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SAS3D ANALYSIS OF NATURAL CONVECTION BOILING BEHAVIOR IN THE SODIUM BOILING TEST FACILITY*

Gail Klein† Floyd Dunn††

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†Oak Ridge National Laboratory, Engineering Technology Division, Advanced Reactor Systems Section.

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Summary

The objective of the initial phase of testing in the Sodium Boiling Test (SBT) Facility,[1] at the Oak Ridge National Laboratory, was to determine the maximum power that could be transferred by a simulated breeder reactor coolant subchannel when the coolant flow is driven by natural convection. In order to aid in the evaluation of the experimental data and to help understand the flow regimes present at the various power levels examined during this test program, a SAS3D[2] computer model of the SBT Facility was developed.

SAS Model Description

The SBT test section consists of a Hastelloy X tube with a 3.25 mm (0.128 in.) ID and a 2.90 mm (0.114 in.) OD wall. These dimensions were selected to correspond to the mean hydraulic diameter of the fuel subassembly of the Fast Flux Test Facility (FFTF). This tube is radiant heated by means of a 16 kW quad-elliptic furnace which simulates core heat loads to a 0.97 m (38 in.) region of the test section.

The following parameters in the SBT test section were equivalently modeled in SAS3D: the test section heat flux, hydraulic diameter, frictional resistance, central pin thermal inertia, and channel flow area. The SBT test section downstream of the furnace is guard heated and simulates the fission gas plenum region of the subassembly. In the SAS3D model, the fission gas plenum is modeled as an adiabatic extension of the test section to simulate the exit hydraulic resistance.

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A coil located at the SBT test section inlet simulates subassembly inlet hydraulic resistance and accommodates thermal growth of the test section. The inertial length of the test section inlet, which is modeled by a lower reflector in SAS3D, was set equal to the actual flow length of the inlet coil traversed by the sodium coolant, and the pressure drop across the test section was adjusted accordingly.

Analysis

Experimental data at low powers, Q = 0.76 kW/ft to Q = 0.89 kW/ft indicates highly unstable boiling, and the system reverts back to single-phase flow. At higher test section powers, the data indicates that the flow becomes more stable and sustained boiling can be maintained for an extensive period of time without any detectable dryout at the outer test-section wall. Large oscillations in the flow downstream of the heated section and the response of the void detectors in this region suggest a slug flow regime. At powers of approximately 1.29 kW/ft permanent dryout conditions were encountered.

The SAS3D Program was used to evaluate a series of these natural convection cases for various powers up to and including the dryout condition. These runs were made with conditions identical to those used in the SBT Facility.

The frictional pressure drop across the void due to vapor streaming was evaluated using both a single phase friction factor, and a two phase frictional factor. The best agreement with the experiment was obtained using a single phase friction factor. For the flow distribution for this particular experiment, the film along the tube walls was assumed to be smooth due to the possible influence of surface tension effects. Using a single phase friction factor, the code qualitatively predicts a net positive flow of vapor liquid slugs up to the test section in the same power range where a similar behavior was observed experimentally, as shown in Figure 1. The power range for observing this type of flow behavior would have to be much lower, if a two phase friction factor were used.

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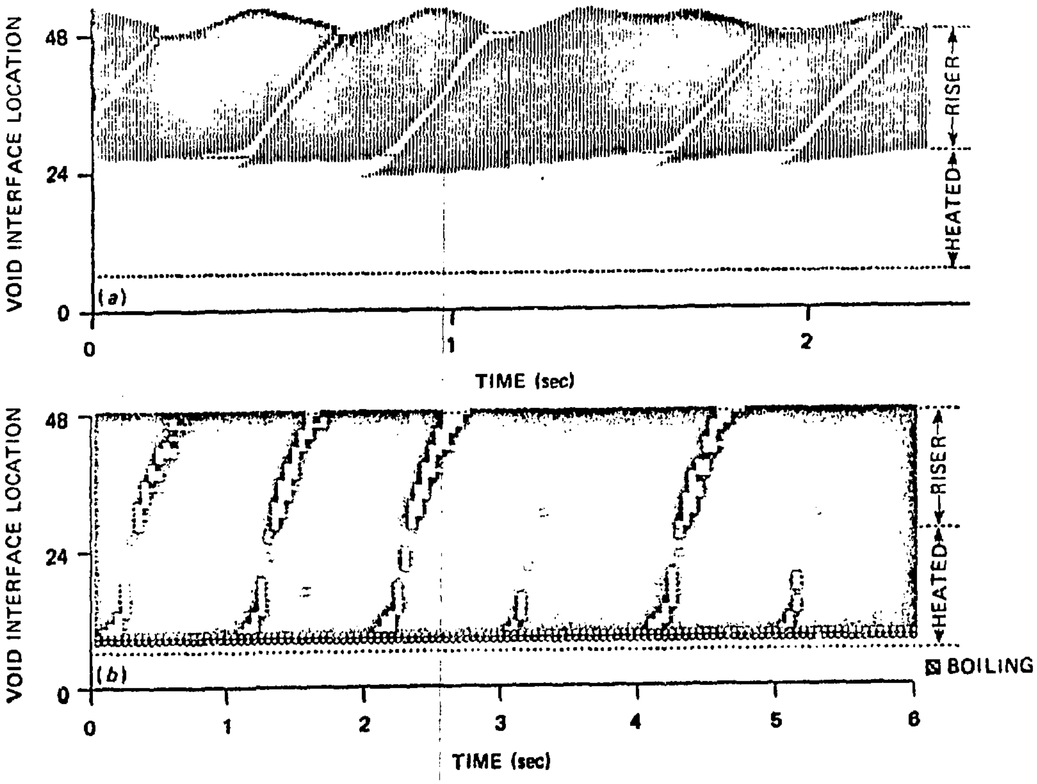

Fig. 1.

*A revision of the time scales will be made at the time of the paper presentation.

One cannot rule out the possibility that the influence of surface tension effects due to the small channel flow area in the experiment may contribute to increasing the length of the liquid slugs, which separate the vapor bubbles. In SAS3D, there is a user-supplied input for the minimum initial slug length. If this value is too small, the liquid slugs which are formed may disappear as they rewet the channel walls during their passage up to the riser (in contrast to the experimental data.) For a fixed liquid slug length, increasing the superheat increases the vapor velocity which drives the liquid slugs out of the test section riser, thus resulting in a decrease in the riser structure temperature. Two additional models besides the one existing in the SAS3D code were examined to determine the effect of the liquid slug length upon the channel flow distribution. In the first model, there was assumed to exist preferred sites along the channel where bubbles first nucleate following a drop in channel pressure after expulsion of a liquid slug out of the top of the channel. In the second model, it was assumed that vapor bubbles nucleate at any axial location within a temperature range extending from T_{sat} to ($T_{sat} + T_{sup}$). If there is a trend toward multiple bubble generation at low superheats (as would be present in SBT following initial injection of argon gas), then conceivably these bubbles will coalesce together as they begin to grow, while pushing the sodium which is separating them around and above the newly formed combined bubble. The choice of model determines the periodicity between formation of vapor bubbles separated by continuous liquid slugs extending up the entire length of the test section. At the same power level, the preferred site model leads to higher structure temperatures than the multiple bubble generation model.

Results and Conclusions

A preliminary assessment of these test results indicate that for channel powers less than 0.408 kW/ft, boiling did not occur. At channel powers around 0.446 kW/ft intermittent boiling occurs, and at channel powers between 0.1 and 1.064 kW/ft, stable boiling is achieved. For channel powers between 1.14 kW/ft and 1.29 kW/ft, localized dryout occurs, followed immediately by rewetting of the structural walls. Permanent dryout leading to clad melt occurs for channel powers greater than 1.29 kW/ft. These results are in reasonable agreement with the SBT test Facility test results.

References

1. P. W. Garrison, et al., "Natural Convection Boiling of Sodium in a Simulated FBR Fuel Assembly Subchannel." Presented at the International Meeting on Fast Reactor Safety Technology, August 19-23, 1979, Seattle, Washington.

2. J. E. Cahalan, et al., A Preliminary User's Guide to Version 1.0 of the SAS3D LMFBR Accident Analysis Computer Code.

Figure Captions

Figure 1. SAS predictions (Q = 1.064 kW/ft) versus SBT experimental void detector data (Q = 1.14 kW/ft).