Office for Nuclear Regulation
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ASSESSMENT REPORT

Civil Nuclear Reactors Programme

NNB GenCo: Hinkley Point C Pre-Construction Safety Report 2012 – Assessment Report for Work Stream B17: Structural Integrity

Assessment Report: ONR-CNRP-AR-13-074
Revision 0
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EXECUTIVE SUMMARY

This assessment report (AR) reviews that portion of the Hinkley Point C Pre-Construction Safety Report 2012 (HPC PCSR2012) that falls within the scope of Work Stream B17 - Structural Integrity. The review date for this report is December 2013 although activity on this work stream is ongoing. There is no single chapter in the PCSR relating specifically to structural integrity. ONR gives priority to those components and systems most relevant to nuclear safety and therefore the focus of the structural integrity intervention relates primarily to the nuclear steam supply system and parts of the steam and power conversion systems. Most of this material lies in HPC PCSR2012 Chapters 5 (Reactor Coolant System and Associated Systems) and 10 (Steam and Power Conversion Systems) which remain largely unchanged from the Generic Design Assessment Pre-Construction Safety Report 2011 (GDA PCSR2011) assessed by ONR. Other Chapters, containing new material beyond GDA PCSR2011 have been reviewed, at a high level, for their relevance to structural integrity. This is found in Chapters 3 (General Design and Safety Aspects), 11 (Discharges and Waste/Spent Fuel), 13 (Hazards Protection), 16 (Risk Reduction and Severe Accident Analysis) and 18 (Human Machine Interface and Operational Aspects).

A final version of the GDA PCSR issued in November 2012 formed the basis for issue by ONR on 13 December 2012 of a Design Acceptance Confirmation (DAC) for the UK EPR™ design. The GDA PCSR addressed only the key elements of the design of a single UK EPR™ unit (the generic features on "the nuclear island") and excluded ancillary installations that a potential purchaser of the design could choose after taking the site location into account. Certain matters were also deemed to be outside the scope of the GDA PCSR.

In contrast HPC PCSR2012 addresses the whole Hinkley Point C licensed site comprising the proposed twin UK EPR™ units and all ancillary installations. Some matters that were outside the scope of GDA PCSR are also addressed in HPC PCSR2012. As the generic features were addressed in the GDA process, my focus is on site-specific documentation that has not been formally assessed by ONR previously. The remaining, generic documentation has been copied into the HPC PCSR2012 from the earlier March 2011 GDA PCSR but this has now been superseded by the November 2012 GDA PCSR report.

It is important to note that HPC PCSR2012 alone is not sufficient to inform a future ONR decision on whether to permission construction of Hinkley Point C. NNB GenCo (NNB) intends to submit a major revision to HPC PCSR2012 before seeking consent for Nuclear Island construction which will fully integrate the final GDA PCSR and will be supported by other documentation.

The major part of HPC PCSR2012 relating to the structural integrity of key components of the nuclear steam supply system is taken from the GDA PCSR2011. During close out of GDA significant changes were introduced to the GDA PCSR2011 in producing the GDA PCSR2012 which formed the basis for award of the Design Acceptance Confirmation of the UK EPR™ generic design. It follows that these changes have not yet been included in the HPC PCSR2012 and are required by ONR to be addressed by NNB in the next update to the PCSR.

The new site specific information presented in HPC PCSR2012 has been reviewed at a high level. The additional information is at a preliminary stage of design and the component safety classification system agreed during final stages of the close-out of GDA issues has yet to be fully implemented. The HPC PCSR 2012 presents no new substantive claims relating to structural integrity.

The outcome of the component classification process will be reviewed by ONR when the new classification scheme, agreed during GDA close-out, is implemented. The strategy for establishing the quality assurance requirements has been produced. Further work is underway to address ONR comments and recent changes in the guidance associated with the French ESPN Order on nuclear pressure equipment. ONR expectations are that conformity assessment requirements are fully defined prior to future procurement of components. Additionally it is expected that the PCSR is updated to include both the latest safety classification and conformity assessment requirements.

NNB GenCo recognises the importance of keeping detailed records for the life of the plant. However, based on recent interventions, I am not yet sufficiently convinced NNB GenCo has adequate arrangements for collation of lifetime records. I have raised a new issue for the Licensee to demonstrate adequate arrangements for collation of suitably detailed lifetime records.

A design change to provide watertight compartments, agreed within GDA, for the fuel transfer tube is now considered impracticable by NNB GenCo. This solution was part of the UKEPR Design Reference and subject to ONR's DAC (Design Acceptance Confirmation) issued in December 2012. NNB GenCo now proposes to present a justification based on demonstration of the integrity of the fuel transfer tube as a high integrity component. The change to an alternative approach is because the responsible designer has indicated the original solution presents significant implementation difficulties. I have raised a new issue for the Licensee to demonstrate that the high integrity approach for the fuel transfer tube is an ALARP solution and submit a formal safety case for assessment by ONR.

I am broadly satisfied that NNB has a good understanding of the requirements of the structural integrity GDA assessment findings and is making significant progress in producing resolution plans, and their implementation where appropriate, to close out GDA assessment findings. However, I have requested further clarification of the timing of the deliverables from resolution plans with respect to the manufacturing programme and development of the safety case to remain confident that NNB are adequately managing project risks.

Because of the importance of the overall quality framework for manufacturing ultrasonic testing of forgings for high integrity components, I have raised a new issue for the Licensee to demonstrate an adequate level of redundancy, diversity and independence for ultrasonic inspections of forgings for HIC pressure boundaries, and shall ensure that the results of these inspections form part of the lifetime records.

I have also raised a new issue for the Licensee to address uncertainties in the adequacy of the RT_{NDT} procedure used in the RCC-M design code for defining fracture toughness in the transition temperature region and for providing an appropriate definition for the onset of upper-shelf.

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LIST OF ABBREVIATIONS

AF	Assessment Finding
AFCEN	Association Française pour les règles de conception, de construction et de surveillance en exploitation des matériels des Chaudières Electro-Nucléaires (French Association for the rules governing the Design, Construction and Operating Supervision of the Equipment for Nuclear Reactors)
ALARP	As low as is reasonably practicable
AR	Assessment Report
ASN	Autorité de Sûreté Nucléaire (French Safety Authority)
BMS	(ONR) How2 Business Management System
CEA	Commissariat à l'énergie atomique (Atomic Energy Commission)
DAC	Design Acceptance Confirmation
EPR	European Reactor
ESPN	Equipements to sous Pression Nucléaires (Nuclear Equipment under Pressure)
FANC	Federal Agency for Nuclear Control (Belgian Nuclear Regulator)
FMA	Fracture Mechanics Assessment
GDA	Generic Design Assessment
HIC	High Integrity Component
HPC	Hinkley Point C
HPC PCSR2012	Hinkley Point C Pre-Construction Safety Report 2012
HSE	Health and Safety Executive
IAEA	International Atomic Energy Agency
IEWG	Independent Expert Working Group
ILW	Intermediate Level Waste
IRSN	Institut de Radioprotection et de Sûreté Nucléaire (Institute of Radioprotection and Nuclear Safety)
ISFS	Interim Spent Fuel Store
ITPIA	Independent Third Party Inspection Agency
LC	Licence Condition
LLI	Long Lead Item
MDF	Material Data File
NDT	Non-Destructive Testing
NNB	NNB GenCo
NPE	Nuclear Pressure Equipment

LIST OF ABBREVIATIONS

NSSS	Nuclear Steam Supply System
ONR	Office for Nuclear Regulation (an agency of HSE)
OPEX	Operating Experience
PCSR	Pre-construction Safety Report
PWR	Pressurised Water Reactor
RCC-M	Règles de Conception et de Construction des Matériels Mécaniques des Ilots Nucléaires (Design and Construction Rules for the Mechanical Components of PWR Nuclear Islands)
RCC-MR	Règles de Conception et de Construction des Matériels Mécaniques des Installations Nucléaires applicables aux structures à haute température et à l'enceinte à vide ITER (Design and Construction Rules for the Mechanical Components of Nuclear Installations for High Temperature Structures and ITER Vacuum Vessel)
RD	Responsible Designer
RP	Resolution Plan (Addressing a GDA Assessment Finding)
RPV	Reactor Pressure Vessel
RSE-M	Règles de Surveillance en Exploitation des Matériels Mécaniques des Ilots Nucléaires (In-Service Inspection Rules for Mechanical Components of PWR Nuclear Islands)
RWMD	Radioactive Waste Management Directive http://www.nda.gov.uk/recruitment/working-for-rwmd.cfm
SAP	Safety Assessment Principle(s) (HSE)
SEPTEN	Service Études et Projets Thermiques et Nucléaires; Electricité de France (EDF Department of Thermal and Nuclear Studies and Projects)
SG	Steam Generator
SSC	System, Structure and Component
TAG	Technical Assessment Guide(s) (ONR)
UK EPR™	EDF and AREVA UK Pressurised Water Reactor Design
WENRA	Western European Nuclear Regulators' Association

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1 INTRODUCTION

1.1 Background

1 This report presents the findings of the assessment of that portion of the Hinkley Point C Pre-Construction Safety Report 2012 (HPC PCSR2012), Ref. 1 that falls within the scope of Work Stream B17 - Structural Integrity.

2 Assessment was undertaken in accordance with the requirements of the Office for Nuclear Regulation (ONR) How2 Business Management System (BMS) procedure AST/003, Ref. 2. The ONR Safety Assessment Principles (SAP), Ref. 3, together with supporting Technical Assessment Guides (TAGs), Ref. 4, have been used as the basis for this assessment.

3 This assessment report (AR) has been written to support a Summary Assessment Report that addresses whether HPC PCSR2012, Ref. 1, demonstrates suitable progress towards meeting ONR's requirement for an adequate Pre-Construction Safety Report. To this end this AR provides guidance through assessment findings (AF) on matters that need to be addressed in the next revision of HPC PCSR.

1.2 Scope

4 The scope of this report covers Work Stream B17 - Structural Integrity. There is no single chapter in the HPC PCSR2012, Ref. 1, relating specifically to structural integrity. ONR gives priority to those components and systems most relevant to nuclear safety and therefore the focus of the HPC structural integrity intervention relates primarily to the nuclear steam supply system (NSSS) and parts of the steam and power conversion systems. Most of this material lies in HPC PCSR2012, Ref. 1, Chapters 5 and 10 which remain largely unchanged from the Generic Design Assessment Pre-Construction Safety Report 2011 (GDA PCSR2011), Ref. 5, assessed by ONR. Other Chapters, containing new material beyond GDA PCSR2011 have been reviewed for their relevance to structural integrity. This is found in sub-Chapters of Chapters 3, 11, 13, 16 and 18 together with PCSR management and quality assurance arrangements given in Chapter 21.

5 A final version of the GDA PCSR issued in November 2012, Ref. 6, formed the basis for issue by ONR on 13 December 2012 of a Design Acceptance Confirmation (DAC), Ref. 7, for the UK EPR^{TM} design. The GDA PCSR addressed only the key elements of the design of a single UK EPR^{TM} unit (the generic features on "the nuclear island") and excluded ancillary installations that a potential purchaser of the design could choose after taking the site location into account. Certain matters were also deemed to be outside the scope of the GDA PCSR.

6 In contrast HPC PCSR2012, Ref. 1, addresses the whole Hinkley Point C licensed site comprising the proposed twin UK EPR^{TM} units and all ancillary installations. Some matters that were outside the scope of GDA PCSR are addressed in HPC PCSR2012, Ref. 1. As the generic features were addressed in the GDA process, attention has been concentrated here on site-specific documentation that has not been formally assessed by ONR previously. The remaining, generic documentation has been copied into the HPC PCSR2012, Ref. 1, from the earlier March 2011 GDA PCSR, Ref. 5, but this has now been superseded by the November 2012 GDA PCSR, Ref. 6. The generic documentation has only been revisited if recent developments have materially affected the case being made.

7 It is important to note that HPC PCSR2012, Ref. 1, alone is not sufficient to inform a future ONR decision on whether to permission construction of Hinkley Point C and NNB GenCo (NNB) intends to submit other supporting documentation. Note also that HPC PCSR2012, Ref. 1, will be superseded by a further site-specific revision intended to fully reflect the final GDA PCSR2012, Ref. 6, and other design changes from Flamanville 3 which is the reference design for Hinkley Point C.

8 It should also be noted the approach to safety function categorisation and safety system classification agreed during GDA is not fully reflected in HPC PCSR2012, Ref. 1, which largely uses the approach employed on Flamanville 3. The integration of the methodology agreed during GDA needs to be demonstrated in the next revision of HPC PCSR. On this basis safety function categorisation and safety system classification is not assessed further in this report.

1.3 Methodology

9 The methodology for the assessment follows the requirements of the ONR BMS ‘produce assessments’ step in the nuclear safety permissioning process and Ref. 2 in particular in relation to mechanics of assessment, Ref. 8.

10 This assessment has been focussed on the submissions given in HPC PCSR2012, Ref. 1, relating to structural integrity as it affects nuclear safety. Primary attention has therefore been given to the nuclear steam supply system forming the pressure boundary of the primary coolant circuit. Other systems and components have only been reviewed at a high level. Material presented in HPC PCSR2012, Ref. 1, from the GDA PCSR2011, Ref. 5, that has already been assessed by ONR as part of GDA has not been reassessed. Where GDA resulted in significant changes to GDA PCSR2011, Ref. 5, as given in the GDA close-out PCSR2012, Ref. 6, these have been highlighted and are expected to be addressed by NNB in the next revision of HPC PCSR2012. New material presented in HPC PCSR2012, Ref. 1, has been reviewed for its relevance to structural integrity as it affects nuclear safety. Where appropriate, reference is also made to additional documentation presented by NNB at Level 4 nuclear steam supply system (NSSS) and structural integrity topic intervention meetings. Particular attention has been focussed on those components where the safety justification requires the highest demands for demonstration of structural integrity, so called ‘high integrity components’ (HICs).

11 This assessment allows ONR to judge whether the NNB submissions provide evidence, relating to structural integrity, of adequate progress being made by NNB in the development of a PCSR to support construction of a UK EPR^{TM} at Hinkley Point C.

2 ASSESSMENT STRATEGY

12 My assessment strategy is set out in this section. This identifies the scope of the assessment and the standards and criteria that have been applied.

2.1 Standards and Criteria

13 The relevant standards and criteria adopted within this assessment are principally the Safety Assessment Principles (SAPs), Ref. 3, internal ONR Technical Assessment Guides (TAGs), Ref. 4, relevant national and international standards and relevant good practice informed from existing practices adopted on UK nuclear licensed sites. The key SAPs and relevant TAGs are detailed within this section. National and international standards and guidance have been referenced where appropriate within the assessment report. Relevant good practice, where applicable, has also been cited within the body of the assessment.

2.2 Safety Assessment Principles

14 The key SAPs applied within the assessment are included within Table 1 of this report.

2.2.1 Technical Assessment Guides

15 The main Technical Assessment Guide which has been used during this assessment is:

- NS-TAST-GD-016 Issue 4. Integrity of Metal Components and Structures (Ref. 4).

2.2.2 National and International Standards and Guidance

16 The structural integrity related SAPs, and relevant IAEA (International Atomic Energy Agency) standards and WENRA (Western European Nuclear Regulators' Association) reference levels are embodied and enlarged on in Ref. 4 and in practice this guide is the principal reference for assessing the structural integrity aspects.

2.3 Use of Technical Support Contractors

17 No technical support contractors were employed to support my assessment given in this report.

2.4 Integration with other Assessment Topics

18 The assessment of structural integrity generally requires input from other topic areas, typically fault studies, internal hazards and probabilistic safety assessments to provide bounding loading conditions and the assessment of the consequences of component failures. The adequacy of the HPC PCSR2012, Ref. 1, to address these topics has been assessed independently of this report on structural integrity.

2.5 Out-of-scope Items

19 The following items are outside the scope of the assessment.

- Re-assessment of the PCSR presented by the Requesting Parties during the GDA of UK EPR™.
- Re-assessment of PCSR supporting documentation presented by the Requesting Parties during the GDA of the UK EPR™.
- Re-assessment of the closure of GDA Issues relating to structural integrity.

ONR has assessed all of the above previously in GDA Step 4 and GDA Issue close out assessment reports.

3 LICENSEE'S SAFETY CASE

3.1 HPC PCSR2012 Material Assessed

20 There is no single chapter in the HPC PCSR2012, Ref.1, relating specifically to structural integrity.

21 Most of this material lies in HPC PCSR2012, Ref. 1, Chapters 5 (Reactor Coolant System and Associated Systems) and 10 (Steam and Power Conversion Systems). These chapters remain largely unchanged from the GDA PCSR2011, Ref. 5 assessed by ONR during Step 4 of the Generic Design Assessment.

22 Other chapters, containing new material beyond GDA PCSR2011, Ref. 5, have been reviewed at a high level, for their relevance to structural integrity. This is found in sub-chapters to Chapter 3 (General Design and Safety Aspects), Chapter 11 (Discharges and Waste/Spent Fuel), Chapter 13 (Hazards Protection), Chapter 16 (Risk Reduction and Severe Accident Analysis) and Chapter 18 (Human Machine Interface and Operational Aspects). Chapter 21 addresses PCSR management and use of Quality Assurance Arrangements.

3.2 GDA Assessment Findings Material Assessed

23 In addition to the HPC PSCR2012, Ref. 1, progress in developing resolution plans for the close out of GDA assessment findings has been presented to ONR by NNB at level 4 meetings on structural integrity and the NSSS. Section 4.3 of this report provides a summary of NNB's progress in this area.

3.3 Other Relevant Material

24 In response to international operating experience of defects reported in the reactor pressure vessels (RPVs) at Doel 3 and Tihange 2 reactors in Belgium, NNB has provided ONR with its assessment of the implications for Hinkley Point C. This has been assessed in a separate ONR Assessment Report and is summarised in Section 4.4 of this report.

4 ONR ASSESSMENT

25 This assessment has been carried out in accordance with ONR HOW2 BMS policy (Ref. 2).

4.1 Scope of Assessment Undertaken

26 The assessment in this report is essentially a high level review of selected Sub-Chapters to check for consistency of the HPC PCSR2012 (Ref. 1) with the Consolidated GDA PCSR2011, Ref. 5. In addition, where the GDA close-out PCSR2012, Ref. 6, is significantly different from the Consolidated GDA PCSR2011, Ref. 5, this has been reported but not discussed in detail. The forward work programme which forms part of the HPC PCSR2012, Ref. 1, Head Document has also received a high level review to check for consistency with safety case principles as set down at the end of GDA Step 4. There is relatively little new information in HPC PCSR2012, Ref. 1, which falls within the structural integrity topic area, but where any such material has been identified it has been reviewed.

27 This assessment also includes a limited review of the progress made by NNB in addressing the assessment findings from GDA. In particular where development or implementation of GDA resolution plans has resulted in significant or new insights then this has been reported. Finally, recent OPEX is considered where this may relevant to the HPC PCSR2012, Ref. 1, or assessment findings previously reported in GDA step 4 and GDA issue close-out reports. An example of this is the discovery of manufacturing defects in RPVs in Belgium.

28 The Head Document for HPC PCSR2012, Ref. 1, Section 0.3 has a table that gives a high level list briefly describing the contents of each chapter and the degree of use of the Consolidated GDA PCSR2011, Ref. 5. Extracts from this table, covering those sections which are particularly relevant to structural integrity, are presented in Table 2 of this assessment report.

29 Section 4.2 gives my assessment of the Head Document, the forward work programme and the content given in each of these sub-sections. Also included is my assessment of NNB progress in addressing GDA assessment findings (Section 4.3) and the implications from recent PWR operating experience in Belgium (Section 4.4) where this adds to my judgements on HPC PCSR2012, Ref. 1.

4.2 Assessment of Hinkley Point C PCSR2012

4.2.1 Head Document

30 The Head Document provides a useful high level route map and introductory commentary on the structure and claims in HPC PCSR2012, Ref. 1. A few of the claims relevant to structural integrity are worth noting here, because they shed light on the content and timescales of the forward work programme which must be undertaken by NNB.

31 The concept of high integrity components (HICs) is a key aspect of the structural integrity case for the UK EPR^{TM}. Sub-Section 5.1.4.1 (Page 69) of the Head Document explains that HICs are grouped into two types, non-breakable and break preclusion, with somewhat different safety case claims for each type. This distinction was explored further during GDA close-out, and consequently the claims have been modified in the GDA close-out PCSR2012, Ref, 6.

32 Another important concept for the UK EPR^{TM} is that, although the legal requirements relating to design and manufacture are different between France and the UK, the controls on quality of products for HPC should be at least equivalent to those applicable in France.

One of the references quoted for Section 5 of the Head Document is the RCC-M Adaptation Document for the procurement of Long Lead Forgings, Issue 2, May 2012, Ref. 9. This claims (Section 5.3) that the Independent Third Party Inspection Agency (ITPIA) contracted to perform conformity assessment will provide equivalence to other EDF EPRs which in France need to comply with the French Nuclear Pressurised Equipment ESPN Order, Ref. 10. This aspect is also relevant to the classification, design and manufacture of nuclear pressure equipment which is discussed later in this assessment report (Section 4.2.3).

33 Work on classification of systems, structures and components (SSCs) continues and this is mentioned in several parts of the Head Document for example Section 10.1 (page 106);

"Work on the classification of SSCs and the applicability of the classification scheme beyond the nuclear island plant is ongoing and, as such, the list of SSCs within the Steam and Power Conversion plant may be subject to change in future safety submissions.

The design is sufficiently well developed and stable, and the design basis described in HPC PCSR2 provides an adequate baseline safety justification for the Steam and Power Conversion Systems to support moving into the construction phase"

34 Revised principles for classification of SSCs were agreed during GDA close-out, and these will need to be applied to the UK EPR^{TM} during design, procurement and manufacture. Consequently it is not clear how the claim that the safety case is ready "to support moving into the construction phase" can be demonstrated until the revised principles have been applied to the key plant components. Progress towards meeting this requirement is discussed further in Section 4.2.3.

35 The timing of work relating to GDA assessment findings is an important factor in the development of the safety case for the UK EPR^{TM}. The Head Document recognises that certain findings needed to be addressed early, for example those relating to material compositions for the long lead item forgings. As stated in Section 5.1.4.3, "In the procurement arrangements for these components, NNB GenCo has incorporated the requirements of three GDA assessment findings that relate to competency of the steelmaker, limits in composition of the main vessel forgings and nickel content of 20MND5 (AF-UKEPR-SI-23, 24 and 27)." I have reviewed the end-of-manufacturing report for the reactor pressure vessel integrated shell forging for compliance with GDA AF-UKEPR-SI-24 and the controls on material composition given in Section 4.1 of Sub-Chapter 5.3. I am not yet satisfied that the chemistry controls on carbon and phosphorus have been demonstrated to meet UK limits and have written to NNB requesting further justification, Ref. 11.

36 However there are a number of other structural integrity assessment findings, whether from the Step 4 GDA or the GDA close-out, which have the potential to affect the design and manufacture of components. Consequently I consider it important for NNB to develop resolution plans for any such findings and to ensure that progress of this work is compatible with the project timescales. Aspects relating to existing GDA assessment findings are discussed in Section 4.3.

4.2.2 Head Document: Forward Work Plan

37 As noted in the HPC PCSR2012, Ref. 1, Head Document, there are five main inputs to the engineering and safety case development that initiate the requirement for Forward Work Activities. These are as follows:

1) Generic Design Assessment (GDA) Issues

2) GDA Assessment Findings
3) GDA Out-of-scope Items
4) Fukushima related recommendations
5) Other Forward Work Activities

38 **Section 3.4.6 – Technical Code for Mechanical equipment (RSE-M).** It was originally anticipated that the independent review of RSE-M as requested in ONR letter NNB 50063R (Ref. 12) would be completed "after first safety-related concrete", but it was not clear at the time of writing how the proposed timetable would link with the design, procurement and manufacturing activities. Section 4.3.2 herein, provides an update on the latest position with regard to both the scope of work and anticipated completion date of the RSE-M independent review. In the context of Codes and Standards, it is particularly noteworthy that EdF SEPTEN represent NNB GenCo on the AFCEN RSE-M mechanical analysis working group, and project arrangements are in place for NNB GenCo to receive feedback from EdF SEPTEN on the discussions and issues arising within the RSE-M working group.

39 **Section 5.2 – GDA Assessment Findings**. It is stated that "There are no GDA Step 4 assessment findings relevant to Chapter 5 of HPC PCSR2012, Ref. 1, that require resolution prior to the ONR milestone of nuclear island safety-related concrete." Whilst this may be true, it potentially obscures the fact that many assessment findings may require work to start early in the design and procurement process to ensure that procurement and manufacturing specifications are adequate. It is potentially misleading to imply that no work is currently required even though an assessment finding might not need to be demonstrably closed until a later generic milestone eg Install RPV. A similar comment may be made about Section 10.2 covering the steam and power conversion systems. Further discussion on the prioritisation of GDA assessment findings is given in Section 4.3.1.

40 **Section 5.4 – Other Items**. There is a substantial list of further work with a statement that a plan to address this will be developed. From the information provided it is not yet clear that there is an adequate link between the work required and the timescales for design, procurement and manufacture.

41 Conclusion of high level review of forward work programme. Whilst I judge that the list of proposed activities is reasonable at this stage of the programme, NNB GenCo has not yet demonstrated an adequate linkage between the forward work programme and the timescales for design, procurement and manufacture of many of the structural integrity components. Progress in developing and implementing an appropriate forward work programme will continue to be monitored at Level 4 Structural Integrity and NSSS Intervention meetings.

4.2.3 Chapter 3: General Design and Safety Aspects

42 **Sub-Chapter 3.1 – General Safety Principles** – has a brief summary (in Section 1.2.1.4.1) of improvements in the reactor coolant system design for the EPR and introduces the concept of high integrity components (HIC). The design change to the main coolant loop cross-over leg agreed during GDA close-out will need to be included when the PCSR is updated. Section 1.2.5 outlines the principles of safety function categorisation and safety classification for SSCs, but this will need to be updated to incorporate the new principles agreed during GDA close-out. The EPR Technical

Guidelines are reproduced in full in Table 1, whereas these were removed from the GDA close-out PCSR at the request of ONR because certain of these guidelines have now been superseded.

43 **Sub-Chapter 3.2 – Classification of structures, equipment and systems** – has details of the classification scheme, as it stood at the end of GDA Step 4. This sub-chapter will need to be updated to bring it in line with development of the classification methodology during GDA close-out. My expectation is that the methodology agreed during GDA close-out will be demonstrated in the next revision of the HPC PCSR prior to construction.

44 A significant amount of work is currently underway by NNB to allocate a safety classification to components of structural significance. Functional requirement notes identify the classification and the functional safety analysis provides the justification for the classification. The current program suggests the functional requirements notes will be available significantly in advance of the functional safety analysis. There is therefore a risk that the classification allocated could be subject to change.

45 Table 1 (Page 32-on) of the HPC PCSR2012, Ref. 1, lists the main mechanical components and their current classification. This will need to be reviewed when the new classification scheme, agreed during GDA close-out, is implemented.

46 While the classification methodology was considered, in principle, to be adequate for GDA close-out I consider there is currently insufficient visibility to form a judgement of the adequacy of the outcome of the process.

47 The classification of components with structural significance not only relates directly to the design and manufacturing requirements but also to the requirements for manufacturing surveillance and compliance. The manufacturing surveillance and compliance requirements influence the quality of the components and thus the assurance of structural integrity.

48 The strategy for establishing the quality assurance, including essential safety and conformity assessment requirements, is established in the (draft) nuclear pressure equipment (NPE) strategy, Ref. 13. This document has not yet been formally approved by NNB.

49 The draft NPE strategy was presented to ONR at a Level 4 meeting, Ref. 13, in April 2013. ONR expressed some reservations as the strategy indicated that relatively low levels of conformity assessment could be applied to components manufactured to a nuclear code that perform a principle role in nuclear safety (mechanical classification M3 and nuclear safety class 1). ONR guidance considers it good practice (safety assessment principles, Ref. 3, EMC18) to subject manufacture and installation operations to appropriate third-party independent inspection to check that processes and procedures are being carried out as required. This would preclude the use of internal production control conformity assessment modules. The current NPE strategy is to use a second-party user inspectorate for components other than those considered to be high integrity. My expectation is that further justification will be provided to address the apparent differences between the strategy and the ONR SAPs in the final NPE strategy.

50 The strategy endeavours to combine the European pressure equipment directive, Ref. 14 and French legislative (ESPN Order, Ref. 10) requirements with the UK pressure equipment regulations, Ref. 15. A number of points raised by ONR with regard to the strategy are currently being addressed by the NNB NPE working group. NNB agreed to report, with the use of an example with a mechanical classification M3 component, how an integrated system for inspection and safety case requirements is to be achieved.

Additionally the recent changes to the guidance from ASN on implementation of the French ESPN Order are also being assessed.

51 ONR expectations are that conformity assessment requirements are fully defined prior to future procurement of components. Additionally it is expected that the HPC PCSR is updated to include both the latest safety classification and conformity assessment requirements. Progress in developing and implementing the safety classification and conformity assessment requirements will continue to be monitored at Level 4 structural integrity and NSSS intervention meetings.

52 **Sub-Chapter 3.4 – Mechanical systems and components** – has much design information on these systems and components. It describes the concept of high integrity component (HIC), where in general it cannot be justified that the consequences of failure are acceptable, with the safety case implications (Sections 0.3.6). However these additions include the concept of three categories of components: HIC, those for which gross failure is tolerable, and those whose failure is unlikely and certain failure modes are tolerable. This third category was not fully accepted by ONR during GDA and led to significant revisions to the safety case principles during GDA close-out. Consequently the changes agreed in GDA PCSR2012, Ref. 6, will need to be incorporated in a future revision of the HPC PCSR.

53 Pages 147-153 provide a significant section (Section 1.6) which addresses the fast fracture risk for HICs. This outlines the principles agreed at the end of GDA step 4, but will need updating to take account of modifications agreed during GDA close-out. This Section refers to more detail on HICs being provided in sub-chapters 5.3, 5.4 and 10.3.

54 Section 3.1 specifies the applicable version of RCC-M as Edition 2007. However the 2008, 2009 and 2010 Addenda have now been specified as applicable. The 2008 Addendum includes the option to select 20MND5 steel grade for the steam generator and pressuriser shells. The option to use 20MND5 for the steam generator and pressuriser shells was accepted within GDA Step 4 as a formal design change and this material has been selected for HPC.

55 There is also a new section 1.1.8 covering pressurised thermal shock which links to the avoidance of fracture methodology introduced for HICs.

56 **Sub-Chapter 3.8 – Codes and standards used in the EPR design** – explains the hierarchy of safety regulations in France with Level 1 being legal requirements, Level 2 being Basic Safety Rules and letters from the French Safety Authority (ASN) and Level 3 being Codes and Standards. There is no detail provided on Tier 1 and Tier 2 requirements, although NNB has accepted that, for example, the main requirements of the ESPN Order, Ref. 10, will be applicable to HPC. There is a commitment in the RCC-M Adaptation Document, Ref. 16, that the ITPIA will provide conformity assessment at a level equivalent to that required by the ESPN Order, Ref. 10.

57 There is a new Section 6: Technical Code for Mechanical equipment – limiting defect size calculation (RSE-M). This explains why RSE-M rather than RCC-M is used for the assessment of fast fracture risk for HICs. It mentions the validation done by CEA supported by IRSN. However it does not mention the comparison between RSE-M and the UK Code, R6, required by NNB to satisfy AF-UKEPR-SI-06. It is important that NNB GenCo progress this review on a timescale which matches the programme for assessment of defect tolerance of HICs. See also Section 4.3.2.

4.2.4 Section 5: Reactor Coolant System and Associated Systems.

58 **Sub-Chapter 5.3 – Reactor Vessel** – adopts the GDA PCSR2011, Ref. 5, without change and provides details of the safety case principles applicable to HICs. The new Section 7 describes the HIC fast fracture methodology. This sub-Chapter will need to be updated in future to take account of the actions agreed when resolving GDA Issues SI-01 and SI-02.

59 **Sub-Chapter 5.4** – **Components and Systems Sizing** – adopts the GDA PCSR2011, Ref. 5, without change and provides details of the application of HIC safety case principles to the main pressure boundary components apart from the RPV. These cover the reactor coolant pump (section 1.6), the steam generator (Section 2.10), the main coolant lines (Section 3.9) and the pressuriser (Section 4.7).

60 Section 2.5.1 introduces the option to use 20MND5 as well as 18MND5 for the steam generator and pressure vessel pressure boundary forgings as a result of the 2008 Addendum to the RCC-M Code and the formal design change introduced during GDA.

4.2.5 Section 10: Steam and Power Conversion Systems

61 Sub-Chapter 10.2 is new and describes the turbo-generator which is assessed under the mechanical engineering topic. Sub-Chapter 10.4 is also new and describes other features of the steam and power conversion systems such as the condenser, condensate extraction, turbine by-pass and gland steam, feedwater supply, cooling water and steam generator blowdown systems. This Sub-Chapter has been considered by mechanical engineering and fault studies topic areas.

62 **Sub-Chapter 10.3 – Main Steam System (safety classified part)** – incorporates new sections 0.3.1.7 and 7 regarding HIC classification of the main steam lines which are taken from the Consolidated GDA PCSR2011, Ref. 5. Section 6.1 has been revised to clarify how the design provides access for inspection of welds. This notes that the counterbores on the main steam lines have been extended to facilitate ultrasonic inspection. (NB. A similar modification for the counterbores of the main coolant lines in the primary circuit was agreed during GDA close-out and will need to be included in the next update of the HPC PCSR).

63 **Sub-chapter 10.5 – Implementation of the break preclusion principle for the main steam lines inside and outside the containment** – sets out the HIC requirements as applicable to break preclusion piping. It states that "Many of requirements relating to the demonstration of break preclusion are common to those described for the reactor coolant system…" This topic was assessed further during GDA close-out and hence the text in HPC PCSR 2012, Ref. 1, will need to be revised accordingly at the next update.

4.2.6 Section 11: Discharges and Waste/Spent Fuel

64 This section of the PCSR summarises the safety function roles, discharges and disposals and provides an overview of the facilities and systems related to radioactive waste and interim storage of solid waste and spent fuel. Section 11 of the HPC PCSR2012, Ref. 1, contains substantial amounts of new material in sub-sections 11.2, 11.3. 11.4 and 11.5. The new content has been reviewed here in the context of structural integrity. The Radiological Discharges and Spent Fuel Topic leads are addressing this section.

65 **Sub-Chapter 11.2 – Waste Management Process and Strategy** – is a partially new section which includes GDA data to deal in part with requirements of the Environment Agency. From my high level review I judge there to be no specific claims relating to structural integrity.

66 **Sub-Chapter 11.3 – Waste Generation, Discharges and Disposals from HPC** – is an all new sub-section. This sub-chapter provides a summary of the discharges and disposals of radioactive and non-radioactive effluents and wastes from the Hinkley Point C site through the commissioning and operation of 2 UK EPR^{TM} units and associated facilities, including the Interim Spent Fuel Store (ISFS) and the Intermediate Level Waste (ILW) building. From my high level review I judge there to be no specific claims relating to structural integrity.

67 **Sub-Chapter 11.4 – Effluent and Waste Treatment Systems Design Architecture** – is a partially new section which includes GDA data. This sub-chapter discusses the aspects related to the waste (gaseous, liquid and solid) treatment systems. It presents the systems that take part in the storage, treatment and/or discharge of effluent produced within the nuclear island and some site facilities. There appears to be little new information with no specific claims relating to structural integrity. Further review may be appropriate as more design information is made available to ONR.

68 **Sub-Chapter 11.5 – Interim Storage Facilities and Disposability** – is new sub-section which discusses the aspects related to the on-site interim storage facilities, for the ILW radioactive operational waste, and spent fuel, produced during the 60 years of HPC operation.

69 The design safety principles for interim storage of ILW were established during GDA and assessment findings given. It is proposed that conditioned ILW will be stored in concrete containers in one facility for both units. The design life of the facility is 60 years. Following interim storage it is anticipated that ILW will be transferred to a national repository. The current design is only at conceptual stage and the structural integrity of containers used eventually for transport will be considered outside of the scope of HPC PSCR2012, Ref. 1, as part of the RWMD application. From my high level review of information presented I judge there to be no specific claims relating to structural integrity. Further review may be appropriate as more design information is made available to ONR.

70 The GDA submission for the interim storage of fuel sets out both wet and dry storage as adequately safe options. The choice of option for a specific location has been left open to the future licensee who is expected to take into account site specific issues. NNB has considered the alternative options and has decided that for HPC wet storage in pools provides the best solution for interim storage.

71 The design of the ISFS is currently only at a conceptual level, and as such there is significantly less detail available than for other site facilities which form part of the generic EPR design. There is no detailed design or quantitative safety analysis available from GDA for a wet storage facility. Sections 2.4 and 2.5 presents a forward work plan of ongoing studies to develop the detailed design and safety justification.

72 The conceptual design of the underwater spent fuel interim facility is described in the synthesis report, Ref. 17, as a supporting reference to HPC PSCR2012, Ref.1. From my high level review of this document I judge there to be a no specific structural integrity claims at this stage of design. The spent fuel pond is sub-ground level and lined with a stainless steel liner. Heat removal is engineered by a combination of multiple passive and active heat exchangers. Heat exchangers are immersed in the fuel pond with no penetrations or leak path capable of draining cooling water from the pond so eliminating loss of pond coolant faults.

4.2.7 Section 13: Hazards protection

73 **Sub-Chapter 13.2 – Internal Hazards Protection** – includes several sections from the GDA PCSR2011, Ref. 5, relating to break preclusion of high energy pipework and has a section (2.5) which claims to exclude leaks or breaks in moderate energy pipework. These principles and claims were modified during GDA close-out and hence will need to be updated in the next revision of the HPC PCSR.

4.2.8 Section 21: HPC PCSR management framework, design development and use and QA arrangements

74 **Sub-Chapter 21.2 – Design development and use of HPC PCSR** – outlines how the PCSR is developed using NNB processes such as Design Review and Acceptance. I have examined the application of such processes as part of my intervention on the Long Lead Item forgings.

75 The review and acceptance process is the subject of a current intervention. From my review of a sample of documentation from the initial contract between EDF and Areva (Contract ‘A’) to provide basic design and safety documentation I am broadly satisfied with the current state of development of the process and further work has been identified to fully meet relevant good practice in the UK. I will follow the development of the NNB GenCo review and acceptance process to ensure it meets my expectations through Level 4 nuclear steam supply system intervention meetings.

76 ONR guidance considers it good practice (safety assessment principles, Ref. 3, EMC20) to retain detailed records of manufacturing, installation and testing activities for review at any time during the plant lifetime. During recent interventions the information intended for inclusion within lifetime records has not fully met ONR expectations. Examples of where these requirements have fallen short of ONR expectations are presented in paragraphs 77-79 below.

77 Responding to ONR letter, Ref. 18, NNB indicated, Ref. 19, that no safety case claims are made by NNB for in-company inspections performed by suppliers of forgings for high integrity components. Furthermore NNB do not review or accept the results of these inspections, and they are not proposed to form part of the lifetime records for Hinkley Point C. ONR replied, Ref. 20, highlighting concerns with an inspection strategy which relies entirely on the results of a single inspection, providing guidance on aspects to be considered in an inspection strategy. NNB expect to provide proposals for a revised strategy to ONR in December 2013.

78 During a review of the first end-of-manufacture report for NSSS forgings, Ref. 21, ONR noted that the report implied the whole forging had been subject to a simulated post weld-heat treatment whereas in fact this only applied to the mechanical test samples. This document ambiguity had not been identified by AREVA, EDF, the independent third party inspection agency or NNB. This report forms a major part of the lifetime records and ONR expects there to be clarity in the documentation to avoid future misinterpretation of documentation. NNB has undertaken to amend the lifetime records to remove the ambiguity.

79 During manufacturing surveillance of a forging supplier for high integrity components, Ref. 22, an inconsistency in heat treatment parameters was identified between the technical manufacturing programme and quality documentation. Evidence of dressing was identified on the inner surface of one of the forgings for which no records were identified and inconsistencies were identified between material test reports. It is unclear what information relating to these issues would be recorded in the lifetime records. The issues

identified during this intervention are being followed up by ONR during Level 4 intervention meetings.

80 NNB identified, in a recent letter, Ref. 23, the importance of keeping detailed records for the life of the plant. However, based on the evidence presented, I am not yet convinced NNB has adequate arrangements for collation of suitably detailed lifetime records.

Issue HPC-PCSR-SI-01 (Level 3)	The Licensee shall demonstrate adequate arrangements for collation of suitably detailed manufacturing and construction lifetime records to demonstrate the quality of manufacture and installation for nuclear pressure equipment.
Milestone Required by ONR	Start of Construction

4.2.9 Section 16: Risk Reduction and Severe Accident Analysis

81 **Sub-Chapter 16.3 – Practically Eliminated Situations** – includes a statement eliminating the potential for fuel damage in the spent fuel pool which repeats the GDA PCSR2011, Ref. 5, claim. This claim was not accepted during GDA and led to Fault Studies GDA Issue GDA-UKEPR-FS-03: Spent Fuel Pool Safety Case Action 3 – Spent Fuel Pool Leaks which are excluded from the Design Basis Analysis.

82 A letter sent to EDF and AREVA by ONR, Ref. 24, indicated an ONR expectation that unless a component is identified as a high integrity component then there needs to be a consequences case and the consequences case needs to consider gross failure. The GDA issue, GI-UKEPR-FS-03 Action 3, was created to indicate this requirement for a consequence analysis for the leaks and to identify the design features and systems required to ensure that the consequences are acceptable.

83 The resolution for this Issue, presented by EDF/AREVA in the updated safety case, PTS DC 10 Revision C, Ref. 25, was assessed by ONR in a close out report, ONR-GDA-AR-12-012, Ref. 26. The resolution presented in response to the GDA issue was considered adequate subject to satisfactory progression and resolution of a further assessment finding identified during the assessment.

84 The resolution was part of the UK EPR™ Design Reference and subject to ONR's DAC (Design Acceptance Confirmation), Ref. 7, issued in December 2012. The design change, agreed within GDA, is presented in Change Management Form (CMF) CMF72.

85 However, NNB is now proposing an alternative approach because, following detailed studies and further optioneering, the design modification proposed during GDA to address FS-03 (CMF72) is considered by the Responsible Designer to present significant implementation difficulties. A number of alternative solutions have been assessed and NNB proposes to justify the plant by demonstrating that the fuel transfer tube can be considered as a high integrity component (HIC).

86 This is an ongoing topic of consideration by NNB and ONR that may result in increased demands on the demonstration of structural integrity of the fuel transfer tube assembly. I consider that a formal safety case would need to be submitted and assessed by ONR before a fundamental change from the GDA Design Reference could be agreed. Currently, I judge that insufficient information has been presented to support the conclusions of the ALARP assessment that the HIC approach is the only practicable solution. Greater detail is required of the HIC safety case claims, arguments and evidence

before any judgment could be made regarding the acceptability of that approach. The next version of the PCSR will require updating to reflect the outcome of this topic.

Issue HPC-PCSR-SI-02 (Level 3)	Before deviating from Change Modification CMF72, the Licensee shall demonstrate that classifying the fuel transfer tube as a high integrity component (HIC) is an ALARP design solution and provide a formal safety case for assessment by ONR.
Milestone Required by ONR	Install RPV

4.2.10 Section 18: Human-Machine Interface and Operational Aspects

87 **Sub-Chapter 18.2 Section 5 – In-service Inspection and Maintenance** – adopts the GDA PCSR2011, Ref. 5, without change and provides the outline strategy for pre-service inspection (PSI) and in-service inspection (ISI). However, the detail of the PSI/ISI programme was outside the scope of the GDA. Flamanville 3 PSI requirements will form the basis for the UK EPR™ PSI requirements, but NNB will develop them to address the UK regulatory context. ISI requirements will be finalised during the detailed design phase taking into account operational experience, inspection capability, regulatory requirements and the results of PSI. Further development of inspection requirements will need to be addressed during the next revision of the HPC PCSR.

4.3 Review of Progress with Resolution Plans for GDA Assessment Findings

88 The purpose of this section is to provide a summary of ONR interventions to assess NNB progress with the development of resolution plans intended to close-out GDA structural integrity assessment findings. Emphasis has been given to assessing the implementation of the NNB process for managing GDA assessment findings, Ref. 27. A sample of assessment findings are reviewed in more detail. The sample has been selected to address those topics where there has been significant development since the GDA assessment findings were published sufficient to warrant further consideration in the next version of the PCSR.

4.3.1 Summary of NNB GenCo Progress to address GDA Assessment Findings

89 The responsibility for closure of GDA assessment findings rests with the licensee and is managed through the definition and monitoring of individual resolution plans. Closure is achieved through the presentation and acceptance of individual closure packs.

90 ONR is adopting a graduated approach to the assessment of NNB's procedure, focussed on those assessment findings considered more significant to the assurance of nuclear safety. ONR category 1 assessment findings are subject to more detailed assessment, ONR category 2 findings will be sampled and category 3 assessment findings will be subject to checks on licensee processes.

91 ONR discussed the assessment findings arising from the GDA Step 4 Structural Integrity report with the NNB Design Authority Structural Integrity team on 10 May 2012, Ref. 28. At this meeting, NNB outlined their approach to the prioritisation of GDA assessment findings defined in the NNB procedure, Ref. 27, which sets the NNB priority according to the required timing of the work. NNB priority 1 was given to those findings where initial work was required prior to the milestone for pouring of nuclear island concrete.

92 A primary objective of the Level 4 meeting on 10 May 2012 was to ensure that NNB had correctly interpreted the background to each of the 42 GDA Step 4 structural integrity assessment findings so that NNB might formulate appropriate resolution plans.

93 A further Level 4 intervention meeting was held with NNB on 28 May 2013, Ref. 29. A primary objective of this meeting was to ensure that NNB had correctly interpreted the background to each of the additional 25 GDA structural integrity assessment findings arising from the close-out of the two GDA Step 4 structural integrity issues. All the additional 25 assessment findings were allocated to the completion milestone of 'Install RPV' during GDA. NNB has reviewed the priority of each of the additional findings concluding that some require work before the start of pouring nuclear island concrete due to the effect on contracts, design, manufacturing or the lead time to complete the work. ONR has also challenged the timing of some of the work required and in two cases NNB has revised the provisional priority assigned.

94 The development of resolutions plans has been a regular agenda item on Level 4 structural integrity and NSSS Level 4 meetings with NNB. Early drafts of resolution plans for most Step 4 assessment findings and high priority GDA close-out assessment findings were made available to ONR. Where appropriate, ONR structural integrity assessors have responded to NNB with comments on the proposed draft resolution plans and email correspondence on specific resolution plans has supplemented discussion at Level 4 meetings.

95 I judge from the information provided, that NNB has made adequate progress in addressing the Step 4 assessment findings and the additional findings from GDA close-out and there do not appear to be any significant differences between NNB GenCo and ONR in interpreting the aims of the findings.

96 In general the scope of work proposed to address the findings appears reasonable. However I expect to see greater clarity on the timing of work for the assessment findings and the linkages to the design, development of the safety case, manufacture and installation of the components.

97 The production and first formal release of resolution plans has been delayed. It was originally intended that all Step 4 resolution plans should be available by September 2013 and all resolution plans for NNB high priority GDA close-out assessment findings to be available in 2013.

98 In summary, I judge that NNB has a clear understanding of the intent of GDA structural integrity findings and has made progress in applying the NNB procedure to develop resolution plans. There has been some delay in formally releasing step 4 resolution plans. I expect to see greater clarity on the timing of work and the linkages to the design, development of the safety case, manufacture and installation of the components. Progress in the development of resolution plans will continue to be monitored at structural integrity and NSSS level 4 meetings.

4.3.2 GDA Step 4 Assessment Finding AF-UKEPR-SI-06

Resolution Plan unique no.	NNB-OSL-PLN-006223 v0.3, 01-02-13 †
GDA Assessment finding	The Licensee shall engage with ND to ensure that the fracture assessment procedure used to calculate the limiting defect sizes will be suitable for supporting a UK based safety case.

Milestone required by ONR	Install RPV			
ONR Category	1		**NNB Priority**	1

† TRIM: 2013/437598

4.3.2.1 Background

99 The UK nuclear structural integrity community extensively uses the R6 procedure for fracture mechanics assessment (FMA), Ref. 30. For this reason, ONR has experience and confidence in the application and validation of R6. However, NNB intends to use a fracture assessment methodology for the UK EPR™ which is derived from the French RSE-M code, Ref. 31 and there is a need for better understanding of the implications of using this alternative approach.

100 Assessment Finding AF-UKEPR-SI-06 arose partially as a result of comparative studies undertaken as part of the GDA assessment which highlighted differences in the R6 and RSE-M FMA methodologies as applied to NSSS components to derive estimates for limiting defect size, (Sections 4.2.3.4 - 4.2.3.5, Ref. 32 refer).

101 The comparative studies identified an important difference in the treatment of the post yield interaction between the primary and secondary stresses in RSE-M Appendix 5.4 compared with the R6 procedure more generally adopted for FMA in the UK to-date. These differences were found to be most significant when applied to thermal shock loads.

102 Notwithstanding the above, more recent comparative studies undertaken on behalf of ONR for the same thermal shock situation, have displayed a higher degree of consistency between estimates for limiting defect size determined from the R6 and RSE-M methodologies, Refs 33 and 34. The latter results have correspondence with recent publications on FMA applications concerned with combined loading (Refs 35 and 36) which suggest that conventional applications of R6 may be overly conservative in contrast to RSE-M, for circumstances which involve secondary stresses in excess of yield. In this context, it is also noteworthy that RSE-M has been developed specifically for application to the assessment of PWR components, whereas R6 has been developed for more generalised applications.

103 It should be noted that AF-UKEPR-SI-06 is related to the following Assessment Findings given in the GDA Close-Out Report, (Annex 2, Ref. 37).

AF-UKEPR-SI-48: Should the Licensee adopt the RSE-M Appendix 5.4 fracture assessment procedure, the Licensee shall ensure that:

- updates to Appendix 5.4 of RSE-M and Appendix A16 of RCC-MR are reviewed as they are released to determine their impact on both future and existing assessments (even if they are only available in French at the time of release);
- they establish a presence on the committee developing Appendix 5.4 of RSE-M and Appendix A16 of RCC-MR; and
- they have a capability to identify any reservations and limitations on the use of RSE-M Appendix 5.4 as identified by the French Nuclear Safety Authority (ASN).

AF-UKEPR-SI-49: Should the Licensee adopt the RSE-M Appendix 5.4 fracture assessment procedure, the Licensee shall ensure that there is a capability to undertake assessment to RSE-M Appendix 5.4 independently of the company supplying the reactor design in order to support the ongoing operation of the reactor. The availability of technical support organisations to allow the UK Nuclear Regulator (ONR) to commission such assessment work independently should also be considered.

AF-UKEPR-SI-50: Should the Licensee adopt the RSE-M Appendix 5.4 fracture assessment procedure, the Licensee shall ensure that the UK methodology for undertaking the fracture assessments based on RSE-M Appendix 5.4 is suitable and sufficient to define the methodology in relation to RSE-M, and to explain and justify departures from RSE-M.

4.3.2.2 Independent Expert Working Group (IEWG) RSE-M Review †

104 In Resolution Plan NNB-OSL-PLN-006223, Ref. 38, NNB has recognised that there is a need to undertake an Independent Review of the RSE-M fracture assessment code to provide greater assurance of the provenance of the code and its applicability to the UK regulatory environment as part of a safety case demonstration for the avoidance of fast fracture relating to HIC components. Consequently, the Independent Expert Working Group (IEWG) has been set up by NNB with the following terms of reference, Ref. 39:

***Terms of Referenc**e The purpose of the independent review is to advise the Health & Safety Executive (HSE) Office for Nuclear Regulation (ONR) and Nuclear New Build Generation Company (NNB GenCo) on whether the fracture mechanics methodology in RSE-M (In-Service Inspection Rules for the Mechanical Components of PWR Nuclear Power Islands), as to be applied by NNB GenCo, is fit for purpose in supporting a UK based structural integrity safety case for the EPR.*

105 The scope of work and regulatory objectives are as stated in the Technical Specification, Ref. 40:

- Develop an improved understanding of RSE-M Appendix 5.4 fracture assessment methodology.
- Provide confidence in the RSE-M methodology.
- Establish the extent of validation of RSE-M by comparison of models with experimental or other available data.
- Comparison of the extent of validation of RSE-M and R6.
- Establish strengths and weaknesses by comparison with R6.
- Compare limits of applicability of RSE-M and R6.
- Develop understanding of the review and update process for RSE-M.
- Provide a view on the availability of independent advice on RSE-M fracture mechanics assessments, and what infrastructure will be needed to support this for the future.

106 I am satisfied that:

† RSE-M Independent Expert Working Group, TRIM Folder: 4.4.2.13113.

- The scope of work proposed in the Technical Specification (Ref. 40) accurately reflects all that is necessary to address AF-UKEPR-SI-06.

107 At the time of writing, there have been three meetings of the IEWG, Ref. 41, with a fourth meeting scheduled for 17 December 2013. Refs. 33, 34 and 42-47, document the progress to-date with respect to the following Tasks specified in Ref. 40:

Task 1.1 General Methodology in RSE-M

Task 1.3 Comparison between the 1997 Edition of RSE-M with 3rd Addendum 2005 and the 2010 Edition of RSE-M

Task 3.1.1 Stress Intensity Factor Solutions and Mixed Mode Loading Rules

Task 3.1.2 Methodology for the Determination of the Mechanical Load Reference Stress and Associated Crack Driving Force J_s

Task 3.1.3 Methodology for the Determination of the Constrained Plasticity Crack Driving Force Parameter K_{cp}

Task 3.2 Methodology for Treatment of Interaction between Primary and Secondary Stresses

Task 3.3.1 Methodology for the Determination of the Plasticity Correction Term k_{th}

Task 3.3.2 Methodology for Treatment of Thermal Stress

Task 3.3.3 Methodology for Treatment of Weld Residual Stress

108 I am satisfied that:

- The rate of progress thus far to address AF-UKEPR-SI-06 is satisfactory and is consistent with a target completion date of the end of 2014 for identified tasks.

4.3.3 GDA Step 4 Assessment Finding AF-UKEPR-SI-07

Resolution Plan unique no.	NNB-OSL-PLN-006224 v 0.3 08-11-12			
GDA Assessment finding	The Licensee shall provide evidence that the capability of the NDT procedures applied during manufacture of safety-related components (but not subject to inspection qualification) is adequate for the purpose.			
Milestone required by ONR	RPV Installation			
ONR Category	1		**NNB Priority**	1

109 I have assessed the (draft) resolution plan for this assessment finding and established that the scope is consistent with the assessment finding in that it covers all the main non-destructive testing (NDT) techniques and both HIC and non-HIC plant.

110 I consider that the methodology for the HICs (described as Phase 1 in the RP) is appropriate. However, I consider that the philosophy proposed for the other safety-related components (described as Phase 2) needs some clarification and/or modification. The proposal is that code-compliant procedures will not be modified, but I consider that this approach risks overlooking those situations where a particular (nuclear or conventional) code or standard does not adequately cover the specific component, material or inspection technique. For example RCC-M does not adequately cover ultrasonic inspection of ferritic welds with near-vertical fusion faces, nor does it adequately cover ultrasonic inspection of austenitic welds and castings. Consequently there is a need to check at the outset whether the Code on which a procedure is to be based does adequately address the specific requirements of the application. For the non-HIC plant, NNB need to clarify how the validity of the Codes used to develop inspection procedures is to be addressed.

111 Although the milestone for completion of AF-UKEPR-SI-07 was set during GDA as ‘Install RPV’, in practice the capability statement for each inspection procedure needs to be in place before the inspection is required and this constraint is recognised in the resolution plan. The other constraints perceived by NNB concern the timely supply of input information to the contractors chosen to prepare capability statements. I consider that this use of specialist contractors for the capability statements, so that they are produced independently of the manufacturers who produce and apply the inspection procedures, is potentially vulnerable to interface difficulties. Consequently I have monitored the production of capability statements and associated ultrasonic inspection procedures for the long lead item forgings to check that the arrangements are adequate.

112 NNB has maintained a record of the dates of issue of the capability statements and ultrasonic procedures in relation to the first inspection dates for all the HICs. The capability statements prepared to date for the HIC components have been of a high quality and, with one exception, the ultrasonic procedures have been approved by NNB in advance of the inspections.

113 As a sample, I have reviewed the ultrasonic inspection procedures and capability statements for the RPV integrated nozzle shell (Refs 48 and 49), the steam generator conical shell (Refs 50 and 51) and the steam generator cylindrical shells (Refs 52 and 53). This review has been reported in more detail in our Assessment Report on defects found recently in RPVs in Belgium (see Section 4.4 below). I am satisfied that NNB has expanded the range of beam angles and inspection surfaces used for the manufacturing inspections, and the increased capability has been evaluated by detailed capability statements.

114 In the case of the pre-heat treatment ultrasonic testing on the RPV nozzle shell, the final procedure, approved by NNB, post-dated the ultrasonic inspection. I have checked that the procedure actually used (JSW: N-8215-30 Rev. C) did not differ from the final approved procedure in any important respects likely to threaten the quality of the inspections. In particular the forging was inspected with compression waves from inside and outside surfaces, and shear wave scans were performed in two circumferential and two axial directions on the outer surface. The final ultrasonic inspection of the nozzle shell was performed with a procedure approved by NNB. I am satisfied that an adequate

inspection procedure has been used for both inspections of this component but I have checked that, for subsequent inspections of HIC forgings, NNB has ensured that procedures and capability statements are approved prior to the inspections starting.

115 I am satisfied that the ultrasonic procedures for ferritic forgings which I have reviewed have an adequate intrinsic capability to detect the defects of concern. However I am not yet convinced that all the key aspects of the quality framework for non-destructive testing of the forgings have been adequately addressed and I have asked NNB to review the overall strategy for these inspections.

116 At the Level 4 structural integrity meeting held on 22 January 2013, I was informed that the current arrangements for inspection at the end of manufacture involved a single manual ultrasonic test without any repeat inspection. I was not convinced that such a single manual inspection could deliver the confidence required for such high integrity components (HICs). I would expect repeat, independent inspection to play a key role in demonstrating confidence in the end of manufacture ultrasonic inspection as part of the wider quality arrangements required for the NDT performed on the HIC forgings. HSE Safety Assessment Principles, Ref. 3, EMC.29 also highlights the importance of redundancy and diversity for inspections of components. Consequently, my letter HPC50100R dated 31 January 2013, Ref. 54, asked NNB to reconsider its strategy for the inspections which justify the quality of HIC forgings.

117 I believe that it is accepted good practice in the UK to apply a level of independent repeat inspection to manual ultrasonic inspection of important components and that the amount of repeat inspection should take account of the safety significance of the component. At a recent level 4 meeting on 23 October 2013, I was informed that NNB intend to adopt this principle more systematically for the HIC forgings, and a formal response is expected in December 2013.

118 A separate topic related to the overall quality framework for non-destructive testing concerns the records of the ‘in-company’ inspections performed by forging manufacturers prior to final machining of the forgings. Because these inspections are classified as non-contractual, NNB does not currently review or accept the results of these inspections, and they are not proposed to form part of the lifetime records for Hinkley Point C. This current proposal not to claim the in-company inspections also implies that the only volumetric inspection of the forgings which supports the safety case is the single contract inspection performed at the end of manufacture. This contract inspection is underpinned by a capability statement.

119 The investigations into the recent discovery of what are believed to be manufacturing defects in two reactor pressure vessels in Belgium (see Section 4.4 below) has highlighted the importance of maintaining detailed records of manufacturing inspections throughout the operating lifetime. This is another reason why I have asked NNB to reconsider the strategy for inspection of forgings and to check that lessons learned from recent experiences are adequately taken into account.

120 Because of the importance of the overall quality framework for inspections including repeat inspection, as well as the need for adequate redundancy and diversity, I judge that an additional action is required to be added to ONR Issue 1649 relating to inspection of high integrity forgings. The requirement is for the Licensee to demonstrate an adequate level of redundancy, diversity and independence for ultrasonic inspections of forgings for HIC pressure boundaries, and ensure the results of these inspections form part of the lifetime records.

121 Although this action is specified to be addressed before the milestone for RPV installation, in practice many of the activities will need to be completed earlier to align with the manufacturing schedule.

Issue HPC-PCSR-SI-03 (Level 3) To be added to ONR Issue 1649	The Licensee shall demonstrate an adequate level of redundancy, diversity and independence for ultrasonic inspections of forgings for HIC pressure boundaries, and shall ensure that the results of these inspections form part of the lifetime records.
Milestone Required by ONR	Install RPV

4.3.4 GDA Step 4 Assessment Finding AF-UKEPR-SI-16

Resolution Plan unique no.	NNB-OSL-PLN-006233 V 0.1 25-7-13			
GDA Assessment finding	The Licensee shall produce a comprehensive material data set for use during the design and assessment process, and also to support through life operation. This will need to cover all relevant data including the basic design data and the confirmatory batch and weld specific test data from the complementary fracture toughness testing programme. It will need to be clearly presented such that the pedigree of the data can be traced following the literature trail with comparison to other international data sets where possible and will need to be updated through life following developments in the field and in the light of through life testing of materials subject to degradation mechanisms.			
Milestone required by ONR	Hot Operations			
ONR Category	1		**NNB Priority**	3

122 There are several GDA assessment findings referring to the requirement for fracture testing testing. ONR places emphasis on the requirement for direct measurement of fracture toughness properties, where practicable, to provide additional evidence supporting the justification of adequate defect tolerance in HIC components. The progress assessed here for AF-UKEPR-SI-16 is also germane to AF-UKEPR-SI-17, AF-UKEPR-SI-18, AF-UKEPR-SI-19, AF-UKEPR-SI-22 and AF-UKEPR-SI-23.

123 This assessment finding requires materials data to be collected to substantiate the mechanical, fatigue and fracture properties used in structural integrity assessments. It is not limited to high integrity components (HICs) although a more rigorous response is expected for those components with a high integrity classification. Data collection from HPC components will continue during manufacturing and fabrication and therefore this assessment finding will not be completed until on-site fabrication has been completed.

124 The material properties used in the HPC structural assessments, and the materials test data used to underpin these properties, is to be defined in materials data files (MDFs) compiled be the Responsible Designer (RD).

125 NNB has initiated a study with the RD to identify any gaps in the generic MDF format and content with Nuclear Generation's R96 Material Handbook which has been adopted previously in the UK as an appropriate means to documenting and maintaining an authoritative reference of materials properties. The gap analysis will be used by NNB to define any additional requirements and a forward work programme to address this.

126 The provisional timescale for producing the gap analysis document is December 2013.

127 I consider that the provision of fracture toughness data from HPC specific forgings and HPC prototype weldments that are classified as high integrity components forms a key component to this assessment finding. NNB is developing a fracture toughness testing strategy and specifications for the manufacture and testing of HIC prototype weldments. I have discussed the development of the fracture toughness testing programme with NNB at several structural integrity level 4 meetings including one dedicated to the topic, Ref. 55. During these discussions I have emphasised my uncertainty about the adequacy of the RT_{NDT} indexing procedure to define the onset of upper shelf at RT_{NDT}+60 °C and to define a lower bound to fracture toughness in the transition temperature regime.

128 The adequacy of the RCC-M M140 qualification requirements to assure adequate fracture toughness in the mid-section of thick section forgings was challenged by ONR in 2011, Ref. 56. In response NNB agreed to undertake an additional fracture toughness programme on a mock-up steam generator tubesheet forging. Provisional data from this experimental programme was reported to ONR at a Level 4 NSSS meeting in September 2013, Ref. 57. I judge that further clarification is required and have placed actions on NNB to provide ONR with a final report on the safety case implications and the strategy for a forward work programme by the end of April 2014.

129 From my assessment of the available data, I recommend that further justification of the RT_{NDT} approach to defining lower bound fracture toughness in the transition temperature region and an adequate definition of the onset of uppershelf toughness is raised as a new assessment finding.

Issue HPC-PCSR-SI-04 (Level 3)	The Licensee shall provide a comprehensive justification of the RT_{NDT} approach to defining lower bound fracture toughness in the transition region and an adequate definition of the onset of upper shelf.
Milestone Required by ONR	Install RPV

130 I have reviewed the scope of the gap analysis study. I judge both the scope and timing for the gap analysis report and the approach outlined in the assessment finding resolution plan to be adequate together with the agreement from NNB to provide further evidence to support the RT_{NDT} approach. Further clarification of the scheduling of the work programme is required once project timescales have been defined to ensure completion prior to the GDA milestone of install RPV.

4.4 Recent PWR International Operating Experience

131 Doel 3 and Tihange 2 are pressurised water reactors (PWRs) in Belgium commissioned in 1982 and 1983 respectively. During Summer 2012, examination of the reactor pressure vessels (RPVs) of these plants revealed a large number (several thousand) of defect indications in some of the parent forgings used in the construction of the RPVs. The

Belgian Licensee (Electrabel) and the Belgian Nuclear Regulator (FANC) have undertaken an extensive programme of work to understand the root cause of the defects. ONR participated in international regulatory expert working groups, set up by FANC, to investigate this issue. There is consensus that the indications relate to defects formed during the steelmaking and forging processes by a hydrogen-induced flaking/cracking mechanism.

132 The implications for the UK in terms of the operating PWR reactor at Sizewell B and the new build programme for Hinkley Point C were assessed by ONR in Ref. 58. WENRA has also provided recommendations for the review of manufacturing and inspection records and additional inspections of reactor pressure vessels of PWR reactors operating in Europe, Ref. 59.

133 The conclusion of the ONR assessment with respect to Hinkley Point C is as follows:

> “We judge that NNB has undertaken a well reasoned comparison between the manufacturing routes for Hinkley Point C forgings with those used at Doel 3 and Tihange 2. We judge that this comparison has identified a number of factors likely to influence the formation of hydrogen-induced defects and that controls are in place to minimise the likelihood of formation of hydrogen-induced defects in Hinkley Point C forgings. The justification for no defects of significance entering service also depends on the adequacy of manufacturing inspection. NNB has expanded the range of the manufacturing inspections and provided detailed assessments of inspection capability. We judge that the NNB inspection techniques and procedures are adequate to detect and report defects of the type reported at Doel 3 and Tihange 2.”

134 Further, more recent, experience of hydrogen-induced cracking during the manufacture of thick section forgings was reported in 2012 during the production of forgings at Creusot Forge/Arcelor Mittal that were intended for another utility. This OPEX was included in the ONR assessment of the occurrence of defects found in the reactor pressure vessels at Doel 3 and Tihange 2. The cause of defect formation was inadequate controls to limit the amount of hydrogen in the steel during manufacture. In response to this OPEX, NNB GenCo implemented an embargo on production of forgings for Hinkley Point C whilst a detailed investigation was completed. Approval for restart of pouring was given by the NNB GenCo Board after being satisfied with additional controls at the forgemaster.

135 This OPEX, and the actions taken by NNB GenCo were assessed by ONR in Reference 60 where it is concluded:

> “We judge that the controls now in place for the manufacture of HPC NSSS firgings are sufficient to render it unlikely that hydrogen induced defects will form. However the possibility of systems or procedural malfunctions cannot be fully dismissed and there remains a requirement for adequate inspection so that should significant defects form they will be detected and appropriate actions taken to prevent defective products from entering service.”

136 Whilst the enhanced NNB procedures were judged to be adequate this operating experience does however reinforce the vigilance required in the implementation of manufacturing and inspection quality controls.

4.5 Comparison with Standards, Guidance and Relevant Good Practice

137 The main code used for the design and manufacture of mechanical parts for the UK EPR^{TM} is the French Code RCC-M. This code has its origins in the American Society for Mechanical Engineers Boiler and Pressure Vessel Code. The RCC-M code has since been developed for particular application to PWRs. The design requirements set by the RCC-M code were reviewed during GDA. They are broadly the same as those for ASME III on a class by class basis and were judged to be generally acceptable for nuclear pressure systems. RCC-M is considered to be an example of relevant good practice but some aspects (primarily quality and inspection) require adaptation to the UK regulatory environment.

5 CONCLUSIONS AND RECOMENDATIONS

5.1 Conclusions

138 This report presents the findings of the ONR assessment of those aspects of the HPC PCSR2012 relating to structural integrity.

139 The major part of HPC PCSR2012 relating to the structural integrity of key components of the nuclear steam supply system is taken from the GDA PCSR2011. During close-out of GDA significant changes were introduced to GDA PCSR2011 in producing the GDA PCSR2012 which formed the basis for award of the Design Acceptance Confirmation of the UK EPR^{TM} generic design. It follows that these changes have not yet been included in the HPC PCSR2012 and ONR expects them to be addressed by NNB in the next update to the PCSR.

140 The new site specific information presented in HPC PCSR2012 has little relevance to structural integrity.

141 The HPC PCSR2012 is largely directed at providing claims, and in some instances arguments, together with explanations of how these will be supported by further evidence to be derived during the manufacture and construction phases of the project.

142 The outcome of the component classification process will be reviewed by ONR when the new classification scheme, agreed during GDA close-out, is implemented. The strategy for establishing the quality assurance requirements has been produced. Further work is underway to address ONR comments and recent changes in the guidance for implementation of the French ESPN Order. ONR expectations are that conformity assessment requirements are fully defined prior to future procurement of components. Additionally it is expected that the PCSR is updated to include both the latest safety classification and conformity assessment requirements. Progress in developing and implementing the safety classification and conformity assessment requirements will continue to be monitored through level 4 meetings.

143 ONR guidance recognises the value of retaining detailed records of manufacturing, installation and testing activities for review at any time during operation. NNB has highlighted the importance of keeping detailed records. Based on the evidence presented I am not yet sufficiently convinced NNB has adequate arrangements for collation of lifetime records and I have therefore raised a new issue on this aspect.

144 A design change, agreed within GDA, to provide watertight compartments for the fuel transfer tube is now considered impracticable by NNB. This solution was part of the UK EPR^{TM} Design Reference and subject to ONR's DAC (Design Acceptance Confirmation) issued in December 2012. NNB now proposes to present a justification based on demonstration of the integrity of the fuel transfer tube as a high integrity component. The change to an alternative approach is because the Responsible Designer has indicated the original solution presents significant implementation difficulties. I have raised a new issue for the Licensee to demonstrate that classifying the fuel transfer tube as a high integrity component is an ALARP design solution.

145 The GDA step 4 and GDA close-out assessment findings have provided guidance on the additional evidence, and the appropriate timing to provide that evidence, expected of the Licensee. I am broadly satisfied that NNB has a good understanding of the requirements of the structural integrity GDA assessment findings and is making significant progress in production of resolution plans and their implementation where appropriate. However I have requested further clarification of the timing of the deliverables from resolution plans

with respect to the manufacturing programme and development of the safety case to remain confident that NNB are adequately managing project risks.

146 My interventions in connection with manufacture of the forgings for the reactor pressure vessel and steam generators at HPC have revealed that the safety case and the lifetime records for these components currently depend on a single, manual ultrasonic inspection performed by the forgemaster at the end of manufacture. NNB does not review or accept the results of 'in-company' inspections and does not require any independent repeat inspection. Because of the importance of the overall quality framework for inspections including repeat inspection, as well as the need for adequate redundancy and diversity, I judge that a new action is required to supplement ONR Issue 1649. "The Licensee shall demonstrate an adequate level of redundancy, diversity and independence for ultrasonic inspections of forgings for HIC pressure boundaries, and shall ensure that the results of these inspections form part of the lifetime records."

147 I have reviewed the end-of-manufacturing report for the reactor pressure vessel integrated nozzle and shell forging for compliance with GDA AF-UKEPR-SI-24 and the controls on material composition given in Section 4.1 of Sub-Chapter 5.3. I am not yet satisfied that the chemistry controls on carbon and phosphorus have been demonstrated to meet UK limits and have written to NNB requesting further justification.

148 In response to a request from ONR, NNB is completing an experimental programme to provide fracture toughness data from a thick section forging prototype of a steam generator tubesheet. Preliminary results suggest further clarification of the significance of these data to the safety justification is required and actions have been placed on NNB to provide a response by April 2014. I have raised a new issue for the Licensee to address uncertainties in the adequacy of the RT_{NDT} procedure used in the RCC-M Code for defining fracture toughness in the transition temperature region and for providing an appropriate definition for the onset of upper-shelf.

149 Operating experience of defects detected during 2012 in the reactor pressure vessels of Doel 3 and Tihange 2 RPVs in Belgium and at Creusot Forge/Accelor Mittal during the manufacture of forgings for another utlity have highlighted the importance attached to manufacturing controls and manufacturing inspections. The implications of this OPEX to HPC has been assessed by ONR. It is concluded that defects of the type recorded at Doel 3 and Tihange 2 are unlikely in HPC forgings, and should they form, would be detected with a high reliability during the manufacture. This experience does however reinforce the vigilance required in the implementation of manufacturing and inspection quality controls.

5.2 Recommendations

With the exception of a number of new issues (Annex 1) no other recommendations have arisen from my assessment of HPC PCSR2012.

6 NEW ISSUES TO BE RECORDED ON ONR ISSUES DATABASE

Issue HPC-PCSR-SI-01 (Level 3)	The Licensee shall demonstrate adequate arrangements for collation of suitably detailed manufacturing and construction lifetime records to demonstrate the quality of manufacture and installation for nuclear pressure equipment.
Milestone Required by ONR	Start of Construction

Issue HPC-PCSR-SI-02 (Level 3)	Before deviating from Change Modification CMF72, the Licensee shall demonstrate that classifying the fuel transfer tube as a high integrity component (HIC) is an ALARP design solution and provide a formal safety case for assessment by ONR.
Milestone Required by ONR	Install RPV

Issue HPC-PCSR-SI-03 (Level 3) To be added to ONR Issue 1649	The Licensee shall demonstrate an adequate level of redundancy, diversity and independence for ultrasonic inspections of forgings for HIC pressure boundaries, and shall ensure that the results of these inspections form part of the lifetime records.
Milestone Required by ONR	Install RPV

Issue HPC-PCSR-SI-04 (Level 3)	The Licensee shall provide a comprehensive justification of the RT_{NDT} approach to defining lower bound fracture toughness in the transition region and an adequate definition of the onset of upper shelf.
Milestone Required by ONR	Install RPV

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Table 1

Relevant Safety Assessment Principles Considered During the Assessment

SAP No.	SAP Title	Description
FP.4	Safety assessment	The dutyholder must demonstrate effective understanding of the hazards and their control for a nuclear site or facility through a comprehensive and systematic process of safety assessment.
MS. 2	Capable Organisation	The organisation should have the capability to secure and maintain the safety of its undertakings.
ECS.3	Safety classification and standards. Standards	Structures, systems and components that are important to safety should be designed, manufactured, constructed, installed, commissioned, quality assured, maintained, tested and inspected to the appropriate standards.
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.2	Integrity of metal components and structures: highest reliability components and structures. Use of scientific and technical issues	The safety case and its assessment should include a comprehensive examination of relevant scientific and technical issues, taking account of precedent when available.
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.
EMC.4	Integrity of metal components and structures: general. Procedural control	Design, manufacture and installation activities should be subject to procedural control.
EMC.5	Integrity of metal components and structures: general. Defects	It should be demonstrated that safety-related components and structures are both free from significant defects and are tolerant of defects.

Table 1

Relevant Safety Assessment Principles Considered During the Assessment

SAP No.	SAP Title	Description
EMC. 6	Integrity of metal components and structures: general. Defects	During the manufacture and throughout the operational life the existence of defects of concern should be able to be established by appropriate means.
EMC.8	Integrity of metal components and structures: design. Requirements for examination	Geometry and access arrangements should have regard to the requirements for examination.
EMC.12	Integrity of metal components and structures: design. Brittle behaviour	Designs in which components of a metal pressure boundary could exhibit brittle behaviour should be avoided.
EMC. 13	Integrity of metal components and structures: manufacture and installation. Materials	Materials employed in manufacture and installation should be shown to be suitable for the purpose of enabling an adequate design to be manufactured, operated, examined and maintained throughout the life of the facility.
EMC.17	Integrity of metal components and structures: manufacture and installation. Examination during manufacture	Provision should be made for examination during manufacture and installation to demonstrate the required standard of workmanship has been achieved.
EMC.18	Integrity of metal components and structures: manufacture and installation. Third Party Inspection	Manufacture and installation operations should be subject to appropriate third-party independent inspection to check that processes and procedures are being carried out as required.
EMC.19	Integrity of metal components and structures: manufacture and installation. Non-conformities	Where non-conformities with the procedures are judged to have a detrimental effect on integrity or significant defects are found and remedial work is necessary, the remedial work should be carried out to an approved procedure and should be subject to the same requirements as the original.

Table 1

Relevant Safety Assessment Principles Considered During the Assessment

SAP No.	SAP Title	Description
EMC.20	Integrity of metal components and structures: manufacture and installation. Records	Detailed records of manufacturing, installation and testing activities should be made and be retained in such a way as to allow review at any time during subsequent operation.
EMC. 23	Integrity of metal components and structures: operation. Ductile Behaviour	For metal pressure vessels and circuits, particularly ferritic steel items, the operating regime should ensure that they display ductile behaviour when significantly stressed.
EMC.27	Integrity of metal components and structures: pre- and in-service examination and testing. Examination	Provision should be made for examination that is reliably capable of demonstrating that the component or structure is manufactured to the required standard and is fit for purpose at all times during service.
EMC.28	Integrity of metal components and structures: pre- and in-service examination and testing. Margins	An adequate margin should exist between the nature of defects of concern and the capability of the examination to detect and characterise a defect.
EMC.29	Integrity of metal components and structures: pre- and in-service examination and testing. Redundancy and diversity	Examination of components and structures should be sufficiently redundant and diverse.
EMC.30	Integrity of metal components and structures: pre- and in-service examination and testing. Control	Personnel, equipment and procedures should be qualified to an extent consistent with the overall safety case and the contribution of examination to the structural integrity aspect of the safety case
EMC.34	Integrity of metal components and structures: analysis. Defect sizes	Where high reliability is required for components and structures and where otherwise appropriate, the sizes of crack-like defects of structural concern should be calculated using verified and validated fracture mechanics methods with verified application

Table 2

Summary of HPC PCSR2012 Chapters relevant to Structural Integrity – Scope of Assessment

Section (Related HPC PSCR2 Chapter)	**Indication of Content Provenance**	**Sections receiving a high level review in this report**
1- Introduction and General Description	Consolidated GDA PCSR 2011 used for two Sub-chapters (1.4 and 1.5) without change. One all new HPC PCSR2 Sub-chapter (1.2). Head Document forms the rest of the introduction. (Sub-chapters 1.1 and 1.3 not used).	None
2 - Site Data and Bounding Character of GDA Site Envelope	All information used is new for HPC PCSR.	None
3 - General Design and Safety Aspects	Consolidated GDA PCSR 2011 data used for six Sub-chapters (3.1, 3.2, 3.3, 3.4, 3.5 and 3.8) without change. One all new HPC PCSR2 Sub-chapter (3.6) – Equipment Qualification – covered by Mechanical Engineering topic area. (Sub-chapter 3.7 not used).	3.1 General safety principles 3.2 Classification 3.4 Mechanical Systems 3.8 Codes and Standards
4 - Reactor and Core Design	All Consolidated GDA PCSR 2011 data used without change.	None
5 - Reactor Coolant System and Associated Systems	Consolidated GDA PCSR 2011 data used for five Sub-chapters (5.0, 5.1, 5.2, 5.3 and 5.4) without change. One partially new HPC PCSR2 Sub-chapter (5.5) on reactor chemistry which includes GDA data (in grey shading).	5.3 Reactor Vessel 5.4 Components and Systems Sizing

10 - Steam and Power Conversion Systems	Consolidated GDA PCSR 2011 data used for four Sub-chapters (10.1, 10.3, 10.5 and 10.6) without change. Two partially new HPC PCSR2 Sub-chapters (10.2 and 10.4) which include GDA data (in grey shading). Additional Sub-chapter (10.7) added which includes GDA data (in grey shading) rearranged in presentation to discuss Secondary System Chemistry.	10.3 Main steam system (safety classified part) 10.5 Implementation of the break preclusion principle for the main steam lines inside and outside the containment
11 - Discharges and Waste/Spent Fuel	Consolidated GDA PCSR 2011 data used for one Sub-chapter (11.0) without change. (Sub-chapter 11.1 not used). Two partially new HPC PCSR2 Sub-chapters (11.2 and 11.4) which include GDA data (in grey shading). Two completely new Sub-chapters (11.3 and 11.5).	11.2 Radioactive Waste Management Process and Strategy 11.3 Waste Generation Discharges and Disposals from HPC 11.4 Effluent Waste Treatment Systems 11.5 Interim Fuel Storage Facilities and Disposability
13 - Hazards Protection	One partially new HPC PCSR2 Sub-chapter (13.1) which includes GDA data (in grey shading). Consolidated GDA PCSR 2011 data used for one Sub-chapter (13.2) supplemented by an additional supporting document.	Sub-chapter 13.2 – Internal Hazards Protection
14 - Design Basis Analysis (DBA)	All Consolidated GDA PCSR 2011 data used without change.	None
16 - Risk Reduction and Severe Accident Reduction	No new sections but GDA close-out of GI-UKEPR-FS-03 Action 3 has been re-opened by NNB	Sub-Chapter 16.3 Practically Eliminated Situations
17 - ALARP Assessment	All Consolidated GDA PCSR 2011 data used without change (except Sub-chapter 17.4 not used).	None

18 – Human Machine Interface and Operational Aspects	Sub-Chapter 18.2, Section 6 covers in-service inspection and maintenance and is extracted directly from the GDA PCSR 2011	Sub-Chapter 18.2 Section 6.
21 – HPC PCSR Management Framework, Design, Development and Use and QA Arrangements	All information used is new for HPC PCSR (except a very small amount of GDA data (in grey shading) in Sub-chapter 21.3 Appendix).	Sub-Chapter 21.2 Design development and use of HPC PCSR
Forward Work Activities	HPC PCSR2 identifies a number of Forward Work Activities that are required to fully develop the safety case. The activities are set out in report reference HPC-NNBOSL-U0-000-RES-000082.	Overview