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# FLOW DYNAMICS OF VOLUME-HEATED BOILING POOLS

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Safety analyses of fast breeder reactors require understanding of the two-phase fluid dynamic and heat transfer characteristics of volume-heated boiling pool systems. Design of direct contact three-phase boilers, of practical interest in the chemical industries, also requires understanding of the fundamental two-phase flow and heat transfer behavior of volume boiling systems. Several experiments have been recently reported relevant to the boundary heat-loss mechanisms of boiling pool systems. Considerably less is known about the two-phase fluid dynamic behavior of such systems. This paper describes an experimental investigation of the steady-state flow dynamics of volume-heated boiling pool systems.

The experimental system contains two copper electrodes which penetrate the entire length the container. The flow crosssection is 8.89 cm by 6.35 cm. The electrically conducting fluid used was a 14 weight solution of zinc sulfate in water. The system was filled to a specified liquid level ($H_0$), a-c power was applied, and feed water was supplied to makeup for evaporative losses. Within a few seconds from boiling initiation, photographic observations of the two-phase flow field were initiated. In addition, the power supplied and boiled-up liquid level were recorded. From

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these data, the pool-average void fraction, $\bar{\alpha}$, and the dimensionless superficial vapor velocity, $j_{g\infty}/U_\infty$, were computed, ($j_{g\infty}$ is the superficial vapor velocity at the top of the pool, and $U_\infty$ is the bubble rise velocity.)

Figure 1 presents visual observations of the two-phase flow fields. At low vapor velocity($j_{g\infty}/U_\infty$ generally less than 1) a bubbly flow regime (represented by Run 402) was observed. At velocities greater than $j_{g\infty}/U_\infty = 4$, a churn-turbulent regime was observed, whose turbulent, chugging characteristics became more intense as $j_{g\infty}/U_\infty$ was increased to approximately 19. This behavior is apparent in the photographs of Fig. 1. Figure 2 shows the measured pool-average void fraction as a function of $j_{g\infty}/U_\infty$, for two sets of runs. Also shown are predictions based upon solution of the steady-state one-dimensional drift flux formulation of the continuity equations for liquid and vapor. Figure 2 indicates that the Zuber-Findlay[1] churn-turbulent drift flux model with distribution parameter $C_0$ between 1.2-1.35 agrees reasonably well with the data for $j_{g\infty}/U_\infty$ beyond approximately 4. This supports the visual observations cited above. For smaller vapor velocities, the bubbly flow model provides a better description of the void-fraction behavior, also consistent with the visual observations. Figure 2, moreover, suggests that the bubbly flow regime was stable to relatively large void fractions, considerably larger than the 30 percent void content suggested in the literature.[3]

Figure 3 summarizes the flow regime observations recorded in the experiments and compares them with available predictions. The slug flow regime was not observed, probably because of the entry length required for establishment of this flow regime. The bubbly flow regime, observed to $j_{g\infty}/U_\infty = 1$, was stable considerably beyond the Wallis[2] transition criterion for bubbly flow. For $j_\infty/U_\infty$ between 1 and 4, the churn-turbulent regime was usually observed. Sometimes, however, a high void fraction foam regime was observed. It is believed that particulate contaminants were present under foaming conditions. Beyond $j_{g\infty}/U_\infty = 4$, a churn flow regime was always observed. The stability of this regime is consistent with the Dukler[3] dispersed flow transition criterion.

The characteristic features of volume-heated boiling pool systems observed in this experiment are:

(i) The churn-turbulent regime is dominant for $j_{g\infty}/U_\infty$ beyond 4. Under these circumstances, the pool-average void fraction is well-characterized by the Zuber-Findlay drift flux model.

(ii) At low vapor generation rates, corresponding to $j_{g\infty}/U_\infty < 4$, the bubbly flow regime was observed at void fractions and vapor velocities in excess of those suggested in the literature. This suggests that bubble coalescence was retarded, perhaps due to the characteristics of the zinc sulfate salt solution.

(iii) System contamination by particulate impurities may have stabilized the bubbles against coalescence, resulting in the sometimes-observed foam behavior.

The above observations point to the need for an improved understanding of the impact of system constituents and possible system impurities on the behavior of the bubbly flow regime in volume-heated boiling pools.

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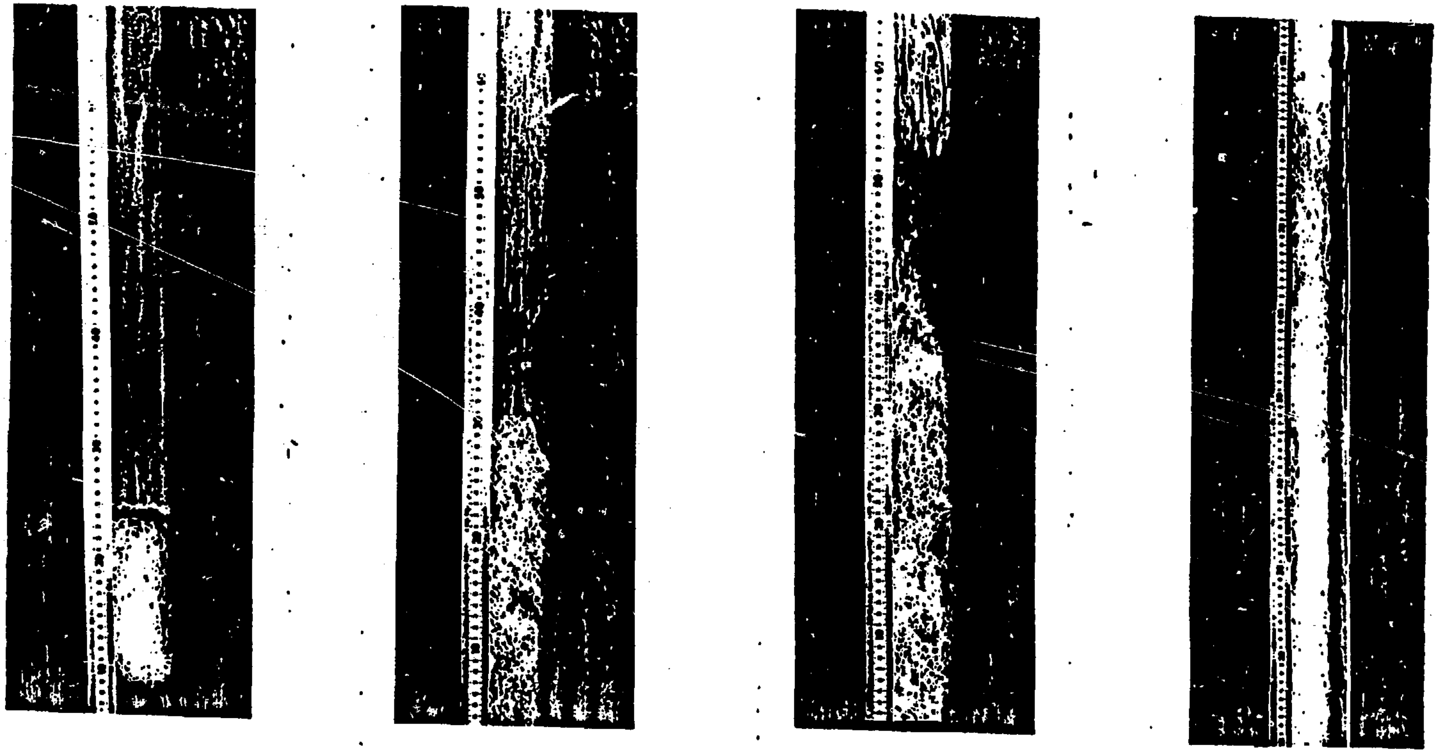

| Run No. | 402 | 413 | 424 | 523 |
|---|---|---|---|---|
| $j_{g\infty}/U_\infty$ | .67 | 4.63 | 8.95 | 19.1 |
| $\overline{\alpha}$ | .37-.40 | .52-.57 | .61-.65 | .68 |
| $H_0$(cm) | 15 | 15 | 15 | 30 |

Figure 1 - Photographic Observations of Boiling Pool Flow Behavior.

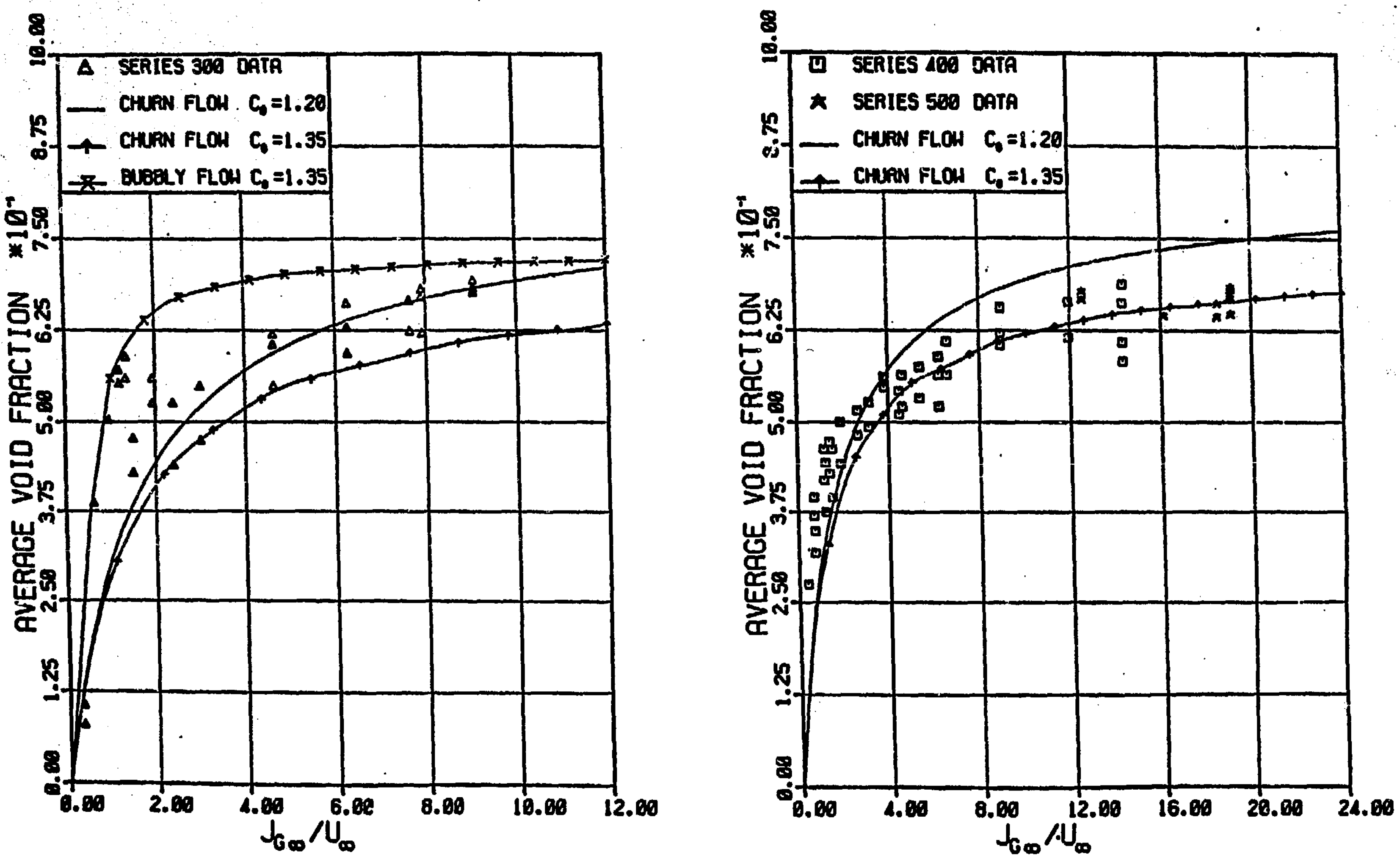


Figure 2 - Pool-Average Void Fraction Predicted and Observed

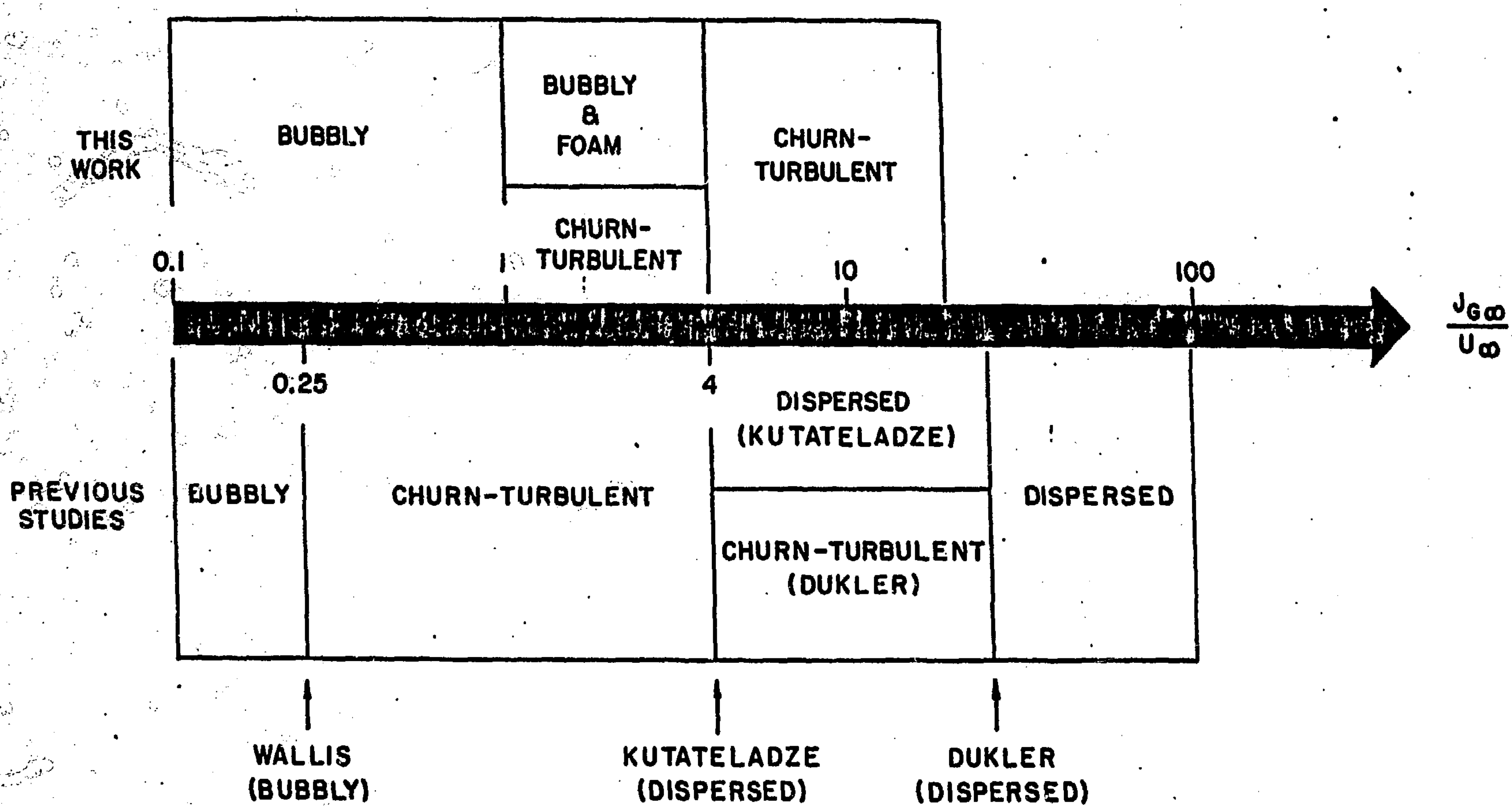


Figure 3 - Summary of Flow Regime Observations