N. Lauben

March 4, 1986

MEMORANDUM FOR: Robert B. Minogue, Director
Office of Nuclear Regulatory Research

FROM: Harold R. Denton, Director
Office of Nuclear Reactor Regulation

SUBJECT: APPENDIX K REVISION

Over the past several months, NRR has been interacting with your staff regarding our review of correlations and models you propose to term "acceptable" in the Appendix K Regulatory Guide. Based on our experience to date, we do not believe it is appropriate to invest our limited resources in detailed revisions of work your office has already determined to be acceptable. Therefore, we propose an alternative to the current approach for developing an ECCS Regulatory Guide that is mutually agreeable to both of us. We propose that RES certify the acceptability of the proposed correlations and models. As a result of our reviews to date, we have identified a minimum set of criteria which we believe each correlation or model must meet, in order to certify it as "acceptable" within the regulatory sense. These are as follows:

1. The RES finding of acceptability for the specified correlations or models is not in conflict with any statements or conclusions contained in the references used to support the model acceptability, and that such a review has been made. Known conflicts have been reviewed and the RES position is defendable.

2. There are no known disagreements with the RES conclusion of acceptability by knowledgeable researchers or experts, either published or otherwise. Any disagreements that are known to exist have been thoroughly reviewed by RES and RES is prepared to defend its conclusions.

3. The correlations or models proposed to be termed acceptable are not in known conflict with other applicable data, correlations, or models, and that such a review has been made. Known disagreements are explainable.

Assuming you can provide us with affirmative findings against these criteria for each model or correlation proposed, we will accept your proposal to call these correlations and models "acceptable", and not perform an NRR review.

Similarly, we would presume you will take the lead to provide all technical defense for the proposed models and correlations before the ACRS, or any other organization as needed.

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It is our understanding, based on recent discussions with your staff, that our proposed criteria are acceptable to you, and that you intend to convene a panel of experts to review the acceptability of your proposed correlations. We strongly endorse and are in full agreement with your approach. We intend to support this effort to the extent practical through attendance at these experts meetings.

For your information and use, the enclosure to this letter documents our comments to date on your proposed correlations and their associated bases.

Harold R. Denton, Director
Office of Nuclear Reactor Regulation

Enclosure:
As stated

cc: V. Stello

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*See previous sheet for concurrence

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ENCLOSURE: NRR COMMENTS ON ECCS REGULATORY GUIDE
CORRELATIONS AND MODELS

1. Comments on the Section, "Initial Stored Energy of the Fuel".

This section provides a brief description and listing of the general features required in a calculation of fuel temperature distribution or stored energy; however, it also omits fission gas release and gap conductance which are important. In addition, correlations are specified for some items, but for most items, no correlation is specified.

A correlation is specified for fuel relocation (fuel cracking and subsequent movements within the cladding). This model has a great deal of uncertainty and is usually adjusted in a fuel code to give agreement with integral data. Therefore, specifying a specific model is not recommended. In addition, our consultants at PNL have recommended a different model, if a model is required.

The Regulatory Guide also specifies a model for cladding creep. Cladding creep is different for each vendor's fuel because the cladding is of different thickness and undergoes a different manufacturing process for each vendor. Therefore, no general correlation should be specified for cladding creep.

Even though maximum stored energy usually occurs early in life when the amount of fission gas release is negligible, this is not always the case and fission gas release then becomes very important. Therefore, if correlations are to be specified, a correlation for fission gas release is needed.

Finally, we recommend that no correlations be specified for any models. Fuel thermal performance codes are highly non-linear and strongly dependent on the interactions of the various component models. Therefore, to specify some models and not others serves no useful purpose. Specifying all models is also not practical because some models should be specific to a vendor's fuel (e.g., densification and cladding creep). Furthermore, all the fuel vendors would have no incentive to provide updated technical information regarding fuel performance if we specified all the models.

2. Comments on the Critical Flow Discharge Model

A. The proposed model is the Henry-Fauske (H-F) model with modifications to the non-equilibrium parameter, N, given in the EPRI report EPRI-NP-2192, which was published over four years ago. Since work on the discharge models and calculations showing comparisons between calculated and experimental results has continued, what is the current situation for models of this type and two-fluid models?

The proposed model is not used in any of the current versions of TRAC or RELAP5 which have two-fluid models.

B. The V. Schrock reply to the RES request for a recommended model refers to the EPRI report, EPRI-NP-2191, "Critical Flow Data Review and Analysis" with the proposed modification to N to improve agreement with the Marviken results. He notes that he is always suspicious of modifications such as this and that a comprehensive review of the data and models has not been made. In contrast to the other proposed models (e.g., wall friction pressure drop, level swell) this proposal has a reasonable non-proprietary coverage of the status of work on the models as the result of the EPRI report. The H-F model with some modification such as the EPRI proposal or the suggestion in ANL/RAS/LWR 79-8 may be reasonable. However, the forced changes in mass flux are large and somewhat arbitrary. The Schrock comment has merit and clouds the issue of a clearcut NRC recommendation. More work to clarify the recommendation is needed.

C. The non-equilibrium parameter, N, which is described as a measure of departure from equilibrium, is restricted to values from 0 to 1. In the EPRI report, two relations for N are given (N=7XEQ for L/D less than or equal to 1.5 and subcooled inlet stagnation conditions and N=100XED otherwise). As the multiplier of XEQ is increased from 7 to 100 the calculated critical flow drops from the original Henry-Fauske values to close to the HEM values. There are large changes for some inlet conditions of interest. The effect of the EPRI proposal on some predicted results is a step decrease in critical flow by factors of roughly 1.5 to 2 (see Figures 6.2 and 6.4 of the EPRI report).

D. In ANLRAS/LWR 79-8, Dec. 1979, "A Comparison of the Marviken Critical Flow Tests with the Henry-Fauske Model", the Marviken test results are compared with the values calculated with a) the H-F model for several choices of the non-equilibrium parameter, N (N=7.1XEQ, N=20XEQ and N=100XEQ, where XEQ is the calculated equilibrium flow quality at the throat) and b) the homogeneous equilibrium flow model (HEM). They concluded that the Henry-Fauske model (XEQ=7.1XEQ) showed excellent agreement with experimental values for subcooled inlet conditions. However, when the fluid at the inlet reached saturated conditions, the homogeneous equilibrium flow model gave better results. In this report, the constant relation for N (N=20XEQ) was recommended "since it is representative yet somewhat conservative".

E. If the EPRI modification to the H-F model is adopted, it will be the first time that upstream geometry conditions as well as flow conditions are included in an "acceptable" model. This model uses L/D as a geometry parameter. However, all Marviken tests had rounded entrances. For LOCA calculations involving breaks in the cold legs, a small or intermediate break or large slit break involves a sharp-edged break with a break length of a few inches (pipe wall thickness) whereas double-ended quillotine breaks in the

primary piping or connected piping would involve rounded inlets. The point of this discussion is that if an inlet geometry condition is included in the acceptable model, some clarification of the applicability of the model should probably be included.

F. The modified (EPRI) model no longer has the good agreement that the original H-F model had with the critical flow data considered before the Marviken tests. Hence we now have two H-F models. We might replace these two models with some other combination of models for the present purpose (e.g., H-F plus HEM).

3. Connects on Wall Friction Pressure Drop

A. With the exception of the Hancox model, the proposed models are not used in any current version of TRAC or RELAP5. RELAP5/MOD1 uses the 1972 proprietary HFTS correlation. TRAC PF1 has a homogeneous model, but has errors according to NUREG/CR-4292. TRAC-BWR uses the Hancox model. However, the treatment of the data base for this model is in the Hancox dissertation which is not available at NRC at present. The NRC library has ordered a copy.

B. The wall friction pressure drop component in the momentum equation is not measured directly, but is backed out of the total pressure drop measurement by subtracting calculated values of the acceleration pressure drop (usually small) and calculated or experimental values of the elevation or gravity pressure drop component (usually significant in vertical flow). As noted on page 6 of AERE-R 9794, only a limited number of combinations of methods for calculating the pressure drop components could be tested. They decided to calculate the acceleration pressure drop from the homogeneous model and the gravity pressure drop from one of two void fraction correlations. The homogeneous void fraction model was used with the wall friction models based on a homogeneous flow model and the proprietary HFTS void fraction model described in their report was used for the remaining wall friction correlations. They didn't show results for those experiments where the elevation pressure drop was obtained from measured void fractions for the given test. In view of the above, the wall friction data base itself is proprietary and there is no data available to review on a non-proprietary basis.

C. The Martinelli-Nelson and Dukler relations in the RES proposal are not recommended in the HFTS discussion, but the Thom and Baroczy relations are recommended non-proprietary correlations. Since the Dukler correlation comparison is made with a homogeneous model void fraction correlation, a direct comparison of this wall friction correlation with the others does not seem possible. The reports supplied for review do not provide enough information to permit consideration of the applicability of the tests and correlations to reactor conditions of interest.

D. The proposed correlations are less prescriptive than those given in Appendix K which gives as acceptable either a) the modified Baroczy

correlation or b) a combination of the Thom correlation for pressures equal to or greater than 250 psia and the Martinelli-Nelson correlation for pressures less than 250 psia.

E. The Hancox correlation is not even mentioned in the HFTS report. I suspect that this is because the HFTS work is directed more towards heat exchanger calculations than nuclear reactor calculations.

F. Although not given in the RES recommendation, the Friedel correlation is one of the non-proprietary correlations which is recommended and appears more suitable for LWR applications. On pages 13 and 14 of AERE-R 9793 they note that it is as good as the Thom correlation for steam-water and does not have the mass velocity limitations of the Baroczy correlation. This correlation should be checked to see if the apparent advantages for LWR application hold up to closer scrutiny.

G. A good non-proprietary review with more emphasis on LWR LOCA applications is needed. We note that for BWRs, the major part of the core pressure drop at normal conditions is due to the irreversible losses associated with the side entry inlet orifices, fuel grids and exit fittings, all of which are obtained from proprietary tests. However, in view of the large scatter in the proposed correlations (factors of 4 for Martinelli-Nelson and 2-1/2 for Baroczy), some perspective is needed. Is there really much need for any better models than currently in Appendix K?

4. Comments on Level Swell

1) The ORNL report provided is a report describing a single set of tests at ORNL for a Westinghouse type PWR (17x17 lattice) and the application of some correlations to the test results. There apparently was no review to obtain all available data pertinent to this problem for reactor conditions of interest, although there is a brief outline of the data used in the Wilson and Yeh correlations. There is no mention of other data pertinent to other PWR vendors or to data pertinent to BWRs. At least for BWRs, other data is available. One report which is not checked independently is not enough to warrant a recommendation in the guide.

5. Comments on Swelling and Rupture of the Cladding and Fuel Rod Thermal Parameters

The Regulatory Guide specifies the following as "acceptable best estimate methods for calculating cladding swelling and rupture".

a. D. Hagrman, EGG-CDAP-5397 (Bacon 2) (ref. A.14).
b. R. Meyer & D. Powers, NUREG-0630

First, NUREG-0630 concludes "Based on the applicable data, we beieve the new cladding correlations presented in this report...provide the best means available today of predicting swelling and rupture

without underestimating the degree of swelling or the incidence of rupture." (emphasis added) Also NUREG-0630 states "there is still uncertainty in these correlations, and further research is needed to confirm or further modify these correlations.

Based on these conclusions, we cannot understand how NUREG-0630 is a "best estimate method" as it was constructed to be conservative. In addition, since the report was issued in 1980, it is not clear to us that any additional research results (if any) have been compared to the NUREG-0630 curves.

The matter is further complicated by the conclusions of the BALON-2 report. Specifically the report states "BALON 2 model predictions are compared to recently proposed licensing standards "(NUREG-0630)" for LOCA analysis. Results of this comparison suggest that the standards may be inadequate because they do not consider several of the parameters that affect cladding shape." In light of this conclusion, we question how RES finds both methods acceptable.