Office for Nuclear Regulation

ASSESSMENT REPORT			
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Project:	Reactor 1 2018 Periodic Shutdown		
Site:	Hartlepool		
Title:	Hartlepool Reactor 1 Periodic Shutdown: Structural Integrity Assessment of the Graphite Core Inspection Findings		
Nuclear Site Licence No:	59		
Licence Condition(s):	28		
ONR Assessment Rating (Mandatory): *(Rating should be based on licensee's original safety case submission)*	GREEN		
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Operating Facilities Division

Assessment of the Graphite Core Inspections

Assessment Report ONR-OFD-AR-17-069
Revision 0
MARCH 2018

EXECUTIVE SUMMARY

This report has been produced as part of the Office for Nuclear Regulation's (ONR) activities to permission the return to service of Hartlepool power station Reactor 1 after its 2018 periodic shutdown. This report considers the work performed by the licensee, EdF Energy Nuclear Generation Limited (NGL), during the shutdown to demonstrate that the reactor's graphite core is in an adequate condition to return to service until its next periodic shutdown.

I undertook a number of activities before and during the shutdown to inspect samples of the work that the licensee was carrying out under Licence Condition 28. I judge that the findings from the graphite inspections do not prevent return to service.

The latest trepanned data have been used in a revised prediction of weight loss. The use of best estimates in the revised calculation needs further consideration and justification after return to service. A level 4 meeting is planned in June 2018 to discuss the issue. However, the existing conservative graphite weight loss calculation does not predict that the current limit will be breached until 2020 at the earliest.

The licensee is preparing a safety case justifying returning Reactor 1 to service following the graphite core inspections at the 2018 periodic shutdown. I have seen a verified version of this return to service safety case and I was satisfied with the arguments.

I conclude that the licensee has undertaken graphite core inspections, measurements and taken trepanned samples that meet or exceed its examination, maintenance, inspection and testing requirements under licence condition 28. I judge that the licensee has adequately reviewed and sentenced the findings of the graphite core inspections and measurements and that the licensee has demonstrated that Hartlepool Reactor 1 graphite core is in an adequate condition to be returned to service.

NGL submitted NP/SC 7474 Addendum 2 for ONR agreement during the next period of operation. This safety case update proposes to increase the average core weight loss limit from 17% to 20% and needs ONR consideration during the next operating period.

There is a need for NGL to produce a post stress reversal safety case before 2020. In a previous assessment of the graphite safety case, ONR had placed a recommendation on NGL to qualify the Secondary Shutdown (SSD) and Tertiary Shutdown (TSD) systems as part of the production of this case.

I therefore recommend that my assessment of the Hartlepool Reactor 1 2018 graphite core inspections and associated safety documentation present no impediment to ONR granting Consent to start-up Hartlepool Reactor 1. The project inspector should note that operation beyond 2020 will require the production of a revision to the graphite core safety case that considers the effects of post-stress reversal of fuel bricks on the graphite core. Furthermore, the project inspector should note that operation beyond 2020 will require ONR's agreement of NP/SC 7474 Addendum 2. This safety case update proposes to raise the active core weight loss limit from 17% to 20%.

From the activities I have sampled relating to the integrity of the graphite core, I have allocated an ONR rating of GREEN.

Recommendations

<u>To NGL Graphite Group Head ([redacted]):</u>

- Recommendation 1: A revision to the safety case is required to support operation beyond stress reversal before 2020. In this revision, seismic qualification of the SSD and TSD should be considered as these systems would be essential in the event of a significant earthquake;

- Recommendation 2: Further justification of the new estimates of the active core weight loss update and why this calculation remains conservative needs to be provided as part of ONR's consideration of NP/SC 7474 Addendum 2.

<u>To ONR Project Inspector ([redacted]):</u>

- Recommendation 3: I recommend that Consent is granted for the return to service of Hartlepool Reactor 1. This is contingent on the project inspector receiving the approved return to service EC with the associated INSA statement.
- Recommendation 4: I recommend that the Project Inspector notes in the PAR that operation beyond 2020 will require the production of a revision to the graphite core safety case that considers the effects of post-stress reversal of fuel bricks on the graphite core.
- Recommendation 5: I recommend that the Project Inspector notes in the PAR that the licensee has recently submitted NP/SC 7474 Addendum 2 for ONR's agreement. This update proposes to raise the graphite weight loss limit from 17% to 20% and needs ONR consideration during the next operating period.

<u>To ONR Graphite Team ([redacted]):</u>

- Recommendation 6: I recommend that the ONR graphite team updates the ONR issue database to:
  (i) add a new issue to follow progress on seismic qualification of the SSD and TSD for post-stress reversal operation and;
  (ii) add a new issue to follow-up on the latest Hartlepool graphite weight loss update with NGL and consider its review as part of the assessment of NP/SC 7474 Addendum 2.

LIST OF ABBREVIATIONS

BMS	Business Management System
EC	Engineering Change
ECIT	Eddy Current Inspection Tool
HOW2	(ONR) Business Management System
GAP	Graphite Assessment Panel
GTAC	Graphite Technical Advisory Committee
GWd	Gigga Watt days
HRA	Hartlepool Power Station
HNB	Hunterston B Power Station
HYA	Heysham A Power Station
INA	Independent Nuclear Assurance
INSA	Independent Nuclear Safety Assessment
KWRC	KeyWay Root Cracking
LC	Licence Condition
MS	Maintenance Schedule
NGL	EdF Energy Nuclear Generation Limited
OI	Outage Intentions
ONR	Office for Nuclear Regulation
RTS	Return To Service
SAP	Safety Assessment Principle(s) (ONR)
SQEP	Suitably Qualified and Experienced Person
SIAL	Structural Integrity Assessment Limit
TAG	Technical Assessment Guide(s) (ONR)
TSC	Technical Support Contractors

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1 INTRODUCTION

1. The nuclear site licence issued to EdF Energy Nuclear Generation Limited (NGL) for Hartlepool power station (HRA) requires the licensee to periodically shut down plant under Licence Condition (LC) 30. This is to enable examination, inspection maintenance and testing to take place in accordance with the requirements of HRA's Plant Maintenance Schedule (MS) under LC28. On completion of the shutdown, the licensee requires Consent from the Office for Nuclear Regulation (ONR) to start- up Reactor 1.

2. The scope of this report covers the integrity of the graphite core of HRA Reactor 1 (R1) and its fitness to permission return to service (RTS) until its next periodic shutdown.

1.1 Background

3. This report presents the findings of the assessment of the graphite inspections carried out by NGL during HRA R1's periodic shutdown. Assessment was undertaken in accordance with the requirements of the ONR How2 Business Management System (BMS) guide NS-PER-GD-014 (Ref. 1). The ONR Safety Assessment Principles (SAP) (Ref. 2), together with Guidance on Mechanics of Assessment (Ref. 3) and supporting Technical Assessment Guides (TAG) (Ref. 4), have been used as the basis for this assessment.

1.2 Scope

4. The scope of this report covers the graphite core inspections conducted during the HRA R1 2018 periodic shutdown.

1.3 Methodology

5. The methodology for the assessment follows HOW2 guidance on mechanics of assessment within the ONR (Ref. 1).

6. My assessment has been focussed primarily on the licensee's activities performed during the shutdown associated with the examination and inspection of Reactor 1 graphite core. I have taken account of developments in the HRA and Heysham 1 (HYA) graphite core safety cases that are mainly separate from the work undertaken during shutdowns.

2 ASSESSMENT STRATEGY

7. The intended assessment strategy for this 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

8. The relevant standards and criteria adopted within this assessment are principally the SAPs (Ref. 2), Guidance on Mechanics of Assessment (Ref. 3) and internal ONR TAGs (Ref. 4). The key SAPs and any relevant TAGs are detailed within this section. Relevant good practice, where applicable, has also been cited within the body of the assessment.

2.2 Safety Assessment Principles

9. The key SAPs applied within the assessment are included within Table 3 of this report.

2.2.1 Technical Assessment Guides

10. The following Technical Assessment Guides have been used as part of this assessment (Ref. 4):

- ONR-TAST-GD-029 Revision 3, Graphite Reactor Cores.

2.2.2 National and International Standards and Guidance

11. Due to the very specific nature of graphite and its unique use in AGRs, I have not utilised national or international standards and guidance in my assessment.

2.3 Use of Technical Support Contractors (TSC)

12. I have not utilised TSC support in my assessment.

2.4 Integration with Other Assessment Topics

13. My assessment report is concerned with the inspections of Reactor 1 graphite core. The findings of this report may be considered by the ONR project inspector in the project assessment report, which will recommend whether to grant Consent to start-up the reactor on completion of the periodic shutdown.

2.5 Out of Scope Items

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

- The thirty six graphite core trepanned samples taken from HRA R1 will be sent to National Nuclear Laboratories at Sellafield for examination and testing. The result of this work is unlikely to be known for at least six to nine months and so I have excluded it from my assessment.

3 LICENSEE'S SAFETY CASE

15. The licensee's safety case for HYA/HRA graphite reactor cores is presented in NP/SC 7570 (Ref. 5) and NP/SC 7623 (Ref. 6). More flexible inspections arrangements are also presented in Engineering Change (EC) 354994 (Ref. 7). NGL recently produced a revision to NP/SC 7474 Addendum 2 (Ref. 8) to justify an increase of the active core weight loss limit from 17% to 20%. At the time of this assessment, this safety case is being reviewed by an ONR Fault Studies specialist.

16. Prior to the shutdown, the licensee produced the outage intentions (OI) document, which outlines the arrangements to deliver the safety related activities undertaken during the shutdown to meet the requirements of the relevant sections of LC 28 and 30 (Ref. 9).

17. Section 4.7.1 of the OI document lists the activities to be undertaken on the graphite core; these being:

- Removal of 30 fuel channel wall samples (trepanned samples) plus up to 6 additional samples to support the graphite weight loss investigations.
- Remote visual inspection and channel bore measurement of 20 fuel channels using the new in-core inspection equipment (NICIE MK2).
- Remote visual inspection of one control rod channel.

18. The licensee considers and sentences the findings of the visual and dimensional inspections via the graphite assessment panel (GAP). This is a body with a requirement for a quorum of suitably qualified and experienced persons (SQEP), who are able to sentence the inspection findings in terms of whether they present challenges to the extant safety case. It also considers matters such as whether the inspections, dimensional measurements and trepanning have been performed adequately.

19. All the cracks observed to date were judged to have initiated from the bore. These bore cracks are associated with tensile stresses due to irradiation. Later in life the licensee predicts that the stresses in the graphite will reverse, resulting in tensile stresses on the outside of the bricks. This is known as stress reversal, or 'turnaround'. It is postulated that keyways on the outside of the bricks act as stress raisers. The tensile internal stresses generated at the keyways could eventually exceed the residual strength of the bricks and cracks will initiate from the keyway. This is known as keyway root cracking (KWRC).

20. Prior to the shutdown the licensee produced a statement of expectations for channel bore measurements (bore distortion) and statistical models to predict the number of axially cracked bricks (singly and doubly cracked) that could be expected to be found during the inspections; see Ref. 10. These documents are utilised by the GAP to inform their judgements.

21. The licensee has produced an RTS EC document (EC 362828, Ref. 11) to justify the return-to-service of HRA R1 following the completion of the outage inspections. This document will be reviewed by the licensee's independent nuclear assurance (INA) function, who will issue an independent nuclear safety assessment (INSA) statement that supports the RTS EC.

22. The RTS EC concludes that the graphite core inspection activities have been met and the results have been assessed by the GAP. The licensee has judged that all the inspection and measurement results are within expectations in terms of the numbers of cracked bricks, brick bore shrinkage and fuel channel distortion.

4 ONR ASSESSMENT

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

4.1 Scope of Assessment Undertaken

24. The scope of my assessment is centred on the licensee’s work associated with the inspection of Reactor 1 graphite core and whether any of the findings challenge the graphite safety case. The scope covers whether there is a challenge now and also up to the next periodic shutdown, currently a maximum of three years after start-up,.

4.2 Assessment

25. I have undertaken my assessment work in three parts.

- I used a variety of documents to inform me of ONR’s finding from previous inspections that I consider are relevant to my assessment. I read the ONR intervention report on the level 4 meeting where NGL presented the HYA/HRA graphite core safety cases NP/SC 7570 (Ref. 5), NP/SC 7623 (Ref. 6) and the justification for ‘flexible inspections’ in Ref. 7. I read the Reactor 1 2018 OI document to inform myself as to the scope of the graphite core inspections (Ref. 9). I read Quintessa’s report (Ref. 10) and used report R54-2017 (Ref. 12) from ONR’s independent advisors from the Graphite Technical Advisory Committee (GTAC) to help me form a view on the adequacy of the graphite inspections.
- I undertook a site inspection at Hartlepool on 8 February 2018 where I sampled the inspection activities being performed on site. I produced an intervention record of my inspection in Ref. 13. At the time of my inspection the licensee had completed all the planned channel inspections and was about to start trepanning samples from the core.
- I observed a GAP meeting on 12th February 2018.
- I reviewed the licensee’s verified RTS EC (Ref. 11).

26. In this assessment report, I consider the scope of the licensee’s shutdown work activities associated with R1 graphite core, the inspection and measurement findings and whether they challenge the extant safety case now and at the start of the reactor’s next periodic shutdown.

4.2.1 Safety case review

27. It was not practicable to include a fully detailed review of the safety case as part of this assessment. However, to help to form a view for the return-to-service of the reactor, I reviewed ONR’s assessments of NP/SC 7570 – Graphite Core Safety Case (Ref. 5) and NP/SC 7623 – AGR Core Safety Case for 43% Graphite Weight Loss (Ref. 6).

28. The limiting case for graphite weight loss is the active core weight loss (ACWL) limit which results from a reactivity fault due to steam-ingress in the reactor. Currently, NP/SC 7623 sets this limit to 17%. However, NGL recently submitted NP/SC 7474 Addendum 2 (Ref. 8) to ONR for review. This update to the safety case effectively requests to raise the ACWL limit from 17% to 20%.

29. At the time of the outage, the core burn-up for HRA R1 is 11805GWd (Ref. 14). The following limits in Table 1 are applicable to HRA at the time of my assessment:

Table 1 Safety Case Limits.

Limiting case	Core burn-up, GWd	Source	Approx. year reached*
Active Core Weight Loss (ACWL)	13,250	NP/SC 7623	2020
Structural Integrity Assessment Limit (SIAL)	13,950	NP/SC 7623	2022
Stress reversal	12,600	NP/SC 7570	2020
Onset of KeyWay Root Cracking (KWRC)	15,230	NP/SC 7570	2025

* *Assuming 90% power for future fuel operation (526GWd / year). Core burnup of 11805GWd at 2018.*

30. From Table 1, it is apparent that:

(i) the SIAL should not be reached within the period of operation.

(ii) a post-stress reversal safety case is required to justify operation beyond 12,600GWd (~2020).

(iii) the current Active Core Weight Loss limit (17%) is predicted to be reached towards the end of the next operating period. Thus ONR assessment of Ref. 8 is not required to enable return to service of Reactor 1, but this will be needed by 2020.

4.2.2 Graphite Weight Loss – NP/SC 7623

31. Assuming conservatively that HRA R1 operates at 100% power (1600 MWth) with 90% availability (i.e. accumulating a burn-up of 526GWd per year), the graphite core at the time of the next statutory outage in 2021 is expected to be over the ACWL limit of 13,250GWd set in NP/SC 7623 (Ref. 6). This estimate was calculated using a conservative model (so-called 'most onerous') in Ref. 15. I requested and received a graphite weight loss update in Ref. 16.

32. NGL uses a computer program called FEAT-DIFFUSE to relate the graphite weight loss limit into an equivalent core burn-up. In the revised estimate for the active core weight loss (Ref. 17), the core burn-up corresponding to 17% weight loss has been revised from 13,250GWd (in NP/SC 7623) to 14,450GWd. Two major changes are immediately apparent in this assessment. Firstly, the Reactive Pore Volume model was implemented in the FEAT-DIFFUSE model. Secondly, the assumptions were changed from a conservative model to a best estimate, which Ref. 15 shows that moving to a best estimate alone takes the 17% weight loss to 14,000GWd.

33. Ref. 16 justifies the increase in core burn-up at 17%, i.e. +1,200GWd, from the additional data included in the database. However, in my opinion, this level of increase mostly reflects the removal of conservatisms in the original model. This is shown in Section 3.5 of Ref. 16. My concern here is that this new model does not consider an appropriate margin as required in SAP EGR. 11 (Ref. 2):

'There should be an adequate margin between the intended operational life and the predicted safe working life of graphite reactor cores. Safety margins should take due account of uncertainty in life predictions.'

34. For the analysis, Section 5.22 of TAG 029 (Ref. 4) recommends to consider graphite weight loss in relation to reactivity faults in the same context as the removal of a control rod from the core (see also ERC.1 of Ref. 2). In effect, the removal of a certain amount of graphite from the core acts to reduce the shutdown/hold-down margins in a similar manner as the removal of one or more control rods from the core.

35. An e-mail was sent to NGL in Ref. 18 to request further explanation from NGL. I recommend that an Issue is added to the ONR database to follow this up.

4.2.3 Graphite Core Safety Case - NP/SC 7570

36. This safety case consolidates brick cracking, weight loss and associated issues related to the nuclear safety requirements of the graphite cores at HYA/HRA to the onset of keyway root cracking for normal and fault conditions and was assessed by ONR in Ref. 19. The safety case was judged to be broadly adequate with the recommendation to seismically qualify the SSD and TSD systems before the onset of KWRC. I recommend that an Issue is added to the ONR database to follow-up on this recommendation with NGL.

37. In NP/SC 7570 (Ref. 5), the definition for 'essentially intact' core is given as 10% axial singly cracked bricks or doubly cracked bricks. Since this safety case is concerned with operation up to stress reversal, these are considered to be axial bore cracks. NP/SC 7570 justifies 100% singly axial cracked bricks until stress reversal at power, as NGL judges that such bricks will remain closed and behave as fully intact bricks. The tolerance of the reactor to 200 doubly cracked bricks is justified in NP/SC 7399 (Ref. 20). NGL considers that circumferential bore cracks do not challenge the structural integrity of the core and placed no limits on their actual count.

4.2.4 Post-stress reversal operation

38. The licensee estimates that stress reversal in peak rated fuel channel bricks is likely to occur at 12,600GWd, with the onset of KWRC at 15,230GWd (Ref. 5). Although onset of KWRC cracking is formally not anticipated within the next operating period, experience at Hunterston (HNB) indicates that KWRC may be observed earlier than predicted by NGL's models.

39. Nevertheless, the four reactors at HYA/HRA are subject to graphite core inspection and dimensional measurement during refuelling outages, which occur at approximately 18 month intervals. I consider that this alleviates the risk associated with early KWRC as these interim inspections provide an additional opportunity to identify KWRC if these were to develop earlier than anticipated.

4.2.5 Bore Cracks

40. Table 2 below (Table 1 in Ref. 10) provides a summary of the bore crack inspections for HRA R1 between June 1987 and December 2016.

Table 2 Summary of bore crack inspections for HRA R1 (Table 1 of Ref. 10).

Date	Reactor Burn-up (TWd)	Channels Inspected	New Significant Cracks Observed
Jun 1987	0.479	B27 J03 P41 W17	
Jun 1990	0.805	J23	
Jun 1995	2.752	E09 M23	
Jul 1998	4.168	H33 H39 K23 N21	
Apr 2001	5.617	E23 H21 J31 J13 K17 N27 P13 Q23	
Sep 2004	7.143	C15 E31 G09 H39 H21 H17 J29 L11 L39 L21 M33 M05 P15 P13 Q05 Q27 R35 T13 V23	H21(9) H21(10) L11 (10) M33(10) Double: P13(11) R35(8)
Jan 2006	7.409	B21 B25 F13 G09 G21 G33 K03 L17 L41 M03 M05 M13 N41 P15 P21 R11 R23 S31 W19 W23	B21(10) M03(9) R11(8)† W23(11)
Sep 2007	8.040	C13 D23 G15 H05 H23 H31 J37 K15 M19 N29 P13 Q21 Q39 R05 R11 R29 R35 U21 V15 W23	H23(8), N29(9), Q21(9) Double: V15(10)
Jan 2011	8.995	D15 D27 F07 H35 J19 K27 N17 P25 Q09 S37 T31 U17 U29	Q09(9) S37(8)
Apr 2011	9.078	C25 D33 E13 K05 N39 U11 V19	D33(8) E13(10) U11(10)
Jun 2011	9.166	C23 D09 E15 E37 F29 G37 H11 J21 L05 L27 M17 M39 P23 Q33 S11 S15 T07 T29 U35 V21	C23(8) L05(11) L27(9) M17(8) U35(9) U35(11) Double: E37(11) T07(7) T29(9)
Apr 2014	10.401	F23 F39 G09 L11 L39 M33 R11 R35 S05 S21	F39(9) L39(11) Double: R11(8)
Aug 2014	10.5452	B17 E07 E21 G29 H13 J33 K23 L05 M23 M25 N19 P03 P13 Q21 Q31 S19 S29 T23 U09 W27	B17(5) E21(10) U09(7) U09(10) W27(9) W27(10) Double: E07(8) S19(11) U09(8)
Dec 2016	11.247	C31 G05 G15 L25 M19 R29 U21 V13	G05(10) Double: G05(9)

† Double axial crack observed in this brick at a subsequent inspection.

41. Table 2 shows that, including the 2016 inspections, a total of 137 channels have been inspected. During these inspections, 42 bricks have been observed to contain full height axial cracks, 11 of which were doubly cracked. Since 9 bricks are inspected in every channel, ~3.5% of the inspections observed new full height axial cracks. This is within the ‘essentially intact’ definition of the core and within the limit of 200 doubly cracked bricks in NP/SC 7399 (Ref. 20).

42. The licensee utilises the statistical models to extrapolate the inspection findings to the whole of the active core, with the latest report being Ref. 10. It is believed that the progress of bore cracking is sufficiently well understood from inspections and supported by statistical analysis such that the number of bore cracks will not challenge the 'essentially intact' definition over the period of validity. I agree with this view since bore cracks are likely to be due to a combination of brick geometry and internal stress due to irradiation early in the life of the reactor. The rate of observance of bore cracks is not increasing, consistent with cracking rate corresponding to an early life phenomenon.

43. Re-inspections of bore cracks provide some evidence that the extent of bore cracking does not progress significantly, as it is expected. In addition, the number of bore cracks in the core which is calculated by the statistical model indicates that these are not increasing. I therefore consider that there is sufficient evidence to support the licensee's judgement that brick cracking will not challenge the structural integrity of the core in the next operating period, noting the predicted onset of KWRC in 2025 (Table 1). NGL will also be performing further visual inspections of HYA and HRA using NICIE2 within the period of consent.

4.2.6 Quintessa's predictions

44. Quintessa issued Ref. 10 prior to the periodic shutdown to inform graphite assessors on the likely outcome of the inspections. Using different statistical models, they predicted that two single cracks were most likely to be found; with no doubly cracked bricks (Table 10 of Ref. 10). They also predicted that a bore crack was most likely in channel T07, Layer 11 (Tables 13-15 of Ref. 10).

4.2.7 Results of graphite inspections

45. During this periodic shutdown, two new full height axial cracks were observed. They are both in channel T07 (Layer 11). This is in agreement with the pre-outage Quintessa's predictions (see Section 4.2.6). The channels being re-inspected showed that bore cracks did not progress since their last inspection. This provides evidence that this damage mechanism does not threaten the structural integrity of the core. Therefore, I consider that the results from the graphite inspections do not challenge the safety case until the next periodic shutdown.

46. I did not consider the result from the trepanning campaign during this periodic shutdown since these will be known only after analysis from NNL. However, I have considered the results from previous trepanning campaigns in my assessment of graphite weight loss in Section 4.2.2.

4.2.8 Visit to site

47. I visited the site during the periodic shutdown on 8 February 2018; see intervention report in Ref. 13. I sampled some of the core inspection findings in my discussion with the licensee and during my observation of the GAP meeting. From this work I am satisfied that the licensee has adequately assessed and sentenced the brick cracking observed during this periodic shutdown. Overall, I judge that the graphite inspection process was clear and met the safety case requirements.

48. Although I was broadly satisfied that the graphite inspections are within the safety case requirements, I noted from this visit that a problem with twisting of the NICIE2 tool body about its gimbal joint still persists. This means that the orientation markings on the top of the tool are not an accurate reflection of the orientation of the lower part of the tool which contains the channel bore measurement feelers and inspection camera. NGL had recently introduced a branch instruction (Ref. 21) to use the end face keys to determine the misorientation of the lower part of the tool, which satisfactorily addresses the problem.

4.2.9 GTAC's views on the inspection strategy

49. In my assessment of the graphite inspections, I have considered the review conducted by ONR's independent Graphite Technical Advisory Committee (GTAC), report R54-2017 (Ref. 12), to help me form an opinion on NGL's inspection strategy. GTAC recognises that there are some operational risks associated with graphite inspections and trepanning activities. Although GTAC's observations were based on the graphite inspections at HNB, I consider that these comments are equally applicable to

HYA/HRA since the inspection strategies for these stations are very similar. GTAC has high confidence in NGL's capability to identify bore cracks and make suitable bore measurements (Observation 5.1).

4.3 Comparison with Standards, Guidance and Relevant Good Practice

50. I have made reference to ONR safety assessment principles (SAP) when undertaking my assessment.

4.4 ONR Assessment Rating

51. Based on what I have observed during my intervention and subsequent assessment of Reactor 1 graphite core inspections, I consider the licensee has performed adequately against the requirements of LC 28, examination, inspection, maintenance and testing of the graphite core, and so have given an ONR rating of GREEN following ONR's rating guide (Ref. 20).

5 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

52. This report has been produced as part of the Office for Nuclear Regulation's (ONR) activities to permission the return to service of Hartlepool power station Reactor 1 after its 2018 periodic shutdown. This report considers the work performed by the licensee, EdF Energy Nuclear Generation Limited (NGL), during the shutdown to demonstrate that the reactor's graphite core is in an adequate condition to return to service until its next periodic shutdown.

53. I undertook a number of activities before and during the shutdown to inspect samples of the work that the licensee was carrying out under Licence Condition 28. I judge that the findings from the graphite inspections do not prevent return to service.

54. The latest trepanned data have been used in a revised prediction of weight loss. The use of best estimates in the revised calculation needs further consideration and justification after return to service. A level 4 meeting is planned in June 2018 to discuss the issue. However, the existing conservative graphite weight loss calculation does not predict that the current limit will be breached until 2020 at the earliest.

55. The licensee is preparing a safety case justifying returning Reactor 1 to service following the graphite core inspections at the 2018 periodic shutdown. I have seen a verified version of this return to service safety case and I was satisfied with the arguments.

56. I conclude that the licensee has undertaken graphite core inspections, measurements and taken trepanned samples that meet or exceed its examination, maintenance, inspection and testing requirements under licence condition 28. I judge that the licensee has adequately reviewed and sentenced the findings of the graphite core inspections and measurements and that the licensee has demonstrated that Hartlepool Reactor 1 graphite core is in an adequate condition to be returned to service.

57. NGL submitted NP/SC 7474 Addendum 2 for ONR agreement during the next period of operation. This safety case update proposes to increase the average core weight loss limit from 17% to 20% and needs ONR consideration during the next operating period.

58. There is a need for NGL to produce a post stress reversal safety case before 2020. In a previous assessment of the graphite safety case, ONR had placed a

recommendation on NGL to qualify the Secondary Shutdown (SSD) and Tertiary Shutdown (TSD) systems as part of the production of this case.

59. I therefore recommend that my assessment of the Hartlepool Reactor 1 2018 graphite core inspections and associated safety documentation present no impediment to ONR granting Consent to start-up Hartlepool Reactor 1. The project inspector should note that operation beyond 2020 will require the production of a revision to the graphite core safety case that considers the effects of post-stress reversal of fuel bricks on the graphite core. Furthermore, the project inspector should note that operation beyond 2020 will require ONR's agreement of NP/SC 7474 Addendum 2. This safety case update proposes to raise the active core weight loss limit from 17% to 20%.

5.2 Recommendations

To NGL Graphite Group Head ([redacted]):

- Recommendation 1: A revision to the safety case is required to support operation beyond stress reversal before 2020. In this revision, seismic qualification of the SSD and TSD should be considered as these systems would be essential in the event of a significant earthquake;
- Recommendation 2: Further justification of the new estimates of the active core weight loss update and why this calculation remains conservative needs to be provided as part of ONR's consideration of NP/SC 7474 Addendum 2.

To ONR Project Inspector ([redacted]):

- Recommendation 3: I recommend that Consent is granted for the return to service of Hartlepool Reactor 1. This is contingent on the project inspector receiving the approved return to service EC with the associated INSA statement.
- Recommendation 4: I recommend that the Project Inspector notes in the PAR that operation beyond 2020 will require the production of a revision to the graphite core safety case that considers the effects of post-stress reversal of fuel bricks on the graphite core.
- Recommendation 5: I recommend that the Project Inspector notes in the PAR that the licensee has recently submitted NP/SC 7474 Addendum 2 for ONR's agreement. This update proposes to raise the graphite weight loss limit from 17% to 20% and needs ONR consideration during the next operating period.

To ONR Graphite team ([redacted]):

- Recommendation 6: I recommend that the ONR graphite team updates the ONR issue database to:
  - (iii) add a new issue to follow progress on seismic qualification of the SSD and TSD for post-stress reversal operation and;
  - (iv) add a new issue to follow-up on the latest HRA graphite weight loss update with NGL and consider its review as part of the assessment of NP/SC 7474 Addendum 2.

6 REFERENCES

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7. EC 354995, Heysham 1 and Hartlepool: More Flexible Inspection Requirements for the Graphite Core. (TRIM 2015/136110).

8. NP/SC 7474 Addendum 2. Hartlepool/Heysham 1 - Supporting Papers – Reactivity Effects of Boiler Tube Failure Faults Extension of the Safety Case to End of Station Life. October 2017. (TRIM 2018/39113).

9. Outage Intentions Document for Unit 1 2018 Statutory Outage. HAR/MO/R/020/230. Issue 000. May 2017. (TRIM 2017/229354).

10. Application of Statistical Models for Brick Cracking to Hartlepool R1 Inspections in January 2018. QRS-3007N-1 Version 1.0. January 2018. (TRIM 2018/39767).

11. EC 362828. Justification for the Return to Service of Hartlepool Reactor 1 following the Graphite Core Inspections at the 2018 Periodic Shutdown. March 2018. (TRIM 2018/84566).

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16. [redacted]. RE: HRA Weightloss updates. Email to [redacted]. 14/02/2018. (TRIM 2018/62478).

17. [redacted]. Weight Loss Calibration and Forecasts for HRA R1. January 2018. (TRIM 2018/57240).

18. [redacted]. Hartlepool Reactor 1. 2018 Graphite Weight Loss Update. 15/02/2018. E-mail to [redacted] (NGL). (TRIM 2018/62622).

19. [redacted]. Assessment of the Consolidated Safety Case for the Graphite Cores of the Heysham 1 and Hartlepool Reactors (NP/SC 7570) (TRIM 2014/129776).

20. NP/SC 7399 Revision 000, Nuclear Safety Committee, Hartlepool/Heysham 1Power Station, Safety Case for the Graphite Core following the Observations of Cracked Graphite Bricks at Hartlepool Reactor 1 during its 2004 Periodic Shutdown." November 2004.

21. E/PROC/ENG/BI/1538. Method for Determining the Orientation of the NICIE Mk2 Using End Face Keys. April 2017. (TRIM 2018/63492).

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Table 3: Relevant Safety Assessment Principles (SAPs) considered for this assessment

SAP No	SAP Title	Description
EGR.1	**Engineering principles: graphite components and structures: Safety case**	The safety case should demonstrate that either: a) the graphite component or structure is free of defects that could impair its safety functions; OR b) the safety functions of the graphite components or structure are tolerant of those defects that might be present.
EGR.2	**Engineering principles: graphite components and structures: Design. Demonstration of tolerance**	The design should demonstrate tolerance of the graphite components and structure safety functions to: Ageing process The schedule of design loadings; and The potential mechanisms of formation of defects from design specification loadings
EGR.3	**Engineering principles: graphite components and structures: Design. Monitoring**	There should be appropriate monitoring systems to enable the graphite structure to be maintained within its safe operating envelope for the duration of the life of the installation.
EGR.4	**Engineering principles: graphite components and structures: design Inspection and surveillance**	Features should be provided to: a) facilitate inspection during manufacture and service; and of materials behaviour. b) permit the inclusion of surveillance specimens for monitoring
EGR.11	**Engineering principles: graphite reactor cores: defect tolerance assessment**	The safe working life of graphite reactor cores should be evaluated.
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.