SAFETY EVALUATION BY THE OFFICE OF NEW REACTORS

RELATED TO AMENDMENT NOS. 86 AND 85

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

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GEORGIA POWER COMPANY

OGLETHORPE POWER CORPORATION

MEAG POWER SPVM, LLC

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VOGTLE ELECTRIC GENERATING PLANT UNITS 3 AND 4

DOCKET NOS. 52-025 AND 52-026

## 1.0 INTRODUCTION

By letter dated October 20, 2016 (Reference 1) and supplemented by letter dated April 28, 2017 (Reference 2), Southern Nuclear Operating Company, Inc. (SNC/licensee) submitted license amendment request (LAR) 16-027 and requested that the U.S. Nuclear Regulatory Commission (NRC) amend the combined licenses (COLs) 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 carbon steel mechanical couplers (couplers) and embedment plates that did not receive all of the nondestructive examination (NDE) specified 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 demonstrating the quality and strength of these inaccessible coupler welds by mechanical testing (static tension testing) of a representative sample of both accessible, uninstalled couplers produced concurrently with those already installed (production couplers) and couplers produced thereafter (supplemental couplers). Throughout the Safety Evaluation (SE), when referring to testing the couplers, this also includes testing the strength of the coupler weld. In addition, previously-performed visual testing (VT) examinations of the production couplers and magnetic particle testing (MT) examinations provide additional information on the

adequacy and the representativeness of the sample coupler welds compared to the inaccessible population. The LAR describes the analytical and testing methods used to demonstrate the quality and strength of the inaccessible couplers.

The NRC staff issued an initial *Federal Register* notice of opportunity to request a hearing and a proposed No Significant Hazards Consideration Determination on March 14, 2017. The supplement, dated April 28, 2017, provide 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 determination as published in the Federal Register on March 14, 2017 (82 FR 13662).

## 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 reinforcing bar (rebar), coupler, and connection weld system discussed in the LAR. Some of these standards include performing NDE on the coupler welds.

Two populations of #9 and #11 sized Lenton® C3J couplers (1 9/16″ and 2″ diameters, respectively) that are welded to carbon steel embedment plates from two different vendors – Cives Steel Company (Cives) and Joseph Oat Corporation (JO) – did not receive the required NDE on their partial joint penetration (PJP) and reinforcing fillet welds. Specifically, these populations of couplers did not receive the required MT. The licensee proposed demonstrating the adequacy of these inaccessible couplers through previously-performed VT examinations of the production couplers, and MT examinations and static tension testing of a representative sample of both accessible, uninstalled production couplers and supplemental couplers. The licensee proposed that satisfactory results of the VT examinations, MT examinations, and static tension testing would justify that the quality and strength of the inaccessible population meets 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 be demonstrated to perform their design function without meeting the specific requirements in AISC N690-1994 Section Q1.26.2.2.

### 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 require 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," states that 10 percent of PJP welds are to be inspected by MT or liquid penetrant testing examinations. AISC N690-1994, Section Q1.26.2.3, "Weld Samples," states 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 states that if the second 10 percent sample does not meet the acceptance criteria, then all welds represented by the samples shall be inspected. Finally, AISC N690-1994, Section Q1.26.3, "Repair and Reexamination," states that all unacceptable welds to be repaired and 100 percent examined with the same method that disclosed the original defects.

## 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 AISC N690-1994 quality standards required by the DCD. 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 couplers manufactured at Cives were installed at both VEGP and Virgil C. Summer Nuclear Station (VCSNS) and manufactured during the same timeframe. Therefore, the test results provided in the LAR for the Cives couplers were combined from both the VEGP and VCSNS accessible populations. The LAR also includes test results from supplemental couplers manufactured from JO. While the data from the two sites is combined, this safety evaluation report only addresses the population of carbon steel embedment plates installed at VEGP that were manufactured by Cives and JO and listed in the Shop Load Numbers and Load Serial Numbers in Enclosure 1, pages 8 through 12, of the LAR and Enclosure 7, page 3, of the supplement to the LAR dated April 28, 2017.

The NRC staff's request for additional information is documented in Reference 6. The NRC staff held a pre-submittal public meeting on April 14, 2016, documented in the meeting summary (Reference 7), to discuss the NRC staff questions (Reference 8) related to the licensee's testing plan.

#### 3.1.1 Scope of Impacted Welds

The licensee provided the total number of Cives and JO couplers that did not receive all of the required NDE and that were shipped to VEGP. The licensee also stated how many shipped couplers are installed and embedded in concrete, and how many shipped couplers are still accessible for testing. The number of Cives couplers was revised in the supplement to the LAR

dated April 28, 2017. The scope of the LAR is the installed couplers at VEGP from Cives and JO. Below is a summary table:

**Table 1: Summary of Manufacturer-Welded Couplers on Carbon Steel Embedment Plates for Vogtle Units 3 & 4**

| | Shipped | | Installed | | Accessible | |
|---|---|---|---|---|---|---|
| | Plates | Couplers | Plates | Couplers | Plates | Couplers |
| Cives | 262 | 1221 | 233 | 873* | 29 | 203 |
| Joseph Oat | 218 | 872 | 202 | 808* | 0 | 0 |

*Couplers to be approved in this LAR

Of the 1221 shipped Cives couplers, 145 couplers were removed and replaced with direct weld rebar (1221 total couplers = 873 installed + 203 uninstalled + 145 replaced with direct weld rebar). All of the installed Cives couplers were under VEGP Unit 3's CA01 module and VEGP Unit 4's CA20 module. Cives manufactured and shipped both #9 and #11 sized couplers to VEGP.

All of the installed JO couplers are part of VEGP Unit 3's CA20 module. The 16 remaining JO plates, with a total of 64 couplers, were scrapped and are, therefore, not available for testing. JO only manufactured and shipped #9 sized couplers.

All of the JO uninstalled production couplers were scrapped. Therefore, they were not available for NDE or mechanical testing. The licensee requested JO to manufacture a supplemental population of 55 embedment plates with a total of 220 #9 sized couplers. These couplers were not intended for installation, but only for testing related to the LAR.

While both #9 and #11 sized couplers were shipped to the VEGP, the licensee states that only #9 sized couplers were installed. However, the licensee included some #11 sized couplers as part of their statistical analysis. The LAR noted that VCSNS did install #11 sized couplers.

3.1.2 Weld Nondestructive Examination Results – Visual and Magnetic Particle Testing Examinations

In order to help justify that the inaccessible weld population that are in service can meet their design function, VT examination records were reviewed and MT examinations were performed on samples of accessible production and supplemental couplers.

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 each of the production coupler VT examination inspection reports were reviewed and Tables 3-1 and 3-2 of the LAR, as updated by the supplement dated April 28, 2017, tabulated the satisfactory vendor VT examination dates for the load packages and load serial numbers at Cives and JO, respectively. Table 3-3 of the LAR lists the satisfactory vendor VT examination dates and load serial numbers for the 220 JO supplemental couplers.

In addition to the VT examinations performed at the vendors, VT examinations were performed on-site before the MT examinations on the uninstalled Cives and supplemental JO couplers. The licensee stated that 24 Cives couplers had unsatisfactory on-site VT examination results. Of the 24 couplers, 22 were scrapped and 2 were still available for static tension testing. For

the JO supplemental couplers, 4 couplers had unsatisfactory VT inspection results. All 4 of these couplers were included in the static tension testing.

For the Cives couplers, 122 couplers (10 percent of the total Cives population of 1221 couplers) were MT examined from the accessible population of 203 production couplers. Enclosure 1, Table 3-12 of the LAR listed the satisfactory results of the Cives couplers' MT examinations. However, the 10 percent sample was only from 3 of the 11 production loads. Therefore, the MT examination samples of Cives couplers were not entirely representative of the population of installed couplers.

For the JO couplers, 110 of the 220 supplemental couplers were selected to account for 10 percent of the 1092 total (872 production and 220 supplemental) couplers. Enclosure 1, Table 3-13 of the LAR listed the JO supplemental coupler MT satisfactory examination results on the first 10 percent sample. Since all of these samples were part of the supplemental population, the sample set was not representative of the population of installed couplers because the couplers were manufactured three years after the manufacture of the installed population.

The licensee recognized that the MT examinations performed on the Cives couplers did not encompass all of the production couplers over time. Furthermore, the licensee recognized that the JO couplers were a supplemental population and not actual production couplers. Since the 10 percent sample sets for both Cives and JO were not representative of their respective installed populations, alternate acceptance criteria were needed to show the adequacy of the inaccessible welds. Therefore, the licensee proposed demonstrating the strength of the coupler welds through static tension testing. This additional testing was used to demonstrate that the impacted populations could meet their design function and could be dispositioned use-as-is.

3.1.3 Licensee Testing Program Overview

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

> 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 in accordance with AISC N690-1994, Section Q1.0.1 to demonstrate the adequacy of the installed #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 provides that mechanical connections shall be qualified for use in construction on the basis that at least six static and three cyclic performance tests 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 ACI 349-01 standard 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 #9 and #11 sized couplers by the vendors as part of the initial qualification tests in accordance with ACI 349-01, Section 12.14.3.4.1. The supplement to the LAR dated April 28, 2017, contained additional information related to the sample selection used for the Phase I testing. The Phase II static tension testing was performed on a representative sample of accessible, uninstalled production couplers and supplemental couplers. Table 2 contains the number and size of the Cives and JO couplers tested in Phase I and Phase II.

**Table 2: Overview of Couplers Tested in Phase I and Phase II**

| | Phase I Testing | | Phase II Testing | |
|---|---|---|---|---|
| | #9 coupler | #11 coupler | #9 coupler | #11 coupler |
| Cives | 2 | 2 | 15 | 3 |
| Joseph Oats | 2 | | 15 | |

For Phase I, the licensee did not use the cyclic tension testing results as part of their analysis because the cyclic testing is only used to show that there is no adverse impact on the coupler system from load cycling during initial qualification testing. Each of the Phase I and Phase II tests were run until failure. For Phase II, the 33 couplers tested take into account the attributes discussed in Section 3.1.4 of this safety evaluation 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 in the Phase II static testing to the coupler weld, 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 stainless steel samples with and without the fixture weld, and the supplement dated April 28, 2017, provided additional hardness testing information. 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." The licensee also stated that the recent Phase II testing was performed in a qualified laboratory using a formal quality assurance program.

3.1.4 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.

Of the 33 Phase II samples, 15 samples were from the JO supplemental population, and 18 samples were from the accessible Cives population. Three of the accessible 18 Cives couplers were #11 sized couplers. As previously discussed, the licensee combined the test data from both vendors into a single data set for analysis.

The licensee stated that semi-automatic gas metal arc welding (GMAW) was the only weld process used on the entire population at both vendors in the horizontal position. The licensee stated that the applicable vendor's welding procedure specifications (WPS) and Production Qualification Records (PQR) were reviewed and qualified in accordance with American Welding Society (AWS) D1.1-2000, "Structural Welding Code-Steel," (Reference 9) and AWS D1.4-1998, "Structural Welding Code-Reinforcing Steel" (Reference 10). The same weld procedures were used for the installed, uninstalled, and supplemental populations. The licensee also reviewed the welder qualification records for both the production and supplemental populations. The supplement to the LAR dated April 28, 2017, stated that both the JO production and supplemental couplers were manufactured to the same WPS revision. Lastly, the work packages were reviewed to confirm that the welds were created to the appropriate WPS and PQR.

The licensee proposed six different test groups for the Phase II static tension testing that could represent the possible inspection results if the installed welds underwent NDE at the vendor. None of the couplers were ground (profiled) to their minimum design specification.

i. Six original production couplers that had satisfactory VT and MT examinations.
ii. Ten original production couplers that had satisfactory VT examinations, but did not receive MT examinations.
iii. Two original production couplers that had unsatisfactory on-site VT examinations, and did not receive MT examinations.
iv. Two supplemental couplers that had satisfactory VT and MT examinations.
v. Nine supplemental couplers that had satisfactory VT examinations, but did not receive MT examinations.
vi. Four supplemental couplers that had unsatisfactory on-site VT examinations, and did not receive MT examinations.

Therefore, 19 of the total number of samples had satisfactory VT examinations and did not receive MT examinations.

The licensee reviewed the Certified Mill Test Reports (CMTRs) for the filler material, and 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 coupler material properties were taken from the four load numbers – the three accessible Cives loads, and the supplemental JO couplers. The minimum required properties are referenced in the statistical analysis of the LAR.

In summary, the licensee tested 30 #9 and 3 #11 sized couplers from the uninstalled and supplemental populations. These 33 couplers take into account the above attributes to ensure that the test results are representative of the inaccessible population. Since the available Cives couplers only represent 3 of the 11 load numbers, and the supplemental JO couplers were manufactured three years after the production couplers, the licensee does not use fabrication schedule as part of its justification.

3.1.5 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 for both the #9 and

#11 sized couplers. Also, the rebar or threads failed before the coupler welds 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 of the LAR. Since each production load had a different CMTR, the licensee stated which load number corresponds to each test coupler.

Since the data was normalized, the results for the #9 and #11 couplers were combined into one data set. First, the licensee calculated the mean and standard deviation of the normalized values. Secondly, the licensee calculated the lower bound 90/95 percent confidence interval for the normalized value based on the sample size. The licensee defined the lower 90/95 percent confidence interval value as the test coefficient, “c”.

The licensee also investigated the failed samples to see if the fixture weld influenced the failure load of each test sample. The supplement to the LAR dated April 28, 2017, states that none of the failures were influenced by the fixture weld and that the results followed a normal distribution.

Using the “c” value, the minimum CMTR values of the tensile strength of the coupler bodies, and the areas of the #9 and #11 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. Using these two values, the licensee then 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 90/95 percent confidence interval system strength from the Phase I results. The same “c” value was used for both the #9 and #11 couplers since the coupler body values only depended on the coupler area (size). Therefore, the factors of safety were calculated for both the #9 and #11 sized couplers. Table 3 contains the licensee’s calculated margins:

**Table 3: 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 upper 90/95 percent failure strength of rebar |
|---|---|---|
| #9 | 2.08 | 1.42 |
| #11 | 2.19 | 1.59 |

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 above both 125 percent of the yield strength of the rebar, and the upper 90/95 percent confidence interval of the failure strength of the rebar for both sizes of couplers. 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 NRC Staff Evaluation

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 determining that the test coupler welds were representative of the inaccessible weld population.

For its evaluation, the NRC reviewed:

- The VEGP UFSAR Section 3.8, "Design of Category I Structures;"
- Portions of NUREG–1793, Supplement 2, "Final Safety Evaluation Report Related to Certification of the AP1000 Standard Plant Design" (Reference 11) which documented the NRC staff's technical evaluation of the relevant aspects of the AP1000 DCD (Reference 12);
- The "Final Safety Evaluation Report for the VEGP Electric Generating Plant Units 3 and 4 Combined License Application" (Reference 13), which documented the NRC staff's technical evaluation of the relevant aspects of the VEGP Units 3 and 4 UFSAR, respectively; 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 VT examination, MT examination, and static tension testing of a representative population in lieu of the required NDE. In order for the results from the test samples to be correlated with the inaccessible welds, justification needed to be presented to demonstrate that the tested welds were representative of the inaccessible welds.

The licensee reviewed each inspection report for both the Cives and JO production couplers to ensure that VT examinations were performed on each coupler and that the VT examination results were satisfactory. The licensee found that VT examinations were performed at the vendors on 100 percent of the welds, and the results were satisfactory. VT examinations were also performed on the supplemental JO couplers. The staff found the VT examinations performed acceptable since the licensee reviewed all of the vendor VT examination reports to ensure that VT examinations were performed in accordance with AISC N690-1994, and that all of the vendor VT examination results were satisfactory.

The on-site VT examinations were performed in addition to the vendor VT examinations that are required by AISC N690-1994. The licensee stated that 24 Cives couplers had unsatisfactory on-site VT examination results. The licensee scrapped 22 out of the 24 couplers in response to a corrective action to prevent these couplers from being installed. While these scrapped 22 couplers were not available, the remaining two couplers were included for static tension testing. The staff reviewed the results of the static tension testing and found that the two couplers had similar results to the couplers that had satisfactory on-site VT examinations. In addition, the two

couplers had similar results to couplers that also had satisfactory MT examinations. Therefore, the staff found the VT examinations performed on-site acceptable since the results were either satisfactory or appropriately dispositioned.

The licensee performed MT examinations on the Cives production couplers that consisted of 10 percent of the total population of 1221 couplers. The licensee also performed MT examinations on the JO supplemental couplers that represented 10 percent of the total combined (production and supplemental) population of couplers. The staff reviewed the specific number of welds that were MT examined and confirmed that the 10 percent MT examination samples account for the entire populations of couplers. For the Cives couplers, the staff concluded that the MT examination results provide some support for the conclusion that the installed couplers are acceptable, but additional support was needed because the tested couplers came from only 3 of the 11 production loads. For the JO couplers, the staff concluded that the MT examination results also provide some support for the conclusion that the installed couplers are acceptable, but additional support was needed because the supplemental couplers were from a different production run.

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 for the entire population of production couplers and supplemental couplers. Only the semi-automatic GMAW weld process was used to fabricate the coupler welds, and the weld processes and positions were the same for each coupler. Since the welds were created using a semi-automatic process, there is confidence that all of the welds are manufactured consistently. Finally, the licensee stated that they reviewed the applicable WPSs, PQRs and welder qualification records 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 found the use of qualified welders, welding processes, and welding procedures in accordance with AWS D1.1 provided 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 found that performing the static tension tests at ambient temperatures was acceptable.

The licensee developed six test groups for the Phase II static tension testing in order to account for each of the potential inspection results. By having samples from each group, the data derived is more representative of the inaccessible population. The majority of the test samples (19/33) had satisfactory VT examinations and did not receive MT examinations. The NRC staff found that the selection of test welds was acceptable since they represent the condition of the inaccessible population. The NRC staff also concluded that testing the two available Cives couplers, and four supplemental JO couplers that failed the on-site VT examination acceptable as it provides more test data as these welds do not meet the design specification and they could represent the potential conditions of the inaccessible population.

Based on the VT and MT examinations that were performed, the review of the welding processes and procedures, and the selection of the tensile testing examination groups, the NRC

staff has reasonable assurance that the supplemental test specimens are representative of the inaccessible weld population and the data derived from the weld testing program represents the inaccessible weld population. However, since the supplemental couplers were produced 3 years after the productions couplers, which might impact the Phase II test results, the NRC staff performed its own independent calculation that is discussed in Section 3.2.4 of this safety evaluation and that included additional conservatism to account for possible differences in production runs.

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 providing that 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 the modules, the staff found 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 staff finds its use acceptable as it provides a minimum standard that can be compared to the strength of the test weld.

The licensee's Phase I testing was performed using samples that were taken during PQR qualification. 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 from 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 staff found not using any of the cyclic testing data required 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.

For the Phase II testing, the licensee used a single set of test data that combined Cives production couplers of two different sizes, as well as the JO supplemental couplers. Therefore, as previously discussed since the supplemental couplers might have an impact on the Phase II test results, the NRC staff performed its own independent calculation that is discussed in Section 3.2.4 of the safety evaluation report which included additional conservatism.

The supplement to the LAR dated April 28, 2017, provided additional information regarding the test fixture design of the coupler welded to the oversized coupler. The NRC staff reviewed this additional information and found that the hardness testing was an acceptable test method since it was consistent with accepted hardness testing practices, and that the results demonstrated that the fixture weld does not have any impact on the strength of the coupler weld.

The NRC staff found the use of ASTM A370 for the Phase I and Phase II static tension testing acceptable as this standard is used throughout industry and the use of this standard provided consistency between each phase of testing, and each individual test itself.

Based on the above review and the results of the NRC staff's independent calculation discussed in Section 3.2.4 of this SE, the staff finds that the licensee's methodology of determining the factors of safety is acceptable.

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 its 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 that the values exceeded 125 percent of yield strength of the rebar for both the #9 and #11 sized couplers.

The licensee's methodology used several conservatisms in its 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, using the minimum CMTR values, and normalizing the break strength of the coupler body to the coupler weld.

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 2.08 and 2.19 for the #9 and #11 sized couplers, respectively. The NRC staff found these factors of safety, with all of their conservatisms, acceptable because they are an additional margin above the minimum ACI 349-01 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 sample sizes, this provided an even more direct comparison to the strength of the coupler weld. Using this criterion, the licensee calculated factors of safety of 1.42 and 1.59 for the #9 and #11 sized couplers, respectively. The staff found these factors of safety, with all of their 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 using a different methodology. The NRC staff used different conservatisms to provide reasonable assurance of the inaccessible couplers' strength using the test coupler data, specifically due to the use of supplemental couplers. Independent of the licensee's methodology, the 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 for the 95/95 percent confidence interval for each

coupler size. The staff notes that the values of the four #9 sized Cives and JO couplers in the Phase I testing were combined due to being from initial qualification testing. The staff used a 95/95 percent confidence interval as an additional conservatism compared to the 90/95 percent requirement in ACI 349-01. Using this k values, the staff calculated the upper 95/95 percent confidence interval for the failure of the system for each coupler size.

For the Phase II data, the staff did not normalize the break strengths of the #9 and #11 sized coupler bodies and combine the data sets. Since the coupler body failed before the coupler weld, the coupler body is weaker and therefore using that value provides a more realistic value. Furthermore, the staff did not combine the #9 sized Cives and JO couplers into a single data set due to the JO couplers not being production couplers. The staff calculated the mean and standard deviation for the 15 #9 sized Cives couplers, the 15 #9 sized supplemental JO Couplers, and 3 #11 sized Cives couplers. Using these three sample sizes, the staff found the three 95/95 percent k values and then calculated the lower failure strength for each data set.

The NRC staff compared these three values to the same acceptance criteria of 125 percent of the yield strength of the rebar and the larger and more conservative upper 95/95 percent failure strength of the coupler systems that was calculated by the NRC staff using the Phase I data. The NRC staff's calculated factors of safety for each vendor and coupler size are in Table 4:

**Table 4: Safety Margins (Factors of Safety) Calculated by NRC Staff**

| Vendor | Coupler Size | Margin compared to 125 percent of the Yield Strength of the rebar | Margin compared to the upper 95/95 percent failure strength of rebar |
|---|---|---|---|
| Cives | #9 | 2.23 | 1.48 |
| Joseph Oat* | #9 | 2.32 | 1.55 |
| Cives | #11 | 2.64 | 1.88 |

*Supplemental couplers

As an additional comparison, the NRC staff performed a t-test to compare the #9 sized production Cives couplers to the #9 sized supplemental JO couplers to see if the two populations were statistically different. The NRC staff used an alpha value of 5 percent. The t-test concluded that there is not a significant difference between the data sets.

The NRC staff found the factors of safety calculated by the licensee comparable with the NRC staff's independent analysis. These factors of safety demonstrate, with a high degree of confidence and margin, that the coupler welds are stronger than the rebar. Therefore, the NRC staff concluded 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 factors of safety determined and verified by the NRC staff, the NRC staff found 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 in the LAR and supplement dated April 28, 2017, 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 noted that the proposed change to UFSAR Subsection 3.8.4.5 is identical to the proposed change in LAR 16-016, as supplemented (References 15 and 16). The licensee also noted that the order of incorporation of either change, following NRC's approval, will not impact review, approval, or incorporation of the change in the other LAR. The staff does not identify any issues with this approach.

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

*[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 Section Q1.26.2.2, for the non-conforming partial penetration welds associated with reinforcement bar size #9 C3J couplers installed on carbon steel embedment plates under CA20 at Vogtle Unit 3 and Unit 4 and under CA01 at Vogtle Unit 3 that did not undergo non-destructive examination at the time of fabrication, as identified in Amendment Nos. [XXX and YYY] for VEGP Units 3 and 4 respectively, the strength and quality of the welds is demonstrated through non-destructive examination and static tension testing of portions of the original production and supplemental, uninstalled populations and through visual examination of the production populations as follows:*

  - *Visual Examination: Coupler welds from the production fabrication populations underwent visual examination by the manufacturers. The manufacturers' 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 populations of #9 sized C3J coupler welds on carbon steel embedment plates is adequate in the ability to perform their intended design function, static tension testing of portions of the original production and supplemental, uninstalled populations of welds is evaluated experimentally in two phases.*

*Phase I: Static tension testing has been performed on a total of four #9 sized couplers. The static tension test results were evaluated to obtain the 90/95% confidence interval break strength. 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 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 30 #9 sized couplers and 3 #11 sized couplers were tested. 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 populations of coupler welds, the test sample population considered factors such as sample size, weld process, semi-automatic processes, human performance factors, welding procedure specification, non-destructive examination, 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 thread). The minimum safety margin with respect to the 125% yield strength of the rebar was calculated to be 2.08 for the #9 sized couplers. The minimum safety margin with respect to the system strength was calculated to be 1.42 for the #9 sized couplers.*

- *Non-destructive examination of portions of the original production and supplemental, uninstalled populations: Magnetic particle examination was performed on 10% of the total populations of welds from the uninstalled original production population and from the uninstalled supplemental population. The magnetic particle examinations provided satisfactory results.]**

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, and describes the test methodology used to calculate the safety margins for each coupler size. Therefore, the NRC staff concluded that the proposed UFSAR wording is acceptable.

3.2.6 Summary

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

(1) The #9 and #11 sized couplers that were used as test specimens are adequately representative of the inaccessible 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 #9 and #11 sized coupler welds successfully demonstrated adequate weld capacity for the inaccessible weld population by either analysis or testing. Therefore, the NRC staff finds that while standards in AISC N690-1994 Sections Q1.26.2.2 related to inspecting all impacted welds were not met, 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, respectively. 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 August 10, 2017. The NRC staff confirmed that the State official had no comments on August 14, 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 (82 FR 13662; published on March 14, 2017) 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-16-1894, "Southern Nuclear Operating Company Vogtle Electric Generating Plant Units 3 and 4 Request for License Amendment: Nondestructive Examination for Welds of Couplers to Carbon Steel Embedment Plates (LAR-16-027)," dated October 20, 2016 (ADAMS Accession No. ML16294A521).

2. ND-17-0576, "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 Carbon Steel Embedment Plates (LAR-16-027S1)," dated April 28, 2017 (ADAMS Accession No. ML17118A129).

3. Vogtle Electric Generating Plant Units 3 and 4 Combined License Updated Final Safety Analysis Report, Revision 5, dated June 17, 2016 (ADAMS Accession No. ML11180A100).

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

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

6. Request for Additional Information Regarding Vogtle, Units 3 and 4 LAR-16-027, dated January 26, 2017 (ADAMS Accession No. ML17026A426).

7. 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. NRC Staff Questions about Cives SS Test Plan, dated April 13, 2016 (ADAMS Accession No. ML16104A053).

9. American Welding Society (AWS) "Structural Welding Code – Steel," 2000 (AWS D1.1-2000).

10. American Welding Society (AWS) "Structural Welding Code – Reinforcing Steel," 1998 (AWS D1.4-1998).

11. 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).

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

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

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. 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).

16. 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. ML16242A400).