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SAS4A SIMULATION OF THE OPERA-15 TWO-DIMENSIONAL
VOIDING EXPERIMENT

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SAS4A Simulation of the OPERA-15 Two-Dimensional Voiding Experiment

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Laural L. Briggs

A major effort is currently being pursued to validate the SAS4A LMFBR accident analysis code¹. Part of this effort involves SAS4A analysis of both in-pile and out-of-pile safety experiments. Such an experiment is the fifteen-pin Out-of-Pile Expulsion and Reentry Apparatus² (OPERA) test run at Argonne National Laboratory. This test uses a fifteen-pin triangular-shaped bundle of simulant fuel pins to demonstrate two-dimensional voiding behavior in a LMFBR subassembly during a Loss-of-Flow (LOF) accident. This experiment was chosen for SAS4A analysis both for its value in code validation and its usefulness in evaluating the limitations of the one-dimensional SAS4A sodium voiding model in accident analysis.

The OPERA-15 experiment progresses through three stages. A single-phase flow coastdown is initiated from steady state conditions and continues for 9.4 s. At this time, localized boiling begins at the hottest spot in the test section and spreads both radially and axially (predominantly radially) over the next two seconds. By 11.4 s, a voided region has been established which fills the cross-sectional area of the test section, and the voided region then continues to spread axially, with flow reversal occurring at 12 s. The first and third stages, then, are characterized by one-dimensional axial flow, whereas the second stage involves two-dimensional void progression.

Because the SAS4A voiding model is restricted to one-dimensional axial voiding, the code cannot explicitly model the two-dimensional voiding behavior observed in the second stage of the OPERA-15 experiment. The comparison of

experimental results with code predictions is therefore of special interest to determine how important explicit modelling of this two-dimensional behavior is in predicting the overall progression of the experiment.

The one-dimensional SAS4A model uses radially averaged coolant temperatures. Accordingly, the code might be expected to predict voiding at about the time the (axial peak) radially averaged temperature in the experiment reaches the saturation temperature; this will certainly be well past 9.4 s. However, the one-dimensional model cannot simulate the increased flow resistance, and corresponding increased rate of flow decrease, which is created in the experiment by the radially propagating voided region. The effect of this flow rate decrease, compared to the case of no additional flow resistance, is to accelerate the rate of radial propagation of the void and to reduce the time required to establish full radial voiding in the test section. Therefore, SAS4A should predict initiation of voiding at a significantly later time than that indicated directly by the average experiment temperatures.

The SAS4A predictions for progression of the experiment are as follows. Beginning with the steady state, the code computes a flow coastdown progression which is quite similar to that of the experiment prior to the start of voiding. This coastdown continues until 12.05 s, when the code boiling criterion is satisfied and a sodium bubble is formed which extends across the entire flow area at the hottest axial location in the test section. Flow reversal occurs at 12.56 s, after which the voided region propagates axially much as it does in the experiment. The main discrepancy, then, is between the code prediction of 12.05 s as the time at which the test section experiences a full radial void and the observed time of 11.4 s for full radial voiding. The difference between the predicted and observed flow

reversal times is consistent with the 11.4 s vs. 12.05 s difference. This discrepancy in time at which full radial voiding is established appears to be a measure of the limitations of the one-dimensional voiding model and is a result of the factors discussed in the preceeding paragraph.

These factors are illustrated clearly in the plot of inlet flow rate versus time shown in Figure 1. The curves show the excellent agreement between SAS4A and OPERA-15 prior to 9.4 s. Shortly after 9.4 s, the two flow rate curves diverge as the experiment mass flow rate begins to decline more rapidly due to the increased flow resistance from the radially voiding region. If the two curves are compared from their respective times of establishment of full radial voiding, it is clear that the code predicts a progression similar to that observed in the experiment, namely a sharp decline in mass flow rate down to flow reversal, followed by the chugging behavior characteristic of loss-of-flow accidents. The difference is that the SAS4A curve is offset from the OPERA-15 curve by about a half a second. Thus, the code predicts the correct overall behavior of the experiment but, due to the one-dimensional modelling, it predicts bulk voiding and flow reversal events later in the transient than observed.

In conclusion, the SAS4A code predictions compare favorably with much of the OPERA-15 data and so provide further validation of the code. However, the analysis does point out the limitations of the one-dimensional voiding model in simulating a strongly two-dimensional void propagation.

References:

1. H. U. Wider, et al., "Status and Validation of the SAS4A Accident Analysis Code System," Proceedings of the International Topical Meeting on Liquid Metal Fast Breeder Reactor Safety and Related Design and Operational Aspects, Lyon, France (July, 1982).
2. T. J. Scale, et al., "OPERA 15-Pin Sodium Expulsion Test," Transactions, American Nuclear Society, 42, p. 495 (November, 1982).

Fig. 1. Comparison of inlet mass flow rates for OPERA-15 and SAS4A.