Agreement to NP/SC 7792 Justification for an increase in the operational allowance for the Hinkley Point B graphite cores for core ages up to 17.2 TWd

Hinkley Point B Power Station
Project Assessment Report

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EXECUTIVE SUMMARY

Title

Agreement to NP/SC 7792 Hinkley Point B Power Station - Justification for an increase in the operational allowance for the Hinkley Point B graphite cores for core ages up to 17.2 TWd.

Permission Requested

Under its arrangements made under Licence Condition 22(1), EDF Energy Nuclear Generation Limited (EDF Energy NGL) has requested that the Office for Nuclear Regulation (ONR) issues an Agreement to NP/SC 7792, which is the safety case for the justification for an increase in the operational allowance for the Hinkley Point B graphite cores for core ages up to 17.2 TWd.

Background

The current graphite core safety case for the Hinkley Point B reactors set an Operational Allowance (OA) and determined a Currently Established Damage Tolerance Level (CEDTL) in terms of the number and size of graphite brick cracks for which safe operation was justified up to a core age of 16.7 TWd.

NP/SC 7792 aims to provide justification for an increase in the OA and CEDTL. The case initially presented by EDF Energy NGL aimed to demonstrate that the above criteria are met at the increased levels of graphite core damage at a core burn-up of up to 17.2 TWd.

The safety case as presented was updated to limit core burn-up to 17.099 TWd for Reactor 3 and 16.932 TWd for Reactor 4 (up to approximately June 2020 for both reactors); these core burn-up limits were set to ensure that operation will remain broadly within the current Hunterston B Reactor 3 core state established in 2018. Hunterston B Reactor 4 has recently been operating on a similar basis.

EDF Energy NGL has also written to ONR in response to a technical query raised during our assessment. The letter and an associated safety case further limit core burn-up to the next graphite core inspections. For Reactor 4 the limit is 16.775 TWd (inspection in February 2020) and for Reactor 3 the limit is 17.031 TWd (inspection in April 2020). Arrangements are in place to ensure adequate control such that the limits can only be released through a further update to the safety case. Consequently the permission considered here is on the basis of these core burn-up limits.

Assessment and inspection work carried out by ONR in consideration of this request

The fundamental nuclear safety requirements of the graphite core of an Advanced Gas Cooled Reactor (AGR) are to:

- Allow unimpeded movement of control rods and fuel.
- Direct gas flows to ensure adequate cooling of the fuel and core.
- Provide neutron moderation and thermal inertia.

Based on the potential for cracked bricks to affect the fundamental nuclear safety requirements of the Hinkley Point B Reactor 3 and 4 cores and taking into account the previous assessment carried out on Hunterston B Reactor 4, the following assessments of NP/SC 7792 have been completed by ONR specialist inspectors:

- The civil engineering assessment has focused on the revised modelling of the pre-stressed concrete pressure vessel (PCPV) and has drawn on the previous assessment of similar modelling carried out in support of the Hunterston B Reactor 4 return to service case (NP/SC 7785).
- The scope of the graphite structural integrity assessment targeted:

  - The areas where differences may exist between Hinkley Point B and Hunterston Reactor 4,
  - Any changes that have been made to the methods since NP/SC 7785 completed its ONR assessment.
- The fault studies assessment has focussed on:
  - The potential effects of graphite cracking on the fuel, including the implications in terms of fuel cooling
  - The free movement of the fuel in refuelling operations.
  - The assessment has also considered the free movement of control rods in fault scenarios.

During ONR's assessment of NP/SC 7792 an issue was identified by EDF Energy NGL regarding the strength of end face keys used in some aspects of the analyses that support the safety case. EDF Energy NGL has addressed this through its normal processes to identify the implications for the safety case provided in NP/SC 7792. The graphite structural integrity inspector has reviewed the output from this process and considers the judgements made by EDF Energy NGL to be reasonable in the context of the permission being sort.

Matters arising from ONR's work

Following assessment of NP/SC 7792 all specialist inspectors consider that the issue of ONR's Agreement to the proposed modification of NP/SC 7792 is acceptable. In support of their assessments, ONR's specialist inspectors have engaged extensively with EDF Energy NGL in technical discussions to ensure that key issues have been adequately addressed.

Conclusion

It is concluded that the operation of Hinkley Point B Reactor 3 to a core burn up of 17.031 TWd for Reactor 3 and 16.775 TWd for Reactor 4 has been adequately justified by EDF Energy NGL and that a Licence Instrument should be issued to EDF Energy NGL.

Recommendations

It is recommended:

That licence instrument 560 is granted to Hinkley Point B to allow implementation of safety case NP/SC 7792.

LIST OF ABBREVIATIONS

AGR	Advanced Gas Cooled Reactor
ALARP	As Low As is Reasonably Practicable
AR	Assessment Report
CEDTL	Currently Established Damage Tolerance Limit
DCB	Doubly Cracked Brick
DTA	Damage Tolerance Assessments
EDF	Électricité de France
EC	Engineering Change
FHA	Full Height Axial
HSB	High Shrinkage Brick
IJCO	Interim Justification for Continued Operation
JPSO	Justified Period of Safe Operation
KWRC	Keyway Root Crack
LC	Licence Condition
LI	Licence Instrument
MCB	Multiply Cracked Brick
NGL	Nuclear Generation Ltd
OA	Operational Allowance
ONR	Office for Nuclear Regulation
PAR	Project Assessment Report
PCPV	Pre-stressed Concrete Pressure Vessel
PRY	Per Reactor Year
PSD	Primary Shutdown
RTS	Return to Service
SCB	Singly Cracked Brick
SSC	Structure, System and Component
TWd	Terawatt Days
UB	Upper Bound

GLOSSARY OF TERMS

Term	Definition
Currently Established Damage Tolerance Level (CEDTL)	The level of brick cracking and crack opening that has currently been assessed and demonstrated to be tolerable, i.e. that does not challenge the fundamental nuclear safety requirements of the core.
Doubly Cracked Brick (DCB)	Doubly axially Cracked Brick (i.e. a brick containing exactly two full height, full thickness axial cracks).
Debris / Fragments	Brick fragments are pieces of graphite brick that remain approximately in position as part of the fuel or control rod channel. Pieces of brick that come free from the channel wall are debris.
Fuel Sleeve	Each fuel element consists of 36 fuel pins arranged in a circular grid and held in place by the lower support grid and two braces. A cylindrical graphite sleeve surrounds the 36 fuel pins with the lower support grid and the braces fitting into grooves on the inside of the graphite sleeve holding the arrangement together.
Full Height Axial	Full height axial crack, extending from top to bottom of a graphite brick.
Sleeve Gapping	The fuel elements are arranged into stringers with 8 fuel elements stacked vertically. The graphite fuel sleeves have grooves in the top and bottom edges so that the top of one fuel sleeve interfaces with the bottom of the sleeve above creating a seal which resists the flow of coolant gas. If the fuel stringer is moved such that it is not straight then the interfaces between the fuel element sleeves could begin to open up on one side leading to gaps and a loss of the gas seal, this could lead to gas flow through the fuel sleeve interfaces disrupting the intended coolant flow.
High Shrinkage Brick (HSB)	High shrinkage bricks are a small number of bricks that, based on conditions during production, may exhibit high shrinkage behaviour and be at risk of early KWRC compared to the main population of bricks.
Hold Down	Ensures that the reactor remains sub-critical following the decay of Xenon 135.
Induced Cracks	Opening of cracked fuel bricks which causes adjacent fuel bricks to also crack.
Keyway Root Cracking (KWRC)	Cracking initiating from a keyway root of a fuel moderator brick, caused by a combination of internally generated shrinkage and thermal stresses and propagating the full height and full thickness of the brick.
Multiply Cracked Brick (MCB)	Multiply axially Cracked Brick (i.e. a brick containing three or more full height, full thickness axial cracks).
Operating Allowance (OA)	The operating limit for the state of the core (in terms of brick cracking and crack opening) which is not to be exceeded during a period of reactor operation and which has been demonstrated to be safe and provides margin to the CEDTL.
Singly Cracked Brick (SCB)	Singly axially Cracked Brick (i.e. a brick containing exactly one full height, full thickness axial crack).

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1. PERMISSION REQUESTED

1. Under derived powers made under Licence Condition 22(1) (Ref.1), EDF Energy Nuclear Generation Limited (NGL) has requested (Ref. 2) that the Office for Nuclear Regulation (ONR) issue Agreement to NP/SC 7792 (Ref. 3), which is the justification for an increase in the operational allowance for the Hinkley Point B graphite cores for core ages up to 17.2 TWd.

2. The safety case as presented was limited to a core burn-up of 17.099 TWd for Reactor 3 and 16.932 TWd for Reactor 4 (up to approximately June 2020 for both reactors); these core burn-up limits had been set to ensure that operation would remain broadly within the current Hunterston B Reactor 3 core state established in 2018. Hunterston B Reactor 4 has recently been operating on a similar basis.

3. EDF Energy NGL has also written to ONR (Ref. 4) in response to a technical query raised during our assessment. The letter and an associated safety case (Ref. 5) further limit core burn-up to the next graphite core inspections. For Reactor 4 the limit is 16.775 TWd (inspection in February 2020) and for Reactor 3 the limit is 17.031 TWd (inspection in April 2020). Arrangements are in place to ensure adequate control such that the limits can only be released through a further update to the safety case. Consequently the permission considered here is on the basis of these core burn-up limits.

2. BACKGROUND

4. Hinkley Point B power station has two advanced gas cooled reactors (AGR) termed Reactors 3 and 4. Each reactor core is made up of around 3,000 graphite fuel bricks measuring 825mm high and 460mm external diameter which are connected together by keys and keyways (see figure 1), bound by a steel restraint system and contained within a concrete pressure vessel which is over three metres thick.

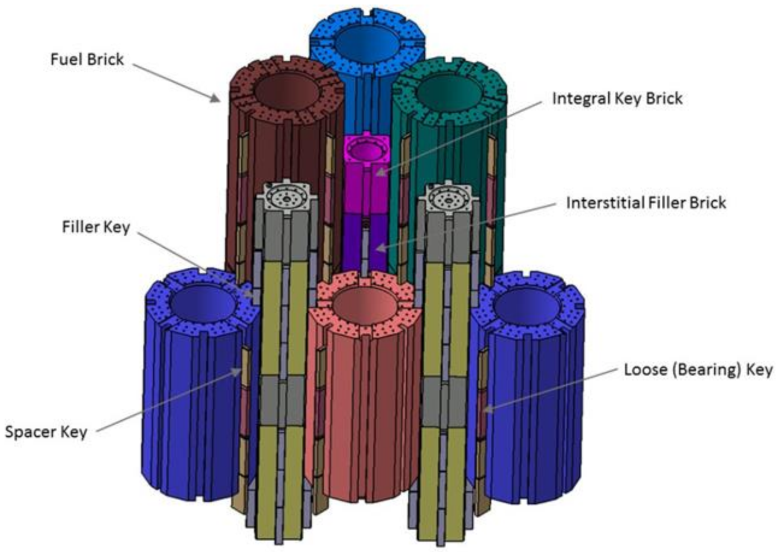

Figure 1 – Graphite Core Arrangement

5. Ceramic uranium oxide fuel is contained within fuel assemblies in channels in the graphite core (see figure 2). Control rods, containing boron, move within control rod channels in the graphite core to control the nuclear reaction and to shut down the reactor.

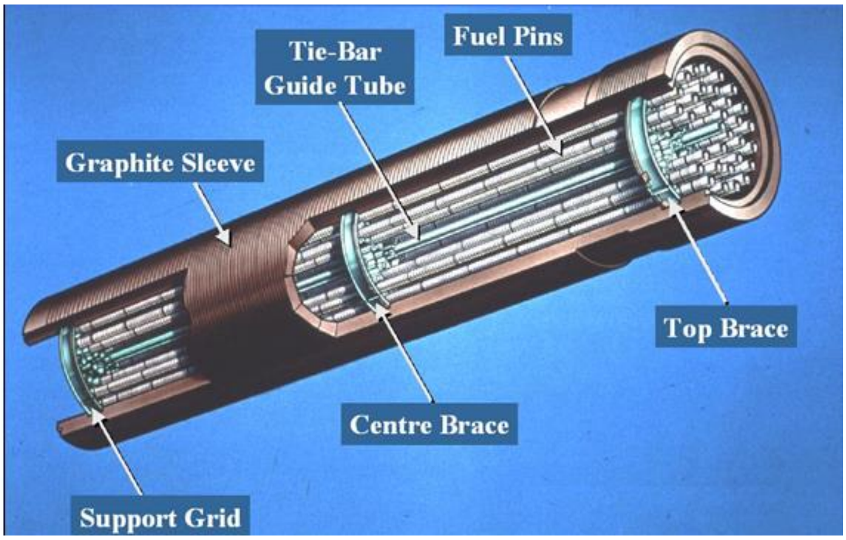

Figure 2 – Fuel Element Example

6. Each reactor has 81 control rods that are used to manage the power in the reactor. 37 control rods are used to control reactor power and day to day operation of the reactor; the remaining control rods are used to shutdown the reactor. 12 of these rods are referred to as super articulated control rods. The super articulated control rods are more flexible than the standard control rods which would enable them to enter channels with higher distortion than standard control rods. The super articulated control rods alone are able to shut down the reactor with longer term hold down of the reactor being provided by a nitrogen injection system. The super articulated control rods and the nitrogen injection system are provided as defence in depth and the safety case presented by the licensee is based on all of the control rods going into the core when required.

7. The fundamental nuclear safety requirements of a graphite core, in normal and fault conditions, are to:

- Allow unimpeded movement of control rods and fuel.
- Direct gas flows to ensure adequate cooling of the fuel and core.
- Provide neutron moderation and thermal inertia.

8. It has long been understood that irradiation of the fuel channel graphite bricks will lead to shrinkage and cracking of the bricks late in reactor lifetime. Such cracking is termed keyway root cracking (KWRC) as it initiates due to stresses which concentrate at the keyways on the outer diameter of the bricks. Figure 3 shows an example of a keyway root crack in a graphite brick, as seen from the fuel channel bore, from a core inspection. Keyway root cracking has the potential to challenge the safety requirements above and consequently the safety case needs to demonstrate that there are no significant implications for these nuclear safety requirements arising from keyway root cracking in order to permit further operation.

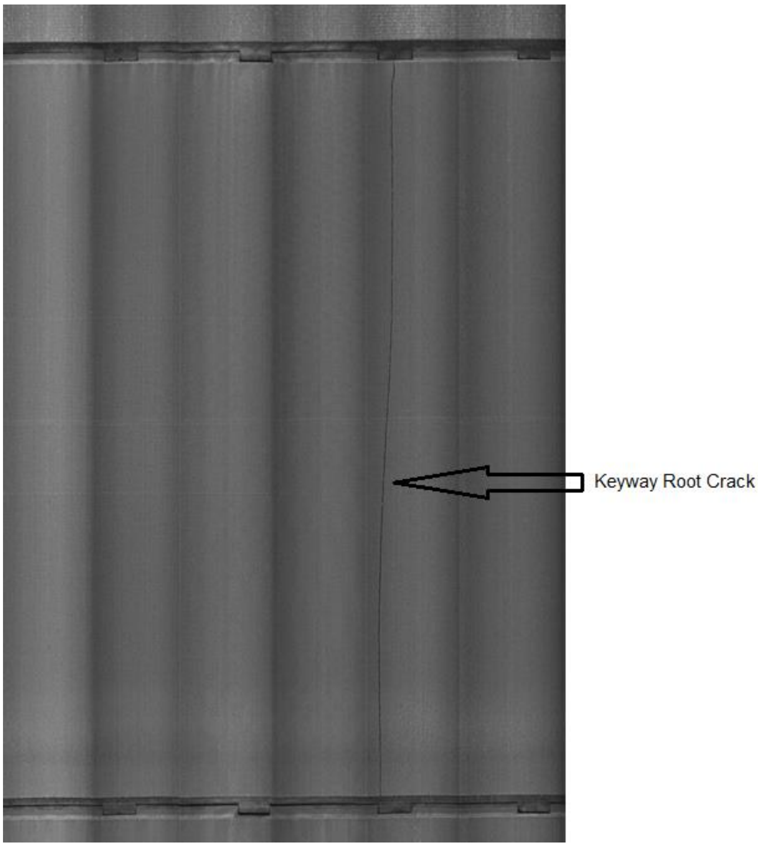

Figure 3 – Keyway Root Crack

9. Keyway root cracking was first observed in the main population of graphite moderator fuel bricks at Hunterston B Reactor 3 in October 2015, and in Reactor 4[1] in September 2017. At Hinkley Point B the first keyway root cracks were first observed in March/April 2019 in Reactor 3 and in February/March 2018 in Reactor 4. Since then, continued operation has been under a safety case, known as NP/SC 7716, which allowed for up to 700 axial cracks (includes keyway route cracking and induced cracks), referred to as the Currently Established Damage Tolerance Level (CEDTL). This is the level of cracking at which it has currently been established that there is no detriment to the nuclear safety functions of the graphite core. To provide a safety margin to the currently established damage tolerance level, a lower Operational Allowance (OA) of 350 axial cracks was also set within which it was intended to operate. In order to monitor the core condition and the number of cracks, the reactor cores have been regularly inspected. Inspection results and modelling are used to determine an appropriate Justified Period of Safe Operation (JPSO). Of the 350 axially cracked bricks:

- no more than 100 were to be singly axially cracked bricks open by more than 12mm,
- no more than 20 were to be are singly cracked bricks open by more than 18mm,
- and, no more than 180 were to be doubly axially cracked bricks.

10. In addition, the safety case was limited to core burn-up of no more than 16.7 TWd.

11. NP/SC 7792, a Category 1 submission (Ref. 3) aimed to extend the OA and CEDTL of the extant safety case NP/SC 7716 through the presentation of new whole core modelling to a core age of 17.2 TWd with more extensive damage than was considered in NP/SC 7716. EC 366104, a Category 2 submission (Ref. 5), presented the predicted

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[1] A full height KWRC was first observed in 2014 in a high shrinkage brick.

core states for both reactors and set the operational limits on burn-up so that the core states of both reactors would remain within the OA set in NP/SC 7792 and remain bounded by the core state of Hunterston B Reactor 3 following its 2018 inspection outage. This set burn-up limits at 17.099 TWd for Hinkley Point B Reactor 3 and 16.932 TWd for R4 (which would be reached around June 2020).

12. Sensitivity studies on the seismic input motion indicated that the unimpeded control rod movement was potentially challenged at the proposed CEDTL when using the upper bound properties of the buildings model in a seismic event. This sensitivity study was done in response to an ONR technical query that was raised during the structural integrity assessment of the seismic tolerance argument. As a consequence ONR is not able to agree the CEDTL proposed in NP/SC 7792.

13. In order to address this issue, EDF Energy NGL has written to ONR (Ref. 4) to seek agreement to operation up to lower core burn-up limits than originally proposed under NP/SC 7792. The proposal limits core burn-up to the next graphite core inspections. For Reactor 4 the limit is 16.775 TWd (inspection in February 2020) and for Reactor 3 the limit is 17.031 TWd (inspection in April 2020). This request is supported by analyses of a reduced core state (effectively a lower CEDTL) than the originally proposed CEDTL. The reduced core state bounds the predictions of the core state for Reactor 3 and Reactor 4 at the next graphite inspections (February and March 2020 for R4 and R3 respectively). It also bounds the 99.9% calculational confidence predicted core states originally proposed under NP/SC 7792 (that would be reached around June 2020). The reduced core state and predicted core states at the time of the inspections are presented in Tables 1 and 2 below.

	16.87 TWd ~1st Jan 2020	**17.031 TWd ~Apr 2020**	17.099 TWd ~Aug 2020 incl. inspect	Hunterston B R3 Current	**Reduced core state**
Total number full height axial cracks	202 (357)	**292 (478)**	331 (530)	413 (529)	**600**
Singly Cracked bricks ≥12 mm	4 (12)	**4 (12)**	5 (13)	5 (14)	**20**
Doubly Cracked Bricks	15 (26)	**19 (32)**	21 (34)	22 (37)	**60**
Multiple Cracked Bricks	1 (8)	**1 (10)**	2 (12)	1 (11)	**20**

Table 1 - Number of cracked bricks at Hinkley Point B R3 - Best Estimate (99.9% confidence)

	16.703 TWd ~1st Jan 2020	**16.775 TWd ~ Feb 2020**	16.818 TWd ~1st Apr 2020	Hunterston B R3 Current	**Reduced core state**
Total number full height axial cracks	229 (349)	**269 (402)**	293 (434)	413 (529)	**600**
Singly Cracked bricks ≥12 mm	3 (12)	**3 (13)**	3 (13)	5 (14)	**20**
Doubly Cracked Bricks	17 (29)	**19 (32)**	20 (33)	22 (37)	**60**
Multiple Cracked Bricks	1 (9)	**2 (10)**	2 (11)	1 (11)	**20**

Table 2 - Number of cracked bricks at Hinkley Point B R4 - Best estimate (99.9% confidence)

14. The letter includes a commitment to underwrite the proposed CEDTL or a revised CEDTL (through revision to safety case) before the outage inspection time of HPB R4 in February 2020. The letter also proposes hold points (coinciding with outages for graphite core inspections of each reactor) controlled via station documentation to ensure adequate control such that the reactors cannot operate past the agreed burn-up limit without an update to the safety case. Such an update would be considered by ONR for assessment and permissioning. The reduction of the CEDTL or "reduced core state" is further discussed in section 3.1.2.

3. ASSESSMENT AND INSPECTION WORK CARRIED OUT BY ONR IN CONSIDERATION OF THIS REQUEST

15. As described in Section 2, the fundamental nuclear safety requirements of a graphite core, in normal and fault conditions, are to:

- Allow unimpeded movement of control rods and fuel.
- Direct gas flows to ensure adequate cooling of the fuel and core.
- Provide neutron moderation and thermal inertia.

16. Based on the nature of the proposal and the potential for cracking to impact on the fundamental safety functions of the graphite core, NP/SC 7792 has been subject to assessment by inspectors in the following specialisms:

- Civil Engineering
- Structural Integrity – Graphite
- Fault Studies

17. The scope of these assessments is described for each specialism in section 3 below. It should also be noted that, in order to support the assessment of NP/SC 7792, ONR specialist inspectors have engaged with the EDF Energy NGL in technical discussions and have raised and resolved a number of technical issues throughout their assessments. This report does not attempt to summarise all of the questions raised and answers provided.

3.1 ASSESSMENT FINDINGS

3.1.1 CIVIL ENGINEERING ASSESSMENT

18. The civil engineering assessment (Ref. 6) focused on the revised modelling of the PCPV and has drawn on the previous assessment of similar modelling carried out in support of the Hunterston B Reactor 4 return to service case (NP/SC 7785) (Ref. 7). As part of that assessment, a number of assessment queries were raised, which have been adequately addressed.

19. One of the key updates to the damage tolerance assessments introduced by this proposal is a revised seismic input motion at the boundary between the core and its supporting structure (the core boundary seismic motion). The core boundary seismic motion is less severe but considered more representative than that previously used. The seismic motion has been derived from revised modelling of the pre-stressed concrete pressure vessel (PCPV), which provides support to the graphite core.

20. The evidence presented describes a number of changes to the seismic modelling of the core, including an updated core boundary seismic motion. The core boundary seismic motion used for previous assessments was based on a seismic analysis performed in 1995 in support of the first Periodic Safety Review (and known as the 'legacy model'). EDF Energy NGL identified unrealistic constraints in this legacy model and now considers that these caused unrealistic and excessive seismic motion in the PCPV computer model. This safety case describes a new analysis model of the PCPV, which

has been developed to update the core boundary input motion for the graphite core assessments.

21. From a civil engineering perspective, the most significant nuclear safety risks addressed by the case relate to the justification that core distortion will not prevent control rod entry during and following a seismic event. This justification is based on the revised seismic modelling of the PCPV.

22. The key findings from the civil engineering assessment are summarised below.

- The specialist inspector judged that the modelling approach was conventional and in general accordance with relevant good practice.
- The changes to the restraints in the existing model, made in order to de-couple the PCPV from the Reactor Building, have been adequately justified.
- The PCPV seismic input motion is considered conservative within the frequency range of significance for the core.
- For frequency ranges of significance to the core response, there was a significant reduction in core seismic input motion for the best estimate model compared with the legacy best estimate model.
- The best estimate material properties for the concrete structure, bearings, rock and backfill are deemed adequate.
- A limited, though acceptable, sensitivity study has been undertaken that considered the effects of uncertainty due to variation in key material properties.
- Based on the sensitivity studies carried out for Hunterston B Reactor 4, the most onerous case for channel distortion margins was obtained from a combination of upper bound properties for the rock, backfill and bearings. However, the safety case claims in relation to the core are based on a best estimate analysis, which may be un-conservative. The licensee has subsequently undertaken sensitivity studies to demonstrate the adequacy of core margins using both upper bound model properties and other combinations of model properties to demonstrate that the bounding case for core distortion is based on upper bound properties. The acceptability of graphite core margins is not within the scope of this report and is considered by the ONR graphite assessment. This is discussed in section 3.1.2
- In producing its final PCPV modelling report, the licensee has satisfactorily addressed the recommendations raised by the previous civil engineering assessment of the preliminary PCPV modelling, which was used as evidence in the recent Hunterston B Reactor 4 return to service safety case NP/SC 7785.
- The effect of the changes to the PCPV modelling on other Structures, Systems and Components (SSCs) and safety cases was insufficiently reported in the safety case. To address existing ONR Regulatory Issue 7168[2], the licensee has now undertaken a review of other safety cases, which is judged to be adequate. The review has identified an area for further work in relation to the effect of increased loading on the Charge Machine Gantry support structure covered by safety case NP/SC 7762. The specialist inspector will follow up progress on this matter, which does not affect the adequacy of the Hinkley Point B graphite core safety case, as part of regulatory engagement on the commitments made in NP/SC 7762, via ONR Regulatory Issue 7503.

23. To conclude, from a civil engineering perspective, the specialist inspector is satisfied with the claims, arguments and evidence laid down within the licensee's safety case. It is judged that the proposal is adequate to justify the issue of a Licence Instrument for Agreement under arrangements made under Licence Condition 22 (1).

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[2] Regulatory issue 7168 was raised following ONR's civil engineering assessment of NP/SC 7785 (Ref. 7), which raised three recommendations to be addressed by EDF Energy NGL. These recommendations were related to the new buildings model. This issue is now closed.

24. An observation was made in relation to ONR's expectations for future safety cases. As the graphite core state changes, additional sensitivity studies into the most onerous combination of PCPV modelling properties may be required to confirm that the use of upper bound properties remains the bounding case for graphite core distortion.

3.1.2 STRUCTURAL INTEGRITY - GRAPHITE ASSESSMENT

25. The scope of the structural integrity - graphite assessment (Ref. 8) is limited to the claims and arguments of the proposed safety case NP/SC 7792 and the supporting JPSO EC 366104. NP/SC 7792 aims to justify the equivalent OA and CEDTL used in the recent Hunterston B graphite safety case (NP/SC 7785) and is based on similar methodologies to those used in NP/SC 7785 which has been assessed previously (Ref. 9).

26. The structural integrity assessment therefore targeted:

- The areas where differences may exist,
- Any changes that have been made to the methods since NP/SC 7785 completed its ONR assessment.

27. For normal operation and non-seismic faults the specialist inspector is content that EDF Energy NGL has provided evidence to demonstrate that the predictions of control rod channel distortions are adequately low for a core state with cracking up to the proposed CEDTL. Evidence provided by EDF Energy NGL also supports that the effects of core distortion on fuel sleeve integrity and fuel sleeve gapping are small so as not to challenge the integrity of the sleeves or the coolant flow.

28. EDF Energy NGL has provided evidence that the predicted control rod channel distortions are low in a 10^{-4} pry seismic event for a core state with cracking up to the proposed CEDTL when using the best estimate properties of the seismic buildings model. However, sensitivity studies on the building model properties seismic input motion indicated that the unimpeded control rod movement is potentially challenged at the proposed CEDTL when using the upper bound (UB) properties of the buildings model for soil, backfill and bearings. These sensitivity studies were performed as a response to ONR technical queries that were raised during the specialist assessment of the seismic tolerance argument. As a consequence ONR is not able to agree the CEDTL proposed in NP/SC 7792.

29. In order to address this issue EDF Energy NGL has written to ONR (Ref. 4) to seek Agreement to operation up to lower core burn-up limits than originally proposed under NP/SC 7792. The proposal limits core burn-up to the next graphite core inspections. For Reactor 4 the limit is 16.775 TWd (inspection in February 2020) and for Reactor 3 the limit is 17.031 TWd (inspection in April 2020). This request is supported by analyses of a reduced core state (effectively a lower CEDTL) than the originally proposed CEDTL. The reduced core state bounds the core state for Reactor 3 and Reactor 4 at the next graphite inspections (February and March 2020 for Reactor 4 and Reactor 3 respectively). It also bounds the 99.9% calculational confidence predicted core states originally proposed in NP/SC 7792 (that would be reached around June 2020). The reduced core state and predicted core states at the time of the inspections are presented in Tables 1 and 2 in section 2.

30. The letter commits to underwrite the originally proposed CEDTL or a revised CEDTL (through revision to the safety case) before the graphite core inspection of Reactor 4 in February 2020. The letter proposes hold points limiting core burn-up of the reactors to the graphite core inspections which are implemented via arrangements at station that do not allow the reactors operate past this burn-up without an update to the safety case which will be considered by ONR for assessment and permissioning.

31. As a result of this, the specialist inspector has focused on the available margins beyond the predicted core state at the time of the graphite core inspection outages. In the extant safety case NP/SC 7716, it was expected that the predicted core state at 99.9% calculational confidence would be within the OA and that there is a margin between the OA and CEDTL (roughly a factor of 2, a margin proposed by NGL in previous safety cases).

32. Based on assessment of the letter and the accompanying seismic tolerance evidence, the specialist inspector concluded that there is adequate support for continued operation of Hinkley Point B Reactor 3 and Reactor 4 up to the planned outages of around February 2020 for Reactor 4 (core burn-up limit of 16.775 TWd) and around April 2020 for Reactor 3 (core burn-up limit of 17.031 TWd).

33. The specialist inspector also considers that the position for Hinkley Point B with regard to the effect of graphite debris on fuel handling and fuel cooling is acceptable for a core state similar to the 2018 Hunterston B Reactor 3 core state, noting that EDF Energy NGL are committed to providing further justification beyond this point.

34. The specialist inspector considers that the latest revision of the CrackSim[3] predictions at the 99.9 percentile are adequately conservative for the prediction of the bounding core state up to the next inspections of Hinkley Point B Reactor 3 and Reactor 4 in April and February 2020 respectively.

35. On this basis the specialist structural integrity inspector is satisfied that the Licensee has provided sufficient evidence with respect to the structural integrity of the graphite core to support continued operation of Hinkley Point B Reactor 3 and Reactor 4 up to the planned outage times, i.e. February 2020 for Reactor 4 (core burn-up limit of 16.775 TWd) and April 2020 for Reactor 3 (core burn-up limit of 17.031 TWd).

36. The specialist inspector has made the following Recommendations:

- Recommendation 1 (to ONR Project Inspector): I recommend that a Licence Instrument is issued to agree to continued operation of HPB reactors under NP/SC 7792 up to the technical specifications burn-up limits defined in EC 366104; those are set to 17.031 TWd for HPB R3 and 16.775 TWd for HPB R4.
- Recommendation 2 (to ONR Operating Facilities Head of Assessment): I recommend that ONR should review and consider any subsequent update to the graphite core safety case that supports further operation of HPB reactors under NP/SC 7792 beyond the next graphite inspections.

37. The ONR Operating Facilities Division Head of Assessment has confirmed that any subsequent update to the safety case will be subject to review and consideration.

3.1.2.1 ANOMALY WITH END FACE KEY STRENGTH MODELLING

38. During ONR assessment of NP/SC 7792, an issue was identified by EDF Energy NGL. The issue was related to an anomaly in the end-face keying system capacities used in the whole core model analysis supporting the Hinkley Point graphite core safety cases, including NP/SC 7792. EDF Energy NGL has addressed this through its normal Safety Case Anomalies Process (SCAP) (Ref 16) to identify the implications for the safety case provided in NP/SC 7792. The output of this SCAP was considered by the ONR structural integrity specialist inspector, who concluded the end-face capacity is sufficiently underpinned by EDF Energy NGL in the SCAP as not to challenge operation under the

[3] CrackSim is a model used by EDF Energy NGL to determine the current and future core state of the Hinkley Point B and the Hunterston B reactors

proposed safety case NP/SC 7792 up to the next graphite inspections of Hinkley Point B reactors.

39. The following recommendation was however raised by the specialist inspector:

40. Recommendation 1: ONR should consider and plan an intervention to look at the effectiveness of NGL's measures in place to reduce potential errors in the development and assessment of the whole core models.

41. I will progress this Recommendation with EDF Energy NGL.

3.1.3 FAULT STUDIES ASSESSMENT

42. The specialist fault studies assessment focussed on ensuring that EDF Energy NGL presented an adequate safety case to justify that the nuclear safety functions of the graphite reactor core are maintained in the presence of graphite brick cracking up to the levels specified in the OA and CEDTL (Ref. 10). The assessment also considers the arguments and evidence presented in the safety case and the supporting category 2 safety case (Ref. 5) in support of the Justified Periods of Safe Operation (JPSOs) for the Hinkley Point B reactors.

43. Based on the fundamental nuclear safety requirements of the graphite core and the potential impact on these of the presence of cracked bricks, the fault studies assessment has focussed on the potential effects of graphite cracking on the fuel including the implications in terms of fuel cooling, and free movement of the fuel in refuelling operations. The assessment has also considered the free movement of control rods in fault scenarios.

44. The specialist inspector notes that the significant technical arguments and evidence in support of both an increase in the OA and setting the JPSO are presented in the submitted category 1 safety case NP/SC 7792. The fault studies assessment has considered whether it adequately demonstrates that the increase in OA should be Agreed, and whether the JPSO can be supported.

45. The specialist inspector also notes that arguments and evidence presented are largely the same as those which were presented for the recent graphite core safety case for Hunterston B Reactor 4, which was assessed by ONR (Ref. 11). In addition, the JPSO for the two Hinkley Point B reactors have been set so that at the end of the period of power operation the core states will be broadly consistent with those at Hunterston B Reactor 4. The assessment report has therefore taken account of the assessment performed on the Hunterston B Reactor 4 safety case to avoid replicating the assessment, and has focussed on determining if the conclusions of that assessment similarly apply to this assessment.

46. This fault studies assessment report concludes that the arguments and evidence presented in the submitted category 1 safety case NP/SC 7792 have adequately demonstrated that, from a fault studies perspective, it is acceptable for ONR to Agree to an increase in the OA on the number of graphite brick cracks for the Hinkley Point B reactors.

47. The fault studies assessment report additionally concludes that the arguments and evidence presented in the submitted category 1 safety case NP/SC 7792 and the supporting category 2 safety case has demonstrated that the proposed JPSO can be supported.

48. The following Recommendation was raised by the specialist fault studies inspector:

Recommendation 1: Prior to ONR agreeing to the modifications to the safety case described in Reference 3, the project inspector should confirm that the graphite specialist inspector is satisfied that EDF Energy NGL has adequately demonstrated that all control rods will insert following a design basis seismic event.

49. I can confirm that the graphite specialist structural integrity inspector is satisfied that EDF Energy NGL have adequately demonstrated that all control rods will insert following a design basis seismic event and that Hinkley Point B Reactor 4 can continue to operate for a period of operation up to a core burn up of 17.031 TWd for Reactor 3 and 16.775 TWd for Reactor 4. Please refer to section 3.1.2 for more information.

3.2 HOLD POINTS

50. As discussed in section 2.1.2 EDF Energy NGL is limiting operation of each reactor to the core burn-up at the 2020 graphite core inspection outages.

51. The case for operation presented by EDF Energy NGL is supported by hold points (coinciding with graphite core inspection outage for each reactor) controlled via station documentation to ensure that the reactors cannot operate past the agreed burn-up limit without further consideration by ONR. These hold points are as follows:

1. Return to service from inspection of R4 (at 16.775 TWd)
2. Return to service from inspection of R3 (at 17.031 TWd)
3. Irradiation at core state equivalent to 99.9% HNB R3 core state (at 17.099 TWd for R3 and 16932 TWd for R4) defined within NP/SC 7792 and subsequent revision of EC 366104.

52. The release of hold points 1 & 2 will require:

- An update to the safety case to modify the burn-up limits, potentially by revising the CEDTL and referencing additional seismic analysis at the upper bound properties.
- Agreement by the Graphite Assessment Panel for return to service following a Graphite Inspection Outage informed by the pre-outage forecasts and the inspection findings of the core state.

53. ONR will consider cases related to return to service following the 2020 graphite core inspection outages.

54. EDF Energy NGL has also committed to the following:

- A detailed analysis of the next inspection results and revised estimate to reach the Hunterston B R3 core state at 99.9% confidence – within 60 days of the inspection for each reactor (no later than 17th May 2020 for R4 and 19th July for R3)
- A report detailing further seismic analysis establishing a suitable upper limit of cracking in the core with adequate margin at the upper bound of seismic excitation (e.g. a potential revision to the CEDTL) – 21st January 2020.

4. MATTERS ARISING FROM ONR'S WORK

55. All ONR specialist inspectors consider agreement to the proposed safety case modification of NP/SC 7792 (Ref. 3) to be acceptable. On that basis I have prepared a licence instrument for Agreement to the justification for an increase in the operational allowance for the Hinkley Point B graphite core ages up to 17.2 TWd. This Agreement is effectively restricted to 17.031 TWd for Reactor 3 and 16.775 TWd for Reactor 4 as

an update to the safety case will be required to operate beyond these core burn-ups which is controlled via hold points. This has been written according to ONR guidance (Ref.12) and is of routine type, for which the text and format have been agreed with the Government legal department. Further legal checking of this licence instrument is therefore unnecessary.

56. I have liaised with the Environment Agency who has confirmed that they have no objections to the operation of reactors 3 and 4 at Hinkley Point B to their next graphite inspection outages in 2020. (Ref. 13).

57. I have confirmed that EDF Energy NGL has followed its own due process. An INSA statement for the case has been submitted (Ref 14) and Nuclear Safety Committee (NSC) meeting minutes have been submitted (Ref 15).

5. CONCLUSION

58. I conclude that, based on the assessments and conclusions made by the ONR specialist inspectors, and the evidence from regulatory interactions with EDF Energy NGL that Hinkley Point B Reactor 3 can continue to operate for a period of operation up to a core burn up of 17.031 TWd and Reactor 4 up to a core burn-up of 16.775 TWd.

6. RECOMMENDATIONS

59. I recommend that licence instrument 560 is granted to Hinkley Point B to implement NP/SC 7792.

7. REFERENCES

1. BEG/SPEC/DAO/020, Nuclear Generation Limited, Company Specification, Modification process, Revision 008, May 2019

2. NSL HPB 51426 R, Request for Agreement Under Arrangements Made Under Licence Condition 22(1), Engineering Change (EC) 365359 – NP/SC 7792 – Justification for an increase in the operational allowance for the Hinkley Point B graphite cores for core ages up to 17.2 TWD (CM9 2019/280003)

3. NP/SC 7792 Hinkley Point B Power Station – Justification for an increase in the operational allowanced for the Hinkley Point B graphite cores for core ages up to 17.2 TWd – EC No 365359, Revision 000, Proposal Version No:09 (CM9 2019/280003)

4. NSL HPB 32376R, Letter, Hinkley Point B: Graphite Core Safety Cases – Continued Operation of R3 and R4, 21 November 2019 (CM9 2019/346662

5. Setting of Justified Period of Safe Operation for HPB R3 and R4 based on Graphite Core Safety Case NP/SC 7792, EC 366104, Proposal Version 04 (CM9 2019/354874)

6. ONR-OFD-AR-19-041 – Justification for an increase in the Operational Allowance for the Hinkley Point B Graphite Cores for Core Ages up to 17.2 TWd - NP/SC 7792 – Civil Engineering Assessment (CM9 2019/268654)

7. ONR-OFD-AR-18-085 – Return to service safety case for Reactor 4 following core inspection results in 2018 0 NP/SC 7785 – Civil Engineering Assessment (CM9 2019/90351)

8. ONR-OFD-AR-19-073 – Justification for an increase in the Operational Allowance for the Hinkley Point B Graphite Cores for Core Ages up to 17.2 TWd – Structural Integrity Assessment (CM9 2019/355116)

9. ONR-OFD-AR-19-007 – Return to service safety case for Hunterston B Reactor 4 following core inspection results in 2018 (NP/SC 7785), Graphite structural integrity assessment (CM9 2019/221481)

10. ONR-OFD-AR-19-056 – Fault Studies Assessment of the Justification for an Increase in the Operational Allowance for the Hinkley Point B Graphite Core for Core Ages up to 17.2 TWd (CM9 2019/274182)

11. ONR-OFD-AR-19-029 – Fault Studies Assessment of the Hunterston B R4 Return to Service Safety Case Following Core Inspection Results in 2018 (CM9 2019/176010)

12. NS-PER-IN-001. Preparation and Issue of Licence Instruments. Revision 8. (CM9 2017/8970)

13. Email, HPB Reactors 3 and 4, received 03 December 2019 (CM9 2019/355427)

14. Full INSA Approval Statement – Justification for an increase in the operational allowances for the Hinkley Point B graphite cores for core ages up to 17.2 TWd (CM9 2019/280003)

15. EDF Energy Nuclear Generation Ltd, Dungeness B and Hinkley Point B Nuclear Safety Committee Minutes of the Meeting, 19 June 2019 (CM9 2019/192846)

16. E/TSK/HPB/15452, EDF NGL, SCAP2, 06 December 2019, (CM9 2019/362298).