Office for Nuclear Regulation

New Reactors Programme

GDA close-out for the AP1000 reactor

GDA Issue GI-AP1000-ME-03 Mechanical System Pipework Design

Assessment Report: ONR-NR-AR-16-016
Revision 2
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EXECUTIVE SUMMARY

Westinghouse Electric Company (WEC) is the reactor design company for the **AP1000®** reactor. Westinghouse completed Generic Design Assessment (GDA) Step 4 in 2011 and paused the regulatory process. Westinghouse achieved an Interim Design Acceptance Confirmation (IDAC), which had 51 GDA issues attached to it. These issues require resolution prior to the award of a Design Acceptance Confirmation (DAC) and before any nuclear safety-related construction can begin on site. Westinghouse re-entered GDA in 2014 to close the 51 issues.

This report presents the Office for Nuclear Regulation's (ONR's) assessment of the Westinghouse **AP1000** reactor design in the area of mechanical engineering. Specifically, this report addresses GDA Issue GI-AP1000-ME-03: Mechanical System Pipework Design (ME-03).

ME-03 was identified in the 'Step 4 Mechanical Engineering Assessment' of Westinghouse's **AP1000** reactor. This assessment recognised that further pipework design justification was required. In particular, to demonstrate that the system pipework incorporates adequate isolation and drainage arrangements. This enables the anticipated Examination, Inspection, Maintenance and Testing (EIMT) activities to be carried out in a safe and controlled manner.

Central to Westinghouse's demonstration, to address the GDA ME-03 actions, is that it has:

- comprehensively screened the **AP1000** pipework designs isolation techniques and drainage methods, ie it has reviewed all of the Class 3 (or higher) pipework Structures, Systems and Components (SSC) that delivers a safety function;
- reviewed and compared United Kingdom (UK) and United States (of America) (US) relevant good practice in the areas of isolations and drainage;
- undertaken an As Low As Reasonably Practicable (ALARP) assessment. This assessment reviewed the hazards and risks, and considered and balanced the available options before arriving at an acceptable ALARP outcome. This outcome proposes both design and operational changes to the **AP1000** plant; and
- committed to implementing the required **AP1000** pipework design changes through its existing Design Change Proposal (DCP) arrangements. ONR's review of Westinghouse's management of safety and quality assurance assessment found these arrangements to be adequate.

My assessment conclusions were that, subject to a future licensee closing the assessment findings highlighted below, Westinghouse has adequately addressed:

- ME-03 Action A1. This justifies that Westinghouse's use of 'freeze seal' technology to allow EIMT of the **AP1000** plant is reasonable.
- ME-03 Action A2. This justifies that Westinghouse's arrangements for **AP1000** pipework EIMT isolations that rely on single valve isolations are reasonable.
- ME-03 Action A3. This justifies that Westinghouse's drainage facilities enable the anticipated **AP1000** EIMT activities to be carried out in a safe and controlled manner.

My judgement was based upon my engagement with Westinghouse, detailed assessment of its three safety case submissions and convergence on the most reasonable practicable pipework design option for the **AP1000** pipework design, ie the ALARP outcome.

The following mechanical factors remain, which are for a future licensee to consider and take forward in its site-specific safety submission. These matters do not undermine the generic safety submission and require licensee input and decision.

Assessment Finding CP-AF-AP1000-ME-09

The licensee shall:

- confirm the use of freeze seal technology, to allow EIMT, is appropriate;
- review national and international freeze seal technology relevant good practice and operating experience; and
- following this review, develop and implement adequate **AP1000** plant freeze seal arrangements (these arrangements should include safe systems of work).

Assessment Finding CP-AF-AP1000-ME-10

The licensee shall:

- ensure all **AP1000** Class 1 or 2 temporary pipework drainage SSCs are designed, manufactured, constructed, installed, commissioned and quality assured to appropriate codes and standards relative to their safety category and classification; and
- develop adequate arrangements for employing temporary drainage equipment on the **AP1000** plant.

In summary, I am content that ‘GDA Issue GI-AP1000-ME-03: Mechanical System Pipework Design’ can be closed.

LIST OF ABBREVIATIONS

ALARA	As Low As Reasonably Achievable
ALARP	As Low As Reasonably Practicable
ALWR	Advanced Light Water Reactor
BDS	Steam Generator Blowdown System
BSO	Basic Safety Objective
CCS	Component Cooling System
CVS	Chemical and Volume Control System
DAC	Design Acceptance Confirmation
DCP	Design Change Proposal
EIMT	Examination, Inspection, Maintenance and Testing
GDA	Generic Design Assessment
HEPA	High-Efficiency Particulate Arresting
HSG	Health and Safety Guide
IAEA	International Atomic Energy Agency
IDAC	Interim Design Acceptance Confirmation
IRWST	In-Containment Refuelling Water Storage Tank
LC	Licence Condition
ONR	Office for Nuclear Regulation
PCSR	Pre-construction Safety Report
PSS	Primary Sampling System
PXS	Passive Containment Cooling System
RCS	Reactor Coolant System
RGP	Relevant Good Practice
RNS	Normal Residual Heat Removal System
SAP	Safety Assessment Principles
SBB	Single Block and Bleed
SFAIRP	So Far As Is Reasonably Practicable
SFS	Spent Fuel Pool Cooling System
SSC	Structure, System and Component
TAG	Technical Assessment Guide
TSC	Technical Support Contractor
UK	United Kingdom
URD	Utility Requirements Document
US	United States (of America)
US NRC	United States (of America) Nuclear Regulatory Commission
WEC	Westinghouse Electric Company
WENRA	Western European Nuclear Regulators' Association

WLS	Liquid Radwaste System (termed Waster Liquid System)
WSS	Solid Radwaste System (termed Waste Solid System)

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1 INTRODUCTION

1.1 Background

1. Westinghouse Electric Company (WEC) completed Generic Design Acceptance (GDA) Step 4 in 2011, pausing the regulatory process. It achieved an Interim Design Acceptance Confirmation (IDAC), which had 51 GDA issues attached to it. These issues require resolution prior to the award of a Design Acceptance Confirmation (DAC) and before any nuclear safety related construction can begin on site. Westinghouse re-entered GDA in 2014 to close the 51 GDA issues.

2. This report presents the Office for Nuclear Regulation (ONR's) mechanical engineering assessment of the Westinghouse **AP1000** reactor design in the area of Examination, Inspection, Maintenance and Testing (EIMT) of the **AP1000** plants pipework systems. Specifically this report addresses ONR's GDA Issue GI-AP1000-ME-03: mechanical system pipework design.

3. The related ONR GDA Step 4 report is published on our website (**www.onr.org.uk/new-reactors/AP1000/reports.htm**). This provides the assessment underpinning the GDA issue. Further information on the GDA process in general is also available on our website (**www.onr.org.uk/new-reactors/index.htm**).

1.2 Scope

4. The scope of this assessment is detailed in ONR's mechanical engineering assessment plan (Ref. 2). This covers Westinghouse's further justification for the pipework design of the **AP1000** plant for systems important to safety. In particular, that the **AP1000** plant system design is required to incorporate adequate isolation and drainage arrangements to enable all anticipated EIMT activities to be carried out in a safe and controlled manner. Consistent with this plan, the assessment is restricted to considering whether the WEC submissions to ONR for GI-AP1000-ME-03 (and its associated three actions: A1 to A3) adequately justify closure of the ME-03 issue.

5. The three ME-03 actions relate to whether Westinghouse adequately justified the **AP1000** plant design's:

   - use of 'freeze seal' technology, to allow EIMT, is appropriate (ME-03 Action A1);
   - arrangements for EIMT isolations that rely on single valve isolations are ALARP (ME-03 Action A2); and
   - drainage facilities enable the anticipated EIMT activities to be carried out in a safe and controlled manner (ME-03 Action A3).

6. This report only presents the ONR assessment undertaken as part of the resolution of the ME-03 GDA Issue. To appreciate the totality of ONR's mechanical engineering assessment of the Westinghouse **AP1000** reactor design, it is recommended that this report be read in conjunction with the Step 4 Mechanical Engineering Assessment of the Westinghouse **AP1000** reactor (Ref. 1).

1.3 Method

7. This assessment complies with internal guidance on the mechanics of assessment in accordance with the requirements of ONR's HOW2 guide NS-PER-GD-014 (Ref. 12).

Whilst this is ONR’s permissioning guidance, it is considered relevant to the mechanical assessment of the ME-03 issue.

1.3.1 Sampling strategy

8. ONR adopts an assessment strategy of sampling. My sampling strategy for this assessment focused on areas of nuclear safety significance; and where there was evidence that Westinghouse’s **AP1000** pipework design arrangement for isolation and drainage may not fully comply with UK Relevant Good Practice (RGP) expectations.

2 ASSESSMENT STRATEGY

2.1 Pre-Construction Safety Report (PCSR)

9. ONR's GDA Guidance to Requesting Parties (www.onr.org.uk/new-reactors/ngn03.pdf) (Ref.6) states that the information required for GDA may be in the form of a 'Pre-Construction Safety Report' (PCSR). Technical Assessment Guide (TAG 051) (Ref. 10) sets out regulatory expectations for a PCSR (www.onr.org.uk/operational/tech_asst_guides/ns-tast-gd-051.pdf).

10. At the end of Step 4, ONR and the Environment Agency raised GDA Issue CC-02 (www.onr.org.uk/new-reactors/reports/step-four/westinghouse-gda-issues/gi-AP1000-CC-02.pdf). This required Westinghouse to submit a consolidated PCSR and associated references to provide the claims, arguments and evidence to substantiate the adequacy of the **AP1000** design reference point (Ref. 8).

11. A separate regulatory assessment report is provided to consider the adequacy of the PCSR and closure of GDA Issue CC-02 (Ref. 11). So this report does not discuss the mechanical engineering aspects of the PCSR. This assessment focused on the supporting documents and evidence specific to ONR's GDA Issue ME-03.

2.2 Standards and criteria

12. The standards and criteria adopted within this assessment are principally: Safety Assessment Principles (SAP) (Ref. 13), internal TAGs (Table 2), relevant national and international standards and relevant good practice informed from existing practices adopted on UK nuclear licensed sites (Section 2.2.3). These standards and criteria are identified individually throughout the report.

2.2.1 Safety Assessment Principles

13. The key SAPs applied within the assessment are included within Table 1.

2.2.2 Technical Assessment Guides

14. The TAGs that have been used as part of this assessment are set out in Table 2.

2.2.3 National and international standards and guidance

15. The following national and international standards and guidance have been used as part of this assessment:

HSG 253 – Health and Safety Executive Guidance of the Safe Isolation of Plant and Equipment (Ref. 17)

16. This document, referred throughout this assessment as "HSG 253", provides guidance on the general principles of safe process isolations. This guidance is equally applicable for nuclear use. HSG 253 describes how to safely isolate plant and equipment, and how to reduce risks of releasing hazardous substances during intrusive activities such as maintenance and sampling. *For the purposes of this assessment this will be termed Examination, Inspection, Maintenance and Testing (EIMT) as designated under LC 28.*

17. HSG 253 includes a methodology for selecting a 'baseline' process isolation standard. Westinghouse used HSG 253 to determine if its proposals for safe isolation met relevant good practice.

18. Glossary to HSG 253 terminology used within this mechanical engineering assessment:

Baseline Isolation Standard is the minimum acceptable standard of final isolation applied under normal circumstances. This standard is based on risk assessment.

Positive Isolation is the complete isolation of plant and equipment to be worked on from other parts of the system.

Proven Isolation is where the effectiveness of valve closure(s) can be confirmed via vent and bleed points before intrusive work commences.

Non-Proven Isolation is where there is no provision to confirm effectiveness of valve closure before breaking into the system.

Boundary Isolation is the insertion of fully pressure rated spades or spectacle blinds at every point of the plant boundary (the 'battery limits'). Typically, such isolation is used on plant maintenance shutdowns or 'turnarounds' where the inventory of hazardous fluids is removed. Full physical isolation of the boundary prevents repressurisation of the system by, or ingress of hazardous materials from, any adjacent live process systems.

International Atomic Energy Agency (IAEA) Safety Guide No. NS-G-1.9, Design of the Reactor Coolant System and Associated Systems in Nuclear Power Plants (Ref. 14)

19. The document provides general guidance on the requirement for providing venting and draining capabilities, which should be delivered by a nuclear plant's piping systems.

Western European Nuclear Regulators' Association (WENRA): Reactor Safety Reference Levels for Existing Reactors (Ref. 15)

20. The Reactor Safety Levels (RLs) reflect expected practices to be implemented in WENRA countries. The emphasis of the RLs is on nuclear safety, primarily focusing on safety of the reactor core and spent fuel. The RLs specifically exclude nuclear security and, with a few exceptions, radiation safety.

****Advanced Light Water Reactor (ALWR) Utility Requirements Document, Revision 8 March 1999 (Ref. 16)**

21. The document contains US recommendations and requirements for valves, vents and drains. A significant design driver of this design guidance claims to be the requirement to minimise the number of valves, with simplicity being the fundamental requirements of the ALWR programme.

22. The document provides the following general design requirements:

- Valves for vents and drains need to be accessible for operation and maintenance in low radiation areas.
- Vents and drains shall be piped to vent and drain systems or have means of providing drainage capabilities to the plant drainage system.

- Overall, piping systems should minimise dead legs and crud traps and should provide water flushing capabilities for drains and traps that cannot be eliminated.

- Process vessels shall be provided within vent and drain connections and shall be designed to allow complete drainage.

- Pumps in nuclear service shall be provided with drain and flush connections for decontamination.

- For tanks, the use of sloped or cone-shaped tanks provides for more complete drainage of the tank and should be utilised where possible.

*** This design guidance document has not been assessed by ONR. However, I considered it appropriate to <u>list for information</u> as Westinghouse used it within its assessment to compare US and UK RGP and identify compliance gaps. Its listing within this report should not be taken as regulatory endorsement as representing RGP.*

2.3 Use of Technical Support Contractors (TSCs)

23. Not applicable.

2.4 Integration with Other Assessment Topics

24. Not applicable.

2.5 Out of scope items

25. This report does not discuss the mechanical engineering aspects of the PCSR to support GI-AP1000-CC-02 (Ref. 11), which is covered by a separate ONR cross-discipline assessment.

3 REQUESTING PARTY'S SUBMISSION TO ADDRESS THE GDA ISSUES

26. Westinghouse's safety case submission, which addresses the GDA ME-03 pipework design issue, is contained in the following risk assessments:

UK-GW-GL-102 AP1000 Plant Assessment of Freeze Seal Application (Ref. 3)

27. The document considers Westinghouse's assessment of the use of pipe freeze technology on the **AP1000** plant. Through an ALARP assessment, it aims to demonstrate that the controlled use of freeze technology to enable **AP1000** plant EIMT is reasonable.

UK-GW-GL-103 AP1000 Plant Assessment of Single Valve EIMT Isolations (Ref. 4)

28. This document considers Westinghouse's assessment of the use of single valve isolations, for EIMT, on the **AP1000** plant. Through an ALARP assessment, Westinghouse aims to demonstrate that the isolated use of single valve isolations to enable **AP1000** plant EIMT is reasonable.

UK-GW-GL-104 AP1000 Plant Assessment of Pipework Drainage Features (Ref. 5)

29. This document considers Westinghouse's assessment of the adequacy of the drainage facilities on the **AP1000** plant. Through an ALARP assessment, it aims to demonstrate that the **AP1000** pipework design is engineered to allow adequate drainage.

30. In brief, each of Westinghouse's assessments adopted the following approach:

- Developed a screening criteria for the selection of isolation techniques and drainage methods.
- Reviewed and compared UK and US relevant good practice.
- Undertook an ALARP assessment, which comprised:
  - a determination of hazards and risks;
  - consideration of the available options; and
  - a comparison of the detriment versus the benefit of the varying options.
- Concluded on the acceptability of the ALARP option, ie the ALARP outcome.

31. Westinghouse confirmed (Ref. 7) its plans to implement the ME-03 report's conclusion, ie findings and physical **AP1000** plant changes, using its design change proposal (DCP) process. The DCPs are to be implemented into the Design Reference Point (DRP) for the UK **AP1000** design (Ref. 8).

32. The DCP process is required to meet the requirements of Licence Condition (LC) 20 relating to modification to design of plant under construction. ONR's review of Westinghouse's management of safety and quality assurance assessment (Ref. 9) found the DCP arrangements to be adequate.

4 ONR ASSESSMENT OF GDA ME-03 ISSUE

33. This mechanical engineering assessment has been carried out in accordance with HOW2 guide NS-PER-GD-014, “Purpose and Scope of Permissioning” (Ref. 12). Whilst GDA is not specifically a permissioning activity, its use is considered appropriate as it sets out ONR’s processes for engaging with a duty holder.

4.1 Scope of Assessment Undertaken

34. I assessed the mechanical aspects of all of the Westinghouse submissions contained in Section 3 of this report, which comprised the following:

- I assessed several iterations of each of the ME-03 isolation and drainage safety case submissions, ie A1 – Freeze Seals, A2 – Single EIMT Isolations and A3 – Drainage.
- I held a series of L4 technical engagements with Westinghouse, where I:
    - discussed my regulatory expectations, based on relevant good practices, as set out with Section 2 of this report; and
    - discussed the associated technical and safety aspects of each of the submissions to converge on the most reasonable practicable pipework design option, ie the acceptable ALARP outcome.

35. My overriding assessment objective considered whether Westinghouse’s safety case submissions (SAP SC.4):

- comprehensively evaluated its **AP1000** pipework design for isolation and drainage;
- through optioneering, adequately covered potential engineering and/or operational improvements to the **AP1000** pipework design;
- adequately considered UK relevant good practice for pipework design; and
- through analysis of the **AP1000** plant hazards, considered the risks associated with each of the activities, ie safe isolation for EIMT and drainage.

36. From the above, I considered whether the proposed **AP1000** pipework design option represented an ALARP outcome that would closed the respective GDA ME-03 issue.

4.2 Assessment

4.2.1 Assessment Reporting Approach

37. This part of the report is divided into three sections covering my assessment of each of the **AP1000** GDA ME-03 pipework design IDAC issues, ie ME03 -A1, ME03 -A2 and ME03 -A3.

38. Each of these sections:

- describes the mechanical engineering regulatory action that ONR placed on Westinghouse to resolve the specific aspect of the GDA pipework design issue; and

- describes my key assessment considerations and conclusions, which includes:
  - my mechanical engineering judgement on the adequacy of Westinghouse's response to close the respective GDA ME-03 issue; and
  - details of any minor shortfalls and assessment findings resulting from my engagement (if applicable).

4.2.2 AP1000 ME-03-A1 – Freeze Seals

Westinghouse ME-03-A1 Action

39. As a result of the generic design assessment (GDA) Step 4 review (Ref. 1), ONR placed the following action on Westinghouse:

"Westinghouse shall generate the arguments and evidence to justify that each isolation that proposes to use pipe freezing technology is ALARP.

"Westinghouse's proposal to use pipe freezing technology to provide process isolation in support of their planned EIMT regime is considered not to be good engineering practice for the anticipated isolation requirements for a new reactor design, but rather a technology utilised to recover from a scenario that has not been generally predicted.

"ONR considers that good engineering practice for a new modern NPP incorporates adequate engineered arrangements for anticipated and planned process isolation to support EIMT activities.

"ONR's expectation is for Westinghouse to review their design and either revise their proposal in line with ONR expectations or demonstrate with appropriate arguments and evidence that the anticipated process isolations that propose the use of pipe freezing technology are ALARP.

"With agreement from the Regulator this action may be completed by alternative means."

Key Assessment Considerations and Regulatory Judgements

40. In response to the regulatory action above, Westinghouse reviewed its current use of freeze technology across the **AP1000** plant. This is reported in Ref. 3. I considered this review to be comprehensive.

41. It is recognised that freeze seal technology is not commonly used in the UK nuclear industry. However, freeze seal technology is widely used in conventional UK industries, eg the UK oil and gas industry, and is also widely used in the US nuclear industry. For the purposes of this assessment, I have considered the use of freeze seals as novel (SAP ERL.1).

42. The challenges associated with freeze seal use are reflected in HSG 253 'The Health and Safety Executive's (HSE) Health and Safety Guide for Safe Isolation of Plant and Equipment in the UK'. HSG 253 considers pipe freezing to be a specialist technique (SAP ERL.4). HSG 253 advises of the advantages and disadvantages of using this technology, the most significant of the disadvantages being associated with its poor application.

43. My assessment of Westinghouse's review of freeze seals across the **AP1000** plant revealed **23 areas** of current use, ie **AP1000** fluid lines that use freeze seal technology. Following an ALARP review, where Westinghouse considered a number of options and associated risks, this has been reduced to **two areas** of proposed use. This reduction has been achieved through its ALARP proposals to either modify the plant to add system isolation valves or, where necessary, remove the hazard by draining down the affected SSC's. In the majority of cases, Westinghouse has demonstrated that by effectively draining down the affected SSC's the risks during EIMT are significantly reduced. I considered Westinghouse's review of its **AP1000** plant to be comprehensive.

44. For the **two areas** that cannot be drained down, Westinghouse proposed using freeze seals. These two areas are contained within the In-Containment Refuelling Water Storage Tank (IRWST) sub-system, which itself is a sub-system of the Passive Containment Cooling System (PXS). In judging whether Westinghouse's proposed continued use of freeze seals is reasonable, I considered the following aspects:

- Using the guidance in HSG 253, Westinghouse has demonstrated that the conventional hazard (pressure, temperature etc) associated with using freeze seals on the IRWST is low.

- Westinghouse has demonstrated that the radiological hazard posed by the IRWST fluid is low, ie at a level below the Base Safety Objective (BSO) of Target 4 (Ref. 13) of the SAP (~ one-third of the BSO). Using ONR's guidance on the categorisation of safety functions and classification of structures, systems and components (TAG NST-GD-094), this corresponds to an expectation of Category C Class 3 isolation, which I considered can be reliably provided by the freeze seals (SAP ERL.1).

  Note – NS-NST-GD-094 provides guidance of a Class 3 'failure frequency' of between E10-1 and E10-2. I considered this to be a reasonable reliability claim for freeze seal use.

- For a low hazard fluid, HSG 253 recommended single and double valve non-proven type isolation. A freeze seal offers non-proven isolation, which does not require the effectiveness of closure to be demonstrated, ie through a 'proven' bleed type system prior to breaking into the system.

- Immediately following the freeze seal use, and before undertaking EIMT activities, Westinghouse proposed the installation of HSG 253 'positive' isolation, ie physically separate the plant subject to EIMT. This will be achieved by adding a blind flange to the end of the pipe and is termed as achieving 'boundary isolation' within HSG 253. I considered this approach reasonable, as it reduces the plant maintainer's time of exposure to risk, and reliance is not placed on the freeze seal for protection during the EIMT activity (SAP NT.2).

- The addition of a primary device, ie isolation valve in place of the use of the freeze seals, was considered by Westinghouse to be disproportionate. Given the low overall safety benefit associated with modifying the plant, I considered this claim to be reasonable (SAP SFAIRP and ALARP / ALARA Guidance – TAG NS-TAST-GD-005).

- HSG 253 identifies that pipe materials, joints and components can be adversely affected by the freezing operation. To address this potential concern, Westinghouse proposed to reduce thermal stresses (SAP EMC.14) by increasing the cooling period, ie forming the ice plug over a period of time. Alternative methods, using ethylene glycol or compressed air as an alternative to liquid nitrogen, are also available which provide a smaller margin of temperature difference. Whilst I consider this approach to be reasonable, it is for the licensee to determine its preferred approach.

- Freeze seal experience in the UK nuclear industry is limited. Westinghouse therefore expects the future licensee to evaluate all available freeze seal RGP and operating experience; and then introduce a freeze seal implementation programme. If adequate freeze seal arrangements (including safe systems of work) are put in place, I considered that this will alleviate the UK's operational experience concerns raised in HSG 253. **I considered this to be an assessment finding.**

Assessment Finding (CP-AF-AP1000-ME-09)

The licensee shall:

- confirm the use of freeze seal technology, to allow EIMT, is appropriate;
- review national and international freeze seal technology relevant good practice and operating experience; and
- following this review, develop and implement adequate AP1000 plant freeze seal arrangements (these arrangements should include safe systems of work).

Minor Shortfall – None identified

Conclusion

45. Subject to adequate closure of Assessment Finding CP-AF-AP1000-ME-09, I consider that Westinghouse has adequately demonstrated that the use of pipework freeze seals is adequate to allow **AP1000** plant EIMT, ie its proposals for future freeze seal use present an acceptable ALARP outcome.

46. I consider that Westinghouse has adequately addressed ME-03 Action A1.

4.2.3 AP10000 ME-03-A2 – Single EIMT Isolations

Westinghouse ME-03-A2 Action

47. As a result of the generic design assessment (GDA) Step 4 review (Ref. 1), ONR placed the following action on Westinghouse:

"Westinghouse shall generate the arguments and evidence to justify that EIMT isolations that rely on single valve isolations are ALARP.

"The IRWST isolation is provided by a single isolation valve to undertake EIMT of the injection squib valves. This does not achieve ONR expectations when considering the IRWST has a capacity circa 2100m^3 and if the single isolation valve was to fail (in its isolation function) then a significant hazard would arise. The system design does not have any other provision to contain the fluid within the IRWST.

"ONR considers a system isolation first design choice is provided by a suitable valve arrangement, with double valve isolation being provided for systems that are subject to

a significant pressure, or temperature, or where there is some other significant hazard eg, a large volume of fluid is held back.

"ONR's expectation is for Westinghouse to review their design and either revise their proposal in line with ONR expectations or demonstrate with appropriate arguments and evidence that all anticipated isolations that propose to use single isolation that are the subject of either a significant pressure, temperature or some other significant hazard are ALARP.

"With agreement from the Regulator this action may be completed by alternative means."

Key Assessment Considerations and Regulatory Judgements

48. In response to the above regulatory action, Westinghouse reviewed its current use of single valve EIMT isolations across the **AP1000** plant. This is reported in Ref. 4.

49. HSG 253 recognises the concept of a 'baseline standard', which is the minimum acceptable standard of final isolation applied under normal circumstances. HSG 253 recommends that you should not use Single Block and Bleed (SBB) as a final isolation method on live plant containing hazardous substances. However, it is accepted that there are circumstances when SBB may be used where the risk assessment has shown it to be acceptable. Where Westinghouse proposes SBB use, to allow EIMT (NS-TAST-GD-009) on the **AP1000** plant, I have assessed whether an acceptable risk assessment has been provided.

50. My assessment of Westinghouse's review of all **AP1000** Class 3 function (or higher) pipework design Structures, Systems and Components (SSCs) revealed the following:

- Westinghouse's review of EIMT isolation across the **AP1000** plant was comprehensive.
- Whilst the majority of the **AP1000** plant systems comply with the HSG 253 recommended isolation method, to allow EIMT, the following systems do not (ie they do not offer either positive or proven isolation):
    - Component Cooling System (CCS)
    - Chemical and Volume Control System (CVS)
    - Normal Residual Heat Removal System (RNS)
    - Spent Fuel Pool Cooling System (SFS)
- For the above systems Westinghouse concluded that it is reasonably practicable to modify the plant, by adding valves and/or blind flanges to achieve 'proven' isolation (or higher). I concurred with this ALARP recommendation, which Westinghouse has agreed to implement in full via its DCP arrangements (Ref. 7).
- For the IRWST, a sub-system of the Passive Containment Cooling System (PXS), Westinghouse considered that achieving the HSG 253 baseline isolation standard of 'proven' isolation is not reasonably practicable. Westinghouse considered that the balance of safety benefit does not outweigh the detriment of modifying the plant (SAP SFAIRP, ALARP, ALARA Guidance and NS-TAST-GD-005). I concurred with Westinghouse's ALARP recommendation. This partly addresses ONR's regulatory action with respect to IRWST isolation. **See**

also (paragraph 4.2.2) freeze seal consideration, which together fully address ONR's IRWST isolation concerns.

51. In judging whether the existing SBB method (non-proven isolation) of PXS isolation for EIMT is reasonable, I considered the following aspects:

- Using the guidance in HSG 253, Westinghouse has demonstrated that the conventional hazards (pressure, temperature etc) associated with the IRWST are low.

- Westinghouse has demonstrated that the radiological hazard posed by the IRWST fluid is low, ie at a level below the BSO of Target 4 (Ref. 13) of the SAP (one-third of the BSO). From ONR's TAG Guidance NST-GD-094, Category C Class 3 type isolation is advised. Westinghouse demonstrated that these Category C isolations are delivered by Class 1 components. On balance, I considered that Class 1 isolations should offer a greater degree of reliability than the Class 3 type isolation recommended for a Category C safety function.

- In arriving at this judgement, I have taken into consideration ONR's guidance (NST-TAST-GD-094) on SSC failure frequencies for normal operation reproduced below.

SSC Class	Failure frequency per year
Class 1	10^{-3} to 10^{-5}
Class 3	10^{-1} to 10^{-2}

- For a low hazard fluid HSG 253 recommends that either single or double valve Category III non-proven isolation is used. For non-proven isolation, HSG 253 states that there is no requirement to confirm the effectiveness of closure prior to breaking into the system, ie through a bleed type system. So, the minimum baseline standard in HSG 253 has been achieved, ie using single isolation.

- With respect to the IRWST flooding risk, which could potentially adversely affect Class 2 **AP1000** components, Westinghouse claimed that the likelihood of gross valve failure of the Class 1 valves (leading to a large flooding hazard) during EIMT is low. Westinghouse claimed that the more likely event would be valve seepage presenting insignificant risk to both the maintainer and Class 2 SSCs. Given the relatively low static pressure (<0.9 Bar) associated with the IRWST, I considered these claims to be reasonable.

- Westinghouse has stated that the 'normally open' single isolation IRWST valves described above are not frequently used. These valves are normally required to remain open to fulfil their safety function, ie they are not required to close. Westinghouse has stated (Ref. 7) that a confirmatory check of their position is undertaken during 12-hour operational surveillance. In addition, the valves are cycled every two years, checking their availability to isolate when required (SAP EMT.5 & 6). I considered that these measures are adequate to confirm that the valves operate reliably.

- I concurred with Westinghouse's finding that it is disproportionate to change the current **AP1000** plant PXS system design to provide either double or proven isolation, ie I considered Westinghouse's extant SBB PXS provisions to be adequate.

Assessment Finding – None identified

Minor Shortfall – None identified

Conclusion

52. I consider that, with the proposed engineering changes implemented, Westinghouse has adequately demonstrated that its **AP1000** plant EIMT isolation arrangements are reasonable, ie they present an acceptable ALARP outcome.

53. I consider that Westinghouse has adequately addressed ME-03 Action A2.

4.2.4 AP10000 ME-03-A3 – Drainage

Westinghouse ME-03-A3 Action

54. As a result of the Generic Design Assessment (GDA) Step 4 review (Ref. 1), ONR placed the following action on Westinghouse:

"Westinghouse shall generate the arguments and evidence to justify that all process pipework designs are adequately engineered to provide drainage facilities to enable the anticipated EIMT activities to be carried out in a safe and controlled manner.

*"Isolation of the motor operator valve to allow EIMT to be carried out on the 4th Stage Squib valves requires the downstream leg of fluid to be drained by ad hoc means ie, splitting of flanges and use of temporary fluid collection containers. This is an example of the **AP1000** design not incorporating adequate engineered arrangements for carrying out anticipated EIMT in a safe and controlled manner.*

"ONR considers that a system design should incorporate adequate engineered arrangements to enable the process pipework to be drained in a safe and controlled manner.

*"ONR's expectation is for Westinghouse to review their design and either revise their proposal in line with ONR expectations or demonstrate with appropriate arguments and evidence that the **AP1000** design incorporates adequate engineered drainage facilities to enable anticipated EIMT activities to be carried out in a safe and controlled manner.*

"With agreement from the Regulator this action may be completed by alternative means."

Key Assessment Considerations and Regulatory Judgements

55. In response to the above regulatory action, Westinghouse reviewed its drainage arrangements across the **AP1000** plant. This is reported in Ref. 5.

56. HSG 253 provides guidance on dedicated draining and venting provisions, in particular the need to safely remove hazardous bulk contents to allow EIMT to be safely performed (SAP EMT.2). Notably, HSG 253 recognises that temporary methods of drainage are acceptable providing they are appropriately managed via safe systems of work (SAP ENM.3), for example, through an appropriate permit to work system. Whilst this is a requirement for a future licensee, I considered that it can be taken forward as part of Assessment Finding CP-AF-AP1000-ME-10.

57. My assessment of Westinghouse's review of all **AP1000** Class 3 function (or higher) SSCs, that deliver a safety function, revealed the following:

- Westinghouse's review of its drainage arrangements across the **AP1000** plant was comprehensive.
- Westinghouse's conservative approach to evaluating the **AP1000** plant draining arrangements. Westinghouse evaluated the draining capabilities of all the Class 3 or higher SSCs requiring EIMT. The initial screening criteria performed by Westinghouse only screened out SSC's with drainage provisions between isolations and did not consider the capability of the system to be drained from a different portion in the initial screening. The later design evaluation performed in Reference 5 determined if the SSC could be drained from a different portion of the system. If a dedicated engineering means of drainage was not available, after screening and evaluation, Westinghouse's ALARP assessment considered what reasonable practicable measures could be taken to achieve safe drainage.
- Whilst the majority of the **AP1000** plant systems comply with HSG 253 drainage guidance to allow EIMT, the following systems do not fully comply:
    - Steam Generator Blowdown System (BDS) x 1 area
    - Chemical and Volume Control System (CVS) x 1 area
    - Reactor Coolant System (RCS) x 1 area – (identified in the regulatory action above, ie EIMT of the 4th stage squib valves)
    - Liquid Radwaste System (WLS) x 2 areas
- For the systems above, Westinghouse concluded that it is reasonably practicable to improve its arrangements by adding draining provisions to the extant **AP1000** plant. For one of the WLS areas, Westinghouse concluded that it is reasonably practicable to use a temporary suction pump to drain the system. This removes the need to physically change the plant. I concurred with this ALARP recommendation, which Westinghouse will progress through its DCP arrangements.
- For features associated with the following systems, the balance of safety benefit (SAP SC.5), ie the reduction in risk versus the detriment of modifying the plant to provide dedicated drainage, was judged by Westinghouse not to be reasonably practicable. I concurred with this recommendation.
    - Chemical and Volume Control System (CVS) x 2 areas (one of which can't be flushed)
    - Primary Sampling System (PSS) x 1 area (can't be flushed)
    - Passive Core Cooling System (PXS) x 1 area (can't be flushed)
    - Spent Fuel Pool Cooling System (SFS) x 1 area (can be flushed)

- Liquid Radwaste System (WLS) x 3 areas (can be flushed)
- Solid Radwaste System (WSS) x 2 areas (can be flushed)

58. In judging the acceptability of Westinghouse's ALARP proposals to use alternative drainage arrangements, I considered the following aspects:

- Westinghouse has demonstrated the ability to flush **seven areas** without local drainage provisions. The advantage of using a water flush, to remove hazardous substances (SAP EKP.1) in less accessible areas of a plant, is recognised in HSG 253. This flushing removes the radiologically hazardous fluid from the SSCs requiring EIMT. The contaminated volume of water, from the SSCs requiring flushing, is removed from the system using existing collection points, eg tanks and drain valves, and is routed via a flexible hose to a drain (SAP EPS.5). It is then treated by the **AP1000** waste processing systems. The use of a flexible hose connector with a threaded end cap, which is then safely routed to a floor drain, is common practice across the **AP1000** plant fluid systems (SAP ECV.3). I considered Westinghouse's proposals, which are to be implemented through its DCP arrangements (Ref. 9), to be reasonable.

- So, given Westinghouse's proposals to remove the hazard inventory by flushing, I concurred that it is not reasonably practicable to fit additional dedicated drainage measures to the seven **AP1000** plant systems as highlighted above.

- For the remaining **three areas** that cannot be flushed, Westinghouse has demonstrated that:

  - For the CVS, which handles makeup water to the reactor circuit, a temporary engineering method is proposed to remove the hazardous inventory. This amounts to approx. 10 litres of radiological inventory in the Category B (NS-TAST-GD-094) estimated range of ingested dose. This method involves siphoning off the trapped liquor from the depressurised check valve body requiring maintenance. This liquor is siphoned into a High-Efficiency Particulate Arresting (HEPA) bottle (SAP ECV.10) for safe disposal. Westinghouse has stated that the temporary drainage equipment is required to be a Class 2 SSC (SAP ECS.2). The licensee will be responsible for ensuring that this temporary equipment satisfies the expectations of SAP ECS.3.

  - Westinghouse's current **AP1000** pipework design does not cover the provision of temporary drainage equipment. So it will be the responsibility of a future licensee to ensure that the safety classification of this temporary equipment is adequate. **I considered this to be an assessment finding.**

  - For the PSS, which is a sampling arrangement that uses compression type fittings, the trapped volume is small (approx. 30 ml). The radiological hazard associated with an ingested dose from this system is small, ie in the Category C (NS-TAST-GD-094) range of potential unmitigated dose. PSS valve disassembly allows for temporary drainage (SAP EPS.5) to be safely undertaken using temporary measures, ie collected in a small collection container.

  - For the PXS, which handles essentially low radiological inventory boronated water, the trapped volume is approx. 2 litres and can be managed via temporary measures (SAP EPS.5), ie collected in a small collection container.

- Westinghouse has, through its risk assessment, demonstrated that using alternative drainage is adequate (SAP EPS.5). I concurred that it is not reasonably practicable to fit permanent drainage features to three **AP1000** systems that cannot be flushed.

Assessment Finding (CP-AF-AP1000-ME-10)

The licensee shall:

- ensure all **AP1000** Class 1 or 2 temporary pipework drainage SSCs are designed, manufactured, constructed, installed, commissioned and quality assured to appropriate codes and standards relative to their safety category and classification; and
- develop adequate arrangements for employing temporary drainage equipment on the **AP1000** plant.

Minor Shortfall – None identified

Conclusion

59. Subject to adequate closure of CP-AF-AP1000-ME-10, I consider that Westinghouse has adequately demonstrated that its drainage arrangements to allow EIMT on the **AP1000** plant are reasonable, ie they present an ALARP outcome.

60. I consider that Westinghouse has adequately addressed ME-03 Action A3.

4.3 Comparison with Standards, Guidance and Relevant Good Practice

61. Section 4.2 of this report highlights the key guidance documents that have informed my judgement on the adequacy of Westinghouse's submissions.

4.4 Overseas regulatory interface

62. Not applicable

4.5 Assessment findings

63. During my assessment two items were identified for a future licensee to take forward in its site-specific safety submissions. Details of these are contained in Annex 1.

64. These two items do not undermine the generic safety submission and are primarily concerned with the provision of site-specific safety case evidence, which will usually become available as the project progresses through the detailed design, construction and commissioning stages.

65. Residual matters are recorded as assessment findings if one or more of the following apply:

- Site-specific information is required to resolve this matter.
- The way to resolve this matter depends on licensee design choices.
- The matter raised is related to operator-specific features, aspects and choices.
- The resolution of this matter requires licensee choices on organisational matters.
- To resolve this matter the plant needs to be at some stage of construction and commissioning.

4.6 Minor shortfalls

66. My assessment has not identified any minor shortfalls.

4.7 ONR Assessment Rating

67. Not Applicable for GDA.

5 CONCLUSIONS

68. This report presents the findings of the mechanical engineering assessment of GDA Issue ME-03 (Ref. 1) relating to the **AP1000** GDA closure phase.

69. My assessment conclusions were that subject to a future licensee closing the assessment findings in Annex 1:

- Westinghouse has justified that the use of freeze seal technology to allow EIMT of the **AP1000** plant is reasonable (Action A1).
- Westinghouse has justified that its arrangements for **AP1000** pipework EIMT isolations that rely on single valve isolations are reasonable (Action A2).
- Westinghouse has justified that its drainage facilities enable the anticipated **AP1000** EIMT activities to be carried out in a safe and controlled manner (Action A3).

70. In summary, I am content that GDA Issue GI-AP1000-ME-03: Mechanical System Pipework Design can be closed.

6 REFERENCES

1. Step 4 Mechanical Engineering Assessment of the Westinghouse **AP1000** Reactor, November 2011, TRIM 2010/581521.
2. UK AP1000 Assessment Plan for Closure of GDA Mechanical Engineering Issues, TRIM 2015/38000.
3. UKP-GW-GL-102 Rev 1**, AP1000** Plant Assessment of Freeze Seal Application, September 2016, TRIM 2016/367070.
4. UKP-GW-GL-103 Rev 1**, AP1000** Plant Assessment of Single Valve EMIT Isolations, August 2016, TRIM 2016/306877.
5. UKP-GW-GL-104 Rev 1**, AP1000** Plant Assessment of Pipe Work Drainage Features, August 2016, TRIM 2016/341661.
6. GDA Guidance to Requesting Parties, www.onr.org.uk/new-reactors/ngn03.pdf
7. Westinghouse email regarding **AP1000** pipework design valve cycling and Design Change Process (DCP) arrangements, August 2016, TRIM 2016/350299.
8. **AP1000** Design Reference Point for UK GDA, January 2017, TRIM 2017/18158
9. Step 4 Management of Safety and Quality Assurance Assessment of the Westinghouse **AP1000** Reactor, ONR-GDA-AR-11-013 Revision 0, 11 November 2011, TRIM 2010/581518.
10. The Purpose, Scope, and Content of Safety Cases, NS-TAST-GD-051 Revision 4, www.onr.org.uk/operational/tech_asst_guides/ns-tast-gd-051.pdf
11. GDA Issue "PCSR to Support GDA", GI-AP1000-CC-02, Revision 3, www.onr.org.uk/new-reactors/reports/step-four/westinghouse-gda-issues/gi-ap1000-cc-02.pdf
12. Purpose and Scope of Permissioning, NS-PER-GD-014, Revision 5, TRIM 2015/304735.
13. Safety Assessment Principles for Nuclear Facilities. 2014 Edition, Revision 0. ONR. November 2014 www.onr.org.uk/saps/saps2014.pdf
14. IAEA Standards and Guidance: IAEA Safety Guide No. NS-G-1.9, Design of the Reactor Coolant System and Associated Systems in Nuclear Power Plants, www.iaea.org
15. Western European Nuclear Regulators' Association: Reactor Safety Levels for Existing Reactors, September 2014, WENRA Statement on Safety objectives for new nuclear power plants WENRA November 2010, Safety of new NPP designs WENRA March 2013. www.wenra.org/
16. Advanced Light Water Reactor Utility Requirements Document, Revision 8, March 1999. www.epri.com
17. HSG 253 The Safe Isolation of Plant and Equipment (Second Edition, published 2006).

Annex 1

Assessment Findings to be addressed during the Forward Programme – GDA Issue ME-03 Pipework Design

Assessment Finding Number	Assessment Finding	Report Section Reference
CP-AF-AP1000-ME-09	The licensee shall: • satisfy itself that the use of freeze seal technology on the **AP1000** plant is adequate to allow EIMT to be undertaken; • review national and international freeze seal technology relevant good practice and operating experience; and • following this review, develop and implement adequate **AP1000** plant freeze seal arrangements (these arrangements should include safe systems of work).	Paragraph 44
CP-AF-AP1000-ME-10	The licensee shall: • ensure all **AP1000** Class 1 or 2 temporary pipework drainage SSCs are designed, manufactured, constructed, installed, commissioned and quality assured to appropriate codes and standards relative to their safety category and classification; and • develop adequate arrangements for employing temporary drainage equipment on the **AP1000** plant.	Paragraph 58

Table 1: Relevant safety assessment principles considered during the assessment

SAP No.	SAP Title	Description
EMC.14	Engineering principles: integrity of metal components and structures: manufacture and installation. Techniques and procedures.	Manufacture and installation should use proven techniques and approved procedures to minimise the occurrence of defects that might affect the integrity of components or structures.
EMT.2	Engineering principles: maintenance, inspection and testing. Frequency.	Structures, systems and components should receive regular and systematic examination, inspection, maintenance and testing as defined in the safety case.
EMT.5	Engineering principles: maintenance, inspection and testing. Procedures.	Commissioning and in-service inspection and test procedures should be adopted that ensure initial and continuing quality and reliability.
EMT.6	Engineering principles: maintenance, inspection and testing. Reliability claims.	Provision should be made for testing, maintaining, monitoring and inspecting structures, systems and components (including portable equipment) in service or at intervals throughout their life, commensurate with the reliability required of each item.
ECS.2	Engineering principles: safety classification and standards. Safety classification of structures, systems and components.	Structures, systems and components that have to deliver safety functions should be identified and classified on the basis of those functions and their significance to safety.
ECS.3.	Engineering principles: safety classification and standards. Codes and standards.	Structures, systems and components that are important to safety should be designed, manufactured, constructed, installed, commissioned, quality assured, maintained, tested and inspected to the appropriate codes and standards.
ECS.5	Engineering principles: safety classification and standards. Use of experience, tests or analysis.	In the absence of applicable or relevant codes and standards, the results of experience, tests, analysis, or a combination thereof, should be applied to demonstrate that the structure, system or component will perform its safety function(s) to a level commensurate with its classification.
ECV.3	Engineering principles: containment and ventilation: containment design. Means of confinement.	The primary means of confining radioactive materials should be through the provision of passive sealed containment systems and intrinsic safety features, in preference to the use of active dynamic systems and components.

SAP No.	SAP Title	Description
ECV.10	Engineering principles: containment and ventilation: ventilation design. Ventilation system safety functions.	The safety functions of the ventilation system should be clearly identified and the safety philosophy for the system in normal, fault and accident conditions should be defined.
EKP.1	Engineering principles: key principles. Design and operation.	The design and operation of nuclear chemical processes and facilities should be fault tolerant and ensure safety functions are delivered with suitable capability and sufficient reliability and robustness.
ERL.1	Engineering principles: reliability claims. Form of claims.	The reliability claimed for any structure, system or component should take into account its novelty, experience relevant to its proposed environment and uncertainties in operating and fault conditions, physical data and design methods.
ERL.4.	Engineering principles: reliability claims. Margins of conservatism.	Where safety-related systems and/or other means are claimed to reduce the frequency of a fault sequence, the safety case should include a margin of conservatism to allow for uncertainties.
ENM.3	Engineering principles: control of nuclear matter. Transfers and accumulation of nuclear matter.	Unnecessary or unintended generation, transfer or accumulation of nuclear matter should be avoided.
EPS.5	Engineering principles: pressure systems. Discharge routes.	Pressure discharge routes should be provided with suitable means to ensure that any release of radioactivity or toxic material from the facility to the environment is minimised. The potential to create an explosive atmosphere from the discharge should also be considered.
NT.2	Numerical targets and legal limits. Time at risk.	There should be sufficient control of radiological hazards at all times.
SC.4	The regulatory assessment of safety cases. Safety case characteristics.	A safety case should be accurate, objective and demonstrably complete for its intended purpose.

Table 2: Technical assessment guides considered during the assessment

Technical Assessment Guide No.	Description
NS-TAST-GD-005	Guidance on the demonstration of ALARP (As Low As Reasonably Practicable)
NS-TAST-GD-009	Examination, inspection, maintenance and testing of items important to safety
NS-TAST-GD-051	The purpose, scope, and content of safety cases
NS-TAST-GD-094	Categorisation of safety functions and classification of structures, systems and components