SAFETY EVALUATION BY THE OFFICE OF NEW REACTORS

RELATED TO AMENDMENT NO. 80 AND 79

TO THE COMBINED LICENSE NOS. NPF-91 AND NPF-92 RESPECTIVELY

SOUTHERN NUCLEAR OPERATING COMPANY, INC.

GEORGIA POWER COMPANY

OGLETHORPE POWER CORPORATION

MEAG POWER SPVM, LLC

MEAG POWER SPVJ, LLC

MEAG POWER SPVP, LLC

CITY OF DALTON

VOGTLE ELECTRIC GENERATING PLANT UNITS 3 AND 4

DOCKET NOS. 52-025 AND 52-026

1.0 INTRODUCTION

By letter dated August 29, 2016 (Reference 1), as supplement by letter dated February 13, 2017 (Reference 2), Southern Nuclear Operating Company, Inc. (SNC/licensee) submitted license amendment request (LAR) 16-016 and requested that the U.S. Nuclear Regulatory Commission (NRC) amend the combined licenses (COL) for Vogtle Electric Generating Plant (VEGP), Units 3 and 4, COL Numbers NPF-91 and NPF-92, respectively.

The LAR would revise the Updated Final Safety Analysis Report (UFSAR) (Reference 3) in the form of departures from the incorporated plant-specific Design Control Document (DCD) Tier 2* information. Specifically, the LAR proposed changes to demonstrate the quality and strength of a specific population of welds between stainless steel mechanical couplers (couplers) and embedment plates that did not receive the nondestructive examinations (NDE) required by the American Institute of Steel Construction (AISC) N690-1994, "Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities" (Reference 4). Since some of these coupler welds are already installed and embedded in concrete, the licensee proposed to demonstrate the adequacy of these inaccessible coupler welds through previously-performed visual testing (VT) examinations of the couplers and static tension testing of a representative sample of accessible, uninstalled couplers produced concurrently with those already installed. The LAR contains the analytical and testing methods used to demonstrate the quality and strength of the inaccessible couplers.

The supplement, dated February 13, 2017, provided additional information that clarified the application, did not expand the scope of the application as originally noticed, and did not change the NRC staff's original proposed no significant hazards consideration determination as published the *Federal Register* on November 8, 2016 (81 FR 78661).

2.0 REGULATORY EVALUATION

2.1 System Description

The design function of the reinforcing bar (rebar), coupler, and connection weld system in VEGP, Units 3 and 4, is to transmit loads from structural steel to reinforced concrete. These types of couplers are used in containment internal structures, seismic Category I structures, and the seismic Category II portion of the annex building located adjacent to the nuclear island.

2.2 Proposed Changes

VEGP, Units 3 and 4, UFSAR, Subsection 3.8.4.5, "Structural Criteria," states that the analysis and design of concrete structures conform to American Concrete Institute (ACI) 349-01, "Code Requirements for Nuclear Safety-Related Structures," (Reference 5) and that the analysis and design of structural steel conform to AISC N690-1994. Both ACI 349-01 and AISC N690-1994 provide design standards for the rebar, coupler, and connection weld system discussed in the LAR. Some of these standards include performing NDE on the coupler welds.

A population of #6 and #9 sized Lenton® C3J couplers (1 ¼" and 1 9/16" diameters, respectively) that are welded to ASTM A240 stainless steel embedment plates did not receive the required NDE on their partial joint penetration (PJP) and reinforcing fillet welds at the vendor. The licensee proposed to demonstrate the adequacy of these inaccessible couplers through taking credit for previously-performed VT examinations of the installed couplers and performing static tension testing on a representative sample of accessible, uninstalled couplers that were produced concurrently with those already installed. The licensee proposed that satisfactory results of the VT examinations and static tension testing would justify that the quality and strength of the inaccessible population meet their design function, and that they could be dispositioned use-as-is.

The proposed changes to UFSAR Subsections 3.8.4.5 and 3.8.4.5.2 document how the inaccessible couplers can perform their design function without meeting the specific requirements in AISC N690-1994 Sections Q1.26.2.2, Q1.26.2.3, and Q1.26.3.

2.3 Regulations and Guidance

Title 10 of the *Code of Federal Regulations* (10 CFR), Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants," Appendix D, "Design Certification Rule for the AP1000 Design," Section VIII.B.6, requires prior NRC approval for changes to Tier 2* information. The proposed changes affect Tier 2* information and therefore requires NRC approval.

The regulations in 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," Appendix A, "General Design Criteria for Nuclear Power Plants," General Design Criterion

(GDC) 1, “Quality Standards and Records,” requires that structures, systems, and components important to safety shall be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed. The proposed changes use alternative acceptance criteria to assure that the subject welds can perform their safety function. Therefore, this GDC is considered in the evaluation.

AISC N690-1994, Section Q1.26.2.2, “Partial-Penetration Welds,” requires that 10 percent of PJP welds are inspected by magnetic particle testing or liquid penetrant testing (PT) examinations. Section Q1.26.2.3, “Weld Samples,” requires that if the first 10 percent of welds inspected do not meet the acceptance criteria, then a second 10 percent sample shall be inspected. Furthermore, Section Q1.26.2.3 requires that if the second 10 percent sample does not meet the acceptance criteria, then all welds represented by the samples shall be inspected. Finally, Section Q1.26.3, “Repair and Reexamination,” requires all unacceptable welds to be repaired and 100 percent examined with the same method that disclosed the original defect(s).

3.0 TECHNICAL EVALUATION

3.1 Background

GDC 1 requires that components are designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed. In the situation described in the LAR, the couplers were not tested to the required quality standards in AISC N690-1994. In its review, the NRC staff will determine if the proposed alternative testing is sufficient to demonstrate that the inaccessible couplers can perform their safety function.

The test results provided in the LAR were from shipments of couplers installed at both VEGP and Virgil C. Summer Nuclear Station (VCSNS), since the couplers were manufactured by the Cives Steel Company (Cives) during the same timeframe. While the data from the two sites is combined, this safety evaluation report only addresses the population of stainless steel embedment plates at VEGP manufactured by Cives listed by the Shop Load Numbers in Table 3-1 on page 8 of Enclosure 1 of the LAR. However, since the LAR references actions taken at both VEGP and VCSNS, the NRC staff’s review discusses actions taken at both sites.

The NRC staff held a pre-submittal public meeting on April 14, 2016, to discuss the NRC staff questions (Reference 6) related to the licensee’s testing plan. The meeting summary can be found at ADAMS Accession No. ML16124B090 (Reference 7).

3.1.1 Scope of Impacted Welds

The licensee provided the number of couplers at VEGP and VCSNS that did not receive the required NDE. The licensee also provided the number of couplers that were already installed and embedded in concrete. Below is a copy of the coupler summary table from the LAR:

Table 2-1: Summary of Manufacturer-Welded Couplers on Stainless Steel Embedment Plates for Vogtle Units 3 and 4 and VCSNS, Units 2 and 3

	C3J Couplers					
	Shipped		Installed		Accessible	
	Plates	Couplers	Plates	Couplers	Plates	Couplers
VCSNS	70	420	35	210	35	210
Vogtle	63	394	27	178	36	216

At VEGP, of the 178 couplers that are embedded in concrete, 118 are #6 sized couplers and 60 are #9 sized couplers. At VCSNS, 150 of the 210 couplers that are embedded in concrete are #6 sized couplers and 60 of the 210 couplers are #9 sized couplers. Therefore, between both sites, there are 268 #6 sized and 120 #9 sized inaccessible couplers from a total of 814 shipped couplers.

Subsequent to the discovery that the required PT examinations had not been performed at the vendor, sampling inspection plans were developed to be implemented at both VEGP and VCSNS to perform PT examinations on 10 percent of the total population of welds at each site, with provisions to perform PT examinations on a second 10 percent sample if any indications were found on the initial 10 percent sample, in accordance with AISC N690-1994. The licensee stated that some welds were ground (profiled) to their minimum design specification before their PT examinations.

At VEGP, the licensee selected samples from the accessible 216 couplers, comprising 10 percent of the entire population of 394 couplers. The licensee stated that the initial 10 percent sample was not representative of all production loads over time. During PT, indications were found on the first 10 percent sample. Therefore, a second 10 percent sample was chosen for testing. The second 10 percent sample of welds also had recordable indications.

At VCSNS, a similar sampling inspection plan was developed, although there were some differences from VEGP's plan. VCSNS selected couplers from the 210 available couplers to comprise 10 percent of the entire population of 420 couplers. Surface profiling was performed on the entire first 10 percent sample, and the PT examination results had 100 percent satisfactory results. However, the first 10 percent sample was not representative of every production load provided over time. Therefore, VCSNS selected and profiled a second 10 percent sample. The second 10 percent sample had recordable indications.

Couplers in the second 10 percent samples from both VEGP and VCSNS had recordable indications. AISC N690-1994, Section Q1.26.2.3, states that if the second 10 percent sample of welds does not meet the acceptance criteria, then all welds should be inspected. Furthermore, Section Q1.26.3 requires that all unacceptable welds be repaired. Due to the inability to inspect and potentially repair all of the inaccessible welds, an alternate approach was needed to show the adequacy of the inaccessible welds.

3.1.2 Licensee Testing Program Overview

AISC N690-1994, Section Q1.0.1, states, in part, that:

> The engineers of any system of design or construction within the scope of this specification, the adequacy of which has been shown by successful use or by

> analysis or test, but which does not conform to or is not covered by this Specification, shall have the right to present the data on which their design is based to the Regulatory Authority for review and approval.

The licensee performed the static tension testing, as permitted by AISC N690-1994, Section Q1.0.1, to demonstrate the adequacy of the installed #6 and #9 sized coupler welds. Consistent with AISC N690-1994, Section Q1.0.1, testing as an alternative to the AISC N690-1994 design provisions can be accepted on a case-by-case basis.

ACI 349-01, Section 12.14.3.4.1, requires that at least the six static and three cyclic performance tests be used to demonstrate that the mechanical connection is capable of developing at least 125 percent of the yield strength of the rebar and that the static tensile strength is not adversely influenced by load cycling. This requirement for the mechanical connection is applied to the coupler weld to demonstrate that the coupler weld is stronger than the rebar, therefore, ensuring that the system will function as intended.

The licensee performed two sets of static tension testing, Phase I and Phase II, to demonstrate that the failure mode for the rebar, coupler, and connecting weld system always occurred in the rebar or threaded connection between the rebar and the coupler. The Phase I data was used as a baseline for comparison to the Phase II results. The Phase I testing was performed on the #6 and #9 sized couplers by the vendor as part of the initial qualification tests required by ACI 349-01, Section 12.14.3.4.1. The Phase II static tension testing was performed on a representative sample of accessible, uninstalled couplers.

In Phase I, the licensee used data from the static tension testing performed by the vendor on fifteen #6 sized couplers and six #9 sized couplers. Each test was run until failure. The licensee did not use the cyclic testing results as part of their analysis because cyclic testing is used during initial qualification testing to show that there is no adverse impact on the coupler system from load cycling.

In Phase II, the licensee statically tested to failure 37 #6 and 10 #9 sized couplers from the uninstalled population. These 47 couplers take into account the attributes discussed in Section 3.1.3 of this safety evaluation report to ensure that the test results are representative of the inaccessible population. The Phase II testing was performed at ambient temperatures.

In an attempt to isolate the failure point to the coupler weld in the Phase II static testing, the licensee welded an oversized coupler onto the test coupler. Due to the proximity of the fixture weld to the test weld, the licensee performed hardness testing to demonstrate that there was no change to the test weld's strength or properties. The licensee stated that hardness testing was performed on samples with and without the fixture weld, and provided additional hardness testing information in the February 13, 2017, supplement. The supplement described the test process, which included cutting and polishing each sample, a Vickers microhardness traverse, etching, and a metallographic examination to demonstrate that neither sample had a hardened heat affected zone, as well as that both samples had similar hardness traverses. Based on these results, the licensee concluded that there was no impact on the test weld due to the fixture weld.

The licensee stated that both Phase I and Phase II static tension testing were performed in accordance with ASTM A370, "Standard Test Methods and Definitions of Mechanical Testing of Steel Products" (Reference 8). The licensee also stated that the recent Phase II testing was performed in a qualified laboratory using a formal quality assurance program.

3.1.3 Accessible Weld Representativeness

To verify that the data derived from the test specimens is adequately representative of the inaccessible weld population, the licensee provided information to show that the test specimens are representative of the inaccessible welds.

AISC N690-1994, Section Q1.26.2, “Minimum examination of welds,” states that all welds shall be VT examined for 100 percent of their length. The licensee stated that VT examination was performed at the vendor on all 394 coupler welds at VEGP and on all 420 coupler welds at VCSNS. The licensee also stated that each of the 8 load packages at VEGP and each of the 8 load packages at VCSNS were reviewed to verify satisfactory VT examination results. Tables 3-1 and 3-2 of the LAR stated the ranges of satisfactory vendor VT examination dates for the load packages at both VEGP and VCSNS.

In addition to the VT examination performed at the vendor, a 100 percent VT examination was performed on-site during receipt inspection. The licensee stated that the receipt inspection records were reviewed at VEGP and VCSNS. The licensee also stated that all of the VT examinations performed at VEGP were satisfactory, except for two plates that were reworked due to only having six of the eight required couplers, and two other couplers that had unsatisfactory VT examination results due to lack of welding metal deposited near their base. The licensee stated that all of the plates at VCSNS had satisfactory VT examination receipt inspections.

The licensee stated that flux-core arc welding (FCAW) and gas tungsten arc welding (GTAW) were the only two weld processes used on the entire population and that the vendor’s applicable welding procedure specifications (WPS) were qualified in accordance with the American Welding Society (AWS) D1.4, “Structural Welding Code – Reinforcing Steel,” (Reference 9) and AWS D1.6, “Structural Welding Code – Stainless Steel” (Reference 10). The licensee also stated that the applicable vendor’s documents and procedures were referenced in the work packages, and that the same three qualified welders performed all of the welds for both the installed and uninstalled populations.

The licensee reviewed the Certified Mill Test Reports (CMTRs) for the filler material, and also reviewed the mechanical properties of the C3J couplers base material for each load number to ensure that they met the appropriate requirements. Additionally, the LAR contained the CMTR mechanical properties for the filler metal, and the C3J couplers base material mechanical properties by load number.

The LAR contained proprietary information related to the manufacturing schedule of the entire impacted population of couplers, which demonstrated that the selected test couplers were manufactured over the entire production run of impacted welds.

The licensee proposed 4 different test groups for the Phase II static tension testing that could represent the possible examination outcomes if the installed welds underwent NDE at the vendor:

i. Couplers that were not profiled and failed PT examination. 22 couplers were placed in this category.
ii. Couplers that were profiled and passed PT examination. 7 couplers were placed in this category.

iii. Couplers that were profiled and still failed PT examination. 16 couplers were placed in this category.

iv. Welds that failed VT examination during receipt inspection due to "lack of welding metal deposited near the base of the coupler." 2 couplers were placed in this category.

In total, the licensee tested 47 #6 and 10 #9 sized couplers from the uninstalled population. These 47 couplers take into account all of the above attributes to ensure that the test results are representative of the inaccessible population.

3.1.4 Licensee Static Tension Testing Results

For the Phase I testing, the licensee indicated that the 90/95 percent confidence interval (i.e., 90 percent probability that the calculated limits contain 95 percent of the population) break strength observed from this testing exceeds 125 percent of yield strength of the rebar acceptance criteria for both the #6 and #9 sized couplers. Further, the rebar or threads failed before the coupler weld for each of the tests.

For the Phase II testing, the licensee stated that all of the test samples failed in the C3J coupler body instead of at the coupler weld. Therefore, since all of the couplers failed in the coupler body, the licensee concluded that the NDE condition of the welds had no impact on the failure strength of the system.

Since all of the samples failed within the coupler body instead of at the test weld, the licensee normalized the break loads with the calculated strength of the coupler body. The licensee assumed that the coupler was completely filled in, and the tensile strength was calculated using the CMTR tensile strength from Table 3-5 in the LAR. Since each production load had a different CMTR, the LAR stated which load number corresponds to each test coupler weld.

The normalized results for the #6 and #9 couplers were combined into one data set. Since the failures occurred through the coupler body, the licensee investigated the failed samples to see if the fixture weld filling in the threaded coupler influenced the failure load of each test sample. The licensee separated the single data set into two groups: one group of results which were influenced by defects (voids, incomplete bonding, etc.) in the fixture weld, and one group of results which were not influenced by fixture weld defects.

After normalizing the results and separating the test data into these two groups, the licensee calculated the mean and standard deviation of the normalized values for each group. The licensee then calculated a 90/95 percent confidence interval for the normalized value for each group based on the sample sizes. The licensee defined the 90/95 percent confidence interval value as the test coefficient, "c". For the remaining calculations, the licensee used the "c" value that corresponded to the group of test results that were not influenced by fixture weld defects. The group of test results that were not influenced by fixture weld defects "c" value was less than the "c" value calculated for the group of test results that were influenced by fixture weld defects.

Using the "c" value that corresponded to the group of test results that were not influenced by fixture weld defects, the minimum CMTR values of the tensile strength of the coupler body, and the areas of the #6 and #9 sized couplers respectively, the licensee was able to estimate the failure strength of each coupler weld size. By using "c," the calculated value took into account the 90/95 percent confidence interval and therefore sample size. The licensee used the different areas for the #6 and #9 sized couplers to calculate the tensile strength for each coupler size.

Using these two tensile strengths, the licensee calculated the following two safety margins (or factors of safety) for each coupler size. The first factor of safety was the calculated tensile strength for each coupler size as described above divided by 125 percent of the yield strength of the rebar. The second factor of safety was the calculated tensile strength for each coupler size, as described above, divided by the calculated upper bound of the 90/95 percent confidence interval system strength from the Phase I results. The same “c” value was used for both the #6 and #9 couplers since the coupler body values only depend on the coupler area (size). Therefore, both factors of safety were calculated for both the #6 and #9 sized couplers. Table 1 contains the licensee’s calculated margins:

Table 1: Licensee Calculated Safety Margins (Factors of Safety) for the Coupler Weld Tensile Strength

Coupler Size	Margin compared to 125 percent of the Yield Strength of the Rebar	Margin compared to the System Strength
#6	2.91	2.16
#9	2.26	1.68

Based on the Phase I and Phase II test data, the licensee concluded that the weakest point within the system is the rebar or threaded connections. The factors of safety also showed that there is margin for both sizes of couplers above the 125 percent of the yield strength of the rebar and the upper bound 90/95 percent confidence interval of the failure strength of the rebar. Therefore, the licensee concluded that the strength of the inaccessible couplers allows them to perform their design function and they can be dispositioned use-as-is.

3.2 <u>NRC Staff Evaluation</u>

The NRC staff’s review focused on the testing and analysis performed to justify the strength and quality of the inaccessible coupler welds, as well as whether the test coupler welds were representative of the inaccessible weld population.

For its evaluation, the NRC staff reviewed:

- The VEGP UFSAR, Section 3.8, “Design of Category I Structures;”
- The “Final Safety Evaluation Report for the VEGP Electric Generating Plant Units 3 and 4 Combined License Application” (Reference 11) which documented the NRC staff’s technical evaluation of the VEGP Units 3 and 4.
- NUREG–1793, Supplement 2, “Final Safety Evaluation Report Related to Certification of the AP1000 Standard Plant Design” (Reference 12), which documented the NRC staff’s technical evaluation of the AP1000 DCD (Reference 13); and
- The applicable ACI 349-01 and AISC N690-1994 requirements.

3.2.1 Test Samples Representing the Inaccessible Population

The licensee's proposal to disposition the inaccessible welds as "use as-is" was based on justifying the quality and strength of the inaccessible welds by using both VT examination and static tension testing in lieu of the required PT examination. To accept that the results from the test samples are correctly correlated with the inaccessible welds, the NRC staff required justification to show that the tested welds were representative of the inaccessible welds.

The NRC staff reviewed the information provided on the VT examinations. The NRC staff finds that the use of the VT examinations are acceptable, because the licensee reviewed all of the vendor VT examination reports to ensure that VT examinations were performed in accordance with the applicable AISC N690-1994 requirements, and all of the vendor VT examination results were satisfactory. The NRC staff also finds the VT examinations performed during receipt inspection acceptable, because the licensee reviewed all of the receipt inspections, and the results were either satisfactory or appropriately dispositioned.

To justify that the manufacturing processes of the accessible couplers were representative of the inaccessible couplers, the licensee explained that the welding processes and procedures are consistent over the entire production run. Only FCAW and GTAW were used to fabricate the coupler welds, and the weld processes and positions were the same for each coupler. Furthermore, since only three qualified welders produced all of the welds, there was consistency within the welders themselves. Finally, the licensee stated that they reviewed the applicable WPSs to determine whether the welding activities were performed in accordance with the applicable AWS Code requirements, and the applicable vendor documents and procedures were referenced in the work packages. The NRC staff finds that the use of qualified welders, welding processes, and welding procedures provide reasonable assurance that each weld was produced with consistent properties over the entire production timeline.

The CMTRs for the filler metal and C3J coupler base material mechanical properties for each load number provided assurance that the initially procured materials had acceptable properties, and were procured in accordance with the design specifications. Additionally, the CMTRs showed that the weld filler metals maintained their properties at lower temperatures. Since the material properties are maintained at lower temperatures that are consistent with the operating temperatures of the couplers, the NRC staff finds that performing the static tension tests at ambient temperatures is acceptable.

While the welding processes were the same over time, selecting samples that were produced throughout the production run also provided assurance that the test samples were representative of the inaccessible welds. Since the test weld couplers were produced during or close to when the inaccessible couplers were produced, the NRC staff finds that the licensee's selection of samples throughout the entire production run is acceptable.

The licensee developed four test groups for the Phase II static tension testing to account for each of the potential examination outcomes. The majority of the test samples (38 of the 47 test welds) contained known, relevant indications due to their PT examination results. Additionally, 16 of the 38 samples with known indications were profiled to their minimum design specification. Static tension testing welds with known indications and welds that are profiled to their minimum design specification provided additional conservatism in the results. The NRC staff finds that the selection of test welds represent the potential NDE conditions of the inaccessible population because the majority of welds that were tested have known, relevant PT examination indications, and that some welds were profiled to their minimum design specification. Therefore, the NRC staff finds the selection of test welds acceptable.

Based on the performed VT examinations, the review of the welding processes and procedures, the selection of samples throughout the production run, and the selection of the tensile testing examination groups, the NRC staff finds that the coupler welds that were used as test specimens are adequately representative of the inaccessible weld population, and therefore the test data represents the inaccessible weld population.

3.2.2 Weld Testing Program

The NRC staff reviewed the use of AISC N690-1994, Section Q1.0.1, to justify using static tension testing. The NRC staff also reviewed the use of the acceptance criteria from ACI 349-01, Section 12.14.3.4, that requires a mechanical connection shall develop at least 125 percent of the yield strength of the rebar. Since AISC N690-1994 is the code of construction for module CA01, the NRC staff finds the use of AISC N690-1994, Section Q1.0.1 acceptable to justify using static tension testing. Additionally, since the acceptance criteria of ACI 349-01 demonstrates that the mechanical system is stronger than 125 percent of the yield strength of the rebar, the NRC staff finds its use acceptable as it provides a minimum requirement that can be compared to the strength of the test weld.

The licensee's Phase I testing was performed during qualification by the vendor in accordance with ACI 349-01. This qualification testing provided a baseline to compare to the test welds, and demonstrated that all failures were in the rebar or mechanical connection, and not in the coupler body or weld. The licensee did not use any cyclic testing data for their Phase I results since the purpose of the Phase II testing was to find the failure of the coupler weld, and comparing those results to the cyclic data would not be appropriate. The NRC staff finds not using any of the cyclic testing data as described by ACI 349-01 acceptable, as the cyclic testing results were only needed to justify that there is no impact on the failure of the rebar due to load cycling during qualification.

In the February 13, 2017, supplement, the licensee provided additional information regarding the test fixture design of the coupler welded to the oversized coupler. The NRC staff reviewed this additional information and finds that the hardness testing to be an acceptable test method and that the results demonstrated that the fixture weld does not have any impact on the strength of the coupler weld.

The NRC staff finds the use of ASTM A370 for the Phase I and Phase II static tension testing acceptable as the use of a standard provided consistency between each phase of testing, and each individual test itself.

Based on the above, the NRC staff finds that the licensee's methodology of determining the factors of safety acceptable. Therefore, the NRC staff has reasonable assurance that the data derived from the weld testing program on the test samples is adequately representative of the inaccessible weld population.

3.2.3 Test Results

The NRC staff performed confirmatory calculations to verify the licensee's calculated values. Using the licensee's test data and methodology, the NRC staff reproduced the same values for both Phase I and Phase II testing. The NRC staff used documentation developed by the Sandia

Corporation to verify the licensee's one-sided tolerance limit, k, for 90/95 percent confidence intervals (Reference 14). The NRC staff used the same document for their own independent analysis, as described in Section 3.2.4 of this safety evaluation.

For the Phase I testing, the licensee calculated the 90/95 percent confidence interval break strength per ACI 349-01, Section B.4.2. Specifically, the licensee used the upper bound 90/95 percent confidence interval while ACI 349-01, Section B.4.2, uses the lower bound 90/95 percent confidence interval (5 percent fractile). However, by using the upper bound 90/95 percent confidence interval, the licensee calculated a more conservative result for the second factor of safety, which used the calculated tensile strength for each coupler size from the Phase II results divided by the calculated upper bound 90/95 percent confidence interval system strength from the Phase I results. Therefore, the NRC staff finds that the licensee's use of the upper bound 90/95 percent confidence interval is acceptable to calculate the second factor of safety. Finally, the NRC staff calculated the lower bound 90/95 percent confidence interval using the Phase I data and confirmed that the values exceeded 125 percent of yield strength of the rebar for both the #6 and #9 sized couplers.

The licensee provided additional information in the February 13, 2017, supplement on the criteria used to separate the Phase II test samples into two groups – the group of test results that were influenced by fixture weld defects, and the group of test results that were not influenced by fixture weld defects. The NRC staff finds the licensee's explanation acceptable since results from the samples that failed due to voids or incomplete bonding of the fixture weld would not have represented the actual strength of the test coupler weld.

The licensee's methodology used several conservatisms in their Phase II analysis. Some of these conservatisms included using a 90/95 percent confidence interval based on the sample size of the Phase I and Phase II test samples, normalizing the break strength of the coupler body to the coupler weld, and eliminating the Phase II test sample results influenced by the fixture weld defects (which provided a smaller sample size). Furthermore, the licensee's calculated "c" value for the group of test results not influenced by fixture weld defects was less than the "c" value calculated group of test results influenced by fixture weld defects. The NRC staff notes that both groups has similar average normalized failure strengths; however, the group not influenced by fixture weld defects had a larger standard deviation, which caused the "c" value to be less than the group influenced by the fixture weld defects.

The licensee's first factor of safety used the calculated 90/95 percent confidence interval tensile strength of the coupler weld divided by 125 percent of the yield strength of the rebar. Using this criteria, the licensee calculated factors of safety of 2.91 and 2.26 for the #6 and #9 sized couplers, respectively. The NRC staff finds these factors of safety, with all of their associated conservatisms, acceptable because they are an additional margin above the minimum code requirement.

The second factor of safety was the calculated tensile strength for each coupler size divided by the calculated upper bound 90/95 percent confidence interval system strength from the Phase I results. Since this value represented the actual system strength using statistical methods to account for the Phase I sample size, this provided an even more direct comparison to the strength of the coupler weld. Using this criteria, the licensee calculated factors of safety of 2.16 and 1.68 for the #6 and #9 sized couplers, respectively. The NRC staff finds these factors of safety, with all of their associated conservatisms, acceptable because they are an additional margin above the system strength.

3.2.4 Independent NRC Staff Analysis of the Test Data

The NRC staff performed an independent analysis of the test data using a different methodology and different conservatisms, as described below, to provide reasonable assurance of the inaccessible couplers' strength. Independent of the licensee's methodology, the NRC staff reviewed the raw data provided to determine reasonable factors of safety.

For the Phase I data, the NRC staff calculated the mean and standard deviation using the provided failure loads and used the k values, as defined in Section 3.2.3 of this safety evaluation, for the 95/95 percent confidence interval. The NRC staff used a 95/95 percent confidence interval as an additional conservatism compared to the 90/95 percent requirement in ACI 349-01. Using these k values, the NRC staff calculated the upper bound 95/95 percent confidence interval for the failure of the system from the Phase I results.

For the Phase II data, the NRC staff did not normalize the break strengths of the #6 and #9 coupler bodies and combine the data sets. Since the coupler body failed before the coupler weld, the coupler body is weaker and provided a more realistic value. The NRC staff calculated the mean and standard deviation for the 37 #6 and 10 #9 sized couplers separately. Using these two sample sizes, the NRC staff found the two 95/95 percent k values and then calculated the lower bound 95/95 percent failure strength for each coupler size.

Consistent with the LAR, the NRC staff also separated the test results for #6 sized couplers into two groups – the group of test results influenced by fixture weld defects, and the group of test results not influenced by fixture weld defects. All 10 of the test results for #9 sized couplers were not influenced by fixture weld defects, and therefore did not need to be separated into two groups. For both of the #6 sized coupler group test results, the NRC staff calculated the mean and standard deviation. The NRC staff then used revised 95/95 percent k values that correlated with the two new sample set sizes to calculate the lower bound 95/95 percent failure strength. After the calculations were complete, both groups had similar average failure strengths. However, the group of test results not influenced by fixture weld defects had a larger standard deviation, causing the 95/95 percent confidence interval strength to be less than the group of test results influenced by fixture weld defects.

The NRC staff compared these two new failure strengths to the same two acceptance criteria – 125 percent of the yield strength of the rebar, and the upper bound 95/95 percent failure strength of the rebar that was calculated by the NRC staff using the Phase I results. The NRC staff's calculated factors of safety for each coupler size are in Table 2:

Table 2: Safety Margins (Factors of Safety) Calculated by NRC Staff

Margin compared to 125 percent of the Yield Strength of the Rebar			
Coupler Size	All Couplers	Influenced by Fixture Weld Defects	Not Influenced by Fixture Weld Defects
#6	3.10	3.32	3.00
#9	2.15	N/A	2.15
Margin compared to the upper bound 95/95 percent failure strength of rebar (System Strength)			
Coupler Size	All Couplers	Influenced by Fixture Weld Defects	Not Influenced by Fixture Weld Defects
#6	2.28	2.45	2.21
#9	1.60	N/A	1.60

The NRC staff found the factors of safety calculated by the licensee consistent with the NRC staff's independent analysis. These factors of safety demonstrate that, with a high degree of confidence and margin, the coupler welds are stronger than the rebar. Therefore, the NRC staff finds that the factors of safety provide reasonable assurance that the coupler welds will not fail before the rebar under normal and accident conditions, and therefore are adequate for fulfilling their intended functions.

Based on the applicant's use of static tension testing, as permitted by AISC N690-1994, Section Q1.0.1, and based on the calculated factors of safety that were verified by the NRC staff, the NRC staff finds that the Phase I and Phase II testing demonstrated that adequate margins exists compared to the ACI 349-01 yield strength requirement and the system strength determined by the Phase I testing.

3.2.5 Licensing Basis Changes

The licensee proposed the following changes to the Vogtle, Units 3 and 4, UFSAR. Specifically, the licensee proposed additions of the following Tier 2* information to UFSAR Subsection 3.8.4.5, "Structural Criteria," and Subsection 3.8.4.5.2, "Supplemental Requirements for Steel Structures."

The licensee proposed to add the following, as shown in underline, to UFSAR Subsection 3.8.4.5, "Structural Criteria:"

> *[The analysis and design of concrete conform to ACI-349 as supplemented below and with clarifications provided in Subsection 3.8.4.4.1. The analysis and design of structural steel conform to AISC-N690 as supplemented below and with clarifications provided in Subsection 3.8.4.5.2. The analysis and design of*

*cold-formed steel structures conform to AISI. The margins of structural safety are as specified by those codes.]**

The licensee proposed to add the following, as shown in underline, to UFSAR Subsection 3.8.4.5.2, "Supplemental Requirements for Steel Structures:"

- *Sections Q1.24 and Q1.25.10 are supplemented as follows:*

  *Shop painting is in accordance with Section M of the Manual of Steel Construction, Load and Resistance Factor Design, First Edition. Exposed areas after installation are field painted in accordance with the applicable portion of Chapter M of the Manual of Steel Construction, Load and Resistance Factor Design, First Edition.]** See Subsection 6.1.2.1 for additional description of the protective coatings.

- *[In Sections Q1.26.2.2, Q1.26.2.3, and Q1.26.3 for the non-conforming partial penetration welds associated with reinforcement bar sizes #6 and #9 C3J couplers installed on ASTM A240 stainless steel embedment plates under CA01 that did not undergo nondestructive examination at the time of fabrication, as identified in Amendment Nos. [XXX and YYY] for VEGP Units 3 and 4, respectively, the quality and strength of the welds is demonstrated through visual examination and through static tension testing of an uninstalled representative population as follows:*

  - *Visual Examination: Coupler welds from the production fabrication population underwent visual examination by the manufacturer. The manufacturer visual examinations provided satisfactory results.*

  - *Static Tension Testing: Weldable coupler connections of reinforcing bar to structural steel shall develop 125% of the specified yield strength of the bar in accordance with ACI 349-01, Section 12.14.3.4. The mechanical connection strength requirement is applied to the weld to demonstrate that the coupler weld is stronger than the reinforcing bar strength requirement, thereby satisfying provisions for design limits outlined in AISC N690-1994. To determine that the population of #6 and #9 C3J coupler welds on ASTM A240 stainless steel embedment plates are adequate in their ability to perform their intended design function, static tension testing of an uninstalled representative population of production welds is evaluated experimentally in two phases.*

    Phase I: Static tension testing has been performed on a total of six #9 sized couplers and a total of fifteen #6 sized couplers. The static tension tests results were evaluated to obtain the 90/95% confidence interval break strength for both coupler sizes. The Phase I test results demonstrate that the 90/95% confidence interval break strength exceeds 125% of the specified yield strength of the reinforcing bar and demonstrate that the rebar or coupler thread is the weak link in the mechanical connection system.

    Phase II: Testing was performed to investigate the strength of the coupler weld. A total of 47 samples were tested, 37 #6 sized couplers and 10 #9 sized couplers. The statically-tested samples failed within the coupler body, and demonstrate that the production PJP with fillet weld is stronger than the coupler body. To confirm that the statically-tested sample population is representative of *the installed population of coupler welds, the test sample population considered factors such as sample size, weld process, automatic/manual processes, human performance factors, welding procedure specifications, non-destructive examination, fabrication schedule, filler metal, and coupler material.*

*Safety margin was calculated using the nominal tensile strength and the 90/95% confidence interval test coefficient based on the test samples and is penalized by lower bound failure modes and a finite sample size. The safety margin, or Factor of Safety (FoS), was calculated against both the 125% yield strength of the rebar and against the system strength (i.e., weakest link of the system, rebar or coupler thread). The minimum safety margin with respect to the 125% yield strength of the rebar was calculated to be 2.91 for the #6 sized couplers and 2.26 for the #9 sized couplers. The minimum safety margin with respect to the system strength was calculated to be 2.16 for the #6 sized couplers and 1.68 for the #9 sized couplers.]**

The NRC staff reviewed the proposed wording and finds that it adequately describes the impacted coupler welds, bounds the scope of the impacted welds by citing the COL Amendment Numbers 80 and 79, and describes the test methodology used to calculate the safety margins for each coupler size. Therefore, the NRC staff finds that the proposed UFSAR wording is acceptable.

3.2.6 Summary

The NRC staff reviewed the licensee's proposed changes and based on the technical evaluation, the NRC staff finds that:

(1) The #6 and #9 sized coupler welds that used as test specimens are adequately representative of the inaccessible weld population, and therefore the test data will represent the inaccessible weld population.

(2) The licensee's methodology to determine factors of safety is acceptable and that the data derived from the weld testing program on the test samples is adequately representative of the inaccessible weld population.

(3) In accordance with AISC N690-1994, Section Q1.0.1, the licensee's testing of the #6 and #9 sized coupler welds successfully demonstrated adequate strength for the inaccessible weld population by either analysis or testing. Therefore, the NRC staff finds that while unable to inspect and potentially repair all of the inaccessible welds in accordance with AISC N690-1994, Sections Q1.26.2.2, Q1.26.2.3, and Q1.26.3, the strength of the welds is still acceptable to meet their intended function.

(4) The proposed changes to UFSAR Subsection 3.8.4.5 and Subsection 3.8.4.5.2 adequately describe the impacted coupler welds, bound the scope of the impacted welds by citing the COL Amendment numbers, and describe the test methodology used to calculate the safety margins for each coupler size.

Based on the fact that the tension testing was performed in accordance with ASTM A370 and the provisions of AISC N690-1994, Section Q1.0.1, the NRC staff finds that the alternative testing demonstrates that the inaccessible couplers meet the required quality standards and will perform their safety function, and that GDC 1 will continue to be met as documented in the Final

Safety Evaluation Reports of the AP1000 DCD and VEGP COL. Therefore, the NRC staff concludes the proposed changes are acceptable.

This approval does not extend to additional populations of couplers that do not meet the requirements in the UFSAR, or the applicable ACI 349-01 and AISC N690-1994 requirements.

4.0 STATE CONSULTATION

In accordance with the Commission's regulations in 10 CFR 50.91(b) (2), the Georgia State official was notified of the proposed issuance of the amendment on April 14, 2017. The NRC staff confirmed that the State official had no comments on April 17, 2017.

5.0 ENVIRONMENTAL CONSIDERATION

The amendment changes a requirement with respect to installation or use of a facility component located within the restricted area as defined in 10 CFR Part 20, "Standards for Protection Against Radiation." The NRC staff has determined that the amendment involves no significant increase in the amounts, and no significant change in the types, of any effluents that may be released offsite, and that there is no significant increase in individual or cumulative occupational radiation exposure. The Commission has previously issued a proposed finding that the amendment involves no significant hazards consideration (81 FR 78666; published on November 8, 2016) and the discussion in Section 3.0 above continues to support that proposed finding. Accordingly, the amendment meets the eligibility criteria for categorical exclusion set forth in 10 CFR 51.22(c)(9). Pursuant to 10 CFR 51.22(b), no environmental impact statement or environmental assessment need be prepared in connection with the issuance of the amendment.

6.0 CONCLUSION

The Commission has concluded, based on the considerations discussed above that: (1) there is reasonable assurance that the health and safety of the public will not be endangered by construction activities in the proposed manner; (2) there is reasonable assurance that such activities will be conducted in compliance with the Commission's regulations; and (3) the issuance of the amendment will not be inimical to the common defense and security or to the health and safety of the public. Therefore, the NRC staff finds the changes proposed in this license amendment to be acceptable.

7.0 REFERENCES

1. ND-16-1287, "Southern Nuclear Operating Company Vogtle Electric Generating Plant Units 3 and 4 Request for License Amendment: Nondestructive Examination for Welds of Couplers to Stainless Steel Embedment Plates (LAR-16-016)," dated August 29, 2016 (ADAMS Accession No. ML16242A399).

2. ND-17-0210, "Southern Nuclear Operating Company Vogtle Electric Generating Plant Units 3 and 4 Supplement to Request for License Amendment: Nondestructive Examination for Welds of Couplers to Stainless Steel Embedment Plates (LAR-16-016S1)," dated February 13, 2017 (ADAMS Accession No. ML17044A298).

3. Vogtle Electric Generating Plant Updated Final Safety Analysis Report (UFSAR), Revision 5, dated June 17, 2016 (ADAMS Accession No. ML11180A100).

4. American Institute of Steel Construction (AISC), “Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities,” 1994 (AISC N690-1994).

5. American Concrete Institute (ACI), “Code Requirements for Nuclear Safety Related Concrete Structures,” 2001 (ACI 349-01).

6. 2016/04/13 Vogtle COL Docs - 4/14/2016 Public Meeting - NRC Staff Questions about Cives SS Test Plan, dated April 13, 2016 (ADAMS Accession No. ML16104A053).

7. 04/14/2016 Summary of Public Meeting with Southern Nuclear Operating Company and South Carolina Electric & Gas to Discuss Safety Review of Licensing Actions, dated June 17, 2016 (ADAMS Accession No. ML16124B090).

8. American Society for Testing and Materials International (ASTM) A370, “Standard Test Methods and Definitions of Mechanical Testing of Steel Products.”

9. American Welding Society (AWS) “Structural Welding Code – Reinforcing Steel,” 1998 (AWS D1.4).

10. American Welding Society “Structural Welding Code – Stainless Steel,” (AWS D1.6).

11. Vogtle Electric Generating Plant, Final Safety Evaluation Report dated August 5, 2011 (Letter: ADAMS Accession No. ML111950510. Final Safety Evaluation Report package: ADAMS Accession No. ML110450302).

12. NUREG-1793, Supplement 2, Final Safety Evaluation Report Related to Certification of the AP1000 Standard Plant Design, dated August 5, 2011 (ADAMS Accession No. ML112061231).

13. AP1000 Design Control Document, Revision 19, dated June 13, 2011 (ADAMS Accession No. ML11171A500).

14. Owen, D.B., “Factors for One-Sided Tolerance Limits and for Variables Sampling Plans,” Sandia Corporation, dated March 1963 (ADAMS Accession No. ML14031A495)

15. Request for Additional Information Vogtle (LAR-16-016) Regarding Stainless Steel Embed Plates, dated January 13, 2017 (ADAMS Accession No. ML17017A161).