Thirty Years Of [redacted] (1976-2006)

05 JUN 2006

British Energy

Hinkley Point B

[redacted] - 2/ONR-7

Superintending Inspector
Health and Safety Executive
Nuclear Safety Directorate
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NUC 452/3/2/P3/E28/BV 413 2003

NUC 452/79/P3/E17/BV 53 2005

For the Attention of [redacted]

Our Ref: LF/AB/BW
Unique No: HPB 50684N
Your Ref: HPB HPB 71030R

2nd June 2006

Dear [redacted]

BRITISH ENERGY GENERATION LIMITED
HINKLEY POINT B POWER STATION, BRIDGWATER
"A REVISED SAFETY CASE FOR THE GRAPHITE CORE: INSPECTION AND MONITORING PROPOSALS FOR 2005-2008" MAY 2005, NP/SC 7147 ADDENDUM 2 REVISION 000

Thank you for your comments on the assessment of the above safety case for the graphite cores at Hinkley Point B and Hunterston B. You have raised several issues and asked several questions. We would welcome an opportunity to discuss the issues with you in more detail and [redacted] will contact you to arrange a suitable date for meeting. We have indicated below the points we would raise under each issue.

Issue 1. *Based on current graphite case you judge that there is a need for more frequent inspection of the graphite core*

Response: You recognise in your comment that the position is changed by the recent graphite core safety case (NSC/06/2187), and you have yet to form your view on the enhancements to the safety case.

In our discussion with you we would like to emphasise which elements of the safety case that have been kept the same:

- Calculation of the conservative on-set of keyway root cracking (2010)
- Time to reach 30% keyway root cracked bricks (additional 5 years)
- Assumption that bricks which crack will prompt double crack
- Comprehensive and bounding modelling of core distortion

[redacted]

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[redacted]

- Assumption that all doubly cracked bricks are aligned and that there is a global sideways force to move the channels to the maximum bound
- Bounding principles of the core inspection
- Confidence that not all bricks will prompt double crack

And those where improvements have been made:

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- Reduced threat from bore cracking (from observation of the core)
- Demonstration that 30% doubly cracked bricks gives equivalent distortion to that presented in the previous case (90% singly, 10% doubly cracked bricks)
- Improved monitoring of the core particularly the analysis of fuel grab load trace which should detect doubly cracked bricks which have sheared or separated and hence be a lead indicator of the degradation of core functionality.
- Demonstration that there is no cliff edge in failure of the control rods to insert.

The recent case has added considerable margin to that presented last year and more importantly has enabled two key elements to change

(a) the inspection level has been set at 30% cracked bricks (assuming the bricks prompt double crack which is very conservative) compared to the 10% used in the last case. Thus a more representative level can be set for inspection in 2006 – a target of <5% cracking to 99.9% confidence
(b) the progression from 5%-30% doubly cracked bricks is considerably longer than the time from 0%-10% used in the case last year.

This margin within the case has allowed the inspection strategy to be based on the current set of Periodic Shutdowns [redacted]
The requirement to inspect in a cold shutdown has been retained since it is judged that there is increased risk of keyway root cracking during such an operating condition.

Issue 2: *You judge that there is a need to develop inspection techniques capable of detecting part through cracks. Until such capability has been demonstrated and implemented you judge it is reasonably practicable to undertake CBMU on every channels inspected by TV. You ask for proposals for*

(a) CBMU of each and every channel de-fuelled for inspection commencing at the periodic shutdown of [redacted] alternatively provide a robust justification explaining why we consider that it is not reasonably practicable to do so
(b) How the capability of core inspection may be enhanced such that part through thickness cracks may be detected and sized.

Response

For (a) a full ALARP assessment needs to consider benefits and dis-benefits of any proposed option, and we attach the ALARP assessment that has been carried out.

[redacted]

To define the benefit of additional inspection, it is necessary to consider the likelihood of partial cracks arising and the safety implications of such partial cracks.

There has been considerable discussion in the previous safety cases of the behaviour of bore cracking and that it is judged that such cracking is probably not full thickness. It is assumed in these cases that such cracking has developed through to full thickness which is conservative. Bore cracking will be discounted from further discussion.

Keyway root cracking is expected to initiate when the tensile stress at the keyway root is greater than the critical failure stress. There are two components to the internal stress – shrinkage stress and thermal stress and these are approximately equal in magnitude. The maximum thermal stress arises during a cold shutdown. The reactor takes ~1½ weeks to reach the coldest temperatures from the time of the trip. Thus the thermal stress takes a time to increase. In such a circumstance the crack will initiate when the critical stress value has been reached, and there in then addition stress to drive the crack forward irrespective of the stress field.

At the initiation of the crack in effectively a cylinder, there is a stress gradient to drive the crack from the keyway towards the brick bore. Several assessments have taken place and there is no indication that the crack will arrest. It is likely that there would be additional thermal stress above the energy to initiate the stress to ensure that the crack would be driven full thickness. Thus, it is judged that the most likely outcome that all single keyway root cracks would propagate to full thickness and full height, and the likelihood of their being un-revealed partial thickness cracks is low.

There has been one assessment when two cracks are initiated from the opposite side of the brick at the same time. Only with perfectly equal properties do both cracks fail to reach the brick bore. This is judged to be an unlikely situation.

Even if the crack did not propagate to the brick bore it is unclear what the safety consequence could be. In a previous safety case (RACSC 2, NP/SC 7147), the core distortion with 100% singly cracked bricks was shown as tolerable. If every brick developed a partial crack and this crack developed to full thickness during operation (due to internal or external stress) there are no safety consequences that have not already been considered.

The likelihood of a single partial crack developing a prompt second crack is negligible from the range of mechanisms previously discussed. The time to delayed secondary cracking is several years, and hence there is little threat from undetected partial cracks even if they arise.

[redacted]

Finally, there is a proposal to inspect a minimum of 13 channels with CBMU during each periodic shutdown with additional inspection required of any channels which are revealed by TV inspection to have a full length axial crack. This inspection will be sufficient to determine that cracking is less than 1% at 90% confidence and 5% at 99.9% confidence. Hence there is already sufficient evidence available to mitigate such a threat which is perceived low risk.

Therefore, by considering the likelihood, the safety consequences and that inspection of 13 channels is already taking place, we judge that there is not a significant benefit in an additional 5 channels of CBMU inspection.

However, although the safety case defines a minimum range of inspection it also requires that an ALARP assessment is required at each periodic shutdown. These have been completed and are attached.

It has been concluded that for [redacted] is ALARP to carry out additional CBMU inspections up to a total of 18 channels.

We would like to take the opportunity to discuss these assessments with you in detail.

In response to (b) we intend to carry out a range of improvements to the graphite core inspection capability of the AGRs and a proposal is going through internal process to secure the appropriate funds. These include a whole range of options and we would like to take the opportunity to discuss the proposals with you. We include the option to develop the capability for partial crack detection.

Issue 3: *Please present proposals for further modelling to ensure that predictions of core displacement, for a given configuration of cracked bricks, are insensitive to time that the cracked brick configuration occurs.*

We are in the process prioritising this work in this financial year. We will discuss the work programme with you at our proposed meeting. Within this programme there is the intention to investigate core distortion beyond the current lifetimes (2011 for HPB/HNB) and we will need to address the modelling requirements. In the simple sense there are six areas we wish to address

(a) Proportion of doubly cracked bricks that are aligned
(b) Driving force to generate core distortion
(c) Channel profiles derived from the core distortion
(d) Brick and key/keyway geometry during differing periods of operation
(e) Realistic proportions of singly and doubly cracked bricks (with correct modelling of singly cracked brick keying system)
(f) Definition of the Withstand Capability of the core distortion.

In parallel to these assessments we are putting together an experimental programme to measure distortion on a ¼ scale model of the core. This model (to include doubly cracked bricks) will have representative brick and key geometry.

[redacted]

Issue 4: *Before start-up of reactor 3, following its periodic shutdown in [redacted] please present proposals for the development of an appropriate safety margin between the actual core and component condition and the currently defined limit of the safety case in terms of frequency of cracked bricks. Your expectation is that this should include as a minimum: a review of the uncertainties in input data and errors between model predictions and rig validation.*

We will discuss the margin within the most recent safety case with you before start-up of Reactor 3. There is already a large margin within the safety case and we believe that there is a misunderstanding in the difference between model predictions and rig validation and how this translates to deployment of the model in the safety case.

The inspection level has been set at 30% cracking with margin to the fraction that would doubly crack. We will need to explore the potential ratio of single to double cracking. Further, the whole core modelling which is shown to be tolerant to 30% double cracking (0r 90% single and 10% double cracking) has a large margin within the methodology that includes:

- a co-operative horizontal core driving force to all the bricks to reach a bounding distortion,
- the alignment of the double cracks within any channel
- a very restrictive set of channel shapes that the control rod and stringer are assessed against
- recognition that very few channels reach the maximum bounding distortion.

On that basis, it should not be necessary to add a further margin between 30% cracking from CCCA and 30% double cracking from whole core modelling.

Issue 5: *You judge there is a pressing need for a Material Test Reactor experiment to obtain materials data, including dimensional change, irradiation creep behaviour and mechanical properties at high weight loss that bounds any future operating condition.*

We note your comment and desire to engage in discussion to ensure that the experiments are optimised to give maximum benefit. We are in full agreement to engage in such discussion.

We are in the process of defining and refining the scope of the proposed experiments. We will discuss the details as they emerge and in particular the outcome from the July 2006 Engineering Review Group.

We are collecting together the information for internal briefing on the need for and benefits of an MTR. In developing an MTR proposed programme, we will show when data could become available.

We also intend to get several independent assessments of our proposals.

[redacted]

I enclose our ALARP assessment of the graphite core inspections proposed for the R3 inspection in 2006. If you have further comments on the points you have raised before the Level 4 meeting in June please contact [redacted]

Yours sincerely

[redacted]

Station Director

Enc:

[redacted]