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Subject:	Re: Followup Comments or the RAI Response
Creation Date:	7/9/03 10:42AM
From:	"Albon Harrison" <awharrison@stpegs.com>

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From: "Albon Harrison" <awharrison@stpegs.com>
To: <MCT@nrc.gov>
Date: 7/9/03 10:43AM
Subject: Re: Followup Comments or the RAI Response

Mohan,

We're preparing a letter, but for your convenience here is the response to #2.

The appropriate reference is CE NPSD-1198-P Rev. 0, which was approved by NRC Safety Evaluation dated February 8, 2002 (attached). WCAP 15973-P was submitted for NRC review to correct an error in the NPSD-1198 flaw growth analysis; however, the corrosion evaluation is not affected.

Wayne Harrison
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>>> "Mohan Thadani" <MCT@nrc.gov> 7/8/03 4:09:51 PM >>>
We hve the following comments on your response to our RAI. Please provide the additional information as requested in the comments, so that we can complete the review in a timely manner..

Thanks.

Mohan

Followup Comments

1) We received the proprietary drawing - thank you.

2) The licensee indicated that the geometry of the nozzle component gap creates the geometry of a crevice and that the corrosion rate was deemed acceptable under WCAP 15973-P, Rev. 0. The licensee stated that: "The component corrosion analysis used the methodology documented in WCAP 15973-P, Rev. 0, which was reviewed by the NRC and a safety evaluation was issued."

There is no record in ADAMS that I could find of an existing safety evaluation issued by the staff for the subject WCAP. There is however, an RAI letter issued July 2, 2003 on the subject WCAP. These two items indicate to me that the safety evaluation the licensee referred to has not been issued.

3. Response acceptable

4. Response acceptable

6. The licensee stated that their successive inspections would be BMV. I don't believe this is sufficient for the following reasons:

a) Lack of field experience with this type of repair
b) Typically, other licensees agree and perform post repair UT
c) The .004" gap between the old and new nozzle sections allow boron to enter in the annulus, which may cause an environment similar to the Davis-Besse configuration, depending on the amount of cracking in the original J-groove

weld.

d) The annulus should be monitored for changes each outage along with the BMV due to c).

e) The Topical Report the licensee cites previous field experience of half-nozzle repairs performed at ANO-1 in 1990. The repair was UT inspected at the 1st and 2nd refueling outages and is currently UT inspected on an every-other-cycle basis. In light of the existing Order, recent field experience and the new location of cracking in the lower head, the monitoring program of just a BMV proposed by the licensee is not adequate.

CC: "Mark McBurnett" <mamcburnett.GWPO_NASSUR.GWDOM_STP@stpegs.com>

February 8, 2002

Mr. Richard Bernier, Chairman
CE Owners Group
Mail Stop 7868
Arizona Public Service Company
Palo Verde Nuclear Generating Station
P.O. Box 52034
Phoenix, Arizona 85072-2034

SUBJECT: SAFETY EVALUATION OF TOPICAL REPORT CE NPSD-1198-P, REVISION 00, "LOW-ALLOY STEEL COMPONENT CORROSION ANALYSIS SUPPORTING SMALL-DIAMETER ALLOY 600/690 NOZZLE REPAIR/REPLACEMENT PROGRAMS" (TAC NO. MB1240)

Dear Mr. Bernier:

On February 15, 2001, the Combustion Engineering Owners Group (CEOG) submitted for staff review and approval Topical Report (TR) CE NPSD-1198-P, Revision 00, "Low-Alloy Steel Component Corrosion Analysis Supporting Small-Diameter Alloy 600/690 Nozzle Repair/Replacement Programs." CE NPSD-1198-P, Revision 00, is applicable to repairs/replacements of leaking Alloy 600 nozzles in the reactor coolant pressure boundary using either the mechanical nozzle seal assembly (MNSA) or half-nozzle repair/replacement techniques using Alloy 690. The MNSA and half-nozzle repair/replacement designs leave the throughwall crack in the Alloy 182/82 J-groove weld intact in its entirety and allow the ferritic portions of the vessels or piping to be exposed to the borated reactor coolant, thus nullifying the purpose of the cladding in the vessel or piping design. The scope of the report only accomplishes the following objectives with respect to these repair/replacement designs: (1) provides an acceptable method for calculating the overall general/crevice corrosion rate for the internal surfaces of the low-alloy or carbon steel materials that will now be exposed to the reactor coolant, (2) provides the results of a thermal-fatigue crack-growth analysis for growing the existing flaw in the Alloy 82/182 weld material into the ferritic portion of the piping or vessels, and (3) provides an assessment of the potential for cracks left in place in the Alloy 82/182 weld materials to grow into the ferritic materials by stress corrosion.

The staff has found that TR CE NPSD-1198-P, Revision 00, "Low-Alloy Steel Component Corrosion Analysis Supporting Small-Diameter Alloy 600/690 Nozzle Repair/Replacement Programs," is acceptable for referencing in licensing applications for Combustion Engineering designed pressurized water reactors to the extent specified and under the limitations delineated in the report and in the associated NRC safety evaluation (SE). The SE defines the basis for acceptance of the report.

Pursuant to 10 CFR 2.790, we have determined that the enclosed SE does not contain proprietary information. However, we will delay placing the SE in the public document room for a period of 10 working days from the date of this letter to provide you with the opportunity to

comment on the proprietary aspects only. If you believe that any information in the enclosure is proprietary, please identify such information line by line and define the basis pursuant to the criteria of 10 CFR 2.790.
We do not intend to repeat our review of the matters described in the subject report, and found acceptable, when the report appears as a reference in license applications, except to ensure that the material presented applies to the specific plant involved. Our acceptance applies only to matters approved in the report.

In accordance with established procedures, the NRC requests that the CEOG publish an accepted version, within 3 months of receipt of this letter. The accepted version shall incorporate (1) this letter and the enclosed SE between the title page and the abstract, and (2) a "-A" (designating "accepted") following the report identification symbol. Should our criteria or regulations change so that our conclusions as to the acceptability of the report are invalidated, the CEOG and/or the applicants referencing the TR will be expected to revise and resubmit their respective documentation, or submit justification for the continued applicability of the TR without revision of their respective documentation.

Sincerely,

/RA/

Stuart A. Richards, Director
Project Directorate IV
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Project No. 692

Enclosure: Safety Evaluation

cc w/encl: See next page

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Sincerely,

/RA/

Stuart A. Richards, Director
Project Directorate IV
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Project No. 692

Enclosure: Safety Evaluation

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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

COMBUSTION ENGINEERING OWNERS GROUP

TOPICAL REPORT CE NPSD-1198-P, REVISION 00,

"LOW-ALLOY STEEL COMPONENT CORROSION ANALYSIS

SUPPORTING SMALL-DIAMETER ALLOY 600/690

NOZZLE REPAIR/REPLACEMENT PROGRAMS"

PROJECT NO. 692

1.0 INTRODUCTION

Vessels and piping in the reactor coolant pressure boundary (RCPB) of pressurized water reactors (PWRs) are fabricated either from SA 516, Grade 70 carbon steel (for the fabrication of piping), or A 302, Grade B, SA 533, Grade B or SA 508, Grade B, low-alloy steels (for fabrication of vessels). These materials are classified as ferritic steel materials. These components are typically clad on their internal surfaces using austenitic stainless steels, which serve the purpose of protecting the carbon or low-alloy steel materials against general corrosion induced by exposure to the borated reactor coolant. Alloy 600 nozzles that penetrate through these components are typically joined to the vessels or piping using partial penetration J-groove welds that are fabricated from Alloy 82/182 weld materials. These welds penetrate completely through the cladding and partially into the ferritic portions of the piping or vessels. Inservice industry experience has demonstrated that these welds are susceptible to primary water stress corrosion cracking (PWSCC).

By letter dated February 15, 2001, the Combustion Engineering Owners Group (CEOG) submitted Letter No. CEOG-01-052 (Reference 1) to the U.S. Nuclear Regulatory Commission (NRC) for staff review and approval of CE NPSD-1198-P, Revision 00, "Low-Alloy Steel Component Corrosion Analysis Supporting Small-Diameter Alloy 600/690 Nozzle Repair/Replacement Programs" (Reference 2). By letter dated July 24, 2001, the CEOG supplemented the information in the topical report with additional information (Reference 3) including proprietary evaluation A-CEOG-9449-1242, Revision 00, "Evaluation of the Corrosion Allowance for Reinforcement and Effective Weld to Support Small Alloy 600 Nozzle Repairs" (Reference 4) and proprietary evaluation A-GEN-PS-0003, Revision 00, "Evaluation of Fatigue Crack Growth Associated with Small Diameter Nozzles in CEOG Plants" (Reference 5).

2.0 EVALUATION

The scope of CE NPSD-1198-P, Revision 00, is only applicable to repairs/replacements of leaking Alloy 600 nozzles in the RCPB using either the mechanical nozzle seal assembly (MNSA) or half-nozzle repair/replacement techniques. The MNSA and half-nozzle repair/replacement designs leave the throughwall crack in the Alloy 182/82 J-groove weld intact in its entirety and allow the ferritic portions of the vessels or piping to be exposed to the borated reactor coolant, thus nullifying the purpose of the austenitic stainless steel cladding in the vessel or piping design. The scope of CE NPSD-1198-P, Revision 00, only accomplishes the following objectives with respect to implementing these repair or replacement methods: (1) provides an acceptable method for calculating the overall general/crevice corrosion rate for the internal surfaces of the low-alloy or carbon steel materials that will now be exposed to the reactor coolant, and for calculating the amount of time the ferritic portions of the vessel or piping would be acceptable if corrosive wall thinning had occurred, (2) provides an acceptable method of calculating the thermal-fatigue crack-growth life of existing flaws in the Alloy 82/182 weld material into the ferritic portion of the piping or vessels, and (3) provides acceptable bases and arguments for concluding that unacceptable growth of the existing flaw by stress corrosion is improbable.

2.1 Summary of Conclusions/Findings in CE NPSD-1198-P, Revision 00

The CEOG summarizes its conclusions with respect to the general corrosion rate, stress corrosion growth rate, and thermal-fatigue crack-growth rate analyses provided in Section 4.0 of CE NPSD-1198-P, Revision 00. In this section, the CEOG made the following conclusions with respect to implementation of MNSA or half-nozzle designs:

1. Summarized the general overall corrosion rates for low-alloy and carbon steel materials, and provided the bounding repair lifetimes for MNSA or half-nozzle repairs of hot leg nozzles, pressurizer nozzles, and pressurizer heater sleeves.

2. Concluded that, based on the general overall corrosion rate and with the exception of one plant, the hot leg nozzles, pressurizer nozzles, and pressurizer heater sleeves will have acceptable repair lives for more than the 40-year lives of the plants. For the U.S. nuclear plant that doesn't meet this criteria, further analysis using actual thickness measurements will be needed to be capable of determining the acceptable hole sizes for implementing MNSA repairs or half-nozzle replacements.

3. Concluded that growth of existing flaws into the ferritic portions of the vessels or piping by thermal-fatigue would satisfy the ASME flaw acceptance criteria for normal operating, emergency, and faulted loading conditions.

4. Concluded that low primary side oxygen levels during normal operations result in corrosion potentials well below the threshold potential for initiation and growth of stress corrosion cracks, and, as a result, that existing cracks in the original weld materials would not propagate by stress corrosion into the ferritic portions of the piping or vessel following implementation of a half-nozzle or MNSA repair method.

5. Concluded that all available laboratory data and field experience indicate that nozzle repairs such as half-nozzle or MNSA repairs are viable long-term repair options for small diameter Alloy 600 nozzles in CEOG plants.

2.2 Evaluation of CEOG's General and Crevice Corrosion Rate Analyses for Internal Surfaces of the Ferritic Vessels or Piping Exposed to Borated Reactor Coolant

In thermodynamics, the potential for chemical reactions to occur are dependent on both energetic and kinetic factors. From an energetic standpoint, the amount of free energy absorbed or released as a result of a chemical reaction is a direct function of both the temperature of the reaction and the concentrations (activities) of the reaction products, and an inverse function of the concentration (activities) of the reactants. For a reversible oxidative reaction that results in corrosion of a metallic element into one of its cationic forms, the oxidative process will only be favorable if the reaction results in a release of free energy to the environment (i.e., if the reaction results in an exothermic free energy change to the environment), and if a strong reductive agent is present that would favor the oxidization of the metallic element.[1] For aqueous solutions, the reductive agent is usually present in the form of dissolved elemental oxygen (which will reduce to the O^{2-} anion), or water or dissolved hydrogen cation (which will reduce to elemental hydrogen gas, H_2). The presence of dissolved oxygen significantly increases the potential for oxidation to occur. The degree of acidity or basicity of the coolant also influences the potential for corrosion to occur.

From a kinetic standpoint, oxidation will proceed only if the reaction kinetics favor the chemical transformation, and hence if the rate constants for the reaction are large enough to produce the change within the lifetime of the component being considered. These reaction rate constants vary as a function of $e^{-1/T}$ (i.e., as an exponential function of -1/T). Therefore, higher temperatures tend to increase the rate constants for the reaction, and tend to increase the overall reaction rates for the oxidative process. However, at high operating temperatures, the low-oxygen conditions that exist in the reactor coolant will tend to nullify the increase in the reaction that may be influenced by this kinetic effect.

The MNSA and half-nozzle repair/replacement designs will leave the ferritic penetration hole surfaces of the vessels or piping exposed to the borated reactor coolant. CEOG evaluates the potential for these surfaces to degrade by general or crevice corrosion in Section 2.0 of the topical report. The CEOG makes its general/creviced corrosion rate evaluation based on the relative chemistry and temperature conditions of the reactor coolant. According to a qualitative review of non-proprietary Figures 1 and 2 in the topical report, exposure to the reactor coolant will be under creviced conditions for the MNSA designs and under bulk coolant conditions for the half-nozzle designs.

The results of the CEOG's evaluation regarding the potential for the surfaces of the ferritic steels to lose materials as a result of corrosion are summarized in Conclusions 1 - 3 of page 29

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1 In thermodynamics, the convention for energy released as a result of an exothermic reaction is signified using negative energy coefficients. In contrast the convention used for endothermic reactions (i.e., reactions that will only proceed if an input of heat is provided) is signified using positive energy coefficients.

of the topical report, and in Conclusions 1 - 4 in Section 2.1 of this safety evaluation (SE). The CEOG's overall corrosion rate for general corrosion of low-alloy or carbon steel materials is summarized in Equation (1) and Conclusion 1 of the topical report and is based on a sum of contributing corrosion rate factors for normal operating conditions, startup conditions, and low temperature outage conditions. These "factors" are the multiplicative results of the corrosion rate values for operating conditions and the CEOG's best estimate for the amount of time (as a percentage of total operating life) that a typical plant would operate in these modes. The CEOG used Conclusions 2 and 3 of the topical report to support the overall corrosion rate given in Conclusion 1.

The CEOG used the results of laboratory corrosion studies as its bases for establishing the general corrosion rates for low-alloy or carbon steel materials during normal operating, startup, and cold-shutdown modes of operation. The laboratory studies used for determining the bounding corrosion rate for normal operating conditions were performed under deaerated conditions, and simulated maximum boron, lithium, and oxygen levels in the reactor coolant under normal operating conditions for a CE designed PWR. The laboratory studies used for determining the corrosion rates for low alloy or carbon steel materials during startup or cold shutdown conditions also simulated the boron, lithium, and oxygen levels for these conditions, but were made under aerated conditions.

During normal operating conditions, the reactor coolant system (RCS) is closed off from being exposed to the reactor building environment, and the system is operated at temperatures in the range of 560-600°F and under hydrogen water chemistry conditions. At these temperatures the concentration of dissolved oxygen in the coolant is normally maintained well below 150 parts per billion (ppb). During cold shutdown and startups, the RCS may be aligned with the reactor building environment. During these modes of operation, the RCS is normally opened up and exposed to the reactor building environment. During these conditions, the concentration of dissolved oxygen in the RCS coolant is normally much higher than it would be during normal operating conditions, when the RCS is sealed off from the reactor building environment. Since the laboratory conditions for the corrosion studies were consistent with chemistry conditions in the reactor coolant during normal operating, startup, and cold-shutdown conditions, the staff concludes that the proposed corrosion rates for normal operating, startup, and cold shutdown conditions provide an acceptable basis for calculating the overall corrosion rate for ferritic carbon and low-alloy steel materials under the borated and hydrogen water chemistry conditions for the reactor coolant. Acceptance of the general corrosion rates for normal operating, startup, and cold shutdown conditions, however, is predicated on the hypothesis that there are no additional laboratory or field data that would make the results of the corrosion studies summarized in the topical report invalid. If new laboratory or field data become available that invalidate the bounding general corrosion rates given in the topical report, the staff requests that the CEOG submit an addendum to the topical report that will provide a summary of the analyses performed on the new data and a new overall general corrosion rate calculation that is based on their results.

The method for calculating the general overall corrosion rate is also dependent on the amount of time (in terms of percentage of total plant life) the plants are estimated to be operating in the normal operating, startup, and cold shutdown modes of operation. These capacity factors, which are normally provided in the design bases for the plant, may vary from plant-to-plant and from the capacity factors used by the CEOG in Equation (1) of the topical report. In this case,

when the staff used an 80 percent capacity factor for normal operations[2], the staff calculated a general overall corrosion rate value that was approximately 40 percent in excess of the corresponding value calculated by the CEOG. This demonstrates that the overall general corrosion rate for determining the repair lives of the nozzles is somewhat dependent on the plant-specific capacity factors for normal operations, startups, and cold-shutdowns of a given plant. Licensees seeking to use the methods of the topical report, will need to perform the following plant-specific calculations in order to confirm that the ferritic portions of the piping or vessels within the scope of the topical report will be acceptable for service throughout the licensed lives of their plants (40 years if the normal licensing basis plant life is used or 60 years if the facility is expected to be approved for extension of the operating license):

1. Calculate the minimum acceptable wall thinning thickness for the ferritic vessel or piping that will adjoin to the MNSA repair or half-nozzle replacement.

2. Calculate the overall general corrosion rate for the ferritic materials based on the calculational methods in the topical report, the general corrosion rates listed in the topical report for normal operations, startup conditions (including hot standby conditions), and cold-shutdown conditions, and the respective design basis capacity factors (in percentage of total plant life) for the operating conditions.

3. Calculate the amount of general corrosion-based thinning for the vessels or piping over the life of the plant, as based on the overall general corrosion rate calculated in Step 2 and the thickness of the ferritic vessel or piping that will adjoin to the MNSA repair or half-nozzle replacement.

4. Determine whether the vessel or piping is acceptable over the remaining life of the plant by comparing the worst case remaining wall thickness to the minimum acceptable wall thickness for the vessel or pipe.

Plant-specific engineering evaluations that have been calculated in accordance with these methods and that demonstrate that the ferritic materials will not be unacceptably degraded by general-corrosion-induced thinning (i.e., demonstrate that the ferritic portions of the components will not be thinned by general corrosion to a size less than the minimum allowable wall thickness for the component) will be sufficient to satisfy the acceptability by analysis provisions of Section XI for defects induced by general-corrosion or crevice-corrosion. These plant-specific engineering evaluations are covered under the scope of 10 CFR 50.70 as being items that may be designated for inspection by duly authorized NRC personnel.

2.3 Evaluation of CEOG's Assessment for Growing Existing Flaw by Thermal-Fatigue and Stress Corrosion Cracking Mechanisms

For operating plants, 10 CFR 50.55a(g)(4) requires licensees to follow the inservice inspection provisions of Section XI to the American Society of Mechanical Engineers (ASME) Code

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2 A significant number of licensees in the industry use 80 percent as the design basis capacity factor for normal operations at power. Use of this in the NRC's independent calculation of the overall corrosion rate for general or crevice-type corrosion is based on this capacity factor.

throughout the service life of their plants. The general inservice inspection requirements of Section XI to the ASME Code require that flaws be evaluated against the flaw acceptance criteria of IWA-3000, and if found unacceptable, be removed or reduced in size, and repaired or replaced. The MNSA and half-nozzle repair/replacement designs will leave the existing flaw in the original Alloy 182/82 J-groove weld intact. The flaw evaluation criteria in CE NPSD-1198-P, Revision 00, assumes that the potential exists for the existing flaws in the original Alloy 182/82 J-groove welds to grow into the ferritic regions of the pipe or vessels by thermal-fatigue or by stress corrosion cracking mechanisms. The CEOG performed crack growth analyses for these crack growth mechanisms to determine the amount of time the existing flaws would be acceptable for service without necessitating removal or reduction of the flaws. The staff's assessments of the CEOG's crack growth analyses for these mechanisms are provided in Sections 2.3.1 and 2.3.2 that follow.

2.3.1 Growth by Thermal-Fatigue

In Conclusion/Finding No. 5, the CEOG concluded that growth of existing flaws into the ferritic portions of the vessels or piping by thermal fatigue would satisfy the ASME flaw acceptance criteria for normal operating, emergency, and faulted loading conditions. The CEOG's assessments supporting this conclusion are provided in Sections 3.2 and 3.3 of the topical report. The CEOG also supported this conclusion in proprietary evaluation A-GEN-PS-0003, Revision 00.

ASME's methods for performing thermal-fatigue crack growth analyses are provided in Non-mandatory Appendix A to Section XI of the ASME Code. The CEOG performed thermal-fatigue analyses of flaws in the bounding pressurizer and hot-leg nozzle J-groove welds. The CEOG's methods were consistent with the thermal fatigue crack growth analysis methods of Appendix A to Section XI of the ASME Code. The CEOG did not perform a thermal-fatigue analysis of the bounding flaws in the cold-leg nozzles, as no incidents of cracking have been reported in the cold-leg nozzles of CE designed facilities, and the cold legs of CE designed plants are operated at significantly lower temperatures than are the corresponding pressurizers and hot legs for the designs. Based on these considerations, this is an acceptable basis for not including a bounding cold-leg nozzle crack growth assessment among those performed for the bounding thermal-fatigue crack growth analyses.

In each assessment, the CEOG assumed an initial flaw shape for the existing flaws in the nozzle J-groove welds and a number of operating cycles that conservatively exceed the number of operating cycles (in terms of heatups and cooldowns of the units) assumed in the design basis of the plants. The CEOG then defined a fracture mechanics based stress intensity factor (K_I) for each bounding flaw evaluation, determined the applicable ranges of K_I (i.e., performed a ΔK_I determination) and the incremental crack growth dimension (Δa) for each bounding evaluation, and calculated the new crack depth dimensions for the flaw at the end of each successive operating cycle being analyzed, and compared the final crack depth for each bounding analysis to the maximum allowable crack depth for the pressurizer and hot-leg pipe.

The staff confirmed that the CEOG's thermal-fatigue crack growth analyses, as summarized in the topical report and provided in proprietary evaluation A-GEN-PS-0003, Revision 00, for the bounding pressurizer and hot-leg nozzle flaws were consistent with the methods of analysis in Appendix A to Section XI of the ASME Code, and satisfied the respective flaw size and stress

intensity factor evaluation criteria of Section XI Paragraphs IWB-3611 and IWB-3612 for both normal/upset and emergency/faulted conditions (i.e., for ASME A and B loading conditions and ASME C and D loading conditions).[3] The staff's review of proprietary evaluation A-GEN-PS-0003, Revision 00, indicated that the number of operational cycles assumed for the bounding thermal-fatigue crack growth analyses were conservative and acceptable for both 40-year lives (i.e., the maximum initial design basis plant life allowed by the Atomic Energy Act of 1954 and by 10 CFR Part 50) and 60-year plant lives (i.e., the maximum design basis plant life allowed by 10 CFR Part 54 for extension of operating licenses for nuclear power generation facilities). The results of the CEOG's thermal-fatigue analyses demonstrate that large margins exist between the final flaw depths calculated for the bounding initial flaw sizes assumed in the fatigue analyses and the critical flaw depths allowed by Code for the bounding pressurizer and hot-leg components in the CEOG membership of nuclear plants.

The staff needs to emphasize that the *da/dn* formula for Equation (7) in CE NPSD-1198-P, Revision 00, had a typographical error in it. The CEOG corrected this error in Attachment 2 to CEOG Letter CEOG-01-199, dated July 24, 2001. While licensees may use the *da/dn* crack growth formulas in Equations (7) and (8) as their bases for calculating thermal-fatigue crack growth of the existing flaw, they should make sure that they use the corrected Equations (7) and (8) that were provided by the CEOG in Attachment 2 (page 22) to CEOG Letter No. CEOG-01-199 (July 24, 2001), and not the versions of Equations (7) and (8) cited in CE NPSD-1198-P, Revision 00.

Licensees seeking to use these thermal fatigue crack growth methods of the topical report and proprietary evaluation A-GEN-PS-0003, Revision 00, will need to perform the following plant-specific thermal fatigue crack growth calculations for the worst-case existing flaw in the nozzle being assessed:

1. Perform maximum allowable crack length and crack depth calculations for the worst case cracks extending into the ferritic portions of the vessels or piping that will adjoin to the MNSA repair or half-nozzle replacement.

2. Perform a thermal fatigue crack growth analysis of the worst-case flaw assumed to occur in the original Alloy 182/82 weld metal that is based on the calculational thermal fatigue crack growth methods in proprietary evaluation A-GEN-PS-0003, Revision 00.

3. Perform a comparison of the maximum crack length and crack depth determined from the growth analysis to the maximum allowable crack length and crack depth to determine whether fatigue growth of the worst case crack will be acceptable over the operating life for the facility (40 years if the normal licensing basis plant life is used or 60 years if the facility is expected to be approved for extension of the operating license).

Plant-specific engineering evaluations that have been calculated in accordance these with methods and that demonstrate that the final flaw sizes will be acceptable for service will be sufficient to satisfy the acceptability by analysis provisions of Section XI of the ASME Code for

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3 These acceptance criteria fall under the scope of Section XI Paragraph IWB-3610, "Acceptance Criteria for Ferritic Steel Components 4 in. and Greater in Thickness."

flaws grown by thermal fatigue. These plant-specific engineering evaluations are covered under the scope of 10 CFR 50.70 as being items that may be designated for inspection by duly authorized NRC personnel.

2.3.2 Growth by Stress Corrosion Cracking

In Conclusion/Finding No. 4, the CEOG concluded that growth of existing flaws into the ferritic portions of the vessels or piping by stress corrosion was not plausible. The CEOG's analysis for supporting this conclusion is provided in Section 3.4 of the topical report. In this section, the CEOG used the following arguments as its bases for concluding that there is a low probability for growing the existing cracks in the original weld metal by stress corrosion:

- During normal operations of the RCS in CE designed reactors, hydrogen overpressure in the RCS significantly reduces the impurity levels of dissolved oxygen to a concentration less than 10 ppb. At these levels, the electro-chemical potential of the coolant is significantly less than required to grow a existing crack by stress corrosion.

- Even if high oxygen concentrations exist in the crevice during the initial stages of normal operations, the oxygen levels will quickly be reduced as a result of iron oxide formation on the surfaces of the ferritic steel. Since the oxygen levels in the bulk-coolant are typically less than 10 ppb during normal operations, there is no mechanism to replenish oxygen in the crevice region, and as a result the low-oxygen condition in the crevice region will quickly be re-established. Thus, the potential to grow the existing cracks by a stress corrosion mechanism will be low.

- Other contaminants (copper ions, sulfates, halides, etc.) that could increase the potential for cracks to grow by stress corrosion are also maintained at extremely low concentrations during normal operations.

The staff typically use -200 Mev as the threshold potential for initiating and growing cracks by stress corrosion. At chemical potentials above this value, the staff considers initiation and growth of cracks by stress corrosion to be plausible. When the chemical potential of the reactor coolant is controlled to magnitudes below this value, the staff considers the potential for cracks to initiate and grow by stress corrosion to be significantly reduced.

At a typical PWR, control of contaminants that could lead to chemical potentials above -200 MeV is accomplished by the combined efforts of the plant operators and chemistry personnel. CE designed reactors do not have any copper alloys in their RCS, therefore incursion of copper ion contaminants is typically not an issue for CE designed reactors. In addition, licensees maintain the RCS chemistry by use of the chemical and volume control system as the method for controlling oxygen, halide and sulfate contaminants to low levels, this includes the use of ion exchangers to purify the reactor coolant. Plant chemistry procedures require plant chemistry personnel to monitor the contaminant levels of the RCS at regular daily intervals. Implementation of design changes to better ion exchange resins and improved chemical monitoring equipment have enabled licensees to control the levels of dissolved oxygen to concentrations less than 10 ppb, and halide and sulfate contaminants to concentrations well below the maximum acceptable levels referred to in the Electric Power Research Institute (EPRI) PWR Primary Water Chemistry Guidelines (i.e., well below 150 ppb).

Licensees owning CE designed plants maintain a significant hydrogen overpressure on their RCS. These practices allow the licensees for these facilities to maintain the electro-chemical potential of the reactor coolant at levels below −200 Mev. The staff therefore concurs that the probability for growing the existing flaws by stress corrosion is extremely low at these facilities.

Licensees seeking to implement MNSA repairs or half-nozzle replacements may use the CEOG's stress corrosion assessment as the bases for concluding that existing flaws in the weld metal will not grow by stress corrosion if they conduct appropriate plant chemistry reviews and if they can demonstrate that a sufficient level of hydrogen overpressure has been implemented for the RCS, and that the oxygen and halide/sulfate concentrations in the reactor coolant have been typically maintained at levels below 10 ppb and 150 ppb, respectively. During the outage in which the half-nozzle or MNSA repairs are scheduled to be implemented, licensees adopting the topical report's stress corrosion crack growth arguments will need to review their plant-specific RCS coolant chemistry histories over the last two operating cycles for their plants, and confirm that these conditions have been met over the last two operating cycles. Plant chemistry records are covered under the scope of 10 CFR 50.70 as being items that may be designated for inspection by duly authorized NRC personnel.

3.0 CONCLUSIONS

The staff's review of the methods in CE NPSD-1198-P, Revision 00, indicates that the CEOG's methods and analyses in the topical report are generally acceptable. The scope of CE NPSD-1198-P, Revision 00, only accomplishes the following objectives with respect to implementing these repair or replacement methods:

1. Provides an acceptable method for calculating the overall general/crevice corrosion rate for the internal surfaces of the low-alloy or carbon steel materials that will now be exposed to the reactor coolant, and for calculating the amount of time the ferritic portions of the vessel or piping would be acceptable if corrosive wall thinning had occurred,

2. Provides an acceptable method of calculating the thermal-fatigue crack-growth life of existing flaws in the Alloy 82/182 weld material into the ferritic portion of the piping or vessels, and

3. Provides acceptable bases and arguments for concluding that unacceptable growth of the existing flaw by stress corrosion is improbable.

The staff's conclusions regarding the CEOG general corrosion assessment, thermal-fatigue crack growth assessment, and stress corrosion cracking growth assessment are provided in Sections 3.1, 3.2, and 3.3, respectively.

3.1 General Corrosion Assessment

The calculation of the general overall corrosion rate for the ferritic materials is dependent on both the individual general corrosion rates for normal operating, startup (including hot-standby), and cold-shutdown conditions provided in Section 2.3.4 of the topical report, and on the individual design-basis capacity factors (in terms of percentage of total plant life) for the amount

of time that a respective nuclear plant is estimated to operate in each of these operating modes. When the staff used an 80 percent capacity factor for normal operations, the staff calculated a general overall corrosion rate that was 40 percent higher than the value calculated by the CEOG. Therefore, the general overall corrosion rate proposed in Equation (1) of the topical report may or may not be conservative, depending on what a plant's design-basis capacity factors for normal operating, startup (including hot standby), and cold shutdown conditions are. Licensees seeking to use the methods of the topical report, will need to perform the following plant-specific calculations in order to confirm that the ferritic portions of the piping or vessels within the scope of the topical report will be acceptable for service throughout the licensed lives of their plants (40 years if the normal licensing basis plant life is used or 60 years if the facility is expected to be approved for extension of the operating license):

1. Calculate the minimum acceptable wall thinning thickness for the ferritic vessel or piping that will adjoin to the MNSA repair or half-nozzle replacement.

2. Calculate the overall general corrosion rate for the ferritic materials based on the calculational methods in the topical report, the general corrosion rates listed in the topical report for normal operations, startup conditions (including hot standby conditions), and cold-shutdown conditions, and the respective design-basis capacity factors (in percentage of total plant life) for the operating conditions.

3. Calculate the amount of general corrosion-based thinning for the vessels or piping over the life of the plant, as based on the overall general corrosion rate calculated in Step 2 and the thickness of the ferritic vessel or piping that will adjoin to the MNSA repair or half-nozzle replacement.

4. Determine whether the vessel or piping is acceptable over the remaining life of the plant by comparing the worst case remaining wall thickness to the minimum acceptable wall thickness for the vessel or pipe.

Plant-specific engineering evaluations that have been calculated in accordance with these methods and that demonstrate that the ferritic materials will not be unacceptably degraded by general-corrosion-induced thinning (i.e., demonstrate that the ferritic portions of the components will not be thinned by general corrosion to a size less than the minimum allowable wall thickness for the component) over the life of the plant (40 years if the normal licensing basis plant life is used or 60 years if the facility is expected to be approved for extension of the operating license) will be sufficient to satisfy the acceptability by analysis provisions of Section XI of the ASME Code for defects induced by general-corrosion or crevice-corrosion.

3.2 Thermal-Fatigue Crack Growth Assessment

The staff determined that the CEOG's methods for calculating the thermal-fatigue repair life of the existing flaws in the original weld metal was consistent with the methods of Appendix A to Section XI of the ASME Code. Licensees seeking to adopt the thermal-fatigue crack growth methods of the topical report and proprietary evaluation A-GEN-PS-0003, Revision 00, will need to perform plant-specific thermal fatigue crack growth analyses of the existing flaws in their nozzles that involve the following calculations:

1. Perform maximum allowable crack length and crack depth calculations for the worst-case cracks extending into the ferritic portions of the vessels or piping that will adjoin to the MNSA repair or half-nozzle replacement.

2. Perform a thermal-fatigue crack growth analysis of the worst case flaw assumed to occur in the original Alloy 182/82 weld metal that is based on the calculational thermal-fatigue crack growth methods in proprietary evaluation A-GEN-PS-0003, Revision 00.

3. Perform a comparison of the maximum crack length and crack depth determined from the growth analysis to the maximum allowable crack length and crack depth to determine whether fatigue growth of the worst case crack will be acceptable over the operating life for the facility (40 years if the normal licensing basis plant life is used or 60 years if the facility is expected to be approved for extension of the operating license).

3.3 Stress Corrosion Crack Growth Assessment

The CEOG used water chemistry and contaminant arguments as its bases for concluding that growth of the existing flaws by stress corrosion was not a plausible mechanism. Based on the staff's assessment given in Section 2.3.2 of this SE, the staff concurs that the probability for growing the existing flaws by stress corrosion will be low as long as concentrations of dissolved oxygen, halide, sulfate, or other harmful contaminants is sufficiently controlled at the plants, and as long as hydrogen water chemistry is implemented at the plants. Licensees seeking to implement MNSA repairs or half-nozzle replacements may use the CEOG's stress corrosion assessment as the bases for concluding that existing flaws in the weld metal will not grow by stress corrosion if they conduct appropriate plant chemistry reviews and if they can demonstrate that a sufficient level of hydrogen overpressure has been implemented for the RCS, and that the contaminant concentrations in the reactor coolant have been typically maintained at levels below 10 ppb for dissolved oxygen, 150 ppb for halide ions, and 150 ppb for sulfate ions. During the outage in which the half-nozzle or MNSA repairs are scheduled to be implemented, licensees adopting the topical report's stress corrosion crack growth arguments will need to review their plant-specific RCS coolant chemistry histories over the last two operating cycles for their plants, and confirm that these conditions have been met over the last two operating cycles.

3.4 Other Considerations

The CEOG's general corrosion rates for normal operations, startups, and cold-shutdown conditions, as applied in Equation (1) of the topical report, are considered by the staff to be acceptable, as long as the existing corrosion data used to determine the bounding rates is applicable. If additional laboratory or field data becomes available that invalidates the topical report's general corrosion rate values for normal operations, startups, and cold-shutdown conditions, CE should send in an addendum to the topical report that evaluates the impact of the new data of the corrosion rate values for normal operations, startups, and cold-shutdown conditions, and that provides a new overall general corrosion rate assessment for the ferritic components under assessment.

The CEOG's thermal fatigue crack growth analysis is only applicable to the evaluation of a single flaw. Should the CEOG desire to extend the scope of its thermal-fatigue crack growth

analysis to the analysis of multiple cracks in near proximity to one another, the CEOG is requested to submit an appropriate addendum to the topical report that provides the new thermal-fatigue crack growth assessment for the multiple flaw orientation.

The scope of CE NPSD-1198-P, Revision 00, does not address whether the MNSA or half-nozzle designs are in compliance with the ASME loading criteria for ASME A, B, C, and D loading conditions (i.e., for normal operating, transient, emergency, and faulted loading conditions), nor does the topical report address any welding considerations. Licensees seeking to implement half-nozzle replacements or MNSA repairs of their Alloy 600 nozzles will need to assess the plant-specific loading conditions for the repair or replacement designs and, for half-nozzle replacements, the welding aspects of the design and determine whether relief is necessary against the alternative method requirements of 10 CFR 50.55a.

4.0 REFERENCES

1. CEOG Letter No. CEOG-01-052, from R. A. Bernier, Chairman CE Owners Group, to the U.S. Nuclear Regulatory Commission Document Control Desk, "Request for Review of CE Owners Group Report CE NPSE-1198-P, 'Low-Alloy Steel Component Corrosion Analysis Supporting Small-Diameter Alloy 600/690 Nozzle Repair/Replacement Programs'," February 15, 2001.

2. Proprietary CE Owners Group Report CE NPSE-1198-P, Revision 00, "Low-Alloy Steel Component Corrosion Analysis Supporting Small-Diameter Alloy 600/690 Nozzle Repair/Replacement Programs," February 2001.

3. Proprietary CEOG Letter No. CEOG-01-199, from R. A. Bernier, Chairman CE Owners Group, to the U.S. Nuclear Regulatory Commission Document Control Desk, "Response to Staff Request for Information Concerning CE NPSD-1198-P," July 24, 2001.

4. Proprietary Evaluation A-CEOG-9449-1242, Revision 00, "Evaluation of the Corrosion Allowance for Reinforcement and Effective Weld to Support Small Alloy 600 Nozzle Repairs," June 2000.

5. Proprietary Evaluation A-GEN-PS-0003, Revision 00, "Evaluation of Fatigue Crack Growth Associated with Small Diameter Nozzles in CEOG Plants," May 2000.

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