

New Reactors Programme
GDA Close-out for the AP1000 Reactor
GDA Issue GI-AP1000-RC-02 Revision 0 – Primary Sampling Systems

Assessment Report: ONR-NR-AR-16-045
Revision 0
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EXECUTIVE SUMMARY

Westinghouse Electric Company LLC (Westinghouse) is the reactor design company for the **AP1000**[®] reactor. Westinghouse completed Generic Design Assessment (GDA) Step 4 in 2011 and opted to pause the regulatory process. At that time, it achieved an Interim Design Acceptance Confirmation (IDAC), which had 51 GDA Issues attached to it. These GDA 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 assessment conducted as part of the close-out of the Office for Nuclear Regulation (ONR) GDA for the **AP1000** reactor design within the topic of Reactor Chemistry. The report specifically addresses GDA Issue GI-AP1000-RC-02 Revision 0, and two associated GDA Issue Actions related to the primary sampling systems.

GI-AP1000-RC-02 arose because the design of the sampling systems that allow the operator to sample, and therefore control, the chemistry of the primary circuit and auxiliary systems in the **AP1000** design is different from other comparable reactors. While there are often good reasons for these differences, their impact on the capabilities, reliability and representativeness of the sampling system was inadequately justified at the end of Step 4. This was further compounded by a late design change which, although a welcome safety improvement, also altered the way the system was intended to operate. Given the importance of this system to the ability to control the operating chemistry adequately, further justification and evidence was sought by ONR.

In response, Westinghouse provided three main submissions. The response to Action 1 was an example sampling schedule for the **AP1000** reactor, which identified the location, frequency and analysis requirements for all modes of plant operation. For Action 2, the first deliverable was a review of relevant good practice in designs for Pressurised Water Reactor primary sampling systems. These two reports were used as inputs to the main submission, which reviewed the **AP1000** design against these. In this main report, in some areas Westinghouse provided justification and evidence to support the adequacy of the existing design. In other areas, Westinghouse proposed design modifications and assessed them using an As Low As Reasonably Practicable (ALARP) process. Westinghouse supported these submissions with a suite of documentation containing further detailed evidence. In addition, Westinghouse provided responses to my Regulatory Queries, and these presented additional clarification and evidence to support the main submissions.

As a result of GI-AP1000-RC-02, Westinghouse have implemented a design change to the Primary Sampling System for the UK **AP1000** plants.

As a result of my assessment of these submissions, meetings and discussions with Westinghouse experts, and consultations with ONR colleagues in different technical areas, my conclusions are:

- The design of the primary sampling systems has been subjected to a detailed review by Westinghouse, which included consideration of relevant good practices and ALARP justifications. This resulted in modifications to the design in three distinct areas, to improve its reliability, capability and representativeness, and therefore its overall ability to meet the requirements of the safety case.
- I am content that sufficient evidence has been provided to demonstrate that the system design is adequate to meet the sampling requirements of the plant during all modes of operation.
- The use of the system for normal operations, in addition to the safety functions it provides during post-accident situations, has been justified by Westinghouse.
- The ability of the design to provide reliable and representative samples for a number of important, but often difficult to sample parameters was considered. I am satisfied that sampling for zinc and hydrogen has been demonstrated to be

within the capability of the design, whereas a specific modification to improve the sampling of corrosion products has been included.

- Westinghouse has proposed a design modification to provide the capability of monitoring boron via an on-line meter. This is an important safety improvement and meets UK regulatory expectations.
- While evidence has been provided to demonstrate that the waste generated by sampling is within the capabilities of the design, I am not convinced that sufficient consideration has been given to minimisation of this waste stream in accordance with the expectations of the Safety Assessment Principles. I consider that, as a minimum, it would be reasonably practicable to implement further modifications to provide the operator with this option should they wish. As this requires more detailed design information and operator choices, I have raised this as an Assessment Finding to be resolved by a future licensee.
- In response to this GDA Issue, Westinghouse has identified updates to the safety case. I have reviewed these updates and am content that they accurately reflect the responses to the GDA Issue.

As a result of this assessment, I have identified five Assessment Findings. These relate to aspects of the detailed design where I judge that further consideration needs to be given to whether it is reasonably practicable to implement additional measures to further reduce risks associated with the sampling system design. These are detailed in my assessment. These matters do not undermine the generic safety submission provided for GDA, and require licensee input and/or decisions to resolve.

Overall, on the basis of my assessment, I am satisfied that GDA Issue GI-AP1000-RC-02 can be closed.

LIST OF ABBREVIATIONS

ALARP	As Low As Reasonably Practicable
BAST	Boric Acid Storage Tank
BCMS	Boron Concentration Measurement System
CCS	Component Cooling water System
CMT	Core Make-up Tank
CP	corrosion product
CVS	Chemical and Volume control System
DAC	Design Acceptance Confirmation
DCP	Design Change Proposal
EHT	Effluent Hold-up Tank
EPRI	Electric Power Research Institute
GDA	Generic Design Assessment
GSP	Grab Sample Panel
HL	Hot Leg
IAEA	International Atomic Energy Agency
IDAC	Interim Design Acceptance Confirmation
IRC	Inside Reactor Containment
IRWST	In-containment Refuelling Water Storage Tank
ONR	Office for Nuclear Regulation
OpEx	operating experience
ORC	Outside Reactor Containment
PASS	Post-Accident Sampling System
PCSR	Pre-Construction Safety Report
PSS	Primary Sampling System
PWR	Pressurised Water Reactor
PXS	Passive Core Cooling System
PZR	Pressuriser
RCS	Reactor Coolant System
RGP	relevant good practice
RNS	Normal Residual Heat Removal System
RO	Regulatory Observation
RQ	Regulatory Query
SAP	Safety Assessment Principle
SFS	Spent Fuel Pool Cooling System
TAG	Technical Assessment Guide
US NRC	United States Nuclear Regulatory Commission
VCT	Volume Control Tank

Westinghouse
WENRA
WLS

Westinghouse Electric Company LLC
Western European Nuclear Regulators Association
Liquid Radwaste System

TABLE OF CONTENTS

1	INTRODUCTION	8
1.1	Background	8
1.2	Scope	8
1.3	Methodology	9
2	ASSESSMENT STRATEGY	10
2.1	Assessment Scope	10
2.2	Related GDA Issues	10
2.3	Assessment Approach	11
2.4	Standards and Criteria	12
2.5	Use of Technical Support Contractors	12
2.6	Integration with Other Assessment Topics	12
2.7	Out of Scope Items	13
3	REQUESTING PARTY'S SAFETY CASE	14
3.1	Overview of the Westinghouse Safety Case for the Primary Sampling Systems	14
3.2	Assessment during GDA Step 4	17
3.3	Summary of the GDA Issue and Actions	17
3.4	Westinghouse Deliverables in Response to the GDA Issue and Actions	17
4	ONR ASSESSMENT OF GDA ISSUE GI-AP1000-RC-02	19
4.1	Scope of Assessment Undertaken	19
4.2	Assessment	19
4.3	Comparison with Standards, Guidance and Relevant Good Practice	40
4.4	Assessment Findings	41
4.5	Minor Shortfalls	41
4.6	ONR Assessment Rating	41
5	CONCLUSIONS	42
6	REFERENCES	44

Tables

Table 1:	Relevant Safety Assessment Principles considered during the assessment
Table 2:	Relevant Technical Assessment Guides considered during the assessment
Table 3:	Summary of main sampling provisions in the AP1000 design

Figures

Figure 1:	AP1000 Primary Sampling System (PSS)
Figure 2:	Boron meter modifications schematic
Figure 3:	Corrosion product sampling modifications schematic
Figure 4:	Sample header modifications schematic
Figure 5:	Effluent recycle modifications schematic
Figure 6:	Final design of the UK AP1000 PSS in response to GI-AP1000-RC-02

Annexes

Annex 1:	GDA Issue, GI-AP1000-RC-02 Revision 0 – Reactor Chemistry – AP1000 [®]
Annex 2:	Assessment Findings to be addressed during the Forward Programme – Reactor Chemistry

1 INTRODUCTION

1.1 Background

1. This report presents the assessment conducted as part of the close-out of the Office for Nuclear Regulation (ONR) Generic Design Assessment (GDA) for the Westinghouse Electric Company LLC (Westinghouse) **AP1000**[®] reactor design within the topic of Reactor Chemistry. The report specifically addresses the GDA Issue GI-AP1000-RC-02 Revision 0 and associated GDA Issue Actions (Ref. 1) related to the primary sampling systems.
2. GDA follows a stepwise approach in a claims-argument-evidence hierarchy. In Step 2, the claims made by Westinghouse were examined and in Step 3 the arguments that underpin those claims were examined. The Step 4 assessment (Ref. 2) reviewed the safety aspects of the **AP1000** reactor in greater detail, by examining the evidence, supporting the claims and arguments made in the safety documentation. Westinghouse completed Step 4 in 2011 and then opted to pause the regulatory process. At that time, it had achieved an Interim Design Acceptance Confirmation (IDAC), which had 51 GDA Issues attached to it. These GDA Issues require resolution prior to the award of a Design Acceptance Confirmation (DAC) and before any nuclear safety-related construction of this reactor design can begin. Westinghouse re-entered the GDA process in 2014 to close the 51 GDA Issues.
3. The purpose of this report is therefore to provide the assessment that underpins the judgement made in closing GDA Issue GI-AP1000-RC-02. This assessment is focused on the deliverables identified within the Westinghouse resolution plan (Ref. 3) published in response to the GDA Issue, and on further assessment that was undertaken of those deliverables.
4. The related GDA Step 4 report (Ref. 2) is published on the ONR website (www.onr.org.uk/new-reactors/ap1000/reports.htm), and this provides the assessment underpinning GI-AP1000-RC-02. Further information on the GDA process in general is also available on the ONR website (www.onr.org.uk/new-reactors/index.htm).

1.2 Scope

5. The scope of this assessment is detailed in the assessment plan (Ref. 4). Consistent with this plan, the assessment is restricted to considering whether the Westinghouse submissions to ONR for GI-AP1000-RC-02 provide an adequate response sufficient to justify closure of the GDA Issue. Importantly, it is not within the scope of this assessment to revisit areas already found by ONR to be satisfactory unless, during my assessment, important safety issues emerged that required the expansion of my assessment scope.
6. As such, this report only presents the assessment undertaken as part of the resolution of GI-AP1000-RC-02 and it is recommended that this report be read in conjunction with the Step 4 Reactor Chemistry assessment of the **AP1000** reactor (Ref. 2) in order to appreciate the totality of the assessment undertaken as part of the GDA process.
7. This assessment focused on the justification for the primary sampling systems, which allow the operator to monitor and control the chemistry within the primary coolant and related auxiliary systems of the **AP1000** design. Proper control of the operating chemistry is required in order to minimise a number of hazards including corrosion of the structural materials and fuel, and to minimise radioactivity within the plant. The sampling systems in the **AP1000** design differ from existing plants, to align with Westinghouse's overall design philosophy of minimisation and simplification wherever possible, and the design continued to evolve throughout GDA. At the end of Step 4, questions still remained regarding the adequacy of the design proposed, in particular

relating to whether the system was capable of meeting the plant requirements and achieving representative sampling. GI-AP1000-RC-02 was raised to ensure that an adequate justification is provided for the primary sampling systems. The scope of assessment here is therefore to ensure that the **AP1000** system design is adequate and is capable of meeting the functional requirements of the plant. This also needs to be reflected appropriately within the safety case.

8. Further details of the scope of assessment can be found in Section 2.1 of my report.
9. Due to this scope, the structure of this report differs from that adopted for previous reports produced within GDA, most notably from the Step 4 Reactor Chemistry assessment (Ref. 2). This is because this report details the assessment of GI-AP1000-RC-02 only, rather than close-out of all GDA Issues associated with Reactor Chemistry. This allows closure of GDA Issues as the work is completed rather than waiting for the resolution of all work in this technical topic.

1.3 Methodology

10. The methodology for the assessment follows HOW2 Guidance on Mechanics of Assessment within the Office for Nuclear Regulation (ONR) (Ref. 5).
11. I have sampled all of the submissions made in response to GI-AP1000-RC-02, to various degrees of breadth and depth. I chose to focus my assessment on those aspects that I judged to have the greatest safety significance, or where the hazards appeared least well controlled. My assessment has also been influenced by the claims made on the primary sampling systems, my previous experience of similar systems for reactors and other nuclear facilities, and the specific gaps in the original submissions made by Westinghouse that led to the GDA Issue.
12. The Safety Assessment Principles (SAPs) (Ref. 6), alongside the relevant Technical Assessment Guides (TAGs) (Ref. 7), have been used as the basis for this assessment.

2 ASSESSMENT STRATEGY

13. The intended assessment strategy for resolution of GI-AP1000-RC-02 is set out in this section. This identifies the scope of the assessment and the standards and criteria that have been applied.

2.1 Assessment Scope

14. This report presents only the assessment undertaken for resolution of Reactor Chemistry GDA Issue GI-AP1000-RC-02, related to the primary sampling systems (Ref. 1). This report does not represent the complete assessment of the **AP1000** reactor in the Reactor Chemistry topic area for GDA, or even the complete assessment of the primary sampling systems. It is recommended that this report be read in conjunction with the Step 3 and Step 4 Reactor Chemistry assessments of the Westinghouse **AP1000** reactor (Refs 8 and 2) in order to appreciate the totality of the assessment undertaken as part of the GDA process. Section 3 of this report provides a brief overview of the background to GI-AP1000-RC-02.
15. This assessment does not revisit aspects of the safety case already accepted as being adequate during previous stages of GDA. However, where the assessment of the Westinghouse responses highlight shortfalls not previously identified during Step 4 or cast doubt on previously accepted arguments, these were assessed within this report.
16. The focus for this assessment was on the adequacy of the justifications provided for the design of the primary sampling systems in the **AP1000** design. The fundamental requirement was to provide suitable and sufficient evidence that the system will be able to deliver representative sampling, in line with the chemistry control requirements necessary to maintain safety. This should consider all operating modes under which sampling is necessary, including during fault and post-accident situations. The GDA Issue identified two Actions in order to provide this information:
- Action 1 asked for a 'sampling schedule', which effectively should define the requirements that the system needs to fulfil.
 - Action 2 asked for a demonstration that the system design can fulfil those requirements. This Action also identified a number of more detailed points that were identified as part of the Step 4 assessment (Ref. 2). These were detailed in the GDA Issue Action, but can be summarised as relating to representative sampling, sampling capabilities and the impact of sampling on safety.
17. Once a suitable justification for the design had been made, this would also need to be reflected appropriately within the safety case, including any limits or conditions that result.
18. This scope of assessment is appropriate for GDA because the **AP1000** design is novel and it is important therefore that options are not foreclosed at the design stage, which would be more difficult to implement at some later stage.
19. Annex 1 of this report contains the full text of the GDA Issue and Action (Ref. 1). Details of the Westinghouse resolution plan, which details the methods by which the requesting party intended to resolve this GDA Issue via identified timescales and deliverables, is contained in Ref. 3 and discussed further in Section 3.

2.2 Related GDA Issues

20. ONR's GDA Guidance to Requesting Parties (Ref. 9) states that the information required for GDA may be in the form of a Pre-Construction Safety Report (PCSR). ONR guidance (NS-TAST-GD-051: The purpose, scope and content of nuclear safety cases, Ref. 7) sets out regulatory expectations for a PCSR. The PCSR is the highest-

level summary of the safety case and provides the links to the detailed arguments and evidence that may reside in a suite of supporting documentation.

21. At the end of Step 4, ONR and the Environment Agency raised GDA Issue GI-AP1000-CC-02 (Ref. 10), requiring 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. A separate assessment report has been prepared to consider the adequacy of the PCSR and closure of GDA Issue GI-AP1000-CC-02. Therefore, this report does not discuss the overall adequacy of the Reactor Chemistry aspects of the PCSR. However, this assessment does consider the specific aspects related to GI-AP1000-RC-02 and the primary sampling systems.
22. An important output from the safety case is any limits or conditions necessary in the interests of safety (also known as Operating Rules). ONR guidance (NS-TAST-GD-035: The limits and conditions for nuclear plant safety, Ref. 7) sets out regulatory expectations.
23. At the end of Step 4, ONR and the Environment Agency raised GDA Issue GI-AP1000-CC-01 (Ref. 11), requiring Westinghouse to demonstrate its arrangements to identify such limits or conditions and key safety requirements, and to document these within the PCSR. A separate assessment report has been prepared to consider the adequacy of the responses and closure of GDA Issue GI-AP1000-CC-01. Therefore, this report does not discuss the overall adequacy of the Reactor Chemistry-related limits and conditions. However, this assessment does consider the specific aspects related to GI-AP1000-RC-02 and the primary sampling systems.

2.3 Assessment Approach

24. The assessment was undertaken by examining the evidence provided by Westinghouse in response to GI-AP1000-RC-02. This was assessed against the expectations and requirements of the SAPs and other guidance considered appropriate. Forming the basis of the assessment undertaken to prepare this report were:
 - submissions made to ONR in accordance with the resolution plan;
 - consideration of internal and international standards and guidance, international experience, operational feedback and expertise and assessments performed by other regulators, especially their findings;
 - interaction with other relevant technical areas (where appropriate);
 - raising and issuing of Regulatory Queries (RQs) as appropriate, followed by assessment of Westinghouse responses; and
 - holding technical meetings to progress the identified lines of enquiry.
25. The following subsections provide an overview of the outcome from each of the information exchange mechanisms in further detail.

2.3.1 Regulatory Queries

26. A total of three RQs were raised with Westinghouse for the assessment of GI-AP1000-RC-02. The responses to the RQs were assessed as part of this assessment. Commentary on the most important and relevant RQ responses is included in the assessment section later in this report as appropriate. The responses provided further evidence to support resolution of the GDA Issue.

2.3.2 Technical Meetings

27. A number of technical meetings with Westinghouse were held during assessment of the GI-AP1000-RC-02 responses. The principal focus of these meetings was to

discuss progress and responses, to facilitate technical exchanges and to hold discussions with Westinghouse technical experts on emergent issues. Important exchanges are referenced within my assessment that follows.

2.4 Standards and Criteria

28. This assessment has been undertaken in line with the requirements of NS-PER-GD-014 (Ref. 12). The standards and criteria adopted within this assessment are principally the SAPs (Ref. 6), internal TAGs (Ref. 7), relevant national and international standards and relevant good practice informed from existing practices adopted on UK nuclear licensed sites. Further details are provided below.

2.4.1 Safety Assessment Principles

29. The key SAPs applied within this assessment are included within Table 1.
30. As the SAPs (Ref. 6) constitute the regulatory principles against which dutyholders' safety cases are judged, they are therefore the basis for ONR's nuclear safety assessment. It is worth noting that the 2014 Edition (Revision 0) of the SAPs was used when performing the assessment described in this report, whereas the original Step 4 assessment used the 2006 Edition. From a Reactor Chemistry perspective, the main change is that the current edition includes specific SAPs relating to chemistry (ECH.1 to 4).

2.4.2 Technical Assessment Guides

31. The TAGs (Ref. 7) that have been used as part of this assessment are set out in Table 2.

2.4.3 National and International Standards and Guidance

32. There are both International Atomic Energy Agency (IAEA) standards (Ref. 13) and Western European Nuclear Regulators Association (WENRA) reference levels (Ref. 14) of relevance. However, they are not specific to primary sampling systems and therefore the SAPs were the foremost standard considered. It should be noted that the latest version of the SAPs (Ref. 6) has been benchmarked against both IAEA and WENRA guidance.

2.5 Use of Technical Support Contractors

33. No technical support work was undertaken to support the assessment of the responses to GI-AP1000-RC-02.
34. However, during Step 4 of GDA a contract was let to undertake a review of relevant good practice for Pressurised Water Reactor (PWR) sampling systems, and to compare this with the existing **AP1000** design at that time (Refs 15 and 16). These reports remain relevant to this assessment and have been considered as part of the assessment process.

2.6 Integration with Other Assessment Topics

35. GDA requires the submission of an adequate, coherent and holistic generic safety case. Regulatory assessment cannot therefore be carried out in isolation as there are often safety issues of a multi-topic or cross-cutting nature. To assess the adequacy of the submissions provided by Westinghouse for GI-AP1000-RC-02, I have required only limited input from other technical disciplines and the assessment reported here is consistent with this. As described in Section 2.2, this assessment was integrated with the wider requirements of GI-AP1000-CC-01 (limits and conditions) and GI-AP1000-CC-02 (PCSR) respectively.

2.7 Out of Scope Items

36. This assessment report for GI-AP1000-RC-02 focuses solely on the primary sampling systems. No specific items within the remit of this GDA Issue have been identified as out of scope.

3 REQUESTING PARTY'S SAFETY CASE

3.1 Overview of the Westinghouse Safety Case for the Primary Sampling Systems

37. As with any PWR, the primary chemistry of the **AP1000** design is important to a number of safety-related aspects of the design, including maintaining the integrity of systems and reducing radioactivity. As such, proper control and maintenance of the desired operating chemistry is important for safety. To be able to achieve this, it is necessary to representatively sample and analyse the coolant. All PWRs feature a system that is designed to facilitate this, while also minimising the exposure of the operators to the hazards of the plant. This system needs to provide data of the necessary quality and quantity during all modes of reactor operation, including shutdown and accident conditions to enable proper recovery and operator actions. A poorly designed or implemented sampling system could result in delays (for example, in recognising changes from normal conditions), operator doses or even unrepresentative sampling of important chemical parameters.
38. The fundamental claim made by Westinghouse for the primary sampling systems in the **AP1000** design is that the design is adequate to deliver the requirements placed upon it in terms of maintaining the operating chemistry within the boundaries of the safety case. Westinghouse also further claimed the primary sampling systems were able to fulfil the sampling-related safety functions necessary in post-accident situations.
39. The conventional approach to sampling system design is to have multiple sample lines that draw fluid from the sampling locations necessary, often on a continuous basis. Specific consideration is given to the hazards associated with the samples, and design features are included to minimise the exposure of the operator to these, such as pressure reduction, cooling provisions and radioactive decay coils. The behaviour of the coolant during sampling needs consideration as this can influence the representativeness of the samples, for example by deposition of species within the sample lines. Unused fluid that is not sampled (but still flows down the sample lines) is returned back to the primary system, minimising the generation of waste.
40. The design for the **AP1000** primary sampling systems differs from this conventional approach for a number of reasons:
- Westinghouse's overall design philosophy is to minimise and simplify systems and components wherever possible, which led to the desire to minimise the number of sample lines and to combine the normal and post-accident functions within the same system.
 - Many of the locations from which samples are taken in the **AP1000** design are within the containment, and as personnel entry is prohibited at power, any sampling line must therefore pass through the containment barrier.
 - The design and operating philosophy of the **AP1000** reactor, in particular the use of grey rods for reactivity control and the operation of the Chemical and Volume Control System (CVS) at full primary system pressures (see Ref. 2 for more details), means that there are currently no means of recycling the sampling effluent back into the system and a reduced number of boron dilutions.
 - The use of sealless reactor coolant pumps allow for the AP1000 plant to not require continuous makeup and letdown of the reactor coolant. This limits the amount of continuous sampling without removing the benefits from the use of sealless reactor coolant pumps.
41. These features were considered more generally as part of the Step 4 assessment (Ref. 2) and are specifically considered as part of GI-AP1000-RC-02 in my assessment that follows (Section 4).

42. These differences led to the design given in Figure 1.

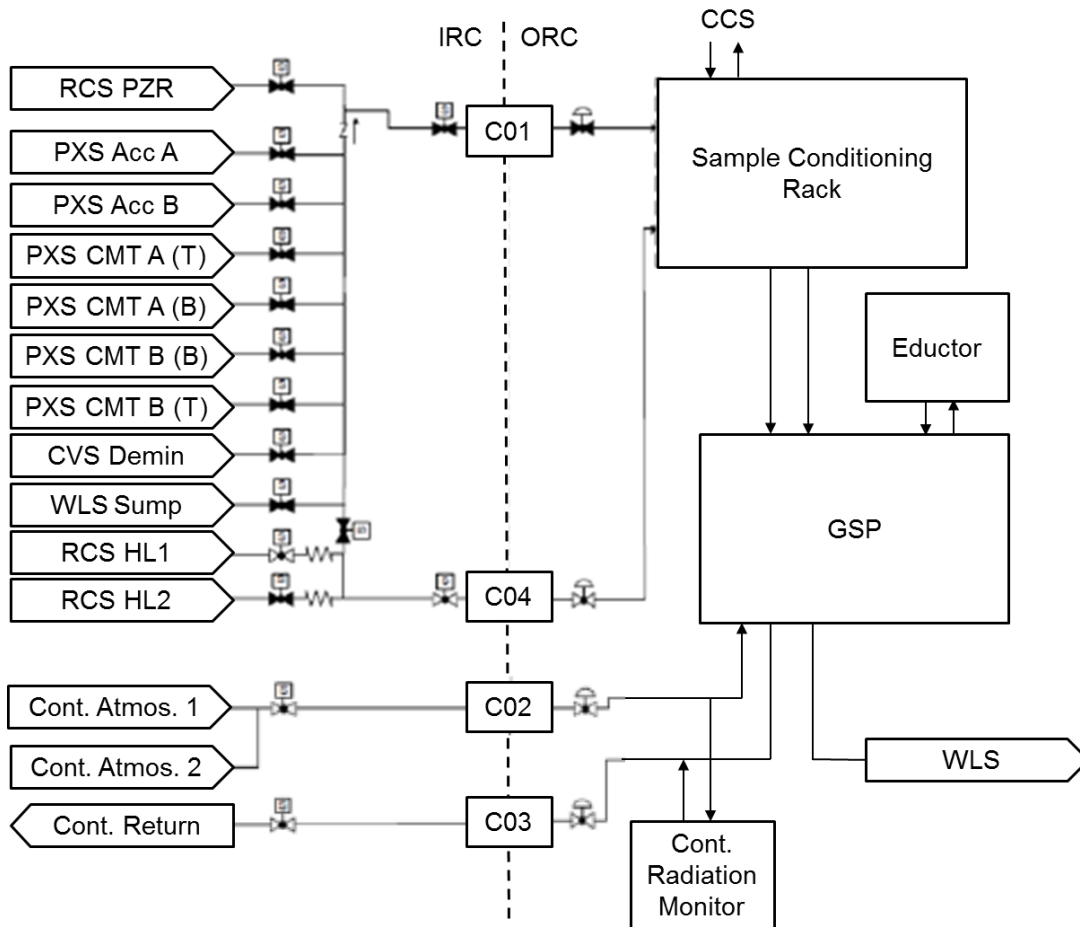


Figure 1: AP1000 Primary Sampling System (PSS)

43. This shows the Primary Sampling System (PSS), which is the main system responsible for sampling the primary circuit and related auxiliary systems in the **AP1000** design. The PSS includes the capability for sampling both liquid and gaseous samples (of the containment atmosphere) during normal operations. Westinghouse states that the PSS must be available for monitoring of the primary coolant during all of the plant operating conditions. Alongside the PSS are a large number of (over 30) 'local' sampling points where grab samples can be taken. These are discussed later in my assessment, and include the boric acid make-up tanks, Residual Heat Removal System (RNS) and In-containment Refuelling Water Storage Tank (IRWST) (through the RNS). Although not part of the PSS, they are within the scope of the primary sampling systems considered by GI-AP1000-RC-02. It should be noted that Figure 1 also includes a design change (Ref. 17) made late within Step 4 to address some of the issues found during the ONR assessment. In short, this change added the second, continuous sample line. Prior to this all the samples passed through a single, intermittently used line. This change was mainly to address concerns over sample representativeness and a lack of redundancy in the system.
44. The overall intent for the PSS is therefore for fluid from those sampling locations within containment (Inside Reactor Containment, IRC) to be delivered to a central sampling location (Outside Reactor Containment, ORC), through one of two sampling lines (via containment penetration C01 or C04). The sample points included are the Reactor Coolant System (RCS) (hot leg 1, hot leg 2 and pressuriser) and related safety systems (Passive Core Cooling System (PXS) accumulators and Core Make-up Tanks (CMT), CVS (demineraliser outlet) and Liquid Radwaste System (WLS) sump). Hot leg

1 is intended to be continuously flowing (but can be alternated with hot leg 2), whereas the other samples share the second sample line on an intermittent basis. Outside containment sample fluid can be extracted via the Grab Sample Panel (GSP), which is a shielded, ventilated enclosure to facilitate sampling, following cooling within the sample conditioning rack. Effluent from the GSP is directed to the WLS.

45. The PSS also performs some safety functions during post-accident sampling conditions in the **AP1000** design. Two separate lines take samples from either the containment sump or hot legs, for liquid samples, or from the containment atmosphere for gas sampling. Samples are drawn using eductors to drive the sample flow. The GSP features provisions to dilute such samples. In a post-accident situation, the containment isolation valves of the PSS are automatically closed on a containment isolation signal. Westinghouse claims that these can be re-opened as necessary to sample the coolant for boron content, to measure the radioactivity (via the hot leg samples) and to determine the composition of the containment (sump liquid and gas phase). The information derived from this sampling can be used to understand the state of the plant and as part of further accident management.
46. A summary of the samples available via the PSS is given in Table 3 below, along with a number of key local samples. This also summarises the sample route, flow conditions and sample composition expected.

Sample	Description	Route	Flow	Composition
Normal Operations				
RCS PZR	Pressuriser liquid	C01	Intermittent	Primary coolant
PXS Acc A	Accumulator tank A	C01	Intermittent	Borated water
PXS Acc B	Accumulator tank B	C01	Intermittent	Borated water
PXS CMT A (T)	Core Make-up Tank A top	C01	Intermittent	Borated water
PXS CMT A (B)	Core Make-up Tank A bottom	C01	Intermittent	Borated water
PXS CMT B (B)	Core Make-up Tank B bottom	C01	Intermittent	Borated water
PXS CMT B (T)	Core Make-up Tank B top	C01	Intermittent	Borated water
CVS Demin	CVS demineraliser outlet	C01	Intermittent	Primary coolant
WLS Sump	Containment sump	C01	Intermittent	Primary coolant
RCS HL1	Hot leg 1	C04	Continuous	Primary coolant
RCS HL2	Hot leg 2	C04	Continuous	Primary coolant
Cont. Atmos. 1 and 2	Operating deck gas	C02	Continuous	Gas
BAST	CVS Boric Acid Storage Tank	Local	Grab	Borated water
RNS	RNS heat exchanger	Local	Grab	Primary coolant
IRWST	In-containment Refuelling Water Storage Tank	Local	Grab	Borated water
SFS	Spent Fuel Pool demineraliser inlet and outlet	Local	Grab	Borated water
Post-Accident Operations				
RCS HL1 or HL2	Hot leg 1 or 2	C04	Intermittent	Primary coolant
WLS Sump	Containment sump	C04	Intermittent	Primary Coolant
Cont. Atmos. 1 and 2	Operating deck gas	C02	Intermittent	Gas

Table 3: Summary of main sampling provisions in the **AP1000** design

3.2 Assessment during GDA Step 4

47. ONR began to assess the primary sampling systems of the **AP1000** reactor during GDA Step 3 and this continued throughout Step 4 (Refs 8 and 2). This also included a specific technical support contract to review the design against relevant good practice for PWR sampling systems (Ref. 16). As discussed more fully in Ref. 2, the design of the PSS evolved throughout Step 4 including the design change already noted (Ref. 17). This change made a welcome safety improvement and removed some of the concerns with the system at that time, but it did not remove them all nor did it provide all of the evidence that the design was adequate.
48. In summary, the main conclusion of the Step 4 assessment for the primary sampling systems was that, due to the ongoing system development, the safety case was incomplete and sufficient justification was lacking for a number of specific aspects. In particular:
- The safety case did not demonstrate that the system design is sufficient to support safe operation of the plant during all modes of operation.
 - A number of samples, which have conventionally been included as part of PWR primary sampling system designs, were not included.
 - The use of a GSP for normal operations was uncertain, especially given the design change to flowing samples.
 - The design did not appear representative of relevant good practice in a number of ways (as defined in detail in the assessment (Ref. 2)).
 - Uncertainty remained over the ability of the design to provide reliable and representative samples for a number of important parameters, potentially affecting zinc, corrosion products and hydrogen.
 - The design did not include the use of a boron meter (or similar technology) nor a justification for why it is not reasonable to do so.
 - Evidence had not been provided to demonstrate that the waste generation is acceptable.
49. Given the importance of this system, and the scale of remaining unresolved concerns, GDA Issue GI-AP1000-RC-02 was raised.

3.3 Summary of the GDA Issue and Actions

50. The full text of GI-AP1000-RC-02 (Ref. 1) and the associated two Actions is in Annex 1.
51. The overall requirement in the GDA Issue was to provide a demonstration that the primary sampling systems in the **AP1000** design are adequate to support safe operation of the plant. Action 1 asked for a 'sampling schedule', which effectively defines the requirements that the system needs to fulfil. Action 2 detailed the specific matters where further evidence was considered necessary.
52. Together, adequate responses to these two Actions should resolve the gaps identified during the Step 4 assessment and provide the coherent safety case necessary to demonstrate the adequacy of the design.

3.4 Westinghouse Deliverables in Response to the GDA Issue and Actions

53. The Westinghouse resolution plan for this GDA Issue is given in Ref. 3. This provides details of the deliverables Westinghouse intended to provide to respond to the Action. The following section contains a brief description of the submitted deliverables that formed the basis of the assessment.

54. The response to Action 1 was provided by a specific report, **AP1000**® Plant Example Sampling Schedule for the Primary Side, UKP-GW-GL-091 (Ref. 18), which provided a definition of the sampling requirements, including frequencies and locations of sampling for all plant modes of operation. This was based on both Westinghouse specific and industry guidance documents.
55. According to Ref. 3, the main route to resolve the GDA Issue would be to evaluate the adequacy of the sampling arrangements for the primary circuit and connected auxiliary systems of the AP1000 plant. This was reported in an overall UK-specific report, **AP1000**® Plant Primary Sampling System – Safety Evaluation, UKP-GW-GL-099 (Ref. 19). This was based on the sampling requirements identified for the plant (in Ref. 18). The purpose of this report was to provide a justification and technical evidence that the **AP1000** plant primary sampling systems are adequate to support safe operation of the plant. Westinghouse intended this report to include matters such as demonstrating that the current design meets its operating requirements in terms of capability of the system, reliability of the system, safe operation and representativeness of the sample. Design alternatives were to be considered and an As Low As is Reasonably Practicable (ALARP) demonstration was to be performed to either justify that the design reduces risks associated with sampling to ALARP or to identify design changes that do so.
56. An important input into Ref. 19 was another report, Definition of Relevant Good Practice for Primary Side Chemistry Sampling System Designs, UKP-GW-GL-101 (Ref. 20). This report defined what Westinghouse considers to be relevant good practice for a sampling system and programme.
57. These three reports, plus other supporting information considered necessary, formed the basis for my assessment of GI-AP1000-RC-02. The assessment of the suitability of any potential design changes that come from these reports is within the scope of my assessment under GI-AP1000-RC-02.
58. In addition to the submissions detailed above, which formed the basis for Westinghouse's resolution plan, responses to the various RQs also informed my assessment. These are referenced throughout Section 4.
59. Finally, Westinghouse provided an update to the PCSR to identify how the resolution of this GDA Issue would be reflected in the overall **AP1000** plant safety case. This is discussed further in Section 4.

4 ONR ASSESSMENT OF GDA ISSUE GI-AP1000-RC-02

60. This assessment has been carried out in accordance with Purpose and Scope of Permissioning, NS-PER-GD-014 (Ref. 12).

4.1 Scope of Assessment Undertaken

61. The scope of my assessment is described in Section 2.1, alongside the description of the submissions that formed the basis for that assessment in Section 3.4.

4.2 Assessment

62. This section describes my assessment of the Westinghouse responses to GI-AP1000-RC-02.

63. Although linked, I have chosen to report my assessment on an individual Action basis, to aid clarity. However, my overall judgement on the adequacy of the response to the GDA Issue was based on consideration of the responses to both Actions together.

4.2.1 Action 1: to provide a detailed schedule of sampling required to support operation of AP1000

64. The detailed sample schedule requested from Westinghouse in response to Action 1 is listed in Ref. 18. That report provided a tabulated list of samples, identifying the location, parameters and frequency. Ref. 18 considered all modes of operation for the plant, albeit slightly differently from how they are defined within the **AP1000** plant Technical Specifications (Ref. 21). This is to align with the operational modes defined in the Electric Power Research Institute (EPRI) guidelines (Ref. 22) and hence the **AP1000** chemistry manual (Ref. 23). Despite these differences in definitions, it is clear that the schedule does indeed cover all plant states.

65. The scope of locations considered within Ref. 18 includes the RCS (hot leg and pressuriser) and primary auxiliary systems (CVS, RNS, accumulators, CMTs, WLS sump, boric acid storage tank, IRWST, spent fuel pool and radwaste systems). The **AP1000** chemistry manual (Ref. 23) specifically considers the design of the plant, with additional information from the EPRI guidelines (Ref. 22) used as a supplement to this. I am content that this approach means that the specific design features have been considered when defining the expected sampling requirements.

66. In order to define the sampling requirements, the approach taken was to use information contained with Westinghouse documentation, mainly the **AP1000** chemistry manual (Ref. 23), Westinghouse supplemental chemistry guidelines (Ref. 24), Technical Specifications (Ref. 21) and the **AP1000** primary water chemistry operating principles (Ref. 25). Additional information was also sourced from the EPRI guidelines (Ref. 22) and a limited amount of current plant operating input (for 2 US and 2 Korean PWRs). Where discrepancies existed, the most penalising condition was used. By using this approach, Westinghouse have clearly met the requirement of Action 1 in linking the schedule back to the requirements defined within the safety case.

67. It should be noted that Westinghouse referred to this sampling schedule as an 'example' of an achievable sampling schedule, as they consider many of the details contained within this to fall under the responsibility of the eventual plant operator. For example, the precise sampling frequencies will depend upon operator-specific choices for chemistry control and procedures. I am satisfied that this distinction is appropriate in the context of GI-AP1000-RC-02, as the information contained therein remains sufficient on which to base a judgement on the adequacy of the sampling systems. In effect, Ref. 18 is the minimum sampling requirements defined by the safety case, with

operator choices potentially increasing this to account for other (such as commercial) considerations. I am content that major changes would be unlikely once licensee specific decisions on chemistry control are taken. Further development of this sampling schedule by a licensee is captured as part of existing Assessment Findings raised during Step 4 (Ref. 2), notably AF-AP1000-RC-01 and AF-AP1000-RC-04.

68. What Ref. 18 does not do is provide or reference the limits that would be expected for the various parameters during the operating modes. This is part of GDA Issue GI-AP1000-CC-01 (Ref. 11) and hence was the subject of ongoing work coincident with development of Ref. 18. For resolving this GDA Issue, I did not consider that detailed information of this nature was necessary, as sufficient is available elsewhere within the safety case and supporting documents (Refs. 23 and 24) to understand the likely concentrations of the species to be measured. This is most relevant to those parameters where the concentrations are very small. As above, AF-AP1000-RC-04 requires further development of the relevant chemistry-related Operating Rules for the **AP1000** plant by a licensee.
69. Similarly, the tabulated schedule defined in Ref. 18 does not consider transients (such as start-up or shutdown). Westinghouse claimed this is because the transients are, by their nature, variable. The defined requirements are in effect those that are necessary once the plant is within the specified modes for a period of time (ie it does not consider the changing of modes). For the most part, this is a reasonable simplification. It is unlikely that different sampling locations or requirements would result; rather, it is the frequency of sampling certain parameters that may increase. Some specific frequency increases are noted within the schedule, for example zinc during start-up. Westinghouse noted that this aspect is considered further as part of the summary report for resolving this Issue (Ref. 19). I therefore considered specific instances where this was relevant as part of my assessment of Action 2, which follows.
70. Post-accident sampling requirements are not included in Ref. 18, which concentrates on normal operations. As the requirements for these situations are unique, and somewhat different from normal sampling, Westinghouse stated that they are included in Ref. 19.
71. In summary, the schedule identified that a large number of parameters are required on a daily basis, mainly from within the primary coolant. The most frequent requirement is for dissolved hydrogen, which is stated as three times daily. Many other parameters are less frequent, either weekly or monthly as these often come from systems where the chemistry is not expected to change rapidly (for example, the safety system storage tanks). These represent the minimum sampling requirements, but operational plants will sample more frequently than this in accordance with their own procedures. I would therefore expect the **AP1000** design to be capable of exceeding this sample schedule.
72. Overall, I am content that Westinghouse has identified the main likely sampling requirements for the **AP1000** design and that these can be clearly linked to the safety case needs, to an extent appropriate for GDA. Some aspects remain unfinished, such as transient periods, but I am satisfied that this information can be used as a suitable input to Action 2 and further substantiated therein. I am therefore content that sufficient has been provided to meet the intent for Action 1.

4.2.2 Action 2: to provide a justification and evidence that the primary sampling systems in AP1000 will support the sampling schedule delivered under Action 1

73. In this part of my assessment, I considered the response to Action 2. In addition to considering the justification for the adequacy of the design to meet the sample schedule defined under Ref. 18, I also considered the more specific gaps identified as a result of the assessment during Step 4 (Ref. 2).

4.2.2.1 Definition of Relevant Good Practice

74. The first submission made by Westinghouse against Action 2 was Definition of Relevant Good Practice for Primary Side Chemistry Sampling System Designs, UKP-GW-GL-101 (Ref. 20). Revision 0 of this report was submitted in June 2015, later updated to Revision 1 in October 2015 mainly to address my queries from RQ-AP1000-1381 (Ref. 26). These queries all related to additional information and evidence requirements. My assessment therefore considered this latter final revision.
75. According to Westinghouse, the purpose of that report was 'to provide a description of relevant good practices and requirements for chemistry grab sampling system designs'. While not an explicit expectation within GI-AP1000-RC-02, I requested Westinghouse consider what relevant good practice (RGP) may be for primary sampling systems in a PWR as part of their resolution plan (Ref. 3). In doing this, my intention was for Westinghouse to perform a critical review, such that they had a basis against which to judge the **AP1000** design (in Ref. 19). A key output from this review was therefore the list of aspects that Westinghouse considered to be RGP, such that a review of the **AP1000** design can be performed against them.
76. The approach taken in Ref. 20 was to consider both the practices and design requirements that are in use, to ensure that samples can be taken in a safe, timely, representative and consistent manner. This considered both normal operations and post-accident sampling. Ref. 20 identified many examples of RGP for sampling.
77. For normal operations, the information used by Westinghouse to inform their considerations is taken from a variety of industry sources but includes Westinghouse documents, EPRI reports, relevant standards (such as ASTM) and current operating reactor information. Importantly, one of the main inputs is the contractor review of RGP undertaken for ONR during Step 4 (Ref. 15). Significantly, Westinghouse do not refute the conclusions made in Ref. 15 regarding what constitutes RGP. Ref. 20 also considered a range of current plant operating experience and practices, as well as undertaking a review of the Institute of Nuclear Power Operations database for relevant operating experience. I am content that this is a suitable range of inputs on which to define RGP for use in resolving this GDA Issue.
78. As with other submissions made by Westinghouse, post-accident sampling considerations were considered separately from normal operations, although the same approach was used. In this case, the inputs were derived from guidance from the United States Nuclear Regulatory Commission (US NRC; Ref. 27) and the EPRI utilities requirements document (which represents an industry consensus view on what a PWR design must deliver). I am content that this represents an appropriate view on what constitutes RGP. However, the main omission is that no consideration is given to the specifics of the **AP1000** plant design, which differs from operating plants due to the incorporation of passive safety features. This may affect where, when and what may need to be sampled following an accident. In other words, is current plant information still relevant? I consider this further in assessing the final deliverable, Ref. 19, in Section 4.2.2.5 but believe that this weakness should at least have been acknowledged within Ref. 20.
79. The output from this report (Ref. 20) was a summary of what Westinghouse considers to be RGP. A number of specific considerations were highlighted, which relate to matters such as sample line requirements, methods of sampling and post-accident sampling requirements. I do not detail these here as they are numerous, but they are fully described in Ref. 20. Generally, these are at a fairly high level but appear reasonable and consistent with the main aspects I would have expected. They are also aligned with the descriptions provided in my contractors report (Ref. 15) and other data

sources, such as Ref. 28, although differences do occur in some instances. I judge that it would have been useful to further consider a number of additional matters, such as the location of sampling (as evidenced by the fact that the operating plant experience cited shows differences in the number and location of samples) and by consideration of other data sources, such as relevant IAEA standards and reports particularly related to post-accident sampling (Refs 13 and 29). As I considered the adequacy of the **AP1000** design as part of my assessment, including these gaps, I do not view the fact that they are not identified in Ref. 20 to be a hindrance for my assessment.

80. Overall, I am satisfied that Ref. 20 provides a suitable description of RGP against which Westinghouse can compare the **AP1000** design. I am content that Westinghouse has undertaken the critical, stand-back review of sampling systems that was intended.

4.2.2.2 Justification for the Design and ALARP Demonstration

81. The main response to GI-AP1000-RC-02 was **AP1000**® Plant Primary Sampling System – Safety Evaluation, UKP-GW-GL-099 (Ref. 19). That report took both Ref. 18 and 20 as inputs. The report provided the overall justifications for why the primary sampling systems are adequate, considering both the sampling requirements and RGP identified elsewhere. Alongside more general descriptions of the sampling system, its functions and operations, the bulk of the report is an ALARP assessment of the plant design. Westinghouse compared the standard plant design (as per the end of GDA Step 4, and as described in Section 3.1) against the defined RGP. Where differences were identified, an ALARP evaluation was performed to identify if potential design modifications are needed. The overall output from Ref. 19 was therefore a UK-specific design for the primary sampling systems.
82. My assessment is based upon Revision 1 of Ref. 19, which was submitted in September 2016. However, the earlier Revision 0 was also submitted to ONR for assessment (March 2016). I had a number of significant concerns with the earlier version of the report and, importantly, I did not agree with the overall conclusion that the design at that time represented the ALARP solution. A number of meetings and interactions were held with Westinghouse in the period between revisions to expand on my concerns and clarify regulatory expectations (notably Refs 30 and 31). This resulted in some significant changes to both the report conclusions and plant design. These were reflected within Revision 1 of the report, as clarified in the subsequent letter from Westinghouse, Ref. 32. My assessment therefore refers to Revision 1, unless stated otherwise. Information from Revision 0 is included only where necessary to support the judgements made on the adequacy of the final response or design.
83. Before discussing my assessment of the conclusions to Ref. 19, I first consider the adequacy of Westinghouse's process and approach. In summary, each aspect of RGP identified in Ref. 20 was considered in turn (for example, one aspect of which is the ability to meet the sampling frequency, as defined in Ref. 18), identifying whether the **AP1000** design can meet that requirement. If so, evidence was provided for why this was the case. If not, an optioneering process considered whether potential design changes could fully or partly address that gap. The options for each gap were then subject to an ALARP assessment to determine if any were reasonably practicable to implement. The optioneering process was generally fairly robust, considering a good range of options, although later in my assessment I discuss some specific examples of where it was less so. I also consider that a number of the options were over-specified (that is, deluxe). Importantly, Westinghouse recognised that combinations may score differently from individual changes and considered a range of 'integrated gap' options. The scoring criteria used relate to nuclear safety, personnel safety, chemistry programme and plant/cost impact, which are weighted at 30% each, except for the latter at 10%. Overall scores range from -3 (detriment) to +3 (improvement), with zero representing no change. The ALARP process used is consistent with internal

Westinghouse guidance (Ref. 33). While I am not content that this particular application of the approach fully meets ONR expectations (as per NS-TAST-GD-005, Ref. 7), I do consider it to be fit for purpose in this instance, especially when the accompanying descriptions in Ref. 19 that substantiate the scoring are considered.

84. An important input to this ALARP process is therefore the identification of the gaps in the **AP1000** design compared with the identified RGP. In total, seven departures from RGP were identified. In summary, these relate to:

- provisions for recycling the sampling effluents back to the primary circuit;
- on-line monitoring for safety-related parameters;
- implementation of isokinetic sampling;
- sample cooling to 25 °C and the cooler location;
- corrosion product sampling capabilities;
- sample header configuration; and
- types and locations of samples.

85. By default, Westinghouse are content that the other aspects of the design for the **AP1000** primary sampling systems meet RGP and reduce risks ALARP. In the following sections of my report, I assess the response against all seven of these gaps, plus other aspects of the design that I consider merit attention. Collectively, my assessment therefore covers all the concerns identified within the Step 4 assessment (Ref. 2), Action 2 of GI-AP1000-RC-02 (Ref. 1) and those identified by Westinghouse. These have been considered under the broad categories of sampling capabilities, representative sampling and safety impacts from sampling. However, I recognise that these categories overlap in most instances.

4.2.2.3 Sampling Capabilities

86. In this part of my assessment, I consider the overall capabilities provided by the **AP1000** primary sampling systems. The three, specific capability-related RGP gaps, where Westinghouse identified further consideration was needed, were:

- on-line monitoring for safety-related parameters;
- corrosion product sampling capabilities; and
- types and locations of samples.

87. These are three of the seven RGP gaps identified by Westinghouse, which align with the third, fourth and sixth points in Action 2 of GI-AP1000-RC-02. In addition to these, I also considered the capabilities for sampling zinc, which is specifically discussed in the Step 4 assessment report (Ref. 2) and the sampling schedule (Ref. 18) more generally.

Sampling Schedule

88. Before discussing a number of more detailed points, it is first worthwhile considering the justification provided that the overall sampling requirements, as per Ref. 18 in response to Action 1, can be met. The conclusion reached by Westinghouse is that the existing design can achieve those requirements. However, Westinghouse recognised that further consideration needs to be given to specific parameters and locations (for example, for corrosion product sampling). These are discussed later in my report, but I agree that the PSS should be functionally capable of meeting the frequencies defined in Ref. 18, primarily through the continuous flowing sample line. Samples via the intermittent line are taken on a weekly or monthly basis in accordance with Ref. 18. The sampling itself will therefore take up little of the available time; however, the largest unknown is the flushing volumes required between different samples. I consider whether this flushing process is achievable later in my assessment. Meeting the requirements of Ref. 18 may therefore place demands on other aspects of the design,

such as waste effluent production, which I consider later (Section 4.2.2.5). While I judge that the sampling schedule may be achievable with the existing PSS design (in terms of frequency), it is clearly very reliant on the single continuous sample line. While it is possible to use both lines interchangeably, I judge that the existing design for the PSS (as Figure 1) suffers from a lack of redundancy. This forms part of my consideration under Section 4.2.2.4 (entitled Representative Sampling).

89. The caveat to this judgement is that I note, as I did in paragraph 69, that these frequencies do not include transient periods when demand may be higher and also may place demands on different samples. I consider this in my assessment regarding the types and locations of samples.

Zinc Sampling

90. The capability to accurately determine the zinc concentration in the **AP1000** design is an important claim within the safety case and was specifically included in Action 2 of GI-AP1000-RC-02. Soluble zinc is added to minimise radiation fields and to mitigate stress corrosion cracking of nickel-based alloys used within the pressure boundary. Strict controls are in place to avoid the addition of too much zinc, as it may start to impact on fuel cladding integrity. More specifically, in the **AP1000** design the large steam generator surface area (15% larger than comparable four-loop plants) combined with core boiling could cause more corrosion products and hence higher levels of activity, if not adequately controlled (see Section 4.2.3 of Ref. 2).
91. For this reason, zinc is limited to less than $\blacksquare \mu\text{g kg}^{-1}$ in the primary coolant, with the expected concentrations maintained within a tight control band of $\blacksquare \pm \blacksquare \mu\text{g kg}^{-1}$. The capability to sample zinc at these concentrations from the primary circuit of a PWR can be difficult due to interactions between the solution and sample line surfaces. Ref. 34 provides further details, and EPRI suggests two possible remedies: have a continuous (uninterrupted) flowing sample; or use a much shorter sample line (for example, CVS inlet).
92. Consideration of zinc sampling RGP was not part of Ref. 20, but was included in Ref. 19, in which Westinghouse concluded that the **AP1000** design is capable of zinc sampling. The main argument for this comes from the use of a continuous sample line, which is expected to be dedicated to hot leg samples (and will therefore equilibrate with zinc quickly). The second remedy suggested by EPRI in Ref. 34 is less relevant to AP1000 given that the CVS is inside containment (and hence would not have a significantly shorter sample line than the hot legs). Further, on the basis of work conducted in response to this GDA Issue, Westinghouse now recommend using the hot leg 1 sample line for zinc sampling as it has a much shorter hot section, which would reduce zinc interactions.
93. I am content that Westinghouse has demonstrated that due consideration has been given to sampling of this important parameter. This conclusion is valid provided the continuous line is only used to sample hot leg 1.

On-line Monitoring

94. On-line monitoring of chemistry parameters may offer advantages over grab sampling, particularly for parameters that may change rapidly. This is most relevant for those parameters where changes would have safety implications that may necessitate prompt operator actions. Westinghouse conceded that such on-line monitoring is becoming more common within PWRs, but maintained that grab sampling is still the main compliance route to demonstrate adequate chemistry control. This is consistent with UK practice. The gap identified in Ref. 19 is therefore to determine if it is reasonably practicable to supplement the capabilities for on-line sampling in the **AP1000** design.

95. The existing design already incorporates on-line monitoring of dissolved oxygen and hydrogen as part of the GSP. These meters are fed from the continuous flowing hot leg sample. The hydrogen meter is an important part of the response to GI-AP1000-RC-03 regarding the hydrogen dosing system because no other commercial PWR adds hydrogen in the same manner as the **AP1000** design. This is discussed more fully in Ref. 35. As a result, Westinghouse specified increased monitoring frequencies for this parameter during normal operations and during start-up and shutdowns. The ability to monitor hydrogen using this meter is dependent on steady flow conditions. I am content that the design should be capable of monitoring hydrogen in a satisfactory manner, but care will be needed during operations to achieve this (for example, closing or opening valves may cause flow disturbances).
96. The other primary coolant parameters that could be considered for on-line monitoring are pH, conductivity or boron. The **AP1000** chemistry manual (Ref. 23) notes that conductivity is a diagnostic parameter only, therefore of limited safety significance, while pH (or actually the pH at the operation temperature (pH_T)) and boron are both control parameters. I am not aware of any instrument which can measure pH accurately at primary coolant temperatures, and this parameter is commonly inferred from measured boron and lithium concentrations, or measured using a grab sample. There is therefore little incentive in measuring pH on-line. There are safety benefits in having the capability to monitor boron given the important role it plays in reactivity control. It is also a suitable candidate because it can change rapidly during fault conditions requiring prompt operator actions. I also consider that it would be RGP to include on-line boron monitoring as this is included at the Sizewell B PWR.
97. While the optioneering conducted in Ref. 19 considered the addition of pH, conductivity and boron meters, I have limited the consideration that follows to those options that include boron. It is clear from the above that on-line meters for the other identified parameters are either impracticable, or the measurements they provide are of limited safety significance.
98. Five options were devised which would give the **AP1000** design the capability to monitor boron on-line. Once subjected to the ALARP assessment, two of these, relating to adding an entirely new sample line and introducing a small circulatory loop fed from the primary circuit within containment, were discounted. The latter was deemed to be infeasible while the former scored poorly due to the safety detriments it introduces (mainly increasing the radwaste and an increase in plant risk caused by an extra containment penetration). The scores from the remaining options ranged from slightly detrimental to beneficial (-0.2 to +0.05). Therefore, there seemed little to choose between these options. Westinghouse stated that their preference is to include a boron meter (BCMS – Boron Concentration Measurement System) upstream of the GSP which would make use of the existing continuous sample line. This is shown in Figure 2.

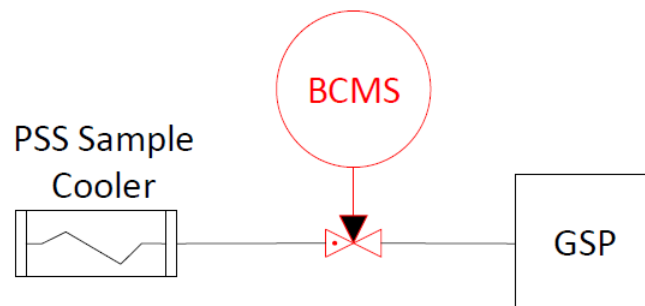


Figure 2: Boron meter modifications schematic

99. On the basis of the evidence presented in Ref. 19, I am satisfied with the consideration given to the inclusion of a boron meter in the **AP1000** design and welcome the proposed change to introduce one.
100. Given the close scoring of a number of different options for how this might be achieved, I queried this in RQ-AP1000-1728 (Ref. 26). The response indicated that the main difference between the options relates to the space available within the GSP and sampling room to be able to accommodate this additional equipment, which is currently restricted. Westinghouse indicated that the detailed design phase will influence the final solution, but at the moment the option to include a meter external to the GSP is seen as optimum. Also, the option of including a non-intrusive external meter based on neutron absorption technology (ie on the outside of pipework) scored low, mainly because Westinghouse considered that this needs to be located on part of the CVS and therefore inside containment. This introduces additional detriments, such as maintenance access. Given the clear safety benefit of this type of technology, mainly by not requiring a break in the containment barrier, I would expect further consideration to be given to whether it is reasonably practicable to include such a meter elsewhere within the plant.
101. Overall therefore, I am content that a boron meter will be included within the UK **AP1000** plant design. This represents a safety improvement. Further justification will need to be provided by the licensee regarding how and where this is implemented within the design and safety case. Given the expected boron control operations in the **AP1000** reactor, I am satisfied that the current proposed design, as defined within Ref. 19, could be demonstrated to be sufficient but this will need to be done at the detailed design phase and with suitable operator input. This should also include matters such as how the boron meter outputs are used by the operators, for example within the control room, the meter technology, its uses by the operators and reliability claims on the meter. **I consider this to be an Assessment Finding:**

CP-AF-AP1000-RC-02 – The licensee shall provide justification for how the boron meter is to be implemented within the detailed plant design and safety case, given the design change to incorporate the capability.

Corrosion Product Sampling Capabilities

102. Irrespective of how much control is placed on plant operations, some quantity of activated corrosion products (CPs) will be generated in any PWR and the **AP1000** plant is no different. The CPs represent a large proportion of the radioactivity within the plant and are the main source of operator doses during outages once deposited on the inside of pipework. The Step 4 assessment (Ref. 2) noted that, while a number of design improvements reduced the sources of CPs in the **AP1000** design, the requirement for stringent controls remained. It is therefore important that consideration is given to the capability to measure CPs, as they are known to be difficult to measure in many operating plants (for example, Refs 22 and 28).
103. When comparing against RGP in Ref. 19, Westinghouse concluded that further consideration needs to be given to the **AP1000** design in this regard. Westinghouse identified the fundamental requirements for CP sampling, based on operating experience (OpEx), as a continuous and steady sample flow, over minimal sample line length, with constant (low) temperature and no exposure to oxygen. Also related to CP sampling is the need, or otherwise, for isokinetic sampling. As Westinghouse identified this as a specific RGP gap, and it is more related to sample representativeness, I consider this separately in Section 4.2.2.4 of my assessment.
104. Three options were considered to enable CP sampling as part of the ALARP assessment in Ref. 19. These are all based on the concept of integrated filter sampling for CPs. In this technique, a flow of coolant is filtered for a defined time before the filter

is subjected to radiochemical analysis. This is common practice within the industry and has been demonstrated to give acceptable results. The difference in the options therefore relates to how to retrieve the coolant for filtering: either by using a new, separate sample line from the primary circuit, or by adding an in-containment recirculating loop, or by adding a capillary sample line from the existing hot leg line. While it is suggested that all three options could meet the RGP requirements for CP sampling, the first two were discounted based on their ALARP scores. The main detriments differ but relate to factors such as the addition of extra components, the inclusion of containment penetrations, the generation of additional sampling effluent (potentially waste) and technical uncertainties. The justifications provided were robust enough to substantiate these conclusions, based on the claimed operating philosophy for the system (namely, continuous, uninterrupted flowing hot leg sample).

105. The final option, of capillary line sampling, has therefore become the selected option. Similar approaches have been used in a number of operating plants worldwide, including Sizewell B in the UK (Ref. 36, for example). As the proposed modification for UK **AP1000** plants will draw flow from the existing continuous hot leg sample, this should meet the RGP defined in Ref. 18. It also has the advantage of creating no additional sampling effluent, as this flow already exists. This is shown in Figure 3.

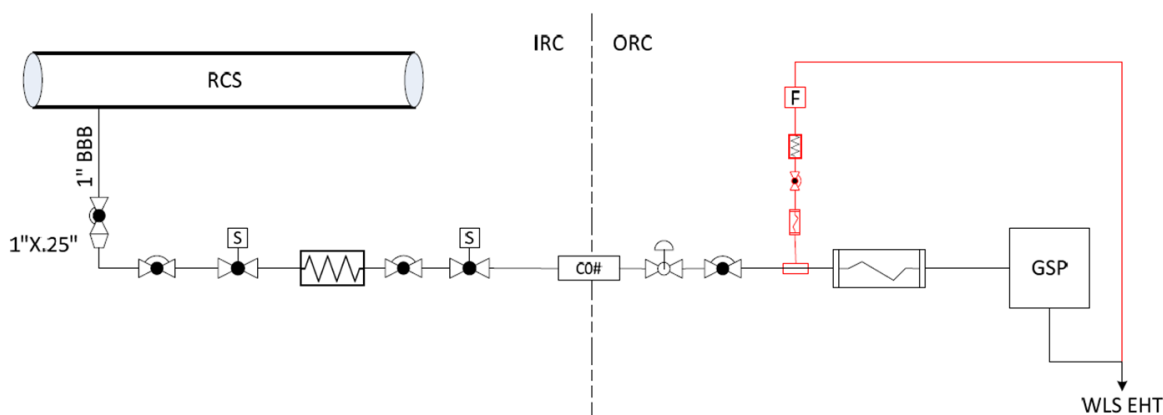


Figure 3: Corrosion product sampling modifications schematic

106. I am satisfied with the consideration given to the capabilities of the **AP1000** design to sample CPs. The addition of a capillary filter sampling device is consistent with many plants worldwide and addresses the deficiencies in the original design. However, this modification will only prove successful if the continuous hot leg sampling line is representative of the main primary coolant flow. I consider this further in Section 4.2.2.4 of my assessment.

Types and Locations of Samples

107. As is evident from the review of operating plants in Refs 18 and 20, there are a number of plants that have additional sampling capabilities to those present within the **AP1000** design. In addition, the samples included within their equivalent to the PSS, as opposed to grab sampling, can differ. Most notably, this is for a number of auxiliary systems such as the Spent Fuel Pool Cooling System (SFS). Westinghouse therefore identified this as a gap for review in Ref. 19. It was also specifically discussed in the Step 2 assessment report (Ref. 2).
108. Firstly, considering the sample locations identifies two potential additions: CVS inlet (that is, upstream of the CVS demineralisers) and pressuriser vapour space. In operating plants, a CVS inlet sample is taken to determine the performance of the CVS demineralisers (in co-ordination with the CVS outlet sample). A secondary use for this sample is as a (potentially) more representative location to determine zinc and CP

concentrations. Westinghouse considered adding a specific sample line to this location. This option, however, assumed that a new continuous sample line would be needed, thus adding many components including a containment penetration. As discussed previously, in paragraph 92, the existing hot leg 1 sample line should be capable of meeting all of the RGP aspects of zinc sampling. The location of the **AP1000** CVS system inside containment negates much of the benefit derived from this location in existing plants, given that the length of piping is not significantly shorter than the hot leg sample. The same arguments would also hold true for CP sampling. Therefore, there is little additional benefit in adding this location to improve the zinc or CP sampling capabilities. Regarding determining the CVS demineraliser performance, Westinghouse argued that the existing hot leg samples are adequate for this purpose.

109. On this basis, the ALARP processes scored this option as a marginal detriment (-0.05), principally due to the assumption that it requires an additional containment penetration. On that basis, I would agree with the conclusion. However, as the overall resolution to GI-AP1000-RC-02 does indeed add such an additional penetration, I decided that this scoring would therefore indicate it would be ALARP to add this sample location. This needs not be the separate line considered by Westinghouse, but could be simply a sample line from the CVS inlet to the PSS sample header within containment. **I consider this to be an Assessment Finding:**

CP-AF-AP1000-RC-03 – The licensee shall justify the omission of a CVS demineraliser inlet sample within the PSS, given the design modifications made for UK plants.

110. During operation of a PWR, non-condensable gases (nitrogen, hydrogen, helium and noble gases) can collect within the pressuriser vapour space. Some plants have a sampling line here to determine the extent of build-up and control the need to vent some of the gas routinely. Too much gas build-up would have nuclear safety significance, first in controlling pressure and second potentially as a flammable atmosphere. In its review, Westinghouse noted that the **AP1000** plant predecessor (AP600) did have a sample line here. It was removed on the basis that, in existing plants, it is not used to sample but rather as a venting line. In contrast, the **AP1000** design includes a specific venting line, which vents the pressuriser vapour to the WLS reactor coolant drain tank, which is further vented to the Gaseous Radwaste System. This feature was added during Step 4 (Ref. 37), as discussed more fully in Ref. 2.
111. Despite this, Westinghouse still considered the addition of a sampling point at this location. Given this is a gaseous sample, a new sample line would be necessary. The subsequent ALARP assessment indicated that there would be significant detriments in implementing this option, combined with no nuclear safety benefits. This has therefore been rejected. I am satisfied with this conclusion and the supporting arguments and evidence, which suggest both that the **AP1000** plant has adequate means to detect (via means other than sampling) and remove non-condensable gases from the pressuriser. Westinghouse confirmed that these are expected to occupy only a small volume (~2%) and therefore not have a significant impact.
112. Finally, Westinghouse also gave specific consideration to adding samples from the RNS, SFS and WLS to the PSS. In the existing **AP1000** design, these samples are all taken via local grab sampling. For all of the samples, the main argument against including these within the PSS was the extent of plant changes necessary. It was further argued that the hazards posed by these samples are not as significant as those locations sampled via the PSS and therefore local grab sampling remains adequate.
113. I am content with these arguments for the SFS and WLS, where it can be shown to be disproportionate to include these within the PSS. This is predicated on the adequacy of the local grab sampling arrangements, which were not considered within Ref. 19. I raised this as part of RQ-AP1000-1728 (Ref. 26). In summary, the response noted that

the detailed design of the local sampling equipment is within the scope of the detailed design phase. Westinghouse noted that feedback from Chinese and US **AP1000** plants will inform the final solution. I consider this to be a reasonable position for GDA, as I accept local grab sampling as sensible in these instances. However, I consider that this should be followed up in the detailed design phase. AF-AP1000-RC-53 is also relevant here (Ref. 2). **I consider this to be an Assessment Finding:**

CP-AF-AP1000-RC-04 – The licensee shall provide evidence that the local grab sampling equipment provides suitable and sufficient sampling capabilities, provides protection to the operators, and gives appropriate consideration to minimisation of radioactive waste, for all modes of operation.

114. In Ref. 19, Westinghouse confirmed that the RNS sample is taken via the systems drain line, which is located outside containment. This line is also used to sample the IRWST. The arguments provided for not including RNS sampling within the PSS were the same as for the SFS and WLS, but only seem to consider normal operations. It also appeared to be inconsistent with the sample schedule in Ref. 18, although this is because the schedule does not consider transients between modes as noted in paragraph 69. As I was aware that other PWR designs need to sample the RNS equivalent on a frequent basis during start-up and shutdown events, I queried why the **AP1000** design was different in RQ-AP1000-1728 (Ref. 26). The response clarified that samples will continue to be taken from the hot leg line, including during transient periods. Westinghouse are confident that RNS sampling will only be necessary prior to the initial connection of the system during a shutdown. If the system pressure is insufficient, samples can be drawn by using the eductor within the GSP. On the basis of this clarification, I am content with the rationale for excluding the RNS sample from the PSS.

4.2.2.4 Representative Sampling

115. A number of design features within a sampling system can affect the representativeness of any sample taken. For homogeneous fluids, representative sampling is straightforward, unless specific effects occur that interfere, such as precipitation. One relevant example of this is for zinc, which I assessed in Section 4.2.2.3. The more difficult area tends to be for two-phase flow, which for PWRs means CP sampling. I assessed the Westinghouse response to this earlier, in the context of the capabilities to sample for CP, whereas this part of my assessment further considers whether those samples will be suitably representative.
116. I first consider the more general requirements related to the general design of the sampling systems (in particular the PSS), before assessing the three RGP gaps where Westinghouse identified that further consideration is needed. These align to parts of the first and second points in Action 2 of GI-AP1000-RC-02. These are:
- implementation of isokinetic sampling;
 - sample cooling to 25 °C and the cooler location; and
 - sample header configuration.

Effects of System Design

117. Ref. 19 noted that the **AP1000** plant is designed in accordance with the requirements of ASTM D3370-10 (Ref. 40) and a number of other American Nuclear Society standards. These standards contain many of the fundamental expectations for factors such as layout, sampling locations and flow rate. Further information is also available in Ref. 17 of how the existing design meets some of these requirements. I do not repeat these in detail here, but consider that these have indeed been reflected in the design.

118. An important consideration is the sampling flow rate, which can affect both homogeneous and two-phase samples. Westinghouse stated that the continuous line will have a linear flow rate of slightly less than $\blacksquare \text{ m s}^{-1}$. There was some uncertainty over this at the end of Step 4, which has now been resolved by Ref. 19. This is aligned with the recommendations of Ref. 40, and consistent with the RGP identified in Refs 15 and 28. In the sample line diameters specified for the PSS, this leads to a Reynolds number much higher than that required to achieve turbulent flow conditions. This is an important part of representative CP sampling. Similarly, the general expectations to minimise sample line length, maintain a slight incline etc were described in Ref. 19. I am therefore content that Westinghouse has considered such matters appropriately within the design. The effect of sample temperature is discussed separately below.
119. For the intermittently used sample line, the important consideration is the flushing process. Westinghouse stated that a sample velocity of 1.8 m s^{-1} and purging a minimum of three volumes of the sample lines at 125% of the sample velocity is required for proper representative sample collection. This is consistent with Ref. 40 (and 15 and 28). This is the idealised case, which assumes that there is no interaction between the sample lines and fluid. However, this is not always the case in PWRs: should interactions occur, a much larger flushing volume would be necessary. This is an important part of the sample header configuration justification assessed below. In any case, the flushing process will need to be defined and controlled by appropriate operating procedures by the future licensee, but there appears no reason why the design should not be capable of achieving this.
120. Overall, I am content that Westinghouse has considered appropriate sources of RGP and OpEx in the design of the **AP1000** plant primary sampling system, related to achieving representative sampling. The more specific aspects where further consideration is warranted are assessed below.

Implementation of Isokinetic Sampling

121. Isokinetic sampling is a particular approach to sampling of particles suspended in a fluid. The key factor is to ensure that the sampled stream enters the probe without changing speed: if it slows down, the proportion of larger particles collected increases; if it speeds up, the proportion of smaller particles increases. This may therefore be relevant for CP measurements. This question of isokinetic sampling was discussed during Step 4 with Westinghouse, who provided a review at that time (Ref. 38), the conclusion of which was that they considered adoption of isokinetic sampling to be unnecessary. Plant OpEx demonstrates that even the best designed PWR sampling systems do not truly sample isokinetically but instead approximate this behaviour, and that they give much more representative results for CP measurements. I am therefore satisfied that isokinetic sampling (in the strictest definition) is not strictly necessary, but it needs to be demonstrated that all reasonable steps have been taken to achieve representative sampling.
122. Westinghouse did identify the lack of isokinetic sampling in the **AP1000** design as a gap compared with RGP and considered further how this might be addressed. In effect, this is answering the question of what more can be done (with isokinetic sampling being just one part). Ref. 19 examined either adding specialist sample probes or using capillary lines. The outcome of the review was that, as discussed in paragraph 105, Westinghouse concluded that the addition of capillary lines meets RGP for CP sampling and is reasonably practicable. The main reason for discounting sample probes was the risk that they may become detached and become a source of debris within the primary circuit. OpEx does indicate that this has occurred in operating plants in the past. However, the type of probe was not considered, nor ways in which the risk of detachment could be avoided. I was therefore not satisfied with this argument.

123. I asked for further evidence in RQ-AP1000-1728 (Ref. 26) on why Westinghouse thought the overall design was adequate, but the response repeated the arguments already found in Refs 38 and 19. I am content that these cover the main factors of relevance, but disagree that the use of sample probes (or more specifically the sampling nozzle interface) has been properly considered. I accept that this is more of a detailed design decision and therefore suitable for consideration in later stages. I **consider this to be an Assessment Finding:**

CP-AF-AP1000-RC-05 – The licensee shall provide justification that appropriate consideration has been given to the sampling nozzle design for the hot leg samples at the detailed design stage, to ensure all reasonably practicable steps are taken to enable representative corrosion product sampling.

Sample Cooling to 25 °C and the Cooler Location

124. The existing PSS design includes sample cooling provisions to cool the extracted samples to at least 52 °C (or lower, as this is the pessimistic design temperature), once they leave containment and enter the auxiliary building. The primary purpose of this cooling is to provide personnel protection to the operators, particularly for the primary circuit samples, which are extracted at over 300 °C. This cooling can affect the representativeness of the samples and Westinghouse identified two particular aspects where this may be the case, namely:
- cooling to a lower temperature (25 °C) for increased compatibility with analysis devices; and
 - determining where is the best place to perform the main sample cooling, particularly for the hottest primary circuit samples.
125. Three options were identified for resolving this gap. The first two options address the first of these points and involve the addition of secondary coolers to the sample lines before the GSP. The options differ in the cooling source, either via connection to the existing plant chilled water system or using electric coolers. The third option considered by Westinghouse addresses the second point and involves moving the existing coolers (fed by the Component Cooling water System (CCS)) closer to the sample location, within containment.
126. Before discussing the results of the ALARP assessment for these options, it is germane to note that I consider that cooling to 25 °C will have only a very marginal nuclear safety benefit. Notwithstanding this, Westinghouse did not find either of these additional cooling options to be reasonably practicable, mainly due to the relatively high plant impact of these additions compared with the marginal benefits. I agree with this conclusion.
127. The final option of moving the coolers closer to the sample source does merit further consideration. This may indeed affect the sample representativeness:
- For zinc, earlier cooling is beneficial, as this slows the interaction with the sample lines.
 - For CPs, cooling has two possible opposite effects. First, the cooling changes the pH which increases the solubility of iron and nickel (dissolving CP), but conversely it decreases the deposition of CP along the sample line. Unfortunately, the balance of these competing effects can be somewhat plant specific, but the general consensus is that cooler sampling lines are better overall, particularly if the sample is turbulent (Refs 28 and 41).
128. The option considered by Westinghouse in Ref. 19 was to move the existing CCS coolers (which are part of the sampling conditioning rack) inside the containment. With space constraints, the closest location identified is near to the delay coils. The main

detriments of doing this are related to the cost and plant impact. As the CCS already serves systems within the containment, there are no additional containment penetrations necessary. However, the deciding factor is that the actual cooling benefits from making this change are small. Hot leg 1 is already at █ °C, whereas hot leg 2 is at █ °C at this location. This is 25 to 35% along the sample line. Given that temperature effects are negligible at <120 °C, there is no benefit in implementing this change. As noted earlier, on this basis, hot leg 1 was identified as the preferred sample for both zinc and CP measurements because it will be at <120 °C for over 80% of its length.

129. I am satisfied that Westinghouse has considered sample cooling and has demonstrated that the existing plant design is adequate. Any change would have minimal impact on sample representativeness.

Sample Header Configuration

130. One of the main differences in the design of the **AP1000** primary sampling systems compared with other PWRs is the use of a manifold inside containment, which connects the various samples so they can be routed through one of the two lines that pass through containment. This was one of the major aspects of the PSS design assessed during Step 4. In particular, the response to Regulatory Observation (RO) RO-AP1000-55 Action 8 (Ref. 39) provided details of the consideration given to the possibility of misrouting of fluids across the sample manifold, especially driven by pressure differential, and the potential for sampling mixed or contaminated samples. The Step 4 report (Ref. 2) concluded that this possibility could be adequately controlled, provided robust controls are put in place by the licensee. However, demonstration that the system is sufficiently robust against this type of fault was part of the justifications required under GI-AP1000-RC-02. In response to the RGP review in Ref. 18, Westinghouse also identified the configuration of the sample header as an area for further review.
131. Two options are identified for further ALARP assessment by Westinghouse; these effectively bound all other options. The first of these involves removing the manifold altogether and reverting to a design whereby individual sample lines from each sampling point pass through containment to the GSP. This therefore requires an additional nine sample lines and associated equipment (although not all lines require decay coils or coolers, for example). There are some obvious benefits to this approach, namely that it entirely removes all concerns regarding representative sampling or inability to deliver the sampling requirements. However, ultimately this option was discounted on ALARP grounds because the detriments are also significant. These include: a large increase in sampling effluent (waste), major changes to the number of containment penetrations, the need for a complete redesign of the GSP, and the increased maintenance burden. However, the most significant detriment is that, in the existing design without recycling of effluent, the coolant volume lost via sampling may change the way the **AP1000** plant is designed to operate. This would require much more frequent make-up operations undermining the design of the CVS. Given the significance of this last point, I am satisfied that it would not be reasonably practicable to modify the design to this extent to improve the sampling system.
132. The other, less extreme, option further splits the manifold. The rationale for this split is based on grouping similar samples, for example the PXS samples are all of similar composition, temperature and pressure and the main requirement is for soluble boron concentration. The benefits and detriments for this option are broadly the same as the previous option; however, the scale of detriments is much smaller given that only one additional (intermittent) sample line is necessary. This alters the ALARP balance and, overall, Westinghouse concluded that it is reasonably practicable to implement this change. This is shown in Figure 4.

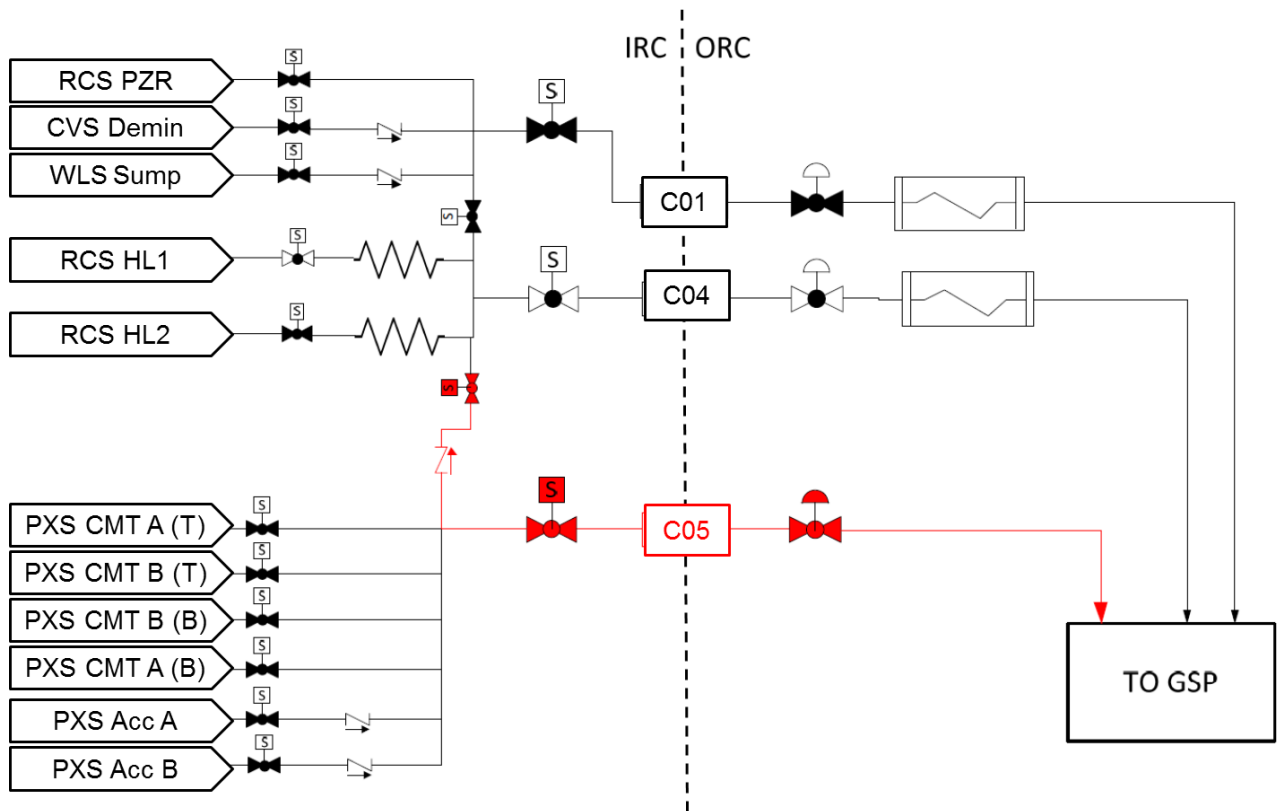


Figure 4: Sample header modifications schematic

133. In effect, this modification creates three sampling manifolds inside containment, each with their own sample line that passes through containment. These are not normally connected, but can be so if necessary due to failures or other reasons. One of these lines (via C04) is continuously open, drawing flow from hot leg 1 (or 2). The other two (PXS samples via C05 and others via C01) are used intermittently in accordance with the sample schedule. I am satisfied that this further split of samples is reasonable. If operated as intended, this arrangement groups similar samples through the same line, minimising the chance of obtaining unrepresentative samples through cross-contamination. Although the WLS sump sample is grouped with the pressuriser liquid and CVS demineraliser outlet sample, it is not intended to be used during normal operations and is mainly included for post-accident situations.
134. I am content that this change improves the PSS and reduces the risks associated with obtaining a non-representative sample. This also allows the operator additional flexibility in sampling, for operational reasons or due to some fault or failure in the PSS. Given the other facets of the **AP1000** design, I agree that this represents a pragmatic solution, and do not think that any further modifications (for example, to four sample lines) would yield any further benefits to nuclear safety. I judge that this resolves the concerns with this aspect of the design.

4.2.2.5 Safety Impacts from Sampling

135. This part of my assessment considers the implications of sampling on safety. It therefore considers matters broader than the ability to control the plant chemistry. The last remaining RGP gap identified by Westinghouse falls within this category: the recycling of sampling effluent. I also considered the GSP design more generally and the post-accident provisions necessary. These were all identified within the Step 4 assessment report (Ref. 2) and GI-AP1000-RC-02 Action 2 (specifically point 5).

136. I do not discuss these in detail below, but I acknowledge that the existing PSS design incorporates a number of features that I would expect to find in any properly designed nuclear sampling system. This includes delay coils, isolation valves, radiation monitoring and interlocks, which serve to protect the operator from the hazards of the plant. All of the PSS lines that pass through containment have class A1 valves, which automatically isolate on a containment isolation signal.

Provisions for Recycling the Sampling Effluents Back to the Primary Circuit

137. One of the main constraints on the PSS design for the **AP1000** reactor arises due to the operating philosophy for the plant and other design considerations. As mentioned previously, the plant utilises grey rods for short-term reactivity control. This reduces the need to frequently dilute (via letdown and make-up) the coolant boron concentration allowing the CVS to be placed inside containment and the Volume Control Tank (VCT) to be removed. In other PWRs, the sampling effluent is often returned back to the primary circuit on a continuous (or semi-continuous) basis via the VCT. The original standard plant design (of one sampling line) directed this effluent to the WLS as waste. The sampling system modification made during Step 4 (to two lines, Ref. 17) continued to direct the effluent to waste. However, the justification did not provide evidence that this was within the plant capabilities, nor whether it was reasonable to do so, especially when SAP RW.2 (Ref. 6) on the minimisation of radwaste is considered. These aspects therefore became part of GI-AP1000-RC-02.
138. Ref. 19 provided further information on the sampling effluent produced. In total, around 25 litres hr⁻¹ (on average) is produced, which is directed to the WLS, based upon one continuously flowing line and intermittent grab sampling in accordance with the sample schedule in Ref. 18. Around 75% of this is from the continuous line. This accounts for around 7% of the total liquid radwaste produced in the **AP1000** design. This demonstrated that the existing design is within the capabilities of the WLS, and provided further context for the optioneering that follows, but also demonstrated that there is very little remaining margin in the sampling input to the WLS, with around 95% of the allowable capacity currently utilised. While it is relevant to demonstrate that the plant can deal with this waste volume appropriately, and this meets the expectation given in the GDA Issue, this is not the same as justifying that it is reasonable to produce this waste. In addition to the expectations of the SAPs, Licence Condition 32 requires the licensee to ‘...make and implement adequate arrangements for minimising so far as is reasonably practicable the rate of production and total quantity of radioactive waste accumulated on the site...’ (Ref. 42). I would therefore expect a robust justification for why this waste cannot be avoided.
139. In Ref. 19, Westinghouse recognised that the lack of recycling within the **AP1000** design is a departure from RGP. Two options were identified to resolve this gap. Both involve collecting the sampling effluent within a tank before returning it to the primary circuit. The first option considers the addition of a new tank to do this, while the second re-tasks an existing WLS Effluent Hold-up Tank (EHT) for the purpose. The benefits of recycling are clear from the preceding paragraph, as this would remove a significant proportion of the plant liquid radwaste. The main detriments cited by Westinghouse against these options are the additional components and complexity required in the plant and the chemistry-related risks associated with introducing the effluent back to the primary coolant, in particular related to the boron and dissolved oxygen concentrations.
140. The conclusion of the ALARP assessment discounted both of these options. The second option, of re-tasking an existing EHT, showed a smaller overall detriment, mainly associated with increased dose to operators. This option is shown below.

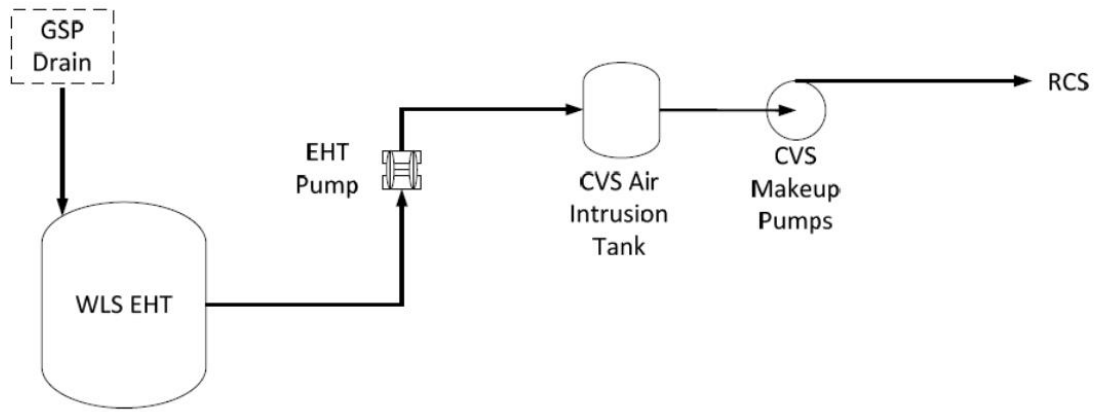


Figure 5: Effluent recycle modifications schematic

141. This scoring was heavily reliant on a number of assumptions. The main ones were that: the effluent must be held up for a long period (numerous days) before it can be recycled, the recycling needs to take place via the existing CVS make-up pumps, and all of the PSS waste is recycled. My consideration of these is:
- The **AP1000** plant is intended to operate with infrequent boron dilutions being necessary (at around weekly intervals), with short-term reactivity control achieved using the grey rods. In the current design, the sampling volume is lost from the system, so the primary circuit inventory is losing around 0.7 m³ per day, out of a volume of around 200 m³. Typically, several mg kg⁻¹ of boron are burnt up in the coolant each day. Using these values, it is possible to estimate the change in primary coolant boron that would result from recycling the sampling effluent with different hold-up times. The increase is shown to be exponential, such that after 5, 10 and 30 days the primary circuit boron would increase by around 0.1, 0.6 and 6 mg kg⁻¹ respectively. The same is true if dissolved oxygen is considered, but the difference here is that the dissolved hydrogen added to the coolant would rapidly remove this. The net effect would be a reduction in the dissolved hydrogen concentration. Assuming 30 days hold-up and effluent saturated with dissolved oxygen, this would reduce the hydrogen concentration from 25 to just under 24 cc kg⁻¹. I am therefore not convinced that these effects are as significant as was suggested in Ref. 19, particularly if the recycling can take place on a more frequent basis.
 - Using the CVS make-up pumps will add the effluent at a high flow rate. However, it is being taken from the primary circuit at only around 30 litres hr⁻¹ and it would seem sensible to try and return it at a similar low rate, ideally on a continuous basis. This would require a similar flow rate to the current zinc injection system in the **AP1000** design (Ref. 43), which suggests this is feasible from an engineering viewpoint. Not using the CVS make-up pumps may also allow the return to feed back into a different location in the CVS, with upstream of the demineralisers and filters potentially offering advantages in clean-up.
 - While complete recycling would be preferable, most of the benefit would be gained by recycling the continuously flowing hot leg sample, as this comprises most of the volume and the majority of the radioactivity. This would also reduce some of the concerns regarding the sample composition not matching the primary coolant.
142. Given this, I am not satisfied that sufficient consideration has been given to recycling the PSS effluent in the **AP1000** design. In particular, I consider that the options examined by Westinghouse are deluxe, and other options have not been demonstrated to be impracticable. Nevertheless, I specifically queried why the EHT option could not be included as an option for the operator, should they decide that reducing radwaste is more important than the Westinghouse assessment has

assumed (RQ-AP1000-1728 (Ref. 26)). In response, Westinghouse noted that, as the WLS has not been subject to detailed design, such a change could be implemented on a site-specific basis with minimal changes to the design. I would therefore consider it to be reasonably practicable to do so, if other more suitable provision cannot be made. I would therefore also expect the licensee to consider other means to achieve recycling of radioactive samples, along the lines described above and to fully document and justify the risks associated with this. **I consider this to be an Assessment Finding:**

CP-AF-AP1000-RC-06 –The licensee shall provide justification for the omission of the capability to recycle the sampling effluent, in order to minimise the production of radioactive waste as low as reasonably practicable.

Use of a GSP for Normal Operations

143. The operator of an **AP1000** plant can collect samples for analysis via two means. The first is to use the GSP located within the main sampling room, while the second involves the sample flow being directed to the radiochemistry laboratory which includes a hooded, ventilated enclosure. The precise equipment within the radiochemistry laboratory is outside the scope of GDA, but Westinghouse expect the GSP to be the main route in normal operations and it is part of the generic design. The GSP is a lead shielded sampling device, which receives cooled, high-pressure liquid samples and then conditions them for sampling. The GSP includes an eductor device to allow sampling when system pressures are insufficient to provide the motive force for the samples. The Step 4 report (Ref. 2) identified that further evidence was required to justify the use of the GSP and this is point 5 of Action 2 of the GDA Issue. In particular, my concern was that it appeared to be based on Post-Accident Sampling Systems (PASS) in current operating plants, many of which have shown poor reliability.
144. Ref. 19 provided additional information on the GSP, including its functions, design and how it is intended to operate. This clarified many aspects of the design, including the features that protect the operator, such as ventilation, leakage detection and mitigation, alarms and interlocks. This includes the response to events such as high temperature, flow, radiation or loss of power. The different sample types available from the GSP were also clarified, which for normal operations include pressurised or depressurised liquid samples and undiluted gaseous samples (both containment and liquid), which should allow the sample schedule defined in Ref. 18 to be met. In response to RQ-AP1000-1728 (Ref. 26), Westinghouse also provided additional clarification on the capabilities of the GSP to sample multiple streams concurrently. Westinghouse noted that the lack of reliability demonstrated by PASS in existing plant is due to them being additional systems, added to the original design at a later date. By using the GSP for normal operations, Westinghouse claimed that the reliability, as well as operator familiarity for post-accident situations, will be much improved.
145. On the basis of the information supplied by Westinghouse in response to GI-AP1000-RC-02, I am satisfied that the adoption of a GSP for normal operations in the **AP1000** design has been justified. While detailed design is not yet complete, I am content that the descriptions given demonstrate protection of the operator. I remain to be convinced that this represents good practice; however, I accept that a suitable level of operator safety can be achieved.

Post-Accident Sampling

146. The PSS also has functions during post-accident sampling conditions in the **AP1000** design. Ref. 19 provided a description of the functions of the PSS in these situations. In a post-accident situation, the containment isolation valves of the PSS are automatically closed on receipt of a containment isolation signal. These can be re-opened as necessary to sample the primary coolant for boron content, to measure the primary activity, to determine the composition of the primary coolant fission products or

to sample the WLS sump for pH. This uses the normal hot leg or WLS sump lines. Sampling of the containment atmosphere is also possible, although a separate dedicated containment hydrogen control system is used to measure hydrogen post-accident. As for normal operations, samples are taken using the GSP, which includes provisions for diluting high-activity samples 'on-line'. The GSP can provide four types of post-accident sample: undiluted degassed liquid, 1000-fold diluted degassed liquid, diluted liquid sample off-gas, and diluted containment atmosphere. High-activity samples are taken using shielded casks and septum and needle assemblies. In the event of an accident, highly contaminated samples can be routed back into the containment sump. The eductor is used to sample when insufficient driving pressure is available at the sample source. This type of arrangement is common to current system designs for post-accident situations.

147. Ref. 19 provided an overview of RGP considered by Westinghouse. This included US NRC requirements (Ref. 27), Westinghouse documentation, IAEA guidance and various requirement documents. Westinghouse concluded that the **AP1000** PSS is capable of fulfilling these functions. Ref. 19 also described the historical background to post-accident sampling in the US, which explains why Westinghouse has chosen the approach of using the GSP for both normal and post-accident situations. Following the Three Mile Island accident, most plant in the US back-fitted a post-accident sampling system. However, over time these suffered reliability issues as they were not used and because the operators were not familiar with them. Westinghouse chose to incorporate a single sampling device into the **AP1000** design with the capability to handle all conditions. I accept the logic in this approach, given that I consider the GSP acceptable for normal operations.
148. As described in paragraph 78, the main gap in Ref. 18 was not to explicitly consider the specifics of the **AP1000** design in terms of the post-accident sampling requirements. Based on the information contained in Ref. 19, I am satisfied that, while the accident sequences may differ, the same fundamental requirements will be necessary and therefore the defined RGP is relevant.
149. In RQ-AP1000-1728 (Ref. 26), I asked Westinghouse for evidence that the GSP design was adequately conceived to cater for the increased radioactivity expected in post-accident samples and considered OpEx. The response provided arguments for how this has been achieved, including zoning calculations and dose assessments. A specific review of OpEx was performed and incorporated into the design. I have not reviewed these references in detail, as I consider the RQ response to be sufficient.
150. I am therefore satisfied that Westinghouse has provided sufficient evidence to demonstrate the adequacy of the post-accident sampling capabilities of the **AP1000** design.

4.2.2.6 Final PSS Design

151. In Ref. 19, design modifications were proposed in a number of discrete areas (namely sample header configuration, on-line boron metering and corrosion product sampling). These individual design modifications have been applied to the existing PSS design, resulting in an integrated PSS design. This differs slightly from the individual changes shown earlier, but provides the same functionality. This is shown in Figure 6.

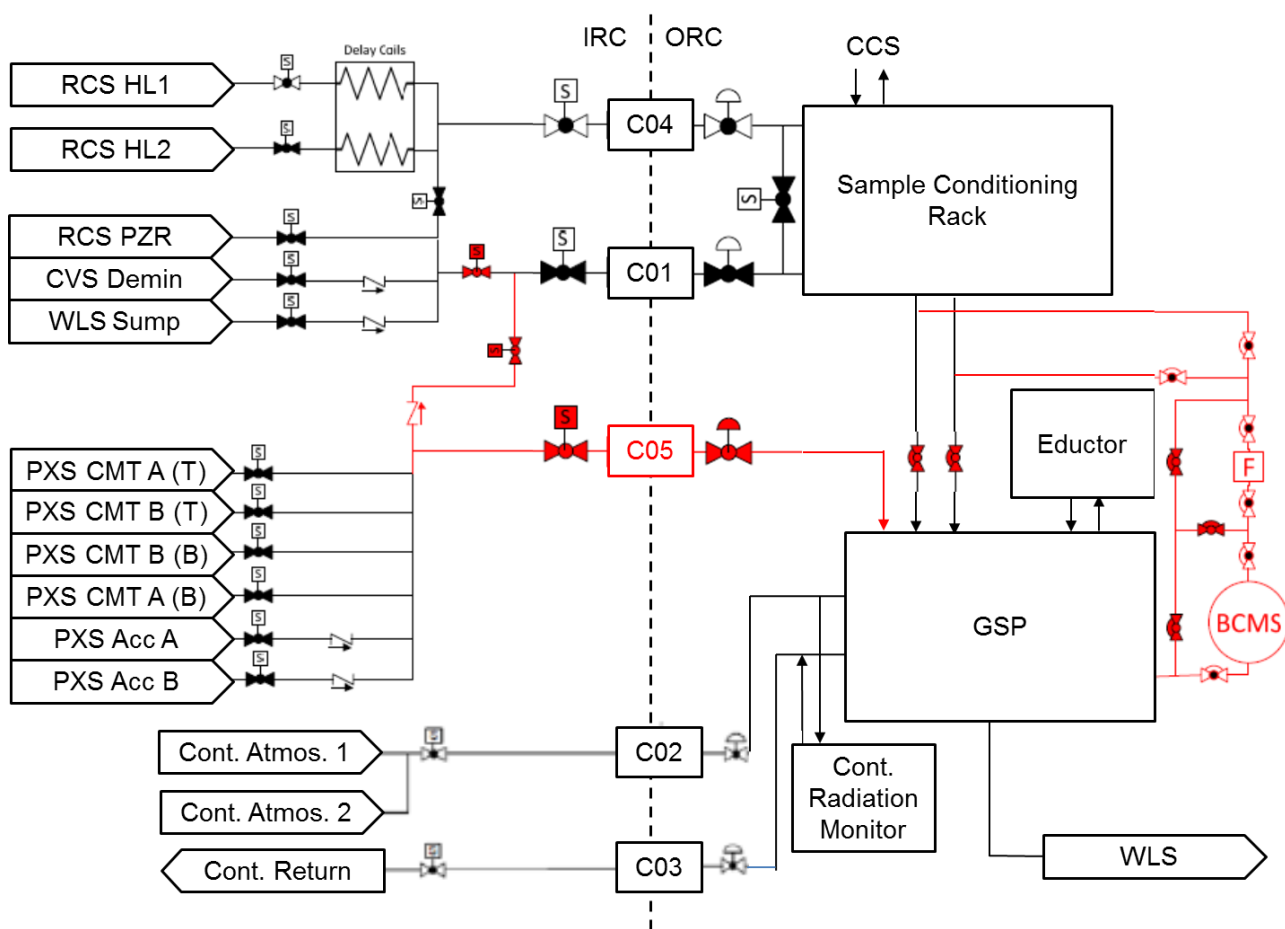


Figure 6: Final design of the UK **AP1000** PSS in response to GI-AP1000-RC-02

152. As noted previously, Ref. 19 also examined a number of other ‘integrated options’, which consist of various combinations of individual modifications considered against each RGP gap. These were mainly rejected on an individual basis, but are reviewed again to determine if collectively the same conclusion remains. Figure 6 is one of these options, and is the only option selected as reasonably practicable to implement. I consider it a strength that Westinghouse has considered the design holistically, and well as in response to individual RGP gaps. Overall, given my assessment of the individual RGP gaps discussed in the previous section of my report, I support the conclusion that the other integrated options considered do not provide additional safety benefits over the design shown in Figure 6.
153. This therefore represents the PSS design to be adopted for any UK **AP1000** plants. In addition to considering the individual aspects of the design, it is important to assess the overall system. I therefore briefly summarise my view against each of the individual aspects covered by GI-AP1000-RC-02 when considered against this complete design:
- **Sampling schedule:** While not specifically aimed at doing so, the modifications have increased the capabilities of the sampling system to meet the requirements of the sampling schedule and have added additional redundancy to cater for breakdown or failures in the system.
 - **Zinc sampling:** Westinghouse has demonstrated that the sampling system should be capable of adequately sampling zinc, and have also identified the best ways to do so within the design.
 - **On-line monitoring:** The modification to add an on-line boron meter is an important safety improvement and, in association with the existing hydrogen and oxygen meters, has demonstrated that an appropriate balance has been struck for using on-line metering.

- Corrosion product sampling capabilities: The modification to include specific CP sampling facilities into the design has provided increased confidence that it should be possible to obtain reliable and representable samples for these.
- Types and locations of samples: The arguments provided by Westinghouse for not including a number of additional sample points within the design remain valid with the proposed final design, with the exception of that for the CVS inlet. On the basis of the evidence presented, it would appear straightforward to incorporate this into the design. This would provide additional capabilities to sample for zinc, CPs and the CVS demineraliser performance.
- Effects of system design: The design modifications have not changed those aspects of the design that could influence sample representativeness (such as flow, turbulence etc) and therefore these remain adequate.
- Implementation of isokinetic sampling: There remains no benefit in implementing isokinetic sampling, provided all reasonable measures are taken to ensure representative CP sampling. Westinghouse has provided evidence that the overall design should be suitable for this, with the exception of the RCS nozzle design. This is resolvable but requires detailed design information not yet available.
- Sample cooling to 25 °C and the cooler location: Collectively, the modifications do not alter the conclusion that all reasonably practicable steps have been taken to cool the samples appropriately.
- Sample header configuration: The modified sample header has reduced the likelihood of obtaining cross-contaminated or unrepresentative samples. This is a reasonable compromise given the design constraints and philosophy.
- Provisions for recycling the sampling effluents back to the primary circuit: No changes to this aspect of the design have been proposed, with all sampling effluent directed to the WLS. The modifications have not increased the volume of sampling waste (and in fact may slightly reduce it due to less flushing necessary) but would tend to make sample recycling easier, given the separation of sample lines on the basis of sample composition. This further strengthens my earlier conclusions, namely that such changes are reasonably practicable.
- Use of a GSP for normal operations: I remain content that the use of a GSP for normal operations has been justified, provided this is considered adequately during detailed design.
- Post-accident sampling: Westinghouse has demonstrated the adequacy of the post-accident sampling capabilities of the design, and the modifications do not affect this.

154. I am therefore satisfied that the final design proposed by Westinghouse in Ref. 19 is adequate to support closure of this GDA Issue. Where I judge that further consideration is necessary, I have raised Assessment Findings.

155. This design is recorded within a specific Design Change Proposal (DCP), APP-GW-GEE-5402 (Ref. 44). This is a draft, but will be subject to the Westinghouse design change approval process and will be included in the final Design Reference Point for GDA. I have reviewed this DCP and am content that it captures the outcome of Ref. 19.

4.2.2.7 Summary

156. In summary, in response to Action 2, Westinghouse has defined relevant good practice in PWR sampling system designs and reviewed the **AP1000** design against this, in addition to the sample schedule defined in response to Action 1. In some areas, Westinghouse has provided justification and evidence to support the adequacy of the existing design. In other areas, design modifications were proposed and assessed using an ALARP process. Based on my assessment of these, I am content that Westinghouse has substantiated the design or has implemented a number of

improvements to the PSS design that resolve the concerns raised during the Step 4 assessment. I have identified three areas where further work is necessary but as these require either more detailed design information or licensee input, I am content for these to be resolved as Assessment Findings. Overall, I am therefore content that sufficient evidence has been provided to meet the intent for Action 2.

4.2.3 PCSR Update

157. As noted in Section 2.2, GI-AP1000-CC-02 (Ref. 10) 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. This would therefore include resolution of all 51 GDA Issues. This assessment does not consider the entirety of chemistry within the PCSR, but does judge whether the proposed changes as a result of resolving GI-AP1000-RC-02 are adequate. The changes were identified by Westinghouse in the associated DCP (Ref. 44) and detailed in an update to the PCSR, Ref. 45.
158. The PCSR (at Revision 0) already contained information on the PSS. The changes made to reflect GI-AP1000-RC-02 were to provide a description of the on-line monitoring capabilities using the boron monitor, a description of the sample header changes and details of the filter to monitor corrosion products. These changes are mainly to reflect the revised design and do not alter the claims, arguments or evidence presented within the safety case. I also confirmed that these changes were applied in the final consolidated PCSR (Ref. 46).
159. Purely in the context of resolving this GDA Issue, I am content that these changes are reasonable.

4.3 Comparison with Standards, Guidance and Relevant Good Practice

160. The standards considered as part of my assessment are defined in Section 2.4, and included in Tables 1 and 2.
161. The foremost standards considered for this assessment were the relevant SAPs (Ref. 6). I have considered these throughout my assessment. However, a summary of these is provided below:
 - SC.2, SC.3, SC.4 and SC.6 relate to the production of an adequate safety case. I am content that Westinghouse has met the intent of these as part of the submissions provided to resolve this GDA Issue.
 - EDR.1 requires due account to be taken of the need for structures, systems and components to be designed to be inherently safe, or to fail in a safe manner, with potential failure modes identified using a formal analysis. I am satisfied that this has been considered to a degree appropriate for a generic design.
 - ECH.1, ECH.2, ECH.3 and ECH.4 relate specifically to the chemistry aspects of safety cases. I am satisfied that Westinghouse has given due consideration to these expectations in resolving this GDA Issue, in particular the expectations of ECH.4 on sampling. The design change proposed has significantly improved the capability of the design to achieve adequate chemistry control, ECH.3. While the final design still does not fully meet RGP, I am content that these departures have either been justified not to be relevant to the design or demonstrated to be disproportionate to implement when the overall plant design is considered. Some of the remaining gaps require detailed design information and operator choices, and hence have been raised as Assessment Findings. I am content that these can be satisfactorily addressed in the future.

- ECV.1 and ECV.2, aspects relating to the prevention and minimisation of leaks, have been considered as part of the PSS design, in particular in relation to the GSP design.
- AM.1 relates to planning for accident measures. The post-accident sampling capabilities of the PSS are an important part of this and Westinghouse has demonstrated the suitability of the design in this regard.
- RW.2 relates to minimisation of waste, both at source and in quantity and activity. While Westinghouse has considered this in their response, I am not satisfied that all reasonably practicable measures have been taken to reduce waste caused by sampling. Insufficient evidence has been provided to demonstrate that it is not reasonably practicable to eliminate this waste at source, via recycling of the sampling effluent within the plant. I am content that as much as possible has been provided for GDA, but further work will be necessary of a future licensee when detailed design information is available. I would expect this to be resolvable by addition of the capability to recycle within the design.

4.4 Assessment Findings

162. In line with the ONR guidance (Ref. 47), during my assessment five items were identified for a future licensee to take forward in its site-specific safety submissions. Annex 2 contains details of these.
163. These matters 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. I have raised these items as Assessment Findings.

4.5 Minor Shortfalls

164. In line with the ONR guidance (Ref. 47), I have not identified any Minor Shortfalls.

4.6 ONR Assessment Rating

165. Not applicable.

5 CONCLUSIONS

166. This report presents the findings of the assessment of GDA Issue GI-AP1000-RC-02 relating to the primary sampling systems for the **AP1000** reactor.
167. The purpose of this report is to document the assessment of the submissions provided by Westinghouse, in order to come to a judgement regarding whether sufficient evidence has been provided to meet the intent of the GDA Issue, such that closure can be recommended.
168. In response to GI-AP1000-RC-02, Westinghouse provided three main submissions. The response to Action 1 was an example sampling schedule for the **AP1000** design, which identified the location, frequency and analysis requirements for all modes of plant operation. For Action 2, the first deliverable was a review of relevant good practice in PWR primary sampling system designs. These two reports were used as inputs to the main submission (Ref. 19), which reviewed the **AP1000** design against these. In some areas, Westinghouse provided justification and evidence to support the adequacy of the existing design. In other areas, design modifications were proposed and assessed using an ALARP process. These submissions were supported by a suite of documentation, which contained further detailed evidence. In addition, Westinghouse provided responses to my Regulatory Queries, providing additional clarification and evidence to support the main submissions.
169. Consequently, a design change has been implemented for the UK **AP1000** plants (Ref. 44). I welcome this change as an important safety improvement. Most of the concerns with the original design have been resolved by this modification. However, a number of areas remain where I am not convinced that a satisfactory position has yet been reached, although I judge that it could be in the future. These remaining areas all require further detailed design information or operator choices to resolve, and therefore cannot be resolved as part of GDA, and I have raised these as Assessment Findings.
170. As a result of my assessment of these submissions, meetings and discussions with Westinghouse, and consultations with ONR colleagues in different technical areas, my conclusions are:
- The design of the primary sampling systems has been subjected to a detailed review, which included consideration of relevant good practices and ALARP considerations. This resulted in modifications in three distinct areas to improve the design in terms of reliability, capability and representativeness and therefore its overall ability to meet the requirements of the safety case.
 - Sufficient evidence has been provided to demonstrate that the system design is adequate to meet the sampling requirements of the plant during all modes of operation.
 - The use of a GSP for normal operations, in addition to the safety functions it provides during post-accident situations, has been justified.
 - The ability of the design to provide reliable and representative samples for a number of important but often difficult to sample parameters has been considered. Sampling for zinc and hydrogen has been demonstrated within the capability of the design, while a specific modification to improve the sampling of corrosion products has been included.
 - Westinghouse has proposed a design modification to provide the capability of monitoring boron via an on-line meter. This is an important safety improvement and meets UK regulatory expectations. The licensee will need to consider how best to achieve this and implement this within the safety case and design in the detailed design phase.
 - While evidence has been provided to demonstrate that the waste generated by sampling is within the capabilities of the design, I am not convinced that sufficient consideration has been given to minimisation of this waste stream in

accordance with the expectations of the SAPs. I consider that, as a minimum, it is reasonably practicable to implement further modifications to provide the operator with this option. As this requires more detailed design information and operator choices, I have raised this as an Assessment Finding.

- In response to this GDA Issue, Westinghouse has proposed updates to the PCSR. I have reviewed these updates and am content that they accurately reflect the responses to the GDA Issue.
171. As a consequence of my assessment, I have identified five Assessment Findings for a future licensee to consider and take forward in its site-specific safety submissions. These relate to aspects of the design where I judge further consideration is required. In particular, these relate to:
- how best to implement boron metering into the design and safety case;
 - inclusion of a CVS demineraliser inlet sample point;
 - evidence that the local sampling equipment maintains operator safety;
 - demonstration that the sample nozzles are suitable for representative sampling;
 - omission of provisions for recycling of the sampling effluent to minimise radioactive waste.
172. These matters do not undermine the generic safety submission, and require licensee input and/or decisions to resolve. I am content that Westinghouse has demonstrated that these could be satisfactorily resolved.
173. Overall, on the basis of my assessment, I am satisfied that GDA Issue GI-AP1000-RC-02 can be closed.

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Table 1: Relevant Safety Assessment Principles considered during the assessment

SAP No	SAP Title	Description
SC.2	Safety case process outputs	The safety case process should produce safety cases that facilitate safe operation.
SC.3	Lifecycle aspects	For each lifecycle stage, control of the hazard should be demonstrated by a valid safety case that takes into account the implications from previous stages and for future stages.
SC.4	Safety case characteristics	A safety case should be accurate, objective and demonstrably complete for its intended purpose.
SC.6	Safety case content and implementation	The safety case for a facility or site should identify the important aspects of operation and management required for maintaining safety and how these will be implemented.
EDR.1	Failure to safety	Due account should be taken of the need for structures, systems and components to be designed to be inherently safe, or to fail in a safe manner, and potential failure modes should be identified, using a formal analysis where appropriate.
ECH.1	Safety cases	Safety cases should, by applying a systematic process, address all chemistry effects important to safety.
ECH.2	Resolution of conflicting chemical effects	Where the effects of different chemistry parameters conflict with one another, the safety case should demonstrate that an appropriate balance for safety has been achieved.
ECH.3	Control of chemistry	Suitable and sufficient systems, processes and procedures should be provided to maintain chemistry parameters within the limits and conditions identified in the safety case.
ECH.4	Monitoring, sampling and analysis	Suitable and sufficient systems, processes and procedures should be provided for monitoring, sampling and analysis so that all chemistry parameters important to safety are properly controlled.
ECV.1	Prevention of leakage	Radioactive material should be contained and the generation of radioactive waste through the spread of contamination by leakage should be prevented.
ECV.2	Minimisation of releases	Containment and associated systems should be designed to minimise radioactive releases to the environment in normal operation, fault and accident conditions.
AM.1	Planning and preparedness	Strategies and plans should be in place to prepare for and manage accidents at the facility and/or site.
RW.2	Generation of radioactive waste	The generation of radioactive waste should be prevented or, where this is not reasonably practicable, minimised in terms of quantity and activity.

Table 2: Relevant Technical Assessment Guides considered during the assessment

Reference	Revision	Title
NS-TAST-GD-004	5	Fundamental Principles
NS-TAST-GD-005	7	Guidance on the Demonstration of ALARP (As Low As Reasonably Practicable)
NS-TAST-GD-020	3	Containment for Reactor Plant
NS-TAST-GD-024	5	Management of Radioactive Materials and Radioactive Waste on Nuclear Licensed Sites
NS-TAST-GD-035	4	The Limits and Conditions for Nuclear Plant Safety
NS-TAST-GD-051	4	The Purpose, Scope and Content of Nuclear Safety Cases
NS-TAST-GD-088	0	Chemistry of Operating Civil Nuclear Reactors

Annex 1: GDA Issue, GI-AP1000-RC-02 Revision 0 – Reactor Chemistry – AP1000®

WESTINGHOUSE AP1000® GENERIC DESIGN ASSESSMENT
GDA ISSUE
PRIMARY SAMPLING SYSTEMS
GI-AP1000-RC-02 REVISION 0

Technical Area		REACTOR CHEMISTRY	
Related Technical Areas		Mechanical Engineering Radiation Protection	
GDA Issue Reference	GI-AP1000-RC-02	GDA Issue Action Reference	GI-AP1000-RC-02.A1
GDA Issue	Demonstrate that the sampling arrangements for the primary circuit and connected auxiliary systems of AP1000 are adequate to support safe operation of the plant.		
GDA Issue Action	<p>Westinghouse to provide a detailed schedule of sampling required to support operation of AP1000.</p> <p>This schedule should include consideration of all modes of operation and should consider:</p> <ul style="list-style-type: none"> • Parameters to be measured from which location and the frequency of sampling. • The schedule should be clearly linked back to the safety case. • Where the sample is expected to be collected (i.e. using the Grab Sample Panel (GSP), radiochemical laboratory or local provisions). • Primary circuit and auxiliaries, including but not limited to the Spent Fuel Pool and Waste Liquid System (WLS). <p>The details should be specific to AP1000 and any differences in plant design; reference to industry guidelines is not a sufficient response in itself.</p> <p>With agreement from the Regulator this action may be completed by alternative means.</p>		

Annex 1: GDA Issue, GI-AP1000-RC-02 Revision 0 – Reactor Chemistry – AP1000® (continued)

WESTINGHOUSE AP1000® GENERIC DESIGN ASSESSMENT
GDA ISSUE
PRIMARY SAMPLING SYSTEMS
GI-AP1000-RC-02 REVISION 0

Technical Area		REACTOR CHEMISTRY	
Related Technical Areas		Mechanical Engineering Radiation Protection	
GDA Issue Reference	GI-AP1000-RC-02	GDA Issue Action Reference	GI-AP1000-RC-02.A2
GDA Issue Action	<p>Westinghouse to provide a justification and evidence that the primary sampling systems (PSS) in AP1000 will support the sampling schedule delivered under A1.</p> <p>The response by Westinghouse should consider:</p> <ul style="list-style-type: none"> • Specific features of the AP1000 design, such as the location of cooling provisions and the maintenance of high pressure lines. • The effect of recent design changes on system performance should be considered, for example the reduction in line diameter. • Specific consideration should be given to representative sampling of zinc, corrosion products and hydrogen. • A justification should be given to which sample lines are or are not included in the PSS, specifically why backup cooling systems are not sampled through the PSS and why the design of AP1000 does not include an inlet sample from the Chemical Volume control System (CVS). • Justification and evidence should be given on the use of a GSP, as opposed to a ventilated enclosure (as expected in the SAPs ECV 1 - ECV1 – 10 and associated paragraphs), and sampling provisions outside of the GSP (i.e. as currently for some systems and not others). • Justification should be provided for not including a boron meter as a means of continuously monitoring the coolant boron concentration now that a design change to flowing samples has been included. • The impact of the design change on the served and dependant systems should be clearly reviewed and documented (for example, the impact of increased PSS flow on the WLS input or CVS make-up requirements). • Evidence should be provided to demonstrate that waste generation of the system is within the safety case and that the design has sufficient redundancy to accommodate operational transients. <p>With agreement from the Regulator this action may be completed by alternative means.</p>		

Annex 2: Assessment Findings to be addressed during the Forward Programme – Reactor Chemistry

Assessment Finding Number	Assessment Finding	Report Section Reference
CP-AF-AP1000-RC-02	The licensee shall provide justification for how the boron meter is to be implemented within the detailed plant design and safety case, given the design change to incorporate the capability.	Paragraph 101
CP-AF-AP1000-RC-03	The licensee shall justify the omission of a CVS demineraliser inlet sample within the PSS, given the design modifications made for UK plants.	Paragraph 109
CP-AF-AP1000-RC-04	The licensee shall provide evidence that the local grab sampling equipment provides suitable and sufficient sampling capabilities, provides protection to the operators, and gives appropriate consideration to minimisation of radioactive waste, for in all modes of operation.	Paragraph 113
CP-AF-AP1000-RC-05	The licensee shall provide justification that appropriate consideration has been given to the sampling nozzle design for the hot leg samples at the detailed design stage, to ensure all reasonably practicable steps are taken to enable representative corrosion product sampling.	Paragraph 123
CP-AF-AP1000-RC-06	The licensee shall provide justification for the omission of the capability to recycle the sampling effluent, in order to minimise the production of radioactive waste as low as reasonably practicable.	Paragraph 142