Office for Nuclear Regulation

ASSESSMENT REPORT			
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Site:	Dungeness B		
Title:	Dungeness B Reactor 22 2018 Periodic Shutdown: Structural Integrity Assessment of the Graphite Core Inspection Findings		
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Licence Condition(s):	30		
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Operating Facilities Division

Dungeness B Reactor 22 2018 Periodic Shutdown – Assessment of the results of the Graphite Core Inspections

Assessment Report ONR-OFD-AR-18-046
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 of Reactor 22 at the Dungeness B power station following the 2018 periodic shutdown, as required under Licence Condition 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 surveys, the results from those surveys, and in addition considers the position on graphite weight loss.

I carried out a site intervention to ensure that the Licensee's arrangements with regard to the graphite inspections and surveys were satisfactory. I was accompanied by another graphite specialist inspector and a chemistry specialist inspector. Based on the evidence I sampled during my intervention, the licensee's arrangements concerning the graphite core inspections for Reactor 22 appeared to be satisfactory. I did not find anything that could prevent return to service of Reactor 22.

I reviewed the graphite inspection sheets and the minutes of the graphite assessment panel meetings against the current safety case and the relevant ONR Safety Assessment Principles. Visual inspection and bore measurements of five fuel channels and two control rods were completed. This met the safety case inspection requirements. These inspections did not reveal any defects. The core distortion was within expectations and did not present any adverse trend. The results from these inspections are therefore as expected and, in my opinion, do not challenge the assumptions in the safety case.

Forty-eight graphite specimens were trepanned from the core to provide further data informing the current weight loss predictions, in line with NGL's target. The trepanned specimens will be sent to National Nuclear Laboratory an analysed in due course. The licensee also carried out eddy-current inspection of the five fuel channels inspected during the periodic shutdown. This is not a safety case requirement but may provide some insight on the distribution of graphite weight loss in these channels.

As part of my assessment, I also reviewed the licensee's latest graphite weight loss update, which includes the weight loss measurements from the graphite trepanned samples of the Dungeness B Reactor 21 2017 periodic shutdown. The revised forecasts predict that the 10% active core weight loss limit should be reached in ~2023, based on best estimates, but did not include uncertainties. The Licensee is preparing a revised safety case including an allowance for the uncertainties in the calculation due to be completed by the end of 2019. Nevertheless, the margin against the 10% limit appears to be sufficient for Dungeness B Reactor 22 to be returned back to service following its 2018 periodic shutdown.

Based on the evidence I sampled during my assessment, I have no objection to the subsequent PAR recommending that consent is given to return Dungeness B Reactor 22 back to service (Recommendation 1). The return-to-service EC had not been completed at the time of my assessment. I recommend that the Project Inspector ensures that the RTS EC summarising the graphite inspection findings has been approved by INSA and submitted to ONR prior to any decision on consent to restart (Recommendation 2).

As part of my assessment, I also considered the evidence presented by NGL concerning the validity of the graphite core seismic safety case and the development of a post-stress reversal safety case. This concern is captured in ONR Issue 6116. I am satisfied that the evidence presented appears to support the existing safety case and that the timescales proposed to

update the existing safety case appear to be reasonable. Nevertheless, to monitor progress with the developments proposed, I am of the opinion that ONR Issue 6116 should remain open until the results of the Damage Tolerance Analysis are available. I will update ONR issue 6116 accordingly following approval of this report.

Recommendations

To the ONR Project Inspector:

- Recommendation 1: Based on my assessment of the Dungeness B Reactor 22 2018 Graphite Core Inspection Results and Justification for Return to Service, I have not found any reason to prevent me recommending that consent is given to Dungeness B Reactor 22 return back to service.
- Recommendation 2: I recommend that the Project Inspector ensures that the RTS EC summarising the graphite inspection findings has been approved by INSA and submitted to ONR prior to any decision on consent to restart.

I have given an overall ONR rating of ‘green’ – no formal action.

LIST OF ABBREVIATIONS

AGR	Advanced Gas-cooled Reactor
ARM	Attack Ratio Multiplier
BMS	Business Management System
DNB	Dungeness B Power Station
DTA	Damage Tolerance Assessment
EC	Engineering Change
FD6	FEAT-DIFFUSE Version 6
GCPT	NGL Graphite Core Project Team
GWd	Giga-Watt day
HOW2	(ONR) Business Management System
INSA	Independent Nuclear Safety Assessment
LC	Licence Condition
MS	Maintenance Schedule
NGL	EDF energy Nuclear Generation Limited
NNL	National Nuclear Laboratory
ONR	Office for Nuclear Regulation
PAR	Project Assessment Report
PECIT	Prototype Eddy-Current Inspection Tool
R	Reactor
RPV	Reactive Pore Volume
RTS	Return-To-Service
SAP	Safety Assessment Principle(s)
SQEP	Suitably Qualified and Experience Person
TAG	Technical Assessment Guide(s) (ONR)
TSSM	Technical & Safety Support Manager

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Table(s)

1 INTRODUCTION

1. During the 2018 Dungeness B (DNB) Reactor 22 (R22) periodic shutdown, the graphite reactor core has undergone surveys, as required by the graphite core safety case (References 1, 2 and 3). The Licensee, EDF Energy Nuclear Generation Limited (NGL), will produce an Engineering Change (EC) to support the return-to-service of the reactor. At the time of my assessment, this EC had not yet been produced. Therefore, my assessment to support ONR's position on the consent to return the reactor to service is based on the findings presented in the GAP minutes and the supporting GAP inspection sheets (Reference 4).

1.1 Background

2. This report assesses the findings of the graphite core inspections of DNB R22 during the 2018 periodic shutdown and supporting documentation provided by NGL. 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 5). The ONR Safety Assessment Principles (SAP) (Reference 6), together with supporting Technical Assessment Guides (TAG) (Reference 7), have been used as the basis for this assessment.

1.2 Scope

3. The scope of this report covers the licensee's activities performed during the shutdown associated with the examination and inspection of DNB R22 graphite core and whether return to service (RTS) is justified.

1.3 Methodology

4. 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 findings of the graphite core inspections during the DNB R22 2018 periodic shutdown.

2 ASSESSMENT STRATEGY

5. The intended assessment strategy for the assessment of the graphite integrity aspects of the Dungeness B R22 2018 periodic shutdown 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

6. The relevant standards and criteria adopted within this assessment are principally the Safety Assessment Principles (SAP) (Reference 6), internal ONR Technical Assessment Guides (TAG) (Reference 7), 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

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

2.2.1 Technical Assessment Guides

8. The following Technical Assessment Guides have been used as part of this assessment (Reference 7):

- ONR-TAST-GD-029 Graphite Reactor Cores

2.2.2 National and International Standards and Guidance

9. 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

10. N/A.

2.4 Integration with Other Assessment Topics

11. N/A.

2.5 Out of Scope Items

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

- Inspection results from all non-graphite related components;
- The findings of the laboratory examinations of the trepanned specimens are not expected before the return to service of DNB R22 and are not considered in this assessment report. They will be used to further develop an understanding of the condition of the graphite reactor core by the NGL Graphite Core Project Team (GCPT).

3 LICENSEE'S SAFETY CASE

13. This section provides a summary of the licensee's safety case and the justification for the RTS of DNB R22. I provide my assessment of the graphite inspection findings in relation to the RTS of DNB R22 in Section 4 of this report.

3.1 Core Burn-up

14. At the time of the 2018 periodic shutdown, the core burn-up for DNB R22 was 9127.3GWd (Reference 9).

3.2 Graphite Core Safety Case

15. The current graphite core safety case exists in a number of documents, with key developments recorded across NP/SC 7274 (Reference 1), NP/SC 7359 (Reference 2) and EC 337681 (Reference 3). NGL considers that the current safety case is valid up to end of 2023, which is NGL's estimate for the time of stress reversal at power.

3.3 Graphite Core Inspections

16. The licensee assesses and sentences the findings of the inspections via the Graphite Assessment Panel (GAP). The GAP provides the body through which sentencing and acceptance of the findings of the graphite core inspections are considered prior to the return to service of the reactor. The GAP meeting is held weekly during the outage and is chaired by DNB and attended by Suitably Qualified and Experienced Persons (SQEPs) from DNB and the Central Technical Office (CTO) in Barnwood. The GAP also includes representatives from the licensee's Independent Nuclear Safety Assessment (INSA) group, who provide oversight and feedback on the process for sentencing inspection results.

3.4 Objectives of the Graphite Inspections

17. During the DNB R22 periodic shutdown inspections were performed within selected channels of the graphite core to determine:

- The number, size and morphology of any cracks observed in the selected channels;
- The change in dimensions of the bricks as a result of irradiation induced shrinkage of the graphite;
- Any change in the distortion of the core in terms of fuel channel bow, brick bow and channel tilt;
- The estimated weight loss of the core based upon trepanned specimens removed from fuel channel walls.

3.5 Reactor Internals Inspection Proposal

18. Prior to the periodic shutdown, NGL issued the intended scope of inspections which is summarised below for the graphite core (Section 3.1 of Reference 10):

- TV inspection of five fuel channels;
- Channel bore measurement of four channels;
- Trepanning of forty-eight graphite specimens;
- Visual inspection of two control rod channels;
- Eddy-current of four fuel channels and one control rod channel using the Prototype Eddy-Current Inspection Tool (PECIT).

3.6 Trepanned Data

19. In October 2017, I wrote to NGL in Reference 11 to request some information concerning the graphite core seismic safety case. As part of my query, I also requested that NGL analyses the trepanning data and incorporate in the graphite weight loss database within one year of the R21 periodic shutdown. NGL provided the information concerning the graphite core seismic safety case in References 12 and 13. NGL provided an update to the GWL forecasts in References 14 and 15, as requested.

4 ONR ASSESSMENT

20. 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

21. The scope of the assessment included a review of the reactor internal inspection proposals, on-site meetings (accompanied by two other ONR specialists) and plant inspections with relevant staff from NGL. The purpose was to determine the adequacy of the work being undertaken on DNB R22 in complying with the requirements of LC28.

22. The activities examined were selected due to their nuclear safety significance and agreed in advance of the visit with station and the site inspector. The assessment included:

- a joint chemistry/graphite intervention at site during the periodic shutdown;
- an examination of the graphite core inspection records from the periodic shutdown;
- a review of the latest graphite weight loss (GWL) forecasts;
- consideration of NGL’s response to ONR letter DNB71296R (Reference 12).

4.2 Assessment

4.2.1 ONR Site Intervention

23. I performed a site intervention with an ONR graphite principal inspector and an ONR chemistry specialist on 12th and 13th September 2018. Reference 16 provides the details of the findings for the intervention. At the time of the intervention, the graphite core arrangements in place appeared to be satisfactory. The graphite inspections carried out were within expectation and that there was a good coverage of the fuel channels inspected. At the time of my inspection, no new cracks had been found. I have established that NGL’s staff training records were up-to-date and consistent with the task requirements. The Quality Plans for the tasks were available and fully up-to-date.

24. Gas Chemistry. For DNB R22, the gas chemistry data presented by the licensee appeared to be within the specifications as per Reference 17. However, we expressed some concerns over recent technical issues with the gas bypass plant for R21 which limited the licensee’s ability to inject a sufficient concentration of methane. Methane is injected into the primary gas coolant as an inhibitor to minimise the effects of radiolytic oxidation of the graphite core. Insufficient methane therefore results in a higher rate of oxidation of the core. The issue concerning gas chemistry for R21 and the implication for the GWL forecasts will be considered separately as part of routine engagement with the licensee, and does not affect the return to service of R22.

4.2.2 Graphite Core Inspection

25. I based the findings of my assessment according to the GAP sheets which NGL produce during the periodic shutdown. The GAP sheets summarise the findings of the graphite core inspections and are endorsed by graphite inspection SQEPs from station and from CTO in Barnwood. I therefore consider that the GAP sheets constitute an accurate summary of the inspection findings. The GAP sheets produced during the outage are available in Reference 4.

26. Visual inspection and bore measurements of five fuel channels and two control rod channels were completed during the periodic shutdown. Eddy-current inspection using

PECIT was carried out on five fuel channels and one control rod channel. The inspections carried out were therefore as proposed in the scope of inspection and met the safety case requirements (Reference 10).

27. The visual inspections and the bore measurements carried out did not identify any anomaly and no new cracks have been observed in the channels inspected (Reference 4). The bore measurements were within NGL's expectations, with no adverse trends. In my opinion, there were no indications from the findings of the inspections that would prevent the RTS of R22.

4.2.3 Graphite Core Trepanning

28. During the outage, forty-eight samples have been retrieved from the core (Reference 18). The samples will be sent to National Nuclear Laboratory (NNL) for measurements and analysis. The results from NNL will be used to update the GWL forecasts but will not be available before the RTS of the reactor.

4.2.4 Graphite Weight Loss Forecasts

29. As part of the RTS, NGL provided the updated GWL forecasts in Reference 15 to demonstrate that the current limit of 10% is not predicted to be reached over the next period of operation. The calibration of the model includes the weight loss measurements up to and including the 2017 trepanned data.

30. There are different limits associated with GWL. However, DNB is limited by the active core weight loss (ACWL) associated with steam/water ingress faults. Currently, the ACWL limit is set at 10% (Reference 19). The definition of the 10% weight loss limit no longer includes allowances for the uncertainties in the GWL calculation (Reference 20). Thus the uncertainties now need to be explicitly considered in the weight loss forecasts.

31. To relate the ACWL to the core burn-up, NGL developed the FEAT-DIFFUSE6 (FD6) thermofluids computer program. EC 357719 (Reference 21) provided an update of the forecasts corresponding to the 10% ACWL limit. According to the FD6 calculation, the latest GWL update EC357719 predicts that the 10% will be reached by the end of 2023, for a core burn-up of 11250GWd. However, I concluded in my assessment in Reference 22 that the uncertainties should also be considered in the forecasts. Recently, a series of Level 4 meetings were held between ONR and NGL to discuss the recommendations from my assessment (References 23 and 24).

32. As requested in Reference 22, NGL produced an update to the GWL forecasts to account for the weight loss measurements from the DNB R21 2017 trepanned samples (References 14 and 15). Reference 15 also includes the Reactive Pore Volume (RPV) model in the methodology, which NGL refers to as 'model FD6.1'. Reference 14 (model FD6) determines that the core burn-up corresponding to the 10% ACWL limit is 11400GWd. The 10% forecast given by model FD6.1 is 11250GWd, which is identical to the previous forecasts in EC357719. I am therefore satisfied that the core burn-up calculations in References 14 and 15 are reasonably consistent with the previous forecasts in EC357719.

33. NGL also provided a comparison between the GWL profiles measured from different types of methane holes (Reference 25). This analysis determined that the changes in GWL are not as large as NGL previously expected in EC357719. At the time of my assessment, NGL revised EC 357719 and included two commitments to produce a revision to the graphite weight loss update including the 2017/2018 trepanned data and to revise the uncertainties before the end of 2019 (Reference 26).

34. Based on the evidence provided, I am of the opinion that the current graphite weight loss forecasts should not prevent the RTS of DNB R22 following its 2018 periodic shutdown.

4.3 Graphite Core Seismic Safety Case

35. In my assessment of the third Periodic Safety Review for DNB in Reference 27, I highlighted a concern that the existing seismic graphite safety case appeared to be out-of-date. Following my assessment, I requested that NGL provides further justification to support the current validity of the graphite core seismic safety case (Reference 11). I also raised Issue 6116 in the ONR database.

36. NGL replied to Reference 11 and provided the justification requested in References 12 and 13. I considered the evidence presented as part of the present assessment to review progress with ONR Issue 6116.

37. Recent analysis in Reference 30 indicates that NGL does not expect stress reversal before the end of 2023, time until which the current safety case is valid. The safety margins calculated in the existing seismic assessment appear to be satisfactory (References 28 and 29) and the validity of the case was further extended in Reference 1. I am therefore satisfied that evidence presented in Reference 11 and the timescales proposed to update the safety case are acceptable.

38. Nevertheless, to monitor progress with the developments proposed, I am of the opinion that ONR Issue 6116 should remain open until the results of the Damage Tolerance Analysis are available. I will update ONR issue 6116 accordingly following approval of this report.

4.4 ONR Assessment Rating

39. Based on the evidence I sampled, I have given a ‘green’ ONR Assessment Rating (Reference 31) to this assessment.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

40. Visual inspection and bore measurements of five fuel channels and two control rods were completed. These inspections did not reveal any defects. The core distortion was within expectations and did not present any adverse trend. Forty-eight graphite specimens were trepanned from the core, which is corresponds to NGL's target. The trepanned specimens will be sent to National Nuclear Laboratory an analysed in due course. These samples will provide further data informing the current weight loss predictions. Although not a formal safety case requirement, the licensee carried out eddy-current inspection of the five fuel channels inspected during the periodic shutdown. The results will be analysed and should provide some insight on the distribution of graphite weight loss in these channels.

41. I carried out an intervention on site during the periodic shutdown. I was accompanied by another graphite specialist inspector and a chemistry specialist inspector. Based on the evidence I sampled during my intervention, the licensee's arrangements concerning the graphite core inspections for Reactor 22 appeared to be satisfactory. I did not find anything that could prevent return to service of Reactor 22.

42. As part of my assessment, I reviewed the licensee's latest graphite weight loss update, which also includes the weight loss measurements from the graphite trepanned samples of the Dungeness B Reactor 21 2017 periodic shutdown. The revised forecasts predict that the 10% active core weight loss limit should be reached in ~2023, based on best estimates, but did not include uncertainties. The Licensee is preparing a revised safety case including an allowance for the uncertainties in the calculation by the end of 2019. Nevertheless, the margin against the 10% limit appears to be sufficient for Dungeness B Reactor 22 to be returned back to service following its 2018 periodic shutdown.

43. Based on the evidence I sampled during my assessment, I have no objection to the subsequent PAR recommending that consent is given to return Dungeness B Reactor 22 back to service (Recommendation 1). The return-to-service EC had not been produced at the time of my assessment. I recommend that the Project Inspector ensures that the RTS EC summarising the graphite inspection findings has been approved by INSA and submitted to ONR prior to any decision on consent to restart (Recommendation 2).

44. As part of my assessment, I also considered the evidence presented by NGL concerning the validity of the graphite core seismic safety case and the development of a post-stress reversal safety case. This concern is captured in ONR Issue 6116. I am satisfied that the evidence presented appears to support the existing safety case and that the timescales proposed to update the existing safety case appear to be reasonable. Nevertheless, to monitor progress with the developments proposed, I am of the opinion that ONR Issue 6116 should remain open until the results of the Damage Tolerance Analysis are available. I will update ONR issue 6116 accordingly following approval of this report.

5.2 Recommendations

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

- Recommendation 1: Based on my assessment of the Dungeness B Reactor 22 2018 Graphite Core Inspection Results and Justification for Return to Service, I have not found any reason to prevent me recommending that consent is given to Dungeness B Reactor 22 return back to service.

- Recommendation 2: I recommend that the Project Inspector ensures that the RTS EC summarising the graphite inspection findings has been approved by INSA and submitted to ONR prior to any decision on consent to restart.

6 REFERENCES

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30. FNC 49998-006/44315R Issue 1. Predictions of Stress Reversal and Keyway at Dungeness B. December 2016. TRIM 2019/10640.

31. ONR Assessment Rating Guide Table – TRIM Ref. 2016/118638.

Table 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.

Table 1 (Continued)

Relevant Safety Assessment Principles Considered During the Assessment

SAP No	SAP Title	Description
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. 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.