Westinghouse

Westinghouse Electric Company
Nuclear Plant Projects
P.O Box 355
Pittsburgh, Pennsylvania 15230-0355
USA

U.S. Nuclear Regulatory Commission
Document Control Desk
Washington, D.C. 20555

Direct tel: 412-374-5355
Direct fax. 412-374-5456
e-mail: corletmm@westinghouse.com

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SUBJECT: Transmittal of Westinghouse Responses to US NRC Requests for Additional Information on the AP1000 Application for Design Certification

This letter transmits the Westinghouse responses to NRC Requests for Additional Information (RAI) regarding our application for Design Certification of the AP1000 Standard Plant. A list of the RAI responses that are transmitted with this letter is provided in Attachment 1. Attachment 2 provides the RAI responses.

Please contact me if you have questions regarding this submittal.

Very truly yours,

M. M. Corletti

M. M. Corletti
Passive Plant Projects & Development
AP600 & AP1000 Projects

/Attachments

1. Table 1, "List of Westinghouse's Responses to RAIs Transmitted in DCP/NRC1577"

2. Westinghouse Non-Proprietary Response to US Nuclear Regulatory Commission Requests for Additional Information dated April 2003

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DCP/NRC1577

April 22, 2003

Attachment 1

"List of Westinghouse's Responses to RAIs Transmitted in DCP/NRC1577"

Attachment 1

Table 1
"List of Westinghouse's Responses to RAIs Transmitted in DCP/NRC1577"
220.003, Rev. 2
220.013, Rev. 2

Attachment 2

Westinghouse Non-Proprietary Response to US Nuclear Regulatory Commission
Requests for Additional Information dated April 2003

AP1000 DESIGN CERTIFICATION REVIEW

Response to Request For Additional Information

RAI Number: 220.003 (Response Revision 2)

Question:

In DCD Section 3.8.2, Westinghouse stated that the containment shell material is SA738, Grade B. Westinghouse further stated, in the same DCD subsection, that this material is included in the ASME Code but is not applicable for containment vessel in the 2000 Addenda. The material has been approved for containment vessels by Code Case N655. This code case was approved by the ASME Code committee on February 25, 2002, but it is not yet published.

The code case approves the use of SA-738, Grade B for Class MC components. Based on paragraph (b) of the reply to the inquiry, the allowable stress intensity (S_{mc} or S) for SA-738, Grade B used in Class MC components is 1.1 x 24.0 = 26.4 ksi at 300°F. This is based on the 1998 ASME Code, Section II, Part D, Table 1A value for S at 300°F, which is 24.0 ksi. This stress intensity limit is applied to the general primary membrane stress intensity at the design pressure and temperature. The hoop stress in the cylinder is +26,297 pounds-per-square inch (psi), based on 59 psi design pressure, t = 1.75", and r = 65' x 12 = 780". The radial stress is -59 psi at the inside shell surface and zero at the outside shell surface, resulting in an average radial stress of -59/2 = -29.5 psi. Therefore, the general primary membrane stress intensity is 26,297 + 29.5 = 26,326.5 psi, which is just below S_{mc} = 26,400 psi, at the design temperature.

Please provide justification for adopting allowable stress values for SA738 Grade B material, which are not of yet included in the current version of the ASME Code, for Class MC components.

Westinghouse Response (Revision 1):

SA738, grade B material is included as an acceptable material for containment vessels in the 2002 Addenda to the ASME Code. The allowable stress values are now included in the Code. The DCD will be revised to show design of the vessel to this latest addendum.

Basis for Code Allowable Stresses

The allowable stresses in Subsection NE of the ASME Code are 1.1 times those of Table 1A in Section II, Part D. (See NE-3112.4). Prior to 1998, Table 1A allowable stresses below the creep range were essentially the lower of 2/3 the specified minimum yield strength or ¼ of the ultimate strength. Two code cases were published in 1998 that allowed the use of a design factor of 3.5 on ultimate, rather than 4.0. This change in the design factor was incorporated into the Code rules with the 1999 Addenda. Effectively, this allows approximately a 14% increase in allowable stress for those materials whose allowable stress is not controlled by 2/3 yield stress. The decrease in design margin was justified on the basis of improvements that have been made to the Code, improvements to the welding processes and NDE, greater controls on material production, and satisfactory experience of other international Codes with the use of lower design margins. Many European standards have lower design margins on ultimate strength and the German Code (AD_Merkblatt) has no factor on ultimate. Almost all codes have a factor of 2/3 on yield strength. The justification for reducing the design margin for Section VIII, Division 1 was reported in a PVRC report, which has been published in WRC Bulletin 435, "Evaluation of Design Margins for ASME Code Section VIII, Division 1", by E. Upitis and K. Mokhtarian, September 1998.

The allowable stress criteria in the latest codes (e.g. ASME 2001 including 2002 Addenda) are conservative. This is demonstrated by continuing studies and proposed revisions being developed for ASME Section VIII vessels. Upitis and Mokhtarian published a second report in the same WRC Bulletin 435, entitled "Evaluation of Design Margins for ASME Code Section VIII, Divisions 1 and 2". The conclusion of this report is that the design margins on ultimate strength can be further reduced for both Division 1 and Division 2 of Section VIII. Additional recommendations have been included on how to improve the quality of the rules contained in these Codes. Based on the conclusions of this report, ASME has requested that PVRC prepare a totally new pressure vessel code which will replace Section VIII, Division 2, and possibly other pressure vessel Codes. The present outline calls for three classes of vessels with design margins of 3.0, 2.4 and 1.875 on ultimate strength, at room temperature only (no factor on ultimate at design temperature). It is proposed that the 2/3 factor on yield strength be kept. Another proposal of significance in the outline is that actual material properties be allowed.

Materials

This section provides additional information on the SA537-Class 2 used in the AP600 containment vessel and SA738 Grade B used in the AP1000 containment vessel. These materials are similar with a slightly higher ultimate strength for the SA738 Grade B.

SA-537 Class 2

This steel has a long history of service for low temperature applications in pressure vessels. It has been in wide use since the 1970's. This material has excellent base metal and, when welded, HAZ toughness for services to –60°F or lower. There is a great deal of data available to support its use. Data for the as welded condition is primarily for thicknesses less than 1 ½". There is also much data available for thicker materials but most of that is in the PWHT condition. (Note that for these materials, PWHT generally deteriorates properties if it has any effect on properties, so data for the PWHT condition should be conservative). This material is readily weldable. Standard practices for higher strength materials to avoid hydrogen cracking such as preheat and electrode control and maintenance are employed routinely to weld these materials without problems.

SA-738 Grade B

This steel is now widely used for low temperature pressure vessel service. It has somewhat higher tensile strength than SA-537 Class 2 yet retains excellent toughness at low temperatures. In recent years, this steel has been used in applications where SA-537 Class 2 was formerly used. There is an increasing volume of data available for the material. This data shows excellent base metal and HAZ toughness properties at temperatures of –20F and down to –50F. CB&I has constructed a spherical storage vessel with plate thickness of up to 1.15 inches for a design metal temperature of –55F. The material is being produced with transverse base metal impact test requirements at –70F.

This material is subject to hydrogen cracking but problems are readily avoided by following proper welding procedures. Welding and non-destructive examination procedures for SA537 Class 2 and SA738 Grade B are similar. Due to higher tensile strength, 85 ksi, equivalent higher strength welding consumables are required for the SA738 materials. Preheat and other welding related variables remain the same.

Design Control Document (DCD) Revision: *included in DCD Revision 3*

3.8.2.2 Applicable Codes, Standards, and Specifications

[*The containment vessel is designed and constructed according to the ~~1998~~**2001** edition of the ASME Code, Section III, Subsection NE, Metal Containment,* ***including the 2002 Addenda***]* ~~including the 1999 and 2000 Addenda. The Combined License applicant may update the Code edition and addenda as defined in subsection 5.2.1.1. The shell material is SA738, Grade B. This material is included in the ASME code but is not applicable for containment vessels in the 2000 Addenda. The material has been approved for containment vessels by Code Case N655. A change is being processed by ASME to include the material for containment vessels in the 2002 edition of the ASME code. The code case will be annulled once the material is included for containment vessels in the code.~~ Stability of the containment vessel and appurtenances is evaluated using ASME Code, Case N-284-1, Metal Containment Shell Buckling Design Methods, Class MC, Section III, Division 1, as published in the 2001 Code Cases, 2001 Edition, July 1, 2001.

Revise third paragraph of subsection 6.2.1.1.2

The containment vessel is designed and constructed in accordance with the ASME Code, Section III, Subsection NE, Metal Containment, ~~including Addenda through 2001,~~ as described in subsection 3.8.2.

PRA Revision:

None

NRC Comments on Revision 1 Response:

Revision 1 of the initial response to RAI 220.003 was submitted by Westinghouse on January 21, 2003. The revision addresses the technical bases for the increased allowable stresses permitted in the 2001 (plus 2002 addenda) Code, compared to earlier code editions. This is acceptable.

The revision also discusses the material issue: SA537, Class 2 vs. SA738, Grade B. The information provided raises more questions than it answers about the suitability of SA738, Grade B as the AP1000 Containment shell material. In the discussion of SA537 Class 2, Westinghouse notes the excellent fracture toughness at low temperature in both the base metal and heat affected zone (HAZ). However, data in the as-welded condition (i.e., no post weld heat treatment [PWHT]) only covers thicknesses below 1.5". For thicker sections, most of the data is for the PWHT condition. This would seem to imply that for thicknesses of 1.5" and greater, PWHT is the common practice. The following parenthetical statement requires further explanation:

> Note that for these materials, PWHT generally deteriorates properties if it has any effect on properties, so that data for the PWHT condition should be conservative.

PWHT is typically used to restore fracture toughness in the HAZ of thick-section welds. Yield and Ultimate Strength is typically higher in the as-welded HAZ when compared to base metal properties, but ductility and fracture toughness is typically lower in the as-welded HAZ when compared to base metal properties. Westinghouse should provide the technical basis for the parenthetical statement.

Since SA537 Class 2 is the AP600 containment shell material, which has been previously accepted, there is no need for Westinghouse to submit a technical basis for the adequacy of the fracture toughness of as-welded sections with thickness of 1.5" and greater, at the minimum temperature required by NE-2000 for AP600.

In the discussion of SA738 Grade B, Westinghouse presents a very weak, qualitative argument for the adequacy of the fracture toughness of as-welded sections with thickness of 1.15" and greater, at the minimum temperature required by NE-2000 for AP1000. Westinghouse needs to provide quantitative evidence that supports its position that adequate fracture toughness, as defined by NE-2000, is achievable for a thickness of 1.75" without PWHT.

Westinghouse Response (Revision 2):

The statement *"PWHT generally deteriorates properties if it has any effect on properties, so that data for the PWHT condition should be conservative."* is based on CBI data for SA537-2 base metal. A large volume of data from CB&I's database of weld qualifications has been analyzed in a recent study. The data was only from A516-70 and A537, Class 1, but the trends identified were the same in both materials and are expected to be similar in SA537, Class 2 and in SA738B. The study indicated the following:

- For base material; Toughness went DOWN due to PWHT two or three times more often than it went up.
- For heat affected zones; Toughness went UP due to PWHT more than 3 times more often than it went down.

The Lowest Service Metal Temperature (LSMT) is specified as -15F. NE-2331 requires impact testing to be done at or below the LSMT. However, for the case where SA738 has thickness between 1.5" and 1.75" and no PWHT is to be applied, the testing temperature is required to be 10F below LSMT (Table NE-4622.7(b)-1, note (2)(b)(1)). The weld metal and heat affected zone must therefore meet 40 ft-lb. average / 35 ft-lb. minimum at -25F.

The plate toughness to be specified for material procurement applies a 30F margin for possible degradation in the HAZ. To ensure 40/35ft-lb in the HAZ at -25F, the plate would be specified to meet 40/35ft-lb at -55F. The 30F is the default margin that is used per NE-4335.2 (b)(2). Additional tests could be done to NE-4335.2 (b)(3) which could lead to a smaller required margin in which case it would be permissible to specify impact testing warmer than -55F in the plate purchase specification.

In judging the toughness of heat affected zones and base metal both as-welded and PWHT conditions need to be evaluated for a structure that is only partly post weld heat treated. The data for both SA537-2 and for SA738B show that good low temperature toughness in base metal and HAZ can be attained with and without PWHT. There is quantitative evidence of adequate toughness in SA738B material with about 1.75" thickness in the as-welded condition. Weld Procedure Qualification Testing was conducted by Chicago Bridge and Iron in 1998 on SA738B with thickness of 1.69" using the SAW weld process. Transverse Charpy V Notch test results on heat affected zones both as-welded and with PWHT were as follows:

Test Temperature	As-welded (HAZ)	after PWHT (at 1125F for 8 hours) (HAZ)
-60F	46ft-lb	86ft-lb
-60F	41ft-lb	92ft-lb
-60F	47ft-lb	93ft-lb
-71F	36ft-lb	92ft-lb
-71F	31ft-lb	105ft-lb
-71F	42ft-lb	106ft-lb

The HAZ toughness was improved by PWHT. This effect held true for tests both at -60F and at -71F. (The explanation for the after-PWHT results being tougher at -71F than they were at -60F is simply natural variation in the HAZ microstructure. It would seem that the notch of -70F specimens happened to line up with a region of somewhat better microstructure than in the 60F specimens.)

Design Control Document (DCD) Revision:

None

PRA Revision:

None

AP1000 DESIGN CERTIFICATION REVIEW

Response to Request For Additional Information

RAI Number: 220.013 (Revision 2)

Question:

AP1000 DCD Subsection 3.8.4.2, "Applicable Codes, Standards and Specifications," references American Concrete Institute (ACI)-349-01, plus supplemental requirements as indicated in Subsection 3.8.4.5. Subsection 3.8.4.5.1 states "Supplement requirements for ACI-349 are given in the position on Regulatory Guide 1.142 [TITLE] in Appendix 1A." The staff notes that this statement and the discussion in Appendix 1A are <u>not</u> designated Tier 2*, although ACI-349-01 itself is designated Tier 2*. Subsection 3.8.4.5.1 also states "[Design of fastening to concrete is in accordance with ACI-349-01, Appendix B.]*"

In Appendix 1A, Westinghouse indicates that the AP1000 position "conforms" to all applicable Regulatory Positions C.1 through C.15 of RG 1.142, Rev. 2, November 2001. A general exception is noted because the RG endorses ACI-349-97, not ACI-349-01. Westinghouse indicates that "The AP1000 uses the latest version of industry standards as of October 2001." In reviewing Appendix 1A, pages 1A-52 and 1A-53, the staff noted two apparent typographical errors. In relation to C.6, it should be "Section 9.2.1" instead of "Section 9.3.1," and in relation to C.15, it should be "Section 11.6" instead of "Section 1.6."

Since the staff has not formally reviewed and endorsed ACI-349-01 at this time, Westinghouse is requested to specifically identify all deviations between ACI-349-97/RG 1.142 and ACI-349-01/Westinghouse Position that affect the AP1000 design, and to provide the technical basis for ensuring that a comparable level of safety is achieved for each such deviation. In addition, Westinghouse is requested to (1) clarify and correct the inconsistency in designation of Tier 2* material noted above, and (2) verify and correct the typographical errors noted above.

Westinghouse Response:
Note: Revision 2 withdraws the additional response that was added in Revision 1

ACI 349 is substantially based on ACI 318 "Building Code Requirements for Reinforced Concrete". ACI 318 is revised on a three or four year cycle with revised codes issued in 1992, 1995, 1999 and 2002. ACI 349-97 was based on the 1992 edition of ACI 318. Revisions were made in ACI 349-01 to make ACI 349 consistent with the 1995 edition of ACI 318. All revisions are marked by a side bar in ACI 349-01. Some of the ACI 318-95 provisions, which have now been included in ACI 349-01, are specifically mentioned in the Regulatory Guide 1.142 endorsing ACI 349-97 and were also specifically considered in the AP600 design. Thus, these changes do not affect the AP1000 design.

ACI 349-01 incorporated substantial changes from ACI 349-97 in Appendix B for anchoring to concrete. This appendix is covered in Draft Regulatory Guide DG-1099.

The changes between ACI-349-97/RG 1.142 and ACI-349-01/Westinghouse Position do not affect the AP1000 design.

Subsection 3.8.4.5.1 is being revised to identify the applicable supplemental requirements for ACI-349 that are given in the position on Regulatory Guide 1.142. These will be designated Tier 2*.

Design Control Document (DCD) Revision: (this is included in DCD Revision 3)

Correct typographical errors In Appendix 1A, pages 1A-52 and 1A-53, in relation to C.6 and C.15.

C.6	ACI 349-97, Section 9.32.1	Conforms	
C. 15		Conforms	The provisions in Section 11.6 of ACI 349-01 are the same as those in ACI 318-99 (Reference 46)

Revise subsection 3.8.4.5.1 Supplemental Requirements for Concrete Structures

[*Supplemental requirements for ACI-349-**01** are given in the position on Regulatory Guide 1.142 in Appendix 1A. **The structural design meets the supplemental requirements identified in Regulatory Positions 2 through 8, 10 through 13, and 15.***]*

[*Design of fastening to concrete is in accordance with ACI 349-01, Appendix B.*]*

PRA Revision:

None