Westinghouse UK
AP1000® GENERIC DESIGN ASSESSMENT
Resolution Plan for GI-AP1000-RC-03
Hydrogen Dosing System

MAIN ASSESSMENT AREA	RELATED ASSESSMENT AREA	RESOLUTION PLAN REVISION	GDA ISSUE REVISION
Reactor Chemistry	Mechanical Engineering	1	0

GDA ISSUE:	Demonstrate that the hydrogen dosing system in **AP1000®** plant has the capacity and capability to provide suitable control over the primary coolant hydrogen concentration during all operating modes and potential faults.
ACTION: GI-AP1000-RC-03.A1	Westinghouse to present a consistent and structured safety case containing suitable and sufficient evidence to support the **AP1000** hydrogen addition system, or other means agreed with the regulator. This evidence should provide confidence that the system will meet the functional requirements of the plant under all modes of operation and anticipated transient conditions. Westinghouse should consider physical testing of the design if sufficient evidence cannot be provided by calculations. The case should include an analysis of the likely faults with the hydrogen addition system. This should include consideration of both under and over dosing of hydrogen. The arrangements, either engineered or administrative, to control these faults should be clearly highlighted. The faults should consider all modes of operation where the hydrogen addition system is required to function. With agreement from the Regulator this action may be completed by alternative means.
RELEVANT REFERENCE DOCUMENTATION RELATED TO GDA ISSUE	
Technical Queries	TQ-**AP1000**-456 - Substantiation of CVS Operating Performance TQ-**AP1000**-711 - Hydrogen Injection TQ-**AP1000**-805 - Control of Primary Circuit Gases During Shutdown TQ-**AP1000**-806 - Control of Primary Circuit Gases During Start-up TQ-**AP1000**-1184 - Control of Hydrogen Dosing

	TQ-**AP1000**-1230 - Hydrogen Addition
Regulatory Observations	RO-**AP1000**-55.A3 - Westinghouse should provide evidence in relation to the chemical behaviour of the Chemical Volume and Control System in the **AP1000** plant
Other Documentation	Step 4 – Reactor Chemistry Assessment of the Westinghouse **AP1000** - AR 11/008 SAPs – SC4, EQU1, EHA7, EMC24, ESS11

Scope of work:

As part of the **AP1000** Chemical and Volume Control System (CVS) the hydrogen addition system was improved by adding a dedicated hydrogen line during GDA Step 4. Westinghouse will provide sufficient evidence to support the **AP1000** hydrogen addition system design. The evidence will take the form of two separate documents and encompass all modes of plant operation and anticipated transient conditions. The evidence provided in these two documents along with existing evidentiary documents will be references to a summary document that provides a coherent safety case for the hydrogen dosing system.

Description of work:

UKP-GW-GL-XXX, Revision 0, "**AP1000** Hydrogen Injection System – Safety Demonstration"

Westinghouse will generate a report, UKP-GW-GL-XXX, that will summarise the arguments and evidence justifying the design of the **AP1000** hydrogen injection system. The system evaluated will be the hydrogen injection system presented during GDA as defined in the design reference point which includes a dedicated hydrogen injection line. This document will provide the arguments and evidence to justify the **AP1000** hydrogen dosing system and will be linked to the PCSR to provide a complete safety case.

The proposed structure of the report is as follows:

1. Introduction
2. Safety Functions of the **AP1000** hydrogen injection system.
   This section will summarise the functions of the **AP1000** hydrogen injection system and their safety basis. A description of the safety importance of hydrogen injection will be provided.
3. Safety Design Criteria of the **AP1000** hydrogen injection system.
   The choice of concentration target, operating band and other design criteria (such as APP-CVS-M3C-015, for the hydrogen injection flow rates) derived from the safety functions will be described.
4. Description of the **AP1000** hydrogen injection system.
   A description of the mechanical design of the **AP1000** hydrogen injection system to support the discussions in the following sections.
5. Demonstration that the **AP1000** hydrogen injection system design criteria are met.

This section will demonstrate (based on supporting evidence, such as APP-CVS-M3C-060, etc.) that the design criteria of the **AP1000** hydrogen injection system are met under all operating conditions and transients.

6. Abnormal events.
   This section will provide a discussion of the chemical consequences of an abnormal event (failure, operator error) in the **AP1000** hydrogen injection system. The time to reach an operational limit will be determined and it will be shown that the CVS allows for recovery from abnormal events.
7. Conclusions.

Appendix A: Failure Mode and Effect Analysis.

Appendix B: Review of Operating Experience for High Pressure Hydrogen Injection Systems.

The following list of documents will be used to support the discussions in UKP-GW-GL-XXX. These documents will also represent the hydrogen injection system as defined in the design reference point.

- APP-CVS-M3-001 (Chemical and Volume Control System (CVS) System Specification Document)
- APP-CVS-M6-001-005 (Piping and Instrumentation Diagram Chemical and Volume System)
- APP-CVS-M3C-067 (Functional Requirements for CVS Hydrogen Injection Package)
- APP-GW-GEM-200 (**AP1000** Chemistry Manual)
- APP-GW-GER-002 (Summary of **AP1000** Chemistry Characterisations)
- APP-CVS-M3C-060 (Chemical and Volume Control System (CVS) Direct Hydrogen Gas Injection Dissolution Evaluation)
- APP-CVS-M3C-015 (Estimated Hydrogen Consumption in the **AP1000** RCS and Range of CVS Hydrogen Injection Rates)

Additionally, Westinghouse will perform validating calculations to provide justification of the **AP1000** hydrogen injection system under anticipated operating conditions and transients. This will include the expected plant response to the various hydrogen addition evolutions.

APP-CVS-M3C-015, Revision 2: "Estimated Hydrogen Consumption in the **AP1000** RCS and Range of CVS Hydrogen Injection Rates"

This calculation determines the hydrogen addition mass flow rates required to achieve and maintain Reactor Coolant System (RCS) hydrogen concentration within the operating range. An analysis is performed to determine the most limiting case for the required flow of hydrogen to ensure there will be sufficient control of the hydrogen in the system for all modes of plant operation. The values from this calculation will be used to determine design parameters for the hydrogen injection package which will regulate the flow of hydrogen from the Plant Gas System (PGS). This calculation also determines the total volume of hydrogen required for an 18 month fuel cycle.

Anticipated conclusions and results:

- Nominal (continuous) hydrogen injection flow rate
- Maximum hydrogen flow rate
- Total volume of hydrogen needed to maintain RCS levels within the operating range
- Total Hydrogen consumption for an 18 month fuel cycle.

APP-CVS-M3C-060 Revision 0: "Chemical and Volume Control System (CVS) Direct Hydrogen Gas Injection Dissolution Evaluation"

This calculation uses input from several groups within Westinghouse including the Westinghouse Fuels, Chemistry and Nuclear Systems groups to identify operating conditions and limitations for the addition of hydrogen for the **AP1000 plant**. It will investigate the use of direct injection of hydrogen and examine the characteristics for hydrogen gas flow from the hydrogen injection point to the RCS. The evaluation of hydrogen dissolution will determine if the desired maximum hydrogen flow rates as specified in the APP-CVS-M3C-015 calculation are reasonable. It will then determine if there is sufficient evidence for hydrogen dissolution and solubility to validate the current design for operation of the hydrogen injection package.

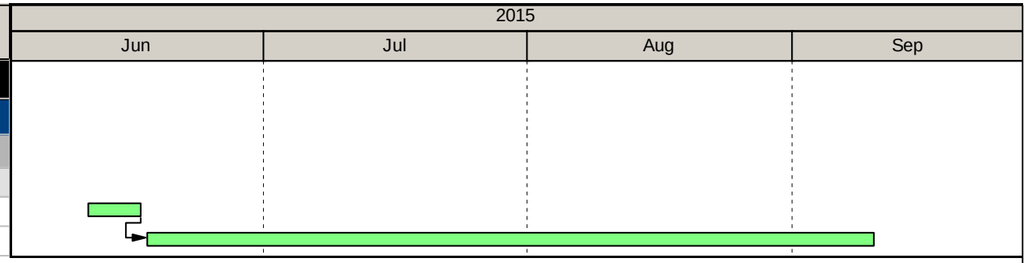
Anticipated conclusions and results:

- Demonstration that the **AP1000** hydrogen injection system design criteria are met.
- Maximum hydrogen solubility of the RCS and feasibility of hydrogen dissolution.
- Limits or precautions for hydrogen injection.

Schedule/ programme milestones:

Please see the following page for the schedule.

#	Activity Name
1	**UK Generic Design Assessment (GDA) Resolution Plans (51)**
2	**REACTOR CHEMISTRY**
3	**RC-03 Hydrogen Dosing System-Resolution Plan**
4	**RC-03 UKP-GW-GL-100, Rev 0, AP1000® Hydrogen Injection System Safety Demonstration**
5	UKP-GW-GL-100 Rev.0, AP1000® Hydrogen Inject Sys Safety Demo-Submit to ONR
6	UKP-GW-GL-100 Rev.0, AP1000® Hydrogen Inject Sys Safety Demo-ONR Review of Submittal



Methodology:

The methodology used to address GI-**AP1000**-RC-03 is to provide a clear demonstration of the **AP1000** hydrogen injection system adequacy to perform its safety functions for all anticipated operating conditions and transients. This will be done by clearly identifying the safety functions and the design criteria and by demonstrating the performance of the hydrogen injection system against those criteria. That demonstration will be supported by evidence combining design evaluations and review of operating experience.

A discussion of the abnormal events related to the **AP1000** hydrogen injection system and their chemical consequences will also be provided. It will be shown that the CVS allows for recovery from abnormal events.

The evidentiary documents will be linked to UKP-GW-GL-XXX, Revision 0, "**AP1000** Hydrogen Injection System – Safety Demonstration", which will be summarised and referenced in the PCSR, Chapter 21. This will provide a complete safety case for the **AP1000** hydrogen dosing system.

Justification of adequacy:

UKP-GW-GL-XXX, "**AP1000** Hydrogen Injection System – Safety Demonstration", will provide a coherent and complete safety justification for the **AP1000** hydrogen injection system. It will summarise the arguments to support the claim that the **AP1000** hydrogen injection system is adequate to fulfil its safety function. The ONR concerns presented in this GDA issue will be addressed and the evidence will be provided by two new validating design evaluations, a failure modes and effects analysis and review of operational experience in addition to existing evidentiary documentation. The discussion will address all anticipated operating conditions and transients, as well as abnormal events (mechanical failure, operator error).

Impact assessment:

The following documents are anticipated to be effected:

- PCSR – Chapter 21
- Design Reference Point
- Master Submission List
- New document UKP-GW-GL-XXX, "**AP1000** Hydrogen Injection System – Safety Demonstration"