Office for Nuclear Regulation

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Dungeness B – 2017 Reactor 21 Periodic Shutdown

Dungeness B R21 2017 Periodic Shutdown: Graphite Core Structural Integrity Assessment

Assessment Report ONR-OFD-AR-17-017
Revision 0
24 August 2017

EXECUTIVE SUMMARY

Dungeness B (DNB) Reactor 21 (R21) has undergone a statutory three-yearly periodic shutdown. During this outage, various inspections and maintenance activities have been performed by the licensee, EDF Energy Nuclear Generation Limited (NGL). For the graphite core, visual inspections and dimensional measurements are performed, together with the removal by trepanning of samples of the graphite for later analysis. The present report summarises the results of my assessment of the inspection activities and other relevant developments concerning the DNB R21 graphite core.

As part of my assessment, I have also considered the graphite weight loss statement provided by NGL in relation to the current 8% weight loss limit. This limit is predicted to be reached in September 2019. I am aware that NGL is seeking to increase this limit to 10% and has submitted a safety case supporting their proposal. The acceptability of this proposal is currently being considered by an ONR Fault Studies inspector.

NGL has also submitted an Engineering Change (EC 357719) to update the graphite weight loss calculations for both DNB reactors. Due to the extensive analysis that NGL has carried out for this EC, I will carry out a separate assessment of EC 357719 to examine the methods in more detail. Continued operations beyond September 2019 will therefore be subject to ONR's acceptance of the 10% graphite weight loss limit case and a positive assessment of EC357719.

In past outages, plant chemistry control for the DNB reactor cores had been judged to be unsatisfactory. NGL recently introduced new plant modifications and processes to improve reactor gas chemistry control. Recent chemistry data have shown that chemistry control has been significantly improved and are now in-line with the rest of the AGR fleet.

Conclusions

I consider that none of the results of the inspections or dimensional measurements made at this outage challenge the integrity of the graphite core. I therefore consider that NGL has carried out a scope of inspection and trepanning that meets its safety case commitments as described in the relevant outage documentation. However, NGL must ensure that up-to-date QA records for contractors are maintained.

I am satisfied with the quality of the graphite inspections, dimensional measurements and the trepanning and that staff performing these tasks are suitably qualified and experienced.

Based on my inspection and the results of my review, I am satisfied that the LC28 and LC30 requirements have been met. I consider that the Project Assessment Report (PAR) can recommend that consent is given to return Dungeness B Reactor 21 back to service at the end of the periodic shutdown. However, I am making some recommendations to NGL and ONR below. I will write my conclusions and recommendations in a letter to NGL.

Based on the significance of these recommendations and delays in the production of safety case documentation, I have ascribed an AMBER ONR Assessment rating.

Recommendations

- **Recommendation to the ONR Project Inspector:** I have no objection to the subsequent PAR recommending that consent is given to return Dungeness B Reactor 21 back to service at the end of the shutdown.

- **Recommendation to the ONR Project Inspector:** I recommend that the PAR reflects that NGL has a boiler modification programme. I recommend that ONR continues to be involved in discussions and the assessment of the boiler

modifications noting the important relationship with average graphite core weight loss.

- **Recommendation to ONR Graphite and Chemistry Team Leaders:** ONR needs to further consider the effectiveness of the recent gas bypass plant improvements in future site inspections and during Level 4 meetings.

- **Recommendation to ONR Graphite and Fault Studies Team Leaders**: I recommend ONR to assess EC 357719, supporting the graphite weight loss update, and EC 353784, justifying an average core weight loss limit of 10%, before the next DNB R22 periodic shutdown in 2018.

- **Recommendation to NGL Graphite Group Head:** Firstly that an update on the seismic safety case for the graphite core is provided in 2017, demonstrating that stress margins particularly in the key/keyway area are likely to be acceptable and that no control rod obstructions could occur at present. Secondly that NGL should inform ONR of the time necessary to produce a safety case that includes full whole core modelling and associated stress analysis for DNB.

- **Recommendation to NGL Graphite Group Head:** I consider it is essential that the trepanning data are analysed and incorporated in the graphite weight loss database within one year of the R21 periodic shutdown.

LIST OF ABBREVIATIONS

ABDS	Automatic Boiler Depressurisation System
ACWL	Average Core Weight Loss
AR	Assessment Report
BMS	Business Management System
BOPS	Boiler Overfeed Protection System
CCMP	Chemistry Condition Monitoring Programme
EC	Engineering Change
EMIT	Examination, Maintenance, Inspection and Testing
FD6	FEAT-DIFFUSE Version 6
fpyo	full power years of operation
GAP	Graphite Assessment Panel
GTAC	Graphite Technical Advisory Committee
GWL	Graphite Weight Loss
HOW2	(ONR) Business Management System
HSL	Health and Safety Laboratory
IAEA	International Atomic Energy Agency
LC	Licence Condition
NGL	EDF Energy Nuclear Generation Ltd.
NNL	National Nuclear Laboratory
ONR	Office for Nuclear Regulation
PAR	Project Assessment Report
PSR3	Third Periodic Safety Review
QA	Quality Assurance
R21	Reactor 21
R22	Reactor 22
REWI	Reactivity Effects of Water Ingress
RTS	Return-To-Service
SAP	Safety Assessment Principle(s)
SRV	Safety Relief Valve
TAG	Technical Assessment Guide(s) (ONR)

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Annex

1 INTRODUCTION

1. In June 2017, Dungeness B Reactor 21 (DNB R21) was taken off line for the three-yearly periodic shutdown in compliance with Licence Condition (LC) 30. During periodic shutdowns, the licensee, EDF Energy Nuclear Generation Limited (NGL) carries out activities according to their Examination Maintenance Inspection and Testing (EMIT) programme under LC28. One objective of the periodic shutdown is to demonstrate that the condition of the graphite core is in accordance with the relevant safety cases. The present report assesses the adequacy of the graphite core inspections and trepanning activities carried out as part of the 2017 periodic shutdown of DNB R21.

2. As part of its commitments, NGL has prepared and submitted to ONR an Engineering Change (EC) 357719 (Ref. 1), which provides an update at 2016 of the graphite core weight loss for DNB R21. Although I consider some of the implications of this EC in the present assessment, I will carry out a detailed assessment of EC 357719 in a separate report.

3. NGL has also submitted EC 358816 to ONR to support extension of the graphite weight loss limit from the current 8% to 10%. As this work is still being assessed by an ONR Fault Studies specialist, I have considered that the graphite weight loss limit remains 8% for the purpose of my assessment.

1.1 Background

4. 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 (Ref. 2). The ONR Safety Assessment Principles (SAP) (Ref. 3), together with supporting Technical Assessment Guides (TAG) (Ref. 4), have been used as the basis for this assessment.

1.2 Scope

5. The scope of this report covers:

- The adequacy of the graphite core inspections performed by NGL during the periodic shutdown of DNB R21 in compliance with LC 28 and LC 30;
- The assessment of the inspection results and their implications for the structural integrity of the graphite core;
- The summary of the graphite weight loss update at 2016.

6. This Assessment Report (AR) is specific to the nuclear safety implications of the DNB return-to-service (RTS) of the graphite core following the 2017 DNB R21 periodic shutdown. This AR has been written to support a Project Assessment Report (PAR) which documents ONR’s overall view on the adequacy of the RTS.

1.3 Methodology

7. The methodology for the assessment follows HOW2 guidance on mechanics of assessment within the Office for Nuclear Regulation (ONR) (Ref. 5). I am familiar with the ONR safety assessment principles (SAP) and have used them in forming my conclusions.

2 ASSESSMENT STRATEGY

8. The intended assessment strategy is set out below. This identifies the scope of the assessment and the standards and criteria that have been applied.

2.1 Standards and Criteria

9. The relevant standards and criteria adopted within this assessment are principally the SAPs (Ref. 2), internal ONR Technical Assessment Guides (TAG) (Ref. 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. National and international standards and guidance have been referenced where appropriate within the assessment report. Relevant good practice, where applicable, has also been cited within the body of the assessment.

2.2 Safety Assessment Principles

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

2.3 Technical Assessment Guides

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

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

2.4 Use of Technical Support Contractors

12. In reaching my conclusions I have taken advice from a number of our contractors, including members of the Graphite Technical Advisory Committee (GTAC) and statisticians from the Health and Safety Laboratory (HSL). I have referenced various notes of meetings or post meeting statements as appropriate.

2.5 Integration with Other Assessment Topics

13. NGL’s proposed extension of the graphite weight loss limit to 10% is currently being considered in a separate assessment by an ONR Fault Studies specialist.

3 LICENSEE'S SAFETY CASE

3.1 Activities performed during the periodic shutdown

3.1.1 Graphite Inspections

14. As for all the Advanced Gas-cooled Reactors (AGR) periodic shutdowns, NGL performs activities in three areas relevant to the graphite. These are visual inspections, dimensional measurements and trepanning. Only the visual and dimensional measurements are analysed before the RTS. The trepanned samples are removed from the site for measurements to be taken and results are not available in the short term.

15. DNB has control rod channels that are 'on-lattice' i.e. they are the same shape and size as the octagonal fuel channel bricks. This is a difference to the other AGRs and means that the DNB trepanning machine can be deployed down control rod channels as well as fuel channels. The trepanned data obtained from these control rod channels will be useful to improve the understanding of graphite weight loss at DNB and across the AGR fleet.

16. During this outage, NGL inspected and measured the dimensions of seven channels, five of which were fuel channels and two were control rod channels.

3.1.2 Inspection Results

17. The results of the visual inspections and the dimensional measurements have been sentenced by the DNB graphite assessment panel (GAP). The minutes of the GAP are normally referenced by the RTS safety case that NGL prepares to summarise the results of inspection of graphite components.

18. No new cracks were found that challenge the safety case. Compared to other AGRs, very few cracks have been reported during the operating lifetime at DNB. This result was not unexpected given the low core burn-up at DNB compared to other AGRs. In NGL's view, the dimensional measurements conducted during the outage do not challenge the safety case.

3.1.3 Graphite Trepanning

19. Prior to the shutdown, a discussion was held with NGL to review the inspection strategy. I have summarised the outcome of this discussion in Ref. 6. The main point concerned the azimuthal trepanning angle from which graphite samples are retrieved. Until now, trepanning had been carried out at an angle of 22.5° (from the north position). During the R21 2017 shutdown, samples have been trepanned from various angles, as shown in the annex of this report. NGL's opinion is that the analysis of these samples will improve the understanding of the methane conditions within the graphite bricks.

20. During the shutdown, graphite trepanning took place on all the inspected fuel channels, except for one (S11) which was planned for visual inspection only. The details of the planned inspections are shown in the annex to this report.

21. Towards the end of the trepanning campaign, NGL experienced some problems with the teeth of the tool. This problem is not unusual as wear grinds out some of the teeth. However, the trepanning tool could not be easily retrieved from the core and required the use of the emergency retract mechanism to recover the trepanning cutter.

22. NGL notified me that 44 graphite samples could be retrieved from the core during the shutdown, out of the 48 originally planned samples. All the planned samples have been trepanned from the fuel channels, where core burn-up is the most significant. I

have enquired about the failure of the trepanning tool in my e-mail to DNB's graphite coordinator (Ref. 7).

23. NGL judged that the time required to decontaminate and replace the tool with a new cutter and a new retract mechanism would exceed the length of the planned shutdown. Since most of the planned samples had been obtained during this shutdown, NGL deemed the number already collected to be acceptable. Therefore, NGL decided not to try and repair the tool during the outage. I discuss this in Section 4.3.

3.2 Graphite Weight Loss (GWL)

3.2.1 GWL Update at 2016

24. NGL has submitted Engineering Change (EC) 357719 (Ref. 1) which provides an update of the GWL at 2016. I do not attempt to provide an extensive review of this EC as part of the present RTS assessment as I will consider this EC in a separate assessment. However, I do comment on the updated graphite weight loss values provided by NGL in Section 4.5.

25. NGL has also sent ONR a letter to summarise the GWL position for DNB (Ref. 8). The statements in this letter are as follows:

- The Active Core Weight Loss (ACWL) for the lead reactor (R22) is conservatively estimated to be 7% at June 2017. The central estimate value of the uncertainty distribution is 5.6%;
- The 8% ACWL limit is conservatively estimated to be reached at ~9,500GWd (September 2019);
- When the conservative estimate of 8% ACWL is reached, the corresponding central estimate value of the uncertainty distribution is 6.4%.

26. The statements above represent NGL's view. I will comment on these in Section 4.5.

3.2.2 Average Core Weight Loss (ACWL) limit

27. There are a number of limiting conditions for graphite weight loss. The one of greatest importance for the DNB reactors is a limit set on the ACWL. This limit is set to provide a safety margin against the point where the core could become more vulnerable to a reactivity increase caused by water ingress following a boiler fault (Reactivity Effects to Water Ingress - REWI). The presence of water in the core can increase moderation. As the graphite loses mass with oxidation, the proportionate effect of a particular level of water ingress is greater, hence the need to define a limit.

28. In 2014, NGL increased the ACWL limit from 6.2% to 10% for most limiting faults, except for a reactivity increase caused by water ingress following a boiler fault which is limited by an ACWL of 8% (Ref. 9). The limit is set by a consideration of the boiler tube integrity and the possible effects that a boiler tube leak could have on the core reactivity.

29. NGL has now recently submitted EC 358816 to ONR to justify an ACWL limit of 10% (Ref. 10). According to NGL, this limit is conservatively estimated to be reached at 11,250GWd (December 2023) at which time the corresponding central estimate value of the uncertainty distribution is ~8%. EC 358816 has not yet formally been accepted by ONR and is currently being reviewed by an ONR Fault Studies inspector.

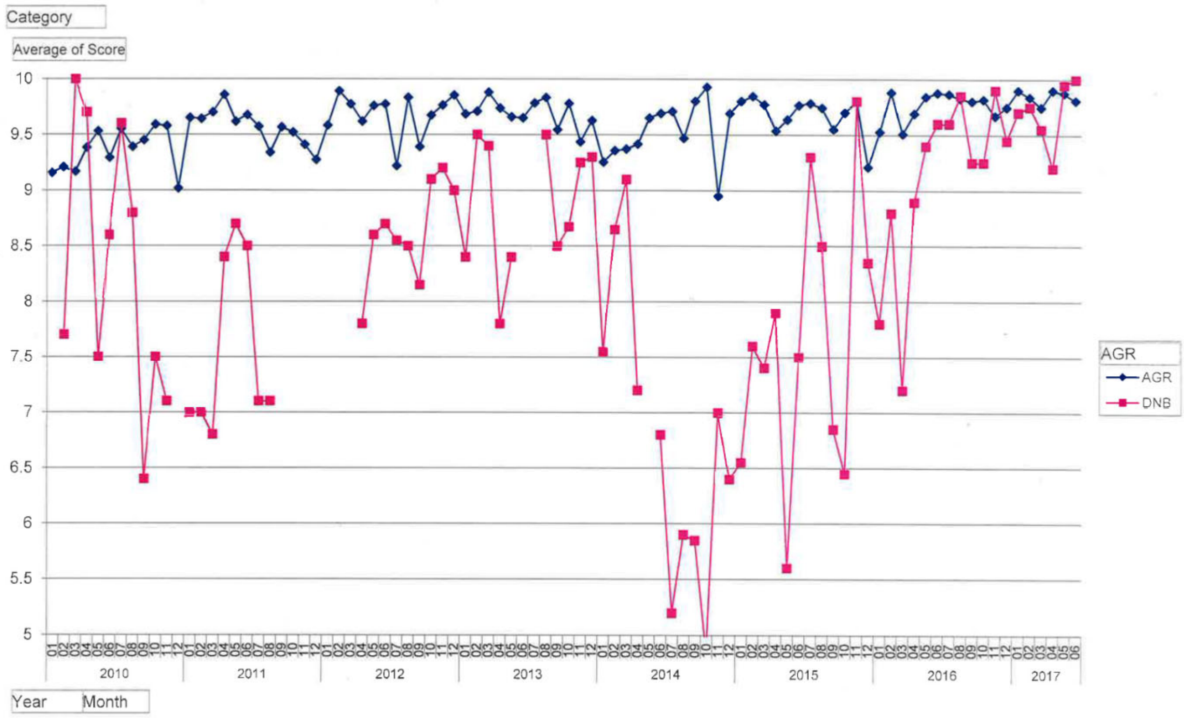
3.3 Gas Chemistry

30. The GWL forecasts involve an assumption about future graphite oxidation rates derived from NGL's graphite oxidation model FEAT-DIFFUSE 6 (FD6). Oxidation rate is dependent, in part, on control of the gas chemistry, particularly the methane

concentration. However, operational requirements mean there is competition between the control of methane and water concentration in the primary gas coolant. Water content must be kept below a certain level to minimise corrosion effects on the steel components, particularly the boilers. On the other hand, methane must be added to the gas to minimise the effects of radiolytic oxidation on the graphite core. In the ionising environment of the core, part of the methane is decomposed into water. Therefore, there is a direct correlation between methane concentration and water concentration in the primary gas coolant.

31. Excess water content in the gas coolant can be removed by drying towers within the gas by pass plant. However, on occasion this has not been sufficient to reduce the water content to acceptable levels. Therefore, to further reduce the water content the station has resorted to reducing the methane concentration in the coolant gas until acceptable water content levels are reached.

32. The station chemist presented Chemistry Condition Monitoring Programme (CCMP) data for DNB primary gas chemistry control over the period from 2010 to 2017 which is shown below.



33. This figure shows a review of the ‘chemistry performance’ (as shown in the y-axis) of DNB against the rest of the AGR fleet. Although CCMP is judged to be a fairly high-level representation of the station chemistry, NGL uses this approach to benchmark each station using a ‘score’. This score takes into account several factors such as gas chemistry control and plant reliability.

34. Station highlighted that recent improvements (2016 onwards) in chemistry control was largely a result of drier tower improvements, with earlier extended periods of poor compliance a result of operation with a single drier tower. Recent bypass plant improvements had resulted in methane and carbon monoxide control improvements on R22 over the previous 6 months (Ref. 11).

35. Historically, there have been a number of issues in the bypass plant which had resulted in challenges in maintaining chemistry control within targeted levels. NGL’s opinion is that issues with the gas bypass plant have impaired gas chemistry control.

NGL stated that improvements to the gas bypass plant and to the chemistry procedures should improve the performance at DNB.

36. To improve chemistry control, NGL has just rolled out a new procedure to record the core burn-up and calculate the actual weight loss over the period (Ref. 12). This document requires that the core burn-up and other plant parameters such as methane concentration and carbon monoxide concentration are recorded daily. An equation is used to calculate the actual graphite oxidation condition corresponding to the gas chemistry conditions. NGL stated that this procedure will enable them to improve monitoring of the core conditions.

3.4 Boiler Improvements

37. NGL has planned boiler improvements to ensure a consolidated long-term safety case for the DNB boilers. Three most significant plant modifications are:

- An Automatic Boiler Depressurisation System (ABDS) to minimise water ingress from a detected boiler tube leak;
- A Boiler Overfeed Protection System (BOPS) to detect a boiler overfeed fault during post-trip and shutdown boiler conditions and automatically isolate the feed supplies to the affected boiler;
- A Reactor Safety Relief Valve Isolation System to detect Safety Relief Valve (SRV) discharge and failure to reseat after an overpressure event and provide the means to remotely isolate (shut) the faulty SRV by operator action, thereby preventing reactor depressurisation.

38. The ABDS, BOPS and Reactor Safety Relief Valve Isolation System are planned for implementation at the 2018, 2020 and 2021 periodic shutdowns. NGL provided details of the programme to ONR in Ref. 13 and Ref. 14. I have discussed these changes with the Nuclear Safety Group at DNB, which I discuss in Section 4.6.

4 ONR ASSESSMENT

39. This assessment has been carried out in accordance with HOW2 guide NS-PER-GD-014, “Purpose and Scope of Permissioning” (Ref. 2).

4.1 Scope of Assessment Undertaken

40. My intervention on the NGL graphite core inspection activities took place during the periodic shutdown of DNB R21 (Ref. 15). I focused on NGL’s arrangements for the graphite core inspection, trepanning and on the primary coolant chemistry control.

41. I visited DNB during the shutdown and met with NGL staff to discuss the results that were available at the time of the inspection. I have completed an intervention report which discusses the details of my findings. This report can be found in Ref. 15.

4.2 Graphite Inspections

42. At the time of my visit, the licensee had completed all 5 of the planned fuel channel inspections. These inspections are detailed in the annex of this report. Two control rod channels had not been inspected at the time of my visit, but were completed later during the shutdown.

43. I have considered the results of the inspections, as discussed at the GAP and recorded in the GAP minutes (Ref. 16). I consider the GAP minutes are an adequate formal statement of the findings. The dimensional measurements made do not challenge the safety case. The results of this inspection were in-line with my expectations for the shutdown.

44. I have requested from NGL a draft EC for the RTS of DNB R21 that I have received in Ref. 17. With respect to graphite, I am satisfied that this document gives a sound account of the inspections having been carried out during the periodic shutdown. However, I have not seen the final version of this EC at the time of my writing. I therefore recommend that the project inspector confirms that the EC is complete and has been subject to an Independent Nuclear Safety Assessment (INSA) before reaching a decision as to whether to recommend that consent to return-to-service is granted.

45. Overall, I judge that NGL has met its commitments in terms of the activities performed at DNB for the graphite. I consider that none of the inspection findings arising from activities performed at the site leads to objections to the granting of consent to return-to-service.

4.3 Graphite Trepanning

46. At the time of my visit of the plant, trepanning was being carried out in the first fuel channel selected for trepanning by NGL (Channel I12) and the 12th sample was being retrieved from the core.

47. NGL contracts out the graphite trepanning tasks to Cavendish Nuclear for all of its AGR reactors. During my discussion with the graphite inspection coordinator, I have established that the Quality Plan was appropriate and I have witnessed that this Quality Plan was being used by staff performing the trepanning operations on the pile cap. I am therefore satisfied that the quality process was being adequately followed. A copy of the Quality Plan can be found in Ref. 18.

48. I have also checked that NGL’s staff training records are up-to-date and consistent with the task requirements. However, NGL could not produce the ‘Suitably Qualified and Experienced Person’ (SQEP) records for the Cavendish Nuclear staff involved in the trepanning activities on the day of my visit. The operators seemed to be sufficiently

knowledgeable and experienced for this task. However, I consider that NGL should have obtained a copy of the training records of the contractors. NGL has subsequently provided me with the records I had requested in an e-mail (Ref. 19).

49. In my opinion, the number of trepanned samples having been retrieved from the core during this shutdown is sufficient and the additional risks associated with decontamination and tool repair did not justify attempting a repair at the time of the shutdown.

4.4 Gas Chemistry

50. I noted an improving trend for DNB, with recent performance approaching that for the rest of the fleet. While some fluctuations were still apparent for recent data associated with DNB R21 (Ref. 11), station expressed an expectation that similar improvements would be achieved from improvements made during the current shutdown.

51. I noted that the procedure to assess the core burn-up and the graphite weight loss is fairly detailed. I consider that the implementation of a daily requirement to evaluate the graphite weight loss calculation is positive.

52. However, although NGL showed me a procedure that they are intending to use in the future (Ref. 20 and Ref. 21), this form has only been recently introduced and has not been used yet. Further inspections during the R22 periodic shutdown in 2018 will need to examine how this form has been used and whether this process has brought an improvement to primary gas chemistry control. It is proposed that ONR inspections carried out during this periodic shutdown would include both graphite and chemistry specialists. I have made a request to the DNB site inspector to check that this process is correctly being implemented after the RTS of the reactor (Ref. 22). I will update the ONR Issues database (No. 1737) to reflect this.

4.5 Active Core Weight Loss (ACWL)

53. ONR wrote to NGL in Ref. 23 to request for the graphite weight loss update documents required before the periodic shutdown and the EC justifying a 10% limit. These documents have been received with some delays and ONR will assess these documents before the next R22 outage in 2018.

54. Ref. 8 indicates that the graphite weight loss is currently estimated to be around 7% at the time of the periodic shutdown of R21. I estimate that the rate of increase in ACWL is ~0.5% per year (Table 2 of EC 357719). I am therefore confident that the current ACWL limit of 8% will not be reached before the start of the DNB R22 periodic shutdown.

55. To calibrate the models used in the safety case, I consider it is essential that the trepanning data are analysed and incorporated in the graphite weight loss dataset within a year of the R21 periodic shutdown. I am adding a recommendation to this effect. I will also organise a Level 4 meeting with NGL to discuss the recent changes to the models.

4.6 Boiler Improvements

56. The risk of Boiler Tube Failures (BTFs) is predicted to increase in the 9%Cr section of the boilers as a result of progressive degradation mechanisms. Tubes may fail during normal operation conditions or as a result of an overpressurisation during shutdown. The consequence of a BTF could lead to a significant water ingress in the reactor core, which could potentially challenge the shutdown and/or the hold-down capability of the reactor. BTF could also lead to an overpressurisation of the reactor pressure vessel and loss of post-trip cooling capability.

57. To consider these risks, NGL has proposed boiler modifications which would allow the termination of BTFs early and minimise the risks associated with steam-water ingress in the reactor. I therefore view these changes as being essential to ensure the long-term nuclear safety of the plant. ONR is currently actively involved in the boiler improvement programme and is pursuing this issue in a specific project. I am adding a recommendation in this AR to reflect this.

4.7 Concern from the PSR3

58. NGL has recently submitted its third periodic safety review (PSR3) for DNB and I will report my assessment of this PSR3 in a separate report. However, I have noted what initially appeared to be a deficiency in the DNB safety case which I would like to report here.

59. The seismic analysis in Ref. 24 was originally produced as part of the PSR1 to support operation until 2007, when the reactor was estimated to experience 13.6 full power years of operation (fpyo). This analysis is referred to in the seismic safety case review carried out as part of the PSR3 (Ref. A.11.9 in Ref. 25).

60. Ref. 24 considers a 10^{-4} per annum probability event and a core age of 15fpyo. This corresponds to a core burn-up of 8,546GWd (assuming a reactor thermal power of 1,560MWth as per the analysis in Ref. 24). However, the results of this analysis indicate that, beyond 11.5fpyo (i.e. 6,552GWd), keyway failures could occur in the inner ring of reflector bricks adjacent to the outermost fuelled bricks (Sections 9.3 and 9.5 of Ref. 24). Further failures could also result but these were not considered in the analysis due to the computer modelling limitations at the time. Based on Table 2 of Ref. 1, the core burn-up at the end of 2017 is ~8,500GWd for R21. This is above the value of 6,552GWd for which failures of the core restraint were anticipated from the finite element model.

61. This result therefore prompted me to request further information from NGL concerning the validity of the seismic analysis (see Ref. 26). In addition, I have proposed that new safety case documents are produced. This request is available in Ref. 27.

62. As a response, NGL has provided more detailed explanations and a report (Ref. 28) produced in 1999. The methodology used for the seismic analysis in this report is based on the relative deformation of the control rod channel, rather than from the stress-to-strength ratio, as in the original report in Ref. 24. Although Ref. 28 only considers operation up to 15fpyo (i.e. 2017), the assessment reports a significant margin for entry of the control rod channels. Moreover, this analysis shows that this margin increases with core age.

63. I note that these assessments are now quite dated and should be revised at the earliest opportunity. However, Ref. 27 and Ref. 28 provide a margin at 15fpyo (i.e. 2017) of 25. This margin is calculated as the ratio between the maximum deformation of the column during a 10^{-4} seismic event and the shape of the control rod that would result in three-point contact in the channel. A margin of unity and below corresponds to control rod insertion impediment.

64. In my view, Refs. 27 and 28 provide a reasonable margin against control rod obstruction during a seismic event. I therefore consider that the seismic justification provided in these references is sufficient for the return-to-service of R21 after the periodic shutdown until an update can be provided at the end of 2017. I make a recommendation to NGL to this effect and I will update the ONR Issues Database.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

65. I am satisfied with the quality of the graphite inspections, dimensional measurements and the trepanning and that staff performing these tasks are suitably qualified and experienced.

66. I consider that none of the results of the inspections or dimensional measurements made at this outage challenge the integrity of the graphite core. I therefore consider that NGL has carried out a scope of inspection and trepanning that meets its safety case commitments as described in the relevant outage documentation. However, NGL needs to ensure that up-to-date QA and training records for contractors are kept maintained and available. I have dealt with this recommendation in my e-mail to NGL in Ref. 29.

67. Based on my inspection and the results of my review, I am satisfied that the LC28 and LC30 requirements have been met. I consider that the Project Assessment Report (PAR) can recommend that consent is given to return Dungeness B Reactor 21 back to service at the end of the periodic shutdown. However, I am making some recommendations to NGL and ONR below.

5.2 Recommendations

- **Recommendation to the ONR Project Inspector:** I have no objection to the subsequent PAR recommending that consent is given to return Dungeness B Reactor 21 back to service at the end of the shutdown.

- **Recommendation to the ONR Project Inspector:** I recommend that the PAR reflects that NGL has a boiler modification programme. I further recommend that ONR continues to be involved in discussions and the assessment of the boiler modifications noting the important relationship with average graphite core weight loss.

- **Recommendation to ONR Graphite and Chemistry Team Leaders:** ONR needs to further consider the effectiveness of the recent gas bypass plant improvements in future site inspections and during Level 4 meetings.

- **Recommendation to ONR Graphite and Fault Studies Team Leaders**: I recommend ONR to assess EC 357719, supporting the graphite weight loss update, and EC 353784, justifying an average core weight loss limit of 10%, before the next DNB R22 periodic shutdown in 2018.

- **Recommendation to NGL Graphite Group Head:** Firstly that an update on the seismic safety case for the graphite core is provided in 2017, demonstrating that stress margins particularly in the key/keyway area are likely to be acceptable and that no control rod obstructions could occur at present. Secondly that NGL should inform ONR of the time necessary to produce a safety case that includes full whole core modelling and associated stress analysis for DNB.

- **Recommendation to NGL Graphite Group Head:** I consider it is essential that the trepanning data are analysed and incorporated in the graphite weight loss database within one year of the R21 periodic shutdown.

68. I will create a new entry on the ONR Issues database to reflect these recommendations. I will also write to NGL to inform them of my conclusions and recommendations.

5.3 ONR Assessment Rating

69. On the basis of the findings above and the late delivery of submissions including Ref. 1, I consider that an AMBER IIS rating (Ref. 30) is justified.

6 REFERENCES

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

4. Technical Assessment Guide (TAG) 29: Graphite Reactor Cores. July 2014. http://www.onr.org.uk/operational/tech_asst_guides/ns-tast-gd-029.pdf

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

6. ONR-OFD-CR-17-106 - Graphite Trepanning & Inspection Strategy at the 2017 DNB R21 Periodic Shutdown - 12 May 2017 (TRIM 2017/193140).

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9. EDF NGL - Dungeness B - Unique Nos GEN 32509 N - NSC Supporting Paper - NP/SC 7467 ADD 2 – EC No 351774 - Extension to the Safety Case for the Reactivity Effects of Boiler Tube failure Faults - April 2014 (TRIM 2014/159424).

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11. DNB R22 Methane and Carbon Monoxide Control – January to June 2017 (TRIM 2017/272460).

12. Dungeness B Power Station: Departmental Instruction – DNB/TNS/000/004, Revision 018, September 2015, Routine Assessment of Reactor Operating Conditions and Provision of Reactor Trimming Advice (TRIM 2017/225527; Ref. B2).

13. DNB Boiler Mods, E-mail from [redacted], 07/02/2017 (TRIM 2017/58071).

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16. GAP Reports. DNB R21 2017 Inspections (TRIM 2017/313176).

17. RE: DNB R21 Return-To-Service EC, e-mail from [redacted] to [redacted], 23/08/2017 (TRIM 2017/325817).

18. E/PROC/ENG/BI/758 Rev. 016, Trepanning of Graphite Core Using the Trepanning Tool Unit at Dungeness B, June 2017 (TRIM 2017/287580).

19. Additional Cavendish SQEP Information – DNB, E-mail from [redacted], 24/07/2017. (TRIM 2017/287958).

20. Departmental Instruction DNB-TNS-000-004 Rev. 018, DNB Routine Assessment of Reactor Operating Conditions, September 2015. (TRIM 2017/318445).

21. DNB-F-TNS-3656, DNB Core Life Monitoring Data. (TRIM 2017/318502).

22. DNB Core Life Monitoring Process, E-mail from [redacted] to [redacted], 17/08/2017. (TRIM 2017/318597).

23. 'DNB average core weight loss', E-mail from [redacted] to [redacted] and [redacted], 28/03/2017. (TRIM 2017/141184).

24. EPD/DNB/REP/0162/96 Issue 1, Seismic Assessment of the Dungeness B Reactor Cores while On-load, October 1997 (TRIM 2017/288958).

25. DAO/REP/JIEF/076/DNB/16 Revision 000. Dungeness B. Periodic Safety Review 3. Supporting Information for Safety Factor 7: Hazards Analysis. July 2016. (TRIM 2017/23610).

26. 'DNB Seismic Safety Case Summary and Current Understanding and Views from [redacted]'. E-mail from [redacted] to [redacted]. 21/08/2017 (TRIM 2017/321804).

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28. 'Seismic Capacity o Dungeness B Control Rods'. Report No 256-04-R-02 Issue 1. 26 October 1999 (TRIM 2017/323575).

29. 'RE: Dungeness visit: 11 and 12 July', E-mail from [redacted] to [redacted], 24/08/2017 (TRIM 2017/326538).

30. ONR Assessment Rating Guide Table – TRIM 2016/118638.

TABLE

Table 1 Relevant Safety Assessment Principles (SAPs) 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 (SAPs) 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.

Office for Nuclear Regulation

Annex

Dungeness B R21 - Graphite Sampling Trepanning Angles in 2017

Having considered the available channels, we are proposing the following:

DNB R21	**I12** Fuel 1	**L17** Fuel 2	**N09** Fuel 3	**R14** Fuel 4	**S11** Fuel 5*	**C15** CR1	**H13** CR2	Region
Layer 12								not sampled
Layer 11								
Layer 10			337.5 (292.5)	247.5 (180)			22.5	axial spread
Layer 9	22.5 + 90	112.5 + 180				67.5		
Layer 8	22.5 + 90	112.5 + 180	337.5 (292.5)	247.5 (180)		67.5	22.5	
Layer 7	22.5 + 90	112.5 + 180	337.5 (292.5)	247.5 (180)		67.5	22.5	peak-rated layers
Layer 6	22.5 + 90	112.5 + 180	337.5 (292.5)	247.5 (180)		67.5	22.5	
Layer 5	22.5 + 90	112.5 + 180	337.5 (292.5)	247.5 (180)		67.5	22.5	
Layer 4	22.5 + 90	112.5 + 180				67.5		axial spread
Layer 3			337.5 (292.5)	247.5 (180)			22.5	
Layer 2								not sampled
Layer 1								
Totals	12	12	6 (12)	6 (12)	0	6	6	**48**

All samples to be taken from the lower position in the brick.
(Bracketed angles are alternative pairs if it is not possible to obtain two samples from any of the planned paired channels)
*Channel Bore Measurement Inspection only (included for completeness).

[redacted]
Graphite Branch
10/04/17