South Carolina Electric and Gas Company
Virgil C. Summer Nuclear Station (VCSNS) Units 2 and 3

NND-14-0450

Enclosure 5

# APP-GW-GLR-603, Revision 4, AP1000 Shield Building Design Details for Select Wall and RC/SC Connections (Non-Proprietary)

F-6.1-2 Rev 1

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May 2014

# AP1000 License Report

# AP1000® Shield Building Design Details for Select Wall and RC/SC Connections

**Note: Except as noted, the information in this document is considered to be Tier 2*.**

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**Record of Revisions**

| Item | Section | Change | Reason for Change |
|---|---|---|---|
| 1 | Cover | Added note about Tier 2* | NRC request |
| 2 | List of Tables | Deleted Table 2 | Table 2 deleted |
| 3 | List of Figures | Added Figure 7 | Figure 7 added |
| 4 | 1 | Added explanation of Tier 2* | Previous revision designated but did not explain Tier 2* |
| 5 | Table 1 | Change "liner plate" to "faceplate" | Consistency with DCD and Shield building report. |
| 6 | Table 1 | Added Connection Dowels | Additional item for material information |
| 7 | Table 1 | Added Shear Lug | Additional items for material |
| 8 | 2 | Updated Shield Building Report Reference | Shield Building Report revised. |
| 9 | 2 | Added note about Tier 2* | Clarification |
| 10 | 3 | Added reference to subsections in Section 3.8 | Section 3.8 revised to refer to GLR-603 |
| 11 | 3 | Added explanation of Tier 2* | Clarification |
| 12 | 4 | Added reference to subsections in Section 3.8 | Section 3.8 revised to refer to GLR-603 |
| 13 | 4 | Added note about implementation of Tier 2* | Consistency with DCD approach for Tier 2* info. |
| 14 | 4 | Change "liner plate" to "faceplate" | Consistency with DCD and Shield building report. |
| 15 | 4 | Added phrase to steel specification to permit steel with equal or better material properties | Resolution of NRC comment. |

| Item | Section | Change | Reason for Change |
|---|---|---|---|
| 16 | 4 | Changed italic font to regular font for reinforcement info. | Since this report is a Tier 2* report additional designation is not needed. |
| 17 | 4 | Revise description of faceplate welds | Clarification |
| 18 | 4 | Added information on connection between the RC Auxiliary Building Roof and steel concrete composite (SC) Shield Building | NRC request |
| 19 | Table 2 | Deleted Table 2 | Information is not proprietary and is moved to DCD Table 3H.5-15 |
| 20 | Figure 1 | Added reference to Tier 2* information in Section 1 | Refer to information added about Tier 2* |
| 21 | Figure 2 | Added reference to Tier 2* information in Section 1 | Refer to information added about Tier 2* |
| 22 | Figure 3 | Added reference to Tier 2* information in Section 1 | Refer to information added about Tier 2* |
| 23 | Figure 3 | Added information on size of gusset and support plates | NRC request |
| 24 | Figure 4 | Added reference to Tier 2* information in Section 1 | Refer to information added about Tier 2* |
| 25 | Figure 5 | Added reference to Tier 2* information in Section 1 | Refer to information added about Tier 2* |
| 26 | Figure 5 | Moved arrows identifying parts | Previous revision did not point to correct locations |
| 27 | Figure 6 | Added reference to Tier 2* information in Section 1 | Refer to information added about Tier 2* |
| 28 | Figure 7 | Figure added to show connection between the RC Auxiliary Building Roof and Steel Concrete Composite (SC) Shield Building | NRC request |

| Item | Section | Change | Reason for Change |
|---|---|---|---|
| Revision 2 | | | |
| 1 | Table 1 | Added items to component list | Component added in revised design |
| 2 | 1 | Editorial | |
| 3 | 4 | Revised description of location of connections | Location of connections shifted. |
| 4 | 4 | Revise description of item welded to endplates | Revised design |
| 5 | 4 | Added mention of consideration of AISC N690 | Added for clarification and completeness |
| 6 | 4 | Editorial change to description of Type 1 Modules | |
| 7 | Figure 1 | Changed Azimuth and Support Plate Width | Location of connections shifted. |
| 8 | Figure 6 | Revised legend | Clarification |
| 9 | Figure 6 | Added note to permit increase tie bar density and size locally | Revised design |
| 10 | Figure 6 | Revise figure to shift vertical connection on right side of figure and move connection zone around penetrations. | Revised design |
| 11 | Figure 7 | Revised figure to show design without radial reinforcement | Revised design |
| 12 | Figure 7 | Revised Note 1 to change reinforcement design requirement | Revised design basis |
| 13 | Figure 7 | Revised Note 2 to clarify design basis | Clarify design basis |
| Revision 3 | | | |
| 1 | List of Figures | Revised title of Figures 4 and 7 | |
| 2 | Section 4 | Revised sentence about location of design detail in licensing basis. | Added for clarification and completeness |

| Item | Section | Change | Reason for Change |
|---|---|---|---|
| 3 | Section 4 | Added paragraph about alternate connection design | Added for clarification and completeness |
| 4 | Section 4 | Added "significant features" to what design details describe | Added for clarification and completeness |
| 5 | Section 4 | Revised description of standard vertical connection | Added for clarification and completeness |
| 6 | Section 4 | Added reference to N690 | Clarify design basis |
| 7 | Section 4 | Added variance for interferences | Clarify design basis |
| 8 | Section 4 | Corrected description of Figure 6. | Clarify design basis |
| 9 | Section 4 | Add discussion of penetrations through wall | Added for clarification and completeness |
| 10 | Section 4 | Revised paragraph to allow for more dense tie bar spacing. | Added for clarification and completeness |
| 11 | Section 4 | Add information to identify variances in aux building to SC wall connections | Added for clarification and completeness |
| 12 | Section 4 | Add reference for supplemental requirements for RC to shield building SC connections identified in Subsection 3.8.4.5.5.6 | Added for clarification and completeness |
| 13 | Section 4 | Added information on coupler requirements | Added for clarification and completeness |
| 14 | Figure 1 | Redrew gusset plate and deleted "Design Minimum" for Support Plate | Clarify design basis |
| 15 | Figure 4 | Redrew Gusset plate | Clarify design basis |
| 16 | Figure 4 | Changed "Typical" in title to "Representative". | Clarify design basis |
| 17 | Figure 6 | Add note about connection design in vicinity of penetrations | Added for clarification and completeness |
| 18 | Figure 7 | Revise note 2 to add information about variances in connection design | Added for clarification and completeness |
| 19 | Figure 7 | Add note to provide reference to supplemental design requirements in Subsection 3.8.4.5.5.6 | Added for clarification and completeness |
| 20 | Figure 7 | Removed the note about the couplers and put the requirement in revised text. | Revised figure does not include couplers. |
| 21 | Figure 7 | Revised title of figure | Clarify use of figure. |
| Revision 4 | | | |

| Item | Section | Change | Reason for Change |
|---|---|---|---|
| 1 | 4 | Added reference to Figure 2 | Clarification of design differences |
| 2 | 4 | Described increased capacity of the tie bars for attachment | Clarification of design differences |
| 3 | 4 | Added description of connection design variations | Clarification of design differences |
| 4 | 4 | Added information on couplers | Added for clarification and completeness |
| 5 | Figure 4 | Changed "Representative" to "Typical" in title | Response to lessons learned |
| 6 | Figure 6 | Revised Note 2 to describe tie bar size and spacing | Added for clarification and completeness |
| 7 | Figure 7 | Changed "Representative" to "Typical" in title | Response to lessons learned |

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## LIST OF FIGURES

# 1 INTRODUCTION

This report documents proprietary design detail information, including Tier 2* information, for the AP1000 Shield Building cylinder and connections to the auxiliary building and basemat as described in design basis documents. *Tier 2** means the portion of the Tier 2 information, designated as such in the AP1000 design control document, which is subject to the change process in Section VIII of the AP1000 design certification rule. An applicant who references the AP1000 design certification rule may not depart from Tier 2* information, without NRC approval. See Section 3.5 of the introduction to the AP1000 Design Control Document (APP-GW-GLR-700) for a discussion of Tier 2* information. This information is consistent with the information previously provided in the Shield Building Report (Reference 1). Except as noted the information in this document is considered to be Tier 2*. A Tier 2* designation for a figure means that the design implemented in fabrication and construction drawings and instructions will have the design shown, an equal design, or a better design for the key structural elements.

The NRC staff, in its review of information in reports and responses to Requests for Additional Information (RAIs) provided by Westinghouse to support the AP1000 Design Certification amendment, identified information that should be incorporated into the Design Control Document (DCD). Some of this information provided to explain, define, and support the Shield Building design has been determined to be information proprietary to the Westinghouse Electric Company LLC. In conformance with the requirements of 10 CFR Section 2.390 Sensitive Unclassified Non-Safeguards Information, including proprietary information submitted to the NRC, may be withheld from public disclosure.

The AP1000 uses the innovative application of steel-concrete composite construction in the design of the shield building. Design information and criteria to demonstrate the strength of the shield building and the response to seismic and other loads is based on [ ]$^{a,c}$. This design information is not publicly available and is proprietary. The NRC staff has determined that some of this detailed design information, in particular key design information for the design and construction of the shield building, is of sufficient importance that it should be incorporated into the DCD. This report considers the design details that are contained within selected portions of the shield building that are incorporated into DCD Section 3H by reference to this document.

The list of components with the material properties used in the enhanced shield building is identified in the following table.

| Table1<br>LIST OF COMPONENTS AND MATERIAL PROPERTIES USED IN THE SHIELD BUILDING | |
|---|---|
| **Component** | **Material** |
| RC to SC Connection Components Stiffener Plate, Faceplate, Gussets, Support Plate, End Plate | ASTM A572 Gr50[1] |
| [ ]$^{a,c}$ Tie Bar in RC/SC Connection | ASTM A706[1] |
| [ ]$^{a,c}$ Tie Bar | ASTM A496[1] |
| [ ]$^{a,c}$ Stud | ASTM A108[1] |
| [ ]$^{a,c}$ | ASTM A615 Gr60[1] |
| [ ]$^{a,c}$ | |
| [ ]$^{a,c}$ | |
| Dowels at connection of Auxiliary Building roof and Shield Building. | |
| Connection with Auxiliary Building Roof Shear Lug, Connection Plate, Stiffener Plate, Backing Plate | ASTM A572 Gr50[1] |

[1]Steel with equal or better material properties may be used in place of the listed material.

## 2 REFERENCES

1. APP-1200-S3R-003; Design Report for the Enhanced Shield Building, Revision 4, June 2011 (Westinghouse Proprietary)

**Note: This reference is not designated as Tier 2*. The information included in the Shield Building report is not considered to be Tier 2* information.**

## 3 REGULATORY IMPACT

This document documents and summarizes key structural design details of the AP1000 shield building. The technical information contained within this report is derived from the information contained in the Shield Building report for selected shield building components. The information included in the Shield Building report was subject to extensive review by the NRC as part of their review of the Shield Building design. The Shield Building report (Reference 1) was docketed during the review.

The information included in the text, table, and figures of this report (APP-GW-GLR-603) is incorporated by reference as part of the DCD in Subsections 3.8.4.1, 3.8.4.5.4, 3.8.4.5.5, 3.8.4.6.1.3, and Appendix 3H.5.7 and is considered to have the same level of importance as information as the reference itself. The generation and

revision of this report is subject to the same process and review as DCD information. Tier 2* information in this report is subject to the same requirements for NRC approval as Tier 2* information in the DCD.

The information included in this report was identified by the NRC as important to their conclusions documented in the Safety Evaluation Report supplement for the AP1000 Design Certification amendment. The information required to be included in this report was discussed with the NRC during meetings and phone call in January, February and March 2011.

# 4 TECHNICAL BACKGROUND

This report identifies selected proprietary design detail information for the AP1000 Shield Building cylinder and connections to the auxiliary building and basemat as described in design basis documents. It is intended to be consistent with the information which was provided in the Shield Building Report (Reference 1) and Appendix 3H5.7 of the DCD.

This report provides the requisite design details that are contained within selected portions of the auxiliary and shield building significant features and critical sections that are part of DCD Subsections 3.8.4.1, 3.8.4.5.4, 3.8.4.5.5, 3.8.4.6.1.3, and Appendix 3H. In compliance with the Tier 2* designation of the information in this report, the design implemented in fabrication and construction drawings and instructions will have the design described, an equal design or a better design for the key structural elements.

**Steel Concrete Composite (SC) Shield Building RC/SC Connection Zone Details (3H.5.7.2)**

Figure 1 shows the representative details for the vertical RC/SC connection zone which are based on Figure 4.1-2 of the enhanced SB design report (Reference 1). The faceplate, support plate, and gusset plates are American Society of Testing Materials (ASTM) A572 Grade 50 or steel with equal or better material properties. The steel faceplate is thickened in this region to 1.0 inch thick. The connection design methodology for the bars connected to the support plates is similar for each of the RC/SC connections and the vertical connections at approximately elevations 100' and 146'-10". The lower connection connects reinforcement bars anchored in the base concrete below the shield building with the SC shield building walls. The upper connection connects the reinforcement bars in the RC shield building wall below the auxiliary building roof with the SC shield building wall at and above the auxiliary building roof.

Vertically oriented hoop bar connections with the SC walls located at Azimuths of approximately 340 degrees and 183 degrees connect the shield building outside the auxiliary building with the RC shield building wall below the auxiliary building roof. Views of the hoop bar [ ]$^{a,c}$ are shown in Figures 2 and 3. Figure 3 shows the connection above Elevation 103'-6" which uses a support plate inside the module to capture the hoop bars. Over the height of the connection of the vertical bars, from approximately Elevations 100' to 103'-6", a different connection detail using an end plate on the connection module is used to allow for welding of the [ ]$^{a,c}$ to the SC modules. The end plate and [ ]$^{a,c}$ to the plate are shown in Figure 2. [

]$^{a,c}$

The gusset and support plates and connecting welds in the connection modules are sized to satisfy AISC N690 criteria. The connection design elements dimensions may vary from those shown in the figures to address local geometry and loads. In the vicinity of penetrations and other interferences the design elements of the connections may be shifted from the design shown in the figure to avoid the interferences. A penetration near Wall Q (approximately Azimuth 340) is located in a corner connection module (see Figure 4) which includes both vertical and horizontal connections. In this module a portion of the horizontal support plate is shifted down to provide clearance between the penetration and the connection of the vertical reinforcing bars. The vertical endplate (shown in Figure 2) is extended above the area of the penetration because of interference between the penetration and the vertical support bracket which provides connections for the hoop bars in the RC wall. As noted below the penetration structural sleeve is designed to replace the tie bars function in the area of the sleeve.

In the vicinity of the steam line and feedwater line penetrations at approximately Azimuth 0 degrees the vertical connection is different than described above. A welded steel connection assembly carries the load from a vertical connection plate on one side of the penetration to the shield building wall faceplates on the other side. The hoop reinforcement is connected to the vertical connection plate similar to the end plate shown in Figure 2. The vertical connection plate is connected to the wall module faceplates with plates on the inner and outer surface of the wall. The connection assembly is designed as a welded steel assembly satisfying the requirements of AISC N690.

The [ ]$^{a,c}$ that are welded to the steel faceplates in the connection modules are ASTM A706 or steel with equal or better material properties. The [ ]$^{a,c}$ are made of ASTM A496 or steel with equal or better material properties.

DCD Table 3H.5-14 (Sheet 3 of 3) shows the plate thickness provided and plate thickness required for mechanical load cases. This location, on the west side at grade, is one of the most stressed locations in the shield building under SSE loading due to overturning of the cylinder. The shear reinforcement required is also calculated. [ ]$^{a,c}$ The out of plane shear capacity is calculated using beam action equations in ACI-349 Section 11, including the reduction in concrete shear strength when the section is under significant tension.

The welds that anchor the faceplates to the RC/SC connection are complete joint penetration (CJP) welds, as defined by AWS A3.0M/A3.0:2010. The welds that connect the faceplate to faceplate are also CJP welds.

**Steel Concrete Composite (SC) Shield Building Wall Panel (3H.5.7.1)**

Figure 5 shows the representative details for a standard (Type 2 module) shield building wall panel which are based on Figure 3.1-2 of the enhanced SB design report (Reference 1). [

]$^{a,c}$ fabricated of ASTM A572 or steel with equal or better material properties steel faceplates on each face. The[ ]$^{a,c}$ are made of ASTM A496 or steel with equal or better material properties. The studs are [ ]$^{a,c}$ made of ASTM A108 material or steel with equal or better material properties.

Type 1 modules are fabricated in the same manner except [ ]$^{a,c}$
Type 1 modules are used in regions with higher out of plane shear.

The studs and tie bars are provided to ensure composite action. [ ]$^{a,c}$ Penetrations through shield building wall panels displace tie bars and studs in the local area. These penetrations through the wall panels and connection modules are designed with the use of a structural sleeve. The structural sleeve is designed to replace the tie bar area and develop the capacity of the tie bars displaced.

DCD Table 3H.5-14 (Sheet 2 of 3) provides details about the loading and plate required and provided for an element with maximum out of plane demand for a Type 2 module outside of [ ]$^{a,c}$ This element is located at elevation 175 ft near wall 7.3 above the auxiliary building roof line. The shear reinforcement required is also calculated. [ ]$^{a,c}$ The out of plane shear capacity is calculated using beam action equations in ACI-349 Section 11, including the reduction in concrete shear strength when the section is under significant tension.

DCD Table 3H.5-14 (Sheet 1 of 3) provides details about the loading and plate required and provided for an element with maximum out of plane demand for a Type 1 module inside of [ ]$^{a,c}$ This element is located at elevation 180 ft near fuel handling building roof line. The shear reinforcement required is also calculated. [ ]$^{a,c}$
The out of plane shear capacity is calculated using beam action equations in ACI-349 Section 11, including the reduction in concrete shear strength when the section is under significant tension.

The tie bars are welded to the steel face plates using a weld detail that will develop 125% of the specified yield of the bar. The faceplates are connected to adjacent panels with a complete joint penetration weld.

Figure 6 shows the locations of Type 1 and Type 2 tie bar spacing provided for global out of plane shear loads in a rolled-out circumferential developed view of the shield building wall. **An increase in the tie bar capacity may be provided to handle local attachments and connections in the area of the attachments and connections. The increased capacity is achieved using reduced spacing between the tie bars or bigger tie bars. The modules which have a decreased spacing for local connections and attachments are not shown on this figure. The spacing of tie bars in these areas may be equal to the spacing of tie bars in Type 1 modules.** The locations of the RC/SC connection zone modules are also shown in Figure 6. This figure is based on Figure 4.1-1 of the enhanced SB design report (Reference 1). The SC Shield Building walls are anchored to the RC basemat and walls by [ ]$^{a,c}$

**Connection Between the RC Auxiliary Building Roof and Steel Concrete Composite (SC) Shield Building (3.8.4.1)**

Figure 7 shows representative details for the connections between the RC auxiliary building roof and the SC Shield building wall. The details of the connections between the auxiliary building roof and the shield building wall vary because of loads on the connection and the orientation of the wall to the roof reinforcement grid. The design variations include the use of spacers or other design elements to accommodate the offset in the elevation for different layers of reinforcement. The variations also include the use of [ ]$^{a,c}$ connected to the vertical surface of design elements. The several different configurations have the roof reinforcement directly connected by welding or mechanical connectors to a connector plate that is welded to shield building wall faceplate or to connector plates built up on the faceplate. The design and construction of the connection within the reinforced concrete roof is governed by ACI-349 and by AISC N690 for steel and weld stress evaluation.

These connections satisfy the supplemental requirements for RC to shield building SC connections identified in Subsection 3.8.4.5.5.6 of plant specific DCDs. [

]$^{a,c}$

[ ]a,c

Note: See Section 1, INTRODUCTION for information on Tier 2* requirements.


a,c

**Figure 2: Plan View of RC/SC Connection of [ ]$^{a,c}$ from Elevation 100 Feet to Elevation 103 Foot, 6 Inches**

Note: See Section 1, INTRODUCTION for information on Tier 2* requirements.

a,c

**Figure 3: Plan View of RC/SC Connection of [ ]$^{a,c}$ above Elevation 103 Feet, 6 Inches**

Note: See Section 1, INTRODUCTION for information on Tier 2* requirements.

a,c

**Figure 4: Typical Interface Between Vertical Bar [ ]$^{a,c}$ and Hoop Bar [ ]$^{a,c}$ at grade**

Note: See Section 1, INTRODUCTION for information on Tier 2* requirements.

a,c

**Figure 5: Nominal SC Panel Details**

Note: See Section 1, INTRODUCTION for information on Tier 2* requirements.


**Figure 6: Rollout View Detailing Nominal Spacing of Tie Bars (Viewed from SB Interior)**

Note: See Section 1, INTRODUCTION for information on Tier 2* requirements.

1. The connection inside the shield building wall is provided by through wall tie bars sized to fully develop the Auxiliary Building Roof reinforcement.
2. This connection is typical of connections in sections of the roof away from discontinuities such as walls or openings and represents the fundamental load path from the Auxiliary Building Roof reinforcement through the connection plates and tie bars to the far face plate of the shield building wall. Details of the connection design between the auxiliary building roof and the shield building wall vary because of loads on the connection and the orientation of the wall to the roof reinforcement grid.
3. See Table 1 for material information for connection reinforcement bars and shear lug.
4. Figure not to scale.
5. See Section 1, INTRODUCTION for information on Tier 2* requirements.
6. Supplemental design requirements for RC to SC shield building connections are provided in Subsection 3.8.4.5.5.6 of the plant specific DCD.

**Figure 7 Typical Auxiliary building RC roof connection to the shield building SC wall**