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ENCLOSURE

TOPICAL REPORT EVALUATION

Report Identification: CENPD-198-P, Supplement 1-P and 2-P
CENPD-198, Supplement 1 and 2 (Non-proprietary)
Report Title: Zircaloy Growth: Application of Zircaloy Irradiation Growth Correlations for the Calculation of Fuel Rod Growth Allowances
Report Date: November 1978
Originating Organization: Combustion Engineering, Inc.
Reviewed by: Core Performance Branch
Division of Systems Safety

Background

Section 4.2 of the Standard Review Plan (Ref. 1) requires that the design analysis performed to establish operational tolerances must account for possible dimensional changes of core components. For Zircaloy core components under in-pile conditions, the dimensional behavior is governed by mechanical interference, creep, and growth. For an axial-dimensional analysis of these effects, Combustion Engineering has submitted the generic topical report, CENPD-198, "Zircaloy Growth: In-Reactor Dimensional Changes in Zircaloy-4 Fuel Assemblies" (Ref. 2).

This topical report provides a literature discussion of the proposed mechanisms of axial growth and in-reactor growth strain data. Elongation due to locking and ridging from pellet-cladding-mechanical interaction (PCMI) and anisotropic diametral creepdown were eliminated as significant contributors to dimensional changes in the axial direction. Hence, in-pile axial-dimensional changes in currently designed C-E fuel rods accrue predominately as a result of irradiation-induced stress-free growth.

This information was then used as support for empirical growth correlations. Best-estimate correlations with upper and lower 95% tolerance limits were described that related growth strain to fast neutron fluence for annealed and cold-worked Zircaloy core components.

Because the report did not specify the manner by which the correlations were to be applied in licensing calculations, the staff evaluation (Ref. 3) specified suitable applications of the correlations for the prediction of fuel rod, guide tube, and assembly axial growth. Combustion Engineering objected (Ref. 4) to those requirements and requested that our position be reevaluated. The reevaluation (Ref. 5) of our position remained unchanged; however, we identified the basis and information that Combustion Engineering might utilize in seeking a relaxation of the conditions that we had placed on the use of the Zircaloy growth correlations. To this end, Combustion Engineering submitted CENPD-198-P, Supplement 1, "Zircaloy Growth: Application of Zircaloy Irradiation Growth Correlations for the Calculation of Fuel Assembly and Fuel Rod Growth Allowances."

Summary of Topical Report

Supplement 1 to CENPD-198 describes the specific design criteria by which Zircaloy growth correlations (described in CENPD-198) for fully annealed guide tube and cold-worked fuel cladding are statistically applied to establish allowances for (1) fuel assembly axial growth and (2) differential axial growth between fuel rods and the fuel assembly structure.

For ensuring an adequate clearance for fuel assembly axial growth, the axial gap is designed to accommodate the growth associated with an upper tolerance limit on the growth correlation for guide tubes of the fuel assembly having the maximum predicted end-of-life axially averaged fast fluence.

For calculating the design clearance between fuel rods and fuel assemblies, it is a C-E design criterion that the axial clearance be capable of accommodating the differential growth of the axially averaged highest fast fluence fuel rod at a probability of 95% or greater. In demonstrating conformance to this criterion, C-E considers fuel rod growth and guide tube growth to be independent random variables. The variables' means and standard deviations are combined using a Monte Carlo technique to obtain a joint density function of differential growth. Finally, the necessary clearance is obtained by combining the differential growth allowance with allowances for component tolerances, differential thermal expansion, and elastic compression and creep of the guide tubes.

In support of those analyses, the report provides tabulations and plots of growth strain data taken from post-irradiation examinations of fuel assemblies from the Maine Yankee and Calvert Cliffs 1 nuclear power plants.

Summary of Regulatory Evaluation

We have reviewed the subject report including the in-reactor data provided in support of the methodology. Also, during our review

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additional questions (Ref. 6) were asked of C-E, and their subsequent responses (Ref. 7), which are contained in Supplement 2 to CENPD-198, were reviewed as well.

We agree with C-E that the analyses described in the report are important, not only for the determination of core operational tolerance, but also for the fuel lifetime and management as well. The consequences of an inadequately designed axial gap to accommodate fuel assembly axial growth may ultimately result in collapse of the holddown springs, hence, resulting in mechnical interference between fuel assemblies and the reactor vessel internals. Failure to adequately design for fuel rod axial growth may result in fuel rod bowing due to mechanical interference between fuel rods and the upper end fittings. In regard to the latter concern, problems with inadequately designed rod growth gaps have been reported in foreign (Obrighein and Beznau) and domestic (Ginna) plants and have necessitated predischarge modifications to fuel assemblies (Ref. 8, 9, and 19).

Supplement 1 to CENPD-198 states that two variables, fuel rod growth and guide tube growth, are used in the Monte Carlo technique to obtain a joint density function representing differential growth. The density function is then combined with other variables to obtain the needed hot shoulder gap. We note, however, that C-E has stated in response to one of our questions that combinations of more than these two variables (fuel rod and guide tube growth) may be used in the Monte Carlo technique to form the joint density function. Specifically, a third random variable representing component tolerances (which was previously used in the calculation of the hot shoulder gap, but after the joint density function was obtained) may now be used directly in the computer calculational technique. For the sake of completeness, we have reviewed this modification to the method that is described in Supplement 1 to CENPD-198 and have found this modification to be acceptable.

It is known that the stress-free irradiation growth rate of zirconium-bearing alloys is primarily dependent upon fast neutron fluence, service temperature, texture or preferred crystallographic orientation, and retained cold work. These later two variables are, in turn, strongly dependent upon the specific fabrication techniques that are employed during the component production. We are aware that C-E is continuing to improve their reactor cores and have, as yet, not standardized fabrication techniques used for all Zircaloy core components. Therefore when the approved version of CENPD-198 is referenced in license applications, a description must be provided of the metallurgical states of the components being analyzed. Should the conditions of these components differ in our judgement by a significant degree from the condition of those components referenced in CENPD-198, then justification must be provided for their applicability to the approved topical report.

Currently CENPD-198 is referenced in several plant safety analysis reports for applications that involve potential burnups for which growth measurements on C-E Zircaloy core components have not been reported. We thus believe that C-E should confirm the conservatism of the design predictions of growth strain with measurements from discharged fuel assemblies.

Our approval of this topical report is limited to Zircaloy growth strains corresponding to axially averaged fast neutron fluences not exceeding $4X10^{21}fn/cm^2$ ($E \geq 0.821$ Mev), an exposure above which C-E has not reported growth strain data on C-E Zircaloy core components. We anticipate that growth strains due to exposures in excess of $4X10^{21}fn/cm^2$ will not exceed those stains predicted by the extrapolation of the C-E growth correlations. However, plant SARs that make reference to CENPD-198 for Zircaloy growth analyses must either provide for confirmatory measurements in their surveillance programs for Zircaloy growth at fluences greater than $4X10^{21}fn/cm^2$ or cite similar data.

Regulatory Position

We have concluded that the topical report is acceptable for reference in license applications involving the calculation of allowances for (1) fuel assembly axial growth and (2) differential axial growth between fuel rods and the fuel assembly structure.

There are, however, two conditions governing our approval. First, because the growth characteristics of Zircaloy components are sensitive to the fabrication process, we will require that where the approved version of CENPD-198 is referenced in future applications that a description be given of the metallurgical state of the components being analyzed. If in our judgement the metallurgical condition of those components do not differ significantly from those described in CENPD-198, then the description may be brief and CENPD-198 may be used; otherwise the use of the CENPD-198 must be justified.

Second, our approval of this topical report is limited to Zircaloy growth strains corresponding to axially averaged fast neutron fluences of $4X10^{21}$ fn/cm^{2} (22500 MWd/t).

The issuance of this SER hereby supersedes the previous staff-imposed restrictions as set forth in References 3 and 5.

References

1. "Fuel System Design," Standard Review Plan, Revision 2, U.S. Nuclear Regulatory Commission Report, NUREG-75/087 (1979).

2. "Zircaloy Growth: In-Reactor Dimensional Changes In Zircaloy-4 Fuel Assemblies," Combustion Engineering Proprietary Report, CENPD-198-P (Non-Proprietary version, CENPD-198), December 1975.

3. K. Kniel, U.S. Nuclear Regulatory Commission, letter to A. E. Scherer, Combustion Engineering, dated June 22, 1976.

4. A. E. Scherer, Combustion Engineering, letter number LD-76-093 to K. Kniel, U.S. Nuclear Regulatory Commission, dated August 16, 1976.

5. K. Kniel, U.S. Nuclear Regulatory Commission, letter to A. E. Scherer, Combustion Engineering, dated November 4, 1976.

6. R. L. Baer, U.S. Nuclear Regulatory Commission, letter to A. E. Scherer, Combustion Engineering, dated August 28, 1978.

7. A. E. Scherer, Combustion Engineering, letter number LD-78-082 to R. L. Baer, U.S. Nuclear Regulatory Commission, dated November 9, 1978.

8. H. Schenk, "Experience from Fuel Performance at KWO," International Atomic Energy Report Number SM-178-15 (October 1973),

9. K. Kuffer and H. R. Lutz, "Experience of Commercial Power Plant Operation in Switzerland," 5th Foratom Conference, Florence (1973)

10. Robert Emmett Ginna, Nuclear Power Plant Unit Number 1, Rochester Gas and Electric Corporation, U.S. Atomic Energy Commission Docket Number 50244-103 (1972).