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-FS-03 Revision 2

Spent Fuel Pool Safety Case

Assessment Report: ONR-GDA-AR-12-012
Revision 0
March 2013

EXECUTIVE SUMMARY

This report presents the close-out part of the Office for Nuclear Regulation's (an agency of HSE) Generic Design Assessment (GDA) within the area of Fault Studies design basis analyses. This report specifically addresses the GDA Issue **GI-UKEPR-FS-03** generated as a result of the GDA Step 4 Fault Studies Assessment of the UK EPR™. My assessment has focused on the deliverables identified within the EDF and AREVA Resolution Plan published in response to this GDA Issue.

During the GDA Step 4 assessment it was concluded that EDF and AREVA had not provided an adequate safety case in support of the Spent Fuel Pool (SFP) and associated fuel handling areas/compartments. There were two aspects where improvements were considered to be necessary. The first is the cask loading pit which is used to transfer the fuel assemblies from the spent fuel pool to a cask for transport from the facility. This compartment houses a penetration at its base to allow loading of the cask. The other aspect was to request a comprehensive safety case to cover the potential failure of the penetrations/openings in the spent fuel pool and connected compartments, which was previously excluded from the safety analysis of the UK EPR™. ONR considered that analysis should be carried out to review the consequences of major failure of these penetrations and openings which could lead to overheating of fuel assemblies and flooding that have not been included as design basis events.

Design basis analyses supporting the operation of the cask loading pit, its associated penetration and other penetrations in fuel transfer route are needed to cover faults involving failure of these penetrations in the spent fuel pool areas. Design basis analysis would also need to be undertaken for loss of cooling water inventory that could result in overheating of irradiated fuel outside the spent fuel pool or during fuel handling for sequences previously omitted by the safety submissions. The GDA Issue **GI-UKEPR-FS-03** was therefore raised requiring EDF and AREVA to provide such a case. In particular, the following three actions were raised:

- The need to determine the updates required to the DBA and PSA safety cases for the initiating faults associated with the cask loading pit.
- Provision of an updated safety case for the spent fuel pool area to incorporate the faults associated with the cask loading pit.
- Provision of consequence analyses for the spent fuel pool penetrations and technical openings that had previously not been considered within the design basis because of the break preclusion arguments.

To address this GDA Issue and associated Actions, EDF and AREVA provided additional information, through a series of analysis reports and technical queries. The main deliverables provided in response to this GDA Issue included a suit of reports which present a deterministic analysis of credible failures of the SFP cooling systems, and failure of penetrations in the walls of pools, which could potentially result in uncovering of fuel assemblies leading to fuel overheating. Gross failures of these penetrations are examined and postulated as bounding cases applying conventional design basis assumptions in analysing the fault transients.

The safety submission considers the internal flooding consequences of the postulated leakages from the pools, and the radiological consequences for operators involved in plant recovery and repair, and identifies additional procedures that may be required in moving the stranded fuel assembly into a safe location prior to taking recovery action.

The safety submission also reviews the operations performed within the spent fuel pool area and examines a number of options to evaluate the relevant safety benefits and mitigations to reduce the overall risk to the plant in fault conditions. As a result, it proposes a number of modifications to the design of the UK EPR™ to improve the performance of different compartments in flooded conditions thus reducing the initiating events leading to challenging consequences. The proposed design modifications, all stemming from Actions relating to the GDA Issue **GI-UKEPR-FS-03**, enhance the safety features of the UK EPR™ including:

- Upgrading the Spent Fuel Pool Cooling System to Class 1 safety classification; this will be seismically qualified to meet the relevant classification requirements.
- Provision of moveable standpipes to cover the drain lines in the Reactor Pool and Internals Compartment in the Reactor Building when these compartments are filled with water; and the provision of covers for the drain lines at the bottom of the Reactor Building Transfer Compartment, Fuel Building Transfer Compartment and Cask Loading Pit when these compartments are filled with water.
- Upgrading of the Spent Fuel Pool Water Makeup System to Class 1 safety classification which is currently part of the Fire Fighting Water Supply and Nuclear Island Fire Fighting Distribution “JAC/JPI” system. This system is seismically qualified to meet the relevant classification requirements.
- Provision of a secondary containment to envelope the Fuel Transfer Tube (FTT) to prevent significant leakages upon gross failure of the tube. This is to be achieved by sealing the rooms accommodating the FTT to contain any water released through the leak site.
- Removal of the personnel access doors to the Reactor Cavity, Reactor Building Transfer Compartment and Fuel Building Transfer Compartment, which are to be replaced with alternative access means.
- Modification of the operating procedures for the transfer of fuel assemblies from the Spent Fuel Pool to the Fuel Transfer Cask to ensure that the fixed gate between the Spent Fuel Pool and the Cask Loading Pit is closed whenever the Penetration Upper Cover is open.

The proposed design modifications are captured in a related Change Management Form.

For Actions 1 and 2 relating to the cask loading pit EDF and AREVA have provided design basis and probabilistic safety justifications that its design is adequate.

From my assessment, I have concluded that EDF and AREVA have strengthened the design basis safety case for the spent fuel pool and the adjacent compartments through the proposed design changes and new analysis performed in response to GDA Issue **GI-UKEPR-FS-03**. In my opinion the proposed modifications take into consideration the implications of the HM Chief Inspector’s final Report on Fukushima associated with the need to minimise penetrations in the design of the spent fuel pools on new reactors,

There are a few areas where additional information needs to be presented or where detailed aspects of the approach require further development. I do not however, consider these to undermine the validity of the results presented, but I have identified these as areas where additional development in the safety case is required during the detailed design phase as the site specific phase progresses. I have therefore raised a number of Assessment Findings to ensure these are resolved satisfactorily by the future licensees.

Overall, based on my assessment undertaken in accordance with ONR procedures and the modifications proposed for the UK EPR™, I am satisfied that the safety case for the cask loading pit and the penetrations in the fuel handling area presented in response to this GDA Issue is adequate. This will be subject to inclusion of the design modifications together with satisfactory progression and resolution of the Assessment Findings identified in Annex 2. The Assessment Findings are to be addressed during the forward work programme for this reactor. For these reasons, I am satisfied that GDA Issue **GI-UKEPR-FS-03** can now be closed.

LIST OF ABBREVIATIONS

ALARP	As Low As Reasonably Practicable
BIE	Bounding Initiating Events
C&I	Control and Instrumentation
CCWS	Component Cooling Water System
CHRS	Containment Heat Removal System
CMF	Change Management Form
DBA	Design Basis Analyses
EDF and AREVA	Electricité de France SA and AREVA NP SAS
EFWS	Emergency Feedwater System
FMEA	Failure Modes and Effects Analysis
FPCS	Fuel Pool Cooling System
FPPS	Fuel Pool Purification System
FSI	Fluid-Structure Interaction
FTT	Fuel Transfer Tube
GDA	Generic Design Assessment
HCLPF	High Confidence of Low Probability of Failure
HF	Human Factors
HIC	High Integrity Components
HM	Her Majesty's
HSE	Health and Safety Executive
HVAC	Heating Ventilation and Air Conditioning
IAEA	International Atomic Energy Agency
IRWST	In-Containment Refuelling Water Storage Tank
JAC	Fire Fighting Water Supply System
JPI	Nuclear Island Fire Fighting System Distribution
MCR	Main Control Room
MDEP	Multinational Design Evaluation Programme
MFWS	Main Feedwater System
NEA	Nuclear Energy Agency
NPP	Nuclear Power Plant
OECD	Organisation for Economic Co-operation and Development
ONR	Office for Nuclear Regulation (an agency of HSE)
PCC	Plant Condition Category

LIST OF ABBREVIATIONS

PCSR	Pre-construction Safety Report
PGA	Peak Ground Acceleration
PIE	Potential Initiating Event
PSA	Probabilistic Safety Assessment
RBWMS	Reactor Boron and Water Makeup System
RHR	Residual Heat Removal
RPV	Reactor Pressure Vessel
SAP	Safety Assessment Principle(s) (HSE)
SED	Nuclear Island Demineralised Water Distribution System
SFP	Spent Fuel Pool
SFPCS	Spent Fuel Pool Cooling System
SIS	Safety Injection System
SMA	Seismic Margin Assessment
SSC	Systems, Structures and Components
TAG	Technical Assessment Guide(s) (ONR)
TQ	Technical Query
TSC	Technical Support Contractor
WENRA	Western European Nuclear Regulators' Association

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1 INTRODUCTION

1.1 Background

1 This report presents the close-out part of the Office for Nuclear Regulation's (an agency of HSE) Generic Design Assessment (GDA) within the area of Fault Studies design basis analyses. This report specifically addresses the GDA Issue **GI-UKEPR-FS-03** and associated Actions (Ref. 6) generated as a result of the GDA Step 4 Fault Studies – Design Basis Faults Assessment of the UK EPR™ (Ref. 7). This GDA Issue relates to the provision of an adequate safety case to support the Spent Fuel Pool (SFP) operations and associated fuel handling areas/compartments, review the potential consequences of loss of cooling faults and the incorporation of the design changes proposed for the UK EPR™. My assessment has focussed on the deliverables identified within the EDF and AREVA Resolution Plans (Ref. 8) published in response to this GDA Issue and on further assessment undertaken of those deliverables.

2 Generic Design Assessment followed a step-wise-approach in a claims-argument-evidence hierarchy. In Step 2 the claims made by 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 presented in the safety documentation.

3 The Step 4 Fault Studies 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. A GDA Issue is an observation of particular significance that requires resolution before ONR, an agency of HSE, would agree to the commencement of nuclear safety related construction of this reactor design within the UK. An Assessment Finding results from a lack of detailed information which has limited the extent of assessment and as a result additional information is required to underpin the assessment. However, they are to be carried forward as part of normal regulatory business during the site specific phase of the project as the detailed design develops.

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 my judgement made to close GDA Issue **GI-UKEPR-FS-03**.

1.2 Methodology

5 My assessment has been undertaken in line with the requirements of the Office for Nuclear Regulation (ONR) HOW2 document PI/FWD, "Permissioning – Purpose and Scope of Permissioning" (Ref. 1), in relation to mechanics of assessment within ONR. The Safety Assessment Principles (SAPs), (Ref. 2), have been used as the basis for this assessment. Ultimately, the goal of assessment is to reach an independent and informed judgment on the adequacy of a nuclear safety case.

6 My assessment has 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.

7 The aim of my assessment is to provide a comprehensive review of the submissions provided in response to the GDA Issue to enable ONR to gain confidence that the

concerns raised have been resolved sufficiently so that they can either be closed or the less safety significant aspects be carried forward as Assessment Findings.

1.3 Structure

8 The Assessment Report structure differs slightly from the structure adopted for the previous reports produced within GDA, most notably the Step 4 Fault Studies Assessment in Ref. 7. Whilst previous reports have made extensive use of sampling, the present report builds on the previous work during GDA and focuses on the resolution of the GDA Issues. As such this report is structured around the assessment of **GI-UKEPR-FS-03** rather than a report detailing close out of all GDA Issues associated with this technical topic area.

9 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 FAULT STUDIES

10 The intended assessment strategy for GDA Close-out for the fault studies topic area was set out in a related assessment plan (Ref. 42) that identified the intended scope of the assessment and the standards and criteria that would be applied. This is summarised in the following Sections.

2.1 Assessment Scope

11 This report presents only the assessment I have undertaken as part of the resolution of the GDA Issue **GI-UKEPR-FS-03**, relating to the provision of an adequate safety case to support the Spent Fuel Pool (SFP) operations and associated fuel handling areas/compartments, and the incorporation of the design change proposed for the UK EPR™ (Ref. 22).

12 This report does not represent the complete assessment of UK EPR™ in the Fault Studies topic area for GDA, or even the complete assessment of the management and protection of fuel assemblies being stored within the spent fuel pool. I recommend that this report be read in conjunction with the Step 4 Fault Studies Assessment (Ref. 7) of the EDF and AREVA UK EPR™ reactor design in order to appreciate the totality of the assessment of the evidence undertaken as part of the GDA process.

13 Similarly, my 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 highlighted and addressed as part of the close-out phase or be identified as Assessment Findings to be taken forward to the site specific phase. As such the possibility of further Assessment Findings being generated as a result of this assessment is not precluded.

14 The full text of the GDA Issue and Actions is provided in Annex 3. Reference 7 provides further background and explanatory information on the GDA Issue and Actions. EDF and AREVA have produced an individual Resolution Plan for the GDA Issue detailing the methods by which they intended to resolve the Issue through identified timescales and deliverables. For additional information see Reference 8.

15 A number of other assessment areas particularly Structural Integrity, Internal Hazards and Human factors have provided input into the overall assessment of this Fault Studies GDA Issue, and my report is consistent with those assessments. Where necessary, for example for more significant assessment items, this is reported in more detail elsewhere as referenced in the assessment section of this report (Section 5).

2.2 Assessment Methodology

16 This report has been prepared in accordance with relevant ONR guidance (Refs. 1 and 41) in coordination with the other assessment disciplines and the scope defined in the assessment plan (Ref. 42).

17 The assessment process consists of examining the evidence provided by EDF and AREVA in responding to the GDA Issue Actions. This is then assessed against the expectations and requirements of the SAPs and other guidance considered appropriate.

18 The basis of the assessment undertaken to prepare this report is therefore:

- Submissions made to ONR in accordance with the Resolution Plan.
- Updates to the Submission / Pre-construction Safety Report (PCSR) and its supporting documentation.
- The Design Reference that relates to the PCSR as set out in UK EPR™ GDA Project Instruction UKEPR-I-002 (Ref. 9) which has been updated throughout GDA Issue Resolution to include agreed design changes.
- Design Change Submissions – which are proposed by EDF and AREVA and submitted in accordance with UK-EPR GDA Project Instruction UKEPR-I-003, (Ref. 10).
- Consideration of internal and international standards and guidance, international experience, operational feedback and expertise and assessments performed by other regulators, especially their findings.
- Interaction with other relevant technical areas, where appropriate.
- Raising and issuing of Technical Queries (TQ) as appropriate, followed by assessment of Requesting Party (RP) responses.
- Holding necessary technical meetings to progress the identified lines of enquiry.

2.3 Assessment Approach

19 The approach to the closure of GDA for the UK EPR™ is described in greater detail in the Fault Studies assessment plan (Ref. 42) and is based upon the assessment methodology described above. The assessment covers the submissions made by EDF and AREVA in response to GDA Issues identified through the GDA process. These submissions are detailed within the EDF and AREVA Resolution Plans for each of the GDA Issues. The closure of each Fault Studies GDA Issue is reflected in a dedicated assessment report to describe the assessment process from the position established at the end of Step 4.

20 The overall strategy for closure of GDA is to build upon the assessment conducted during Step 4 and earlier, focussing on the detailed examination of the evidence presented by EDF and AREVA to support the satisfactory resolution of the GDA Issue Actions.

21 The following subsections provide an overview of the outcome from each of the information exchange mechanisms in further detail.

2.3.1 Technical Queries

22 I issued one Technical Query to EDF and AREVA relating to the operation of the proposed upgrades to the SFP cooling systems during close-out of **GI-UKEPR-FS-03** for UK EPR™, (Ref. 13).

23 I assessed EDF and AREVA's responses to this TQ as part of this assessment. Commentary on the most important and relevant TQ responses is included in the assessment section later in this report as appropriate. The responses provided by EDF and AREVA to these actions supplied further evidence supporting the overall judgement on the adequacy of resolution of the GDA Issues.

2.3.2 Technical Meetings

24 Provisions were made for a series of technical meetings with EDF and AREVA during assessment of the GDA Issue Action responses. These meetings occurred at appropriate points during 2011 and 2012 to monitor progress on the development of the safety enhancements resulting from the proposed modifications. I was also supported by colleagues from Structural Integrity and Internal Hazards together with colleagues from Human Factors disciplines, where appropriate, to cover significant concerns raised in the resolution of this GDA Issue. These meeting were complemented by a number of teleconferences and smaller meetings, as necessary.

25 The principal focus of the meetings was to discuss progress and responses, to facilitate technical exchanges and to hold discussions with EDF and AREVA technical experts on emergent issues.

2.4 Standards and Criteria

26 In assessment of submissions supporting the closure of the **GI-UKEPR-FS-03** GDA Issue for UK EPR™, my judgements have been made against the 2006 HSE Safety Assessment Principles (SAP) for Nuclear Facilities (Ref. 2). In particular, the fault analysis and design basis accident SAPs (FA.1 to FA.9), the severe accident SAPs (FA.15 to FA.16), the assurance of validity SAPs (FA.17 to FA.22), the numerical target SAPs (NT.1, Target 4, Target 7 to Target 9) and the engineering principles SAPs (EKP.2, EKP.3, EKP.5, EDR.1 to EDR.4, ESS.1, ESS.2, ESS.7 to ESS.9, ESS.11, ERC.1 to ERC.3) have been considered. The Integrity of Metal Components and Structures are covered by engineering principles, EMC.1 to EMC.3. The following international standards and guidance have also been used as part of this assessment

- Safety of Nuclear Power Plants: Design. Safety Requirements. International Atomic Energy Agency (IAEA). Safety Standards Series No. NS-R-1 (Ref. 5).
- Western European Nuclear Regulators' Association (WENRA) Reactor Reference Safety Levels (Ref. 4).

27 The principle SAPs considered relevant to the close-out assessment are listed in Table 1.

28 In addition, the following principle Technical Assessment Guides (TAG) have been used as part of this assessment (Ref. 3):

- T/AST/034 – *Transient analysis for Design Basis Accidents in Nuclear Reactors*;
- T/AST/030 – *Probabilistic Safety Analysis*;
- T/AST/017 – *Structural Integrity Civil Engineering Aspects;* and
- T/AST/013 – *External Hazards.*

29 EDF and AREVA have assessed the safety case against their own design requirements.

2.5 Use of Technical Support Contractors

30 It has not been necessary to employ the services of a Technical Support Contractor (TSC) as part of my assessment and resolution of this GDA Issue.

2.6 Out-of-scope Items

31 EDF and AREVA have added no items as out of scope to those identified during the Step 4 assessment.

2.7 Working with Other Regulators

32 Interface with other international regulators has been principally by multilateral contact which has helped me to share the latest developments in this topic area. The contacts were enabled through Organisation for Economic Co-operation and Development (OECD) Nuclear Energy Agency (NEA) working group meetings in the context of the Multinational Design Evaluation Programme (MDEP) and other OECD ongoing NEA research working groups.

3 BACKGROUND TO THE GDA ISSUE AND EDF AND AREVA'S RESPONSES

3.1 Overview of the EDF and AREVA Safety Case for the Spent Fuel Pool

33 The design of the spent fuel pool, its cooling system and the fuel route is described in the PCSR (Ref. 12), with the requirements for spent fuel cooling set out in the system design manual (Ref. 26).

34 The main safety criteria for faults in the spent fuel pool are that the fuel remains covered by water while in the storage racks, and that sub-criticality is preserved. In addition, the fuel is needed to be covered by water while being handled and transferred in the fuel route.

35 The spent fuel pool purification and cooling system {Spent Fuel Pool Purification System / Spent Fuel Pool Cooling System (FPPS / FPCS)} is required to remove the decay heat from spent fuel assemblies in the pool. The FPCS comprises two identical main trains, each equipped with two pumps and a heat exchanger cooled by the Component Cooling Water System (CCWS). The system also includes a third train as an independent diverse cooling expected to operate when the main cooling trains are unavailable. The third train is equipped with a single pump and a heat exchanger supplied by the component cooling train. It also contributes to the containment of radioactive substances by preventing the fuel in the storage rack from being uncovered.

36 The FPPS / FPCS is designed such that a leak or a break from the system will not result in the direct uncovering of fuel stored in the SFP rack, even without any isolation action. Draining through a pipe connected to the pool should not lead to the uncovery of an assembly being handled before the drainage pipe can be isolated or the fuel placed in a safe position. If the drainage leads to a loss of cooling, then emergency makeup is available to avoid the delayed uncovering (as a result of boiling or evaporation) of fuel in the rack and to re-establish the water level to a height sufficient to allow the restart of at least one train of FPCS. In addition, Makeup water is available from the IRWST, Reactor Boron and Water Makeup System (RBWMS), the demineralised water supply and the fire protection systems.

37 Design basis spent fuel pool faults are considered in the PCSR Chapter 14, alongside reactor faults. They are also described in the Fault Schedule, Sub-chapter 14.7 of November 2009 PCSR. For all Plant Condition Category (PCC) faults, the PCSR imposes a temperature limit criteria of 80°C for faults without draining and no boiling for faults involving a fuel pool draining (with the long term temperatures returning to below 80°C once FPCS has been restored). A temperature limit of 95°C is applied for RRC-A faults, which is further covered as part of the discussion and assessment of the SFP within the GDA Step 4 Fault Studies – Design Basis Faults Assessment of UK EPR™ reactor design (Ref. 7).

38 Isolatable piping failures on systems connected to the spent fuel pool (in all reactor operating states) are identified as PCC-3 design basis incidents. For some of the identified pipe failures, the elevation of the pipes or anti-siphon devices prevent the pool water draining to a level where the main FPCS pumps would automatically shutdown. For a piping failure on a skimming line, it is claimed that the operator has sufficient time following the raising of low level alarms to remove the floating skimming device (only used in the Reactor Building), reach a controlled state and subsequently reach a safe shutdown state.

39 For failures in the FPCS pipework on the suction side of the pumps, water could drain down beyond the automatic shutdown level of the FPCS pumps. Provision of siphon

breakers and / or uncovery of the suction pipe stop the level from dropping too low and it is claimed that the breached FPCS train can be isolated using two redundant valves on the suction pipe.

40 An isolatable break in a pipe in the Safety Injection System (SIS) (<250 mm diameter) or a non-isolatable break in a line connected to the primary circuit (<50 mm diameter) could result in the drainage from the spent fuel pool if it occurred during cold shutdown with the reactor cavity flooded for refuelling. These faults are identified as PCC-4 design basis accidents. For the isolatable break, it is claimed that the SIS / (Residual Heat Removal) RHR suction line will be automatically isolated by the closure of two redundant motorised valves upon detection of a low water level in the reactor building transfer compartment.

3.2 Assessment during GDA Step 4

41 The full Assessment of the UK EPR™ Spent Fuel Pool safety case during Step 4 is reported in Ref. 7.

42 The spent fuel assemblies are exported from the facility via the Cask Loading Pit. When necessary, the Cask Loading Pit will be filled with water from the Fuel Building Transfer Compartment, which will be emptied. The fuel assembly will be lifted out of the underwater fuel storage rack in the SFP using the Spent Fuel Mast Bridge, transferred to the Cask Loading Pit and lowered into a shielded cask, located at the base of the Cask Loading Pit. Once loaded and conditioned, the cask will be transported from the facility.

43 During GDA Step 4 assessment of the UK EPR™ SFP safety case, it became apparent that faults associated with the Cask Loading Pit and the despatch of fuel from the SFP had not been considered in the PCSR (either deterministically or in the PSA). The Cask Loading Pit is usually isolated by a hinged, permanent water-tight door and when empty, further isolated by a Penstock. However, to remove spent fuel from the pool, these doors and gates are opened. Fuel is despatched through a penetration in the bottom of Cask Loading Pit into a “docked” spent fuel cask. This operation and the installed systems which facilitate it have the potential to cause faults which are a threat to either the spent fuel in the storage racks or to an individual fuel assembly being handled.

44 Subsequent interactions with EDF and AREVA, including a visit to Chooz B Nuclear Power Plant (NPP) in France which has a similar design of SFP to that proposed for the UK EPR™, established that the design of the Cask Loading Pit and the management of transporting spent fuel off-site is a mature process that builds upon operational experience in France.

45 In discussions with EDF and AREVA, evidence has been provided to show that the Cask Loading Pit design provides features that guard against potential faults, including preventive, defence in depth measures and mitigation features. It was therefore concluded that it should be possible for EDF and AREVA to make an acceptable safety case for their Cask Loading Pit design, including the despatch of fuel through a penetration in its base. For this reason, **GI-UKEPR-FS-03**, Actions 1 and 2 was raised requiring EDF and AREVA to provide such a case. The GDA Issue required EDF and AREVA to provide both design basis analysis, probabilistic safety analysis and update the subsequent safety case accordingly.

46 The Actions from this GDA Issue required that the design basis analyses supporting the Cask Loading Pit relating to its operation and penetration should be revisited. The Actions requested that this should be done within the Pre-construction Safety Report to cover the faults involving water inventory reductions in the SFP and other pools which

could potentially result in overheating of irradiated fuel outside the reactor in normal operation or during fuel handling.

47 In addition, the consolidated PCSR for GDA Step 4 identified that leaks from a number of non-isolable sections of pipe associated with the SFP were excluded from the design basis analysis by invoking the break preclusion approach for these sections of pipe.

48 The UK EPR™ safety case identifies a small number of components where gross failure has not been addressed in the deterministic safety analyses and where in general it cannot be justified that the consequences of failure are acceptable (Ref. 32). These are identified as the High Integrity Components (HIC), and a rigorous demonstration over and above normal pressure vessel design code requirements is necessary in order to show that the likelihood of gross failure is sufficiently low that it can be discounted in line with SAPs EMC.1 to EMC.3.

49 The safety case as presented in GDA Step 4 consolidated PCSR did not identify these non-isolable sections of pipe associated with the spent fuel pool as HIC. The break preclusion approach referred to in the safety case is a methodology applied in France for excluding failure from pipework, but does not in itself provide the level of justification required by the ONR Safety Assessment Principles that the likelihood of failure is so low that it can be discounted in the UK EPR™ safety case. Thus the failure of these non-isolable sections of fuel pool pipework had been excluded from the design basis analysis without the level of justification required by ONR for such components.

50 GDA Issue **GI-UKEPR-FS-03,** Action 3, was therefore created to provide a consequence analysis of the leaks from this pipework and to identify the design features and systems required to ensure that the consequences are acceptable.

51 The Resolution Plan (Ref. 8) provided by EDF and AREVA in response to GDA Issue **GI-UKEPR-FS-03** was broken down into the component of GDA Issue Actions discussed in Section 3.3.

52 The approach for Action 3 was to provide design basis analyses of the consequences of failure on these non-isolable sections of pipework with a consideration of enhancements to the current design should the consequences be found to be unacceptable.

53 The failure mode for the pipework was identified to be a leak with area of Dt/4 [1] rather than a guillotine failure due to the pipework being classed as a medium energy system (<20 bar and 100^{o}C) with a nominal diameter greater than 50 mm in a safety classified system.

54 In addition to these considerations, ONR took the opportunity to review the implications of Recommendation 14 of the Final HM Chief Inspector of Nuclear Installations Report on Fukushima event (Ref. 31) associated with the need to minimise penetrations in the design of the spent fuel pools on new reactors. This recommendation covers the claims made in relation to pipe failures as well as the claims associated with the lower penetrations and openings within the spent fuel pool and the adjacent compartments.

55 The safety submission also considers the internal flooding consequences of the postulated leakages from the pools, and the radiological consequences for operators involved in plant recovery and repair. It also identifies additional procedures that may be required in returning the stranded fuel assembly to a safe location prior to taking recovery

[1] Where “D” is the Diameter, and “t” represents wall thickness

action. All relevant plant states are considered in the analysis, including normal operation, core loading and unloading operations, and operations involving transfer of spent fuel to the fuel cask.

56 The GDA Issue for the Spent Fuel Pool Safety Case, including Action 3, is shown in Annex 3.

3.3 Summary of the GDA Issue and Actions

57 GDA Issue **GI-UKEPR-FS-03** and its associated three Actions are given in Ref. 6. Further explanatory information on the resolution of this Issue and Actions is provided in Ref. 8.

58 On the basis of the claims, arguments and evidence presented to the end of Step 4, it was considered that the UK EPR™ safety case related to the SFP and associated fuel handling areas/compartments required further work in three discrete areas before I could be satisfied for resolution of the GDA Issue.

59 The following provides the Actions associated with the GDA Issue **GI-UKEPR-FS-03** generated as a result of the Step 4 Fault Studies – Design Basis Faults Assessment that require EDF and AREVA to:

Action 1:

- Evaluate cask loading pit initiating events and determine the updates required to DBA or PSA safety cases for faults associated with the cask loading pit, covering the relative importance of administrative controls, interlocks, equipments, equipment classification, operator actions and associated claims.

Action 2:

- Provide an updated safety case for the spent fuel pool, incorporating the faults associated with the cask loading pit covering faults identified by Action 1. If additions to the DBA are required; the category of the additional events (PCC-3 and 4) should be determined and adequate calculations or As Low As Reasonably Practicable (ALARP) analysis undertaken.

Action 3:

- Provide consequences analysis for spent fuel pool leaks previously excluded from the design basis analysis presented in the PCSR by evoking a break preclusion concept. Rigour is required to show that the likelihood of failure is so low that the consequences of failure can be discounted. A consequences analysis of the identified leaks is to be provided, and a safety case, with accompanying ALARP arguments, identifying the design features and systems required to ensure the consequences are acceptable.

60 The information provided by EDF and AREVA in response to this GDA Issue, as detailed within their Resolution Plan (Ref. 8), was broken down into the component GDA Issue Actions and then further broken down into specific deliverables for detailed assessment.

4 EDF AND AREVA DELIVERABLES IN RESPONSE TO THE GDA ISSUE

61 The information provided by EDF and AREVA in response to this GDA Issue, as detailed within their Resolution Plan (Ref. 8), was broken down into the component GDA Issue Actions and then further broken down into specific deliverables for detailed assessment:

GDA Issue Action	Technical Area	Deliverable	Ref.
GI-UKEPR-FS-03.A2	Impact on the Probabilistic Safety Assessment of the initiating events identified for the Cask Loading Process	ECESN120833 Rev A	27
GI-UKEPR-FS-03.A2	Design Basis analysis of faults associated to the spent fuel pool safety case	ECESN120587 Rev A	49
GI-UKEPR-FS-03.A1	Failure Mode and Effects Analysis for the Spent Fuel Mast Bridge	ECESN120111 Rev A	50
GI-UKEPR-FS-03.A1	FMEA for the Spent Fuel Pool Isolation gates, the Spent Fuel Cask Transfer Facility and burn up device	ECESN110231 Rev A	45
GI-UKEPR-FS-03.A1	Quantification of the New Initiating Events Identified for the Spent Fuel Cask Transfer Facility and SF Loading Process	ECESN112038 Rev A	46
GI-UKEPR-FS-03.A1	Estimated reliability parameters of PTR [FPCS], PMC [FHS] and DMK (spent fuel handling) systems equipment used for fuel building pool leak prevention and fuel handling	D4550.34/4134 Rev A	51
GI-UKEPR-FS-03.A2 & A3	Spent Fuel Pool Safety Case	PTS DC 10, Rev C	36
GI-UKEPR-FS-03.A1	Upgrade of the Safety Classification of the two main Spent Fuel Pool Cooling Chains	Change Management Form #38	9
GI-UKEPR-FS-03.A3	Modification to install cover plates and standpipes over floor drains in flooded compartments	Change Management Form #70	9
GI-UKEPR-FS-03.A2	Upgrade of classification of SFP make up Safety Feature (part of JAC/JPI	Change Management Form #71	9
GI-UKEPR-FS-03.A2	Modification to provide leaktight containment of the FTT	Change Management Form #72	9
GI-UKEPR-FS-03.A3	Modification to remove personnel access doors to the flooded compartments	Change Management Form #73	9

GDA Issue Action	Technical Area	Deliverable	Ref.
GI-UKEPR-FS-03.A1	Modification to Cask Loading Procedure	Change Management Form #74	9
GI-UKEPR-FS-03.A1 to A3	PCSR – Sub-Chapter 16.4	Specific Studies	38

62 An overview of the key deliverable is provided within this section. It is important to note that this information is supplementary to the information provided within the November 2009 and March 2011 PCSR (Refs. 11 and 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 the fault studies topic. Rather they form further detailed arguments and evidence to supplement those already provided during earlier Steps within the GDA Process.

63 The principal submission in support of the GDA Issue **GI-UKEPR-FS-03** is the updated SFP safety case presented in Ref. 36. This submission covers the faults involving the loss of water inventory within the SFP and the adjacent compartments which could potentially result in overheating of irradiated fuel that may be stranded outside the reactor in the normal operation or fuel handling operation during refuelling.

64 EDF and AREVA (Ref. 36) provide a deterministic analysis of the credible failures of the cooling systems; penetrations; personnel access doors and engineered openings in the walls of the pools. The failure of any of these could potentially result in uncovering the fuel assemblies and with consequent fuel overheating. Gross failure of these penetrations are postulated as bounding cases using conventional design basis assumptions in analysing the fault transients.

65 The updated safety case also considers internal flooding consequences of the postulated leakages from the flooded SFP areas, and the radiological consequences for operators involved in plant recovery and repair.

66 All relevant plant states are considered in the analysis, including normal operation, core loading and unloading operations, and operations involving transfer of spent fuel to the Cask Loading Pit for ultimate transport from the facility.

67 EDF and AREVA have proposed (Ref. 36) a number of design modifications for the prevention and mitigation of the postulated faults. Relevant design modifications to improve resilience of the plant against beyond design basis faults that have been introduced following the Fukushima event are also reviewed within Ref. 36.

5 ONR ASSESSMENT

68 Further to the assessment work undertaken during Step 4 (Ref. 7), and the resulting GDA Issue **GI-UKEPR-FS-03** (Ref. 6), my assessment focused on substantiation of the approach adopted in preparation of the spent fuel pool safety case. This covered management and protection of fuel assemblies whilst being transferred between different compartments within the fuel route, and potential consequences associated with a failure of the water tight barrier to perform the required safety function when the compartments are flooded. Identified deliverables intended to provide the requisite evidence was provided within the responses contained in the Resolution Plan (Ref. 8) provided by EDF and AREVA at the end of Step 4 of GDA.

69 This assessment has been carried out in accordance with the ONR HOW2 document PI/FWD, “Permissioning – Purpose and Scope of Permissioning” (Ref. 1).

5.1 Scope of Assessment Undertaken

70 The scope of the assessment has been to consider the expectations described in the GDA Issue, **GI-UKEPR-FS-03**, and the associated GDA Issue Actions. These are detailed within Annex 3 of this report. For each of the following areas further evidence was sought by the provision of documentation covering the following topics:

- A revised safety case including the evaluation of the Cask Loading Pit initiating events and to determine the updates required to DBA or PSA cases for faults associated with the Cask Loading Pit.
- An updated safety case for the spent fuel pool incorporating the faults associated with the Cask Loading Pit.
- Provision of the consequence analysis for spent fuel pool leaks which are excluded from the design basis analysis, and justification of the structural integrity claims supporting the overall safety case for the spent fuel pool.

71 The scope of this assessment is neither to undertake further assessment of the PCSR nor to extend this assessment beyond the expectations stated within the GDA Issue Actions. However, should information be identified that has an affect on the claims made for other aspects of fault studies such that the existing safety case is undermined, these have been addressed.

5.2 Spent Fuel Pool Cooling System

72 The decay heat of spent fuel assemblies stored within the SFP is removed by dedicated closed cooling loops that pump the water from the pool, through a heat exchanger before it is returned to the SFP at a lower level. The Fuel Pool Cooling System (FPCS) comprises of three independent cooling trains; two constituting the main cooling trains (trains 1 and 2) and a third train, offering a diverse line of protection against increase in the spent fuel pool bulk temperature.

73 The concern relating to the load and availability of the cooling system supporting the spent fuel pool during beyond design basis accident conditions was highlighted during the tsunami damaged Daiichi nuclear power plants in Fukushima. This issue is also the subject of the GDA Issue **GI-UKRPR-CC-03,** which is assessed and reported in Ref. 23. However, due to its significance within the spent fuel pool safety case, the key safety related aspects of the cooling system are covered in this report.

74 In the UK EPR™ design, the FPCS loops 1 and 2 are two identical trains that provide the main cooling function for the SFP. Each train is equipped with two pumps delivering 100% of the required flowrate to remove the decay heat and a heat exchanger supplied by the reactor Component Cooling Water System (CCWS). Each train is assigned to one of the two CCWS headers, allowing each train to be supplied by one of the two CCWS trains. Each of the geographically segregated main spent fuel pool cooling trains 1 and 2 is supplied by a different electrical train and may be supplied by a neighbouring train during electrical switchboard maintenance operations. The outline schematic diagram of one of the main cooling trains, where the train is in service, is shown in Figure 1.

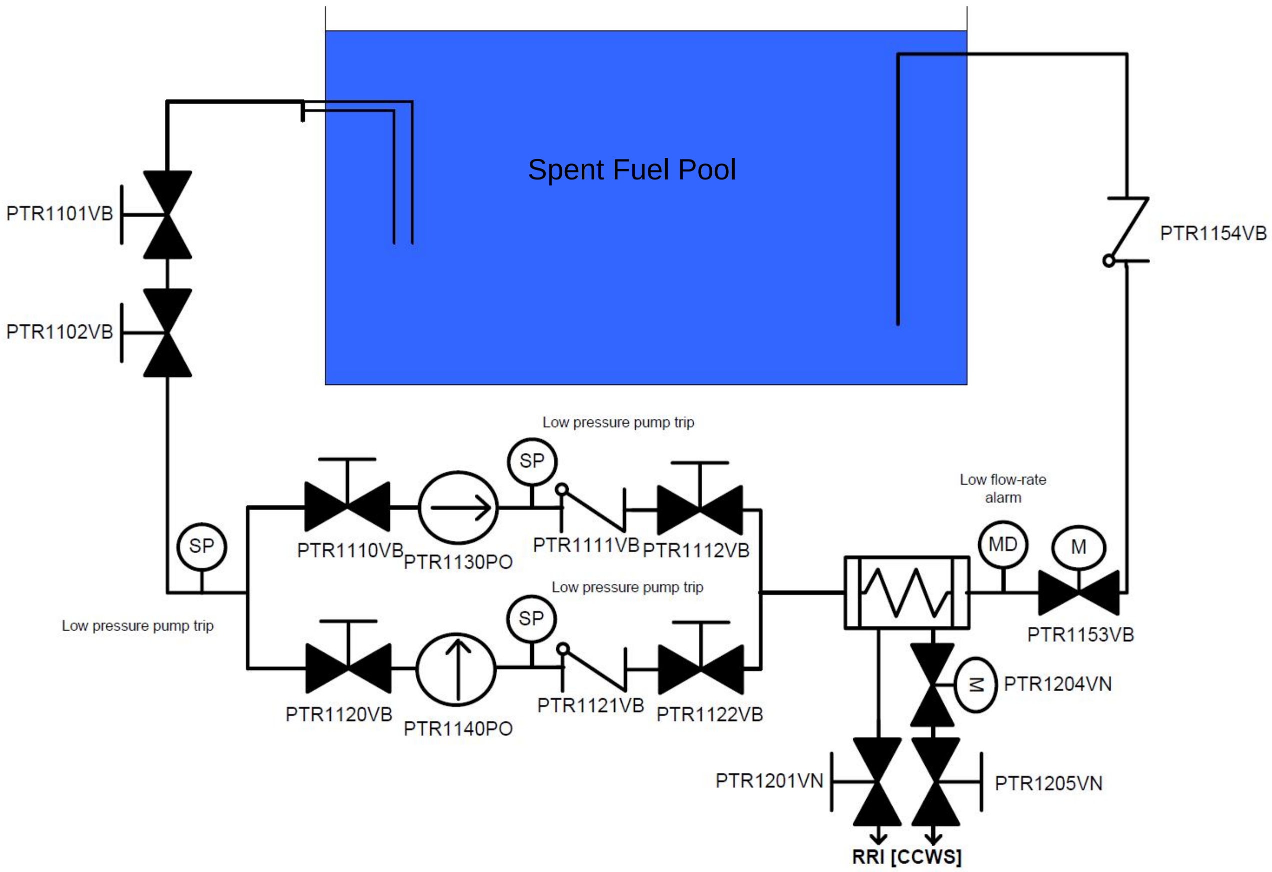

Figure 1. Schematic view of the FPCS Main Cooling Train 1 – Single Pump in Service

75 The third train is developed as an independent diverse cooling system that will be expected to operate when the main cooling trains are unavailable. The third train is equipped with a single pump and a heat exchanger supplied by the component cooling train shared with the Containment Heat Removal System (CHRS) and fully independent of the CCWS. The 3rd train of the SFP cooling system is supplied by electrical division 1 and may also be supplied by electrical division 2 during electrical switchboard maintenance operations. The outline schematic diagram of the 3rd cooling train, where the train is in service, is shown in Figure 2.

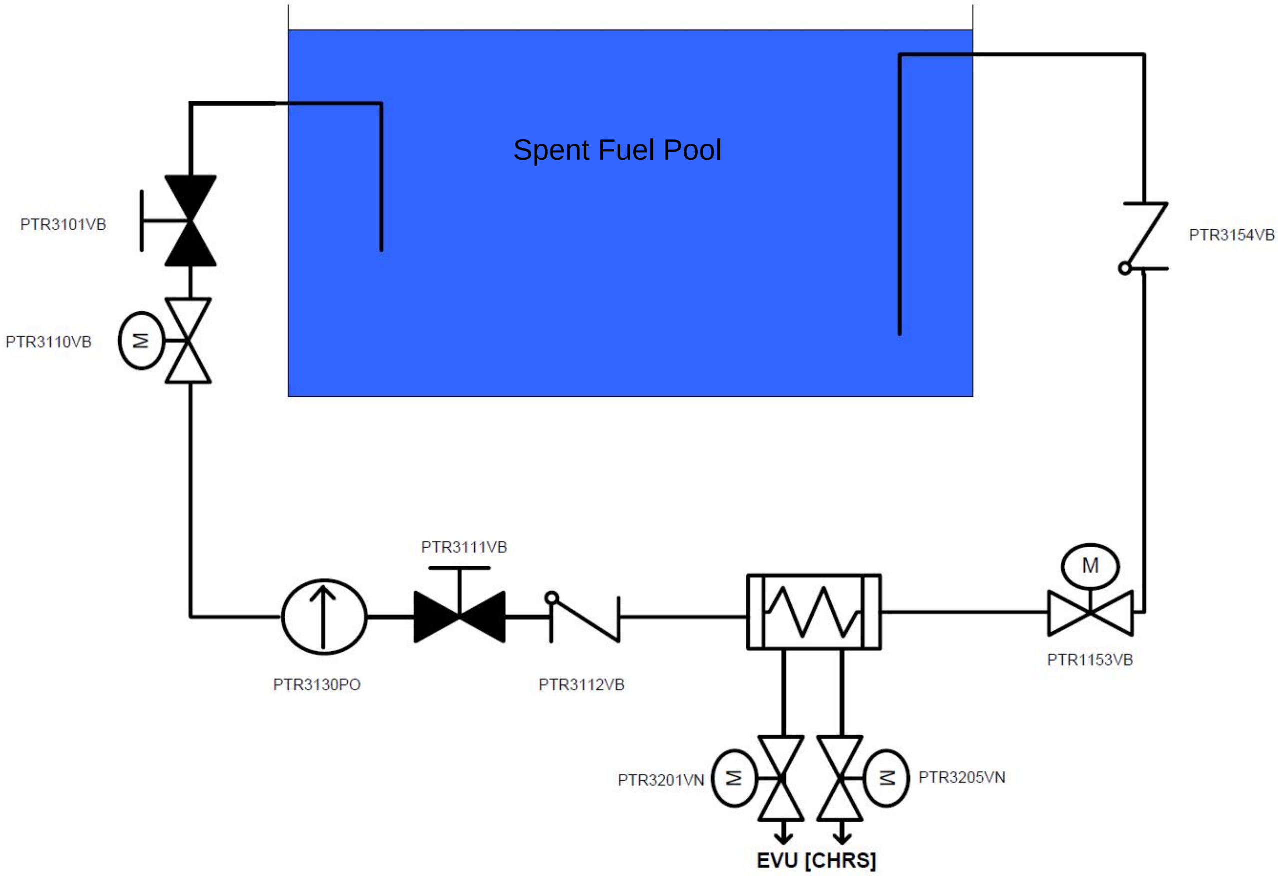

Figure 2. Schematic view of the FPCS 3rd Cooling Train – Pump in Closed Position

5.2.1 Safety Case Approach

76 The original design of the SFP two main cooling trains was classified at Class 2, with the third cooling train being classified at Class 3. The cross cutting GDA Issue Action **GI-UKRPR-CC-01.A7** was raised at the GDA Step 4 review of the UK EPR™ (Ref. 24) requesting justification of allocation of Class 2 Systems, Structures and Components (SSC) classification relating to the spent fuel pool main cooling system. In response to this GDA Issue Action, EDF and AREVA have performed a full review of the SFP cooling system which was supported by an ALARP examination of the risks to the operation of the system.

77 EDF and AREVA have subsequently developed and examined three different options and tested these against the safety functional requirements expected from these systems. The study has resulted in reclassification of the spent fuel pool cooling system as this is designed to offer the first line of defence in removing the decay heat from the stored fuel. The safety submission discusses the operator intervention in successful initiation of the cooling systems and concludes that the operator actions can be successfully completed in sufficient time to prevent prolonged loss of functionality from the proposed systems in such a time scale that will not degrade single phase cooling capability.

5.2.2 Safety Classification of the SFP Cooling Trains

78 In response to the cross cutting GDA Issue Action, **GI-UKEPR-CC-01.A7,** EDF and AREVA provided (Ref. 17) the results of analysis to demonstrate that reasonably practicable measures are adopted in deriving the safety classification of the SFP cooling trains. The analysis examines three different options on operational and functional requirements which included the system safety features relating to the start-up of the main cooling systems. This study concludes that considering the main functional requirement of the system is to offer a first line of protection to remove heat from the SFP and to minimise the frequency of loss of cooling to the pool, the system is to be developed to meet the requirements of a Category A function requiring at least one Class 1 system. This spent fuel pool cooling train includes a redundant protection line that is supplied from the same feeder within the SFP. The modification for the system upgrade is covered by **UKEPR-CMF-38.**

79 EDF and AREVA have given a commitment (Ref. 19) to upgrade the SFP cooling system and have identified the scope of the associated design changes in Ref. 18 which will be taken forward and applied during the detailed design phase of the site specific licensing process of the UK EPR™. The general requirements associated with the classification of structures, systems and components are provided in Ref. 20. This has been assessed and reported as part of the cross cutting GDA Issue **GI-UKEPR-CC-01** on classification and categorisation closure report (Ref. 21).

80 EDF and AREVA have also developed (Ref. 17) a diverse third line of protection to remove the decay heat from the SFP when the main cooling trains are not available. This train is initiated manually. The Control and Instrumentation (C&I) signals for the two primary SFP trains are treated via the reactor protection system, and the signals operating the third diverse line of cooling system, that is provided to protect against the loss of cooling, is treated via the safety automation system. The system offering the diverse line of protection is to be developed at Class 2 which is covered by the relevant form **UKEPR-CMF-36.**

81 Figure 1 presents the schematic diagram of one of the cooling trains and its main components that are provided to remove heat loading from the SFP. I note the absence of a zero flow line around the pumps in the cooling trains, which is normally included as part of the system to protect the pump and supply piping in situations where the pump is inadvertently aligned and operated with a valve downstream being shut.

82 In response to a query in TQ-EPR-1616 (Ref. 13) relating to the absence of a zero flow line, EDF and AREVA have stated that the valves around the pumps are normally open (except during maintenance periods) to allow the start-up of a pump or a cooling train from the Main Control Room (MCR) without the need for any local action. The TQ response also indicates that in the case of misalignment an alarm on low flow in the discharge line is initiated into the control room. It is also claimed that, should the problem remain, and pressure sensors detect low flow on the common suction side and/or discharge of the pump, it will be automatically tripped. EDF and AREVA have therefore concluded that the mechanical configuration and the design of the C&I justifies the absence a of zero flow line around the pumps within the main SFP cooling trains.

83 I have considered the response and judge that whilst the presence of the instrumentation to monitor the flow in the discharge line informing the operator of fault conditions within the coolant line offer some protection to the pump and adjacent piping, it is unlikely to be an adequate justification to protect the pumps in fault conditions or misalignments. Specifically, in accordance with SAP FP.3 and EKP.1, I consider that the current proposals which rely on the C&I do not demonstrate a robust protection of the system for

continued operation. In addition to the expectation set out in SAP EDR.1, I note that IEC 61508 - Part 1 Sections 7.4 and 7.6 recommending that where effective solutions can be achieved by adopting simpler technology that may offer advantages because of the reduced complexity in operation and maintenance, it should be employed. The utilisation of this approach may also be critical to achieving the required functional safety in actual operation.

84 From the information provided in response to TQ-EPR-1616 (Ref. 13) and supporting information, I have judged that there is a lack of clarity in strategy for tripping the pump in adverse conditions in order to minimise risk to plant operation. I have therefore raised an Assessment Finding requesting the licensee to perform an examination of the proposed option to further explore the advantages of such a concept during the detailed design phase as part of the site specific activities. This justification is expected to provide a justification of the SFP cooling system configuration and the reliance on the C&I to protect the system. The justification should also demonstrate sufficient level of integrity of the proposed claims on the C&I to maintain and protect the operation of the cooling system.

85 The following Assessment Finding has therefore been raised:

> ***AF-UKEPR-FS-77:*** *The Licensee shall provide a justification of the proposed system configuration to demonstrate that reliance on the C&I to protect the FPCS pumps and adjacent piping is most appropriate for the overall system availability and operation*.
>
> ***Required timescale:*** *Install RPV*

5.2.3 Support System to the SFP Cooling Trains

86 In addition, EDF and AREVA propose in Ref. 17 to initiate the third cooling train when the main cooling trains are unavailable either due to maintenance, loss of secondary coolant from CCWS or a generalised station blackout. Ref. 17 also provides an overview of the equipment supporting the operation of the third train of the SFP cooling system.

87 The proposed third cooling train utilises the CHRS cooling capability as the heat sink within its heat exchanger and the current submission does not discuss the overall heat removal capability of the CHRS when in demand. For this reason, in TQ-EPR-1616 (Ref. 13), I requested EDF and AREVA to provide justification that the third train will meet the expected safety classification; and that the CHRS will have adequate capacity in prolonged accident conditions such that the overall heat removal capability of the system is not degraded. In their response, EDF and AREVA have indicated that the evidence to justify the classification of the diverse line of protection is analysed as part of the GDA Issue Action **GI-UKEPR-CC-01.A05** using the classification approach provided in Ref. 20. This approach is proposed to be applied during the detailed design phase as part of the detailed site specific activities. It should be noted that sample assessment of this submission has been performed by other disciplines and it is reported in close out of the Classification of the UK EPR™ Cross Cutting GDA Issue report, Ref. 21.

88 In addition, EDF and AREVA, in their response state that the third train cooling chain is qualified for long term operation and in environments that may exist in severe accident conditions. They have also given assurances that consideration has been given to the requirements of this cooling train and the CHRS is configured to provide heat removal capability to the system in prolonged accident conditions. In the absence of substantiated qualification of the cooling load of the system, I have raised an Assessment Finding requesting the licensee to perform an assessment of the loading on the CHRS in

prolonged accident conditions during the detailed design phase as part of the detailed site specific activities. This justification is expected to provide the system configuration and the total heat loading on the system.

89 The following Assessment Finding has been raised:

> ***AF-UKEPR-FS-78:*** *The Licensee shall provide a justification of the proposed system configuration to demonstrate that the heat loading from the SFP cooling system does not degrade the CHRS operation and performance in prolonged accident conditions*.
>
> ***Required timescale:*** *Mechanical, Electrical and C&I Safety Systems, Structures and Components – Delivery to site*

5.2.4 Manual Intervention and Operation of the SFP Cooling Trains

90 The successful initiation and operation of the proposed SFP cooling system presented in Ref. 17 requires a combination of local to the plant manual and remote activities for its successful operations. EDF and AREVA in this submission offer no evidence that the Human Factors (HF) and Probabilistic Safety Assessment (PSA) has been employed in design of this system. For this reason, in TQ-EPR-1616 (Ref. 13), I requested EDF and AREVA to provide confirmation that human factors and PSA has been used to support the design development of the system. In their response, EDF and AREVA have provided assurances that the adequacy of the Spent Fuel Pool Cooling System (SFPCS) has been subject to a PSA, and the human interventions and actions relating to the operation of the system have been modelled in the PSA study.

91 The response also states that for the actuation of a SFPCS train from the Main Control Room, a human failure is considered with a probability of [redacted]. For the actions outside of the Main Control Room, a human failure is considered with a probability of [redacted]. With these figures, for the loss of cooling events, the frequency of boiling in the SFP is evaluated at [redacted], and the frequency of any stored fuel damage is evaluated at [redacted]. Although no proportionate substantiation has been provided for the claims for manual action supporting the preferred option for the design basis case.

92 Based on these PSA results, EDF and AREVA have considered that the design of the SFPCS meets the overall objective of safe operation of the system. The plant operability and human interactions issues relating to plant operations are assessed as part of the overall plant performance in normal operating and accident conditions within the Human Factors discipline. The acceptability of reliance on manual actions as the ALARP option is considered to be dependent on potential disadvantages arising from automation of the manual actions, which is further considered in the Identification and Substantiation of human safety claims close-out report of the GDA Issue **GI-UKEPR-HF-01** (Ref. 25).

5.2.5 Spent Fuel Pool Water Make-up System

93 The cooling function of the SFP is provided by a main cooling system consisting of three cooling trains (discussed in the previous Sections), which is backed-up by a diverse emergency makeup system designed to keep the fuel assemblies covered if the main system fails. This additional water supply from the Fire Fighting System (JAC) system, which is delivered via the Nuclear Island Fire Fighting System (JPI) and can be used to make up water loss within the SFP at a rate of 150 m^3/h. The system includes a

dedicated sub-system which is designed to provide a diverse means of cooling to the Spent Fuel Pool by supplying emergency make-up water to prevent uncovering of fuel assemblies in the event of failure of the cooling trains of the spent fuel pool cooling system.

94 The SFP make-up function of the JAC/JPI systems is further described in Ref. 36. The make-up is supplied by either of two redundant lines routed through Safeguard Building 1 and 4, and it is actuated manually from the MCR by operation of motorized valves in response to an SFP low level alarm. Two redundant supply tanks are provided in the JAC system as a water storage source, which have a total capacity of 2600m^3. An overview (3D representation) of the spent fuel pool water make up system is shown in Figure 3.

[redacted]

Figure 3. Schematic view of the Spent Fuel Pool Emergency Water Make-Up Pipes

95 The safety feature group providing the diverse make-up function within the JAC/JPI was previously at Class 2 but EDF and AREVA have upgraded this subsystem to Class 1 as an outcome of the discussions during the closure of this GDA Issue as reflected within the SFP safety case (Ref. 36).

96 The modification to upgrade the make-up safety classification is also supported by the additional complementary analysis work that EDF and AREVA have performed resulting from the post-Fukushima review. This system is to provide a further ultimate make-up system for the SFP using a motor driven pump and dedicated supply pipework that would be available in beyond design basis accident conditions involving total loss of AC power.

97 In addition, EDF and AREVA in Ref. 20 set out the requirement for at least one Class 1 protection system to be available to reach a controlled state in infrequent events is satisfied. Upgrading the make-up system to Class 1 will allow the system to be tolerant to single failures in the worst plant maintenance state. The Class 1 designation ensures that the system will also withstand the design basis seismic event without loss of function.

98 As a result of the analysis undertaken, the modification **UKEPR-CMF-71** (see Section 7.1) has been identified for incorporation into the reference design for GDA.

- **UKEPR-CMF-71**: This modification involves upgrading the safety class of the safety feature group providing the SFP emergency makeup function (part of the JAC/JPI system) from Class 2 to Class 1. The modification will mainly involve classification upgrades to the C&I and electrical support systems.

99 Although I have accepted the argument and the need for the modification and upgrading of the water make-up system, I note that the Class 1 water make up system appears to be vulnerable to a passive single failure which may be caused by a blockage of the single inlet pipe. Given the need for water make up into the spent fuel pool, I am raising an Assessment Finding requiring the future licensee to justify that the water make-up system configuration is not vulnerable to a passive single failure, and to demonstrate the system can be tested for all reasonably foreseeable conditions in accordance with its safety classification.

100 The following Assessment Finding has been raised:

> ***AF-UKEPR-FS-79:*** *The Licensee shall provide a justification of the proposed SFP water make-up system configuration to demonstrate that it is not vulnerable to a passive single failure.*
>
> ***Required timescale:*** *Install RPV*

5.3 SPENT FUEL POOL LEAKS - DESIGN BASIS ANALYSIS

5.3.1 Leak Based Failure Mode

101 The assumption of a leak based failure mode for safety classified moderate energy pipework with a diameter >50mm was discussed with EDF and AREVA in the context of resolving the Internal Hazards GDA Issue related to the Internal Flooding Case, **GI-UKEPR-IH-03** which is further discussed in Ref. 43.

102 EDF and AREVA argued that the safety classified pipework was designed, installed and maintained to high standards and the lower energy level meant that a pipe would not fail in a gross manner. They stated that their approach was consistent with IAEA guidance on internal flooding cases (NS-G-1.11, Ref. 33). Whilst the IAEA guidance does recognise that claims can be made associated with leak rather than break in pipework with a ND>50mm and bases the leak size on the pipe thickness multiplied by the diameter divided by four (Dt/4), it doesn't address the expectations of the HSE SAPs and those of ONR Structural Integrity Assessors.

103 ONR's position was that it was not possible to justify that moderate energy pipework would always fail in a leak mode rather than a break mode in all circumstances and ONR's experience in the UK confirmed that moderate energy pipework did not always fail in a leak mode. The approach is also not compatible with the SAPs on the 'Integrity of Metal Components and Structures'. Paragraphs 243-247 of the SAPs state that unless a component is in the highest reliability category then the consequences of gross failure need to be explicitly considered. These highest reliability components require an in depth explanation of the measures over and above normal practice to justify the claim the likelihood of failure is so low that it can be discounted, which equates to the High Integrity Claim (HIC) in the UK EPR™ safety case.

104 A letter (Ref. 34) was sent to EDF and AREVA reiterating the ONR's expectations:

- *"Unless a component is identified as a High Integrity Component, then there needs to be a consequences case.*
- *The consequences case needs to consider gross failure.*
- *It may be appropriate to use realistic assumptions in assessing the consequence case, but that does not extend to classing a small leak as a gross failure"*

5.3.2 Impact of Conclusions on the Leak Based Failure Mode

105 Considering the arguments presented in the initial draft of the SFP safety case and its significance and potential impact on other discipline areas, discussions on the resolution of the SFP Safety Case GDA Issue, **GI-UKEPR-FS-03**, were held in conjunction with discussions on the Internal Hazards GDA Issue related to the Internal Flooding Case, **GI-UKEPR-IH-03**. It was also recognised that the conclusions on the leak based failure mode would particularly affect the resolution of GDA Issue **GI-UKEPR-FS-03,** Action 3.

106 The discussions with EDF and AREVA concluded that it was no longer appropriate to provide a beyond design basis analysis of the consequences of a leak type failure of the non-isolable pipework as indicated in the Resolution plan for Action 3 of **GI-UKEPR-FS-03**. Instead the update to the overall safety case for the spent fuel pool to be provided against Action 2 of this GDA Issue would need to include the effect of gross failure of the non-isolable pipework on pool drainage within the design basis unless specific measures were taken to exclude such failures either by justifying an increase in the integrity claim on the pipework to an HIC level or by incorporating other engineered safeguards to exclude the possibility of pool drainage without the need for a higher integrity claim on the pipework.

107 I was content that the original deliverable planned against Action 3 would no longer be provided, and the work to address this GDA Issue Action, i.e. that the failure of non-isolable sections of fuel pool pipework had been excluded from the design basis analysis without proper justification, would now be addressed through the update to the overall safety case for the spent fuel pool to be provided against Action 2 of **GI-UKEPR-FS-03**.

108 The revised safety case route map for the resolution of **GI-UKEPR-FS-03** (Ref. 35), reflects this change.

5.3.3 Safety Case for Spent Fuel Pool Cooling and Pool Drainage Faults – Non-isolable Pipework

109 EDF and AREVA in Ref. 36 provide the updated safety case for the spent fuel pool cooling and pool drainage faults to address Action 2 and Action 3 of **GI-UKEPR-FS-03** as described in the covering letter to the report (Ref. 37).

110 Failure of the non-isolable sections of pipework identified in resolution plan for Action 3 of this GDA Issue have now been included in the list of bounding initiating events in the safety case, Table 3 of Ref. 36. The events associated with the non-isolable pipework are:

- Non-isolable pipe break in fuel pool filtering and fuel pool cooling system – top entry pipe.
- Non-isolable pipe break in fuel pool filtering and fuel pool cooling system – bottom entry pipe.
- Fuel transfer tube.

5.3.3.1 Top Entry Pipes

111 EDF and AREVA in Ref. 36, state that the failure of the top entry pipes should be considered as an infrequent event within the design basis Plant Condition Category PCC-4 range of events (10^{-4} to 10^{-6}). Failure leads to a limited degree of pool drainage and demonstrates that the consequences of failure are acceptable.

112 In addition, Pipework failure in terms of a guillotine break is conceded as a Postulated Initiating Event (Ref. 36), and I accept that there are no unsubstantiated claims on the integrity of the pipework.

5.3.3.2 Bottom Entry Pipe

113 The failure of a bottom entry pipe could lead to complete drainage through the floor drain of the compartment to which it is connected; the reactor cavity, internals compartment, reactor building transfer compartment, fuel building transfer compartment or Cask Loading Pit. The failure would not affect normal operation as the SFP itself has no floor entry pipes, but it could lead to the uncovering of a fuel assembly during a fuel transfer operation. The cooling of the fuel assembly could not be assured under such circumstances and the consequences would be unacceptable.

114 A simplified schematic diagram of the spent fuel pool, floor penetrations, adjacent compartments, technical openings and the Heating Ventilation and Air Conditioning (HVAC) penetrations are shown in Figure 4.

[redacted]

Figure 4. Schematic view of the Technical openings and HVAC penetration within the SFP

115 A design modification is proposed to introduce a secondary closure to these floor drains (see Fig. 4) which would provide an independent method of preventing drainage. In the case of the Reactor Building Transfer Compartment, Fuel Building Transfer Compartment and Cask Loading Pit this would be in the form of a hinged cover plate. In the case of the Reactor Cavity and Internals Compartment it would be in the form of a standpipe. The secondary closures would be put in place manually and controlled by administrative procedures; EDF and AREVA (Ref. 36) claim that no monitoring of the cover devices is considered necessary.

116 Thus two independent failures would be required for a drainage event to occur and Ref. 36 claims that the probability of a failure of both the non-isolable pipework and the secondary closure is sufficiently low that it can be discounted from the design basis event (Section 3.2.6.1). Therefore, there is no consequence leg to the case as the consequences of such a leak are not acceptable and Table 3 of Ref. 36, which lists the Bounding Initiating Events (BIE), states that this initiating event has been eliminated by design modification.

117 The probability of failure of the non-isolable pipework in a situation which could lead to fuel damage is considered to be very low and below a PCC-4 event. No statement is made about the reliability of the secondary closures.

118 The very low probability of pipework failure (below a PCC-4 event which is below 10^{-6} per year) is argued on the basis of the quality of the pipe, the inspection regime, the limited

extent of vulnerable pipework and the short time at risk when fuel handling is taking place. There is no explicit breakdown of the relative contribution of these aspects. To achieve a failure rate of below 10^{-6} per year for a section of pipework would normally require a set of very specific arguments to be made, as whilst that level of reliability (and associated demonstration) is not as high as would be needed in order to discount gross failure, it is higher than the reliability that would normally be claimed for a pipework system. However, in this situation a time at risk argument is also included in the probability as failure is only significant during a fuel assembly handling operation. Taking this time at risk argument into account means that the actual claim on the integrity of the pipework itself will not be excessive as it will be in the PCC-4 design basis frequency of 10^{-4} to 10^{-6} per year. No details are provided of the design of the pipework, so I am unable to take any credit for any of the positive comments made for the non-isolable pipework, but the integrity claim does not look to be excessive in comparison to what would be expected for a general section of safety classified pipework.

119 The reliability of the secondary closure is not stated. It is independent but controlled by administrative procedures without position monitoring.

120 The reliability required by the combination of the non-isolable pipe, secondary closure and time at risk is not defined in Ref. 36. Table 3 of this reference states that the event has been eliminated by the design modification which would appear to be a much higher reliability threshold than simply discounting the event from the design basis as stated in Section 3.2.6.1 of Ref. 36. This makes judging the overall case for discounting drainage event from a floor drain difficult as not only is the reliability of the secondary closure not stated, but the overall reliability required to eliminate the fault as an initiating event is not defined.

121 I consider that the proposal to incorporate secondary closures is a useful design modification. In order to claim the fault to be eliminated as an initiating event, it will be necessary to show a very high reliability for the floor drain arrangements as there will be a need to show that the drainage event is a low probability event, and beyond the level where the event would be considered as a beyond design basis accident.

122 Based on some very approximate numbers for the reliability of the different components in this system, I judge that there is the potential to provide a combined reliability that will allow the fault to be eliminated as an initiating event, without placing claims that cannot be substantiated on either the pipework, time at risk argument or the secondary closure, whilst recognising that if necessary a higher reliability could be assigned to the secondary closure by incorporating position monitoring or similar measures.

123 These aspects will need to be demonstrated in a more detailed safety case in the site specific phase including defining the reliability needed to eliminate drainage from a floor drain as a bounding initiating event. I have therefore raised Assessment Finding **AF-UKEPR-FS-80** requiring the future licensee to develop the case further during the site specific phase for the floor drains in order to establish the reliability claims being placed on the pipework and the secondary closures in order to confirm that the required overall reliability can be achieved using justifiable claims for the reliability of the non-isolable pipework and secondary closures.

> ***AF-UKEPR-FS-80:*** *The Licensee shall develop the detail of the safety case for the floor drains to ensure that the reliability, necessary to claim that drainage events from these features have been eliminated, can be achieved using justifiable claims for the reliability for the non-isolable pipework and the secondary closures.*
>
> ***Required Timescale:*** *Long lead items and SSC procurement specifications*.

5.3.3.3 Fuel Transfer Tube

124 The spent fuel is transferred from the Reactor Building Transfer Compartment into the Fuel Building Transfer Compartment in flooded condition, via the Fuel Transfer Tube (FTT) shown in Figure 4. The consequences of the failure of the FTT in flooded conditions were considered in respect of internal flooding and the cooling of a fuel assembly being handled. In terms of internal flooding it concludes that the breach would be unacceptable if it occurred inside the reactor building annulus as it could lead to the failure of multiple trains of essential cooling systems, and in terms of a fuel assembly it would be unacceptable as the assembly could not be brought to a location where it could be cooled.

125 A design modification is proposed to make the rooms enclosing the fuel transfer tube watertight and therefore two independent failures would be needed for a drainage event to occur. Ref. 36 claims that the probability of such a double failure is sufficiently low that it does not need to be considered as a design basis event. Again Table 3 of Ref. 36 states that the initiating event has been eliminated by design modifications and there is no consequence assessment.

126 The probability of failure of the fuel transfer tube pipework in a situation where fuel handling is taking place is considered to be very low and below a PCC-4 event. No claims are stated for the reliability of the watertight rooms providing the secondary containment.

127 The very low probability of fuel transfer tube failure (below a PCC-4 event which is below 10^{-6} per year) is again argued on the basis of the quality of the transfer tube, the inspection regime, the limited tube length and the short time at risk when fuel handling is taking place and there is no explicit breakdown of the relative contribution of these aspects. These are the same arguments applied to the non-isolable pipework on the bottom entry pipes and no details are provided of the claim. For the bottom entry situation I judged that this would not place an unjustifiable claim on the integrity of the non-isolable pipework when the time at risk argument is taken into account. In the case of the fuel transfer tube the time at risk argument will still be present, but may be less as the concern here should be when the transfer area is flooded rather than just when the fuel is being handled due to the concerns with regard to flooding the reactor building annulus. However, I judge that this time at risk argument is still sufficient for EDF and AREVA (Ref. 36) not to have placed an unjustifiable claim on the integrity of the transfer tube.

128 The details of the watertight rooms and their reliability are not discussed in Ref. 36 as the details of the design modification have not have been finalised. I accept that the watertight rooms are independent and will have a real safety benefit.

129 In the same way as described for the Bottom Entry Pipe, the reliability required by the combination of the fuel transfer tube, watertight rooms and time at risk argument is not defined in Ref. 36. This makes judging the overall case difficult.

130 I do however consider that the proposal to incorporate the watertight rooms around the FTT is a beneficial design modification. Again in order to claim the fault to be eliminated as an initiating event it will be necessary to show a very high reliability for the transfer tube arrangement, as there will be a need to show that the drainage event is a low probability event, and beyond the level where the event would be considered as a beyond design basis accident.

131 Based on some very approximate numbers for the reliability of the different components in this system, I judge that there is the potential to provide a combined reliability that will

allow the fault to be eliminated as an initiating event without placing claims that cannot be substantiated on either the transfer tube, time at risk argument or the watertight rooms.

132 These aspects will need to be demonstrated in a more detailed safety case in the site specific phase including defining the reliability needed to eliminate drainage of Fuel Transfer Tube failure as a bounding initiating event. I am therefore raising Assessment Finding ***AF-UKEPR-FS-81*** requiring the future licensees to develop the case further during the site specific phase for the transfer tube in order to establish the reliability claims being placed on the transfer tube itself, and the watertight rooms in order to confirm that the required overall reliability can be achieved using justifiable claims for the reliability of the transfer tube and watertight rooms.

> ***AF-UKEPR-FS-81:*** *The Licensee shall develop a safety case for the fuel transfer tube as the detailed design develops to ensure that the reliability, necessary to claim that drainage events from these features have been eliminated, can be achieved using justifiable claims for the reliability for the fuel transfer tube itself and the watertight rooms.*
>
> ***Required Timescale:*** Long lead items and SSC procurement specifications.

133 The resolution of the **AF-UKEPR-FS-81** would need to be cognisant of the aspects of the Assessment Finding **AF-UKEPR-FS-83.**

5.4 Safety Case for Spent Fuel Pool Cooling and Pool Drainage Faults, other Integrity Claims

134 EDF and AREVA (Ref. 36) also considered other potential initiating events that could lead to drainage as a result of a structural integrity failure and these are described in the following paragraphs.

5.4.1 Technical Openings

135 EDF and AREVA in Ref. 36 claim a very low probability of gross failure for the doors covering the technical openings (below a PCC-4 event) which are shown schematically in Figure 4. This very low failure probability figure is claimed to be due to the quality of the design, the use of a leakage monitoring system and limited time at risk, but no details are provided to substantiate these claims or their relative contributions to the overall reliability. However, Ref. 36 also demonstrates that the consequences of failure of the doors are acceptable. Given that the consequences of failure are acceptable, the integrity claim on the door does not need to be the primary argument for the case. Thus, whilst the doors should be well engineered, appropriately maintained and operated through life, I am satisfied that there is no requirement to place an unjustifiable claim on the integrity of the door.

5.4.2 Personnel Access Doors

136 Gross failure of one of the personnel access doors, shown schematically in Figure 4, has not previously been considered as part of the design basis event for the UK EPR™. The design of the doors is the same as the technical openings described above. EDF and AREVA in Ref. 36, however, accept that the consequences of the gross failure of a personnel access door are not acceptable. Thus, rather than attempting to formally justify

a very high integrity claim on these doors, EDF and AREVA have proposed a design modification to remove the personnel access doors from the design so that they cannot form a drainage path. As a consequence there are no longer any claims on the integrity of the personnel access doors.

5.4.3 Cask Loading Pit – Gross Failure of the Bellows

137 The gross failure of the bellows between the bottom penetration in the Cask Loading Pit and the cask itself would lead to drainage of the Cask Loading Pit (including dewatering of a fuel assembly in the spent fuel mast bridge) and a partial draining of the spent fuel pool (including loss of biological protection above the spent fuel pool) if the gate between the two compartments was not in place.

138 EDF and AREVA (Ref. 36) argue that the bellows are designed to a high standard, are seismically qualified, have two barriers both of which would need to fail in order to cause leakage, and are protected against internal and external mechanical damage in order to show that failure is considered to be an infrequent event in the PCC-4 frequency range, and thus needs to be considered as a design basis event. The partial drainage of the spent fuel pool if the gate between the spent fuel pool and cask loading pit were not closed would lead to difficulties in returning the exposed fuel assembly in the cask transfer pit to a location where it could be cooled. Thus EDF and AREVA (Ref. 36) propose a modification to the operating procedure to ensure that the gate between the two compartments is closed before the upper cover above the cask is opened. With this modification to the operating procedure the consequences of a failure of bellows are considered acceptable.

139 Detailed evidence has not been provided to support the infrequent event failure frequency in the PCC-4 frequency range, but I judge that this is a reasonable claim. However, I do not believe it would have been possible to justify a significant increase in the integrity claim on the bellows from an infrequent event in the PCC-4 frequency range to a much lower risk reduction category. I therefore consider the modification to the operating procedure, to ensure that the consequences of failure of the bellows are acceptable, to be necessary.

5.4.4 Cavity Seal Ring between the RPV Flange and Pool Floor

140 Although not identified as one of the bounding initiating events in the safety case, Ref. 36 does identify the failure of the cavity seal ring between the Reactor Pressure Vessel (RPV) flange and pool floor as another potential leak source. The consequences of a drain down from this initiator have not been assessed in the report, but a failure of the seal could lead to a complete drainage of water from the RPV compartment and internal storage compartment and a partial drain down of the reactor building transfer compartments down to the 10.90m level (assuming the gates separating these compartments were open).

141 The consequences of this drain down would be important if a fuel assembly was being handled in the reactor compartment, with the potential for overheating of a fuel assembly and difficulty in accessing the area to replace the fuel assembly back into the reactor or into the transfer compartment. In addition, the consequences may be similar to the gross failure of a technical opening, which is bounding initiating event 9 (BIE 9) presented in Ref. 36, albeit that the water level in the reactor compartment would drop to the [redacted] level compared with +9.90m level for a technical opening (see Figure 12 of

Ref. 36). The consequences of BIE 9 are considered to be acceptable as the fuel handling machine would be allowed to continue and take the fuel assembly to a safe location, but it is not clear if that would still be the case for this initiating event as the water level in the reactor compartment would be lower thus reducing the radiation shielding above the fuel in the RPV.

142 The cavity seal ring is made from [redacted] stainless steel plate welded to the external ledge seal at the outer edge of the RPV at its inner edge and the seal support ring embedded in the concrete pool floor at its outer edge. [redacted] EDF and AREVA (Ref. 36) describe the cavity seal ring as being seismically qualified and designed against the cyclic loading of the plant.

143 A cross sectional view and the Position of the Cavity Seal Ring is shown in Figure 5.

[redacted]

Figure 5. A Cross Sectional View Providing the Position of the Cavity Seal Ring

144 EDF and AREVA (Ref. 36) consider the possibility of leakage from the welds connecting the seal to the seal support ring and the seal to the RPV. It concludes that the leakage from the weld between the seal and seal support ring would be detected by a dedicated system for detection and recovery of leaks similar to the pool liner leak detection system. A system to detect the presence of water in the bottom of the RPV cavity following a leak between the seal and the RPV will have to be developed during the site specific design. Leakage from a failure of the seal ring plate itself or, if multiple plates are used to

manufacture the seal, the failure of the welds joining the plates together, is not considered.

145 In addition, EDF and AREVA claim (Ref. 36) that the construction standards applied to the seal ring, the applied loads and the provision of leak detection means that a failure leading to rapid drainage of the pools is discounted from the UK EPR™ design. It claims that failure of the seal ring welds would lead to localised leakages that would be detected by the leakage monitoring systems and that it is not conceivable that such failure could lead to massive draining of the pool.

146 No substantive evidence is provided in Ref. 36 to support these claims apart from a diagram showing the design of the seal. The seal is over [redacted] wide, but the gap between the RPV external ledge seal and the concrete of the pool floor is only of the order to [redacted]. Thus the width of unsupported seal is quite small and I would accept that it is more likely that the seal will leak rather than fail in a manner that would lead to rapid drainage. However, whilst it is more likely I am unable to accept that it is inconceivable without a detailed structural integrity case to support this claim addressing:

- Initial integrity of the cavity seal ring;
- Integrity through life including in-service inspection and the potential for damage;
- A demonstration that the failure mode is limited leakage rather than a more substantial leak; and
- Detectable rates of leakage and the response in the case of detecting leakage.

147 For the purposes of GDA, I am prepared to accept the assertion that the failure mode should be small scale leakage rather than rapid drainage, however this will have to be demonstrated during the site specific phase. Thus as well as implementing a leak detection system for the RPV cavity during the site specific phase, the safety case for the cavity seal ring also needs to be developed further. The potential for leakage needs to be recognised as a Bounding Initiating Event, the consequences of such a leak need to be assessed to see if they are acceptable or not and a structural integrity case developed to support the integrity claim placed on the seal ring by the safety case (which will in turn depend on whether the consequences of failure are acceptable or not).

148 In summary, in addition to the risk associated with the loss of coolant from the flooded compartments and flooding of the RPV cavity due to the failure of cavity seal ring, there is potential for steam explosion if a transient develops into a severe accident and subsequent loss of RPV integrity. The seal ring integrity is also required in a severe accident as part of the strategy of retaining a dry reactor pressure vessel pit and corium spreading compartment. I am therefore raising the following Assessment Finding requiring the future Licensee to develop the safety case for the RPV cavity seal ring.

> ***AF-UKEPR-FS-82:*** *The Licensee shall develop the safety case for spent fuel pool drainage faults to include the potential for leakage from the RPV cavity seal ring as a potential initiating event and a structural integrity case to support the claims placed on the seal ring by the safety case. Any necessary modifications such as leak detection in the reactor cavity pit should be incorporated into the design during the site licensing phase and the site specific PCSR and associated safety case documentation updated as necessary to address this failure mode as a potential initiating event.*
>
> ***Required Timescale:*** *Long lead items and SSC procurement specifications*.

5.5 Spent Fuel Pool Safety Case– Consequence Analysis

149 The assessment has focussed on the potential internal flooding consequences associated with leaks and breaks in pipework and other technical openings/penetrations within the SFP areas of the UK EPR™ design, see Figure 4.

150 The potential for gross failure of pipework or other penetrations resulting in drainage of one or more fuel pools was identified during GDA and discussed in the preceding sections. The following penetrations associated with the potential for drainage of the spent fuel pool together with consequential flooding were identified:

- Non-isolable break in the Fuel Pool Cooling System pipework including the purification lines.
- Gross failure of the Fuel Transfer Tube.
- Gross failure of a Technical Opening within the Reactor Pool.
- Drainage of the Cask Loading Pit due to failure of bellows.

151 I have considered the analysis provided within safety submissions above, including the potential initiating events and associated consequences, and note the modifications to the design that have been identified. I judge that these modifications will enhance the robustness of the internal flooding safety case through the minimisation and protection of penetrations which, in the event of failure, could lead to flooding of the Containment, Annulus, or Fuel Building. In areas where additional protection is not employed, a consequences case is provided, which demonstrates the acceptability of flooding as a result of gross failure of technical openings/ penetrations.

5.5.1 Non-isolable Break in the Fuel Pool Cooling System Pipework

152 EDF and AREVA (Ref. 36) detail two potential non-isolable breaks; one in a top entry pipe between the pool wall and first isolation valve, and a break in any of the FPCS pipes connected to the floors of the Reactor Cavity, the Internals Compartment, the Reactor Building Transfer Compartment, the Fuel Building Transfer Compartment or the Cask Loading Pit. In terms of water volumes and potential consequences, failure of an FPCS pipe connected to the floor is the most significant given the potential for the affected pond to be drained.

153 The analysis considers the bounding flood event within the Fuel Building to be the gross failure of a personnel access door and states that the volume of water released into the Fuel Building would be insufficient to affect Division 1, given that the water would stay beneath the 0.0m level within Division 4. As a result, any consequential flooding arising from failure of the FPCS pipework may result in complete drainage of a pool, but would be bounded by failure of a personnel access door. Whilst I am satisfied for bounding cases to be used to demonstrate a worst case scenario, this event is different to failure of the FPCS lines and the principles of ALARP should apply to reducing the risks associated with drain down of the fuel pool. The analysis does identify that these doors are to be removed, and has thus identified the need for modifications to prevent drainage of the pool through a break in the FPCS as well as the need to provide a more robust mechanism by which to provide emergency make up water via the Nuclear Island Fire Protection System /Classified Fire Fighting Water Supply System (JPI/JAC).

154 In the event of complete drainage of the affected Reactor Building pool, there would be insufficient water released to result in the water level within the Containment exceeding 0.0m level and the submission states that this is acceptable from an internal flooding

perspective based on the analysis work undertaken associated with the multi-legged safety case for internal flooding (Ref. 40). Reference 40 was assessed under GDA Issue, **GI-UKEPR-IH-03**, and I am satisfied that the claim associated with the acceptability of flooding to a height of 0.0m level within the Containment has been adequately substantiated. However, a modification has been identified that minimises the potential for significant flooding within the Reactor Building Containment.

155 As a result of the analysis undertaken, the design change proposals **UKEPR-CMF-70** and **UKEPR-CMF-71** (see Section 7.1) have been identified for incorporation into the reference design for GDA.

- **UKEPR-CMF-70:** This modification consists of installing cover plates and standpipes for temporary isolation of pool purification lines in the floors of flooded compartments, avoiding risk of draining compartments due to gross failure of the purification lines.
- **UKEPR-CMF-71:** This modification involves upgrading the safety class of the Safety Feature Group providing the Spent Fuel Pool emergency make-up function (part of the JAC/JPI system) from Class 2 to Class 1. The modification will mainly involve classification upgrades to C&I and electrical support systems.

156 I am, therefore, satisfied that the modification, **UKEPR-CMF-70**, will minimise the potential for significant flooding of the Fuel Building and Reactor Building.

157 In addition, I note that the modification **UKEPR-CMF-71** would result in an increased system capability of introducing water into the Fuel Building or Reactor Building for makeup purposes. The introduction of water and any potential impact on the internal flooding safety case, should the leak not be isolated, is covered in Internal Hazards closure report (Ref. 43). However, it is reasonable to assume that appropriate steps could be taken within the time available to ensure that loss of more than one division is prevented. As a result, I am satisfied that design change proposal **UKEPR-CMF-71**, would not have a detrimental effect on the internal flooding safety case.

5.5.2 Gross Failure of the Fuel Transfer Tube

158 The potential for flooding of the Reactor Building Annulus as a result of gross failure of the Fuel Transfer Tube had been previously identified as a result of the analysis undertaken to support the GDA for UK EPR™. The consequences of failure of the Fuel Transfer Tube were not acceptable, given the volume of water that could be released and the lack of segregation together with the height of redundant safety classified equipment contained within the Annulus. The design change proposal **UKEPR-CMF-72** (see Section 7.1) has therefore been identified for incorporation into the reference design for GDA.

- **UKEPR-CMF-72:** This design change proposal consists of making the rooms enclosing the Fuel Transfer Tube watertight to a pressure corresponding to the maximum water level in the pools. It will prevent draining of compartments in the event of gross failure of the Fuel Transfer Tube, when the fuel assemblies are being transferred between the Reactor Building and Fuel Building.

159 I am satisfied that the above modification will provide additional barrier against the flooding of the Reactor Building Annulus and that the provision of a water tight room surrounding the Fuel Transfer Tube will prevent gross failure of the tube that could potentially result in loss of multiple trains of redundant safety classified systems. Given that the detail design has yet to be developed for this modification, I am raising

Assessment Finding **AF-UKEPR-FS-83** to ensure that confirmation is provided for the qualification of the water tight barriers surrounding the Fuel Transfer Tube during the site specific detailed design activities.

> ***AF-UKEPR-FS-83:*** *The Licensee shall provide evidence that the water tight barriers surrounding the Fuel Transfer Tube are appropriately qualified.*
>
> ***Required timescale:*** *Mechanical, Electrical, and C&I Safety Systems – Before inactive commissioning.*

5.5.3 Gross Failure of a Personnel Access Door or Technical Opening within the Reactor Pool

160 As mentioned previously, the bounding scenario associated with the Fuel Building and Reactor Building pools is gross failure of a personnel access door (shown in Figure 4), three of which are now to be removed from the design (see Section 5.4, unacceptable outcome relating to a stranded and exposed fuel assembly). The internal flooding consequence analysis undertaken within Ref. 40, identified that it would be possible to flood the Reactor Building Containment to the 0.0m level without unacceptable consequences. In addition gross failure of a personnel access door is claimed to be bounded by other Plant Condition Category, PCC-3 and PCC-4 transient scenarios within the Reactor Building Containment e.g. a failure in the Main Feedwater System (MFWS) and the Emergency Feedwater System (EFWS).

161 As mentioned earlier, failure of a personnel access door within the Fuel Building is claimed not to result in loss of more than one division due to the released volume of water being less than the retention volume within which it would be contained (Division 4 of the Fuel Building).

162 As a result of the analysis undertaken, design change proposal **UKEPR-CMF-73** has been identified for incorporation into the reference design for GDA.

- **UKEPR-CMF-73:** This modification will remove the risk of draining the flooded compartments caused by a hypothetical gross failure of the personnel access doors, when fuel assemblies are being transferred between the Reactor Building and Fuel Building.

163 Other technical openings within the Reactor Building Pool, such as cable penetrations and HVAC ductwork have been identified within the Reactor Pool which, in the event of failure, could result in draining of the pool to the level of the penetration in question. Flooding through these penetrations has been analysed within the submission and demonstrated that the water would drain to the In-Containment Refuelling Water Storage Tank (IRWST). As this flooding event is bounded by gross failure of the personnel access doors, I am satisfied that failure of a technical opening within the Reactor Building pool would not result in unacceptable consequences.

5.5.4 Drainage of the Cask Loading Pit due to Failure of Bellows

164 The failure of the bellows within the Cask Loading Pit would result in the maximum volume being released into Division 1. As was the case with the Fuel Building Transfer Compartment, the maximum volume released would be contained within the Fuel Building, however, in this scenario the water would be contained beneath the 0.0m level of Division 1 as opposed to Division 4. The modifications proposed in relation to removal

of the personnel access doors and the provision of covers over the floor drains would result in a maximum release through the Cask Loading Pit of [redacted]. This volume is significantly less than the bounding scenario analysed for failure of the personnel access door within the transfer compartment.

165 The design change proposal **UKEPR-CMF-74** has been identified for incorporation into the reference design for GDA.

- **UKEPR-CMF-74:** This design change proposal consists of modifying the cask loading procedures so that the door between the SFP and the Cask Loading Pit will be closed before the penetration upper cover is opened to allow a fuel assembly to be lowered into the fuel cask. This will create a second barrier to prevent draining of the Spent Fuel Pool following hypothetical failure of the bellows connecting the fuel cask to the bottom penetration in the Cask Loading Pit. The modification will allow operators to potentially continue working in the Spent Fuel Pool Hall to recover a dewatered fuel assembly in the Cask Loading Pit in the case of failure of the bellows.

166 The above modification would result in a reduction in the volume of water released into Division 4 of the Fuel Building and that given the event is bounded by complete drainage of the Fuel Building Pools, I am satisfied that the loss of more than one division due to internal flooding would be prevented.

5.6 Spent Fuel Pool - Seismic Consideration

167 EDF and AREVA (Ref. 29) have provided the analysis of robustness of the UK EPR™ against a beyond design basis earthquake essentially relying upon the Seismic Margin Assessment (SMA) reported in Chapter 15.6 of the PCSR (Ref. 30). The analysis uses the PSA to identify those safety classified systems, structures and components necessary to ensure that a minimum set of key safety functions on the reactor are maintained following a seismic event.

168 For each System, Structure and Component (SSC) a conservative fragility analysis of its seismic withstand capability is performed to determine the maximum Peak Ground Acceleration (PGA) for which there is a High Confidence of Low Probability of Failure (HCLPF) for the SSC. [redacted]. It should also be noted that although the application of SMA has been applied to a limited number of SSCs for GDA, the Ref. 29 concludes that the UK EPR™ could tolerate a seismic event with a maximum peak ground acceleration (PGA) of [redacted], which is considerably in excess of the design basis earthquake corresponding to a 0.25 g PGA.

169 The robustness report (Ref. 29) presents the argument that for those components within the scope of the GDA assessment, the SMA demonstrates that, with the exception of the fuel spacer grids, the UK EPR™ could tolerate a seismic event with a maximum PGA of [redacted], which is considerably in excess of the design basis earthquake corresponding to a 0.25 g PGA. However, it should be noted that the seismic margin analysis was only performed for the 'at power' state.

170 In response to Regulators questions, EDF and AREVA revised the report to address shutdown states by including information on the HCLPF calculations for the US EPR™, and this was adequate to show that EDF and AREVA had investigated beyond design basis behaviour and justified there was sufficient margin for extreme events. EDF and AREVA had also added an appraisal of load combinations in the revised report.

Additional discussion of the classification of the main structures can be found in ONR's close-out report of the GDA Issue **GI-UKEPR-CC-03** relating to the Fukushima lessons learnt for the UK EPR™ (Ref. 22).

171 Although ONR concluded (Ref. 22) that EDF and AREVA have provided sufficient information to demonstrate the robustness of the UK EPR™ design against a beyond design basis seismic event at a level comparable to that experienced at Fukushima, an Assessment Finding **AF-UKEPR-CC-13** was raised requiring a future UK EPR™ licensee to complete the seismic analysis on the detailed site specific design to demonstrate its robustness against beyond design basis seismic events for all plant operating states.

172 I note the robustness analysis concluded that the seismic design margin of the UK EPR™ is sufficient to withstand a seismic event comparable to that which occurred at Fukushima and that the probability of occurrence of an earthquake in any given year of this magnitude in the UK is very low. Notwithstanding this general conclusion, I also note the modifications introduced under the present safety case to remove penetrations in flooded compartments, or to introduce secondary closures, will reduce the likelihood of pool draining in extreme seismic events. These modifications will also contribute to meeting Recommendation 14 in the ONR review report on Fukushima at (Ref. 31), which requested that the number of penetrations that could lead to drainage of fuel storage pools in new reactors was minimised.

173 I do however note the absence of the Fluid-Structure Interaction (FSI) within the current analysis supporting the UK EPR™ plant for the cases when the adjacent compartments are flooded to enable fuel transfer between the reactor and the spent fuel pool. Recognising that the presence of FSI and any resulting sloshing could adversely impact the qualification of the SSCs in the flooded condition, I have raised Assessment Finding **AF-UKEPR-FS-84** requesting the licensee to perform an assessment of the loadings due to the FSI within the flooded compartments during a seismic event giving consideration to the effects of sloshing. This is required to be developed during site specific design development stage to fully justify the resilience of the plant in all reasonably foreseeable conditions during the shutdown states.

> ***AF-UKEPR-FS-84:*** The Licensee shall provide validated evidence that the structural integrity *of the containment and the spent fuel pool facility during shutdown condition have been examined for the UK EPR™. This justification should be supported by sensitivity assessment to identify the plant resilience to seismic events beyond design basis. This analysis should include the impact of Fluid Structure Interaction (FSI) and give consideration to the effects of sloshing that may exists when the reactor pool is flooded.*
>
> ***Required timescale:*** *Long lead items and SSC procurement specifications*

5.7 SPENT FUEL POOL - PSA CONSIDERATIONS

174 The probabilistic safety assessment of the Potential Initiating Events (PIE) in the fuel building is identified to assess their impact on the existing fuel building, reported in Ref. 27. This study covers the consequences of the initiating events and calculates their frequencies to determine their impact on the extant UK EPR™ Level 1 and 2 probabilistic safety analyses. As the revised study (Ref. 27) was produced in response to Action 2 of **GI-UKEPR-FS-03**, it is based on the 2011 GDA UK EPR™ design and does not include the design modifications being proposed as part of the resolution of Action 3 of the GDA Issue **GI-UKEPR-FS-03.**

175 The proposed modifications to the SFP adjacent compartments, the fuel route and the procedural changes are quite significant and will impact the configuration of the processes within the Cask Loading Pit and the supporting cooling systems. I therefore consider that some of the faults considered in this PSA may not be directly relevant to the plant with the proposed modifications; and the conclusions of the current study may not specifically be relevant to the UK EPR™ plant. I do however acknowledge that inclusion of the proposed modifications will favourably influence the overall plant risk profile.

176 In summary, in view of the above and given the lower degree of complexity of the spent fuel pool and its adjacent compartments with the proposed modifications, compared with the original submission, a detailed review of the PSA provided in Ref. 27 is not appropriate at this stage. I also note the Assessment Findings **AF-UK EPR-PSA-004** and **AF-UK EPR-PSA-014** which were raised as part of the GDA Step 4 Probabilistic Safety Analysis of the EDF and AREVA UK EPR™ Reactor (Ref. 28) requiring the future licensees to provide and implement a consistent process to capture assumptions supporting the plant PSA and to ensure that faults that are not yet included in the PSA are incorporated as the detailed design is evolved. I look to the resolution of these Assessment Findings during the detailed design activities.

177 In my opinion there is still a need to review and update the PSA of the spent fuel pool and the adjacent compartments incorporating the proposed modifications to support next stages of the detailed design and operation. I am therefore raising the following Assessment Finding requiring a future licensee to fully develop the PSA for the detailed site-specific design which is described below.

> ***AF-UKEPR-FS-85:*** *The Licensee shall develop and update the SFP PSA (including Cask Loading Pit faults) considering all the relevant modifications and any other update of the deterministic safety case and provide a full scope, modern and well documented SFP PSA for the UK EPR™ plant (including evaluation of fuel damage, radioactive releases and consequences).*
>
> ***Required timescale:*** *Mechanical, Electrical and C&I Safety Systems, Structures and Components –delivery to Site*

178 In resolution of this Assessment Finding, ONR will seek evidence of the implementation of a procedure expected to be developed as part of **AF-UK EPR-PSA-046** (Ref. 28), for the use of this PSA to support next stage of the design and operation of the UK EPR™.

179 In addition, the resolution of this Assessment Finding is expected to be consistent with international good practice and ONR expectations identified in the relevant guide TAG/30, and the revised PSA should cover areas such as:

- Relevant configurations, operational states and the associated faults, providing point in time risks when relevant.
- Relevant fault trees in the model so dependencies can be captured (including support systems, actuation signals and operator errors dependencies).
- Consideration of potential dependencies/shared system with the reactor.

6 ASSESSMENT CONCLUSIONS

180 To address the GDA Issue and associated Actions, EDF and AREVA have undertaken a number of optioneering analyses which has lead to additional features enhancing the safety of the UK EPR™ within the Fault Studies assessment topic area during the close-out phase of GDA. They have made significant progress in addressing the Actions relating to GDA Issue **GI-UKEPR-FS-03** in support of the provision of a safety case for the SFP and adjacent compartments identified by the GDA Step 4 assessment report.

6.1 Cask Loading Pit - Initiating Faults

181 EDF and AREVA have identified bounding design basis events relating to the draining of the SFP via the Cask Loading Pit. EDF and AREVA have undertaken a Failure Modes and Effects Analysis (FMEA) on systems and components in order to define deterministic and probabilistic requirements for the three bounding initiating events focusing on the spent fuel mast bridge, and spent fuel cask transfer facility and fuel assembly burn-up measurement system. The analysis has covered a wide range of fault types including major load path failures, human failures and failures in sealing and cask bellows arrangements.

6.2 Non-Isolable Pipework

182 A consequence analysis of leaks from non-isolable pipework had been excluded from the initial design basis analysis without proper justification. The original resolution plan envisaged providing a beyond design basis consequence assessment for the failure of these non-isolable pipes using a leak based failure mode. Through discussions on the resolution of the Internal Hazards Internal Flooding GDA Issue, **GI-UKEPR-IH-03**, it was concluded that such an approach would not be acceptable and the overall safety case would need to be updated to recognise the potential for gross failure of the non-isolable pipework. Thus the original deliverable planned against Action 3 of **GI-UKEPR-FS-03** was not provided, and the work is thus addressed through the update to the overall safety case for the spent fuel pool, provided against Action 2 of **GI-UKEPR-FS-03.**

183 In the case of the top entry pipes it is shown that the consequences of failure of these non-isolable pipe is acceptable, and the case is based on that premise.

184 In the case of the bottom entry pipes attached to the floor drains and the fuel transfer tube pipe, the failure of these non-isolable sections of pipe is not acceptable if it occurred during a fuel transfer operation. EDF and AREVA have therefore proposed design modifications to introduce independent closures/containments to reduce the probability of a draining event to the level at which it does not need to be considered as an initiating event.

185 The details of the case still have to be developed, but I consider these are beneficial design modifications and judge that they should enable the drainage events to be discounted as an initiating event without placing unjustifiable claims on the integrity of the non-isolable pipework, transfer tube, secondary closures or watertight rooms.

6.3 Other Integrity Claims in the Spent Fuel Pool Cooling and Drainage Faults Safety Case

186 The revised safety case for the Spent Fuel Pool also includes other potential bounding initiating events that could lead to drainage as a result of a structural integrity failure: the technical opening; the personnel access doors; the bellows in the cask loading pit; and the RPV cavity seal ring.

187 I judge that the integrity claims placed on the technical openings and the bellows in the cask loading pit appear justifiable, and the need for an integrity claim on the personnel access doors has been eliminated by a design modification to remove the personnel access doors from the design.

188 The integrity claims on the RPV cavity seal ring are that a failure of the seal ring welds would lead to localised leakage that would be detected by leakage monitoring systems and that it is not conceivable that such a failure could lead to massive drainage of the pool. A modification to incorporate a leak detection system for the RPV cavity will be implemented during the site specific phase. The consequences of such an event are not provided in the revised safety case and no substantive evidence is provided to support the integrity claims. For the purposes of GDA, I have accepted the assertion that the failure mode should be small scale leakage rather than rapid drainage based on the limited gap between the RPV external ledge seal and concrete of the pool floor. However, this will have to be demonstrated during the site specific phase, and the safety case for the cavity seal ring will have to be developed further during the site specific phase.

6.4 Consequences of the Drainage Faults of the Flooded Compartment

189 EDF and AREVA have also provided safety submissions associated with the safety case for spent fuel cooling, and I judge that pool drainage faults have been adequately addressed covering the consequential internal flooding scenarios and have shown that the internal flooding events are bounded by loss of the complete water inventory from the fuel pools contained within Fuel Building and Reactor Building. The proposed modification ensures that failure of the FTT does not result in loss of multiple redundant safety classified systems within the Reactor Building Annulus and I have requested confirmation of the qualification of the water tight barriers surrounding the fuel transfer tube.

6.5 Overall Conclusions

190 In my opinion, EDF and AREVA have considerably strengthened the design basis safety for the Spent Fuel Pool and adjacent compartments including the Cask Loading Pit for the UK EPR™ through the additional safety case information and revised analysis performed in response to GDA Issue **GI-UKEPR-FS-03**. EDF and AREVA have performed additional reviews of a number of options the outcome of which has resulted in important design changes to the penetrations and engineered openings on the UK EPR™. This work also identified some important changes in operating procedures that together with the changes in the design will, in my opinion, improve the safety of the design. These changes have been proactively identified by EDF and AREVA to improve the performance of the Spent Fuel Pool operations with the proposed design changes for the UK EPR™ identified in Section 7.2.

191 I have also identified a few areas where additional information needs to be provided or where detailed aspects of the approach require further development. I do not however, consider these to undermine the validity of the results presented, but I have identified these as areas where additional development in the safety case is required during the detailed design phase as the site specific phase progresses. I have therefore raised a number of Assessment Findings to ensure these are resolved satisfactorily by the future licensees. In making my judgement, I have also taken account of the commitment given by EDF and AREVA for additional design modifications that are intended to improve the UK EPR™ plant resilience in beyond design basis events identified in the supporting submission (Ref. 47) which has been considered as part of the Fukushima related Cross Cutting GDA Issue **GI-UKEPR-CC-03**. The expectations relating to these commitments are captured in Assessment Finding **AF-UKEPR-CC-16**.

192 Overall, based on my assessment undertaken in accordance with ONR procedures, I am satisfied that the safety case for the Spent Fuel Pool and fuel route faults presented in the supporting documentation submitted in response to GDA Issue **GI-UKEPR-FS-03** is adequate subject to satisfactory progression and resolution of the Assessment Findings identified in Annex 2. These are to be addressed during the forward work programme for this reactor. For this reason, I am satisfied that GDA Issue **GI-UKEPR-FS-03** can now be closed.

7 PCSR REVIEW AND DESIGN REFERENCE UPDATE

193 Sub-chapter 16.4 (Ref. 44) considers the Spent Fuel Pool drainage faults and I have reviewed the update to this sub-chapter of the PCSR. Chapter 16 covers risk reduction and severe accident analyses, and sub-chapter 16.4 covers specific studies. The sub-chapter addresses the non-isolable breaks in the fuel pool filtering and fuel pool cooling system, gross failure of the transfer tube, gross failure of a technical opening and cask loading pit bellows failure and reflects the design changes on these aspects.

194 Additional sub-chapter 16.6 to the UK EPR™ PCSR (Ref. 44) provides a high level summary and references to the reviews undertaken by EDF and AREVA to demonstrate the robustness of the UK EPR™ against extreme events and summarised potential design enhancements arising from these reviews and other potential enhancements related to other GDA Issues such as **GI-UKEPR-CC-03.**

195 Sub-chapter 16.4 does not address the failure of the cavity seal ring between the RPV flange and the pool floor. The safety case for this fault will need to be developed during the site licensing phase. The site specific PCSR will need to be updated to include this potential failure mode and the measures to address this fault, and I have included this within the Assessment Findings.

196 These chapters were reviewed to ensure that the outcome of the GDA assessment had been appropriately captured within the PCSR. I am satisfied that the revised Chapters accurately reflect the analysis work and the proposed design modifications developed to justify the closure of **GI-UKEPR-FS-03**.

7.1 Design Reference Update - Review of Related CMFs

197 The design reference document (Ref. 9) has been updated to reflect the commitments made by EDF and AREVA in respect of the classification of pressure retaining components. The following Change Management Forms (CMF) have been raised to address these commitments:

- **UKEPR-CMF-38 –** Modification to upgrade the Safety Classification of the two main Spent Fuel Pool Cooling Chains to Class 1.
- **UKEPR-CMF-70 –** Modification to install cover plates and standpipes over floor drains in flooded compartments.
- **UKEPR-CMF-71 -** Upgrade of classification of fuel pool make up Safety Feature (part of JAC/JPI).
- **UKEPR-CMF-72 -** Modification to provide leaktight containment of the fuel transfer tube.
- **UKEPR-CMF-73 -** Modification to remove personnel access doors to the reactor cavity and fuel transfer compartments.
- **UKEPR-CMF-74 -** Modification to cask loading procedure.

198 These CMFs capture the commitments to update the design reference in respect of the main design modifications to address drainage faults from the SFP. However the design changes to detect water in the bottom of the RPV cavity to support the case for the cavity seal ring will not be developed till the site specific phase and are not included as a CMF.

8 ASSESSMENT FINDINGS

199 The following Assessment Findings have been raised.

AF-UKEPR-FS-77: The Licensee shall provide a justification of the proposed system configuration to demonstrate that reliance on the I&C to protect the FPCS pumps and adjacent piping is most appropriate for the overall system availability and operation.

Required timescale: *Install RPV.*

AF-UKEPR-FS-78: The Licensee shall provide a justification of the proposed system configuration to demonstrate that the heat loading from the SFP cooling system does not degrade the CHRS operation and performance in prolonged accident conditions.

Required timescale: *Mechanical, Electrical and C&I Safety Systems, Structures and Components – Delivery to site.*

AF-UKEPR-FS-79: The Licensee shall provide a justification of the proposed SFP water make-up system configuration to demonstrate that it is not vulnerable to a passive single failure.

Required timescale: *Install RPV.*

AF-UKEPR-FS-80: *The Licensee shall develop the detail of the safety case for the floor drains to ensure that the reliability, necessary to claim that drainage events from these features have been eliminated, can be achieved using justifiable claims for the reliability for the non-isolable pipework and the secondary closures.*

Required timescale: *Long lead items and SSC procurement specifications.*

AF-UKEPR-FS-81: *The Licensee shall develop a safety case for the fuel transfer tube as the detailed design develops to ensure that the reliability, necessary to claim that drainage events from these features have been eliminated, can be achieved using justifiable claims for the reliability for the fuel transfer tube itself and the watertight rooms.*

Required timescale: *Long lead items and SSC procurement specifications.*

AF-UKEPR-FS-82: *The Licensee shall develop the safety case for spent fuel pool drainage faults to include the potential for leakage from the RPV cavity seal ring as a potential initiating event and a structural integrity case to support the claims placed on the seal ring by the safety case. Any necessary modifications such as leak detection in the reactor cavity pit should be incorporated into the design during the site licensing phase and the site specific PCSR and associated safety case documentation updated as necessary to address this failure mode as a potential initiating event.*

Required timescale: *Long lead items and SSC procurement specification.*

AF-UKEPR-FS-83: *The Licensee shall provide evidence that the water tight barriers surrounding the Fuel Transfer Tube are appropriately qualified.*

Required timescale: *Mechanical, Electrical, and C&I Safety Systems – Before inactive commissioning.*

AF-UKEPR-FS-84: The Licensee shall provide validated evidence that the structural integrity *of the containment and the spent fuel pool facility during shutdown condition have been examined for the UK EPR™. This justification should be supported by sensitivity assessment to identify the plant resilience to seismic events beyond design basis. This analysis should include the impact of Fluid Structure Interaction (FSI) and give consideration to the effects of sloshing that may exists when the reactor pool is flooded.*

Required timescale: *Long lead items and SSC procurement specifications*

AF-UKEPR-FS-85: *The Licensee shall develop and update the SFP PSA (including Cask Loading Pit faults) considering all the relevant modifications and any other update of the deterministic safety case and provide a full scope, modern and well documented SFP PSA for the UK EPR™ plant (including evaluation of fuel damage, radioactive releases and consequences).*

Required timescale: *Mechanical, Electrical and C&I Safety Systems, Structures and Components –delivery to Site.*

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Table 1

Relevant Safety Assessment Principles Considered for Close-out of GI-UKEPR-FS-03 Revision 2

SAP No.	SAP Title	Description
EMC.1	Integrity of metal components and structures: highest reliability components and structures. Safety case and assessment	The safety case should be especially robust and the corresponding assessment suitably demanding, in order that an engineering judgement can be made for two key requirements: the metal component or structure should be as defect-free as possible; the metal component or structure should be tolerant of defects.
EMC.3	Integrity of metal components and structures: highest reliability components and structures.	Evidence, evidence should be provided to demonstrate that the necessary level of integrity has been achieved for the most demanding situations.
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.
EKP.1	Inherent safety	The underpinning safety aim for any nuclear facility should be an inherently safe design, consistent with the operational purposes of the facility.
ESS.19	Dedication to a single task	A safety system should be dedicated to the single task of performing its safety function.
ESS.24	Minimum operational equipment requirements	The minimum amount of operational safety system equipment for which any specified facility operation will be permitted should be defined and shown to meet the single failure criterion.

Table 1

Relevant Safety Assessment Principles Considered for Close-out of GI-UKEPR-FS-03 Revision 2

SAP No.	SAP Title	Description
FA.17	Assurance of validity of data and models	Theoretical models should adequately represent the facility and site.
FA.4	Design Basis Analysis: Fault tolerance	DBA should be carried out to provide a robust demonstration of the fault tolerance of the engineering design and the effectiveness of the safety measures.
FA.7	Consequences	Analysis of design basis fault sequences should use appropriate tools and techniques, and be performed on a conservative basis to demonstrate that consequences are ALARP.
FP.3	Optimisation of protection	Protection must be optimized to provide the highest level of safety that is reasonably practicable.
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.
EDR.1	Design for reliability, failure to safety	Due account should be taken of the need for structures, systems and components important to safety to be designed to be inherently safe or to fail in a safe manner and potential failure modes should be identified, using a formal analysis where appropriate.

…

Annex 1

Deliverables and Associated Technical Queries Raised During Close-out Phase

GI-UKEPR-FS-03 Revision 2 – Spent Fuel Pool – EDF and AREVA Deliverables

GDA Issue Action	Topic	Document Ref.	Title	Ref.
GI-UKEPR-FS-03.A2	Fault Studies	ECESN120833	Impact on the Probabilistic Safety Assessment of the initiating events identified for the Cask Loading Process	27
GI-UKEPR-FS-03.A2	Fault Studies	ECESN120587	Design Basis analysis of faults associated to the spent fuel pool safety case	49
GI-UKEPR-FS-03.A1	Fault Studies	ECESN120111	Failure Mode and Effects Analysis for the Spent Fuel Mast Bridge	50
GI-UKEPR-FS-03.A1	Fault Studies	ECESN110231	FMEA for the Spent Fuel Pool Isolation gates, the Spent Fuel Cask Transfer Facility and burn up device	45
GI-UKEPR-FS-03.A1	Fault Studies	ECESN112038	Quantification of the New Initiating Events Identified for the Spent Fuel Cask Transfer Facility and SF Loading Process	46
GI-UKEPR-FS-03.A1	Fault Studies	D4550.34/4134	Estimated reliability parameters of PTR [FPCS], PMC [FHS] and DMK (spent fuel handling) systems equipment used for fuel building pool leak prevention and fuel handling	51
GI-UKEPR-FS-03.A2 & A3	Fault Studies	PTS DC 10, Rev C	Spent Fuel Pool Safety Case	36
GI-UKEPR-FS-03.A1	Fault Studies	Change Management Form #38	Upgrade of the Safety Classification of the two main Spent Fuel Pool Cooling Chains	9

Annex 1

Deliverables and Associated Technical Queries Raised During Close-out Phase

GI-UKEPR-FS-03 Revision 2 – Spent Fuel Pool – EDF and AREVA Deliverables

GDA Issue Action	Topic	Document Ref.	Title	Ref.
GI-UKEPR-FS-03.A3	Fault Studies	Change Management Form #70	Modification to install cover plates and standpipes over floor drains in flooded compartments	9
GI-UKEPR-FS-03.A2	Fault Studies	Change Management Form #71	Upgrade of classification of SFP make up Safety Feature (part of JAC/JPI	9
GI-UKEPR-FS-03.A2	Fault Studies	Change Management Form #72	Modification to provide leaktight containment of the FTT	9
GI-UKEPR-FS-03.A3	Fault Studies	Change Management Form #73	Modification to remove personnel access doors to the flooded compartments	9
GI-UKEPR-FS-03.A1	Fault Studies	Change Management Form #74	Modification to Cask Loading Procedure	9
GI-UKEPR-FS-03.A1 to A3	Fault Studies	Specific Studies	PCSR – Sub-Chapter 16.4	38

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Annex 2

GDA Assessment Findings Arising from GDA Close-out for GI-UKEPR-FS-03 Rev 2

Finding No.	Assessment Finding	MILESTONE
AF-UKEPR-FS-77	Provide a justification of the proposed system configuration to demonstrate that reliance on the C&I to protect the FPCS pumps and adjacent piping is most appropriate for the overall system availability and operation.	Install RPV.
AF-UKEPR-FS-78	Provide a justification of the proposed system configuration to demonstrate that the heat loading from the SFP cooling system does not degrade the CHRS operation and performance in prolonged accident conditions.	Mechanical, Electrical and C&I Safety Systems, Structures and Components – Delivery to site.
AF-UKEPR-FS-79	Provide a justification of the proposed SFP water make-up system configuration to demonstrate that it is not vulnerable to a passive single failure.	Install RPV.
AF-UKEPR-FS-80	Develop the detail of the safety case for the floor drains to ensure that the reliability, necessary to claim that drainage events from these features have been eliminated, can be achieved using justifiable claims for the reliability for the non-isolable pipework and the secondary closures.	Long lead items and SSC procurement specifications.
AF-UKEPR-FS-81	Develop a safety case for the fuel transfer tube as the detailed design develops to ensure that the reliability, necessary to claim that drainage events from these features have been eliminated, can be achieved using justifiable claims for the reliability for the fuel transfer tube itself and the watertight rooms.	Long lead items and SSC procurement specifications.

Annex 2

GDA Assessment Findings Arising from GDA Close-out for GI-UKEPR-FS-03 Rev 2

Finding No.	Assessment Finding	MILESTONE
AF-UKEPR-FS-82	Develop the safety case for spent fuel pool drainage faults to include the potential for leakage from the RPV cavity seal ring as a potential initiating event and a structural integrity case to support the claims placed on the seal ring by the safety case. Any necessary modifications such as leak detection in the reactor cavity pit should be incorporated into the design during the site licensing phase and the site specific PCSR and associated safety case documentation updated as necessary to address this failure mode as a potential initiating event.	Long lead items and SSC procurement specification.
AF-UKEPR-FS-83	Provide evidence that the water tight barriers surrounding the Fuel Transfer Tube are appropriately qualified.	Mechanical, Electrical, and C&I Safety Systems – Before inactive commissioning.
AF-UKEPR-FS-84	Provide validated evidence that the structural integrity of the containment and the spent fuel pool facility during shutdown condition have been examined for the UK EPR™. This justification should be supported by sensitivity assessment to identify the plant resilience to seismic events beyond design basis. This analysis should include the impact of Fluid Structure Interaction (FSI) and give consideration to the effects of sloshing that may exists when the reactor pool is flooded.	Long lead items and SSC procurement specifications.
AF-UKEPR-FS-85	Develop and update the SFP PSA (including Cask Loading Pit faults) considering all the relevant modifications and any other update of the deterministic safety case and provide a full scope, modern and well documented SFP PSA for the UK EPR™ plant (including evaluation of fuel damage, radioactive releases and consequences).	Mechanical, Electrical and C&I Safety Systems, Structures and Components –delivery to Site.

…

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 <u>during</u> 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-FS-03 – Fault Studies – UK EPR™

EDF AND AREVA UK EPR GENERIC DESIGN ASSESSMENT

GDA ISSUE

SPENT FUEL POOL SAFETY CASE

GI-UKEPR-FS-03 REVISION 2

Technical Area		**FAULT STUDIES**	
Related Technical Areas		Probabilistic Safety Assessment Mechanical Engineering Structural Integrity Internal Hazards	
GDA Issue Reference	**GI-UKEPR-FS-03**	**GDA Issue Action Reference**	**GI-UKEPR-FS-03.A1**
GDA Issue	The safety case for the spent fuel pool is to be extended to consider faults associated with the Cask Loading Pit and leaks currently excluded from the design basis by break preclusion arguments.		
GDA Issue Action	EDF and AREVA to evaluate Cask Loading Pit Initiating Events. They need to determine the updates required to DBA or PSA safety cases for faults associated with the cask loading pit. A FMECA (Failure Modes, Effects and Criticality Assessment) should be performed to determine failure modes leading to the fault events. For each fault, initiating events and sequences leading to a faulty state need to be determined. Frequencies associated to each initiating event need to be determined. Faults needed to be added to the PSA and/or DBA safety cases appropriately. A report should be provided to ONR presenting the considered initiating events, sequences and attributed frequencies. This report should identify for each family of faults if it will be included in the PSA and DBA safety cases. The relative importance of administrative controls, interlocks, equipments, equipment classification, operator actions and associated claims should be included and described. With agreement from the Regulator this action may be completed by alternative means.		

Annex 3

GDA Issue, GI-UKEPR-FS-03 – Fault Studies – UK EPR™

EDF AND AREVA UK EPR GENERIC DESIGN ASSESSMENT

GDA ISSUE

SPENT FUEL POOL SAFETY CASE

GI-UKEPR-FS-03 REVISION 2

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Structural Integrity
Internal Hazards</td></tr>
<tr><td>GDA Issue Reference</td><td colspan="2">GI-UKEPR-FS-03</td><td>GDA Issue Action Reference</td><td>GI-UKEPR-FS-03.A2</td></tr>
<tr><td>GDA Issue Action</td><td colspan="4">EDF and AREVA to provide an updated safety case for the spent fuel pool, incorporating the faults associated with the cask loading pit.

The safety case needs to formalised:
If new PSA initiating events are identified by Action 1, additional event trees need to be incorporated into the PSA model.
If additions to the DBA are required: the category of the additional events (PCC-3/4) should be determined and adequate calculations or ALARP analysis undertaken to ensure that all criteria are met.
A report should be provided to ONR describing the proposed changes to the safety case.

EDF and AREVA shall update the PCSR accordingly with the agreed safety case developed through Action 1 and this Action.

With agreement from the Regulator this action may be completed by alternative means.</td></tr>
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Annex 3

GDA Issue, GI-UKEPR-FS-03 – Fault Studies – UK EPR™

EDF AND AREVA UK EPR GENERIC DESIGN ASSESSMENT

GDA ISSUE

SPENT FUEL POOL SAFETY CASE

GI-UKEPR-FS-03 REVISION 2

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<tr><td>GDA Issue Action</td><td colspan="4">EDF and AREVA shall provide a consequences analysis for spent fuel pool leaks previously not considered within the design basis because of break preclusion arguments.

EDF and AREVA identify a number of leaks associated with spent fuel pool which are currently excluded from the design basis analysis presented in the PCSR by evoking a break preclusion concept.

The rigour required to show that the likelihood of failure is so low that the consequences of failure can be discounted is high in UK and should not be put forward to avoid making a consequences analysis. While a small number of High Integrity Components (HIC) have been recognised associated with the primary reactor circuit, the safety case as currently presented does not identify the spent fuel pool components as part of the HIC envelope.

A consequences analysis of the identified leaks is to be provided, and a safety case (with accompanying ALARP arguments) identifying the design features and systems required to ensure the consequences are acceptable shall be submitted to ONR for assessment.

The PCSR is to be updated to reflect any changes in the safety case.

With agreement from the Regulator this action may be completed by alternative means.</td></tr>
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