g for the OBE and 2.0g for the SSE.

In its report, GE-NE-B13-01805-122 (Ref. 6), which is attached to Reference 9, GE reconstructed the original CNS licensing basis, primary structure seismic model that includes a detailed representation of the reactor pressure vessel (RPV) and internals. The seismic input motion used in the revised analysis corresponds to the N69 W component of the July 21, 1952, Taft earthquake, normalized to peak ground acceleration of 0.10g and 0.20g for OBE and SSE, respectively. GE generated the in-structure response spectra at a total of 26 nodal locations of the primary structure models, including six nodal locations for the RPV internals.

Horizontal spectra for both the OBE and the SSE, both in North-South (NS) and East-West (EW) directions, were generated for 0.5 percent and 5.0 percent damping. To account for parameter variation, all spectra were peak broadened by +/- 15 percent. The generated spectra are provided in Appendices B, C, D, and E of Reference 6.

As stated in Attachment 3 to Reference 1, Node 46, at the elevation 949 feet 5 inches, corresponds to the location at core shroud attachment, and is most applicable to the core spray internal piping. The accelerations for Node 46 in the EW direction, therefore, were used for the evaluation. A fundamental frequency of 12 Hz was assumed for the core spray internal piping. This is conservative because, according to the Electric Power Research Institute (EPRI) report (Ref. 3), the fundamental frequency for core spray internal piping that is in the same configuration as CNS would be closer to 25 Hz. With this frequency, the in-vessel spectral accelerations at Node 46 in the EW direction are found to be 0.5g and 0.9g for the OBE and the SSE, respectively. In the static equivalent acceleration method, the acceleration is multiplied by a factor of 1.5 to account for the contributions of higher modes. This leads to the accelerations of 0.75g and 1.35g for the OBE and the SSE, respectively.

For CNS, the vertical seismic accelerations are derived by taking two-thirds of the values derived from horizontal ground response spectra. Based on the frequency of 12 Hz, the corresponding vertical seismic accelerations were conservatively taken as 0.12g and 0.24g for the OBE and the SSE, respectively.

The staff has reviewed the methodology of the above seismic analysis and the spectral accelerations generated and found them to be reasonable.

Since the flaw evaluation is performed based on the resultant OBE and SSE stresses, the revised flaw size can be determined from the original flaw evaluation by using a common reduction factor derived from the ratios of the new and old accelerations. Comparing the above equivalent static accelerations to the accelerations used in the original analysis, GE arrived at the following reduction factors:

OBE Horizontal new value of 0.75g vs 5.0g ---------- for a reduction factor of 0.15
OBE Vertical new value of 0.12g vs 1.0g ---------- for a reduction factor of 0.12

SSE Horizontal new value of 1.35g vs 10.0g --------- for a reduction factor of 0.14
SSE Vertical new value of 0.24g vs 2.0g -------------- for a reduction factor of 0.12

The seismic-induced stresses found in the original flaw evaluation will be conservatively multiplied by a common factor of 0.15 for both the OBE and the SSE cases. This reduction in seismic stresses would, subsequently, result in a corresponding increase in allowable flaw size from the revised fracture mechanics evaluation. The staff finds the seismic loading reduction factor, as derived by GE, to be reasonable for the revised fracture mechanics evaluation.

The licensee also indicated in the evaluation that under a worst-case condition for the core spray system, a conservative internal pressure of 162.7 psi could be seen at the location of the flaws, instead of the originally assumed 150 psi. With this higher internal pressure and the reduced seismic stresses, based on the use of the above reduction factor, the licensee arrived at a revised allowable flaw length of 13.3 inches, instead of the previously calculated 11.7 inches. The present allowable margin, in the beginning of Cycle 19, therefore, is 13.3 - 9.5, or 3.8 inches. The predicted margin at the end of the Cycle 19, based on an assumed bounding crack growth of 1.2 inches during the cycle, is 3.8 minus 1.2, or 2.6 inches.

As the licensee stated, the 1995 data shows a flaw size on Weld A1 as 8.9 inches, which increased by only 0.6 inch during the two subsequent operating cycles. At this rate (0.3 inch per cycle), the 3.8-inch margin will be used up in 12 operating cycles. The situation in Weld A21 will be even less critical.

Even with the assumption of the crack growth rate of 1.2 inches per cycle (18 months), as per the BWRVIP criteria (Ref. 3), at least three additional operating cycles, following Refueling Outage 18 (RFO 18), are expected before the integrity of the weld reaches the analyzed limits. Based on these results, the licensee considered that the critical weld should remain acceptable up to at least RFO 21, unless future inspections show dramatically increased flaw growth.

The staff considers the above licensee’s assessment acceptable.

4.0 CONCLUSION

The staff has completed the review of the licensee’s submittal and concludes that the CNS can use the revised fracture mechanics methodology in its future submittals regarding the evaluation of core spray piping weld flaws. The staff’s decision is based on the four reasons stated above in Section 3.1. Hence, as long as the predicted flaw length is less than the allowable flaw length in future flaw evaluations using the revised methodology, there is reasonable assurance regarding the structural integrity of the subject core spray piping weld.

Furthermore, based on the information provided by NPPD, the staff determined that the seismic load reduction performed by GE is reasonable. The staff also determined that the critical welds should be acceptable up to at least RFO 21. The staff agrees that, at this time, no repair or replacement of the internal core spray piping will be necessary. However, if significant new flaws are identified during the inspections scheduled for RFO 19, the potential need for repair or replacement should be considered.

Principal Contributors: A. Lee
S. Sheng

Date: March 3, 2000

5.0 REFERENCES

(1) Letter, NPPD to NRC Document Control Desk, “Inspection of Reactor Vessel Internal Core Spray Piping, Cooper Nuclear Station,” dated November 6, 1998.

(2) Letter, NPPD to NRC Document Control Desk, “Inspection of Core Spray Spargers and Piping,” dated November 27, 1996.

(3) EPRI Report Number TR-106740 “BWRVIP-18, BWR Core Spray Internals Inspection and Flaw Evaluation Guidelines,” dated July 1996. (Proprietary information. Not publicly available.)

(4) Letter, NPPD to NRC Document Control Desk, “Inspection of Core Spray Spargers and Piping,” dated May 7, 1997.

(5) Letter, NRC to NPPD, “Cooper Nuclear Station - Evaluation of Core Spray Piping Indications During Refueling Outage 17,” dated May 9, 1997.

(6) GE Report GE-NE-B13-01805-122, “NPPD Primary Structure Seismic Model Regeneration and Seismic Analysis,” Revision 1, Class II, DRF B13-01858, dated March 1998. (Proprietary information. Not publicly available.)

(7) Letter, NPPD to NRC Document Control Desk, “IE Bulletin 80-13 Response; Visual Inspection of Core Spray Spargers,” dated November 22, 1995.

(8) Letter, NPPD to NRC Document Control Desk, “Follow-up Information to IE Bulletin 80-13 Response,” dated December 18, 1995.

(9) Letter, D. K. Henrie (GE) to NPPD, “Cooper - Seismic Analysis Final Report Transmittal,” dated March 21, 1998. (Proprietary information. Not publicly available.)