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AUTHOR(S): Clay P. Booker

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Los Alamos Los Alamos National Laboratory
Los Alamos, New Mexico 87545

POSTTEST TRAC-PD2/MOD1 PREDICTIONS FOR FLECHT SEASET TEST 31504*

Clay P. Booker
Safety Code Development
Energy Division
Los Alamos National Laboratory
Los Alamos, NM 87545

ABSTRACT

The Transient Reactor Analysis Code (TRAC) being developed at the Los Alamos National Laboratory under the sponsorship of the Reactor Safety Research Division of the US Nuclear Regulatory Commission is an advanced, best-estimate systems code to analyze light-water-reactor accidents. TRAC-PD2/MOD1 is a publicly released version of TRAC that is used primarily to analyze large-break loss-of-coolant accidents in pressurized-water reactors (PWRs). TRAC-PD2 can calculate, among other things, reflood phenomena.

In this paper we compare TRAC posttest predictions with test 31504 reflood data from the Full-Length Emergency Core Heat Transfer (FLECHT) System Effects and Separate Effects Tests (SEASET) facility. A false top-down quench is predicted near the top of the core and the subcooling is underpredicted at the bottom of the core. However, the overall TRAC predictions are good, especially near the center of the core.

INTRODUCTION

In this report we assess the capability of the Transient Reactor Analysis Code, TRAC |1|, to make accurate posttest predictions for the Full-Length Emergency Core Heat Transfer (FLECHT) System Effects and Separate Effects Tests (SEASET) run 31504. This experiment was an unblocked bundle, low-flooding rate, forced reflood test. We include a description of the TRAC model for the FLECHT SEASET facility, pertinent TRAC predictions, comparisons between the TRAC predictions and the test data, and a concise analysis of our results.

TEST DESCRIPTION

The FLECHT SEASET facility was designed to provide heat-transfer and simulated primary-system performance data for a typical pressurized-water reactor (PWR) during reflood. The facility basically consists of a low-mass test vessel, a water supply, associated piping, a rod bundle, and instrumentation |2|. The rod bundle includes electrically heated rods with a 3.66-m heated section. The rods, identical in size, are arranged such that they duplicate the lattice of a Westinghouse 17 × 17 nuclear fuel assembly.

*Work performed under the auspices of the US Nuclear Regulatory Commission.

In test 31504, the bundle was unblocked and consisted of 161 rods, 2 of which were unpowered. It was a forced reflood test with a nominal 2.46-cm/s reflood rate. The initial and boundary conditions are described more completely in the next section.

TRAC MODEL

Some important TRAC features are two-phase nonequilibrium hydrodynamics, flow-regime-dependent constitutive equations, a two-fluid hydrodynamics model of the VESSEL component, a reflood tracking capability for both bottom reflood and falling quench fronts, and a multidimensional model of the VESSEL.

TRAC-PD2/MOD1 (version 27.0), a publicly released PWR version, corrects several coding errors but does not add any model changes to a previously released version, TRAC-PD2 (version 26.0).

Figure 1 shows the TRAC model for the FLECHT SEASET facility. The FILL and BREAK components simulate the test boundary conditions. The two PIPE components represent some of the major system piping. The two-dimensional option for the VESSEL component models the low-mass test vessel; because there is no radial power gradient and the bundle length-to-diameter ratio is large, we assume that one-dimensional flow is appropriate. The VESSEL has 16 levels and levels 3-17 are heated. Lumped-parameter heat slabs in levels 3-17 simulate the heat capacity of the low-mass housing. The TRAC code references elevations within the VESSEL with respect to the VESSEL bottom, as shown in the right half of Fig. 1; however, the available experimental data reference elevations with respect to the location where heating begins, as shown in the left half of Fig. 1. For convenience, we have referenced these TRAC predictions and analyses from the elevation where heating begins.

Figures 2-4 show some of the initial conditions for test 31504. In each of these figures, unconnected triangular symbols represent the experimental data; the solid curve represents the least-squares fit of the TRAC calculations to the experimental data. The TRAC data points (circular symbols) in Fig. 2 represent the initial heat-slab temperatures at the VESSEL cell centers. The TRAC clad temperatures in Fig. 3 are specified at the cell edges. The initial TRAC vapor temperatures in Fig. 4 are specified at the cell centers. Figure 5 shows the injection velocity for the FILL component; the FILL supplies water at a constant 326.5 K. The TRAC power decay curve closely corresponds with that of the data. The BREAK component maintains a constant 0.27745-MPa backpressure.

RESULTS

Figures 6-17 show average-rod temperature as a function of time at selected elevations above the location where heating begins both for the TRAC predictions and for the FLECHT SEASET data. To the right of the plot is a rectangular legend box that contains pertinent plot information. The information in the upper portion of the box indicates that a solid curve represents the TRAC prediction (TRAC-PD2 designates version TRAC-PD2/MOD1) whereas a curve constructed of circles or triangles represents the FLECHT SEASET data. An instrument designation identifies the FLECHT SEASET data; for example, the instrument designation 9G-0.305 in Fig. 6 specifies that

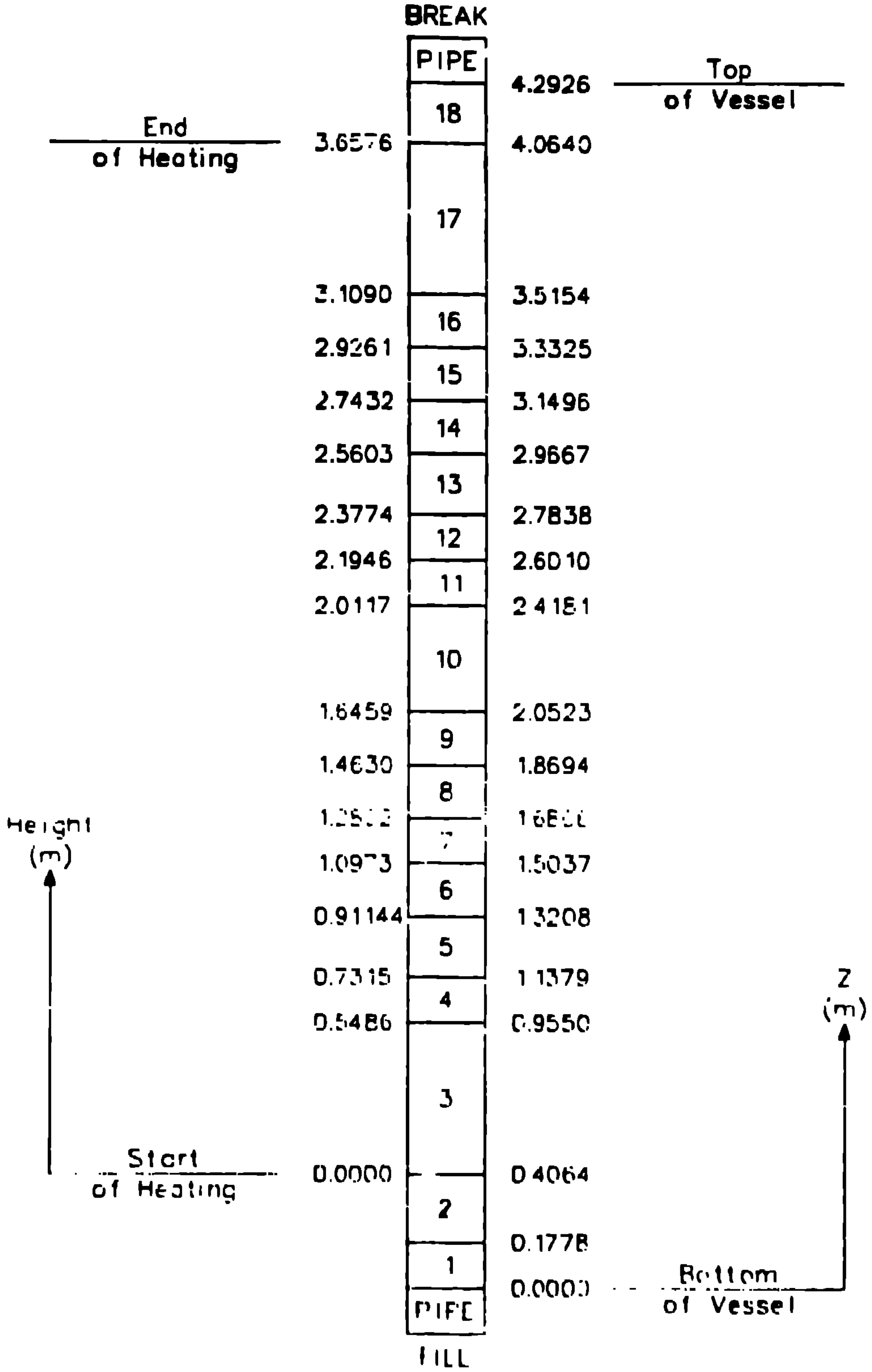

FIGURE 1 : TRAC MODEL OF THE FLECHT SEASET FACILITY

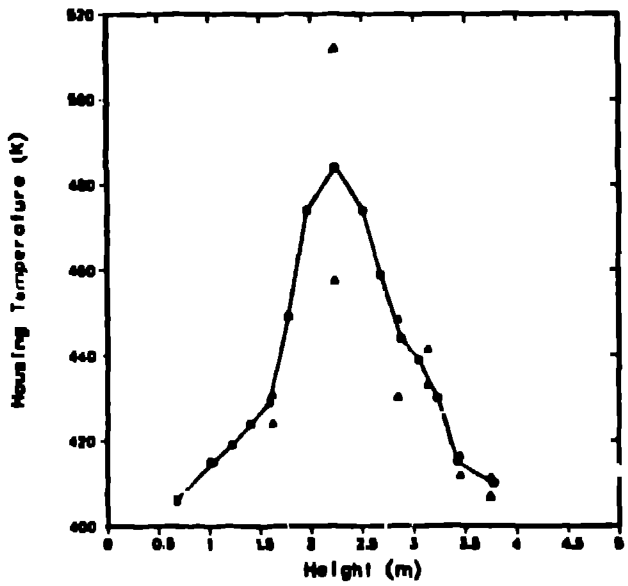

FIGURE 2 : INITIAL HOUSING-TEMPERATURE DISTRIBUTION

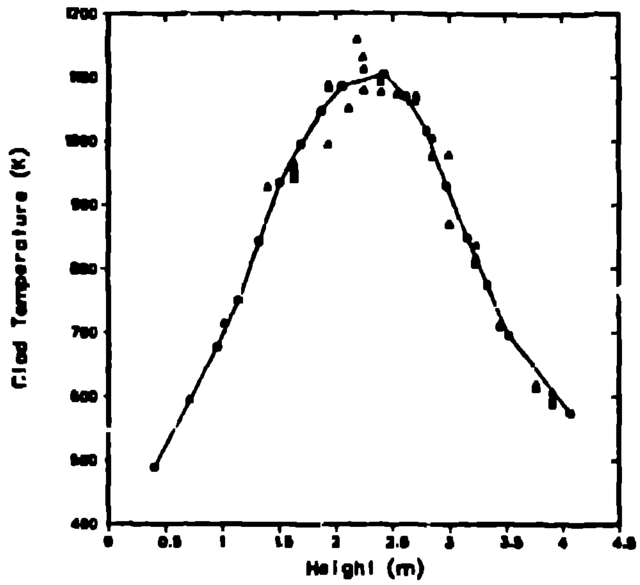

FIGURE 3 : INITIAL AVERAGE-ROD-TEMPERATURE DISTRIBUTION

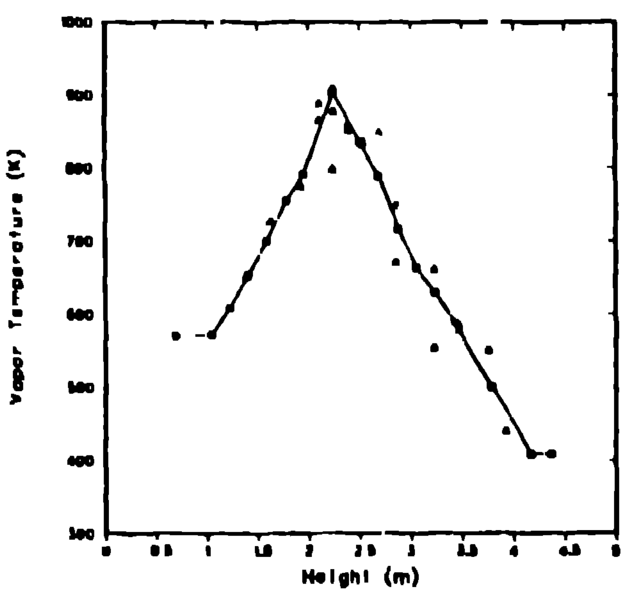

FIGURE 4 : INITIAL VAPOR-TEMPERATURE DISTRIBUTION

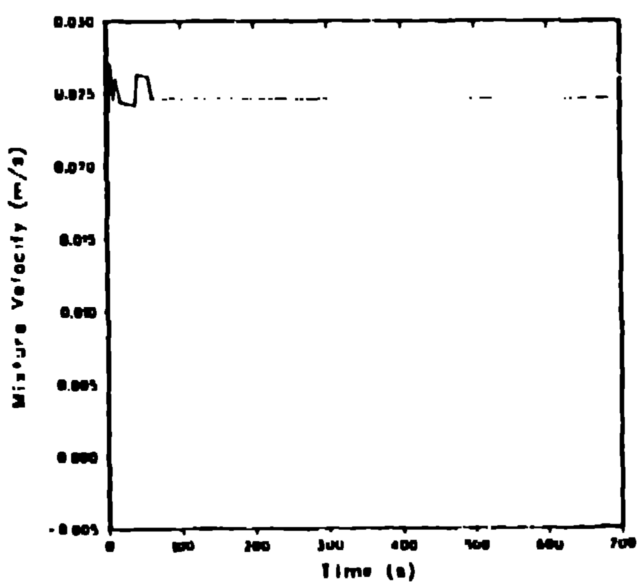

FIGURE 5 : FILL INJECTION VELOCITY

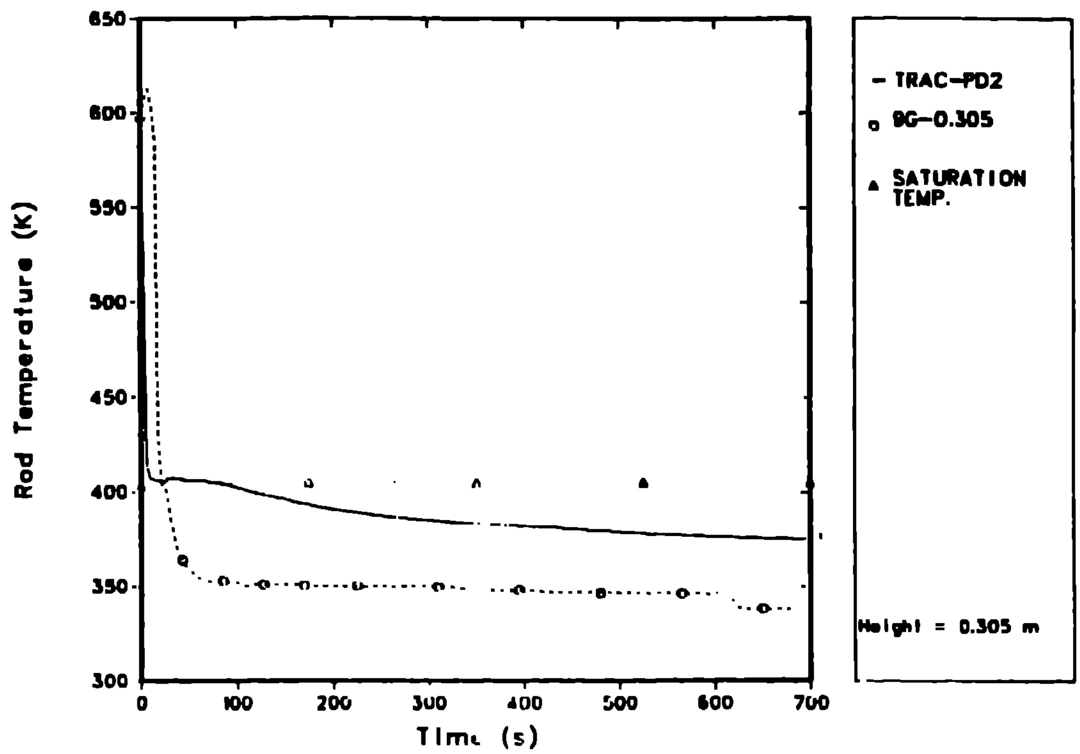

FIGURE 6: AVERAGE-ROD TEMPERATURE AT 0.305-m ELEVATION

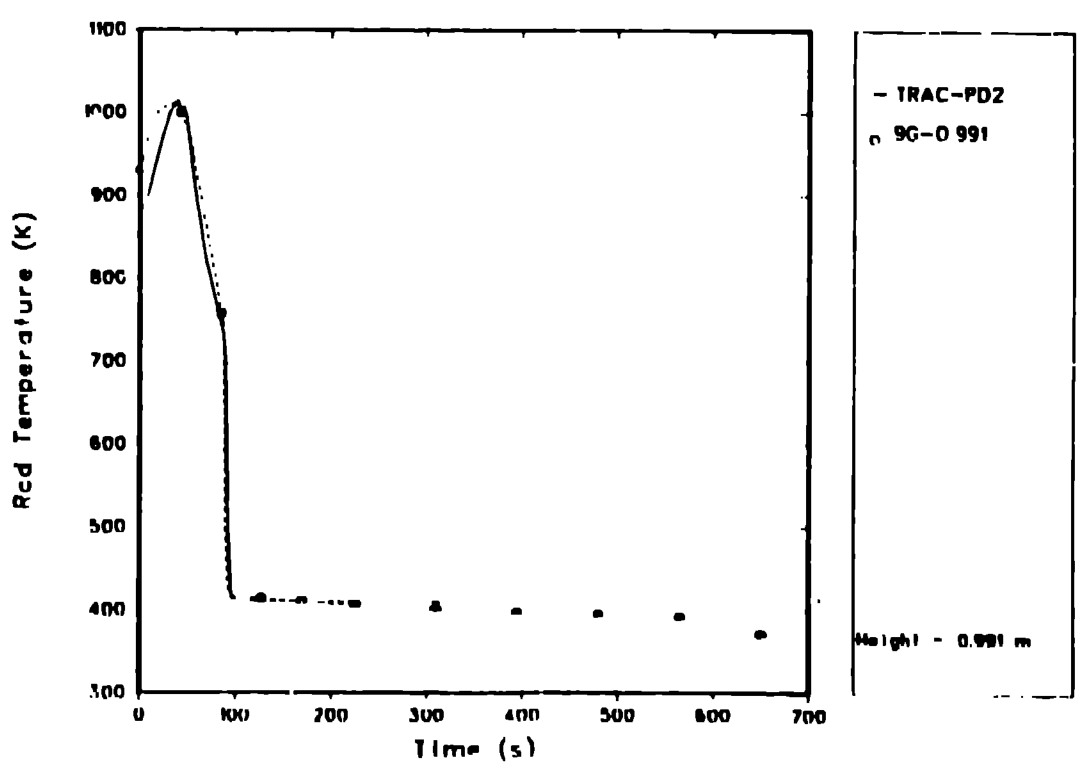

FIGURE 7 : AVERAGE-ROD TEMPERATURE AT 0.9991-m ELEVATION

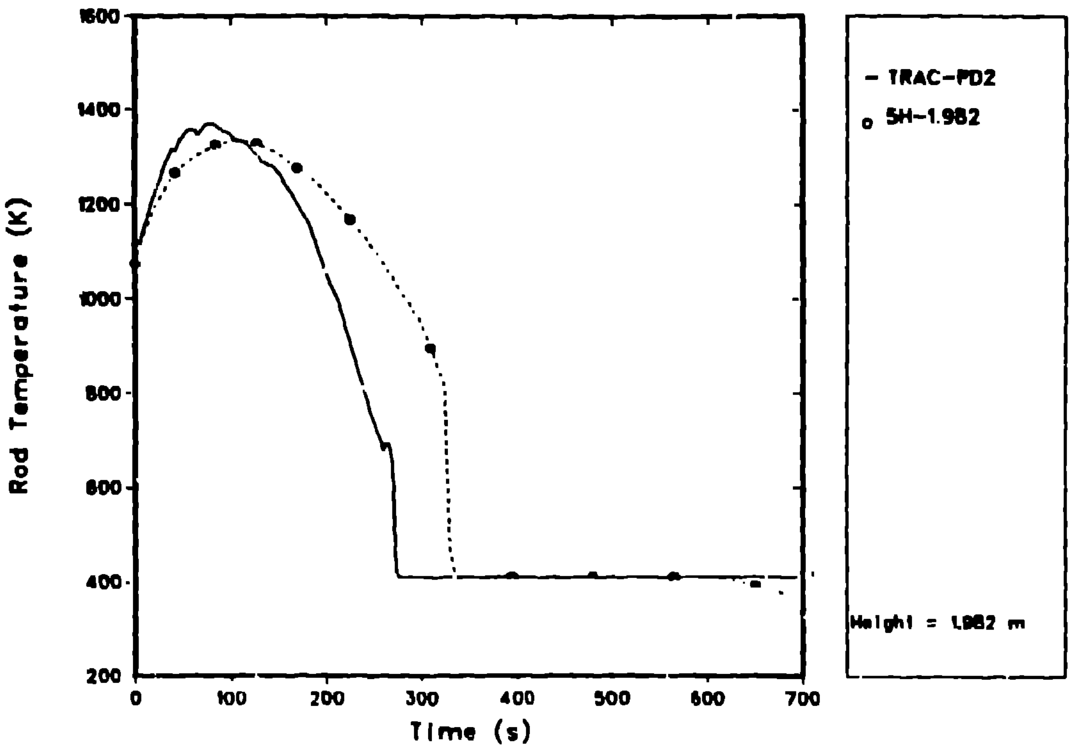

FIGURE 9 : AVERAGE-ROD TEMPERATURE AT 1.982-m ELEVATION

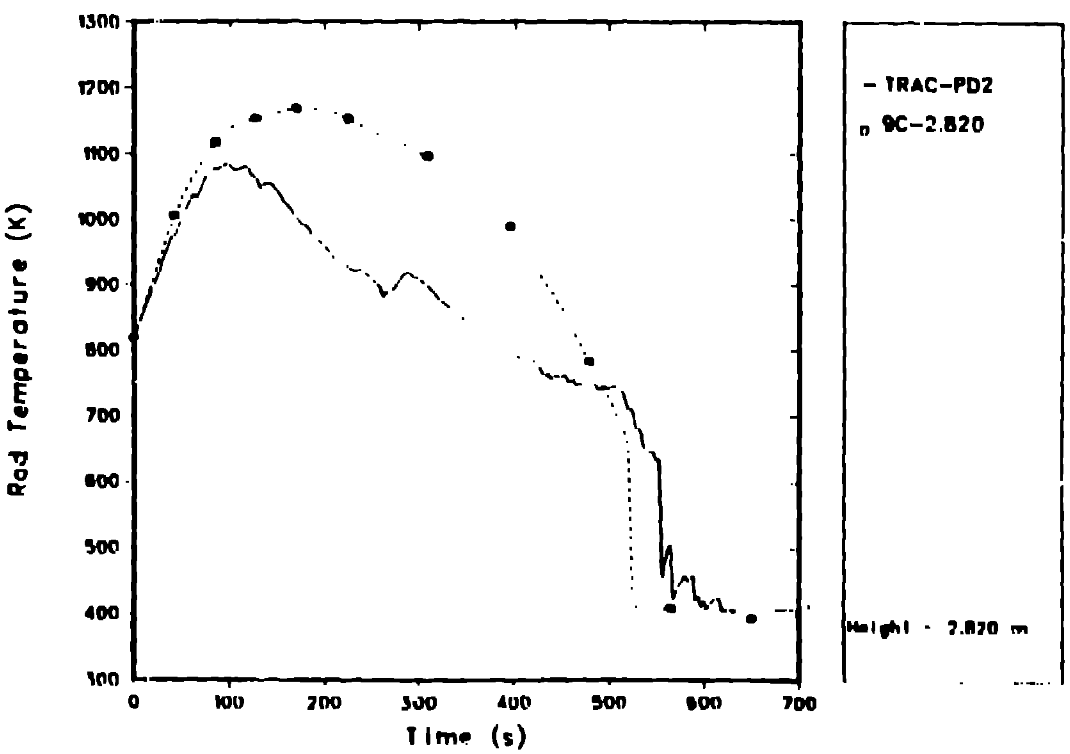

FIGURE 9 : AVERAGE-ROD TEMPERATURE AT 2.820-m ELEVATION

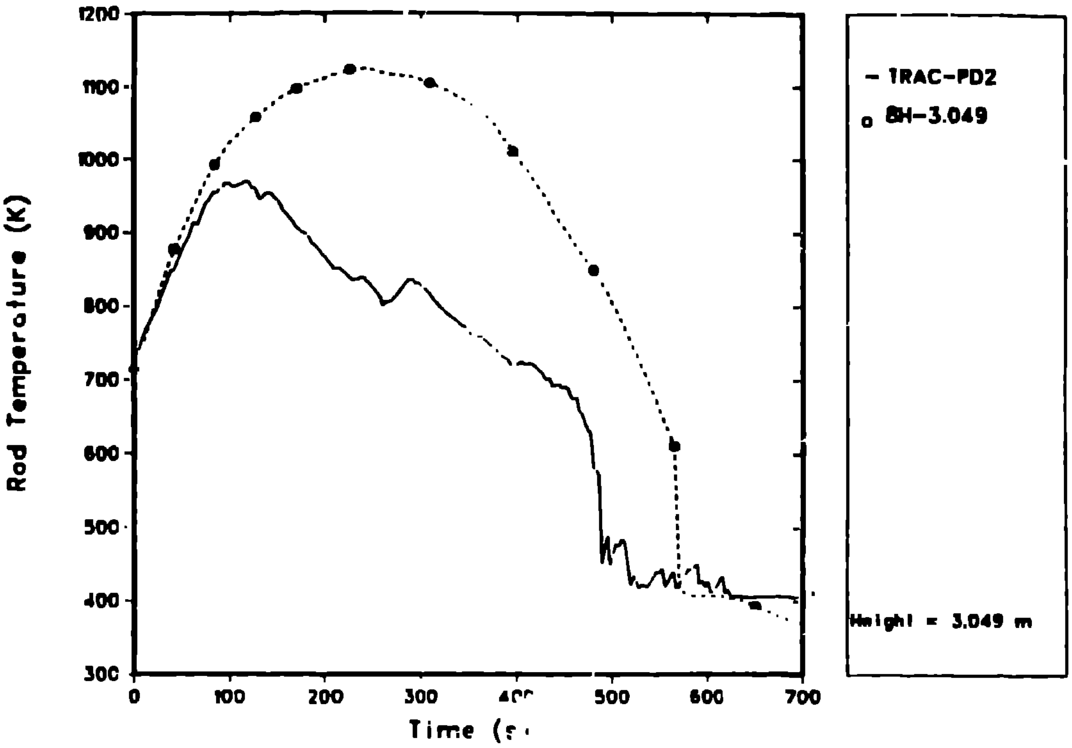

FIGURE 10 : AVERAGE-ROD TEMPERATURE AT 3.049-m ELEVATION

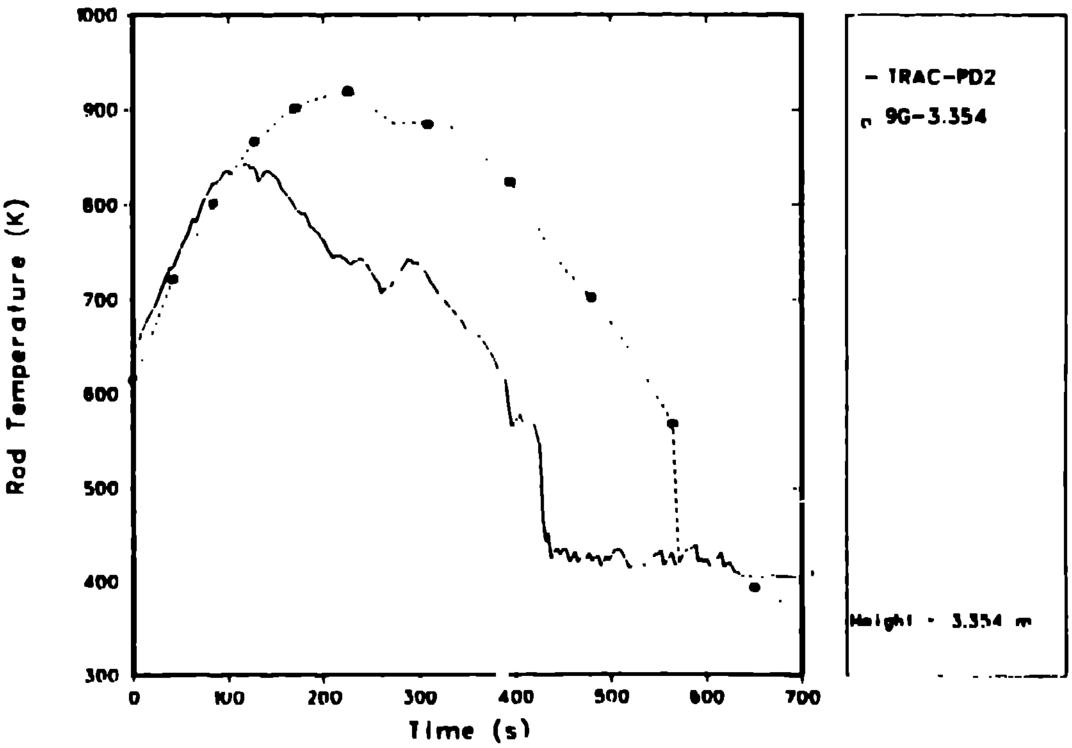

FIGURE 11 : AVERAGE-ROD TEMPERATURE AT 3.354-m ELEVATION

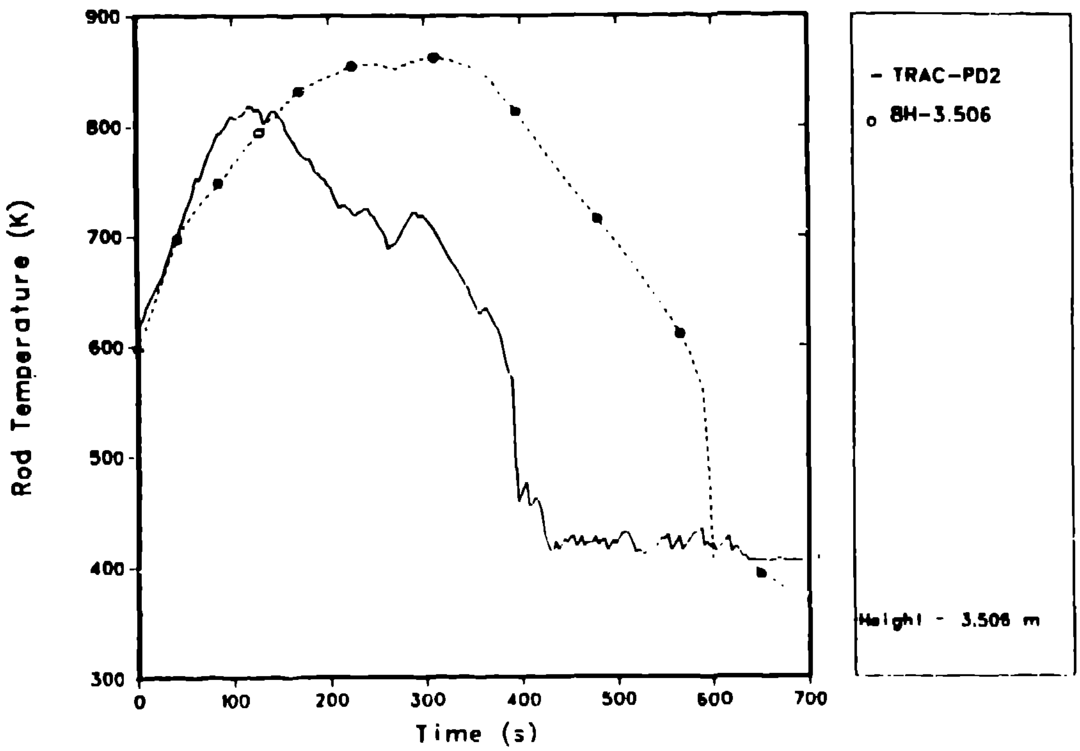

FIGURE 12 : AVERAGE-ROD TEMPERATURE AT 3.506-m ELEVATION

9G is a horizontal location in the rod bundle and that 0.305 is the axial elevation of the instrument in meters above the bottom of the heated length. Data error bars are contained within the symbol. The radial location within the rod, just inside the clad, is the same both for the TRAC prediction and for the FLECHT SEASET data. In Fig. 6, a dotted curve with triangular symbols represents the water saturation temperature for the corresponding TRAC cell. The information at the bottom of the legend box gives the axial elevation above the bottom of the heated length for the TRAC prediction.

Figure 13 shows elevation vs quench time both for the TRAC average-rod prediction (solid curve with circular symbols) and the FLECHT SEASET data (triangular symbols). The FLECHT SEASET quench times |2| were calculated by the Westinghouse Quench Program staff. The TRAC predictions for quench time are based on the rod temperature curves and we assume that the quench occurs when the slope of the TRAC curve approaches vertical.

For most of the calculation, TRAC does a good job of predicting the clad temperature of the rods. For the lower half of the heated zone, the TRAC predictions for quench time, quench temperature, turnaround time, and peak temperature are typically within experimental scatter; Figure 13 clearly shows this for quench time. In the next one-quarter of the heated zone, TRAC begins to predict an early quench (Fig. 13). Also, the calculated turnaround time is early and the calculated peak temperatur starts to deviate below the data. In the top one-quarter of the heated zo·, TRAC predicts a top-down quench that the data do not indicate; Figure 13 most clearly shows this trend. Moreover,

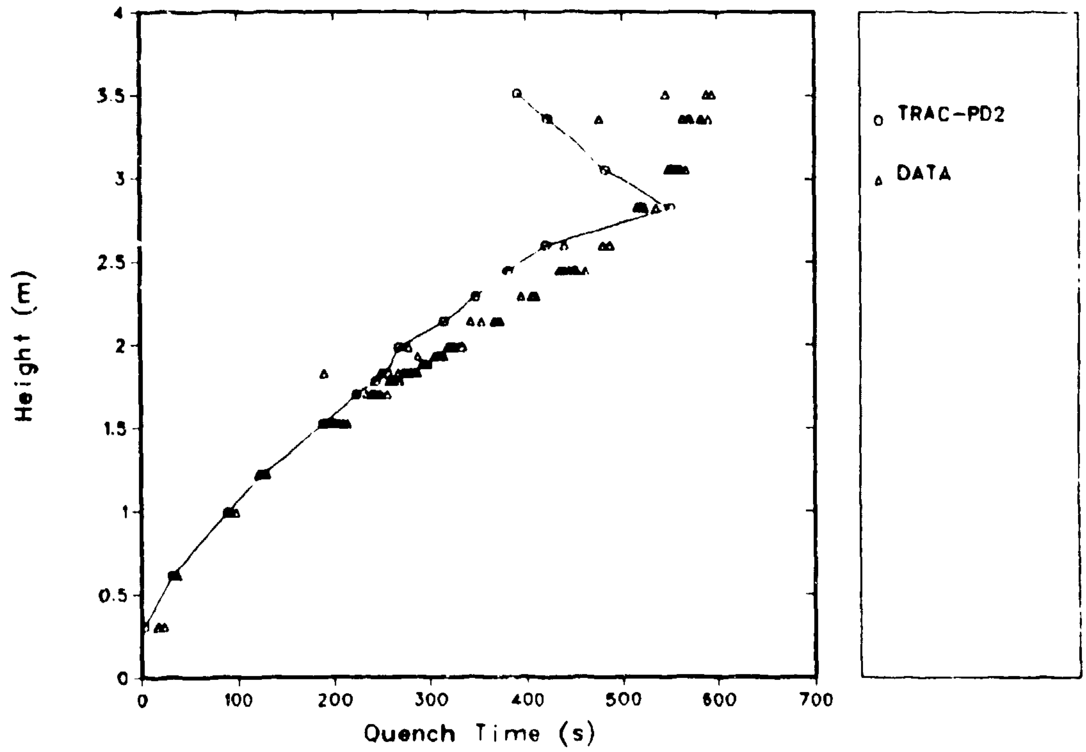

FIGURE 13 : ELEVATION VS QUENCH TIME

in the upper one-quarter, the peak-temperature prediction is low and the TRAC turnaround time is early. Apparently, the top-down cooling and the low peak-temperature prediction are caused by an overpredicted entrainment in the TRAC-PD2/MOD1 code. Increasing the TRAC value for the droplet Weber number from 4 to 16, resulting in a very large drop size, does not reduce the problem significantly even though the increasing Weber number should tend to decrease entrainment. Another code change that appears to affect entrainment more is the correction of the TRAC-PD2/MOD1 interfacial shear calculation |3, 4|. Figures 14 and 15 show the effect of this correction; these figures have an additional curve for the corrected TRAC-PD2/MOD1, represented by a dotted line with triangular symbols and labeled CORRECTED TRAC-PD2. Clearly, these changes are insufficient to correct the top-down quench behavior or the underpredicted peak clad temperatures in the upper part of the heated zone. The FLECHT SEASET rod bundle contains eight grid spacers |2|, which will serve to de-entrain liquid and reduce droplet size; however, TRAC does not model the grid spacers.

An unexplained phenomenon occurs in the bottom 0.610 m of the heated zone. As Fig. 6 shows, the saturation temperature in the data immediately drops well below the experimental saturation temperature when quench occurs--about 50 K lower at 0.305 m. On the other hand, the TRAC prediction drops to saturation when quench occurs and then slowly drops below. Increasing the TRAC heat-transfer coefficient by 30% increases the TRAC predicted subcooling but the temperature still does not fall as fast nor as far as that in the data. This difference remains unexplained. boiling but this possibility was not explored.

To the author's knowledge, only one other TRAC prediction for test 31504 has been made--by L. Neymotin at Brookhaven National Laboratory [3]. His model differs significantly from the Los Alamos TRAC model. His heat slabs are more than twice as hot initially and have about four times more surface area per unit mass. Further, the upper half of his vessel component is more finely noded; the lower half is more coarsely noded. Based on the three plots in Ref. 3, his TRAC predictions for the bottom half of the core are only marginally closer to the data and his TRAC predictions for the upper half of the core are no better than those presented in this paper.

CONCLUSIONS

Overall, TRAC has predicted well the behavior of FLECHT SEASET run 31504. TRAC's major shortcomings are its tendencies to predict an unrealistic top-down quench at the top of the heated zone because of excessive entrainment and to predict excessive cooling in general above the core midplane. The discrepancies between the calculated cladding temperature and the data in the bottom section of the core after quench require a more detailed analysis before a satisfactory explanation can be given; such an analysis was beyond the scope of this task.

REFERENCES

1. "TRAC-PD2, An Advanced Best-Estimate Computer Program for Pressurized Water Reactor Loss-of-Coolant Accident Analysis," Los Alamos National Laboratory report LA-8709-MS [NUREG/CR-2054] (April 1981).

2. M. J. Loftus, L. E. Hochreiter, C. E. Conway, C. E. Dodge, A. Tong, E. R. Rosal, M. M. Valkovic, and S. Wong, "PWR FLECHT SEASET Unblocked Bundle, Forced and Gravity Reflood Task Data Report," Westinghouse report WCAP-9699 [NUREG/CR-1532, EPRI NP-1459] (June 1980).

3. L. Neymotin, "FLECHT SEASET Forced Reflood Tests," Brookhaven National Laboratory Quarterly Progress Report, Section 7.1.5 (April-June 1981).

4. P. Saha, "BNL Corrections to TRAC-PD2 (Version 26.0)," (internal control number), Brookhaven National Laboratory memorandum to Fuat Odar, Nuclear Regulatory Commission (August 20, 1981).