Office for Nuclear Regulation

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Boiler spine recovery project

Heysham 1 & Hartlepool Reactors 1 and 2 : COMPLIANCE ARRANGEMENTS FOR BOILER SPINE WELD TEMPERATURES

Project Assessment Report ONR-CNRP-PAR-15-025
Revision 0
January 2016

EXECUTIVE SUMMARY

Permission Requested

This report presents the justification to issue agreement under Licence Condition 22(1) for EdF Energy Nuclear Generation Ltd (NGL) to implement a version update of "*Compliance arrangements for boiler spine weld temperatures (Heysham 1 – EC356499, Revision 003, Version 003 7 Hartlepool - EC356574, Rev 000, Version 000)"*.

The project assessment report considers the proposal, as applied to the four reactors at Heysham 1 and Hartlepool power stations.

Background

The reactors at Heysham 1 and Hartlepool are currently operating at reduced power following the discovery of a defect in one of the eight boiler spines at Heysham 1 Reactor 1.

The defects were judged by NGL to be affected by the operating temperature. NGL demonstrated that by reducing the temperature of the weld site; the crack growth mechanism could be effectively reduced. This temperature reduction has, to date, been delivered by operating the reactors at reduced power. However, NGL made a commitment to identify longer term solutions to the problem, including development of a cooling modification to reduce weld 12.3 temperatures. The cooling modifications were installed on all four reactors at Heysham 1 and Hartlepool power stations during 2015 outages.

Thermal modelling work was undertaken by NGL to substantiate the capability of the installed cooling modification to act as a surrogate for the reduced operating power. This was intended to demonstrate that the necessary temperature reduction, local to weld 12.3 could be delivered through the modification in place of de-rating the reactor. The thermal modelling work, supported by new analysis and arguments that any defect would become apparent through periodic inspection before reaching a critical size (forewarning of failure arguments) were presented to ONR in November 2015 for the four Heysham 1 and Hartlepool reactors.

During assessment of the safety case, ONR identified areas of uncertainty associated with the thermal modelling used to underpin the cooling modification effectiveness. In order to provide the necessary confidence to ONR, NGL self-imposed a reduction on full power operations. This restriction equates to approximately 10°C, providing the temperature reduction required to facilitate the forewarning of failure argument. NGL wrote to ONR confirming that no change to the 10°C temperature reduction, nor the manner by which it is achieved would be made, without he agreement of ONR. Based on these controls, ONR issued a consent to Heysham 1 reactor 1 and associated acknowledgments to the other three reactors to allow increased power in November 2015.

NGL has now completed additional work, supporting the thermal model and demonstration of the cooling modification effectiveness supported by plant data. As such, NGL now seeks agreement from ONR to implement revised compliance arrangements which remove the power restriction and claiming the required temperature reduction at the critical weld 12.3 wholly through the cooling modification.

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

The ONR project inspector and ONR specialist fault studies assessor have sampled NGL's submission, supporting evidence and proposed arrangements.

The specialist fault studies assessor has completed his assessment and produced an addendum to the original fault studies assessment report reflecting on the new information received from NGL. This assessment has been used to support the decisions made within this project assessment report.

Matters arising from ONR's work

The ONR fault studies assessor is satisfied that there is now sufficient evidence to support the validity of the thermal model in respect of the calculation of weld 12.3 temperatures and its use in deriving the compliance algorithm.

The ONR fault studies assessor acknowledges that the compliance algorithm includes an allowance for uncertainties of ~15°C.

Based on the sampling undertaken, the ONR fault studies assessor supports the implementation of the revised compliance arrangements, noting that application of the new absolute temperature algorithms will provide appropriate assurance that weld 12.3 remains below the 530°C temperature limit specified in the safety case.

Conclusions

Based on ONR's review of the presented case, and the sampling undertaken by the specialist assessor, no significant issues have been identified and the new plant thermocouple data supports the modelling of the effectiveness of the modification to cool weld 12.3. Permissioning of the proposed activity was therefore supported.

Recommendation

Based on the assessment undertaken, it was the recommendation of the author of this project assessment report that the superintending inspector should:

- sign this project assessment report, confirming support for the ONR technical and regulatory arguments used to justify issuing Heysham 1 and Hartlepool licence instruments 597 & 555 respectively; and

- sign Heysham 1 and Hartlepool licence instrument numbers 597 & 555 respectively.

LIST OF ABBREVIATIONS

ALARP	As low as reasonably practicable
BAWG	Boiler Assessment Working Group
EAN	Engineering Advice Note
EC	Engineering Change
HRA	Hartlepool nuclear power station
HYA	Heysham 1 nuclear power station
INA	Independent Nuclear Assurance (NGL internal regulator)
INSA	Independent Nuclear Safety Assessment
NGL	EDF Energy Nuclear Generation Ltd
NSC	Nuclear Safety Committee
HOW2	(Office for Nuclear Regulation) Business Management System
ONR	Office for Nuclear Regulation
SAP	Safety Assessment Principle(s)
SFAIRP	So far as is reasonably practicable
TAG	Technical Assessment Guide (ONR)

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1 PERMISSION REQUESTED

1. EdF Energy Nuclear Generation Ltd (NGL) have requested *(Ref. 1)* agreement from the Office for Nuclear Regulation (ONR), under Licence Condition 22(1) to implement an update of Engineering Change (EC): "Compliance arrangements for boiler spine weld temperatures (Heysham 1 EC356499, Revision 003, Proposal Version 000 & Hartlepool EC356574, Revision 002, Proposal Version 000)" *(Ref. 2)* allowing return to full power operations of the four reactors at Heysham 1 (HYA) and Hartlepool (HRA) power stations.

2 BACKGROUND

2. The reactors at Heysham 1 and Hartlepool are currently operating at reduced power following the discovery of a defect in one of the eight boiler spines at Heysham 1 Reactor 1.

3. The defects were judged by NGL to be affected by the operating temperature. NGL demonstrated that by reducing the temperature of the weld site; the crack growth mechanism could be effectively reduced. This temperature reduction has, to date, been delivered by operating the reactors at reduced power. However, NGL made a commitment to identify longer term solutions to the problem, including development of a cooling modification to reduce weld 12.3 temperatures. The cooling modifications were installed on all four reactors at Heysham 1 and Hartlepool power stations during 2015 outages.

4. Thermal modelling work was undertaken by NGL to substantiate the capability of the installed cooling modification to act as a surrogate for the reduced operating power. This was intended to demonstrate that the necessary temperature reduction, local to weld 12.3 could be delivered through the modification in place of de-rating the reactor. The thermal modelling work, supported by new analysis and arguments that any defect would become apparent through periodic inspection before reaching a critical size (forewarning of failure arguments) were presented to ONR in November 2015 in NP/SC 7728 for HYA Reactor 2 and similar submissions for the other three reactors.

5. During assessment of the safety case, ONR identified areas of uncertainty associated with the thermal modelling used to underpin the effectiveness of the cooling modification. In order to provide the necessary confidence to ONR, NGL self-imposed a reduction on full power operations. This restriction equated to 10°C and provides the temperature reduction required to facilitate the forewarning of failure argument. NGL wrote to ONR *(Ref. 3)* confirming that no change to the 10°C temperature reduction, nor the manner by which it is achieved would be made, without the agreement of ONR.

6. Following independent assessment *(Ref. 9)* of these controls, ONR issued a consent to HYA reactor 2 and associated acknowledgments *(Ref. 10)* to the other three reactors to allow increased power in November 2015.

7. NGL has now completed additional work, supporting the thermal model and demonstration of the cooling modification effectiveness supported by plant data. As such, NGL now seeks agreement from ONR to implement the revised compliance arrangements, removing the power restriction and claiming the required temperature reduction wholly through the cooling modification.

3 SUMMARY OF THE LICENSEE'S PROPOSAL

3.1 PROPOSAL HISTORY

8. Revisions 000 *(reactor 2 only)* and 001 *(reactor 1 & 2)* of the HYA and HRA proposals detailed the use of the new absolute temperature compliance algorithm for calculating weld 12.3 temperatures (see table below). However, due to the uncertainties associated with the effectiveness of the cooling modifications, the compliance arrangements were updated to continue utilising the existing temperature delta[3] compliance equation. Under these arrangements reactor power was restricted to provide a temperature reduction of 10°C local to boiler spine weld 12.3. The 10°C temperature reduction local to weld 12.3 is calculated (i.e. not directly measured), and is relative to full power operations. This 10°C temperature reduction provided sufficient margin to account for the uncertainties associated with the cooling modification capability. NGL considered this approach to be an interim measure whilst work continued to validate the cooling modifications.

9. NGL's new absolute temperature algorithm takes full benefit of the installation of the cooling modification. The algorithm has also been used during the interim phase as a confirmatory check that temperatures local to weld 12.3 remain below the 530°C limit specified in *Reference 4* , ensuring that the forewarning of failure claims made within the case were not undermined.

10. *Table 1* provides a revision history of the compliance arrangements including the current two revisions [HYA Rev003 & HRA Rev002 (highlighted)].

REV	HEYSHAM 1 – EC356499	HARTLEPOOL – EC356574
000	• Covered increased power of reactor 2 only. • Operation required use of both the temperature delta algorithm and absolute temperature algorithm	• Covered increased power of reactor 2 only. • Operation required use of both temperature delta algorithm and absolute temperature algorithm
001	• Expanded arguments to include reactor 1 increase in power. Operation still required use of both the temperature delta algorithm and the absolute temperature algorithm.	• Expanded arguments to include reactor 1 increase in power. • Operation still required use of both the temperature delta algorithm and the absolute temperature algorithm.
002	• Administrative change only, no change to document or safety case.	• Updated to remove the temperature delta algorithm. • Full claim made on cooling modification benefit using absolute temperature algorithm only for operation.
003	• Updated to remove the temperature delta algorithm. • Full claim made on cooling modification benefit using absolute temperature algorithm only for operation.	

Table 1 - EC Revision Summary

[3] Temperature delta algorithm refers to the compliance arrangements used to calculate temperature reductions, necessary to deliver adequate protection to weld 12.3. This is in contrast to the new absolute temperature algorithm which provides capability to calculate actual temperatures along the boiler spine.

3.2 UPDATED REVISION

11. NGL now has increased levels of confidence in the thermal model and the capability of the cooling modification. This confidence is based on evidence from spine thermocouple readings; further rig testing and thermal analyses consolidated in an Engineering Advice Note *(Ref. 5)* and supplemented by an addendum *(Ref. 6)* containing additional plant data taken from the Hartlepool thermocouples installed during a late-2015 re-fuelling outage. NGL therefore consider that it is no longer necessary to operate the reactors to a target temperature reduction via the temperature delta compliance equation.

12. NGL proposes to update the extant compliance arrangements ECs *(Ref. 2)* to reflect this revised position. The changes will:

- Remove the requirement to use the temperature delta compliance algorithm.
- Claim the absolute temperature algorithm and thermal model.
- Claim full benefit of the installed cooling modification, demonstrating that this provides the required reduction in temperature, local to weld 12.3 to deliver a forewarning of failure argument for a spine with undetected weld buttering.

4 MATTERS ARISING FROM ONR'S WORK

13. ONR has already undertaken a comprehensive independent assessment *(Ref. 9)*.of the full power case[4] *(Ref. 4).* This assessment has also been considered bounding for the all four of the Heysham & Hartlepool reactors. The decision was therefore taken to assess only the changes to the compliance arrangements. This work focused on sampling the supporting evidence and plant data used to validate the thermal model and underpin the capability of the installed cooling modifications.

14. The original fault studies assessment *(Ref. 11)* of the increased power case *(Ref. 4)* noted a shortfall in confidence levels associated with the new absolute compliance arrangements. The shortfall was associated with the validation of the thermal model and its ability to accurately model the temperature of the boiler spine, local to weld 12.3. The ONR specialist fault studies assessor recommended that additional plant data was required to validate the model and better underpin the claims made on the cooling modification capability. NGL took the decision to restrict reactor power, providing the 10°C temperature reduction required in order for a forewarning of failure argument to be made.

15. Temperature measurements have now been received from thermocouples located within HYA reactor 1 and HRA reactors 1 and 2. These values have been used by NGL to further validate the thermal model and to underpin the capability of the absolute temperature compliance arrangements.

16. An ONR specialist fault studies assessor carried out an assessment of the revised compliance arrangements EC *(Ref. 2)* and its supporting evidence. Given the limited scope associated with the compliance arrangement changes, the assessment note *(Ref. 12)* was prepared as an addendum to the original fault studies assessment. This approach was agreed by both the Operating Reactors – Head of Assessment, and by the Fault Studies Professional Lead *(Ref. 13).*

17. The findings of the fault studies assessment are summarised below:

[4] Whilst each of the four reactors across HYA and HRA have their own safety case, the safety justifications within are common. ONR recognised this fact during assessment and subsequent acknowledgement of the separate cases.

4.1 FAULT STUDIES ASSESSMENT

18. It is the considered opinion of the ONR fault studies assessor that, the thermocouple measurements from HYA Reactor 1 and HRA Reactor 1 provide valuable validation evidence in support of the thermal modelling and benefits of the cooling modelling.

19. Thermocouple measurements taken from HRA reactor 2 do show a significant discrepancy between measured and calculated temperatures. The ONR fault studies assessor notes however that these thermocouples were originally installed as a pilot exercise to trial the installation technique; as such they are some distance away from the critical weld 12.3. *Reference 5* notes that there were difficulties during installation and that, due to the nature of the trial, a lower level of attention was paid to the positioning of the sled than applied to subsequent installations. *Reference 5* concludes that there is a lower level confidence in the thermocouples being close to the spine surface for this installation.

20. The temperature readings taken from the thermocouples installed at HYA R1 and HRA R1 are accepted by the Fault Studies assessor as supporting the thermal modelling predictions for cooling modification effectiveness. The values from these thermocouples are considered to be more representative of the temperatures local to weld 12.3 and therefore provide good validation of the thermal model in respect of the calculation of weld 12.3 temperatures and the use of the model in deriving the compliance algorithm. In reaching his view, the ONR fault studies assessor acknowledges that the compliance algorithm includes an allowance for uncertainties of ~15°C.

21. The ONR fault studies assessor is satisfied that the evidence from the Northampton test rig does indicate that the effect of the thermocouple sled on the local thermal environment may result in thermocouples reading high. However, the assessor notes that in his view, it is difficult to quantify the effect on plant without further 3D modelling. This work is understood to be progressing.

22. Consequently, the ONR fault studies assessor supports the implementation of the revised compliance arrangements (Ref. 2), noting that application of the new absolute temperature algorithms will provide appropriate assurance that weld 12.3 remains below the 530°C temperature limit specified in the safety case (Ref. 4).

4.2 LICENSEE'S PROCESSES

23. The revised compliance arrangements have completed NGL's due process, having completed validation. Both ECs are category 3, there is therefore no requirement for them to be a seen at Nuclear Safety Committee.

24. An Independent nuclear safety assessment (INSA) has been completed on both of the ECs. INSA certificates, both dated 14 December 2015 have been issued (*Ref. 8)* with no caveats applied to the cases.

25. The updated evidence supporting the compliance arrangements *(Ref. 7)* was discussed and agreed at the boiler assessment working group (BAWG) at a meeting held on 11th December 2015.

26. Based on the above, I am satisfied that the ECs have completed NGL's due process.

5 CONCLUSIONS

27. ONR needed to be confident that at least a 10°C reduction was being provided by the cooling modification. The thermocouple data from HRA R1 now provides sufficient confidence in the thermal modelling for ONR to support a return to full power operations at the four reactors across HYA and HRA. This support is underpinned by the knowledge that the effectiveness of the cooling modification is sufficient to provide an effective forewarning of failure of growth of any defect across the population of the boiler spines, including for a weld 12.3 containing undetected weld buttering.

28. Based on my review of the presented case, and the sampling undertaken by the specialist assessor, no significant issues have been identified. I therefore support the permissioning of the proposed activity.

6 RECOMMENDATION

29. Based on the assessment undertaken, it is the recommendation of the author of this project assessment report that the superintending inspector should:

- sign this project assessment report, confirming support for the ONR technical and regulatory arguments used to justify issuing Heysham 1 and Hartlepool licence instruments *597 & 555* respectively; and
- sign Heysham 1 and Hartlepool licence instrument numbers *597 & 555* respectively.

7 REFERENCES

1. *Heysham 1 Letter of request – NSL/HYA/50786(Y) dated 14 December 2015 (TRIM: 2015/473953)*

   Hartlepool Letter of request – NSL/HRA/51091R dated 14 December 2015 (TRIM: 2015/473817)

2. *Updated Compliance arrangements for Heysham 1 - EC356499, Rev 003, Ver 000 (TRIM: 2015/473963)*

   Updated Compliance Arrangements for Hartlepool – EC356574, Rev 002, Ver 000 (TRIM: 2015/473815)

3. *Letter of request for Consent for Heysham 1 reactor 2 to increase power, dated 19 November 2015 - NSL/HYA/50781 (TRIM: 2015/442778)*

   Letter of request for Acknowledgement for Heysham 1 reactor 1 to increase power, dated 27 November 2015 - NSL/HYA/50784(Y) (TRIM: 2015/455075)

   Letter of request for Acknowledgement for Hartlepool reactor 1 to increase power, dated 7 December 2015 – NSL HRA 51090R (TRIM: 2015/465516)

   Letter of request for Acknowledgement for Hartlepool reactor 2 to increase power, dated 23 November 2015 - NSL HRA 51088R (TRIM: 2015/444932)

4. *NP/SC 7728 Heysham 1 Reactor 2 - boiler spine structural integrity safety case & justification for return to full power following implementation of the spine cooling modification, EC No:355061, Version No: 005 (TRIM: 2015/370461)*

5. *Engineering advice note – Hartlepool and Heysham 1 power Stations Further Information Supporting Validation of the Boiler Spine Thermal Model – FCP/EAN/BSR/AGR/006, Rev 000 (TRIM: 2015/473819)*

6. *Engineering advice note addendum with Hartlepool thermocouple data (TRIM: 2016/36496)*

7. *Boiler Spine Recovery – Further Evidence to Support Temperature Compliance Arrangement for Full Power Operation at Heysham 1 and Hartlepool - BAWG/P(15)6 (TRIM: 2015/473818)*

8. *HYA INSA certificate for EC356499 dated 14 Dec 2015, Rev 003, Ver 000 (TRIM: 2015/473957)*

   HRA INSA certificate for EC356574 dated 14 Dec 2015, Rev 002, Ver 000 (TRIM: 2015/473816)

9. *ONR Consent project assessment report of Heysham 1 reactor 2 Full power case – ONR-HYA-PAR-15-017 (TRIM:2015/370461)*

10. *ONR Acknowledgement project assessment report of Heysham 1 reactor 1 Full power case – ONR-HYA-PAR-15-022 (TRIM: 2015/455256)*

    ONR Acknowledgement project assessment report of Hartlepool reactor 1 Full power case – ONR-HYA-PAR-15-024 (TRIM: 2015/458907)

    ONR Acknowledgement project assessment report of Hartlepool reactor 2 Full power case – ONR-HYA-PAR-15-021 (TRIM: 2015/437481)

11. *ONR Fault studies assessment report of HYA increased power case (NP/SC 7728) – ONR-HYA-AR-15-055 (TRIM: 2015/425723)*

12. *ONR Fault studies assessment report of HYA/HRA Compliance EC (EC356499 & EC356574)– ONR-CNRP-AR-15-055 (TRIM:* 2015/476154*)*

13. *Letter of agreement in approach taken for assessment of the updated compliance arrangements ECs*

Head of Assessment (TRIM: 2015/472378)

14. ONR HOW2 Business management System

http://www.onr.org.uk/operational/assessment/index.htm

Purpose and Scope of Permissioning - NS-PER-GD-014 Rev 4

Guidance on the production of Reports - NS-TAST-GD-084, Rev 8

Peer Review for Technical Assurance NS-TAST-GD-085, Rev 4

15. Safety Assessment Principles for Nuclear Facilities. 2014 Edition Revision 0. November 2014.

http://www.onr.org.uk/saps/saps2014.pdf