Westinghouse UK
AP1000® GENERIC DESIGN ASSESSMENT
Resolution Plan for GI-AP1000-FD-02
Tolerability of Depressurisation Forces in LBLOCA

MAIN ASSESSMENT AREA	RELATED ASSESSMENT AREA(S)	RESOLUTION PLAN REVISION	GDA ISSUE REVISION
Fuel Design	Fault Studies	3	0

GDA ISSUE:	Demonstrate that pressure forces associated with the depressurisation of the primary circuit are sufficiently limited that a coolable geometry is maintained in the core.
ACTION: GI-AP1000-FD-02.A1	Present arguments and analysis of the impact of depressurisation loads from large LOCA on the analysis of loss of coolable geometry. ONR requires a suitable set of safety arguments and evidence to demonstrate that, in the event of a large LOCA, the reactor pressure vessel internals will not be damaged sufficiently for the assumptions of the safety case to be invalid. This needs to be documented in an assessment report and referenced from the safety report. Please note that an acceptable case for preclusion of the double-ended break has not been made, and in any event, the fault is still likely to be viewed as risk significant, so its consequences would need to be considered even if it were not deemed to be a Design Basis fault. With agreement from the Regulator this action may be completed by alternative means.
RELEVANT REFERENCE DOCUMENTATION RELATED TO GDA ISSUE	
Technical Queries	TQ-**AP1000**-1168 - LBLOCA Blow-down forces
Regulatory Observations	
Other Documentation	

Scope of work:
The scope of work is being presented as a dual option solution path. There is a primary path and a backup path; either solution path is considered to be sufficient to resolve ONR's concern. **Primary Solution**: This approach will employ a mechanistic pipe break assessment on the cold leg and hot leg lines. This assessment will consider the following: • Determine a mechanistic but conservative pipe break opening time. It is advantageous for this determination to not rely on pipe material properties, but rather to emphasise the fluid inertia characteristics in the corresponding thrust calculations.

- Best-estimate RCS parameters for developing initial conditions.

With the above considerations a hydrodynamic load calculation will be performed that will provide input to the core plate motion analysis.

The hydrodynamic loads will be input to the reactor engineering system model (RESM) and will be used to generate core plate motions. Key aspects of this analysis include:

- Best-estimate analysis eliminating load combination multipliers and associated knockdown factors commensurate with ASME code type linear-elastic analyses. The purpose of this assumption is to allow for the performance of a best-estimate mechanistic analysis
- Assessment that ensures gross failure of the internals that prevents core cooling does not occur. It is important to note that the assessment of the internals performance is secondary to the grid crush assessment. A qualitative assessment of the internals will be performed to confirm validity of the core plate motions.

The upper and lower core plate motions will be input to the Nuclear Fuel (NF) multi-assembly model to determine the extent of grid crush and to demarcate whether grid crush is limited to periphery assemblies or if in-board grid crush occurs.

Based on the results of the grid crush assessment a justification will be made regarding the maintainability of coolable geometry. For instance:

- If grid crush is restricted to the periphery assemblies a burnup argument vs. grid crush (%) can be made that demonstrates the periphery assemblies have a lower $F_{\Delta H}$ and F_Q and are not limiting for PCT, and that coolable geometry is maintained.
- If grid crush is restricted to the periphery assemblies, but there is a large deformation in the periphery grid crush such that a large percentage of the flow area is eliminated a calculation will have to be performed to demonstrate the periphery assembly does not exceed allowable PCT limits.
- Similarly, if in-board grid occurs a calculation will have to be performed to demonstrate the plant does not exceed allowable PCT limits.

The following provides a summary of the Primary Solution assessment.

A. Determine hydrodynamic loads associated DEG LOCA pipe breaks, considering break opening time and best estimate RCS initial conditions.
B. Determine corresponding upper and lower core plate motions associated with hydrodynamic loads in Step A. Step B will provide core plate motion input to fuel grid crush assessment in Step C.
C. Determine the percentage of grid crush associated with the double ended guillotine LOCA hydrodynamic loads. Discern whether it is only peripheral grid crush or if in-board grid-crush occurs.
D. Provide overall assessment based on the results in Step C

Backup Solution: The backup solution will only be used if the Primary Solution does not reach satisfactory results. One reason would be if the amount of fuel damage is not limited.

In the Backup Solution the loop piping will be classified as high safety significance (HSS). The result of this classification will push the initiation event frequency (IEV) of a large LOCA DEG rupture to <1E-07 / year. As a result, this event would not be considered in design basis or in design extension analysis; this rupture would be treated the same as a reactor vessel rupture.

Revise the source term based on the expected fuel damage. Perform offsite dose calculations with the increased source term.

Review the PSA assumptions and revise the probability of large LOCA and the consequences.

A summary of the Backup Solution is shown below:

A. Re-classification of loop piping as HSS.
B. Perform offsite dose calculation (with updated source term for quantified fuel failure) respective of site specific atmospheric dispersion factors (χ/Q) to demonstrate consequences are less than allowable.
C. Review / revise the PSA assumptions, both probability of large LOCA and consequences.

Once a solution is developed (Primary or Backup), the PCSR will be updated to be consistent.

Description of work:

<u>Primary Solution</u>:

1. Thrust forces resulting from a DEG rupture of the HL and CL forgings will be calculated. The thrust force calculation will account for:
    a. Flow momentum induced thrust forces
    b. Flow inertia impact on break opening time and corresponding thrust calculation
    c. Best estimate RCS parameters to establish initial conditions

2. Thrust forces will be input to the RESM (Ansys) model to generate upper and lower core plate motions.
    a. Knockdown factors, load combinations, and load combination multipliers commensurate with ASME analyses will be eliminated. The purpose of this assumption is to allow for the performance of a best-estimate mechanistic analysis.
    b. A qualitative assessment of the validity of the core plate motions will determine applicability of results for assessing coolable geometry.

3. The NF multi-assembly model will utilise core plate motions developed in Step 2 to determine the extent of grid crush, and to determine if grid crush is limited to the periphery assemblies or if in-board grid crush occurs.

4. Develop assessment of coolable geometry based on the results of Step 3. It is difficult to ascertain the exact scope of work related to Step 4 until the results of

Step 3 are completed. Step 4 could be relatively easy. For instance if the Step 3 assessment demonstrates a low percentage (small flow area reduction) in the periphery assemblies, then a burnup argument can be employed to demonstrate these assemblies are not limiting for PCT and thus coolable geometry is maintained. However, if a large percentage of grid crush in the periphery assemblies occurs, or if non-negligible amount of in-board grid crush occurs it may be necessary to develop hot rod axial temperature profiles to be used as input to a MATARE code suite calculation to ensure coolable is maintained. The exact scope of Step 4 will not become evident until Step 3 is completed.

Backup Solution:

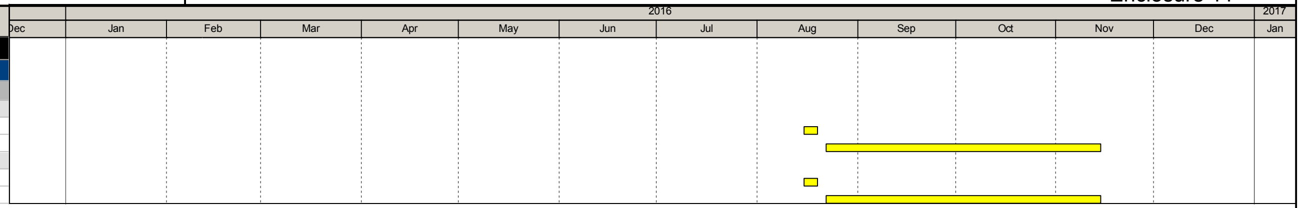
1. Re-classify the loop piping as HSS
    a. This will include necessary fatigue/fracture analyses to enable HSS classification.
    b. Update PCSR accordingly to include necessary tests and inspections commensurate with HSS classification

2. Reflecting an HSS classification a dose analysis that conforms to the guidance in NS-TAST-GD-030 Rev. 4 will be performed to quantify the dose releases associated with an event occurrence <1E-07pa.

3. If the gross failure of an HSS loop forging results in a radiation exposure in excess of the criteria identified by the Fault Study guidance the PSA assumptions leading to the limiting probability of a LBLOCA and corresponding consequences will be updated accordingly.

Schedule/ programme milestones:
Please see the following page for the detailed schedule.

#	Activity Name
1	**UK Generic Design Assessment (GDA) Resolution Plans (51)**
2	**FUEL DESIGN**
3	**FD.02 Tolerability of Depressurisation Forces in LBLOCA-Resolution Plan**
4	**FD.02 5th Phase - Develop UKP Report (NPE Group)**
5	UKP Report -Submit to ONR
6	UKP Report-ONR Review of Submittal
7	**FD.02 Development of PCSR Mark-Ups**
8	PCSR Mark-ups-Submit to ONR
9	PCSR Mark-ups-ONR Review of Submittal



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Methodology:

Primary Solution:

1. Westinghouse internal methodologies will be employed to determine the mechanistic hydrodynamic loads associated with a DER of the loop forgings.
    a. The MULTIFLEX tool in conjunction with the THRUST code will be used to calculate the resultant hydrodynamic forces on internals for use in determining upper and lower core plate motions.

2. The resultant forces will be used as inputs to the Reactor Engineering System Model (RESM).
    a. The RESM model will generate upper and lower core plate motions for use in the grid crush assessment.
    b. A qualitative assessment of the validity of the core plate motions will determine applicability of results for assessing coolable geometry.
    c. The RESM model will eliminate knockdown factors, appropriate load combinations, and load multipliers commensurate with ASME analyses. The purpose of this assumption is to allow for the performance of a best-estimate mechanistic analysis.

3. Nuclear Fuel Methodologies with WEGAP will be used to assess the extent of grid crush and will demarcate whether grid crush is restricted to periphery assemblies or includes in-board assemblies.
    a. NF methods are benchmarked to fuel assembly load and destruction testing for grid and fuel rod stiffness

4. The results of Step 3 will be used to provide an assessment demonstrating the ability of the **AP1000**® reactor to maintain coolable geometry during a design basis LOCA. Step 4 assessment for periphery only low percentage grid crush will utilise a qualitative assessment to demonstrate coolable geometry is maintained. This assessment will rely on lower burnups of periphery assemblies and the bounding assessment previously performed for the hot assembly/rod utilising the MATARE suite calculations.

    If the periphery assemblies demonstrate a high percentage of grid crush or in-board grid crush occurs such that a lower assembly burnup argument cannot be employed to demonstrate the bounding nature of the previous analyses, then a more detailed assessment will need to be performed. This assessment will include:
    a. Westinghouse Cobra/Trac analysis accounting for flow area reduction commensurate with the results of Step 3 to develop mechanistic axial temperature profiles (based on thermal hydraulics solution) on the limiting periphery or in-board fuel assemblies.
    b. The axial temperature profiles will be input to a MATARE code suite calculation to determine the extent of clad ballooning and demonstrate clad burst does not occur.

Backup Solution:

The “Description of Work” section contains sufficient information to understand the methodology that will be utilised for the backup solution. Where they exist, Westinghouse internal methodologies will be utilised in the performance of the dose analyses and will be verified to conform to pertinent ONR guidance.

Classification of HSS for the loop forgings will be in accordance with UKP-GW-GLR-004 Rev. 0, and will conform to pertinent ONR guidance.

It is important to note that other potential solutions exist such as increasing the stiffness or rigidity of the fuel grids to minimise the percentage of grid crush during a design basis LOCA. If the primary solution cannot be employed successfully Westinghouse will consider other potential solutions prior to reclassifying the loop piping.

Justification of adequacy:
The “Description of Work," and “Methodology” sections contain sufficient information to provide a justification of adequacy.

Impact assessment:
The relevant chapters in the PCSR will be updated as appropriate.