CONF-830609--69

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DE85 004815

Analysis of Closed-Pool Boilup Using the TRANSIT-HYDRO Code *

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January 4, 1983

The benign termination of the transition phase of a hypothetical LMFBR accident rests on the avoidance of highly energetic recriticalities prior to escape of bottled molten core materials from the active core region. In scenarios where molten fuel is trapped due to axial blockages, the maintenance of subcritical configurations until radial flow paths develop requires stable boil-up of the molten fuel/steel mixture. This paper describes the analysis of an experiment investigating the behavior of closed boiling pools using the two-fluid hydrodynamics module of TRANSIT-HYDRO, a deterministic transition-phase analysis code[1].

The closed-pool boilup experiment conducted by Cho and Lambert[2] featured a pressure vessel with a volumetric arrangement of electrical resistance

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* Work performed under the auspices of the U.S. Department of Energy

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heaters in a water pool and a set of condensing coils above the pool. Tests were performed at various power levels and for different condenser configurations. Average pool boilup was observed through ports in the thermally-isolated vessel and these data points were paired with the maximum superficial vapor velocities computed from the pressure, temperature, and condenser readings.

As a result of limited heat loss to the vessel walls, the pool did not develop a significant radial recirculation pattern. This lack of two-dimensional effects made analysis with the one-dimensional TWOFLU module of TRANSIT-HYDRO suitable[3]. The interfacial exchange terms for heat, mass, and momentum transfer between the water pool and steam were based on the flow-regime independent models proposed by Kelly and Kazimi[4]. The boiling rate is determined from a linear interpolation from the temperature at which bubbles are just expected to enter the flow field (bulk water temperature equal to the bubble detachment temperature) and the temperature at which all heating of the liquid is used for boiling (bulk water temperature equal to the saturation temperature). Non-boiling heat exchange between the phases is treated with a conduction-type model driven by the difference between the vapor and the interface (saturation) temperatures.

Several interphase drag models besides the Kelly and Kazimi model were tested. The model which generated boilup predictions consistent with the experimental results over a range of average pool void fractions was a modification of the inertial drag force given by Kelly and Kazimi, which in terms of force per unit volume, F, is

$$F = \frac{(1 - \theta)}{\theta \cdot D} \cdot \frac{\bar{\rho}\,|U| \cdot U}{2} \tag{1}$$

where $\bar{\rho}$ is the total cell smeared density, θ is the vapor volume fraction, D is the diameter of the vessel, and U is the relative velocity $(U_g - U_\ell)$.

The analysis showed that steady-state boilup could be achieved with good agreement between calculated and experimentally-obtained local variables. A plot of typical void distributions at different power levels is given in Figure 1. The stable distributions are the result of condensed liquid falling as droplets to the pool surface, while in the pool there is a small downward velocity as evaporating liquid is replaced. A series of runs were made holding the drag model constant and varying parameters such as pool height, condenser configuration, and heating rate. Data from these runs duplicated the pattern of experimental points in Figure 2 for average boilup versus maximum superficial vapor velocity. The TRANSIT-HYDRO line marked on Figure 2 was generating using a constant initial pool height at different heating rates. The drag model of Equation 1 provided a trend for boilup which diverged from those predicted using churn-turbulent flow assumptions, but which agreed with experimental results.

In summary, the TRANSIT-HYDRO code served as a useful tool in analyzing a closed, boiling pool. Given that insulating fuel crusts are expected to form on disrupted assembly walls in LMFBR transition-phase accidents, the one-dimensional two-fluid module of TRANSIT-HYDRO should adequately model the closed boiling fuel/steel pool as well.

REFERENCES

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FIGURE CAPTIONS

Figure 1	Void Distributions in the Vessel at Various Power Rates
Figure 2	Comparison of Computed Boilup Data with Experimental Results and with a Theoretical Prediction Based on a Churn-Turbulent Drift-Flux Correlation

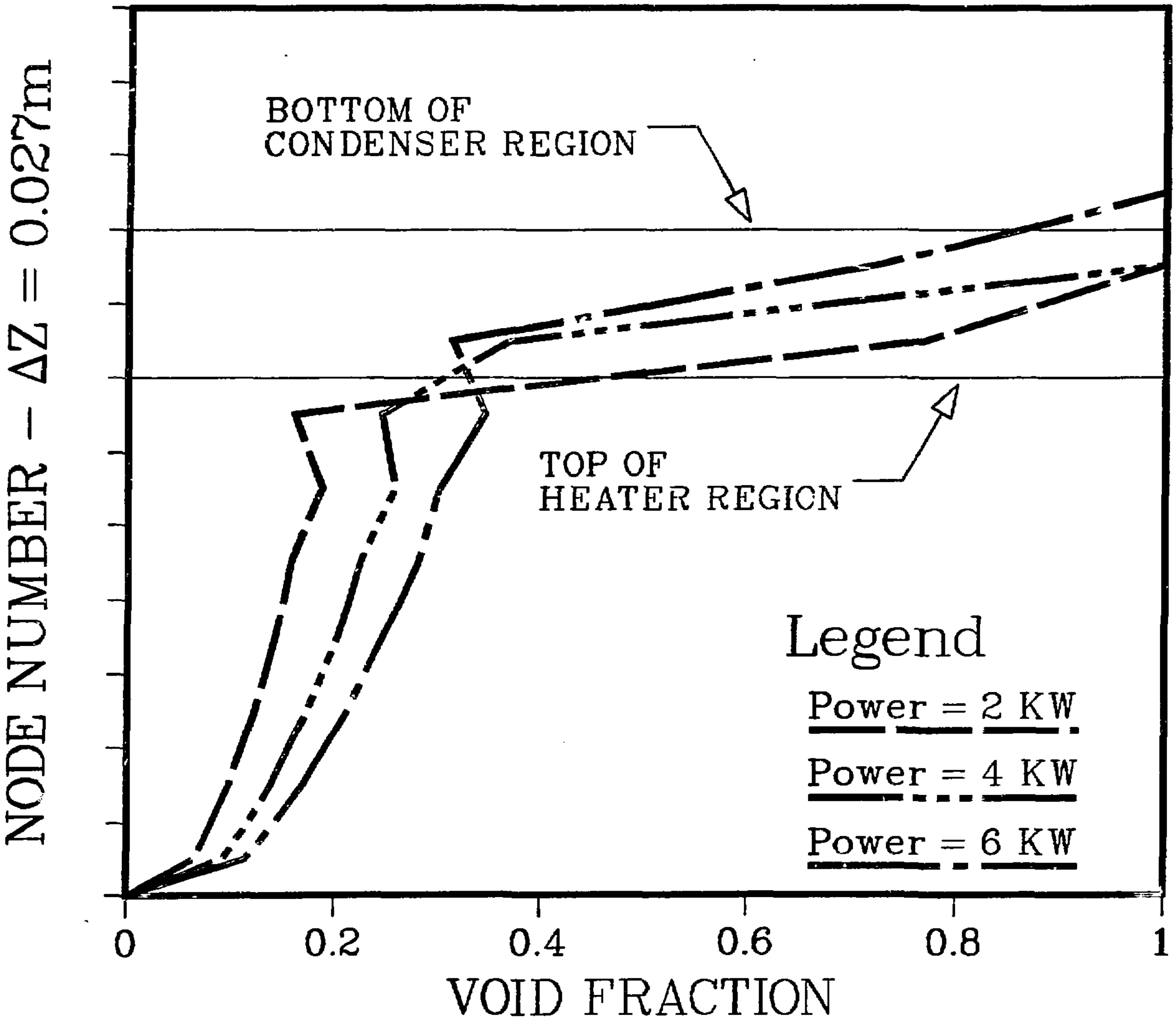

Fig. 1. Void Distributions in the Vessel at Various Power Rates.

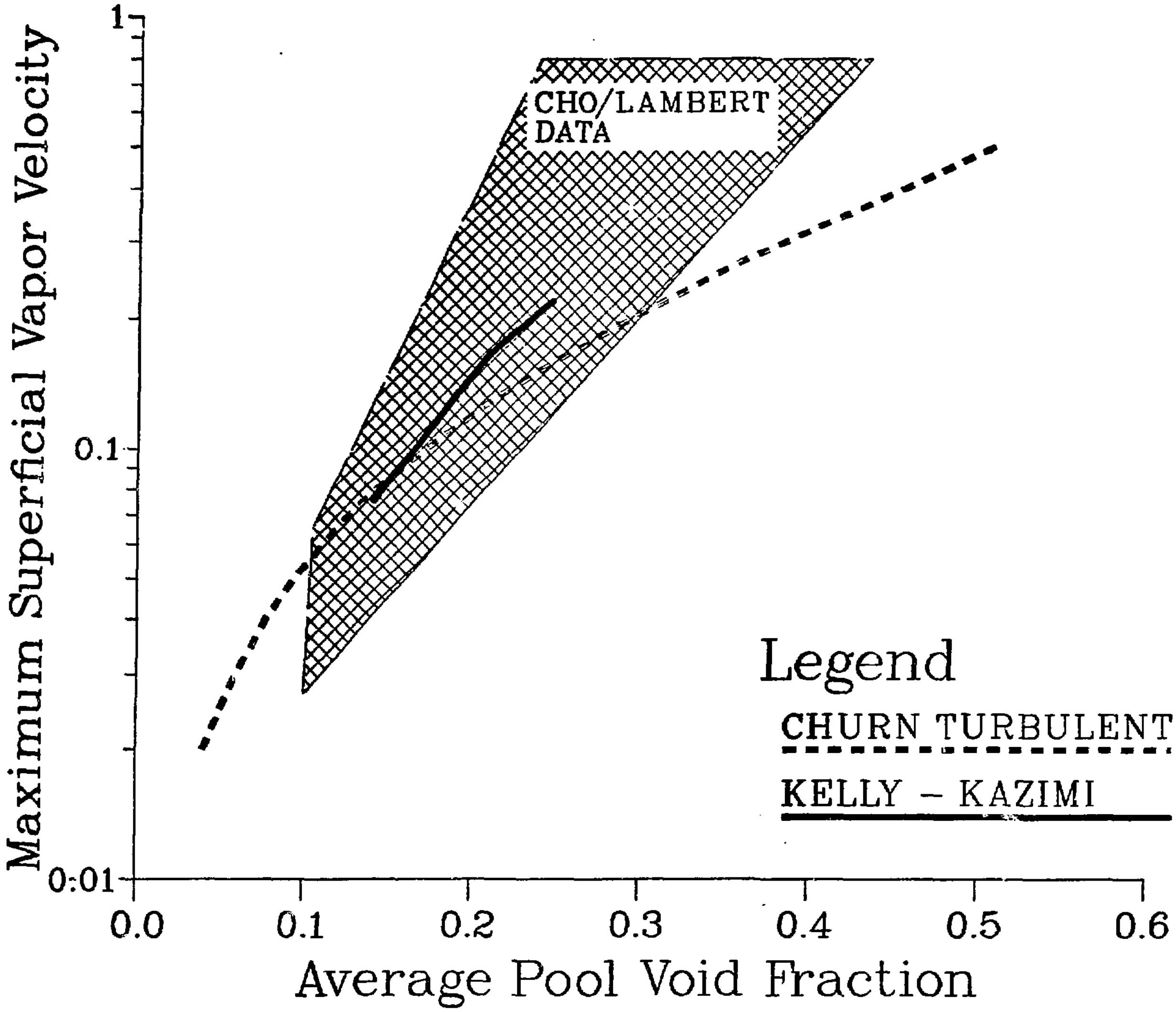

Fig. 2. Comparison of Computed Boilup Data with Experimental Results and with a Theoretical Prediction Based on a Churn-Turbulent Drift-Flux Correlation.