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Release

POWER SYSTEMS

February 29, 1980
LD-80-011

Mr. R. P. Denise
Acting Assistant Director for
Reactor Safety
Division of Systems Safety
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

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Subject: Fuel Cladding Deformation Models for LOCA Analyses

Reference: NRC letter from R. P. Denise to A. E. Scherer, dated January 31, 1980

Dear Mr. Denise:

In response to your request in the reference letter, Combustion Engineering (C-E) has prepared the attached comments on cladding deformation as affected by temperature ramp rate and pre-rupture plastic strain.

The C-E cladding deformation model does not include temperature ramp rate dependence. Incorporation of temperature ramp rate dependence in our cladding deformation models would require major computer code modifications. Based on previous sensitivity studies we conclude that the omission of this parameter does not significantly affect peak cladding temperatures. Therefore, in light of the limited impact on our LOCA analysis results, we do not recommend inclusion of temperature ramp rate in the cladding deformation models.

If I can be of further assistance on these subjects, please contact me or Mr. J. Longo at (203)688-1911, Extension 4414.

Very truly yours,

COMBUSTION ENGINEERING, INC.

MAR 10 1980

A. E. Scherer
Director
Nuclear Licensing

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Attachment

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C-E Comments on Temperature Ramp Rate and Prerupture Plastic Strain

References:
(1) NRC letter, R. P. Denise to A. E. Scherer, dated January 31, 1980
(2) C-E Letter, LD-79-067, A. E. Scherer to D. G. Eisenhut, dated November 16, 1979
(3) NUREG-0630, "Cladding Swelling and Rupture Models for LOCA Analysis," D. A. Powers and R. O. Meyers, November, 1979

The following comments apply to Reference (1) concerning the effect of temperature ramp rate and prerupture plastic strain on zircaloy cladding deformation during a LOCA.

1. Temperature Ramp Rate

1.1 Comment on Temperature Ramp Rate Effect on Calculation of Peak Cladding Temperature

Reference 3 presents LOCA clad swelling and rupture models that depend on temperature ramp rate. The C-E clad behavior models for LOCA do not have temperature ramp rate dependence. The impact of including ramp rate effects in C-E's LOCA models was reported to NRC in Reference 2. As described in Reference 2, the use of the NRC recommended ORNL correlation for rupture temperature would possibly lead to earlier rupture times and higher rupture strains and blockages in C-E's LOCA analyses. Based on the results of various sensitivity studies using revised heat transfer models, C-E has concluded that the reported peak clad temperature for all C-E operating plants would not be significantly affected by these temperature ramp rate effects.

It should be noted that implementation of any temperature ramp rate dependent calculational method would require a major computer code revision. In view of the limited significance of temperature ramp rate effects in C-E LOCA calculations, we do not believe that these computer code revisions are necessary.

1.2 Comment on Ramp Rate Calculation Methods

If it is required that temperature ramp rate effects be considered in clad deformation models, C-E recommends that the determination of the temperature ramp rate in the analytical model be the same as defined from the experimental data correlation. For example, the NRC model for rupture temperature in Reference 3 is the ORNL empirical correlation. The measured temperature ramp rate used to empirically correlate the ORNL rupture temperature data is the constant value established prior to local clad deformation and not the value observed at the time of rupture. Therefore, to be consistent with the correlation, the LOCA fuel performance computer code should calculate a temperature ramp rate for the early heatup period prior to rupture.

1.3 Comment on NRC Method for Ramp Rate Calculation

The attachment to Reference 1, describes a weighted-average method for calculating temperature ramp rate in TOODEE2. In this method, a temperature dependent weighting function is used to bias the average temperature ramp rate in favor of the ramp rate nearest the rupture temperature. The advantages of this method are that any calculational instabilities tend to smooth out and that for a typical LOCA, a positive ramp rate is calculated even though the cladding may actually be cooling off. A positive ramp rate is necessary for the new NRC models which apply only for clad heatup transients. One of the disadvantages of this method is that the weighted-average ramp rate is not consistent with the ramp rate defined for the ORNL empirical correlation for rupture temperature as discussed in 1.2, above. That is, the weighted-average method favors the ramp rate nearest to the failure temperature and the empirical correlation uses the ramp rate in the early heatup period prior to failure. Another disadvantage is that under special circumstances, where the predicted rupture temperature decreases rapidly due to a decrease in the weighted-average ramp rate, clad failure may be predicted to occur during the time period of clad cooldown even though the ORNL rupture temperature correlation applies only for clad heatup.

From a metallurgical viewpoint, clad failure depends on the temperature history. For a temperature ramp test, the temperature ramp rate is no doubt a suitable parameter characterizing the temperature history; however, for a LOCA analysis, the temperature ramp rate does not, in general, characterize the temperature-time history of the cladding. The weighted-average method, described in Reference 1, attempts to recognize the temperature history, but is not consistent with the empirical correlations. The weighted-average method could be employed provided the empirical correlations were rederived using the weighted-average ramp rate as a parameter.

2. Prerupture Plastic Strain

The NRC recommended model for plastic strain is the Coffman Model which predicts the amount of strain as a function of the instantaneous temperature. This temperature dependence severely limits the adequacy of plastic strain analysis in near isothermal or cooldown conditions. Like clad failure, plastic strain is dependent on temperature-time history or time-at-temperature and not just temperature. C-E agrees with the staff's position stated in Reference 1, that this aspect of the cladding analysis warrants further study.

The significance of prerupture plastic strain in LOCA analysis is not readily obvious due to several competing influences of plastic strain on the overall LOCA result (peak clad temperature). Plastic strain reduces the gap conductance between the fuel and clad producing lower clad temperatures and lower internal pressures, both of which tend to delay rupture. Also plastic strain produces a larger surface area for convective cooling. On the other hand, plastic strain increases flow blockage. Reactor coolant may be redistributed in the hot subchannel thereby reducing convective heat transfer at the hot spot elevations. Therefore, even though pre-rupture plastic strain would increase clad deformation before rupture, it is not obvious that this would increase peak cladding temperatures.