SPECIAL REPORT

FORT CALHOUN STATION
UNIT NO. 1

END OF CYCLE 9 CEA INSPECTION RESULTS
AND IMPACT ON CYCLE 10 OPERATION

1.0 Introduction

During the End of Cycle (EOC) 9 Refueling Outage (in 1985) a CEA inspection program was conducted in which all fingers of all full length CEA's were inspected. The inspections consisted of eddy current test (ECT) measurements which examined profilometry, wear, circumferential cladding strain, and CEA integrity. ECT integrity testing identical to that performed during EOC 9 was performed on 22 CEA's at EOC 7. Other physical measurements similar to those listed above for EOC 9 had been performed at EOC 7 using a mechanical profilometer on 17 selected CEA fingers.

As a result of the EOC 9 ECT measurements, it was determined that all full length CEA fingers had maintained their integrity through nine operating cycles; however, a trend was observed where the lower 4 inches of the CEA cladding indicated total circumferential strains as high as Seven CEA's were found to have one or more fingers exhibiting total strains greater than or equal to two CEA's in this group contained two fingers exceeding strain, thus resulting in a total of nine fingers with strains greater or equal to If exposed through Cycle 10, several CEA's would be expected to exceed the cladding strain design criterion. Ten new CEA's, consisting of two CEA's stored on-site and eight CEA's fabricated (on emergency notice) by Combustion Engineering, were obtained and used for replacement of the CEA's exhibiting the highest strains. The District, in conjunction with Combustion Engineering, initiated a program of activities to address questions related to the continued use of the remaining full length CEA's through Cycle 10. This program also included mechanical profilometry validation of the ECT profilometry technique.

The basis for continued use of 35 of the 45 original full length CEA's through Cycle 10 is discussed below. In addition, the District also performed a scoping analysis which addressed the impact on shutdown margin of the failure of all CEA fingers expected to exceed total strain during Cycle 10. The District then examined the effect that these CEA finger failures would have on the conclusions of the Main Steam Line Break analysis.

This report summarizes the results of the CEA profilometry testing as it applies to the use of the CEA's loaded into the core for Cycle 10 operations.

2.0 Strain Requirements

2.1 Strain Design Criteria

The original design of the CEA fingers anticipated swelling of B_4C pellets within the cladding boundary, due to the B-10 (n,α) Li-7 reaction within the B_4C pellets. A criterion of 1% mean unrecoverable circumferential cladding strain was adopted as a design basis for C-E control rods.

A Maine Yankee CEA containing an all B_4C finger essentially identical to that at Fort Calhoun Station, was recently examined at a hot cell as part of an EPRI project. The Inconel-625 clad CEA which have been operated in a PWR radiation environment, was found to have maintained cladding integrity with a total measured strain of This strain was determined to be composed of a

As a result of C-E evaluation of the Fort Calhoun strain data with respect to the Maine Yankee - EPRI and CE/KWU research programs, Combustion Engineering concluded that the "...level of strain where CEA fingers would begin to show ruptures has yet to be established." It was further concluded that the new data, now available confirms the strain criterion which is being used.

2.2 Maximum End of Cycle 10 Strain

The rate at which the cladding strain grows as a result of the swelling of B_4C pellets in contact with the Inconel-625 cladding was evaluated for the Fort Calhoun Station CEA's. C-E evaluated the strain growth rate using the mechanical profilometry measurements made at the end of Cycle 7 and the supplemental mechanical profilometry data from EOC 9. Based on an evalaution of 15 pairs of data from the EOC 7 and 9 tests, and expected average strain growth rate for Cycle 10 was derived. The expected incremental strain for Cycle 10 was determined to be

3.0 Cycle 10 Impacts

3.1 New CEA's

The ten CEA's that contained fingers with the highest strain values at EOC 9 were replaced as previously described.

3.2 Original CEA's

The 35 CEA's that were retained for use in Cycle 10 were evaluated with respect to projected EOC 10 strain and the total strain limit. The maximum strain for the fingers of each CEA was used as the representative strain for that CEA. The incremental strain increase of for Cycle 10 was then added to the representative values. The maximum strain arrived at for an EOC 10 CEA finger was Since this value is below the total strain limit of it was concluded that none of the CEA fingers used in the Fort Calhoun Cycle 10 core would exceed the total strain limit of at the end of the cycle.

3.3 Physics Analysis

The Omaha Public Power District performed a physics scoping analysis to evaluate the effect of CEA finger failures. This analysis was performed in parallel to Combustion Engineering's evaluation, from which it was concluded that no CEA's would exceed the total strain limit in Cycle 10. For the physics analysis, all fingers that were projected to exceed strain during Cycle 10 were assumed to fail with the loss of all B_4C. Use of the strain value was justified by field data which showed that the eight fingers which had a total strain of or greater had maintained their integrity. The total strain was also substantially less than the C-E total strain limit of As a result of these calculations, the Cycle 10 CEA loading pattern was modified to minimize the effects of potential individual CEA finger failures. The pattern changes included both moving CEA's to different locations and rotating the individual CEA's to minimize scram worth losses resulting from projected finger failures.

The Hot Zero Power calculations showed that the shutdown margin with the fingers failed is still greater than the Technical Specification 2.10.2 value shutdown margin requirement of 4.0% delta rho. The Hot Full Power cases indicated a scram worth less than the value assumed in the Safety Analysis. Section 3.4 addresses the hot full power scram worth reduction.

3.4 Main Steam Line Break Evaluation

The Hot Full Power Main Steam Line Break was analyzed for the reduced shutdown margin. This review assumed a scram worth of 4.25% delta rho which is approximately 1% delta rho less than that determined from Section 3.3. Due to the less severe cooldown curve of Cycle 10 as opposed to the Updated Safety Analysis Report (USAR) containing Cycle 8 and Cycle 1 results, the reactivity loss was more than offset by the cooldown curve reactivity gains. Thus, no return to critical was found to occur for the Cycle 10 core with the postulated reduced scram worth. This review verified that the results reported in the Fort Calhoun Station USAR remain bounding.

4.0 Cycle 11 CEA Program

During the Cycle 10 refueling outage, the District plans to replace all full-length CEA's not replaced during the EOC 9 Refueling Outage.

5.0 Conclusions

Combustion Engineering measured the total strain on all CEA fingers in the Fort Calhoun core. They identified that the maximum total strain for any CEA finger that would be used during Cycle 10 is Based on CEA measurements performed by C-E at EOC 7 in conjunction with the EOC 9 tests, an average incremental strain increase of total strain is expected for Cycle 10. Therefore, the maximum anticipated total strain at the End of Cycle 10 will be This is less than the design limit of total strain.

Although not necessary to justify continued use of the 35 CEA's of the original design, the District examined the effects of single CEA finger failures. The Cycle 10 loading pattern was adjusted to minimize the impact of any failures, 10 CEA's were replaced, and the USAR results for the Hot Full Power Main Steam Line Break were confirmed to be bounding.

Therefore, the continued use of the 10 new and 35 original CEA's at the Fort Calhoun Station during Cycle 10 operation is deemed to be acceptable.