July 3, 2001

Mr. W. R. McCollum, Jr.
Vice President, Oconee Site
Duke Energy Corporation
7800 Rochester Highway
Seneca, SC 29672

SUBJECT: OCONEE NUCLEAR STATION, UNIT 2 RE: USE OF ALTERNATIVE FOLLOWING WELD REPAIR OF REACTOR VESSEL HEAD-TO-CONTROL ROD DRIVE MECHANISM NOZZLE END WELD REPAIR REQUEST FOR RELIEF NUMBER 01-08 (TAC NO. MB1917)

Dear Mr. McCollum:

By letter dated May 13, 2001, pursuant to 10 CFR 50.55a(a)(3)(ii), you submitted Request for Relief Number 01-08 from the American Society of Mechanical Engineers (ASME) Code repair requirements and requested approval of an alternative for evaluating the control rod drive mechanism (CRDM) nozzle end weld repairs for CRDM Nos. 4, 6, 18, and 30 for Oconee Nuclear Station, Unit 2. The alternative has two elements: (1) a flaw evaluation to justify the welding solidification anomaly at the root of the repair welds where the CRDM nozzle, vessel head, and the repair weld join; and (2) another flaw evaluation to justify not removing the remaining flawed CRDM nozzle J-groove welds. Both flaw evaluations were based on the criteria of IWB-3612 of the ASME Code. Supplementary information was supplied by letters dated May 16 and 22, 2001. By letter dated June 7, 2001, you removed the Proprietary designation from certain information contained in the earlier submittals.

Based on the enclosed safety evaluation, the staff has concluded that repairs to CRDM Nos. 4, 6, 18, and 30 on Unit 2 are acceptable for operation for at least the next six calender years since the calculated safety factors for all flaws considered are greater than the Code specified safety factor of 3.16. Hence, the licensee has satisfied the Section XI requirements for flawed components by demonstrating that the proposed alternatives would provide an acceptable level of quality and safety, and thus the alternatives are authorized pursuant to 10 CFR 50.55a(3)(ii). You are reminded that since the flaws in the J-groove welds are detected flaws, the areas must be reexamined during the next inspection period per Section IWB-2420 of the ASME Code.

Sincerely,

/RA/

Richard L. Emch, Jr., Chief, Section 1
Project Directorate II
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket No. 50-270

Enclosure: As stated

cc w/encl: See next page

Mr. W. R. McCollum, Jr.
Vice President, Oconee Site
Duke Energy Corporation
7800 Rochester Highway
Seneca, SC 29672

July 3, 2001

SUBJECT: OCONEE NUCLEAR STATION, UNIT 2 RE: USE OF ALTERNATIVE FOLLOWING WELD REPAIR OF REACTOR VESSEL HEAD-TO-CONTROL ROD DRIVE MECHANISM NOZZLE END WELD REPAIR REQUEST FOR RELIEF NUMBER 01-08 (TAC NO. MB1917)

Dear Mr. McCollum:

By letter dated May 13, 2001, pursuant to 10 CFR 50.55a(a)(3)(ii), you submitted Request for Relief Number 01-08 from the American Society of Mechanical Engineers (ASME) Code repair requirements and requested approval of an alternative for evaluating the control rod drive mechanism (CRDM) nozzle end weld repairs for CRDM Nos. 4, 6, 18, and 30 for Oconee Nuclear Station, Unit 2. The alternative has two elements: (1) a flaw evaluation to justify the welding solidification anomaly at the root of the repair welds where the CRDM nozzle, vessel head, and the repair weld join; and (2) another flaw evaluation to justify not removing the remaining flawed CRDM nozzle J-groove welds. Both flaw evaluations were based on the criteria of IWB-3612 of the ASME Code. Supplementary information was supplied by letters dated May 16 and 22, 2001. By letter dated June 7, 2001, you removed the Proprietary designation from certain information contained in the earlier submittals.

Based on the enclosed safety evaluation, the staff has concluded that repairs to CRDM Nos. 4, 6, 18, and 30 on Unit 2 are acceptable for operation for at least the next six calender years since the calculated safety factors for all flaws considered are greater than the Code specified safety factor of 3.16. Hence, the licensee has satisfied the Section XI requirements for flawed components by demonstrating that the proposed alternatives would provide an acceptable level of quality and safety, and thus the alternatives are authorized pursuant to 10 CFR 50.55a(3)(ii). You are reminded that since the flaws in the J-groove welds are detected flaws, the areas must be reexamined during the next inspection period per Section IWB-2420 of the ASME Code.

Sincerely,

/RA/
Richard L. Emch, Jr., Chief, Section 1
Project Directorate II
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket No. 50-270

Enclosure: As stated

cc w/encl: See next page

<u>Distribution:</u>
PUBLIC
PD II-1 Rdg.
RidsNrrDlpmLpdii1 (paper copy)
RidsNrrLACHawes (paper copy)
SSheng
RidsNrrPMDLaBarge (paper copy)
RidsOgcRp
RidsAcrsAcnwMailCenter
RidsRgn2MailCenter
GHill(2)
SRosenberg, EDO
COgle, RII

Accession No. ML011840433

Document Name: C:\Program Files\Adobe\Acrobat 4.0\PDF Output\B1917 REL .WPD *See previous concurrence

OFFICE	PM:PDII/S1	LA:PDII/S1	DE/EMCB*	OGC*	SC:PDII/S1
NAME	DLaBarge	CHawes	KWichman	RHoefling	REmch
DATE	6/29/01	7/3/01	6/18/01	6/26/01	7/3/01

OFFICIAL RECORD COPY

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

CRDM NOZZLE END WELD REPAIR AND THE REMAINING FLAWED J-GROOVE WELD

DUKE ENERGY CORPORATION

OCONEE NUCLEAR STATION, UNIT 2

DOCKET NO. 50-270

1.0 INTRODUCTION

By letter dated May 13, 2001, Duke Energy Corporation (the licensee), pursuant to 10 CFR 50.55a(a)(3)(ii), submitted a Request for Relief Number 01-08 from the American Society of Mechanical Engineers (ASME) Code repair requirements and requested approval of an alternative for evaluating the control rod drive mechanism (CRDM) nozzle end weld repairs for CRDM Nos. 4, 6, 18, and 30 for Oconee Nuclear Station, Unit 2. The alternative has two elements: (1) a flaw evaluation to justify the welding solidification anomaly at the root of the repair welds where the CRDM nozzle, vessel head, and the repair weld join; and (2) another flaw evaluation to justify not removing the remaining flawed CRDM nozzle J-groove welds. Both flaw evaluations were based on the criteria of IWB-3612 of the ASME Code. In response to the staff's requests for additional information, the licensee supplied supplemental information in letters dated May 16 and 22, 2001. By letter dated June 7, 2001, the licensee removed the Proprietary designation from certain information contained in the submittals.

2.0 REGULATIONS AND REQUIREMENTS

The Codes of record for the repair of the CRDM nozzle end welds are the 1989 Section III and 1992 Section XI ASME Codes. NB-5330(b) of Section III of the 1989 Code requires that indications characterized as cracks, lack of fusion, or incomplete penetration are unacceptable regardless of length. This rule applies to the disposition of the weld anomaly in the CRDM nozzle inner-diameter (ID) temper-bead weld repairs.

IWA-4310 of Section XI of the 1992 Code requires that defects shall be removed or reduced in size in accordance with this paragraph, or alternatively, the defect removal area and any remaining portion of the flaw may be evaluated in accordance with the appropriate flaw evaluation rules of Section XI. This rule applies to the disposition of the flaw in the remaining J-groove welds that the licensee did not remove.

3.0 PROPOSED ALTERNATIVE METHODOLOGY

In lieu of the regulations and requirements described in Section 2.0, the licensee proposed to use IWB-3612 criteria for the linear elastic fracture mechanics (LEFM) analysis and IWB-3642

Enclosure

criteria for the limit load analysis for evaluating the weld anomaly in the CRDM nozzle ID temper-bead weld repairs for CRDM Nos. 4, 6, 18, and 30. Further, the licensee proposed to use IWB-3612 criteria for the LEFM analysis for evaluating the flaw in the remaining J-groove welds for these CRDMs.

4.0 <u>LICENSEE'S EVALUATION OF THE ALTERNATIVE METHODOLOGY</u>

4.1 Flaw Evaluation of the Weld Anomaly in the Weld Repair (Report 32-5012625-00)

Based on 12 samples of sections taken from the weld repair of a CRDM nozzle in the Midland reactor vessel head using the same welding process as the current field repair, the licensee concluded that the anomaly in the current weld repair could be represented by a semi-circular flaw of depth of 0.1 inch located at the root of the nozzle weld repair. This flaw depth has also been confirmed by ultrasonic testing (UT) examinations. The materials are SA-533B low alloy steel for the vessel head, Alloy 600 for the CRDM nozzles, and Alloy 690 for the weld repairs. Their yield strength and fracture toughness are from the ASME Code, with the exception that the fracture toughness for Alloy 600 and Alloy 690 were inferred from test-based critical J-integral, J_c, data. Two crack propagation paths, radial and axial, or Path 1 and 2, were considered. For the radial crack path, a 360-degree part-through outer-diameter (OD) flaw and an axial semi-circular OD surface flaw were assumed separately. For the axial crack path, a semi-circular surface flaw in a flat plate was assumed. The licensee then employed the crack growth rate of Paragraph A-4300 of the Code for low alloy steel in an air environment to predict the fatigue crack growth for the reactor vessel head and the crack growth rate of Section C-3210 of Appendix C of the Code for austenitic steels in an air environment to predict the fatigue crack growth for the nozzle and the repair weld. The applied stresses used in the fatigue crack growth calculation were derived from six heatup/cooldown cycles per year for eight operating years. The highest stress was found at the uphill location (the high point) along the circumference of the weld repair of the nozzle.

The applied Stress Intensity Factor (K) associated with the 360-degree part-throughwall OD flaw subjected to a higher-order stress distribution was obtained from the Buchalet and Bamford solution for a 360-degree part-through ID flaw, then modified by the K ratio of Kumar's OD solution to the ID solution for uniform tension. The applied K associated with the axial semi-circular OD surface flaw was obtained from the Raju-Newman solution for cylindrical vessels. The applied K associated with the semi-circular surface flaw in a flat plate was obtained from the Raju-Newman solution for plates. The licensee's calculations indicated that the resulting final crack depths after eight operating years are only slightly larger than the original crack depth of 0.1 inch for the three cases mentioned above. Based on the final crack depths, the licensee calculated the safety factors for them by comparing their applied K values to the fracture toughness of 200 ksi$\sqrt{\text{inch}}$. The safety factors were found to be much greater than the code specified safety factor of 3.16; hence, the licensee concluded that the CRDM nozzles with the proposed weld repair could be operated for eight operating years.

4.2 Flaw Evaluation of the Remaining J-groove Weld (Report 32-5012649-00)

After the removal of the lower portion of the subject CRDM nozzles by boring, the licensee proposed to leave the remaining J-groove weld in place. Due to the original CRDM leakage, the licensee assumed that the remaining J-groove welds contain degraded or cracked weld material. To avoid the need for a flaw characterization by UT, the licensee assumed that a corner crack existed in the J-groove welds. A maximum possible flaw depth of 1.455 inches was assumed for such flaws, making the crack front reach the weld-head interface. As was the case for Section 4.1, the yield strength and fracture toughness for SA-533B low alloy steel (vessel head), Alloy 600 (CRDM nozzle), and Alloy 690 (weld repair) are from the ASME Code, with the same cut-off fracture toughness of 200 ksi√inch for Alloy 600 and Alloy 690.

The licensee then employed the crack growth rate of Paragraph A-4300 of the Code for low alloy steel in a primary water environment to predict the fatigue crack growth for the reactor vessel head. The applied stresses used in the fatigue crack growth calculation were derived from six heatup/cooldown cycles per year for about 11.7 operating years (70 cycles). The highest stress was found at the uphill side of the nozzle bore (the high point) perpendicular to the crack face. To assess the effect due to residual stresses, the licensee performed a three-dimensional elastic-plastic finite element method (FEM) analysis of the weld repair, simulating the entire welding process. The results from this exercise indicated that the residual stresses are negligibly low at the weld-head interface where the crack tip intersects and could be neglected in the subsequent applied K evaluation.

The licensee used the applied K formula for a corner flaw in the subsequent fatigue analysis. The resulting crack depth after 11.7 operating years is calculated to be only slightly larger than the initial crack depth of 1.455 inches. Based on this final crack depth, the licensee calculated the safety factor for it by comparing its applied K value to the fracture toughness of 200 ksi√inch for the vessel head material. The safety factor was found to be greater than the code specified safety factor of 3.16; hence, the licensee concluded that CRDM Nozzle Nos. 4, 6, 18, and 30 could be operated for 11.7 operating years with the remaining flawed J-groove weld.

5.0 STAFF'S EVALUATION OF THE ALTERNATIVE METHODOLOGY

5.1 Flaw Evaluation of the Weld Anomaly in the Weld Repair

The licensee's representation of the weld anomaly by a semi-circular flaw of depth of 0.1 inch is reasonable because the assumption was based on 12 samples of sections taken from similar weld repairs. UT examinations of the current repair have also confirmed that the assumed depth is bounding. Using the Code specified yield strength and fracture toughness for the SA-533B low alloy steel (the vessel head), Alloy 600 (the CRDM nozzle), and Alloy 690 (the weld repair) is a standard practice for Section XI analyses. Although the fracture toughness for Alloy 600 and Alloy 690 is not available in the Code, the licensee's approach of using 200 ksi√inch is conservative because it is much less than the K_{Jc} values derived from the critical J_c values from the test results of unirradiated Alloy 600 material. The assumption of the 360-degree part-through OD flaw and the axial semi-circular OD surface flaw for the radial crack path and the semi-circular surface flaw in a flat plate for the axial crack path covered the most likely crack paths and is, therefore, appropriate. Further, using the Code specified crack growth rate of A-4300 for low alloy steel in an air environment to predict the fatigue crack growth for the reactor vessel head and crack growth rate of Section C-3210 of Appendix C of the Code for austenitic steels in an air environment to predict the fatigue crack growth for the nozzle and the repair weld is also appropriate.

In the applied K calculations for the various crack shapes considered in the submittal, the licensee employed some LEFM solutions that have not been formally approved by the NRC:

the Buchalet and Bamford solution for a 360-degree part-through ID flaw on cylindrical vessels subjected to a higher-order stress distribution, Kumar's solution for an ID or OD flaw on vessels subjected to uniform tension, the Raju-Newman solution for the axial semi-circular OD surface flaw on vessels, and the Raju-Newman solution for a semi-circular surface flaw on plates. The Buchalet and Bamford solution is acceptable because this FEM-based solution has been validated against Rice's solution using the line spring method and Labben's solution using Bueckner's weight functions. The Kumar solution is acceptable because the staff has validated the results by using Erdogan's solution based on singular integral equations. The Raju-Newman FEM solutions for the two configurations are acceptable because the results using both solutions have been validated against results using other methodologies as reported in the original papers. After adding the crack growth for eight operating years for the three cases mentioned above to the initial crack depth of 0.1 inch, the licensee obtained the safety factors for the three cases corresponding to the fracture toughness of 200 ksi√inch. The resulting safety factors are two times greater than the code specified safety factor of 3.16; hence, the staff agrees with the licensee's conclusion that the CRDM Nozzle Nos. 4, 6, 18, and 30 with the proposed weld repairs could be operated for eight operating years.

5.2 Flaw Evaluation of the Remaining J-groove Weld

The licensee's representation of the flaw in the remaining J-groove welds by a corner crack with a flaw depth of 1.455 inches is very conservative because this flaw, which was assumed to fracture completely through the remaining J-groove weld, was not a result of flaw characterization by UT, but was determined by the maximum possible flaw that could exist in the remaining J-groove welds. Further, as discussed in Section 5.1, it is appropriate to use the Code specified yield strength and fracture toughness for the SA-533B low alloy steel (the vessel head) in the flaw evaluation. Using the Code-specified crack growth rate per Paragraph A-4300 of the Code for low alloy steel in a primary water environment (due to leakage) to predict the fatigue crack growth for the reactor vessel head is a standard practice and is, therefore, acceptable.

The staff found that the applied K formula used by the licensee for the nozzle corner flaw was based on the influence functions using the boundary-integral-equation method. Employing this applied K formula is appropriate because it has been approved by the NRC in its review of previous submittals by the General Electric Company on the crack growth evaluation for feedwater nozzles. As to the residual stresses, the licensee's three-dimensional elastic-plastic FEM results indicated that the residual stresses are negligibly low at the weld-head interface and became compressive in the vessel head. Based on LEFM, the staff determined that the contribution to the applied K due to the residual stresses described above would be negligible. After adding the crack growth for 11.7 operating years to the initial crack depth of 1.455 inch, the licensee obtained the safety factor corresponding to the fracture toughness of 200 ksi√inch. The resulting safety factor is greater than the code specified safety factor of 3.16; hence, the staff agrees with the licensee's conclusion that CRDM Nozzle Nos. 4, 6, 18, and 30 could be operated for 11.7 operating years with the remaining flawed J-groove welds. It should be noted that, in addition to the conservatism inherent in the Section XI flaw evaluation procedure, two additional sources of significant conservatism are present: (1) the through weld assumption for the corner crack, and (2) the use of the cut-off fracture toughness of 200 ksi√inch. Therefore, the real margin is larger than that indicated by the licensee's calculated safety factor.

6.0 CONCLUSION

The staff has reviewed the licensee's flaw evaluation for the proposed weld repairs to CRDM Nozzle Nos. 4, 6, 18, and 30 and on the remaining J-groove welds that the licensee proposed to leave in operation. Based on the evaluations, the staff has determined that Oconee Unit 2 could be operated with the proposed CRDM nozzle configuration for the subject CRDMs for at least the next six calender years since the calculated safety factors for all flaws considered are greater than the Code specified safety factor of 3.16. Hence, the licensee's evaluation has satisfied the Section XI requirements for flawed components and the licensee has demonstrated that the proposed alternatives would provide an acceptable level of quality and safety for the subject repairs and thus the alternatives are authorized pursuant to 10 CFR 50.55a(3)(ii). However, since flaws in the J-groove weld are detected flaws, the areas must to be reexamined during the next inspection period per ASME Code Section IWB-2420.

Principal Contributor: Simon Sheng

Date: July 3, 2001

cc:
Ms. Lisa F. Vaughn
Legal Department (PBO5E)
Duke Energy Corporation
422 South Church Street
Charlotte, North Carolina 28201-1006

Anne W. Cottingham, Esquire
Winston and Strawn
1400 L Street, NW
Washington, DC 20005

Manager, LIS
NUS Corporation
2650 McCormick Drive, 3rd Floor
Clearwater, Florida 34619-1035

Senior Resident Inspector
U. S. Nuclear Regulatory
Commission
7812B Rochester Highway
Seneca, South Carolina 29672

Virgil R. Autry, Director
Division of Radioactive Waste Management
Bureau of Land and Waste Management
Department of Health and Environmental
Control
2600 Bull Street
Columbia, South Carolina 29201-1708

Mr. Michael A. Schoppman
Framatome ANP
1911 North Ft. Myer Drive
Suite 705
Rosslyn, VA 22209

Mr. L. E. Nicholson
Compliance Manager
Duke Energy Corporation
Oconee Nuclear Site
7800 Rochester Highway
Seneca, South Carolina 29672

Ms. Karen E. Long
Assistant Attorney General
North Carolina Department of
Justice
P. O. Box 629
Raleigh, North Carolina 27602

Mr. C. Jeffrey Thomas
Manager - Nuclear Regulatory
Licensing
Duke Energy Corporation
526 South Church Street
Charlotte, North Carolina 28201-1006

Mr. Richard M. Fry, Director
Division of Radiation Protection
North Carolina Department of
Environment, Health, and
Natural Resources
3825 Barrett Drive
Raleigh, North Carolina 27609-7721

Mr. Peter R. Harden, IV
VP-Customer Relations and Sales
Westinghouse Electric Company
5929 Carnegie Blvd.
Suite 500
Charlotte, North Carolina 28209