June 17, 2003

Mr. J. A. Stall
Senior Vice President, Nuclear and
Chief Nuclear Officer
Florida Power and Light Company
P.O. Box 14000
Juno Beach, Florida 33408-0420

SUBJECT: SAINT LUCIE NUCLEAR PLANT, UNITS 1 AND 2 - RELIEF REQUEST NOS. 20, 21, 30 AND 31, REVISION 2, REGARDING REACTOR VESSEL HEAD PENETRATION WELD REPAIR AND FLAW EVALUATION (TAC NOS. MB6379 AND MB6380)

Dear Mr. Stall:

By a letter dated September 26, 2003, Florida Power and Light Company, et al. (the licensee), submitted Relief Requests (RRs) 20 and 21, Rev. 2, for St. Lucie Unit 1 and RRs 30 and 31, Rev. 2, for St. Lucie Unit 2, requesting relief from certain requirements specified in American Society of Mechanical Engineers Boiler and Pressure Vessel Code, Section XI. In accordance with Title 10 of the *Code of Federal Regulation* (10 CFR) Section 50.55a(a)(3)(i), RRs 20 and 30 proposed to use the temper bead technique as an alternate to welding requirements of the code of record. In accordance with 10 CFR 50.55a(g)(5)(iii), RRs 21 and 31 requested relief from the requirements for flaw characterization and reinspection in successive inspection periods.

A Request for Additional Information was issued on January 30, 2003. The licensee provided the additional information in a letter dated April 14, 2003.

The U.S. Nuclear Regulatory Commission (NRC) staff has reviewed the relief requests. For RRs 20 and 30, the NRC staff determined that the licensee's proposed alternative provides an acceptable level of quality and safety. Therefore, pursuant to 10 CFR 50.55a(a)(3)(i) the alternative proposed in RR 20, Rev. 2, is authorized for use at St. Lucie Unit 1 for the third 10-year Inservice Inspection (ISI) interval, which ends February 10, 2008, and RR 30, Rev. 2, is authorized for use at St. Lucie Unit 2 for the second 10-year ISI interval, which ends August 7, 2003.

For RRs 21 and 31, the NRC staff determined that adherence to the requirements of the Code is impractical. The licensee's request and supporting information on the impracticality of characterizing flaws in remnant J-groove welds provide reasonable assurance of structural integrity of the repair. Therefore, pursuant to 10 CFR 50.55a(g)(6)(i), RR 21, Rev. 2, is granted for St. Lucie Unit 1 for the third 10-year ISI interval, which ends February 10, 2008, and RR 31, Rev. 2, is granted for St. Lucie Unit 2 for the second 10-year ISI interval, which ends August 7, 2003. Granting relief pursuant to 10 CFR 50.55a(g)(6)(i) is authorized by law and will not endanger life or property or the common defense and security, and is otherwise in the public

interest giving due consideration to the burden upon the licensee that could result if the requirements were imposed on the facility.

In order to prevent a delay in outage activities, verbal authorization for RRs 30 and 31 for St. Lucie Unit 2 was granted in a telephone conversation on May 27, 2003. Participants in the call were A. Howe and B. Moroney of the NRC Staff and W. Jefferson, G. Madden, S. Collard, C. Ward, E. Belizar, and J. Hoffman of the St. Lucie staff.

Further details of the bases for the NRC staff's conclusions are contained in the enclosed Safety Evaluation. If you have any questions regarding this issue, please contact Brendan Moroney at (301) 415-3974.

Sincerely,

/RA by K. Jabbour Acting for/

Allen G. Howe, Section Chief, Section 2
Project Directorate II
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket No. 50-335 and 50-389

Enclosure: Safety Evaluation

cc: See next page

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Florida Power and Light Company

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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

INSERVICE INSPECTION PROGRAM

RELIEF REQUEST NOS. 20, 21, 30 AND 31, REVISION 2

FLORIDA POWER AND LIGHT COMPANY, ET AL.

SAINT LUCIE, UNITS 1 AND 2

DOCKET NOS. 50-335 AND 50-389

1.0 INTRODUCTION

By a letter dated September 26, 2003, Florida Power and Light Company, et al. (the licensee), submitted Relief Requests (RRs) 20 and 21, Revision 2, for St. Lucie Unit 1 and RRs 30 and 31, Revision 2, for St. Lucie Unit 2, requesting relief from certain requirements specified in American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Code), Section XI. In accordance with Title 10 of the *Code of Federal Regulation* (10 CFR) Section 50.55a(a)(3)(i), RRs 20 and 30 proposed to use the temper bead technique as an alternate to welding requirements of the code of record. In accordance with 10 CFR 50.55a(g)(5)(iii), RRs 21 and 31 requested relief from the requirements for flaw characterization and reinspection in successive inspection periods.

A Request for Additional Information was issued on January 30, 2003. The licensee provided the additional information in a letter dated April 14, 2003.

2.0 REGULATORY EVALUATION

The Inservice Inspection (ISI) of the 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 10 CFR 50.55a(g), except where specific relief has been granted by the Commission pursuant to 10 CFR 50.55a(g)(6)(i). As stated in 10 CFR 50.55a(a)(3), alternatives to the requirements of paragraph (g) may be used, when authorized by the U.S. 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) 12 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 St. Lucie Unit 1 third 10-year ISI interval and the St. Lucie Unit 2 second 10-year ISI interval is the 1989 Edition of the ASME Boiler and Pressure Vessel Code.

3.0 TECHNICAL EVALUATION

3.1 Relief Request Nos. 20 and 30, Repair of Reactor Vessel Closure Head Penetration Welds

3.1.1 Code Requirements for which Relief is Requested

The Construction Code of record for the St. Lucie Unit 1 reactor vessel and head is the 1965 Edition of ASME Section III through the Winter 1967 Addenda; and for St. Lucie Unit 2 the Construction Code of record is the 1971 Edition of ASME Section III through the Summer 1972 Addenda.

ASME Section XI, subarticle IWA-4120 specifies the following: "Repairs shall be performed in accordance with the Owner's Design Specification and the original Construction Code of the component or system. Later Editions and Addenda of the Construction Code or of ASME Section III, either in their entirety or portions thereof, and Code Cases may be used." The licensee stated that the proposed repairs will be conducted in accordance with the 1989 Edition of ASME Section III, no Addenda of Section III, Subsection NB and the alternatives requested.

Subarticle IWA-4310 requires the repair of any flaw (associated with the J-groove weld attaching the penetration to the head) which cannot be accepted by the rules of the original Construction Code. Per subarticle IWA-4120, repair welding must be done in accordance with the original Construction Code. Therefore, for any J-groove weld excavation that resulted in a repair within 1/8 inch of the ferritic material of the vessel head, subarticle NB-4622 of Section III requires a postweld heat treatment (PWHT) for the repair weld or the use of a temper bead weld technique.

The licensee is seeking relief from subparagraphs NB-4622.1 and NB-4622.5 which require a postweld heat treatment for a repair weld, paragraph NB-5245 which requires a progressive surface examination, dye penetrant (PT) or magnetic particle (MT) at the lesser of ½ the maximum weld thickness or ½ inch as well as the final weld surface, and paragraph NB-6111 which requires a hydrostatic test.

3.1.2 Licensee's Proposed Alternative to Code

The licensee's stated alternative is to utilize a temper bead weld procedure, without the majority of the PWHT control requirements as stated in the subparagraphs of subarticle NB-4622 which no longer apply.

The licensee went on to state that subparagraph NB-4622.11 requires a 350°F preheat and a postweld soak at 450°F to 550°F for 4 hours. The proposed alternative does not require this heat treatment because the use of the extremely low hydrogen Gas Tungsten Arc Welding (GTAW) temper bead procedure does not require the hydrogen bake-out.

The subarticle NB-4622 temper bead procedure requires the use of the shielded metal arc welding (SMAW) welding process with covered electrodes. In the alternative, the licensee requests the use of the GTAW which will be shielded with welding grade argon which typically produces porosity free welds.

Subarticle NB-5245 requires progressive surface examination at the lesser of ½ the maximum weld thickness or ½ inch, as well as a surface examination of the final weld surface. The licensee proposes PT and ultrasonic examination (UT) no sooner than 48 hours after the weld has cooled to ambient temperature. Paragraph NB-6111 requires that a hydrostatic test be performed after the repair. The licensee stated that a system leakage test will be performed as an alternative.

3.1.3 <u>Licensee's Basis for Relief</u>

The licensee stated that quality temper bead welds, without preheat and postheat, can be made based on welding procedure qualification test data derived from machine GTAW ambient temperature temper bead welding process. The proposed alternative welding technique has been demonstrated as an acceptable method for performing welds without preheat and postheat. 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, including Duane Arnold, Nine Mile Point, FitzPatrick, Crystal River, Oconee 1 and 3, Surry 1, Millstone 2 and Three Mile Island 1. The licensee indicated the results of procedure qualification work undertaken to date indicate that the process produces sound and tough welds with typical tensile test results being ductile breaks in the weld metal.

The licensee stated that use of a GTAW temper bead welding technique to avoid the need for postweld heat treatment is based on research that has been performed by Electric Power Research Institute (EPRI) and other organizations. EPRI Report GC-111050, "Ambient Temperature Preheat for Machine GTAW Temper Bead Applications," dated November 1998, demonstrates that carefully controlled heat input and bead placement allow subsequent welding passes to relieve stress and temper the heat affected zones (HAZ) of the base material and preceding weld passes. Data presented in Tables 4-1 and 4-2 of the report show results of procedure qualifications performed with 300°F preheats and 500°F postweld heat treatments, as well as with no preheat and postheat treatment. From that data, the licensee asserts that equivalent toughness is achieved in base metal and heat affected zones in both cases.

The licensee indicated that the temper bead process has been shown to be effective by research, successful procedure qualifications, and the many successful repairs performed since the technique was developed. Many acceptable Procedure Qualifications (PQRs) and Welding Procedure Specifications (WPSs) presently exist

and have been used to perform numerous successful repairs. These include repairs performed in accordance with all of the Construction Sections of the ASME Code, as well as the National Board Inspection Code. The use of the automatic or machine GTAW process utilized for temper bead welding allows more precise control of heat input, bead placement, and bead size and contour than the SMAW process required by NB-4622. The licensee's position is that the very precise control over these factors afforded by the alternative provides more effective tempering and eliminates the need to grind or machine the first layer of the repair.

The licensee indicated that the subparagraph NB-4622.11 temper bead procedure requires a 350°F preheat and a postweld soak at 450°F to 550°F for 4 hours for P-No. 3 materials. Typically, these kinds of restrictions are used to mitigate the effects of the solution of atomic hydrogen in ferritic materials prone to hydrogen embrittlement cracking. The susceptibility of ferritic steels is directly related to their ability to transform to martensite with appropriate heat treatment. The P-No. 3 material of the reactor vessel head is able to produce martensite from the heating and cooling cycles associated with welding. However, the proposed alternative mitigates this propensity without the use of elevated preheat and postweld hydrogen bake-out.

The NB-4622.11 temper bead procedure requires the use of the SMAW welding process. Even the low hydrogen electrodes, which are required by NB-4622, may be a source of hydrogen unless very stringent electrode baking and storage procedures are followed. The only shielding of the molten weld puddle and surrounding metal from moisture in the atmosphere is from the evolution of gases created by the flux and from the slag that forms from the flux and covers the molten weld metal. Because of the possibility of contaminating the weld with hydrogen, NB-4622 temper bead procedures require preheat and postweld hydrogen bake-out. The licensee stated the proposed alternative temper bead procedure utilizes a welding process that is inherently free of hydrogen. The GTAW process relies on bare welding electrodes with no flux to trap moisture. An inert gas blanket positively shields the weld and surrounding material from the atmosphere and moisture it may contain. To further reduce the likelihood of any hydrogen evolution or absorption, the alternative procedure requires particular care to ensure the weld region is free of all sources of hydrogen. The GTAW process will be shielded with welding grade argon which typically produces porosity free welds. A typical argon flow rate would be adjusted to assure adequate shielding of the weld without creating a venturi effect that might draw oxygen or water vapor from the ambient atmosphere into the weld. The F-No. 43 (ERNiCrFe-7) filler metal that would be used for the repairs is not subject to hydrogen embrittlement cracking.

In lieu of using thermocouples for interpass temperature measurements, the licensee indicated that calculations show that the maximum interpass temperature will never be exceeded based on a maximum allowable low welding heat input, weld bead placement, travel speed, and conservative preheat temperature assumptions. They stated the calculation supports the conclusion that when 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 affect on the low-alloy steel HAZ. The calculation is based on a typical inter-bead interval of 5 minutes. The 5-minute inter-bead interval is based on the time: (1) required to explore the previous

weld deposit with the two remote cameras housed in the weld head, (2) to shift the starting location of the next weld bead circumferentially away from the end of the previous weld-bead, and (3) to shift the starting location of the next bead axially to ensure a 50% weld bead overlap required to properly execute the temper bead technique.

The licensee stated a welding mockup on the full size Midland reactor pressure vessel (RPV) head was used to demonstrate the welding technique described. Thermocouples were placed in a variety of locations to monitor the temperature of the RPV head during welding. During the mockup, the licensee indicated that all thermocouples fluctuated less than 15°F throughout the 18-hour welding cycle. A 300°F minimum preheat was used, therefore, for ambient temperature conditions used for the weld alternative proposed, the 350°F maximum interpass temperature will not be exceeded.

The licensee stated that the automated repair method described above leaves a slight gap between the replacement lower nozzle and the bore in the RPV head, which would expose a small amount of ferritic low-alloy steel to the primary coolant. The effect of corrosion on the exposed area -- both reduction in RPV head thickness and primary coolant iron release rates -- has been evaluated by Framatome-ANP. The results of this evaluation concluded that the total corrosion would be insignificant when compared to the thickness of the RPV closure head. It was also concluded that the total estimated iron release from a total of all replaced control element drive mechanism (CEDM) nozzles would be significantly less than the total iron release from all other sources.

The alternative (to the requirements of NB-5245) nondestructive examination (NDE) was discussed. The licensee indicated that UT will be performed in lieu of radiography (RT) due to the repair weld configuration. Meaningful RT cannot be performed because the weld configuration and geometry of the penetration in the RPV head provide an obstruction for the x-ray path and interpretation would be very difficult. The licensee stated UT is considered adequate and superior to RT for this geometry. The new structural weld is sized like a coaxial cylinder partial penetration weld. The ASME Section III original requirements for progressive PT were in lieu of volumetric examination. Volumetric examination is not practical for a conventional partial penetration weld configuration, however, this weld configuration is suitable for UT and a final surface PT will also be performed.

The licensee indicated that effectiveness of the UT techniques to characterize the weld defects has been qualified by demonstration on a mockup of the temper bead weld involving the same metals used for the repair. Notches were machined into the mockup at depths of 0.10", 0.15", and 0.25" in order to quantify the ability of UT to characterize these depths of penetration into the nozzle. The depth characterization is done using tip diffraction UT techniques that have the ability to measure the depth of a reflector relative to the nozzle bore. The results showed that each of the notches in the mockup could be measured using the 45° transducer.

During the examination, 45° and 70°longitudinal wave angle beams are used, one directed up and the other directed down along the nozzle axis. These beams are effective at detecting defects near the root of the weld because of the impedance

change at the weld triple point where the Alloy 600, Alloy 52 and ferritic RPV head meet. The 45° transducer is effective at depth characterization by measuring the time interval to the tip of the reflector relative to the transducer contact surface. The 70° longitudinal wave provides additional qualitative data to support information obtained with the 45° transducer. Together, the licensee stated these transducers provide good characterization of possible defects and are routinely used for examination of austenitic welds in the nuclear industry for flaw detection and sizing.

The weld is also examined in the circumferential direction using 45° longitudinal waves in both the clockwise and counterclockwise directions to look for transverse fabrication flaws. A 0° transducer is also used to look radially outward to examine the weld and adjacent metal for laminar type flaws and evidence of under bead cracking. The final weld surface and a band around the weld area will be examined using PT. The purpose for the examination of the band is to assure all flaws associated with the weld area have been removed or addressed. The final examination of the new weld and immediate surrounding area within the band will be sufficient to verify that defects have not been induced in the low-alloy RPV head metal due to the welding process. The PT examination is also consistent with the Construction Code requirements.

The licensee's justification for performing a system leakage test with a 4-hour hold time in lieu of a hydrostatic test was discussed. The licensee stated that industry experience has demonstrated that leaks are not being discovered as a result of hydrostatic test pressures propagating a pre-existing flaw through wall. Most leaks are being found when the system is at normal operating pressure. Hydrostatic tests are time consuming, require extensive operator support, and usually mean radiation exposure to personnel. These tests place a burden on the systems, increase radiation exposure and costs, require significant setup time, and add marginal value to the repair quality. These tests result in hardship without a compensating increase in the level of quality and safety. The licensee stated that performing the system leakage test with a 4-hour hold time will provide reasonable assurance that flaws will be discovered.

The licensee concluded that quality temper bead welds can be performed with 50°F minimum preheat and no post heat treatment based on Framatome-ANP welding procedure qualification test data using machine GTAW ambient temperature temper bead welding. They stated the qualification of the ambient temperature temper bead welding process demonstrates that the proposed alternative provides an acceptable level of quality and safety.

3.1.4 Evaluation

The 1989 Edition of ASME Section III, paragraph NB-4622.11, "Temper Bead Weld Repair to Dissimilar Metal Welds or Buttering," states that whenever PWHT is impractical or impossible, limited weld repairs to dissimilar metal welds of P-No. 1 and P-No. 3 material or weld filler metal A-No. 8 (Section IX, QW-442) or F-No. 43 (Section IX, QW-432) may be made without PWHT or after the final PWHT, provided the requirements of the paragraphs NB-4622.11(a) through (g) are met.

The requirements of subarticles NB-4451, 4452, 4453, and 4622 of the 1989 Edition of ASME Section III are also applicable to the contemplated repairs. Specifically, alternatives are being proposed for the following subparagraphs of ASME Section III, subarticle NB-4622:

NB-4622.1 establishes the requirement for PWHT of welds including repair welds. In lieu of the requirements of this subparagraph the licensee proposes to utilize a temper bead weld procedure, obviating the need for postweld stress relief.

NB-4622.2 establishes the requirement for time at temperature recording of the PWHT and their availability for review by the inspector. This requirement of the subparagraph will not apply because the proposed alternative does not involve PWHT.

NB-4622.3 discusses the definition of nominal thickness as it pertains to time at temperature for PWHT. The subparagraph is not applicable in this case because the proposed alternative involves no PWHT.

NB-4622.4 establishes the holding times at temperature for PWHT. The subparagraph is not applicable in this case because the proposed alternative involves no PWHT.

NB-4622.5 establishes PWHT requirements when different P-number materials are joined. This subparagraph is not applicable because the proposed alternative involves no PWHT.

NB-4622.6 establishes PWHT requirements for non-pressure retaining parts. The subparagraph is not applicable in this case because the potential repairs in question will be to pressure retaining parts. Furthermore, the proposed alternative involves no PWHT.

NB-4622.7 establishes exemptions from mandatory PWHT requirements. Sub-subparagraphs NB-4622.7(a) through NB-4622.7(f) are not applicable in this case because they pertain to conditions that do not exist for the proposed repairs. Sub-subparagraph NB-4622.7(g) discusses exemptions to weld repairs to dissimilar metal welds if the requirements of subparagraph NB-4622.11 are met. This sub-subparagraph does not apply because the ambient temperature temper bead repair is being proposed as an alternative to the requirements of subparagraph NB-4622.11.

NB-4622.8 establishes exemptions from PWHT for nozzle to component welds and branch connection to run piping welds. Sub-subparagraph NB-4622.8(a) establishes criteria for exemption of PWHT for partial penetration welds. This is not applicable to the proposed repairs because the criteria involve buttering layers at least 1/4 inch thick which will not exist for the welds in question. Sub-subparagraph NB-4622.8(b) also does not apply because it discusses full penetration welds and the welds in question are specially designed pressure boundary, structural welds.

NB-4622.9 establishes requirements for temper bead repairs to P-No. 1 and P-No. 3 materials and A-Nos. 1, 2, 10, or 11 filler metals. The subparagraph does not apply in this case because the proposed repairs will involve F-No. 43 filler metals.

NB-4622.10 establishes requirements for repair welding to cladding after PWHT. The subparagraph does not apply in this case because the proposed repair alternative does not involve repairs to cladding.

NB-4622.11 discusses temper bead weld repair to dissimilar metal welds or buttering and would apply to the proposed repairs as follows:

Sub-subparagraph NB-4622.11(a) requires surface examination prior to repair in accordance with Article NB-5000 (NB-4622.11(d)(3). The proposed alternative will include surface examination prior to repair consistent with Article NB-5000.

Sub-subparagraph NB-4622.11(b) contains requirements for the maximum extent of repair. The proposed alternative includes the same limitations on the maximum extent of repair.

Sub-subparagraph NB-4622.11(c) discusses the repair welding procedure and welder qualification in accordance with ASME Section IX and the additional requirements of Article NB-4000. The proposed alternative will satisfy these requirements. In addition, subparagraph NB-4622.11(c) requires the Welding Procedure Specification include the following requirements:

NB-4622.11(c)(1) requires the area to be welded be suitably prepared for welding in accordance with the written procedure to be used for the repair. The proposed alternative will satisfy this requirement.

NB-4622.11(c)(2) requires the use of the SMAW process with covered electrodes meeting either the A-No. 8 or F-No. 43 classifications. The proposed alternative utilizes GTAW with bare electrodes meeting either the A-No. 8 or F-No. 43 classifications.

NB-4622.11(c)(3) discusses requirements for covered electrodes pertaining to hermetically sealed containers or storage in heated ovens. These requirements do not apply because the proposed alternative uses bare electrodes that do not require storage in heated ovens since bare electrodes will not pick up moisture from the atmosphere.

NB-4622.11(c)(4) discusses requirements for storage of covered electrodes during repair welding. These requirements do not apply because the proposed alternative utilizes bare electrodes, which do not require any special storage conditions to prevent the pickup of moisture from the atmosphere.

NB-4622.11(c)(5) requires preheat to a minimum temperature of 350°F prior to repair welding. The proposed alternative does not require this preheat or a postheat treatment. The use of a GTAW ambient temperature temper bead welding technique to avoid the need for preheat and postweld heat treatment is based on research that has been performed by EPRI (EPRI Report GC-111050, "Ambient Temperature Preheat for Machine GTAW Temper Bead Applications," dated November 1998). The research demonstrates that carefully controlled heat input and bead placement allow subsequent welding passes to relieve stress and temper the HAZ of the base material and preceding weld passes. Data presented in the report show the results of procedure qualifications

performed with 300°F preheats and 500°F postheats, as well as with no preheat and postheat. From that data, it is clear that equivalent toughness is achieved in base metal and HAZ in both cases. The ambient temperature temper bead process has been shown effective by research, successful procedure qualifications, and many successful repairs performed since the technique was developed.

NB-4622.11(c)(6) establishes requirements for electrode diameters for the first, second, and subsequent layers of the repair weld and requires removal of the weld bead crown before deposition of the second layer. Because the proposed alternative uses weld filler metal much smaller than the 3/32, 1/8, and 5/32 inch electrodes required by sub-subparagraph NB-4622.11(c)(6), the requirement to remove the weld crown of the first layer is unnecessary and the proposed alternative does not include the requirement. On ferritic materials made with the SMAW process, the weld reinforcement crown is removed to allow heat from the second weld layer to penetrate to the untempered ferritic base metal below it. However, when repairs are performed to dissimilar materials using nonferritic weld metal and using a low heat input machine GTAW process, the heat from welding is much more controlled and heat from the second weld layer penetrates to the untempered ferritic base metal below it and tempers it. Therefore, deletion of this requirement is acceptable.

NB-4622.11(c)(7) requires the preheated area to be heated from 450°F - 660°F for a minimum period of 4 hours, after welding is completed. The proposed alternative does not require this heat treatment because the use of the extremely low hydrogen GTAW temper bead procedure does not require the hydrogen bake-out. The proposed alternative temper bead procedure utilizes a welding process that is inherently free of hydrogen. The GTAW process relies on bare welding electrodes with no flux to trap moisture. An inert gas blanket positively shields the weld and surrounding material from the atmosphere and moisture it may contain. To further reduce the likelihood of any hydrogen evolution or absorption, the alternative procedure requires particular care to ensure the weld region is free of all sources of hydrogen. The GTAW process will be shielded with welding grade argon which typically produces porosity free welds. The F-No. 43 (ERNiCrFe-7) filler metal that would be used for the repairs is not subject to hydrogen embrittlement cracking. (Also see NB-4622.11(c)(5) above.)

NB-4622.11(c)(8) requires welding subsequent to the hydrogen bake-out of sub-subparagraph NB-4622.11(c)(7) be done with a minimum preheat of 100°F and maximum interpass temperature of 350°F. Since the proposed preheat and interpass shown in NB-4622.11(c)(7) above will not be done, this requirement does not apply to this welding.

NB-4622.11(d)(1) requires a PT after the hydrogen bake-out described in sub-subparagraph NB-4622.11(c)(7). The proposed alternative does not require the hydrogen bake-out nor does it require the in-process dye penetrant examination.

NB-4622.11(d)(2) requires PT and RT of the repair welds after a minimum of 48 hours at ambient temperature. UT is required, if practical. The proposed alternative includes the requirements for both UT and PT inspection after a minimum of 48 hours at ambient temperature. The geometry of the RPV head and the orientation of the inner bore of the

CEDM nozzles make effective RT impractical. The thickness of the RPV head limits the sensitivity of the detection of defects in the new pressure boundary weld. The density changes between the base and weld metal and residual radiation from the base metal would render the film image inconclusive. The high area dose of radiation would cause fogging of the film. Because of these conditions, the NRC staff concludes RT is impractical for this type of repair. In addition, the performance of UT is considered an acceptable volumetric alternative to the Code required RT because the weld configuration is more conducive to effective UT based on successful industry performance demonstrations and data provided by the licensee.

NB-4622.11(e) establishes the requirements for documentation of the weld repairs in accordance with subarticle NB-4130. The proposed alternative will comply with that requirement.

NB-4622.11(f) establishes requirements for the procedure qualification test plate. The proposed alternative complies with those requirements, except that the root width and included angle of the cavity are stipulated to be no greater than the minimum specified for the repair. In addition, the location of the V-notch for the Charpy test is more stringently controlled in the proposed alternative than in subarticle NB-4622.11(f).

NB-4622.11(g) establishes requirements for welder performance qualification relating to physical obstructions that might impair the welder's ability to make sound repairs which are pertinent to the SMAW manual welding process. The proposed alternative involves a machine GTAW process and requires welding operators be qualified in accordance with ASME Section IX. The use of a machine process eliminates concerns about obstructions, which might interfere with the welder's abilities since these obstructions will have to be eliminated to accommodate the welding machine.

The use of a GTAW temper bead welding technique to avoid the need for postweld heat treatment is based on research that has been performed by EPRI and other organizations. The research demonstrates that carefully controlled heat input and bead placement allow subsequent welding passes to relieve stress and temper the HAZ of the base material and preceding weld passes. Data presented in the report show the results of procedure qualifications performed with 300°F preheats and 500°F preheats, as well as with no preheat and postheat. From that data, it is clear that equivalent toughness is achieved in base metal and heat affected zones in both cases. The temper bead process has been shown to be effective by research, successful procedure qualifications, and many successful repairs performed since the technique was developed. Many acceptable PQRs and WPSs presently exist and have been utilized to perform numerous successful repairs. The use of the automatic or machine GTAW process utilized for temper bead welding allows more precise control of heat input, bead placement, and bead size and contour than the manual SMAW process required by subarticle NB-4622. The very precise control over these factors afforded by the alternative provides more effective tempering and eliminates the need to grind or machine the first layer of the repair.

NB-5245 requires that a PT or MT be performed both progressively during welding and on the final weld. The alternative proposed by the licensee is to perform UT and PT

examination of the final repair weld. The staff agrees that the final configuration of the new structural weld is more conducive to using UT since its configuration is sized like a coaxial cylinder partial penetration weld. Numerous UT demonstrations have been conducted by the industry which have shown that this volumetric method is effective. In addition, the ASME Section III original requirements for progressive PT were in lieu of volumetric examination. Therefore, the staff concludes that the licensee's alternative to perform UT of the final repair weld versus progressive PT provides an acceptable level of quality and safety.

The licensee's proposed alternative to perform a system leakage test with a 4-hour hold time is based on industry experience which demonstrates that leaks are not being discovered as a result of hydrostatic test pressures propagating a pre-existing flaw through wall. Most leaks are being found when the system is at normal operating pressure. Hydrostatic tests are time consuming, require extensive operator support, and usually mean radiation exposure to personnel. These tests place a burden on the systems, increase radiation exposure and costs, require significant setup time, and add marginal value to the repair quality. These tests result in hardships without a compensating increase in the level of quality and safety.

Subarticle NB-6111 states that: "All pressure retaining components, appurtenances and completed systems shall be pressure tested. The preferred method shall be a hydrostatic test using water as the test medium." NB-6221 requires that components shall be tested at not less than 1.25 times their Design Pressure. NB-6223 requires a minimum holding time of 10 minutes prior to beginning the examination for leakage. IWA-5214(d) states that where the system hydrostatic test imposes system conditions which conflicts with limitations included in the plant Technical Specifications, a system inservice test at nominal operating temperature shall be acceptable in lieu of the system hydrostatic test.

The staff agrees with the licensee's position that hydrostatic tests are time consuming, require extensive operator support, and usually mean radiation exposure to personnel. In addition to the above, isolation of certain pieces of equipment such as safety reliefs for overpressurization of the system are required along with specialized equipment to perform the hydrostatic test. Secondly, the shorter hold time allowed by the hydrostatic test may not allow small leakage paths to be identified. The longer hold time used with the licensee's proposed alternative would allow for small leakage paths to be identified. The staff concludes that the licensee's proposed alternative to perform a system leakage test in accordance with the requirements of IWA-5000 of Section XI, with the exception that the system will be held at system operating pressure and temperature with a 4-hour hold time, provides reasonable assurance that the system boundary is structurally intact, and is therefore, acceptable.

Finally, in its supplemental letter dated April 14, 2003, the licensee indicated that it would be performing ultrasonic inspection of the CEDM nozzles per the frequency and authorized inspection techniques under Order EA-03-009 issued on February 11, 2003. This course of action will assure that the structural integrity of the CEDM nozzle and surrounding areas are monitored at a frequency that corresponds with the effective degradation years of the operating unit, which for the current RPV heads at St. Lucie

Units 1 and 2, is every refueling outage. The staff concludes that this course of action provides an acceptable level of quality and safety.

3.1.5 Conclusion

The staff concludes that the licensee's proposed alternative to use ambient temperature temper bead welding to repair flaws in the reactor vessel closure head CEDM nozzle penetrations, as described in RRs 20 and 30, Rev. 2, provides an acceptable level of quality and safety. Therefore, pursuant to 10 CFR 50.55a(a)(3)(i), the staff authorizes the proposed alternative for use at St. Lucie Units 1 and 2, in their third and second ISI intervals, respectively. All other ASME Code, Section XI requirements for which relief was not specifically requested and approved in this safety evaluation remain applicable, including third party review by the Authorized Nuclear Inservice Inspector.

3.2 Relief Request Nos. 21 and 31, Characterization of Remaining Flaws

3.2.1 Code Requirements for which Relief is Requested

The ISI Code of record for St. Lucie Units 1 and 2 is the ASME Section XI, 1989 Edition, no Addendum. Subparagraph IWA-3100(a) requires that evaluation shall be made of flaws detected during an inservice examination as required by IWB-3000 for Class 1 pressure retaining components.

Subparagraphs IWA-3300(b) and IWB-3420 require that detected flaw(s) shall be characterized to establish the dimensions of the flaws.

Subparagraphs IWB-2420(b) and (c) require reinspection of a flaw evaluated as acceptable for continued service for three successive periods.

3.2.2 Licensee's Proposed Alternative to Code

Pursuant to 10 CFR 50.55a(g)(5)(iii), the licensee is seeking relief from using NDE methods to characterize flaws that remain in the CEDM J-groove weld after repair due to impracticality. Furthermore, the licensee is requesting relief from the successive inspection requirements of these flaws, because it remains impractical to characterize the flaws through NDE.

3.2.3 Licensee's Basis for Relief

The licensee stated that the exterior surface of the RPV head will be examined for evidence of leakage at the junction of the head penetrations. Penetrations with verified leakage will be investigated and those with leakage will be repaired. The repair process consists of machining the lower portion of the CEDM nozzle to approximately mid-wall thickness of the RPV head above the existing J-groove weld, then welding the remaining nozzle plus a new nozzle section to the wall of the reactor vessel. The licensee indicated that not all of the flaws in the original pressure boundary J-groove weld will be removed through the machining process.

The licensee’s position is that the original CEDM nozzle to RPV head weld configuration is extremely difficult to UT due to the compound curvature of the head and fillet radius. These conditions preclude ultrasonic coupling to the RPV head and control of the sound beam in order to perform flaw sizing with reasonable confidence in measuring the flaw dimension from the inner surface of the head. They indicated it is impractical and the technology does not exist to characterize flaw geometries that may remain in the remnant J-groove weld. Another issue is the dissimilar metal interface between the Ni-Cr-Fe weld and the low-alloy steel closure head which increases the difficulty of UT. Similarly, impediments to examination from the outer surface of the RPV head exist due to the proximity of adjacent nozzle penetrations, according to the licensee. Based on these physical limitations, the licensee stated that the inability to characterize the flaws will continue in the foreseeable future, making successive examinations impractical.

For analysis purposes, the licensee assumed that one or more flaws may exist in the J-groove weld from the weld surface to the RPV head base metal interface. They indicated that based on extensive industry experience and Framatome-ANP direct experience, there are no known cases where flaws initiating in an Alloy 82/182 weld have propagated into the ferritic base metal. They stated that stress-corrosion cracking (SCC) of carbon and low-alloy steels is not a problem under boiling-water reactor or pressurized-water reactor conditions. Instead, an interdendritic crack, propagating from the J-groove weld area, is expected to blunt and cease propagation. They indicated that this has been the case for interdendritic SCC of stainless steel cladding cracks in charging pumps, and in recent events with primary water SCC (PWSCC) of Alloy 600 weld metals at the Oconee 1 and V.C. Summer nuclear plants.

The licensee indicated a fracture mechanics evaluation would be performed to determine if the degraded J-groove weld metal could be left in the vessel, 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 2 times the axial stress at the same location, the preferential direction for cracking would be axially, or radially with respect to the nozzle. The licensee postulated that a radial crack in the Alloy 182 weld metal would propagate due to PWSCC, through the weld and butter, to the interface with the low-alloy RPV head and that it would blunt and arrest at the butter-to-head interface. They indicated that ductile crack growth through the Alloy 182 metal 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 RPV head metal are low, it will be assumed that a small flaw could initiate in the low-alloy steel metal and grow by fatigue. The licensee states that a small flaw in the RPV head 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 RPV head by fatigue crack growth, under cyclic loading conditions associated with heatup and cooldown and other applicable transients.

The licensee stated that residual stresses will not be included in the flaw evaluation since it was demonstrated by analysis that these stresses are compressive in the low-alloy steel base metal. They indicated any residual stresses that remained in the area of the weld following the boring operation would be relieved by such a deep crack, and therefore, need not be considered. Flaw evaluations would be performed for a

postulated radial corner crack on the RPV head penetration, where stresses are the highest and the radial distance from the inside corner to the low-alloy steel base metal is the greatest. Fatigue crack growth calculated for the remaining operation life should be small and the final flaw size will be shown to meet the requirements of the ASME Code for ferritic metals.

The licensee indicated that there would be a number of analyses performed on the new pressure boundary weld for the CEDM nozzle remnant. This is the weld joining the old upper CEDM nozzle section and the new lower CEDM nozzle section together to the RPV head. One analysis will be performed using a three dimensional model of a CEDM nozzle located at the most severe hillside orientation. The analytical model would include the RPV head, CEDM nozzle, proposed new weld and remnant portions of the original J-groove welds. The model is analyzed for thermal transient conditions pertinent to St. Lucie Unit 1 and Unit 2 design specifications. The resulting maximum thermal gradients will be applied to the model along with the coincident internal pressure values. A computer program called ANSYS will then calculate the stresses throughout the model (which includes the new welds). The calculated stress values are then compared to the ASME Code, Section III, NB-3000 criteria for: design conditions; normal, operating and upset conditions; emergency conditions; faulted conditions; and testing conditions.

The licensee stated a primary stress analysis for design conditions will be performed. A maximum Primary General Membrane Stress Intensity will be calculated and shown to be less than the maximum allowed by the ASME Code. The maximum cumulative fatigue usage factor will be calculated, and allowable years of future plant operation will be based on the maximum allowed ASME Code cumulative usage factor criterion of 1.0.

3.2.4 Evaluation

IWA-3300(a) of the 1989 Edition of the ASME Code states that flaws detected by the preservice and inservice examinations shall be sized by the bounding rectangle or square for the purpose of description and dimensioning. IWA-3300(b) of the ASME Code states that flaws shall be characterized in accordance with IWA-3310 through IWA-3390 as applicable. IWB-3132.4(a) of the ASME Code states that components whose volumetric or surface examinations reveal flaws that exceed the acceptance standards listed in Table IWB-3410-1 shall be acceptable for service without the flaw removal, repair, or replacement if an analytical evaluation, as described in IWB-3600, meets the acceptance criteria of IWB-3600.

The repair plan consists of partially machining out the CEDM nozzle through the section of the J-groove weld which attaches the nozzle to the RPV head, up to approximately mid-wall. At mid-wall, the remaining portion of the nozzle is welded and acts as the pressure retaining boundary between the shortened nozzle and inside bore of the RPV head. A replacement lower nozzle will then be welded after a PT examination is performed on the prepared surface. The weld will be placed such that it does not overlap the previously severed J-groove weld. This repair action changes the code category of the remnant J-groove weld from Examination Category B-O, Pressure Retaining Welds in Control Rod Housings, to a non-pressure retaining weld, which is

part of the base metal thickness. The newly deposited repair weld area is now considered the new pressure retaining weld and examined as Examination Category B-O under the ISI program. The licensee's alternative is to eliminate the ASME Code requirements of characterization and successive inspections of defects that may remain in the remnant J-groove weld.

The licensee's position is that the original CEDM nozzle to RPV head weld configuration is extremely difficult to UT due to the compound curvature of the head and fillet radius. These conditions preclude ultrasonic coupling to the RPV head and control of the sound beam in order to perform flaw sizing with reasonable confidence in measuring the flaw dimension from the inner surface of the head. They indicated it is impractical and the technology does not exist to characterize flaw geometries that may exist in the J-groove weld. Another issue is the dissimilar metal interface between the Ni-Cr-Fe weld and the low-alloy steel closure head which increases the difficulty of UT. Impediments to examination from the outer surface of the RPV head exist due to proximity of adjacent nozzle penetrations, according to the licensee. Based on these physical limitations, the licensee stated that the inability to characterize the flaws will continue in the foreseeable future, making subsequent examinations impractical.

The staff agrees that examination of any flaws in the J-groove weld region is impractical due to both the configuration and the metallurgical structure of the J-groove weld. 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. If examination of the J-groove weld were to be attempted from the inside diameter of the head, the cladding would provide an acoustic interface which would severely limit a confident examination of the weld material. Radiography of this area is impractical because circumferentially-oriented flaws are perpendicular to gamma and x-rays. Dye penetrant and magnetic particle examination will not provide useful volumetric information since these are surface techniques. Secondly, the highly attenuative, coarse-grained metallurgical structure of the Alloy 600 J-groove weld does not lend itself to ultrasonic examination, based on many years of industry experience with this material. Based on the discussion above, the staff concludes that compliance with the flaw characterization and successive inspection requirements of the ASME Code for the remnant J-groove weld is impractical.

In its supplemental letter dated April 14, 2003, the licensee provided information that indicated they have performed the analyses and calculations mentioned as the basis for their justification in the initial submittal dated September 26, 2002. The information provided by the licensee was provided in the form of a summary with conclusions for each calculation performed.

Calculation 1 for St. Lucie Unit 1 is a fracture mechanics analysis performed to evaluate a 0.100" semi-circular flaw extending 360° around the circumference at the triple point location where the Alloy 600, Alloy 52 and low-alloy steel head meet. Fatigue crack growth (FCG) was analyzed in eight different crack propagation paths. Acceptance was based on the 1989 Edition of ASME Code Section XI criteria for applied stress intensity and limit load. For FCG in propagation paths 1, 3, 6, and 8, FCG analysis of a

continuous external circumferential flaw in the weld resulted in a fracture toughness margin of 15.2 which is nearly 5 times greater than the Code minimum of 3.16. The limit load analysis for a continuous external circumferential flaw in the weld resulted in a limit load margin of 5.18 which is greater than the Code minimum margin of 3.0. The FCG analysis of a semi-circular external axial flaw in the weld resulted in a fracture toughness margin of 13.3 which is nearly 4 times greater than the minimum margin of 3.16. Finally, the FCG analysis of a semi-circular surface flaw at the weld/head interface resulted in a fracture toughness margin of 15.9 which is nearly 4 times greater than the minimum Code required margin of 3.16.

Calculation 2 for St. Lucie Unit 1 is a finite element model of the most severe side hill penetration to analyze the primary stress intensities for temper bead bore weld analysis. Thermal stresses were determined for the appropriate design transients and a fatigue analysis was performed. Design, emergency, faulted and test conditions cases were evaluated and compared against the appropriate ASME Section III stress limits. The local membrane stress intensity value was calculated to be 23.6 ksi, which did not exceed the maximum allowed under subparagraph NB-3221.2 of 40.1 ksi. The general primary stress intensity under subparagraph NB-3221.1 was calculated to be 15.1 ksi, which is less than the maximum allowable value of 26.7 ksi. And finally, the cumulative fatigue usage factor was determined to be 0.430, which is less than the Code allowable maximum of 1.0.

Calculation 3 for St. Lucie Unit 1 is a fracture mechanics analysis to evaluate a postulated large radial crack (0.795") in the remnants of the original J-groove weld and butter at the CEDM nozzle reactor vessel head penetration after machining. The transients and frequency of occurrence in the following table were used:

Transient	Frequency
Heatup and Cooldown	12.5 cycles/year
Plant Loading and Unloading	50.0 cycles/year
Remaining Transients	62.0 cycles/year
Leak Test	5.0 cycles/year
Loss of Secondary Pressure	5.0 cycles

The licensee stated that the analysis shows that the residual hoop stress changes from tensile to compressive in the buttering and continues to be compressive into the ferritic low-alloy steel reactor vessel head. The staff concludes that this is consistent with published technical data and, therefore, is acceptable. The postulated radial crack was considered acceptable by the licensee for 20 years of operation with a safety margin of 3.17 which exceeds the Code minimum of 3.16. Similarly, Calculations 4, 5 and 6 were performed on St. Lucie Unit 2 and found by the licensee to be within Code acceptable limits and is therefore, acceptable to the staff.

The NRC staff concludes that characterization of the flaws in the remnant CEDM J-groove welds and conformance to the successive inspection requirements would be impractical. In addition, the rationale and information provided by the licensee, under the analyses described above, provide reasonable assurance that no significant crack growth will occur in the RPV head pressure boundary and the structural integrity of the repair weld will perform satisfactorily for an extended period of time with a sufficient margin of safety.

3.2.5 Conclusion

The NRC staff concludes that requiring the licensee to comply with the Construction Code repair and NDE requirements is impractical. The licensee's request and supporting information on the impracticality of characterizing flaws in remnant J-groove welds as stated under RRs 21 and 31, Rev. 2, for St. Lucie Units 1 and 2, respectively, provides reasonable assurance of structural integrity of the repair. Therefore, relief is granted pursuant to 10 CFR 50.55a(g)(6)(i) for St. Lucie Units 1 and 2, in their third and second ISI intervals, respectively. This grant of relief is authorized by law and will not endanger life or property or the common defense and security and is otherwise in the public interest giving due consideration to the burden upon the licensee that could result if the requirements were imposed on the facility. All other ASME Code, Section XI requirements for which relief was not specifically requested and approved in this safety evaluation remain applicable, including third party review by the Authorized Nuclear Inservice Inspector.

4.0 CONCLUSION

For RRs 20 and 30, the NRC staff determined that the licensee's proposed alternative provides an acceptable level of quality and safety. Therefore, pursuant to 10 CFR 50.55a(a)(3)(i) the alternative proposed in RR 20, Rev. 2, is authorized for use at St. Lucie Unit 1 for the third 10-year ISI interval, which ends February 10, 2008, and RR 30, Rev. 2, is authorized for use at St. Lucie Unit 2 for the second 10-year ISI interval, which ends August 7, 2003.

For RRs 21 and 31, the NRC staff determined that adherence to the requirements of the Code is impractical. The licensee's request and supporting information on the impracticality of characterizing flaws in remnant J-groove welds provides reasonable assurance of structural integrity of the repair. Therefore, pursuant to 10 CFR 50.55a(g)(6)(i), RR 21, Rev. 2, is granted for St. Lucie Unit 1 for the third 10-year ISI interval, which ends February 10, 2008, and RR 31, Rev. 2, is granted for St. Lucie Unit 2 for the second 10-year ISI interval, which ends August 7, 2003. Granting relief pursuant to 10 CFR 50.55a(g)(6)(i) is authorized by law and will not endanger life or property or the common defense and security, and is otherwise in the public interest giving due consideration to the burden upon the licensee that could result if the requirements were imposed on the facility.

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