Office for Nuclear Regulation

ASSESSMENT REPORT			
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Project:	Torness Reactor 2 2018 Periodic Shutdown		
Site:	Torness		
Title:	Torness Reactor 2 2018 Periodic Shutdown: Structural Integrity Assessment of the Graphite Core Inspection Findings		
Nuclear Site Licence No:	Sc.14		
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ONR Assessment Rating (Mandatory): *(Rating should be based on licensee's original safety case submission)*	GREEN		
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‡ *Hard-copy of document signed-off, TRIM version updated with authors / approver / acceptor names and dates and record finalised*

Operating Facilities Division

Torness Reactor 2 2018 Periodic Shutdown – Assessment of the results of the Graphite Core Inspections

Assessment Report ONR-OFD-AR-18-051
Revision 0
08 NOVEMBER 2018

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EXECUTIVE SUMMARY

During the 2018 Torness Reactor 2 periodic shutdown, the graphite reactor core has undergone surveys, as required by the graphite core safety case. The Licensee, EDF Energy Nuclear Generation Limited (NGL), is producing an Engineering Change (EC) 363392 safety case to support the return-to-service of the reactor following the periodic shutdown inspections. EC363392 will summarise the findings of the inspection and claims that these support the overall graphite safety case. As part of Licence Condition 30, I have assessed the inspection evidence that will be used to support the graphite core aspects of the Engineering Change return to service document and compared this with the current graphite safety case and the relevant Safety Assessment Principles. This report presents the conclusions of my assessment of the inspection activities during the periodic shutdown.

During the periodic shutdown, the Licensee carried out visual inspection and bore channel measurements from sixteen fuel channels and visual inspection of one control rod channel. Thirty-five samples were trepanned from the core. This therefore satisfies the requirements from the Maintenance Schedule. The trepanned samples will be analysed in due course to provide some information on the properties of the core. No new defects were found during the inspections of the graphite core. According to the information shared by the Licensee, the measurements from the bore of the fuel channels were within expectations and did not reveal any adverse finding.

During the periodic shutdown, eleven of the sixteen faces of the graphite peripheral wall were inspected, five of which had already been inspected in 2015. Some bricks were found to be cracked, approximately 2.0% of the total number of peripheral bricks. The findings from the re-inspected faces of the peripheral bricks indicate that progress of damage had been slow and insignificant between 2015 and 2018. Overall, the defects observed seem to be uniformly distributed around the core of the reactor, with little evidence of clustering of defects. The findings of the peripheral wall inspections seem to be consistent with previous observations in all four reactors at Heysham 2 and Torness. I therefore consider that the inspection findings appear to be consistent with the safety case and should not prevent the return to service of the reactor.

I carried out an intervention at site during the periodic shutdown. Based on the evidence I sampled during the intervention, the licensee's arrangements concerning the graphite core inspections appeared to be satisfactory at the time.

During the trepanning campaign in the core, one of the trepanning holes was performed in an incorrect orientation, possibly extending into a keyway through the thickness of the brick. NGL will justify the tolerability of this issue within the RTS EC. Therefore, I will review NGL's consideration of this issue when the RTS EC has been produced and I will provide a statement on its adequacy to the project inspector as part of the considerations for the Project Assessment Report (PAR); Recommendation 1.

Apart from the trepanning issue identified during the outage, all other structural integrity aspects of the inspections of the graphite core and the peripheral bricks do not appear to present any impediment to the return to service of Torness Reactor 2 (Recommendation 2).

I have therefore attributed an overall ONR rating of 'green' – no formal action.

Recommendations

To ONR Project Inspector:

- Recommendation 1: An error has been made during the trepanning campaign of the graphite core. I recommend that a decision on this error be considered separately to this Assessment. I will review NGL's consideration of this issue in the RTS EC, which is yet to be produced, and provide a statement on its adequacy to the project inspector as part of the considerations for the PAR.
- Recommendation 2: All other aspects of the inspections of the graphite core and the peripheral bricks do not appear to present any impediment to the return to service of Torness Reactor 2. I recommend that the Project Inspector issues a Licence Instrument for restart of the reactor, following resolution of Recommendation 1.

LIST OF ABBREVIATIONS

AGR	Advanced Gas-cooled Reactor
BMS	Business Management System
CTO	Central Technical Office
CR	Condition Report
EC	Engineering Change
GAP	Graphite Assessment Panel
GBIM	Gas Baffle Inspection Manipulator
GCPT	Graphite Core Project Team
GWd	Giga-Watt day
HOW2	(ONR) Business Management System
HYB	Heysham 2 Power Station
INSA	Independent Nuclear Safety Assurance
LC	Licence Condition
MS	Maintenance Schedule
NCR	Non-Conformance Report
NGL	EDF energy Nuclear Generation Limited
NICIE2	New In-Core Inspection Equipment 2
NNL	National Nuclear Laboratory
ONR	Office for Nuclear Regulation
PAR	Project Assessment Report
PBAP	Peripheral Brick Assessment Panel
PECIT	Prototype Eddy-Current Inspection Tool
R	Reactor
RTS	Return-To-Service
SAP	Safety Assessment Principle(s)
SQEP	Suitably Qualified and Experience Person
TAG	Technical Assessment Guide(s) (ONR)
TOR	Torness Power Station

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1 INTRODUCTION

1. During the 2018 Torness (TOR) Reactor 2 (R2) periodic shutdown, the graphite reactor core has undergone surveys, as required by the Maintenance, Inspection and Testing Schedule (MITS). The Licensee, EDF Energy Nuclear Generation Limited (NGL), is producing an Engineering Change (EC) 363392 (Reference 1) safety case to support the return-to-service of the reactor. The RTS EC document is supplemented by the listings of inspections, assessments and acceptance commentaries from the GAP meeting minutes and presented to INA for formal clearance before submission to ONR. Therefore, assessment of the final graphite core structural integrity inspection results as part of Licence Condition (LC) 30 (3) will be based on the findings presented in the supporting documents of the RTS EC.

1.1 Background

2. NGL's intended scope of the graphite inspections during the periodic shutdown of TOR R2 covered inspections and sampling of fuel channels and inspection of the peripheral shield wall. Inspection of fuel channels has been performed routinely by NGL at all of the Advanced Gas-cooled Reactors (AGR) in the fleet. However, inspection of the peripheral shield wall is unique to TOR and Heysham 2 (HYB) stations as this is a unique design feature of the reactors at these sites. NGL committed to performing inspections of the graphite peripheral shield wall at HYB/TOR as a result of the observation of cracking of peripheral bricks at TOR Reactor 2 (R2) in 2015. The peripheral bricks at HYB R8, TOR R1 and HYB R7 were inspected in 2016, 2017 and 2018 respectively. This periodic shutdown provided the first opportunity to re-inspect the peripheral bricks since their first inspection in 2015. NGL provided justification of continued operation following the discovery of peripheral cracked bricks in EC356536 (Reference 2).

3. ONR recently assessed NP/SC 7663: graphite core post-stress reversal safety case (Reference 3). This safety case justifies operation up to onset of keyway root cracking and up to 14% active core weight loss, i.e. ~2022 according to NGL's graphite property models.

4. The present report assesses the findings of the graphite core inspections of TOR R2 during the 2018 periodic shutdown, as presented in EC363392 and supporting references (Reference 1). 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 4). The ONR Safety Assessment Principles (SAP) (Reference 5), together with supporting Technical Assessment Guides (TAG) (Reference 6), have been used as the basis for this assessment.

1.2 Scope

5. The scope of this report covers the licensee's activities performed during the shutdown associated with the examination and inspection of TOR R2 graphite core and whether RTS is justified. For my assessment, I have taken account of recent developments in the HYB and TOR graphite core safety cases including the claims, arguments and evidence presented in EC 356536 (Reference 2).

1.3 Methodology

6. The methodology for the assessment follows HOW2 guidance on mechanics of assessment within the Office for Nuclear Regulation (ONR) (Reference 7). This assessment has been focussed primarily on the results of the graphite core inspections during the TOR R2 2018 periodic shutdown as detailed in the EC supporting the RTS of the reactor (Reference 1).

2 ASSESSMENT STRATEGY

7. The intended assessment strategy for the assessment of the graphite integrity aspects of the TOR R2 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

8. The relevant standards and criteria adopted within this assessment are principally the Safety Assessment Principles (SAP) (Reference 5), internal ONR Technical Assessment Guides (TAG) (Reference 6), 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

9. The key SAPs applied within the assessment are included within Table 2 of this report.

2.2.1 Technical Assessment Guides

10. The following Technical Assessment Guides have been used as part of this assessment (Reference 6):

- ONR-TAST-GD-029 Graphite Reactor Cores

2.2.2 National and International Standards and Guidance

11. 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

12. N/A.

2.4 Integration with Other Assessment Topics

13. N/A.

2.5 Out of Scope Items

14. 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 TOR R2 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 Graphite Core Project Team (GCPT).

3 LICENSEE'S SAFETY CASE

15. This section provides a summary of the licensee's safety case and the justification for the RTS of TOR R2. I provide my assessment of the graphite inspection findings in relation to the RTS of TOR R2 in Section 4 of this report.

3.1 Core burn-up

16. At the time of the 2018 periodic shutdown, the core burn-up for TOR R2 was 13269GWd (Reference 8).

3.2 Activities performed during the statutory outage

17. Prior to the periodic shutdown, NGL issued the intended scope of inspections for the reactor internals and the graphite core, including the graphite peripheral wall (Reference 9). The activities performed during the outage corresponded to the scope of inspections proposed.

18. Sixteen out of sixteen fuel channels and one control rod channel were visually inspected. Bore measurements were taken from the sixteen fuel channels. Trepanning took place on five channels and thirty-five trepanned samples were produced. The level of inspection is in agreement with the Maintenance Schedule (MS).

19. Remote visual inspections of the peripheral bricks were also performed using the Gas Baffle Inspection Manipulator (GBIM). During the outage, NGL inspected eleven out of sixteen faces of the peripheral walls, five of which had already been inspected in 2015; see Figure 1.

20. Although not an MS requirement, eight fuel channels were inspected using eddy current. NGL will analyse the results from the eddy-current inspections separately. These should provide some information on graphite weight loss distribution and improve the accuracy of NGL's graphite weight loss models.

3.3 Objectives of the graphite core inspections

21. During the TOR R2 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.

22. The assessment compares the findings of the graphite inspection against expectations from the historical data to determine whether they could pose any challenge to the RTS of the reactor.

3.4 Graphite Assessment Panel

23. 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 the TOR Nuclear Safety Group head and attended by Suitably Qualified

and Experienced Persons (SQEPs) from TOR and the Central Technical Office (CTO) in Barnwood. The GAP also includes representatives from the licensee's Independent Nuclear Safety Assurance (INSA) group, who provide oversight and feedback on the process for sentencing inspection results.

24. During the periodic shutdown, the findings from the graphite core inspection are discussed during the GAP meeting. GAP sheets and GAP minutes summarising the graphite inspection findings are produced and endorsed by the GAP members. I consider that the GAP minutes provide a reliable account of the inspection findings during the outage. NGL provided the GAP sheets and minutes of the meetings in Reference 10.

3.5 Peripheral bricks inspections

25. A level 4 meeting was held in January 2018 for NGL to explain recent progress and inspection strategy during the 2018 peripheral bricks inspections (Reference 11). NGL produced EC 356536 (Reference 2) to justify continued operation following the discovery of cracked peripheral bricks. The EC relies on the three following claims:

- claim 1: the consequences of cracking found to date and from a postulated small number of failed bricks is acceptable;
- claim 2: the rate of progression of the cracking is low and therefore degradation to unacceptable levels is not expected with a 3 year inter-outage period;
- claim 3: continued operation of all four reactors is ALARP based upon a strategy of inspections at statutory outages.

26. A Level 4 meeting was held in January 2018 with NGL to discuss their inspection strategy concerning the peripheral bricks during the 2018 HYB R7 and TOR R2 periodic shutdowns (Reference 12). In 2015, 9 of the 16 peripheral faces had been inspected during the TOR R2 periodic shutdown. These inspections revealed 22 cracks in 20 different bricks. During the current periodic shutdown, 11 of the 16 peripheral walls were inspected, 5 of which had been inspected in 2015 (Figure 1).

27. The Peripheral Brick Assessment Panel (PBAP) provides a process similar to the GAP for the inspection of the peripheral bricks at HYB/TOR. When the peripheral brick inspections are carried out, video footage is being recorded and kept in NGL's files. The defects are reported and summarised in Non-Conformance Reports (NCRs). Each NCR is reviewed, discussed and sentenced by the PBAP; see Reference 13. The defects are categorised according to their type and morphology.

28. Prior to the periodic shutdown, NGL issued the acceptance criteria for the inspection findings of the peripheral bricks (Reference 12). When the inspections have been completed, the PBAP reviews the defects against the acceptance criteria to determine whether the inspection findings are consistent with expectations. NGL also produces a 'face map' which shows the different locations of the defects observed (Reference 13). NGL uses the face maps to determine the overall distribution of defects and whether any clustering of defects is apparent.

29. NGL concluded that the findings of the peripheral bricks inspections were consistent with the current safety case and that no further inspection of the peripheral shield wall was required (Reference 13).

4 ONR ASSESSMENT

30. 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

31. The scope of the assessment included a review of the reactor internal proposals, on-site meetings and plant inspections with relevant staff from NGL. In my assessment of the RTS documents provided by NGL, I considered the following items:

- Intervention at site during the periodic shutdown;
- Examination of the graphite core inspection records from the periodic shutdown;
- Examination of the peripheral bricks inspection records from the periodic shutdown.

4.2 Assessment

4.2.1 Site intervention

32. I carried out a site intervention at TOR during the periodic shutdown on 1st October to assess the licensee’s arrangements with regard to the graphite core and peripheral bricks inspections. The activities examined were selected due to their nuclear safety significance and agreed in advance of the visit with station and the site inspector. I reported the conclusions of my intervention in Reference 14.

33. At the time of the intervention, NGL had inspected fifteen fuel channels out of the sixteen required from the MS. During the intervention, I carried out the following activities:

- Confirmation of Maintenance Schedule requirements and progress against them;
- Inspect the core inspection and peripheral bricks inspection equipment;
- Inspect the calibration records of the inspection equipment;
- Inspect the quality of the inspection video footage;
- Inspect the training records of inspection staff.

34. At the time of my intervention on site, the graphite inspections carried out were within expectation and no new cracks had been found in the channels inspected. NGL had completed the inspection of the first five faces of the peripheral wall. NGL presented the findings of the inspection. The defects in the peripheral bricks which had been carried out did not appear to have progressed since in 2015. NGL stated that that the findings were consistent with the assumptions in EC 356536 (Reference 2). I have established that NGL’s staff training records are up-to-date and consistent with the task requirements. The quality plans for the tasks were available and fully up-to-date. From my observations, I concluded that NGL’s LC28 arrangements appeared to be satisfactory.

4.2.2 Graphite core inspections

35. NGL completed the visual inspection of sixteen fuel channels and one control rod channel. No new defects were reported (Reference 10). The bore diameter measurements are consistent with expectations and do not appear to present any adverse trend.

36. Thirty-five trepanned samples were retrieved from the graphite core, which is the target set before the outage. NGL therefore achieved their target for the periodic shutdown.

37. During trepanning, one of the samples was retrieved from an incorrect angle. NGL provided details of the trepanning error and confirmed that the dosimetry conditions would be accounted for during analysis (References 15 and 16). However, one of the trepanning holes was performed in an incorrect orientation, possibly extending into a keyway through the thickness of the brick. NGL will provide justification of why this issue is tolerable within the RTS EC. This has not yet been produced. Therefore, when this EC is produced, I will review NGL's consideration of this issue and provide a statement on its adequacy to the project inspector as part of the considerations for the PAR (Recommendation 1).

38. Based on the evidence NGL presented, I am satisfied that the findings of the inspection of the graphite core carried out during the periodic shutdown appear to be within expectations and within the bounds of the safety case.

4.2.3 Peripheral bricks inspections

39. Eleven of the sixteen faces of the peripheral wall were inspected during the periodic shutdown, five of which were already inspected in 2015 (Figure 1). This corresponds to NGL's inspection target prior to the periodic shutdown. I am therefore satisfied by this achievement. NGL produced Table 1 below summarising the findings of the peripheral brick inspections.

Table 1: Summary of the findings during the 2018 TOR R2 peripheral shield wall inspections.

Section (from EC 356536 App 3)	Description	Category	No. of NCRs	No. of Bricks *
1.1	Bricks with "Chicken Wire" cracking	A	0	0
1.3	Bricks with linear crack	A	15	15
1.5	Branched cracks	A	12	10#
1.7	Morphology not seen previously	B	1	1
1.8	Linear Features	A	42	42
2.3	Adjacent bricks significantly radially misaligned >2mm	B	0	0
2.5	Significant circumferential gapping observed between adjacent bricks >5mm	B	0	0
2.6	Very significant circumferential gapping observed between adjacent bricks >20mm	C	0	0
3.2	Large piece of graphite missing (>100x100mm or equivalent 10000mm^2)	B	0	0
3.3	Complete brick(s) missing	C	0	0
3.4	Graphite debris identified on restraint beams	B	0	0
3.5	Blockage or partial blockage of re-entrant flow annulus between restraint tank and core	C	0	0
No Category assigned	Minor scratch or score mark not thought to be crack & misc debris	N/A	27	N/A
Total Assessed			97	68

* The number of bricks may be less than the number of NCRs as in some instances multiple NCRs have been raised on a single brick (e.g. both faces of a corner brick) and debris NCRs don't apply to a brick.
# Reduced from 11 to 10 in PBAP 010 as it was identified that S2526/02 and S2531/01 are both on layer 8 face 4 brick 1.

40. According to Table 1, 28 cracks in 26 cracked bricks were observed from the 11 faces inspected. This corresponds to ~2.0% of the overall number of peripheral bricks. The number of cracks therefore appears to be consistent with previous observations.

41. The face map shows that the defects appear to be overall uniformly distributed around the core of the reactor, with little evidence for clustering of defects (Reference 13).

42. In my opinion, the morphology of the cracks appears to be consistent with the cracks previously seen in the other reactors at HYB and TOR. Inspection of the defects previously observed in 2015 showed that damage had progressed slightly since 2015 in some instances, e.g. NCR S2565/02 and NCR S2553/01 (Reference 13); see Figures 2 and 3. In Figure 3, a small branch, which was not visible in 2015, seems to be present in 2018. I informed NGL by e-mail that these cracks could be considered for future inspections in three years' time (Reference 17). NGL confirmed that the crack recorded in NCR S2553/01 was visible from the 2015 footage.

43. The cracks which were re-inspected during the periodic shutdown do not appear to have progressed, except the crack recorded in NCR S2565/02. In the latter case, progression appears to have been slow between 2015 and 2018, which is consistent with the safety case EC356536. I am therefore satisfied that the findings of the peripheral brick inspections appear to be consistent with EC356536.

44. I therefore consider that the findings of the peripheral bricks appear to be within NGL's acceptance criteria and should not prevent the return to service of the reactor.

4.3 ONR Assessment Rating

45. Based on the evidence I sampled, I have allocated an ONR rating of 'green' – no formal action (Reference 18).

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

46. This report presents the findings of the ONR assessment of the 2018 Torness Reactor 2 periodic shutdown. This includes the licensee's site work i.e. the graphite visual inspections, dimensional measurements, trepanning and eddy current inspection using PECIT, together with the safety case produced to justify return to service of TOR R2 with cracked peripheral wall bricks.

47. During the periodic shutdown, NGL carried out visual inspection and bore channel measurements from sixteen fuel channels and visual inspection of one control rod channel. Thirty-five samples were trepanned from the core. This therefore satisfies the requirements from the Maintenance Schedule. The trepanned samples will be analysed in due course to provide some information on the properties of the core. No new defects were found during the inspections of the graphite core. According to the information shared by the Licensee, the measurements from the bore of the fuel channels were within expectations and did not reveal any adverse finding.

48. During the periodic shutdown, eleven of the sixteen faces of the graphite peripheral wall were inspected, five of which had already been inspected in 2015. Some bricks were found to be cracked, approximately 2.0% of the total number of peripheral bricks. The findings from the re-inspected faces of the peripheral bricks indicate that progress of damage had been slow and insignificant between 2015 and 2018. Overall, the defects observed seem to be uniformly distributed around the core of the reactor, with little evidence of clustering of defects. The findings of the peripheral wall inspections seem to be consistent with previous observations in all four reactors at Heysham 2 and Torness. I therefore consider that the inspection findings appear to be consistent with the safety case and should not prevent the return to service of the reactor.

49. I carried out an intervention at site during the periodic shutdown. Based on the evidence I sampled during the intervention, the licensee's arrangements concerning the graphite core inspections appeared to be satisfactory. In my opinion, the findings from the inspection of the graphite core are within the bounds of NGL's safety case and do not present any impediment to return to service of Torness Reactor 2.

50. During the trepanning campaign in the core, one of the trepanned holes was performed in an incorrect orientation, possibly extending into a keyway through the thickness of the brick. NGL will provide justification of why this issue is tolerable within the RTS EC. This has not yet been produced. Therefore, when this EC is produced, I will review NGL's consideration of this issue and provide a statement on its adequacy to the project inspector as part of the considerations for the PAR (Recommendation 1).

51. Apart from the trepanning issue identified during the outage, all other structural integrity aspects of the inspections of the graphite core and the peripheral bricks do not, in my opinion, present any impediment to the return to service of Torness Reactor 2 (Recommendation 2).

5.2 Recommendations

To ONR Project Inspector:

- Recommendation 1: An error has been made during the trepanning campaign of the graphite core. I recommend that a decision on this error be considered separately to this Assessment. I will review NGL's consideration of this issue in the RTS EC, which is yet to be produced, and provide a statement on its adequacy to the project inspector as part of the considerations for the PAR.

- Recommendation 2: All other aspects of the inspections of the graphite core and the peripheral bricks do not appear to present any impediment to the return to service of Torness Reactor 2. I recommend that the Project Inspector issues a Licence Instrument for restart of the reactor, following resolution of Recommendation 1.

6 REFERENCES

1. Torness Reactor 2 Statutory Outage 2018. EC363392. Return to service EC.
2. EC 356536 Revision 004, Proposal No. 3, Justified Continued Operation (JCO) in light of the discovery of cracked peripheral bricks during the 2015 Torness R2, 2016 Heysham 2 R8 and Torness R1 2017 outage inspections. (TRIM 2018/189035).
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14. Torness - ONR-OFD-IR-18-130 - Reactor 2 Graphite Intervention – 1st October 2018. (TRIM 2018/322434).
15. Trepanning and Fuel Channel Inspection of J73. Trepanning error in Channel V75. Graphite. Torness Reactor 2. Periodic Shutdown 2018. (TRIM 2018/334008).
16. RE: Torness R2: Trepanning Error Fuel Channel V75. Graphite Inspection. 2018 Periodic Shutdown. (TRIM 201/347369).
17. TOR R2 RTS EC: Sections summarising the peripheral brick inspections. (TRIM 2018/360955).
18. ONR Assessment Rating Guide Table. (TRIM 2016/118638).

7 FIGURES

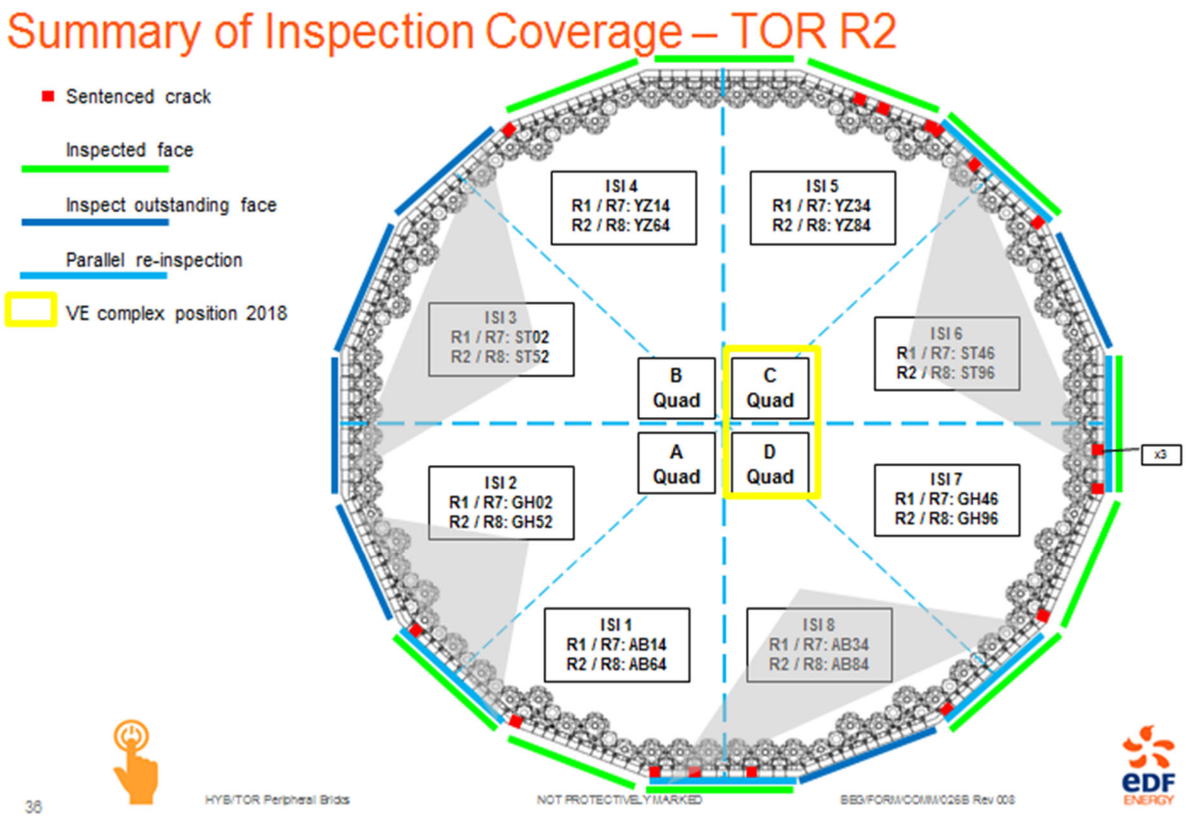


Figure 1: Peripheral brick inspections during the 2018 TOR R2 outage.

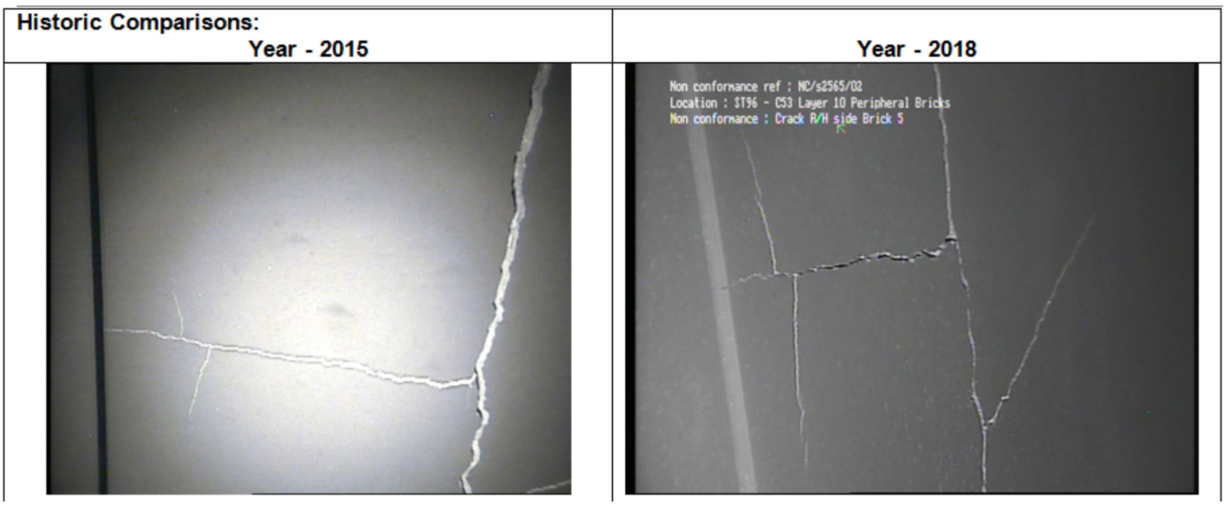


Figure 2: NCR S2565/02: Comparison between 2015 and 2018 inspections.

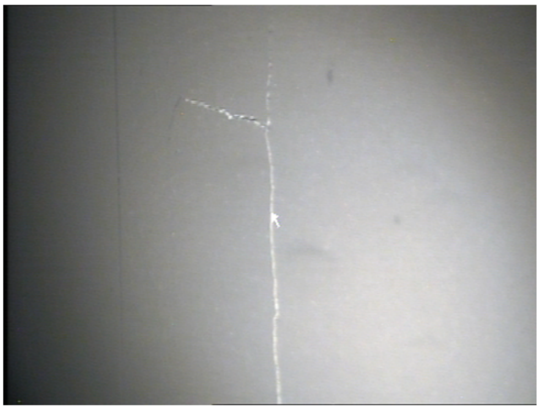
Historic Comparisons: Year - 2015	Year - 2018
	

Figure 3: NCR S2553/01: Comparison between 2015 and 2018 inspections.

Table 2: 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 2 (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.