CONF-830932--4

COMMIX-1A Analysis of Fluid and Thermal Mixing CONF-830932--4

in a Model Cold Leg and Downcomer of a PWR DE83 014741

by

B. C-J. Chen, B. K. Cha, C. C. Miao, W. T. Sha,
Argonne National Laboratory

J. H. Kim and B. K. H. Sun
Electric Power Research Institute

Summary

The issue of thermal shock of a PWR pressure vessel has been under considerable attention recently. A number of experimental as well as analytical studies have been performed to investigate the effect of the thermal transient on the pressure vessel due to the high pressure injection (HPI) of the cold fluid into the cold leg. This process has been called "Pressurized Thermal Shock" (PTS). This paper is an analytical study of PTS by using COMMIX-1A.

Experimental investigations were performed at CREARE[1-3] and SAI[4]. In the CREARE experiment, a 1/5 scale model was set up to simulate a cold leg and downcomer of a PWR. Tests with several different ratios of hot loop flow versus cold HPI flow were performed to study the effect of the flow ratio on the fluid and thermal mixing process in the system, especially in the downcomer region.

Analytical investigations[5-8] also proceeded in parallel with the experiments. Quite a few analytical investigations were performed with the COMMIX-1A code. However, in this version of COMMIX, the effect of the numerical diffusion was not addressed. Furthermore, most of the analyses were performed with rectangular zig-zag geometries to approximate the curved surfaces. The approximation further enhanced the numerical diffusion. Also, in most of the analyses the turbulent flow was mostly accounted for by using simple constant effective viscosities or mixing length turbulent model. The inaccuracies resulted from these three simplifications were not quantified. In order to improve the accuracy of the analyses, three measures were taken in the present analysis. To minimize the numerical diffusion, extreme fine meshes were used. To better model the turbulent flow, one-equation (κ) turbulent model was used. To better represent the geometries, curved surfaces were modeled by several slanted planes for the calculation.

By using these improvements, one of the CREARE test (#51) was reanalyzed to study the effect of these improvements. A total of 7477 computational cells was used for the reanalysis with most of mesh concentration in the pipe. Figure 1 shows the geometry of the configuration under consideration. The cold leg is modeled by an octogon. The 60° HPI injection is modelled as a square pipe with exactly 60° inclination. Since the injection angle affects

greatly the split of flows in the cold leg, accurate representation of the injection angle is important in the analysis. The nozzle at the end of the cold leg was modelled by eight inclined planes. The step in the belt line of the downcomer was also modeled. Figure 2 shows the computational meshes and the thermocouple locations.

The initial condition of the test before the transient was at 64.1°C with a loop flow of 2.52×10^{-4} m^3/s. At the start of the transient cold fluid with temperature of 16.67°C and flow rate of 1.35×10^{-4} m^3/s was injected into the cold leg through the HPI pipe (5.08 cm I.D). Part of the cold fluid propagated upstream of the cold leg, while most of it flowed downstream toward the downcomer. By the time the flow reached the nozzle, significant amount of mixing had taken place. Therefore, the measured temperatures were very close to the mixed mean temperature in the downcomer region below the cold leg. This mixing process was predicted by the COMMIX code as well. A typical comparison between the calculations and the experimentally meausured values are given in Fig. 3 for five thermocouple locations near the nozzle. The open circle shows the previous calculation[10] based on 1247 cells with rectangular zig-zag geometries and constant turbulence viscosities. The solid circles show the present calculations based on 7477 cells and one-equation turbulence model. There is significant improvement in the present calculations over the previous coarse mesh calculations. Also, the present calculation shows less mixing than the previous one. Calculations with these fine meshes, but without the one-equation turbulence model, were also performed. The results were slightly worse than the present calculations with the one-equation turbulence model. This comparison reveals that the main error in the coarse mesh calculation is due to the numerical diffusion, which artificially enhances the fluid mixing. Therefore, reduction of numerical diffusion is more important than the inclusion of a turbulence model in the present case.

In summary, COMMIX-1A was used to simulate the CREARE test #51. Fine meshes were used. Curved surfaces were modelled by several slanted planes. One-equation (κ) turbulence model was included. All the mixing processes observed in the experiment were predicted by the code. Excellent agreements were obtained between the experimental measurements and the calculated temperature for all the thermocouples throughout the configuration. Future improvement of the COMMIX code will be in the area of reducing numerical diffusion, such as implementation of the skewed-upwind-difference scheme, and improvement of the turbulent models. Both tasks are currently underway.

References

1. P. H. Rothe, et al., "Fluid and Thermal Mixing in a Model Cold Leg and Downcomer with Vent Valve Flow", EPRI NP-2227, March 1982.

2. P. H. Rothe, et al., "Fluid and Thermal Mixing in a Model Cold Leg and Downcomer with Loop Flow", EPRI NP-2312, April 1982.

3. P. H. Rothe and M. W. Fanning, "Evaluation of Thermal Mixing Data from a Model Cold Leg and Downcomer", EPRI NP-2773, December 1982.

4. A. Hashemi and J. Goodman, "Thermal Mixing in a Rectangular Geometry Model of a Cold Leg with High Pressure Injection and a Downcomer", SAI-306-82-PA, November 1982.

5. R. W. Lyczkowski, et al., "Prediction of Thermal Stratification in the Cold Leg of a PWR During a LOCA", Trans. Am. Nucl. Soc. 39, 1057, (1981).

6. "Reactor Thermal Shock Problem - I & II", in Trans. Am. Nucl. Soc. 41, p. 255-265, June 1982.

7. Y. A. Hassan, "COMMIX Prediction of a Thermal Mixing Test", Trans. Am. Nucl. Soc. 41, 387, (1982).

8. C-L. Lin, J. H. Kim, and B. K. H. Sun, "Numerical Simulation of Thermal and Fluid Mixing in the Cold Leg and Downcomer of a Model Geometry During a PWR Primary Side Overcooling", Proceeding on the 2nd Int. Topl. Mtg. Nuclear Reactor Thermal Hydraulics, Santa Barbara, CA, Jan. 11-14, 1983.

9. H. M. Domanus, W. T. Sha, R. C. Schmitt, and V. L. Shah, "COMMIX-1A: A Three-Dimensional Transient Single-Phase Computer Program for Thermal Hydraulic Analysis of Single and Multicomponent Systems", ANL-82-25, NUREG/CR-2896, To be published in 1983.

10. R. W. Lyczkowski, et al., "Three-Dimensional Analysis of Thermal and Fluid Mixing in Cold Leg and Downcomer for Scaled Experiments and Generic Full-Scale Pressurized Water Reactors", To be published under EPRI project RP 2122-1 in 1983.

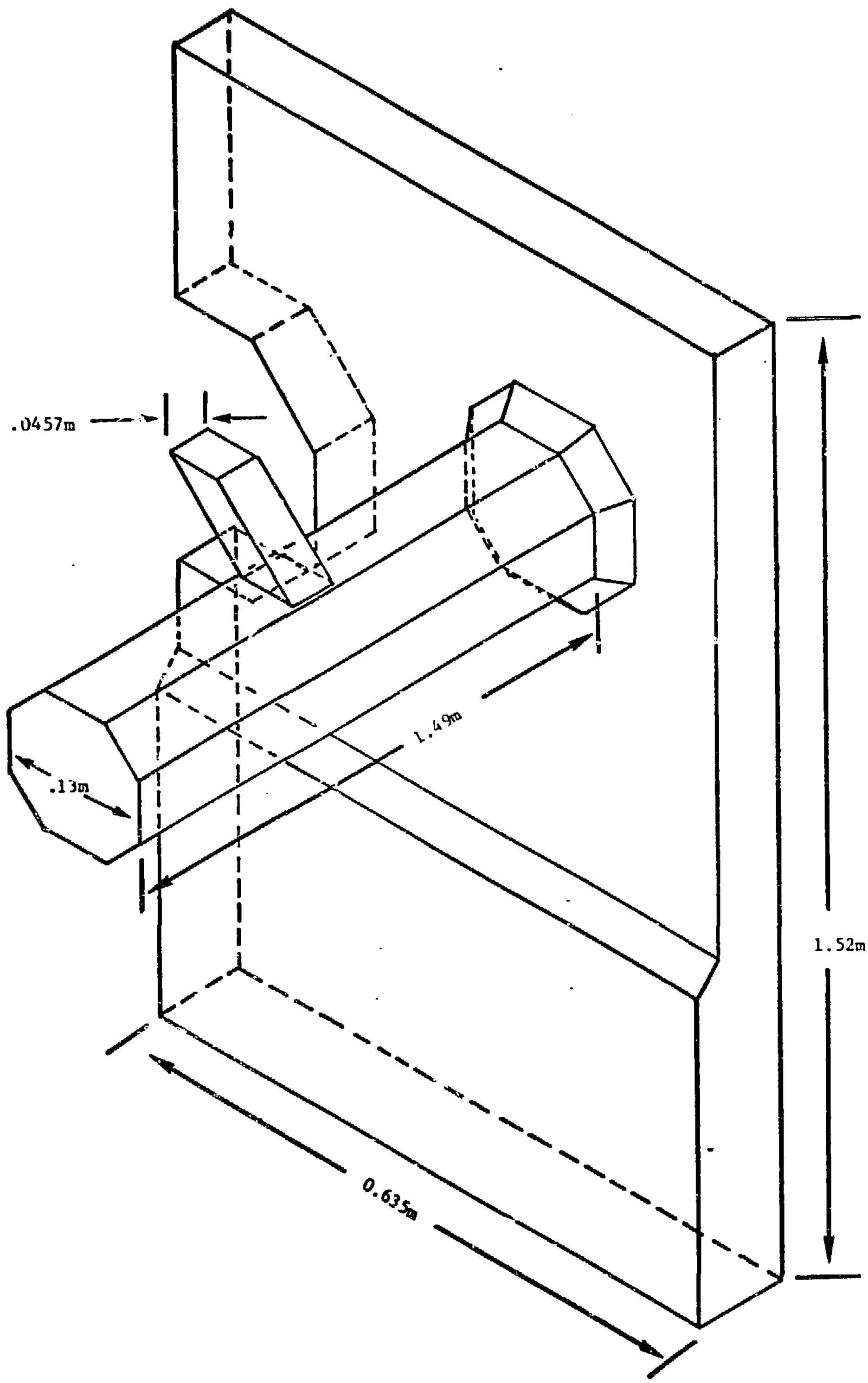

Fig. 1. COMMIX model of CREARE Test # 51 geometry

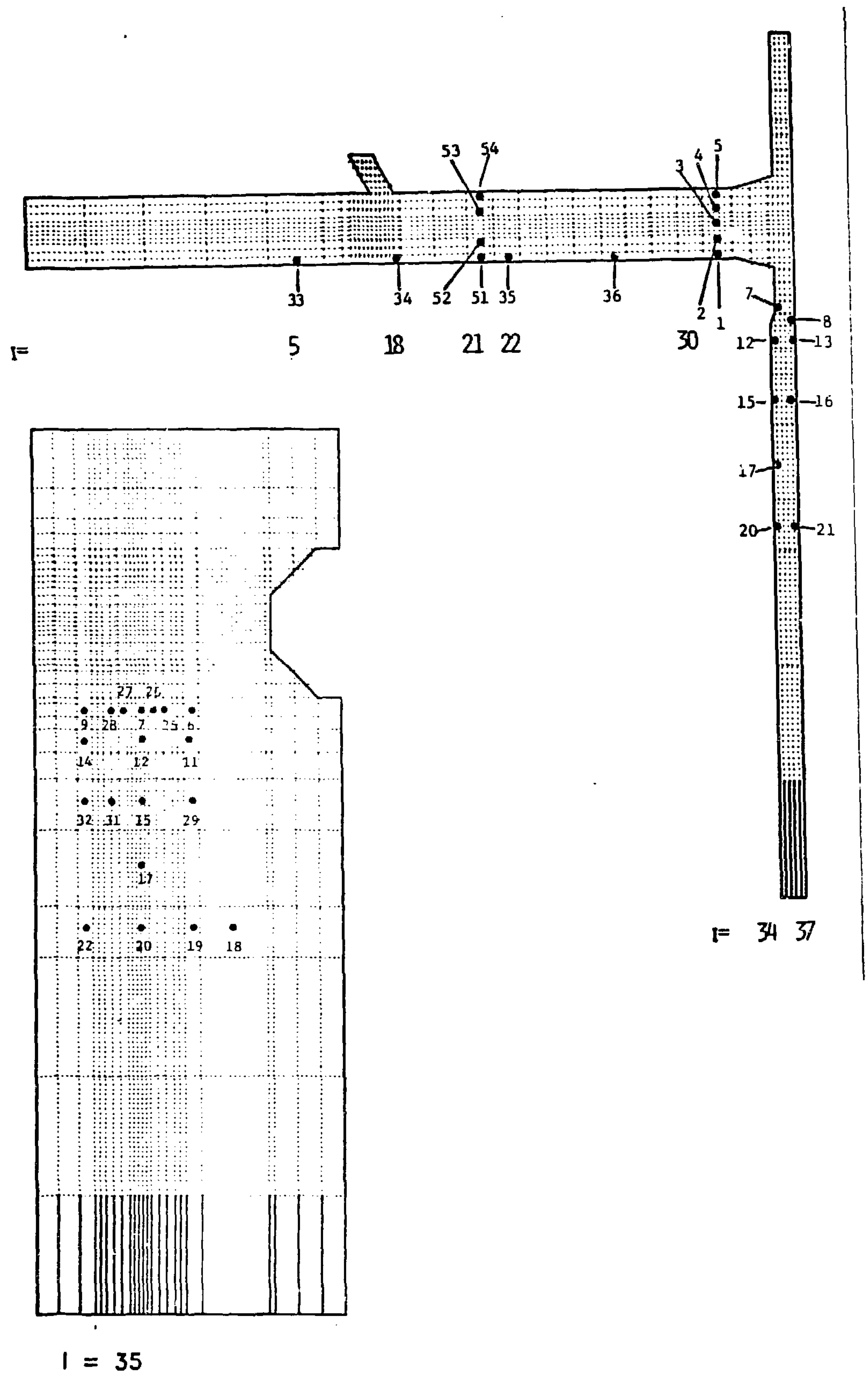

Fig. 2. Computational meshes used in the COMMIX calculation and the thermocouple locations.

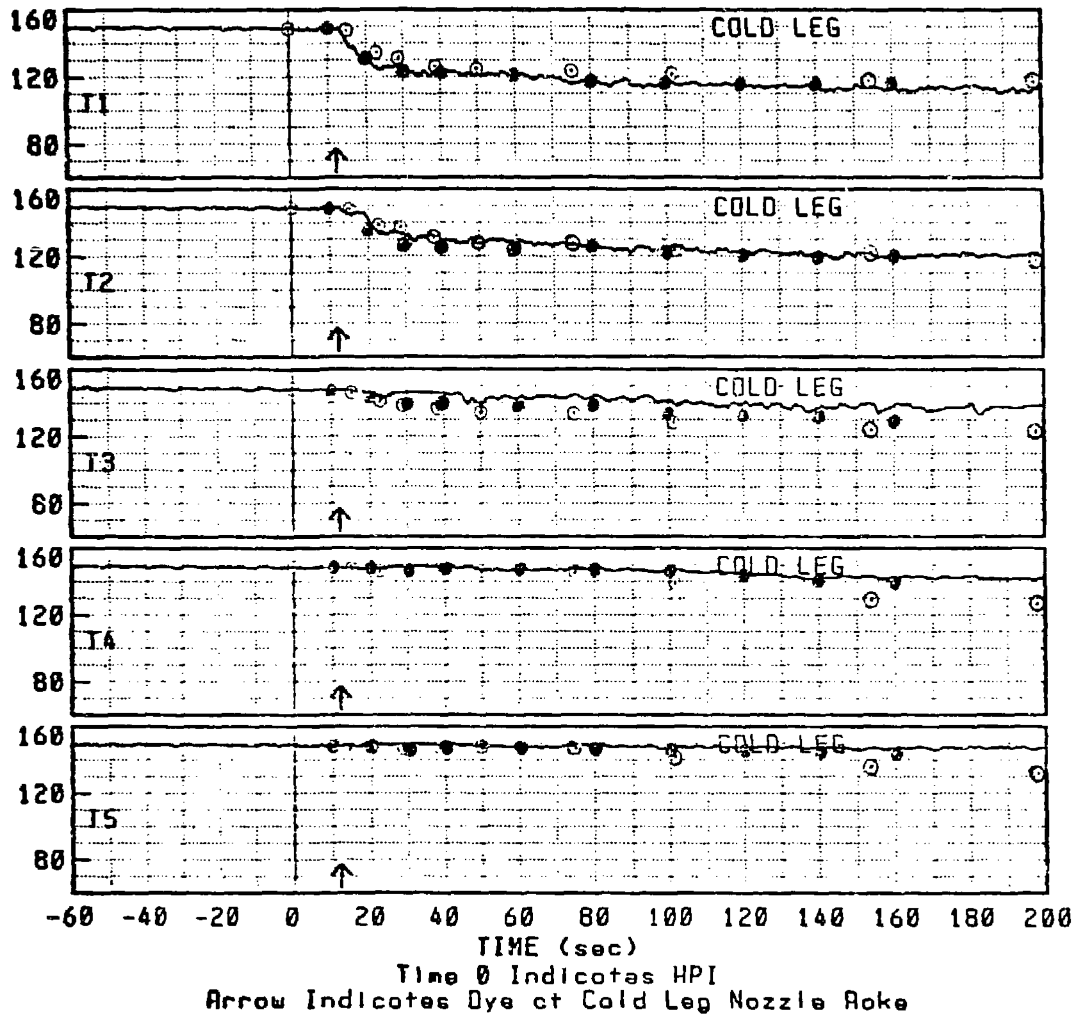

Fig. 3. Comparison between experimental data and COMMIX calculations using coarse meshes and constant viscosity (in O) and fine meshes and one equation turbulence model (in ●).

DISCLAIMER