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Project Title: INVESTIGATION OF POST-CHF HEAT TRANSFER FOR WATER-COOLED REACTOR APPLICATION AND DEVELOPMENT OF TWO-PHASE FLOW INSTRUMENTATION

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INVESTIGATION OF POST-CHF HEAT TRANSFER FOR WATER-COOLED REACTOR APPLICATION AND DEVELOPMENT OF TWO-PHASE FLOW INSTRUMENTATION

1. Post-CHF Experiments (*S. Nijhawan, R. Sundaram, J. Chen*)

Recent investigation of post-CHF heat transfer mechanisms have shown that thermodynamic nonequilibrium effects can play a major role in determining heat transfer rates. The nonequilibrium effect is defined as the superheating of vapor in a two-phase mixture implying that the actual quality of the mixture is lower than the equilibrium quality.

In this investigation, vapor temperatures have been measured under well-established post-CHF conditions over a range of system parameters. A differentially aspirated microthermocouple probe was used to measure the nonequilibrium vapor temperature in a 1.41 cm diameter tubular test section. The test section was operated at post-CHF conditions at low pressure (150-450 kPa), low flow rates (18-70 Kg/m^2-2) and a wide range of equilibrium quality (10%-75%). Over 200 data points have been collected and of these about 60 percent are at a constant distance from the dryout point while the remaining 40 percent have varying post-CHF lengths. Recent efforts have concentrated on analysis of these data to delineate the observed effects of various system parameters on the nonequilibrium vapor temperature. In most cases, the magnitude of vapor superheat was a significant fraction (up to 80%) of the wall superheat.

In general, the vapor superheat increases with increase in wall heat flux and decreases with increasing flow rate. A vapor nonequilibrium ratio is defined as the ratio of observed vapor superheat to the maximum possible superheat for no further evaporation after dryout. Figure 1 shows this ratio to be inversely proportional to vapor flow rate and directly proportional to the equilibrium quality at dryout.

The effect of axial distance on vapor temperature is shown in Figure 2. The vapor superheat is seen to increase with increasing distance from dryout for constant flow rate, heat flux and equilibrium quality. Also shown in the figure is the actual quality of the two-phase mixture, calculated using the measured vapor temperature. It can be seen that there can be significant deviation from equilibrium under these conditions.

2. Correlation Development (*R. Sundaram, S. Nijhawan, J. Chen*)

Development of improved correlations for post-CHF heat transfer is being continued on two fronts. First, low flow data provided by the Babcock & Wilcox Company are being used to modify the phenomenological correlation for vapor heat transfer. In particular, the effect of heat sinks due to the presence of dispersed liquid droplets is found to be significant at low flow rates. Substantial enhancement of the wall heat transfer (increase in the vapor heat transfer coefficient by a factor of 1:6) is found. Semi-empirical corrections for this effect is being developed.

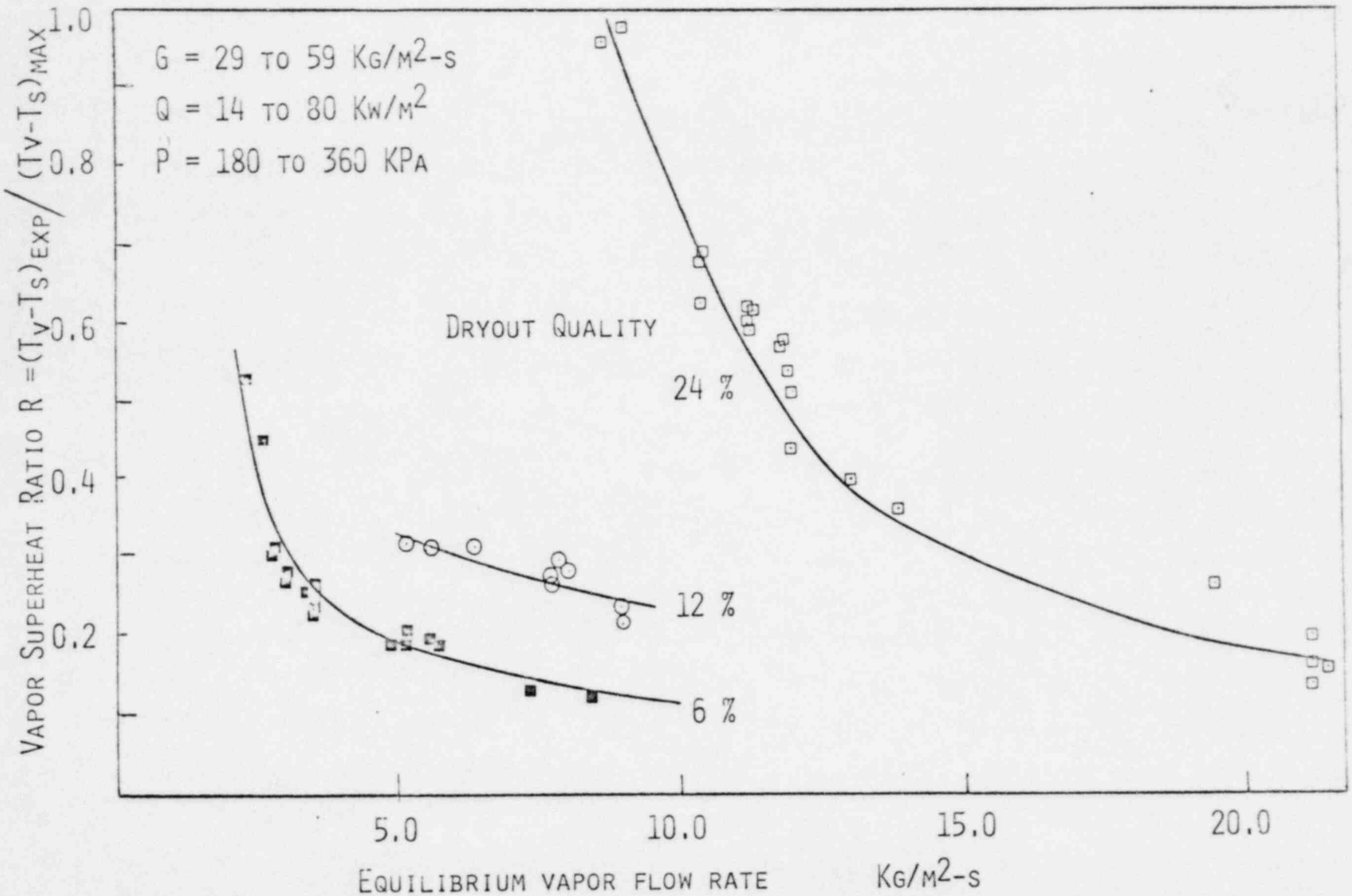
In a second related effort, similar analysis is being pursued using the post-CHF data developed here at Lehigh for low pressure and low flow rates (results of Item 1) described above. The same trend indicating enhanced wall heat transfer was observed. This consistent parametric behavior, seen in the results from two completely different experiments, is a strong argument for the effectivenss of heat sink enhancement in post-CHF heat transfer.

3. Instrumentation Development (*S. Lau, L. Lee, R. Sundaram, J. Chen*)

In this report period, the film instrumentation modules constructed by ORNL were mounted in our air-water counter flow apparatus. Measurements of film thickness with this new probe have been completed, including necessary calibrations. Initial measurement of film flow rates with the associated EP probes are in progress.

4. Analysis of Flow-Film Heat Transfer (*S. Webb, J. Chen*)

Work continues in the development of an analytical model to predict post-CHF dispersed flow heat transfer. The thermal transport model has now been amplified with an associated momentum transport model to account for addition of vapor due to evaporation of distributed liquid droplets. Results of this theoretical model are being compared to the experimentally measured nonequilibrium vapor heat transfer described in Item 1 above.



VAPOR SUPERHEAT RATIO R =(TV-TS)EXP/(TV-TS)MAX
G = 29 TO 59 KG/M2-S
Q = 14 TO 80 KW/M2
P = 180 TO 360 KPA
DRYOUT QUALITY
24 %
12 %
6 %
1.0
0.8
0.6
0.4
0.2
5.0
10.0
15.0
20.0
EQUILIBRIUM VAPOR FLOW RATE
KG/M2-S

Fig 1

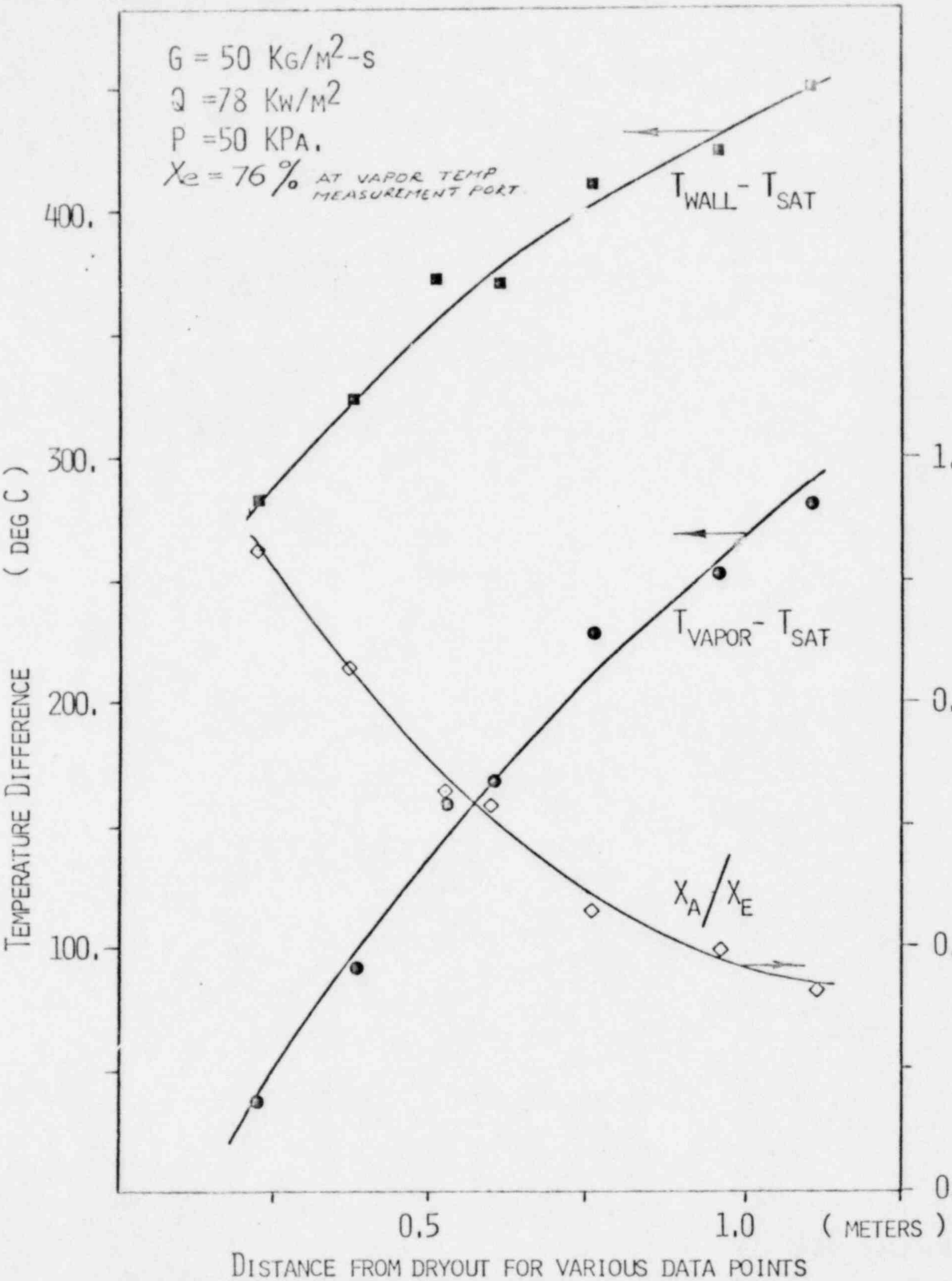

G = 50 Kg/m2-s
Q =78 Kw/m2
P =50 KPa.
Xe = 76 % at vapor temp measurement port
TWALL - TSAT
TVAPOR - TSAT
XA/XE
400.
300.
200.
100.
1.0
0.9
0.8
0.7
Temperature Difference (deg C)
0.5
1.0
(meters)
Distance from dryout for various data points

Fig 2