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ARKANSAS NUCLEAR ONE, UNIT 2

CYCLE 4 SHOULDER GAP EVALUATION

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I. INTRODUCTION

Arkansas Nuclear One, Unit 2 (ANO-2) completed Cycle 3 on September 26, 1983. During the refueling outage, inspections of the shoulder gaps (distance between the top of the fuel rods and the bottom of the upper end fitting) in several fuel assemblies were performed. This report summarizes those inspections and also describes the evaluation of the predicted shoulder gaps for fuel assemblies being operated for a third cycle in Cycle 4.

Shoulder gaps decrease with residence time in the reactor due to differential growth between the fuel rods and the fuel assembly structure (guide tubes). Measurements of shoulder gap changes have now been made on selected ANO-2 fuel assemblies after Cycles 1, 2, and 3.

The measurements after Cycle 2 had indicated that the shoulder gap was decreasing at a faster rate than expected. Since the fuel assemblies at ANO-2 are the lead exposure assemblies of the C-E 16 x 16 fuel design, a conservative prediction was made for the third cycle shoulder gap decrease rate. Use of the prediction, in combination with the measurements, had indicated that there was a potential for rods in some Batch C assemblies to come into contact with the upper end fitting before the end of Cycle 3. A design modification was implemented in order to increase the shoulder gaps in those assemblies.

The shoulder gap measurements taken after Cycle 3 have provided the opportunity to monitor the actual behavior of the 16 x 16 fuel design at typical three cycle exposures, and thus permit a more accurate evaluation of the next batch (Batch D) being inserted for a third cycle of operation. The measurements also have been used to determine whether a Batch C demonstration assembly had sufficient shoulder gap to operate for a fourth cycle in Cycle 4.

A statistically based method has been used to evaluate shoulder gap clearance during Cycle 4. The method utilized both the measured Batch D performance thru two cycles and that of Batch C in its third cycle. Based on the evaluation, it was concluded that all Batch D assemblies would satisfy the criterion of 95% probability that the worst rod would not contact the upper end fitting during Cycle 4. This maintained the original design basis of the Batch D fuel. Therefore, none of the Batch D assemblies were modified for purposes of operation in Cycle 4.

One Batch D assembly was modified duringthe Cycle 3 outage in order to prepare it for a potential fourth cycle of operation in Cycle 5. The design modification incorporated stainless steel spacer shims that were essentially the same as those used in the Cycle 2 outage, except for a slightly shorter length.

The Batch C demonstration assembly could not be shown to have sufficient shoulder gap for a fourth cycle of operation. It will be replaced by a Batch A assembly in Cycle 4. All Cycle 4 fuel management studies and safety analyses had considered the option of either the Batch A or Batch C assembly being present in Cycle 4.

II. SHOULDER GAP MEASUREMENTS

The fuel inspection program which provided the data for the evaluation of Cycle 4 shoulder gap clearance consisted of shoulder gap measurements in eight Batch C and sixteen Batch D fuel assemblies. Each assembly was examined on all four faces, and measurements were made on all peripheral fuel rods and (with the exception of one Batch D assembly) on any measurable interior rods which might be limiting. A total of seven Batch E assemblies were measured to gather information for future evaluations.

Eight Batch C assemblies were inspected. These included two characterized demonstration assemblies which had exhibited high gap closure rates during their initial two cycles; and six non-characterized assemblies, with two each in the categories of high, moderate, and low gap change rates thru the end of Cycle 2. Important conclusions from the Batch C inspections are summarized below.

a. Those Batch C rods which had shown high shoulder gap change rates in earlier cycles continued to have high rates in Cycle 3 (rates are defined as inches of closure per unit of fluence). Therefore, it is not possible to take advantage of reduced rates of closure as the fuel assembly achieves higher exposures.

b. The highest rate of shoulder gap change observed was less limiting than the maximum rates assumed in the Cycle 3 projection that determined which Batch C assemblies required modification for continued operation. All four of the measured Batch C assemblies that were not modified for Cycle 3 continued to have adequate shoulder gap clearance. All four measured Batch C assemblies that had been modified also had adequate shoulder gap clearance. None of the eight assemblies had shoulder gap change rates as high as the maximum rate used to determine whether they required modification for Cycle 3.

c. The Batch C assemblies which had moderate or low change rates thru two cycles continued to exhibit similar behavior in their third cycle.

A total of sixteen of the 60 Batch D assemblies loaded for Cycle 4 were measured. The Batch D assemblies that were measured included two characterized demonstration assemblies, which contained various test rods and which had been measured following Cycle 2. The other Batch D assemblies were the remaining three Batch D assemblies inspected after one cycle, and eleven assemblies whose selection was biased to include a large representation of those which will have accumulated high exposures after three cycles.

Significant conclusions from the Batch D inspections are listed below.

a. The shoulder gap change rates in Batch D were lower thru the first two cycles of operation than those in Batch C fuel thru its first two cycles. The maximum observed shoulder gap change in any Batch D assembly was about 85% of the maximum observed in Batch C at comparable fluences.

b. For those Batch D assemblies that had shoulder gap measurements taken after both cycles 2 and 3, there was a trend toward lower shoulder gap change rates in the second cycle of operation (Cycle 3).

III. SHOULDER GAP EVALUATION

The criterion used to evaluate the shoulder gap clearance in Batch D fuel was that, at the 95% probability level or greater, the worst rod in the fuel assembly will not have shoulder gap closure at the end of operation (end of Cycle 4). The statistical method which was used to determine the status of the Batch D assemblies with respect to the criterion is summarized below.

a. Limiting shoulder gap change rates thru two cycles were determined for the inspected Batch D assemblies, based on measurements of peripheral fuel rods and end of Cycle 3 fluences. The maximum Batch D rate was less than the highest Batch C rate determined after Cycle 2.

b. The Batch D assemblies were divided into two groups, depending on their calculated fluences at the end of Cycle 4. This separation was based on the fact that the lower fluence group could be evaluated by the use of a single shoulder gap change rate applied throughout life, which did not take credit for improved Batch D behavior. It was necessary to take some credit for the improved behavior in the higher-fluence group. The fluence cutoff between groups was 7.6×10^{21} nvt.

c. An end-of-Cycle 4 maximum shoulder gap change was calculated for the lower-fluence Batch D group. The maximum value was obtained by multiplying the highest individual fuel rod fluence at end of Cycle 4 (for fuel rods in this group) by the highest Batch C peripheral rod gap change rate determined for three cycles of operation. The use of the Batch C rate for the entire three cycles of Batch D operation is very conservative based on the differences noted earlier between the two batches.

d. An end-of-Cycle 4 maximum shoulder gap change was calculated for the higher-fluence Batch D group by a slightly different method. For these assemblies, different rates were used for two different periods of operation. For the first two cycles (Cycles 2 and 3), a rate was used which was equal to the maximum rate for any measured peripheral shoulder gap in the group of assemblies. For the third cycle (Cycle 4) the shoulder gap change rate was selected to be equal to the maximum rate observed for Cycle 3 in any of the measured Batch C assemblies. The predicted shoulder gap change within the higher-fluence Batch D group was obtained by multiplying the two rates by the appropriate increments of fluence for rods within the group. The maximum predicted shoulder gap change resulted from the most adverse combination of fluences during the two periods.

e. The two resulting maximum shoulder gap changes (one from Step c and one from Step d) were compared to the minimum available shoulder gap at the beginning of life. This minimum gap was based on adverse tolerances, maximum differential thermal expansion between the fuel rods and guide tubes, and elastic compression of the guide tubes under the fuel assembly holddown force.

f. In both cases, the maximum Batch D shoulder gap change was less than the beginning of life value. Since each of the rates used in the evaluation represented at least an upper 95/95 value, the calculated gap changes also represented at least 95/95 values.

The conclusion from this statistical analysis was that all Batch D assemblies would satisfy the gap criterion for standard rods throughout Cycle 4. Therefore, none of the Batch D assemblies required modification to provide additional clearance.

A special case was made for the two Batch D demonstration assemblies which contained test fuel rods with experimental Niobia-doped fuel pellets. In some cases (approximately six rods per assembly) the test rods exhibited rates of shoulder gap decrease higher than those of standard Batch C and D fuel rods. The difference is thought to be due to higher fuel pellet swelling in Niobia-doped fuel pellets. The method outlined below was used to evaluate the Cycle 4 performance of the test rods.

a. Several of the test rods had been measured after both Cycles 2 and 3, as part of the test program. In all cases, rods which had shown the high gap change rates had a lower Cycle 3 rate than that in Cycle 2. This indicated a reduced rate effect at higher exposures. Therefore, the assumption of the same change rate in Cycle 4 as that observed over the first two cycles was conservative.

b. For each test rod that was measured, a specific two-cycle average change rate was determined and used to extrapolate its performance during Cycle 4. The calculated Cycle 4 fluence increment for each rod was utilized.

c. The measured gap at the end of Cycle 3 was then reduced by the value obtained in Step b. The resulting end-of-Cycle 4 prediction was corrected for operating conditions and examined for clearance.

The conclusion from this analysis was that none of the measured test rods would be predicted to contact during Cycle 4. Photographs of the test assemblies were examined and it was determined that all of the limiting rods had been measured. Therefore, the two test assemblies did not require modification for Cycle 4 operation.

Since it is desired to operate one of the assemblies for a fourth cycle, and since all of the equipment and parts were available to modify Batch D assemblies, additional shoulder gap was provided for assembly D040 by a method essentially the same as that used on Batch C assemblies at the end of Cycle 2. The design modification is further described in Reference 1. The six high change rate test rods containing Niobia-doped fuel pellets were removed from D040, since application of the observed rates in these test rods by the method described earlier indicated the potential for contact during Cycle 5. The test rod locations involved are scattered in the interior of the test assembly.

Another special case was one of the Batch C demonstration assemblies, which had been considered as a potential core center assembly for Cycle 4. As noted in Section II, high change rate Batch C fuel rods did not exhibit a reduced rate during Cycle 3. Using the same limiting Batch C rate used for the Batch D evaluation, some of the rods in the Batch C demonstration assembly would be predicted to contact the upper end fitting during Cycle 4. Therefore, the option of substituting a Batch A assembly in the core center was chosen for Cycle 4. This option had been considered in all fuel management and safety analysis work.

IV. CONCLUSIONS

1. It was determined that all of the Batch D assemblies satisfied the shoulder gap criterion for Cycle 4 without requiring increases in the shoulder gap.

2. One Batch D demonstration assembly was modified to prepare it for a potential fourth cycle of operation in Cycle 5. Certain test rods were removed from this assembly because of observed high growth rates, and were replaced with dummy rods. The assembly modification incorporated stainless steel spacer shims that had essentially the same design as those used to modify Batch C fuel assemblies during the Cycle 2 outage.

3. The Batch C demonstration assembly could not be shown to have sufficient shoulder gap for a fourth cycle of operation. A Batch A assembly will be substituted for the Batch C assembly as planned.

REFERENCES

1. John R. Marshall (AP&L) to Robert A. Clark (NRC), Docket No. 50-368, Letter No. 2CAN038308, August 19, 1983.