May 24, 2005

Mr. R. T. Ridenoure
Vice President - Chief Nuclear Officer
Omaha Public Power District
Fort Calhoun Station, FC-2-4 Adm.
Post Office Box 550
Fort Calhoun, NE 68023-0550

SUBJECT: FORT CALHOUN STATION, UNIT NO. 1 - RELAXATION REQUEST FROM U.S. NUCLEAR REGULATORY COMMISSION (NRC) ORDER EA-03-009 FOR THE CONTROL ELEMENT DRIVE MECHANISM NOZZLES (TAC NO. MC6726)

Dear Mr. Ridenoure:

By letter dated May 14, 2005, as supplemented by letters dated May 17, May 18, and May 19, 2005. Omaha Public Power District (OPPD, the licensee) requested relaxation from certain requirements of the First Revised NRC Order EA-03-009 (Order), dated February 20, 2004, for the Fort Calhoun Station, Unit 1 (FCS). The Order requires specific examinations of the reactor pressure vessel (RPV) head and vessel head penetration (VHP) nozzles of all pressurized water reactor plants. Section IV, paragraph F, of the Order states that requests for relaxation of the Order associated with specific penetration nozzles will be evaluated by the NRC staff using the procedure for evaluating proposed alternatives to the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code) in accordance with 10 CFR 50.55a(a)(3).

Specifically, pursuant to the process specified in Section IV, Paragraph F of the Order, OPPD requested relaxation to implement an alternative to the requirements of Section IV, paragraph C.(5)(b)(ii), of the Order for 25 of the control element drive mechanisms (CEDMs) penetration nozzles in the RPV head at FCS. The NRC staff has completed its review and concludes that OPPD_s proposed alternative provides reasonable assurance of the structural integrity of the RPV head, VHP nozzles, and welds. Further inspection of these nozzles in accordance with Section IV, paragraph C.(5)(b), of the Order, would result in hardship without a compensating increase in the level of quality and safety. Thus, you have demonstrated good cause for the requested relaxation. Therefore, pursuant to Section IV, paragraph F, of the Order, the staff authorizes the proposed alternative inspection for the referenced CEDM nozzles at FCS, subject to the following condition:

> If the NRC staff finds that the crack-growth formula in industry report MRP-55 is unacceptable, OPPD shall revise its analysis that justifies relaxation of the First Revised Order within 30 days after the NRC informs OPPD of an NRC-approved crack-growth formula. If OPPD's revised analysis shows that the crack growth acceptance criteria are exceeded prior to the end of the current operating cycle, this relaxation is rescinded and OPPD shall, within 72 hours, submit to the NRC written justification for continued operation. If the revised analysis shows that the crack growth acceptance criteria are

exceeded during the subsequent operating cycle, OPPD shall, within 30 days, submit the revised analysis for NRC review. If the revised analysis shows that the crack growth acceptance criteria are not exceeded during either the current operating cycle or the subsequent operating cycle, OPPD shall, within 30 days, submit a letter to the NRC confirming that its analysis has been revised. Any future crack-growth analyses performed for this and future cycles for RPV head penetrations must be based on an acceptable crack growth rate formula.

The staff's related Safety Evaluation is enclosed.

Be aware that when vessel head inspections are performed using ASME Code requirements, acceptance criteria, or qualified personnel, those activities and all related activities fall within the jurisdiction of the ASME Code. Therefore, Order-related inspection activities may be subject to third party review, including those by the Authorized Nuclear Inservice Inspector.

Sincerely,

/RA/

Herbert N. Berkow, Director
Project Directorate IV
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket No. 50-285

Enclosure: Safety Evaluation

cc w/ encl: See next page

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Sincerely,

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Herbert N. Berkow, Director
Project Directorate IV
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

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Enclosure: Safety Evaluation

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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

FIRST REVISED NRC ORDER (EA-03-009) RELAXATION REQUEST

EXAMINATION COVERAGE

FOR REACTOR PRESSURE VESSEL HEAD AND PENETRATION NOZZLES

OMAHA PUBLIC POWER DISTRICT

FORT CALHOUN STATION, UNIT 1

DOCKET NUMBER 50-285

1.0 INTRODUCTION

The First Revised NRC Order EA-03-009 (Order), issued on February 20, 2004, requires specific examinations of the reactor pressure vessel (RPV) head and vessel head penetration (VHP) nozzles of all pressurized water reactor plants. Section IV, paragraph F, of the Order states that requests for relaxation of the Order associated with specific penetration nozzles will be evaluated by the US Nuclear Regulatory Commission (NRC) staff using the procedure for evaluating proposed alternatives to the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code) in accordance with Section 50.55a(a)(3) of Title 10 of the *Code of Federal Regulations* (10 CFR). Section IV, paragraph F, of the Order states that a request for relaxation regarding inspection of specific nozzles shall address the following criteria: (1) the proposed alternative(s) for inspection of specific nozzles will provide an acceptable level of quality and safety, or (2) compliance with this Order for specific nozzles would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

For the Fort Calhoun Station, Unit 1 (FCS), which has been determined to have a high susceptibility to primary water stress-corrosion cracking (PWSCC), in accordance with Section IV, paragraph A and B, of the Order, the following inspections are required to be performed every refueling outage (RFO) in accordance with Section IV, paragraph C.(5)(a) and paragraph C.(5)(b) of the Order:

(a) Bare metal visual [BMV] examination of 100 percent of the RPV head surface (including 360° around each RPV head penetration nozzle). For RPV heads with the surface obscured by support structure interferences which are located at RPV head elevations downslope from the outermost RPV head penetration, a bare metal visual inspection of no less than 95 percent of the RPV head surface may be performed provided that the examination shall include those areas of the RPV head upslope and downslope from the support structure interference to identify any evidence of boron or corrosive product. Should any evidence of boron or corrosive product be identified, the licensee shall examine the RPV head surface under the support structure to ensure that the RPV head is not degraded.

(b) For each penetration, perform a nonvisual NDE [nondestructive examination] in accordance with either (i), (ii), or (iii):

(i) Ultrasonic testing of the RPV head penetration nozzle volume (i.e., nozzle base material) from 2 inches above the highest point of the root of the J-groove weld (on a horizontal plane perpendicular to the nozzle axis) to 2 inches below the lowest point at the toe of the J-groove weld on a horizontal plane perpendicular to the nozzle axis (or bottom of the nozzle if less than 2 inches [See Figure IV-1]); OR from 2 inches above the highest point of the root of the J-groove weld (on a horizontal plane perpendicular to the nozzle axis) to 1.0-inch below the lowest point at the toe of the J-groove weld (on a horizontal plane perpendicular to the nozzle axis) and including all RPV head penetration nozzle surfaces below the J-groove weld that have an operating stress level (including all residual and normal operation stresses) of 20 ksi tension and greater (see Figure IV-2). In addition, an assessment shall be made to determine if leakage has occurred into the annulus between the RPV head penetration nozzle and the RPV head low-alloy steel.

(ii) Eddy current testing (ECT) or dye penetrant testing (PT) of the entire wetted surface of the J-groove weld and the wetted surface of the RPV head penetration nozzle base material from at least 2 inches above the highest point of the root of the J-groove weld (on a horizontal plane perpendicular to the nozzle axis) to 2 inches below the lowest point at the toe of the J-groove weld on a horizontal plane perpendicular to the nozzle axis (or the bottom of the nozzle if less than 2 inches [See Figure IV-3]); OR from 2 inches above the highest point of the root of the J-groove weld (on a horizontal plane perpendicular to the nozzle axis) to 1.0-inch below the lowest point at the toe of the J-groove weld (on a horizontal plane perpendicular to the nozzle axis) and including all RPV head penetration nozzle surfaces below the J-groove weld have an operating stress level (including all residual and normal operation stresses) of 20 ksi tension and greater (see Figure IV-4).

(iii) A combination of (i) and (ii) to cover equivalent volumes, surfaces, and leak paths of the RPV head penetration nozzle base material and J-groove weld as described in (i) and (ii). Substitution of a portion of a volumetric exam on a nozzle with a surface examination may be performed with the following requirements:

1. On nozzle material below the J-groove weld, both the outside diameter [OD] and inside diameter [ID] surfaces of the nozzle must be examined.

2. On nozzle material above the J-groove weld, surface examination of the inside diameter surface of the nozzle is permitted provided a surface examination of the J-groove weld is also performed.

Footnote 3 of the Order provides specific criteria for examination of repaired VHP nozzles.

By letter dated May 14, 2005, as supplemented by letters dated May 17, May 18, and May 19, 2005, OPPD requested relaxation to implement an alternative to the requirements of Section IV, paragraph C.(5)(b)(ii), of the Order for RPV head penetration nozzles at FCS. The May 14, 2005, relaxation request superseded the request made on April 7, 2005.

2.0 RELAXATION REQUEST FOR EXAMINATION COVERAGE OF CONTROL ELEMENT DRIVE MECHANISMS (CEDMS) PENETRATION NOZZLES OF THE REACTOR PRESSURE VESSEL HEAD

2.1 Order Requirements for Which Relaxation is Requested

The licensee has requested relaxation from Section IV, paragraph C.(5)(b)(ii) of the First Revised NRC Order. The specific relaxation requested is identified below:

2.2 Licensee's Proposed Alternative

The licensee seeks relaxation from the Order where inspection coverage is limited by inaccessible areas of the ID surface in 25 of its 41 CEDM penetration nozzles for FCS. The licensee stated that relaxation is requested from Section IV, paragraph IV.C.(5)(b)(ii) of the Order that requires ECT of the entire wetted surface of the J-groove weld and the wetted surface of the RPV head penetration nozzle base material from 2 inches above the highest point of the root of the J-groove weld (on a horizontal plane perpendicular to the nozzle axis).

The licensee proposes to examine each of the CEDM nozzles in accordance with the Order requirements to the maximum extent possible. The licensee stated that the minimum examination coverage for the nozzle ID surface, except for Nozzle No. 25, will be at least 1.06 inches above the highest point of the J-groove weld. For Nozzle No. 25, the licensee could only inspect 280 degrees in circumference. A circumferential section of 80 degrees of the ID surface could not be examined due to physical constraint.

2.3 Licensee_s Basis for Relaxation

2.3.1 Affected Nozzles, Except Nozzle No. 25

The licensee stated that a portion of the wetted surface of the RPV head penetration nozzle base material above the highest point of the root of the J-groove weld (on a horizontal plane perpendicular to the nozzle axis) can not be accessed by the ECT device in 25 of the 41 CEDM penetrations (refer to Table 1). Among these penetrations, Nozzle No. 25 is further limited in examination coverage and will be discussed separately. There are three types of physical constraints that limit the examination of nozzles as identified in Table 1.

1) Lack of Vertical Scan Coverage - Some CEDM penetration nozzles have a small area (generally less than 0.25 inches in length axially) at the top of the axial scan area that was not covered due to random constraints on axial travel. Generally, these areas do not extend the full circumference around each nozzle. These

   constraints were due to either mechanical clearance between the thermal sleeve and the nozzle, or hard deposits possibly from boron or crud buildup in the nozzle to thermal sleeve gap. This resistance caused probe travel stoppage when forces met allowable limits intended to protect probe integrity. This issue affected the inspection of CEDM penetration Nozzles 6, 7, 8, 10, 12, 14, 19, 22, 23, 24, 26, 28, 29, 30, 31, 32, 33, 34, 35, 37, 38, 39, 40, and 41, as shown in Table 1.

Table 1 CEDM Nozzles with Limited Examination Coverage

CEDM Nozzle	**Percent (%) Inspection Coverage Obtained**	**Lowest Coverage Obtained (inches above J-groove weld)**	**Relaxation Requested (remaining distance in inches above the J-groove weld)**	**Applicability** **1 - Lack of Vertical Scan Coverage** **2 - CEDM Thermal Sleeve Tab Interference** **3 - Mechanical Limits of Probe Delivery System**	**Bounding Total Stress**
6	99.01	1.75	0.25	1	≤ 12 ksi
7	98.62	1.73	0.27	1	≤ 12 ksi
8	99.38	1.83	0.17	1	≤ 12 ksi
10	99.09	1.77	0.23	1	≤ 12 ksi
12	99.30	1.73	0.27	1	≤ 12 ksi
14	99.27	1.74	0.26	1	≤ 12 ksi
19	99.22	1.49	0.51	1	≤ 12 ksi
22	98.94	1.75	0.25	1, 2	≤ 14 ksi
23	99.05	1.79	0.21	1, 2	≤ 14 ksi
24	98.81	1.87	0.13	1, 2	≤ 14 ksi
25	75.18	1.57	0.43	1, 2 and thermal sleeve interference	≤ 14 ksi
26	97.79	1.61	0.39	1, 2	≤ 14 ksi
28	99.18	1.47	0.53	1, 2	≤ 14 ksi
29	99.77	1.89	0.11	1, 2	≤ 14 ksi
30	97.34	1.65	0.35	1, 2	≤ 14 ksi
31	99.53	1.81	0.19	1, 2	≤ 14 ksi
32	97.76	1.71	0.29	1, 2	≤ 14 ksi
33	96.99	1.59	0.41	1, 2	≤ 14 ksi
34	99.12	1.57	0.43	1, 2	≤ 14 ksi
35	99.25	1.83	0.17	1, 2	≤ 14 ksi
37	99.38	1.87	0.13	1, 2	≤ 14 ksi
38	94.85	1.42	0.58	1, 2, 3	≤ 15 ksi
39	93.35	1.26	0.74	1, 2, 3	≤ 15 ksi
40	93.61	1.06	0.94	1, 2, 3	≤ 15 ksi
41	93.20	1.06	0.94	1, 2, 3	≤ 15 ksi

2) CEDM Thermal Sleeve Tab Interference - The blade-type ECT nozzle probe is designed to be inserted between the nozzle and thermal sleeve for the ID surface examination of the nozzle base material. Each thermal sleeve has four, 1/8 inch

wide by 1/4 inch high centering tabs on its outer surface, spaced 90 degrees apart. Probe insertion was limited whenever the end of the blade contacts a tab. This prevented scanning above the height for the combined width of the blade and tab (approximately 9/16 inches), at four locations 90 degrees apart in affected penetrations. This affected the inspection of CEDM penetration nozzles 22, 23, 24, 26, 28, 29, 30, 31, 32, 33, 34, 35, 37, 38, 39, 40, and 41, as shown in Table 1. Full-height scanning can still be accomplished between the centering tabs where there is no interference between tabs and the probe.

3) Mechanical Limits of Probe Delivery System - Mechanical limitations in probe travel (at 8.00 inches) occurred due to the addition on the probe delivery mechanism of the special tool needed to apply sufficient force on the thermal sleeves. This prevented full axial coverage at the top of the circumferential scan area. The probe delivery mechanism was originally designed to allow full coverage of the area. However, the nozzle examination areas made accessible only through use of the special tool were significantly larger than the areas made inaccessible by its use. This affects CEDM penetration nozzles 38, 39, 40, and 41 as shown on the appropriate Figures of the licensee□s submittal.

The licensee stated that, except for Nozzle No. 25, the ECT inspections covered at least to 1.06 inches above the J-groove weld, where stresses are much higher than the un-inspected areas. The stress analysis has shown that the stress in the un-inspected area is very low, at approximately only 15 ksi. Cracks will not initiate or propagate at this stress level. The licensee further stated that the un-inspected area will only account for less than 10 percent of the total area in each nozzle being inspected and is insignificant.

The licensee has considered alternative methods to meet the Order requirement of examining 100 percent of the area to 2 inches above the weld. However, full probe access would require removal of, or rotating the thermal sleeves. It is estimated that the removal of thermal sleeves would result in an average of 2 man-REM and extend the outage duration by 20 hours per affected CEDM penetration. This could result in significant radiation exposure (approximately 50 man-REM for 25 nozzles) and extend the outage by 500 hours. In order to rotate the thermal sleeves to allow for ID inspection of these affected CEDM nozzles, FCS would have to build equipment to clamp onto the nozzle and thermal sleeve to enable rotation to occur. Rotating the thermal sleeves could also result in significant radiation exposure and outage delays. In addition, rotating, or removal of the thermal sleeves could have the potential for deforming the thermal sleeves and create operational problems with control rod movement.

In conclusion, the licensee stated for the affected nozzles that the inspection coverage of less than 10 percent of the total area for each of the CEDM nozzles would not significantly affect OPPD_s inspection results. Since the maximum hoop stress is only 15 ksi in the region where inspection coverage is less than 100 percent, PWSCC initiation in the un-inspected region is extremely unlikely. The completed bare metal visual inspection over the vessel head found no evidence of any leakage. Obtaining inspection data for these areas as required by the Order would result in hardship or unusual difficulty without a compensating increase in the level of

quality and safety. The completed inspection coverage area is sufficient to ensure that structural integrity of the nozzles are maintained over the single cycle of operation prior to the vessel head replacement during the fall 2006 RFO.

2.3.2 CEDM Nozzle No. 25

In addition to the physical constraints that limit the examination of nozzles due to random constraints on axial travel and thermal sleeve tab interference (examples 1 and 2 from Section 2.3.1), the licensee stated that CEDM Nozzle No. 25 has a circumferential area of approximately 80 degrees that can not be scanned due to lack of clearance between the thermal sleeve and the nozzle for the probe. As with all of the other nozzles, this nozzle was washed in an attempt to remove any potential boron or deposited crud, and the pusher tool was used on it at the maximum allowable pressure in an effort to open up the thermal sleeve to nozzle gap but these efforts were not successful on this nozzle. Further efforts to open up this gap were deemed to be undesirable without causing significant damage to the thermal sleeve. This results in the inability to achieve full 360-degree coverage for CEDM Nozzle No. 25. Therefore, relaxation is requested for this area of CEDM Nozzle No. 25.

The licensee has performed deterministic fracture mechanics analysis to evaluate stresses in the nozzle for which relaxation is requested. A reactor head temperature of 588°F was used for the calculations. This analysis establishes that the scope of relaxation requested would not significantly affect the continued safe operation of the RPV head for one additional operating cycle, after which it will be replaced. Additionally, crack growth analysis indicates that nozzle ejection is an extremely unlikely scenario and that leakage would occur prior to ejection. This indicates that a robust safety margin exists with respect to the single cycle of operation. Additionally, the licensee has performed a probabilistic fracture mechanics evaluation for the areas proposed for relaxation. This analysis concludes that the partial inspection coverage appears to be acceptable, and does not result in significant differences in the probability of leakage or nozzle ejection from full 100 percent inspection coverage.

The licensee stated that it utilizes a continuous on-line reactor coolant system (RCS) leak rate calculation and leakage-monitoring program at FCS to support early detection of changes in RCS leakage. The value of this tool was proven when control room operators identified a 0.1 gpm increase in the RCS leakage trend and were able to identify and isolate a charging pump packing leak in approximately one hour. Any significant penetration nozzle leaks over the next cycle prior to RPV head replacement would be manifested as unidentified RCS leakage and receive prompt attention for mitigation (including containment entry for visual inspection). FCS_s policy is to resolve unidentified RCS leakage when it occurs.

The FCS RPV head has forty-eight penetrations, which have nozzles made from five different heats of material. Based on industry operating experience, all of the heats of material have performed well, and none of the heats have shown any occurrence of PWSCC. It is also accepted that the likelihood for PWSCC increases as the yield strength exceeds 50 ksi. Nozzle No. 25 has a yield strength of 37 ksi, well below 50 ksi and, therefore, has very low probability of PWSCC. In conclusion, based on relatively low FCS nozzle temperatures of 588°F, fabrication using Huntington Alloy 600, and relatively low yield strength, Nozzle No. 25 has a relatively low susceptibility to PWSCC.

The licensee also discussed the hardship it would result in if a 100 percent examination has to be performed on Nozzle No. 25. The rod control system at FCS is a unique design that uses a rack and pinion CEDM. The rack and pinion design imposes a significant constraint on performance of a RPV head inspection because the CEDM extension shaft that connects the drive mechanism to the Control Element Assembly (CEA) remains installed in the RPV head nozzle when the reactor is disassembled. The presence of the CEDM extension shaft severely limits access to the nozzle ID for inspection purposes. Inspection access is further complicated by the thermal sleeve that is installed in the annulus between the CEDM extension shaft and the CEDM nozzle.

FCS has a _scram weight_ at the end of each CEDM extension shaft that precludes the CEDM extension shaft removal from the top of the RPV head, necessitating their removal from below the RPV head. In order to remove the CEDM extension shaft on CEDM Nozzle No. 25, the RPV head will be installed on the reactor vessel and the CEDM extension shaft will be lowered until it rests on the CEA spider. The CEDM connector nut will then be removed and the reactor head will be lifted and placed on the head stand. It is anticipated that the CEDM extension shaft will be left resting in the Upper Guide Structure in the reactor vessel. However, since this operation has never been performed, it is not certain that the CEDM connector bolt will disengage smoothly from the CEDM rack assembly and slide downward while the RPV head is being lifted. Additional rack extensions may need to be removed to gain proper clearance and a pathway to access CEDM Nozzle No. 25.

When the thermal sleeve is removed, the ID inspection of CEDM Nozzle No. 25 can be completed with the normal eddy-current inspection equipment used for the RPV head inspection. For re-assembly after completion of the inspection, the reactor vessel head would be positioned approximately nine feet above the reactor vessel and tooling would be inserted through the tool access tube into the space below the RPV head. The tooling would then be threaded into a connection on the top of the CEDM connector bolt and the CEDM extension shaft assembly would be hoisted up through the CEDM nozzle and mated with the CEDM rack assembly.

The dose for the activities to complete inspection of the remaining 80 degrees on the ID of CEDM Nozzle No. 25 is estimated at 10 man-REM. Many of the activities must be performed regardless of the number of CEDM extension shafts and thermal sleeves requiring removal. Therefore, the estimated dose to remove one CEDM extension shaft and thermal sleeve is much higher than the estimated dose per nozzle, if all extension shafts and thermal sleeves were to be removed.

The licensee stated that completion of the inspection of CEDM Nozzle No. 25 according to the Order requirements, due to the technical and radiological challenges involved, would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

3.0 STAFF EVALUATION

The NRC staff_s review of this request was based on criterion (2) of paragraph F of Section IV of the Order, which states:

> Compliance with this Order for specific nozzles would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

3.1 Staff Evaluation of Affected CEDM Nozzles, Except Nozzle No. 25

Within the context of the licensee_s proposed alternative examination of the RPV head penetration nozzles, the licensee has demonstrated hardship that would result from implementing 100 percent examination coverage to 2 inches above the highest point of the root of the J-groove weld in the 24 CEDM nozzles identified in Table 1.

The FCS CEDM penetrations have guide/thermal sleeves, with 4 weld tabs 90 degrees apart, inside the CEDM penetration to position the CEDM shaft. The blade-type ECT nozzle probe is designed to be inserted between the nozzle and thermal sleeve for ID surface examination of the nozzle base material. Probe insertion will be limited whenever the end of the blade contacts a tab. This will prevent scanning at four locations in each of the nozzles. In the affected penetrations located in the outer periphery, the free scan distance is less than the required 2 inches above the root of the weld. Full-height scanning can still be accomplished between the centering tabs where there is no interference between tabs and the probe. The licensee proposed to examine the CEDM penetration nozzles to a minimum of 1.06 inches above the highest point of the root of the J-groove weld for the nozzles that could not achieve full coverage. The total of the un-inspected area is estimated to be less than 10 percent of the total area inspected for each nozzle.

The licensee identified 24 nozzles, in addition to Nozzle No. 25, to have such limitation in the examination coverage above the J-groove weld. In order to meet the Order requirement to examine 2 inches above the root of the weld, it would require either rotation or removal of the thermal sleeve, which would cause significant radiation exposure and extension of the outage duration. In addition, performing either task could have the potential to deform the thermal sleeves and create operational problems with control rod movement, which is a safety concern.

The NRC staff agrees that the nozzle_s configuration makes inspection in accordance with the Order very difficult and would create a hardship. This evaluation focuses on the issue of whether there is a compensating increase in the level of quality and safety such that these nozzles should be inspected in accordance with the Order despite of the hardship.

The phenomenon of concern is PWSCC, which typically initiates in the areas of highest stress. The area of CEDM penetrations that has the highest residual stress is the area adjacent to the J-groove weld. Therefore, it is most unlikely that PWSCC will initiate in an area more than 1.06 inches away from the J-groove weld.

The licensee performed a stress analysis in support of this relaxation request. In the analysis, the hoop stresses in the penetration nozzle consist of steady state operation loads and weld residual stresses. Based on the analysis, it showed that for all affected penetrations, the highest bounding hoop stress on the ID surface at 1.06 inches above the highest point of the root of the J-groove weld is 15 ksi and occurs on the uphill side of the 41.7-degree nozzle. On the OD surface, the analysis showed that both hoop and axial stresses at 1.06 inch above the highest point of the root of the J-groove weld are much lower in all cases. Therefore, the bounding hoop stress in the un-inspected area is only 15 ksi. It is commonly accepted that a minimum stress level of 20 ksi should be present for PWSCC initiation. Since the bounding hoop stress is only 15 ksi in the un-inspected areas, PWSCC initiation in this region is unlikely.

The licensee performed crack growth analysis in the un-inspected region. The purpose of the calculation is to determine the maximum flaw size for an axial flaw initiated from the nozzle inside surface that would grow to 75 percent of the wall thickness in a single fuel cycle (18 months). One fuel cycle was chosen since the licensee will be installing a new RPV head during the fall 2006 RFO. The methodology used in the crack growth calculation is consistent with the NRC_s flaw evaluation guidelines for the upper RPV head penetrations. The PWSCC crack growth rate used in the NRC flaw evaluation guidelines is the same as that recommended in _Materials

Reliability Program (MRP) Crack Growth Rates for Evaluating Primary Water Stress Corrosion Cracking (PWSCC) of Thick Wall Alloy 600 Material (MRP-55) Revision 1._ The NRC staff has made a preliminary assessment of the crack-growth formula, but has not yet made a final determination on the acceptability of the subject industry report. Should the NRC staff determine the crack-growth formula used by the licensee to be unacceptable, the licensee will be required to revise its analysis to incorporate an acceptable crack-growth formula as described below:

> If the NRC staff finds that the crack-growth formula in industry report MRP-55 is unacceptable, OPPD shall revise its analysis that justifies relaxation of the First Revised Order within 30 days after the NRC informs OPPD of an NRC-approved crack-growth formula. If OPPD_s revised analysis shows that the crack growth acceptance criteria are exceeded prior to the end of the current operating cycle, this relaxation is rescinded and OPPD shall, within 72 hours, submit to the NRC written justification for continued operation. If the revised analysis shows that the crack growth acceptance criteria are exceeded during the subsequent operating cycle, OPPD shall, within 30 days, submit the revised analysis for NRC review. If the revised analysis shows that the crack growth acceptance criteria are not exceeded during either the current operating cycle or the subsequent operating cycle, OPPD shall, within 30 days, submit a letter to the NRC confirming that its analysis has been revised. Any future crack-growth analyses performed for this and future cycles for RPV head penetrations must be based on an acceptable crack growth rate formula.

In a letter dated May 14, 2005, the licensee agreed to the above condition.

The licensee_s stress analysis demonstrates that the axial residual stresses decline very quickly with distance away from the J-groove weld. It also showed that the axial stresses are much lower than the hoop stresses at locations 1.06 inches above the root of the J-groove weld. Therefore, initiation and propagation of circumferential flaws are not predicted in this region.

For a bounding crack growth calculation of an axial flaw, an aspect ratio of 6 is assumed. The crack growth results are summarized in Table 2 for both the downhill and uphill side of the of CEDM nozzle locations at FCS.

Table 2
Minimum Flaw Size to Reach 75% of Wall Thickness in One Fuel Cycle for CEDM Nozzle Penetrations
(Aspect Ratio = 6)

	Min. Flaw Size (% throughwall)	Min. Flaw Size (% throughwall)
CEDM Nozzle Angle (∘)	Downhill	uphill
37.3	68.5	69.1
41.7	68.2	68.6

Based on the results given in Table 2, for an ID axial surface flaw, a minimum initial flaw depth of 0.26 inch (68 percent part-through wall) is required to reach 75 percent of the wall thickness in one fuel cycle. For an aspect ratio of 6, the minimum initial flaw length is 1.56 inches long. Due to the low probability of PWSCC initiation in the low stress region that is more than 1.06 inches above the root of the J-groove weld on the uphill side, the existence of a 68 percent part-through wall ID axial surface flaw with an initial flaw length of 1.56 inches in that region is unlikely.

The area that cannot be inspected for the CEDM ID scans is less than 10 percent of the total area being inspected, which is insignificant. In addition, the un-inspected areas in each nozzle are at four separate locations. It is very unlikely that an initial flaw size, as discussed above, will be missed when all other areas are examined.

The licensee has performed bare metal visual examinations of the RPV head during the three most recent refueling outages (2002, 2003, and the current outage). No reportable indications were found during any of these inspections. Industry experience has also shown that there has no incidence of cracking resulting in leakage in any of the Combustion Engineering (CE) plants. FCS currently has a CE fabricated RPV head. In addition, the licensee will replace the reactor vessel head in the next outage.

Based on the above discussion, the staff finds that : 1) the un-inspected area has a low stress level and is unlikely to initiate PWSCC, and 2) the size of the un-inspected area is very small and that if a significant crack were to exist, it would very likely be detected by the examination. Therefore, the staff concludes that the completed inspection coverage area is sufficient to ensure that structural integrity of the nozzles are maintained during the next full cycle of operation for the 24 CEDM nozzles identified in Table 1, other than Nozzle No. 25 which is evaluated in the following section.

3.2 Staff Evaluation of Nozzle No. 25

In addition to the physical constraints that limit the examination of nozzles due to random constraints on axial travel and thermal sleeve tab interference (examples 1 and 2 from Section 2.3.1), CEDM Nozzle No. 25 has a circumferential area of approximately 80 degrees that could not be scanned due to lack of clearance between the thermal sleeve and the nozzle for the probe. The nozzle was washed in an attempt to remove any potential boron or deposited crud, and the pusher tool was used on it at the maximum allowable pressure in an effort to open up the thermal sleeve to nozzle gap but these efforts were not successful on this nozzle. Further efforts to open up this gap were deemed to be undesirable without causing significant damage to the thermal sleeve.

The licensee has considered alternative means of examining the areas for which relaxation is requested. The licensee considered cutting the thermal sleeve of Nozzle No. 25 but concluded it would cause significant hardship or unusual difficulty without a compensating increase in the level of quality and safety. The hardship identified by the licensee includes the following:

> The unique control rod design is such that the control rod extension shaft on CEDM Nozzle No. 25 can not be removed from the top of the vessel head. The extension shaft in the control rod is 21 ft in length, thus can not be easily removed from under the head when the head is in the lay-down stand. The rod must be removed, before the thermal sleeve can be removed, by a series of operation maneuvers described below:
>
> The RPV head will be placed on the reactor vessel and the CEDM extension shaft will be lowered until it rests on the CEA spider. The CEDM connector nut will then be removed and the reactor head will be lifted and placed on the head stand. It is anticipated that the CEDM extension shaft will be left resting in the Upper Guide Structure in the reactor vessel. With the CEDM extension shaft removed, the RPV head will be placed in the head lay down area. The thermal sleeve will be cut above the CEDM nozzle inspection area and removed. When the thermal sleeve has been removed, the ID inspection of CEDM Nozzle No. 25 can be completed with the normal eddy-current inspection equipment used

for the RPV head inspection. For re-assembly after completion of the inspection, the reactor vessel head will be positioned approximately nine feet above the reactor vessel and tooling will be inserted through the tool access tube into the space below the RPV head. The tooling will then be threaded into a connection on the top of the CEDM connector bolt and the CEDM extension shaft assembly will be hoisted up through the CEDM nozzle and mated with the CEDM rack assembly. The CEDM extension shaft will also need to be manually oriented during the hoisting operation to ensure that it mates properly with the CEDM rack assembly. An additional uncertainty is the ability to properly realign the CEDM extension shaft with the rack assembly. The clearances between the two components are very tight and the CEDM extension shaft must be inserted upward through the entire length of the rack assembly. Once the CEDM extension shaft has been reinstalled, reactor reassembly can be performed in accordance with the normal sequence of refueling activities. The total estimated dose to complete inspection of CEDM Nozzle No. 25 is estimated at 10 man-rem. There would also be a significant extension of the outage duration.

Due to the unique design of FCS CEDMs, no vendor has any experience in such an operation. The control rod and its related components will be at the risk of being damaged when performing this operation, thus it poses a safety concern.

Within the context of the licensee_s proposed alternative examination of the RPV head penetration nozzles, the licensee has demonstrated the hardship that would result from implementing 100 percent examination coverage of the ID surface area in Nozzle No. 25. The staff agrees that the nozzle_s unique design and configuration make inspection in accordance with the Order very difficult and would create hardship. The following evaluation focuses on the issue of whether there is a compensating increase in the level of quality and safety such that these nozzles should be inspected in accordance with the Order despite of the hardship.

The licensee_s request to relax the examination requirement of 100 percent examination coverage is supported by the following bases:

1) The FCS RPV head has forty-eight penetrations, which have nozzles made from five different heats of material using Huntington Alloy 600. All of the heats of material have performed well, and none of the heats have shown any industry occurrence of PWSCC. It is also accepted that the likelihood for PWSCC increases as the yield strength exceeds 50 ksi. Nozzle No. 25 has a yield strength of 37 ksi, well below 50 ksi and, therefore, has low probability of PWSCC. Therefore, based on relatively low FCS nozzle temperature of 588°F, and the use of Huntington Alloy 600, with a relatively low yield strength, Nozzle No. 25 has a relatively low susceptibility to PWSCC.
2) During this outage, the licensee performed examination of wetted surface of all 41 CEDM nozzles and 6 ICI nozzles, including ID, OD, and the J-groove weld surfaces. Based on the examination, no flaws were detected. It is very unlikely that a significant crack would exist in the un-inspected area that would challenge the structural integrity of the nozzle.

3) The licensee has performed BMV examinations of the RPV head during the three most recent refueling outages (2002, 2003, and the current outage). No reportable indications were found during any of these inspections. Industry experience has also shown that there has been no incidence of cracking resulting in vessel head nozzle leakage in any of

the CE plants. FCS has a CE fabricated RPV head. In addition, the licensee will replace the reactor vessel head in the next refueling outage.

4) Even if a flaw were to exist in the un-inspected area, it should take time to propagate to a through-wall crack. Also, the probability of such an occurrence in Nozzle No. 25 is low considering its low susceptibility to PWSCC.

5) The licensee will replace its vessel head during the next refueling outage after an 18-month operation. Even if there is minor leakage, the potential corrosion damage to the vessel head would be insignificant.

6) In a worst case scenario, assuming a circumferential through-wall flaw exists in the 80-degree section of the un-inspected area, the licensee_s analysis concluded that it will take 16 years for the flaw to propagate to a critical flaw size of 300 degrees in circumference. In addition, the analysis is based on a conservative assumption that a through-wall flaw existed in the un-inspected area while in fact, the BMV inspection did not identify any leakage. The staff notes that there is large safety margin in the licensee's analysis to support a 1.5 years of operation (only 1.5 years needed verses 16 years supported by the analysis). Therefore, the calculation by the licensee provides sufficient safety margin before the next refueling outage during which the vessel head is scheduled to be replaced. Based on the above, the staff finds that a postulated flaw in the un-inspected area will not challenge the structural integrity of the nozzle, prior to the end of the next operating cycle.

Based on the above discussion, the staff finds that, due to the technical and radiological challenges involved, the inspection of CEDM Nozzle No. 25, in accordance with the Order requirements, would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety. In addition, the staff finds that the inspection performed by the licensee on Nozzle No. 25 provides reasonable assurance of the structural integrity of the nozzle. Therefore, the licensee has demonstrated hardship that would result from complying with the Order inspection requirement without a compensating increase in the level of quality and safety.

4.0 CONCLUSION

The NRC staff concludes that the licensee_s proposed alternative for the examination of 25 CEDM nozzles, with a minimum coverage of 1.06 inches above the highest point of the root of the J-groove weld (on a horizontal plane perpendicular to the nozzle axis), and for the examination of Nozzle No. 25 with a coverage of 280 degrees in circumference on the ID surface, provides reasonable assurance of the structural integrity of the RPV head, VHP nozzles, and welds. Further inspection of these nozzles in accordance with Section IV, paragraph C.(5)(b), of the First Revised NRC Order EA-03-009, dated February 20, 2004, would result in hardship without a compensating increase in the level of quality and safety. The staff finds that the licensee has demonstrated good cause for the requested relaxation. Therefore, pursuant to Section IV, paragraph F, of the Order, the staff authorizes the proposed alternative inspection for the referenced CEDM nozzles at FCS, subject to the following condition:

> If the NRC staff finds that the crack-growth formula in industry report MRP-55 is unacceptable, OPPD shall revise its analysis that justifies relaxation of the First Revised Order within 30 days after the NRC informs OPPD of an NRC-approved crack-growth

formula. If OPPD_s revised analysis shows that the crack growth acceptance criteria are exceeded prior to the end of the current operating cycle, this relaxation is rescinded and OPPD shall, within 72 hours, submit to the NRC written justification for continued operation. If the revised analysis shows that the crack growth acceptance criteria are exceeded during the subsequent operating cycle, OPPD shall, within 30 days, submit the revised analysis for NRC review. If the revised analysis shows that the crack growth acceptance criteria are not exceeded during either the current operating cycle or the subsequent operating cycle, OPPD shall, within 30 days, submit a letter to the NRC confirming that its analysis has been revised. Any future crack-growth analyses performed for this and future cycles for RPV head penetrations must be based on an acceptable crack growth rate formula.

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