CONF-830609--22

COMPARISON OF ONE- AND TWO-DIMENSIONAL SODIUM-BOILING MODELS*

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Summary Prepared for Submission to the
1983 ANS Annual Meeting

June 12-17, 1983

Detroit, Michigan



*This research is sponsored by the Office of Breeder Technology Projects, U.S. Department of Energy under contract W-7405-eng-26 with the Union Carbide Corporation.



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# COMPARISON OF ONE- AND TWO-DIMENSIONAL SODIUM-BOILING MODELS

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## SUMMARY

Prediction of sodium boiling and dryout in the fuel subassemblies of a Liquid Metal Fast Breeder Reactor (LMFBR) under certain accident conditions is of paramount importance in LMFBR safety. In the present paper, boiling and dryout calculations performed by two computer codes, one-dimensional (1-D), LOOP-1 and two-dimensional (2-D), THORAX are presented and compared with experimental data.

Both THORAX and LOOP-1 are codes developed at Oak Ridge National Laboratory. They are similar in the way they treat sodium two-phase flow using a compressible equilibrium model with slip between the phases. The slip S, the ratio of vapor to liquid velocities, is calculated by the formula

$$S = 1 + Cx \tag{1}$$

where C is selected by the user and x is the mixture quality. LOOP-1 models the LMFBR bundle one dimensionally by assuming uniform properties over the cross section. While LOOP-1 can model the complete loop system with several interconnected legs (test section, bypass leg, pump leg, etc.), THORAX is a bundle code and only models one leg, the test section.

Both programs solve the equations of continuity, momentum and energy conservation by a fully implicit method, using upstream finite differences for the convective terms in order to enhance numerical stability.

THORAX uses two interacting flow channels, one representing the interior subchannels and the other the edge subchannels of the bundle. Therefore, two

equations of conservation of momentum have to be solved in THORAX, one in the axial direction and the other in the radial direction. Both programs use the SIMPLE interative algorithm [1] to obtain the solution of the finite-difference formulation of the differential equations. Boiling initiation is defined as the time when the quality anywhere in the test bundle exceeds the value of zero, and dryout is defined to occur when the quality becomes unity. Additional information about THORAX can be found in Refs. 2 through 4.

The transient chosen for this paper was a controlled flow reduction test performed in the Thermal Hydraulic Out-of-Reactor Safety (THORS) Facility 19-pin Bundle 6A [5]. The specific test used was Test 73E Run 102A, with a total power of 300 kW (15.8 kW/pin). The initial steady-state inlet flow was 1.25 L/s (Fig. 1). It was then reduced in five seconds to 0.49 L/s by decreasing the pump head to a lower value which was kept constant during the rest of the transient. Three seconds after the flow was reduced (eight seconds on the scale of Fig. 1), boiling started; at about 22 s of the scale of Fig. 1, dry-out occurred, and the inlet flow dropped to a value near zero, characteristic of the static (Ledinegg) excursion type instability. THORAX predicts boiling initiation at about eight seconds, and dryout at 20.1 s [3].

THORAX uses a value of C=10 for Eq. (1), as derived from data in Ref. 6. An equivalent run with the program LOOP-1, also using C=10, yielded boiling initiation at 11.3 s and dryout at 12.3 s. Boiling is predicted by LOOP-1 later than the experimental value. As LOOP-1 is 1-D, all the cross section of the bundle has to be under saturation conditions in order to predict boiling initiation.

In the experiments, boiling occurs first in the central portion of the bundle at the downstream end of the heated section, and THORAX predicts this behavior quite well. On the other hand, the dryout time predicted by LOOP-1 is much shorter than that observed experimentally, which is a conservative result. However, by using a value of C=100 in Eq. (1), and multiplying the homogeneous friction factor used by LOOP-1 to predict the friction losses by the factor

$$F = 1 + Ax \qquad (2)$$

with a value of A=0.76, a calculated dryout time of 22 s was also obtained. Boiling initiation was also predicted at 11.3 s. Using these artificial slip ratios and friction factors, the code LOOP-1 predicts dryout times correctly for a wide variety of tests performed in 19- [5] and 61-pin [7] bundles. Previous predictions performed with other 1-D models [8-9] were inadequate.

The inlet flow calculated by LOOP-1 after boiling initiation is always smaller than the experimental value. The 2-D model in THORAX predicts the inlet flow quite accurately, as boiling occurs for a good part of the transient only in the central nodes of the bundle, and a substantial fraction of the axial flow is directed to the outer non-boiling regions. Therefore, the total bundle flow is larger than that calculated by the 1-D code which assumes that the complete cross section of the bundle is boiling.

In conclusion, the 1-D model LOOP-1 is a very fast running code that can be used as a scoping tool to predict boiling initiation and dryout times. However, 2-D models are needed for more precise calculations. A new loop code, LOOP-2, 2-D in the bundle and 1-D in the rest of the loop, is under development.

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FIGURE CAPTION

Fig. 1. Experimental test section inlet flow for Test 73E Run 102A (THORS Bundle 6A) and values calculated by THORAX and LOOP-1.

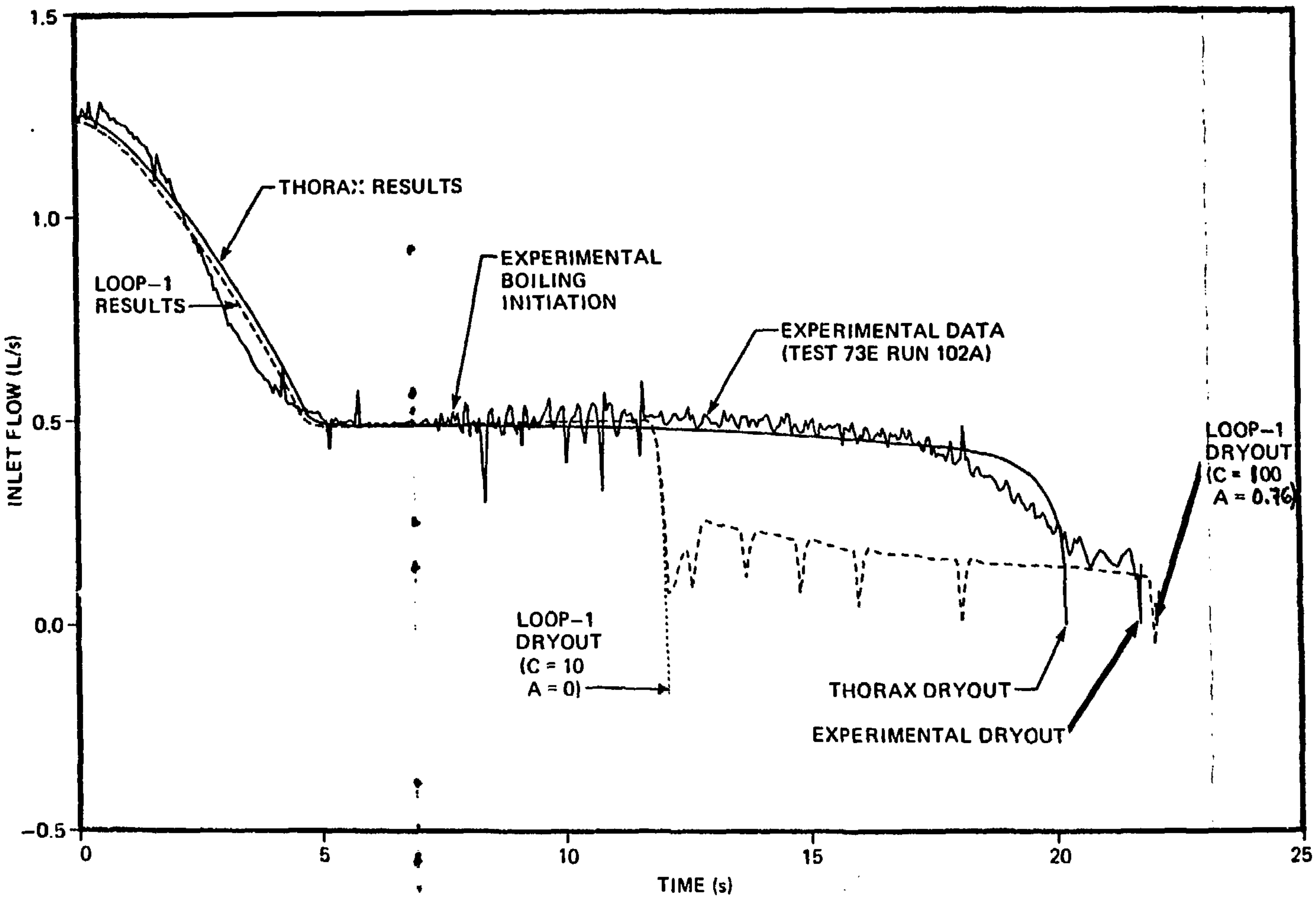


Fig. 1. Experimental test section inlet flow for Test 73E, Run 102A (THORS Bundle 6A) and values calculated by THORAX and LOOP-1.