Westinghouse UK
AP1000® GENERIC DESIGN ASSESSMENT
Resolution Plan for GI-AP1000-FS-05
Potential Enhancements to the Diverse Safety Injection System

MAIN ASSESSMENT AREA	RELATED ASSESSMENT AREA(S)	RESOLUTION PLAN REVISON	GDA ISSUE REVISION
Fault Studies	Mechanical Engineering C&I PSA Human Factors	2	1

GDA ISSUE:	Westinghouse is to examine whether it is reasonably practicable to enhance the design of the RNS system in its role as the diverse safety injection system on the **AP1000®** plant.
ACTION: GI-AP1000-FS-05.A1	Westinghouse is to examine whether it is reasonably practical to enhance the design of the RNS system in its role as providing a diverse means of safety injection on the **AP1000** plant. Westinghouse will have to perform an ALARP review identifying potential options for enhancing the design of the RNS system. The options considered include automating its actuation using an appropriately classified (C&I) system that is diverse from the PMS, segregating the water supply of the system from the IRWST, and increasing the pressure head of the RNS system. It is accepted that the RNS system is not the principal means of fulfilling the nuclear safety function and so an A2 classification for the system should suffice for this function. In considering the options, Westinghouse will have to identify the potential safety benefits of the different options using both design basis transient analysis and probabilistic analysis techniques. If any design modifications are proposed for the **AP1000** plant, they will have to complete the six-stage modification process for inclusion within the consolidated PCSR. With agreement from the Regulator this action may be completed by alternative means.
RELEVANT REFERENCE DOCUMENTATION RELATED TO GDA ISSUE	
Technical Queries	TQ-**AP1000**-1101
Regulatory Observations	
Other Documentation	

Scope of work:

Small break loss of coolant accidents are amongst the most frequent faults in the decrease of RCS inventory. On the **AP1000** plant, primary protection for such faults is provided by the protection and monitoring system (PMS) tripping the reactor and initiating safety injection from the core make-up tanks (CMTs) and decay heat removal by the passive residual heat removal heat exchanger (PRHR HX). As the water level in the CMTs falls, the PMS initiates automatic depressurisation using the automatic depressurisation system (ADS). The sequence of events eventually results in gravity fed safety injection from the in-containment refuelling water storage tank (IRWST) entering the core to establish medium-term post-trip cooling once the reactor has sufficiently depressurised.

In its assessment of 'frequent faults' provided in UKP-GW-GL-067 and in the overall fault schedule included in Appendix 8A of revision 0 of the PCSR, Westinghouse has identified that the RNS system provides a diverse means of safety injection for the more frequent small break LOCA events. As noted by the ONR in the issue definition, depending on the break size, while the RNS can perform this role without the need for the ADS stage-4 valves to open, there may be still a need for the ADS stage-1, 2 & 3 valves to open in order for the RNS to inject. Should automatic actuation from the PMS be assumed loss due to common mode failure, consistent with the assessment approach for frequent faults, then the ADS stage 1, 2, 3 valves would need to be opened using manual DAS controls.

For small breaks around 4" (10cm), the operator has slightly over 30 minutes in which to actuate ADS 1,2,3 and to align / actuate the RNS. Note that if the operator is able to deduce that the LOCA is not a large break of one of the DVI lines (which would be clearly indicated by a much faster draining of the associated CMT) the RNS would be aligned to the take suction from the IRWST, otherwise the cast loading pit would be used as the suction source.

Westinghouse is therefore asked to examine whether it is reasonably practicable to enhance the design of the RNS system in its role as the diverse safety injection system on the **AP1000** plant.

Description of work:

Westinghouse will perform an ALARP review to evaluate potential options for enhancing the design of the RNS system, to either confirm the design as ALARP as is, or identifying ALARP options and implement necessary design change proposals, as applicable.

In general, ONR and Westinghouse have confirmed agreement and understanding that the RNS is appropriately designed as a class 2 system for the **AP1000** plant, given that the primary safety function is provided for the **AP1000** plant by the passive systems. However, based on the consideration provided in the issue statement, Westinghouse has agreed to evaluate possible enhancements and optimisation of the design as part of an ALARP assessment.

To perform this ALARP assessment, Westinghouse will initially review LOCA frequencies to appropriately define 'frequent' (i.e. initiating event frequency higher than 1E-3/yr) small

break LOCA. 'Cliff Edge' small break LOCAs (i.e. initiating event frequency higher than 1E-4/yr) will also be defined. This information will be used to define an appropriate spectrum of sensitivity studies to allow an engineering assessment of the system. Thus, available Small Break LOCA analyses will be reviewed and if necessary additional cases will be analysed with the RELAP code, using an approach consistent with the other studies performed by Westinghouse for the diverse case of other faults (e.g. ATWS). These two steps and especially the sensitivity studies will allow a complete characterisation of the current design, especially in terms of time available for operator action under different scenarios. Overall Risk reduction considerations will also be included in the assessment as part of the evaluation of benefits, not necessary limited to frequent faults.

Once this analytical basis is established, Westinghouse will proceed to consider several alternative design options to address specific potential enhancements to the standard design. These options will then be evaluated against the standard design to assess their benefits (and dis-benefits), issues and practicality.

As requested by ONR in the issue definition following discussions with Westinghosue during the GDA review, the options considered will include automating RNS actuation, segregating the water supply of the system from the IRWST and increasing the pressure head of the system.

The ALARP assessment will be conducted in the following manner:

1) Small Break LOCA Mitigation characterisation for diverse safety case

   - Definition of small break LOCA in term of probabilities and definition of 'frequent' small break LOCAs

   - Analysis of **AP1000** small break LOCA response for the diverse case, covering breaks of different size and addressing the defined and justified 'frequent fault' spectrum, including characterisation of operator action time requirements.

2) Explore possible design enhancement options including, but not limited to those listed the work description.
   - The main objective of this step is to ensure that the options to be considered in the ALARP assessment are a sufficient and comprehensive list of design options, and provide adequate justification

3) ALARP assessment. Based on the results of the assessment of 'frequent' breaks, provide an ALARP assessment of the existing design against potential alternative options, including the following:
   - <u>Increase of **AP1000** RNS Pressure Injection assessment</u>

     - Analyse of the required RNS pressure pumps increase

     - Qualitative impact analysis of **AP1000** components design

change

- Qualitative impact analysis of RNS system operation
- Safety benefits discussion

➢ Segregating water supply of the system from the IRWST

- Qualitative design assessment
- Safety benefits discussion

➢ Automatic RNS actuation (I&C) assessment

- RNS reliability analysis:
  1) With operator action only
  2) With automatic actuation
- Initial RNS operating modes prior to a SBLOCA
- RNS water supply versus break location discussion
- Discussion of RNS & RCS components alignment following DVI line and no DVI line breaks
- I&C design change requirements for automatic RNS actuation following DVI and no DVI line breaks
- Safety benefits discussion

➢ Provide Assessment of any additional options determined in item 2.

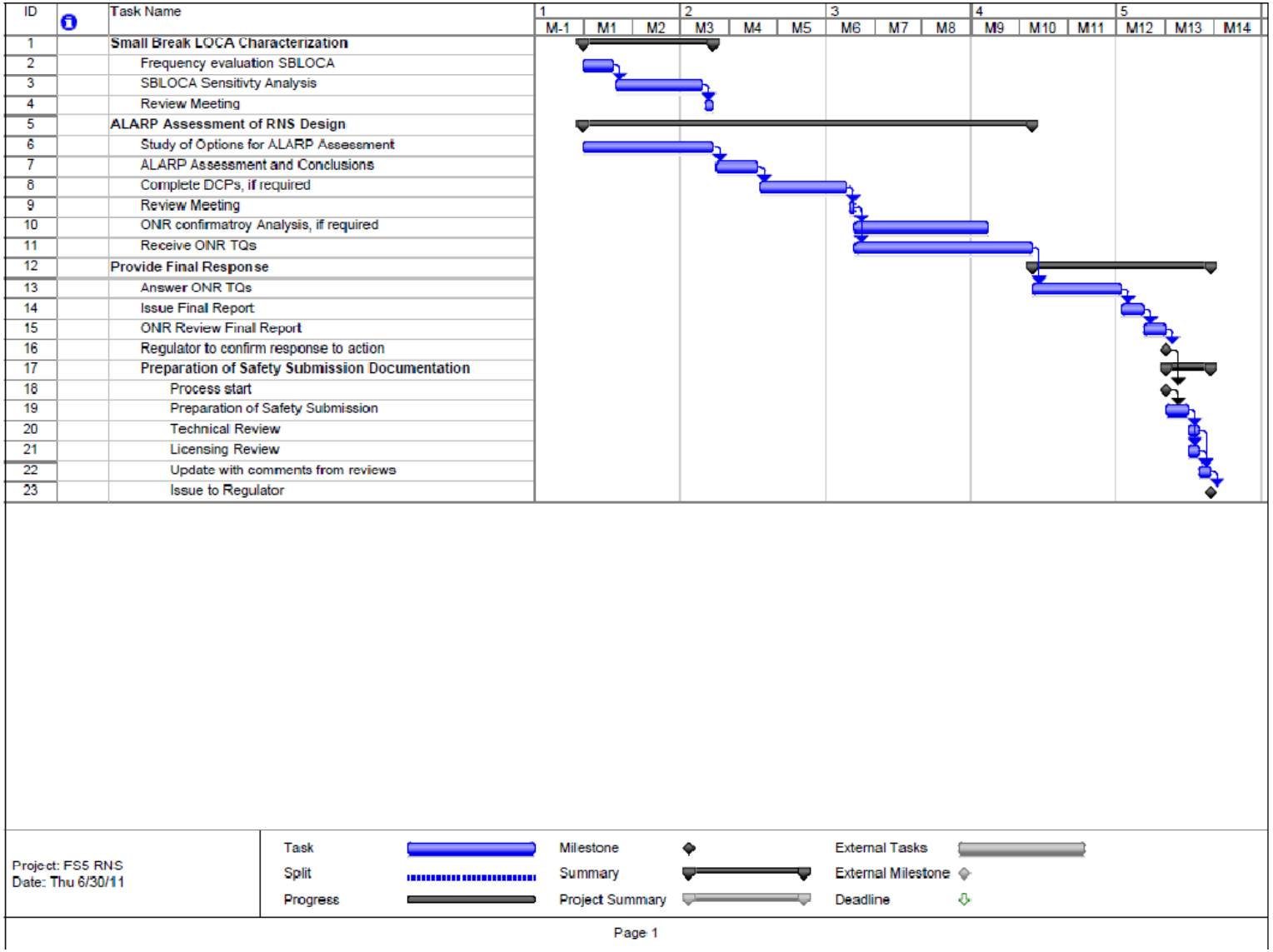
4) If ONR determines that confirmatory analysis is required, provide appropriate input and discussion

5) ALARP conclusions. Based on the options development and assessment, the ALARP study will be completed and, if appropriate, any relevant design change defined via the Westinghouse Design Change Control Process and reviewed with ONR to confirm alignment on the overall conclusions.

6) Any design change deemed appropriate due during the course of this assessment, if any, will be progressed through the Change Control Process for the **AP1000** design, as defined by NSNP 3.4.1.

Schedule/ programme milestones:

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



Methodology:

As discussed in the outline provided above, the following key steps and associated methodology will be adopted in this overall ALARP Assessment:

Small Break LCOA sensitivity studies and plant response characterisation

Small Break LOCA sensitivity studies required for this assessment will be performed with the thermal hydraulic code RELAP5 Mod 3.3. While not the validated methodology for DB SBLOCA analyses, this code provides the necessary flexibility to perform this assessment. This assessment will be conducted with an approach consistent with that adopted in the evaluation of the diverse case for other faults (e.g. ATWS), and will be conducted with realistic input assumptions consistent with the analysis of ATWS transient (i.e. without necessarily the same conservatism used for design basis analyses for the principal safety case). In summary:

- For the Safety Case, SBLOCA with Class 1 Systems, NOTRUMP analyses are performed under design basis assumptions, using approved methodologies as described in the PCSR.
- For the Diverse Case, SBLOCA with postulated common mode failure of the principal means of protection, RELAP studies are performed with realistic assumptions, as adequately justified.

ALARP Assessment and considered design options

- Based on the assessment results for diverse mean of protection for SBLOCA, ALARP assessment will be conducted to compare the existing design against a range of alternative options to conclude if any alternative option represents an ALARP alternative to the current design. The following discussion provides a brief outline of the approach that will be used to evaluate each option
- For the first alternative, increase of **AP1000** pressure injection, the system design will be evaluated. For this evaluation the Small break LOCA response characterised in the sensitivity studies will be reviewed to identify the potential benefit associated with different increases to the RNS pumps head. A range of options to ensure a complete ALARP assessment will be considered, ranging from limited pressure head increases to more significant changes. Benefits and practicality for a number of options will be considered. In general, three different options would be considered: first, limited changes and their potential impact on the transient response and time to operator action will be assessed. Then, more significant increases will be evaluated to identify what changes would be required to eliminate the need for ADS actuation. The impact of this pressure increase on 1) **AP1000** components (RNS pumps, RNS heat exchangers, RNS piping, diesels), 2) normal RNS operation will be discussed and considered in the ALARP study. An evaluation of the safety advantages and disadvantages associate with potential changes will conclude the assessment.
- Assessment of RNS water supply. Westinghouse will review the overall RNS alignment and water supply approach, considering both the different operating modes and required operator actions, to either confirm the current approach, or identify improvements that could be implemented. This assessment will be conducted as an optimisation study of the available water supplies, to confirm that the design approach makes use of the best available option, considering human

factors. An evaluation of the safety advantages and disadvantages associate with potential changes will conclude the assessment.

- Automatic RNS actuation (I&C) assessment will include RNS reliability analysis with operator action only and with automatic actuation, considering the break spectrum defined in previous activities. The goal of this analysis would be to quantitatively evaluate the maximum improvement that a very reliable automatic control feature would achieve. Detailed discussions about 1) initial RNS alignment prior to a postulated break, 2) RNS water supply versus break location will be provided. This assessment will define I&C change requirements in order to automatically actuate RNS, and thus evaluate their practicality and the safety advantages and disadvantages associate with potential changes.
- Design changes deemed appropriate, if any, during this assessment will be progressed through the Change Control Process for the **AP1000** design, NSNP 3.4.1 to the point of Configuration Control Board challenge and approval, but not implementation.

Justification of adequacy:

1. ONR's concern about the time for operator action during a range of SBLOCAs will be assessed using thermal hydraulic code RELAP.
2. SBLOCA evaluations will provide a time at which ADS/RNS manual actuation should be taken such that the PCT remains under 1200C
3. Level of detail for ALARP assessment will be based on the previous results.

Impact assessment:

- PCSR, chapter 9.
- UKP-GW-GL-067, if required
- UKP-GW-GL-077, if required
- Incorporation of any design changes, if any, will be addressed as appropriate in the PCSR.