Office for Nuclear Regulation

ASSESSMENT REPORT			
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Site:	Heysham 2		
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Operating Facilities Division

Heysham 2 Reactor 7 2018 Periodic Shutdown – Assessment of the results of the Graphite Core Inspections

Assessment Report ONR-OFD-AR-18-016
Revision 0
29 June 2018

EXECUTIVE SUMMARY

The licensee, EDF Energy Nuclear Generation Limited (NGL), of Heysham 2 (HYB) power station has shutdown Reactor 7 (R7) under licence condition (LC) 30. During the periodic shutdown, the graphite reactor core has undergone inspections, as required under LC28.

An intervention was performed during the periodic shutdown to determine the adequacy of the inspections. There are no outstanding actions from that intervention which would prevent consent being granted by Office for Nuclear Regulation (ONR) to the return to service of HYB R7.

NGL inspected and measured the bore of sixteen fuel channels and one control rod channel, as per the Maintenance Schedule requirements. During these inspections, one new full circumferential crack was observed in a newly inspected fuel channel. No full height axial crack has been found. The brick and channel distortions measured were small. The results of these inspections are therefore as expected and, in my opinion, these do not challenge the assumptions of the safety case.

In addition the peripheral bricks surrounding the reactor were inspected for the first time at this reactor since the discovery of a number of cracked bricks in similar locations during the 2015 TOR Reactor 2 (R2), 2016 HYB Reactor 8 (R8) and 2017 TOR Reactor 1 (R1) periodic shutdowns. Before the periodic shutdown, NGL submitted safety cases ECs 356531 (HYB) and 356536 (TOR) to justify operation following the discovery of cracked peripheral bricks. The claims and arguments presented are consistent with the results of the inspections to date. I consider that the findings from the peripheral bricks inspections during this periodic shutdown do not challenge the claims and arguments in safety case EC 356531 (JCO 4).

The licensee estimates that the most highly irradiated graphite bricks in HYB R7 will experience ‘turnaround’ by the end of 2018. Turnaround is a point in time where the stress state in the bricks will slowly be reversed from tension to compression at the bore and from compression to tension at outer section of the bricks. The licensee has therefore presented a revised safety case, NP/SC 7663, to support operation beyond the point of turnaround. In itself, this mechanism does not challenge the safety of the reactor, but this will represent the start of the next phase in the lifetime of the reactor. ONR is undertaking the assessment of this case, but completion of the assessment is not required prior to the return to service of HYB R7.

In my opinion, the graphite core inspections results are within the bounds of NGL’s safety case and do not present any impediment to return to service of HYB R7. I have no objection to the subsequent PAR recommending that consent is given to return Heysham 2 Reactor 7 back to service.

Recommendations

My recommendations are as follows.

To the ONR Project Inspector:

- Recommendation 1: I have based my assessment on approved inspection sheets and from a verified statement provided by the licensee in advance of the Engineering Change (EC) justifying return to service. I therefore recommend the ONR Project Inspector confirms that the Independent Nuclear Safety Assessment (INSA) statement for the return to service engineering change is submitted as part of the licensee’s application for consent to return to service to confirm that this EC has completed the Licensee’s due process.

To NGL’s HYB/TOR Safety Case Group Head:

- Recommendation 2: Continued inspection of the peripheral bricks appears to be necessary to ensure that the condition of the peripheral wall at all four HYB/TOR reactors does not deteriorate.

I have given an ONR Assessment rating of Green, no formal action.

LIST OF ABBREVIATIONS

AGR	Advanced Gas-cooled Reactor
BMS	Business Management System
EC	Engineering Change
EIM	EDF Integrated Model
GWd	Giga-Watt day
HOW2	(ONR) Business Management System
HSL	Health & Safety Laboratory
HYB	Heysham 2 Power Station
INSA	Independent Nuclear Safety Assessment
JCO	Justification for Continued Operation
LC	Licence Condition
MAP	Monitoring Assessment Panel
NCR	Non-Conformance Report
NGL	EDF energy Nuclear Generation Limited
NICIE2	New In-Core Inspection Equipment Mark 2
ONR	Office for Nuclear Regulation
PAR	Project Assessment Report
PBAP	Peripheral Brick Assessment Panel
R	Reactor
RTS	Return-To-Service
SAP	Safety Assessment Principle(s)
SQEP	Suitably Qualified and Experience Person
TAG	Technical Assessment Guide(s) (ONR)
TOR	Torness Power Station
UoB	University of Birmingham

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1 INTRODUCTION

1. The licensee, EDF Energy Nuclear Generation Limited (NGL), of Heysham 2 (HYB) power station has shutdown Reactor 7 (R7) under licence condition (LC) 30. During the periodic shutdown of HYB R7 the graphite reactor core has undergone surveys, as required under LC28.

2. NGL has completed its graphite core inspection schedule and will request Consent from ONR to restart HYB R7. My assessment of the final graphite core structural integrity inspection results is based on the findings provided by NGL in supporting inspection results documents.

3. This report presents the results of my assessment of the structural integrity findings related to the graphite core inspections during the 2018 HYB R7 inspections. I also considered the claims, arguments and evidence presented by the licensee in Engineering Change (EC) 351531 (Reference 1). NGL developed this EC and its corresponding EC for Torness (TOR), EC 356536 (Reference 2), following the discovery of cracks in the peripheral shield wall bricks at TOR R2 in 2015 (Reference 3), HYB R8 in 2016 (Reference 4) and TOR R1 in 2017 (Reference 5).

1.1 Background

4. NGL's intended scope of the graphite inspections during the periodic shutdown of HYB R7 covered inspections and sampling of fuel channels and inspection of the peripheral shield wall. Inspection of fuel channels has been performed routinely by NGL at all of the Advanced Gas-cooled Reactors (AGR) in the fleet. However, inspection of the peripheral shield wall is unique to TOR and HYB stations as this is a design feature of the reactors at these sites.

5. NGL committed to performing inspections of the graphite peripheral shield wall at these reactors as a result of the observation of cracking of peripheral bricks at TOR Reactor 2 (R2) in 2015, where 17 cracked bricks were observed after inspection of 10 of the 16 faces of the peripheral wall which approximates to 1.5% of the peripheral bricks being cracked (Reference 3).

6. Subsequently, in the HYB R8 2016 statutory outage, 22 cracked peripheral bricks were found from an inspection of 9 out of 16 faces, indicating a percentage of cracking of around 2.4% (Reference 4). The recent TOR Reactor 1 (R1) 2017 statutory inspection revealed a further 25 cracked peripheral bricks (1.6%) from inspecting 13 out of 16 faces of the peripheral wall.

7. Overall, there is consistency with the amount of cracked peripheral bricks from the reactors inspected, i.e. 1.5% for TOR R2, 2.4% for HYB R8 and 1.6% for TOR R1 (Reference 5). There is also some resemblance in the morphology of the cracks found at all three reactors already inspected, which suggests a common mechanism of failure.

8. NGL has conducted extensive test programmes on the root cause investigation since the discovery of peripheral brick cracking in 2015. However, so far NGL has not provided a definitive explanation as to the damage mechanism. As the peripheral bricks at HYB/TOR reactors had never been directly inspected for cracking before 2015, there is little knowledge about the timing of the cracking and hence the rate of crack progression.

9. Since the peripheral brick inspections, NGL considered the significance of peripheral cracked bricks on all four reactor cores at HYB/TOR and issued a Justification for Continued Operation (JCO) in ECs 356531 & 356536 (Reference 1 and Reference 2).

Following peripheral brick inspection at TOR R2 in 2015, HYB R8 in 2016 and TOR R1 in 2017, this is the first dedicated inspection of this kind for HYB R7.

10. Assessment was undertaken in accordance with the requirements of the Office for Nuclear Regulation (ONR) How2 Business Management System (BMS) guide NS-PER-GD-014 (Reference 6). The ONR Safety Assessment Principles (SAP) (Reference 7), together with supporting Technical Assessment Guides (TAG) (Reference 8), have been used as the basis for this assessment.

1.2 Scope

11. The scope of this report covers the licensee's activities performed during the shutdown associated with the examination and inspection of HYB R7 graphite core and considers whether the results are consistent with the HYB R7 safety case and whether return-to-service is justified. I have taken account of recent developments in the HYB and TOR graphite core safety cases including the claims, arguments and evidence presented in EC 356531.

1.3 Methodology

12. The methodology for the assessment follows HOW2 guidance on mechanics of assessment within the Office for Nuclear Regulation (ONR) (Reference 9). This assessment has been focussed primarily on the licensee's arrangements for the graphite core inspections and the findings from the current periodic shutdown, including inspections from the peripheral bricks.

2 ASSESSMENT STRATEGY

13. The intended assessment strategy for my assessment 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

14. The relevant standards and criteria adopted within this assessment are principally the Safety Assessment Principles (SAP) (Reference 7), internal ONR Technical Assessment Guides (TAG) (Reference 8), relevant national and international standards and relevant good practice informed from existing practices adopted on UK nuclear licensed sites. The key SAPs and any relevant TAGs are detailed within this section.

2.2 Safety Assessment Principles

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

2.2.1 Technical Assessment Guides

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

- ONR-TAST-GD-029 – Graphite Reactor Cores.

2.2.2 National and International Standards and Guidance

17. Due to the uniqueness of the AGR design and the lack of availability of international experience with the design of AGR graphite reactor cores, I have not explicitly referred to international standards and guidance as part of this assessment.

2.3 Use of Technical Support Contractors

18. N/A.

2.4 Integration with Other Assessment Topics

19. N/A.

2.5 Out of Scope Items

20. The following items are outside the scope of the assessment:

- Inspection results from all non-graphite related components.

3 LICENSEE'S SAFETY CASE

21. This section provides a summary of the licensee's safety case and the justification for the return to service (RTS) of HYB R7. I provide my assessment of the graphite inspection findings in relation to the RTS of HYB R7 in Section 4 of this report.

3.1 Graphite weight loss limits

22. There are several limits placed on graphite weight loss at HYB/TOR. The most significant of these limits are given below (Reference 10):

- the mean weight loss over a peak irradiated brick limit is 17.5%, which NGL estimates to be reached for a core burn-up of 16,500GWd.
- the average active core weight loss limit is 14%, estimated to be reached for a core burn-up of 16,200GWd (Reference 11).

23. At the time of the 2018 periodic shutdown, the core burn-up for HYB R7 was 13,844GWd (Reference 12). The above core burn-up limits are not anticipated to be reached before 2022.

3.2 Bore cracking

24. Bore cracking is an early-life damage phenomenon associated with a number of factors such as the geometry of the brick and tensile stresses at the bore in early life of the reactor. NGL defined an 'essentially intact' core as containing fewer than 10% axially cracked bricks (double or single) arising from axial bore cracking and keyway root cracking of disparate mode bricks, and any singly cracked bricks have not opened more than 12 mm at the outer diameter (References 13 and 14).

25. Since the start of operation, a relatively small number of bore cracks have been found in the HYB/TOR reactors. To date, three bore cracks have been observed in the HYB R7 core (Table 1 of Reference 15). Bore cracks can have different morphology but are essentially either axial or circumferential. Of these, NGL demonstrated that circumferential cracks were reasonably benign and considered that only fully axial cracks were of significance for the core. Prior to the outage, the licensee carries out a pre-outage estimation of the number of bore cracks that could be observed using statistical analysis; see Reference 15. Prior to these inspections, this model predicted that up to one new fully axial bore crack and one new circumferential bore crack were most likely to be observed. Keyway root cracking is not expected until post-stress reversal has occurred and was therefore not considered to be a concern at the time of the outage.

3.3 Post-Stress Reversal Safety Case

26. As graphite is irradiated, it first experiences a period of dimensional shrinkage and expansion at later stages of its life. Due to its location closer to the fuel, the bore of the brick is subjected to a higher neutron dose than its outer section. This difference in rates of dimensional change between the bore and the outer section of the bricks is responsible for internal stresses. In the early stages of life of the reactor, the internal stresses in the bricks are tensile at the bore of the brick and compressive at the outer diameter. In the later stages of life of the reactor, the stresses in some of the bricks reverse to tensile in the outer sections and compressive at the bore. This stage is referred to as 'post-stress reversal'.

27. NGL recently submitted NP/SC 7663 – Graphite Core Safety Case (Reference 14) to support post-stress reversal operation as the Licensee predicts that the most irradiated bricks will experience turnaround by the end of 2018.

3.4 Outage intentions

28. For this outage, NGL's intended scope of graphite inspections is summarised below (Reference 16):

- Inspection of a minimum of 16 fuel channels both visually and dimensionally using a New In-Core Inspection Equipment (NICIE2);
- Trepanning of a minimum of 24 graphite specimens to a depth of 65mm with a target of between 30 - 36 and an upper limit of 42;
- Visual inspection of one control rod channel;
- Inspection of a minimum of 9 out of 16 faces of the peripheral shield wall with an upper target of 13 faces.

29. The sixteen fuel channels selected for inspection during the shutdown are listed below. Five of these fuel channels are re-inspections:

- Depressurised in air phase: X23, C25, L23, Q13, S21, H27, G19 and T25
- Depressurised CO_2 phase: P37, L11, K35, L37, R33, U09, P29 and E27
- Control rod channel: BC20

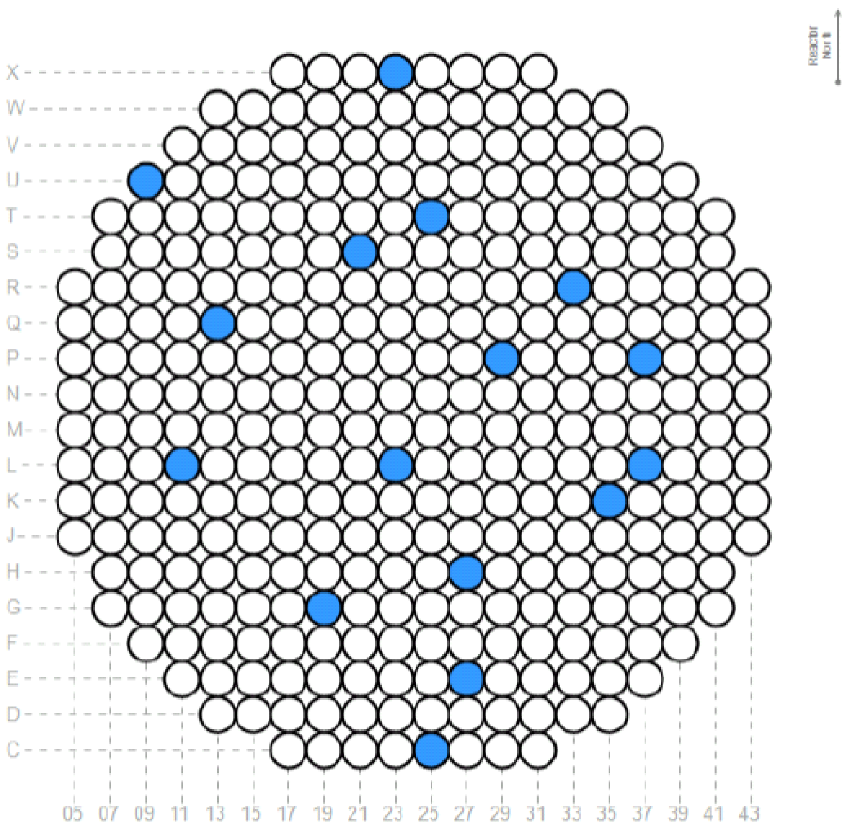

Figure 1: Core map showing the fuel channels inspected during 2018 HYB R7 periodic shutdown (Reference 15).

30. To analyse and sentence the results of the graphite core inspections, the licensee set up a Graphite Assessment Panel which is composed of personnel having been accredited as a Suitably Qualified and Experienced Person ('SQEP'). The members of the GAP are engineers and managers from the station, from the Central Technical Office (CTO) at Barnwood and from contractors involved with these inspections. The guidelines to help identify the different types of defects in the core are available in Reference 17. The licensee argued that only the crack opening of full height axial cracks are structurally significant for the core as excessive opening of these cracks

could cause distortion of adjacent channels. This judgement was considered and deemed to be reasonable in paragraph 43 of Reference 18.

3.5 Peripheral bricks inspections

31. HYB is currently operating under Justification for Continued Operation (JCO) EC 356531 Revision 004 (JCO4), which is the most recent revision to the graphite core safety case (Reference 1). This safety case has been developed following finding cracks in the peripheral shield wall at TOR R2 in 2015, HYB R8 in 2016 and TOR R1 in 2017. EC 356536 is the equivalent EC for the TOR reactors (Reference 2).

32. Continued operation in ECs 356531 & 356531 is based on the three following claims :

- Claim 1 - The consequences of cracking found to date and from a postulated small number of failed bricks is acceptable;
- Claim 2 - The rate of progression of the cracking is low and therefore degradation to unacceptable levels is not expected with a three year inter-outage period;
- Claim 3 – Continued Operation of all four reactors is ALARP based upon a strategy of inspections at statutory outages.

33. I consider these claims, arguments and supporting evidence in Section 4 as part of my assessment of RTS of HYB R7. The INSA certificate for this EC is shown in Appendix 2 of this report and in Reference 19.

34. NGL listed the assessment criteria for the results of the peripheral brick inspections in Reference 20. These criteria are based on the inspection results from HYB R8, TOR R1 and TOR R2. Any observations outside these bounds would require further work before HYB R7 could be returned to service.

35. For the inspection planned during the outage, the licensee defined the following scope of inspections:

- Eleven faces distributed between all four quadrants, including both faces with historical evidence of potential cracks;
- Minimum of nine faces will be adequate to establish consistency with other three reactors;
- Three edge channels with NICIE2.

36. Figure 2 shows the eleven peripheral faces planned for inspection during the 2018 HYB R7 periodic shutdown and for future inspections.

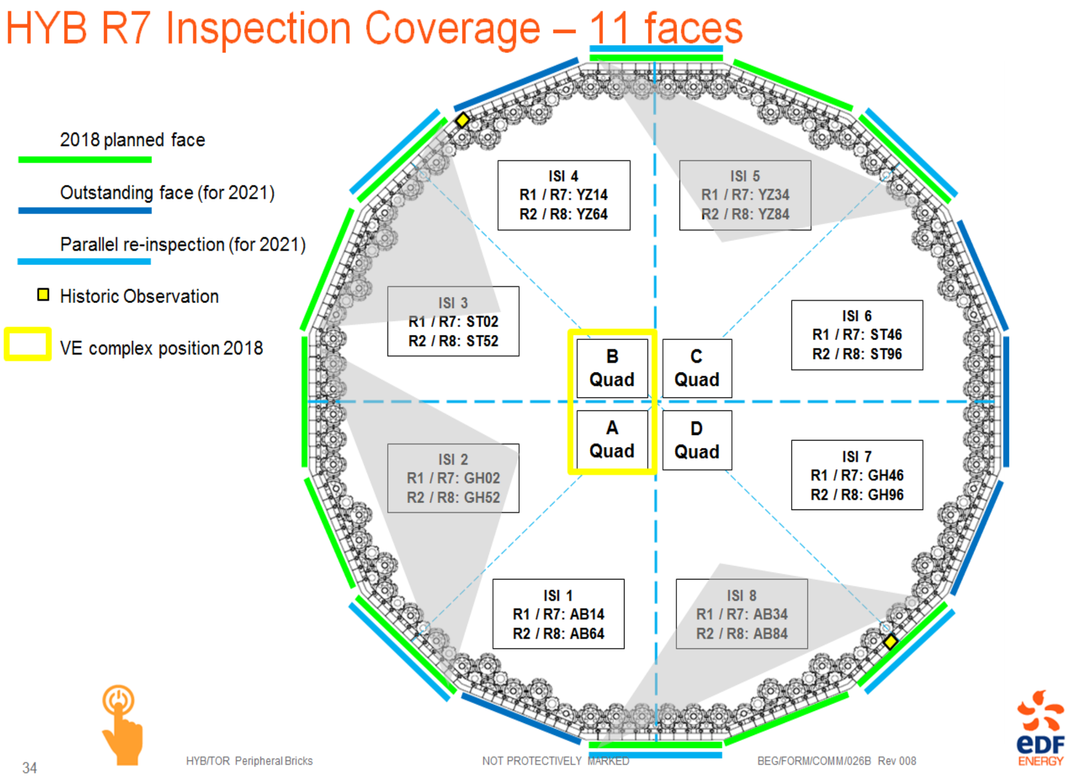

Figure 2: Planned inspections of the peripheral bricks for the 2018 HYB R7 outage (Reference 21).

37. Defects or movements of the bricks observed during the peripheral wall inspections are reported in Non-Conformance Reports (NCRs). To review and sentence the results of the peripheral brick inspections, the licensee set up a Peripheral Brick Assessment Panel (PBAP) which is formed of SQEP personnel from the station, CTO and from contractors involved with the peripheral bricks inspections. The PBAP gathered every one or two days during the outage, depending on the amount of inspection results available for sentencing. A copy of the PBAP sentencing process is available in Reference 22.

38. Before the outage, NGL prepared an assessment sheet to help categorise the defects and defined a route A, B or C depending on the observations. In route A, the observations do not challenge the safety case. In route B, NGL would have to carry out some relatively minor work before the RTS of the reactor. Route C would challenge the assumptions in the current safety case and NGL would have to carry out some major re-work if a significant number of cracks were found during the inspections.

4 ONR ASSESSMENT

39. This assessment has been carried out in accordance with HOW2 guide NS-PER-GD-014, “Purpose and Scope of Permissioning” (Reference 1).

4.1 Scope of Assessment Undertaken

40. In relation to the graphite core I carried out the following inspections in order to determine compliance with LC 28: Examination, inspection, maintenance and testing.

- Inspection of the quality of the graphite core inspections
- Inspection of training records and quality control procedures of the licensee
- Observation of a Peripheral Brick Assessment Panel (PBAP) meeting.

41. I also assessed the current core burn-up of the HYB R7 in relation with the applicable safety case limits to form a view on the proximity of the graphite core to its operational limits before its next periodic shutdown in three years’ time.

4.2 Site intervention

42. I performed an intervention at HYB on 30th May 2018 with the project inspector during the periodic shutdown to inspect the adequacy of the licensee’s examinations and inspections of the graphite core. At the time of my intervention, the inspection team had completed all 16 fuel channel inspections. I sampled the inspection footage from fuel channel K35, which records showed to contain a fully circumferential crack. In my opinion, the video footage was of adequate quality and the crack was clearly visible on the screen.

43. Inspections of the graphite peripheral shield walls were being conducted at the time of the intervention. The peripheral brick inspections utilise a peripheral manipulator, which is different to the equipment used for the fuel channel inspections and is primarily used for reactor internals such as the core restraint. At the time of my intervention, NGL had completed three out of a targeted eleven sides of inspection and had observed linear cracks in a small number of bricks. My inspection of training records and inspection staff found that the inspections were being performed by suitably qualified and experienced personnel.

44. Overall, from the activities I sampled during my intervention I found that NGL was complying with LC 28 in respect of the graphite core inspections and I had attributed an ONR rating of ‘green’ – adequate – for this intervention (Reference 23).

4.3 Graphite fuel channel inspections

45. The licensee uses the New In-Service Inspection Equipment Mk II (NICIE2) tool to visually inspect and measure the fuel channels at HYB. This tool is equipped with a camera, transducers and ‘feelers’ which measure the channel tilt and bore dimensions. The licensee then analyses the data and produces GAP sheets which are reviewed during the GAP meetings. Any defect found is also reviewed during the GAP, sentenced and endorsed by its members. The results of the visual inspections and the dimensional measurements have been sentenced by the HYB graphite assessment panel (GAP). The minutes of the GAP are normally referenced by the RTS safety case that NGL prepares to summarise the results of inspection of steel and graphite components.

46. NGL’s process is to ensure the quality of the data immediately after a channel inspection has been completed. For this process, the data are transferred from the NICIE2 to an assessor. Once the initial assessment of the data is complete, the assessor confirms by e-mail that the inspection team can move to the next channel. An

example of a confirmation e-mail is in Reference 24. During the first channel inspection (Channel U09), the assessor identified that the noise in the data was not acceptable and required that the channel was re-inspected. The inspection team checked the NICIE2 equipment and noticed that a switch was not in the correct setting. The team then re-inspected the channel with the correct configuration settings and the data were re-examined for quality. This is captured in Reference 25. I also note that NGL proposed to carry out its own investigation to determine the reasons for the wrong configuration setting during the first inspection. In view of recent similar issues at HPB and HNB, I am supportive of this investigation.

47. In my opinion, it is positive that NGL identified this error immediately after the channel inspection was completed and carried out a re-inspection of the channel with the correct settings. This provides confidence that the licensee’s verification process in place has been efficient.

4.4 Results of the fuel and control rod channels inspections

48. For this periodic shutdown, NGL inspected and measured the bore of sixteen fuel channels and one control rod channel, as per the Maintenance Schedule (MS) requirements. NGL submitted a copy of the graphite core inspection results and of the GAP minutes in Reference 26. I am therefore satisfied that the MS requirements have been met.

49. During these inspections, only one new full circumferential crack was observed in a newly inspected fuel channel (K35, layer 8). There were no full height axial cracks and no defects were observed in the inspected control rod channel. Figure 3 shows the circumferential crack observed in Channel K35, layer 8, during the inspections. This crack was sentenced as a bore crack by the GAP, which seems to be appropriate considering that keyway root cracks are expected to be axial due to the design of the bricks.

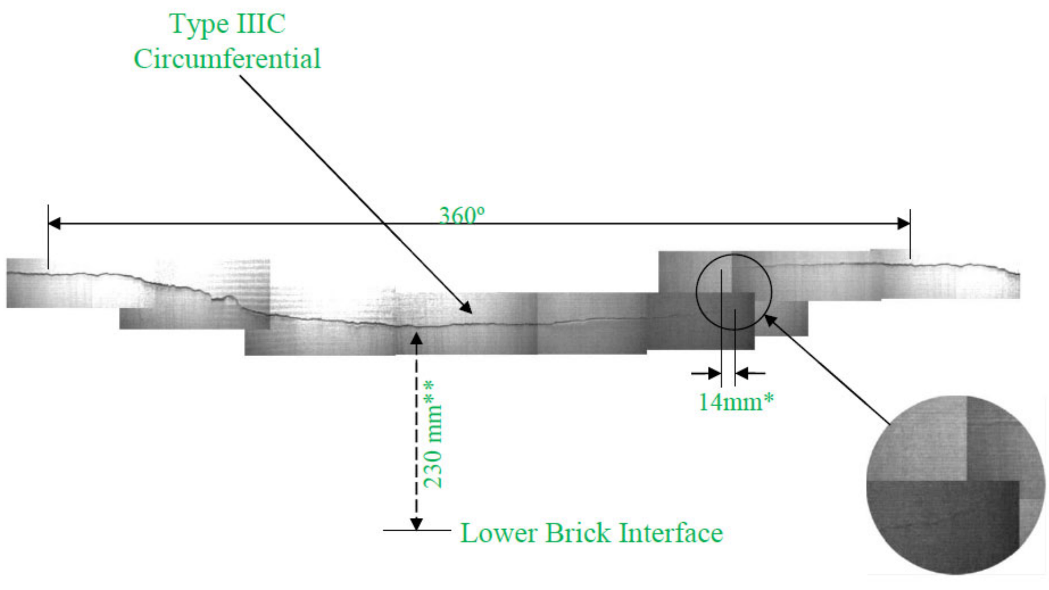

Figure 3: Circumferential crack observed in fuel channel K35, layer 8 (Reference 26).

50. The brick and channel distortions measured were within expectation. The control rod channel did not reveal any defect. The results of these inspections are therefore as expected and do not challenge the assumptions of the safety case.

51. This is the second circumferential bore crack observed in the HYB R7 graphite core (see Table 1 of Reference 15). No full height axial crack has yet been observed in this reactor although two smaller cracks have been observed (‘Type IIIA’ as per Table 1 of Reference 15). I therefore consider that the results of these inspections do not challenge the licensee’s ‘intact core’ definition, i.e. 10% cracking.

4.5 Core distortion

52. During the graphite core inspections, the licensee carries out visual and bore measurements using NICIE2. From the bore measurements, the licensee calculates the shutdown core distortion using a computer program called Core Distortion Pinning. This program extrapolates the core distortion of the fuel channels to the whole of the core, including the results of previous inspections. The distortion ‘map’ calculated resulting from the inspection at this outage is shown Figure 4:

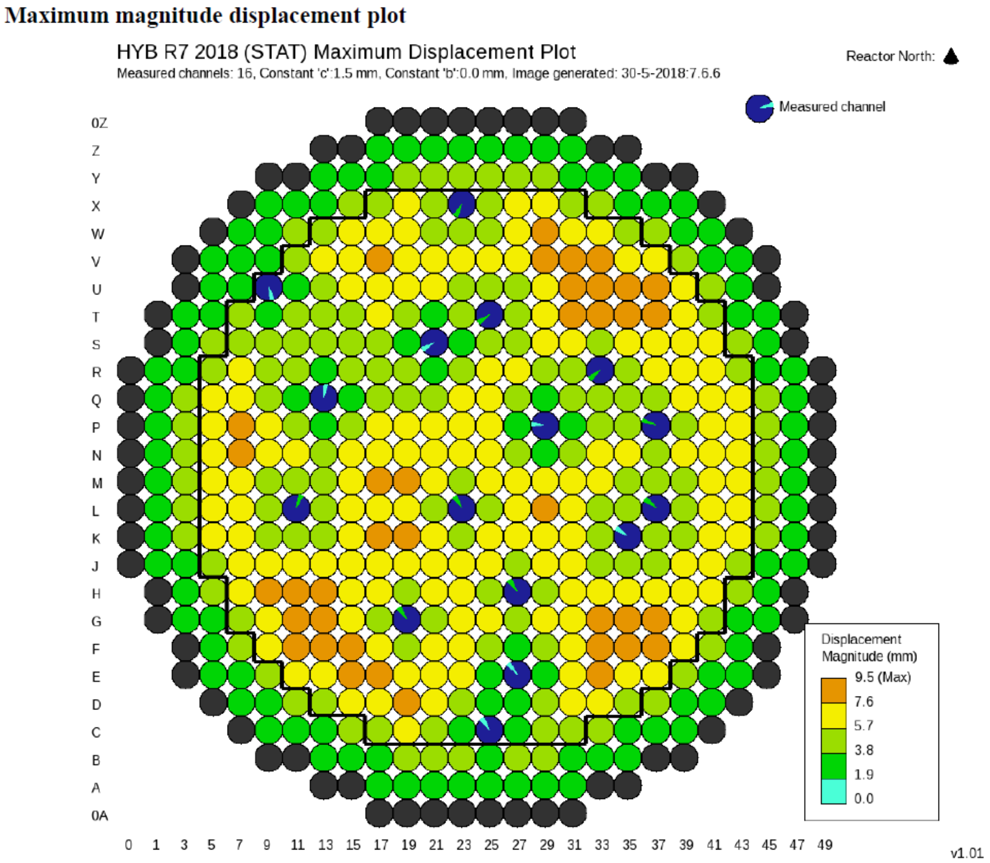

Figure 4: Core distortion map calculated using Core Distortion Pinning program.

53. The displacements in Figure 4 show that the channel displacement relative to the base layer is generally less than 9.5mm. Measured core distortions of channel tilt and bow appear to be similar, or not significantly worse, than previous core measurements. Therefore, I do not expect this level of distortion to be a concern for the safety of the core.

4.6 Keyway root cracking

54. To date, keyway root cracking (KRC) has only been observed in the HPB and HNB reactor cores. According to NGL’s latest forecasts, the earliest core burn-up at which parts of the core are predicted to undergo keyway root cracking is 16.0TWd for HYB and TOR. This estimate was based on a material model which is referred to as EDF Integrated Model (EIM) v1.2. Considering the current core burn-up for HYB R7 (13.8TWd), which is the lead reactor in terms of burn-up and the predicted rate of

0.5TWd/year, onset of KRC in the HYB/TOR cores is not expected until approximately 2022 (Reference 27).

55. The validity of this model for post-onset of KRC behaviour of the core is still being considered by ONR. However, the time at which EIM v1.2 predicts onset of KRC is based on the experience with HNB and HPB. Core burn up at HNB Reactor 3 was 15.199TWd when KRC was first discovered and it was 15.967TWd at HPB R4. Therefore, I consider that the core burn-up of 16TWd provides a reasonable estimate for the onset of KRC at HYB/TOR. I therefore consider that the estimate for the time of KRC provided by EIM v1.2 is more likely to be reasonable than previous materials models developed by NGL. However, it is important that the inspection strategy is such that detection of earlier onset can be detected before limits on the number of cracked bricks are challenged. The current inspections strategy and its ability to detect early onset of KRC will be considered as part of ONR assessment of the post-stress reversal safety case for HYB/TOR (Reference 16).

4.7 Graphite trepanning

56. At HYB/TOR, the licensee now carries out some ‘deep-cutter’ trepanning of length up to 70mm, compared to 40mm in earlier sampling, compared with a brick through wall thickness of 82mm. Graphite trepanning was carried out and thirty-one samples were retrieved from the core (Reference 12). The number of samples retrieved during the outage meets the MS requirements of minimum twenty-four samples, with a target between thirty and thirty-five samples.

57. I consider that this is a good achievement for the graphite inspection team and will provide significant extra data to support graphite weight loss predictions. The weight loss and materials properties data derived from the trepanned specimens will not be available for several months. However, I reviewed the results obtained from the latest trepanning campaign during the HYB R8 2016 periodic shutdown in Reference 11.

4.8 Graphite weight loss

58. HYB and TOR rely on the statistical analysis to determine graphite weight loss but there are issues with the thermofluid analysis which may affect the weight loss prediction. The latest graphite weight loss forecasts by NGL estimate that the graphite weight loss limit will not be reached before 2022 at the earliest. Therefore, I consider at the current time there is an acceptable margin between the level of graphite core weight loss and the limits in the safety case. The methods used to support the predicted graphite core weight loss will be considered as part of the ONR assessment on NP/SC 7663 supporting post-stress reversal operation for HYB/TOR.

4.9 Peripheral brick inspections

59. In January 2018, ONR and NGL held a Level 4 meeting for NGL to explain the changes in JCO4 and the peripheral bricks inspection strategy during the 2018 HYB R7 outage. The contact record for this meeting is in Reference 21. During this meeting, ONR requested further information concerning the limitation of the temperature modelling, a copy of the statistical analysis report, details about the repeat inspection planned at TOR R2 in 2018 and criteria for arrowhead passages inspections. These actions have been addressed in Reference 22.

60. During the outage, NGL achieved their target inspections and completed 11oo16 faces of the peripheral shield walls, which satisfies the MS requirements. NGL also provided ONR with all the inspection reports and minutes of the Peripheral Brick Assessment Panel (PBAP) in Reference 28. Prior to the outage, the licensee issued a route map to help the assessors with the sentencing of defects (Reference 20).

61. The defects observed are reviewed and sentenced by the PBAP. Photos and comments are collated into NCRs which are circulated to the PBAP members in advance of the meeting, including an estimate of the dimensions where applicable. The defects are then categorised according to their type such as linear crack (category 1.3), branched crack (category 1.1), brick misalignment (category 2.*x*, where *x* is between 1 and 5 according to the significance of the misalignment) or debris seen on the restraint beams (category 3.5). The results are then summarised in the final PBAP meeting and approved for the RTS EC.

62. On 4th June, I observed a PBAP meeting during the outage. At the time, the PBAP members were reviewing the latest inspection findings summarised in PBAP inspection sheets (Reference 28). The group was quorate in accordance with their terms of reference, complied with their crack sentencing procedures and was composed of suitably qualified and experienced personnel. I observed that there was sufficient information presented in the PBAP inspection sheets for the panel to be able to come to an informed conclusion. In my opinion, the PBAP process I observed was adequate and there was some level of questioning from different PBAP members before a judgement was agreed to. During this meeting, I enquired about the significance of the report of 'missing graphite' observed in inspection sheet W092/05.

63. Figure 5 shows this defect being sentenced during the PBAP (peripheral wall W092/05).

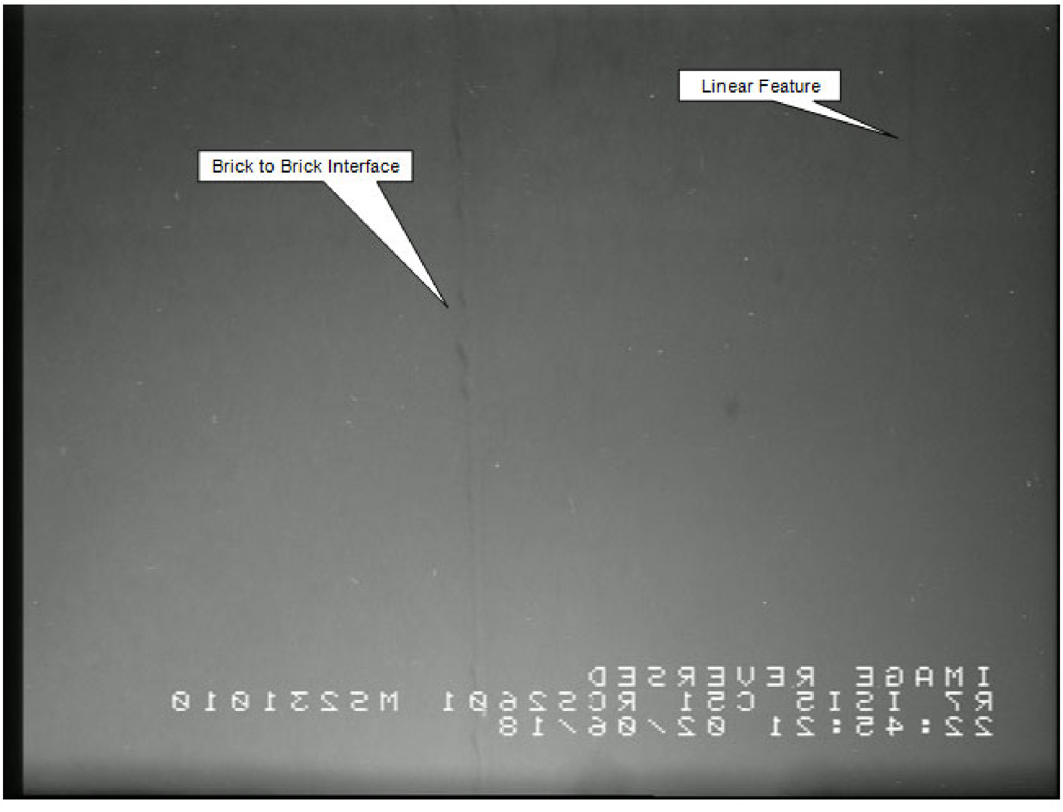

Figure 5: Peripheral Wall Inspection W092/05 – Layer 3, Face 16, Brick 8: example of 'missing graphite'.

64. Figure 5 shows eroded pieces of graphite at the interface between the peripheral wall bricks. This was classified as 1.8 (linear feature) by the PBAP. During the meeting, I asked the PBAP members for clarification concerning the missing pieces of graphite. NGL explained that the size of the missing edges of the graphite brick was small, ~0.5mm, and noted that it was most likely a machining mark or a scratch. The PBAP did not consider this to be significant and confirmed that a classification of 1.8 was appropriate.

65. In my opinion, the resolution of the camera does not allow for a definitive conclusion to be drawn. However, I consider that these defects are small and do not present a crack-like feature. I therefore do not consider that these are likely to be of any significance for the integrity of the core.

66. I subsequently observed the final PBAP meeting on 12th June which reviewed all of the results from the peripheral brick inspections. Prior to the meeting, NGL provided me with the results of the inspections in the PBAP sheets in Reference 29, including a ‘face map’ of the core summarising the location and type of the defects found during the inspections. During the meeting, NGL concluded that the defects found were generally uniform although they did notice some clustering at the bottom of Face 11. These were all sentenced as ‘linear features’ (Category 1.8) and therefore, in the opinion of the licensee, these are likely to be due to mishandling during installation.

67. Figure 6 below shows an example of the linear features observed at the bottom of Face 11.

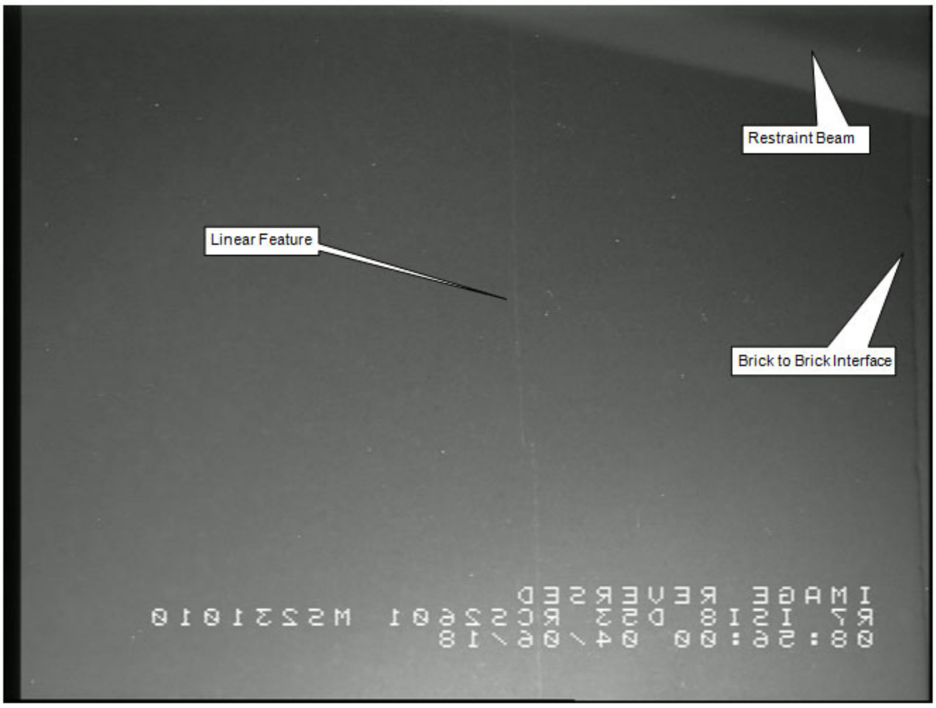

Figure 6: Peripheral Wall Inspection W108/02 – Layer 1, Face 11, Brick 7: linear feature.

68. The two defects shown in Figure 6 are relatively straight and do not seem to exhibit a marked thickness through the brick. Also, the two marks do not join up and abruptly stop at a very close distance. This suggests that there is no active mechanism to drive the defects to join up. I therefore conclude that the features shown in this figure are unlikely to be cracks and that machining marks or score marks during installation could be a possible cause for these defects. As a comparison, Figure 7 shows a linear crack (inspection sheet W081/02 in Reference 28).

Figure 7: Peripheral Wall Inspection W081/02 – Layer 1, Face 4, Brick 6: linear crack.

69. The defect shown in Figure 7 is not as straight as a linear feature and seems to be show darker edges, suggesting deeper propagation into the brick than linear features. The peripheral bricks inspections also showed that there could be some damage local to the corners, such as shown in Figure 8.

Figure 8: Peripheral Wall Inspection W078/01, Layer 10, Face 3, Brick 1: corner crack.

70. The type of damage shown in Figure 8 indicates cracking at the corner between the faces. I consider that this type of defect could be significant due to the potential for a panel to generate debris, disturb the cooling flow around the core or create some distortion of the core in the nearby fuel and control rod channels.

71. NGL carried out the inspection of three edge channels, U09, C25 and X23 to confirm that the level of distortion observed in these channels was not significantly affected by any damage or movement in the peripheral wall panels. There was no significant distortion from the bore measurements (Reference 29), with the largest channel bow being 2mm and the maximum tilt being 4mm. These measurements therefore seem to confirm that the peripheral bricks cracks do not cause additional movement of the core walls. However, I consider that the results of these inspections needs to be confirmed in future inspections as the channels inspected were not in the proximity of significant cracking. I also consider that peripheral bricks inspections should maximise the number of corner bricks which can be inspected and that NGL should propose a plausible mechanism to explain these observations. I am adding this as a recommendation to NGL.

72. According to the PBAP minutes, the peripheral brick inspections revealed 8 bricks with linear cracks, 31 bricks with linear features, 1 branched crack and 25 minor scratches or score marks (Reference 29). This is a total of 13 cracked bricks extrapolated to the entire peripheral shield wall, which approximates to 1% cracked bricks, if the incidence of cracking is uniformly distributed. These results are summarised in Table 1.

Table 1: Inspection results of peripheral bricks in the HYB/TOR reactors.

Reactor (Inspection date)	Number of faces inspected (out of 16) and percentage of total coverage	Number of cracked bricks inspected	Extrapolated number of cracked bricks to 16 faces
HYB R7 (2018)	11 (68.75%)	9	13
TOR R1 (2017)	13 (81.25%)	25	31
HYB R8 (2016)	9 (56%)	22	40
TOR R2 (2015)	10 (62.5%)	17	28

73. Overall, NGL claims that the cracking observed in HYB R7 is broadly consistent with that seen in TOR R2 2015, HYB R8 2016 and TOR R1 2017 but notes that the number of cracks found at HYB R7 is significantly less than in the other reactors. Table 2 below shows the overall inspection results from the peripheral bricks inspections.

Table 2: PBAP results from inspection of the peripheral bricks in HYB R7.

Section (from EC 356536 App 3)	Description	Category	No. of NCRs	No. of Bricks *
1.1	Bricks with "Chicken Wire" cracking	A	0	0
1.3	Bricks with linear crack	A	8	8
1.5	Branched cracks	A	1	1
1.7	Morphology not seen on TOR R2 or HYB R8	B	0	0
1.8	Linear Features	A	31	31
2.3	Adjacent bricks significantly radially misaligned >2mm	B	0	0
2.5	Significant circumferential gapping observed between adjacent bricks >5mm	B	0	0
2.6	Very significant circumferential gapping observed between adjacent bricks >20mm	C	0	0
3.2	Large piece of graphite missing (>100x100mm or equivalent 10000mm^2)	B	0	0
3.3	Complete brick(s) missing	C	0	0
3.4	Graphite debris identified on restraint beams	B	0	0
3.5	Blockage or partial blockage of re-entrant flow annulus between restraint tank and core	C	0	0
No Category assigned	Minor scratch or score mark not thought to be crack & misc debris	N/A	25	N/A
Total Assessed			65	40

*The number of bricks may be less than the number of NCRs as in some instances multiple NCRs have been raised on a single brick (e.g. both faces of a corner brick) and debris NCRs don't apply to a brick.

74. At the end of the final PBAP meeting I also observed on 11th June, I commented that, compared to HYB R8, there seemed to be approximately as many less cracked bricks (category 1.3) in HYB R7 as more linear features (category 1.8) and I therefore enquired about the possibility that some of the cracks may have been classed as linear features.

75. I requested further evidence from the licensee that some of the linear features were appropriately categorised in Reference 30. NGL provided their response in Reference 31. NGL considers that the category of a cracked brick (category 1.3) is conservatively assumed in cases where the quality of the image is not sufficient to ascertain its categorisation into 'linear feature' (category 1.8). JCO 3 (Reference 32) included a count of both categories and concluded that the overall number of cracked bricks and bricks containing a linear feature was low compared to the overall number of peripheral bricks (1892 bricks in total according to JCO 3). However, NGL did not discount the possibility that categorisation errors could be made for some of the bricks further away from the camera.

76. Overall, I consider that the number of bricks containing a crack or a linear feature is low compared to the total number of bricks (~2.1% of the total). I consider that the inspection findings from the HYB R7 peripheral bricks do not challenge the claims and arguments in EC 356531 (JCO 4). However, continued inspection will be necessary to demonstrate that there is no significant deterioration in the condition of the peripheral wall at all four HYB/TOR reactors.

4.10 Consideration of EC 356531 (JCO 4)

4.10.1 Design considerations

77. HYB and TOR reactors are surrounded by sixteen graphite wall panels which act as neutron reflectors. According to Reference 32, there are 1892 bricks that make-up the peripheral shield. Of these, 352 peripheral bricks support the restraint beams and 1540 do not.

78. The main purpose of the peripheral brick wall is to facilitate the flow of the remaining component of the re-entrant gas to ensure that this flow does not by-pass the upper core by entering the core through its side and to ensure that some of this upward flow is forced through orifice holes in the peripheral bricks to aid the cooling of the restraint rods and inserts. Although peripheral bricks do not have a significant structural function, failure of the bricks could lead to debris formation and partial blockage of the cooling gas re-entrant flow.

4.10.2 Results of the licensee's investigation

79. NGL carried out an extensive programme of testing and numerical analysis to investigate the possible causes for cracking in the peripheral bricks. A statistical analysis of the number and location of the cracks concluded that (Reference 33):

- variability in graphite properties seems to be the most significant factor;
- the corner bricks appear to be more likely to crack than would be expected by chance.

80. However, this analysis did not differentiate between the different types of cracks observed and did not provide an insight about the plausible mechanisms. Testing of graphite bricks similar to those from those used for the peripheral wall was also carried out and reported to ONR in Reference 21. These experiments did not provide any insight as to the possible cracking mechanisms.

81. Thermal analysis in Reference 34 concluded that the temperatures of the core are mostly sensitive to nuclear heating in graphite, but that blockage of the coolant flow in the periphery of the core or the missing panels would not significantly affect the temperature of the core. In my view, this result can be explained by the large volume available for gas flow around the reactor. It seems credible that a significant number of panels would have to fail entirely before any significant effect on the core temperature could be observed.

82. According to the results from the licensee's own investigation, the two most likely causes are due to (Reference 35):

- poor manufacturing tolerances which might have resulted in the edges of the bricks not equally sharing loads;
- pre-existence of initiating defects in the bricks.

4.10.3 University of Birmingham review

83. At ONR's request, the University of Birmingham (UoB) in Reference 36 undertook a comprehensive review of the work carried out by the licensee to investigate peripheral bricks cracking. I referred to this review to help provide a view on my assessment of EC 356531 (Reference 1).

84. The bricks are made of lower grade GCMC graphite. This type of graphite has been subjected to only one impregnation instead of two as it is the case for the more refined grade GCMB. However, strength tests seemed to indicate that there are no significant differences between these two grades (Reference 36).

85. The UoB review concluded that the licensee had put a significant effort into the investigation of the root causes of the cracking, including numerical analyses and experimental testing of full bricks. The authors of the review consider that the normal operation conditions of the peripheral bricks are unlikely to lead to any mechanism that could initiate a progressive growth of small manufacturing defects.

4.10.4 Claim 1 in EC 356531 – acceptable consequences

86. The first claim is supported by the following arguments:

- **Argument 1.1:** The peripheral bricks do not perform any significant structural function therefore the presence of cracking does not lead to additional loads on other structures;
- **Argument 1.2:** The main purpose of the peripheral bricks is to direct gas flow and the cracking does not significantly affect this function;
- **Argument 1.3:** The extent of cracking within the population of peripheral bricks is low;
- **Argument 1.4:** The core restraint system(s) are undamaged and are continuing to function as expected and there is no evidence of significant distortion in the peripheral core channels;
- **Argument 1.5:** Results from historical MAP monitoring.

87. From my review of the design of the core, I concluded that the bricks do not seem to bear any structurally significant load. The main function of the peripheral walls is to provide additional neutron reflector capacity to the core, thereby limiting neutron leakage, and to guide gas coolant flow towards the top of the reactor. In this respect, it is therefore likely that a partial failure of a wall panel would cause limited structural damage to the core itself. I consider that the relatively small number of cracks found during the peripheral bricks inspections suggest that large failure of a peripheral brick is not likely at present.

88. Limited inspections of the core restraint revealed no evidence of degradation. The low distortion values measured in the edge channels also suggest that thermal expansion of the diagrid and thermal movements of the graphite core are accommodated by the core restraints as expected. These observations support the licensee's argument that the core restraints function as expected.

89. I received a copy of the minutes of the Monitoring Assessment Panel (MAP) from NGL in Reference 19. The MAP reviews key operating parameters such as control rod drop times, fuel load grab trace during refuelling, power output in different channels, and temperatures. All the parameters reviewed were within the expected range. I am therefore satisfied that no adverse trend seems to be apparent from these parameters, which supports the fifth argument of this claim.

90. Overall, I consider that the inspection results from the 2018 HYB R7 periodic shutdown do not challenge claim 1 of EC 356531.

4.10.5 Claim 2 – slow progress of cracking

- **Argument 2.1:** All credible damage mechanisms have been considered and the most likely cause(s) determined
- **Argument 2.2:** All 4 reactors are sufficiently similar that they can be treated as single population with regard to the rate of peripheral brick cracking apart from the Torness gas circulator impellor disintegration event(s).

91. In the current inspection results from the peripheral bricks, the number of cracked bricks and the morphology of the defects were consistent with those found during the inspections of the other reactors. Until 2015, there was only very limited peripheral bricks inspections and the first re-inspection of the cracked bricks will be for TOR R2 in October 2018. The results of these inspections will therefore inform on the validity of this claim.

4.10.6 Assessment of Claim 3 – ALARP

92. This claim is supported by the following arguments:

- **Argument 3.1**: claims 1 and 2 show that the risk from existing cracking or cracking that could develop between statutory outages is low
- **Argument 3.2**: the planned inspections of peripheral bricks and peripheral fuel channels on R7 and R2 at the 2018 statutory outages are reasonably practical.

93. Inspection of the reactor internals involves some risks associated with potential contamination of personnel or equipment failure inside the pressure boundary of the reactor. On this basis, I consider that the licensee's proposal to inspect a target number of eleven faces out of sixteen faces, with a minimum of nine faces, at each three-yearly periodic shutdown is currently acceptable.

4.10.7 Conclusion of EC 356531 consideration

94. I am broadly content with the claims and arguments in the EC and the results from the peripheral bricks inspections carried out during the periodic shutdown do not challenge the case.

4.11 Return to Service Safety Case

95. I have based my assessment on approved inspection sheets and from a verified statement provided by the licensee in advance of the Engineering Change (EC) justifying return to service. I therefore recommend the ONR Project Inspector confirms that the Independent Nuclear Safety Assessment (INSA) statement for the return to service engineering change is submitted as part of the licensee's application for consent to return to service to confirm that this EC has completed the Licensee's due process.

4.12 ONR Rating

96. With reference to the ONR assessment rating guide (Reference 37) I judge that the licensee's work and submissions are rated Green, requiring no formal action.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

97. The licensee, EDF Energy Nuclear Generation Limited (NGL), of Heysham 2 (HYB) power station has shutdown Reactor 7 (R7) under licence condition (LC) 30. During the periodic shutdown of HYB R7, the graphite reactor core has undergone inspections, as required under LC28. An intervention was performed during the periodic shutdown to determine the adequacy of the inspections. There are no outstanding actions from that intervention, which would prevent consent being granted by Office for Nuclear Regulation (ONR) to the return to service of HYB R7.

98. During the periodic shutdown, NGL inspected and measured the bore of sixteen fuel channels and one control rod channel, as per the Maintenance Schedule requirements. During these inspections, one new full circumferential crack was observed in a newly inspected fuel channel. No full height axial crack has been found. The brick and channel distortions measured were small. The results of these inspections, in my opinion, do not challenge the assumptions of the safety case.

99. In addition the peripheral bricks surrounding the reactor were inspected for the first time at this reactor since the discovery of a number of cracked bricks in similar locations during the 2015 TOR Reactor 2 (R2), 2016 HYB Reactor 8 (R8) and 2017 TOR Reactor 1 (R1) periodic shutdowns. Before the periodic shutdown, NGL submitted ECs 356531 (HYB) and 356536 (TOR) to justify operation following the discovery of cracked peripheral bricks. I consider that the findings from the peripheral bricks inspections during this periodic shutdown do not challenge the claims and arguments in EC 356531 (JCO 4).

100. The licensee estimates that the most highly irradiated graphite bricks in HYB R7 will experience ‘turnaround’ by the end of 2018. Turnaround is a point in time where the stress state in the bricks will slowly be reversed from tension to compression at the bore and from compression to tension at outer section of the bricks. The licensee has therefore presented a revised safety case, NP/SC 7663, to support operation beyond the point of turnaround. In itself, this mechanism does not challenge the safety of the reactor, but this will represent the start of the next phase in the lifetime of the reactor. ONR is undertaking the assessment of this case, but completion of the assessment is not required prior to the return to service of HYB R7.

101. In my opinion, the graphite core inspections results are within the bounds of NGL’s safety case and do not present any impediment to return to service of HYB R7. I have no objection to the subsequent PAR recommending that consent is given to return Heysham 2 Reactor 7 back to service.

5.2 Recommendations

102. My recommendations are as follows.

<u>To the ONR Project Inspector:</u>

- Recommendation 1: I have based my assessment on approved inspection sheets and from a verified statement provided by the licensee in advance of the Engineering Change (EC) justifying return to service. I therefore recommend the ONR Project Inspector confirms that the Independent Nuclear Safety Assessment (INSA) statement for the return to service engineering change is submitted as part of the licensee’s application for consent to return to service to confirm that this EC has completed the Licensee’s due process.

<u>To NGL’s HYB/TOR Safety Case Group Head:</u>

- Recommendation 2: Continued inspection of the peripheral bricks appears to be necessary to ensure that the condition of the peripheral wall at all four HYB/TOR reactors does not deteriorate.

6 REFERENCES

1. EC 356531 Revision 004, Proposal No. 3, Justified Continued Operation (JCO) in light of the discovery of cracked peripheral bricks during the 2015 Torness R2, Heysham 2 R8 and Torness R1 2017 outage inspections. (TRIM 2018/161662).

2. EC 356536 Revision 004, Proposal No. 3, Justified Continued Operation (JCO) in light of the discovery of cracked peripheral bricks during the 2015 Torness R2, 2016 Heysham 2 R8 and Torness R1 2017 outage inspections. (TRIM 2018/189035).

3. ONR-CNRP-AR-15-047 Revision 0. Return to service of Torness R2 after the 2015 outage – graphite aspects - including assessment of EC356528 the justification for return to service with cracked graphite peripheral shielding bricks. 08 September 2015 (TRIM 2016/327473).

4. ONR-OFP-AR-16-048 Revision 0. Heysham 2 Reactor 8 2016 Periodic Shutdown – Assessment of the results of the Graphite Core Inspections. 03 November 2016. (TRIM 2016/426948).

5. ONR-OFD-AR-17-009 Revision 0. Torness (TOR) Reactor 1 (R1) 2017 Periodic Shutdown – Assessment of the results of the Graphite Core Inspections. 24 May 2017. (TRIM 2017/189621).

6. ONR HOW2 Guide NS-PER-GD-014 Revision 4 - Purpose and Scope of Permissioning. July 2014. http://www.onr.org.uk/operational/assessment/index.htm

7. Safety Assessment Principles for Nuclear Facilities. 2014 Edition Revision 0. November 2014. http://www.onr.org.uk/saps/saps2014.pdf

8. Graphite Reactor Cores NS-TAST-GD-029 Revision 3. ONR. July 2014 http://www.onr.org.uk/operational/tech_asst_guides/index.htm

9. Guidance on Mechanics of Assessment within the Office for Nuclear Regulation (ONR) – TRIM Reference 2013/204124

10. HYB-TOR JCO: Safety Case for At-Power, In-reactor Faults with increased Levels of Graphite Weight Loss at HYB/TOR (TRIM 2014/130260).

11. Technical Assessment of Recent Updates to the Forecasts of Weight Loss at Heysham 2 and Torness. DAO/EAN/JIEC/230/AGR/17 Revision 000. May 2017. (TRIM 2018/61141).

12. RE: Heysham 2 R7 2018 Outage: NICIE2 inspection results. TRIM 2018/187566.

13. NP/SC 7359 Issue 1 Further Substantiation of the Safety Case for Bore Cracking of Graphite Core Bricks HAR HYA HYB DNB TOR, February 2004. (TRIM 2013/404659).

14. Heysham 2 / Torness Graphite Core Safety Case NP/SC 7663 Version 03. 26 May 2017 - Post-Stress Reversal. (TRIM 2017/457269).

15. Quintessa Report. Application of Statistical Models for Brick Cracking to Heysham 2 Reactor 7 Inspections in May 2018. Pre-inspection report. QRS-3007N-7. Version 1.0. May 2018. (TRIM 2018/188739).

16. Heysham 2 Reactor 7 Outage 2018 (S11 R7) – Proposals for the Inspection of the Reactor Internals & Materials Monitoring. March 2018. HB/REPS/SD265 Revision 002. (TRIM 2018/185142).

17. Guidelines for Sentencing Defects in Graphite Core Bricks. DAO/REP/JIEC/072/AGR/09. Revision 006. May 2017. (TRIM 2018/182729).

18. ONR-CNRP-AR-14-115 Revision 0, Assessment of the Single-Axially-Cracked-Brick-Opening Safety Case for the Hinkley Point B and Hunterston B Power Station Graphite Cores. May 2015. TRIM 2015/75438.

19. RE: INSA certificate for EC 356531 and MAP minutes. (TRIM 2018/202740).

20. Heysham 2/Torness Peripheral Graphite Brick Cracking: Assessment of Findings from the R7 2018 Statutory Outage. (TRIM 2018/189057).

21. EDF - ONR-OFD-CR-17-604 - Level 4 - HYB/TOR Peripheral Brick Cracking - 16 January 2018. (TRIM 2018/20820).

22. Peripheral Brick Assessment Panel (PBAP) Decision Making Process. Heysham 2 R7. 2018 Periodic Shutdown. (TRIM 2018/185139).

23. ONR-OFD-IR-18-040. Inspection of the Heysham B Reactor 7 Graphite Core Inspection Arrangements during its 2018 Statutory Outage. 30 May 2018. (TRIM 2018/185217).

24. RE: Heysham 2 R7 2018 Outage: NICIE2 inspection results. (TRIM 2018/187566).

25. Minutes HYB R7 2018 GAP4 Ratified. (TRIM 2018/190159).

26. HYB R7 2018 GAP Sheets. Graphite Assessment Panel. Heysham 2 Reactor 7 2018 Periodic Shutdown. (TRIM 2018/188472).

27. Predictions of Keyway Root Cracking at Heysham 2 and Torness Using EDF Energy Integrated Methodology V1.2. (TRIM 2018/190624).

28. PBAP Minutes & NCRs HYB R7 2018 Inspections. Peripheral Brick Inspection Results. Heysham 2 Reactor 7. May-June 2018. (TRIM 2018/190340).

29. HYB R7 2018 Peripheral Bricks Inspections PBAP 009 (Final). (TRIM 2018/195381).

30. PBAP Question - Numbers of linear cracks and linear features in HYB R7 and HYB R8. (TRIM 2018/195218).

31. RE: PBAP Question - Numbers of linear cracks and linear features in HYB R7 and HYB R8. (TRIM 2018/202267).

32. EC 356536 003, JCO in light of the discovery of cracked peripheral bricks during the 2015 Torness R2 and 2016 Heysham 2 R8 outage inspections. (TRIM 2017/159591).

33. QRS-1921A-1v2.0. Statistical Analysis of Cracking in Peripheral Shield Bricks at Heysham 2 and Torness. October 2017. (TRIM 2018/196293).

34. Summary of Flow and Thermal Effects of Cracked Peripheral Shielding Bricks. E/EAN/BCDB/0129/AGR/17. October 2017. (TRIM 2018/189039).

35. Graphite Core Peripheral Brick Cracking Sentencing Possible Causes – Updated to Include Additional Evidence. DAO/REP/JICB/047/AGR/15. April 2016. Heysham 2 and Torness Power Stations. (TRIM 2018/192406).

36. University of Birmingham Review of NGL root cause investigation programme for TOR/HYB peripheral brick cracking. January 2017. ONR Reference ONR173. (TRIM 2017/100552).

37. ONR Assessment Rating Guide Table – TRIM Reference 2016/118638.

Annex 1

Relevant Safety Assessment Principles Considered During the Assessment

SAP No	SAP Title	Description
EGR. 1	**Engineering principles:** **graphite components and structures: safety case**	The safety case should demonstrate that either: a) graphite reactor core is free of defects that could impair its safety functions; or b) the safety functions of the graphite reactor core are tolerant of those defects that might be present.
EGR. 2	**Engineering principles:** **graphite reactor cores: design: monitoring**	The design should demonstrate tolerance of graphite reactor core safety functions to: a) ageing processes; b) the schedule of design loadings (including combinations of loadings); and c) potential mechanisms of formation of, and defects caused by, design specification loadings.
EGR. 10	**Engineering principles:** **graphite reactor cores: defect tolerance assessment**	An assessment of the effects of defects in graphite reactor cores should be undertaken to establish the tolerance of their safety functions during normal operation, faults and accidents. The assessment should include plant transients and tests, together with internal and external hazards.
EGR. 15	**Engineering principles:** **graphite components and structures: examination, inspection, surveillance, sampling and testing:** **Extent and frequency**	In-service examination, inspection, surveillance, and sampling should be of sufficient extent and frequency to give sufficient confidence that degradation of graphite components and structures will be detected well in advance of any defects affecting safety function.

Annex 2 – INSA Certificate EC 356531

Protect - Proprietary
EDF Energy Nuclear Generation Ltd
Milestone Full INSA Approval Statement

Station: Heysham 2
EC No./Rev No.: 356531/004 **NP/SC No.:** n/a
Version No.: 01
Title: JCO IN LIGHT OF THE DISCOVERY OF CRACKED PERIPHERAL BRICKS DURING THE 2015 TORNESS R2, 2016 HEYSHAM 2 R8 AND TORNESS R1 2017 OUTAGE INSPECTIONS

INSA Engineer: [redacted]

Date of Approval: **13/12/2017**

I confirm that an Independent Nuclear Safety Assessment to the requirements of the Site Licence Arrangements has been completed.

1. Scope of INSA:

The main elements of the safety case were presented in earlier Revisions and remain unchanged and thus the INSA for Revisions 001 - 003 deals with the majority of the safety case claims. The updates in this Revision include a review of inspections data and an update to the thermal modelling of reactor components adjacent to the peripheral shield wall. A forward inspection strategy for the 2018 outages is proposed.

2. Basis for acceptance:

- This version of the EC puts in place the inspection strategy for the forthcoming Heysham R7 Periodic Outage. The inspection results will be monitored via a Peripheral Brick Assessment Panel (PBAP) and any non-conformances will be sanctioned by the PBAP members against predefined assessment criteria. INA will be a quorate member of this panel.

- The proposal considers that the condition of the peripheral brick walls on all four reactors is understood and therefore the results from any of the 2018 periodic outages if outside expectations will require a revision to the safety case (this proposal). The formal reporting of the inspection results will be included in a return to service EC.

3. Commitments requiring INA review: none.