January 30, 2004

Mr. Rick A. Muench
President and Chief Executive Officer
Wolf Creek Nuclear Operating Corporation
Post Office Box 411
Burlington, KS 66839

SUBJECT: WOLF CREEK GENERATING STATION - EVALUATION OF CRACKING IN COMPONENT COOLING WATER SYSTEM PIPING (TAC NO. MB5147)

Dear Mr. Muench:

In refueling outage (RFO) 12 for Wolf Creek Generating Station (WCGS), Wolf Creek Nuclear Operating Corporation (WCNOC) identified a large number of weld indications in the component cooling water (CCW) system. Because the root cause of the indications were not known in RFO 12 and the indications were identified as possibly being caused by stress corrosion cracking (SCC), WCNOC and the NRC both agreed to work on the further analysis of the weld indications to determine their root cause. Each party had its own investigation and its own contractors, to maintain independence, but there were to be periodic meetings and communications between the parties to share information determined by each party. The NRC staff's work on this issue was under the subject TAC No. MB5147.

There was one meeting held with WCNOC on June 11, 2002, which addressed what information would be shared. The meeting summary was issued on July 22, 2002 (available at ADAMS Accession No. ML021770439). Region IV also participated in the meeting.

In the letter dated April 18, 2003 (RA 03-0059), WCNOC submitted three reports that evaluated several samples of piping removed from the CCW system. The destructive examinations of the piping found no significant SCC. This included the destructive examinations conducted by the NRC staff's contractor. Based on the enclosed evaluation, the staff believes that no additional action on its part is required, and the subject TAC is closed. Thank you for your staff's work with the NRC on this program. If you have any questions on the staff's evaluation, contact me at 301-415-1307, or at jnd@nrc.gov, through the internet.

Sincerely,

/RA/

Jack Donohew, Senior Project Manager, Section 2
Project Directorate IV
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket No. 50-482

Enclosure: Staff Evaluation

cc w/encl: See next page

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EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO COMPONENT COOLING WATER SYSTEM PIPE WELD CRACKING

WOLF CREEK NUCLEAR OPERATING CORPORATION

WOLF CREEK GENERATING STATION

DOCKET NO. 50-482

1.0 INTRODUCTION

In refueling outage (RFO) 12, Wolf Creek Nuclear Operating Corporation, the licensee for the Wolf Creek Generating Station (WCGS), identified a large number of weld indications in the component cooling water (CCW) system. In conference calls on April 11 and 18, 2002, the licensee stated that the indications were possibly caused by stress corrosion cracking (SCC) which had not previously been found in such carbon steel piping operating below 140^{o}F. The licensee had not determined an exact root cause of the indications. These indications were found by ultrasonic testing (UT) by the licensee.

The NRC and the licensee agreed to work jointly on the further analysis of the indications to determine the root cause. A level of independence was maintained by both parties, but there were to be periodic meetings and conference calls between the parties to share the information acquired by each party. The NRC and the licensee each had its own investigation of the CCW piping and its own contractors.

2.0 BACKGROUND

WCGS is a pressurized water reactor which began commercial power operation in September 1985. The CCW system is the plant cooling system for reactor auxiliaries. It provides cooling water to selected essential and non-essential components during normal plant operation, including shutdown, and also provides cooling water to several engineered safety feature systems during a loss-of-coolant or main steam line break accident. During an emergency cold shutdown, the CCW system also provides cooling to essential components inside containment. The CCW system is a closed loop system which serves as an intermediate barrier between the service water system and the essential service water system, and potentially radioactive systems in order to prevent the uncontrolled release of radioactivity from the plant.

The CCW piping are classified as ASME Code Class 3. ASME Code Section XI inservice inspection requires visual examination of Class 3 piping; it does not require volumetric examination.

The only meeting held between the licensee and the NRC was the preliminary meeting held on June 11, 2002. The meeting was held at the request of the NRC to discuss the program to (1) investigate the CCW system pipe weld indications found by the licensee, and (2) determine the root cause for the indications. A meeting summary was issued on July 22, 2002 (available at ADAMS Accession No. ML021770439).

3.0 DISCUSSION

The first evidence of SCC in the CCW system carbon steel piping, which was operated at about 150°F, was observed by the licensee in 1994. In 2000, during RFO 11, the licensee observed leaks through weld cracks in carbon steel CCW piping operating at about 150°F. These cracks were investigated and the results of the investigation are reported in 1995 by Dominion Engineering (Reference 1) and in a series of Altran Corporation reports (References 2, 3, 4, 5, and 6). The root cause investigation of the cracking identified during RFO 11 confirmed that the cracking mechanism was SCC.

The UT inspections were part of an inspection program established as a corrective action (Performance Improvement Request 2000-2899), which resulted from the SCC on CCW piping and the letdown heat exchanger identified and repaired during RFO 11. During RFO 12, the licensee augmented the visual examination by performing ultrasonic test (UT) inspections of CCW pipes that serve as return lines from various heat exchangers associated with the reactor coolant pumps (RCPs). Indications up to the full 360 degree circumference of the pipe were identified. The indications were found on piping that is carbon steel, 3-inch schedule 160 and 4-inch schedule 40.

Based on the previous root cause investigation of cracking in the CCW system, and the similarity to the cracking identified in RFO 11, the licensee believed that the UT indications identified during RFO 12 on the CCW piping were also the result of SCC, and replaced or repaired 35 welds in the 3-inch schedule 160 piping and 2 welds in the 4-inch schedule 40 piping. The number of welds inspected, the number of welds rejected and the number of welds replaced or repaired during RFO 11 and RFO 12 are identified in the attached CCW Piping Table, which was prepared by the licensee and given to the staff.

Following identification of the crack indications during RFO 12, two indications that extended around the full circumference of the pipe were partially sized by UT for depth. The depth sizing indicated that the indications extended to 90 percent through wall over large fractions of their length. The licensee provided representative samples of the pipes with the worst indications to the NRC and the Atomic Energy of Canada Ltd. (AECL) for evaluation. The licensee also contracted with Roger W. Staehle to investigate the overall problem of SCC in the CWS system and to recommend remedial action.

In a letter to the NRC dated April 18, 2003 (Reference 7), the licensee submitted three reports evaluating several samples of piping that were removed from the CCW system in WCGS. Enclosure I to this letter contained the Electric Power Research Institute (EPRI) report entitled "Wolf Creek Nuclear Operating Corporation Pipe Evaluation" (Reference 8). Enclosure II contained the EPRI report entitled "Evaluation of NDE of CCW Piping at Wolf Creek Generation Station" (Reference 9). Enclosure III contained a report by Roger W. Staehle entitled

"Assessment of Stress Corrosion Cracking (SCC) in the Component Cooling Water System (CCW) of the Wolf Creek Pressurized Water Reactor (WCNOC)" (Reference 10).

The Staehle report discusses the results of: (1) a destructive investigation by the AECL of samples that contained the indications that extended the full circumference of the pipe and 90 percent through wall; (2) a characterization of microbial and fungal activity in the CCW system; and (3) a review of previous experiences of SCC in carbon steel piping, and corrosion inhibition practices of domestic and international utilities. The report also contains an extensive compilation of data related to SCC of carbon steel piping and options for minimizing, or preventing, SCC.

The results of the investigation of the CCW pipe weld indications are discussed below:

3.1 Results of Destructive Investigation

The destructive investigation of the piping samples by the AECL revealed no significant SCC in the circumferential direction; however, SCC in the longitudinal direction was found to a depth of 1.3 mm (0.047" compared to a wall thickness of 0.438"). No SCC was observed in the analyses performed by the Naval Surface Warfare Center (Reference 11), a contractor to the NRC, and none was observed by EPRI (Reference 8).

3.2 Results of Microbial and Fungal Investigation

The microbial and fungal investigation revealed no microbes, fungi, or sulfate reducing bacteria that would produce aggressive species from metabolism that could accelerate corrosion.

3.3 Results of Industry Survey and Experiences

SCC in carbon steel piping in low temperature aerated coolant has also been observed in McGuire 1 and 2, Cooper, Cook 1 and 2 and Callaway. SCC was observed at McGuire 1 after 13 years of operation and at McGuire 2 after 10 years of operation. SCC was observed at Cooper after 5 years of operation and again after 20 years of operation. SCC was observed at Cook 1 after 13 years of operation and at Cook 2 after 10 years of operation. SCC was observed in Callaway, about half-way through its time of operation.

In terms of inhibitors used by plants, Reference 10 indicates that McGuire 1 and 2, Cooper, and Cook 1 and 2 utilized nitrite inhibitors in their piping. Both Callaway and Wolf Creek utilize molybdate as inhibitors in their piping.

Dominion Engineering attributed the cracking at McGuire 1 and 2, Cooper, and Cook 1 and 2 to the formation of nitrates resulting from microbes oxidizing nitrites. However, Staehle indicates that there is little support for this interpretation. The industry survey indicates that nine domestic plants and four international plants that utilize molybdate as an inhibitor. Sixteen domestic plants utilize nitrite as an inhibitor; ten domestic plants utilize molybdate-nitrite as an inhibitor; three domestic plants utilize boron compound-nitrite as an inhibitor; and one domestic plant utilizes hydrazine-nitrite as an inhibitor. Because many plants have utilized molybdate and nitrites as inhibitors and have not had SCC, the use of molybdate and nitrites cannot be considered a significant contributor to SCC at this time.

3.4 Results of the EPRI Evaluation of WCGS UT Inspection Procedure

Since large circumferential flaws were not detected as a result of the destructive examination, the licensee requested that EPRI review its UT inspection procedure for detecting and sizing circumferentially oriented flaws. The EPRI report (Reference 9) contains an evaluation of the UT procedure utilized by the licensee to identify and size the indications in the CCW welds. Since large areas of interbead lack of fusion were present in the weld, EPRI felt that the WCGS examiners had a tendency to associate the reflections from the lack of fusion with upper extremities of an inside surface crack and the reflections from a double counterbore with an initiation point for an inside surface crack. Because the counterbore contained two distinct cuts, it is likely that the two cuts were assumed to be a crack signal and a counterbore signal occurring simultaneously. EPRI concluded that accurate cross-sectional plotting of the weld and ultrasonic search unit locations should have shown that separate reflectors were being observed, rather than one large reflector (crack).

The EPRI report indicates that the NDE procedure was not strictly followed with respect to the removal of external weld reinforcement, acquisition of internal and external surface contours, recording of indication location, or plotting of indications on a cross-sectional drawing of the component. EPRI also felt that procedural enhancements could be made by the inclusion of flaw discrimination techniques. Flaw discrimination methodology could include criteria such as observing that flaw amplitude should remain at similar amplitude, or increased amplitude, when higher angle search units are applied.

3.5 Actions Taken by the Licensee

As a result of the investigation, the licensee has increased the pH in the CCW system from 8.5–9.0 range to 9.5–9.6 range, which they indicate will reduce the piping's susceptibility to SCC. The licensee also stated that they will revise their UT procedures in accordance with the EPRI recommendations. Since no significant SCC was detected during RFO 12, the licensee will not perform any UT inspection during RFO 13.

4.0 CONCLUSIONS

As discussed above, the destructive examinations performed by AECL, EPRI and the NRC on the CCW piping removed during the WCGS RFO 12, found no significant SCC. Based on the licensee's statement that it will revise its UT procedures in accordance with the above EPRI recommendations, the licensee has taken sufficient corrective action to evaluate and improve its UT procedures for inspection of CCW piping at WCGS. Because many plants have utilized molybdate and nitrites as inhibitors and have not had SCC, the use of molybdate and nitrites cannot be considered a significant contributor to SCC at this time. Based on its evaluation of the information provided by the licensee and the work of the NRC contractor, the NRC staff concludes that no additional action is required at this time.

With no significant SCC found by the NRC and licensee contractors, the importance of the program diminished. No further meetings between the NRC and licensee were held beyond the one meeting held on June 11, 2002, although there were further conference calls.

5.0 REFERENCES

1. "Review of McGuire and Wolf Creek Component Cooling Water System Cracking," Dominion Engineering Report R-4323-00-2, Revision 0, May 1995.

2. "Failure Analysis of Cracked Welds in Component Cooling Water Piping," Altran Technical Report No. 00617-TR-001, Revision 0, August 2000.

3. "Failure Analysis of Cracked Component Cooling Water System Welds," Altran Technical Report No. 00628-TR-001, Revision 0, February 2001.

4. "Root Cause Investigation of CCWS System Weld Cracking," Altran Technical Report No. 00628-TR-002, Revision 0, April 2001.

5. "Failure Analysis of Cracked Component Cooling Water System Welds," Altran Technical Report No. 00628-TR-001, Revision 1, May 2001.

6. "Root Cause Investigation of CCWS System Weld Cracking," Altran Technical Report No. 00628-TR-002, Revision 2, June 2001.

7. "Docket No. 50-482: Submittal of Wolf Creek Nuclear Operating Corporation (WCNOC) Evaluation of Stress Corrosion Cracking for Component System Piping," WCNOC Letter to the NRC, April 18, 2003.

8. "Wolf Creek Nuclear Operating Corporation Pipe Evaluation," Andy McGehee, P. E., EPRI RRAC, August 23, 2002.

9. "Evaluation of NDE of CCW Piping at Wolf Creek Generating Station," Stan Walker, EPRI NDE Center, August 29, 2002.

10. "Assessment of Stress Corrosion Cracking (SCC) in the Component Cooling Water System (CCW) of the Wolf Creek Pressurized Water Reactor (WCNOC)," Roger W. Staehle, Staehle Consulting, April 10, 2003.

11. "Metallurgical Investigation into the Cause of Cracking in Piping for the Containment Cooling Water System at Wolf Creek," Naval Surface Warfare Center, Carderock, Maryland, December 5, 2002.

Attachment: CCW Piping Table

CCW PIPING TABLE

Function/Use	Pipe Schedule	Service Condition (estimated Temp and Duty Cycle)	Pipe Size (in.)	Total # Welds	# Weld UT (RF11)	# Weld UT (RF12)	# Welds rejected w/indications (RF 11)	# Welds rejected w/indications (RF 12)	# Welds repaired/ replaced (RF 11)	# Welds repaired/ replaced (RF 12)
RCP Thermal Barrier Run	160	Continuous (130 deg)	3"	127	2	58	0	35	0	110 (Note 3)
RCP Thermal Barrier Run	120	Continuous (130 deg)	4"	45	0	32	0	0	NA	(Note 4)
RCP Thermal Barrier Return Header (Class 2)	120		4"	17	0	17	0	1 (Note 5)	0	1
Letdown Hx Return	40	Continuous (160 deg)	6"	56	46	0	31	NA	41 (Note 2)	NA
Seal Water Hx Return	40	Continuous (24/7/365) (118 deg)	4"	19	2	0	0	0	0	NA
RCP Upper Bearing (UB) Coolor Return	40	Continuous (116 deg)	4"	64	2	6	1	0	1	0
RCP Lower Bearing (LB) Cooler Return	40	Continuous (116 deg)	1"	39 (Note 1)	0	0	NA	NA	NA	NA
RCP Motor Air (MA) Cooler Return	40	Continuous (113 deg)	4"	111	4	12	1	2	1	2
RCP Motor Air (MA) Cooler Return	40	Continuous (113 deg)	6"	34	0	0	NA	NA	NA	NA
RCP UB/LB/MA Return Header	40		8"	43	0	0	NA	NA	NA	NA
RCP UB/LB/MA Return Header	40		10"	20	0	0	NA	NA	NA	NA
RCP UB/LB/MA Return Header	40		12"	14	0	0	NA	NA	NA	NA
RCP UB/LB/MA Return Header (Class 2)	40		12"	12	0	0	NA	NA	NA	NA
RCDT Hx Return (Radwaste)	40	Continuous (110-130 deg)	4"	14	0	0	NA	NA	NA	NA
Fuel Pool Hx Return (Radwaste)	.375 wall nominal	Continuous/Temperatures over 100 F only during refuel. (24/7/365) (150 deg)	12"							
CCP Oil Cooler Return	40	Intermittent. (135 deg) (3000 hr/yr. '85 to '89, 200 hr/yr. '90 to '94). Cycle 12: 68 hr.	2"							
RHR Hx Return	.375 wall nominal	Intermittent - shutdown during a refuel - 800 hr/yr (130 deg)	18"							
RHR Pump Seal HX Return	80	Intermittent - 800 hr/yr (160 deg)	1"							
SI Pump Oil Cooler Return	40	8 hr/yr (150 deg)	2"							
Excess Letdown Hx Return	40	Intermittent <10 hrs/year (195 deg)	4"	11	0	0	NA	NA	NA	NA

NOTES:
(1) Includes 10 socket welds.
(2) 10 welds were replaced without inspection.
(3) All piping is being replaced except for small sections that are being inspected and found to be free from cracks.
(4) All welds verified free from cracks. Welds will be replaced only if required to facilitate other repairs.
(5) Indication was a 1/4 inch weld defect, not a crack.