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CONF-830901--14

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LA-UR--83-2780

DE84 001303

AUTHOR(S) John K. Meier

SUBMITTED TO American Nuclear Society
Anticipated and Abnormal Plant Transients in
Light Water Reactors
September 26-29, 1983
Jackson, Wyoming

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

MASTER

A TRAC-PF1 ANALYSIS OF LOFT STEAM-GENERATOR FEEDWATER TRANSIENT TEST L9-1

John K. Meier

Safety Code Development Group, MS K553
Los Alamos National Laboratory
Los Alamos, NM 87545

ABSTRACT

The Transient Reactor Analysis Code (TRAC-PF1) calculations were compared to test data from Loss-of-Fluid Test (LOFT) L9-1, which was a loss-of-feedwater transient. This paper includes descriptions of the test and the TRAC input and compares the TRAC-calculated results with the test data. We conclude that the code predicted the experiment well, given the uncertainties in the boundary conditions. The analysis indicates the need to model all the flow paths and heat structures, and to improve the TRAC wall condensation heat-transfer model.

INTRODUCTION

The Loss-of-Fluid Test (LOFT) L9-1 data was compared to the Transient Reactor Analysis Code (TRAC-PF1) calculated results as part of the independent assessment of TRAC-PF1. This experiment was a loss of steam-generator feedwater transient in which decay heat and pump operation caused the system to heat for a long period of time. The experiment was divided phenomenally into two time periods. In the first 100 s, the steam generator dried out and the resulting high primary-system pressure caused a reactor scram. To analyze this part of the transient, we had to calculate accurately the heat and mass transfer in the steam-generator secondary side and the pressurizer. We obtained reasonably accurate calculations of this time period by varying the input description within the test-data limitations. After 100 s, the decay heat and the pump operation caused the primary-system temperature to increase. The TRAC-PF1 program calculated this portion of the test well when its wall condensation heat-transfer coefficient was modified.

TEST DESCRIPTION

LOFT L9-1 simulated a loss-of-feedwater accident (anticipated transient) with a delayed reactor scram and no feedwater injection (multiple failures). More detailed descriptions of the test apparatus, test procedure, and test results may be found in Refs. 1, 2, and 3.

Several important phenomena occurred during the experiment. When the feedwater was discontinued to the steam generator, the heat transfer from the primary side degraded. An increase in the average temperature of the primary-side liquid caused a fluid expansion that forced water into the pressurizer and increased the primary-side system pressure. In response to the pressure increase, the pressurizer-spray system was activated. This system temporarily controlled the increase in the system pressure, but eventually the steam-generator heat transfer degraded so severely that the primary-system pressure increase caused the reactor to scram. As a result of the scram signal, the reactor shut down and the steam-generator steam-control valve began to close. After the valve closed, the primary-system pressure increased until the pressurizer spray again controlled the primary-system pressure.

TRAC-PF1 INPUT MODEL DESCRIPTION

Figures 1 and 2 show the TRAC-PF1 input model used for the vessel, the broken loop, and the intact loop. The model included 43 one-dimensional components with a total of 150 fluid volumes. Twelve one-dimensional components consisting of 51 nodes was used to model the vessel. They were selected over a three-dimensional model because the length of the transient made a fast-running input model worthwhile.

The major code-related difficulties encountered in this analysis pertained to the modeling of the trips, the steam generator, and the pressurizer. In the case of the trips, the main difficulty was in controlling the steam-generator-secondary liquid level and the steam-control valve during the steady-state calculation. A quasi-steady state was obtained by regulating the inlet water with a liquid-level-dependent FILL component and by reducing greatly the closing and opening rate of the steam-control valve during the steady-state run. The proportional controllers in the newest version of the code, TRAC-PF1/MOD1, should alleviate this problem.

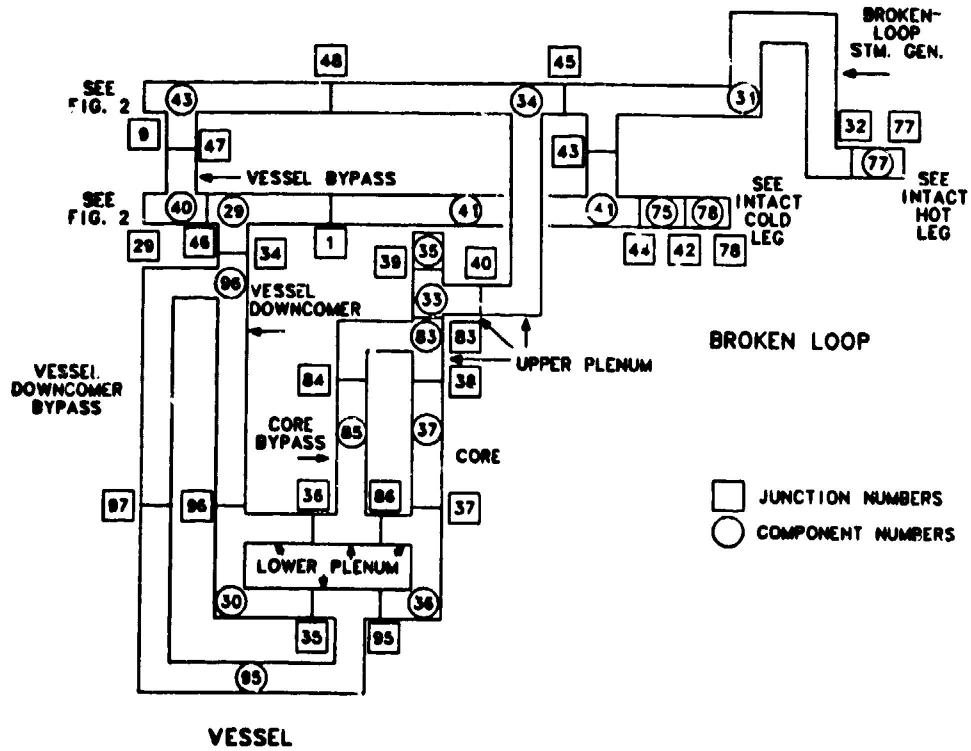
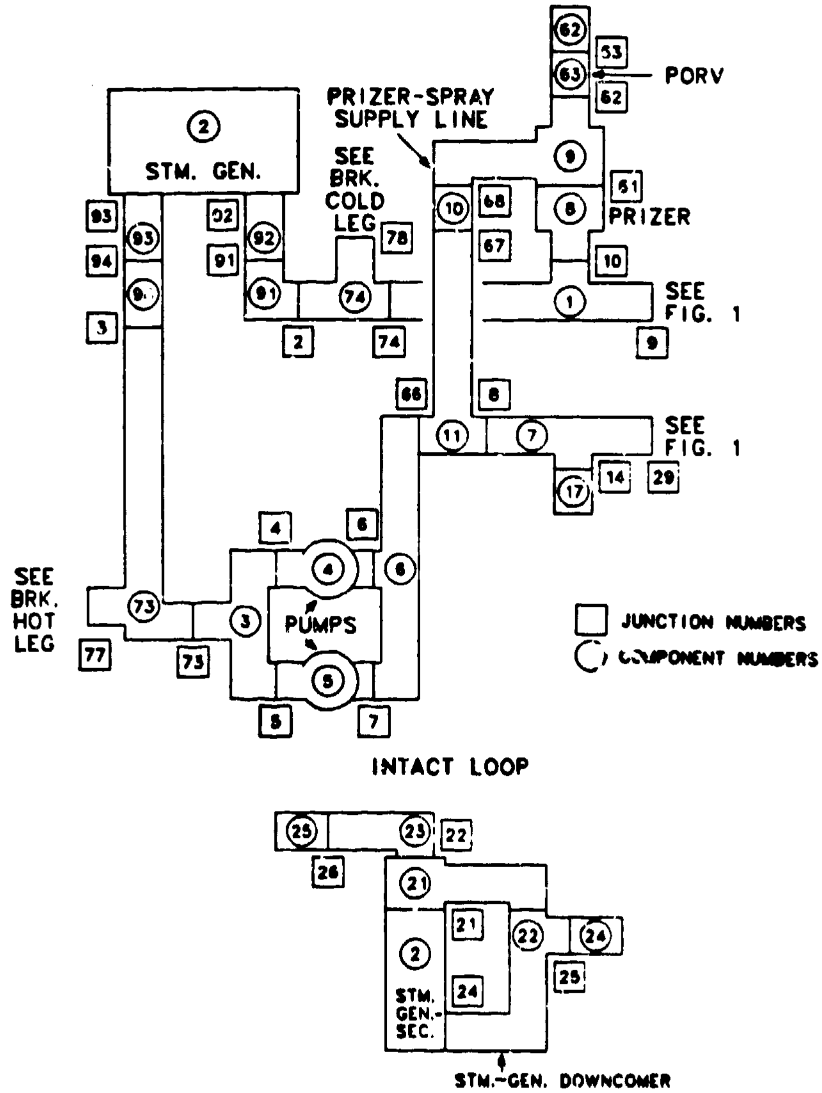


Fig. 1.
TRAC-PF1 input model of the vessel and the broken loop for LOFT L9-1.

In the case of the steam generator, the phase-separation and heat-transfer processes that occur in the secondary side are very complicated. Accurate calculations for this type of transient require precise analysis of these heat-transfer processes.

The following example illustrates how an error in the calculation of these processes can cause problems in the remaining analysis. Scram initiation occurs on a high-pressure trip. The timing of that trip depends on the primary-system pressure increase. The pressure increase reflects two different phenomena: the primary-system heating resulting in the thermal expansion of the primary-system liquid, and the effectiveness of the pressurizer spray to counteract the pressure increase. If inadequate phase-separation models calculate an incorrect liquid distribution in the steam-generator secondary, the heat tranufer can degrade prematurely and cause an early calculated reactor scram. Following scram, vaporization of the remaining liquid removes heat from the primary system. This heat loss causes much lower primary-system pressures and affects the rest of the analysis.



STEAM-GENERATOR SECONDARY

Fig. 2.
TRAC-PF1 input model of the intact loop for LOFT L9-1.

In the pressurizer modeling we found that the expanding primary-system fluid forced cold liquid into the pressurizer. The resulting stratification effects were difficult for the pressurizer component to model. The new pressurizer model in TRAC-PF1/MOD1 was designed specifically to address these types of problems.

DATA COMPARISONS

The primary-system steam-generator-outlet temperature comparison (Fig. 3) was the most interesting in this analysis. The test data and the calculated results agreed well. After the scram, this agreement implied that TRAC modeled the correct heat addition from the core and pumps; the correct amount of fluid in the system; and, most importantly, the correct heat transfer to the metal structure, piping, etc. When this test was calculated initially, the predicted rate of temperature increase was 1/3 greater than the measured rate. To eliminate this discrepancy, we added bypass flow paths in the downcomer and core and more detailed modeling of the steam-generator inlet and outlet plenums. We also modifed TRAC-PF1 so that a 50-MW/m^2 heat flux was used when the heat-transfer regime was condensation to the walls. The value of 50-MW/m^2 was a somewhat arbitrary value for the heat-transfer coefficient which was chosen to drive the liquid and wall surface to the same temperature. In the steam-generator-secondary downcomer outer wall where this type of heat transfer is important, the heat-transfer rate is conduction limited. Therefore, there is considerable leeway in the value of the

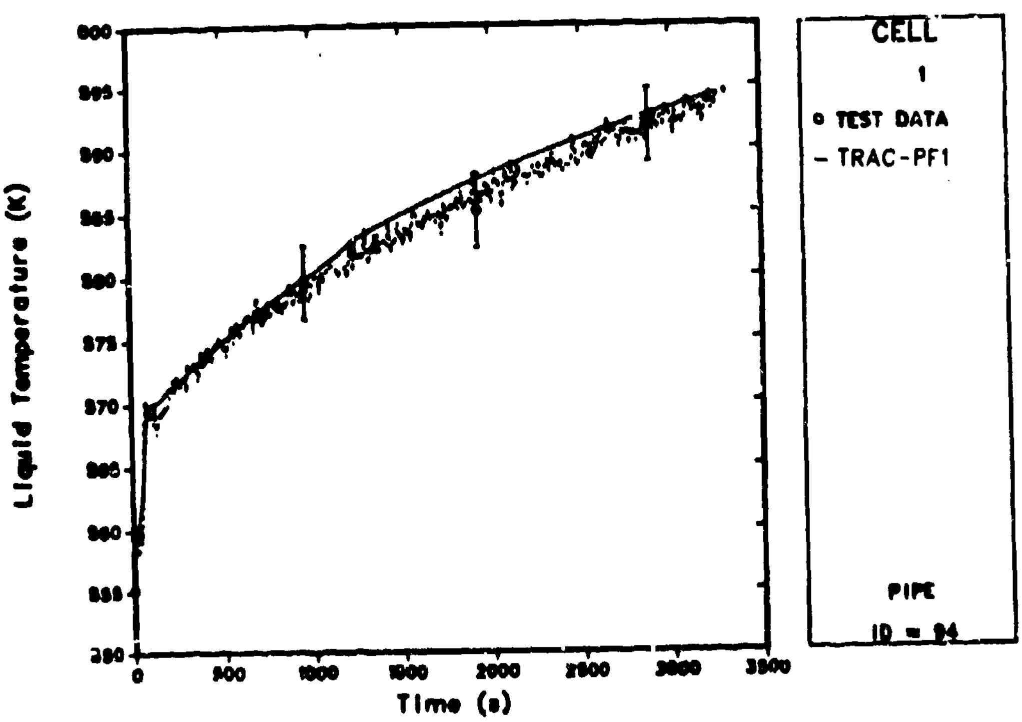


Fig. 3.
Comparison of the TRAC-calculated and the measured primary-system steam-generator-outlet temperatures for LOFT L9-1.

heat-transfer coefficient which could be used and still obtain reasonable calculated results. More sophisticated changes to the condensation heat transfer are included in TRAC-PF1/MOD1.

Figure 4 compares the mass flows from the secondary steam-flow control valve. The test data and the calculated results agreed fairly well. The difference between the initial flow rates was caused by the different feedwater temperatures in the analysis and in the test. In subsequent analyses we used the actual feedwater temperature and obtained the same initial flow rate. Figure 5 compares the pressures on the steam-generator secondary side. The previously mentioned difference in feedwater temperatures is partially responsible for the divergence between the test and calculated pressures during the first 50 s.

Figure 6 shows the pressurizer pressure resulting from the expansion of the primary liquid as it heated and the action of the pressurizer spray. In general, this comparison is good. Although the measured and the calculated primary-system fluid-temperature increases correlated closely, the pressure traces diverged from 5 to 30 s. The discrepancies were caused by difficulties in modeling the compression of the pressurizer vapor by the liquid inflow. Also in

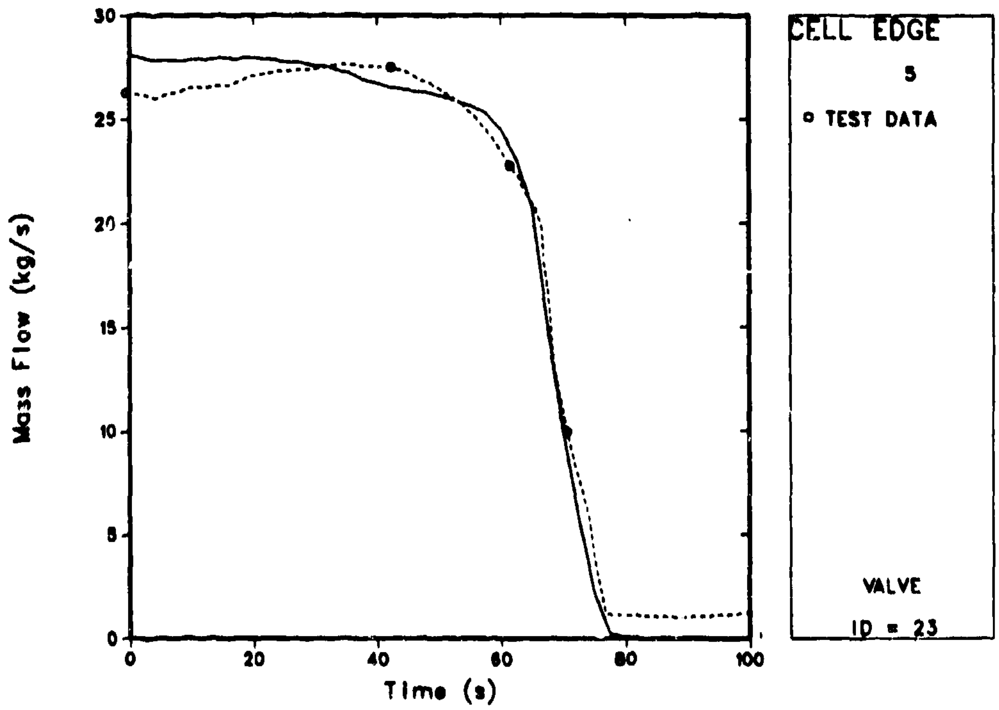


Fig. 4.
Comparison of the TRAC-calculated and the measured steam-line mass flows for LOFT L1-9.

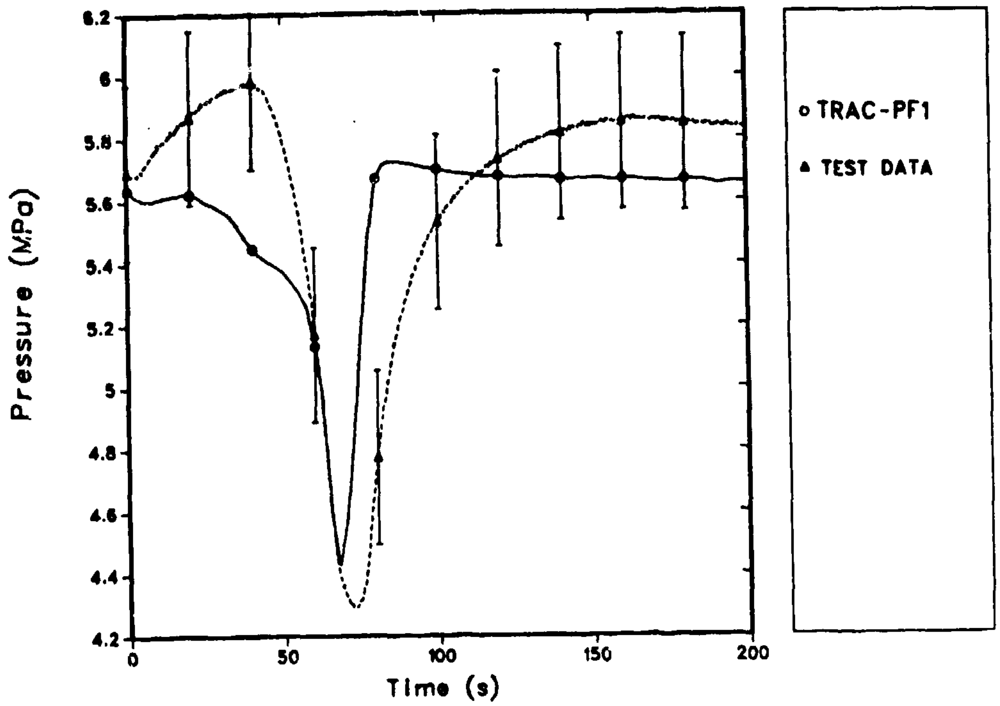


Fig. 5.
Comparison of the TRAC-calculated and the measured pressures on the steam-generator secondary side for LOFT L1-9.

Fig. 6 during the 100 s after scram, there is a noticeable difference between the test data and the analytical results wherein the analytical results exhibit several saw-tooth transients. We believe this is partially a result of differences in the calculated and actual heat-transfer processes within the steam-generator secondary. In the analytical model, the remaining water in the steam generator after scram boils immediately thereby dropping the primary-system pressure. After all the water vaporizes, the heat transfer in the secondary drops rapidly causing the pressure in the primary system to rise and the pressurizer sprays to activate. In the test we believe the remaining water is puddled in the bottom of the secondary and boils away more gradually with a more gradual effect on primary-system pressure.

Figure 7 shows how the cycling pressurizer spray controlled the system pressure to ~1000 s. After that time, the spray was discontinued and the pressure increased until the cycling power-operated relief valve (PORV) began to control the system pressure. This process continued until ~3260 s when the PORV was locked open to decrease the system pressure.

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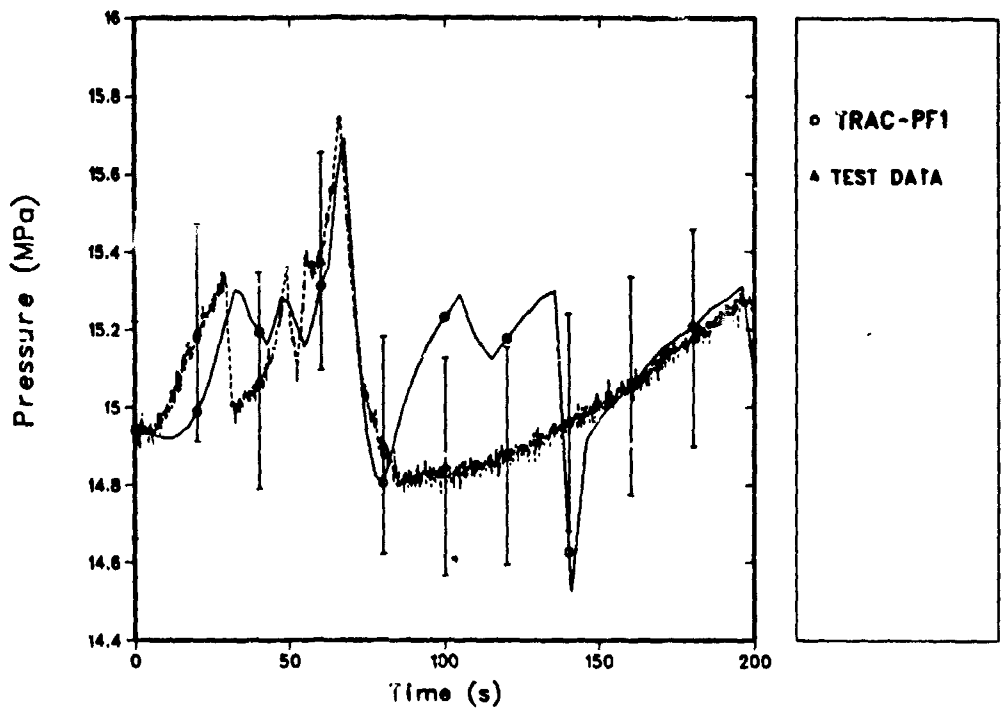

Fig. 6.
Comparison of the TRAC-calculated and the measured pressurizer pressures for LOFT L1-9.

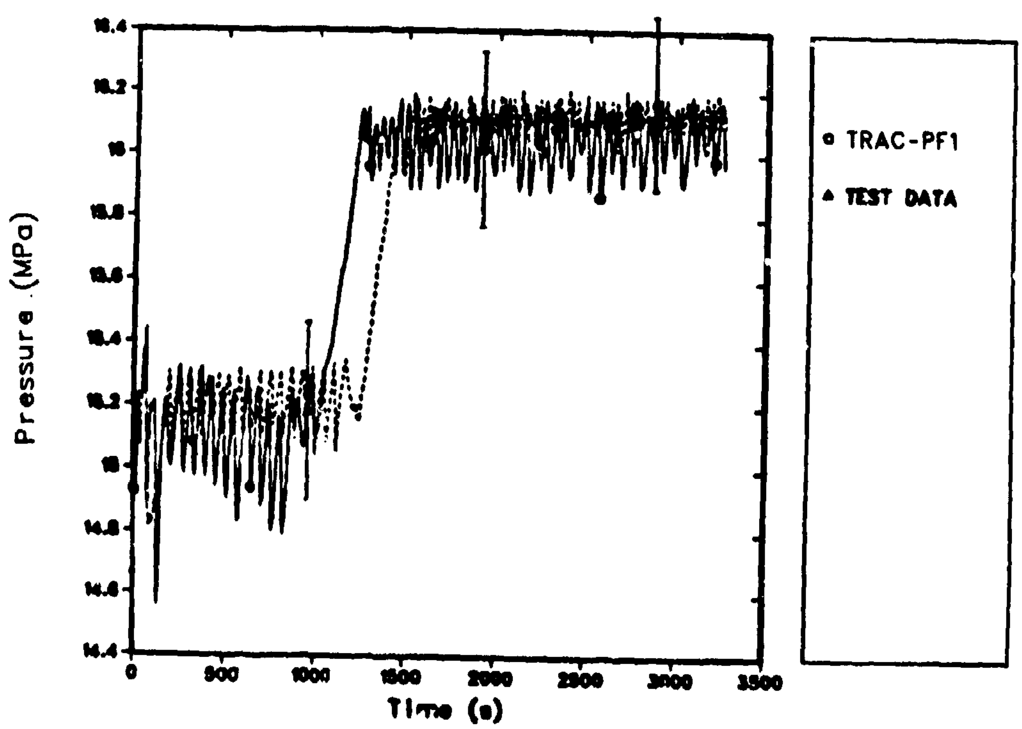

Fig. 7.
Comparison of the TRAC-calculated and the measured pressurizer pressure for LOFT L1-9.

CONCLUSIONS

The code calculated the experiment well, given the uncertainties in the boundary conditions. The analysis indicates the need to model all the flow paths and heat structures and to improve the TRAC condensation heat-transfer model. An improved condensation model is incorporated in the soon-to-be-released TRAC-PF1/MOD1.

REFERENCES

1. Douglas L. Reeder, "LOFT System and Test Description (5.5-Ft Nuclear Core 1 LOCES)," Idaho National Engineering Laboratory, NUREG/CR-0247 TREE-1208, July 1978.

2. R. J. Beelman, "LOFT Experiment Operating Specification Anticipated Transients With Multiple Failures Test Series L9, Nuclear Test L9-1/L3-3/L8-1A," Idaho National Engineering Laboratory, EGG-LOFT-5334, April 1981.

3. Mary L. McCormick-Barger and Janice M. Divine, "Experiment Data Report for LOFT Anticipated Transient With Multiple Failures Experiment L9-1 and Small Break Experiment L3-3," Idaho National Engineering Laboratory, NUREG/CR-2119, EGG-2101, June 1981.