Docket No. 50-331

JUL 19 1973

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Iowa Electric Light & Power Company
ATTN: Mr. Duane Arnold
Chairman of the Board and
President
Security Building
P. O. Box 351
Cedar Rapids, Iowa 52406

Gentlemen:

By letter of November 20, 1972, the Commission's Regulatory staff requested that you provide the necessary analyses and other relevant data for determining the consequences of densification and the effects on normal operation, anticipated transients, and accidents, including the loss-of-coolant accident. Your response of January 15, 1973 stated that the General Electric report NEDM-10735 "Densification Considerations in BWR Fuel Design and Performance," December 1972, serves as your answer to our request.

As you are aware, five additional proprietary supplements to NEDM-10735 have been submitted by General Electric Company in response to questions raised by the staff as a result of our review of NEDM-10735 and the succeeding supplements.

The enclosure represents the staff's conclusions on BWR fuel densification as a result of our review and provides the essential elements to be included in your analyses to account for the effects of fuel densification in the Duane Arnold Energy Center core. Therefore, we request that you provide the necessary analyses and other relevant data for determining the consequences of densification and the effects on normal operation, anticipated transients, and accidents, including the postulated loss-of-coolant accident, using the guidance provided in the enclosure. If the analyses indicate that changes in design or operating conditions are necessary to maintain required margins, you should submit proposed changes and operating limitations with the analyses.

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| SURNAME ▶ | MMaigret<br>x7791 | W. Butler | | | | |
| DATE ▶ | 7/18/73 | 7/18/73 | | | | |

In order that the Regulatory staff can conduct an expeditious and orderly review of these matters, we request that you submit the analyses and additional information within 30 days from the date of this letter. It is requested that this information be provided with one signed original and thirty-nine additional copies.

Sincerely,

Original signed by
Gerald Owsley
Walter R. Butler, Chief
Boiling Water Reactors Branch No. 1
Directorate of Licensing

Enclosure:
Model for Fuel Densification

cc: w/encl.

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## GE MODEL FOR FUEL DENSIFICATION

The General Electric fuel densification model is described in NEDM-10735 and Supplements 1, 2, 3, 4, and 5 to NEDM-10735 (see references 1 through 6). The GE model when modified as described below is considered to be suitably conservative for the evaluation of densification effects in BWR fuel.

Possible effects of fuel densification are: (1) power spikes due to axial gap formation; (2) increase in LHGR because of pellet length shortening; (3) creep collapse of the cladding due to axial gap formation; and (4) changes in stored energy due to increased radial gap size. Similarly, the GE model for fuel densification consists of four parts: power spike model, linear heat generation model, clad creep collapse model and stored energy model. The required modifications to each of these models are listed below.

### Power Spike Model

The GE power spike model is acceptable as it is described in NEDM-10735 and Supplement 1 to NEDM-10735 and modified in Supplement 5 of NEDM-10735 as long as it is used in conjunction with a maximum axial gap size given by the following equation:

$$\Delta L = \left(\frac{0.965 - \rho_i}{2} + 0.004\right) L$$

where $\Delta L$ = maximum axial gap length

$L$ = fuel column length

$\rho_i$ = mean value of measured initial pellet density (geometric)

0.004 = allowance for irradiation induced cladding growth and axial strain caused by fuel-clad mechanical interaction

Linear Heat Generation Model

The following expression should be used to calculate the decrease in fuel column length in determinations of the linear heat generation rate:

$$\Delta L = \frac{0.965 - \rho_i}{2} L$$

where: $\Delta L$ = decrease in fuel column length

$L$ = fuel column length

$\rho_i$ = mean value of measured initial pellet density (geometric)

Credit can be taken for fuel column length increase due to thermal expansion, and for the actual measured length of the fuel column.

Clad Creep Collapse Model

Examination of exposed BWR fuel rods (Ref. 5) and Regulatory staff calculations show that clad collapse will not occur in typical BWR fuel during the first cycle of operation. Consequently, no additional creep collapse calculations are required for the first cycle of typical BWR fuel.

For reactors in subsequent cycles of operation the GE creep collapse model, described in NEDM-10735 and its supplements, should be used with the following modifications:

1. The equation used to calculate the change in ovality due to the increasing creep strain should account for the ovality change due to change in curvature as well as for the ovality change due to change in rod circumference.

2. A conservative value should be used for the clad temperature. Axial temperature variations in the vicinity of a fuel gap as affected by thermal radiation from the ends of the pellets and by axial heat conduction should be taken into account. Effects from any buildup of oxide and crud on the clad surfaces should also be considered.
3. The calculations should be made for the fuel rod having the worst combination of fast neutron flux and clad temperature.
4. No credit should be taken for fission gas pressure buildup.
5. No credit should be taken for end effects. An infinitely long, unsupported length of cladding should be assumed.
6. Conservative values for clad wall thickness and initial ovality should be used. An acceptable approach is to use the two standard deviation limit of as fabricated dimensions.

Stored Energy Model

The GE stored energy model is based on $UO_2$ thermal conductivity and heat capacity given in Section D of Reference 6, a flux depression factor of 1.0, and a gap coefficient of 1000 Btu/hr-ft$^2$ F applied to each fuel rod within the hot fuel assembly. The selection of the gap coefficient in this model should be modified as follows.

(1) Changes in gap conductance due to variations in LHGR, gap size (or g/D) and initial fuel pellet density should be accounted for.

(2) A gap conductance vs. LHGR curve that based on available experimental data predicts with 95 percent confidence that 90 percent of future events will exceed predictions, should be used.

(3) Instantaneous densification should be assumed, i.e., pellet OD and gap size should be calculated using the following equation:

$$\Delta r = \frac{0.965 - \rho_i + 2\sigma}{3} r$$

where: $\Delta r$ = reduction in pellet radius

$r$ = initial pellet radius

$\sigma$ = standard deviation in the measured probability distribution of pellet density

$\rho_i$ = mean value of measured initial pellet density (geometric)

The gap size and pellet, OD, corrected for instantaneous densification, should be used for the selection of the gap conductance vs. LHGR curve.

(4) The fuel pellet located at the most critical position for normal operation, anticipated transients and postulated accident conditions should be analyzed with the densified pellet size as given by the equation under item (3).

(5) In calculations which are sensitive to bundle stored energy, for the 48 neighboring pellets in the same horizontal plane, the standard deviation used in the equation can be replaced by the standard deviation in mean boat pellet density.

(6) Since the assembly average stored energy is one of the most important inputs to BWR LOCA evaluation, a Technical Specification limit should be imposed on maximum permitted assembly power.

References


1. D. C. Ditmore and R. B. Elkins: "Densification Considerations in BWR Fuel Design and Performance" NEDM-10735, December 1972.

2. "Responses to AEC Questions - NEDM-10735," NEDM-10735 Supplement 1, April, 1973.

3. Responses to AEC Questions NEDM-10735 Supplement 1, "NEDM-10735 Supplement 2, May, 1973.

4. "Responses to AEC Questions NEDM-10735 Supplement 1, "NEDM-10735 Supplement 3, June 1973.

5. "Responses to AEC Question NEDM-10735" NEDM-10735 Supplement 4, July 1973.

6. "Densification Considerations in BWR Fuel," NEDM-10735 Supplement 5, July 1973.

7. B. C. Slifer and J. E. Hench, "Loss-of-Coolant Accident & Emergency Core Cooling Models for General Electric Boiling Water Reactors," NEDO-10329, April 1971.