Office for Nuclear Regulation

ASSESSMENT REPORT			
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Site:	Hartlepool		
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Document Acceptance

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† Where required in accordance with ONR How2 BMS Document NS-PER-GD-016
‡ Hard-copy of document signed-off, TRIM version updated with authors / approver / acceptor names and dates and record finalised

Operating Facilities Division

Hartlepool Reactor 2 2019 Periodic Shutdown – Assessment of the results of the Graphite Core Inspections

Assessment Report ONR-OFD-AR-19-055
Revision 0
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EXECUTIVE SUMMARY

This report has been produced as part of the Office for Nuclear Regulation's (ONR) activities to permission the return to service (RTS) of Reactor 2 at the Hartlepool power station following the 2019 periodic shutdown, as required under Licence Condition (LC) 30. The licensee, EDF Energy Nuclear Generation Limited (NGL), has undertaken inspections and surveys of the graphite reactor core as required by the graphite core safety case and Licence Condition 28. This report presents the conclusions of my assessment of the adequacy of those inspections and of the inspection findings.

At the time of writing this assessment report, only 10 of the 20 fuel channels planned for inspection had been completed. The remaining 10 fuel channels were planned to be inspected after re-pressurisation of the reactor. The delay was due to the reduced cooling rate of the reactor caused by the high sea water temperatures at the time of the shutdown. I have therefore based my assessment on the inspection findings available, i.e. 10 fuel channels and 1 control rod (CR) channel. The Project Inspector will need to confirm with the author of this report that the graphite inspections are complete and that the findings from these inspections do not challenge the safety case prior to granting consent to return to service. (Recommendation 1).

As part of the justification for the return to service of the reactor, NGL produces Engineering Change (EC) 363869 which summarises the findings of the graphite core inspections during the HRA R2 periodic shutdown. This EC has yet to be completed yet as the ten fuel channel inspections are still to be completed. I have therefore based my assessment on the information available from the Graphite Assessment Panel (GAP) inspection sheets and the GAP minutes. These documents are endorsed by graphite specialists from NGL and from NGL's Independent Nuclear Safety Assurance (INSA). I therefore consider that the information presented in the GAP sheets and in the GAP minutes is suitable and sufficient to inform my judgements. However, the Project Inspector should ensure that EC 363869 summarising the findings of the graphite inspections is presented to ONR as part of the RTS and has been through the INSA process (Recommendation 2).

Bore measurements were taken from 10 of the fuel channels inspected. Thirty-six graphite specimens were trepanned from the core, which is in line with NGL's target before the periodic shutdown. Provided the remaining 10 fuel channels are complete before the RTS, I consider that the level of graphite inspections carried out for this periodic shutdown is consistent with the Maintenance Schedule requirements.

All the defects observed in the fuel channels were sentenced as bore cracks by the GAP. Two of the channels inspected during previous campaigns were known to have 1 doubly cracked brick (channel U15, layer 11), 1 fully axial crack in a singly cracked brick (channel P39, layer 10) and 1 fully circumferential crack (channel U15, layer 9). In addition, NGL reported the following newly observed cracks during the 2019 periodic shutdown:

- 1 doubly cracked brick (channel W25, layer 11);
- 3 fully axial cracks in a singly cracked brick (channel L29, layer 10; channel M35, layer 11; channel W25, layer 8);
- 1 fully circumferential crack (channel L19, layer 10).

A fully circumferential defect was found during the inspection of CR channel Q22. Based on a review of the inspection video, commissioning video for this channel and examples of machining defects observed in other CR channels, I am content that this defect is likely to be a machining defect. In addition, I am content that this defect is unlikely to develop into a crack in service due to the low irradiation of CR channels.

However, the views from the GAP, i.e. that circumferential defects in CR channels can be discounted in the future, could be the result of misunderstanding about the significance of defects in control rod channels. Following my observation of the GAP, I questioned whether the procedure for the inspection of control rod channels and the GAP process should be reviewed in light of these observations. I will raise a Level 4 issue on the ONR Regulatory Issue database to capture this observation and follow up with NGL.

The level of cracking observed in the fuel channels is consistent with the findings from previous inspections. The core distortion measurements were consistent with historical observations. Keyway root cracking is not expected at Hartlepool until approximately 2022 according to NGL's models. In my opinion, the results from the graphite core inspections are within expectations and do not challenge the assumptions of the safety case.

During the periodic shutdown, I carried out a site intervention to evaluate NGL's arrangements for the graphite core inspections with respect to the ONR Safety Assessment Principles (SAPs). The findings of this intervention are reported in a separate report. From my observations, I am content that NGL's arrangements appeared to be satisfactory.

Based upon the sampling I undertook during the periodic shutdown, the evidence presented, and the conclusions above I judge that the licensee has undertaken sufficient inspection and assessment to support the safe return to service of Hartlepool Reactor 2 from a graphite core integrity perspective. I also judge that the findings from these inspections do not challenge the safety case. I therefore have no objection to the subsequent Project Assessment Report recommending that consent is given to return Hartlepool Reactor 2 back to service (Recommendation 3) subject to Recommendation 1 and 2 being satisfactorily addressed.

I consider that the findings graphite inspections from the Hartlepool Reactor 2 2019 periodic shutdown should not prevent the return-to-service of the reactor. I have therefore attributed an overall ONR rating of 'GREEN' – no formal action.

Recommendations

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

- Recommendation 1: At the time of my assessment, only 10 of the 20 fuel channels planned for inspection had been completed. The Project Inspector will need to confirm with the author of this report that that the graphite inspections are complete and that the findings from these inspections do not challenge the safety case prior to granting consent to return to service;
- Recommendation 2: The Project Inspector will need to ensure that EC 363869 summarising the findings of the graphite inspections is provided to ONR as part of the justification for the return to service and that is has been through the INSA process;
- Recommendation 3: Based on my assessment of the Hartlepool Reactor 2 2019 Graphite Core Inspection Results and justification for return to service, I have no objection to the subsequent Project Assessment Report recommending that consent is given to return Hartlepool Reactor 2 back to service, subject to Recommendation 1 and 2 being satisfactorily addressed.

LIST OF ABBREVIATIONS

ACWL	Active Core Weight Loss
AGR	Advanced Gas-cooled Reactor
BMS	Business Management System
CR	Control Rod
CTO	Central Technical Office
EC	Engineering Change
ECIT	Eddy Current Inspection Tool
GAP	Graphite Assessment Panel
GWd	Giga-Watt day
HOW2	(ONR) Business Management System
HRA	Hartlepool Power Station
INSA	Independent Nuclear Safety Assessment
JCO	Justification for Continued Operation
KRC	Keyway Root Cracking
LC	Licence Condition
MS	Maintenance Schedule
NGL	EDF energy Nuclear Generation Limited
NICIE2	New In-Core Inspection Equipment Mark 2
NNL	National Nuclear Laboratory
ONR	Office for Nuclear Regulation
PAR	Project Assessment Report
PBWL	Peak-rate Brick Weight Loss
R	Reactor
RTS	Return-To-Service
SAP	Safety Assessment Principle(s)
SIAL	Structural Integrity Assessment Limit
TAG	Technical Assessment Guide(s) (ONR)

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1 INTRODUCTION

1.1 Background

1. The conditions attached to the nuclear site licence issued to Nuclear Generation Limited (NGL) for Hartlepool (HRA) power station 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 Hartlepool Plant Maintenance Schedule (MS) under LC 28. On completion of the shutdown, the licensee requires Consent from ONR for return to service (RTS).

2. This report assesses the graphite core integrity aspects of the licensee's activities during the 2019 HRA R2 periodic outage. The scope of this assessment has focused on the adequacy of NGLs arrangements for conducting the graphite inspections and the implication of the results.

3. As part of the justification for the RTS of the reactor, NGL will produce Engineering Change (EC) 363869, which summarises the findings of the graphite core inspections during the 2019 HRA R2 periodic shutdown. At the time of writing this assessment report, only 10 of the 20 fuel channels planned for inspection had been completed. The remaining 10 fuel channels were planned to be inspected after re-pressurisation of the reactor. The delay was due to the reduced cooling rate of the reactor caused by the high sea water temperatures at the time of the shutdown. I have therefore based my assessment on the inspection findings available, i.e. 10 fuel channels and 1 control rod (CR) channel. The Project Inspector will need to confirm with the author of this report that the graphite inspections are complete and that the findings from these inspections do not challenge the safety case prior to granting consent to return to service. (Recommendation 1).

4. As part of the justification for the RTS of the reactor, NGL produces Engineering Change (EC) 363869 which summarises the findings of the graphite core inspections during the HRA R2 periodic shutdown. This EC has yet to be completed yet as the ten fuel channel inspections are still to be completed. I have therefore based my assessment on the information available from the Graphite Assessment Panel (GAP) inspection sheets and the GAP minutes. These documents are endorsed by graphite specialists from NGL and from NGL's Independent Nuclear Safety Assurance (INSA). I therefore consider that the information presented in the GAP sheets and in the GAP minutes is suitable and sufficient to inform my judgements. However, the Project Inspector should ensure that EC 363869 summarising the findings of the graphite inspections is presented to ONR as part of the RTS and has been through the INSA process (Recommendation 2).

5. Assessment was undertaken in accordance with the requirements of ONR How2 Business Management System (BMS) guide NS-PER-GD-014 (Reference 2). The ONR SAPs (Reference 3), together with supporting Technical Assessment Guides (TAG) (Reference 4), have been used as the basis for this assessment.

1.2 Methodology

6. The methodology for the assessment follows HOW2 guidance on mechanics of assessment within the Office for Nuclear Regulation (ONR) (Reference 5). 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.

7. I have taken cognisance of guidance provided by the ONR in the SAPs and Technical Assessment Guides (TAGs) that are relevant to structural integrity, in making my

judgement. Details of these SAPs and TAGs are provided in section 2 of my assessment.

2 ASSESSMENT STRATEGY

8. The intended assessment strategy, including the standards and criteria, for my assessment is set out in this section.

2.1 Standards and Criteria

9. The relevant standards and criteria adopted within this assessment are principally the SAPs (Reference 3), internal ONR TAGs (Reference 4), 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

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

2.2.1 Technical Assessment Guides

11. The following TAG has 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

12. 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

2.4 No technical support contractors were used for this assessment report.

2.5 Integration with Other Assessment Topics

13. N/A.

2.6 Out of Scope Items

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

- structural components other than the graphite core and the core restraints are considered as a separate assessment.

3 LICENSEE'S SAFETY CASE

15. This section provides the licensee's views on the safety case and the justification for the RTS of HRA R2.

3.1 Graphite Assessment Panel

16. The GAP consists of graphite specialists from NGL's Central Technical Office (CTO), NGL's INSA and from specialists at Station. The information from the graphite inspections, e.g. bore measurements, crack size and morphology, etc., is collated into GAP inspection sheets. The sentencing (Reference 6) of defects observed in the graphite core are endorsed at the GAP. The GAP also considers matters such as whether the inspections, dimensional measurements and trepanning have been performed adequately. The minutes of the GAP meeting are circulated between the members for endorsement.

17. If significant inspection findings are identified during outages that are not within the bounds of the existing safety case, the GAP can recommend either further inspections be conducted or a change to the safety case be made. If required, NGL will also update the maintenance schedule (MS) to meet the safety case requirements.

3.2 Return to service engineering change

18. NGL will summarise the results from the graphite inspections in EC 363869. However, this EC was still being produced, at the time of my assessment, and was therefore not available for review. In the place of the EC I have relied upon the GAP inspection sheets and minutes from the GAP meetings are endorsed by NGL's INSA and will be used to provide evidence in EC 363869 (see Recommendation 1). These are available in Reference 1 .

3.3 Core burn-up at the time of the periodic shutdown

19. At the time of the periodic shutdown, the core burn-up of the reactor was 12872 GWd (Reference 7).

3.4 Activities performed during the periodic shutdown

20. As part of NGL's core inspection activities during the 2019 periodic shutdown of HRA R2, the Licensee committed to the following minimum requirements as part of its compliance with LC 28:

- Visual inspections from the bore of 20 fuel channels and one CR channel;
- Of the visually inspected fuel channels, bore measurements from 10 channels;
- Trepanning of a minimum of 30 samples from 6 fuel channels, with a target of 36 samples subject to an assessment of reasonable practicability by the GAP.

3.5 Results of the Graphite Inspections

21. In lieu of the RTS EC, NGL provided a summary of the channels inspected and the findings from the graphite core inspections in Reference 8.

- 7 full height axial cracks in 5 bricks: channel W25 Layer 11 and channel U15 Layer 9 have 2 full height axial cracks;
- 1 full extent axial in channel L29 Layer 10. This crack is full height, over 80%, but is arrested by the full circumferential crack before the top of the brick;
- 2 fully circumferential cracks (L29 Layer 10 and U15 layer 11).

3.6 Graphite trepanning

22. Thirty-six samples have been trepanned from six fuel channels during the outage (Reference 8). The samples will be sent to NNL for measurements and analysis. The results from NNL will be used to update the graphite weight loss forecasts, but these will not be available before the RTS of the reactor.

4 ONR ASSESSMENT

23. 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

24. The scope of this report covers:

- The adequacy of the graphite core inspections performed by NGL during the periodic shutdown of HRA R2 in compliance with LC 28 and LC 30 expectations;
- The assessment of the inspection results as reported in the GAP inspection sheets and minutes (Reference 1);
- The consideration of the inspection findings with regards to the HYA/HRA graphite safety case.

25. During the shutdown, the Eddy Current Inspection Tool (ECIT) was deployed in 7 fuel channels and in the CR channel. The results from the ECIT inspection should provide qualitative information on the density close to the surface of the channels inspected. However, these inspections are not claimed as part of the safety case. I therefore did not consider the implications of the ECIT inspections for the safety case and hence RTS.

4.2 Site intervention

26. I performed a site intervention at HRA on 23rd August 2019 during the periodic shutdown to inspect the adequacy of the licensee’s examinations and inspections of the graphite core; see Reference 9.

27. Following my intervention, I considered that the licensee’s arrangements with regards to graphite core inspection during this outage are suitable and adequate. In my opinion, the visual records and the data that I sampled were of adequate quality for NGL to form an accurate judgement and sentence the cracks.

28. 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’ – no formal action – for this intervention.

4.3 Graphite fuel channel inspections

29. For this periodic shutdown, NGL complied with the MS by visually inspected the bore of 20 fuel channels and 1 CR channel. Bore measurements were also taken from 10 of the fuel channels inspected. Four edge channels and four near-edge channels have been inspected, where cracks are the most likely to be present. I consider that there is a good coverage of the reactor for the inspections.

30. All cracks observed have been sentenced as bore cracks by the GAP. Two of the channels inspected during previous campaigns were known to have 1 doubly cracked brick (channel U15, layer 11), 1 fully axial crack in a singly cracked brick (channel P39, layer 10) and 1 fully circumferential crack (channel U15, layer 9). In addition, NGL reported the following newly observed cracks during the 2019 periodic shutdown:

- 1 doubly cracked brick (channel W25, layer 11);
- 3 fully axial cracks in a singly cracked brick (channel L29, layer 10; channel M35, layer 11; channel W25, layer 8);
- 1 fully circumferential crack (channel L19, layer 10).

31. According to NGL, all the cracks observed have originated from the bore. It was claimed that the 'lipping in' observed in the cardioid plots is characteristic of such bore cracks. Based on current predictions the onset of keyway root cracking (KRC) is not predicted to occur at HRA for at least for another few years (see Section 4.6.2). I therefore consider that the classification of the observed defects as bore cracks is reasonable.

32. The number of fully axial bore cracks is consistent with previous outage, i.e. around 5% of the bricks inspected. The safety case defines the concept of 'essentially intact core' as being up to 10% of the bricks being singly cracked with full height axial defects. In my opinion, the inspection findings from the HRA R2 2019 graphite core inspections therefore do not appear to challenge the safety case assumptions.

33. I therefore consider that the findings from the graphite core inspections do not appear to present any challenge to the assumptions in the current safety case.

4.4 CR channel Q22

34. During the periodic shutdown, one CR channel (Q22) was visually inspected. During the inspection of Q22 a fully circumferential defect was observed in layer 10 approximately 227mm from the brick interface. Figure 1 shows a montage of the fully circumferential defect observed in Q22.

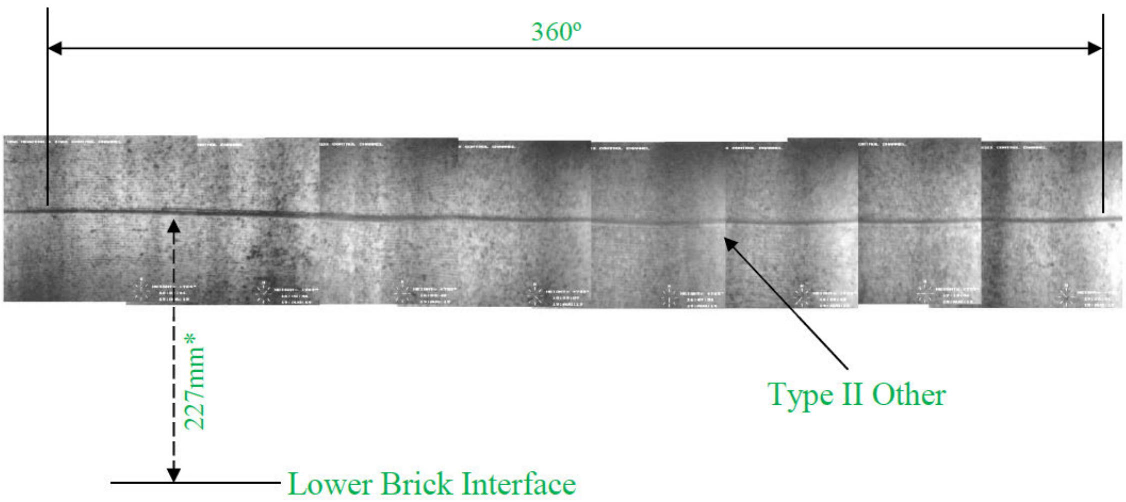

Figure 2: Circumferential defect observed in CR channel Q22 (References 1 and 14).

35. It was my opinion that the quality of the images did not allow for a conclusive opinion to be drawn on to the origin of the defect. It was therefore decided to conduct an additional intervention at the Wood offices in Knutsford. The findings from this intervention are reported in Reference 10.

36. During periodic shutdowns, NGL commissions a team of graphite specialists from Wood to review the video footage from the inspections and collates the information in a GAP sheet with comments about the morphology of the crack, location, size, etc. Where bore measurements have been carried out, the GAP sheet also includes ovality and bowing of the bricks as well as channel angle. The Wood team who produces the GAP sheets is a member of the GAP.

37. Based on this intervention, I consider that Wood representative's identification of the defect, informing the licensee (NGL), and sentencing of the defect to prompt discussion at the GAP is appropriate and demonstrates a good questioning attitude.

38. From the video footage I observed, the defect appears to be consistent with other machining marks of limited depth. No crack-like feature appears to be present from the footage. A similar video footage showed that a similar defect taken had been observed in other CR channels, i.e. Layer 15 of 1L14 observed for HRA R1 in 2018 (Reference 11). This defect was classed as a manufacturing defect and had a similar morphology as the defect observed at the current outage. The video footage taken during commissioning indicates that the defect was likely to have been present at the time of construction (Reference 12). Hence, I am content that the defect observed in control rod channel Q22 is likely to have been caused by machining during the manufacture of the brick.

39. It is my opinion that a 360° scan of the defect (as performed for other similar observations) would have improved the sentencing of this defect. However, I consider that the video provides images of sufficient quality for the defect on Q22 to have been adequately sentenced by the GAP.

40. NGL produced Reference 14 which assesses the defect, the condition of the surrounding reactor core and the implications on the existing safety case. The evidence presented in Reference 14 appears to support the judgement that the fully circumferential defect in CR channel Q22 is a machining defect and I have focused my assessment on whether this indication could affect the integrity of the core. I have not taken a view on Reference 13 which argues that the presence of cracks in CR channels is acceptable.

41. In my opinion, the irradiation in CR channels is likely to be too low for any significant driving force to be present at the location of the defect for the machining mark to develop into a crack. There is also no evidence from the inspection videos of any horizontal displacement which could indicate a crack. I therefore conclude that the circumferential defect observed in CR channel Q22 is unlikely to present a challenge to the structural integrity of the core or to result in impediment to CR entry.

4.5 Observation of the GAP

42. On the 11th September 2019, I observed a GAP meeting arranged to review and sentence the fully circumferential defect found in CR channel Q22 during the inspections (see Section 4.4 above).

43. I subsequently highlighted a number of concerns to the GAP in Reference 15. I noted that the assessment team having brought the defect to the GAP's attention for review was a positive case of questioning attitude. However, I noted that the GAP members did not challenge the views being presented to them and that fully circumferential defects in CR channels seemed to be seen as not being safety significant. I consider that fully circumferential defects can be significant as these could result in ledges and impairment to CR entry or to debris which could be produced during CR entry.

44. The views from the GAP, i.e. that circumferential defects in CR channels can be discounted in the future, could be the result of misunderstanding about the significance of defects in control rod channels. Following my observation of the GAP, I questioned whether the procedure for the inspection of control rod channels and the GAP process should be reviewed in light of these observations (Reference 15). I will raise a Level 4 issue on the ONR Regulatory Issue database to capture this observation and follow up with NGL.

4.6 Current safety case limits

4.6.1 Graphite weight loss

45. In 2019, NGL submitted a Justification for Continued Operation (JCO) justifying the graphite weight loss limits for Heysham 1 and HRA Reference 16 . At the time of my assessment, the 43% SIAL and the 20% ACWL limit were predicted to be reached at the end of March 2020 and at the end of December 2020 respectively, although there were still some uncertainties about the actual dates. However, ONR's independent technical support contractor has identified an error in the statistical analysis model used to support the limits meant that the period of validity of the JCO could be shorter (Reference 16). Following my assessment of the JCO in Reference 16, I identified the two main recommendations:

- Recommendation 1: NGL should inform ONR regarding the significance of the use of a logarithmic scale rather than a linear scale on the validity of the JCO, including the forecasts other AGRs for which a similar model has been used, e.g. Heysham 2/Torness. NGL should also determine if the Safety Case Anomaly Process should be entered.
- Recommendation 2: NGL should provide the definition of the peak-rated brick weight loss (PBWL) limit, a description of the fault that the PBWL limit relates to and forecasts which are consistent with the definition in the assessment of the limit.

46. I also provided a number of recommendations regarding the development of the graphite weight loss model, but these could be addressed as part of the safety case following the JCO. I provided these recommendations to NGL by letter in Reference 17. NGL's work to address these concerns is being followed as part of ONR's regulatory engagement.

47. However, the graphite weight loss limits above will not be met until next year and I am satisfied that the licensee process is to manage it. I am confident that NGL process will be updated in a timely manner. The recommendations raised in Reference 16 should therefore not be an issue for the RTS of the reactor.

48. The 36 trepanned samples obtained during the periodic shutdown of the reactor will be used to update the graphite weight loss models. I consider that this is a good achievement for this periodic shutdown and meets the MS requirements.

4.6.2 Brick cracking

49. According to NP/SC 7570, onset of KRC is not predicted until a core burn-up of 13500GWd at HRA, i.e. ~2022 (Reference 18). KRC could therefore occur before the end of the next period of operation. At HRA, inspections of the core are also carried out during refuelling outages between periodic shutdowns. In my opinion, the current inspection regime should therefore allow for KRCs to be observed before the number of cracks increases beyond the current 'essentially intact core' definition in the safety case. NGL is producing a safety case to justify operation beyond the current limit.

50. The current safety case limit of 13500GWd in NP/SC 7570 (Reference 18) is expected to be reached within the next operating period. NGL is currently in the process of producing a safety case to justify continued operation beyond the current limit. This work is being followed by ONR's regulatory engagement with NGL.

4.7 ONR Rating

51. I have attributed an overall ONR rating of 'GREEN' – no formal action, based on the ONR rating guide table (Reference 19).

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

52. At the time of writing this assessment report, only 10 of the 20 fuel channels planned for inspection had been completed. The remaining 10 fuel channels were planned to be inspected after re-pressurisation of the reactor. The delay was due to the reduced cooling rate of the reactor caused by the high sea water temperatures at the time of the shutdown. I have therefore based my assessment on the inspection findings available, i.e. 10 fuel channels and 1 CR channel. The Project Inspector will need to confirm with the author of this report that the graphite inspections are complete and that the findings from these inspections do not challenge the safety case prior to granting consent to return to service. (Recommendation 1).

53. As part of the justification for the RTS of the reactor, NGL produces EC 363869 which summarises the findings of the graphite core inspections during the HRA R2 periodic shutdown. This EC has yet to be completed yet as the ten fuel channel inspections are still to be completed. I have therefore based my assessment on the information available from the GAP inspection sheets and the GAP minutes. These documents are endorsed by graphite specialists from NGL and from NGL's INSA. I therefore consider that the information presented in the GAP sheets and in the GAP minutes is suitable and sufficient to inform my judgements. However, the Project Inspector should ensure that EC 363869 summarising the findings of the graphite inspections is presented to ONR as part of the RTS and has been through the INSA process (Recommendation 2).

54. All the defects observed in the fuel channels were sentenced as bore cracks by the GAP. Two of the channels inspected during previous campaigns were known to have 1 doubly cracked brick (channel U15, layer 11), 1 fully axial crack in a singly cracked brick (channel P39, layer 10) and 1 fully circumferential crack (channel U15, layer 9). In addition, NGL reported the following newly observed cracks during the 2019 periodic shutdown:

- 1 doubly cracked brick (channel W25, layer 11);
- 3 fully axial cracks in a singly cracked brick (channel L29, layer 10; channel M35, layer 11; channel W25, layer 8);
- 1 fully circumferential crack (channel L19, layer 10).

55. A fully circumferential defect was found during the inspection of CR channel Q22. Based on a review of the inspection video, commissioning video for this channel and examples of machining defects observed in other CR channels, I am content that this defect is likely to be a machining defect. In addition, I am content that this defect is unlikely to develop into a crack in service due to the low irradiation of CR channels.

56. However, the views from the GAP, i.e. that circumferential defects in CR channels can be discounted in the future, could be the result of misunderstanding about the significance of defects in control rod channels. Following my observation of the GAP, I questioned whether the procedure for the inspection of control rod channels and the GAP process should be reviewed in light of these observations. I will raise a Level 4 issue on the ONR Regulatory Issue database to capture this observation and follow up with NGL.

57. The level of cracking observed in the fuel channels is consistent with the findings from previous inspections. The core distortion measurements were consistent with historical observations. Keyway root cracking is not expected at Hartlepool until approximately 2022 according to NGL's models. In my opinion, the results from the graphite core inspections are within expectations and do not challenge the assumptions of the safety case.

58. During the periodic shutdown, I carried out a site intervention to evaluate NGL's arrangements for the graphite core inspections with respect to the ONR SAPs. The findings of this intervention are reported in a separate report. From my observations, I am content that NGL's arrangements appeared to be satisfactory.

59. Based upon the sampling I undertook during the periodic shutdown, the evidence presented, and the conclusions above I judge that the licensee has undertaken sufficient inspection and assessment to support the safe return to service of Hartlepool Reactor 2 from a graphite core integrity perspective. I also judge that the findings from these inspections do not challenge the safety case. I therefore have no objection to the subsequent Project Assessment Report recommending that consent is given to return Hartlepool Reactor 2 back to service (Recommendation 3) subject to Recommendation 1 and 2 being satisfactorily addressed.

Recommendations

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

- Recommendation 1: At the time of my assessment, only 10 of the 20 fuel channels planned for inspection had been completed. The Project Inspector will need to confirm with the author of this report that that the graphite inspections are complete and that the findings from these inspections do not challenge the safety case prior to granting consent to return to service;
- Recommendation 2: The Project Inspector will need to ensure that EC 363869 summarising the findings of the graphite inspections is provided to ONR as part of the justification for the return to service and that is has been through the INSA process;
- Recommendation 3: Based on my assessment of the Hartlepool Reactor 2 2019 Graphite Core Inspection Results and justification for return to service, I have no objection to the subsequent Project Assessment Report recommending that consent is given to return Hartlepool Reactor 2 back to service, subject to Recommendation 1 and 2 being satisfactorily addressed.

6 REFERENCES

1. Graphite Inspections. GAP Sheets & Minutes Hartlepool Reactor 2 - 2019 Periodic Shutdown (CM9 2019/271787).

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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.7	**Engineering principles: graphite reactor cores: component and core condition assessment**	Analytical models should be developed to enable the prediction of graphite reactor core material properties, displacements, stresses, loads and condition.
EGR.8	**Engineering principles: graphite reactor cores: component and core condition assessment**	Predictive models should be shown to be valid for the particular application and circumstances by reference to established physical data, experiment or other means.
EGR.9	**Engineering principles: graphite reactor cores: component and core condition assessment**	Extrapolation and interpolation from available materials properties data should be undertaken with care, and data and model validity beyond the limits of current knowledge should be robustly justified.
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.

Annex 1 (Continued)

SAP No	SAP Title	Description
EGR.11	**Engineering principles: graphite reactor cores: defect tolerance assessment**	The safe working life of graphite reactor cores should be evaluated.
EGR.12	**Engineering principles: graphite reactor cores: defect tolerance assessment**	Operational limits (operating rules) should be established on the degree of graphite brick ageing, including the amounts of cracking, dimensional change and weight loss. To take account of uncertainties in measurement and analysis, there should be an adequate margin between these operational limits and the maximum tolerable amount of any calculated brick ageing.
EGR.13	**Engineering principles: graphite reactor cores: defect tolerance assessment**	Data used in the analysis should be soundly based and demonstrably conservative. Studies should be undertaken to establish the sensitivity to analysis parameters.
EGR.14	**Engineering principles: graphite reactor cores: monitoring**	The design, manufacture, operation, maintenance, inspection and testing of monitoring systems should be commensurate with the duties and reliabilities claimed in the safety case.
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.