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Your ref: Docket No. 52-006
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October 21, 2009

Subject: Non-Proprietary Version of NRC Comment Letter (10/15/09) on AP1000 Shield Building

We appreciate the opportunity to review the subject letter and comments pursuant to 10 CFR 2.390 regarding its content for proprietary information or other information that should be withheld from public disclosure. We have removed the information to be withheld in the non-proprietary attachment. The basis for withholding this information is provided below.

Westinghouse requests the NRC to redact this information from the public version of your letter to Westinghouse dated October 15, 2009.

The information being redacted is of a type customarily held in confidence by Westinghouse and not customarily disclosed to the public. The justification for holding this information proprietary is identified by superscripts to the left of the right-hand bracket in the attachment. The superscripts are defined below:

(a) The information reveals the distinguishing aspects of a process (or component, structure, tool, method, etc.) where prevention of its use by any of Westinghouse's competitors without license from Westinghouse constitutes a competitive economic advantage over other companies.

(c) Its use by a competitor would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing a similar product.

(e) It reveals aspects of past, present, or future Westinghouse or customer funded development plans and programs of potential commercial value to Westinghouse.

(f) It contains patentable ideas, for which patent protection may be desirable.

Questions or requests for additional information related to content and preparation of this report should be directed to Robert Sisk Manager AP1000 Licensing and Customer Interface, Westinghouse Electric Company, LLC, P.O. Box 355, Pittsburgh, Pennsylvania 15230-0355.

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Please send copies of such questions or requests to the prospective applicants for combined licenses referencing the AP1000 Design Certification. A representative for each applicant is included on the cc: list of this letter.

Very truly yours,

Robert Sisk, Manager
Licensing and Customer Interface
Regulatory Affairs and Standardization

/Enclosure

1. Details of Key Technical Issues Resulting from NRC Staff Review of AP1000 SHIELD BUILDING DESIGN REPORT APP-1200-SR3-003, Revision 0 (Non-Proprietary Information)

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Attachment 1

Non-Proprietary Information

Details of Key Technical Issues Resulting from NRC Staff Review of AP1000 SHIELD BUILDING DESIGN REPORT APP-1200-SR3-003, Revision 0

Details of Key Technical Issues
Resulting from NRC Staff Review of
AP1000 SHIELD BUILDING DESIGN REPORT
APP-1200-SR3-003, Revision 0

The following provides the NRC staff's findings and descriptions of key technical issues from the review of the AP1000 shield building (SB) design report, "Design for the AP1000 Enhanced Shield Building," (APP-1200-S3R-003, Revision 0) dated, August 31,2009.

Safety Function of the Shield Building

The shield building serves the following primary functions:

1. Provides shielding for the containment vessel and the radioactive systems and components located in the containment building.
2. Protects the containment building from external events during normal operations.
3. Provides the required shielding for radioactive airborne materials that may be dispersed in the containment as well as radioactive particles in the water distributed throughout the containment during accident conditions.
4. Provides support for the primary containment cooling water storage tank (PCCWST) for containment cooling.
5. Provides for natural air circulation cooling of containment.

Regulatory Basis

Title 10 of the Code of Federal Regulations, (10 CFR) Section 50.55a, "Codes and Standards", and 10 CFR Part 50, Appendix A, "General Design Criteria for Nuclear Power Plants," General Design Criterion (GDC) 1, "Quality Standards and Records," require safety-related structures be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed. GDC 2, "Design bases for protection against natural phenomena," requires safety-related structures to withstand the most severe natural phenomena such as winds, tornadoes, floods, earthquakes, and the appropriate combination of all loads.

NRC Staff Findings

The NRC staff reviewed the Westinghouse Electric Company (WEC) submittal, "Design Methodology for AP1000 Enhanced Shield Building", (APP-1200-SR3-003, Rev. 0), dated August 31,2009. The NRC staff found that the shield building design report does not provide sufficient information on the SB design with respect to detailing, design, analysis, construction, inspection, and testing to demonstrate that it will perform its intended safety function under design loads. Therefore, the shield building is not in compliance with 10 CFR 50.55a, GDC 1, and GDC 2. The items discussed below constitute the most significant issues which must be resolved.

ENCLOSURE

<u>Key Issues</u>

Detailing, Design, and Analysis

1. Westinghouse (WEC) has not demonstrated that it adequately designed and detailed [ ][a,c,e,f]

2. [ ][a,c,e,f] lacks design and detailing information [ ][a,c,e,f] . Thus, it cannot be determined [.][a,c,e,f]
3. [.][a,c,e,f]

4. The use of a simple shell element for representing the [ ][a,c,e,f] may be adequate for performing preliminary evaluations of overall building responses,[.][a,c,e,f]

5. WEC has not considered the self-consolidating concrete (SCC) material properties [ ][a,c,e,f] (e.g., higher shrinkage and creep strains, less shear resistance and ductility compared to that of normal concrete) [ ][a,c,e,f]

6. WEC has not considered the daily and seasonal thermal cycling effect on the fatigue of welded joints [.][a,c,e,f]

7. The thickness [ ][a,c,e,f] to be less than required, [.][a,c,e,f]

8. WEC has not provided sufficient information to demonstrate that the effects of local buckling [.][a,c,e,f]

Construction and Inspection

WEC has not provided construction and inspection methods required [.][a,c,e,f]

Testing

1. [ ).][a,c,e,f]

2. [

]a,c,e,f

Support to the Key Issues:

Detailing, Design, and Analysis

1. Detailing and Design [ ]a,c,e,f

Reinforcement Detailing

WEC has not demonstrated [ ]a,c,e,f. The WEC design did not consider the effects of shrinkage and creep of concrete, thermal effects, and out-of-plane shear stress. [ ]a,c,e,f . The American Concrete Institute (ACI) Code requires that stirrups be continuous between the two principal steel reinforcing bars, and designed with sufficient anchorage to develop its yield strength. However, [ ]a,c,e,f

[ ]a,c,e,f

For structural analysis, WEC assumed that the whole 36-inch-thick wall was represented by one homogeneous element, and for design purposes [ ]a,c,e,f

Therefore, in order for the design/analysis results to be valid, it must be demonstrated that [ ]a,c,e,f. The process for ensuring this behavior, as well as for providing sufficient ductility, is called reinforcement "detailing".

Experience has shown that good reinforcement detailing is vital to satisfactory performance of structures subjected to earthquakes, high-winds, shrinkage, creep, and thermal effects. ACI 318-08 Building Code (Reference 1) devotes the whole Chapter 7, "Details of Reinforcement", to the requirements of reinforcement detailing for ordinary structures, and specifies additional detailing requirements for earthquake-resistant structures in Chapter 21, "Earthquake-Resistant Structures".

Earthquakes (Seismic) and Tornados (High-Winds)

Earthquakes and winds create out-of-plane shear stress [ ][a,c,e,f] The out-of-plane shear stress is highest in the middle of the thru-wall section, [ ][a,c,e,f] . As soon as the stress exceeds the concrete shear strength, cracking occurs. In ordinary RC structural wall design, stirrups (continuous full-length steel reinforcing bars perpendicular to, and hooked around, the inner and outer vertical principal steel reinforcing bars) are provided when shear stress reaches a certain value. In RC members, stirrups carry tensile and shear stresses across concrete cracks and restrain them from growing and widening, thus increasing the strength and ductility.

Out-of-plane shear tests (Reference 2) on reinforced concrete slabs without stirrups have clearly indicated that the failure mode exhibited a brittle shear failure mode. However, test data (Reference 2) also indicate that a small number of stirrups not only increased the shear strength of the slabs, but also changed the brittle shear failure modes to ductile flexural failure modes. To provide a minimum amount of ductility for ordinary structures, Section 11.4.6, "Minimum Shear Reinforcement," of ACI 318-08 Building Code, requires the spacing of stirrups to be placed a little less than one-half of the depth of the member when the shear stress level exceeds half of the concrete shear strength. The code requirement to compare the shear stress level against one-half of the shear strength, instead of the full shear strength, is a consensus of professional structural engineers to account for some unforeseen load increase by providing some ductiity to counter that load increase. [ ][a,c,e,f]

Further, for earthquake resistant structures, Chapter 21, of the ACI 318-08 Building Code requires the design of structural elements and structures to be substantially tied together and ductile so that they can ride along with earthquake ground motions and survive severe earthquakes without a structural collapse. The code requirements in the Chapter 21 are intended to provide confinement to concrete and maintain lateral support for the principal steel reinforcing bars [ ][a,c,e,f]

Shrinkage and Creep Effect

Shrinkage and creep of concrete are part of the nature of concrete materials and cannot be avoided. Cracking in concrete [ ][a,c,e,f] can occur when concrete shrinks and creeps while being restrained by faceplates and steel studs. This is a particular concern due to the potential for SCC material to exhibit approximately twice the shrinkage and creep strains compared ordinary concrete. [ ][a,c,e,f] AC1318-08 Building Code, Section 7.12, "Shrinkage and Temperature Reinforcement," requires shrinkage and temperature reinforcement to be placed no farther apart than 18 inches.

Thermal Effects

The effects of thermal loads [ ][a,c,e,f] are potentially significant. The differences in coefficients of thermal expansion between concrete and steel will result in shear stresses in both meridional and hoop directions that are generated at the interface of the faceplate and concrete. Additionally, a thermal gradient exists [ ][a,c,e,f] . As a result of this thermal gradient, tensile and bending stresses are introduced in the walL. The magnitude of the tensile stress was calculated and reported on page 24 of the report. It states, [ ][a,c,e,f]

Size Effect

Out-of-plane shear tests (References 3,4, and 5) on reinforced concrete beams and slabs without stirrups have shown that the shear strength decreases as the depth of members increased, which is called the "size effect." Not considering size effects for the design of thick members can lead to an unconservative design for shear because it assumes concrete can take the share of total shear stress more than it actually can, and thus reduces the amount of stirrups to be added to the members. WEC has not reduced the shear strength for the 36-inchthick wall in its design and has not demonstrated that the SC module wall does not have a size effect. [ ][a,c,e,f]

2. [ ][a,c,e,f]

   [ ][a,c,e,f] The stress condition at, or near, the interface [ ][a,c,e,f] includes flexure, axial, shear, and torsion, that is complex, especially near the area where the auxiliary building roof is anchored to the [ ][a,c,e,f]

3. Analysis of [ ][a,c,e,f]

   The NRC staff determined that the[ ][a,c,e,f] relies on a complicated load path comprised of imbedded steel plates, tubes, and channels. The ring girder consists of [ ][a,c,e,f]

4. Analysis Methods

Finite Element Analysis

WEC used [ ][a,c,e,f] to represent the [ ][a,c,e,f] . While [ ][a,c,e,f] for a preliminary evaluation on the overall building response, this approach [ ][a,c,e,f] along the thickness of the wall module and at local stress concentrations. [ ][a,c,e,f] capture the localized stress and strain conditions. [ ][a,c,e,f] . The NRC staff determined that [ ][a,c,e,f] for the purpose of performing an advanced, detailed, and final analysis.

Seismic Input to Roof

Table 4.3-1 "Seismic Design Accelerations" gives the x, y, and z seismic acceleration vs. height profiles from El. 180' to El. 327', used in the equivalent static analysis for the SB roof structure. [ ][a,c,e,f]

5. Self-Consolidating Concrete

Recent research reported by the National Cooperative Highway Research Program (NCHRP) in the 2009 NCHRP Report 628, "Self Consolidating Concrete for Precast, Prestressed Concrete Bridge Elements," (Reference 6) shows that shear resistance and ductiliy of SCC is less than that of normal concrete. A study by Oliva and Cramer (Reference 7) in 2008 showed that SCC may exhibit higher dimension change due to creep and shrinkage than conventional concrete, depending on the materials and mix design of SCC. Creep and shrinkage strains of SCC reported in the paper were observed to be approximately twice that of a normal mix.

[ ][a,c,e,f] . Based on discussions with concrete experts, the NRC staff is aware that SCC can leave construction joint surfaces that behave poorly as compared to conventional concrete under shear friction. This concern would apply to the construction joints within the SC walls.

In Chapter 2, [ ][a,c,e,f]

whether [ ]a,c,e,f. Further, the report does not address the differences [ ]a,c,e,f between using SCC and conventional concrete.

6. Thermal Cycling Effect

The effects of solar heating [ ]a,c,e,f expand during daylight hours, and the expansion [ ]a,c,e,f creates stresses [

]a,c,e,f . As a result of expansion and contraction [ ]a,c,e,f and thermal gradient reversals along the radial direction of the wall, not only is concrete cracking induced by stresses a problem, but also fatigue due to thermal cycling. [ ]a,c,e,f

7. Thickness [ ]a,c,e,f

In Section 3.6.2.5 (page 140) of the report, WEC states [ ]a,c,e,f

Section 3.4.3 (page 86) states that [

]a,c,e,f. Furthermore, Section 3.4.5.2 (page 92) of the report states that [

]a,c,e,f

8. Potential Local [ ]a,c,e,f

The AP1000 PCCWST rests on the roof of the SB structure and contains a minimum of 6.3 millon pounds of water. The weight of the water continuously bears on [

]a,c,e,f . The consideration of this stress redistribution phenomenon is required by the ACI 318-08 Building Code, Section 10.13, "Composite Compression Members," in buckling strength calculation for the RC steel composite structural members.

The NRC staff is concerned about the potential local buckling mode resulting from:

- the added compressive stress [ ]a,c,e,f resulting from this stress redistribution phenomenon due to concrete creep,

- · reduced concrete tensile strength, as a whole, [ ][a,c,e,f] resulting from concrete cracking induced by shrinkage and creep of concrete, thermal stresses, and seismic and wind loads,
- · the reduced [ ][a,c,e,f] buckling strength, as a result of an initial deformed shape caused by the wet concrete construction load,
- · the potential cracking planes forming in both meridional and hoop directions [ ][a,c,e,f],
  · the potential degraded [ ][a,c,e,f] strength [ ][a,c,e,f]
- · the potential damage to [ ][a,c,e,f], and [
- · the lack of [ ][a,c,e,f] and the potential [ ][a,c,e,f] remains unresolved.

Construction and Inspection

NRC staff discussion with concrete experts has identified that segregation of SCC dropped through layers of reinforcing steel has occurred in practice. Further, the NRC staff determined that the congested design [ ][a,c,e,f] will make proper concrete placement difficult. [ ][a,c,e,f] The development of these methods and procedures is needed to help ensure the safety of the design, particularly for new construction.

The NRC staff determined that the [ ][a,c,e,f]. In addition, the mockups should represent [ ][a,c,e,f]

[.][a,c,e,f]

Testing

1. Differences between Test Specimens [ ][a,c,e,f]

   [ ][a,c,e,f]

[

]a,c,e,f

2. In-Plane Shear and Tension Test [ ]a,c,e,f

[

]a,c,e,f

[

]a,c,e,f

[

]a,c,e,f

References

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8. Japan Electric Association Code, Guideline-4618, "Technical Guidelines for Aseismic Design of Steel Plate Concrete Structures - for Buildings and Structures", 2005.