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November 10, 1983

Mr. Harold R. Denton, Director
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Subject: Dresden Station Unit 3
Supplment to Proposed Amendment
to DPR-25, Report and Evaluation
of ASEA-ATOM BWR Control Blade
Cracking Identified at Oskarshamn-2
NRC Docket No. 50-249

Reference (a): B. Rybak letter to H. R. Denton
dated July 18, 1983.

Dear Mr. Denton:

As your are aware, (see Reference (a)) Commonwealth Edison plans to install eight ASEA-ATOM (A-A) control blades in the upcoming cycle of Dresden 3, as part of an EPRI-sponsored project (RP1628-2) to use an improved control blade design for U.S. BWRs. The following discussion and attached A-A letter provide an update to the discussion of A-A control blade performance contained in the referenced letter.

Recent inspections of A-A control blades in the Oskarshamn 2 BWR in Sweden have revealed indications of cracking in the blade wings at high burnups. Visual inspections of the 29 control blades with highest exposure showed that cracks occurred on 16 blade wings distributed among 10 of the control blades. ASEA-ATOM has conducted a preliminary evaluation of the blade inspections. The results of their evaluation are contained in the attached report (Attachment 1).

The occurrence of cracks in other A-A control blades does not result in a reduction of safety margins at Dresden 3 for several reasons. First, the reported cracks have occurred at burnup levels greater than those expected in two eighteen month cycles at Dresden 3. In addition, the test program for the eight Dresden blades involves a complete visual inspection of all blades after each cycle of operation. Unlike the current blade design, the A-A solid sheath design allows direct visual examination without disassembly. There will also be further inspections of European A-A blades prior to reaching high burnups in the Dresden blades. Finally, the stainless steel in the A-A control blades to be used at Dresden has been fabricated with tighter chemistry controls than the 10 year old blades inspected at Oskarshamn, further reducing the risk of cracks due to intergranular stress corrosion. Four of these blades use hafnium instead of boron carbide in the top six inches and would therefore be even less susceptible to IGSCC from B_4C swelling.

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In summary, CECo feels that the identification of blade cracking at Oskarshamn 2 should not affect the Dresden Unit 3 demonstration program for A-A control blades and is merely updating the available information on the performance to date of the blades. CECo will provide additional information on this matter as it becomes available.

Please address any questions you may have concerning this matter to this office.

Very truly yours,

B. Rybak

B. Rybak
Nuclear Licensing Administrator

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cc: NRC Resident Inspector - Dresden
R. Gilbert - NRR

Attachments

7609N

ATTACHMENT 1

ASEA-ATOM

Dealt with by
Mr Ö Bernander, (021)-107522
For the attention of
Copy:

Our Date
1983-10-14
Your Date

Our reference
C530.0970
Your reference

Dr David Franklin
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U S A

Mr Henry E Bliss, Director
Nuclear Fuel Services
Commonwealth Edison Co
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U S A

Dear Mr Bliss,

Subject: Recent Experience from Inspections of Exposed Control Blades

This letter is a summary and discussion of our recent experience from a visual inspection of control blades in the Oskarshamn-2 BWR in Sweden. On August 29, 1983, indications were first obtained of cracks on blade surfaces. Subsequent examination of a large number of blades showed visual crack occurrence above a certain local boron-10 (B-10) depletion. The preliminary conclusions conveyed to you during our meeting in Chicago on Sep. 6 still appear to hold. Results from further investigations will be forwarded to you as well as to the Electric Power Research Institute. The contents of this letter may be used by you to the extent required in support of your licensing efforts.

The findings from Oskarshamn-2 have been duly reported to the Swedish licensing body, the Nuclear Power Inspectorate. The Inspectorate was satisfied with the conclusions as reported in this letter and with the control blade management suggested by the power utility. This blade management implied the removal of blades with visible cracking and replacement with either fresh spare blades or other exposed blades. The only constraint was that maximum exposure until the next blade inspection should not appreciably exceed the critical level observed to result in blade cracking. In effect, this permits cracking to occur during a cycle but with an expected limited B_4C loss.

Of course, results from more detailed investigations may well influence future control blade management.

1. Introduction

ASEA-ATOM employs a unique control blade design for BWRs. It uses vibratorily compacted boron carbide (B_4C) powder in horizontally drilled holes in stainless steel sheets which form the blade wings of the cruciform structure. The design is described in the topical report for eight control blades delivered to the Commonwealth Edison Co. for use in the Dresden Unit 3 reactor (Ref. 1). The control blades for Dresden-3 are provided within a program sponsored by EPRI (RP1628-2) for verifying their performance in a U.S. reactor.

The design of the absorber section of the control blades for Dresden-3 is based on that used in Swedish and Finnish BWRs. However, improvements have been made to promote extended service life by the use of hafnium in the top 6 inches of four of the blades, and by reducing silicon and phosphorus content of the steel in six of the blades. These added features should significantly delay onset of any stress corrosion cracking that may limit service life before reactivity worth reduction through B-10 depletion becomes limiting.

The experience of control blade usage in AA-design reactors is of interest for determining potential mechanical limitations of the service life of the improved blades. Examinations have therefore been carried out on exposure leading blades in different Swedish reactors. By the end of 1982, control blades from Oskarshamn-1 and Barsebeck-1 had been examined and were found to be in good condition. Peak axial B-10 burnups were in the range of 40 to 50 %. These B-10 depletion values are averages along B_4C holes; true maximum local values (at the blade wing edge) are then of the order of 60 to 80 %, B-10 depletion. Further examinations of high-exposure control blades were planned for the Oskarshamn-2 refueling outage in August 1983. The reactor had completed its 8th operating cycle with all control blades still in their original locations from the initial cycle. Visible cracks were then found on two blades. This prompted additiona examinations of blades in this reactor as well as in Ringhals-1.

2. Control Blade Examination Results

In Oskarshamn-2 the 29 control blades with highest exposure were visually examined in the spent fuel pool using a periscope and a television camera. The blade wing surfaces can be directly observed for checking of mechanical integrity or corrosion. Defects were found according to the following description.

Cracks were seen on 16 blade wings distributed among 10 of the control blades. The cracks were located within 2 inches from the upper end of the absorber zone and extended horizontally along the B_4C-filled holes. The cracks had varying lengths and tended to start at the outer edge of the blade wing but only on one side of a B_4C hole. The cracks did not propagate onto the edge of the wing. In two cases the cracks were certain to penetrate into the B_4C hole since bubbles came out of the cracks when the blades were lifted higher up in the pool.

The average B-10 depletion in the top 6 inches of B_4C was in the range 24 to 29 % except for one blade which had approx. 20 %. It is, however, more appropriate to use the depletion at the actual location of the cracks at the very top end of the absorber zone. Calculations indicate these local B-10 depletions to be in the rang 46 to 54 % (horizontally averaged across blade). This local exposure peaking is a result of the large power gradients at the blade tip in most operating conditions. Even for fully withdrawn control blades, a significant exposure contribution is obtained at the blade tip.

There was no noticeable warping of the blade wings or other dimensional or structural defects.

Inspection of the seven exposure-leading control blade in the Ringhals-1 reactor showed no defects. This was to be expected on the basis of the result from Oskarshamn-2 since the highest B-10 depletions were slightly below those at which cracking had been observed in Oskarshamn-2.

3. Discussion on Cause of Defects

The probable failure mechanism is inter granular stress corrosion cracking. Buildup of large circumferential stresses in the stainless steel (type AISI 304L) around the neutron absorber occurs when the B_4C swells upon neutron irradiation. The swelling is due to accumulation of the nuclear reaction products heliu and lithium in the B_4C crystal grains. Evidence for this process is given in Ref. 2. Crack initiation will then primarily depend on local burnup of B-10, but pressure buildup from released He gas may also contribute significantly to the stresses.

Cracking is generally expected to occur on one side of the blade wing surface since the wall thickness will always tend to be thinner on one side due to dimensional tolerances in the manufacturing of the blades.

This is in agreement with observations and may well explain much of the statistics of crack occurrence.

The cracks tend to appear near the blade wing edge where local B-10 burnup is the highest. The depletion at the blade tip edge is in the order of 70 to 80 %.

4. Consequences of Blade Cracking

Cracking of the blade wing surfaces may cause loss of B_4C and structural deformations and weakening.

Experience from control blades of a different design (Ref. 2) shows that B_4C is lost from high B-10 burnup regions when water intrusion takes place. Pressure changes in the reactor vessel and thus on the blade surface causes water to alternately enter and leave through a crack, thus enabling dissolved boron or small B_4C particles to escape from the blade. Such leaching or washout is expected only when the cracks have become visible and then only from the immediate vicinity of the crack. It is reasonable to assume - because of the complex access geometry - that other B_4C-filled holes will not be appreciably affected, although water will have passage to all B_4C holes through the narrow channel along the blade wing edge. This should be true at least in the short term perspective as for instance during the cycle when through-wall cracks develop.

When B_4C loss is assumed to be restricted to a short segment at the top end - as in the case of Oskarshamn-2 - the reduction in reactivity worth with respect to shutdown margin requirements is acceptably small. Thus there is no safety concern in the situation when cracks develop during an operating cycle. Behaviour in the longer term can only be judged after detailed examination of failed control blades.

Blade wings can be expected to warp when cracks develop. Any deformations are, however, assumed to be small since the central part of the blade structure will still be quite rigid. This is supported by the experience from Oskarshamn-2. Hence, significantly increased friction between control blades and adjacent fuel channels because of reduced dimensional tolerances is not to be expected.

The experience from Oskarshamn-2 yields a threshold level of local B-10 depletion at which cracks occur that may cause loss of B_4C. The accumulated operating time at power during which the failed control blades had been more or less inserted into the core exceeds the possible accumulated exposure for the improved blades in control cells (in Single Rod Sequences) in the Dresden-3 core of at least two 18-month cycles.

There is thus adequate time to draw on further operating experience of control blades in the Swedish reactors before the third 18-month cycle with the ASEA-ATOM type blades takes place in Dresden-3.

We expect that actual control blade performance will allow three 18-month operating cycles in the Dresden-3 reactor in spite of the observed cracking in Oskarshamn-2. The expectation is based not only on the improved design features of the blades delivered to Dresden-3 but also on the fact that the manufacturing techniques have improved over the years which has resulted in a more uniform quality standard.

5. Continued Examinations

It is the intention of ASEA-ATOM to carry out a more detailed inspection of failed blade samples from Oskarshamn-2. The program planning is still going on but will at least involve identification of type of cracking, extent of B_4C loss, and dimensional measurements.

References

1. ASEA-ATOM TR 82-98 (Rev. 1)
   Performance Verification of an
   Improved BWR Control Blade Design

2. Nuclear Technology, vol. 60 (March 1983), 362
   Operational Experience with and
   Postirradiation Examinations on
   Boiling Water Reactor Control Rods.

Sincerely yours,

AKTIEBOLAGET ASEA-ATOM
Fuel Department

Erland Tenerz

Copy to EPRI, David Franklin