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**Agreement to NP/SC 7753 – safety case for operation of the hot box dome with regions  
of elevated temperature.**

**Hartlepool and Heysham 1 Power Stations.  
Project Assessment Report**

Project Assessment Report ONR-OFD-PAR-18-002  
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## EXECUTIVE SUMMARY

### Title

Agreement to NP/SC 7753 – safety case for operation of the hot box dome with regions of elevated temperature.

### Permission Requested

Under derived powers made under Licence Condition 22(1), the licensee of Hartlepool (HRA) and Heysham 1 (HYA) power stations, EDF Energy Nuclear Generation Limited, has requested that the Office for Nuclear Regulation (ONR) issue agreement to, or acknowledgment of, NP/SC 7753, which is the safety case for operation of the hot box domes with regions of elevated temperature.

### Background

The hot box domes are welded steel structures within the HRA and HYA reactors. Each forms a pressure boundary between lower temperature (T1), higher pressure re-entrant gas above the reactor core and higher temperature (T2), lower pressure reactor outlet gas in the upper plenum of the reactor. To prevent their degradation the hot box domes are covered with a layer of insulation and presently restricted to a maximum operating temperature of 380°C at the upper surface. Compliance with that limit is established by regular monitoring of temperature data, which is calculated by means of an algorithm using data from thermocouples located beneath the hot box domes.

Following a trend of increasing temperature in the central region of the hot box domes, attributed to degradation of insulation, the licensee has taken mitigating steps that include drilling of bleed flow holes, introduction of a flow directing cowl (HYA Reactor 2 only) and revision of compliance arrangements. These measures have afforded some benefit but may not have entirely arrested the trend of rising temperature for each reactor, hence the licensee considers it possible that operating temperatures may exceed 380°C in future.

In that event, compliance could be restored by reduction of reactor power and/or T1. The licensee wishes to avoid those measures, claiming they may reduce boiler lifetimes. Instead the licensee seeks to justify an increased temperature limit. Based on the results of new thermal analysis and structural integrity assessments, and accounting for an appraisal of the current safety case to examine the effects of increased temperature, NP/SC 7753 is intended to justify a new operating limit of 390°C for the upper surface of the hot box domes.

A deaerator pressure control system (DAPCS) has been installed in three of the four reactors (not at HRA Reactor 2). Its purpose is to limit loss of power output should T1 be reduced in future to maintain compliance with the temperature limit. The effect of DAPCS operation would be to maintain T2 despite a reduction of T1. This may increase loads on the boiler tailpipes and so could increase the frequency of their failure. The licensee is working to establish the effect of DAPCS operation on boiler tube integrity and no DAPCS is presently operating.

### ONR assessment and inspection in consideration of this request

NP/SC 7753 has been the subject of ONR structural integrity and fault studies specialist assessments. ONR staff have engaged with the licensee in technical discussions to support that work.

Fault studies specialist assessment has concentrated on arguments and evidence given in NP/SC 7753 to substantiate a claim that the environment in which the hot box domes operate is adequately understood. This has included consideration of the arrangement, comprising thermocouple measurements and a compliance algorithm, used by the licensee to determine temperatures at the upper surface of the hot box domes. The ONR fault studies specialist has also reviewed the bounding faults identified in NP/SC 7753 and the effects of an increased temperature limit on the hot box dome in those conditions.

Structural integrity specialist assessment has concentrated on arguments and evidence given in NP/SC 7753 to substantiate the following claims of NP/SC 7753:

- Gross structural failure of the hot box dome remains incredible for the predicted operating environment.

- The integrity and functionality of components associated with the hot box dome are not challenged by the presence of hot spots.
- The consequences of dome failure remain unchanged and the increase in risk associated with operating the dome with hot spots of 390°C peak temperature is acceptably low and as low as reasonably practicable.

The structural integrity specialist assessment has considered diverse evidence relating to those claims. Key aspects include new analyses that demonstrate margins against failure at 390°C, identification of degradation mechanisms and the outcome of inspection and monitoring of the hot box domes.

#### **Matters arising from ONR's work**

Both specialist inspectors consider agreement to the proposed modification of NP/SC 7753 to be acceptable. Structural integrity assessment has raised two regulatory issues. These are for the licensee to provide a strategy address the possibility of thermocouple failures in future, a commitment of NP/SC 7753, and to account for the effects of DAPCS operation on boiler tube integrity. Both aspects relate to the licensee's commitments for contingency planning, rather than the present safety case for the hot box domes, and so resolution of those matters will proceed as normal regulatory business.

#### **Conclusion**

I conclude that an operating limit of 390°C for the upper surface of the HRA/HYA hot box domes has been adequately justified by the licensee.

#### **Recommendation**

I recommend :

- agreement to the modification proposed in NP/SC 7753, which is to increase the operating limit for the upper surface of the HRA/HYA hot box domes from 380°C to 390°C.
- that licence instrument 565 is granted to HRA to implement NP/SC 7753.
- that licence instrument 614 is granted to HYA to implement NP/SC 7753.

## ABBREVIATIONS

DAPCS	Deaerator Pressure Control System
HRA	Hartlepool Power Station
HYA	Heysham 1 Power Station
INSA	Independent Nuclear Safety Assessment
NSC	Nuclear Safety Committee
ONR	Office for Nuclear Regulation

## TABLE OF CONTENTS

1. PERMISSION REQUESTED.....	9
2. BACKGROUND.....	9
3. ASSESSMENT AND INSPECTION WORK CARRIED OUT BY ONR IN CONSIDERATION OF THIS REQUEST .....	9
4. MATTERS ARISING FROM ONR'S WORK.....	11
5. CONCLUSIONS .....	12
6. RECOMMENDATIONS .....	12
7. REFERENCES .....	14

## 1 PERMISSION REQUESTED

1. Under derived powers made under Licence Condition 22(1), the licensee has requested (Refs. 1 & 2) that the Office for Nuclear Regulation (ONR) issue agreement to, or acknowledgment of, NP/SC 7753 (Ref. 3), which is the safety case for operation of the Hartlepool (HRA) and Heysham 1 (HYA) hot box domes with regions of elevated temperature.

## 2 BACKGROUND

2. The hot box domes are welded steel structures within the HRA and HYA reactors. Each forms a pressure boundary between lower temperature (T1), higher pressure re-entrant gas above the reactor core and higher temperature (T2), lower pressure reactor outlet gas in the upper plenum of the reactor. The upper surface of each hot box dome is covered with a layer of insulation, attached by welded retention strips.
3. The hot box domes are presently restricted to a maximum operating temperature of 380°C on the upper surface. The limit was prescribed to prevent creep damage, oxidation and loss of strength. The licensee asserts that the limit resulted from the methods and approaches of its time, with deliberate conservatism to counter assessment uncertainty and simplification.
4. Compliance with the temperature limit is established by regular monitoring of temperature data. Thermocouples are fitted both above and below each hot box domes in varying configurations across the four reactors. The licensee has concluded that the above-dome thermocouples do not register true metal temperature, hence there is no direct and effective indication of temperature at the upper surface. Instead, this is calculated by means of a compliance algorithm using data from thermocouples located beneath the hot box domes.
5. The licensee has investigated an observed trend of rising hot box dome temperatures and attributes the phenomenon to degradation of insulation. Such degradation results in increased permeability of insulation to reactor gas; increased gas flow through insulation results in higher temperatures at the upper surface of the hot box domes.
6. The licensee has have taken measures intended to control rising temperature:
  - Bleed hole drilling to increase flow of cool gas through the dome central region. This has been effected on the central control rod guide tube in each reactor, with hole drilling of four additional channels on both reactors at HYA.
  - A cowl installed on the HYA Reactor 2 central control rod guide. Its purpose is to direct exhausting nozzle cooling gas onto insulation cover plates in the vicinity, so enhancing the cooling effect of the bleed hole.
7. These have afforded some benefit but may not have entirely arrested the trend. Therefore the licensee considers it possible that temperatures may exceed the 380°C limit in future. In that event compliance could be restored by reducing reactor power and/or T1. The licensee asserts that those measures deviate from the intended method of plant operation and may reduce boiler lifetimes in consequence. The licensee therefore wishes to avoid their introduction and instead seeks to justify an increased maximum temperature limit.
8. Accounting for the results of new thermal analysis and structural integrity assessments, and based on an appraisal of the current safety case, NP/SC 7753 proposes a new maximum temperature limit of 390°C for the upper surface of the hot box domes of HRA and HYA. The following claims are presented to justify that proposal:

- Claim 1: The environment in which the hot box dome operates is adequately understood.
- Claim 2: Gross structural failure of the hot box dome remains incredible for the predicted operating environment.
- Claim 3: The integrity and functionality of components associated with the hot box dome are not challenged by the presence of hot spots.
- Claim 4: The consequences of dome failure remain unchanged and the increase in risk associated with operating the dome with hot spots of 390°C peak temperature is acceptably low and as low as reasonably practicable.
9. NP/SC 7753 identifies evidence to substantiate these claims; key aspects are summarised below.
- The results of thermal modelling are identified to represent the temperature profile of the hot box domes. Thermal data provide input to a range of structural integrity assessments. Fault conditions are reviewed to determine bounding conditions for analysis. The results of structural integrity assessments are presented to demonstrate that an operating limit of 390°C will not significantly affect the hot box domes, such that no significant in-service degradation mechanisms exist without adequate margins having been established. The results of sensitivity studies are identified to demonstrate that margins remain at temperatures up to at least 410°C.
  - Inspection data is identified as evidence of the absence of structurally significant defects. The results of fracture analysis are presented to demonstrate defect tolerance.
  - Monitoring and inspection are claimed to forewarn of significant failure. Inspections from above and below the dome are conducted during periodic shutdown. Thermocouple data is monitored each day of operation: anomalous temperature data may indicate degradation, prompting investigation and mitigating action. The licensee contends that, if gross loss of insulation were to occur and pass undetected by thermocouple monitoring, subsequent gross failure of a hot box dome would not occur in the interval between inspections.
  - It is argued that the performance and retention of the hot box dome insulation will not be adversely affected by the proposed change. Visual inspection is reported to show that the exterior of the insulation remains intact and in good condition. Commissioning tests have established margins for all insulation attachment components, and demonstrated tolerance to the failure of one retention strip. Assessment results are identified as evidence that an operating limit of 390°C does not significantly affect the structural integrity of insulation attachment welds.
  - It is argued that hot box dome insulation local temperatures are unaffected by the proposed change. Hence accelerated degradation of insulation is not expected. The licensee argues that, if degradation does occur, its progress would be gradual and revealed by thermocouple monitoring to prompt mitigating action.
  - The licensee acknowledges that gross structural failure of a hot box dome is an intolerable event and so classifies the hot box domes as highest reliability components. However, it is contended that the consequences of partial failure are tolerable, and a hot box dome would continue to function with weld failure across an entire ligament. Evidence is identified to substantiate that argument. Protection to shut-down and hold-down the reactor with partial failure of a hot

box dome is reviewed and the licensee concludes it is unaffected by the effects of the increased temperature limit.

10. NP/SC 7753 has been verified and undergone Independent Nuclear Safety Assessment (INSA) by the licensee. NP/SC 7753 has also been submitted to the licensee's Nuclear Safety Committee (NSC) for consideration and advice.
11. In addition to the modifications described earlier (para. 6) a deaerator pressure control system (DAPCS) has been installed in 3 of the 4 reactors. Its purpose is to limit loss of power output should T1 be reduced in future to sustain compliance with operating temperature limits. The effect of DAPCS operation would be to maintain T2 despite reduction of T1. The licensee acknowledges that this may result in increased load on boiler tailpipes and so increase the frequency of their failure. No DAPCS is presently operating and work by the licensee to assess the effect of its operation on boiler tube integrity is underway. No DAPCS has been installed at HRA Reactor 2, where the licensee forecasts that temperatures will remain below the present limit until operation ceases.

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

12. NP/SC 7753 has been the subject of ONR fault studies and structural integrity specialist assessments (Refs. 5 & 6). Technical engagements between ONR and licensee staff have supported that work (Refs. 7 & 8).
13. Fault studies specialist assessment has concentrated on arguments and evidence given in NP/SC 7753 to substantiate its first claim. The conclusions of fault studies specialist assessment (Ref. 5) are as follows:
  - The nuclear safety implications of the modification have been properly addressed.
  - The updated thermal model is suitable as an input to the structural integrity analysis for the purpose of determining the dome withstand capability to areas of elevated temperature.
  - The compliance algorithms have been adequately conceived and provide a suitable method of ensuring compliance with the 390°C limit.
  - The bounding faults identified by the licensee are appropriate and the effects of the operating temperature limit increase on the hot box dome in these fault conditions have been considered and found to be acceptable.
  - The increase in risk associated with operating the dome with a temperature limit of 390°C is acceptably low.
14. Structural integrity specialist assessment has concentrated on claims two to four of NP/SC 7753. The conclusions of structural integrity specialist assessment (Ref. 6) are as follows:
  - There is evidence the proposed change will have only a limited effect on structural integrity. New thermal analysis shows that regions of elevated temperature will be limited both in number and extent. They are shown to occur only near the upper surface and toward the centre of the dome, predominantly in parent material. At the few locations where regions of elevated temperature intersect welds, thermal analysis shows that local temperatures will not exceed 380°C.
  - The effects of operation with an increased temperature limit have been adequately considered by the licensee. Degradation mechanisms have been comprehensively identified. Structural integrity assessments demonstrate

acceptable margins against failure at 390°C. The inspection capability claimed in demonstration of defect tolerance is adequately justified.

- The structural integrity analyses apply relevant good practice, are sufficiently comprehensive and adequately conservative. Accompanying sensitivity studies show that significant cliff-edge effects are absent to at least 410°C.
  - The hot box domes contain no significant recorded defects. Whilst future degradation cannot entirely be precluded, this would be unexpected and likely to occur only gradually. Adequate monitoring is specified to reveal significant degradation in good time, provided that effective temperature monitoring continues.
  - There is evidence that the risk of partial failure of a hot box dome is tolerable and that such failure could be detected. Analysis shows that protection would remain available with partial dome failure.
15. Both specialist assessments have been conducted, reported and reviewed according to ONR guidance (Ref. 9). Their findings provide the basis for the conclusion and recommendations of this report.
16. I have confirmed the satisfactory outcome of verification (recorded in Ref. 3) and INSA (recorded in attachments to Refs. 1 and 2) by the licensee. I have also reviewed NSC deliberations regarding NP/SC 7753 (Ref. 4). I am satisfied the outcome of these efforts by the licensee to verify and validate NP/SC 7753 is broadly compatible with the assessment findings of ONR.

#### **4 MATTERS ARISING FROM ONR'S WORK**

17. Both ONR specialist inspectors consider agreement to the proposed modification of NP/SC 7753 to be acceptable. On that basis I have prepared licence instruments, one each for HRA and HYA. These have been written according to ONR guidance of Ref. 10 and are of routine type, for which the text and format have been agreed with the Government legal department. Further legal checking of these licence instruments is therefore unnecessary.
18. Structural integrity assessment has raised two regulatory issues. These are for the licensee to provide a strategy address to thermocouple failures, a commitment of NP/SC 7753, and to account for the effects of DAPCS operation on boiler tube integrity. Both aspects relate to the licensee's commitments for contingency planning, rather than the present safety case for the hot box domes, and so resolution of those matters will proceed as normal regulatory business.
19. Ref. 3 proposes an increased operating temperature limit for the HRA and HYA hot box domes, hence the scope of this assessment is restricted to matters of nuclear safety. I therefore do not consider that consultation with other Government departments or agencies is warranted. Nor do I judge it necessary to consult with ONR communications staff regarding media aspects.

#### **5 CONCLUSION**

20. I conclude that an operating limit of 390°C for the upper surface of the HRA and HYA hot box domes has been adequately justified by the licensee.

#### **6 RECOMMENDATIONS**

21. I recommend:
- agreement to the modification proposed in NP/SC 7753, which is to increase the operating limit for the upper surface of the HRA and HYA hot box domes from 380°C to 390°C.

- that licence instrument 565 is granted to HRA to implement NP/SC 7753.
- that licence instrument 614 is granted to HYA to implement NP/SC 7753.

## 7 REFERENCES

- 1 NSL HRA 51140R. NGL Hartlepool Power Station. Nuclear Site Licence No. 59. Request for Agreement or Acknowledgement under Derived Powers Made Under Licence Condition 22(1). NP/SC 7753. TRIM 2017/114313.
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- 10 NS-PER-IN-001. Preparation and Issue of Licence Instruments. Revision 7. TRIM 2016/30390.