Westinghouse UK
AP1000® GENERIC DESIGN ASSESSMENT
Resolution Plan for GI-AP1000-CE-02
Further Justification of Novel Form of Structure for the Steel/ Concrete Composite Wall to the Enhanced Shield Building

MAIN ASSESSMENT AREA	RELATED ASSESSMENT AREA(S)	RESOLUTION PLAN REVISION	GDA ISSUE REVISION
Civil Engineering	PSA Internal Hazards	3	1

GDA ISSUE:	Further justification of the novel design used for the steel/concrete composite wall proposed for the Enhanced Shield Building within the nuclear island.
ACTION: GI-AP1000-CE-02.A1	Provide further justification on the steel material used for the tie bars in the SC wall of the ESB. The tie bar material specified by Westinghouse to A496 does not appear to comply with the normal European requirements for reinforcement in seismic design specifically with respect to its ductility. It is the Regulator's view that more appropriate steel grades should be considered. Westinghouse must therefore either propose a more suitable grade or provide justification why the A496 material specified is appropriate to use as shear reinforcement in seismic design taking into account European expectations for seismic design. With agreement from the Regulator this action may be completed by alternative means.
ACTION: GI-AP1000-CE-02.A2	Provide further substantiation of the demand calculations for the tie bars to justify: • the total demand tensile force in the ties from simultaneous loads, including secondary effects. • the combination of tensile forces calculated above with simultaneous shear forces calculated under Action A5. • justification of the combined tensile strength and shear strength of the tie bars (tensile strength to be confirmed under Action A1. Shear strength to be confirmed under Action A5, Item 2). • provide demand versus capacity ratios. With agreement from the Regulator this action may be completed by alternative means.
ACTION: GI-AP1000-CE-02.A3	Provide a clear statement in the methodology that the out of plane shear is taken on the reinforcement alone.

	Provide a comparison of the proposed ACI 349-01 design methodology for out of plane shear and provision of shear reinforcement with alternative codes. Provide further calculations to alternative codes: • JEAG 4618. • Draft AISC N690 App N9. • Any others deemed applicable by Westinghouse, including first principles. In order to justify that the provision of ties as shear reinforcement in the ESB SC wall. With agreement from the Regulator this action may be completed by alternative means.
ACTION: GI-AP1000-CE-02.A4	Provide additional justification for the proposed design methodology for in-plane shear when combined with other loads. Provide further calculations for in-plane shear to alternative codes: • JEAG 4618. • Draft AISC N690 App N9. • Any others deemed applicable by Westinghouse, including first principles. In order to justify that the plates still have sufficient margin above the demand levels when these codes are used for design. These calculations should consider all the coincident loads present for each critical loadcase, such as those described in actions A2 and A5 of this GDA Issue. These calculations should also include the symmetric sharing of in plane shear stress used by these codes. Following the above, provide the limitations on combined loadings (e.g. moment and axial load) for which the Westinghouse methodology of asymmetric sharing of in-plane shear stress is applicable. With agreement from the Regulator this action may be completed by alternative means.
ACTION: GI-AP1000-CE-02.A5	The adequacy of the shear connection between the face plates and the concrete needs to be verified for the general areas and the connection zones. Provide the following substantiation with respect to the shear connectors: • Justify that the strength reduction factor of 0.75 for shear studs taken from ACI 349-01 B.4.4 is appropriate and provide sensitivity of this. (This is an identical action to GI-AP1000-CE-01.A7 item 1). • Justify the nominal and design shear capacity for the tie bars. This is to be used in the capacity calculation in Action A2 of this GDA Issue.

	• Justification for omission of any tension force in the shear studs (resulting from restraining the plate in compression) is required, and, if a tension force is required, the effect on the stud shear capacity needs to be considered. • Provide calculations to justify that the development length will be satisfied for the re-calculated shear resistance of the ties and studs. With agreement from the Regulator this action may be completed by alternative means.
ACTION: GI-AP1000-CE-02.A6	Westinghouse shall provide further justification for: • The base connection of the ESB to the RC wall below. • The connection between the Auxiliary Building roof and the ESB. • The calculation of stresses at the transition from the typical 3ft wall to the 4.5ft wall at the air inlet region, and the justification that the tie bar arrangement is sufficient to provide a competent transition. With agreement from the Regulator this action may be completed by alternative means.
ACTION: GI-AP1000-CE-02.A7	Westinghouse is required to justify how the thermal analysis models transient thermal effects, such as environmentally induced transients. Justification should be provided that the plate and shear connector design will provide margin over the demand for the thermal loadcases. The concern is that frequent/daily thermal cycles could lead to cyclic forces on shear connections adjacent to cracks and degrade their capacity. The restraint forces in the studs/ties induced by restraining the compression plate against expansion must also be included in Actions A2 and A5. With agreement from the Regulator this action may be completed by alternative means.
ACTION: GI-AP1000-CE-02.A8	Westinghouse is required to provide evidence on the effect of fire on the ESB SC wall generally. It is not claimed as a fire barrier. Westinghouse is also required to consider if vapour pressure within the ESB SC wall is a concern. This action is concerned with the structural stability of the ESB circular SC wall following a potential fire. Therefore, a quantification of the fire magnitude that the structure can withstand without structural collapse shall be provided. This should include possible fires outside the building and internal fires within the shield building annulus or in the auxiliary building adjacent to RC/SC connections.

	With agreement from the Regulator this action may be completed by alternative means.
ACTION: GI-AP1000-CE-02.A9	Westinghouse is required to provide further substantiation on the reliability of the Enhanced Shield Building as follows: • Clearly identify the target reliability expected from the design of Class 1 and Seismic Class 1 civil structures which are SC modules. • Demonstrate that the reliabilities identified above can be provided using the design methodologies adopted. This demonstration can be undertaken using whatever methods are seen as appropriate, however the following should be addressed: - Reliability of the Code in terms of mechanistic representation of structural behaviour. - Assumptions over the reliability of the engineer using the code. - Suitability of partial safety factors adopted in the design for both materials and loads. - Comparison with other codes for Nuclear Work. - Assumptions over the quality of materials/ construction. - Assumptions made over the long term behaviour of materials. - Assumptions made over the probability of the loadings used in the design. • Assess the effects on the calculation of HCLPF for the ESB SC wall based on the completion of actions A1 to A8 of this GDA Issue. With agreement from the Regulator this action may be completed by alternative means.
RELEVANT REFERENCE DOCUMENTATION RELATED TO GDA ISSUE	
Technical Queries	TQ-**AP1000**-0069 design methodology for civil modules TQ-**AP1000**-0319 supporting documents TQ-**AP1000**-0447 civil module testing programme TQ-**AP1000**-0613 Japanese standard JEAG 4618 TQ-**AP1000**-0664 resistance of connectors TQ-**AP1000**-0665 self compacting concrete placement loads TQ-**AP1000**-0740 shear interface flow TQ-**AP1000**-0741 Shield Building – shear resistance of tie bars TQ-**AP1000**-0904 Enhanced Shield Building Wall – testing of SC construction. TQ-**AP1000**-1042 Enhanced Shield Building Cladding (Siding)

	TQ-**AP1000**-1079 thermal stress analysis and design of SC Modules TQ-**AP1000**-1085 Queries on ESB design report TQ-**AP1000**-1176 Shield Building – tie bar function
Regulatory Observations	RO-**AP1000**-041 containing ROA-041.A1 (s/s by RI-002) RO-**AP1000**-079 containing ROA-079.A1 to A8.
Other Documentation	APP-1200-S3R-003

Scope of work:

Action 1
Westinghouse will provide further justification on the steel material used for the tie bars in the SC wall of the ESB to demonstrate why A496 is appropriate to use as shear reinforcement in a seismic design taking into account European expectations for seismic design.

Action 2
Westinghouse will provide further justification of the design tensile load present in the tie bars due to combined loading effect.

Action 3
Westinghouse will further justify the ties as shear reinforcement in the shield bundling cylindrical wall. The justification will include the following:

1. A clear statement in the methodology that the out of plane shear is taken on the reinforcement alone.

2. A comparison of the proposed ACI 349-01 design methodology for out of plane shear and provision of shear reinforcement with alternative codes.

Action 4
Westinghouse will provide additional justification for the proposed design methodology for in-plane shear when combined with other loads by performing the following:

1. Further calculations for in-plane shear to alternative codes.

2. In conjunction with item 1, Westinghouse will define the limitation on combined loading (e.g. moment and axial load) for which the defined methodology of asymmetric sharing of the in-plane shear stress is applicable.

Action 5
Westinghouse will demonstrate the adequacy of the shear connection between the face plates and the concrete in general areas and in the connection zones by providing the following:

1. Justification along with a supporting sensitivity assessment that the strength reduction factor of 0.75 for shear studs taken from ACI 349-01 B.4.4 is appropriate.

2. Justification of the nominal and design shear capacity for the tie bars.

3. Justification for omission of any tension force in the shear studs (resulting from restraining the plate in compression), and, if a tension force is required, the effect on the stud shear capacity will be considered.

4. Calculations to justify that the development length will be satisfied for the re-calculated shear resistance of the ties and studs.

Action 6
Westinghouse will provide further justification for the following:

1. The base connection of the ESB to the RC wall below. Additional information will be provided as required for queries Q33, Q35 and Q36 of TQ-**AP1000**-1085.

2. The connection between the Auxiliary Building roof and the ESB. Additional information will be provided as required for Q31, Q40, Q41, Q42, Q53 and Q54 of TQ-**AP1000**-1085.

3. The calculation of stresses at the transition from the typical 3ft wall to the 4.5ft wall at the air inlet region, and the justification that the tie bar arrangement is sufficient to provide a competent transition.

Action 7
Westinghouse will provide further justification how the thermal analysis models transient thermal effects.

Action 8
In conjunction with the information provided in response to GI-**AP1000**-CE-01 Action 7, Westinghouse will provide the following:

1. Evidence on the effect of a fire on the ESB steel concrete composite wall.

2. Evidence to demonstrate that vapour pressure within the ESC steel concrete composite wall is not a concern.

Action 9
Westinghouse will provide further substantiation on the long term reliability of the shield building as follows:

1. Provide relevant reliability calculations for the shield building based on a Eurocode based approach and justify that the calculated reliability is sufficient.

2. Assess any potential impacts on the shield building HCLPF calculations based on the responses to Actions 1-8.

Description of work:

Action 1

Information regarding the use of ASTM A496 for the shield building tie bars is provided in Appendix 3H of the shield building design report. Typically the demand on these bars is low so the ductility of the tie bar is not a major concern. However, this material does not directly align with the requirements to use as shear reinforcement in seismic design. To address this action, Westinghouse will compare ASMT A496 with typical material properties approved for use in seismic design in Europe and demonstrate given the low demand adequate ductility is provided.

Action 2

In response to this action Westinghouse will revise the response to TQ 1085 question 8 to further justify why the appropriate total simultaneous tensile load on the tie bars has been considered. The revised response will provide a justification for why axial thermal stresses are not included. As part of the revised response, Westinghouse will review Table H.1-1 of the shield building design report to ensure inconsistencies do not exist between the revised response and the table. The revised response will further justify that there is sufficient capacity in the tie bars for the shield building with respect to demand particularly when subjected to combined shear and tension loading.

Action 3

1. As described in the Discussion portion of GDA Issue, Westinghouse has provided evidence during Step 4 in Appendix 3H of the shield building design report to demonstrate that the out of plane shear resistance of the concrete in the shield building is not required to resist the mechanical or thermal load combinations. In response to this action, it will be made clear in the PCSR that the out of plane shear capacity of the shield building is based on the strength of steel alone.

2. As discussed in Section 2.4 of the shield building design report, the **AP1000**® shield building has been evaluated against the JEAG design guidance. The JEAG design guide represents the consensus of an expert technical committee in Japan regarding SC structures. Westinghouse has also done a JEAG evaluation for the shield building relative to the design that was presented in Revision 0 of the shield building report. Since that time, the shield building design has been enhanced by the addition of additional shear reinforcement. Since the JEAG is primarily based on plate stresses, the enhancements made to the design would improve the results in the existing evaluation. The existing evaluation will be submitted to address this item.

   In addition to this, Westinghouse will provide further out of plane shear calculations based on the existing draft guidance in AISC N690 Appendix 9A; however, as this is draft guidance Westinghouse does not intend to reference this guidance in its design methodology. The information is being provided as the request of ONR to provide additional assurance of the robustness of the building design.

Action 4

1. As discussed in Section 2.4 of the shield building design report, the **AP1000** shield building was evaluated against the JEAG design guidance. The JEAG

design guide represents the consensus of an expert technical committee in Japan regarding SC structures. Westinghouse has also done a JEAG evaluation for the shield building relative to the design that was presented in Revision 0 of the shield building report. Since that time, the shield building design has been enhanced by the addition of additional shear reinforcement. Since the JEAG is primarily based on plate stresses, the enhancements made to the design would improve the results in the existing evaluation. The existing evaluation will be submitted to address this item.

In addition to this, Westinghouse will provide further in plane shear calculations based on the existing draft guidance in AISC N690 Appendix 9A; however, as this is draft guidance Westinghouse does not intend to reference this guidance in its design methodology. The information is being provided as the request of ONR to provide additional assurance of the robustness of the building design.

2. Item 2 is very similar in nature to item 2 in GI-**AP1000**-CE-01 Action 3. Westinghouse will justify that the response provided for the action related to CA modules will address any limitations to the Westinghouse methodology for addressing combined loads in the shield building.

Action 5

1. Item 1 in this Action is identical to item 1 in GI-**AP1000**-CE-01 Action 4. The response provided for the action related to CA modules will provide the necessary evidence to also address these actions.

2. The response to TQ 1176 demonstrates that the shear capacity of the tested tie bars is within 10% of the shear stud design capacity. Therefore, for the purpose of liner plate development, Westinghouse has considered the tie bar to have equivalent shear strength as the shear stud. In response to this item, Westinghouse will revise the response to TQ 1176 to provide further evidence that it is reasonable to assume equal shear capacity of the tie bars and in the shear studs when considering plate development. The response will justify that assuming equal shear capacity is reasonable and does not significantly affect the structures design margin.

3. In response to this item, Westinghouse will provide a justification for why it is appropriate to assume that tension in the studs is assumed to be negligible. Westinghouse will provide the response in a revision to the response to question 14 from TQ 1085. The response will consider the information available in alternative codes.

4. Based on the response to Action 5 item 2, Westinghouse will review if it is necessary to recalculate the shear resistance of the ties and studs.

Action 6

1. Responses to questions Q33, Q35, and Q36 of TQ 1085 were provided to ONR late in GDA Step 4. To address this item, Westinghouse will support ONR's review of these responses.

2. Responses to questions Q31, Q40, Q41, Q42, Q53, and Q54 of TQ 1085 were

provided in January of 2011. ONR has indicated that further questions remain regarding the connection of the auxiliary building roof to the shield building. Resolution of this item will require further interaction between Westinghouse and ONR so that Westinghouse fully understands ONR's concerns regarding shear transfer into the shear lug. Based on this interaction, Westinghouse will revise the responses to the previously submitted questions to address ONR's specific concerns.

3. Questions regarding the transition region in the shield building between the cylindrical wall and air inlets were raised during a joint meeting between Westinghouse, ONR, and the US NRC. In responses to those questions, Westinghouse provided additionally information about the transition region in Appendix 3H of the shield building design report. To address this issue, Westinghouse will provide the supporting calculations for the information contained within Appendix 3H of the shield building report.

Action 7

In the UK, Westinghouse has committed to providing cladding of the external plate of the shield building to limit the effects of environmental thermal transients induced from exposure to solar gain. For the shield building, Westinghouse has performed calculations that demonstrate the structure is capable withstanding load combinations that include thermal loading. These calculations in combination with commitment to clad the external plate of the shield building will demonstrate that the appropriate effects potentially caused by thermal transients have been considered in the design of the shield building.

Action 8

The items required under Action 8 are very similar to the actions required for GI-**AP1000**-CE-01.A7. The calculations provided in support of Action 7 of GI-**AP1000**-CE-01 will provide supporting evidence to also address these actions. Based on the supporting calculations performed for GI-**AP1000**-CE-01.A7, Westinghouse will also describe the potential consequences of a fire on the SC portion of the shield building. This will include an appraisal of the effects of a localized fire (on the SC portion of the shield building) on the overall integrity of the shield building. The SC portion of the shield building is much less likely than the CA modules to be subjected to a fire. The portions of the shield building interior to the nuclear island are designed as a standard reinforced concrete structure. No significant fire hazards exist along the west wall of the shield building or on the roof of the auxiliary building in the connection region to the auxiliary building. For a fire to effect the SC structure of the shield building, it would likely have to come from a beyond design basis source and it would likely be in an area where it could be quickly extinguished prior to causing any structural damage. With this understanding and the information developed in support of Action 7 to GI-**AP1000**-CE-01, Westinghouse will provide a justification for why the SC portion of the shield building will not be affected by fire hazards.

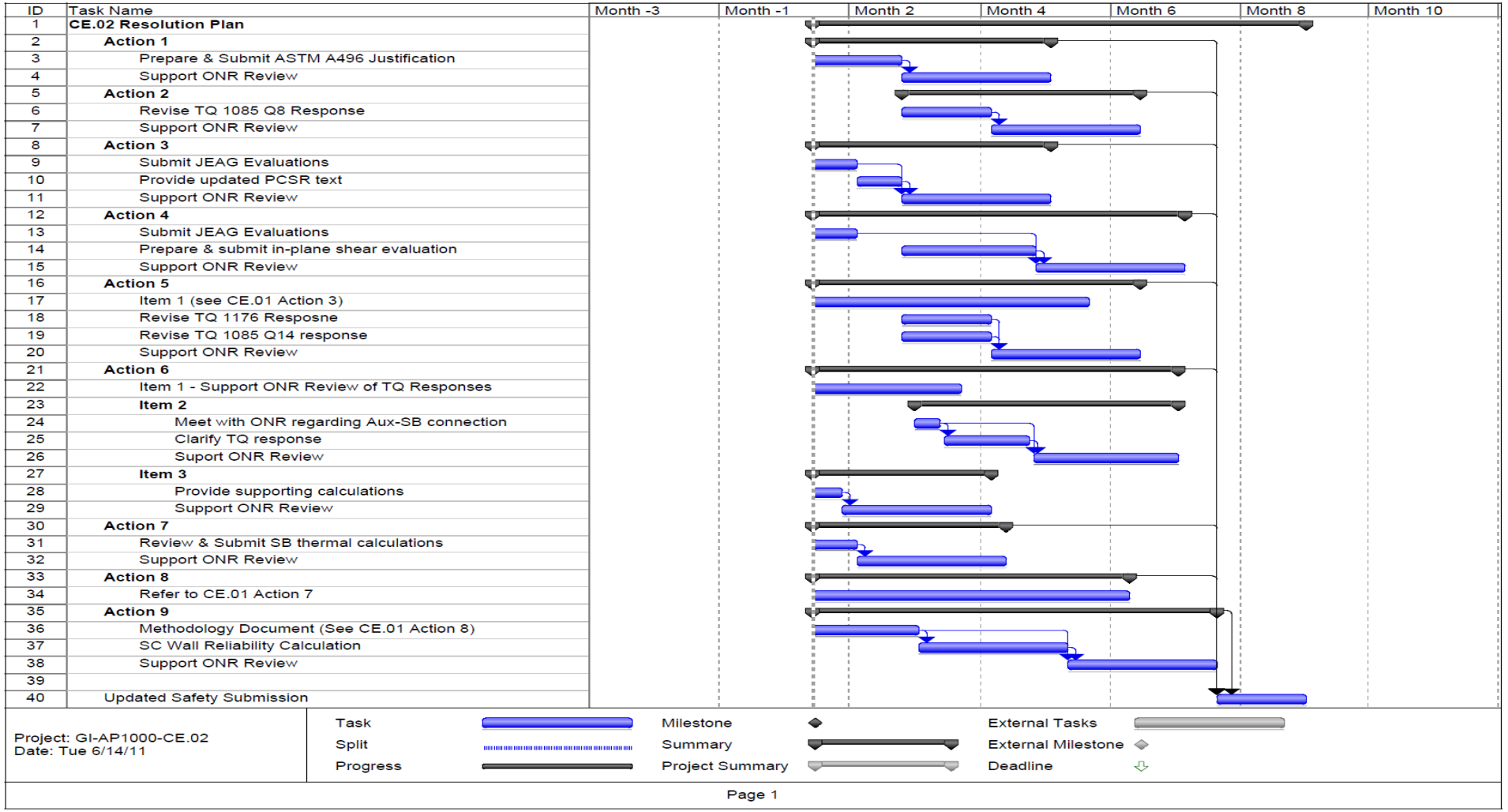
Action 9

The information required to address Action 9 is very similar in nature to the information required to address Action 8 of GI-**AP1000**-CE-01. In response to the similar Action for the CA modules, Westinghouse has proposed to perform a structural reliability evaluation of the CA modules in accordance with the Eurocodes. To execute this task

Westinghouse will generate an assessment methodology specific for the **AP1000** SC structures. The methodology developed for that Action will be used in response to these items. Westinghouse will apply that methodology to the cylindrical wall of the shield building to demonstrate the reliability of the SC portion of the shield building.

Schedule/ programme milestones:

Because all Resolution Plan start dates are subject to future contract placements, dates are presently unidentified; therefore schedule dates have been anonymised for consistency. Actual dates will be inserted when contracts are placed.



ID	Task Name
1	**CE.02 Resolution Plan**
2	**Action 1**
3	Prepare & Submit ASTM A496 Justification
4	Support ONR Review
5	**Action 2**
6	Revise TQ 1085 Q8 Response
7	Support ONR Review
8	**Action 3**
9	Submit JEAG Evaluations
10	Provide updated PCSR text
11	Support ONR Review
12	**Action 4**
13	Submit JEAG Evaluations
14	Prepare & submit in-plane shear evaluation
15	Support ONR Review
16	**Action 5**
17	Item 1 (see CE.01 Action 3)
18	Revise TQ 1176 Resposne
19	Revise TQ 1085 Q14 response
20	Support ONR Review
21	**Action 6**
22	Item 1 - Support ONR Review of TQ Responses
23	**Item 2**
24	Meet with ONR regarding Aux-SB connection
25	Clarify TQ response
26	Suport ONR Review
27	**Item 3**
28	Provide supporting calculations
29	Support ONR Review
30	**Action 7**
31	Review & Submit SB thermal calculations
32	Support ONR Review
33	**Action 8**
34	Refer to CE.01 Action 7
35	**Action 9**
36	Methodology Document (See CE.01 Action 8)
37	SC Wall Reliability Calculation
38	Support ONR Review
39	
40	Updated Safety Submission

Note: ONR review time indicated on the schedule is a generic assumption. Actual review time may be shorter or longer.

Methodology:

Action 1
The justification that A496 is an appropriate material will be based on demonstrating that it can perform its prescribed function claimed within the supporting shield building analysis.

Action 2
The combined axial tension and shear load on the tie bars has been calculated according to ACI 349-01. Westinghouse will review its current calculations and either include the additional loads noted by the ONR or justify why it is acceptable to exclude them.

Action 3
For item 1, please refer to the description of work. For item 2, the methodology employed will be based on JEAG 4619 and the existing draft AISC N690 Appendix 9A.

Action 4
The methodology employed will be based on JEAG 4619 and the existing draft AISC N690 Appendix 9A. The calculations in combination with information described in GI-**AP1000**-CE-01 Action 3 will provide a basis to support the design methodology for assessing in-plane shear when combined with other loads.

Action 5
Supporting justification will be further developed based on the results of Westinghouse testing, sensitivity calculations and consideration of alternative codes.

Action 6
For items 1 and 2, Westinghouse will work with ONR to support their review of the identified connections. For item 3, the supporting calculations will be provided.

Action 7
Supporting thermal analysis will be provided to demonstrate the structures can continue to perform its safety functions when subject to thermal transients.

Action 8
Hand calculations and FEA from GI-**AP1000**-CE-01 Action 7 will be referenced and a supporting justification will be provided to justify why the SC portion of the shield building will not be affected by fire hazards.

Action 9
The general structural reliability assessment will be based on the approach provided in the Eurocodes. A specific methodology for applying this approach to the **AP1000** SC structures will be developed as part of this action. Any HCLPF calculations that need to be revised will be updated based on the methodology employed for the HCLPF calculations already submitted. Westinghouse will justify that the appropriate failure modes are considered in any updated HCLPF calculations.

Justification of adequacy:

Action 1
The plan presented in the Description of Work for Action 1 aligns with the scope outlined in the GDA Issue as defined by ONR. The shield building supporting design calculations will demonstrate that the A486 tie bars are capable of performing their intended safety function.

Action 2
The plan presented in the Description of Work for Action 2 aligns with the scope outlined in the GDA Issue as defined by ONR. The existing calculations demonstrate large margins without crediting the concrete strength or considering the location of the occurrence of the maximum compression and out-of-plane shear loads (e.g. the region of 17 inch tie bar spacing will not see the maximum compression load). This provides confidence that consideration of the potential additional loads will not change the overall conclusion that the tie bars can satisfactorily perform their safety function.

Action 3
The plan presented in the Description of Work for Action 3 aligns with the scope outlined in the GDA Issue as defined by ONR, and it aligns with the similar issue action from GI-**AP1000**-CE-01. Existing calculations demonstrate the shield buildings can comply with the requirements in JEAG 4618.

Action 4
The plan presented in the Description of Work for Action 4 aligns with the scope outlined in the GDA Issue as defined by ONR, and it aligns with the similar issue action from GI-**AP1000**-CE-01. The additional calculations will provide further evidence that the shield building has sufficient in-plane shear capacity.

Action 5
The plan presented in the Description of Work for Action 1 aligns with the scope outlined in the GDA Issue as defined by ONR. The detailed analysis provided in the shield building design report demonstrates that significant margin exists in the structures design. This will support the response that will further demonstrate adequate shear reinforcement is provided in the design of the structure.

Action 6
The information required to address item 1 has already been provided, and the primary work associated with this item will be to support questions that may arise based on the regulatory review of these submittals.

For items 2 and 3, the plan presented in the Description of Work for Action 6 aligns with the scope outlined in the GDA Issue as defined by ONR. The supporting calculations will demonstrate that identified connection and transition regions have adequate reinforcement and that the forces will be transferred through the connections.

Action 7
The plan presented in the Description of Work for Action 7 aligns with the scope outlined in the GDA Issue as defined by ONR. The commitment to add cladding to the shield building in combination with the supporting analysis provides confidence that the

structures will continue to perform its safety functions when subject to thermal transients.

Action 8
The plan presented in the Description of Work for Action 7 relies on working that will be completed to address similar action for GI-**AP1000**-CE-01. Based on the supporting calculations performed for GI-**AP1000**-CE-01.A7, Westinghouse will also describe the potential consequences of a fire on the SC portion of the shield building. The combination of the supporting calculations and the low likelihood that the SC portion of the shield building will be subjected to a significant fire will provide justify that the SC portion of the shield building is unlikely to be affected by fire hazards.

Action 9
Based on the information provided to date and the design margins exhibited in the analysis and testing, Westinghouse believes this action can be addressed by providing a Eurocode type structural reliability evaluation for the cylindrical wall of the shield building.

Impact assessment:

The Safety Submission Documents (Pre-Construction Safety Report (primarily chapter 16), Environment Report and its supporting documents, Design Reference Point, Plant Life Cycle Safety Report, Master Submission List and Roadmap) will be updated as appropriate.