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University of Cincinnati
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Quarterly Progress Report
Period Ending March 31, 1974

"Investigation of Pressure Drops
and Heat Transfer Coefficients
for Loss of Coolant Evaluation"

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Contract AT(11-1)2152
"Investigation of Pressure Drops
and Heat Transfer Coefficients
for Loss of Coolant Evaluation"

Quarterly Report for Period
Jan. 1 to Mar. 31, 1974

This contract has as its objective the study of pressure drop and heat transfer phenomena of importance during the loss of coolant accident. The study is divided into three experiments

- a) Transient Pressure Drop Investigation
- b) Two-Phase Pressure Drop and Flow Pattern Study
- c) Transition Boiling and Reflooding Heat Transfer Tests

1. Transient Pressure Drop Investigation

The transient pressure drop apparatus operates by discharging heated Freon 113 from a large storage accumulator to the test lines. The Freon flashes across a needle valve and proceeds to a 3-way valve. The valve directs a portion of the two-phase mixture to a storage accumulator and the remainder to the test section. By appropriately varying the position of the 3-way valve, a sinusoidally varying flow is obtained.

The data obtained were previously analyzed by considering the phase shift between the Δp and flow curves. These phase shifts were compared with predictions based upon one dimensional momentum theory coupled with the assumption of homogeneous flow. It was previously observed that the phase shift across the contraction was reasonably explained while a discrepancy existed between observed and predicted shifts for the combined

expansion-contraction. In this quarter, the impedance technique was used to predict the head fluctuation to flow fluctuation ratio. The observed ratio was consistently higher than the predicted ratio. The discrepancy was observed for both contraction and combined contraction-expansion data and was greatest at the highest voids. It is not yet clear whether this discrepancy is real or is the result of a programming or other error.

Reports have continued to provide a void fraction measurement which is not derived from the turbine flowmeter reading. A capacitance type voidmeter, of the design used in the steady state Freon loop, has been constructed and installed in the transient apparatus. Initial transient runs with this unit in operation are underway.

II. Two Phase Pressure Drop and Flow Pattern Study

Experimental: These experiments, which are being conducted in a recirculating loop using Freon 113, have measured pressure drop across abrupt area changes. Analyses of the data obtained have been based on the assumption that the quality of the Freon stream does not change significantly across the test section. To determine whether this assumption is correct, a second capacitance type voidmeter has been installed upstream of the test section. A series of runs were made in which void measurements were obtained both upstream and downstream of the test section.

The data obtained indicated that the amount of vaporization which occurred was far below that which would be predicted assuming thermodynamic equilibrium. Except at the highest mass velocity used, the amount of vaporization appears to be negligible. Corrections for the

additional acceleration pressure drop due to the observed vaporization will be made. These are not expected to significantly alter the previous conclusions.

Analysis of Relationship Between Pressure Drops in Straight Pipe and Across Area Changes

It has been previously reported⁽¹⁾ that the transition from homogeneous to non-homogeneous flow could be correlated by use of a modified Baker plot wherein G_g/λ was plotted against $G_L \lambda/G_g$. Further examination of the data show that it is equally well represented by plotting G_g/λ vs $G_t \lambda/G_g$ where G_t = total or mixture mass velocity (lbs/hr ft²). The flow pattern transition appears to occur when $G_t = 2 \times 10^6$.

This criterion has been compared with the extensive steam water data of Muscetolla⁽²⁾, the steam water data of Fitzsimmons⁽³⁾ and the air-water data of Petrick⁽⁴⁾. In all cases when $G_t > 2 \times 10^6$, the pressure drop data is well represented by the prediction obtained assuming the flow to be homogeneous.

One might expect that the pressure drop across abrupt expansions, where it was necessary to assume slip flow to obtain an adequate correlation, might show similar behavior. This is found to be the case. As the mass velocity (based on larger pipe) approaches 2×10^6 lbs/hr ft²,

the correlation coefficient for the homogeneous model steadily improves. The data of Fitzsimmons⁽³⁾, all obtained at $G > 2 \times 10^6$, are well represented by the homogeneous model. The proposed criterion for the transition to homogeneous flow would thus seem to provide an adequate basis for determination of where the homogeneous model may be used for two-phase pressure drop calculations.

Transition Boiling and Reflooding Heat Transfer Tests

These experiments are being conducted in a heat transfer loop which uses hot mercury as the heat source. Boiling of water takes place in an annulus around the vertical steel pipe containing the mercury. Visual observation of the process is possible since the outer pipe of the annulus is of glass.

During this quarter, the necessary loop repairs were completed and the loop returned to service. Extensive transition boiling data were obtained at two different mass flow rates. This data has been shown in Fig. 1 on wall heat flux, q'' , versus ΔT_{sat} (difference between wall temperature and saturation temperature of the water). The data has also been compared with the pool nucleate boiling data of Addoms⁽⁵⁾.

In spite of the wide scatter, the general data trend shows both the nucleate and transition boiling regimes. The nucleate boiling data is in the same region as Addoms' pool boiling data.

The scatter in the data may be due to the difference in quality between the various data points in addition to inherent errors in measurement. The cause of the scatter is being explored.

There is no obvious difference between the data at the two different flow rates except that the peak heat flux is slightly greater at the rate. The peak heat flux is about 20-30% of the peak pool boiling heat flux. This may be explained by the fact that the void fraction is 0.8-0.9. Recent work by Griffith⁽⁶⁾ with low velocity Freon boiling on vertical surfaces has shown that, at void fractions of 0.8-0.9, the critical heat flux in flow boiling is indeed 0.2-0.3 times that in pool boiling.

References

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- (2) Muscetolla, A., Report CISE-R-27.
- (3) Fitzsimmons, D.E., USAE Report HW-80970 Rev. 1 (1964).
- (4) Petrick, M. USAE Report ANL-5787.
- (5) Addoms, J.N., Sc.D. Thesis in Chemical Engineering, M.I.T. (1948).
- (6) Griffith, P., "Transient Critical Heat Flux," Reactor Safety Research Conference, Washington, D.C. (1973).

Fig. 1. U.C. BOILING DATA

Δ P: 0-10 psig ; G: 3.18×10^4

$\circ$ P: 0-10 psig ; G: 6.36×10^4

----- ADDOMS' POOL NUCLEATE BOILING DATA

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