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EFFECT OF REFLOOD PREDICTION UNCERTAINTIES ON LOFT CLADDING OXIDATION

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SUMMARY

The FLOOD4(1) and RELAP4/MOD6(2) computer codes, which are used to perform LOFT reflood analysis, have been compared to FLECHT-SET(3) and Semiscale gravity feed tests(4) to provide an evaluation of core reflood prediction techniques and an identification of phenomena important to LOFT reflood behavior. These comparisons provide a basis for estimating uncertainty in cladding temperature history during the LOFT loss-of-coolant experiments (LOCEs). The bounds on the cladding temperature response are then utilized to estimate a range of expected cladding oxidation and embrittlement which is essential for identifying special equipment needed during replacement, storage, and post-test examination of LOFT fuel modules.

FLOOD4 couples the system hydraulic response with core heat transfer and steam generation. Four heat transfer correlations simulate the boiling curve and liquid entrainment, fallback and vaporization in the steam generators are modeled. FLOOD4 requires user input multipliers to specify the dispersed flow heat transfer, liquid entrainment and correlations to describe liquid fallback from the upper plenum region. The fraction of liquid vaporized in the steam generators must also be user input.

RELAP4/MOD6 is an extension of the RELAP4 thermal hydraulic code developed for core reflood analysis. RELAP4/MOD6 models liquid entrainment, upper plenum de-entrainment, liquid fallback and core superheat. A moving mesh axial nodalization scheme is used to provide detailed predictions of fuel rod and fluid behavior near the quench front. A heat transfer package specific to reflood analysis has been developed and incorporated into RELAP4/MOD6. The entrainment, de-entrainment, and heat transfer correlations require user input multipliers.

Parametric studies with FLOOD4, documented in Reference 1, and the developmental verification[5] of RELAP4/MOD6 indicated that code predictions, particularly quench times, were sensitive to the modeling of liquid entrainment, dispersed flow heat transfer and liquid vaporization in the steam generators.

Comparison of FLOOD4 and RELAP4/MOD6 predictions with Semiscale gravity feed tests and FLECHT-SET data indicate the codes usually predict the peak cladding temperatures to within 50 K. Quench and temperature turn around times are not as well predicted. FLOOD4 generally predicts quench times to within 50-70 seconds while RELAP4/MOD6 may over predict by as much as 100-200 seconds.

Based on the above comparisons, it was assumed that cladding temperature bounds during reflood for the LOFT tests could be defined using a $\pm$ 50 K uncertainty in the FLOOD4 calculated peak cladding temperature and $\pm$ 100 second uncertainty in the FLOOD4 predicted quench time. These uncertainties were applied to the best-estimate FLOOD4 cladding temperature history to define the temperature bounds for the L2-3 and L2-4 tests. Figure 1 shows the resulting temperature envelope for the L2-4 center module cladding oxidation for these two tests. The results indicate (1) insignificant cladding oxidation of peripheral fuel modules even during the high power tests, and (2) significant oxidation may occur for the center module fuel rods for the high power test (L2-4) although the percent of oxidized cladding is predicted to be less than 17% at the peak cladding temperature location.

Comparison of current reflood analytical models with FLECHT-SET and Semiscale reflood data have provided a basis for assessing the uncertainty in cladding temperature response during the reflood portion of the LOFT loss-of-coolant experiment. The temperature bounds provide a baseline for future thermal-hydraulic and fuel rod model verification and provide a basis for (1) evaluating cladding mechanical degradation resulting from cladding oxidation and (2) for specifying post-test fuel handling.

1. R. L. Benedetti, Potential Influence of Three Dimensional Effects on PWR LOCA Behavior, TREE-NUREG-1031 (Appendix B) (February 1977).

2. RELAP4/MOD6 - A Computer Program for Transient Thermal-Hydraulic Analysis of Nuclear Reactors and Related Systems, User's Manual, Volume I and II, PG-R-77-06 (March 1977).

3. J. P. Waring and L. C. Hochreiter, PWR FLECHT-SET Phase B1 Evaluation REPLAT, WCMP-8583, Westinghouse Electric Corporation (August 1975).

4. G. E. McCreery, Thermal-Hydraulic Analysis of Semiscale MOD1 REFLOOD Test Series (Gravity Feed Tests), TREE-NUREG-1010 (January 1977).

5. C. D. Fletcher, Developmental Verification of RELAP4/MOD6 Update 1 with FLECHT LFR Cosine Test Data Base, PG-R-77-24 (July 1977).

TABLE I

Range of Cladding Oxidation Predicted for
L2-3 and L2-4 Tests

Test/Fuel Module	Case	Percent of Cladding Oxidized
L2-3/Center	Base	1.0
	Upper bound	2.0
	Lower bound	0.5
L2-4/Center	Base	6.0
	Upper bound	13.0
	Lower bound	4.0
L2-4 Peripheral	Base	0.6
	Upper bound	1.5
	Lower bound	0.5

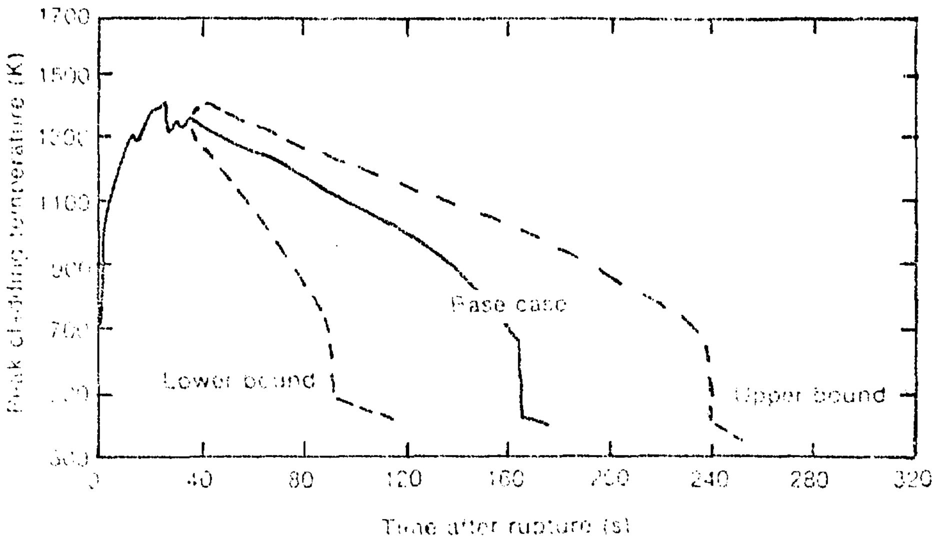

Fig. 1 Central module peak cladding temperature bounds during L2-4.