Office for Nuclear Regulation
An agency of HSE

Generic Design Assessment – New Civil Reactor Build

GDA Close-out for the EDF and AREVA UK EPR™ Reactor

GDA Issue GI-UKEPR-IH-04 Revision 2 – Consequences of Missile Generation Arising from Failure of RCC-M Components

Assessment Report: ONR-GDA-AR-12-015
Revision 0
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EXECUTIVE SUMMARY

This report presents the close-out of the Office for Nuclear Regulation's (an agency of HSE) Generic Design Assessment (GDA) for the GDA Issue **GI-UKEPR-IH-04 Revision 2** and the associated GDA Issue Actions generated as a result of the GDA Step 4 Internal Hazards assessment of the UK EPR™. The assessment has focussed on the deliverables identified within the EDF and AREVA Resolution Plans published in response to the GDA Issue and on further assessment undertaken of those deliverables.

During Step 4 it became apparent that the arguments and evidence in support of the claims made associated with missile generation arising from failure of RCC-M components that were not designated as High Integrity Components (HIC) had not been presented. This was due to claims associated with discounting the potential for missiles being generated from RCC-M components as well as implicit claims made on structures in place to prevent missiles resulting in loss of more than one redundancy. As a result the GDA Issue was raised which required EDF and AREVA to provide substantiation of the claims made within the PCSR associated with the preclusion of missile generation from failure of RCC-M components which are not designated HIC as defined in the consolidated PCSR

The approach taken by EDF and AREVA was to produce detailed consequence analyses for a number of potential missiles, which aimed to demonstrate the risk to nuclear safety was ALARP. These analyses were included within the Response Plan provided for this GDA Issue by EDF and AREVA.

Further to the receipt of the deliverables detailed within the Response Plan together with the responses to the Technical Query (TQ) raised, I am satisfied that the safety case for internal missile for the UK EPR™ is adequate. One Assessment Finding has been raised in relation to the identification of the barriers claimed within the analysis undertaken to prevent missiles impacting on safety related plant and equipment.

My judgement is based upon the following factors:

- The approach to the assessment of the quantitative consequences of the most bounding missile scenarios is in line with UK expectations and those detailed within the HSE SAPs and international guidance.
- The analysis undertaken has considered the most onerous potential missile events and the calculations performed for the potential missiles have been comprehensive.
- The failure mechanisms that result in the generation of missiles are considered to be reasonable and bounding.
- It is positive to note that the passive structural barriers have been identified within the analysis to protect against the effects of internal missile, however, there is a need for them to be captured within the safety case given that they perform a nuclear safety function in the prevention of a potential missile resulting in loss of more than one division.

I am, therefore, satisfied that GDA Issue, **GI-UKEPR-IH-04**, can now be closed.

LIST OF ABBREVIATIONS

ALARP	As Low As Reasonably Practicable
AREVA	AREVA NP SAS
CCWS	Component Cooling Water System
CMF	Change Modification Form
CVCS	Chemical and Volume Control System
DAC	Design Acceptance Confirmation
EBS	Extra Borating System
EDF	Electricité de France SA
GDA	Generic Design Assessment
HIC	High Integrity Components
HP	High Pressure
HSE	Health and Safety Executive
IAEA	International Atomic Energy Agency
IRWST	In-containment Refuelling Water Storage Tank
LOCA	Loss of Coolant Accident
NSS	Nuclear Sampling System
NVDS	Nuclear Vent and Drain System
ONR	Office for Nuclear Regulation (an agency of HSE)
PCC	Plant Condition Category
PCSR	Pre-construction Safety Report
RCP	Reactor Coolant Pump
RCS	Reactor Coolant System
RES	Nuclear Sampling System – Secondary Side
SAPs	HSE Safety Assessment Principle(s)
SIS	Safety Injection System
SSC	Systems, Structures and Components
SSSS	Standstill Seal System
TAG	Technical Assessment Guide(s)
TQ	Technical Query
UK EPR™	EDF and AREVA UK specific pressurised water reactor design
WENRA	Western European Nuclear Regulators' Association

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1 INTRODUCTION

1.1 Background

1 This report presents the close-out of the Office for Nuclear Regulation's (an agency of HSE) Generic Design Assessment (GDA) for the GDA Issue **GI-UKEPR-IH-04 Revision 2** and the associated GDA Issue Action (Ref. 6) generated as a result of the GDA Step 4 Internal Hazards Assessment of the UK EPR™ (Ref. 7). The assessment has focussed on the deliverables identified within the EDF and AREVA Resolution Plans (Ref. 8) published in response to the GDA Issue and on further assessment undertaken of those deliverables.

2 GDA followed a step-wise-approach in a claims-argument-evidence hierarchy. In Step 2 the claims made by the EDF and AREVA were examined and in Step 3 the arguments that underpin those claims were examined. The Step 4 assessment reviewed the safety aspects of the UK EPR™ reactor in greater detail, by examining the evidence, supporting the claims and arguments made in the safety documentation.

3 The Step 4 Internal Hazards Assessment identified a number of GDA Issues and Assessment Findings as part of the assessment of the evidence associated with the UK EPR™ reactor design. GDA Issues are unresolved issues considered by regulators to be significant, but resolvable, and which require resolution before nuclear island safety related construction of such a reactor could be considered. Assessment Findings are findings that are identified during the regulators' GDA assessment that are important to safety, but not considered critical to the decision to start nuclear island safety related construction of such a reactor.

4 The Step 4 assessment concluded that the UK EPR™ reactor was suitable for construction in the UK subject to resolution of 31 GDA Issues. The purpose of this report is to provide the assessment which underpins the judgement made in closing GDA Issue **GI-UKEPR-IH-04**.

1.2 Scope

5 This report presents only the assessment undertaken as part of the resolution of this GDA Issue and it is recommended that this report be read in conjunction with the Step 4 Internal Hazards Assessment of the EDF and AREVA UK EPR™ in order to appreciate the totality of the assessment of the evidence undertaken as part of the GDA process.

6 This assessment report is not intended to revisit aspects of assessment already undertaken and confirmed as being adequate during previous stages of the GDA. However, should evidence from the assessment of EDF and AREVA's responses to GDA Issues highlight shortfalls not previously identified during Step 4, there will be a need for these aspects of the assessment to be addressed as part of the close-out phase or be identified as assessment findings to be taken forward to the site specific phase.

7 The possibility of further assessment findings being generated as a result of this assessment is not precluded given that resolution of the GDA Issues may leave aspects of the assessment requiring further detailed evidence when the information becomes available at a later stage.

8 During Step 4 it became apparent that the arguments and evidence associated with missile generation arising from failure of RCC-M components not designated as High Integrity Components (HIC) had not been presented. This was due to claims associated with discounting the potential for missiles being generated from RCC-M components as well as implicit claims made on structures in place to prevent missiles resulting in loss of

more than one redundancy. As a result the GDA Issue was raised which required EDF and AREVA to provide substantiation of the claims made within the PCSR (Ref. 11) associated with the preclusion of missile generation from failure of RCC-M components which are not designated HIC as defined in the March 2011 Consolidated PCSR (Ref. 12).

9 ONR suggested that this could be undertaken through detailed analysis of the consequences of failure which should include consideration of the following aspects of the case:

- Identification of those potential sources of internal missile which could result in a threat to nuclear safety significant SSCs.
- Analysis of the consequences of failure.
- Identification of passive features such as barriers and restraints.
- Examination, maintenance, inspection, and testing as a potential part of a multi-legged safety justification for missiles.
- Any further defence in depth and ALARP measures that could be implemented into the design.
- Any identified design changes and their implementation within the PCSR.
- The impact of the changes made to the PCSR relating to the outcome of this substantiation on other safety case submissions such as civil engineering and mechanical engineering.

1.3 Methodology

10 The methodology applied to this assessment is identical to the approach taken during Step 4 which followed the ONR HOW2 document PI/FWD, “Permissioning – Purpose and Scope of Permissioning” (Ref. 1), in relation to mechanics of assessment within ONR.

11 This assessment has been focussed primarily on the submissions relating to resolution of the GDA Issue as well as any further requests for information or justification derived from assessment of those specific deliverables.

12 The assessment allows ONR to judge whether the submissions provided in response to the GDA Issue are sufficient to allow it be closed. Where requirements for more detailed evidence have been identified that are appropriate to be provided at the design, construction or commissioning phases of the project these can be carried forward as assessment findings.

1.4 Structure

13 This assessment report structure differs slightly from the structure adopted for the previous reports produced within GDA, most notably the Step 4 Internal Hazards Assessment of the UK EPR™ (Ref. 7). The report has been structured to reflect the assessment of the individual GDA Issue rather than a report detailing close-out of all GDA Issues associated with this technical area.

14 The reasoning behind adopting this report structure is to allow closure of GDA Issues as the work is completed rather than having to wait for the completion of all the GDA work in this technical area.

2 ONR'S ASSESSMENT STRATEGY FOR INTERNAL HAZARDS

15 The intended assessment strategy for GDA Close-out for the internal hazards topic area was set out in an assessment plan (Ref. 13) that identified the intended scope of the assessment and the standards and criteria that would be applied.

16 The overall basis for the assessment of the GDA Issues are the internal hazards elements of:

- Submissions made to ONR in accordance with the resolution plans.
- Update to the Submission / Pre-construction Safety Report (PCSR) / Supporting Documentation.
- The Design Reference that relates to the Submission / PCSR as set out in UK EPR™ GDA Project Instruction UKEPR-I-002 (Ref. 9) which will be updated throughout GDA Issue resolution and includes Change Management Forms (CMF).

2.1 The Approach to Assessment for GDA Close-out

17 The approach to the closure of a GDA Issue for the UK EPR™ Project involves:

- Assessment of submissions made by EDF and AREVA in response to the GDA Issue identified through the GDA process. These submissions are detailed within the EDF and AREVA Resolution Plan for the GDA Issue.
- In the event of requiring further supporting evidence for the assessment, Technical Queries (TQ) have been generated (Ref. 15).

18 If the assessment of the submissions together with any design changes requested by EDF and AREVA are judged acceptable, the GDA Issue can be cleared.

2.2 Standards and Criteria

19 The relevant standards and criteria adopted within this assessment are principally the Safety Assessment Principles (SAP) (Ref. 2), internal ONR Technical Assessment Guides (TAG) (Ref. 3), relevant national and international standards and relevant good practice informed from existing practices adopted on UK nuclear licensed sites. The key SAPs and relevant TAGs have been detailed within this section. National and international standards and guidance have been referenced where appropriate within the assessment report. Relevant good practice, where applicable, has also been cited within the body of the assessment.

2.2.1 Safety Assessment Principles

20 The key Safety Assessment Principles (SAPs) (Ref. 2) applied within the Internal Hazards Assessment of the EDF and AREVA UK EPR™ (Ref. 7) are included within Table 1 of this report.

2.2.2 Technical Assessment Guides

21 The following Technical Assessment Guides have been used as part of this assessment (Ref. 3):

- T/AST/006 Issue 03 - Deterministic Safety Analysis and the Use of Engineering Principles in Safety Assessment.
- T/AST/014 Issue 02 - Internal Hazards.
- T/AST/017 Issue 02 - Structural Integrity Civil Engineering Aspects.

- T/AST/036 Issue 02 – Diversity, Redundancy, Segregation and Layout of Mechanical Plant.
- T/AST/051 Issue 01 – Guidance on the Purpose, Scope and Content of Nuclear Safety Cases.

2.2.3 International Standards and Guidance

22 The following international standards and guidance have been used as part of this assessment:

- Western European Nuclear Regulators' Association. Reactor Harmonization Group. WENRA Reactor Reference Safety Levels (Ref. 4).
- Safety of Nuclear Power Plants: Design. Safety Requirements, NS-R-1 (Ref. 5).
- Protection against Internal Hazards other than Fires and Explosions in the Design of Nuclear Power Plants. Safety Guide, NS-G-1.11 (Ref. 5).

2.3 Use of Technical Support Contractors

23 No Technical Support Contractors were utilised in the assessment of this GDA Issue.

2.4 Out-of-scope Items

24 As part of the GDA close out, no items have been identified as being out of scope by EDF and AREVA as a result of this assessment.

3 EDF AND AREVA DELIVERABLES IN RESPONSE TO THE GDA ISSUE

25 In response to the GDA Issue, EDF and AREVA provided a Resolution Plan (Ref. 8) detailing how they intended to address the above points. The Resolution Plan stated that a dedicated internal missile safety case would be provided which would address:

- The identification of the potential sources of internal missile from RCC-M components which are not designated HIC as defined in the PCSR including a justification for the screening and the selection of the components to be taken forward for detailed consequence analysis.
- The detailed deterministic analysis of the consequences of failure of the non-High Integrity Components (vessels, tanks, exchangers and valves) identified.
- The details of the passive barriers claimed as part of the non-HIC RCC-M components missile case.

26 For Non-HIC components, EDF and AREVA proposed that the internal missile case would include consideration of:

- Identification of potential sources of internal missile which could result in a threat to nuclear safety significant Systems, Structures and Components (SSCs).
- Analysis of the consequences of failure.
- Identification of passive barriers and restraints claimed in the safety case.
- Examination, maintenance, inspection, and testing as a potential part of a multi-legged safety justification for missile
- Any further defence in depth and ALARP measures that could be implemented into the design.
- Any identified design changes and their implementation within the PCSR.

27 The information provided by EDF and AREVA in response to this GDA Issue was broken down into the following specific deliverables for detailed assessment:

Table 1
Specific Deliverables Subject to Assessment

GDA Issue Action	Internal Hazard	Deliverable	Ref.
GI-UKEPR-IH-04.A1	Internal Missile	Internal Missiles – Selection of the RCC-M components for which a detailed analysis is performed.	17
GI-UKEPR-IH-04.A1	Internal Missile	Internal Missiles – Detailed analysis of the selected safety classified components gross failure	18
GI-UKEPR-IH-02.A4	Internal Missile - Verfication and Validation	Internal Missiles – Risk assessment report on building structure and layout.	19

28 It is recognised that the final deliverable has been submitted under GDA Issue **GI-UKEPR-IH-02** (Ref. 20). However, this report forms a key reference to the claims made for valve generated missiles and impact on building structures and layout. This submission has therefore, been subject to assessment within this assessment report.

29 An overview of each of the deliverables is provided within this section. It is important to note that this information is supplementary to the information provided within the March 2011 Consolidated PCSR (Ref. 12) which has already been subject to assessment during earlier stages of GDA. In addition, it is important to note that the deliverables are not intended to provide the complete safety case for internal hazards. Rather they form further detailed arguments and evidence to supplement those already provided during earlier Steps within the GDA Process.

30 It is important to recognise the deliverables associated with this GDA Issue use the existing French approach to classification and categorisation of Structures, Systems, and Components (SSCs). The use of categorisation and classification is addressed as part of the work undertaken in response to the cross cutting GDA Issue, **GI-UKEPR-CC-01**.

3.1 Internal Missiles – Selection of the RCC-M components for which a detailed analysis is performed.

31 The scope of the above submission (Ref. 17) addresses both missiles arising from failures of rotating equipment such as pumps, fans, compressors and from failure of high energy components such as valves, tanks and vessels, and heat exchangers.

32 The March 2011 Consolidated PCSR (Ref. 12) identified that failures of many rotating plant items are discounted due to design measures or low levels of energy transfer. The specific case of failure of the Reactor Coolant Pump (RCP) flywheel is discounted as it is claimed as a High Integrity Component. The claims made for the high energy RCC-M components are similar to those made for the rotating plant in that they are considered to be sufficiently unlikely as not to warrant analysis and are therefore discounted in the deterministic analysis. Not all these claims were accepted and a GDA Issue was raised.

33 Further to the GDA Issue, EDF and AREVA accepted that further analysis was required for the UK EPR™ and proposed producing a detailed internal missile safety case considering equipment within the Reactor Building and Fuel Building where there is the potential for missile generation. This submission identifies these specific cases for assessment with a view to capturing the outcome of the consequence analysis within the internal missile safety case. The submission identifies that the analysis to be undertaken is for defence in depth purposes.

34 The submission states that missiles generated from failure of moderate energy components are discounted due to insufficient energy inherent within the circuit.

3.1.1 Missiles Generated as a Result of Failures of Non-HIC RCC-M Tanks

35 The following four failures of Non-HIC RCC-M tanks in the Reactor Building and Fuel Building have been considered as part of the analysis undertaken by EDF and AREVA:

- Standstill Seal System (SSSS) (DEA) Nitrogen Tanks
- CVCS Regenerative Heat Exchanger
- CVCS High Pressure Coolers
- Nuclear Sampling System (NSS) Heat Exchangers

36 The tanks selected for assessment have been chosen due to their safety classified and high energy nature. An overview is provided for each of the tanks selected which includes their safety classification, mechanical classification, their location, as well as their operating temperatures and pressures.

3.1.2 Missiles Generated as a Result of Failures of Non HIC RCC-M Valves

37 The following three high energy classified valves in the Reactor Building have been considered as part of the analysis undertaken by EDF and AREVA:

- Pressuriser Valves,
- Chemical and Volume Control Valves,
- Safety Injection Valves.

38 These valves are considered to be representative as they constitute the range of classified valves that are significant in relation to mass and pressure, are high energy from primary circuit systems, and they are in different locations within the Reactor Building.

39 The Pressuriser Valves are classified as F1 in terms of their operation and M1 mechanically. [redacted]. There is no equipment located on or above the slab which performs a safety function. There is analysis of the missile impact on the reinforced concrete structure, including the slab, within a supporting submission (Ref. 19) referenced from the document.

40 The Chemical and Volume Control Valves are identified for further analysis specifically valve [redacted]. The failure of this valve is solely associated with the analysis presented for the building structures (Ref. 19).

41 The final valves that are considered within the submission (Ref. 17) are associated with the Safety Injection System; these valves are F1 in terms of their operation and M3 mechanically. The four valves are contained within separated Safety Injection System (SIS) compartments [redacted]. Once again, the structural effects arising from failure of the valves and the resultant potential missiles are addressed within the building structure analysis (Ref. 19)

3.2 Internal Missile – Detailed analysis of the selected safety classified components gross failure

42 The four vessels and tanks selected for further analysis within the first submission (Ref. 17) in support of resolution of this GDA Issue are:

- SSSS Nitrogen Tanks
- CVCS Regenerative Heat Exchanger
- CVCS High Pressure Coolers
- NSS Heat Exchangers

43 The submission, “Internal Missile – Detailed analysis of the selected safety classified components gross failure” (Ref. 18), provides the detailed consequence analysis associated with failure of the selected vessels and tanks, which has been summarised within this section. Missiles generated as a result of valve failures have been considered within Reference 19 given that the claims are all associated with building structures.

44 With regard to the potential for SIS Accumulator failure, detailed consequence analysis was undertaken and the submission was provided separately during Step 4. The need for internal hazards assessment of the submission was identified within the Step 4 Structural Integrity assessment report as it was not subject to internal hazards assessment during Step 4. SIS Accumulators are, therefore, not considered within the submission from EDF and AREVA, however an overview of the consequence analysis together with my assessment of the submission is included within this assessment report.

3.2.1 SSSS Nitrogen Tanks

45 The SSSS system for UK EPR™ forms part of the reactor coolant system. It is required to ensure the leak tightness of the Reactor Coolant Pumps (RCP) when they are tripped and the Chemical and Volume Control System (CVCS) and Component Cooling Water System (CCWS) are both unavailable. They are located within the Reactor Building [redacted] adjacent to each of the much larger SIS Accumulators. [redacted]

[redacted]

[redacted]

46 The SSSS nitrogen tanks are constructed of stainless steel and are mounted in the vertical orientation and secured through the use of two supports anchored into the inner concrete wall. It is claimed that should a tank fail then the resultant missile would have a vertical trajectory and as a result not impact on the adjacent safety classified plant and equipment.

47 The submission cites that the consequences of failure of the nitrogen tanks are bounded by failure of an SIS accumulator. It details the significant differences in volume and pressure of the tanks stating that the nitrogen tanks are 157 times smaller than the SIS accumulators and that the operating pressures for the nitrogen tanks and the SIS accumulators are 10 and 46 bar respectively. On this basis the submission claims that potential missiles are unlikely to penetrate the metallic floor above the tanks or perforate the concrete slab below [redacted].

48 In addition the location of each of the tanks is such that they are spatially segregated within the Reactor Building and separated by the barriers that enclose the SIS accumulators. The analysis assumes that all equipment identified within the boundary of the SIS accumulator compartment as shown within Figure 2 is lost.

[redacted]

49 The submission for the failure of the SSSS nitrogen tanks concludes that the mechanical and functional aspects are bounded by the failure of the accumulators as the nitrogen tanks are located adjacent to them. This conclusion is supported by the detailed consequences analysis which has been undertaken for the accumulators (Ref. 21)

3.2.2 Analysis of SIS Accumulator Gross Failure

50 The above report was submitted to ONR in August 2010 in response to the issue of Regulatory Observation, **(RO-UKEPR-019)** (Ref. 24). The report provides a detailed consequence analysis associated with failure of an SIS Accumulator. It considers two failure modes:

- Sudden and complete break of the lowest circumferential weld,
- Sudden and complete break of a longitudinal weld in the shell.

51 The report undertakes analysis of the two specific consequence analyses for each potential initiating event:

- A mechanical study of the consequences associated with the above failures including identification of damage on the surrounding structures including the Containment.
- A functional analysis which considers loss of all the components in the zone surrounding each SIS accumulator, based upon the damage identified through the mechanical study.

52 Figure 3, shows the location of the SIS Accumulators within containment.

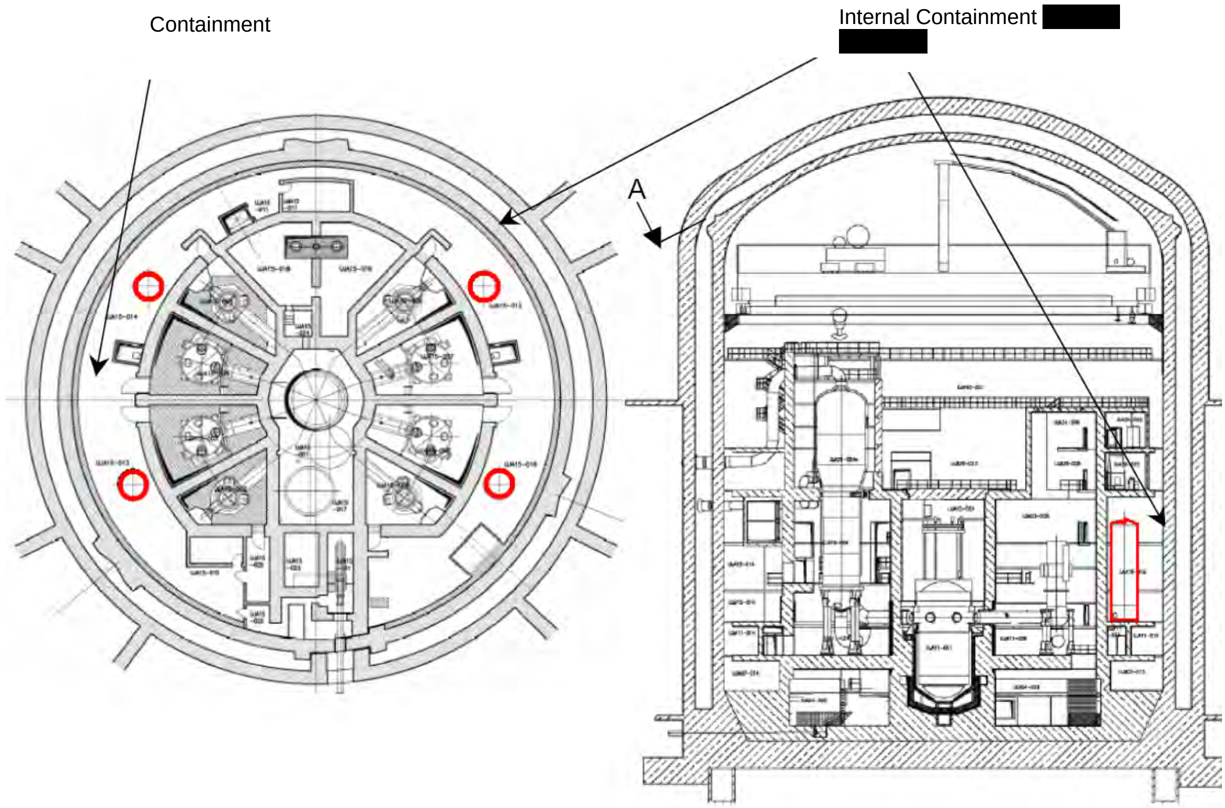

Figure 3: Plan and Section views illustrating the location of the SIS Accumulators

53 [redacted]

[redacted]

[redacted]

[redacted]

[redacted]

54 The report assumes that due to the means for supporting and attaching the tank to the civil structures, only a complete and immediate break of the accumulator cap was considered possible to generate an internal missile. This is due to the cap being located above the upper circumferential weld. Two further credible gross failures were identified associated with the SIS accumulators, namely:

- Failure of the circumferential weld at the base of the accumulator, and,
- Failure of the longitudinal weld on the shell of the accumulator.

55 The failure locations for each of the assessed gross failures are identified within Figure 6 below.

[redacted]

[redacted]

56 The resistance of the Containment has been subject to analysis and determines that potential missiles have a maximum impact energy of 6.25MJ.

57 The initial analysis associated with complete break of the circumferential weld of the SIS Accumulator cap concluded that:

- The calculations result in an ejection speed of the cap of [redacted] with the kinetic impact energy on the slab above calculated to be 5.7MJ.
- The slab reinforcement above (level 19.5m situated 4.5 m above the top of the accumulator) retains the projectile.
- The impact will, however, create secondary projectiles but they are unlikely to cause any damage due to the fact that they consist of only small concrete fragments.

58 It is then concluded that the gross failure of the SIS Accumulator are bounded by the existing PCC events:

- Loss of normal feedwater with feedwater small line break (PCC-3), and
- A small break LOCA (PCC-3).

59 Following on from the initial missile analysis, mechanical and functional analyses have been undertaken to determine the nuclear safety impact of such a missile.

60 The mechanical analysis shows that in the event of accumulator failure through either of the initial failure mechanisms, there would be no damage beyond the zone containing the SIS accumulator nor would there be perforation of the Containment. [redacted]

[redacted]

61 The functional analysis focuses on loss of pipes, valves, and other equipment in the large zone around the SIS accumulator as can be seen in Figure 2. The main Plant Condition Category (PCC) events arising from the postulated initiating events are associated with loss of normal feedwater (isolatable) with feedwater small line break (PCC-3) and small break LOCA (PCC-3). According to the functional analysis undertaken both these events would be tolerable as all the necessary systems and equipment required to reach a controlled and a safe state remain available after gross failure of an SIS accumulator. In addition the plant and equipment required to undertake bleed and feed functions are unaffected by gross failure of an SIS accumulator and thus provide an additional deterministic line of protection against this unlikely event.

62 The mechanical and functional analyses conclude that all plant and equipment necessary to achieve a controlled and safe state remain available following the potential PCC events identified associated with gross failure of an SIS Accumulator.

3.2.3 Regenerative Heat Exchangers

63 The CVCS regenerative heat exchanger recovers heat from the CVCS letdown flow and reheats the charging flow. The equipment is located on the [redacted] level of the Reactor Building in room [redacted]. It is a U-tube heat exchanger based upon opposing flows and it takes the letdown flow from the reactor coolant system which passes through the heat exchanger tubes while purified charging flow passes through the shell side. Both flows are high energy with the tube side inlet temperature and pressure of [redacted] and [redacted] bar gauge respectively and the shell outlet temperature and pressure of [redacted] and [redacted] bar gauge respectively.

64 The regenerative exchanger is mounted in a horizontal orientation, with a mass during operation of approximately 20 tonnes. The submission claims that complete break in the shell is unlikely to generate an internal missile, with the exception of the body of the heat exchanger and, hence, concludes that this is the most severe gross failure.

65 The consequences of failure of the heat exchanger have the potential to breach the barrier, [redacted] and result in a secondary missile which would be stopped by the barrier, [redacted]. Figure 7 illustrates the location of the heat exchanger and the two walls in question.

[redacted]

66 There is a reference (Ref. 25) within the submission that analyses the effects of a missile generated from the regenerative heat exchanger on the civil structures and concludes that such a missile would not perforate the second barrier. There is also an assumption that any plant or equipment not in the trajectory of the missile will not break but only leak.

67 A functional analysis is undertaken on the plant and equipment located within each of the above rooms which have been identified as being vulnerable to the effects of internal missiles. The analysis identifies that there is the potential for one F1 redundancy to be lost for each of the following safety functions:

- [redacted]
- [redacted]
- [redacted]
- [redacted]

68 [redacted]

69 The loss of the above F1 redundancies could result in a number of Plant Condition Category (PCC) transients ranging from PCC-2 to PCC-4.

70 The submission concludes that all the initiated PCC transients can be managed as all safety functions required are available and not damaged by the initiating event. The plant controlled and safe state can be reached despite the fact that more than one F1 redundancy is lost for the function.

3.2.4 High Pressure Coolers

71 The high pressure (HP) coolers cool down the letdown flow to a temperature appropriate for demineraliser and degasification system operation. Each cooler is able to cool down the complete letdown flow that is pre-cooled for the regenerative heat exchanger during normal operation. Only one train is operated during normal operation. Both HP coolers

are located at [redacted] level within rooms [redacted] within the Reactor Building Containment. Figure 8, shows the location of both rooms.

[redacted]

[redacted]

[redacted]

[redacted]

72 The HP coolers are a U-tube type heat exchanger based on the counter flow principle. The letdown flow taken from the RCS passes through the heat exchanger tubes while the CCWS passes through the heat exchanger shell side. There are connections on the tube and shell sides for drains and vents.

73 Each cooler is mounted horizontally fixed by anchoring at the wall and floor with each weighing approximately 12 tonnes during operation. Figure 9 below shows the high pressure heat exchanger, [redacted].

[redacted]

[redacted]

74 During operation the tube side is high energy with temperatures and pressures of [redacted] and up to [redacted] bar respectively. The shell side is at temperatures and pressures of [redacted] and [redacted] bar respectively, is considered moderate energy, and

as a result only failure of the heat exchanger tubes is considered. The potential for damage to the shells as a result of tube failure is, however, considered.

75 If the leak tightness of the shell is not directly impaired by the tube failure, pressure will increase within the shell and the CCWS circuit. However, overpressure protection to prevent failure of the HP Coolers is claimed. In addition, tube leaks are detected by:

- An increase in flow rate and temperature in the HP cooler line on the CCWS side.
- An activity increase at the cooling train downstream of the affected cooler.

76 Should one of the above mechanisms detect a leak then the HP cooler is automatically isolated through closure of a number of valves on detection of increased temperature, flow or activity. In addition rupture discs are installed in the event of a high pressure break within a HP cooler tube during operation.

77 The submission concludes that missile generation arising from failure of an HP cooler would not be possible; however, a functional analysis of the HP cooler is performed for defence in depth purposes.

78 The functional analysis considers a failure of one of the tubes of the CVCS cooler as the tube side is the only high energy part of the HP cooler and that failure is contained within the room housing the HP cooler. Should there be a failure in one of the tubes, the affected system section can be isolated and the system can be operated by means of the parallel train.

79 The analysis has identified that the following safety classified functions could be lost in the event of a HP cooler failure:

- The CVCS, the Nuclear Sampling System (NSS), and the Nuclear Vent and Drain System (NVDS) in room [redacted].
- The CVCS and the NVDS in room [redacted].

80 There is no loss of F1 safety classified redundancy as a result of HP cooler failure, however, there are a number of PCC transients identified including the PCC-4 events:

- [redacted]
- [redacted]

81 The submission states that all the PCC transients can be managed as the safety functions will remain available through the automatic isolation and other redundant systems. It concludes that, based upon the analysis of pipe break (Ref. 22) and the functional analysis presented which considers loss of all equipment within the room including pipework, the potential consequences are acceptable.

3.2.5 Primary Heat Exchangers

82 The NSS primary heat exchangers are used to cool down samples from the RCS and all three are located at the [redacted] level of the Fuel Building in room [redacted] as shown in Figure 10.

[redacted]

[redacted]

83 The heat exchangers of the nuclear sampling systems are of a helical coil type to avoid the potential for deposition of active solids in pipes and equipment. The CCWS serves to cool down the shell side of the cooler in a counter flow to the Sample flow from the RCS.

84 During operation, only the tube side is high energy with temperatures and pressures of [redacted] respectively. The shell of the exchanger is subject to moderate energy conditions with temperatures and pressures of [redacted]. Consequently only failure of the heat exchanger tubes together with consideration of potential damage to the shell is considered.

85 If the leak tightness of the shell is not directly impaired by the tube failure, the pressure will increase in the shell and the CCWS circuit. However, the circuit is protected against overpressure, and thus it is claimed that missile generation is not considered as possible due to such protection. Again, automatic isolation in the event of increased temperature, flow, or activity would be triggered.

86 The submission concludes that missile generation arising from failure of the primary heat exchangers would not be possible; however, a functional analysis is performed for defence in depth purposes.

87 The analysis undertaken considers the room in which the heat exchangers are located and considers loss of all safety classified equipment therein. The systems assumed to be impaired are the NSS, the nuclear sampling system – secondary side (RES), the CCWS, and the NVDS.

88 The F1 systems identified as being lost as a result of failure of a heat exchanger are:

- [redacted]
- [redacted]

[redacted]

89 As with the previous missile examples, there are a number of PCC transients that could arise as a result of loss of all three heat exchangers within this room, the most significant being [redacted], however, this transient could not be avoided as it is generated by the initial failure of the NSS system. This event is mitigated through the [redacted]. All other functions to achieve a controlled and safe state remain available following this initiating event.

90 The functional analysis concludes that the potential damage to structures and equipment due to failure of the primary heat exchangers is acceptable.

91 Overall the submission concludes that the results of the functional analysis performed in the impacted area associated with gross failure of the selected RCC-M components show that the consequences are acceptable from a nuclear safety perspective. In addition PCC transients can be managed and a plant controlled and safe state can be reached.

3.3 Internal Missiles – Risk assessment report on building structure and layout

92 The risk assessment report on building structure and layout (Ref. 19) forms a key reference to the report, *"Internal Missiles – Selection of the RCC-M components for which a detailed analysis is performed"* which has already been summarised within Section 3.1 of this report. The specific areas of interest within the submission are associated with impact and perforation calculations associated with valve generated missiles. The submission considers the impact on civil structures associated with missiles arising from missiles generated from the following systems:

- Pressuriser
- Chemical and Volume Control System
- Safety Injection System

93 As mentioned previously the thickness of the slab above the pressuriser is [redacted] thick and is constructed of reinforced concrete. The calculations identify that a missile arising from failure of the most onerous valves within the pressuriser compartment would result in a missile weighing approximately 250kg due to the section of missile being generated from the upper part of the valve body. Figure 11, illustrates the section of valve that is anticipated to fail and result in missile generation. The total mass of the valve is [redacted], however, the assumption that the top section of the valve generates the missile is an acceptable argument because of the valve body design.

[redacted]

[redacted]

94 The calculated impact velocity of the missile generated as a result of valve failure is [redacted] perforating to a depth of [redacted]. This is approximately half way into the reinforced concrete slab and hence the report concludes that for pressuriser generated valve missiles that the slab would not be compromised and that any missiles generated within the Pressuriser Compartment would be contained.

95 The CVCS containment isolation valves are considered to be the bounding case and the valve, [redacted] has been analysed from a missile generation perspective. Given the design and orientation of the valve the submission assumes that any missile generated as a result of failure would be ejected vertically and would impact the [redacted] deck, 1.5m above the top of the valve. It is claimed that the deck forms a missile barrier for the purposes of the safety case.

96 The same calculations were performed for the pressuriser valve which resulted in an impact velocity of [redacted] which results in an impact depth of [redacted]. This is significantly less than [redacted] thick deck and hence it is claimed that any missile arising from failure of the CVCS valve head would not breach the claimed barrier.

97 The Safety Injection System (SIS) valves have been considered as bounding cases and are located at the base of the SIS Accumulators at a level of +5.15m within containment. Figure 12 illustrates the valve in relation to the base of the accumulator.

[redacted]

[redacted]

98 The total mass of the valve is [redacted], of which it has been calculated that a missile weighing approximately 1570kg could be generated. The missile is assumed to pass through each of the metal decks at 8.70m and 13.80m without any loss of energy. At the 19.30m level there is a reinforced concrete slab [redacted] thick, which is claimed as a missile barrier.

99 The consequences associated with missile generation arising from the postulated failure have been analysed and detailed within the submission. The most significant equipment that would be lost would be one of the four SIS Accumulators, which would consequently result in the following PCC transients:

- [redacted]
- [redacted]

100 The submission concludes that safety classified equipment remains available to ensure that these transients are manageable and given the availability of this equipment, the consequences of missile generation arising from failure is acceptable.

101 The overall conclusion of the report detailing the effects of missiles generated from valves within the UK EPR™ design cites that missiles generated as a result of failures of valves do not threaten plant safety due to both the passive features in relation to barriers and the provision of redundant safety classified equipment.

4 ONR ASSESSMENT

102 Further to the assessment work undertaken during Step 4 (Ref. 7), and the resulting GDA Issue **GI-UKEPR-IH-04** (Ref. 6), this assessment focuses on arguments and evidence identified within the EDF and AREVA deliverables which are intended to provide the requisite evidence. This evidence was provided within the responses contained within the Resolution Plan (Ref. 8) provided by EDF and AREVA at the end of Step 4 of GDA.

103 This assessment has been carried out in accordance with the ONR HOW2 document PI/FWD, "Permissioning - Purpose and Scope of Permissioning" (Ref. 1).

4.1 Scope of Assessment Undertaken

104 The scope of the assessment has been to consider the expectations within the GDA Issue, **GI-UKEPR-IH-04**, and the associated GDA Issue Action which is detailed within Annex 3 of this report. For each of the following areas further arguments and evidence was sought:

- Identification of those potential sources of internal missile which could result in a threat to nuclear safety significant SSCs.
- Analysis of the consequences of failure.
- Passive features such as barriers and restraints.

105 The scope of this assessment is not to undertake further assessment of the PCSR nor is it intended to extend this assessment beyond the expectations stated within the GDA Issue Action. However, where information has been identified that has an affect on the claims made for other aspects of internal hazards such that the existing case is undermined, these have been addressed.

4.2 Assessment

106 The two submissions provided to support closure of this GDA Issue have been summarised within Sections 3.1 and 3.2 and consider the selection and detailed analysis of the potential consequences of missile generation for a number of scenarios that are considered as being representative of the limiting cases. These submissions have been subject to assessment within sections 4.2.1 and 4.2.2 below. In addition, two key references to the submission relating to building structures and layout (Ref. 19) and accumulator gross failure (Ref. 21) have been sampled, as part of a deep slice into the supporting evidence to ensure that the principal claims made within the analyses are robust. These documents have also been summarised within Sections 3.3 and 3.4 respectively.

4.2.1 Internal Missiles – Selection of the RCC-M components for which a detailed analysis is performed

107 This submission relates primarily to the identification of RCC-M components which are representative of the potential missiles that could be generated through failure of valves and tanks. It provides details of the classification of the valves together with their associated operating temperatures and pressures.

108 HICs have been discounted from the analysis undertaken due to the nature of their design. Discounting failure of HIC was subject to detailed assessment during previous Steps of GDA by structural integrity specialists and the arguments presented for discounting potential missiles is bounded by the analysis undertaken within that area. I am satisfied that the analysis does not need to consider potential missiles arising from failure of high integrity components.

109 There is an argument presented associated with the preclusion of missile generation from moderate energy components (temperatures less than 100^{o}C and pressures less than 20 bar). This argument is based upon the low energy contained in the circuit and, hence, the potential for missiles to result in damage to the civil structures containing the SSCs is low. This is a reasonable assertion given the onerous nature of the analysis undertaken for areas within Containment coupled with the high degree of segregation afforded by the civil structures.

110 Pipework generated missiles are also not considered within the scope of the analysis due to the type of materials used and the identified failure mechanisms. I agree that missiles generated as a result of pipe break can be discounted due to the failure mechanisms associated with pipework such that they are more likely to break and whip rather than generate missiles. In addition, there has been extensive work undertaken as part of the high energy line break studies which demonstrated that the effects of pipewhip on specific items of plant has been shown to be acceptable. This aspect was subject to assessment during Step 4 of the GDA and reported within the Step 4 Internal Hazards Assessment Report for UK EPR™ (Ref. 7).

111 I accept that the valves identified within the analysis are representative of the bounding scenarios due to their significant mass and pressure, being high energy, and their location within the reactor building. The key arguments presented in relation to the consequences are associated with the building structure and layout and as such the submission refers to the report, *"EPR – Internal missiles – Risk assessment report on building structure and layout"* provided in support of **GI-UKEPR-IH-02**. As part of my sample into the arguments and evidence, I have subjected this to assessment which is contained within Section 4.2.3 of this assessment report.

112 I am satisfied that the selection of the specific valves is bounding and will be representative of the potential worst case missile generation scenario for the valves in question. The arguments and evidence associated with the claims made upon building structures has been subject to assessment within Section 4.2.3, part of which has been undertaken on the approach to the calculation of perforation depths undertaken by civil engineering assessors.

113 The vessels and tanks identified for detailed assessment are those that are safety classified but not identified as HIC. The approach taken to the identification of the vessels and tanks that are to be subject to the detailed analysis is similar to that applied for the valves in that they have been selected on the basis of mass and pressure, high energy, and location. The potential missile scenarios analysed are considered to be representative of the limiting cases. One of the five tanks identified is the SIS accumulator, which was subject to assessment from a structural integrity perspective during Step 4. The structural integrity assessors identified the need for further assessment to be undertaken from internal hazards perspective; hence its consideration within this GDA Issue. Again, there are arguments presented associated with building structure and layout, which as mentioned previously has been assessed within Section 4.2.3 of this report.

114 To conclude, I am therefore satisfied that the approach taken to the basis of the arguments relating to the preclusion of missile generation from high integrity components, moderate energy systems, and pipe break is acceptable. Furthermore, I am content that the selection of those components for detailed analysis is bounded.

4.2.2 Internal Missile – Detailed analysis of the selected safety classified components gross failure

115 Following on from the identification of the potential missiles a detailed analysis was undertaken of the following four vessels and tanks that were identified as requiring further more detailed analysis:

- SSSS Nitrogen Tanks
- CVCS Regenerative Heat Exchanger
- CVCS High Pressure Coolers
- NSS Heat Exchangers

116 The approach considered both a mechanical analysis and a functional analysis of the potential missiles generated arising from failure of the vessels and tanks. The mechanical analysis considered the areas impacted by the missiles, whilst the functional analysis took into account the safety classified equipment that could be lost in the event of missile generation. The approach involved a comprehensive analysis of loss of all plant within the impacted area in which the vessels and tanks were located. It considered the identification of safety functions and potential PCC events. It also took into account the redundancy of plant and equipment, geographical location and the presence of civil structures. Finally, it considered the adequacy of the design in relation to the acceptability of the consequences of missile generation.

117 I am satisfied with this comprehensive approach to the analysis of the potential consequences associated with missile generation arising from the failure of RCC-M vessels and tanks.

118 Each of the vessels and tanks have been considered as part of the detailed assessment to ascertain the adequacy of the provisions in place and to determine whether the consequences of each of the scenarios analysed are ALARP.

4.2.2.1 SSSS Nitrogen Tanks

119 The arguments presented in the event of failure and subsequent missile generation associated with the SSSS tanks are associated with vertical trajectory of the missile given its orientation and location of anchor points into the structure. The basis of the argument associated with vertical trajectory of any postulated missiles is associated with the anchoring of the valve to the structure which holds it in the vertical orientation. I am satisfied that such an arrangement would serve to ensure that any potential missiles arising from failure of the SSSS tanks would follow a vertical trajectory.

120 Conservatism is applied in relation to the building structures in that the metallic floor directly above and the concrete slab below, which is [redacted] thick, is assumed to be perforated. The impacted structures are considered to be bounded by those structures analysed for SIS Accumulator failure due to their adjacent location.

121 I am satisfied that the consequences of missiles generated arising from failure of the SSSS tanks has been adequately mitigated through the analysis of the potential missile trajectory, structural support to the tank and through bounding the consequences by virtue of failure of an SIS Accumulator.

4.2.2.2 CVCS Regenerative Heat Exchanger

122 The arguments associated with the CVCS Regenerative Heat Exchanger, [redacted], consider the potential source of missiles arising from failure of the

flanges at either end of the U-tube exchanger. The potential for disruptive failure and subsequent missile generation from a weld failure elsewhere in the heat exchanger shell are discounted due to the design. This assumption is reasonable given that the U shaped geometry of the shell filled with individual tubes would tend to preclude missile generation from the shell itself and the robustly designed support structure would prevent the whole of the heat exchanger acting as a missile.

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123 The analysis considers the loss of the barrier between [redacted] due to the energy and perforation of the barrier, [redacted]. This barrier is considered to be claimed as it forms a means to reduce the energy associated with propagation of the missile generated from failure of the regenerative heat exchanger. The analysis then identifies that barrier [redacted] would be impacted and the missile arrested by that barrier. This is, therefore, a claim on the barrier to prevent further propagation of the missile. These barriers should be identified as having nuclear safety claims associated with their design and construction within the safety case given the nuclear safety significance of the barrier in question. An assessment finding has therefore been raised to ensure that barriers claimed for the protection of plant and equipment from the effects of missiles are identified:

> ***AF-UKEPR-IH-08:*** *The Licensee shall ensure that all barriers claimed for the protection of nuclear safety related plant and equipment against the effects of internal missile are specifically identified and documented within the safety case within the site specific design.*
>
> ***Required Timescale:*** *Mechanical, Electrical, and C&I Safety Systems – Before inactive commissioning.*

124 The reference to the impact calculations undertaken on the civil structures in the case of regenerative heat exchanger failure were requested under a TQ **(TQ-EPR-1583)** (Ref. 15), to which Reference 25 was provided. The approach to the calculation of perforation depth of potential missiles is based upon the same methodology as used for dropped load and impact on a reinforced concrete slab (Ref. 26). The calculations associated with perforation of the concrete barriers by the postulated missiles, detailed within reference 25, have been reviewed by civil engineering assessors. Their assessment (Ref. 27) concludes that they are satisfied the calculations sampled from Reference 19 have been carried out correctly and that the selection of which of the two methods to use was also carried out correctly for these examples. However, they also conclude that there is a need to justify the calculation methods for the civil structures as well as to develop an internal missile methodology document. Their assessment (Ref. 27) therefore includes assessment findings in relation to these aspects **(AF-UKEPR-CE-82 and AF-UKEPR-CE-83)**.

4.2.2.3 CVCS High Pressure Coolers

125 The analysis undertaken for the CVCS HP Coolers provides claims and arguments associated with detection and isolation by overpressure protection and automatic isolation of the HP cooler. In addition, there are claims made on rupture disks to mitigate the effects of a break in the HP cooler during operation.

126 With regard to the potential for missiles to result in loss of more than one redundancy, I am satisfied that the analysis presented provides adequate justification that a missile arising from failure of one HP cooler would not affect the redundant cooler given the detection, isolation, and segregation provided.

4.2.2.4 NSS Heat Exchangers

127 The principal arguments associated with missile generation arising from failure of a Primary Heat Exchanger are based upon acceptability of loss from a nuclear safety perspective as, although there would be [redacted]. The functions associated with achieving a safe state would all remain given that this system is primarily associated with sampling of the RCS and hence would not impact the shutdown and post trip cooling. Gross failure of all three primary heat exchangers and subsequent consequences associated with [redacted] have been shown to be acceptable from a nuclear consequences perspective. I believe that it would be unlikely for a missile to result in loss of all three Primary Heat Exchangers given the size and energies involved in the failure, however, the subsequent consequence analysis demonstrates that, with the detection and automatic isolation in place, the impact on nuclear safety is acceptable given the limited release and the ability to bring the plant to a safe state using F1 functions not affected by a gross failure of a Primary Heat Exchanger. I am therefore satisfied that the consequences of gross failure of a Primary Heat Exchanger resulting in missile generation are acceptable and the SSCs in place to protect against such an event are acceptable.

4.2.3 Internal Missiles – Risk assessment report on building structure and layout

128 The submission assessed within 4.2.2 above is reliant on the risk assessment report on building structure and layout in relation to the claims made on barriers in the event of valve generated missile. There are barriers claimed in the event of failure of the SSSS nitrogen tanks and the regenerative heat exchanger. In the case of the SSSS nitrogen tanks, failure is bounded by the analysis undertaken on the SIS accumulators, addressed within Section 4.2.4 of this assessment report, and for the regenerative heat exchanger, this has been addressed as part of 4.2.2 above.

129 The submission provides supporting evidence associated with a subset of valves considered to be the most onerous in terms of the potential nuclear safety consequences. The valves selected for assessment have been discussed within Section 4.2.1 above. The claims are primarily placed upon the size of the potential missile and the impact/perforation depth on the claimed barriers in place in order to prevent loss of more than one redundancy.

130 In the case of failure of the pressuriser valves, the selection of the valve with highest energy and representative missile mass is considered an appropriate approach due to the consideration of the most bounding case. The basis by which the failure location of the valve is identified appears reasonable given the design of the valve. The vertical trajectory of any potential missile is in line with my expectations, given that a partial failure would be unlikely to generate a missile. The mass of the missile is estimated as being 250kg out of a total valve mass of [redacted] and is acceptable given the location of the anticipated failure of the valve. This judgement is based upon the relative mass of the missile in comparison to the valve which can be seen within Figure 11 of Section 3.3. The assumption that approximately [redacted] of the mass of the valve is located above the red line is reasonable when considering the break location and that the most bounding missile has been considered when informing the impact calculations due to the mass of the missile.

131 The potential perforation of the missile into the [redacted] reinforced concrete slab located above the pressuriser valves was assessed by civil engineering assessors. The assessment was limited to the applicability of the methodology applied to the calculations undertaken. Their assessment (Ref. 27) concludes that they are satisfied the calculations sampled from Reference 19 have been carried out correctly and that the selection of which of the two methods to use was also carried out correctly for these examples.

132 For the CVCS valves, the evidence presented within the submission is similar to that for the pressuriser valves with the assumption on missile mass and claims made upon building structures and perforation. In this case, the missile mass has been estimated as 300kg against a total valve mass of [redacted]. The section at which the valve fails is considerable lower down the valve body than was presumed for the pressuriser valve. This is taken into consideration in the estimate of the potential mass of the missile being a far greater proportion of the total mass. I am satisfied that this assumption is reasonable and that there is sufficient conservatism applied in the potential mass of the missile.

133 There is a claim made on the concrete slab located above [redacted] which is [redacted] thick to arrest the postulated missile. The calculations undertaken found the perforation depth of the missile to be [redacted] which is considerably lower than the thickness of the slab and hence the missile postulated in this case would not breach the barrier. The assessment work undertaken by civil engineering assessors confirmed that the approach to calculating the perforation depth was in line with ONR expectations.

134 Finally, the potential for a missile to be generated as a result of failure of an SIS valve located at the base of the SIS Accumulator was claimed to be bounded by the failure of the accumulator itself, which was subject to a separate detailed consequence analysis (Ref. 21) during Step 4. As a result, the analysis of gross failure of an accumulator has been assessed within Section 4.2.4. of this assessment report.

135 I am satisfied that the consequences of missile generation arising from failure of the selected valves identified as bounding has been adequately addressed as part of the UK EPR™ design, however, the need to identify the barriers claimed as part of the safety case for internal missiles is required, **AF-UKEPR-IH-08** refers.

4.2.4 Analysis of Safety Injection System (SIS) Accumulator Gross Failure

136 During Step 4, SIS accumulator failure was subject to assessment from a structural integrity perspective, and it concluded that the Accumulators are Class 1 components with a Category A safety function but at the time of writing the Step 4 Structural Integrity assessment the classification of the mechanical components were M3, the lowest level of safety classified mechanical component. This was identified as requiring resolution through a Cross Cutting GDA Issue **(GI-UKEPR-CC-01.A4)** (Ref. 23). In addition, the consequences of gross failure of an accumulator were not fully assessed by ONR during Step 4 and the need to undertake the assessment was captured as part of this GDA Issue.

137 The Structural Integrity assessment undertaken during previous Steps of the GDA process requested EDF and AREVA within a Regulatory Observation, **(RO-UKEPR-019)** (Ref. 24), to:

"Provide a rationale justifying the failures of mechanical components taken in consideration for safety analysis. Based on this rationale, provide a unified and complete list of components whose failure is discounted (non breakable, break preclusion and no missile). Demonstrate how gross failure is taken into account, by mitigation or prevention."

138 The Accumulators are not claimed to be high integrity components and were initially assigned an M3 classification, however, this classification has since been increased to M2 further to EDF and AREVA addressing the expectations of the cross cutting GDA Issue, **GI-UKEPR-CC.01** in relation to classification and categorisation. Further consequence analysis was therefore required as a result of the expectations detailed within the Structural Integrity and Internal Hazards SAPs. This submission was provided in response to these expectations given the F1 safety classification of the accumulators.

139 It is important to stress that the design and manufacture of the accumulators are to a high specification and ONR accept that such failures would be unlikely. However, in light of the mechanical classification of the component, quantitative consequence analysis was expected to be undertaken to demonstrate that should failure in the manner postulated occur, sufficient redundancy would remain in place such that the effects on nuclear safety are acceptable.

140 The submission provided by EDF and AREVA details the quantitative consequence analysis to support the safety case for internal missile generation. It provides detailed consequence analysis of two potential missiles arising from failure of the accumulator, namely, failure of the circumferential weld at the base of the accumulator and a longitudinal weld failure on the shell.

141 The Lisega arms and anchor plates, that the body of the accumulator is attached to are therefore claimed as a means to prevent movement or ejection of missiles other than the accumulator cap, however, this forms a defence in depth function given that the consequences of gross failure of the accumulator have been assumed.

142 As is the case for other missiles that have been subject to analysis, there is a need for the barriers that are claimed to prevent missiles affecting more than one division to be identified. The assessment finding, **AF-UKEPR-IH-08,** once again applies.

143 The failures analysed consider missile trajectories both vertically and laterally and detailed calculations were provided from both a mechanical and functional perspective. I am satisfied that this approach is a thorough and robust approach which is bounding in the event of failure of an accumulator.

4.3 Comparison with Standards, Guidance and Relevant Good Practice

144 The Safety Assessment Principles (SAPs) (Ref. 2) consider, from both a structural integrity perspective as well as an internal hazards perspective, the need to consider the consequences of failure of plant and equipment which has the potential to impact on nuclear safety.

145 The SAPs, state within paragraph 243 relating to structural integrity:

"Discounting gross failure of a component or structure is an onerous route to constructing a safety case. Such a case should provide in-depth explanation of the measures over and above normal practice that support and justify the claim. If discounting gross failure cannot be justified, it may be possible to consider a case based on consequences (see paragraph 246)."

146 Paragraph 246 of the SAPs provides clarification associated with the expectations associated with the analysis of consequences:

"Where:

a) the case cannot meet the level needed for a claim that the likelihood of a failure event can be discounted, and *b) all practical avenues to improve the structural integrity case have been exhausted;*

the basis of the safety case needs to be revisited and the consequences of gross failure of components or structures explicitly considered. This would potentially involve a site-specific evaluation of short and long-term off-site consequences and would still require some estimate of the reliability of the components or structures in question. This broadening of the basis of the safety case would clearly require involvement of disciplines in addition to structural integrity."

147 Leading on from the expectations detailed within the section of the SAPs relating to structural integrity there are the expectations relating to the need for consequence analysis within the internal hazards SAPs, which state within EHA.14:

Engineering principles: external and internal hazards	**Fire, explosion, missiles, toxic gases etc – sources of harm**	**EHA.14**
Sources that could give rise to fire, explosion, missiles, toxic gas release, collapsing or falling loads, pipe failure effects, or internal and external flooding **should be identified, specified quantitatively and their potential as a source of harm to the nuclear facility assessed**.		

148 The International Atomic Energy Agency (IAEA) guidance NS-G-1.11 (Ref. 5) considers the need for barriers and physical separation to be adopted when there is the potential for missiles to result in loss of redundancy and that such barriers should be sited close to the source of the missiles. EDF and AREVA have claimed such protection within the design but not explicitly captured the location of the barriers that are claimed in the safety case.

149 Paragraph 3.27 of NS-G-1.11 states:

"Evaluation of the adequacy of barriers, whether they are structures provided for other purposes or special missile barriers, necessitates the consideration of both local and general effects of missiles on the barrier. Depending upon the postulated missile's mass, velocity and impact area, the local or the general effect of the missile may dominate, but both should be evaluated. Local effects of missiles are penetration, perforation, scabbing or the ejection of concrete blocks and spalling, which are limited mainly to the area of impact on the target. General effects of missiles include buckling or structural failures in bending, tension or shear. Small missiles such as valve stems will have mainly local effects, while large, slow moving missiles such as those arising from structural collapse or falling loads will have mainly general effects."

150 As can be noted, the expectations of the SAPs and international guidance have been met with the inclusion of detailed consequence analysis, however, there is a need for the barriers to be identified as part of the internal missile safety case and as a result, an assessment finding **(AF-UKEPR-IH-08)** has been raised.

5 REVIEW OF THE UPDATE TO THE PCSR

5.1 13.2. Internal Hazards

151 Section 4 of Chapter 13.2 of the PCSR (Ref. 28) considers internal missile generation. The submission was reviewed to ensure that the outcome of the GDA assessment had been appropriately captured therein.

152 The PCSR has been reviewed and I am satisfied that it reflects the findings from the GDA and the text has been updated to include reference to the supporting analysis work undertaken within References 18 and 19. In addition, an overview of the detailed consequence analysis is provided associated with internal missiles arising from failure of Non-HIC RCC-M components.

6 ASSESSMENT FINDINGS

6.1 Additional Assessment Findings

153 The following assessment finding has been raised that requires to be resolved during the site specific phase:

> ***AF-UKEPR-IH-08:*** *The Licensee shall ensure that all barriers claimed for the protection of nuclear safety related plant and equipment against the effects of internal missile are specifically identified and documented within the safety case within the site specific design.*
>
> ***Required Timescale:*** *Mechanical, Electrical, and C&I Safety Systems – Before inactive commissioning.*

6.2 Impacted Step 4 Assessment Findings

154 No assessment findings raised during Step 4 have been impacted as a result of this assessment.

7 ASSESSMENT CONCLUSIONS

155 Further to the GDA Issue, **GI-UKEPR-IH04** and receipt of the deliverables detailed within the Response Plan together with the responses to the TQs raised, I am satisfied that the safety case for internal missile for the UK EPR™ is adequate. One assessment finding has been raised in relation to the identification of the barriers claimed within the analysis undertaken to prevent missiles impacting on safety related plant and equipment.

156 My judgement of the adequacy of the response to the GDA issue was based upon the following factors:

- The approach to the assessment of the quantitative consequences of the most bounding missile scenarios is in line with UK expectations and those detailed within the HSE SAPs and international guidance.
- The analysis undertaken has considered the most onerous potential missile events and the calculations performed for the potential missiles has been comprehensive.
- The failure mechanisms that result in the generation of missiles are considered to be reasonable and bounding.
- It is positive to note that the passive structural barriers have been identified within the analysis to protect against the effects of internal missile, however, there is a need for them to be captured within the safety case given that they perform a nuclear safety function in the prevention of a potential missile resulting in loss of more than one division.

157 I am, therefore, satisfied that GDA Issue, **GI-UKEPR-IH-04**, can now be closed.

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15 *EDF and AREVA UK EPR™ - Schedule of Technical Queries Raised during GDA Close-out.* Office for Nuclear Regulation. TRIM Ref. 2011/389411.

16 *Identification of High Integrity Components: components whose gross failure is discounted.* ENSNDR090183 Revision B, EDF, December 2010. TRIM Ref. 2011/85939

17 *Internal Missiles – Selection of the RCC-M components for which a detailed analysis is performed.* ECEIG111942 Revision A, EDF, October 2011. TRIM Ref. 2011/553024.

18 *Internal Missiles – Detailed analysis of the selected safety classified components gross failure*. ECEIG112173, Revision A, EDF, January 2012. TRIM Ref. 2012/53665

19 *EPR Internal Missiles – Risk assessment report on building structure and layout.* ECEIG091634, Revision B1, EDF, April 2011. TRIM Ref. 2011/324014

20 *GDA Issue GI-UKEPR-IH-02 Revision 2.* ONR. July 2011. TRIM Ref. 2011/385309. (in TRIM folder 5.1.3.6348.)

21 *Analysis of SIS accumulator gross failure.* ENSNDR100062 Revision B, EDF, May 2010. TRIM Ref. 2011/92455.

22 *First stage analysis report on the consequences of high energy line break – Reactor Building.* ECEF092040 Revision A1, EDF, March 2010. TRIM Ref. 2011/92754.

23 *GDA Issue GI-UKEPR-CC-01 Revision 1.* ONR. July 2011. TRIM Ref. 2011/385286. (in TRIM folder 5.1.3.6348.)

24 *Categorisation of Safety Function, Classification of Structures - Systems and Components - "Non Breakable", "Break Preclusion" and "No Missile" Items.* RO-UKEPR-019, ONR, January 2009. TRIM 2010/195011.

25 *Impact calculation on the civil structures in case of failure of the regenerative heat exchanger RCV6220EX,* ECEIG112399 Revision A, EDF, January 2012. TRIM 2012/109272

26 *Methods with regard to the risk of dropped loads for UKEPR for concrete structure,* ENGSGC100483 Revision B, EDF February 2012. TRIM 2012/116384.

27 *GDA Close-out for the EDF and AREVA UK EPR™ Reactor – GDA Issue GI-UKEPR-CE-02 Revision 1 – Use of ETC-C for the Design and Construction of the UK EPR™* ONR Assessment Report ONR-GDA-AR-12-004, Revision 0, TRIM 2012/4.

28 PCSR Sub-Chapter 13.2 Update – Internal Hazards Protection, UKEPR-0002-132 Issue 04, 13th September 2012, TRIM 2012/367280.

Table 2

Relevant Safety Assessment Principles Considered for Close-out of GI-UKEPR-IH-04 Revision 2

SAP No.	SAP Title	Description
SC.4	Safety case characteristics	A safety case should be accurate, objective and demonstrably complete for its intended purpose.
EKP.3	Defence in depth	A nuclear facility should be so designed and operated that defence in depth against potentially significant faults or failures is achieved by the provision of several levels of protection.
EKP.4	Safety function	The safety function(s) to be delivered within the facility should be identified by a structured analysis.
EKP.5	Safety Measures	Safety measures should be identified to deliver the required safety function(s).
ECS.1	Safety Categorisation	The safety functions to be delivered within the facility, both during normal operation and in the event of a fault or accident, should be categorised based on their significance with regard to safety.
ECS.2	Safety classification of structures, systems and components	Structures, systems and components that have to deliver safety functions should be identified and classified on the basis of those functions and their significance with regard to safety.
EDR.2	Redundancy, diversity and segregation	Redundancy, diversity and segregation should be incorporated as appropriate within the designs of structures, systems and components important to safety.
EDR.4	Single failure criterion	During any normally permissible state of plant availability no single random failure, assumed to occur anywhere within the systems provided to secure a safety function, should prevent the performance of that safety function.

Table 2

Relevant Safety Assessment Principles Considered for Close-out of GI-UKEPR-IH-04 Revision 2

SAP No.	SAP Title	Description
ELO.4	Minimisation of the effects of incidents	The design and layout of the site and its facilities, the plant within a facility and support facilities and services should be such that the effects of incidents are minimised.
EHA.1	Identification	External and internal hazards that could affect the safety of the facility should be identified and treated as events that can give rise to possible initiating faults.
EHA.3	Design basis events	For each internal or external hazard, which cannot be excluded on the basis of either low frequency or insignificant consequence, a design basis event should be derived.
EHA.4	Frequency of exceedance	The design basis event for an internal and external hazard should conservatively have a predicted frequency of exceedance in accordance with the fault analysis requirements (FA.5).
EHA.5	Operating conditions	Hazard design basis faults should be assumed to occur simultaneously with the most adverse normal facility operating condition.
EHA.6	Analysis	Analyses should take into account simultaneous effects, common cause failure, defence in depth and consequential effects.
EHA.14	Fire, explosion, missiles, toxic gases etc – sources of harm	Sources that could give rise to fire, explosion, missiles, toxic gas release, collapsing or falling loads, pipe failure effects, or internal and external flooding should be identified, specified quantitatively and their potential as a source of harm to the nuclear facility assessed.
FA.6	Fault sequences	For each initiating fault in the design basis, the relevant design basis fault sequences should be identified.

Annex 1

Deliverables and Associated Technical Queries Raised During Close-out Phase

EDF and AREVA Deliverables subject to assessment during GDA Close Out.

GDA Issue Action / Associated GDA Step	Internal Hazards Area	Document Ref.	Title	Ref.
GI-UKEPR-IH-04.A1	Internal Missile	ECEIG111942 Revision A	*Internal Missiles – Selection of the RCC-M components for which a detailed analysis is performed.*	17
GI-UKEPR-IH-04.A1	Internal Missile	ECEIG112173, Revision A	*Internal Missiles – Detailed analysis of the selected safety classified components gross failure*.	18
GI-UKEPR-IH-02.A4	Verification and Validation	ECEIG091634, Revision B1	*EPR Internal Missiles – Risk assessment report on building structure and layout.*	19
RO-UKEPR-019 and Step 4 Structural Integrity Assessment	Internal Missile	ENSNDR100062 Revision B	*Analysis of SIS accumulator gross failure.*	21
TQ-EPR-1583	Internal Missile	ECEIG112399	*Impact calculation on the civil structures in case of failure of the regenerative heat exchanger RCV6220EX*	25

Annex 1

Deliverables and Associated Technical Queries Raised During Close-out Phase

Technical Queries Raised During GDA Close Out Assessment

TQ Reference	GDA Issue Action	Related Submission	Description
TQ-EPR-1583	**GI-UKEPR-IH-04.A1**	ECEIG112173 Rev A – Regenerative Heat Exchanger Analysis	As part of the deep slice sample into the evidence supporting the internal missile safety case, the technical reference to the calculations undertaken relating to missile perforation arising from failure of the regenerative heat exchanger RCV6220EX is required. **Technical Question.** Please provide reference 14 to the above submission entitled, *"Impact calculation on the civil structures in case of the regenerative heat exchanger RCV6220EX failure"*, ECEIG112399.

Annex 2

GDA Assessment Findings Arising from GDA Close-out for Internal Hazards GDA Issue GI-UKEPR-IH-04

Finding No.	Assessment Finding	MILESTONE (by which this item should be addressed)
AF-UKEPR-IH-08	The Licensee shall ensure that all barriers claimed for the protection of nuclear safety related plant and equipment against the effects of internal missile are specifically identified and documented within the safety case within the site specific design.	*Mechanical, Electrical, and C&I systems – Before inactive commissioning.*

Note: It is the responsibility of the Licensees / Operators to have adequate arrangements to address the Assessment Findings. Future Licensees / Operators can adopt alternative means to those indicated in the findings which give an equivalent level of safety.

For Assessment Findings relevant to the operational phase of the reactor, the Licensees / Operators must adequately address the findings during the operational phase. For other Assessment Findings, it is the regulators' expectation that the findings are adequately addressed no later than the milestones indicated above.

Annex 3

GDA Issue, GI-UKEPR-IH-04 – Internal Hazards – UK EPR™

EDF AND AREVA UK EPR GENERIC DESIGN ASSESSMENT

GDA ISSUE

CONSEQUENCES OF MISSILE GENERATION ARISING FROM FAILURE OF RCC-M COMPONENTS

GI-UKEPR-IH-04 REVISION 2

<table>
<tr><td colspan="2">Technical Area</td><td colspan="2">INTERNAL HAZARDS</td></tr>
<tr><td colspan="2">Related Technical Areas</td><td colspan="2">Structural Integrity
Civil Engineering
Fault Studies</td></tr>
<tr><td>GDA Issue Reference</td><td>GI-UKEPR-IH-04</td><td>GDA Issue Action Reference</td><td>GI-UKEPR-IH-04.A1</td></tr>
<tr><td>GDA Issue</td><td colspan="3">Consequences of missile generation arising from failure of RCC-M Components.</td></tr>
<tr><td>GDA Issue Action</td><td colspan="3">Provide substantiation of the claims made within the PCSR associated with the preclusion of missile generation from failure of RCC-M components which are not designated as High Integrity Components (HIC) as defined in the consolidated PCSR. This could be undertaken through detailed analysis of the consequences of failure. The detailed analysis should include consideration of:
Identification of those potential sources of internal missile which could result in a threat to nuclear safety significant SSCs.
Analysis of the consequences of failure.
Passive features such as barriers and restraints.
Examination, maintenance, inspection, and testing as a potential part of a multi-legged safety justification for missiles.
Any further defence in depth and ALARP measures that could be implemented into the design.
Any identified design changes and their implementation within the PCSR.
The impact of the changes made to the PCSR relating to the outcome of this substantiation on other safety case submissions such as civil engineering and mechanical engineering.
The list above should not be considered to be exhaustive and the items detailed above are provided as a means to inform EDF and AREVA of ONR expectations.
With agreement from the Regulator this action may be completed by alternative means.</td></tr>
</table>