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SAS3A ANALYSIS OF NATURAL CONVECTION BOILING BEHAVIOR IN THE SODIUM BOILING TEST FACILITY*

MASTER

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ABSTRACT

An analysis of natural convection boiling behavior in the Sodium Boiling Test (SBT) Facility has been performed using the SAS3A computer code. The predictions from this analysis indicate that stable boiling can be achieved for extensive periods of time for channel powers less than 1.4 kW and indicate intermittent dryout at higher powers up to at least 1.7 kW. The results of this analysis are in reasonable agreement with the SBT Facility test results.

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SUMMARY

The objective of the initial phase of testing in the Sodium Boiling Test (SBT) Facility,[1,2] 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 SAS3A[3] computer model of the SBT Facility was developed.

SAS Model Description

The basic calculational model in SAS was designed such that a single fuel pin and its associated coolant, cladding and structure represent the behavior of either full- or semi-scaled subassemblies containing heat generating fuel pins. However, the configuration of the SBT test section, as shown in Figure 1, does not readily lend itself to modeling with the SAS code. The test section consists of a Hastelloy X tube with a 3.25mm (0.128 in.) ID and a 2.90mm (0.114 in.) wall. These dimensions were selected to correspond to the mean hydraulic diameter of the fuel subassembly of the Fast Flux Test Facility. This tube is radiant heated by means of a 16 kW quad-elliptic furnace which simulates core heat loads to a 0.97m (38 in.) region of the test section. Thus, the heat transfer surface is the inner surface of the tube rather than the outer surface of the fuel pin as in the SAS model.

Heat flux and frictional resistance effects were simulated by setting the fuel pin and hydraulic diameters, used in SAS, to the SBT test section inside diameter. Due to the geometry change, it was necessary to ensure that the volume fraction of the sodium in the SAS modeled test section (where $V_{f_{Na}}$ =

$\frac{\text{coolant volume}}{\text{volume of fuel+clad+coolant}}$) was maintained equal to that in the actual test section. Heat transfer to the SAS structural node was neglected. In addition, the heat capacity of the central pin used in the SAS model was set equal to the heat capacity of the SBT test-section wall.

The SBT test section downstream of the furnace is guard heated and simulates the fission gas plenum region of the subassembly. In the SAS model, the fission gas plenum is modeled as an adiabatic extension of the test section to simulate the exit hydraulic resistance.

A coil located at the SBT test section inlet simulates subassembly inlet hydraulic resistance and accommodates thermal growth of the test section. However, there is no capability in SAS for modelling such a coil, and approximations had to be made. The inertial length of the test section inlet was set equal to the actual flow length of the inlet coil, as traversed by the sodium coolant. Since the SBT test section, as modeled in SAS, was coupled to a return line using the hydraulic coupling option, the vertical length of the return line was increased by an equivalent amount, such that the pressure head term was not altered by this approximation.

Results

The SAS program was used to evaluate a series of 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:

a) upper plenum pressure of 97.2 KPa (12.1 psia);
b) test section inlet temperature of 420°C (790°F);
c) upper plenum temperature of 590°C (1100°F).

For the low power boiling runs, Q = 1 kW to Q = 1.1 kW, the SAS code predicts highly unstable boiling, and the system reverts back to single-phase flow. This is seen in Figures 2a and 2b. At higher test section power (i.e., Q = 1.2 kW), the flow became more stable, and the code predicts that sustained boiling can be maintained for an extensive period of time without any detectable dryout at the outer test-section wall.

At 1.4 kW, the code predicts very short (5 second) dryout intervals followed by rewetting of the test section walls associated with the re-establishment of the pre-dryout flow pattern (see Figure 3). As test section power is increased, the dryout intervals become more frequent and of longer duration, as shown in Figure 4 for Q = 1.7 kW.

The tendencies for the re-establishment of single-phase flow at low test section power and for dryout at a test section power of approximately 1.7 kW are both substantiated by SBT data. However, there is some disagreement between the predicted and experimentally determined temperature oscillations during dryout-rewet cycles. This is due in part to the fact that the experimentally measured wall temperature, at the outer surface of the thick wall (2.9 mm) test section, is not responsive to rapid changes of the sodium temperature. Also, as to be expected, there is some experimental error associated with the determination of the exact magnitude of the power input to the experimental test section. Both of these factors complicate direct comparisons with the SAS code predictions.

Conclusions

A preliminary assessment of these test results indicate that for channel powers less than 1.4 kW, stable, low-pressure sodium boiling occurs, and intermittent dryout is indicated at higher powers up to at least 1.7 kW. These results are in reasonable agreement with the SBT Facility test results.

REFERENCES

1. M. H. Fontana and J. L. Wantland, Breeder Reactor Safety and Core Systems Programs Progress Report for October-December 1977, ORNL/TM-6288.
2. M. H. Fontana and J. L. Wantland, Breeder Reactor Safety and Core Systems Programs Progress Report for April-June 1978, ORNL/TM-6558.
3. F. E. Dunn, The SAS LMFBR Accident Analysis Computer Code, Reactor Analysis and Safety Division, Argonne National Laboratory, ANL-8138, October 1974.

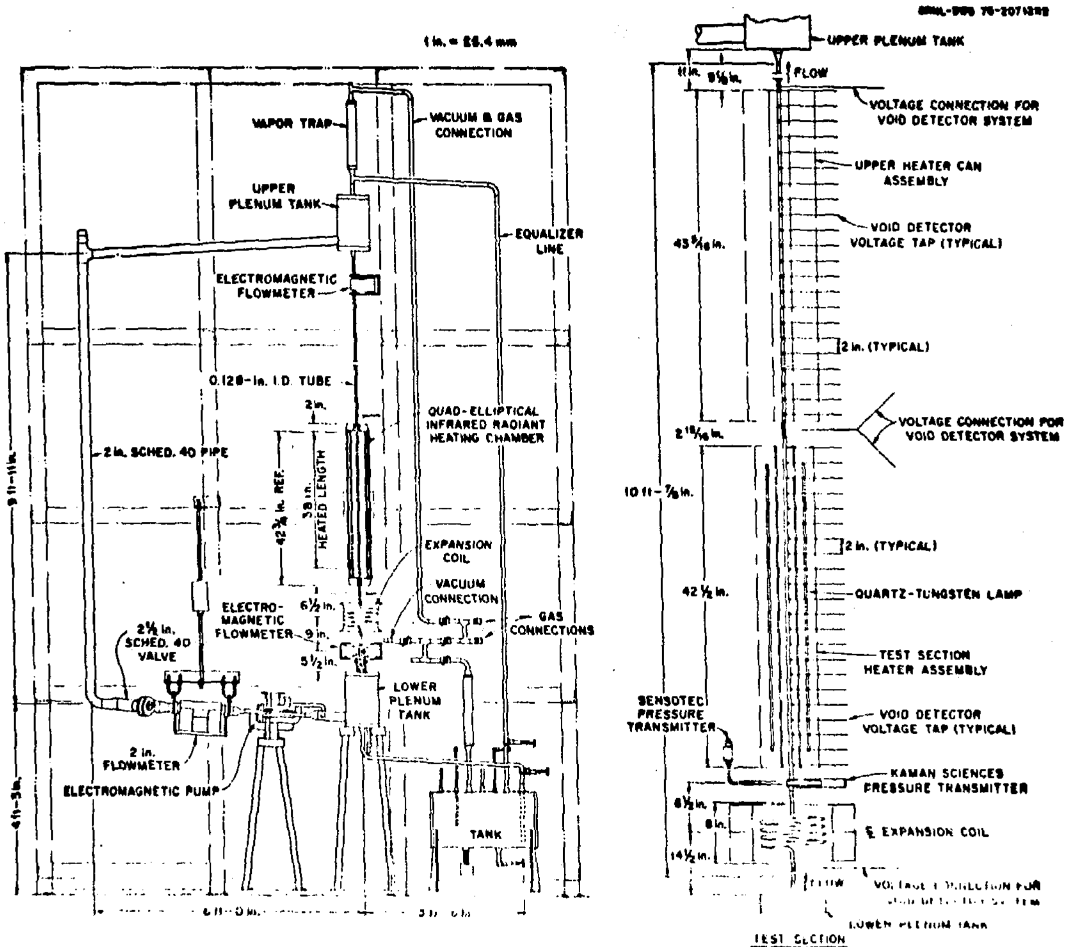
FIGURE CAPTIONS

Fig. 1. LMFBR Program - Sodium Boiling Test Facility

Fig. 2. SAS SBTF study, Q = 1.1 kW, no film motion [ORNL-DWG 79-4350]
a) Flow normalized to the test section inlet velocity vs time
b) Void interface location vs time
Axial distance from the test section inlet is specified in units of centimeters

Fig. 3. SAS SBTF study, Q = 1.4 kW, interface location vs time [ORNL-DWG 79-4351]
Double crosshatched areas indicate dryouts
Axial distance from the test section inlet is specified in units of centimeters

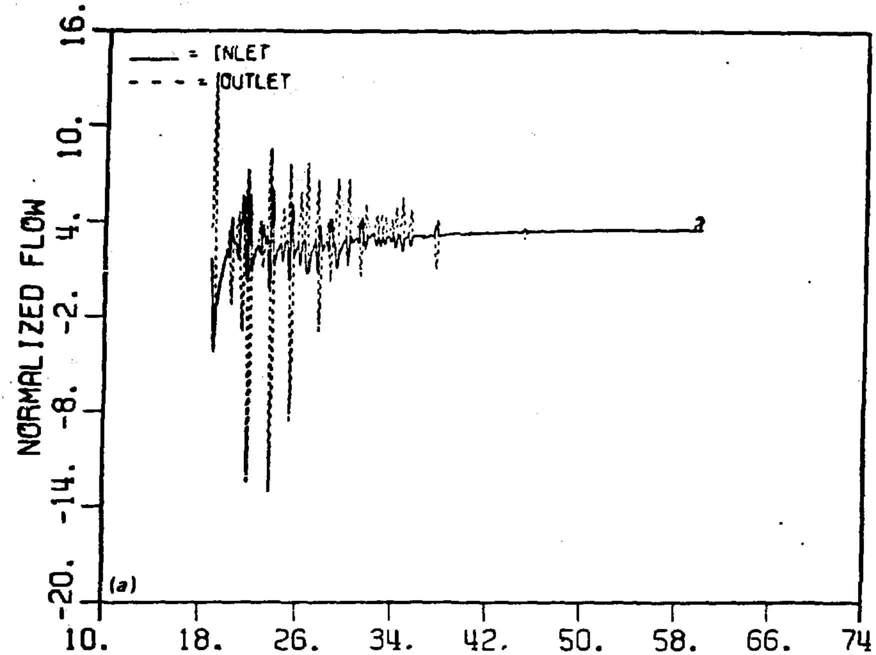
Fig. 4. SAS SBTF study, Q = 1.7 kW, interface location vs time [ORNL-DWG 79-4352]
Double crosshatched areas indicate dryouts
Axial distance from the test section inlet is specified in units of centimeters



LMFBR Program—Sodium Boiling Test Facility

Fig. 1

ORNL-DWG 79-4350 ETD



- Fig. 2a

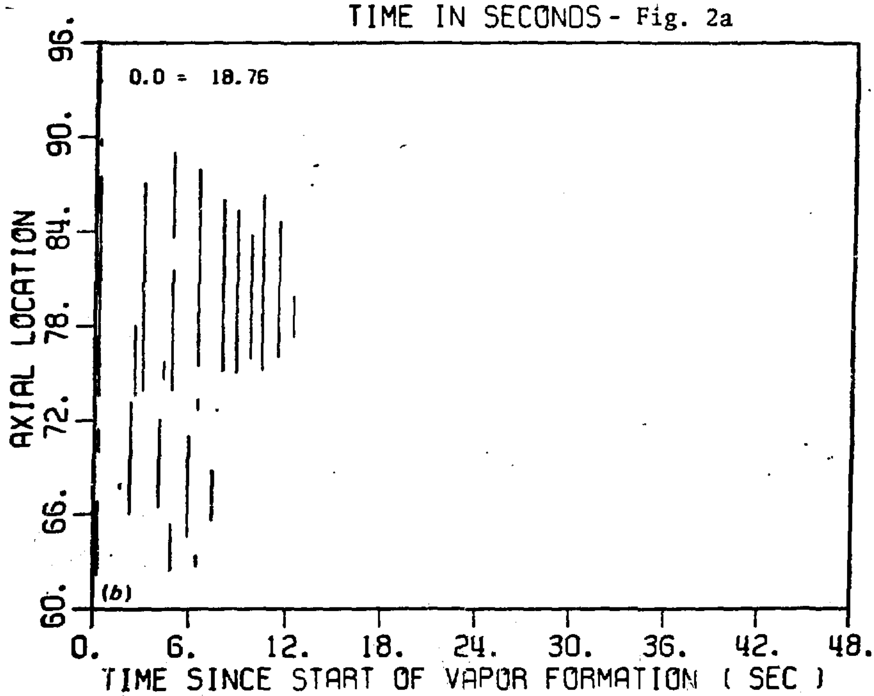


Fig. 2b

Fig. 2

ORNL-DWG 79-4351 ETD

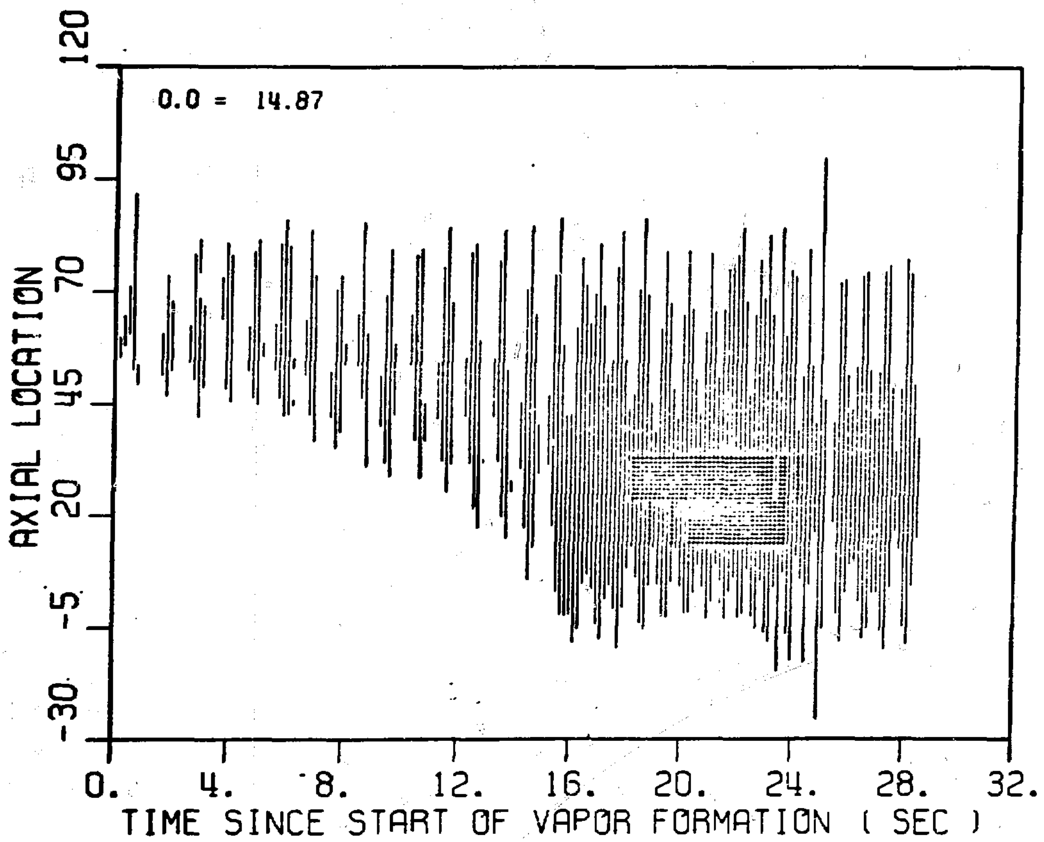


Fig. 3

ORNL–DWG 79–4352 ETD

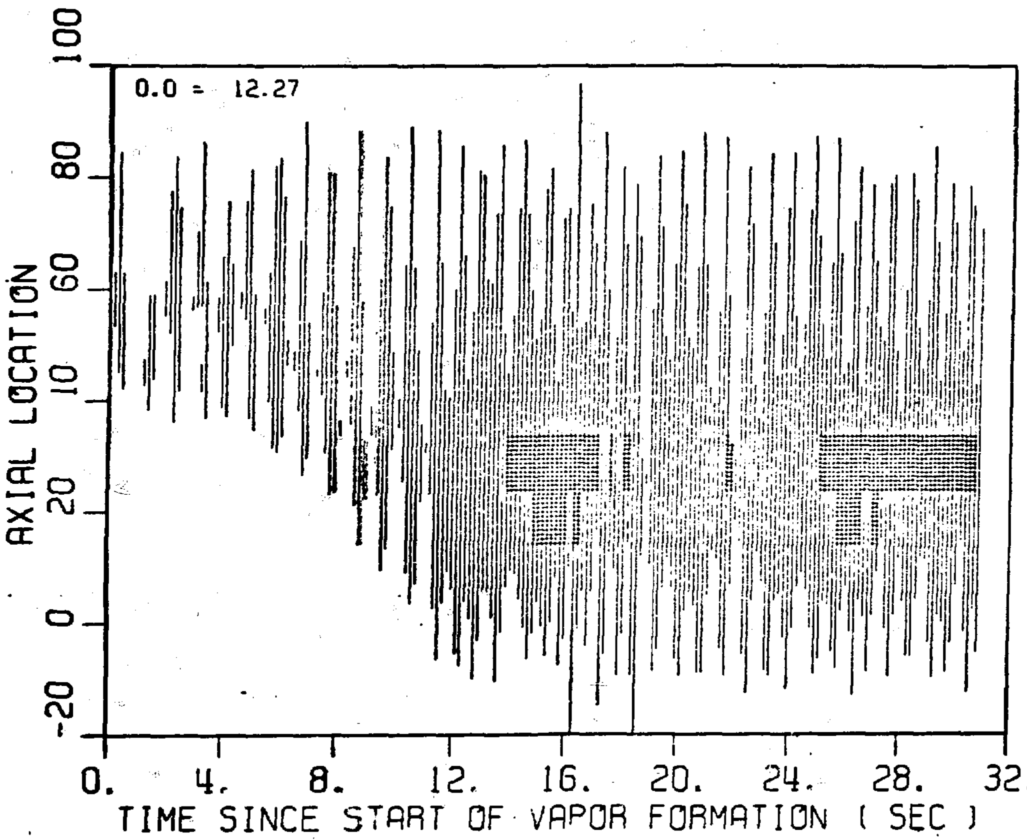


Fig. 4