Westinghouse UK
AP1000® GENERIC DESIGN ASSESSMENT
Resolution Plan for GI-AP1000-SI-04
Containment Vessel

MAIN ASSESSMENT AREA	RELATED ASSESSMENT AREA(S)	RESOLUTION PLAN REVISION	GDA ISSUE REVISION
Structural Integrity	-	7	0

GDA ISSUE:	Fracture Analysis of Containment Vessel.
ACTION: GI-AP1000-SI-04.A1	Provide sufficient evidence to show that the containment vessel has adequate tolerance to the thermal shock due to the flow of PCS water onto the top head. Activities required to be carried out by Westinghouse are: • Provide a report with the structure proposed during GDA to show that the containment vessel has adequate tolerance to the thermal shock due to the flow of PCS water onto the top head. • Provide adequate responses to any questions arising from assessment by ONR of documents submitted. With agreement from the Regulator this action may be completed by alternative means.
ACTION: GI-AP1000-SI-04.A2	Provide sufficient evidence to show that the containment vessel has adequate tolerance to small defects given the high residual stress associated with welds which have not undergone post weld heat treatment. It is anticipated that simple fracture mechanics calculations will be required to show adequate defect tolerance. It may be necessary to critically review the input parameters (design temperatures, pressures, residual stresses, likely manufacturing flaws etc) to ensure that they are self consistent and realistic. Activities required to be carried out by Westinghouse are: • Provide sufficient evidence to show that the containment vessel has adequate tolerance to small defects in the absence of post weld heat treatment. • Provide adequate responses to any questions arising from assessment by ONR of documents submitted. With agreement from the Regulator this action may be completed by alternative means.
RELEVANT REFERENCE DOCUMENTATION RELATED TO GDA ISSUE	
Technical Queries	TQ-**AP1000**-732

	TQ-**AP1000**-1040 TQ-**AP1000**-1248
Regulatory Observations	
Other Documentation	APP-MV50-S2C-036, Rev. 0 UKP-GW-GL-067, Rev. 0

Scope of work:
The key activities which will need to be completed to close this GDA Issue are: • Completion of the analysis to demonstrate that the containment vessel can withstand the thermal shock due to the flow of PCS water. • Provide additional information to demonstrate that the containment vessel provides a sufficiently reliable barrier in the absence of post weld heat treatment of the welds.

Description of work:
Westinghouse has completed an analysis (APP-MV50-S2C-036) to demonstrate that the Containment Vessel (CV) will continue to perform its safety functions when subjected to the limiting stresses which occur when water from the passive containment cooling water storage tank (PCCWST) is poured on the CV during a design basis event with a mass and energy release inside containment. A bounding evaluation has been performed assuming cold water conservatively set to 4.4°C (40°F) is poured onto the CV top head. 4.4°C (40°F) is the minimum temperature of the water in the PCCWST per the Technical Specifications at which the plant can continue operations. The Passive Containment Cooling System (PCS) is equipped with heaters to maintain the water temperature above the minimum temperature during normal operations. When water from the PCCWST is initially poured onto the CV, pressure and temperature inside containment would typically be low; however, for the purpose of this assessment it is assumed that the CV will heat up to its design temperature and pressure of 148.9°C (300°F) and 406.8 kPa (59 psig) before the cold water is poured on the CV. This assumption is very conservative since during the limiting transient, which is a main steam line break inside containment, flow from the PCCWST is automatically initiated when pressure inside containment exceeds 42.75 kPa (6.2 psig). There are no load combinations with higher metal temperature or lower water temperatures as documented in the CV design specification. An appropriate metal temperature has been used to calculate the fracture toughness. The metal temperature used to calculate the fracture toughness values has been shown to be bounding. The methodology used to perform the assessment is described below. The appropriate residual weld stresses have been included in the calculation. The assessment demonstrates that the resulting stress intensity factors are below the calculated fracture toughness values and the evaluated critical flaw sizes are larger by a margin than a realistic postulated defect with an allowance for in-service growth or degradation. The same assessment also demonstrates that in the absence of post weld held

treatment (PWHT), a small flaw will not result in failure of the CV, which was queried in TQ-**AP1000**-1248. TQ-**AP1000**-1248 queried what arguments and evidence show that the CV provides a sufficiently reliable barrier in the absence of PWHT. TQ-**AP1000**-1248 was initially raised late in Step 4. The TQ was received by Westinghouse on 11 January, 2011.

The **AP1000®** containment vessel is designed in accordance with the ASME Boiler and Pressure Vessel Code, Section III, "Rules for the Construction of Nuclear Power Plant Components," Subsection NE. Section NE-4622.7 of the ASME code exempts vessels such as the **AP1000** CV from PWHT. Additionally, the fracture mechanics analysis described above will further demonstrate that the CV will not fail when subjected to limiting design transients with relatively large flaw sizes.

As part of the response, Westinghouse justifies that it has evaluated an appropriate and conservative load case as described above. The transient the TSC evaluated is an unrealistic transient. There is no **AP1000** transient where the containment vessel will not be coated in cooling water as design pressure increases, see discussion in Appendix A of UKP-GW-GL-067. It is not possible that the outside of the vessel will be -28°C (18.4°F) when the pressurisation inside containment occurs. Containment design temperature is normally maintained between 10°C (50°F) and 48.9°C (120°F), as discussed in Section 20K.1.4.2 of the Pre-Construction Safety Report (UKP-GW-GL-793). It is not possible that the outer shell of the vessel could drop to its minimum design temperature assuming inside containment is initially approximately 21.1°C (70°F), there is a mass and energy release inside containment, and the vessel is coated in cooling water from the PCCWST that is no colder than 4.4°C (40°F). The evaluation described above demonstrates that the CV provides a sufficiently reliable barrier in the absence of PWHT of the welds.

The following deliverables will therefore be provided in response to this GDA issue:

- APP-MV50-S2C-036, Rev. 0, "**AP100**0 Containment Vessel Top Head Fracture Analysis due to PCS Flow Actuation"
- Response to ONR Regulatory Queries

Schedule/ programme milestones:

Please see the following page for the schedule.

Activity Name	2016																2017
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	
UK Generic Design Assessment (GDA) Resolution Plans (51)																	
STRUCTURAL INTEGRITY																	
SI.04 Containment Vessel-Resolution Plan																	
SI.04 Fracture Analysis of Containment Vessel																	
APP-MV50-S2C-036 R0 - Submit to ONR																	
APP-MV50-S2C-036 R0 - ONR Review of Submittal																	
APP-MV50-S2C-036 R1 (If Required) - Submit to ONR																	
APP-MV50-S2C-036 R1 (If Required) - ONR Review of Submittal																	

Methodology:

The evaluated load case was based on the transient described in the scope of work. The stress intensity factors were calculated according to ASME 2010, Section XI, Division 1, Appendix A, Article A-3000, and the fracture toughness values were calculated according to ASME 2010, Section XI, Division 1, Appendix A, Article A-4000. The fracture toughness values used are appropriate for the containment vessel and are consistent with the requirements of ASME Section XI, Article A-4200(b). The fracture toughness values taken from ASME XI have been shown to be conservative for the materials used for the containment vessel.

To account for the residual weld stress, the pressure stress, and the thermal stress due to the PCS actuation, a linear stress distribution through the thickness was assumed. The thermal stress is calculated based on Hooke's law for a plate held at the edges with thermal expansion.

The calculations demonstrate that the stress intensity factors are below the fracture toughness values and the evaluated critical flaw sizes are smaller than a realistic postulated defect.

Justification of adequacy:

Please refer to the description of work. The analysis described demonstrates that the CV is tolerant to the thermal shock it will conservatively experience during a design basis accident. The analysis also further validates that PWHT is not required to relieve residual weld stresses by demonstrating that a limiting transient will not challenge the structural integrity of the CV in the absence of PWHT.

Timely closure of the actions defined in this Issue will be reached through maintaining quality interaction with ONR and using existing processes to assure closure of open items.

Impact assessment:

The primary safety submission document potentially affected by this Issue is the PCSR. Based on closure of the issue, it may be necessary to update Appendix 20K of the PCSR.