



Heysham 2 / Torness Graphite Core Safety Case

**Agreement under arrangements made under License Condition LC22(1) to NP/SC 7663:
Post-stress reversal graphite core safety case**

Project Assessment Report ONR-OFD-PAR-18-016
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EXECUTIVE SUMMARY

Agreement under arrangements made under Licence Condition LC22(1) to NP/SC 7663: Post-stress reversal graphite core safety case.

Permission Requested

Licence Condition 22 (1) requires the licensee to make and implement adequate arrangements to control any modification (or experiment) carried out on any part of the existing plant or processes which may affect safety. This permission (an Agreement) is granted under derived powers through these arrangements.

In accordance with its arrangements made under Licence Condition 22(1), EDF Nuclear Generation Ltd (NGL) has requested that ONR issue an agreement to NP/SC 7663, the graphite core safety case covering post-stress reversal operation at Heysham 2/Torness (HY2/TOR).

Background

The licensee produced a programme of safety case development which follows the three stages of the graphite core in the active regions of the AGRs: (i) shrinkage to a minimum, (ii) followed by swelling and (iii) keyway root cracking (KRC) towards the end of life of the station. NP/SC 7663 covers the intermediate period that is considered to occur after the graphite bricks have experienced stress reversal, but before the initiation of KRC. In NP/SC 7663, stress reversal and onset of KRC in the bricks subjected to the highest fluence were expected for a core burn-up of 14.2TWd and 16.0TWd respectively, i.e. in December 2018 and 2022, at the time of the safety case production.

Under its own arrangements, the licensee requested ONR's agreement or acknowledgement of NP/SC 7663 to support the operation of the HY2/TOR graphite reactor cores beyond the point of stress reversal, up to the onset of KRC.

Assessment and inspection work carried out by ONR in consideration of this request

As a graphite specialist inspector within ONR, I have carried out the review of the claims, arguments and evidence in safety case NP/SC 7663. There was no involvement from other specialisms within ONR since the safety case is not related to other disciplines.

Matters arising from ONR's work

I am broadly satisfied with the claims, arguments and evidence laid down within the Licensee's safety case. ONR's assessment report has identified a number of areas to be addressed by NGL which will be monitored by ONR through a Regulatory Issue.

Conclusions

I am satisfied with the claims, arguments and evidence laid down within the safety case. It is my opinion that NGL have provided sufficient evidence to adequately demonstrate that safety case NP/SC 7663 is acceptable and can be implemented by NGL.

Recommendation

It is recommended that a Licence Instrument is issued to EDF Energy Nuclear Generation Limited for Agreement to the implementation of the graphite core safety case at HY2/TOR as presented in NP/SC 7663 proposal 03.

LIST OF ABBREVIATIONS

AGR	Advanced Gas-cooled Reactor
ALARP	As Low As Reasonably Practicable
CCCA	Core Component Condition Assessment
DTA	Damage Tolerance Assessment
HOW2	(Office for Nuclear Regulation) Business Management System
HY2	Heysham B Power Station
KRC	Keyway Root Cracking
LC	Licence Condition
ONR	Office for Nuclear Regulation
NGL	EDF Nuclear Generation Ltd
PAR	Project Assessment Report
SACR	Super Articulated Control Rods
SAP	Safety Assessment Principle(s)
TAG	Technical Assessment Guide (ONR)
TOR	Torness Power Station

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1 PERMISSION REQUESTED

1. This Office for Nuclear Regulation (ONR) Project Assessment Report (PAR) has been produced in accordance with ONR's HOW2 guide – Purpose and Scope of Permissioning [1]. This PAR records regulatory views and judgements in consideration of EDF Energy Nuclear Generation Limited's (NGL's) request for Agreement under Licence Condition (LC) 22(1) of the Heysham 2 (HY2) / Torness (TOR) Graphite Core Safety Case. The assessment was carried out in accordance with the Technical Assessment Guide (TAG) guidelines in [2].

2 BACKGROUND

2. The reactor core of Advanced Gas-cooled Reactors (AGRs) is made up of a large number of graphite bricks used as a moderator, structural component and a neutron reflector. As graphite is irradiated in the reactor, it first experiences a period of dimensional shrinkage due to the internal structure of graphite. As it is subjected to a higher neutron dose, the bore of the bricks initially shrinks more rapidly than its outer sections. This produces internal stresses and dimensional changes within the bricks, which develop as tensile at the bore and compressive on the outside section.
3. As the brick accumulates increasing irradiation fluence, due to the internal microstructure of graphite, the stresses at the bore of the brick reverse from tension to compression. This phenomenon is described as the stress-reversal stage of the brick and therefore depends on the level of irradiated dose accumulated in the brick. Beyond the point of stress reversal, the tensile stresses in the outer sections of the bricks continue to increase until a point of failure which is expected to initiate from the keyways since these act as a stress concentrator. This type of cracking is known as keyway root cracking (KRC) and is expected to be one of the limiting degradation mechanisms of the core.
4. The licensee has produced a large programme of safety case development, backed by continuing research, to justify continued operation. NGL sees the need for three safety cases for each pair of power stations throughout their lives. Safety cases have been prepared or are at the planning stage to cover the graphite-moderated cores of the NGL AGR power stations through stages of their lives:
 - operation before stress reversal;
 - operation after stress-reversal and before KRC;
 - operation beyond onset of KRC.
5. The three stages above follow the pattern of dimensional change shown by the graphite in the active regions of the AGR reactor cores: shrinkage to a minimum followed by swelling and KRC towards the end of life of the station. NP/SC 7663 covers the intermediate period that is considered to occur after the graphite bricks have experienced stress reversal, but before the initiation of KRC. In NP/SC 7663, stress reversal and onset of KRC in the bricks subjected to the highest fluence were expected at the end of 2018 and in 2022 respectively at the time of the production of the third proposal of the safety case.
6. Under its own arrangements, the licensee requested ONR's agreement or acknowledgement of NP/SC 7663 [3] and [4] to support the operation of the HY2/TOR graphite reactor cores beyond the point of stress reversal, up to the onset of KRC.

3 ASSESSMENT AND INSPECTION WORK CARRIED OUT BY ONR IN CONSIDERATION OF THIS REQUEST

7. As an ONR graphite specialist inspector, I carried out an assessment of NP/SC 7663 reported in my assessment report in [5].
8. The work undertaken by ONR can summarised as follows:
 - To review the production and content of the safety case;
 - To assess the adequacy of any recommendations made by the licensee as a result of the reviews it has conducted;
 - To identify any additional issues or site system shortfalls against modern standards;
 - To decide upon the suitability of the submission and to agree an improvement programme to address any significant issues.

4 MATTERS ARISING FROM ONR'S WORK

9. NP/SC 7663 is supported by six claims referred to as the Core Component Condition Assessment (CCCA) claim, the Damage Tolerance Assessment (DTA) claim, core inspections, monitoring, consequences assessment and As Low As Reasonably Practicable (ALARP) plant modification. The main areas of focus and discussion during this assessment were to confirm the adequacy of NGL's arguments and evidence supporting the six claims of the safety case.
10. All these activities are described within and referenced in my assessment report [5]. Overall, I judge that the arguments presented in NP/SC 7663 are reasonable. From the assessments I sampled, I am of the opinion that ONR should not object to operation of the reactors within the period delimited by the safety case, up to the onset of KRC.

5 CONCLUSIONS

11. I conclude that although there are several areas for continuing monitoring and review by ONR, the claims, arguments and evidence presented in the safety case are broadly acceptable. From the assessments I sampled, I am of the opinion that ONR Agrees the implementation of the safety case, described in NP/SC 7763: Heysham 2 / Torness Graphite Core Safety Case.

6 RECOMMENDATIONS

12. Based on the findings presented in this PAR, I recommend that ONR gives Agreement to EDF NGL to implement the safety case, described in NP/SC 7763: Heysham B / Torness Graphite Core Safety Case.
13. I have made the following recommendations in the Assessment Report [5]:

To the ONR Superintending Inspector:

- Recommendation 1: Overall, I judge that the arguments presented in NP/SC 7663 are broadly acceptable. From the assessments I sampled, I am of the opinion that ONR should provide agreement to safety case NP/SC 7663 revision 3.

To NGL:

- Recommendation 2: NP/SC 7663 acknowledges that 'further work is needed to set down the safety case for operating with large numbers of large brick fragments and pieces of debris. Without such a justification, operation with many singly axially cracked bricks open by more than 3.6mm is not fully

justified.’ NGL should inform ONR when the results of this work are available and how these results inform the assumptions regarding singly-cracked brick opening.

- Recommendation 3: The estimates for the number of cracks from the statistical analysis should be estimated at the 99.9th percentile confidence level.
- Recommendation 4: NGL needs to demonstrate that extrapolation of the graphite weight loss calculations beyond the available trepanned data is conservative.
- Recommendation 5: The GCORE analyses are likely to have been carried out before the graphite weight loss profile was found to be increasing towards the back of the bricks in 2016. NGL needs to use the more recent forecasts of weight loss and update the graphite properties in the models in order to appropriately model the graphite behaviour.
- Recommendation 6: NGL should update the Damage Tolerance Assessment (DTA) to include real-time damage analysis in the models and consider recent experience with the Hinkley Point B and Hunterston B safety case.
- Recommendation 7: NGL needs to improve the current fuel channel inspection regime and consider whether it is ALARP to develop an inspection tool capable of measuring the bore diameter of the control rod channels in advance of onset of KRC. NGL also needs to demonstrate how the bore diameter measurements are compared to models.
- Recommendation 8: NGL should consider implementing an upgrade to the secondary and the tertiary shutdown systems to supply both reactors and in the event of a 10^{-4} p.a. seismic event before the onset of KRC.

The recommendations above will be communicated to the licensee in a letter and a new Regulatory Issue will be raised to capture them. Progress will be monitored as part of ONR’s normal regulatory activity.

7 REFERENCES

1. *ONR HOW2 Guide - Purpose and Scope of Permissioning - NS-PER-GD-014 Revision 4*. July 2014. <http://www.onr.org.uk/operational/assessment/index.htm>
2. Graphite Reactor Cores NS-TAST-GD-029 Revision 3, ONR, July 2014.
http://www.onr.org.uk/operational/tech_asst_guides/index.htm
3. Torness - TOR 50625 R - Request for Acknowledge or Agreement under arrangements made under Licence Condition 22(1) - NP/SC 7663 Graphite Core Safety Case - 15 August 2018. TRIM 2018/277886.
4. EDF - NSL/HYB51094R - NP/SC 7663 Heysham 2 Power Station: Graphite Core Safety Case - 31 August 2018. TRIM 2018/286435.
5. ONR Assessment Report, Structural Integrity Consideration of Post-Stress Reversal Graphite Core Safety Case NP/SC 7663, ONR-OFD-AR-18-019, Revision 0, August 2018. TRIM 2018/218089.