February 13, 1985

Docket Nos. 50-266
and 50-301

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Mr. C. W. Fay, Vice President
Nuclear Power Department
Wisconsin Electric Power Company
231 West Michigan Street, Room 308
Milwaukee, Wisconsin 53201

Dear Mr. Fay:

SUBJECT: DEVELOPMENT OF AN ACCEPTABLE ECCS EVALUATION MODEL WHICH INCLUDES THE EFFECT OF UPPER PLENUM INJECTION-POINT BEACH UNIT NOS. 1 AND 2

This letter is sent to you as the licensee of two of six operating Westinghouse two-loop plants which use upper plenum injection (UPI) in their emergency core cooling systems (ECCS). Point Beach is operating under 10 CFR Part 50.46(a)(2)(v) using a Westinghouse evaluation model that was accepted by the staff on an interim basis in a 1978 staff Safety Evaluation Report. Continued plant operation was accepted on the basis that "the long term effort to produce an acceptable ECCS evaluation model for treating Upper Plenum Injection should continue unless the two-loop plant owners propose to modify the ECCS hardware to eliminate Upper Plenum Injection."

The staff met with representatives of Wisconsin Electric Power Company, the other UPI licensees, and Westinghouse on July 24, 1984 to discuss current evaluation models (EM) submitted to demonstrate compliance with 10 CFR §50.46 and 10 CFR Part 50, Appendix K.

The staff has completed its evaluation of current EMs submitted by Westinghouse and Exxon. The current EM submittals continue to have deficiencies similar to those identified by the staff in our 1978 SERs. Briefly, there are problems with inadequate documentation, absence of sensitivity studies, absence of physically meaningful models addressing upper plenum phenomena, the effects of UPI on refill, reflood, and heat and mass transfer, an absence of comparison of EM predictions with experiments (e.g., experimental data from Semiscale and the Cylindrical Core Test Facility), and lack of consideration of the differences between UPI and non-UPI plants. The staff evaluation of the deficiencies in the current EM submittals is enclosed. Consequently, there is disagreement between your efforts and the staff regarding the degree of compliance which currently exists to meet the requirements of 10 CFR 50.46 and Appendix K.

Utilizing the enclosed guidance, provide a response regarding each of the areas in question to include plans, schedules and efforts to be expended regarding each area identified as a staff concern. To the extent practical you should address each area and document the technical basis (by reference where possible) you rely upon to assure compliance with 10 CFR 50.46 and Appendix K. Your response should be submitted within 60 days from receipt of this letter.

The reporting and/cr recordkeeping requirements of this letter affect fewer than ten respondents; therefore, OMB clearance is not required under P.L. 96-511.

Sincerely,

Original signed by:

James R. Miller, Chief
Operating Reactors Branch #3
Division of Licensing

Enclosure:
Evaluation and Guidance

cc w/enclosure
See next page

DL:ORB#3	DL:ORB#3	DL:ORB#3
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2/12/85	2/12/85	2/13/85

Enclosure 1

EVALUATION AND GUIDANCE REGARDING PROPOSED WESTINGHOUSE AND EXXON MODELS FOR LARGE BREAK LOCA ANALYSIS FOR UPI PLANTS

On July 24, 1984, during a meeting at the NRC Offices, the licensees requested detailed guidance on what should be included in any future evaluation model (EM) submittals for Westinghouse two-loop plants that use upper plenum injection (UPI) during emergency core cooling (ECC). That guidance is given here relative to the Westinghouse EM submittals and the Exxon EM submittals. The guidance is similar because the Westinghouse and Exxon submittals suffer from similar deficiencies. The guidance ends with comments on plant-specific acceptance criteria for an ECC system (ECCS).

A. INTRODUCTION

The staff Safety Evaluation Reports (SERs) of 3/78 and 9/78 allowed for continued plant operation [per 10 CFR 50.46(a)(2)(v)] but they stated that the then-existing EM submittals for UPI plants were in need of improvement. In particular, the SERs cited the need for revised EM submittals which would consider the thermal and hydraulic characteristics of the core and of the reactor system, and the need for better documentation and sensitivity studies. The current EM submittals continue to have deficiencies similar to those identified by the staff in our 1978 SERs.

There are two parts of 10 CFR 50 Appendix K that are particularly relevant to the perceived deficiencies in the current EM submittals for UPI plants. The first is part I.D., "Post Blowdown Phenomena; Heat Removal by the ECCS." The first five paragraphs of that part relate to PWRs, and our current understanding of UPI plants indicates that compliance with those paragraphs requires interpretation and analysis quite different from that for non-UPI plants. The second part of Appendix K that is particularly relevant is part II, paragraphs 3, 4 and 5 which (1) require sensitivity studies to address assumed phenomena, (2) require predictions of appropriate data by EMs, and (3) require the EMs to account for reactor differences such as UPI.

Section B of this evaluation and guidance document focuses on some of the deficiencies in the current EM submittals and how the deficiencies are related to the Appendix K paragraphs cited above. Sections C and D address the changes made by Westinghouse and Exxon to their standard non-UPI EMs in order to account for UPI and elaborate some of the concerns raised in section B. Section E is a summary of all prior sections; section F addresses plant-specific acceptance criteria for an ECCS.

There are additional compliance or compliance documentation issues related to other portions of Appendix K. These become apparent upon a line-by-line examination of Appendix K. However, they are not included here, either because (like Appendix K part I.B) they are not obviously significant in the context of the current EM submittals or because (like Appendix K part I.A) they would be better addressed when the staff is assured that a more appropriate EM exists for UPI plants.

B. DEFICIENCIES IN THE CURRENT EM SUBMITTALS

The conservativeness or appropriateness of the relationships among percent of the upper core plate covered by water in the upper plenum, top down quench, core heat transfer, upper plenum heat transfer, and UPI water penetration has not been demonstrated.

The current EM submittals do not account for pooling of UPI water in the upper plenum; they assume that UPI water falls quickly into the core. Semiscale data, Cylindrical Core Test Facility (CCTF) data and TRAC analyses indicate that significant upper plenum pooling occurs for a range of UPI conditions. There are several effects of pooling. First, it calls into serious question the correlations used for vertical and horizontal entrainment of UPI water by steam flow. These correlations did not consider the existence of pooling or frothing. Second, pooling adds a hydrostatic head which is not accounted for in the current EM submittals. Third, a pool or froth of any significant depth (as shown in the current data and analyses) clearly indicates virtually 100% of the upper plenum is covered by UPI water within a very short time of the beginning of reflood, negating the physics of the EM submittals. The pooling must be accounted for or the licensees must provide experimental data showing a different phenomenon exists in a UPI plant under UPI conditions.

During core reflood, the CCTF data and TRAC calculations show that flows at the core entrance plane are downward for UPI. Hot rod heat transfer and carryover rate fraction correlations, which are key ingredients in classical non-UPI EM reflood analysis, are derived from reflood experiments with forced upward flow. The current EM submittals for UPI plants use reflood correlations based on forced upward flow, but no basis has been provided showing that this data can be related to UPI plants. A basis must be provided or some parameter other than flooding rate (such as quench height) needs to be used along with a mass inventory procedure that more nearly describes the mass flow behavior in a UPI system. Alternatively, a more mechanistic model could be developed.

The current EM submittals assume refill is similar to that for non-UPI plants; the differences in hydraulics and heat transfer during refill are not addressed. Injection of UPI water into the upper plenum during refill may cause steam binding and delay water accumulation in the lower plenum and core, and this is not considered.

C. THE RECENT WESTINGHOUSE EM SUBMITTALS

Westinghouse proposed to determine the effects of UPI by making ten modifications to the WREFLOOD code (which is one part of the 1981 Westinghouse EM). Evaluation and guidance comments are provided for each of the ten modifications as follows, using the modification sequence and titles selected by Westinghouse.

1. Metal Heat Transfer to UPI Water.

Heat transfer from upper plenum metal to UPI water is calculated by a lumped thermal capacitance model. It is necessary to show that either (a) the coefficients used in the model are correct, (b) sensitivity studies show that results are insensitive to the values chosen for the coefficients, or (c) the coefficients selected are conservative for all cases and conditions of interest.

2. Upper Plenum Injection Flow Distribution

Westinghouse (W) assumes that safety injection (SI) forces ECC water into the upper plenum and this water covers only part of the core. The percent core coverage is important because the W UPI EM uses different analyses for the covered and uncovered core regions.

Acceptance of the partial core coverage concept would require explanation of experimental data from the Semiscale and CCTF test facilities which indicate upper plenum pooling occurs in the test facilities and hence may occur in UPI plants. It would also require determination and analysis of worst case coverage conditions and consideration of steam-water interactions.

3. Decay Heat and Stored Energy

This section of the Westinghouse EM submittal says, in full, that

> "The decay heat calculation uses ANS plus 20 percent. The initial stored energy at the beginning of reflood is based on the stored energy at the end of blowdown plus a calculation that adds the decay heat generated through the refill period to the core stored energy."

In evaluating the significance of this portion of the proposed model, the staff notes that the docketed EM submittals indicate that the refill period includes 14.45 seconds of pumped UPI before bottom of core recovery (BOCREC). The proposed Westinghouse EM ignores this UPI water during refill, which should be conservative relative to vessel inventory. However, it is necessary to address the effect of this 14.45 seconds of pumped UPI on (a) steam generation and steam flow or steam binding, (b) changes in fuel and metal wall stored energy prior to BOCREC, and (c) reflood, this being done with (d) 1 and 2 trains of SI operable. Alternately, (e) it is necessary to show that the proposed treatment is conservative and that injection of UPI water before BOCREC will not cause steam binding and delay BOCREC.

4. Fuel Rod with Top Quench Front

Operation of an SI train injects ECCS water into the upper plenum. The W model assumes that this UPI water covers a fixed percentage part of the core, and that it will flow downward into that part of the core and cause a top-down quench.

Westinghouse assumed that the time required for the top-down quench to reach the midplane of a fuel bundle was a specific linear function of the UPI mass flow rate per fuel assembly. Adequate technical justification of the function describing the top down quench would require (a) much more specific identification of the experimental data used to develop the quench-time function, (b) a showing that the data applies to the UPI situation, and (c) a showing that the flow per assembly is a valid correlation parameter.

Westinghouse stated that it used a quench-time function which is a "bound to the [experimental data] since more rapid quenching increases heat transfer to UPI water and results in more steam generation." This more rapid steam generation is presumably detrimental because it will impede reflood. However, to justify use of this bounding quench function, it would be necessary to show that an over-estimate of top down quench speed (and/or of UPI flow per assembly) will not cause an underestimate of peak cladding temperature (PCT).

5. Core Heat Transfer Model

The Westinghouse non-UPI EM uses very simple heat generation and heat transfer models to determine core exit fluid conditions. Westinghouse has made what appears to be relatively simple modifications to its non-UPI EM to account for heat transfer in the top down quench region. No adequate justification is given for using this simplified model under UPI conditions.

6. Core Steam Generation

It is necessary to clarify the location of the UPI water, and whether part of it is held up in a pool in the upper plenum; and it is necessary to demonstrate that the correlation for carryover from core to upper plenum is applicable to two-loop UPI plants.

The staff notes that water can be injected into the upper plenum at a rate which may be more than 10 times as large as the rate at which water can be injected into the intact cold leg, and that these flows determine the peak cladding temperature after the accumulators are empty. The licensees must submit a reflood and refill model which considers these flows and relevant thermal and hydraulic characteristics. The licensee must specifically show how and why the water injected into the intact cold leg is or is not bypassed throughout the transient.

7. Condensation

The licensee must explain and justify (a) what happens if the falling subcooled UPI water can condense all the rising steam in the covered region, and (b) the the equations and assumptions coupling the covered and uncovered regions.

8. Vertical Entrainment

Steam may be generated by the UPI water falling through the core. This steam is assumed to entrain and carry part of the UPI water upward. Westinghouse has not shown that the expe-imental data on entrainment was applicable to the conditions in a UPI plant, or that there exists a reasonable technical basis for extrapolating the correlation outside the data base.

9. Horizontal Entrainment

Westinghouse assumed that 1.67% of the ECCS water which is injected into the upper plenum is entrained by horizontally moving steam which carries this 1.67% of UPI water into the hot legs. The Westinghouse entrainment model hasn't been proven valid because the model is based on (a) entrainment test data which has not been demonstrated to be applicable to the conditions in the upper plenum of a UPI plant, and on (b) air flow tests which have not been documented enough to be reviewed. Any new submittal will have to address the data from the CCTF experiments which imply that a frothy mixture exists up to the hot leg nozzle.

10. Total Steam Addition Due to UPI

No theoretical justification has been given for assuming that there is no interaction of the steam-water mixture rising vertically from the bottom quench front and the steam-water mixture rising vertically from the falling UPI liquid. Further, the quality of each steam-water mixture is calculated by a different method, and there has been no discussion of the effects of different flow rates even though the two flow rates may be vastly different.

D. TOTAL EXXON SUBMITTALS

Exxon Nuclear Company (ENC) proposed to determine the effects of UPI by use of a model called "REFLEX/UPI," created by making four modifications to the refill and reflood portions of the existing non-UPI EM. Evaluation and guidance comments are provided for each of the four modification as follows, using the modification sequence selected by ENC.

1. REFLEX/UPI: Refill Model

No attempt has been made to consider the effects of UPI on pressure in the upper plenum and in the reactor core. [These pressures can affect refill. They must be given consideration as part of the consideration of the thermal and hydraulic characteristics of the core and of the reactor system required by Appendix K part I.D.3 (K.I.D.3)].

2. REFLEX/UPI: Energy Release Model Components

ENC uses the term "energy release" to mean "heat transfer [to ECCS fluids]." Energy release is discussed separately for the core and upper plenum regions.

a. Core energy release model component

The ENC model assumes that water does not build up above any part of the core, so one analysis method is used for all parts of the core. This assumption is not acceptable because it conflicts with experimental data from Semiscale and the CCTF and from analytical data from Sandia TRAC calculations.

b. Upper plenum structure energy release component

It is necessary to document and justify choices for dimensions and properties and demonstrate that a conduction-limited solution is applicable.

3. REFLEX/UPI: System Equations During Reflood

3.1 Physically, ENC assumes that water injected into the upper plenum will flow into the core or will be entrained by steam and carried into the steam generators, but will in no case contribute to any liquid pool buildup in the upper plenum. The staff will not accept this assumption in the absence of experimental data which not only confirms this assumption, but overrides the results on pool buildup now available from experiments and TRAC calculations.

3.2 Given the above assumption, ENC assumes that the subcooled water injected into the upper plenum mixes with the steam rising from the core and that the mixture comes to thermodynamic equilibrium instantaneously. The use of UPI water to condense steam rising from the core has the effect of decreasing the possibility of steam binding, and the assumption of thermodynamic equilibrium mixing will cause the greatest possible decrease in such steam binding. ENC must demonstrate the acceptability of this assumption.

3.3 The reactor system is modeled as a system of nodes, junctions and loops. The equations used for the REFLEX/UPI EM are stated to differ in only three cases from the equations used for the REFLEX model.

a. Core loop equation

ENC assumes that the pressure drops due to friction and area change are balanced by the gravitational levels in the downcomer and core. It should be shown that (a) the core loop equation can allow reverse flow from the core to the downcomer to the break, (b) the frictional data used is relevant and applicable for the complex flow expected in the UPI plant, and (c) terms have not been improperly omitted from the momentum equation (per K.I.C.3).

b. Core exit junction

The ENC core exit junction equation makes tractable the set of equations covering the entire reactor system because it allows ENC to compute the steam flow rate W_g as proportional to a linear combination of energy releases. The equation for W_g is not acceptable until ENC demonstrates that (a) there is no liquid pooling in the upper plenum, (b) the various energy release terms are insensitive to changes in the assumed parameters governing them, (c) the assumption of all energy releases occurring at the upper plenum does not violate the thermal hydraulics of the real system, and (d) super heated steam can never exist in the upper plenum, even at the start of UPI.

c. Upper plenum exit junction equation

Saturated water accompanies the saturated steam flowing from the upper plenum into the hot legs. The assumption of 1.6% horizontal entrainment must be better justified, and (b) the ENC model does not address carryover of fluid from core inlet to core exit plane, contrary to the requirement of K.I.D.3.

4. REFLEX/UPI: Output

ENC indicated that the "principal output of REFLEX/UPI is the core reflood rate and fluid conditions as a function of time during reflood ... for ... subsequent hot rod heatup analyses." The equation for the reflood rate uses a carry-over rate fraction (CRF) term. ENC must document (a) the validity of using the CRF concept for UPI plants, (b) the actual ENC procedure for using the CRF, (c) the validity of the correlation at the very high reflood rates (over 5 inches per second) shown in ENC's Figure 4.2, and (d) the availability of water to provide these reflood rates.

E. SUMMARY

Section A identified Appendix K parts I.D and II.3, 4, 5 as being particularly relevant to the perceived deficiencies in the current EM submittals. Section B then documented the ways in which the EM submittals did not meet the requirements of Appendix K. Sections C and D examined, on a component-by-component basis, the ways in which the Westinghouse and Exxon EM submittals did not meet the requirements of Appendix K.

The staff's main concerns were over inadequate documentation, absence of sensitivity studies, absence of a physically meaningful model addressing upper plenum phenomena, the effects of UPI on refill, reflood, and heat and mass transfer, an absence of comparison of EM predictions with experiments, lack of consideration of the differences between UPI and non-UPI plants, and non-compliance with various required features of Appendix K. These concerns were documented for both the Westinghouse and Exxon EM submittals.

The best general guidance we can give is that an EM must account for all relevant phenomena or the licensees must obtain and submit relevant and applicable experimental data and analysis which justifies use of a simpler EM. The EM must meet the standards of acceptability specified in Appendix K Part II.5, including a demonstration of a level of safety and margin of conservatism comparable to the acceptable EMs.

The licensees must responsively address the guidance provided here before the staff can find that the EM submittals meet the requirements of 10 CFR 50 Appendix K.

F. 10 CFR 50.46 AND GDC 35, PLANT-SPECIFIC ACCEPTANCE CRITERIA FOR ECCSs

After an EM has been found acceptable as a calculational framework, it is necessary to determine whether the ECCS of an individual UPI plant is acceptable. This is done by testing the ECCS against 10 CFR 50.46 and against General Design Criterion 35 (GDC 35).

Licensees can facilitate reviews by documenting conformance to all parts of Appendix K and 10 CFR 50.46 and GDC 35 on an item-by-item basis, by providing the material called for in Regulatory Guide 1.70, and by ensuring the availability of the materials needed by the staff in using the Standard Review Plan (especially sections 6.3 and 15.6.5).

The staff review of EM submittals does take into account significant differences in the reactors to which the EMs apply. This was shown in the safety evaluation report (SER) on plants equipped with upper head injection

(NUREG-0297, page 1-3). This flexibility is inherent in the procedures normally used by the staff to ensure acceptability of an EM and of any ECCS described by that EM [as demonstrated in the individual sections of the "Standard Review Plan" (esp. 6.3 and 15.6.5) and in Regulatory Guide 1.70]. However, where there were large uncertainties in phenomena or in experimental data, the staff has required that each uncertainty be conservatively bounded by the models and correlations used in an EM. Currently, the staff is willing to accept an alternate approach in which an EM would conservatively bound only the overall uncertainty in the phenomena and experimental data, provided of course that the EM conforms to all required features of Appendix K. This willingness is documented in NRC Information Report SECY-83-472, "Emergency Core Cooling System Analysis Methods," 11-17-83.