

**HEALTH & SAFETY EXECUTIVE**  
**NUCLEAR SAFETY DIRECTORATE**  
**ASSESSMENT REPORT**

Site : Hinkley Point B, Hunterston B  
Project : Graphite core safety case  
Title : Assessment of revised safety case for operation of Hinkley  
Point B and Hunterston B Reactor 4 cores to [REDACTED]

Licence No. 52 and Sc11  
Licence Condition No. 14, 22, 28, 30  
ARF No. 19279, 20084, 20561, 20562, 20729  
Assessment Rating: Orange  
Time spent on ARF: Total of 52.5 staff-days  
(13 days for 20561, 8.5 days for 20562, 3 days for 19279, 7.5 days for 20084, 20.5 days for 20729))

Author: [REDACTED] Signed: ..... Date: .....

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File: NUC 133/13/3 Part 2 Enclosure 83  
NUC 452/3/2 Part 3 Enclosure 15  
NUC 453/3/2 Part 3 Enclosure 5

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## SUMMARY

### Overview

1. NP/SC 7147 Addendum 2 / NSC/05/2184 presents the safety case for operation of Hinkley Point B and Hunterston B Reactor 4 graphite cores over the period between their periodic shutdowns in [REDACTED] and the Reactor 3 graphite cores up to their next periodic shutdowns [REDACTED]. It considers the implications of recent observations of bore cracks at [REDACTED] and presents strengthened inspection, sampling and monitoring legs. British Energy intend to present another safety submission before the Reactor 3 periodic shutdowns currently scheduled for [REDACTED] NSC meeting.

### Objective and Scope

2. The objective of this assessment is to establish the adequacy of the revised safety case for the graphite cores for operation of Hinkley Point B and Hunterston B for Reactor 4 up to their periodic shutdowns [REDACTED] and the Reactor 3 graphite cores up to their next periodic shutdowns in [REDACTED]. The scope of assessment is limited primarily to NP/SC 7147 Addendum 2 / NSC/05/2184 and selected key supporting references, although the outcome of previous assessments of related safety cases and the previous two safety cases were also considered.

3. The NII Graphite Technical Advisory Committee (GTAC) is currently working through a programme of questions relating to the AGR core safety cases and the underlying methodologies. The programme of work is almost complete and this report assesses the advice in the context of the safety cases and associated documentation considered here.

### Key Conclusions

4. I judge that there are significant uncertainties in the predictions of component and core condition, primarily due to the absence of materials properties data and knowledge as to the cracking behaviour of irradiated graphite. This leads to uncertainty in the timing, morphology and configuration of defective graphite components in the AGR cores. As a result whilst keyway-initiated cracking, leading to single or doubly cracked bricks, is one possible outcome of graphite ageing other defect morphologies may be equally likely.

5. I judge that the analyses presented by British Energy demonstrate significant tolerance of core safety functions to single and doubly cracked bricks. However, I judge that it is not possible to bound all possible component defect morphologies and configurations of defective graphite components in the AGR cores as this may be infinite. Other configurations of defective graphite components may present a greater challenge to core safety functions than single and doubly cracked bricks.

6. Recent core inspection data at Hinkley Point B and Hunterston B suggest, based upon brick shape change with irradiation shrinkage, that some bricks in the flattened region of the core are already at stress-reversal. Sensitivity studies indicate that at this stage some bricks may have passed stress reversal [REDACTED] and keyway-root initiated cracking is predicted to occur [REDACTED].

I judge that the likelihood of a challenge to core safety functions over an operating period of 3 years is highly uncertain. I judge that it is reasonably practicable to

increase the core inspection frequency in response to stress-reversal to mitigate uncertainty. I judge that this will ensure that any component and core degradation that is significantly different to that predicted by British Energy may be detected, and an appropriate response developed, before core safety functions are degraded.

8. I judge that an appropriate time between inspections to revalidate the safety case is [REDACTED]. This has the benefit of inspection data being available from one reactor core at each station [REDACTED] (I judge that there are sufficient differences in the irradiation behaviour of Hinkley Point B and Hunterston B cores to justify this approach). If inspection is not undertaken at this or a similar frequency, whilst I do not believe that a large release due to failure to shutdown on demand is a likely scenario, some lesser event (such as impairment of control rod insertion or fuel movement) is I believe inevitable at some stage if a vigilant precautionary approach is not adopted. Furthermore, if there are no historical data to indicate how degradation develops with time there is I believe an increased likelihood of increased risk should we agree to continued operation. Increased frequency of inspection from stress-reversal onwards should provide some assurance of the rate of defect development that may not be available if inspection continues at three yearly intervals. I judge that the likelihood of failure to achieve shutdown and hold-down on demand, due to graphite component and core degradation, is likely to be less than [REDACTED] operating period.

9. There are currently no means of detecting sub-surface keyway-initiated cracks. This is a significant shortfall in the safety case. I judge it essential to develop a means to detect sub-surface cracking initiated from the periphery of the bricks before it is through thickness and may therefore be seen during fuel channel TV inspections. If this is not achieved there is a reasonable likelihood that extensive sub-surface cracking may be present and subsequent propagation to the surface may occur over a relatively short time period due to the enhanced radiolytic oxidation occurring at the fuel channel wall.

### **Key Recommendations**

10. I recommend that we write to British Energy to advise of the need for more frequent inspection to validate their predictions.

11. I recommend that we ask British Energy to develop inspection techniques capable of detecting and distinguishing sub-surface initiated cracks. Until such capability is demonstrated and implemented to undertake CBMU on every channel that is examined by TV inspection as this has the potential to reveal sub-surface defects.

12. I recommend that we ask British Energy to undertake a review of uncertainties in input data and errors between whole core model predictions and rig validation tests to establish what is an appropriate safety margin between model predictions and actual component and core distortion.

## CONCLUSIONS

118. I judge that there are significant uncertainties in the predictions of component and core condition, primarily due to the absence of materials properties data and knowledge as to the cracking behaviour of irradiated graphite. This leads to uncertainty in the timing, morphology and configuration of defective graphite components in the AGR cores. As a result whilst keyway-initiated cracking, leading to single or doubly cracked bricks, is one possible outcome of graphite ageing other defect morphologies may be equally likely.

119. I judge that the analyses presented by British Energy demonstrate significant tolerance of core safety functions to single and doubly cracked bricks. However, I judge that it is not possible to bound all possible component defect morphologies and configurations of defective graphite components in the AGR cores as this may be infinite. Other configurations of defective graphite components may present a greater challenge to core safety functions than single and doubly cracked bricks.

120. Recent core inspection data at Hinkley Point B and Hunterston B suggest, based upon brick shape change with irradiation shrinkage, that some bricks in the flattened region of the core are already at stress-reversal. Sensitivity studies indicate that at this stage some bricks may have passed stress reversal some [REDACTED] and keyway-root initiated cracking is predicted to occur [REDACTED].

121. I judge that the likelihood of a challenge to core safety functions over an operating period of 3 years is highly uncertain. I judge that it is reasonably practicable to increase the core inspection frequency in response to stress-reversal to mitigate uncertainty. I judge that this will ensure that any component and core degradation that is significantly different to that predicted by British Energy may be detected, and an appropriate response developed, before core safety functions are degraded.

122. I judge that an appropriate time between inspections to revalidate the safety case is [REDACTED]. This has the benefit of inspection data being available from one reactor core at each station [REDACTED] (I judge that there are sufficient differences in the irradiation behaviour of Hinkley Point B and Hunterston B cores to justify this approach). If inspection is not undertaken at this or a similar frequency, whilst I do not believe that a large release due to failure to shutdown on demand is a likely scenario, some lesser event (such as impairment of control rod insertion or fuel movement) is I believe inevitable at some stage if a vigilant precautionary approach is not adopted. Furthermore, if there are no historical data to indicate how degradation develops with time there is I believe an increased likelihood of increased risk should we agree to continued operation. Increased frequency of inspection from stress-reversal onwards should provide some assurance of the rate of defect development that may not be available if inspection continues at three yearly intervals. I judge that the likelihood of failure to achieve shutdown and hold-down on demand, due to graphite component and core degradation, is likely to be less than [REDACTED] operating period.

123. There are currently no means of detecting sub-surface keyway-initiated cracks. This is a significant shortfall in the safety case. I judge it essential to develop a means to detect sub-surface cracking initiated from the periphery of the bricks before it is through thickness and may therefore be seen during fuel channel TV inspections. If this is not achieved there is a reasonable likelihood that extensive sub-surface cracking may be present and subsequent propagation to the surface may occur over a relatively

short time period due to the enhanced radiolytic oxidation occurring at the fuel channel wall.

124. The current safety case states that "It is currently proposed that, at each of the [REDACTED] shutdowns, TV inspection will be carried out in at least 24 fuel channels, CBMU inspections will be carried out in at least 14-15 fuel channels ...". The most recent proposals indicate that BE intend to reduce this intent to 18 fuel channels for TV inspection and 13 for CBMU. I judge that the decision to reduce the number of channel inspections in [REDACTED] compared with the proposal in the current safety case requires a robust justification.

125. I judge that there is a pressing need for a Materials Testing Reactor experiment to obtain materials data, including dimensional change and irradiation creep behaviour, that bounds any future operating condition. British Energy advised at a recent Level 4 meeting that they are proceeding with a detailed design review for an MTR experiment and this will be reviewed at the Engineering Review Group meeting in [REDACTED]

← why remove this date

## RECOMMENDATIONS

### Those Requiring Regulatory Action

126. I recommend that we write to British Energy to advise of the need for more frequent inspection to validate their predictions.

127. I recommend that we ask British Energy to develop inspection techniques capable of detecting and distinguishing sub-surface initiated cracks. Until such capability is demonstrated and implemented to undertake CBMU on every channel that is examined by TV inspection as this has the potential to reveal sub-surface defects.

128. I recommend that BE should take steps to ensure that the predictions of core displacement, for a given configuration of cracked bricks, are insensitive to time that the cracked brick configuration occurs. This would achieve independence in the CCCA and Damage Tolerance legs of the safety case and ensure that the predicted displacements are both bounding and time insensitive.

129. I recommend that we ask British Energy to undertake a review of uncertainties in input data and errors between model predictions and rig validation tests to establish what is an appropriate safety margin between model predictions and actual component and core distortion.

130. I recommend that we write to British Energy to seek their justification for reducing the inspection intent in the current safety case from 24 to 18 fuel channels for TV inspection and from 14-15 to 13 fuel channels for CBMU.

### Those Requiring Assessment Action

131. I recommend that assessment of the basis of the safety case for high radiolytic weight losses, predicted to occur at Hinkley Point B around [REDACTED] is assessed in more detail when the revised safety case is submitted for the return to power of [REDACTED] cores, following the periodic shutdowns in [REDACTED] and when weight loss data are available from British Energy.

132. The seismic response of a defected structure is an important aspect of the safety case and I recommend that this aspect of the safety case is assessed in more detail by the appropriate experts in NII.