August 29, 2003

Mr. George Vanderheyden, Vice President
Calvert Cliffs Nuclear Power Plant, Inc.
Calvert Cliffs Nuclear Power Plant
1650 Calvert Cliffs Parkway
Lusby, MD 20657-4702

SUBJECT: CALVERT CLIFFS NUCLEAR POWER PLANT, UNIT NOS. 1 AND 2 - RELIEF REQUEST TO USE ALTERNATIVE TECHNIQUES FOR REACTOR VESSEL HEAD REPAIR (TAC NOS. MB4013 AND MB4014)

Dear Mr. Vanderheyden:

By letter dated February 7, 2002, as supplemented by letters dated December 18, 2002, and January 20, 2003, Calvert Cliffs Nuclear Power Plant, Inc., (CCNPPI), submitted relief requests for the CCNPP, Unit Nos. 1 and 2. Relief was requested from certain requirements of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code) Section XI, 1989 Edition for the reactor vessel head control rod drive mechanism penetration nozzle repair. Specifically, CCNPPI proposed weld repairs using an alternative temper bead welding requirement and alternatives to ASME Code non-destructive examinations and flaw evaluation requirements.

The U.S. Nuclear Regulatory Commission (NRC) staff has completed its review as documented in the enclosed safety evaluation. The NRC staff determined that CCNPPI has demonstrated that the proposed alternatives to the ASME Code requirements provide an acceptable level of quality and safety. Therefore, pursuant to 10 CFR 50.55a(a)(3)(i), the NRC staff authorizes the relief requests for the third 10-year interval.

Sincerely,

/RA/

Richard J. Laufer, Chief, Section 1
Project Directorate 1
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket Nos. 50-317 and 50-318

Enclosure: Safety Evaluation

cc w/encl: See next page

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ADAMS Accession Number: ML032160511 **See previous concurrence
*Safety evaluation dated 7/28/2003 - no significant changes made

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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELIEF REQUESTS REGARDING IWA-3300 AND NB-5330(b) REQUIREMENTS

AND THE USE OF MODIFIED CODE CASE N-638

CALVERT CLIFFS NUCLEAR POWER PLANT, UNIT NOS. 1 AND 2

DOCKET NOS. 50-317 AND 50-318

1.0 INTRODUCTION

The inservice inspection (ISI) of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code) Class 1, Class 2, and Class 3 components is to be performed in accordance with Section XI of the ASME Code and applicable edition and addenda as required by Title 10 of the *Code of Federal Regulations* (10 CFR) Section 50.55a(g), except where specific relief has been granted by the Commission pursuant to 10 CFR 50.55a(g)(6)(i). 10 CFR 50.55a(a)(3) states in part that alternatives to the requirements of paragraph (g) may be used, when authorized by the Nuclear Regulatory Commission (NRC), if the licensee demonstrates that: (i) the proposed alternatives would provide an acceptable level of quality and safety, or (ii) compliance with the specified requirements would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

Pursuant to 10 CFR 50.55a(g)(4), ASME Code Class 1, 2, and 3 components (including supports) must meet the requirements, except the design and access provisions and the preservice examination requirements, set forth in the ASME Code, Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components," to the extent practical within the limitations of design, geometry, and materials of construction of the components. The regulations require that inservice examination of components and system pressure tests conducted during the first 10-year interval and subsequent intervals comply with the requirements in the latest edition and addenda of Section XI of the ASME Code incorporated by reference in 10 CFR 50.55a(b) twelve months prior to the start of the 120-month interval, subject to the limitations and modifications listed therein. The ISI code of record for the third 10-year ISI interval at Calvert Cliffs, Unit Nos. 1 and 2, is the 1989 Edition with no Addenda of Section XI of the ASME Code (except for Subsections IWE and IWL).

By letter dated February 7, 2002, as supplemented by letters dated December 18, 2002, and January 20, 2003, Calvert Cliffs Nuclear Power Plant, Inc. (CCNPPI or the licensee), submitted relief requests which requested relief from certain welding repair requirements at Calvert Cliffs, Unit Nos. 1 and 2. Specifically, in lieu of fully characterizing the flaw that remained in the control element drive mechanism (CEDM) J-groove weld after a limited J-groove weld removal, the licensee requested approval to use the worst-case assumption to estimate the crack extent and orientation. The postulated crack extent and orientation will than be evaluated versus the

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flaw acceptance criteria in IWB-3600. In addition, the licensee has requested approval to use the modified methodology of ASME Code, Section XI, Code Case N-638 to support reactor vessel closure head repair. Also, as a result of the NRC staff's review, the licensee submitted an additional request, in its December 18, 2002, submittal, for relief from the 1992 Edition no Addenda to ASME Code, Section III, Paragraph NB-5330, to perform a fracture mechanics evaluation of a postulated weld anomaly in the CEDM nozzle inside diameter temper bead repair.

Calvert Cliffs is currently in its third 10-year ISI interval. The construction code for Calvert Cliffs is the ASME Section III 1965 Edition including Addenda through Winter 1967, Class A, and their ISI Code of record is the 1998 Edition, no Addenda of Section XI of the ASME Code (except for Subsections IWE and IWL). Pursuant to 10 CFR 50.55a(a)(3)(i), the licensee requested relief from the requirements of the following Code requirements.

2.0 TECHNICAL EVALUATION ON RELIEF FROM IWA-3300 REQUIREMENT

This relief request applies to the CEDM nozzle J-groove weld.

2.1 Code Requirements for which Relief is Requested

IWA-3300 of the 1998 Edition of the ASME Code states that "(a) Flaws detected by the preservice and inservice examinations shall be sized by the bounding rectangle or square for the purpose of description and dimensioning. The dimensions of a flaw shall be determined by the size of a rectangle or square that fully contains the area of the flaw....". Therefore, the licensee's sizing of an existing flaw in the CEDM nozzle J-groove weld by postulation and using this assumed flaw size in its flaw evaluation is considered as an alternative to that specified in the ASME Code. Pursuant to 10 CFR 50.55a(a)(3)(i), the licensee requested relief from ASME XI IWA-3300 on flaw characterization.

2.2 Licensee's Proposed Alternative to Code

In lieu of fully characterizing the flaw that remains in the J-groove weld after a limited J-groove weld removal, the licensee proposed to use the worst-case assumption to estimate the crack extent and orientation. The postulated crack extent and orientation will then be evaluated versus the flaw acceptance criteria in IWB-3600.

2.3 Licensee's Bases for Relief:

> Experience gained from the repairs performed manually on the Oconee Unit 1 and Unit 3 (CEDM) nozzles indicated that removal and repair of the defective portions of the original J-groove partial penetration welds were time consuming and radiation dose intensive. The previous repairs indicated that more remote automated repair methods were needed to reduce radiation dose to repair personnel. For the Calvert Cliffs repairs, a remote semi-automated repair method is planned for each nozzle requiring repair. Using a remote tool, each nozzle requiring repair will first receive a roll expansion into the RVCH [reactor vessel closure head] base material to ensure that the nozzle will not move during subsequent repair operations. Second, a semi-automated machining tool, from underneath the RVCH, will remove the lower portion of the nozzle to a depth above the existing J-groove partial penetration weld. This operation will sever the existing

J-groove partial penetration weld from the CEDM nozzle. Third, a chamfer will be machined into the end of the CEDM nozzle in preparation for the repair weld. Fourth, the original J-groove weld will be chamfered to assure the remaining weld metal is thinner than the maximum allowable flaw size. Finally, a semi-automated weld tool, utilizing the machine gas tungsten-arc welding process, will then be used to install a new Alloy 690 pressure boundary weld between the shortened nozzle and the inside bore of the RVCH base material (See Figures 3 and 4 of Attachment 2). [See application dated February 7, 2002]. This weld also attaches the replacement CEDM lower nozzle guide funnel to the lower end of the shortened upper portion of the CEDM nozzle.

It is intended, as part of the new repair methodology and to reduce radiation dose to repair personnel, that the original J-groove partial penetration welds will be left in place. These welds will no longer function as pressure boundary CEDM nozzle to RVCH welds. However, the possible existence of flaws in these welds mandates that the flaw growth potential be evaluated.

The requirements of IWA-4611.1 allows two options for determining the disposition of discovered flaws. The subject flaws are either removed as part of the repair process or left as-is and evaluated per the rules of IWB-3000.

The assumptions of IWB-3600 are that the flaws are fully characterized in order to compare the calculated flaw parameters to the acceptance criteria in IWB-3600. However, the original CEDM nozzle to RVCH J-groove weld is extremely difficult to examine ultrasonically (UT) due to the compound curvature and fillet radius. These conditions preclude ultrasonic coupling and control of the sound beam needed to perform flaw sizing with reasonable confidence in the measured flaw dimension. Therefore, it is impractical to, and presently no nondestructive examination technology has been identified that can characterize the flaw geometry that may exist therein. Not only is the configuration not conducive to UT, but the dissimilar metal interface between the Alloy 600 weld and the low alloy steel RVCH increases the UT difficulty. Therefore, it is not possible to accurately characterize flaw sizes.

As previously discussed, after the boring and removal of the nozzle end, the remaining weld will be chamfered to assure the remaining weld metal is thinner than the maximum allowable flaw size. Since it has been determined that through-wall cracking in the J-groove weld will most likely accompany a leaking CEDM nozzle, it must be assumed that the “as-left” condition of the remaining J-groove weld includes degraded or cracked weld material.

A fracture mechanics evaluation will be performed to determine if degraded J-groove weld material could be left in the RVCH, with no examination to size any flaws that might remain following the repair. Since the hoop stresses in the J-groove weld are generally about two times the axial stress at the same location, the preferential direction for cracking is axial, or radial relative to the nozzle. It will be postulated that a radial flaw in the Alloy 182 weld metal will propagate by primary water stress corrosion cracking (PWSCC) through the weld and butter, to the interface with the low alloy steel head. It is fully expected that such a flaw would then blunt and arrest at the butter-to-head interface. The repair design will specify that the inside corner of the J-groove weld be chamfered.

Crack growth through the Alloy 182 material would tend to relieve the residual stresses in the weld as the crack grew to its final size and blunted. Although residual stresses in the RVCH material are low, it will be assumed that a small flaw could initiate in the low alloy steel RVCH material and grow by fatigue. It will be postulated that a small flaw in the RVCH would combine with a large stress corrosion crack in the weld to form a radial corner flaw that would propagate into the low alloy steel head by fatigue crack growth under cyclic loading associated with heat-up and cool-down and other applicable transients.

Residual stresses will not be included in the flaw evaluations since it will be demonstrated by analysis that these stresses are compressive in the RVCH low alloy steel base material. Any residual stresses that remain in the area of the weld following the boring operation would be relieved by such a deep crack, and therefore need not be considered.

It will be postulated that a small flaw in the RVCH would combine with a large stress corrosion crack in the weld to form a radial corner flaw that would propagate into the low alloy steel head by fatigue crack growth under cyclic loading associated with heat-up and cool-down and other applicable transients.

Flaw evaluations will be performed for a postulated radial corner crack on the uphill side of the head penetration, where stresses are the highest. Hoop stresses will be used since they are perpendicular to the plane of the crack. Fatigue crack growth, calculated for at least 8 to 10 years of operation, will be small, and the final flaw size will meet the fracture toughness requirements of the ASME Code using an upper shelf value of 200 ksi√in for ferritic materials.

2.4 <u>Staff Evaluation</u>

The repair being proposed by the licensee will move the pressure boundary from the J-groove weld to the temper bead repair weld. As stated above, a fracture mechanics evaluation will be performed to determine if degraded J-groove weld material could be left in the RVCH, with no examination to size any flaws that may remain following the repair. Flaw evaluations will also be performed for a postulated radial corner crack on the uphill side of the head penetration, where the staff agrees that the stresses are the highest.

Since the licensee does not plan to remove the J-groove weld completely, the structural integrity of the remaining J-groove weld with a through-wall indication has to be demonstrated. This can be accomplished by a Section XI flaw evaluation provided that the flaw could be characterized by UT. However, instead of sizing the flaw by UT, the licensee requested relief from this IWA-3300 requirement, and proposed to use a conservatively assumed flaw size based on the J-groove weld geometry. The licensee assumed that the flaw in the remaining J-groove weld was a corner crack with a crack front reaching the closure head base material. This assumption is conservative because the flaw was determined by the maximum possible flaw size that could exist in the remaining J-groove weld. Therefore, approval of the relief request now depends on the acceptance of the flaw evaluation of the postulated flaw in the J-groove weld.

The NRC staff has determined that examination of any flaws in the J-groove weld region with volumetric methods is impractical due to the configuration. The angle of incidence from the outer surface of the closure head base material does not permit perpendicular interrogation by ultrasonic shear wave techniques of circumferentially oriented flaws and the physical proximity of the nozzle does not allow for longitudinal scrutiny of the area of interest. Cladding will provide an acoustic interface which will severely limit a confident examination of the weld material. Radiography of this area is impractical due to orientation of circumferentially oriented flaws being perpendicular to gamma and x-rays. Although dye penetrant and magnetic particle examinations will provide reference points on the surface, they can only be used as inference of crack growth.

The NRC staff has reviewed the licensee's description of the flaw evaluation that it will perform if CEDM nozzle leakage is identified in the coming outage and the proposed repair is to be implemented. The staff concludes that the methodology is the same as that approved in the Oconee 2 and Surry units safety evaluations (SEs), as documented in the letter from the NRC to Duke Energy Corporation, dated July 3, 2001, and the letter to Virginia Electric and Power Company, dated October 1, 2002. In summary, the licensee proposed to use a postulated radial flaw of the largest size that could exist in the remaining J-groove weld, a crack growth calculation considering heat-up and cool-down cycles and other transients, and the Code specified evaluation criteria of IWB-3600 to determine the acceptance of the postulated flaw.

The licensee states, "Calculations will be performed to show that the remaining flaws within the base material are acceptable for at least 8 to 10 years." Based on the staff's prior evaluations on similar CEDM nozzle repairs using the same flaw evaluation methodology for J-groove weld flaws left in place, the staff concludes that if the proposed repair is implemented and the flaw evaluation is performed, the calculated safety factor will exceed the code specified safety factor of 3.16 at the end of at least 5 years of operation. It should be noted that, in addition to the conservatism in the Section XI flaw evaluation procedure, two additional sources of conservatism are present: the through weld assumption for the corner crack and the use of the cut-off fracture toughness of 200 ksi$\sqrt{\text{inch}}$ for the vessel head material. Therefore, the actual margins will be larger than those indicated by the calculated safety factors using the proposed methodology.

2.5 Conclusion

Based on the discussion above, regarding the request for relief from the IWA-3300 requirement to fully characterize flaws left in service, the staff concludes that the proposal to not completely remove the flaws discovered in the remaining J-groove partial penetration welds is acceptable. Since no additional inspections are planned, the flaws will not be fully characterized. CCNPPI will use worst-case assumptions to conservatively estimate the crack extent and orientation. The postulated crack extent and orientation will be evaluated using the rules of IWB-3600. The licensee's actions provide assurance of structural integrity. CCNPPI has demonstrated that the proposed alternatives to the ASME Code requirements provide an acceptable level of quality and safety. Therefore, pursuant to 10 CFR 50.55a(a)(3)(i), the proposed alternative is authorized for the third 10-year interval.

3.0 LICENSEE'S BASIS FOR RELIEF REQUEST TO USE MODIFIED METHODOLOGY OF ASME SECTION XI, CODE CASE N-638

3.1 Component for which Relief is Requested

Reactor Vessel Closure Head (RVCH) Penetration Welds, ASME Class I.

3.2 Code Requirements for which Relief is Requested

The 1998 Edition no Addenda of ASME Section XI, IWA-4600(b) requires that when post-weld heat treatment is not to be performed, the following provisions may be used.

The welding methods of IWA-4620, IWA-4630, or IWA-4640 may be used in lieu of the welding and nondestructive examination (NDE) requirements of the Construction Code or Section III, provided the requirements of IWA-4610 are met.

The 1998 Edition no Addenda of ASME Section XI IWA-4610(a) requires the area to be welded plus a band around the area of at least 1-1/2 times the component thickness or 5 inches, whichever is less, shall be preheated and maintained at a minimum temperature of 350 °F for the shielded metal-arc welding (SMAW) process and 300 °F for the gas tungsten-arc welding (GTAW) process during welding. The maximum interpass temperature shall be 450 °F. Thermocouples and recording instruments shall be used to monitor the process temperatures. Their attachment and removal shall be in accordance with ASME Section III.

3.3 Licensee's Proposed Alternative to Code

Pursuant to 10 CFR 50.55a(a)(3)(i), CCNPPI proposes alternatives to the ASME Code requirements concerning the CCNPP repair/replacement of Code Class 1, 2, and 3 components for the third 10-year ISI interval. Calvert Cliffs Technical Specification 4.0.5 states in part, "Inservice Inspection of ASME Code Class 1, 2, and 3 components...shall be performed in accordance with Section XI of the ASME Boiler and Pressure Vessel Code and applicable Addenda as required by 10 CFR [Part] 50, Section 50.55a(g)... " Paragraph 10 CFR 50.55a(a)(3)(i) allows the use of alternatives to the requirements of paragraph 50.55a(g), that provide an acceptable level of quality and safety, when authorized by the Director of the Office of Nuclear Reactor Regulation.

The third 10-year ISI Program Plan for Calvert Cliffs, Unit Nos. 1 and 2 meets the requirements of the 1998 Edition, no Addenda of Section XI of ASME Code (except for subsections IWE and IWL) as approved by the NRC. The proposed alternatives to the Code requirements will be used in the event flaws requiring repair in the RVCH penetrations are discovered during inspections.

Section XI, Code Case N-638 provides an ambient temperature temper bead repair methodology that is an alternative to the preheat and post-weld heat soak requirements of Section XI, IWA-4633.2(d) and IWA-4610(a). CCNPPI plans to perform RVCH penetration repairs by welding the RVCH (P-No. 3 base material) and CEDM nozzle (P-No. 43 base material) with filler material F-No. 43. The Code Case N-638 methodology was developed to repair full penetration reactor pressure vessel welds. The application for Calvert Cliffs involves

making new partial penetration welds in the RVCH; hence, portions of Code Case N-638 methodology requirements either do not apply or require substitution of equivalent requirements applicable to partial penetration welds. Therefore, CCNPPI is proposing a modified methodology of Code Case N-638, as outlined in Attachment 2 to the February 7, 2002, letter, as an alternative to the Code requirement. The proposed alternative would allow use of an ambient temperature automatic or machine GTAW temper bead process for certain repairs to RVCH penetrations. This process would be used as an alternative to the preheat and post-weld heat soak requirements of ASME Code, Section XI attachment welds when 1/8 inch or less of non-ferritic weld deposit exists above the original fusion line.

Pursuant to 10 CFR 50.55a(a)(3)(i), the proposed alternative is requested on the basis the proposed alternative provides an acceptable level of quality and safety.

3.4 Licensee's Basis for Relief

The repair process will consist of the following activities: using a remote tool from below the RVCH, each nozzle requiring repair will first receive a roll expansion into the RVCH base material to insure that the nozzle will not move during the repair operations. A semi-automated machining tool, operating underneath the RVCH, will remove the entire lower portion of the CEDM nozzle to a depth above the existing J-groove partial penetration weld. The machining tool will also perform the CEDM nozzle repair weld preparation. The operation will sever the existing J-groove partial penetration weld from the CEDM nozzles. The machined surfaces will be cleaned, and then examined using a penetrant test (PT). The repair weld will be performed with a remotely operated machine GTAW weld head, using the ambient temperature temper bead process to install the new ERNiCrFe-7 (Alloy 52) pressure boundary weld between the shortened nozzle and the inside bore of the RVCH base material, with 50 °F minimum preheat temperature. The final weld face will be machined and/or ground. The final weld will be liquid penetrant and ultrasonically examined prior to the abrasive water jet conditioning, to preclude masking by the abrasive water jet process. The final inside diameter surface of the CEDM nozzle near the new weld and the new weld will then be conditioned by abrasive water-jet conditioning to create a final surface that is in compression, to produce optimum resistance to primary water stress corrosion cracking.

Quality temper bead welds, without preheat and post-weld heat soak, can be made based on welding procedure qualification test data derived from the machine GTAW ambient temperature temper bead welding process. The proposed alternative repair technique has been demonstrated as an acceptable method for performing pressure vessel repairs. The ambient temperature temper bead technique has been approved by the NRC as having an acceptable level of quality and safety and was successfully used at several sites.

Results of procedure qualification work indicate that the process produces sound and tough welds. For instance, typical tensile test results have been ductile breaks in the weld metal. Procedure Qualifications using P-No. 3 Group No. 3 base material exhibited improved Charpy V-notch properties in the heat affected zone (HAZ), from both absorbed energy, lateral expansion, and shear fracture perspectives, compared to the unaffected base material.

The absorbed energy, lateral expansion, and percent shear were greater for the HAZ than the unaffected base material at two different test temperatures. It is clear from these results that

the machine GTAW temper bead process has the capability of producing acceptable repair welds. Based on prior welding procedure qualification test data using machine GTAW ambient temperature temper bead welding, quality temper bead welds can be performed with 50 °F minimum preheat and no post-weld heat soak. Additional qualifications were performed on the same P-3 Group-3 base material using the same filler material (Alloy 52, American Welding Society Class ERNiCrFe-7), with similar low heat input controls as will be used in the repairs. Also, the qualifications did not include post-weld heat soak. The qualification of the ambient temperature temper bead welding process demonstrates that the proposed alternative provides an acceptable level of quality and safety.

Access to the repair area is limited and does not allow the monitoring of interpass temperature with thermocouples at the repair area. In lieu of using thermocouples for interpass temperature measurements, calculations show that the maximum interpass temperature will not be exceeded based on a maximum allowable low welding heat input, weld bead placement, travel speed, and conservative preheat temperature assumptions. The calculation supports the conclusion that using the maximum heat input through the third layer of the weld, the interpass temperature returns to near ambient temperature. Heat input beyond the third layer will not have a metallurgical effect on the low alloy steel HAZ.

The calculation is based on a typical inter-bead time interval of 5 minutes. The 5-minute inter-bead interval is based on:

1) the time required to explore the previous weld deposit with the two remote cameras housed in the weld head,

2) the time to shift the starting location of the next weld bead circumferentially away from the end of the previous weld-bead, and

3) the time to shift the starting location of the next bead axially to insure a 50 percent weld bead overlap required to properly execute the temper bead technique.

A welding mock-up on the full-size Midland RVCH, which is similar to the Calvert Cliffs RVCH, was used to demonstrate the welding technique described herein. During the mock-up, thermocouples were placed to monitor the temperature of the head during welding. Thermocouples were placed on the outside surface of the closure head within a 5-inch band surrounding the CEDM nozzle. Three other thermocouples were placed on the closure head inside surface. One of the three thermocouples was placed 1-1/2 inches from the CEDM nozzle penetration on the lower hillside. The other inside surface thermocouples were placed at the edge of the 5-inch band surrounding the CEDM nozzle, one on the lower hillside, the second on the upper hillside. During the mock-up, all thermocouples fluctuated less than 15 °F throughout the welding cycle. Based on past experience, it is believed that the temperature fluctuation was due more to the resistance heating temperature variations than the low heat input from the welding process. For the Midland RVCH mock-up application 300 °F minimum preheat temperature was used. Therefore, for ambient temperature conditions used for this repair, maintenance of the 350 °F maximum interpass temperature will not be a concern.

Preheat temperature will be monitored using either thermocouples or contact pyrometers placed at readily accessible locations on the closure head exterior surface and probably outside the 5-inch band. The closure head preheat temperature will be essentially the same as the

reactor building ambient temperature. Therefore, closure head preheat temperature monitoring in the weld region is unnecessary and only results in additional personnel dose associated with thermocouple placement and removal.

3.5 Staff Evaluation

The NRC staff has evaluated the licensee's request and supporting information on the proposal to perform repairs to reactor pressure vessel head penetrations when 1/8 inch or less of non-ferritic weld deposit exists above the original fusion line, in accordance with CCNPPI's relief request to use a modified methodology of ASME Section XI, Code Case N-638 at CCNPP, Unit Nos. 1 and 2, and concludes that it provides an acceptable alternative method of weld repair.

This is based on the data from the welding procedure qualification tests using the machine GTAW ambient temperature temper bead welding showing that quality temper bead welds can be performed with a 50 °F minimum preheat and no post-heat treatment. The data that resulted shows that when using P-No. 3, Group No. 3 base materials, the HAZ exhibited improved Charpy V-notch properties from both absorbed energy and lateral expansion perspectives, compared to the unaffected base.

The licensee's proposed alternative to examination includes that the final weld will be examined using the liquid penetrant and ultrasonic examination methods. The band around the area of at least 1-1/2 times the component thickness cannot be examined due to the physical configuration of the partial penetration weld. Therefore, the liquid penetrant examination coverage will include the final weld surface and base metal at least ½ inch around the nozzle. The ultrasonic examination will include the base metal ½ inch above the weld and the weld surface. To reduce the possibility of hydrogen embrittlement, the ambient temperature automatic and machine GTAW temper bead processes require specific controls to ensure the weld region is free of all sources of hydrogen, as described in the proposed alternative. The 48-hour delay before final examination required by the proposed alternative provides time for any hydrogen delayed cracking to occur. Thus, in the highly unlikely event that hydrogen induced cracking did occur, it would be detected.

Calculations show that the maximum interpass temperature will not be exceeded based on a maximum allowable low welding heat input, weld bead placement, travel speed, and conservative preheat temperature assumptions. The calculation supports the conclusion that using the maximum heat input through the third layer of the weld, the interpass temperature returns to near ambient temperature. Also, tests on a full size mockup demonstrate that a 350°F maximum interpass temperature can be maintained; thereby making interpass temperature measurements using thermocouples unnecessary. Also, heat input beyond the third layer will have little metallurgical effect on the low alloy steel HAZ.

The use of the ambient temperature automatic or machine GTAW temper bead process would allow more precise control of heat input, bead placement, and bead size and contour than the manual SMAW process required by ASME Code, Section XI, IWA-4600. The very precise control over these factors afforded by the process provides more effective tempering and eliminates the need to grind or machine the first layer of the repair required by these Code sections.

Paragraph NB-5245 of ASME Section III requires incremental and final surface examination of partial penetration welds. Due to the welding layer deposition sequence (i.e., each layer is deposited parallel to the penetration centerline), the specific requirements of NB-5245 cannot be met. The Construction Code requirement for progressive surface examination was because volumetric examination is not practical for conventional partial penetration weld configurations. Therefore, the licensee will perform an ultrasonic examination and a final surface examination.

The staff concluded that sufficient information is present in Electric Power Research Institute Report GC-11105C to indicate that both cold and delayed hydrogen cracking is unlikely. The ultrasonic examination will provide assurance that each weld pass will meet the Code acceptance criteria and the final surface examination will assure any delayed cracking will be detected should it occur. Based on the above discussion, the staff concludes that the alternative NDE provides reasonable assurance of the structural integrity of the weld.

Recent experience gained from the performance of manual repairs to other plants' CEDM nozzles indicated that more remote automated repair methods were needed to reduce radiation dose to repair personnel and still provided acceptable levels of quality and safety. Since Calvert Cliffs recognizes the importance of as low as reasonably achievable principles, this remote repair method has been developed for the possibility of leaking nozzles at Calvert Cliffs. This approach for repair of leaking CEDM nozzles will significantly reduce radiation dose to repair personnel while still maintaining acceptable levels of quality and safety.

3.6 Conclusion

The staff concludes that the licensee's request and supporting information on the proposal to perform repairs to RVCH penetration welds, in accordance with CCNPPI's Relief Request to use a modified methodology of ASME Section XI, Code Case N-638 at CCNPP, Unit Nos. 1 and 2, provides an acceptable alternative method of weld repair. Therefore, pursuant to 10 CFR 50.55a(a)(3)(i), the relief request is authorized since the applicant has demonstrated that proposed alternative provides an acceptable level of quality and safety.

4.0 EVALUATION ON RELIEF FROM NB-5330(b) REQUIREMENT

This relief request also applies to the new mid-wall weld.

4.1 Code Requirements for which Relief is Requested

NB-5330 of the 1992 Edition of the ASME Code states that "Indications characterized as cracks, lack of fusion, or incomplete penetration are unacceptable regardless of length." Therefore, acceptance of the new mid-wall weld, which may contain a triple point anomaly as reported in similar weld applications, by using Section XI flaw evaluations is considered as an alternative to that specified in the ASME Code, Section III. Pursuant to 10 CFR 50.55a(a)(3)(i), the licensee requested relief from ASME Section III NB-5330(b) on ultrasonic acceptance standards for Class 1 welds.

4.2 Licensee's Proposed Alternative to Code

In lieu of using the ultrasonic acceptance standards of NB-5330(b) for the new mid-wall weld, the licensee proposed to perform a fracture mechanics evaluation of a postulated weld anomaly in the new mid-wall weld in accordance with IWB-3600 of the 1998 Edition of the ASME Code.

4.3 Licensee's Bases for Relief:

Following the repair of the control element drive mechanism (CEDM) nozzles, it is anticipated that the ultrasonic (UT) examination signal response of the repair weld triple point (intersection of weld material, penetration tube, and vessel head) may result in a UT indication. This UT indication may be from this weld triple point response and may not be distinguishable from a crack or incomplete penetration type flaw response and therefore can only be characterized as unacceptable in accordance with NB-5330(b). This indication may extend from the existing crevice into the weld at angles from 0 to 90 degrees, where 90 degrees is in the through-thickness direction of the nozzle and zero degrees is along the low alloy steel fusion line. Mock-up testing has verified that the anomalies are common and do not exceed 0.1 inch in length. The typical length is closer to 0.05 inches.

We performed a fracture mechanics evaluation of a postulated weld anomaly in the CEDM nozzle ID temper bead weld repair for Calvert Cliffs Units 1 and 2. The postulated anomaly is a 0.1-inch semicircular flaw extending 360 degrees around the circumference at the weld triple point location. The anomaly is assumed to propagate in each of two directions on the uphill and downhill sides of the nozzle. Flaw acceptance is based on the 1998 ASME Code Section XI criteria for applied stress intensity factor (IWB-3612) and limit load (IWB-3642).

The results of the analysis demonstrate that a 0.1-inch weld anomaly is acceptable for at least 25 years of operation following a CEDM nozzle ID temper bead weld repair. Significant design margins have been demonstrated for all flaw propagation paths considered in the analysis. The minimum fracture toughness margin has been shown to be 13.1, compared to the required margin of 3.16 for normal operation conditions per Section XI, IWB-3612. Fatigue crack growth is minimal along each flaw propagation path, with the maximum flaw size being only 0.113 inch. A limit load analysis was also performed considering the ductile Alloy 600/690 materials. This analysis showed a limit load margin of 5.03 for normal operating conditions, compared to the required margin of 3.0 per Section XI, IWB-3642.

4.4 Staff Evaluation

Even if the welding and examination of the new mid-wall weld is perfectly executed, the licensee still needs to demonstrate the structural integrity of the repaired component. Thus, approval of the relief request also depends on the acceptance of a Section III (structural) evaluation of the new mid-wall weld and a flaw evaluation if the UT examination of the weld repair shows defects or anomalies. To address this concern, the licensee has provided additional information in its letters of December 18, 2002, and January 20, 2003, in regard to its Section III and fracture mechanics analyses. This information includes the calculated margins

for the primary stress intensities for design, emergency, faulted, and test conditions, and the primary plus secondary stress intensity range for normal and upset conditions. Further, the fatigue cumulative factor usage was calculated to be 0.997 with an operating life of 40 years. Since these calculated margins indicate that the Section III criteria are satisfied, the structural integrity of the weld repair has been demonstrated for an operating life of 40 years.

For the concern that during the welding process, a 0.1-inch weld anomaly may be formed due to lack of fusion at the triple point, the licensee performed a flaw evaluation based on three assumed crack shapes: (1) a 360-degree circumferential crack on the outer diameter (OD) of the CEDM nozzle, (2) an axially oriented semi-circular OD surface flaw, and (3) a semi-circular, cylindrically oriented flaw along the weld and vessel head interface, all with a crack depth of 0.1 inch. The licensee's approach is consistent with the methodology that was applied to a similar CEDM weld repair for Oconee 2 (NRC SE dated July 3, 2001, for submittal dated May 13, 2001) and Surry units (NRC SE dated October 1, 2002, for submittal dated October 30, 2001). After adding the crack growth for 25-operating years to the initial crack depth for the three cases, the licensee obtained safety factors for the three cases based on the fracture toughness of 200 ksi√inch. The resulting safety factors for all cases are several times greater than the Code specified safety factor of 3.16; hence, the staff determined that the CEDM nozzles with the proposed weld repair and the associated flaw evaluation considering 25 years of crack growth are acceptable. It should be mentioned, however, that regardless of the years that were derived from these analytical evaluations, future inspections shall be conducted as specified in Section 4.5, below.

The staff noted that this configuration included a crevice that exists between the reactor vessel head and the CEDM nozzle; therefore, the staff was concerned with the possibility of crevice corrosion. By letter dated November 6, 2002, the staff requested the licensee to address crevice corrosion. CCNPPI indicated in its response dated December 18, 2002, that they had performed an evaluation that addresses the effects of corrosion on the exposed low alloy steel surface arising from the inner diameter temper bead repair of CEDM nozzles. Their evaluation determined that galvanic corrosion, hydrogen embrittlement, stress corrosion cracking, and crevice corrosion are not expected to be a concern for the exposed low alloy steel base metal. The licensee also indicated that the gap between the reactor vessel head and the CEDM nozzle is eventually expected to fill with corrosion products, thus general corrosion will cease. The long-term low alloy steel general corrosion rate and overall release of iron into the reactor coolant system is expected to be negligible. Furthermore, the licensee indicated that Alloy 690 and its weld metals are the best available replacement materials for Alloy 600 and its weld metals in a pressurized-water reactor (PWR) environment.

As indicated in "Corrosion Testing of Inconel Alloy 690 for PWR Steam Generators," Journal of Materials for Energy Systems, Vol. 4, No. 3, dated December 1982, results were published that showed that Alloy 690 weld materials were more resistant to intergranular stress corrosion cracking than Alloy 600 weld materials. In addition, proceedings of the Eighth International Symposium on Environmental Degradation of Materials in Nuclear Power Systems-Water Reactors, "Evaluation of Weld Metals 82, 152, 52, and Alloy 690 Stress Corrosion Cracking and Corrosion Fatigue Susceptibility," dated August 1997, indicated that a recent study provided corrosion comparisons of stress-relieved Alloy 600, as-welded Alloy 600, as-welded Alloy 690, and Alloy 690 weld metals and Alloy 690 base metal. For the constant extension rate tests performed at $1X10^{-6}$ ($second^{-1}$), none of the tested material exhibited stress-corrosion cracking in PWR primary water or chloride faulted primary water.

The field and test data show that as-welded Alloy 600 weld metal and Alloy 600 base metal are prone to PWSCC. Field and test data show that as-welded Alloy 690 weld and Alloy 690 base metal are more resistant to PWSCC than Alloy 600 material. Therefore, the staff has determined that Alloy 690 and its weld metals are not likely to degrade from exposure to typical primary water environments. The staff determined that the applicant adequately addressed crevice corrosion and agreed that long-term effects of corrosion would be negligible for carbon steel reactor vessel penetrations to Alloy 690 using Alloy 690 weld material.

4.5 Future Inspections

IWB-3132.4(b) of the ASME Code states where the acceptance criteria of IWB-3600 are satisfied, the area containing the flaw shall be subsequently reexamined in accordance with IWB-2420(b) and (c). IWB-2420(b) states if the flaw indications or relevant conditions are evaluated in accordance with IWB-3132.4 or IWB-3142.4, respectively, and the component qualifies as acceptable for continued service, the areas containing such flaw indications or relevant conditions shall be reexamined during the next three inspection periods listed in the schedules of the inspection programs of IWB-2410.

Successive inspections are not required on the as-left J-groove weld if the new mid-wall weld is not deposited over it. It is not part of the pressure retaining boundary and it cannot be scrutinized by NDE with confidence. Also, the flaw evaluation discussed in Section 2.4 would indicate that the evaluation meets the ASME rules and the remaining flaws with the base material are acceptable for at least 5 years of operation. If, however, due to the curvature of the head, the new weld is deposited over a portion of the as-left J-groove weld, one successive inspection would be required. This is partly because we must assume there are flaws in the as-left J-groove weld that is now a portion of the new pressure retaining boundary, and that these flaws continue to be exposed to a PWR coolant environment.

For the new pressure-retaining mid-wall weld, one successive inspection, after one cycle of operation is required. Since the proposed repair deploys an abrasive water jet peening after the post repair NDE, the required successive inspection is to be UT because a PT would be questionable after any form of peening. This successive inspection and the one mentioned above for the J-groove weld are staff imposed NDE because of the newness of the repair design, rather than a Code requirement, which does not exist for this application. Regarding the triple point anomaly of this new mid-wall weld, if the post repair NDE finds an anomaly, and it does not exceed the limit of the flaw tolerance analysis, it is considered acceptable for continued service, but three successive inspections would be required.

The staff position with respect to monitoring the performance of repairs to J-groove welds and nozzle material is that there should be successive inspections to assure cracking under the repairs remains dormant. This concern is due to the safety significance of the component and the fact that there is little field experience with these repairs in service. As a result of the February 11, 2003, Order, any repairs to CRDM nozzles and J-groove welds will automatically require the subject plant be placed into the high susceptibility category. Each high susceptibility plant must perform a Bare Metal Visual Examination of the reactor pressure vessel head and a UT or eddy current testing of the wetted surfaces after each cycle of operation. This action is to continue after each cycle of operation until such time the staff rescinds the Order for the

specific unit or the head is replaced. This action provides reasonable assurance of the continued structural integrity of the repairs.

4.6 Conclusion

Based on the discussion in Section 3.4 regarding the relief request to use the modified Code Case N-638, the staff has concluded that the proposed alternative to use the ambient temperature temper bead process and the proposed in-process and post-repair examinations as described by the licensee, will assure adequate structural integrity, provided no anomaly exists at the triple point. If an anomaly exists and the licensee determines that the anomaly is acceptable for continued service, the licensee must follow the provisions of IWB-2420(b) and (c) regarding successive inspections to ensure weld integrity. Therefore, pursuant to 10 CFR 50.55a(a)(3)(i), the licensee's proposed alternative described in this relief request is authorized for the third 10-year interval. If a triple point anomaly exists as discussed in Section 4 above, the staff has concluded that the proposal to perform a fracture mechanics evaluation of a postulated weld anomaly in the new mid-wall weld is acceptable because the licensee's actions provide assurance of structural integrity of the new mid-wall weld. Therefore, pursuant to 10 CFR 50.55a(a)(3)(i), this relief request is granted for the third 10-year interval.

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