UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

SUPPORTING ORDER FOR MODIFICATION OF LICENSE

RELATED TO ERROR IN WESTINGHOUSE ECCS EVALUATION MODEL

Introduction

Westinghouse was informed on March 21, 1978 by one of their licensees that an error had been discovered in their ECCS Evaluation Model. This error was common to both the blowdown and heatup codes. Westinghouse determined by analyses that the fuel rod heat balance equation in the LOCTA IV & SATAN VI codes was in error and that the LOCA analyses previously submitted by their customers were incorrect and predicted peak clad temperatures (PCT's) which were too low. Westinghouse determined that only half of the volumetric heat generation due to metal-water reaction was used in calculating the cladding temperatures. Thus an unreviewed safety question existed since preliminary estimates indicated that some plants would not meet the 2200°F limit of 10 CFR 50.46 at the calculated maximum overall peaking factor limit. Westinghouse notified their customers and NRC on March 23, 1978 while the utilities notified NRC through the regional Offices of Inspection and Enforcement.

Promptly upon notification by Westinghouse, the NRC staff assessed the immediate safety significance of this information. We noted certain points that indicated no immedate action was required to assure safe operation of the plants. First, most plants operate at a peaking factor significantly below the maximum peaking factor used for safety calculations. By making safety computations at factors higher than actual operating levels, the facility has a wide range of flexibility, without the need for hour to hour recomputations of core status. The difference between the actual peaking factors and the maximum calculated peaking factors, for most plants, would offset the penalty resulting from the correction of the error. Second, for most reactors there are

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a number of very plant-specific parameters which bear upon aspects of the ECCS performance calculations. Utilities do not generally take credit for these plant-specific parameters preferring to provide a simpler computation which conservatively disregards these individually small credits. Third, the error in the Westinghouse computations relates to the zirconium-water reaction heat source. This is an aspect of Appendix K, which is generally recognized to be very conservative. New experimental data indicate that the methods required by Appendix K appreciably over estimate the heat source. Thus, while the error in fact entails a deviation from a specific requirement of Appendix K, it does not entail a matter of immediate safety significance.

Westinghouse continued to evaluate the impact of the error on previous plant specific LOCA analyses and performed scoping calculations, sensitivity studies and some plant-specific reanalyses. In addition, Westinghouse investigated several modifications to the previously approved methods which if approved by the NRC staff would offset some of the immediate impact of the error on Technical Specification limits and on the plants operating flexibility.

On March 29, 1978, Westinghouse and several of their customers met with members of the NRC staff in Bethesda. Westinghouse described in detail the origin of the error, explained how it affected the LOCA analyses, and how the error had been corrected and characterized its affect on current plant specific analyses. In order to avoid reduction in the overall peaking factor (F_Q), Westinghouse presented a description of three proposed ECCS-LOCA evaluation model modifications which would contribute a compensating reduction of PCT. They were characterized as follows:

1. <u>Revised FLECHT 15 x 15 Heat Transfer Correlation</u>

   This new reflood heat transfer correlation which had been recently developed and submitted by Westinghouse in Reference (1) was proposed as a replacement for the currently approved FLECHT correlation. To determine the benefit, the proposed correlation was incorporated into the LOCTA IV heatup code and was found to result in improved heat transfer during the reflood portion of the LOCA.

2. Revised Zircaloy Emissivity

Based on recent EPRI data (Reference 2), Westinghouse proposed to modify the presently approved equation for Zircaloy cladding emissivity to a constant value of 0.9. The higher emissivity (previously below 0.8) provides increased radiative heat transfer from the hot fuel pin during the steam cooling period of reflood.

3. Post-CHF Heat Transfer

Westinghouse proposed to replace their present post-CHF transition boiling heat transfer correlation with the Dougall-Rohsenow film boiling correlation (Reference 3) which they stated was included in Appendix K to 10 CFR Part 50 as an acceptable post-CHF correlation.

These three model modifications were classified as generic, applicable to all plant analyses. Subsequently, as discussed below, these changes were rejected by the NRC staff as providing generic benefit. However, a portion of the credit proposed by Westinghouse was approved by the NRC staff for certain specific plants, which had provided specific calculations with the new 15 x 15 correlation. During the period March 29 to April 18, 1978, Westinghouse provided us with additional sensitivity analyses and plant specific analysis in which they evaluated the effects of some changes to plant-specific inputs in the LOCA analyses. These were as follows:

1. Assumed Plant Power Level

A reduction of the plant power level assumed in the SATAN VI blowdown analyses from 102% of the Engineered Safeguards Design Power (ESDR) level to 102% of rated power was proposed. Previously, analyses had been performed at approximately 4.5% over the rated power. This change was worth aproximately 0.01 in F_Q, and is refered to as ΔF_{ESDR} in Table 1.

2. COCO Code Input

A modification to the COCO code input (Reference 3) to more realistically model the painted containment walls was proposed. Since the paint on containment walls provides additional resistance to heat loss into the walls, the COCO code calculates an increase in containment back pressure, which results in a benefit to the calculated peak cladding temperature of 0 to 40°F, during the reflooding transient. The magnitude of the benefit is dependent on the type of plant and the heat transfer properties of the paint, and results in up to 0.03 benefit in F_Q, and is referred to as ΔF_{CP} in Table 1.

3. Initial Fuel Pellet Temperature

A modification of the initial fuel pellet temperature from the design basis to the actual as-built pellet temperatures was proposed. In the present LOCA calculations, Westinghouse has assumed margins in the initial pellet temperature. The margin available is plant-specific and ranges from 28°F to 58°F. Use of the actual pellet temperature rather than the assumed value results in a reduction in pellet temperature (stored energy) at the end of blowdown, as calculated by the SATAN code, of approximately 1/3 of the initial pellet temperature margin. Westinghouse has provided sensitivity analyses which indicate that a 37°F reduction in fuel pellet temperature at end of blowdown is worth approximately 0.1 in F_Q. This is referred to as ΔF_{PT} in Table 1.

4. Accumulator Water Volume Consideration

Westinghouse has evaluated the effect on ECCS performance of reducing the accumulator water volume, and has determined that for those plants for which the downcomer is refilled before the accumulators are emptied, there is a benefit in PCT. The sensitivity studies have indicated that this benefit in F_Q is plant-specific. This is referred to as ΔF_{ACV} in Table 1.

5. Steam Generator Tube Plugging Consideration

In previous analyses, Westinghouse has assumed values of steam generator tube plugging which were greater than the actual plant-specific degree of plugging. Sensitivity analyses submitted in Referance 4 were used to evaluate the benefit available by realistically representing the plant-specific data. For the plants affected, the benefit in PCT ranged from 7 to 66°F which was conservatively worth from 0.007 to 0.66 in F_Q. This is referred to as ΔF_{SG} in Table 1.

Discussion and Evaluation

The information provided by Westinghouse was separated into two categories; the generic evaluation model modifications and the plant-specific sensitivity studies and reanalyses. The NRC staff reviewed the peaking factor limits proposed by Westinghouse to verify their conservatism.

The metal-water reaction heat generation error in the Westinghouse ECCS evaluation model was evaluated by us to determine an appropriate interim penalty. Westinghouse provided two preliminary separate effects calculations which indicated that a maximum penalty of from 0.14 to 0.17 was appropriate to compensate for the model error. The staff conservatively rounded this penalty up to 0.20.(Reference 5)

Westinghouse also proposed several compensating generic changes in their evaluation model to offset any necessary reductions in peaking factor due to the error. These changes were assessed by us as follows:(Reference 5)

1. No credit would be given at this time for the changes in the post-CHF heat transfer correlation and new Zircaloy emissivity data.

2. Partial credit (70%) would be given at this time for the use of the new 15 x 15 FLECHT correlation only for plants which had provided a specific calculation demonstrating that such credit was appropriate.

Based on this review we developed recommended interim peaking factor limits for all the operating plants and decided that any other plant-specific interim factors (benefits) not related to the generic review should be considered separately. In addition, the staff reviewed plant-specific reanalyses for DC Cook Unit Nos. 1 and 2, Zion Unit Nos. 1 and 2 and Turkey Point Unit No. 3 which had corrected the error in metal-water reaction. In these analyses the Dougall-Rohsenow and Zircaloy emissivity credits were not considered, while the new 15 x 15 FLECHT correlation was included. We concluded that these reanalyses could serve as a basis for conservatively determining interim peaking factor limits for these plants.

For most of the operating plants our generic review resulted in a lower allowable peaking factor than Westinghouse had proposed. However, in one case, Westinghouse had proposed more limiting peaking factors in order to prevent clad temperatures at the rupture node from exceeding 2200°F. We concluded that it would be properly conservative to use the minimum of these values.

Based on plant-specific sensitivity studies, performed by Westinghouse, the licensees have submitted requests for interim plant-specific benefits. We reviewed these sensitivity studies and recommended that appropriate credits be accepted. The results of these analyses are shown in Table 1.

We informed each licensee by telephone on April 3, 1978, that they should administratively reduce the plant's peaking factor limit from the limit contained in the Technical Specifications to the interim peaking factor limit contained in the right hand column of Table 1. In those cases where the limit in Table 1 is 2.32, this represents no change from the Technical Specifications limit. The peaking factor limit of 2.32 is generally supported and approved for Westinghouse reactors employing constant axial offset control operating procedures (Reference 6).

For the reactors having an interim peaking factor limit of 2.31, we requested no further justification of the limit. This is because the generic analysis supporting the limit of 2.32 approaches the limit only at beginning of the first cycle. Since the affected reactors have operated past this point, it is clear that the maximum attainable peaking factor will be less than 2.32. While this margin has not been quantified, we are convinced it is substantially greater than the 0.01 for which we are requiring no additional justification from the plants with an interim limit of 2.31.

For the reactors with an interim limit less than 2.31 we requested that the licensee furnish administratively imposed procedures to replace Technical Specifications either:

1. To provide a plant specific constant axial offset control analysis of 18 cases of load following which would ensure that the interim limit would not be exceeded in normal operation of the power plant, or, at its option, if such analysis were unobtainable, inappropriate or insufficient,

2. To institute procedures for axial power distribution monitoring of the interim limit using a system designed for this purpose. If such systems do not exist manual procedures could be used as indicated in our Standard Technical Specifications 3/4 2.6 and ancillary Specifications.

We requested the licensees to confirm by letter that they have adopted the above interim LOCA analyses, interim peaking factor limits and administrative procedures by April 10, 1978, if their reactors were operating, and by April 17, 1978, if the reactors were not operating.

Conclusion

We conclude that when final revised calculations for the facility are submitted using the revised and corrected model, they will demonstrate that with the peaking factors set forth herein, operation will conform to the criteria of 10 CFR 50.46(b). Such revised calculations fully conforming to 10 CFR 50.46 are to be provided for the facility as soon as possible.

As discussed herein, the peaking factor limits specified in the particular Orders or Exemptions issued for the affected facilities, with operating surveillance requirements, as applicable, specified in Orders or Exemptions for particular plants, will assure that the ECCS will conform to the performance requirements of 10 CFR 50.46(b). Accordingly, limits on calculated peak clad temperature, maximum cladding oxidation, maximum hydrogen generation, coolable geometry and long term cooling provide reasonable assurance that the public health and safety will not be endangered.

Date: December 20, 1978

References

1. R. S. Dougall, W. M. Rohsenow, "Film Boiling on the Inside of Vertical Tubes with Upward Flow of the Fluid at Low Qualities", MIT Report 9079-26, September 1963.

2. EPRI Report NP-525, "High Temperature Properties of Zircaloy-Oxygen Alloy", March 1977.

3. WCAP-9220, "Westinghouse ECCS Evaluation Model, February 1978 Version", February 1978.

4. WCAP-8986 - "Perturbation Technique For Calculating ECCS Cooling Performance", February 1977.

5. Memorandum: Rosztoczy to Eisenhut and Ross, "Metal-Water Reaction Heat Generation Error in Westinghouse ECCS Evaluation Model Computer Program," April 7, 1978.

6. T. Morita, et al., "Power Distribution Control and Load Following Procedures," WCAP-8385 (Proprietary) and WCAP-8403 (Non-Proprietary), September 1974.

TABLE 1 F_Q Analysis	PCT °F	F_Q OLD	ΔF_T	ΔF_{ZrO_2}	ΔF_{FLECHT}	F_{PCT}	F_{SE}	$F_{Q,MIN}$	ΔF_{ESDR}	ΔF_{CP}	ΔF_{PT}	ΔF_{SG}	ΔF_{ACV}	F_Q LIMIT
<u>2 Loop</u>														
Pt. Beach 1	2025	2.32	.16	-.2	-	2.28	2.32	2.28	.01	-	-	.029	-	2.32
Pt. Beach 2	2025	2.32	.16	-.2	-	2.28	2.32	2.28	.01	-	-	.066	-	2.32
Ginna	1972	2.32	.26	-.2	-	2.32	2.32	2.32	-	-	-	.053	-	2.32
Kewaunee	2172	2.25	.03	-.2	.05	2.13	2.25	2.13	.01	.02	-	-	-	2.16
Prairie Island 1/2	2187	2.32	.01	-.2	.05	2.18	2.26	2.18	.01	.02	-	-	.03	2.24(+)
<u>3 Loop</u>														
North Anna	2181	2.32	.02	-.2	-	2.14	2.32	2.14	-	-	-	-	-	2.14
Beaver Valley	2041	2.32	.15	-.2	-	2.27	2.32	2.27	-	-	.036	-	-	2.31
Farley	1991	2.32	.24	-.2	-	2.32	2.32	2.32	.01	.005	-	-	-	2.32
Surry 1	2177	1.85	.02	-.2	.06	1.73	1.84	1.73	-	.03	.025	.023	-	1.81
Surry 2	2177	1.85	.02	-.2	.06	1.73	1.84	1.73	-	.03	.025	.023	-	1.81
Turkey Point 3	2019*	1.90	.14	0	-.03	2.01	2.05	2.01	-	-	-	.020	-	2.03
Turkey Point 4	2195	2.05	.00	-.2	.05	1.90	1.91	1.90	-	-	-	.01	-	1.91
<u>4 Loop</u>														
Indian Point 2	2086	2.32	.11	-.2	-	2.23	2.23	2.23	.01	-	-	-	-	2.24
Indian Point 3	2125	2.32	.07	-.2	.06	2.25	2.19	2.19	.01	-	.03	-	-	2.23
Trojan	1975	2.32	.26	-.2	-	2.32	2.32	2.32	.01	-	.037	-	-	2.32
Salem 1	2135	2.32	.06	-.2	-	2.18	2.32	2.18	.01	-	.024	-	-	2.21
Zion 1/2	2189**	2.07	-	0	-.03	2.04	-	2.04	-	-	-	-	-	2.04(+)
Cook 1	2161*	1.90	.03	0	-.03	1.90	1.98	1.90	-	-	-	-	-	1.90
Cook 2	2190*	2.10	.01	0	0	2.11	-	2.11	0	0	0	0	0	2.11

F_T - Credit in F_Q for PCT margin to 2200°F limit.

F_{ZrO_2} - Metal Water Reaction penalty on F_Q.

F_{FLECHT} - Credit in F_Q for improvements to 15x15 FLECHT Correlation.

F_{PCT} - Staff estimated F_Q based on 2200°F PCT limit.

F_{SE} - Westinghouse proposed F_Q based on stored energy sensitivity studies.

*Denotes reanalysis at F_Q old value error corrected.

**Denotes reanalyses at F_Q old value, error corrected, accumulator Vol. Change of 100 ft^3, accumulator pressure of 650 psia

(+) These limits are applicable assuming licensee modifies accumulator conditions as appropriate. If not, Prairie Island 1/2 F_Q=2.21, Zion 1/2 F_Q=1.9