University of Cincinnati
Department of Chemical and Nuclear Engineering

Quarterly Progress Report
Period Ending June 30, 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
April 1 to June 30, 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.

I. 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 then proceeds to a 2-way valve. There a portion of the two-phase mixture is directed to a storage accumulator and the remainder is directed through the test section. By appropriately varying the position of the 3-way valve, a sinusoidally varying flow is obtained.

During the previous quarter, a capacitance type voidmeter, of the design successfully used in the steady state Freon loop, was constructed and installed in the transient apparatus. Estimates of the void fraction were previously obtained from the output of the turbine flow meter. It was previously assumed that the flow was homogeneous and hence that the void fraction could be calculated from the volumetric flow rate and the

measured mass flow rate. This assumption appears to be in error. The void fractions indicated by the void meter are consistently higher than previously calculated. The discrepancies are greatest at high fractions.

There appears to be a consistent relationship between void fractions calculated from the turbine meter reading and those measured by the capacitance sensor. A calibration curve was therefore prepared and earlier data was reanalyzed in terms of the revised void determination.

Figure 1 compares the observed phase shift data for the contraction with the values calculated by the impedance method. The shaded area represents the error band introduced by uncertainty in the sonic velocity of the two phase mixture. Generally reasonable agreement is obtained. Figure 2 shows the same comparison for the measurements taken across the contraction and expansion in series. Here the agreement is somewhat less satisfactory.

Figs. 3 and 4 compare the calculated values of the ratios of head to flow fluctuation with measured values. Again the shaded area represents the error band due to uncertainty in sonic velocity. Use of the revised void fraction values materially improves the observed agreement. The large discrepancy between observation and calculation indicated in the last quarterly report is largely removed.

In Fig. 3 and 4, the circles indicate the points calculated using α obtained from the capacitance void meter but using the reading of the turbine meter directly to obtain flow fluctuation. To be consistent with the void measurements, the actual flow must be higher than that so indicated. The lower end of the error lines connected to the circle data points indicate the head to flow ratios obtained when this correction is made.

II. Two Phase Pressure Drop and Flow Pattern Study

Experimental. These experiments, which are being conducted in a circulating loop using Freon 113, have measured pressure drop across abrupt area changes. Previous pressure drop data were obtained using an 18 in. long section between the abrupt area changes. It is desirable to determine the effect of this length. The previous test section has therefore been replaced by a unit containing a 2 in. length between the abrupt area changes. Testing of this new section is beginning.

On completion of the current tests a 1 in. separation between area changes will be examined. This separation would be very much like many obstructions encountered in reactor systems. The applicability of the previously developed analysis to these test sections will be examined.

Analytical. A revised statistical analysis has been conducted for all available contraction and expansion pressure drop data under conditions where the area changes were substantially separated. The analysis included the high velocity data of Fitzsimmons⁽¹⁾ which had not been previously considered. The slip flow model described in the quarterly for the period ending Dec. 31, 1973 (COO-2152-10) provided the best overall fit of the data ($R^2 = 0.96$). The homogeneous model provided a very poor fit at low flows but the fit improved with increasing mass velocity. For $G \geq 2 \times 10^6$, the value of R^2 was .936.

The analysis of the contraction data confirmed the previous conclusion. Model F (see report COO-2152-10) provided the best overall fit although the homogeneous model was very nearly as good. For $G \geq 2 \times 10^6$, the homogeneous model was slightly superior ($R^2 = .98$) to model F ($R^2 = .95$). The results for contraction and expansion ΔP would appear to add further

confirmation to the conclusion that homogeneous flow prevails when $G \geq 2 \times 10^6$ lbs/hr ft².

Transition Boiling and Reflooding Heat Transfer Tests. These experiments are being conducted in a heat transfer loop using hot mercury as the heat source. Boiling of water occurs in an annulus around the vertical pipe containing mercury. Visual observation is possible since the outer pipe of the annulus is of glass.

In the previous quarter, transition boiling heat transfer data were obtained at two flow rates. Additional data at lower flow rates were obtained during this quarter. The latest data (see fig. 5) were obtained with heating tapes wound around a second glass pipe placed around the glass pipe carrying the water. In this way it is possible to carry the experiment out more nearly under adiabatic conditions.

The data obtained under the more nearly adiabatic conditions show the full boiling curve more clearly than the data previously obtained. These data are more like those expected and hence the runs at the higher flow rates are being repeated under the revised conditions.

In the previous quarterly report, it was observed that the low initial heat fluxes seen may have been due to the fact that at low flows, the critical heat flux decreases with an increase in void fraction. This was confirmed by Griffith⁽²⁾ in his experiments with Freon. It was also suggested by Tong⁽³⁾, that in the presence of a non-heated wall, the actual quality be related to the equilibrium quality by the relation:

$$x_{\text{actual}} = x_{\text{equil.}} (D_h/D_e)^{1/2}$$

where D_h = equivalent diameter based on heated perimeter and

D_e = equivalent diameter based on wetted perimeter.

Using the above relationship, $(q''_{cr}/q''_{cr,pool})$ was plotted against α' , the void fraction based on x_{actual} (Fig. 6). This shows reasonable agreement with the trend predicted by Griffith. It is suspected that the scatter in the data could be further minimized by including a correction for flow rate. This is now being investigated.

References

1. Fitzsimmons, D.E. "Two-Phase Pressure Drop in Piping Components," HW-80970 Rev. 1 (1964).
2. Griffith, P., "Transient Critical Heat Flux," Reactor Safety Conference, Washington, D.C. (1973).
3. Tong, L.S., and Young, J.D., "A Phenomenological Transition and Film Boiling Heat Transfer Correlations," to be presented at the International Heat Transfer Conference, Tokyo (1974).

FIGURE 1

FIGURE 2

FIG. 5 q_{WALL} VS. T_{WALL} WITH HEATED OUTSIDE WALL

FIG. 6. ($q''_{cv}/q''_{cv, pool}$) VS. x^* FOR VARIOUS DATA