HEAT TRANSFER MEASUREMENT OF ANNULAR TWO-PHASE FLOW IN A HORIZONTAL AND A SLIGHTLY UPWARD INCLINED TUBE

By

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For my parents Bill and Sharon, whose sacrifice, love, and pride have kept me going through and through.

To my parents, who are the standards by which I measure myself.

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NOMENCLATURE

English Letter Symbols

A	cross sectional area, ft^2 or m^2
A	annular
ABS	annular/bubbly slug
atm	atmosphere or atmospheric
AW	annular wavy
AWG	American Wire Gauge
BS	bubbly slug
BTU	British thermal unit
C	Celsius
C_p, C_{pl}, c	specific heat at constant pressure, $Btu/(lb_m \cdot {}^\circ F)$ or $J/kg \cdot K$
C_f, c_f	coefficient of friction
D, d	inside diameter of a circular tube, ft or m
f	f-stop setting for camera shutter speed
F	Fahrenheit
F	modified Froude number
ft	foot or feet
g	acceleration due to gravity, ft/s^2 or m/s^2
gpm	gallons per minute
$Heat_{in}$	power input through by the test section

$Heat_{taken}$	power taken by the test fluid, Btu/hr or W
h	heat transfer coefficient, Btu/(s·ft^2·°F) or W/(m^2·K)
hi	local peripheral heat transfer coefficient, Btu/(s·ft^2·°F) or W/(m^2·K)
hr	hour
Hz	Hertz or cycles (s^{-1})
i	enthalpy
I	electrical current, Amps, A
I.D.	inner diameter
in	inches
K	wavy flow, dimensionless parameter
K	velocity ratio ($=U_G/U_L$) Dimensionless parameter
k	thermal conductivity, Btu/(hr·ft·°F) or W/(m·K)
kg	kilograms
L	liter
L, l	length of test section, ft or m
Lb, lb	pounds
m	mass flow rate, lb_m/s or kg/s
m	meters
Nu	Nusselt number (=hD/k), dimensionless
Nth	number of finite-difference sections in the theta-direction (peripheral) which is equal to the number of thermocouples at each station
P	pressure

Pr	Prandtl number
psi	pounds per square inch (lb/in^2), unit of pressure
PT	pressure tap
Q,q	rate of heat transfer, Btu/hr or W
Q	generated heat, Btu/hr or W
Q	volumetric flow rate, ft^3/min, or m^3/min
q"	heat flux, $Btu/(hr \cdot ft^2)$ or W/m^2
R	resistance ($=\gamma l/A$), Ω
R	Rankine
Re	Reynolds number ($=DG/\mu$), dimensionless
r_i	tube inside radius, ft or m
Δr	incremental radius, ft or m
RMS	root mean square
SCFM	standard cubic feet per minute, (ft^3/min)
SL	slug
St	stratified
St.	station
T	dispersed bubble flow dimensionless parameter
T	temperature, °F or °C
TC	thermocouple
TMP	temporary
V	velocity, ft/s or m/s
U	uncertainty interval, dimensionless

V	voltage drop through the test section, Volts,V
W	watt or watts
W	wavy
WS	wavy/slug
X	distance from the pipe inlet to the thermocouple station, ft or m
X	Martinelli parameter, dimensionless:
x	local distance along the test section from the inlet, ft or m
x	flow quality ($=m_g/m_t$), dimensionless
x^+	axial distance inside a tube ($=(x/r_o)/(RePr)$), dimensionless
Y	dimensionless inclination parameter
y	local weigh fraction vapor, dimensionless
δz	length of element, ft or m

Greek Letter Symbols

α	angle between the pipe axis and the horizontal, positive for downward flow, rad
γ	electric resistivity of the element, $\mu\Omega\cdot$in or $\Omega\cdot$m
Δ	change in...
Θ	radial dimension of pipe, rads
ρ	density, lb_m/ft^3
μ	viscosity, lb_m/ft-hr

Subscripts and Superscripts

a	denotes air
b,bulk	bulk or mixed-mean fluid condition
cal	evaluated based on calculation or correlation
D	evaluated based on diameter
exp	evaluated based on experimental data
FR	denotes flow rate
f	denotes fluid
G,g	denotes gas
i	evaluated based on the inside wall
i	index of the finite-difference grid points radial direction starting from the outside surface of the tube
in	evaluated on inlet condition
j	index of the finite-difference grid points radial peripheral direction starting from top of the tube and increasing clockwise
L,l	denotes liquid
m	mean
out	evaluated at the outlet condition
o	evaluated based on the outside wall
SG	denotes superficial gas
SL	denotes superficial liquid
TP	two-phase
w,wall	denotes condition at inside wall of tube

w	denotes water
x	evaluated at a particular point along the surface

CHAPTER I

INTRODUCTION

This chapter discusses the subject, history, scope, objectives, and limitations of the research done for this thesis. Contained in this chapter is a brief discussion of what two-phase flows are and where they are experienced in industry; the history of the two-phase flow research associated with this laboratory; the scope, objectives, and limitations that are associated with the development of this thesis and research.

1.1 Background

Two-phase flow is a characteristic term used to define a gas-liquid, gas-solid, or a liquid-solid flow, occurring simultaneously in a pipe, channel, or other conduit. Such a flow can be created using two separate fluids or species, or by a single fluid or species that has undergone a physical change of state, from solid to liquid or from liquid to a gas. This type of flow can be observed in long pipelines containing petroleum, oil, and natural gas products; or in well bores, refrigeration processes, and the boiling effect in nuclear reactors.

This study focuses on the application and measurement of heat transfer on a two-phase, air-water flow experiencing an annular pattern at the horizontal and at slightly upward inclined angles. Annular flow is a unique flow pattern because of its flow characteristics and because it is the least studied of all the two-phase flow patterns.

Annular flow is characterized by high gas flow rates and moderate to low liquid flow rates. This creates a liquid annulus with a gas core traveling at a high velocity and a liquid sheath traveling along the outside of the gas core. This is the same type of pattern that can be observed in pipes that experience phase changes such as those in condensers and evaporators. This being the case it is important for designers of such applications to better understand the types of heat transfer rates that will be observed in their designs. The aim of this thesis is to provide a substantial amount of information to aid in such applications.

The test apparatus used was built and tested during the Ph.D. work of Dongwoo Kim (2000), and the Masters work of Jae-yong Kim (1999), Venkata Ryali (1999), and Steve Trimble (2001). This thesis is a continuation of the work that was started during their graduate studies.

Various authors have investigated the behavior and characteristics of two-phase flows over the past 50 years. However, an insufficient amount of data exists in the open literature for annular two-phase heat transfer properties at the horizontal or at an inclined angle. Some data for horizontal, air-water, annular flow, heat transfer exists in the open literature, such as Pletcher (1966), but the bulk of the data found is slug flow oriented. Other data is mainly concerned with vertically oriented applications of two-phase flow, focuses on flow patterns different from that of annular, and uses fluids other than air and water. Kim *et al.* (1999) conducted a comprehensive literature search to find data and correlations for two-phase heat transfer. This topic is discussed in more detail in Chapter II.

1.2 Objective of Study

The objectives of this study are to gather quality annular data at the horizontal and inclined positions of 5° and 7°, and compare it against other flow pattern behaviors and results. In order to fulfill these goals, eight objectives have been set forth. These objectives are:

1) Modification of existing test apparatus
2) Calibration of new thermocouples and thermal probes
3) Installation of new data acquisition devices
4) Testing and comparison of single-phase flow with known correlations for test setup validity
5) Flow pattern mapping
6) Testing and comparison of slug flow data with existing slug flow data and known correlation for test setup validity
7) Heat transfer measurements and analysis for annular two-phase flow at the horizontal and inclined positions of 5° and 7°
8) Development of a correlation specific to two-phase, air-water, annular flow

1.3 Scope and Limitations

The results reported in this thesis are:

1) Comprehensive literature search
2) Description of test setup and modifications made to create a state-of-the-art test facility

3) Single phase heat transfer data for validation of test setup

4) Slug flow heat transfer data for validation of test setup for multi-phase flows

5) Annular heat transfer data for horizontal, 5°, and 7° tests

6) Analysis of the heat transfer data for horizontal, 5°, and 7° tests

7) Heat transfer correlation development for annular flow

8) Conclusions and recommendations for further development

This study was initiated by relocating the old test setup to a new and more research-oriented facility. While moving the setup, modifications were approved to further the scope and abilities of the research. Newer, more sophisticated and accurate devices, which are discussed in Chapter III, were incorporated into the apparatus. With these additions, a broader scope of two-phase flow patterns and measurements could be made.

CHAPTER II

LITERATURE SURVEY

The primary objective of this thesis is to gather accurate data concerning heat transfer properties in horizontal, air-water, annular flow in a pipe. From this data, a better understanding of heat transfer characteristics for this particular flow pattern, should be made. In addition to horizontal data, the influence of pipe inclination on heat transfer properties in annular flow will be investigated.

To support these sets of data, literature describing the physical properties of two-phase flow was investigated. Such an investigation started with the understanding of what fluid velocities, or flow rates, annular flow patterns develop and stabilize. Such a method would require the use of a flow regime map. The difficulty with the determination of what flow pattern map to gauge the basis of this research on, is that very few consistent profiles exist. Many authors have published data for different types of fluid flows and tube sizes, yet there is little agreement as to the classifications of the flow patterns. Thus, the exploration of many different cases will allow for the creation of a general plan for the development of a good set of annular flow rates to test.

Heat Transfer studies for two-phase flows are dominated by the presence of vertically oriented tests. Very little quantitative data exists in the open literature to compare with, thus making horizontal heat transfer in pipes difficult at best to experiment with. Few authors have studied horizontal two-phase flow and fewer still have experimented with air-water mixtures. These facts alone make this experiment a significant contribution to the understanding of two-phase flow heat transfer.

2.1 Flow Regime Mapping

The first step in determining what type of flow pattern is present in the test setup is to compare it with open literature focused on the mapping of different flow regimes in two-phase flow. Many authors have tackled this subject, one of the first dating back to Baker (1954). Others include Hoogendoorn (1959), Taitel and Dukler (1976), Barnea and Yacoub (1983), and Ewing *et al.* (1999) to name a few. Each of these authors focuses on different tube diameters and different fluids to flow through the setup. This greatly affects the type of map produced.

Hoogendoorn (1959) presented a paper that focused on the gathering of information on two-phase air-water and air-oil mixtures in horizontal smooth pipes with diameters ranging from 24 mm to 140 mm, and rough pipes with inner diameters of 50 mm. Hoogendoorn (1959) used flow rates of approximately 0.02 to 320 m^3/hr for the liquid side, which was produced using four centrifugal pumps and a pressure vessel. Air was used from a 6.5 atm supply producing a maximum flow rate of 1800 kg/hr. This setup was the largest to be found in the literature search. With these specifications and mechanical power, the scope of Hoogendoorn (1959) was far greater than this paper.

Taitel and Dukler (1976) presented their data in a model that represented five basic flow regimes. These regimes were stratified, intermittent, dispersed bubble, wavy, and annular flow. Five dimensionless groups were discussed and each of the respective patterns was formulated into a dimensionless quantity, X, T, Y, F, and K. In order of appearance, the variables are the Martinelli parameter (X), dispersed bubble flow parameter (T), inclination parameter (Y), modified Froude number (F), and the wavy flow parameter (K). Each of these dimensionless quantities could be determined from the operating conditions. These five equations could then be solved to produce a flow regime map for any type of operating condition at any inclination.

Barnea and Yacoub (1983) later performed more tests on smaller diameter pipes, less than 12.3 mm. Again, these tests proved that the formulations created by Taitel and Dukler (1976), were accurate and predict numerous flow patterns for a multitude of flow setups.

Kim and Ghajar (2002) developed a seven-pattern description for two-phase flow that consisted of stratified, wavy, wavy/slug, slug, wavy/annular, annular/bubbly and or annular/bubbly/slug, and bubbly/slug. This pattern can be seen in Figure 2.1. Kim and Ghajar (2002) presented research that was performed on the same test apparatus used for the current experiment. Since this subject is a continuation of their work, much of the information contained in this section is based on their findings. Kim and Ghajar (2002) also created a table containing data on minimum and maximum flow rates for specific types of flow patterns. This data can be seen in Table 2.1.

The flow pattern map created by Kim and Ghajar (2002), used 150 data points, 20 Stratified, 50 Slug, 20 Wavy, 30 Bubbly/Slug or Annular/Bubbly/Slug, and 30 Annular/Wavy. Photographs of each flow pattern were taken, Figure 2.2, to visually represent the type of flow pattern that was under observation. This would allow for a general consensus of the flow pattern. Kim and Ghajar (2002) researched many of the flow pattern maps that were available and concluded that the Taitel and Dukler (1976) map was the standard by which many investigators based their findings. Once the data had been collected, comparisons against the findings and procedures of Taitel and Dukler (1976) were made and the result is Figure 2.1.

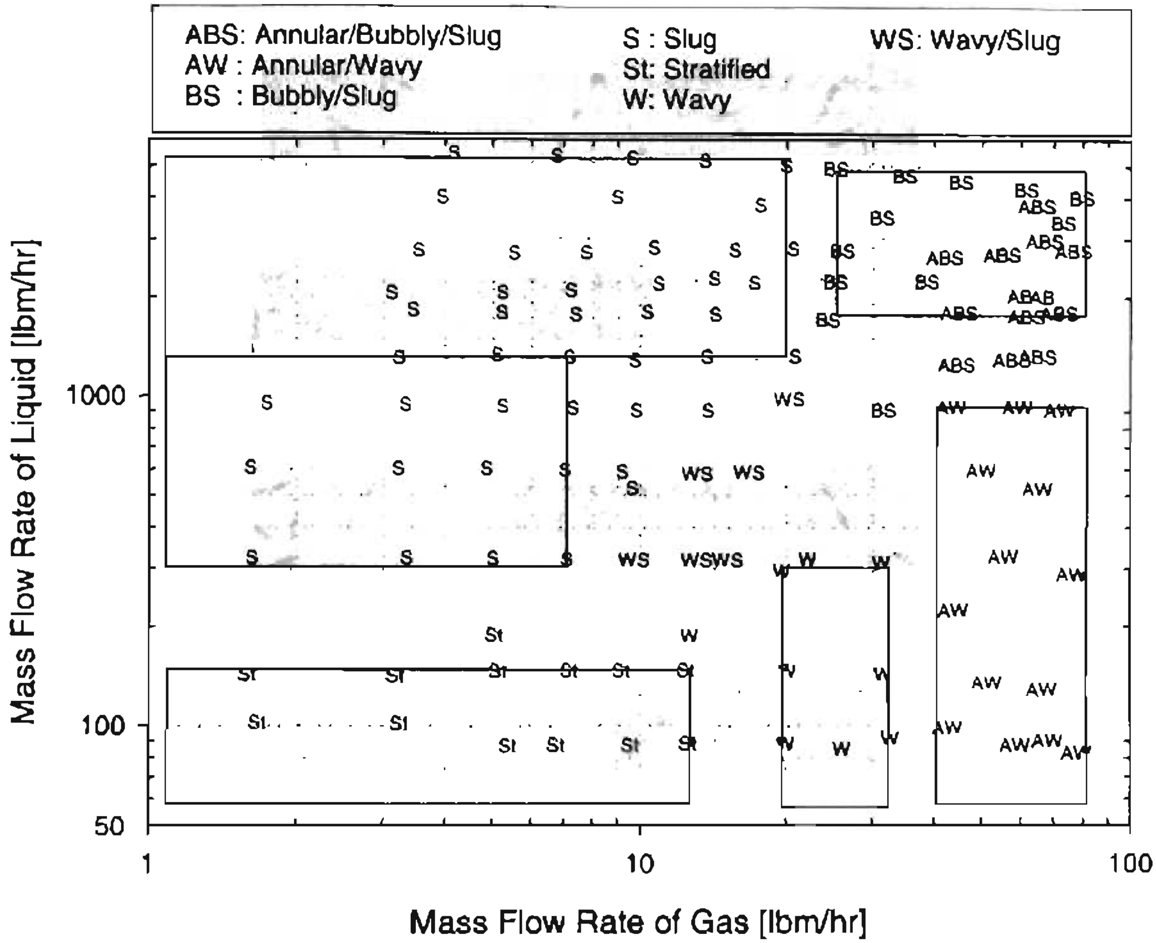


Figure 2.1 Observed Flow Pattern Data versus the Corresponding Mass Flow Rates of Air and Water, Kim and Ghajar (2002)

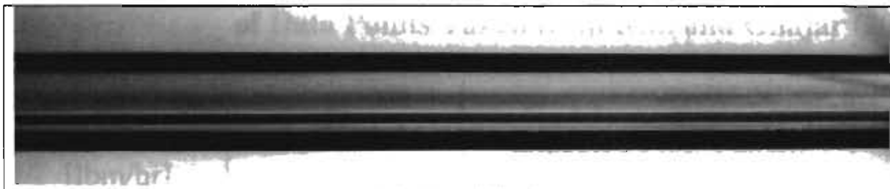
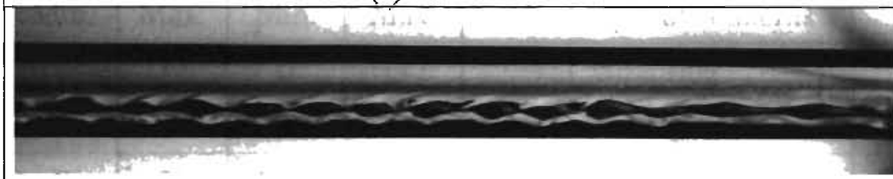
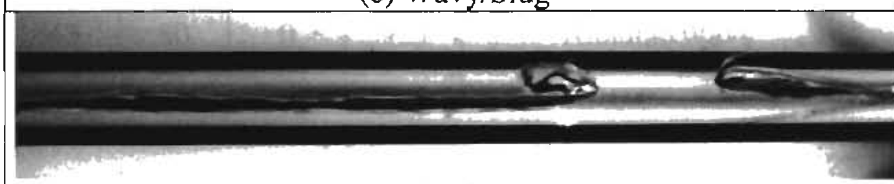
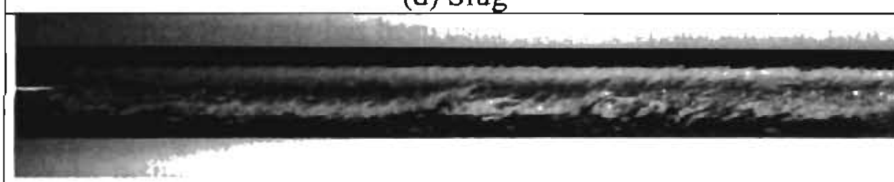
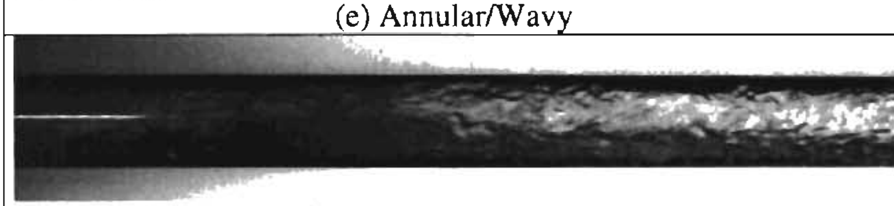
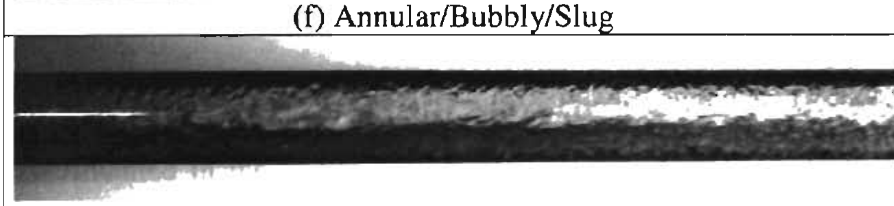
 (a) Stratified	$\dot{m}_L$ = 139.4 [lbm/hr] $\dot{m}_G$ = 2.7 [lbm/hr] f = 8 @ 1/2000 [sec]
 (b) Wavy	$\dot{m}_L$ = 185.7 [lbm/hr] $\dot{m}_G$ = 18.8 [lbm/hr] f = 8 @ 1/2000 [sec]
 (c) Wavy/Slug	$\dot{m}_L$ = 600.4 [lbm/hr] $\dot{m}_G$ = 16.5 [lbm/hr] f = 8 @ 1/2000 [sec]
 (d) Slug	$\dot{m}_L$ = 1069.2 [lbm/hr] $\dot{m}_G$ = 2.8 [lbm/hr] f = 8 @ 1/2000 [sec]
 (e) Annular/Wavy	$\dot{m}_L$ = 412.9 [lbm/hr] $\dot{m}_G$ = 68.1 [lbm/hr] f = 8 @ 1/2000 [sec]
 (f) Annular/Bubbly/Slug	$\dot{m}_L$ = 2311.9 [lbm/hr] $\dot{m}_G$ = 74.0 [lbm/hr] f = 8 @ 1/2000 [sec]
 (g) Bubbly/Slug	$\dot{m}_L$ = 4021.3 [lbm/hr] $\dot{m}_G$ = 74.0 [lbm/hr] f = 8 @ 1/2000 [sec]

Figure 2.2 Photographs of Flow Patterns Measured by Kim and Ghajar (2002)

Table 2.1 Air-Water Mass Flow Rate Values for Various Flow Patterns and Number of Data Points Taken from Kim and Ghajar (2002)

$\dot{m}_G$ [lbm/hr]		$\dot{m}_L$ [lbm/hr]		Expected Flow Pattern	Prospective Number of Data Points
Min.	Max.	Min.	Max.	All of the Flow Patterns	150
0	12	0	147	Stratified	-
0	7	300	1300	Slug	25
0	20	1300	5460	Slug	30
20	32	0	310	Wavy	20
10	30	300	800	Wavy/Slug	-
24	80	1080	4890	Bubbly/Slug or Annular/Bubbly/Slug	35
43	80	0	925	Annular/Wavy	40

2.2 Two-Phase Heat Transfer in a Pipe

Once a flow rate has been established to create annular flow, the next phase of the research would be to investigate the open literature for heat transfer in a horizontal or slightly inclined tube. Few authors have tackled inclined heat transfer research, thus limiting the amount of available data for comparison. Kim *et al* (1999) compiled a comprehensive list of published data containing the authors who had researched heat transfer in a two-phase flow regime either for a vertical or for a horizontal apparatus, and the corresponding heat transfer correlations. Of the twenty papers studied, six experimented in the horizontal orientation and of those, only three focused on an air-water mixture. Of those three, two papers focused on an annular flow pattern. These papers were written by Martin and Sims (1971) and Shah (1981). Martin and Sims (1971) does not immediately apply to this study because the test setup used was a square duct, not a round pipe as is studied in this research. Shah (1981) focused on bubbly, slug, frothy, frothy-annular, and misty flow patterns, but not a pure annular flow. This fact alone makes this thesis project a valuable resource in developing a solid two-phase heat transfer data base for an annular flow pattern and filling the void created by the lack of research on this topic.

One paper was found that is similar to the current study and immediately focuses on the heat transfer qualities of annular flow. That paper is the work of Pletcher (1966). Pletcher (1966) measured 48 data points in a 1 in. pipe experiencing an annular flow, using an electric heating method similar to the one used in this project. Pletcher (1966) did not develop a correlation for annular flow, but those 48 points become an important tool in the comparison of the data measured in this research. If the comparison of the data is consistent with that of Pletcher (1966), at similar flow rates and Reynolds numbers, then the two data sets could be combined to further the database of raw annular flow. This database could then be used to create a set of empirical constants for use with the correlation of Kim and Ghajar (2002). Since these 48 points are the only raw data points in the open literature for annular flow, the work of Pletcher (1966) will be used as a guide throughout the duration of this experiment.

Another paper that was found for heat transfer in a pipe experiencing annular flow, was that of Pletcher and McManus (1968). This paper was the result of the experimentation of Pletcher (1966). This paper briefly explains the apparatus used in the experiments, thermocouple orientations, flow rates, pressure drops, and heat transfer results. This paper does not delve as deeply into the experimentation process as the doctoral work of Pletcher (1966) does, and therefore was not focused on as strictly.

Hetsroni *et al.* (1998a & b) published two papers that discussed the heat transfer relationships for two-phase flow experiencing intermittent air-water flow. The intermittent air-water flow was limited mainly to bubbly flow and slug flow. One of these papers was developed under horizontal conditions, Hetsroni *et al.* (1998a) and the other was developed for the upward inclined tube, Hetsroni *et al.* (1998b). The results of Hetsroni *et al.* (1998b) state that under slightly inclined conditions the heat transfer rate is drastically enhanced. Hetsroni *et al.* (1998a & b) worked with large diameter pipes, typically 5 cm, and used a non-uniform and transient heat flux to the pipe wall. They did not list any details on the experimentation parameters other than the superficial liquid and gas velocities, Froude number, and inclination angle. This being the case, the information taken from Hetsroni *et al.* (1998b) should be that the heat transfer rate should be drastically enhanced as we incline the pipe.

Trimble (2001) performed research based on the claims made by Hetsroni *et al.* (1998b) that inclined slug flow enhanced heat transfer properties. Data was taken at the horizontal, 2°, and 5° positions. The results were in agreement with Hetsroni et al (1998b) and did show an enhancement in the heat transfer properties as the tube was subjected to 2° and 5° inclinations. The data collected during the experimentation was compared against the data of Kim and Ghajar (2002) first, to prove the validity of the experimentation at the horizontal. The results of Trimble (2001) can be found in the following literatures, Kim *et al.* (2001), and Trimble *et al.* (2002).

Kim *et al.* (1999) compared all of the correlations with data that was found in the open literature for each of the different types of flows and mixtures. For the horizontal case of annular flow, only the correlations set forth by Shah (1981), predicted the experimental data well.

Shah (1981) gathered 672 data points from 18 experimental studies and created correlations for the span of flow rates and orientations. Extensive literature searches were performed by Shah (1981) and the table presented by him is similar to that presented by Kim and Ghajar (2002). From this data we find that in the past twenty years, little new data has been presented for predicting two-phase heat transfer in tubes. Shah (1981), Kim *et al.* (1999), and Kim and Ghajar (2002) compile all the known literatures for two-phase heat transfer correlations. After more extensive searching, no new data presented itself.

Listed in Table 2.2 are the correlations gathered by Kim *et al.* (1999), and Table 2.3 lists the limitations and conditions for each of these correlations. Using seven sets of experimental data to assess the validity of the correlations, see Table 2.4 for a list of experimental data parameters, a comparison was made of each correlation and how well the correlation predicted experimental values for two-phase, two-component flows. Once the calculations for each correlation were completed, recommendations as to which correlation worked best for specific fluids, flow patterns, and orientations were made. These recommendations can be found in Table 2.5 for vertical and horizontal pipes.

Kim and Ghajar (2002) developed a correlation for horizontal pipes, based on the doctoral work of Kim (2000). This correlation can be found in Table 2.6. This correlation was designed to encompass a wide range of flow patterns, including wavy-annular and slug flows, by changing the given parameters and exponential values according to flow pattern. This correlation is not designed, however, for pure annular flow. The experimental data from this experiment will be used in conjunction with the Kim and Ghajar (2002) correlation to assure validity of the data, and will also be used to calculate new empirical constants specific to air-water, annular flow.

Table 2.2 Correlations for Two-Phase Heat Transfer, Kim *et al.* (1999)

Source	Heat Transfer Correlations	Source	Heat Transfer Correlations
Aggour (1978)	$h_{TP}/h_L = (1-\alpha)^{-1/3}$ Laminar (L) $Nu_L = 1.615\,(Re_{SL}\,Pr_L\,D/L)^{1/3}(\mu_B/\mu_W)^{0.14}$ (L) $h_{TP}/h_L = (1-\alpha)^{-0.83}$ Turbulent (T) $Nu_L = 0.0155 \cdot Re_{SL}^{0.83}\,Pr_L^{0.5}\,(\mu_B/\mu_W)^{0.33}$ (T)	Knott et al. (1959)	$\dfrac{h_{TP}}{h_L} = \left(1 + \dfrac{V_{SG}}{V_{SL}}\right)^{1/3}$ where h_L is from Sieder & Tate [1936]
Chu & Jones (1980)	$Nu_{TP} = 0.43\,(Re_{TP})^{0.55}(Pr_L)^{1/3}\left(\dfrac{\mu_B}{\mu_W}\right)^{0.14}\left(\dfrac{Pa}{P}\right)^{0.17}$	Kudirka et al. (1965)	$Nu_{TP} = 125\left(\dfrac{V_{SG}}{V_{SL}}\right)^{1/8}\left(\dfrac{\mu_G}{\mu_L}\right)^{0.6}(Re_{SL})^{1/4}(Pr_L)^{1/3}\left(\dfrac{\mu_B}{\mu_W}\right)^{0.1}$
Davis & David (1964)	$Nu_{TP} = 0.060\left(\dfrac{\rho_L}{\rho_G}\right)^{0.28}\left(\dfrac{DG_t x}{\mu_L}\right)^{0.87} Pr_L^{0.4}$	Martin & Sims (1971)	$\dfrac{h_{TP}}{h_L} = 1 + 0.64\sqrt{\dfrac{V_{SG}}{V_{SL}}}$ where h_L is from Sieder & Tate [1936]
Dorresteijn (1970)	$h_{TP}/h_L = (1-\alpha)^{-1/3}$ (L) $h_{TP}/h_L = (1-\alpha)^{-0.8}$ (T) $Nu_L = 0.0123\,Re_{SL}^{0.9}\,Pr_L^{0.33}(\mu_B/\mu_W)^{0.14}$	Oliver & Wright (1964)	$Nu_{TP} = Nu_L\left(\dfrac{1.2}{R_L^{0.36}} - \dfrac{0.2}{R_L}\right)$ $Nu_L = 1.615\left[\dfrac{(Q_G + Q_L)\rho D}{A\mu}Pr_L\,D/L\right]^{1/3}(\mu_B/\mu_W)^{0.14}$
Dusseau (1968)	$Nu_{TP} = 0.029\,(Re_{TP})^{0.87}(Pr_L)^{0.4}$	Ravipudi & Godbold (1978)	$Nu_{TP} = 0.56\left(\dfrac{V_{SG}}{V_{SL}}\right)^{0.3}\left(\dfrac{\mu_G}{\mu_L}\right)^{0.2}(Re_{SL})^{0.6}(Pr_L)^{1/3}\left(\dfrac{\mu_B}{\mu_W}\right)^{0.14}$
Elamvaluthi & Srinivas (1984)	$Nu_{TP} = 0.5\left(\dfrac{\mu_G}{\mu_L}\right)^{1/4}(Re_{TP})^{0.7}(Pr_L)^{1/3}\left(\dfrac{\mu_B}{\mu_W}\right)^{0.14}$	Rezkallah & Sims (1987)	$h_{TP}/h_L = (1-\alpha)^{-0.9}$ where h_L is from Sieder & Tate [1936]
Groothuis & Hendall (1959)	$Nu_{TP} = 0.029\,(Re_{TP})^{0.87}(Pr_L)^{1/3}(\mu_B/\mu_W)^{0.14}$ (for water-air)	Serizawa et al. (1975)	$\dfrac{h_{TP}}{h_L} = 1 + 462\,X_{TT}^{-1.27}$ where h_L is from Sieder & Tate [1936]

Table 2.2 Correlations for Two-Phase Heat Transfer, Kim *et al.* (1999) cont.

Source	Heat Transfer Correlations	Source	Heat Transfer Correlations
Groothuis & Hendall (1959)	$Nu_{TP} = 2.6\,(Re_{TP})^{0.39}(Pr_L)^{1/3}(\mu_B/\mu_W)^{0.14}$ (for (gas-oil)-air)		
Hughmark (1965)	$Nu_{TP} = 1.75\,(R_L)^{-1/2}\left(\frac{\dot{m}_L c_L}{R_L k_L L}\right)^{1/3}\left(\frac{\mu_B}{\mu_W}\right)^{0.14}$	Shah (1981)	$\frac{h_{TP}}{h_L} = \left(1+\frac{V_{SG}}{V_{SL}}\right)^{1/4}$ $Nu_L = 1.86\,(Re_{SL}\,Pr_L\,D/L)^{1/3}(\mu_B/\mu_W)^{0.14}$ (L) $Nu_L = 0.023\,Re_{SL}^{0.8}Pr_L^{0.4}(\mu_B/\mu_W)^{0.14}$ (T)
Khoze et al. (1976)	$Nu_{TP} = 0.26\,Re_{SG}^{0.2}\,Re_{SL}^{0.55}\,Pr_L^{0.4}$	Ueda & Hanaoka (1967)	$Nu_{TP} = 0.075(Re_M)^{0.6}\frac{Pr_L}{1+0.035(Pr_L-1)}$
King (1952)	$\frac{h_{TP}}{h_L} = \frac{R_L^{-0.52}}{1+0.025\,Re_{SG}^{0.5}}\left[\left(\frac{\Delta P}{\Delta L}\right)_{TP} / \left(\frac{\Delta P}{\Delta L}\right)_L\right]^{0.32}$ $Nu_L = 0.023\,Re_{SL}^{0.8}Pr_L^{0.4}$	Vijay et al. (1982)	$h_{TP}/h_L = (\Delta P_{TPF}/\Delta P_L)^{0.451}$ $Nu_L = 1.615\,(Re_{SL}Pr_L\,D/L)^{1/3}(\mu_B/\mu_W)^{0.14}$ (L) $Nu_L = 0.0155\,Re_{SL}^{0.83}Pr_L^{0.5}(\mu_B/\mu_W)^{0.33}$ (T)
		Sieder & Tate (1936)	$Nu_L = 1.86\,(Re_{SL}\,Pr_L\,D/L)^{1/3}(\mu_B/\mu_W)^{0.14}$ (L) $Nu_L = 0.027\,Re_{SL}^{0.8}Pr_L^{0.33}(\mu_B/\mu_W)^{0.14}$ (T)

Note: α and R_L are taken from the original experimental data for this study. $Re_{SL} < 2000$ implies laminar flow, otherwise turbulent; and for Shah (1981)], replace 2000 by 170. With regard to the eqs. given for Shah (1981)] above, the laminar two-phase correlation was used along with the appropriate single phase correlation, since Shah (1981) recommended a graphical turbulent two-phase correlation.

Table 2.3 Limitations of the Heat Transfer Correlations Found by Kim *et al.* (1999)

Source	Fluid	L/D	m_g/m_l	V_{SG}/V_{SL}	Re_{SG}	Re_{SL}	Flow Pattern	Orient	Comments
Aggour (1978)	A-W, Helium-W, Freon12-W	52.1	7.5×10^{-5} - 5.72×10^{-2}	0.02-470	13.95 - 2.09×10^{5}		B, S, A, G-S, G-F, S-A, A-M	V	
Chu & Jones (1980)	W-A	34		0.12 - 4.64	540 - 2700	16000 - 112000	B, S, F-A	V	
Davis & David (1964)	Gas-Liquid						A, M-A	H & V	
Dorresteijn (1970)	A-Oil	16		0.004 - 4500		300-66000	B, S, A	V	
Dusseau (1968)	A-W	67	45 -350		0-4.29×10^{4}	1.4×10^{4} - 4.9×10^{4}	F	V	
Elamvaluthi & Srinivas (1984)	A-Water, A-Glycerin	86		0.3-2.5 0.6-4.6		300-14300	B, S	V	
Groothius & Hendal (1959)	A-W, Gas-Oil-A	14.3	244-977 269-513	1-250 0.6-80		>5000 1400-3500		V	
Hughmark (1965)	Gas-Liquid						S	H	Correlation for Slug Flow Only
Khoze et al. (1976)	A-W, A-Poly methylsiloxane, A-Diphenyloxide	60-80			4000-37000	3.5-210	A	V	
King (1952)	A-W	252		1.21-6.94	1570- 8.28×10^{4}	22500- 11.9×10^{4}	S	H	Correlation for Slug Flow Only

Table 2.3 Limitations of the Heat Transfer Correlations Found by Kim *et al.* (1999) *cont.*

Source	Fluid	L/D	m_g/m_l	V_{SG}/V_{SL}	Re_{SG}	Re_{SL}	Flow Pattern	Orient	Comments
Knott et al. (1959)	Petroleum oil-Nitrogen Gas	118.6	1.57×10^{-3}-1.9	0.1-40	6.7-162	126-3920	B	V	
Kudirka et al. (1965)	A-W, A-Ethylene Glycol	17.6	1.92×10^{-4}-0.1427 0-0.11	0.16-75 0.25-67		5.5×10^{4}-49.5×10^{4} 380-1700	B, S, F	V	
Martin & Sims (1971)	A-W	17		0.08-276			B, S, A	H	Tests Performed on Rectangular Channel
Oliver & Wright (1964)	A-85% Glycol, A-1.5% SCMC, A-0.5% Polyox					500-1800	S	H	
Ravipudi & Godbold (1978)	A-W, A-Toluene, A-Benzene, A-Methanol			1-90	3562-82532	8554-89626	F	V	
Rezkallah & Sims (1987)	A,W,Oil,etc; 13 Liquid-Gas Combinations	52.1		0.01-7030		1.8-1.3×10^{5}	B, S, C, A, F, B-S, B-F, S-C, S-A, C-A, F-A	V	
Serizawa et al. (1975)	A-W	35					B	V	
Shah (1981)	A, W, Oil, Nitrogen, Glycol, etc.; 10 Combinations			0.004-4500		7-253000	B, S, F, F-A, M	H & V	Wide Range of Parameters, Applicable to This Test Setup
Ueda & Hanaoka (1967)	A-Liquid	67	9.4×10^{-4}-0.059	4-50			S, A	V	
Vijay et al. (1982)	A-W, A-Glycerin, Helium-W, Freon12-W	52.1		0.005-7670		1.8-130000	B, S, F, A, M, B-F, S-A, F-A, A-M	V	

Table 2.4 Ranges of Experimental Data Used by Kim *et al.* (1999)

Water-Air Vertical Data (139 Points) of Vijay [1978]	$16.71 < \dot{m}_L$ (lbm/hr) ≤ 8996 $0.058 \leq \dot{m}_G$ (lbm/hr) ≤ 216.82 $0.007 \leq X_{TT} \leq 433.04$ $0.061 \leq \Delta P_{TP}$ (psi) ≤ 17.048 $5.503 \leq Pr_L \leq 6.982$ $101.5 \leq h_{TP}$ (Btu/hr-ft^2-°F) ≤ 7042.3	$0.06 \leq V_{SL}$(ft/sec) ≤ 34.80 $0.164 \leq V_{SG}$(ft/sec) ≤ 460.202 $59.64 \leq T_{MIX}$ (°F) ≤ 83.94 $0.007 \leq \Delta P_{TPF}$ (psi) ≤ 16.74 $0.708 \leq Pr_G \leq 0.710$ $0.813 \leq \mu_W/\mu_B \leq 0.933$	$231.83 \leq Re_{SL} \leq 126630$ $43.42 \leq Re_{SG} \leq 163020$ $14.62 \leq P_{MIX}$ (psi) ≤ 74.44 $0.033 \leq \alpha \leq 0.997$ $11.03 \leq Nu_{TP} \leq 776.12$ $L/D = 52.1$, $D = 0.46$ in.
Glycerin-Air Vertical Data (57 Points) of Vijay [1978]	$100.5 \leq \dot{m}_L$ (lbm/hr) ≤ 1242.5 $0.085 \leq \dot{m}_G$ (lbm/hr) ≤ 99.302 $0.15 \leq X_{TT} \leq 407.905$ $1.317 \leq \Delta P_{TP}$ (psi) ≤ 20.022 $6307.04 \leq Pr_L \leq 6962.605$ $54.84 \leq h_{TP}$ (Btu/hr-ft^2-°F) ≤ 159.91	$0.31 \leq V_{SL}$(ft/sec) ≤ 3.80 $0.217 \leq V_{SG}$(ft/sec) ≤ 117.303 $80.40 \leq T_{MIX}$ (°F) ≤ 82.59 $1.07 \leq \Delta P_{TPF}$ (psi) ≤ 19.771 $0.708 \leq Pr_G \leq 0.709$ $0.513 \leq \mu_W/\mu_B \leq 0.610$	$1.77 \leq Re_{SL} \leq 21.16$ $63.22 \leq Re_{SG} \leq 73698$ $17.08 \leq P_{MIX}$ (psi) ≤ 62.47 $0.0521 \leq \alpha \leq 0.9648$ $12.78 \leq Nu_{TP} \leq 37.26$ $L/D = 52.1$, $D = 0.46$ in.
Silicone-Air Vertical Data (162 points) of Rezkallah [1987]	$17.3 \leq \dot{m}_L$ (lbm/hr) ≤ 196 $0.07 \leq \dot{m}_G$ (lbm/hr) ≤ 157.26 $72.46 \leq T_W$ (°F) ≤ 113.90 $0.037 \leq \Delta P_{TP}$ (psi) ≤ 9.767 $61.0 \leq Pr_L \leq 76.5$ $29.9 \leq h_{TP}$ (Btu/hr-ft^2-°F) ≤ 683.0	$0.072 \leq V_{SL}$(ft/sec) ≤ 30.20 $0.17 \leq V_{SG}$(ft/sec) ≤ 363.63 $66.09 \leq T_B$ (°F) ≤ 89.0 $0.094 \leq \Delta P_{TPF}$ (psi) ≤ 9.074 $0.079 \leq Pr_G < 0.710$	$47.0 \leq Re_{SL} \leq 20930$ $52.1 \leq Re_{SG} \leq 118160$ $13.9 \leq P_{MIX}$ (psi) ≤ 45.3 $0.011 \leq \alpha \leq 0.996$ $17.3 \leq Nu_{TP} \leq 386.8$ $L/D = 52.1$, $D = 0.46$ in.
Water-Helium Vertical Data (53 Points) of Aggour [1978]	$267 \leq \dot{m}_L$ (lbm/hr) ≤ 8996 $0.020 \leq \dot{m}_G$ (lbm/hr) ≤ 33.7 $0.16 \leq X_{TT} \leq 769.6$ $0.3 \leq \Delta P_{TP}$ (psi) ≤ 13.2 $5.78 \leq Pr_L \leq 7.04$ $794 \leq h_{TP}$ (Btu/hr-ft^2-°F) ≤ 6061	$1.03 \leq V_{SL}$(ft/sec) ≤ 34.70 $0.423 \leq V_{SG}$(ft/sec) ≤ 483.6 $67.4 \leq T_{MIX}$ (°F) ≤ 82.0 $0.01 \leq \Delta P_{TPF}$ (psi) ≤ 12.5 $0.6908 \leq Pr_G \leq 0.691$ $83.9 \leq T_W$ (°F) ≤ 95.7	$3841 \leq Re_{SL} \leq 125840$ $14.0 \leq Re_{SG} \leq 23159$ $15.5 \leq P_{MIX}$ (psi) ≤ 53.3 $0.038 \leq \alpha \leq 0.958$ $86.6 \leq Nu_{TP} \leq 668.2$ $L/D = 52.1$, $D = 0.46$ in
Water-Freon 12 Vertical Data (44 Points) of Aggour [1978]	$267 \leq \dot{m}_L$ (lbm/hr) ≤ 3598 $0.84 \leq \dot{m}_G$ (lbm/hr) ≤ 206.59 $0.16 \leq X_{TT} \leq 226.5$ $0.04 \leq \Delta P_{TP}$ (psi) ≤ 4.92 $5.63 \leq Pr_L \leq 6.29$ $800 \leq h_{TP}$ (Btu/hr-ft^2-°F) ≤ 4344	$1.03 \leq V_{SL}$(ft/sec) ≤ 13.89 $0.51 \leq V_{SG}$(ft/sec) ≤ 117.7 $75.26 \leq T_{MIX}$ (°F) ≤ 83.89 $0.02 \leq \Delta P_{TPF}$ (psi) ≤ 4.48 $0.769 \leq Pr_G \leq 0.77$ $90.36 \leq T_W$ (°F) ≤ 94.89	$4190 \leq Re_{SL} \leq 51556$ $859.5 \leq Re_{SG} \leq 209430$ $15.8 \leq P_{MIX}$ (psi) ≤ 27.8 $0.035 \leq \alpha \leq 0.934$ $87.1 \leq Nu_{TP} \leq 472.4$ $L/D = 52.1$, $D = 0.46$ in
Water-Air Horizontal Data (48 points) of Pletcher [1966]	$0.069 \leq \dot{m}_L$ (lbm/sec) ≤ 0.3876 $0.22 \leq \Delta P_M/L$ (lbf/ft^3) ≤ 26.35 $7.23 \leq \phi_l \leq 68.0$ $7372 \leq q''$ (Btu/hr-ft^2) ≤ 11077	$0.03 \leq \dot{m}_G$ (lbm/sec) ≤ 0.2568 $0.021 \leq X_{TT} \leq 0.490$ $73.6 \leq T_W$ (°F) ≤ 107.1 $433 \leq h_{TP}$ (Btu/hr-ft^2-°F) ≤ 1043.8	$7.84 \leq \Delta P/L$ (lbf/ft^3) ≤ 137.5 $1.45 \leq \phi_g \leq 3.54$ $64.9 \leq T_{MIX}$ (°F) ≤ 99.4 $L/D = 60.0$, $D = 1.0$ in.
Water-Air Horizontal Data (21 points) of King [1952]	$1375 \leq \dot{m}_L$ (lbm/hr) ≤ 6410 $1570 \leq Re_{SG} \leq 84200$ $136.8 \leq T_{MIX}$ (°F) < 144.85 $1.027 \leq \Delta P_{TP}$ (psi) ≤ 22.403 $1.35 \leq h_{TP} / h_L \leq 3.34$	$0.82 \leq \dot{m}_G$ (SCFM) ≤ 43.7 $0.41 \leq X_{TT} \leq 29.10$ $184.3 \leq T_W$ (°F) ≤ 211.3 $1462 \leq h_{TP}$ (Btu/hr-ft^2-°F) ≤ 4415 $1.35 \leq \phi_l \leq 8.20$	$22500 \leq Re_{SL} \leq 119000$ $0.117 \leq R_L \leq 0.746$ $15.8 \leq P_{MIX}$ (psi) ≤ 55.0 $0.33 \leq V_{SG}/V_{SL} \leq 7.65$ $L/D = 252$, $D = 0.737$ in.

Table 2.5 Recommended Correlations for Two-Phase Heat Transfer, Kim *et al.* (1999)

Source	Correlation	Vertical Experimental Pipe													Horizontal	
		Water-Air Vijay (1978)				Glycerin-Air Vijay (1978)				Silicone-Air Rezkallah (1987)					W-A King (1952)	
		B	S	F	A	B	S	F	A	B	S	C	A	F	A	S
Aggour (1978)	$h_{TP}/h_L = (1-\alpha)^{-1/3}$ Laminar (L) $Nu_L = 1.615\,(Re_{SL} Pr_L\, D/L)^{1/3} (\mu_B/\mu_W)^{0.14}$ (L) $h_{TP}/h_L = (1-\alpha)^{-0.83}$ Turbulent (T) $Nu_L = 0.0155\, Re_{SL}^{0.83} Pr_L^{0.5} (\mu_B/\mu_W)^{0.33}$ (T)	√	√			√	√	√	√							
Chu & Jones (1980)	$Nu_{TP} = 0.43\,(Re_{TP})^{0.55} (Pr_L)^{1/3} \left(\frac{\mu_B}{\mu_W}\right)^{0.14} \left(\frac{Pa}{P}\right)^{0.17}$				√											√
King (1952)	$\frac{h_{TP}}{h_L} = \frac{R_L^{-0.52}}{1+0.025\,Re_{SG}^{0.5}} \left[\left(\frac{\Delta P}{\Delta L}\right)_{TP} / \left(\frac{\Delta P}{\Delta L}\right)_L\right]^{0.32}$ $Nu_L = 0.023\, Re_{SL}^{0.8} Pr_L^{0.4}$	insufficient experimental information provided				insufficient experimental information provided				insufficient experimental information provided						√
Knott et al. (1959)	$\frac{h_{TP}}{h_L} = \left(1+\frac{V_{SG}}{V_{SL}}\right)^{1/3}$ where h_L is from Sider & Tate(1936)	√		√										√		
Kudirka et al. (1965)	$Nu_{TP} = 125 \left(\frac{V_{SG}}{V_{SL}}\right)^{1/8} \left(\frac{\mu_G}{\mu_L}\right)^{0.6} (Re_{SL})^{1/4} (Pr_L)^{1/3} \left(\frac{\mu_B}{\mu_W}\right)^{0.14}$															√
Martin & Sims (1971)	$\frac{h_{TP}}{h_L} = 1 + 0.64\sqrt{\frac{V_{SG}}{V_{SL}}}$ where h_L is from Sider & Tate(1936)	√														√
Ravipudi & Godbold (1978)	$Nu_{TP} = 0.56 \left(\frac{V_{SG}}{V_{SL}}\right)^{0.3} \left(\frac{\mu_G}{\mu_L}\right)^{0.2} (Re_{SL})^{0.6} (Pr_L)^{1/3} \left(\frac{\mu_B}{\mu_W}\right)^{0.14}$				√							√	√			√
Rezkallah & Sims (1987))	$h_{TP}/h_L = (1-\alpha)^{-0.9}$ where h_L is from Sider & Tate (1936)	√								√	√	√				
Shah (1981)	$\frac{h_{TP}}{h_L} = \left(1+\frac{V_{SG}}{V_{SL}}\right)^{1/4}$ $Nu_L = 1.86\,(Re_{SL}\, Pr_L\, D/L)^{1/3} (\mu_B/\mu_W)^{0.14}$ (L) $Nu_L = 0.023\, Re_{SL}^{0.8} Pr_L^{0.4} (\mu_B/\mu_W)^{0.14}$ (T)	√		√		√				√				√	√	

√ = Recommended Correlation based on the predictions of the experimental data within ±30% deviations.

Table 2.6 Horizontal Correlation and Respective Parameters of Kim and Ghajar (2002)

General Form of the Two-Phase Heat Transfer Coefficient Correlation:

$$h_{TP} = (1-\alpha)h_L\left[1 + C\left(\frac{x}{1-x}\right)^m\left(\frac{\alpha}{1-\alpha}\right)^n\left(\frac{Pr_G}{Pr_L}\right)^p\left(\frac{\mu_G}{\mu_L}\right)^q\right]$$

Experimental Data	Value of C and Exponents (m, n, p, q)					Mean Dev. (%)	rms Dev. (%)	Number of Data within ±20%	Range of Dev (%)	Range of Parameter				
	C	m	n	p	q					Re_{SL}	$\left(\frac{x}{1-x}\right)$	$\left(\frac{\alpha}{1-\alpha}\right)$	$\left(\frac{Pr_G}{Pr_L}\right)$	$\left(\frac{\mu_G}{\mu_L}\right)$
Slug and Bubbly/Slug Bubbly/Slug/Annular 89 data points from Kim (2000)	2.86	0.42	0.35	0.66	-0.72	0.36	12.29	82	-25.17 and 31.31	2468 and 35503	6.9×10^{-4} and 0.03	0.36 and 3.45	0.102 and 0.137	0.015 and 0.028
Slug 21 data points from King (1952)						12.79	20.78	10	-31.13 and 35.13	22500 and 119000	7.1×10^{-4} and 0.11	0.34 and 7.55	0.23 and 0.25	0.041 and 0.044
Wavy-Annular 41 data points from Kim (2000)	1.58	1.40	0.54	-1.93	-0.09	1.15	3.38	41	-12.77 and 19.26	2163 and 4985	0.05 and 0.13	3.10 and 4.55	0.10 and 0.11	0.015 and 0.018
Wavy 20 data points from Kim (2000)	27.89	3.10	-4.44	-9.65	1.56	3.60	16.49	16	-19.79 and 34.42	636 and 1829	0.08 and 0.25	4.87 and 8.85	0.102 and 0.107	0.016 and 0.021
All of the Data Points for Kim (2000) 150 data points	See Above for the Values for Each Flow Pattern					1.01	12.08	139	-25.17 and 34.42	636 and 35503	6.9×10^{-4} and 0.25	0.36 and 8.85	0.102 and 0.137	0.015 and 0.028

CHAPTER III

EXPERIMENTAL EQUIPMENT AND CALIBRATION

In this chapter each of the vital components of the test setup are discussed. All of the specifics of the test loop are discussed to relate a better understanding of the type of instruments used. Figure 3.1 shows an overall diagram of the test setup.

This chapter also explains calibration procedures used for thermocouples, flow meters, the voltmeter, and the ammeter. Also discussed are results from tests of single-phase heat transfer and from twelve slug flow tests.

3.1 Test Section Descriptions

3.1.1 Test Cradle

The test section rests atop an aluminum I-beam that is supported by a pivoting foot and a stationary foot that is incorporated with a small electric jack. The beam was constructed for the Chemical Engineering Department at Oklahoma State University to aid research in Hydrodynamic Jump research. The project was completed and the beam was no longer in use and was gladly donated to this project.

The I-beam is approximately 30 ft in length and can rise to an elevation of approximately 8° above horizontal. This feature is especially beneficial in keeping the test section free from stresses that might be caused while lifting it manually and placing static pillars underneath one end to elevate it. This method elevates and supports the

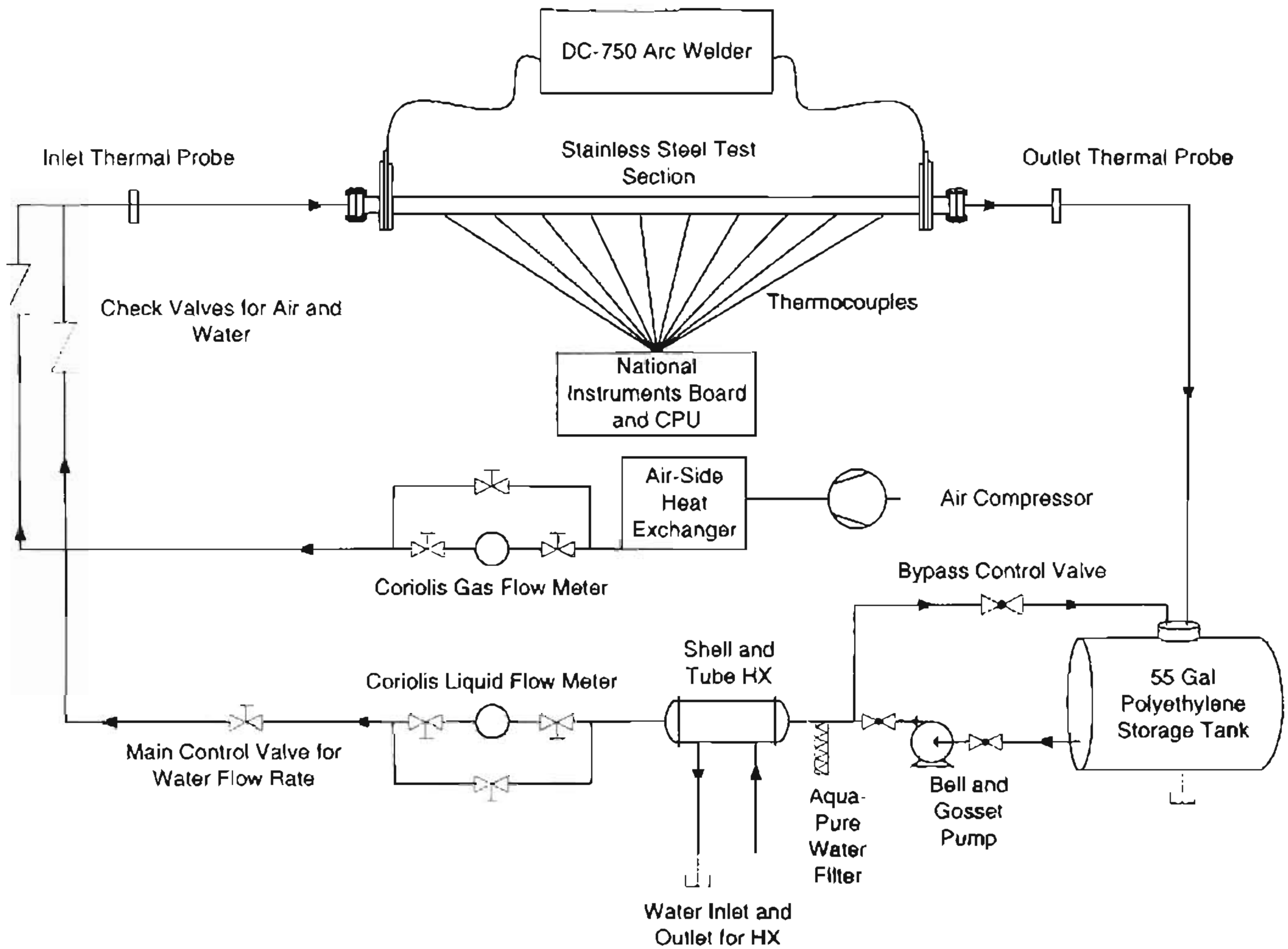


Figure 3.1 Experimental Setup

entire beam keeping it free from stresses that might crack or loosen joints causing leaks.

Inclination angles of the test cradle were measured with a contractors angle-measuring tool, and with a more precise digital data acquisition device that uses a small x-y axis accelerometer to determine the angle to within 0.5°.

3.1.2 Water Supply

The primary fluids used in this research project are air and water. The water was acquired and distilled by the Chemistry Department at Oklahoma State University and is stored in a 55-gallon cylindrical polyethylene tank. From this point, a pump draws the water through a bypass valve back into the 55-gallon tank or pushes the water through an Aqua-Pure, AP12T water filter and into a cross-flow heat exchanger. The bypass is one of the ways that the regulation of the flow rate was controlled. The other is the gate valve that is located directly after the Coriolis flow meter, which is discussed later.

The water purification is to eliminate any bacterial growth and to capture any foreign objects that may be introduced into the system. The Aqua-Pure AP12T purification system uses AP110 cartridges and has an allowable pressure of 125 psi and a maximum operating temperature of 100 °F or 38 °C.

Cooling water used for the heat exchanger is drawn from the city utilities. From the spigot water flows at an average rate of 10 gpm through the cross flow heat exchanger. Once leaving the heat exchanger the water is dumped into a drain.

3.1.3 Pump

The pump is a Bell & Gosset Series 1535 Coupled Centrifugal Pump. The pump size is a 3545 D10. This specific pump has specifications that are far above what was needed to supply the flow rates required to create all of the flow patterns and pressure requirements for this project. The pump produces enough flow to produce any flow pattern desired, ranging from the miniscule stratified flow requiring less than 3 lbm/min, to the plug flow which can use up to 80 lbm/min. Using the full capabilities of the pump, and assuming that pressure drops across filters are at minimal values, 160 lbm/min can be produced.

3.1.4 Heat Exchanger

The heat exchanger used to remove excess heat from the test water is an ITT Standard model BCF 4063 one shell and two-tube pass heat exchanger purchased from Thermal Engineering Company of Tulsa. The heat exchanger has an effective shell area of 21.2 ft^2 (1.97 m^2) and a maximum duty of 67190 Btu/hr (19.7 kW). Water into the heat exchanger was taken directly from the wall tap located in the lab. On average approximately 10 gpm were passed through the heat exchanger to ensure the most heat transfer possible.

3.1.5 Flow Meters and Flow Regulation

From the heat exchanger, the water flows into the larger Model CMF125 Coriolis Flow Meter, or if it is desired to by pass the flow meter, a bypass loop is incorporated into the design of the piping. The bypass loop is open and the pathway to the flow meters closed upon startup. This ensures that no air or abrupt pressure changes damages the inner workings of the flow meter.

The Coriolis flow meter was donated by Micro Motion. A Digital Field-Mount Transmitter Model RFT9739 displays the flow rate in lbm/min, L/min, density of the fluid in g/cm^3, temperature in °C, total lbm, total L, and an inventory of total lbm/min and L/min.

Once the water has passed the Coriolis flow meter, it then passes through a 1 inch, twelve turn gate valve. This gate valve helps to regulate the amount of flow that is entering the test section. From this point, the water travels through a 1 inch I.D. hose, through a check valve, and enters the test section.

3.1.6 Air Supply

An air compressor located in an adjacent room next to the test facility provides the airflow needed to produce the multiphase air-water patterns desired. Keeping the compressor in a separate room was done intentionally to keep the noise and physical hazard to a minimum.

The air compressor is an Ingersoll-Rand T30 Model 2545 Industrial Air Compressor. The air compressor was fitted with an unloader valve and a dump valve to keep the air pressure as constant as possible with no dramatic fluctuations. The maximum pressure possible is approximately 170 psi, with a minimum of approximately 50 psi, while the compressor is running.

Outside air was taken into the compressor and brought inside. Once inside the air was passed through a copper coil, which was submerged in running water. This was done to lower the temperature of the air. Energy in the form of heat from the compressor, and the high temperatures of the Oklahoma Summer raised the air temperature drastically. The air temperature desired was near what the inlet water temperature was. In order to do this the air was blown through the coil in the water.

3.1.7 Controls

The controls section of this project is a conjunction of ball and gate valves placed in specific areas to help monitor the amount of flow coming from either the air or the waterside. Both the air and the water flow rates are measured using two Model CMF025 and CMF125 Coriolis Flow Meters provided generously from Micro Motion Inc. Two Model RFT9739 Field–Mount Transmitters from Micro Motion/Fisher-Rosemount were used to read the flow rates of both the Coriolis flow meters.

3.1.8 Mixing Section

The mixing section of the test apparatus is shown in Figure 3.2. This type of mixer was successfully used by Ewing *et al.* (1999) in their two-phase experimental setup to generate a multitude of flow patterns.

The mixer is the point of the test section where the water and air are introduced simultaneously into the tube. The water is injected into the system through a 1 inch copper Tee. Through the other end of the Tee a reducer bushing is in place to hold the compression fitting that will secure the ½ inch I.D. 304 Stainless Steel tube that the air will be pushed through. The other end of the copper Tee runs into the observation section of the test setup.

3.1.9 Test Section

The test section of this setup is a 1.097 in I.D. 316 Stainless Steel Pipe. A schematic drawing can be seen in Figure 3.3. Each end is threaded to an original nylon

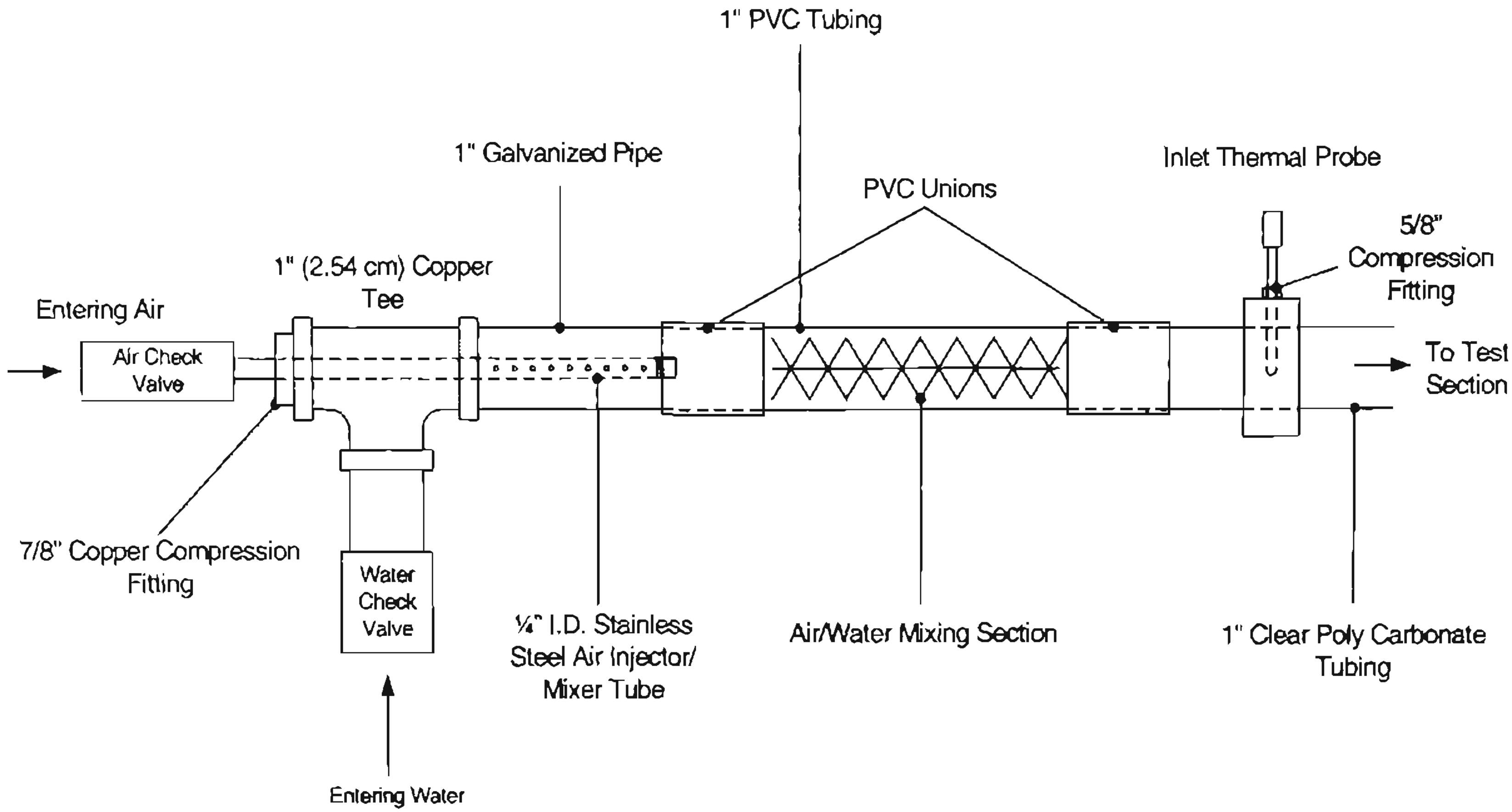


Figure 3.2 Air-Water Mixing Section

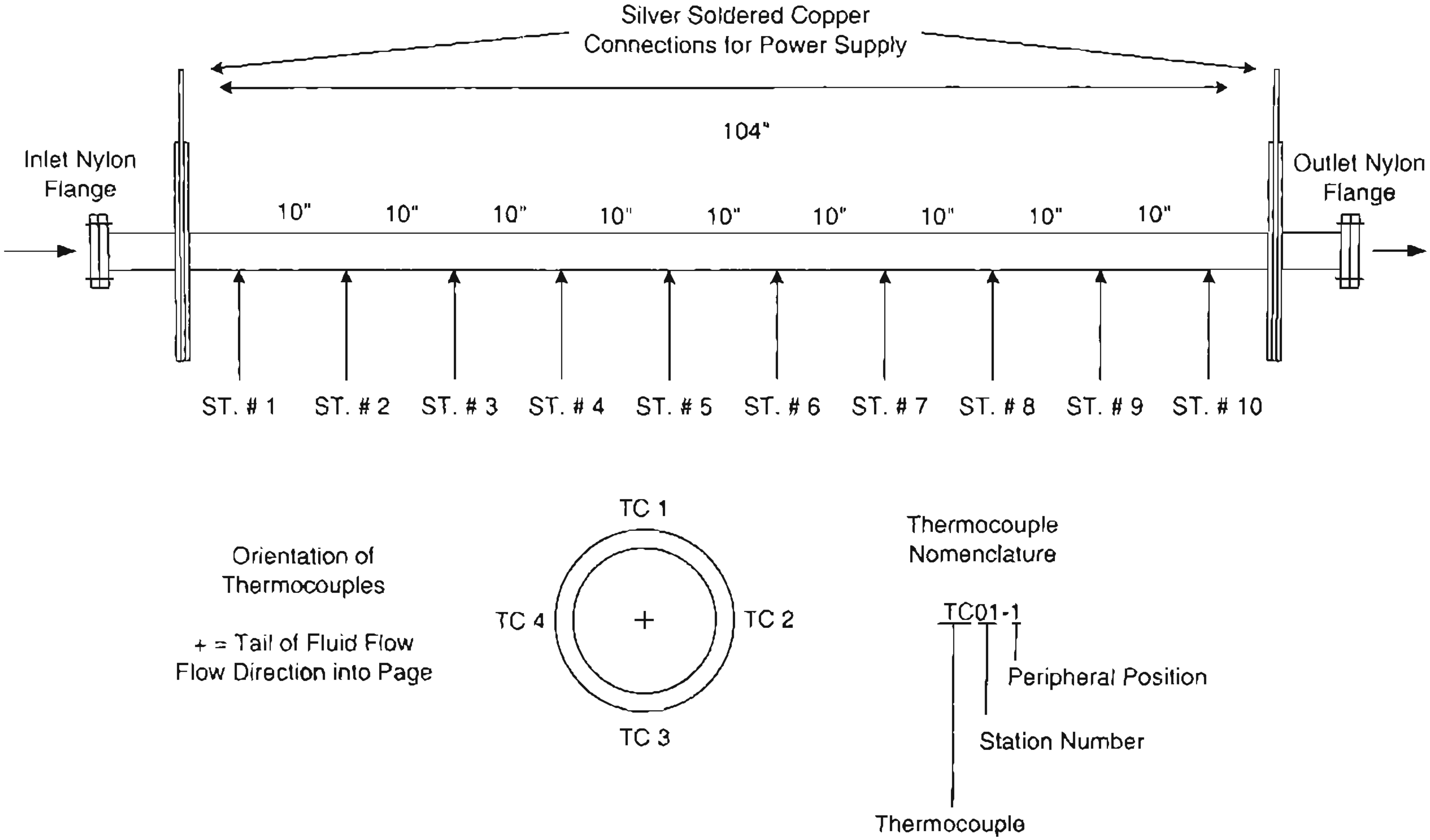


Figure 3.3 Stainless Steel Test Section

flange, Figure 3.4, which was created in the machine shop at Oklahoma State University. Each flange contains two O-rings. One O-ring contains flow in the radial direction and the other contains the flow trying to escape in the lateral direction. The lateral controlling O-ring is located on the polycarbonate tubing side. Polycarbonate tubing is located on each side of the test section. This type of tubing allows for an anterior and posterior observation section.

Also connected to each end of the test section is a copper plate, insulated with phenolic boards. This is the attachment point where the LINCOLNWELD SA-750 arc welder is attached with 4 gauge, insulated cables.

3.1.10 Power/Uniform Heat Source

The uniform wall heat flux is supplied by running high amperage current through the stainless steel test section. Two copper plates were silver soldered onto the stainless steel test section that provided a path in which the current flowed. A LINCOLNWELD SA-750 arc welder provided this current for the heat flux. This specific welder is capable of producing up to 750 amperes. Previously the welder had been located inside the actual testing room. After moving the lab, a small shed was built for the welder behind the building used to house the test section. The controls were moved inside the test facility, which greatly reduced the amount of heat that was previously generated into the room, and the amount of noise produced by the rotating welder fan blades.

3.1.11 Data Acquisition System

A National Instruments Data Acquisition System is used to record and store data measured during this project. Everything from the temperatures measured by the

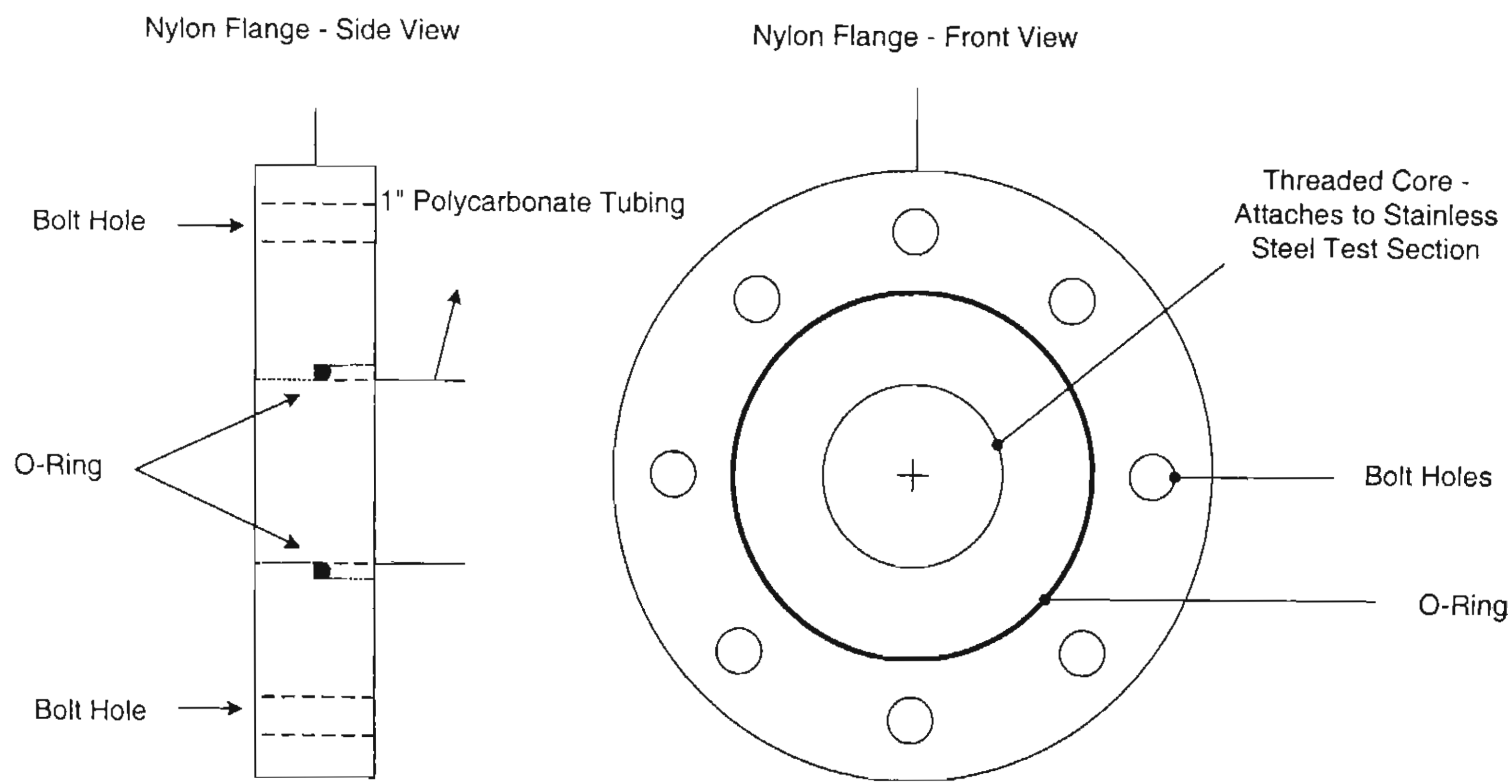


Figure 3.4 Nylon Flange Assemblies

thermocouples to the average current through the test section, to the flow rates measured by the flow meters was recorded and stored by this system.

The first part of the acquisition system was the framework which everything was housed in. An AC powered four-slot SCXI 1000 Chassis that serves as a low noise environment for signal conditioning, supplying power and control circuitry was used to house four NI SCXI modules.

There were two SCXI 1102/B/C modules plugged into the SCXI 1000 chassis. The SCXI 1102/B/C module is for signal conditioning of thermocouples, low-bandwidth volt and millivolt sources, 4 to 20 mA current sources, and 0 to 20 mA process-current sources. The module has 32 different analog input channels and one cold-junction sensor channel. Each channel has an amplifier with a selectable gain of 1 to 100. Each channel also has a three-pole low pass filter with a 2 Hz cutoff frequency to reject 60 Hz noise.

One SCXI 1125 Module was also incorporated into the acquisition system. The SCXI 1125 module is an eight-channel isolated analog input conditioning module with 12 programmable gain settings from 1 to 2000 and 2 programmable filter settings of 4Hz and 10 kHz on each channel.

Two shielded SCXI 1303 32-Channel Isothermal Terminal Blocks connected to the two SCXI 1102/B/C Modules. These have a high accuracy thermistor, cold-junction temperature sensor and an isothermal copper plane to minimize the temperature gradient across the screw terminals, which are used to attach the blocks to the terminals. The signals from the differential pressure transducers, flow meters and thermocouple probes are connected to these two modules.

One shielded SCXI 1313 8-Channel High Voltage Attenuator Terminal Block with screw terminals connecting to the SCXI 1125 module are also included in the acquisition system. Each channel has a precision 100:1 resistive voltage divider that can measure voltages of up to 300 V_{rms} or ± 300 V DC with the SCXI 1125. This block reads the system pressure and the voltage across and current through the test section.

Finally, for recording and storing data a computer based user interface had to be used. In order to accomplish this task, a graphical programming language, LabVIEW, was used to create the interface. The programming and creation of the interface and user program was done by Jae-yong Kim, a PhD candidate and member of the two-phase flow research team.

3.2 Thermocouples and Thermocouple Calibration

3.2.1 Thermocouples

Omega TT-T-30, T-Type Thermocouples were used to measure the temperature of the test section. The thermocouple wire was shipped as a continuous 1000 ft roll with a deviation of approximately 0.3° at 200° Fahrenheit. Each thermocouple was attached to the extension wire by wrapping a bare connection from the T-type thermocouple to a bare connection of extension wire. Once twisted and contact was made between wires, they were soldered together. By twisting them together, a direct path would be made for the voltage to travel and losses would be minimized.

The wires were attached with an Omega SMPW-T-M and SMPW-T-F connectors. A 16 in lead was wired from the data acquisition board to a female end of the connector for each thermocouple and probe. This was to prevent having to remove the data card when wishing to replace a thermocouple. Instead, the 20 ft extension wire could be removed and fixed with a new thermocouple while never having to disturb the data acquisition devices.

Two Omega TMQSS-125U-6 thermal probes were used to measure the water temperatures in the mixing or inlet section, one at the inlet of the mixing section and one located at the exit of the test section. The thermal probes were also attached with the connectors and were run with the same 20 ft stretches of extension wire as were the thermocouples to keep uniformity among the temperature reading devices.

3.2.2 Thermocouple and Probe Calibration

A total of 55 thermocouples were made and each, along with the two OMEGA TMQSS-125U-6 thermal probes, and one spare TMQSS-125U-6 thermal probe, were calibrated against a constant temperature oil bath to check the accuracy of each and that each of the devices was working properly. Of the 55 thermocouples made, 40 were actually used on the test section along with the two inlet and outlet probes. The other 15 thermocouples and one thermal probe were used as spares.

The bath used to calibrate the thermocouples was a Neslab RTE 740 with a Digital Plus readout. This bath was a brand new machine and had been calibrated at the factory. Ethylene Glycol was the calibration fluid.

Seven temperatures were measured with the thermocouples starting with 10 °C and finishing with 40 °C in increments of 5 °C. Maximum temperatures for previous experiments rarely reached above 24 °C or below 15 °C. Since the range was so small and thermocouples are normally linear in nature, the thermocouples were not calibrated with extremely low or high temperatures. The desired range for an acceptable thermocouple reading deviation was ± 0.5 °C.

After calibration, all thermocouples and probes were compared against the bath temperature in an Excel spreadsheet and fitted with a linear regression equation, which corrected any deviations that the thermocouple may have had. Once fitted, the equation was written into the data acquisition code for an adjusted fit. A sample calibration curve, representative of all thermocouples calibrated, for Thermocouple 1 at Station 1 is given in Figure 3.5. The other calibration equations can be found in Appendix A.

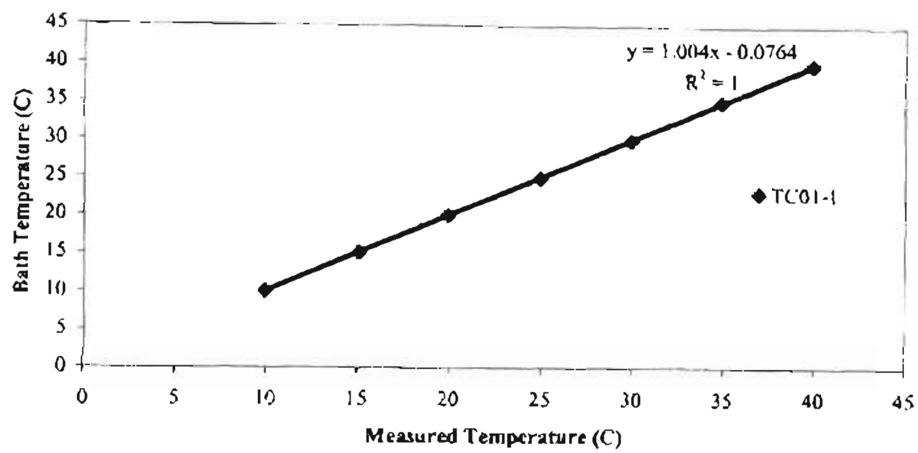


Figure 3.5 Calibration Curve for Thermocouple 1, TC01-1

<u>3.2.3 Thermocouple Attachment</u>

Once calibration had been completed the thermocouples were attached to the test section with OMEGABOND 101 epoxy, and the probes were inserted into the inlet and outlet areas and secured with Omega BRLK-18-14 compression fittings. OMEGABOND 101 is a highly electrical resistive, high heat conducting two-part epoxy. This epoxy has an Electrical Insulation Volume Resistivity of 10^{15} ohm-cm and Thermal Conductivity of 7.2 (BTU-in)/(hr-ft^2-°F).

Attachment of the thermocouples to the test section is a two-day process. The first step in securing a good attachment is to clean the area where the thermocouple will be attached. Low concentration ammonia or other cleaning solvent should be applied and allowed to dry. Once dry wipe the area clean with a rubbing alcohol to remove all film and dirt that may have been left behind. After the alcohol has evaporated mix the OMEGABOND 101 and apply a small drop, approximately 1 to 2 mm in diameter, and allow 24 hrs to dry. Four drops were placed at each station for the four thermocouples that were to be attached. The four drops were placed on the pipe starting from the top of the pipe and then every 90° clockwise from there. Figure 3.3 shows the placement of these thermocouples. After the epoxy had dried, the hardened drops were lightly filed to create a flat surface for the thermocouples to rest in. The filing was minimal and great care was taken to ensure that the thermocouple bead would not touch the pipe.

The thermocouple extension wires were attached to the test setup and secured. The actual thermocouple wires were then taped to the stainless steel test section in a position where the bead was atop of its respective station epoxy droplet. Once the bead was in place, another small 1 to 2 mm droplet of OMEGABOND 101 was placed over the bead and allowed 24 hrs. to dry. While the epoxy was curing, no electrical or fluid movement was sent through the pipe.

After the 24 hour drying period, the tape used to secure the thermocouple wire was removed so that no adverse heating or cooling effects could be contributed to it. The thermocouples were then insulated with fiberglass, vinyl backed, pipe insulation. Two insulation layers were used and then the insulation was contained with a plastic wrapping to keep the insulation in place.

3.3 Isothermal Trials, Pre and Post Heat Checks

3.3.1 Isothermal Trials

Isothermal runs were performed at many different flow rates after the epoxy had cured. The purpose of the isothermal tests was to ensure that the epoxy had no effect on the way that the thermocouples behaved. A small Visual Basic Applications program was written to perform calculations that would adjust the raw data using the calibrated thermocouple and thermal probe equations. Once the data had been adjusted using the corresponding equation, the values for each thermocouple and thermal probe were averaged. These values were then graphed against the respective position along the test section (for thermocouple position explanation see Figure 3.3, Thermal Probes denoted by TP). These profiles can be seen in Figure 3.6. From the graph, it can be seen that there is little deviation in the raw data temperature profile, the topmost lines, from one test run to the next. The bottom two lines are a representation of the raw and adjusted temperature values for the 20 °C calibration run. Once the raw data has been filtered through the calibration equations, the line becomes straight and the temperatures are all within 0.5 °C of the known temperature. These isothermal comparisons are vital to the calibration process because they reveal any thermocouple variance as time passes. Future isothermal runs may be performed and compared to the original profiles. If any change is observed, then it will be easy to determine if a thermocouple is acting correctly or needs replacing.

3.3.2 Pre-Heat Checks

Before any actual heated runs were performed with the new data acquisition

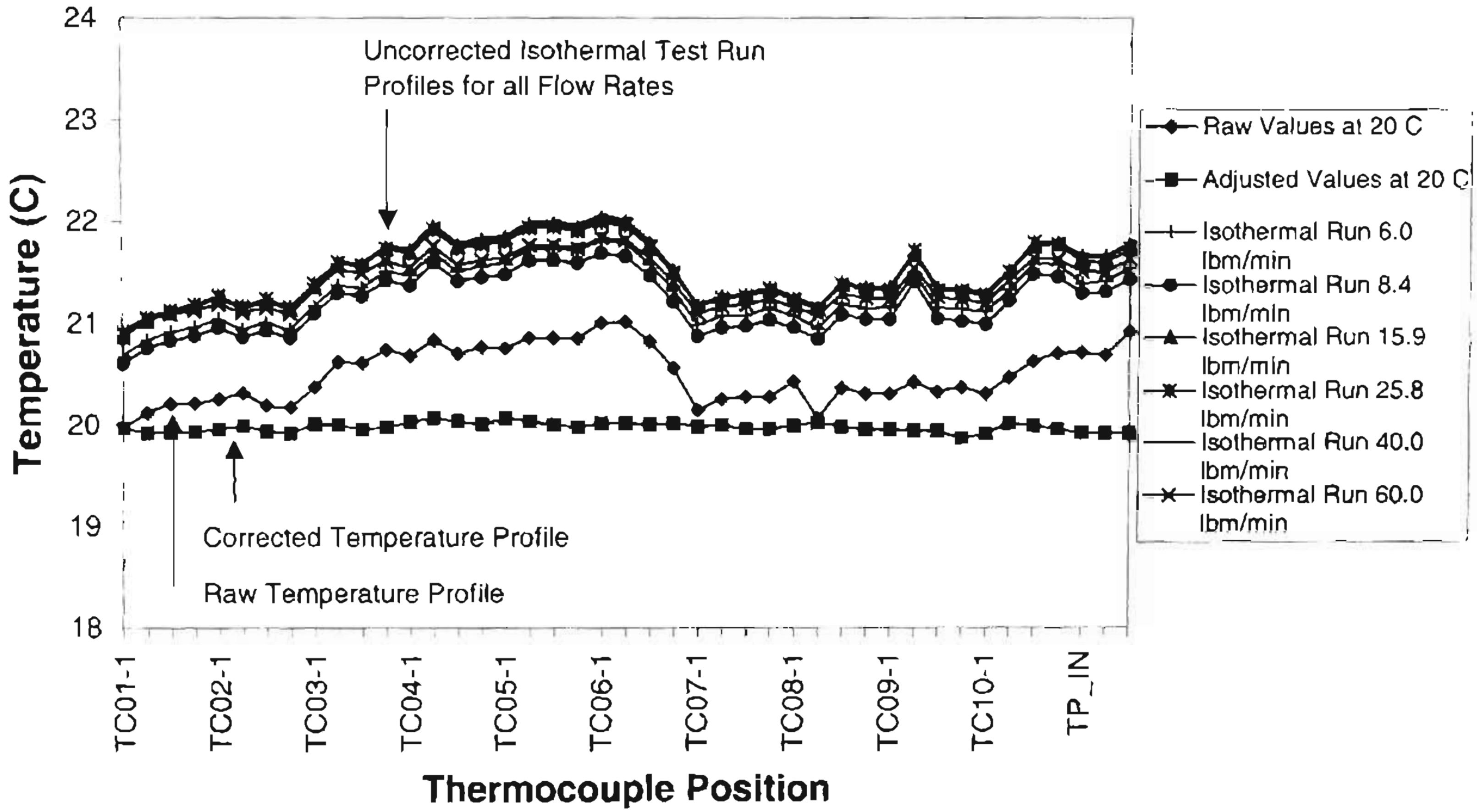


Figure 3.6 Isothermal Run Comparison

system, a heated run was performed to check and see if any of the thermocouple beads were touching the pipe. To measure this all thermocouple terminals were removed from the National Instruments system. The welder was started and the minimal amount of current that could be produced by the welder alone was administered to the pipe. This value was approximately 345 amperes maximum and 287 amperes minimum. The end of each thermocouple was checked to see if the electrical resistivity was on the order of a Mega ohm or more. OMEGABOND 101 has a high electrical insulation value of 10^{15} ohm-cm. This means that it has a high electrical resistivity. So, if any current or voltage from the pipe were channeling through the thermocouples, it would be read by a multimeter that was attached to the thermocouple terminals. By removing the thermocouples, it was assured that if any current were traveling through the thermocouples, the data acquisition system would be safe from any possible damage.

3.3.3 Post-Heat Checks

Upon completion of the heated run, which affirmed that no thermocouple bead was touching the pipe, another isothermal run was performed. It was revealed that during the first heated run, the characteristics of the thermocouples had changed. The profile that was created by the thermocouple temperature averages was not typical of the previous isothermal runs, as can be seen in Figure 3.7. It is believed that the curing of the epoxy had not completed at the time of the heated test run. During the test run, the heat caused the pipe to expand and the epoxy to completely cure. Once this happened the thermocouples began to behave in a different manner. To remedy this behavior, many more isothermal runs were performed. After each run, the data was averaged and

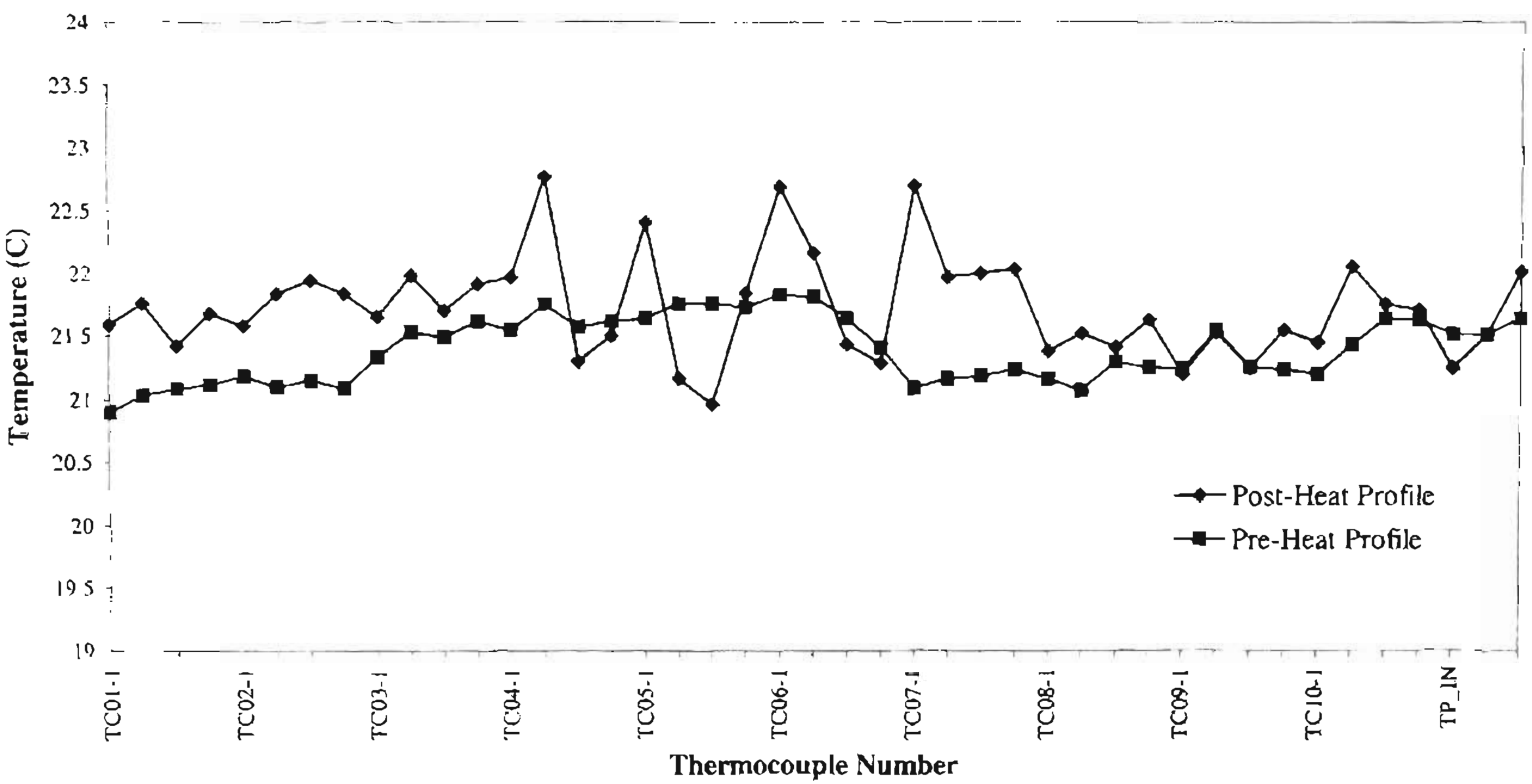


Figure 3.7 Pre-Heat and Post-Heat Isothermal Comparison

graphed. Each time the same pattern as the Post-Heat Profile, seen in Figure 3.7, was observed. More heated runs were then instituted to see if any more changes would occur as a result of the heating. No more changes were observed in the behavior of the thermocouples. Once this had been established, each thermocouple average for each isothermal run that had been performed post-heat was then averaged into a single value. Each thermocouple temperature was then compared to that average for that specific test run. What was concluded was that each thermocouple's deviation from test run average was the same for each case. Table 3.1 contains each thermocouple's post-heat deviation from average.

Once each thermocouple's or probe's deviation had been determined, the value was then added to or subtracted from the original calibration equation for each.

Table 3.1 Post-Heat Thermocouple Deviations from Average

Position	Thermocouple Station									
	1	2	3	4	5	6	7	8	9	10
1	-0.1392	-0.14876	-0.08773	0.234388	0.681605	0.96367	0.98264	-0.34608	-0.52468	-0.27736
2	0.028216	0.112462	0.246509	1.04343	-0.55994	0.437326	0.257222	-0.20109	-0.19768	0.325489
3	-0.3054	0.222726	-0.02977	-0.42828	-0.76496	-0.28785	0.28351	-0.31521	-0.47886	0.024244
4	-0.04686	0.121098	0.178193	-0.22547	0.117427	-0.43934	0.308606	-0.09075	-0.17975	-0.02508
		Inlet Probe		-0.50279		Outlet Probe		-0.22984		

3.4 Other Calibrations

3.4.1 Air and Water Mass Flow Rate Calibration

A field transmitter was provided to read mass flow rate values during testing. To record the data by hand and enter it into the computer later was burdensome and time consuming and many times was prone to mistakes while entering the data. The data acquisition system was designed to read such data and was used to interface with the transmitters and record the data automatically. In order to do this accurately, the readings had to be calibrated.

The data acquisition devices have a range of 4-20 mA. In order for the computer to distinguish the correct flow rate, the flow rates had to be set and then the amperage read from the computer console. Once the data had been established, a line was fitted to the comparison of the flow rate and the current measured by the computer and then fitted with an equation that would relate the amperage to a corresponding flow rate. Figures 3.8 and 3.9 represent the calibration curves for the air and water mass flow rates

3.4.2 Voltmeter and Ammeter Measurements

The voltmeter was incorporated into the measurement system to calculate the voltage drop across the test section. The voltage drop was used in conjunction with the amperage to determine the average heat flux that was passed through the system. The average heat flux was then compared with the computer programs Ht2002 and Rht02m (See Section 3.5), calculated average heat flux value to determine the overall heat balance.

The voltage drop was determined by measuring the voltage at the inlet and outlet of the test section. This was done by wiring 26 AWG wire to the silver soldered connections located at each end of the test section and connecting it directly into the data acquisition system. The two values were then subtracted from one another to get the overall voltage drop.

The ammeter used to collect the amperage readings during testing was created by using a 50 millivolt shunt that was installed on the silver solder connection on the exit

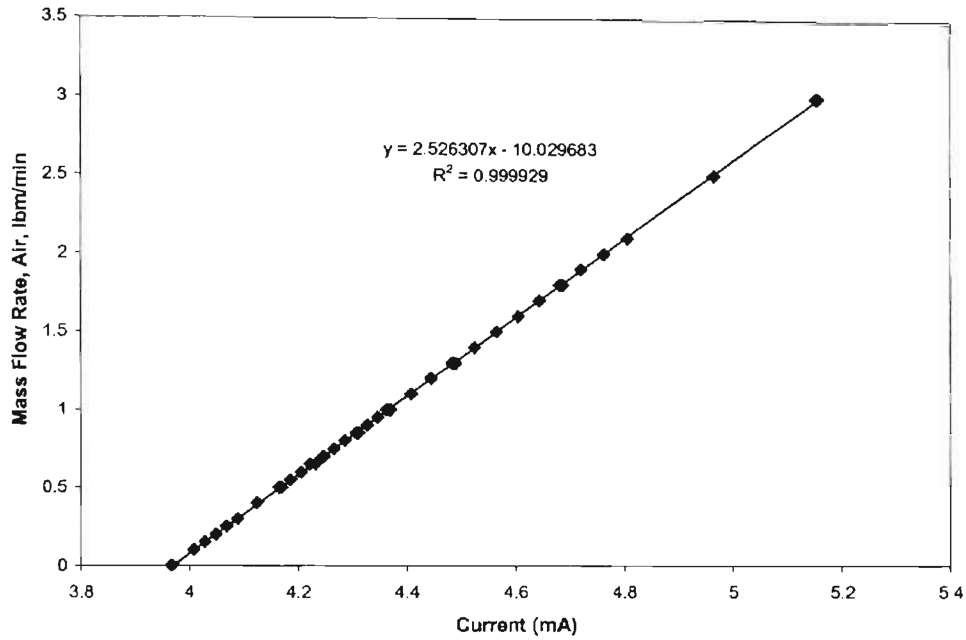


Figure 3.8 Air Mass Flow Rate Calibration Curve

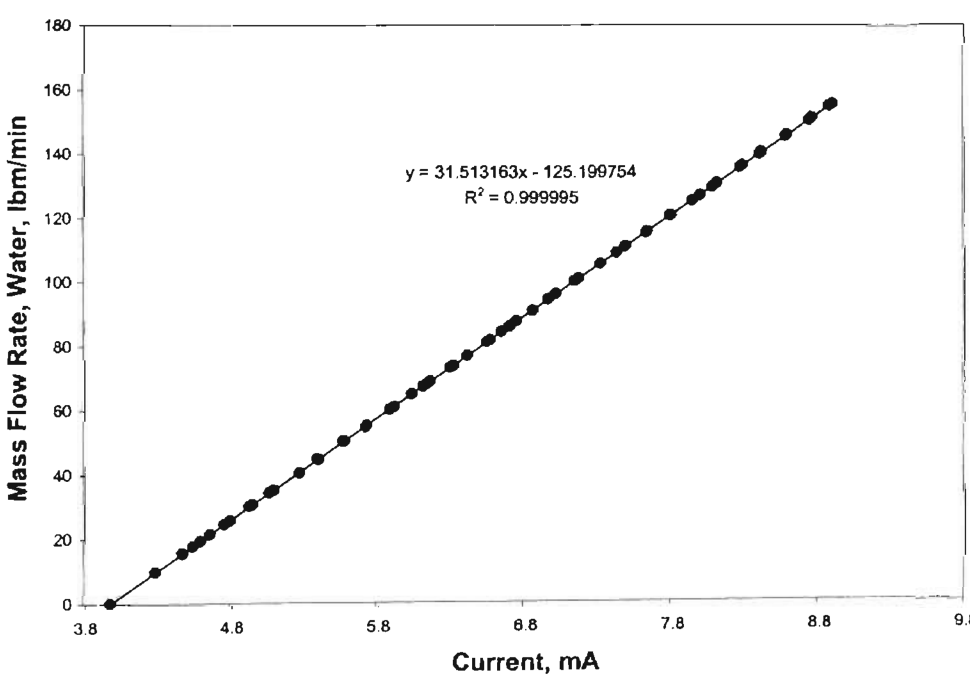


Figure 3.9 Water Mass Flow Rate Calibration Curve

end of the test section. Knowing the voltage drop and the resistance, the amperage of the test section could be determined by using the equation, I = V/R. This was done using the data acquisition system.

3.5 Data Reduction Program

3.5.1 Background

The experimental procedure for the calculation of the overall heat transfer coefficient is discussed in this section. A computer program named RHt99K, developed by Kim (2000), Ryali (1999), and Kim (1999), was modified and used to calculate the desired parameters from the measured data of each test run. These parameters were the outside surface wall temperature of the pipe, the inlet and outlet bulk temperatures, gas and liquid flow rates, voltage drop across the test section, and the current carried by the test section. Modified by the author to fulfill the current project requirements, the new program was renamed RHt02m. RHt02m was developed to handle the annular flow experiments and another program Ht2002 was used to reduce the Single-Phase experimental data. Ht2002 was similar to that of RHt02m. The difference between Ht2002 and Rht02m was the introduction of the second fluid flow. The calculations are identical in each program with minor modifications to the input and output.

Ghajar and Zurigat (1991) created the interactive computer program which calculated the local inside wall temperatures and local heat transfer coefficients from local outside wall temperatures measured at different axial locations along a horizontal, stainless steel pipe. Four major sections exist in Ghajar and Zurigat's (1991) program. These sections were the input, finite-difference analysis, fluid properties, and output. The four sections of the program are discussed below.

3.5.2 Input Data

The inputs of this program included the voltage drop across the pipe, the current carried by the pipe, the volumetric flow rates of the air and water, the bulk fluid temperatures at the inlet and exit, and the outside wall temperature data for all 40 thermocouple locations.

The data file obtained from the National Instruments Data Acquisition System, was arranged in a specified format by a subroutine named Datared99F. Datared99F was originally a separate program used to input data into the RHt99m program. For this research, it was integrated into the RHt02m program as a subroutine. This would allow for the use of only one computer program.

Datared99F directly read all the necessary information from the data file (.DAT) that was produced by the National Instruments System and averaged all the temperature values for each station, as well as the averaged voltage drop, averaged amperage through the pipe, and the average air and water flow rates. The data was stored in a temporary file (.TMP) for the main RHt02m program to access.

3.5.3 Finite Difference Formulations

No modifications were made to the development of the finite-difference calculations. Only the way that the information for this research was arranged in the input and the way the calculated information was output was changed. This information can also be found in the research papers by Kim (1999) and Kim (2000).

The numerical solution of the conduction equation with internal heat generation, variable thermal conductivity, and variable electrical resistivity was based on the following assumptions:

- Steady state conditions exist.
- Peripheral and radial wall conduction exists.
- Axial conduction is negligible.
- The electrical resistivity and thermal conductivity of the tube wall are functions of temperature.

Based on these assumptions, the expressions for the calculation of the local inside wall temperatures, heat flux, and the local peripheral heat transfer coefficients are developed.

- **<u>Local Inside Wall Temperature and Local Inside Wall Heat Flux</u>**

The heat balance on a segment of the tube wall at any particular station is given by Equation (3.1) and is illustrated by Figure 3.10:

$$Q_g = Q_1 + Q_2 + Q_3 + Q_4 \tag{3.1}$$

From Fourier's law of heat conduction in a given direction the following equation applies

$$Q = -kA\frac{dT}{dn} \tag{3.2}$$

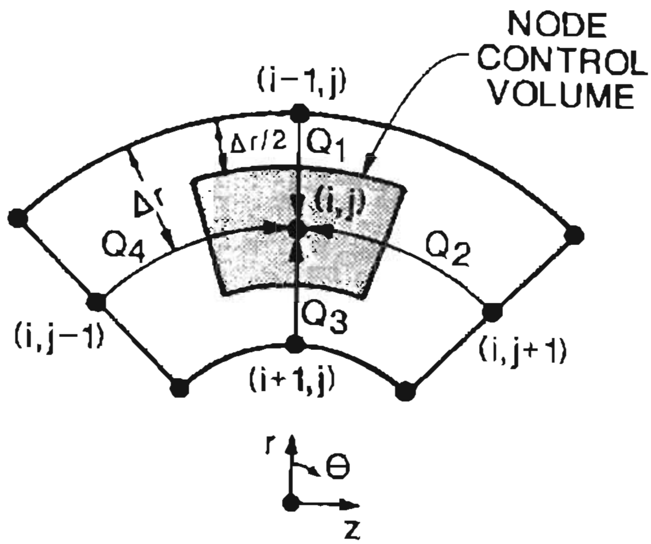


Figure 3.10 Finite-Difference Grid Arrangement (Ghajar and Zurigat, 1991)

Now substituting Fourier's law into Equation (3.1) and applying the finite-difference formulation for the radial (i) and peripheral (j) directions:

$$Q_1 = \frac{(k_{i,j} + k_{i-1,j})}{2} \frac{2\pi\left(r_i + \frac{\Delta r}{2}\right)\Delta z}{N_{TH}} \frac{(T_{i,j} - T_{i-1,j})}{\Delta r} \tag{3.3}$$

$$Q_2 = \frac{(k_{i,j} + k_{i,j+1})}{2} (\Delta r \Delta z) \frac{(T_{i,j} - T_{i,j+1})}{\left(\frac{2\pi r_i}{N_{TH}}\right)} \tag{3.4}$$

$$Q_3 = \frac{(k_{i,j} + k_{i+1,j})}{2} \frac{2\pi\left(r_i - \frac{\Delta r}{2}\right)\Delta z}{N_{TH}} \frac{(T_{i,j} - T_{i+1,j})}{\Delta r} \tag{3.5}$$

$$Q_4 = \frac{(k_{i,j} + k_{i,j-1})}{2} (\Delta r \Delta z) \frac{(T_{i,j} - T_{i,j-1})}{\left(\frac{2\pi r_i}{N_{TH}}\right)} \tag{3.6}$$

where

k = thermal conductivity

r_i = tube inside radius

Q = rate of heat transfer

T = temperature

Δz = length of element

Δr = incremental radius

N_{TH} = number of finite-difference sections in the θ-direction (peripheral) which is equal to the number of thermocouples at each station.

i and j = the indices of the finite-difference grid points, i is the radial direction starting from the outside surface of the tube and j is the peripheral direction starting from top of the tube and increasing clockwise.

The heat generated (Q_g) at i, j element volume is given by equation (3.7):

$$Q_g = I^2 R \tag{3.7}$$

where

I = Current

R = $\gamma l / A$ = resistance

γ = electrical resistivity of the element

l = Δz = length of the element

A = $(2\pi r_i / N_{TH})\Delta r$ = cross-sectional area of the element

Substituting the above definitions into Equation (3.7) gives:

$$Q_g = I^2 \frac{\gamma \Delta z}{\left(\frac{2\pi r_i}{N_{TH}}\right)\Delta r} \tag{3.8}$$

Substitution of Equations (3.3) through (3.6), and Equation (3.8) into Equation (3.1) and solving for $T_{i+1,j}$ yields Equation (3.9):

$$T_{i+1,j} = T_{i,j} - \left\{ \frac{I^2 \gamma N_{TH}}{(2\pi r_i \Delta r)} - \frac{(k_{i,j} + k_{i-1,j})}{\Delta r} \frac{\pi\left(r_i + \frac{\Delta r}{2}\right)}{N_{TH}} (T_{i,j} - T_{i-1,j}) - (k_{i,j} + k_{i,j+1}) \frac{\Delta r N_{TH}}{4\pi r_i} (T_{i,j} - T_{i,j-1}) - (k_{i,j} + k_{i,j+1}) \frac{\Delta r N_{TH}}{4\pi r_i} (T_{i,j} - T_{i,j+1}) \right\} \left\{ \frac{\Delta r N_{TH} (k_{i,j} + k_{i+1,j})}{\pi\left(r_i - \frac{\Delta r}{2}\right)} \right\} \tag{3.9}$$

Equation (3.9) was used to calculate the temperature of the interior nodes, such as those seen in Figure 3.10. In Equation (3.9), the thermal conductivity (k) and electrical resistivity (γ) of each node control volume, were determined as a function of temperature from the following equations developed by Ghajar and Zurigat (1991), for a pipe of 316 stainless steel:

$$k = 7.27 + 0.0038T \tag{3.10}$$

$$\gamma = 27.67 + 0.0213T \tag{3.11}$$

where T is the temperature in °F, k is the thermal conductivity in Btu/hr-ft-°F, and γ is the electrical resistivity in micro-ohm-in.

Once the local inside wall temperatures were calculated from Equation (3.9), the local peripheral inside wall heat flux could be calculated from the heat balance equation, Equation (3.1).

Calculation of Local Peripheral and Local Average Heat Transfer Coefficients

From the local inside wall temperature, the local peripheral inside wall heat flux and the local bulk fluid temperature, the local peripheral heat transfer coefficient could be calculated from Equation 3.12:

$$h_i = \dot{q}_i'' / (T_{wi} - T_b) \tag{3.12}$$

where

h_i = local peripheral heat transfer coefficient

$\dot{q}_i''$ = local peripheral inside wall heat flux

T_{wi} = local inside wall temperature

T_b = bulk fluid temperature at the thermocouple station

Using Equation (3.12) it was assumed that the bulk fluid temperature increased linearly from the inlet of the pipe to the outlet. This linear increase was calculated according to Equation (3.13):

$$T_b = T_{in} + (T_{out} - T_{in})\, X/L \tag{3.13}$$

Where

T_b = bulk temperature

T_{in} = bulk inlet temperature

T_{out} = bulk outlet temperature

X = distance from the pipe inlet to the thermocouple station

L = total length of the test section

The local average heat transfer coefficient at each station could then be calculated by Equation (3.14):

$$\bar{h}_i = \bar{q}_i'' / \left(\bar{T}_{wi} - T_b\right) \tag{3.14}$$

where

$\bar{h}_i$	=	local average heat transfer coefficient
$\bar{q}_i''$	=	average peripheral inside wall heat flux at a station
$\bar{T}_{wi}$	=	average inside wall temperature at a station

3.5.4 Physical Properties of the Fluids

The equations used for the fluid properties or air and water, which were used in this research, are given in Table 3.2. These correlations were developed by Vijay (1978).

Table 3.2 Physical Properties of the Fluids used in This Study

Fluid	Equation for the Physical Property (T = Temperature in °F except where noted)	Range of Validity & Accuracy	Source
Air	ρ (lbm/ft^3) = P/RT where P in lbf/ft^2, T in °R, and R = 53.34 ft-lbf/lbm°R	$P \le 150$ psi	Vijay (1978)
	Cp (Btu/lbm-°F) = $7.540\times10^{-6}T + 0.2401$	$-10 \le T \le 242$, 0.2%	
	μ (lbm/ft-hr) = $-2.673\times10^{-8}T^2 + 6.819\times10^{-5}T + 0.03936$	$-10 \le T \le 242$, 0.1%	
	k (Btu/hr-ft-°F) = $-6.154\times10^{-9}T^2 + 2.591\times10^{-5}T + 0.01313$	$-10 \le T \le 242$, 0.2%	
Water	ρ (lbm/ft^3) = $\{2.101\times10^{-8}T^2 - 1.303\times10^{-6}T + 0.01602\}^{-1}$	$32 \le T \le 212$, 0.1%	Vijay (1978)
	Cp (Btu/lbm-°F) = $1.337\times10^{-6}T^2 - 3.374\times10^{-4}T + 1.018$	$32 \le T \le 212$, 0.3%	
	μ (lbm/ft-hr) = $\{1.207\times10^{-5}T^2 + 3.863\times10^{-3}T + 0.09461\}^{-1}$	$32 \le T \le 212$, 1.0%	
	k (Btu/hr-ft-°F) = $4.722\times10^{-4}T + 0.3149$	$32 \le T \le 176$, 0.2%	
	σ (lbf/ft) = $5.52288\times10^{-12}T^3 - 8.05936\times10^{-9}T^2 - 4.75886\times10^{-6}T + 5.346\times10^{-3}T$	$68 \le T \le 150$	

3.5.5 Output

Figure 3.11 shows a sample output data file using the Computer Program, RHt02m. The output data file starts with the run number for a quick reference and a

RUN NUMBER 8471
TWO - PHASE
07-16-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	.95	GPM
MASS FLOW RATE WATER	=	7.9	LBM/MIN
MASS FLOW RATE GAS	=	1.49	LBM/MIN
MASS FLUX	=	72171	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.32	FT/S
GAS VELOCITY	=	51.49	FT/S
GAS VISCOSITY	=	385.37E-09	LBM-S/FT^2
INLET TEMPERATURE	=	74.70	F
OUTLET TEMPERATURE	=	82.13	F
RE NUMBER LIQUID	=	3118	
RE NUMBER GAS	=	27982	
AVERAGE PR NUMBER	=	6.03	
CURRENT TO TUBE	=	355.3	AMPS
VOLTAGE DROP IN TUBE	=	3.69	VOLTS
AVERAGE HEAT FLUX	=	1805	BTU/(SQ.FT-HR)
Q-AMP*VOLT	=	4473	BTU/HR
Q=M*C*(T2-T1)	=	4430	BTU/HR
HEAT BALANCE ERROR	=	.95	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	93.89	93.65	93.00	94.10	94.51	95.66	96.13	96.86	97.08	97.27
2	87.83	84.07	86.65	85.56	87.09	86.52	83.70	86.58	87.52	87.94
3	77.83	78.14	78.62	79.15	79.79	80.26	80.79	81.29	81.77	82.01
4	84.35	83.62	83.69	84.43	85.01	85.72	86.74	88.40	86.89	87.84

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	93.26	93.05	92.37	93.49	93.89	95.05	95.51	96.25	96.48	96.66
2	87.11	83.30	85.92	84.80	86.35	85.76	86.95	85.80	86.75	87.17
3	76.97	77.31	77.78	78.32	78.96	79.43	79.95	80.46	80.95	81.18
4	83.59	82.85	82.93	83.66	84.24	84.95	85.97	87.65	86.11	87.07

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	3718	3709	3681	3728	3745	3793	3813	3844	3854	[illegible]
2	3465	3311	3416	3371	3434	3410	3458	3412	3450	3467
3	3062	3075	3093	3114	3139	3158	3178	3198	3217	3227
4	3322	3293	3296	3325	3349	3377	3419	3487	3424	3463

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1086	1035	1085	1053	1070	1043	1059	1048	1036	1048
2	1235	1330	1263	1311	1287	1322	1306	1350	1335	1330
3	1495	1429	1453	1434	1445	1435	1451	1445	1426	1438
4	1324	1341	1338	1340	1340	1343	1330	1304	1351	1333

RUN NUMBER 8471

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	60	60	68	65	67	64	66	65	66	69
2	101	180	136	175	155	189	175	241	218	240
3	845	1021	1257	1464	1607	2175	3102	5640	43766	-3209
4	157	193	212	213	216	217	205	175	260	245

RUN NUMBER 8471
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	2993.89	6.31	6.4	2.204	1.947	75.20	85.23	62.26	33.57
2	3021.39	6.25	15.5	2.184	1.973	75.91	84.13	[illegible]	40.93
3	3049.00	6.18	24.6	2.164	1.958	76.63	84.75	62.24	41.39
4	3076.70	6.12	33.7	2.144	1.951	77.34	85.07	62.24	43.47
5	3104.50	6.06	42.8	2.125	1.932	78.06	85.86	62.23	43.03
6	3132.40	6.00	52.0	2.106	1.922	78.77	86.30	62.22	44.57
7	3160.40	5.94	61.1	2.088	1.904	79.49	87.10	62.22	44.05
8	3188.50	5.88	70.2	2.069	1.894	80.20	87.54	62.21	45.65
9	3216.70	5.82	79.3	2.051	1.894	80.92	87.57	62.20	50.28
10	3244.99	5.77	88.4	2.033	1.884	81.63	88.02	62.20	52.33

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

Figure 3.11 Sample Output Data File from Computer Program RHt02m

summary of some of the important information about the experimental run such as mass flow rate, mass flux, fluid velocity, room temperature, inlet and outlet temperatures, averaged Reynolds and Prandtl numbers, current and voltage drop across the test section, average heat flux, and heat balance error. The calculated inside wall temperatures, liquid superficial Reynolds numbers, inside surface peripheral heat fluxes, and the peripheral heat transfer coefficients for each thermocouple station along the pipe are listed immediately after the run summary. Finally, for each station, superficial liquid Reynolds number, liquid Prandtl number, location from the tube entrance, liquid viscosity at the local bulk temperature, liquid viscosity at the local inside wall temperature, fluid bulk temperature, inside wall temperature, liquid density, and the local average Nusselt number are listed.

3.6 Heat Transfer in a Horizontal Pipe

3.6.1 Single Phase Flow Heat Transfer

Before any two-phase measurements could be taken, single-phase analysis to confirm the integrity of the setup had to be performed. This methodology was taken from Kim (1999), who had performed the single-phase analysis previously on the same test setup. Five correlations were used to compare single-phase data. These authors were Colburn (1933), Sieder and Tate (1936), two Gnielinski (1976) equations, and Ghajar and Tam's (1994) correlation.

Twenty-six single-phase data points were collected. The correlations of Colburn (1933), Sieder and Tate (1936), Gnielinski (1976), and Ghajar and Tam (1994) were used to predict Nusselt numbers. Gnielinski (1976) gives three correlations in the paper but only the first and third correlation will be used in this comparison. These predicted

Nusselt numbers were then compared to the Nusselt numbers calculated by the computer program Ht2002 (See Section 3.5). Each correlation is described below.

Comparison of each of these correlations with the experimental data was used to establish the accuracy of the test setup. Data from Station 7 was used for the comparison. This station was chosen over the others because of its position from the entrance and the exit. At this station, no adverse exit effects would be experienced and the position was far enough away from the entrance to assure that the flow was fully developed.

3.6.2 Colburn (1933)

Using data that fell within the limitations of the Colburn (1933) correlation, a total of 11 points were used to predict Nusselt numbers. Table 3.3 shows the comparison between the experimental and predicted Nusselt numbers.

Colburn (1933) correlation:

$$Nu = 0.023\,\mathrm{Re}^{0.8}\,\mathrm{Pr}^{1/3} \tag{3.15}$$

where $\mathrm{Re} \geq 10{,}000,\ 0.6 \leq \mathrm{Pr} \leq 160$

Table 3.3 shows that the Colburn correlation produced a minimum deviation of 10.2% and a maximum deviation of 19.6%. Minimum Reynolds number was 10,507 and the maximum Reynolds number was 20,579. Figure 3.12 shows the Nusselt number comparison of experimental and predicted in graphical form. A ±20% deviation band

Table 3.3 Colburn (1933) Single Phase Heat Transfer Results

Run Number	Prandtl Number	Reynolds Number	Experimental Nusselt Number	Colburn (1933) Nusselt Number	% Deviation $(Nu_{exp}-Nu_{cal})/Nu_{exp}$
9A	6.39	14929	113.8	93.2	18.1
8401A	6.38	20579	150.1	120.4	19.6
8402 A	6.31	16121	119.8	98.7	17.6
8406A	6.23	10628	84.6	70.4	16.8
8407A	6.24	12749	98.8	81.5	17.5
8421 A	6.14	10507	82.3	69.4	15.6
8422 A	6.13	11026	86.5	72.1	16.6
8423 A	6.17	11645	90.5	75.5	16.6
8424 A	6.22	12154	93.1	78.4	15.8
8425 A	6.2	12934	99.1	82.3	17.0
8426 A	6.21	13552	95.1	85.4	10.2

was set as the basis for determining valid data. All data from this correlation fell within this deviation band.

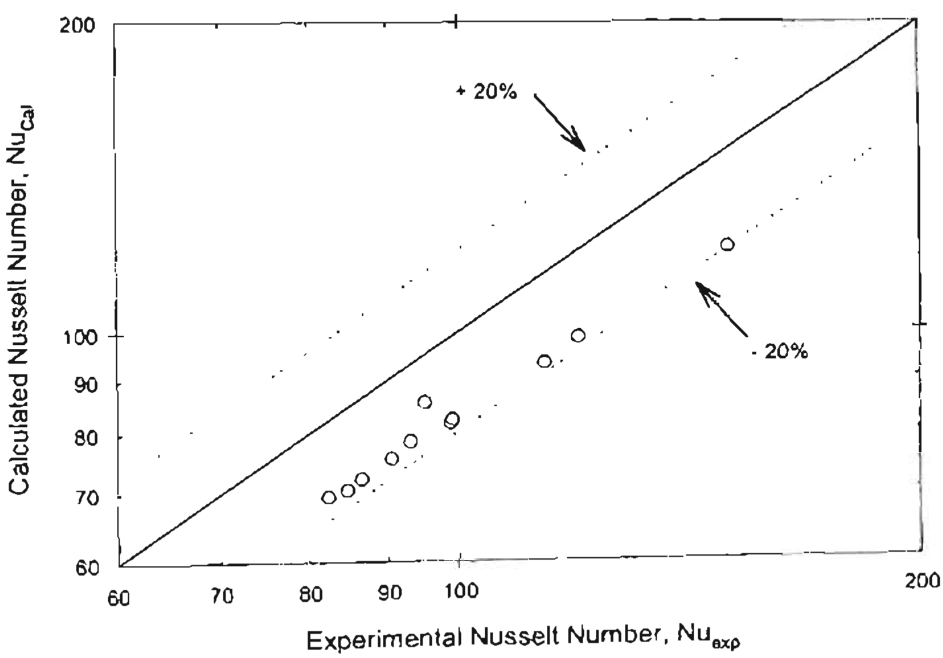


Figure 3.12 Comparison of Single Phase Experimental Nusselt Numbers with those Predicted by Colburn's (1933) Correlation

3.6.3 Sieder & Tate (1936)

A total of 11 points fell within the limitations of the Sieder & Tate (1936) correlation requirements. The results can be seen in Table 3.4 and Figure 3.13. Using this correlation, a minimum deviation of 9.7% and a maximum of 19.4% were obtained. Maximum Reynolds number was 20,579 and minimum Reynolds number was 10,507. The results posted are within tolerable ranges, but for single-phase, the results produced by this correlation, and Coburn's (1933) correlation are not accurate enough.

Sieder and Tate (1936) correlation:

$$Nu = 0.023\,\mathrm{Re}^{0.8}\,\mathrm{Pr}^{1/3}(\mu_b/\mu_w)^{0.14} \tag{3.16}$$

where $\mathrm{Re} \geq 10{,}000,\ 0.7 \leq \mathrm{Pr} \leq 16{,}700$

Table 3.4 Sieder and Tate (1936) Single Phase Heat Transfer Results

Run Number	Prandtl Number	Reynolds Number	Experimental Nusselt Number	Sieder & Tate (1936) Nusselt Number	% Deviation $(Nu_{exp}-Nu_{cal})/Nu_{exp}$
9A	6.39	14929	113.8	93.7	17.7
8401A	6.38	20579	150.1	121.0	19.4
8402 A	6.31	16121	119.8	99.2	17.2
8406A	6.23	10628	84.6	70.8	16.4
8407A	6.24	12749	98.8	81.9	17.1
8421 A	6.14	10507	82.3	69.8	15.2
8422 A	6.13	11026	86.5	72.5	16.2
8423 A	6.17	11645	90.5	75.9	16.1
8424 A	6.22	12154	93.1	78.8	15.4
8425 A	6.2	12934	99.1	82.7	16.6
8426 A	6.21	13552	95.1	85.9	9.7

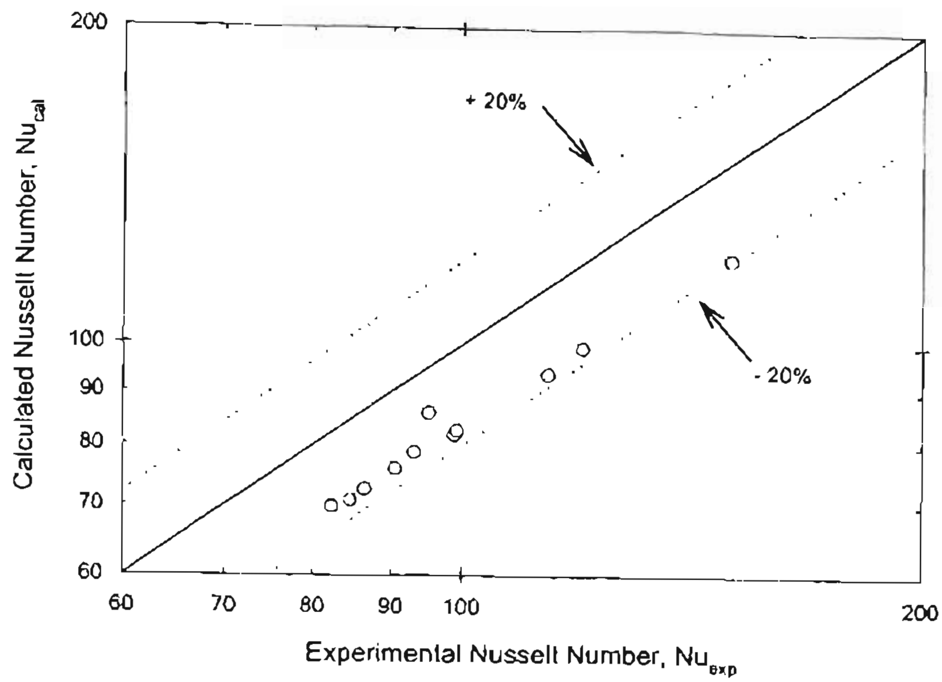


Figure 3.13 Comparison of Single Phase Experimental Nusselt Numbers with those Predicted by Sieder and Tate's (1936) Correlation

3.6.4 Gnielinski (1976)

The majority of the data points, 26, fell within the correlation parameters for both of Gnielinski's correlations. Gnielinski (1976) [1] produced the best results of any of the correlations used to determine single-phase Nusselt numbers. All data points fell within the ±20% deviation band and many of those points resided well within a ±10% deviation band. This correlation is considered among the scientific community to be one of the leading single-phase correlations in the open literature. This being the case, the fact that the results are well within a tolerable deviation band, the test setup can be assumed accurate. The results for this correlation can be found in Tables 3.5 and 3.6, and Figures 3.14 and 3.15.

Gnielinski [1] (1976) correlation:

$$Nu = \frac{(c_f/2)(\text{Re}-1000)\text{Pr}}{1+12.7(c_f/2)^{1/2}(\text{Pr}^{2/3}-1)} \tag{3.17}$$

where $\frac{1}{\sqrt{c_f}} = 1.58\ln \text{Re} - 3.28$; Filonenko Correlation

$0.5 \le \text{Pr} \le 2{,}000,\ 2{,}300 \le \text{Re} \le 5\times10^6$

Gnielinski [3] (1976) correlation:

$$Nu = 0.012(\text{Re}^{0.87}-280)\text{Pr}^{0.4} \tag{3.18}$$

where $1.5 \le \text{Pr} \le 500,\ 3{,}000 \le \text{Re} \le 1\times10^6$

3.6.5 Ghajar & Tam (1994)

A total of 17 points were used for the correlation created by Ghajar & Tam (1994). The results for these test runs can be found in Table 3.7 and Figure 3.16. Ghajar & Tam (1994) presented a correlation, which predicted the single-phase results to within 13.2% maximum deviation. The deviation range was from 2.9% to 13.2%.

Ghajar and Tam (1994) correlation:

$$Nu = 0.023\text{Re}^{0.8}\text{Pr}^{0.385}(x/D_i)^{-0.0054}(\mu_b/\mu_w)^{0.14} \tag{3.19}$$

where $3 \le x/D_i \le 192,\ 7000 \le \text{Re} \le 49000$

$4 \le \text{Pr} \le 34,\ 1.1 \le \mu_b/\mu_w \le 1.7$

After comparison of all the single-phase heat transfer data, it can be seen that all data points fell within the desired ±20% deviation band. This being the case for all five correlations, the test setup is assumed to be performing as expected and that data taken from it in single-phase situations is accurate to an expected degree.

Table 3.5 Gnielinski (1976) [1] Single Phase Heat Transfer Results

Run Number	Prandtl Number	Reynolds Number	Experimental Nusselt Number	Gnielinski (1976) [1] Nusselt Number	% Deviation $(Nu_{exp}-Nu_{cal})/Nu_{exp}$
9A	6.39	14929	113.8	110.4	3.0
8400A	6.32	8365	68.1	64.8	5.0
8401A	6.38	20579	150.1	146.6	2.3
8402 A	6.31	16121	119.8	117.7	1.8
8405 A	6.29	5842	47.7	45.6	4.5
8406A	6.23	10628	84.6	80.5	4.9
8407A	6.24	12749	98.8	95.0	3.9
8408 A	6.18	3053	25.1	22.0	12.2
8409 A	6.18	2716	21.5	18.9	12.2
8410 A	6.19	2951	23.3	21.1	9.3
8411 A	6.18	3344	22.9	24.6	-7.5
8412 A	6.13	3745	24.1	28.1	-16.5
8413 A	6.24	4655	36.7	36.0	2.0
8414 A	6.23	5122	40.9	39.7	3.0
8415 A	6.26	6634	52.9	51.6	2.4
8416 A	6.2	7221	58.5	55.9	4.4
8417 A	6.22	7702	61.9	59.5	3.8
8418 A	6.25	8368	66.7	64.5	3.3
8419 A	6.18	9156	73.5	69.9	4.9
8420 A	6.22	9676	76.7	73.7	3.9
8421 A	6.14	10507	82.3	79.2	3.8
8422 A	6.13	11026	86.5	82.7	4.4
8423 A	6.17	11645	90.5	87.1	3.7
8424 A	6.22	12154	93.1	90.8	2.4
8425 A	6.2	12934	99.1	96.0	3.2
8426 A	6.21	13552	95.1	100.2	-5.3

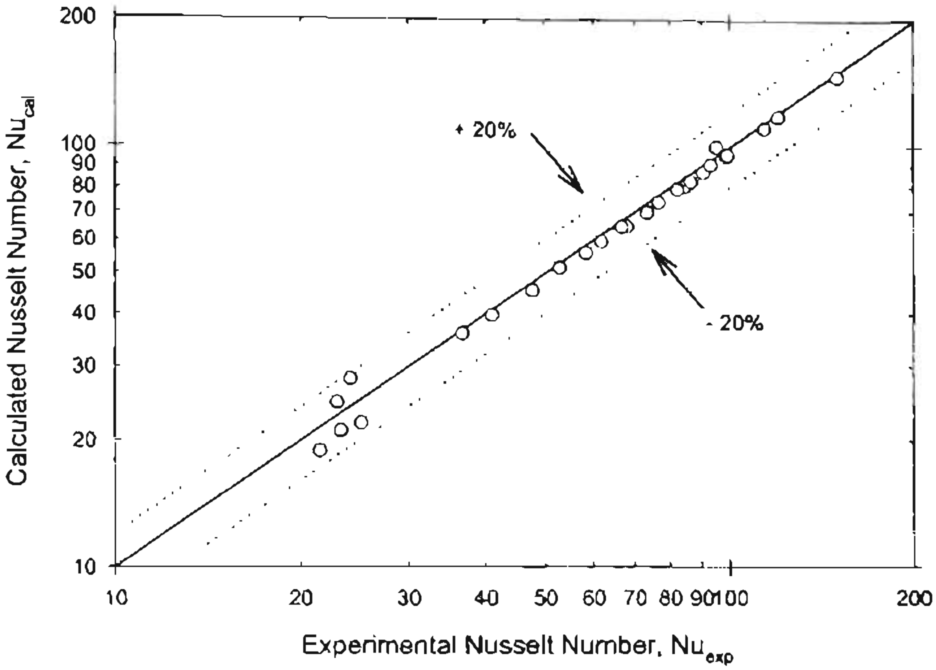


Figure 3.14 Comparison of Single Phase Experimental Nusselt Numbers with those Predicted by Gnielinski's (1976) [1] Correlation

Table 3.6 Gnielinski (1976) [3] Single Phase Heat Transfer Results

Run Number	Prandtl Number	Reynolds Number	Experimental Nusselt Number	Gnielinski (1976) [3] Nusselt Number	% Deviation $(Nu_{exp}-Nu_{cal})/Nu_{exp}$
9A	6.39	14929	113.8	100.8	11.4
8400A	6.32	8365	68.1	57.8	15.1
8401A	6.38	20579	150.1	135.4	9.8
8402 A	6.31	16121	119.8	107.7	10.1
8405 A	6.29	5842	47.7	40.4	15.4
8406A	6.23	10628	84.6	72.5	14.4
8407A	6.24	12749	98.8	86.1	12.9
8408 A	6.18	3053	25.1	19.8	21.1
8411 A	6.18	3344	22.9	22.0	4.1
8412 A	6.13	3745	24.1	24.9	-3.4
8413 A	6.24	4655	36.7	31.8	13.4
8414 A	6.23	5122	41.0	35.1	14.3
8415 A	6.26	6634	52.9	45.8	13.4
8416 A	6.2	7221	58.5	49.7	15.1
8417 A	6.22	7702	61.9	53.0	14.4
8418 A	6.25	8368	66.7	57.6	13.7
8419 A	6.18	9156	73.5	62.6	14.9
8420 A	6.22	9676	76.7	66.2	13.7
8421 A	6.14	10507	82.3	71.2	13.4
8422 A	6.13	11026	86.5	74.6	13.8
8423 A	6.17	11645	90.5	78.7	13.0
8424 A	6.22	12154	93.1	82.2	11.7
8425 A	6.2	12934	99.1	87.1	12.2
8426 A	6.21	13552	95.1	91.0	4.3

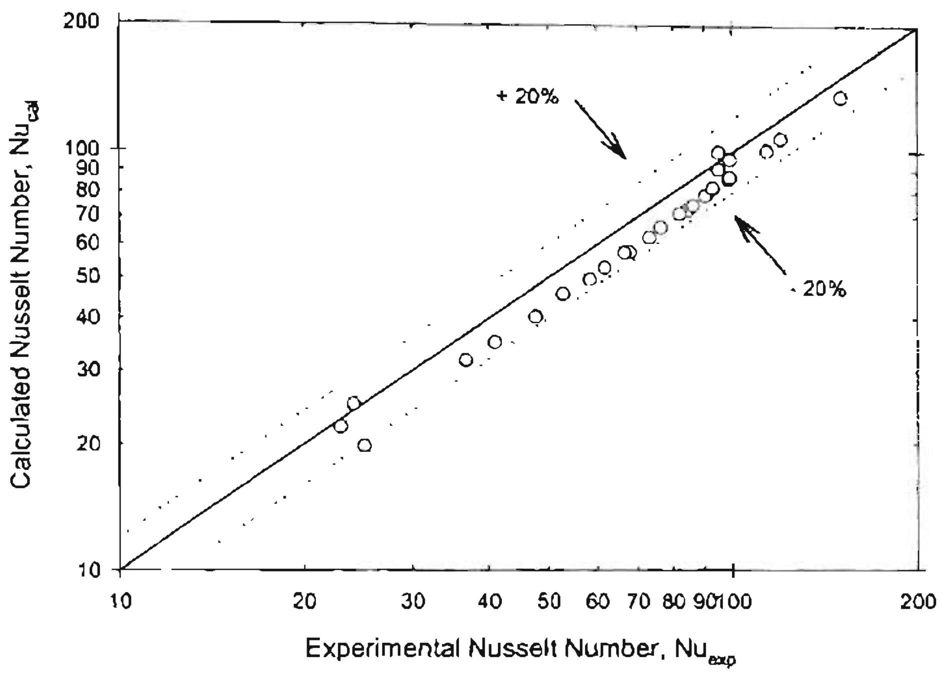


Figure 3.15 Comparison of Single Phase Experimental Nusselt Numbers with those Predicted by Gnielinski's (1976) [3] Correlation

Table 3.7 Ghajar & Tam (1994) Single Phase Heat Transfer Results

Run Number	Prandtl Number	Reynolds Number	Experimental Nusselt Number	Ghajar & Tam (1994) Nusselt Number	% Deviation $(Nu_{exp}-Nu_{cal})/Nu_{exp}$
9A	6.39	14929	113.8	101.0	11.2
8400A	6.32	8365	68.1	63.5	6.8
8401A	6.38	20579	150.1	130.3	13.2
8402 A	6.31	16121	119.8	107.0	10.7
8406A	6.23	10628	84.6	76.4	9.7
8407A	6.24	12749	98.8	88.4	10.6
8416 A	6.2	7221	58.5	55.9	4.4
8417 A	6.22	7702	61.9	58.9	4.8
8418 A	6.25	8368	66.7	63.0	5.6
8419 A	6.18	9156	73.5	67.5	8.2
8420 A	6.22	9676	76.7	70.7	7.9
8421 A	6.14	10507	82.3	75.2	8.6
8422 A	6.13	11026	86.5	78.1	9.6
8423 A	6.17	11645	90.5	81.8	9.6
8424 A	6.22	12154	93.1	84.7	9.0
8425 A	6.2	12934	99.1	89.0	10.2
8426 A	6.21	13552	95.1	92.4	2.9

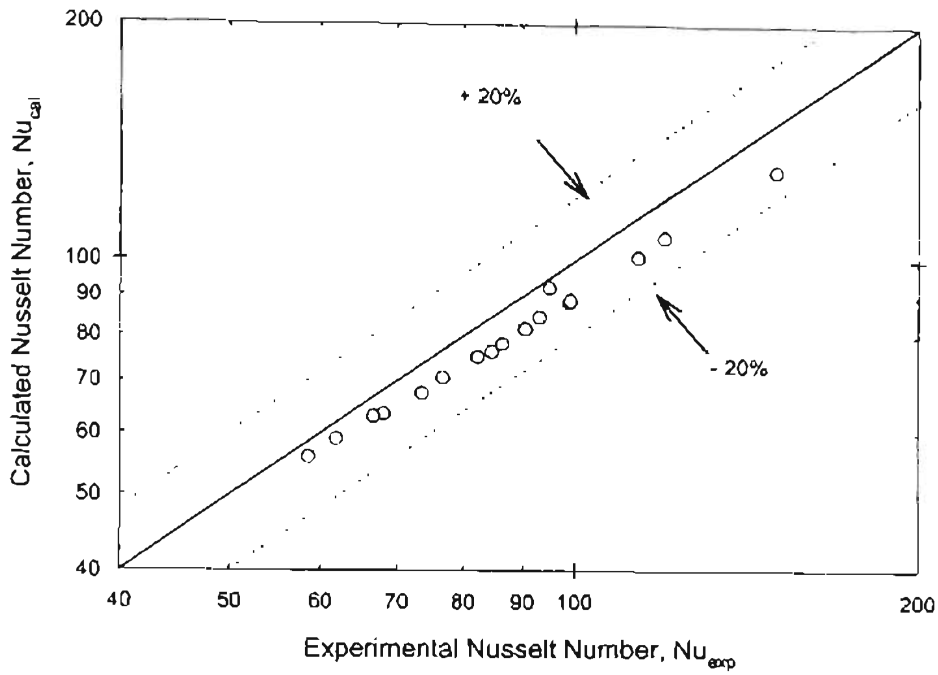


Figure 3.16 Comparison of Single Phase Experimental Nusselt Numbers with those Predicted by Ghajar and Tam's (1994) Correlation

3.7 Slug Flow Comparison

3.7.1 Slug Flow Data

A series of two-phase, air-water, slug flow test runs were performed after the single-phase experiments were completed, for comparison against the correlation presented by Kim and Ghajar (2002) and the existing data of Trimble *et al.* (2002). A great deal of research has been performed on air-water slug flow through a horizontal pipe by Kim (2000), Kim and Ghajar (2002), Trimble (2001), and Trimble *et al.*(2002), and the data is readily available for comparison. Matching the data of the current study with that of above-mentioned references would support the validity of the two-phase data produced by the current test setup.

Twelve data points for horizontal, air-water, slug flow were measured. Reynolds numbers ranged from a maximum of 27,816 to a minimum of 7,510 for water, and from a maximum of 2,994 to a minimum of 1,043 for the air. Results can be seen in Table 3.8.

Table 3.8 Horizontal, Air-Water, Slug Flow Heat Transfer Measurement Results

Run Number	Re_{SL} (Water)	Re_{SG} (Air)	h_{TP} (BTU/(ft^2-hr-°F))
8448	8361	2407	280
8449	26748	1646	866
8450	27816	2036	926
8451	14611	1650	481
8452	13637	2994	439
8453	27540	1428	890
8454	7510	1043	250
8455	25445	1634	850
8456	13220	1839	443
8457	10192	2985	344
8458	13589	2392	458
8460	4279	1781	183

3.7.2 Comparison with the Raw Data of Kim (2000) and Trimble (2001)

Data from Trimble (2001) and Kim (2000) was used in conjunction with the slug flow data measured for this experiment to make a comparison of the accuracy of the current data. The twelve data points were compared to a table found in Trimble (2001) that compared the data of Kim (2000) with the then current data of Trimble (2001) using the overall heat transfer coefficients and the superficial liquid and gas Reynolds numbers (Re_{SL} and Re_{SG}). Superficial Reynolds numbers are calculated by assuming the entire medium is filled with the specific fluid in consideration. If the liquid superficial Reynolds number is desired, then the calculation is done based on a pipe filled with water. The same is done for the air superficial Reynolds number.

The results of this comparison are listed in Table 3.9. This is a straightforward comparison of the work of Kim (2000) and Trimble (2001). This data is not a complete comparison of all the available data, but rather a small comparison of random runs to ensure that the data is both repeatable and comparable. Should the data taken in all three experiments agree with one another, then that would be proof enough that the data taken in this study is, repeatable, accurate, and reliable.

Table 3.9 Comparison of Kim (2000) , Trimble (2001), and Current Study Data

Source	Run Number	Re_{SL}	Re_{SG}	h_{TP} (BTU/(ft^2-hr-°F)	% Difference		
					Re_{SL}	Re_{SG}	h_{TP}
Kim	7147	4056	927	212			
Trimble	8318	4428	2230	204	-9.2	-140.6	3.8
Current	8460	4279	1781	167.63	-5.0	-92.1	20.9
Kim	7146	4186	1687	201			
Trimble	8315	4391	2202	343.7	-4.9	-30.5	-71.0
Current	8460	4279	1781	167.63	-2.2	-5.6	16.6
Kim	7110	10093	3120	385			
Trimble	8316	10253	2454	401	-1.6	21.3	-4.2
Current	8457	10192	2985	360.45	-1.0	4.3	6.4
Kim	7116	13240	2532	467			
Trimble	8322	13452	2234	498	-1.6	11.8	-6.6
Current	8458	13589	2392	472.13	-2.6	5.5	-1.1
Kim	7116	13240	2532	467			
Trimble	8331	14788	2064	458	-11.7	18.5	1.9
Current	8451	14611	1650	499.35	-10.4	34.8	-6.9
Kim	7107	24429	3813	758			
Trimble	8335	22284	2652	757	8.8	30.4	0.1
Current	8459	21593	2688	745	11.6	29.5	1.8

Table 3.9 shows that of the slug flow test runs performed during this study, the runs that matched those of Kim (2000) and Trimble (2001) fell within a percent difference ranging from a maximum of 11.6% and a minimum of –1.0% for liquid Reynolds numbers, and a maximum of –92.1% and a minimum of 4.3% for gas Reynolds numbers. Heat transfer coefficients had a maximum percent difference of 20.9% and a

minimum of −1.1%. When comparing the data of Trimble (2001) against the data of Kim (2000), it can be seen that the current study matched if not exceeded the comparisons made by Trimble (2001). Percent differences for the air Reynolds numbers deviate more than that of the water Reynolds numbers because of the difficulty in accurately gauging and controlling the air flow. Fluctuations in compressor cycling, and difficulty in setting the pin needle valve used to control the air flow can be contributed to the error in these comparisons. Because the airflow does not weigh as heavily as the water flow in the determination of the heat transfer coefficient, the deviation can be high for the airflow Reynolds number and the heat transfer coefficient can still be matched. The liquid Reynolds number is a much more vital component of the heat transfer mechanism in air-water slug flow and is able to be controlled much easier due to the constant flow of the centrifugal pump. This allows more accurate liquid Reynolds numbers to be maintained than the air.

From the straightforward comparison made above, it can be seen that the two-phase flow results are reproducible and accurate.

3.7.3 Comparison of Current Data with Kim and Ghajar (2002) Correlation

The paper of Kim and Ghajar (2002) proposed a two-phase flow correlation that could predict slug flow heat transfer properties accurately, see Table 2.6. This correlation was used in conjunction with the straight up comparison of the data in Table 3.9 to further ensure that the 12 data points were accurate. Listed in Table 3.10 are the results of those calculations.

Table 3.10 Kim & Ghajar (2002) Slug Flow Data Correlation Results

Run Number	Re_{SL}	Re_{SG}	Current Study h_{TP} (BTU/(ft²-hr-°F)	Kim & Ghajar (2002) (BTU/(ft²-hr-°F)	% Deviation $(h_{TP}-h_{TPCAL})/h_{TP}$	% RMS
8448	8361	2407	267	363	-36%	13%
8449	26748	1646	867	789	9%	1%
8450	27816	2036	926	827	11%	1%
8451	14611	1650	482	505	-5%	0%
8452	13637	2994	439	520	-18%	3%
8453	27540	1428	890	794	11%	1%
8454	7510	1043	251	296	-18%	3%
8455	25445	1634	851	734	14%	2%
8456	13220	1839	443	468	-6%	0%
8457	10192	2985	344	419	-22%	5%
8458	13589	2392	458	491	-7%	1%
8460	4279	1781	162	224	-38%	15%
AVG	16079	1986	532	536	-9%	4%

Of the twelve data points taken, 83% fell within a 30% deviation band, and 75% fell within a 20% deviation band. The maximum deviation was –38% mean with a 15% rms value, and the minimum was –5% mean with a 0% rms. Average deviation values can be found in Table 3.10. They are a mean deviation of –9% with a 4% rms deviation. The correlation of Kim and Ghajar (2002) reveals that the slug flow data taken during the current study is predictable using given correlations and can be deemed as accurate and beneficial to the study of two-phase flow. Evidence can be seen in Figure 3.17. This figure shows the data points falling within a ±20% deviation band.

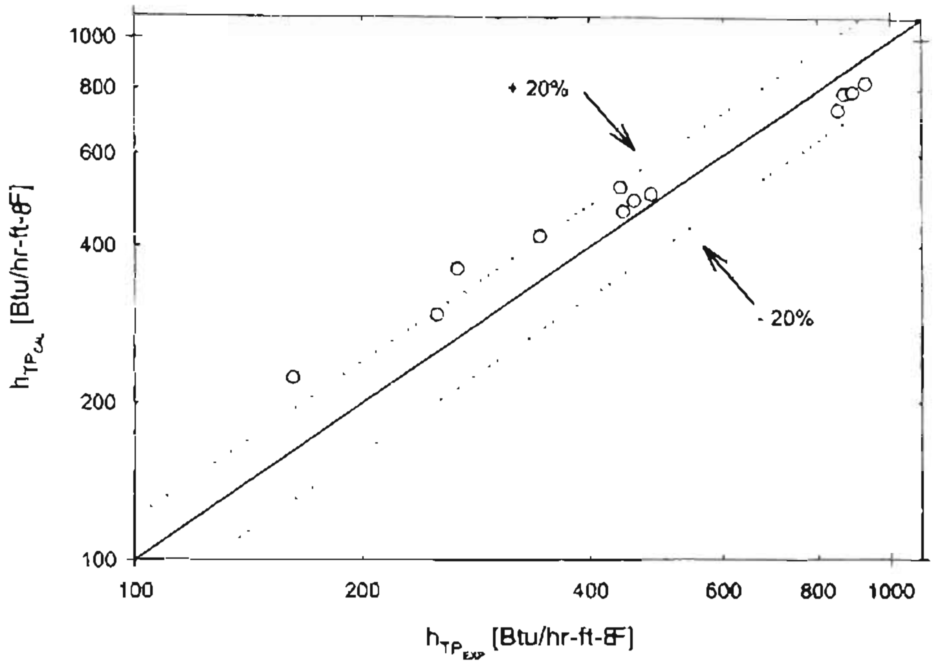


Figure 3.17 Experimental Heat Transfer Coefficient Comparison with those of Kim & Ghajar (2002) Correlation for Two-Phase, Slug Flow, Heat Transfer

CHAPTER IV

RESULTS AND DISCUSSION

This chapter discusses the initial findings of the experiment, the methodology of calculating the overall heat transfer coefficient, the heat transfer results of the current investigation for horizontal and inclined annular flow, and new constants for annular flow for use with the two-phase Kim and Ghajar (2002) correlation. The results of the air-water, two phase heat transfer data experiencing an annular flow pattern in a horizontal and slightly inclined pipe, at steady state with a uniform wall heat flux are presented. A total of 88 data points were measured, 30 data points at the horizontal position, 29 at the 5-degree position, and 29 at the 7-degree position. Horizontal pipe results were tabulated and compared with the annular flow horizontal pipe data of Pletcher (1966), and the horizontal slug flow data of Kim and Ghajar (2002) and Trimble *et al.* (2002). The 5-degree and 7-degree inclined pipe positions were also tabulated, and were compared against each other, the horizontal data, and the inclined slug flow data of Trimble *et al.* (2002). The characteristics of the overall heat transfer coefficient (h_{TP}) were studied as the flow rates of the air and water were varied, along with the inclination of the pipe. Through this research, a better understanding of the characteristics of two-phase, air-water, annular flow heat transfer is to be gained.

4.1 Initial Results

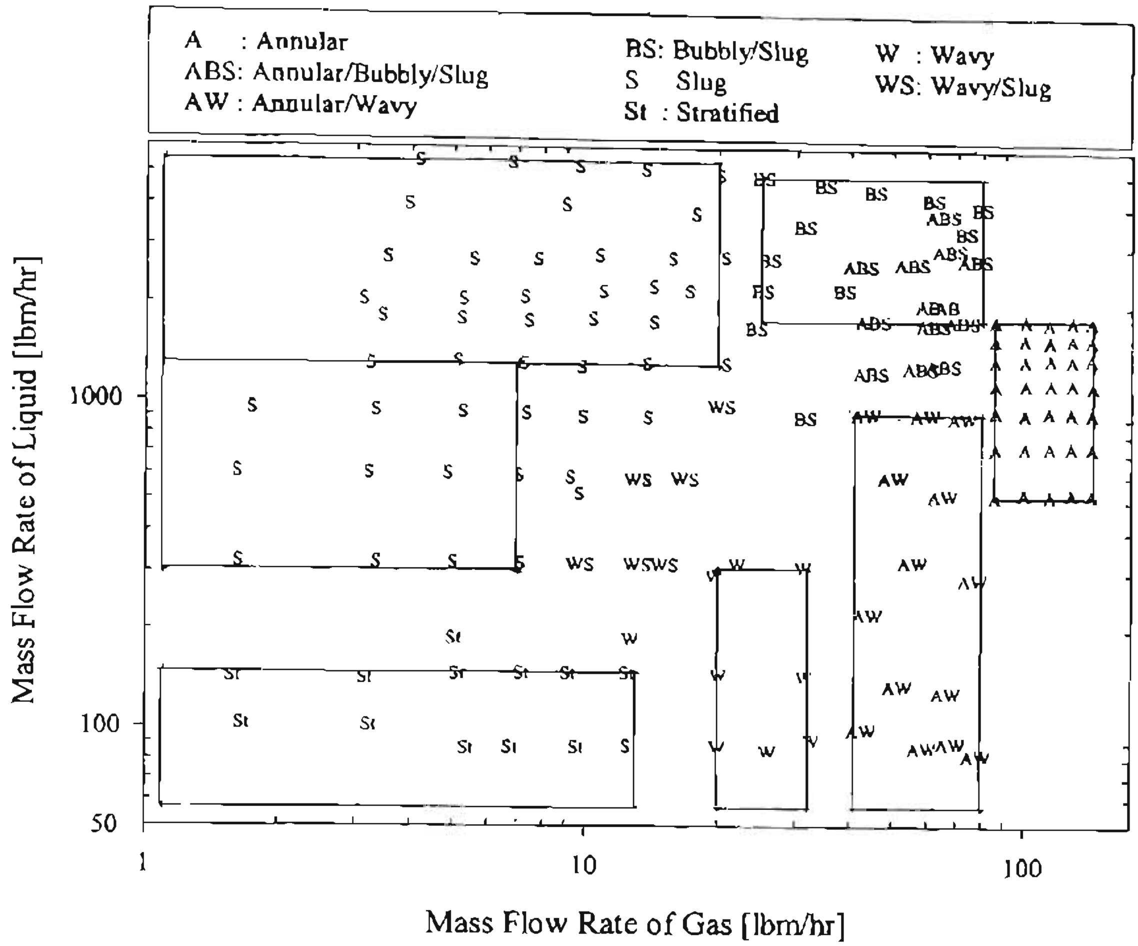
4.1.1 Flow Pattern Mapping

The determination of flow pattern was done by comparison against the data of Kim and Ghajar (2002), see Figures 2.1, 2.2 and Table 2.1. The mass flow rates used by Kim and Ghajar (2002) were used to plot areas of specific flow patterns by using the information provided by Taitel and Dukler (1976). This graph was used to determine if the flow patterns for these tests were in the appropriate ranges. The ranges for the current experimental data were slightly larger than the ranges used by Kim and Ghajar (2002), and can be seen in the Revised Figure 2.1. Figure 2.1 was modified to show the pure annular flow area on the map, by Samit Nabar, another Masters Student working on this project. These ranges were from 87 to 118 lbm/hr for the gas (air) and 438 to 1266 lbm/hr for the liquid (water).

Visual confirmations that the fluids were acting in an annular flow pattern were made during each test run. This was to ensure that the pattern remained constant through the test section and did not collapse before the outlet of the test pipe. Through all 88 test runs, the pattern did not collapse near the exit of the pipe. All 88 test runs remained consistently annular.

4.1.2 Heat Balance

Initial results of the experiment yielded results that were unexpected. Such results were marred by two phenomenon. The first area of concern was the representative values of the heat balance performed for each test. During the initial testing of the apparatus,



Revised Figure 2.1 Observed Flow Pattern Data versus the Corresponding Mass Flow Rates of Air and Water, Kim and Ghajar (2002)

single-phase data was measured using water as the test fluid. A heat balance was performed for each of these tests with a maximum error of 11.5%, a minimum of 0.68% and an average heat balance error of 4.2%. This result concluded that no large amount of heat was being lost to the environment and that no excess source of heat was being added to the system from an unknown source. Slug flow data was also measured for further justification of the test setup. As with the single-phase data, after each data point measurement a heat balance error calculation was performed. The results were typical to the results that were experienced during the single-phase experiments and the balance resulted in a maximum error of 10.4%, a minimum error of 6.9%, and an average heat balance error of 8.0%. Having gathered two data sets, annular flow heat balance results were expected to be similar to those of the single phase and slug flow trials. The minimum heat balance error result of the first annular test run was 16%, and the next few ranged from 18% to 32%. This large and unexpected increase in heat balance error was a source for concern since it was unknown where the heat was being lost.

The loss was found to be accredited to the entrainment of water particles in the core of the flow. These droplets of water carry heat and are termed as immeasurable heat. Pletcher (1966) experienced the same results and accommodated for them in a rather complex manner. Pletcher (1966) went to greater depths to solve the entrainment heat balance error by calculating apparent specific heats, the humidity of the gas exiting the system, and the total pressure at which the flow was operating, in order to accurately predict the amount of heat loss from the system to the gas core. The calculations for this experiment did not exercise the depth or detail that Pletcher (1966) did because this measurement is not vital to the results of the tests. It is, however, important in the aspect that it acts as a flag, dictating whether or not the tests were behaving in an expected manner and not losing vital heat to the environment.

To solve this problem in a simple manner, a new heat balance equation was formulated. The new formula contained the original formula, seen in Equation (4.1), plus a new term that accounted for the difference in enthalpy rise between the inlet and outlet of the test section. This new term can be seen in Equation (4.2).

$$q_{balance} = \dot{m}_{water} \cdot c_{p,Water}(T_{out} - T_{in}) + \dot{m}_{air} \cdot c_{p,air}(T_{out} - T_{in}) \tag{4.1}$$

$$q_{balance} = \dot{m}_{water}\, c_{p,Water}(T_{out} - T_{in}) + \dot{m}_{air} \cdot c_{p,air}(T_{out} - T_{in}) + 2 \cdot \dot{m}_{air}(i_{air,1} - i_{air,2}) \tag{4.2}$$

Equation (4.1) calculates the total heat flux in the system by summing all of the heat fluxes added to the system. The total heat flux is composed of the heat flux through the water, the heat flux through the air, and the heat flux from the evaporation and entrainment of the water in the air-stream. The heat flux of the water is determined by multiplying the mass flow rate of the water and the specific heat of the water with the change in bulk temperature. The heat flux of the air is calculated in the same manner only with the properties of air. The missing element for the annular flow is the amount of entrainment and evaporation from the liquid to the gas and the heat associated with the process. To accommodate this loss, the change in enthalpy was multiplied by the mass flow rate of the air. This would give an approximation to the amount of heat being transferred due to evaporation and entrainment.

To better explain the method used to define the heat balance, Figure 4.1 was created. From this figure, it can be seen that the terms of Equation (4.2) coincide with the terms of the different fluxes for water, air, and evaporation. From this figure, it can be seen that the air heat flux, the water heat flux, and the evaporation heat flux are all added together to obtain the total heat flux of the system. The evaporation occurs in two unique regions, the top of the annulus and the bottom of the annulus. This was accounted for by multiplying the evaporation term of Equation (4.2) by a factor of 2. Though this is not the precise manner which Pletcher (1966) used to calculate his heat balance, but it does provide a substantial calculation and result in which to monitor the heat added to the system.

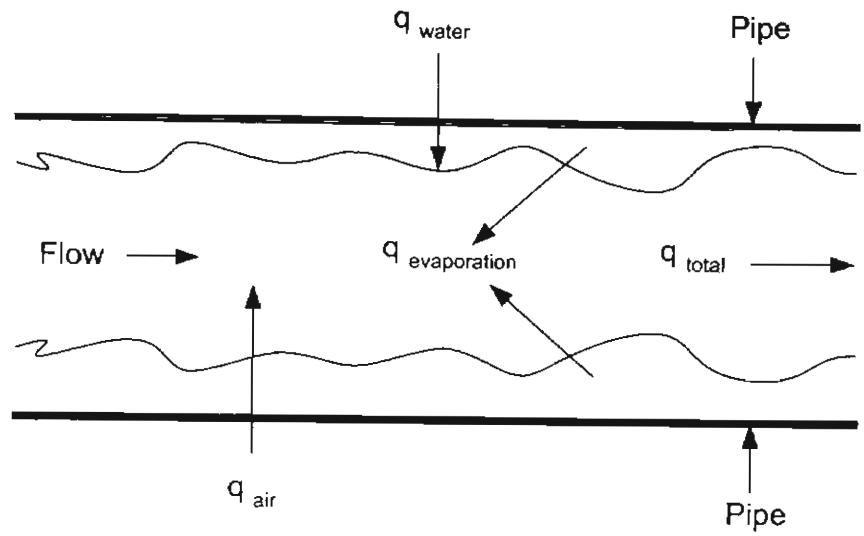


Figure 4.1 Heat Balance for Annular Flow

The results were acceptable, bringing the heat balance back to an average value of 8.7% with a maximum value of 14.7% and a minimum value of 0.1%.

4.1.3 Heat Transfer Coefficient

The second phenomenon experienced during the span of the initial experiments, had to do with the results of the local heat transfer coefficients at the last three stations. These stations results became unstable as tests were performed. This was evident through the nature of the values that were produced. These values were not physically possible, sometimes becoming incredibly large or becoming negative. This behavior can be contributed to what Pletcher (1966) experienced and termed as "end effects".

End effects are a result of the change in temperature at the end of the pipe being small when compared against the bulk temperature of the fluid. Typical results of a single-phase experiment comparing the bulk temperatures and the wall temperatures should show the bulk temperature line rising at a gentle slope, while the wall temperature line rises in a sharp curve to eventually level out into a parallel line with the bulk temperature line. An example of this can be seen in Figure 4.2. Two-phase annular flow does not share this behavior Instead a drop in the temperature at the last few stations can be observed. Figure 4.3 shows the occurrence as was experienced by Pletcher (1966). Similar results were observed during the current experimentation. Figure 4.4 shows a temperature profile that was witnessed during one of the 88 experimental runs performed during the current study. The top two lines are the calculated inside pipe wall temperature and the measured outside pipe wall temperatures and the bottom line is the bulk temperature profile. The equation used for the bulk temperature calculation is given in Equation (4.3). The first section of the profile is the developing region, similar to the developing region in Figure 4.2. However, immediately after the profile develops it begins to decrease in slope instead of leveling off and becoming a parallel line with regards to the bulk temperature profile. At the end of the inside and outside wall temperature profiles, the distance between it and the bulk temperature profile line decreases even further revealing the presence of the end effects. Though the end effects are not as significant as those measured by Pletcher (1966), the same end effect phenomenon was experienced. These effects often lead to erroneous heat transfer coefficient results occurring at the last three stations (see Table 4.1).

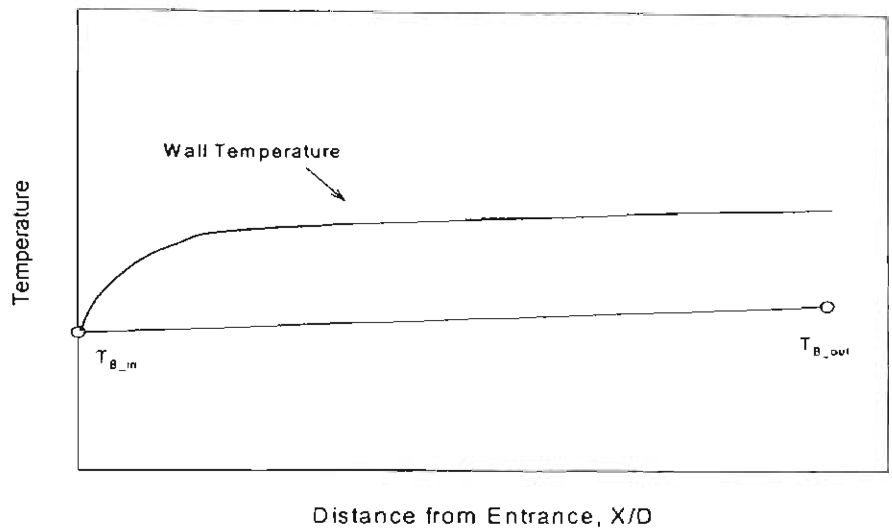


Figure 4.2 Characteristic Wall and Bulk Temperature Variation for Uniform Heat Flux

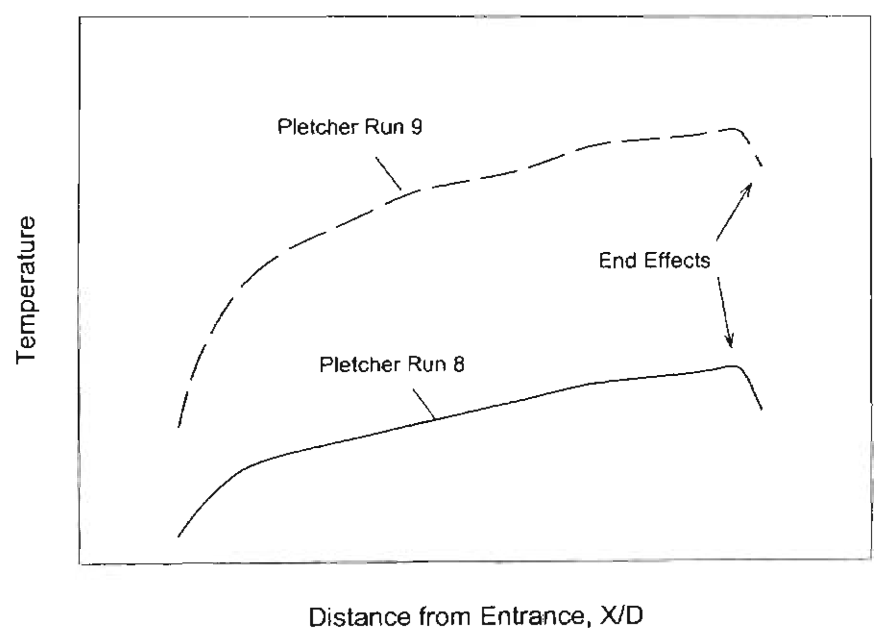


Figure 4.3 Pletcher (1966) Wall Temperatures with "End Effects"

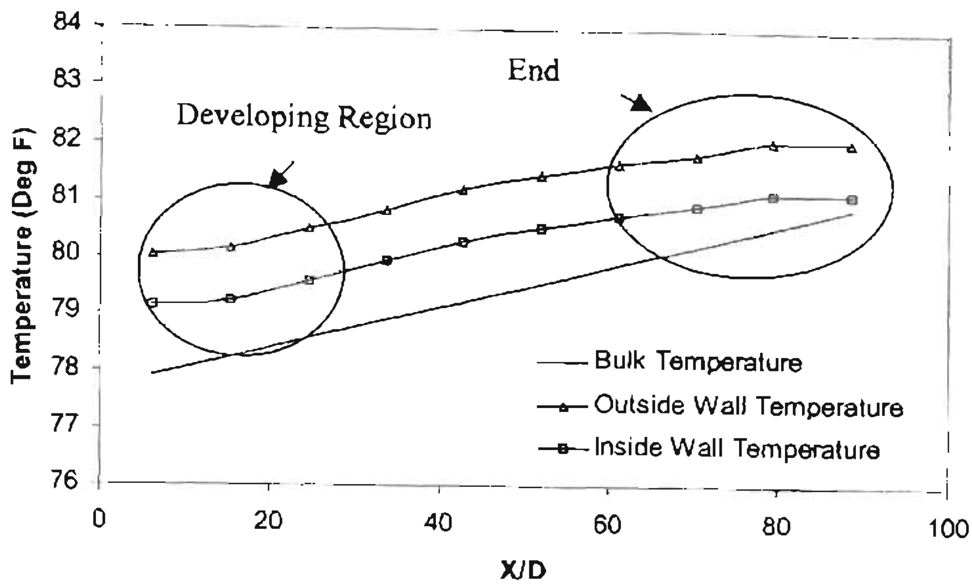


Figure 4.4 Bulk and Wall Temperature Variations Showing "End Effects"

$$T_b = T_{in} + (T_{out} - T_{in})\, X/L \qquad (4.3)$$

Where

T_b	=	bulk temperature
T_{in}	=	bulk inlet temperature
T_{out}	=	bulk outlet temperature
X	=	distance from the pipe inlet to the thermocouple station
L	=	total length of the test section

The equation that is used to determine the heat transfer coefficient, h_{TP}, is given in Equation (4.4). From this equation, it can be seen why the difference between the bulk and wall temperatures is so important. If the bulk and wall temperature difference grows large, the value of the heat transfer coefficient decreases. Should the bulk and wall temperature difference value become small, the heat transfer coefficient could become unrealistically large. In the extreme cases, the values became large and negative because the value of the wall temperature had become less than the bulk temperature. An example of this can be seen in Table 4.1. This is an unrealistic result and so therefore, the last three stations, 8, 9, and 10, were ignored while averaging the overall heat transfer coefficient values because they exhibited the largest amount of variance in their respective values of the local heat transfer coefficients

$$h_i = \dot{q}_i'' / (T_{wi} - T_b) \tag{4.4}$$

where

h_i	=	local peripheral inside heat transfer coefficient
$\dot{q}_i''$	=	local peripheral inside wall heat flux
T_{wi}	=	local inside wall temperature
T_b	=	bulk fluid temperature at the thermocouple station

Table 4.1 Unrealistic Peripheral Heat Transfer Coefficient Values

Peripheral Heat Transfer Coefficient, BTU/(SQ.FT-HR-F)										
Station	1	2	3	4	5	6	7	8	9	10
Position										
Top	58	56	66	60	62	60	62	60	60	64
Right	101	174	131	165	147	178	166	229	215	229
Bottom	831	1038	1234	1394	1492	2096	3055	7248	**-47926**	**-2763**
Left	153	183	201	199	203	206	196	165	245	231

Pletcher (1966) corrected this phenomenon, by extrapolating the data as though no end effects existed. Seeing the similarities in the observation of end effects occurring during the current experiment and the experiment of Pletcher (1966), supports the claim that the data taken during the current experiment is accurate.

4.1.4 Circumferential Heat Transfer Coefficient Variance

Initial horizontal data displayed a unique pattern of local two-phase heat transfer coefficient (h_{TP}) values. Local h_{TP} values at the top of the pipe were consistently lower than the left and right side, which were often very similar in value, and the bottom value was the highest of the four positions. Table 4.2 displays the results of the local h_{TP} values for Run # 8477.

Table 4.2 Peripheral Heat Transfer Coefficient Values

Peripheral Heat Transfer Coefficient, BTU/(SQ.FT-HR-F)										
Station	1	2	3	4	5	6	7	8	9	10
Position										
Top	219	137	169	160	165	160	168	166	170	179
Right	230	314	274	333	299	335	328	435	423	434
Bottom	1245	1418	1497	1401	1347	1488	1683	2178	2523	5561
Left	435	352	402	374	376	388	381	339	441	434

This can be attributed to gravitational effects pulling more of the water mass to the bottom of the annulus, causing a thinning of the water at the top and at the sides of the pipe. Pictures were taken that help support this claim. Figure 4.5 shows a horizontal air-water annular test run where this occurrence is evident. The dark bands at the top and bottom are the shadows of the water. The band at the top of the picture is thin because there is little water traveling across the top of the pipe. The bottom has a much more prominent black band. This black band is the bulk of the water flowing across the pipe surface. The white area in the middle of the pipe is the gas core.

Because water is a better conductor of heat than air, wherever the most water is located, the heat transfer coefficient is higher. In this case, since the bulk of the water is at the bottom of the flow, the bottom heat transfer coefficient results should be larger than the sides or the top of the pipe. Table 4.2 proves this, and concludes that the bottom of the pipe will be the dominant heat transfer location.

Figure 4.5 Annular Flow Pattern

4.1.5 Methodology of Overall Heat Transfer Coefficient Averaging

One of the most important sections of the results sheet produced by the computer program Rht02m (Chapter III, Section 3.5) is the grid of local heat transfer coefficients. The program calculates four coefficients for each station on the pipe. A top, right, bottom, and left local heat transfer coefficient is calculated which encompasses the entire behavior of the pipe. For two-phase annular flow the greatest heat transfer coefficient will be found along the bottom of the pipe while the top has the smallest heat transfer coefficient. This, as mentioned in Section 4.1.4, is due to gravity effects drawing the bulk of the water to the bottom of the pipe. Since water is an excellent conductor of heat, the heat transfer coefficient at the bottom is therefore greater than the rest of the tube. To get a representative value for the heat transfer coefficient, an average of each station was calculated, and then those average values were averaged up to the seventh station. A sample calculation can be seen in Table 4.3. For example, station one had all four values added together and averaged. Top, left, right, and bottom local heat transfer coefficients were averaged to get a representative overall value. This was repeated across the table for each station as can be seen in Table 4.3 under the row labeled Station Avg. Once this was completed, another average was taken by adding stations 1 and 2, then 1, 2, and 3 and so on until all ten stations were averaged. Again, since end effects played a prominent role in the results of stations 8, 9, and 10 only the average up to station 7 was used. The averaging process can be seen in the row labeled Running Avg. The Running average is the overall heat transfer coefficient.

Table 4.3 Sample Averaging of Heat Transfer Coefficient

Peripheral Heat Transfer Coefficient, BTU/(SQ.FT-HR-F)										
Station	1	2	3	4	5	6	7	8	9	10
Position										
Top	219	137	169	160	165	160	168	166	170	179
Right	230	314	274	333	299	335	328	435	423	434
Bottom	1245	1418	1497	1401	1347	1488	1683	2178	2523	5561
Left	435	352	402	374	376	388	381	339	441	434
Station Avg.	532.3	555.3	585.5	567.0	546.8	592.8	640.0	779.5	889.3	1652.0
Running Avg.		543.8	557.7	560.0	557.4	563.3	574.2	599.9	632.0	734.0

Station 7 was chosen for reporting the results because it was far enough away from the end so that no end effects could be seen and far enough from the entrance to assume that the flow had developed fully and no entrance effects would be observed. This method was chosen because it was the same method used by Kim (2000) and Trimble (2001). During their research, the overall heat transfer coefficient was calculated in this manner.

4.2 Horizontal Experimental Data

In this section, the thirty data points of air-water, annular, two-phase flow that were measured during the course of this experiment at the horizontal position are presented. Discussed first are the tabulated results of this experiment, followed by the interpretation of key elements of the data. The data is then compared against the annular flow data of Pletcher (1966), and the slug flow data of Kim (2000) and Trimble (2001).

4.2.1 Horizontal Annular Air-Water Experimental Data

A total of thirty data points were measured at the horizontal position during this experiment. These results can be seen in Table 4.4. Each test run was based on the superficial Reynolds numbers of the air and water. Superficial Reynolds numbers are a form of Reynolds number calculation specific to multi-phase flows, where the Reynolds number is calculated as though the fluid it represents is the only fluid in the medium. Superficial Reynolds numbers for the liquid ranged from a minimum of 2,863 to a maximum of 8,298. The superficial gas Reynolds numbers ranged from a minimum of 27,347 to a maximum of 36,896. These ranges were selected for testing because they fell within the capabilities of the test apparatus. These values also fell within the lower ranges of the parameters set by Pletcher (1966). Pletcher (1966) performed tests on the pressure drop and heat transfer properties of air-water, annular flow in a horizontal pipe based on the mass flow rates of the water and air as opposed to using Reynolds numbers as done in current studies. The Reynolds numbers were recreated from the data measured by Pletcher (1966), and were used as a map to plot the ranges for the current tests. The ranges that were measured by Pletcher (1966) for the airflow rates were much larger than the current test setup could match. It is hoped that through this research, an overlapping database can be created, thus providing a more substantial foundation for future comparisons.

Table 4.4 lists data in accordance with the test run number. Each test run has a unique set of Reynolds numbers for the liquid and the gas as well as an overall heat flux measurement in BTU/(hr-ft^2). Also included is the average current subjected to the test section, the average voltage drop across the test section, and the average heat transfer coefficient, (h_{TP}), value at Station 7. Flow rates of the liquid and the gas are also included in Table 4.4. From the table it can be seen that the minimum amperage introduced to the test section was 320 amps and the maximum was 418.4 amps with an average amperage value of 379.9 amps. The resulting voltage drops were a minimum of 3.3 and 4.27 volts with an average of 3.88 volts. These two values were used to calculate the approximate heat flux that the test section encountered. These values were then used to compare against the heat flux calculated by the computer program Rht02m (See Chapter III) to determine the heat balance error, which was discussed in Section 4.1.2.

The minimum average heat transfer coefficient measured was 457 BTU/(ft^2-hr-F) and the maximum was 722 BTU/(ft^2-hr-F) with an average value of 577 BTU/(ft^2-hr-F). Each of these heat transfer coefficient values was measured at Station 7. As discussed before this was done in order to remove the end effects from the results.

4.2.2 Horizontal Annular Air-Water Experimental Analysis

Once all of the horizontal heat transfer data had been collected, it was entered into a 3-Dimensional graph, Figure 4.5, and plotted against the superficial Reynolds numbers (Re_{SL} and Re_{SG}). Examining this graph allows for a better interpretation and understanding of the physical characteristics of the heat transfer properties experienced during air-water, annular flow patterns. This graph also allows for the comparison of the air-water, annular flow pattern behavior against the slug flow pattern behaviors that were investigated by Kim and Ghajar (2002).

Study of Figure 4.5 reveals the behavior of horizontal, air-water, annular flow, heat transfer characteristics. As the liquid Reynolds number (Re_{SL}) is increased upon a fixed gas Reynolds number (Re_{SG}) the heat transfer coefficient steadily increases. If this comparison is reversed and the gas Reynolds number (Re_{SG}) is increased at a fixed liquid Reynolds number (Re_{SL}) the heat transfer coefficient only slightly increases. This behavior reveals that the dominant mechanism behind the heat transfer of air-water, annular flow is the liquid Reynolds number.

Upon further study of Figure 4.6, it begins to appear that at higher liquid Reynolds numbers, a plateau occurs in the heat transfer coefficient values. This occurrence was also experienced by Pletcher and McManus (1968). Pletcher and McManus (1968) found that the outlet temperature of the fluid decreased while the wall temperature was kept steady. This decrease was due to the higher rate of mass transfer caused by evaporation and entrainment of water particles by the fast moving air stream. This is the phenomenon termed as "end effects" discussed earlier in this chapter. This effect decreased the heat transfer coefficient (h_{TP}). Pletcher and McManus (1968) also found that at higher liquid Reynolds numbers, above 30,000, the overall heat transfer coefficient, h_{TP}, reached a maximum and then began to fall. Figure 4.6 begins to follow such a trend, but since the liquid Reynolds numbers are relatively low compared with those of Pletcher (1966) and Pletcher and McManus (1968) the full scope of this phenomenon cannot be explored.

Table 4.4 Heat Transfer Results for the Horizontal Position

Horizontal								
Run #	Gas Mass Flow Rate (lbm/min)	Re_{SG}	Liquid Mass Flow Rate (lbm/min)	Re_{SL}	Heat Flux BTU/(hr-ft^2)	Average Current (amps)	Average Voltage Drop (Volts)	Avg h_{TP} BTU/(ft^2-hr-F)
8471	1.49	27982	7.9	3118	1805	355.3	3.69	515
8472	1.54	28748	14.4	5711	2109	392.6	3.9	521
8473	1.47	27498	18.7	7350	2115	393.7	3.9	589
8474	1.46	27347	7.3	2863	1454	320	3.3	498
8475	1.61	30137	8.1	3242	1795	360	3.62	506
8476	1.62	30386	12.3	4897	2004	377	3.86	507
8477	1.64	30617	16.5	6577	2098	386	3.95	574
8478	1.80	33699	8.0	3246	2004	375.9	3.87	457
8479	1.79	33404	12.4	4965	2130	388.7	3.98	541
8480	1.97	36836	8.4	3336	1868	366.6	3.7	499
8481	1.93	36069	12.3	4917	1886	370.1	3.7	574
8482	1.92	35901	16.6	6646	1899	367.7	3.75	621
8483	1.78	33291	16.8	6656	2064	380.5	3.94	595
8484	1.90	35463	16.9	6725	2181	398	3.98	623
8485	1.97	36896	21.1	8298	1913	368.5	3.77	707
8486	1.95	36489	19.0	7549	2052	387	3.85	688
8487	1.55	29002	8.2	3239	1815	360	3.66	546
8488	1.60	29837	11.2	4479	2035	381.9	3.87	528
8489	1.57	29403	16.5	6577	2012	378.4	3.86	573
8490	1.56	29263	20.6	8223	2082	384.6	3.93	706
8491	1.67	31263	8.7	3515	2065	385.5	3.89	536
8492	1.67	31113	11.4	4621	2330	408.7	4.14	548
8493	1.65	30887	15.8	6366	2506	4.26.2	4.27	652
8494	1.67	31148	20.5	8204	2443	418.4	4.24	696
8495	1.71	32040	9.0	3572	1822	359.5	3.68	536
8496	1.74	32433	11.8	4764	2127	387.1	3.99	551
8497	1.95	36415	8.2	3316	2013	371.9	3.93	508
8498	1.96	36704	11.6	4672	2078	383	3.94	578
8499	1.68	31382	16.3	6569	2177	395.2	4	615
8500	1.71	31970	20.7	8295	2434	414.9	4.26	722
Maximum	1.97	36896	21.1	8298	2506	418.4	4.27	722
Minimum	1.46	27347	7.3	2863	1454	320	3.3	457

The current research does give more depth to the understanding and availability of annular flow data. This data seemingly follows the same patterns and traits as those observed by Pletcher (1966) and Pletcher and McManus (1968).

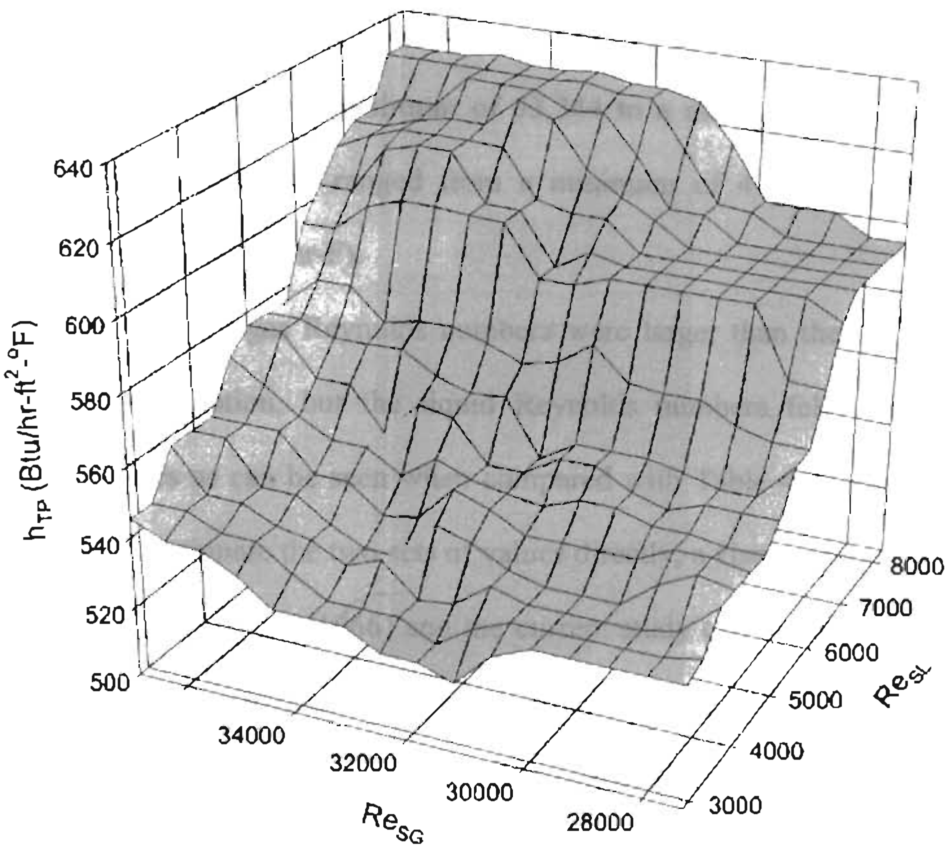


Figure 4.6 Variation of Heat Transfer Coefficient with Superficial Liquid Reynolds Number (Re_{SL}) and Superficial Gas Reynolds Number (Re_{SG}) for Annular Flow

4.2.3 Horizontal Annular Data Comparison with Data of Pletcher (1966)

Since the horizontal data behaved similarly to the data of Pletcher (1966), the next logical step would be to compare the two sets of data separately and jointly. Given the data provided by Pletcher (1966), the superficial Reynolds numbers (Re_{SL} and Re_{SG}) were recreated and along with the heat transfer coefficient measured by Pletcher (1966), entered into a 3-D graph, Figure 4.7, for analysis. This analysis will allow for a comparison of the current results with the historical data of Pletcher (1966).

Three variables were desired for this comparison and they were the superficial liquid Reynolds number (Re_{SL}) superficial gas Reynolds number (Re_{SG}) and the averaged heat transfer coefficient (h_{TP}). The superficial liquid Reynolds numbers (Re_{SL}) ranged in value from a minimum of 1,429 to a maximum of 9,776. The superficial gas Reynolds numbers (Re_{SL}) ranged from a minimum of 33,344 to a maximum of 293,140. Heat transfer coefficients (h_{TP}) then ranged from a minimum of 410.7 Btu/(ft^2-hr-F) to a maximum of 1,412.7 Btu/(ft^2-hr-F).

The values of the gas Reynolds numbers were larger than the values measured during this experimentation, but the liquid Reynolds numbers fell within the same parameter boundaries as can be seen when compared with Table 4.4. Though this fact makes it difficult to compare the two sets of values directly, a visual comparison of the 3-D representations for Pletcher (1966) and the current study can be made to analyze the behaviors of the air-water, annular flow pattern data sets.

Figure 4.7 represents the data of Pletcher (1966) in a 3-Dimensional view. This representation clearly shows the findings of Pletcher and McManus (1968), by saying that a maximum value of h_{TP} occurs at a fixed liquid Reynolds number as you increase the gas Reynolds number, followed by a decrease. Figure 4.7 reveals the higher side of the air-water, annular flow pattern behavior while Figure 4.6 shows the lower side behavior.

Using the data of Pletcher (1966) and the current experimental data, a composite graph of the annular flow heat transfer coefficient characteristics were created, Figure 4.8. This three-dimensional representation again bolsters the claim that the key mechanism in the air-water annular flow heat transfer coefficient is the liquid Reynolds number. Figure 4.8 does not fully represent the merging of Figures 4.6 and 4.7. This is

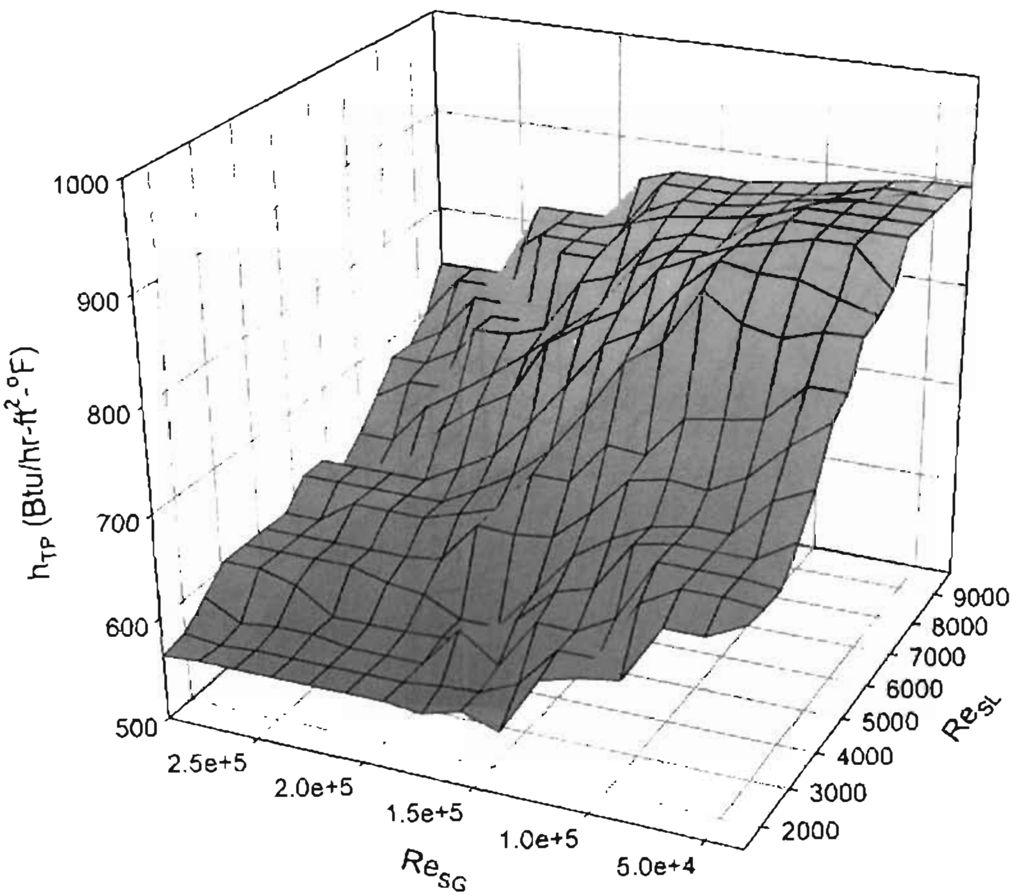


Figure 4.7 Variation of Pletcher's (1966) Annular Flow Heat Transfer Coefficient with Re_{SL} and Re_{SG}

because these graphs are created with a software program called Sigma Plot, that transforms and smoothes the experimental data. Figure 4.8 is a predicted representation based upon the actual data measured during this experiment and the experimentation of Pletcher (1966).

Figure 4.8 gives a complete representation of the annular flow characteristics. Combining the two sets of data gives a complete explanation of how the flow behaves at a wide range of Reynolds numbers. This pattern is still consistent with the findings of

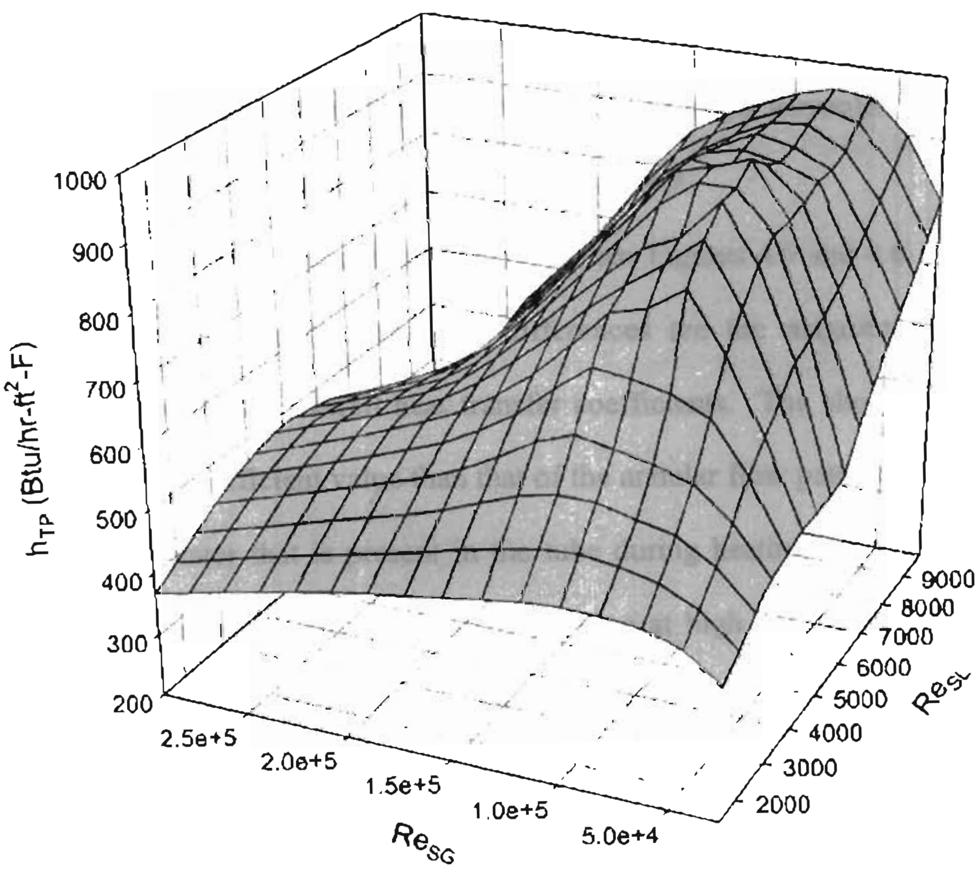


Figure 4.8 Variation of the Annular Flow Heat Transfer Data of Present Study and Pletcher (1966) with Re_{SL} and Re_{SG}

this project and the findings of Pletcher and McManus (1968). The heat transfer coefficient increases with the liquid Reynolds number and slightly increases with the gas

Reynolds number until the gas Reynolds number becomes too large and the evaporation and entrainment become the dominating factors thus decreasing the overall heat transfer properties.

4.2.4 Horizontal Annular Data Comparison with Slug Flow Data

The next step in analyzing the horizontal annular data would be to see how it compares with other flow patterns and their heat transfer properties. Kim and Ghajar (2002) processed and developed a large quantity of slug flow data for air-water, two-phase flow. From this data a three-dimensional graph was created revealing the heat transfer coefficient properties as a function of the liquid and gas Reynolds numbers. This three-dimensional representation can be seen in Figure 4.9.

Similarities and differences are apparent when Figures 4.9 and 4.6 are compared against one another. The first apparent differences are the magnitudes of the gas Reynolds numbers and the overall heat transfer coefficients. The slug flow data has a higher heat transfer coefficient value than that of the annular flow pattern. This is caused by the amount of water that is present in the tube during heating. During a slug flow pattern, the slugs are repeatedly fired down the pipe at high velocities. This does not allow the pipe to rapidly gain heat, but rather constantly carries the heat away in the larger mass of the slug. In the annular flow, the thin layer of liquid along the walls, primarily the top, and sides of the pipe, cannot dissipate the heat as quickly as slug flow. This difference is the cause of the larger heat transfer coefficient associated with slug flows, and the smaller heat transfer coefficient that was found through the current study.

The next area to be studied is the actual behavior of the two flows as opposed to the overall magnitudes of the parameters. The two flows are similar in nature, depending mostly upon the liquid Reynolds number to establish the size of the heat transfer coefficient. During slug flow, if the gas Reynolds number is fixed and the liquid Reynolds number increased, the heat transfer coefficient increases as well. If the liquid Reynolds number is fixed and the gas Reynolds number increased, there is little or no increase in the heat transfer coefficient. This is different from the annular flow pattern behavior in that as the gas Reynolds number is increased at a fixed liquid Reynolds number, the heat transfer coefficient increases. The heat transfer coefficient will continue to increase until the gas Reynolds number becomes so large that entrainment and evaporation become the dominating mechanisms and begin to decrease the temperature difference of the wall and bulk temperature. This will then decrease the heat transfer coefficient.

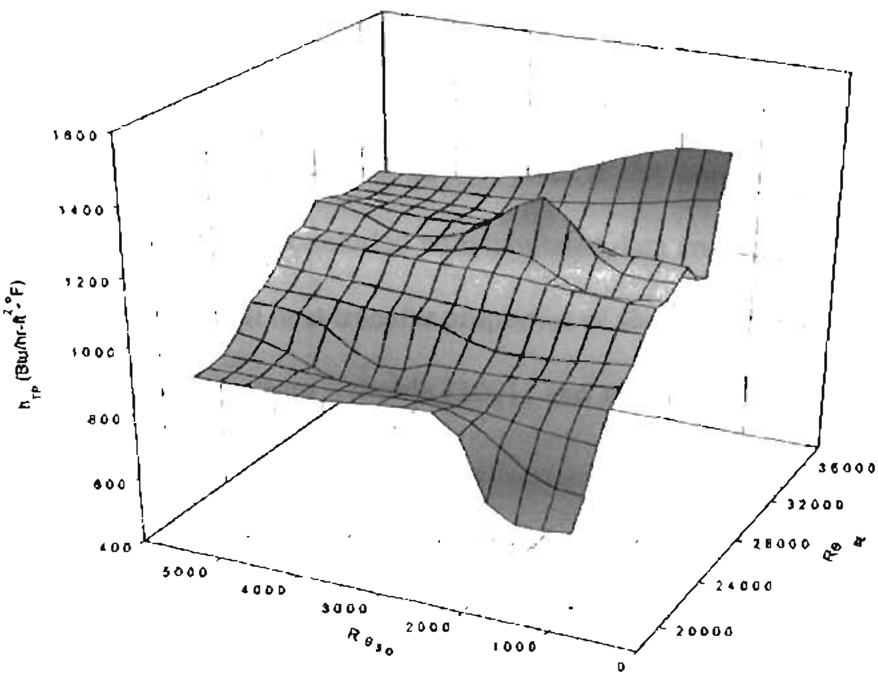


Figure 4.9 Kim and Ghajar's (2002) Slug Flow Heat Transfer Behavior with ReSL and ReSG

4.3 Inclined Data

In this section, the results of the inclined data are discussed. With previous experiments of slug flow data, Trimble *et al.* (2002), an increase in heat transfer properties was observed as the inclination angle of the pipe was increased. This section compares the inclined data of the current study to see if any increase, or decrease, is associated with inclined annular flow.

4.3.1 Background

Trimble (2001) performed research on inclined slug flow heat transfer properties in an effort to verify claims made by Hetsroni *et. al.* (1998b) who stated that based on his research, slug flows experience an increase in heat transfer as the inclination angle of the pipe was increased. No specific details on the magnitude of the increase were given in that paper.

Trimble (2001) performed 62 test runs at the horizontal, 2°, and 5° positions. From his research, it was concluded with tabulated data and graphs, that indeed there was an increase in the overall heat transfer properties of slug flows in an inclined pipe. Figure 4.10 and Table 4.5 are from Trimble (2001) and represent the findings of inclined slug flow.

The question now arises as to whether there is an increase in the heat transfer coefficient for annular flow patterns in a slightly inclined pipe, as was seen with slug flow.

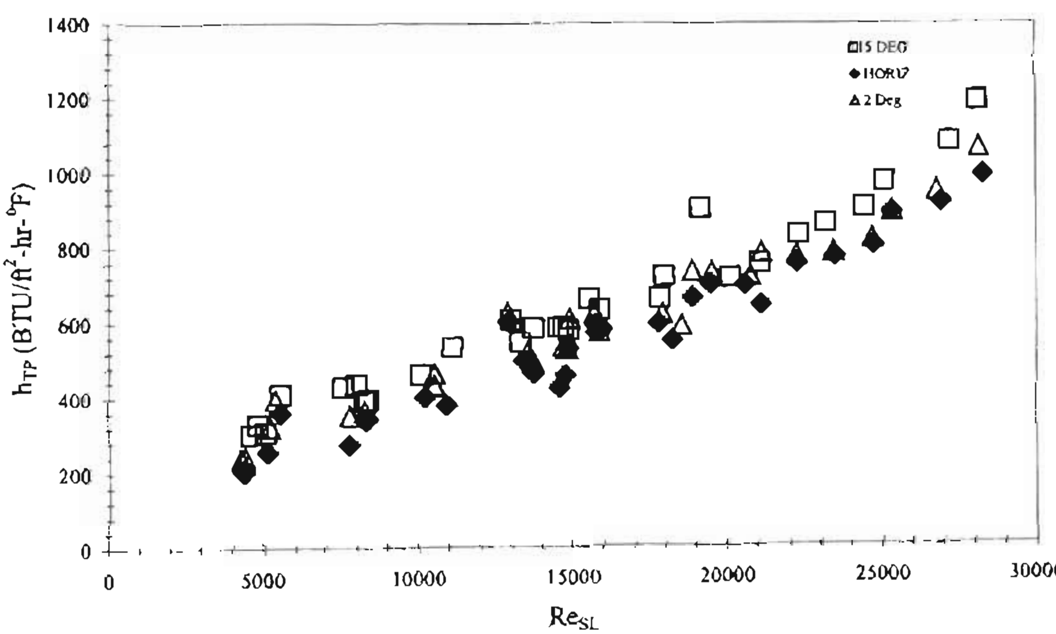


Figure 4.10 Two-Phase Heat Transfer Coefficient as a Function of Re_{SL} for Horizontal and Inclined Data of Trimble (2001)

Table 4.5 Statistical Results of Slug Flow Heat Transfer Coefficient Comparison of Trimble (2001)

Data Set	Maximum Percentage h_{TP} Change	Minimum Percentage h_{TP} Change	Average Percentage h_{TP} Change	Std Dev. Percentage h_{TP} Change
Horizontal to 5°	58.47	0.82	21.76	15.33
Horizontal to 2°	28.23	0.22	9.81	8.13
5° to 2°	28.97	-5.03	10.32	9.61

4.3.2 Comparison of Inclination Data

All 88 data points were used to compare the effects of inclination on the overall heat transfer coefficient properties. Data from each set of data, 0°, 5°, and 7°, was matched according to the Reynolds numbers that were associated with the test run. All 30 of the test runs for the horizontal position were repeated at the inclined angles so as to match the parameters of the Reynolds numbers as closely as possible.

Horizontal data was used as the basis of comparison. This would ensure that if a positive increase in heat transfer was measured with a positive inclination angle, it would result in a positive value. If a decrease were measured, then the value would be negative.

4.3.3 Comparison of Horizontal and 5° Data

Comparison of the data was done by finding the difference between the two values, horizontal and 5°, for each Reynolds number, and for the overall heat transfer coefficient. The maximum difference between the superficial gas Reynolds number, Re_{SG}, was –1,839 (-6.0%), and a difference of –214 (-4.6%) for the superficial liquid Reynolds number, Re_{SL}. The minimum differences for Re_{SG} and Re_{SL} were –4 (0.06%) and 10 (0.03%) respectively. The overall heat transfer coefficient had a maximum difference of –78 (-13%) and a minimum difference of –2 (-0.29%). The average percent change was –0.9%. This value suggests that little heat transfer enhancement was found as a result of raising the test apparatus from horizontal to 5°. Upon further study of Table 4.6, it can be seen that the percent differences for the three parameters, Re_{SL}, Re_{SG}, and h_{TP} vary evenly in the positive and negative directions. There is no one sided distribution of positive or negative values, which suggests that on average the heat transfer properties stay the same as you incline the test setup.

Liquid Reynolds numbers were easily controlled and replicated for the 5° incline test runs as can be seen by the small deviation percentage in Table 4.6. The gas Reynolds numbers were more difficult to control due to fluctuations in the air compressor cycle, the fluctuations in outside air density and humidity, and the sensitivity of the needle valve used to control the flowrate.

4.3.4 Comparison of Horizontal and 7° Data

The next comparison made was with the horizontal and the 7° data, seen in Table 4.7. The maximum difference between the superficial gas Reynolds number, Re_{SG}, was –388 (-1.3%), and a difference of –148 (–1.8%) for the superficial liquid Reynolds number, Re_{SL}. The minimum differences for Re_{SG} and Re_{SL} were –10 (–0.03%) and 2 (0.03%) respectively. The overall heat transfer coefficient had a maximum difference of –82 (–15.92%) and a minimum difference of 3 (0.43%). The average percent change was -2.7%. This value suggests that a small decrease in heat transfer exists because of raising the test apparatus from horizontal to 7°. This decrease could be attributed to the uncertainty associated with the heat transfer measurements, see Appendix C for a discussion of the uncertainty calculations. Again, an even distribution of positive and negative values exists for the percent differences of the three parameters.

4.3.5 Comparison of 5° and 7° Data

The final comparison made was with the 5° and the 7° data. The comparison can be seen in Table 4.8. The maximum difference between the superficial gas Reynolds number, Re_{SG}, was 1594 (5.0%), and a difference of –201 (–4.4%) for the superficial liquid Reynolds number, Re_{SL}. The minimum differences for Re_{SG} and Re_{SL} were –37 (-0.1%) and 4 (0.1%) respectively. The overall heat transfer coefficient had a maximum difference of –98 (–21.9%) and a minimum difference of –1 (–0.1%). The average percent change was –1.8%. Again a negative value was found for the average percent change in the overall heat transfer coefficient. This agrees with the horizontal and 5°, and horizontal and 7° data by showing a small decrease in the overall heat transfer coefficient as the pipe inclination angle is increased. This small decrease could again be attributed to the uncertainty in heat transfer measurements as mentioned previously, see Appendix C for the discussion of the uncertainty calculations.

4.3.6 Comparison of Annular Flow Inclination Data with Inclined Slug Flow Data

Figure 4.11 is a graph of the current data, plotted against the superficial liquid Reynolds number. This graph can be compared with that of Figure 4.10 for the slug flow data. Figure 4.10 shows the three sets of inclined data for slug flow and how at similar liquid Reynolds numbers, the values increase as the inclination angle is increased. Figure 4.11 reveals that this is not the case with annular flow. Instead, the values lay one on top of each other revealing that a small increase in inclination angle does not affect the characteristics of air-water, annular flow.

Table 4.6 Horizontal and Five Degree Experimental Data Comparison

Index	Re_{SL}		ΔRe_{SL}	ΔRe_{SL} (%)	Re_{SG}		ΔRe_{SG}	ΔRe_{SG} (%)	h_{TP} (BTU/ft^2-hr-°F)		Δh_{TP}	Δh_{TP} (%)
	5 Degs	Horizontal			5 Degs	Horizontal			5 Degs	Horizontal		
1	2886	2863	23	0.8	27639	27347	292	1.1	515	498	17	3.3
2	7311	7350	-39	-0.5	27386	27498	-112	-0.4	568	589	-21	-3.7
3	3131	3118	13	0.4	27819	27982	-163	-0.6	482	515	-33	-6.8
4	5704	5711	-7	-0.1	28599	28748	-149	-0.5	536	521	15	2.8
5	3327	3239	88	2.6	29051	29002	49	0.2	475	546	-71	-14.9
6	8172	8223	-51	-0.6	29530	29263	267	0.9	628	706	-78	-12.4
7	6573	6577	-4	-0.1	29635	29403	232	0.8	580	573	7	1.2
8	4449	4479	-30	-0.7	29528	29837	-309	-1.0	509	528	-19	-3.7
9	3363	3242	121	3.6	30602	30137	465	1.5	546	506	40	7.2
10	4683	4897	-214	-4.6	30325	30386	-61	-0.2	519	507	12	2.3
11	6631	6577	54	0.8	30627	30617	10	0.0	615	574	41	6.6
12	6497	6366	131	2.0	30414	30887	-473	-1.6	613	652	-39	-6.4
13	4772	4621	151	3.2	30899	31113	-214	-0.7	536	548	-12	-2.2
14	8187	8204	-17	-0.2	31783	31148	635	2.0	694	696	-2	-0.3
15	3555	3515	40	1.1	31029	31263	-234	-0.8	502	536	-34	-6.8
16	6457	6569	-112	-1.7	31118	31382	-264	-0.8	606	615	-9	-1.5
17	8259	8295	-36	-0.4	30335	31970	-1635	-5.4	699	722	-23	-3.3
18	3422	3572	-150	-4.4	31944	32040	-96	-0.3	479	536	-57	-11.9
19	4834	4764	70	1.4	30594	32433	-1839	-6.0	531	551	-20	-3.8
20	6649	6656	-7	-0.1	33208	33291	-83	-0.2	625	595	30	4.8
21	4998	4965	33	0.7	33551	33404	147	0.4	555	541	14	2.5
22	3234	3246	-12	-0.4	33477	33699	-222	-0.7	499	457	42	8.4
23	6696	6646	50	0.7	36853	35901	952	2.6	657	621	36	5.5
24	4946	4917	29	0.6	36641	36069	572	1.6	601	574	27	4.5
25	3286	3316	-30	-0.9	36867	36415	452	1.2	513	508	5	1.0
26	7670	7549	121	1.6	36231	36489	-258	-0.7	684	688	-4	-0.6
27	4636	4672	-36	-0.8	36892	36704	188	0.5	559	578	-19	-3.3
28	3224	3336	-112	-3.5	36886	36836	50	0.1	509	499	10	2.0
29	8322	8298	24	0.3	36560	36896	-336	-0.9	723	707	16	2.2

Table 4.9 is a summation of the percent changes for the overall heat transfer coefficient. The table shows that the greatest heat transfer change occurred from the horizontal to the 7° position. The greatest average heat change was observed to occur at the 7° inclination as well.

When the annular data of Table 4.9 is compared with the slug flow data of Trimble (2001) in Table 4.5, the differences are evident. Trimble (2001) observed a 58% maximum increase from the horizontal to the 5° position with a 22% average increase in the overall heat transfer coefficient. Annular flow showed a slight decrease of –0.9% in its average heat transfer coefficient and a maximum percentage change of 8.4% at the same inclination interval. Trimble (2001) did not conduct experiments at 7°; therefore, the horizontal to 7° annular data was not compared. However, from the simple comparisons of the two tables, it can clearly be seen that the effects of inclination are much more prominent in slug flows. This is most likely due to the amount of water flowing through the pipe in the slug flow pattern.

Table 4.7 Horizontal and Seven Degree Experimental Data Comparison

Index	Re_{SL}		ΔRe_{SL}	ΔRe_{SL} (%)	Re_{SG}		ΔRe_{SG}	ΔRe_{SG} (%)	h_{TP} (BTU/ft^2-hr-^{o}F)		Δh_{TP}	Δh_{TP} (%)
	7 Degs	Horizontal			7 Degs	Horizontal			7 Degs	Horizontal		
1	2861	2863	-2	-0.1	27173	27347	-174	-0.6	428	498	-70	-16.4
2	7315	7350	-35	-0.5	27258	27498	-240	-0.9	595	589	6	1.0
3	3101	3118	-17	-0.5	27643	27982	-339	-1.2	433	515	-82	-18.9
4	5654	5711	-57	-1.0	28643	28748	-105	-0.4	530	521	9	1.7
5	3286	3239	47	1.4	28732	29002	-270	-0.9	466	546	-80	-17.2
6	8075	8223	-148	-1.8	29036	29263	-227	-0.8	643	706	-63	-9.8
7	6459	6577	-118	-1.8	29448	29403	45	0.2	588	573	15	2.6
8	4378	4479	-101	-2.3	29818	29837	-19	-0.1	505	528	-23	-4.6
9	3253	3242	11	0.3	30065	30137	-72	-0.2	448	506	-58	-13.0
10	4856	4897	-41	-0.8	30044	30386	-342	-1.1	517	507	10	1.9
11	6541	6577	-36	-0.6	30574	30617	-43	-0.1	602	574	28	4.6
12	6334	6366	-32	-0.5	30728	30887	-159	-0.5	609	652	-43	-7.1
13	4571	4621	-50	-1.1	31095	31113	-18	-0.1	508	548	-40	-7.9
14	8264	8204	60	0.7	31036	31148	-112	-0.4	693	696	-3	-0.4
15	3574	3515	59	1.7	31231	31263	-32	-0.1	481	536	-55	-11.4
16	6566	6569	-3	0.0	30994	31382	-388	-1.3	612	615	-3	-0.5
17	8289	8295	-6	-0.1	31838	31970	-132	-0.4	690	722	-32	-4.6
18	3509	3572	-63	-1.8	31907	32040	-133	-0.4	496	536	-40	-8.1
19	4700	4764	-64	-1.4	32188	32433	-245	-0.8	527	551	-24	-4.6
20	6658	6656	2	0.0	33066	33291	-225	-0.7	663	595	68	10.3
21	4909	4965	-56	-1.1	33228	33404	-176	-0.5	573	541	32	5.6
22	3257	3246	11	0.3	33720	33699	21	0.1	515	457	58	11.3
23	6715	6646	69	1.0	35923	35901	22	0.1	668	621	47	7.0
24	4939	4917	22	0.4	35879	36069	-190	-0.5	577	574	3	0.5
25	3291	3316	-25	-0.8	36324	36415	-91	-0.3	486	508	-22	-4.5
26	7574	7549	25	0.3	36104	36489	-385	-1.1	692	688	4	0.6
27	4616	4672	-56	-1.2	36597	36704	-107	-0.3	554	578	-24	-4.3
28	3294	3336	-42	-1.3	37068	36836	232	0.6	496	499	-3	-0.6
29	8355	8298	57	0.7	36886	36896	-10	0.0	766	707	59	7.7

Table 4.8 Seven Degree and Five Degree Experimental Data Comparison

Index	Re_{SL} 5 Degs	Re_{SL} 7 Degs	ΔRe_{SL}	ΔRe_{SG} (%)	Re_{SG} 5 Degs	Re_{SG} 7 Degs	ΔRe_{SG}	ΔRe_{SG} (%)	h_{TP} (BTU/ft^2-hr-°F) 5 Degs	h_{TP} (BTU/ft^2-hr-°F) 7 Degs	Δh_{TP}	Δh_{TP} (%)
1	2886	2861	25	-0.9	27639	27173	466	-1.7	515	428	87.00	-20.3
2	7311	7315	-4	0.1	27386	27258	128	-0.5	568	595	-27.00	4.5
3	3131	3101	30	-1.0	27819	27643	176	-0.6	482	433	49.00	-11.3
4	5704	5654	50	-0.9	28599	28643	-44	0.2	536	530	6.00	-1.1
5	3327	3286	41	-1.2	29051	28732	319	-1.1	475	466	9.00	-1.9
6	8172	8075	97	-1.2	29530	29036	494	-1.7	628	643	-15.00	2.3
7	6573	6459	114	-1.8	29635	29448	187	-0.6	580	588	-8.00	1.4
8	4449	4378	71	-1.6	29528	29818	-290	1.0	509	505	4.00	-0.8
9	3363	3253	110	-3.4	30602	30065	537	-1.8	546	448	98.00	-21.9
10	4683	4856	-173	3.6	30325	30044	281	-0.9	519	517	2.00	-0.4
11	6631	6541	90	-1.4	30627	30574	53	-0.2	615	602	13.00	-2.2
12	6497	6334	163	-2.6	30414	30728	-314	1.0	613	609	4.00	-0.7
13	4772	4571	201	-4.4	30899	31095	-196	0.6	536	508	28.00	-5.5
14	8187	8264	-77	0.9	31783	31036	747	-2.4	694	693	1.00	-0.1
15	3555	3574	-19	0.5	31029	31231	-202	0.6	502	481	21.00	-4.4
16	6457	6566	-109	1.7	31118	30994	124	-0.4	606	612	-6.00	1.0
17	8259	8289	-30	0.4	30335	31838	-1503	4.7	699	690	9.00	-1.3
18	3422	3509	-87	2.5	31944	31907	37	-0.1	479	496	-17.00	3.4
19	4834	4700	134	-2.9	30594	32188	-1594	5.0	531	527	4.00	-0.8
20	6649	6658	-9	0.1	33208	33066	142	-0.4	625	663	-38.00	5.7
21	4998	4909	89	-1.8	33551	33228	323	-1.0	555	573	-18.00	3.1
22	3234	3257	-23	0.7	33477	33720	-243	0.7	499	515	-16.00	3.1
23	6696	6715	-19	0.3	36853	35923	930	-2.6	657	668	-11.00	1.6
24	4946	4939	7	-0.1	36641	35879	762	-2.1	601	577	24.00	-4.2
25	3286	3291	-5	0.2	36867	36324	543	-1.5	513	486	27.00	-5.6
26	7670	7574	96	-1.3	36231	36104	127	-0.4	684	692	-8.00	1.2
27	4636	4616	20	-0.4	36892	36597	295	-0.8	559	554	5.32	-1.0
28	3224	3294	-70	2.1	36886	37068	-182	0.5	509	496	13.00	-2.6
29	8322	8355	-33	0.4	36560	36886	-326	0.9	723	766	-43.00	5.6

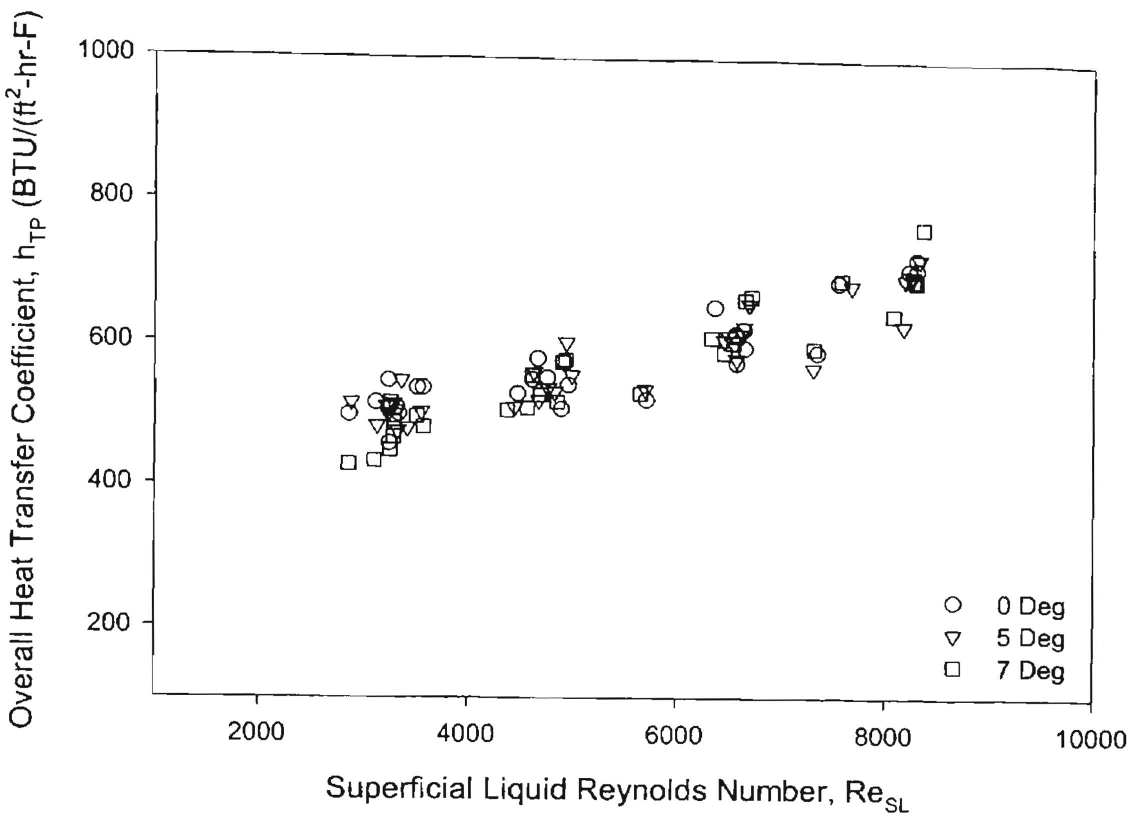


Figure 4.11 Annular Two-Phase Heat Transfer Coefficient As a Function of Re_{SL} for Horizontal and Inclined Data

Table 4.9 Statistical Results of Annular Flow Heat Transfer Coefficient Comparison

Data Set	Maximum Percentage h_{TP} Change	Minimum Percentage h_{TP} Change	Average Percentage h_{TP} Change	Std Dev. Percentage h_{TP} Change
Horizontal to 5°	8.4	-14.9	-0.9	5.9
Horizontal to 7°	11.3	-19.0	-2.7	8.0
5° to 7°	5.73	-21.88	-1.8	6.5

Based upon the findings of this current study and the comparison of the data against that of the slug flow results, it can be concluded that there is little influence in the overall heat transfer coefficient for annular two-phase air-water flow. Though there seems to be a small decrease in the overall heat transfer coefficient as the pipe is raised, the magnitude of the value does not suggest that the difference is large enough to greatly influence the overall heat transfer coefficient on a large scale value as seen with slug flow data of Trimble (2001).

4.4 Annular Flow Heat Transfer Correlation Data

In this section, new constants were obtained to help predict annular flow heat transfer results using the general correlation of Kim and Ghajar (2002) presented in Table 2.6. The results of the annular test runs were fit with new constants using a regression program located within the computer software Sigma Plot. The regression program was modified to calculate the new constants for the general equation of Kim and Ghajar (2002) for horizontal two-phase flow.

Two sets of constants for the Kim & Ghajar (2002) correlation were established. One set was determined for the horizontal data and the other set was determined using the horizontal data and the data of Pletcher (1966) to produce a wider range of parameters in which the correlation could be applied. The new constants for the correlation can be found in Table 4.10.

4.4.1 Annular Flow Heat Transfer Correlation Development

The 30 data points measured at the horizontal position were used to develop the new constants for the general equation suggested by Kim and Ghajar (2002). Sigma Plot was programmed to fit the general equation with new constants. Many trial runs were performed to obtain the best set of constants for the Kim and Ghajar (2002) general correlation, and the results can be seen in Table 4.10. From Table 4.10 it can be seen that all 30 of the horizontal, air-water, annular heat transfer data points fell within

Table 4.10 Recommended Values for Kim and Ghajar (2002) Correlation for Annular Flow in a Horizontal Pipe

General Form of the Two-Phase Heat Transfer Coefficient Correlation:

$$h_{TP} = (1-\alpha)h_L\left[1 + C\left(\frac{x}{1-x}\right)^m\left(\frac{\alpha}{1-\alpha}\right)^n\left(\frac{Pr_G}{Pr_L}\right)^p\left(\frac{\mu_G}{\mu_L}\right)^q\right]$$

Experimental Data	Value of C and Exponents (m, n, p, q)					Mean Dev. (%)	rms Dev. (%)	Number of Data within ±15%	Range of Dev. (%)	Range of Parameter				
	C	m	n	p	q					Re_{SL}	$\left(\frac{x}{1-x}\right)$	$\left(\frac{\alpha}{1-\alpha}\right)$	$\left(\frac{Pr_G}{Pr_L}\right)$	$\left(\frac{\mu_G}{\mu_L}\right)$
Horizontal Data from Current Study (30 Points)	0.23	-0.20	1.90	-1.35	0.99	0.16	0.36	30	13.54 and −8.50	2863 and 8298	0.076 and 0.237	8.25 and 15.71	0.117 and 0.121	0.021 and 0.022

a ±15% deviation band. The prediction had a mean deviation of 0.16% with a deviation range of 13.5% and –8.5%. Figure 4.12 shows the pattern of the predicted data points using the new constants for the Kim and Ghajar (2002) correlation. From Figure 4.12, it can be seen that there are no outliers and the data is confined to a narrow band of error, thus revealing a good prediction for these 30 data points.

Since it was found that inclination of the pipe had no effect on the heat transfer properties of annular flow, the new constants developed for the Kim and Ghajar (2002) general correlation were used to predict the inclined data heat transfer results. The results can be found in Figure 4.13. Figure 4.13 reveals that the predictions made for the inclined data using the new Kim and Ghajar (2002) constants fall within the previously established ±15% deviation band. Only two predictions for the 5-degree inclination data and only one for the 7-degree inclination data fall outside of the ±15% deviation band. The error shows no major difference within the established uncertainty of 14.8% (See Section 4.5) and further supports the evidence that inclination has no effect on the overall heat transfer properties of annular flow. Thus of the 88 data points measured during this experimentation, 85 of the 88 data points are within a deviation of ±15%.

4.4.2 Prediction of Pletcher's (1966) Data

The new constants obtained for the Kim and Ghajar (2002) general equation were next used to predict the 48 data points of Pletcher (1966), to determine the applicability of the new correlation. The results can be seen in Figure 4.14. The results were not successful having outliers well outside of the desired ±25% deviation band. Only 20 of

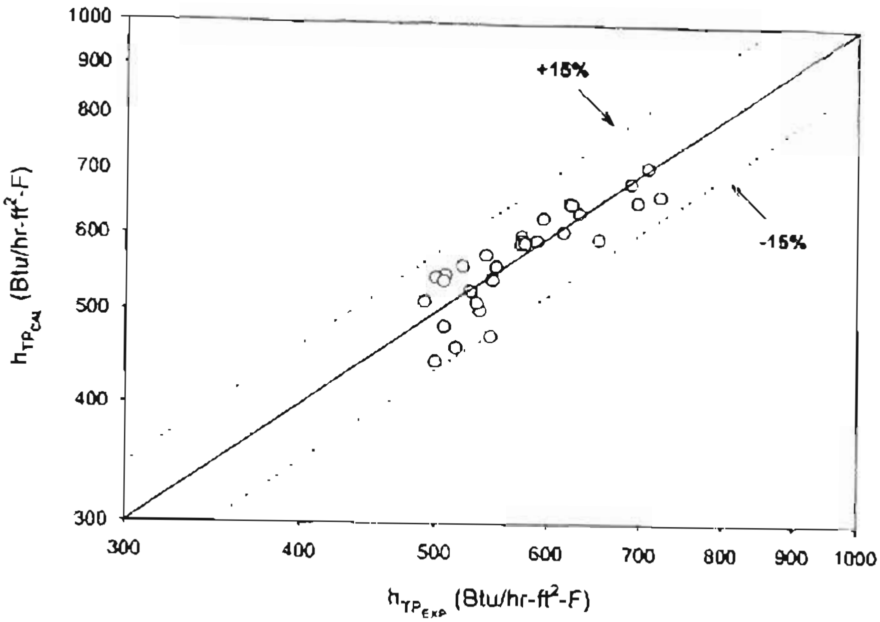


Figure 4.12 Annular Flow Correlation Prediction for Current Study using New Constants for Kim and Ghajar (2002) Correlation

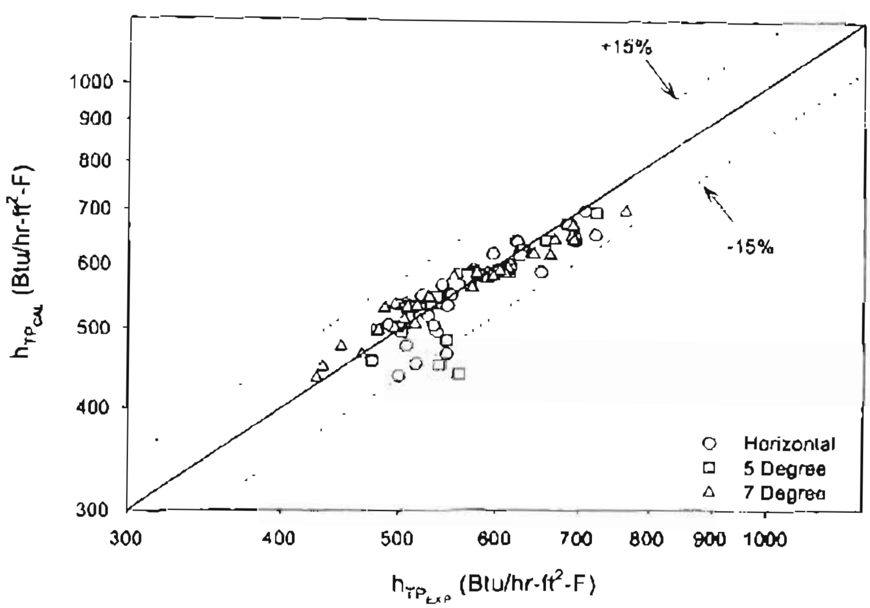


Figure 4.13 Annular Flow Correlation Prediction for Current Study Inclined Data using New Constants for Kim and Ghajar (2002) Correlation

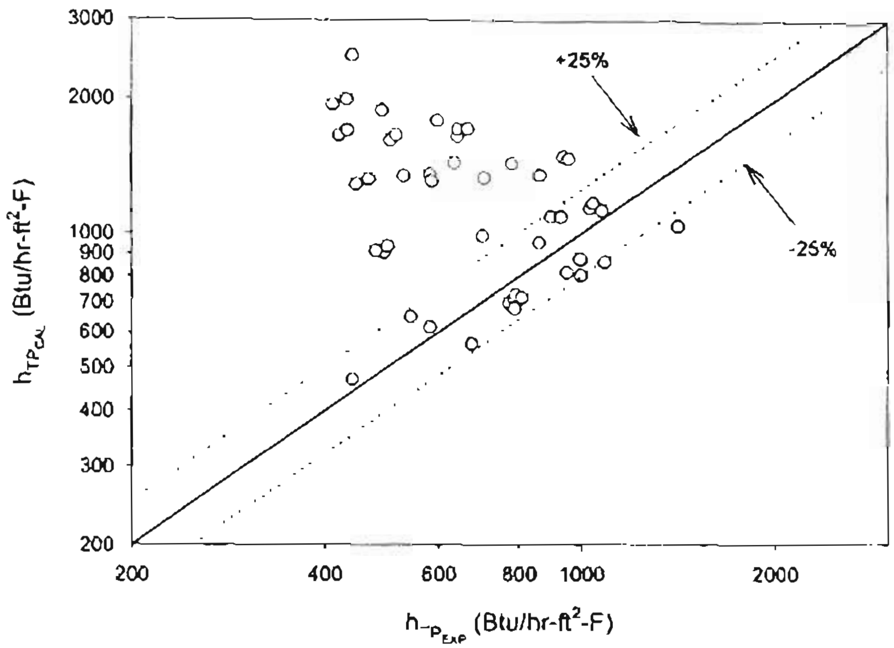


Figure 4.14 Annular Flow Correlation Prediction for data of Pletcher (1966) using New Constants for the Kim and Ghajar (2002) Correlation

the 48 data points measured by Pletcher (1966) fell within the desired ±25% deviation band. The deviation range for these 48 data points was 26.3% to –466.0%.

Upon further examination of the flow parameters set by Pletcher (1966), it was found that the flow rates by which Pletcher set his experimentation were well outside the parameters of the Revised Figure 2.1. These higher flow rates bring into question whether the test pipe of Pletcher (1966) developed dry-out because of such high flow rates of air. Dry out is an occurrence of two-phase flow where the liquid is blown away from the medium wall because of high gas flow rates. This would cause for abnormal heating resulting in poor heat transfer coefficient measurement.

Dry out was avoided during this experimentation by observing the flow at the entrance and exit of the pipe to verify that the pipe walls were wetted as the annular flow passed through the pipe. Pletcher's methods of verifying the absence of dry-out are unknown. It is believed that some of the data measured by Pletcher experienced this occurrence thus causing the large deviation of predicted values from the new constants of the Kim and Ghajar (2002) equation.

Taking the data of Pletcher (1966) and organizing it into the appropriate flow patterns as suggested by Revised Figure 2.1, new predictions were made using the current constants for the annular flow pattern. The results can be seen in Figure 4.15. Of the 48 test points measured by Pletcher (1966), only 17 fell within the parameters set forth by this research. All other points fell outside of the parameters set by Revised Figure 2.1 and therefore could not be predicted with the current correlation constants. Of the 17 points that were deemed as pure annular flow, 15 fell within the desired ±25% deviation band when used with the annular flow constants for the Kim and Ghajar (2002) correlation. The deviation ranges for this prediction were a minimum of –40.4% and a maximum of 26.3 with a median value of 1.8%. This prediction shows that the new

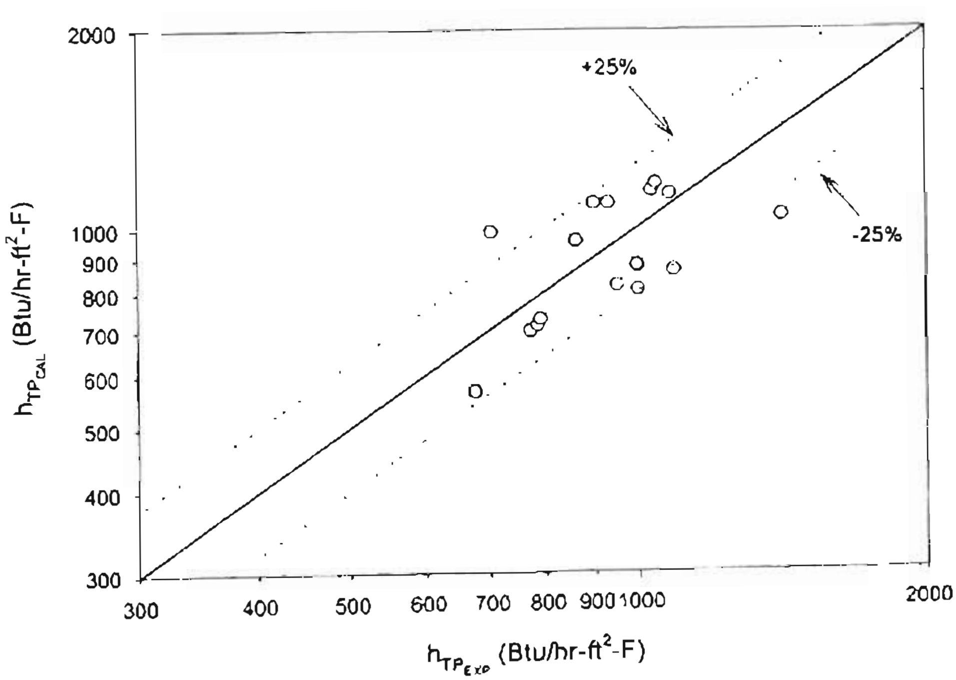


Figure 4.15 Annular Flow Data of Pletcher (1966) (17 Points)

constants for annular flow used with the Kim and Ghajar (2002) general correlation can predict pure annular flow heat transfer coefficient results within acceptable deviation ranges.

4.5 Uncertainty

Uncertainty calculations were performed for each of the 88 test runs performed in this research. Using the method described by Kline and McClintock (1953), an uncertainty of 14.8% was found for the heat transfer measurements in this research. The methodology and discussion can be found in Appendix C.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

A total of 88 air-water, annular heat transfer runs were performed during this research. Measurements were taken at the horizontal position (30 points), at 5° above horizontal (29 points), and 7° above horizontal (29 points). These results were reduced and placed into 3-dimensional graphs, were compared against the slug flow data of Kim and Ghajar (2002) and Trimble *et al.* (2002), and compared against one another to observe and report the influences of inclination on the results of heat transfer properties experiencing annular flow patterns in air-water mixtures. The results were also used to create new constants for the Kim and Ghajar (2002) general correlation for two-phase, air-water, heat transfer coefficient prediction.

5.1 Conclusions

The objectives of this study (See Chapter I), were designed to gather quality heat transfer data in an annular flow pattern in a horizontal and slightly inclined pipe. From the data, a compilation of vital annular flow heat transfer data parameters could be formulated and compared with the data of other flow patterns, namely slug flow, and could be compared against the inclination data to determine if the inclination angle had any adverse effects on the results.

The horizontal data that was measured during this experiment was compiled into a 3-dimensional graph representing the behavior of annular flow through a range of Reynolds numbers for air and water. The behavioral pattern relates how the heat transfer coefficient (h_{TP}) behaves as the Reynolds numbers are increased or decreased. This graph is similar to the slug flow graphs of Kim and Ghajar (2002).

Comparisons of the annular flow heat transfer data and the slug flow data of Kim and Ghajar (2002) and Trimble *et al.*(2002) were made to distinguish the differences and similarities between the two flow patterns. It was found that the slug flow pattern and the annular flow pattern were so dissimilar, that the 3-dimensional representations were nothing alike. However, the flows were both largely dependent upon the liquid Reynolds numbers to determine the overall heat transfer coefficient (h_{TP}). The difference between the two flows was that after a certain air Reynolds number for annular flow, the heat transfer coefficient began to decrease. This was caused by the mechanism of entrainment and mass diffusion to the gas core. Slug flow did not show any such behavior.

The horizontal data was then used to compare heat transfer coefficient results against those of the inclination data. Slug flow results show that as the pipe is inclined, the overall heat transfer results increase. The results for the annular data however, showed no signs of increase of decrease, but a steady value pattern for the overall heat transfer coefficient.

The horizontal data was also used to formulate new annular flow heat transfer constants for the Kim and Ghajar (2002) general correlation. It was found that these new constants predicted the annular flow heat transfer data of the current project to within $\pm 15\%$. Since the inclination angle was found to have no adverse effects on the heat transfer results, the new constants were also used to predict the inclined data. It was found that the new constants predicted the inclined annular data to within the previously set ±15% deviation.

5.2 Recommendations

Further studies upon this subject could allow for a more precise prediction of annular flow heat transfer data. It is recommended that additional runs be performed, and particular attention be paid to the dry out scenarios of higher flow rate annular flows. If a better understanding of when and where this occurs is gained, a more definitive annular flow region could be defined. This data could also reveal the best flow rates at which heat transfer occurs.

Additional horizontal runs would benefit the research by allowing for the inclusion in the formulation of the annular heat transfer constants for the Kim and Ghajar (2002) general correlation. If the recommendation of dry out study was initiated and the annular flow region were better defined, then a broader range of data could be measured, thus expanding the limitations of the current constants for the annular flow correlation.

BIBLIOGRAPHY

Aggour, M.A. (1978), "Hydrodynamics and Heat Transfer in Two-Phase Two-Component Flow," Ph.D. Thesis, University of Manitoba, Canada.

Baker, O. (1954), "Simultaneous Flow of Oil and Gas," *Oil and Gas J.*, Vol. 53, pp. 185-195.

Barnea, D. and N. Yacoub (1983), "Heat Transfer in Vertical Upwards Gas-Liquid Slug Flow," *Int. J. Heat Mass Transfer*, Vol. 26, No. 9, pp. 1365-1376.

Chu, Y-C. and B.G. Jones (1980), "Convective Heat Transfer Coefficient Studies in Upward and Downward, Vertical, Two-Phase, Non-Boiling Flows," *AIChE Symp. Series*, Vol. 76, pp. 79-90.

Colburn, A.P. (1933), "A Method of Correlating Forced Convection Heat Transfer Data and a Comparison with Liquid Friction," *Trans. Am. Inst. Chem. Engrs*, Vol. 29, pp. 174-210.

Davis, E.J. and M.M. David (1964), "Two-Phase Gas-Liquid Convection Heat Transfer," *I&EC Fundamentals*, Vol. 3, No. 2, pp. 111-118.

Dorresteijn, W.R. (1970), "Experimental Study of Heat Transfer in Upward and Downward Two-Phase Flow of Air and Oil Through 70 mm Tubes," *Proc. 4th Int. Heat Transfer Conf.*, Vol. 5, B 5.9, pp. 1-10.

Dusseau, W. T. (1968), "Overall Heat Transfer Coefficient for Air-Water Froth in a Vertical Pipe," M. S. Thesis, Chemical Engineering, Vanderbilt University.

Elamvaluthi, G. and N.S. Srinivas (1984), "Two-Phase Heat Transfer in Two Component Vertical Flows," *Int. J. Multiphase Flow*, Vol. 10, No. 2, pp. 237-242.

Ewing, M. E., Weinandy, J. J. and Christensen, R. N. (1999), "Observations of Two-Phase Flow Patterns in a Horizontal Circular Channel," *Heat Transfer Engineering*, Vol. 20, No. 1, pp. 9-14.

Ghajar, A. J. and Tam, L. M., "Heat Transfer Measurements and Correlations in the Transition Region for a Circular Tube with Three Different Inlet Configurations," *Experimental Thermal and Fluid Science*, Vol. 8, No. 1, pp. 79-90, 1994.

Ghajar, A. J. and Zurigat, Y. H., "Microcomputer-Assisted Heat Transfer Measurements/Analysis in a Circular Tube," _International Journal of Applied Engineering Education_, Vol. 7, No. 2, pp. 125-134, 1991.

Gnielinski, V. (1976), "New Equations for Heat and Mass Transfer in Turbulent Pipe and Channel Flow," _Int. Chem. Eng._, Vol. 16, No. 2, pp. 359-368.

Groothuis, H. and W.P. Hendal (1959), "Heat Transfer in Two-Phase Flow," _Chemical Engineering Science_, Vol. 11, pp. 212-220.

Hestroni, G., Yi, J. H., Hu, B. G., Mosyak, L. P., Ziskind, G. (1998a) "Heat Transfer in Intermittent Air-Water Flows – Part II," _Int. J. Multiphase Flow_, Vol. 24, No. 2, pp. 165-188, 1998.

Hestroni, G., Yi, J. H., Hu, B. G., Mosyak, L. P., Ziskind, G. (1998b) "Heat Transfer in Intermittent Air-Water Flows – Part II," _Int. J. Multiphase Flow_, Vol. 24, No. 2, pp. 189-212, 1998.

Hoogendoorn, C.J. (1959), "Gas-Liquid Flow in Horizontal Pipes," _Chemical Engineering Science_, Vol. 9, pp. 205-217.

Hughmark, G.A. (1965), "Holdup and Heat Transfer in Horizontal Slug Gas Liquid Flow," _Chem. Engng. Sci._, Vol. 20, pp. 1007-1010.

Khoze, A.N., S. V. Dunayev, and V. A. Sparin (1976), "Heat and Mass Transfer in Rising Two-Phase Flows in Rectangular Channels," _Heat Transfer Soviet Research_, Vol. 8, No. 3, pp. 87 - 90.

Kim, D. (2000) "An Experimental and Empirical Investigation of Convective Heat Transfer for Gas-Liquid Two-Phase Flow in Vertical and Horizontal Pipes," Ph.D. Dissertation, Oklahoma State University.

Kim, D., Ghajar, A. J., Dougherty, R. L., and Ryali, V.K., (1999), "Comparison of Twenty Two-Phase Heat Transfer Correlations with Seven Sets of Experimental Data, Including Flow Pattern and Tube Orientation Effects," _Heat Transfer Engineering_, Vol. 20, No. 1, pp. 15-40.

Kim, D., and Ghajar, A. J., (2002), "Heat Transfer Measurements and Correlations for Air-Water Flow of Different Flow Patterns in a Horizontal Pipe," Experimental Thermal and Fluid Science, Vol. 25, No. 8, pp 659-676.

Kim, J. (1999) "Construction and Performance Testing of a Uniform Heat Flux Two-Phase Gas-Liquid Experimental Setup Using a Horizontal Circular Tube," M.S. Thesis, Oklahoma State University.

Kim, J. (2000) "Construction and Performance Testing of a Uniform Heat Flux Two-Phase Gas-Liquid Experimental Setup Using a Horizontal Circular Tube," M.S. Thesis, Oklahoma State University.

Kim, J., Trimble, S., and Ghajar, A. J. (2001), "Heat Transfer of Slug Air-Water Flow in a Slightly Upward Inclined Tube," In the *Proceedings of the Heat Transfer Division – 2001*, editors B. Yang et al., ASME, IMECE 2001/HTD-24162, 2001.

King, C.D.G. (1952), "Heat Transfer and Pressure Drop for an Air-Water Mixture Flowing in a 0.737 Inch I.D. Horizontal Tube," M.S. Thesis, University of California.

Kline, S. J. and McClintock, F. A. (1953), "Describing Uncertainties in Single-Sample Experiments," *Mech. Engr.*, Vol. 1, pp. 3-8.

Knott, R.F., R.N. Anderson, A. Acrivos and E.E. Petersen (1959), "An Experimental Study of Heat Transfer to Nitrogen-Oil Mixtures," *Ind. and Engineering Chemistry*, Vol. 51, No. 11, pp. 1369-1372.

Kudirka, A.A., R. J. Grosh and P.W. McFadden (1965), "Heat Transfer in Two-Phase Flow of Gas-Liquid Mixtures," *I & EC Fundamentals*, Vol. 4, No. 3, pp. 339-344.

Martin, B. W. and G. E. Sims (1971), "Forced Convection Heat Transfer to Water With Air Injection in a Rectangular Duct," *Int. J. Heat Mass Transfer*, Vol. 14, pp. 1115-1134.

Oliver, D. R. and S. J. Wright (1964), "Pressure Drop and Heat Transfer in Gas-Liquid Slug Flow in Horizontal Tubes," *British Chem. Engrg.*, Vol. 9, No. 9, pp. 590 - 596.

Pletcher, R.H. (1966), "An Experimental and Analytical Study of Heat Transfer and Pressure Drop in Horizontal Annular Two-Phase, Two-Component Flow," Ph.D. Thesis, Cornell University.

Pletcher, R.H. and H.N. McManus, Jr. (1968), "Heat Transfer and Pressure Drop in Horizontal Annular Two-Phase, Two-Component Flow," *Int. J. Heat Mass Transfer*, Vol. 11, pp. 1087-1104.

Ravipudi, S.R. and T.M. Godbold (1978), "The Effect of Mass Transfer on Heat Transfer Rates for Two-Phase Flow in a Vertical Pipe," *Proc. 6th Int. Heat Transfer Conf.*, Toronto, Vol. 1, pp. 505-510.

Rezkallah, K.S. (1987), "Heat Transfer and Hydrodynamics in Two-Phase Two-Component Flow in a Vertical Tube," PhD. Thesis, University of Manitoba, Winnipeg Canada, 1987.

Rezkallah, K.S. and G.E. Sims (1987), "An Examination of Correlations of Mean Heat Transfer Coefficients in Two-Phase and Two-Component Flow in Vertical Tubes," *AIChE Symp. Series*, Vol. 83, pp. 109-114.

Ryali, V. K (1999), "Design, Construction and Testing of a Single-Phase and Two-Phase Fluid Flow System in a Horizontal Circular Tube with Constant Heat Flux," MS Thesis, School of Mechanical and Aerospace Engineering, Oklahoma State University, Stillwater, Oklahoma.

Serizawa, A., I. Kataoka and I. Michiyoshi (1975), "Turbulence Structure of Air-Water Bubbly Flow-III. Transport Properties," *Int. J. Multiphase Flow*, Vol. 2, pp. 247-259.

Shah, M.M. (1981), "Generalized Prediction of Heat Transfer During Two Component Gas-Liquid Flow in Tubes and Other Channels," *AIChE Symp. Series*, Vol. 77, No. 208, pp. 140-151.

Sieder, E.N. and G.E. Tate (1936), "Heat Transfer and Pressure Drop of Liquids in Tubes," *Ind. Eng. Chem.*, Vol. 28, No. 12, p. 1429.

Taitel, Y. and A.E. Dukler (1976), "A Model for Predicting Flow Regime Transitions in Horizontal and Near Horizontal Gas-Liquid Flow," *AIChE Journal*, Vol. 22, No. 1, pp. 47-54.

Trimble, S.A. (2001), "Heat Transfer Measurements in Air-Water Slug Flow in a Horizontal and Slightly Upward Inclined Tube," M.S. Thesis, Tulsa University

Trimble, S., Kim, J., and Ghajar, A. J. (2002), "Experimental Heat Transfer Comparison in Air-Water Slug Flow in a Slightly Upward Inclined Tube," Heat Transfer 2002, *Proceedings of the Twelfth International Heat Transfer Conference*, Elsevier, pp. 569-574, 2002.

Ueda, T. and M. Hanaoka (1967), "On Upward Flow of Gas-Liquid Mixtures in Vertical Tubes: 3rd. Report, Heat Transfer Results and Analysis," *Bull. JSME*, Vol. 10, pp. 1008-1015.

Vijay, M.M. (1978), "A Study of Heat Transfer in Two-Phase Two-Component Flow in a Vertical Tube," PhD. Thesis, University of Manitoba, Winnipeg Canada, 1978.

Vijay, M.M., M.A. Aggour and G.E. Sims (1982), "A Correlation of Mean Heat Transfer Coefficients for Two-Phase Two-Component Flow in a Vertical Tube," *Proceedings of 7th Int. Heat Transfer Conference*, Vol. 5, pp. 367-372.

APPENDIX A

THERMOCOUPLE CALIBRATION EQUATIONS

TC01-1	y = 1.004x - 0.0764	R^2 = 1.0000
TC01-2	y = 1.0015x - 0.2317	R^2 = 0.9999
TC01-3	y = 1.0047x - 0.3761	R^2 = 0.9999
TC01-4	y = 1.0051x - 0.3862	R^2 = 0.9999
TC02-1	y = 1.0039x - 0.3806	R^2 = 1.0000
TC02-2	y = 1.0032x - 0.1788	R^2 = 0.9996
TC02-3	y = 1.0039x - 0.3294	R^2 = 1.0000
TC02-4	y = 1.0048x - 0.3506	R^2 = 0.9999
TC03-1	y = 1.0011x - 0.3858	R^2 = 1.0000
TC03-2	y = 1.0003x - 0.6256	R^2 = 1.0000
TC03-3	y = 1.0028x - 0.7137	R^2 = 1.0000
TC03-4	y = 1.0064x - 0.8922	R^2 = 1.0000
TC04-1	y = 0.9978x - 0.6054	R^2 = 0.9999
TC04-2	y = 0.9939x - 0.6378	R^2 = 0.9998
TC04-3	y = 0.9957x - 0.5758	R^2 = 0.9999
TC04-4	y = 1.0018x - 0.8015	R^2 = 1.0000
TC05-1	y = 0.9932x - 0.5485	R^2 = 0.9998
TC05-2	y = 0.9938x - 0.6867	R^2 = 0.9999
TC05-3	y = 0.9971x - 0.7887	R^2 = 0.9999
TC05-4	y = 0.9975x - 0.8152	R^2 = 1.0000
TC06-1	y = 0.9962x - 0.9077	R^2 = 0.9999
TC06-2	y = 0.9948x - 0.8795	R^2 = 0.9999
TC06-3	y = 0.9954x - 0.7124	R^2 = 0.9999
TC06-4	y = 0.9987x - 0.5191	R^2 = 1.0000
TC07-1	y = 1.0029x - 0.2257	R^2 = 1.0000
TC07-2	y = 0.9997x - 0.2532	R^2 = 1.0000
TC07-3	y = 1.001x - 0.3428	R^2 = 1.0000
TC07-4	y = 1.0021x - 0.3593	R^2 = 1.0000
TC08-1	y = 1.0446x - 0.4249	R^2 = 0.9990
TC08-2	y= 0.9982x - 0.0011	R^2 = 1.0000
TC08-3	y = 1.0026x - 0.4375	R^2 = 1.0000
TC08-4	y = 1.0021x - 0.4041	R^2 = 1.0000
TC09-1	y = 1.0013x - 0.3741	R^2 = 1.0000
TC09-2	y = 1.0018x - 0.5177	R^2 = 1.0000
TC09-3	y = 1.002x - 0.4327	R^2 = 1.0000
TC09-4	y = 1.0038x - 0.5192	R^2 = 1.0000
TC10-1	y = 1.0037x - 0.477	R^2 = 0.9999
TC10-2	y = 0.9986x - 0.4291	R^2 = 1.0000
TC10-3	y = 0.9991x - 0.6143	R^2 = 1.0000
TC10-4	y = 1.0015x - 0.776	R^2 = 1.0000
TP_IN	y = 1.0003x - 0.7934	R^2 = 1.0000
TP_OUT	y = 1.001x - 0.7931	R^2 = 1.0000

x = measured temperature   y = adjusted temperature R^2 = Residual

APPENDIX B-1

SLUG FLOW DATA

RUN NUMBER 8448
MULTI-PHASE
07-09-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	2.57	GPM
MASS FLOW RATE WATER	=	21.3	LBM/MIN
MASS FLOW RATE GAS	=	.13	LBM/MIN
MASS FLUX	=	195159	LBM/(SQ.FT-HR)
FLUID VELOCITY	=	.87	FT/S
GAS VELOCITY	=	3.83	FT/S
ROOM TEMPERATURE	=	73.85	F
INLET TEMPERATURE	=	75.60	F
OUTLET TEMPERATURE	=	79.88	F
RE NUMBER LIQUID	=	8361	
RE NUMBER GAS	=	2407	
AVERAGE PR NUMBER	=	6.09	
CURRENT TO TUBE	=	402.6	AMPS
VOLTAGE DROP IN TUBE	=	4.32	VOLTS
AVERAGE HEAT FLUX	=	2396	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5935	BTU/HR
Q=M*C*(T2-T1)	=	5483	BTU/HR
HEAT BALANCE ERROR	=	7.62	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	88.92	89.43	89.67	90.21	90.44	90.89	91.02	91.50	91.86	91.84
2	85.50	84.78	87.30	86.74	87.90	87.74	88.58	87.88	88.42	88.88
3	80.65	80.48	80.97	81.28	81.65	81.99	82.31	82.61	82.93	81.70
4	86.01	86.04	86.20	86.52	86.92	87.45	87.76	89.01	88.37	88.88

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	88.01	88.53	88.76	89.31	89.53	89.98	90.11	90.59	90.96	90.93
2	84.56	83.82	86.37	85.80	86.97	86.80	87.65	86.94	87.48	87.95
3	79.62	79.45	79.93	80.25	80.61	80.95	81.27	81.57	81.90	81.66
4	85.07	85.10	85.26	85.58	85.98	86.51	86.82	88.08	87.43	87.95

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	9469	9527	9552	9613	9637	9688	9702	9756	9796	9793
2	9090	9011	9289	9226	9354	9336	9429	9351	9410	9462
3	8560	8542	8593	8627	8665	8702	8736	8768	8803	8777
4	9147	9150	9167	9201	9245	9304	9338	9477	9405	9462

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1568	1546	1574	1558	1573	1566	1578	1579	1563	1576
2	1631	1654	1600	1626	1604	1619	1604	1652	1627	1612
3	1780	1776	1798	1788	1799	1795	1802	1802	1793	1811
4	1619	1622	1629	1631	1629	1626	1625	1601	1628	1612

RUN NUMBER 8448

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	129	126	130	127	131	130	134	133	132	139
2	188	219	165	187	170	182	172	199	196	193
3	476	563	558	572	584	596	618	643	660	677
4	176	184	190	193	193	189	192	172	197	193

RUN NUMBER 8448
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	8167.38	6.25	6.4	2.184	1.968	75.89	84.32	62.25	51.25
2	8210.34	6.21	15.5	2.173	1.970	76.30	84.23	62.25	54.94
3	8253.39	6.17	24.6	2.162	1.950	76.71	85.08	62.24	51.58
4	8296.52	6.14	33.7	2.150	1.947	77.12	85.25	62.24	51.20
5	8339.75	6.10	42.8	2.139	1.934	77.53	85.77	62.24	52.16
6	8383.07	6.07	52.0	2.128	1.928	77.95	86.06	62.23	51.13
7	8426.47	6.03	61.1	2.117	1.919	78.36	86.46	62.23	51.19
8	8469.96	6.00	70.2	2.106	1.911	78.77	86.80	62.22	53.69
9	8513.54	5.96	79.3	2.096	1.908	79.18	86.94	62.22	55.51
10	8557.21	5.93	88.4	2.085	1.904	79.59	87.13	62.22	57.19

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8449
MULTI-PHASE
07-09-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	8.28	GPM
MASS FLOW RATE WATER	=	68.9	LBM/MIN
MASS FLOW RATE GAS	=	09	LBM/MIN
MASS FLUX	=	529711	LBM/(SQ.FT-HR)
FLUID VELOCITY	=	2.81	FT/S
GAS VELOCITY	=	2.16	FT/S
ROOM TEMPERATURE	=	73.50	F
INLET TEMPERATURE	=	76.41	F
OUTLET TEMPERATURE	=	77.71	F
RE NUMBER LIQUID	=	26748	
RE NUMBER GAS	=	1646	
AVERAGE PR NUMBER	=	6.14	
CURRENT TO TUBE	=	399.3	AMPS
VOLTAGE DROP IN TUBE	=	4.27	VOLTS
AVERAGE HEAT FLUX	=	2346	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5817	BTU/HR
Q=M*C*(T2-T1)	=	5367	BTU/HR
HEAT BALANCE ERROR	=	7.72	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	80.02	80.27	80.13	80.22	80.26	80.42	80.27	80.51	80.53	80.53
2	79.13	79.19	79.61	79.56	79.91	80.04	80.08	79.95	79.97	80.23
3	79.21	78.94	79.17	79.33	79.43	79.63	79.67	79.64	79.71	79.40
4	79.52	79.54	79.57	79.80	79.87	79.95	79.88	80.13	80.20	80.18

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	79.09	79.35	79.20	79.29	79.35	79.49	79.34	79.58	79.58	79.60
2	78.19	78.25	78.67	78.62	78.97	79.10	79.14	79.01	78.98	79.30
3	78.27	78.00	78.23	78.39	78.49	78.69	78.73	78.70	78.77	78.45
4	78.58	78.60	78.63	78.86	78.93	79.01	78.94	79.19	79.26	79.25

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	27440	27526	27477	27507	27527	27575	27523	27606	27606	27613
2	27130	27151	27296	27278	27399	27443	27457	27412	27401	27509
3	27159	27066	27144	27199	27233	27301	27315	27305	27329	27221
4	27265	27272	27282	27361	27385	27412	27388	27474	27496	27492

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1597	1592	1601	1602	1606	1605	1608	1604	1604	1607
2	1627	1626	1616	1621	1614	1615	1613	1619	1621	1609
3	1618	1626	1626	1624	1627	1625	1623	1626	1625	1636
4	1617	1617	1617	1615	1615	1618	1618	1614	1614	1610

RUN NUMBER 8449

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR F)

	1	2	3	4	5	6	7	8	9	10
1	615	584	653	662	683	678	769	726	770	814
2	964	1000	839	927	817	815	850	988	1093	961
3	912	1183	1099	1072	1093	1038	1096	1228	1279	1975
4	776	816	858	811	834	856	955	886	913	992

RUN NUMBER 8449
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	26558.62	6.19	6.4	2.168	2.113	76.50	78.53	62.25	207.60
2	26600.82	6.18	15.5	2.164	2.112	76.62	78.55	62.24	219.42
3	26643.05	6.17	24.6	2.161	2.109	76.75	78.68	62.24	218.27
4	26685.30	6.16	33.7	2.157	2.106	76.87	78.79	62.24	220.25
5	26727.58	6.15	42.8	2.154	2.102	77.00	78.94	62.24	217.95
6	26769.89	6.14	52.0	2.150	2.098	77.12	79.07	62.24	216.55
7	26812.22	6.13	61.1	2.147	2.099	77.25	79.04	62.24	235.34
8	26854.58	6.12	70.2	2.144	2.097	77.37	79.12	62.24	241.56
9	26896.97	6.11	79.3	2.140	2.096	77.50	79.15	62.24	255.81
10	26939.38	6.10	88.4	2.137	2.096	77.62	79.15	62.24	276.72

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8450
MULTI-PHASE
07 09 2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	8.56	GPM
MASS FLOW RATE WATER	=	71.2	LBM/MIN
MASS FLOW RATE GAS	=	.11	LBM/MIN
MASS FLUX	=	650939	LBM/(SQ.FT-HR)
FLUID VELOCITY	=	2.91	FT/S
GAS VELOCITY	=	2.59	FT/S
ROOM TEMPERATURE	=	74.00	F
INLET TEMPERATURE	=	76.75	F
OUTLET TEMPERATURE	=	78.32	F
RE NUMBER LIQUID	=	27816	
RE NUMBER GAS	=	2036	
AVERAGE PR NUMBER	=	6.10	
CURRENT TO TUBE	=	451.8	AMPS
VOLTAGE DROP IN TUBE	=	4.71	VOLTS
AVERAGE HEAT FLUX	=	2931	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	7261	BTU/HR
Q=M*C*(T2-T1)	=	6701	BTU/HR
HEAT BALANCE ERROR	=	7.71	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	81.06	81.31	81 28	81.40	81.49	81.65	81.60	81.84	81.89	81.90
2	80.21	80 25	80 74	80.64	81.07	81.18	81.30	81.19	81.16	81.52
3	80.17	79.86	80 32	80.28	80.37	80.62	80.71	80.73	80.81	80.48
4	80.37	80.57	80.64	80.88	80.94	81.09	81.05	81 40	81.45	81.44

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	79 87	80 12	80.09	80.21	80 30	80.46	80.41	80.65	80.70	80.71
2	79 00	79 04	79.54	79.44	79 82	79.98	80.10	79.99	79 96	80 32
3	78.97	78.65	78.93	79.07	79 16	79.41	79.50	79.52	79.60	79.27
4	79.37	79.37	79.44	79.68	79 74	79.89	79.85	80.20	80.25	80.24

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	28640	28730	28718	28760	28792	28849	28830	28916	28934	28937
2	28333	28348	28523	28486	28623	28679	28722	28682	28671	28801
3	28320	28209	28301	28358	28389	28478	28510	28516	28545	28426
4	28463	28463	28487	28573	28594	28647	28632	28758	28775	28772

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	2052	2046	2055	2053	2057	2057	2060	2057	2056	2060
2	2080	2078	2069	2075	2068	2070	2067	2073	2076	2063
3	2076	2084	2085	2083	2086	2084	2083	2086	2084	2097
4	2071	2070	2072	2069	2070	2077	2073	2066	2068	2065

RUN NUMBER 8450

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT HR-F)

	1	2	3	4	5	6	7	8	9	10
1	681	656	701	708	725	722	779	752	780	826
2	968	1019	868	975	875	873	883	999	1036	977
3	983	1267	1189	1181	1226	1157	1196	1296	1354	1995
4	824	876	908	872	908	909	993	903	945	1018

RUN NUMBER 8450
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	27579.00	6 16	6.4	2.158	2.092	76.86	79 30	62.24	221.19
2	27631.78	6.15	15.5	2.154	2.091	77.01	79.30	62.24	236.21
3	27684.60	6.14	24.6	2.149	2.087	77.16	79.49	62.24	231.49
4	27737.47	6.12	33.7	2.145	2.085	77.31	79.60	62.24	236 11
5	27790.37	6.11	42.8	2.141	2.081	77.46	79.75	62.24	235 69
6	27843.31	6.10	52.0	2.137	2.076	77.61	79.93	62 24	232.71
7	27896.30	6.08	61.1	2 133	2.075	77.76	79.96	62.23	245 44
8	27949.32	6.07	70.2	2 129	2.072	77.91	80.00	62.23	248.15
9	28002.38	6.06	79.3	2 125	2.071	78.06	80.13	62.23	261.97
10	28055.48	6.05	88.4	2 121	2.071	78.21	80.13	62.23	281.47

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8451
MULTI-PHASE
07-09 2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	4.48	GPM
MASS FLOW RATE WATER	=	37.3	LBM/MIN
MASS FLOW RATE GAS	=	.09	LBM/MIN
MASS FLUX	=	341004	LBM/(SQ.FT HR)
FLUID VELOCITY	=	1.52	FT/S
GAS VELOCITY	=	2.50	FT/S
ROOM TEMPERATURE	=	74.91	F
INLET TEMPERATURE	=	76.27	F
OUTLET TEMPERATURE	=	79.23	F
RE NUMBER LIQUID	=	14611	
RE NUMBER GAS	=	1650	
AVERAGE PR NUMBER	=	6.09	
CURRENT TO TUBE	=	455.2	AMPS
VOLTAGE DROP IN TUBE	=	4.65	VOLTS
AVERAGE HEAT FLUX	=	2915	BTU/(SQ FT HR)
Q-AMP*VOLT	=	7223	BTU/HR
Q=M*C*(T2-T1)	=	6620	BTU/HR
HEAT BALANCE ERROR	=	8.35	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	84.31	84.93	85.12	85.51	85.78	86.07	86.02	86.27	86.39	86.37
2	82.31	82.32	83.63	83.40	84.15	84.22	84.65	84.36	84.58	85.03
3	80.98	80.70	81.04	81.29	81.54	81.86	82.09	82.25	82.44	82.15
4	82.98	83.12	83.19	83.49	83.68	84.02	84.18	84.97	84.72	84.96

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	83.12	83.74	83.93	84.32	84.59	84.88	84.82	85.07	85.20	85.17
2	81.09	81.09	82.42	82.19	82.94	83.00	83.44	83.14	83.36	83.62
3	79.74	79.45	79.79	80.04	80.29	80.61	80.84	80.99	81.19	80.89
4	81.77	81.91	81.97	82.27	82.46	82.80	82.96	83.76	83.50	83.75

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	15611	15730	15764	15839	15890	15945	15935	15983	16006	16001
2	15230	15231	15480	15435	15578	15590	15672	15616	15658	15745
3	14978	14925	14988	15035	15081	15140	15183	15213	15249	15193
4	15357	15383	15396	15452	15488	15552	15582	15733	15685	15731

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	2061	2047	2061	2052	2058	2056	2065	2065	2062	2071
2	2113	2118	2091	2106	2094	2100	2092	2105	2101	2088
3	2148	2157	2167	2162	2168	2165	2167	2170	2165	2181
4	2096	2097	2103	2104	2106	2105	2104	2089	2100	2090

RUN NUMBER 8451

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	310	292	299	293	294	294	310	312	319	337
2	457	488	388	433	392	410	397	449	455	435
3	657	800	788	796	809	797	815	856	866	1174
4	395	407	426	425	434	429	439	374	441	442

RUN NUMBER 8451
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	14376.99	6.20	6.4	2.168	2.038	76.47	81.43	62.25	113.07
2	14429.04	6.17	15.5	2.160	2.035	76.75	81.55	62.24	114.80
3	14481.16	6.15	24.6	2.153	2.023	77.04	82.01	62.24	110.35
4	14533.36	6.12	33.7	2.145	2.019	77.32	82.31	62.24	112.75
5	14585.63	6.10	42.8	2.137	2.010	77.61	82.57	62.24	110.91
6	14637.97	6.07	52.0	2.130	2.004	77.89	82.82	62.23	111.56
7	14690.39	6.05	61.1	2.122	1.999	78.19	83.02	62.23	113.65
8	14742.89	6.02	70.2	2.114	1.994	78.46	83.24	62.23	114.98
9	14795.46	6.00	79.3	2.107	1.992	78.75	83.31	62.23	120.04
10	14848.10	5.98	88.4	2.099	1.990	79.03	83.41	62.22	125.52

NOTE- TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8452
MULTI-PHASE
07-09-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	4.19	GPM
MASS FLOW RATE WATER	=	34.9	LBM/MIN
MASS FLOW RATE GAS	=	.16	LBM/MIN
MASS FLUX	=	318842	LBM/(SQ.FT-HR)
FLUID VELOCITY	=	1.42	FT/S
GAS VELOCITY	=	4.43	FT/S
ROOM TEMPERATURE	=	76.04	F
INLET TEMPERATURE	=	75.93	F
OUTLET TEMPERATURE	=	79.22	F
RE NUMBER LIQUID	=	13617	
RE NUMBER GAS	=	2994	
AVERAGE PR NUMBER	=	6 10	
CURRENT TO TUBE	=	456.7	AMPS
VOLTAGE DROP IN TUBE	=	4.76	VOLTS
AVERAGE HEAT FLUX	=	2994	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	7417	BTU/HR
Q=M*C*(T2-T1)	=	6758	BTU/HR
HEAT BALANCE ERROR	=	8.88	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	85.77	86.15	86 48	86.85	87.05	87.36	87.36	87.82	87.98	87.98
2	83.16	83.01	84 78	84.44	85.29	85.27	85.81	85.41	85.72	86.15
3	80.66	80.43	80.79	81.05	81.33	81.61	81.86	82.05	82.22	82.06
4	83.79	83.92	84.14	84.47	84.70	85.05	85.27	86.16	85.81	86.10

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	84.58	84.96	85.28	85.66	85.85	86.17	86.16	86.62	86.79	86.78
2	82.13	81.78	83.57	83.22	84.08	84.05	84.60	84.21	84.50	84.94
3	79.39	79.16	79.51	79.77	80.05	80.33	80.58	80.77	80.94	80.77
4	82.57	82 70	82 92	83.25	83.48	83.83	84.05	84.95	84.59	84.69

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	14855	14924	14981	15048	15083	15139	15138	15221	15250	15245
2	14424	14361	14677	14615	14767	14762	14859	14790	14842	14920
3	13945	13905	13965	14011	14059	14108	14151	14184	14215	14185
4	14501	14524	14562	14620	14661	14723	14762	14922	14858	14911

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	2062	2049	2067	2057	2067	2063	2073	2069	2064	2073
2	2115	2126	2091	2108	2093	2101	2091	2110	2106	2094
3	2195	2198	2215	2208	2216	2213	2217	2219	2214	2228
4	2104	2103	2107	2107	2108	2107	2105	2091	2104	2095

RUN NUMBER 8452

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	246	242	244	241	245	245	256	251	255	266
2	356	404	310	346	315	333	320	362	362	352
3	689	832	826	838	852	861	884	930	985	1258
4	330	340	346	344	349	347	352	318	356	356

RUN NUMBER 8452
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	13397.91	6.22	6.4	2.176	2.020	76.21	82.17	62.25	93.04
2	13450.94	6.19	15.5	2.167	2.020	76.52	82.15	62.25	98.41
3	13504.06	6.16	24.6	2 158	2.004	76.83	82.82	62.24	92.52
4	13557.27	6.14	33.7	2.150	2.000	77.14	82.98	62.24	94.95
5	13610.55	6.11	42.8	2.142	1.991	77.45	83.37	62.24	93.67
6	13663.92	6.08	52.0	2.133	1.985	77.76	83.60	62.23	94.93
7	13717.38	6.06	61 1	2.125	1.979	78.07	83.85	62.23	95.86
8	13770.91	6.03	70.2	2.117	1.972	78.38	84.14	62.23	96.19
9	13824 51	6.01	79.3	2.108	1.971	78.69	84.20	62.23	100.39
10	13878.23	5.98	88.4	2.100	1.967	79.00	84.34	62.22	103.57

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8453
MULTI-PHASE
07-09-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	8.37	GPM
MASS FLOW RATE WATER	=	69.6	LBM/MIN
MASS FLOW RATE GAS	=	08	LBM/MIN
MASS FLUX	=	636270	LBM/(SQ.FT-HR)
FLUID VELOCITY	=	2.84	FT/S
GAS VELOCITY	=	2.63	FT/S
ROOM TEMPERATURE	=	76 83	F
INLET TEMPERATURE	=	77.79	F
OUTLET TEMPERATURE	=	79.32	F
RE NUMBER LIQUID	=	27540	
RE NUMBER GAS	=	1428	
AVERAGE PR NUMBER	=	6.02	
CURRENT TO TUBE	=	451 8	AMPS
VOLTAGE DROP IN TUBE	=	4.45	VOLTS
AVERAGE HEAT FLUX	=	2769	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	6860	BTU/HR
Q=M*C*(T2-T1)	=	6382	BTU/HR
HEAT BALANCE ERROR	=	6.97	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	82.49	82 81	82.57	82.57	82.58	82.71	82.61	82.88	82.92	82 99
2	81.23	81.32	81.83	81.74	82.12	82 24	82.34	82.22	82 24	82.58
3	81.26	81.01	81 26	81.45	81.56	81.76	81.87	81.90	81.95	81.70
4	81.56	81.62	81.69	81.96	82.02	82.12	82.13	82.44	82.50	82.52

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	81.31	81.63	81.38	81.38	81.39	81.52	81.41	81.69	81.73	81.80
2	80.02	80 11	80 63	80.54	80.92	81.04	81.14	81.02	81.04	81 18
3	80 08	79.80	80.05	80.24	80.35	80.55	80.66	80.69	80.74	80.49
4	80.38	80.42	80 49	80.76	80.82	80.92	80.93	81.24	81.30	81.32

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	28494	28607	28520	28520	28522	28568	28532	28627	28641	28665
2	28047	28078	28258	28226	28360	28401	28437	28393	28400	28521
3	28066	27971	28058	28124	28162	28232	28270	28280	28298	28209
4	28170	28184	28208	28303	28324	28359	28362	28471	28492	28500

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	2044	2037	2051	2054	2059	2059	2063	2058	2058	2061
2	2088	2087	2074	2079	2071	2072	2070	2077	2078	2067
3	2075	2084	2085	2083	2086	2083	2082	2084	2084	2095
4	2079	2079	2078	2073	2074	2075	2075	2071	2071	2069

RUN NUMBER 8453

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT HR-F)

	1	2	3	4	5	6	7	8	9	10
1	599	567	642	674	708	712	781	744	774	799
2	982	1007	849	944	849	859	875	992	1056	954
3	950	1183	1118	1031	1115	1082	1102	1177	1245	1650
4	837	875	904	855	887	906	964	894	918	981

RUN NUMBER 8453
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	27312.80	6.07	6.4	2.130	2.063	77 89	80.44	62.23	212.00
2	27363.34	6.06	15.5	2.126	2.062	78 04	80.49	62.23	220.81
3	27413.91	6.05	24.6	2.122	2.058	78.19	80.64	62.23	220.75
4	27464.53	6.04	33.7	2.118	2.056	78.33	80.73	62.23	225.76
5	27515.18	6 02	42.8	2 114	2.052	78.48	80.87	62.23	226.41
6	27565.87	6.01	52.0	2.110	2.049	78.63	81.01	62.23	227.30
7	27616.59	6.00	61.1	2.106	2.048	78.78	81.04	62.22	239.04
8	27667.36	5.99	70.2	2.102	2.045	78.92	81.16	62.22	241.63
9	27718 15	5 97	79.3	2.098	2.044	79.07	81.20	62.22	253.45
10	27768 99	5 96	88 4	2.095	2.043	79.22	81.25	62.22	266.18

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8454
MULTI-PHASE
07-10-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	2.25	GPM
MASS FLOW RATE WATER	=	18.7	LBM/MIN
MASS FLOW RATE GAS	=	.06	LBM/MIN
MASS FLUX	=	171314	LBM/(SQ.FT-HR)
FLUID VELOCITY	=	.76	FT/S
GAS VELOCITY	=	1.93	FT/S
ROOM TEMPERATURE	=	74.53	F
INLET TEMPERATURE	=	77.18	F
OUTLET TEMPERATURE	=	81.97	F
RE NUMBER LIQUID	=	7510	
RE NUMBER GAS	=	1043	
AVERAGE PR NUMBER	=	5.93	
CURRENT TO TUBE	=	416.2	AMPS
VOLTAGE DROP IN TUBE	=	4.23	VOLTS
AVERAGE HEAT FLUX	=	2425	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	6007	BTU/HR
Q=M*C*(T2-T1)	=	5382	BTU/HR
HEAT BALANCE ERROR	=	10.41	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	93.65	94.17	94.18	94.77	95.05	95.33	95.24	95.61	96.16	96.05
2	87.33	86.40	89.47	88.51	89.89	89.43	90.53	89.62	90.58	91.10
3	83.06	82.89	83.45	83.84	84.27	84.85	85.24	85.67	86.05	85.56
4	87.77	87.66	87.81	87.87	88.36	88.93	89.59	91.24	90.25	90.98

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	92.72	93.25	93.24	93.84	94.12	94.40	94.29	94.66	95.22	95.10
2	86.30	85.35	88.46	87.48	88.87	88.40	89.51	88.58	89.55	90.08
3	81.97	81.81	82.35	82.76	83.18	83.77	84.15	84.58	84.97	84.46
4	86.74	86.63	86.78	86.83	87.32	87.89	88.56	90.23	89.22	89.96

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	8773	8826	8825	8885	8912	8940	8930	8967	9022	9010
2	8146	8055	8355	8260	8396	8350	8458	8368	8462	8514
3	7735	7719	7770	7808	7848	7904	7941	7982	8019	7970
4	8189	8178	8192	8198	8245	8301	8365	8528	8429	8502

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1608	1582	1623	1597	1615	1609	1634	1635	1621	1640
2	1792	1820	1750	1787	1762	1785	1761	1796	1783	1762
3	1882	1873	1901	1880	1893	1880	1893	1892	1883	1911
4	1781	1788	1793	1804	1801	1798	1786	1754	1791	1765

RUN NUMBER 8454

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	105	103	109	106	109	110	116	117	115	121
2	203	246	174	207	184	207	190	228	213	208
3	421	487	483	485	494	474	487	491	498	679
4	192	206	214	227	225	222	215	184	223	212

RUN NUMBER 8454
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	7317.84	6.11	6.4	2.140	1.908	77.50	86.93	62.24	48.92
2	7360.39	6.07	15.5	2.128	1.912	77.96	86.76	62.23	52.40
3	7403.04	6.03	24.6	2.115	1.891	78.42	87.71	62.23	49.65
4	7445.79	5.99	33.7	2.103	1.890	78.88	87.73	62.22	52.10
5	7488.63	5.95	42.8	2.091	1.876	79.34	88.37	62.22	51.02
6	7531.57	5.91	52.0	2.079	1.871	79.81	88.61	62.22	52.26
7	7574.61	5.88	61.1	2.068	1.860	80.27	89.13	62.21	51.93
8	7617.74	5.84	70.2	2.056	1.851	80.73	89.51	62.21	52.36
9	7660.97	5.80	79.3	2.044	1.847	81.19	89.74	62.20	53.77
10	7704.29	5.76	88.4	2.033	1.843	81.65	89.90	62.20	55.69

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8455
MULTI-PHASE
07-10-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	7.67	GPM
MASS FLOW RATE WATER	=	63.8	LBM/MIN
MASS FLOW RATE GAS	=	.09	LBM/MIN
MASS FLUX	=	582896	LBM/(SQ.FT-HR)
FLUID VELOCITY	=	2.60	FT/S
GAS VELOCITY	=	3.02	FT/S
ROOM TEMPERATURE	=	74.04	F
INLET TEMPERATURE	=	78.31	F
OUTLET TEMPERATURE	=	80.16	F
RE NUMBER LIQUID	=	25445	
RE NUMBER GAS	=	1634	
AVERAGE PR NUMBER	=	5.96	
CURRENT TO TUBE	=	473.4	AMPS
VOLTAGE DROP IN TUBE	=	4.64	VOLTS
AVERAGE HEAT FLUX	=	3025	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	7495	BTU/HR
Q=M*C*(T2-T1)	=	7070	BTU/HR
HEAT BALANCE ERROR	=	5.68	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	83.67	84.09	83.94	84.02	84.05	84.20	84.06	84.36	84.50	84.47
2	82.32	82.40	83.04	82.88	83.34	83.52	83.65	83.54	83.54	83.95
3	82.10	81.81	82.14	82.36	82.46	82.77	82.86	82.93	83.05	82.60
4	82.56	82.72	82.80	83.08	83.18	83.38	83.37	83.84	83.86	83.85

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	82.37	82.79	82.64	82.72	82.74	82.89	82.75	83.05	83.19	83.16
2	80.99	81.07	81.72	81.56	82.02	82.20	82.33	82.22	82.22	82.64
3	80.78	80.48	80.81	81.03	81.13	81.44	81.53	81.60	81.72	81.26
4	81.24	81.40	81.48	81.76	81.86	82.06	82.05	82.52	82.54	82.54

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	26445	26582	26531	26557	26565	26613	26567	26665	26710	26700
2	26004	26030	26237	26184	26334	26391	26434	26397	26396	26531
3	25935	25840	25945	26016	26047	26147	26176	26198	26237	26090
4	26082	26133	26159	26249	26281	26345	26342	26495	26501	26498

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	2244	2237	2250	2250	2256	2258	2263	2260	2257	2263
2	2290	2290	2277	2285	2275	2277	2273	2281	2284	2267
3	2285	2296	2297	2293	2298	2295	2294	2298	2295	2312
4	2284	2282	2283	2280	2279	2280	2280	2273	2276	2270

RUN NUMBER 8455

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR F)

	1	2	3	4	5	6	7	8	9	10
1	570	534	585	600	627	632	697	670	676	724
2	895	930	776	882	791	791	802	898	967	871
3	976	1229	1137	1111	1158	1084	1130	1196	1231	1885
4	815	819	849	816	839	833	894	799	847	908

RUN NUMBER 8455
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	25192.26	6.03	6.4	2.115	2.040	78.43	81.34	62.23	204.10
2	25248.40	6.01	15.5	2.110	2.038	78.61	81.44	62.23	210.24
3	25304.59	6.00	24.6	2.106	2.032	78.79	81.66	62.22	206.78
4	25360.83	5.98	33.7	2.101	2.030	78.97	81.77	62.22	212.12
5	25417.11	5.97	42.8	2.096	2.026	79.15	81.94	62.22	212.51
6	25473.45	5.95	52.0	2.092	2.020	79.32	82.15	62.22	210.08
7	25529.83	5.94	61.1	2.087	2.020	79.50	82.17	62.22	222.68
8	25586.27	5.92	70.2	2.083	2.015	79.68	82.35	62.22	222.26
9	25642.75	5.91	79.3	2.078	2.014	79.86	82.42	62.21	231.58
10	25699.28	5.89	88.4	2.073	2.014	80.04	82.40	62.21	250.92

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8456
MULTI PHASE
07 10-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	4.06	GPM
MASS FLOW RATE WATER	=	33.8	LBM/MIN
MASS FLOW RATE GAS	=	.10	LBM/MIN
MASS FLUX	=	308914	LBM/(SQ.FT HR)
FLUID VELOCITY	=	1.38	FT/S
GAS VELOCITY	=	3.38	FT/S
ROOM TEMPERATURE	=	74.42	F
INLET TEMPERATURE	=	76.09	F
OUTLET TEMPERATURE	=	79.21	F
RE NUMBER LIQUID	=	13220	
RE NUMBER GAS	=	1839	
AVERAGE PR NUMBER	=	6.09	
CURRENT TO TUBE	=	447 6	AMPS
VOLTAGE DROP IN TUBE	=	4.47	VOLTS
AVERAGE HEAT FLUX	=	2756	BTU/(SQ.FT-HR)
Q-AMP*VOLT	=	6827	BTU/HR
Q=M*C*(T2-T1)	=	6322	BTU/HR
HEAT BALANCE ERROR	=	7.40	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	84.53	85.21	85.39	85.94	86.07	86.41	86.47	86.80	87.05	86.97
2	82.63	82 63	84.02	83.81	84.61	84.60	85.14	84.79	85.12	85.54
3	80.76	80.51	80.89	81.16	81 41	81 74	81 94	82.15	82.36	82.07
4	82.94	83.27	83.42	83.77	84.02	84 36	84 63	85.49	85.22	85.45

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	83 38	84.06	84.24	84.79	84.92	85.26	85.31	85.65	85.90	85.81
2	81 45	81 45	82.85	82 63	83.44	83 43	83.97	83.61	83.95	84.38
3	79.55	79.30	79.67	79 94	80.19	80.52	80.72	80.93	81.14	80.84
4	81.77	82.10	82.24	82.59	82.84	83.18	83 46	84.33	84.05	84.28

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	14187	14305	14334	14430	14451	14510	14520	14577	14621	14606
2	13859	13858	14097	14060	14198	14196	14289	14328	14284	14358
3	13538	13495	13558	13604	13645	13701	13734	13770	13806	13755
4	13912	13968	13993	14053	14096	14154	14200	14349	14302	14342

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1989	1976	1992	1980	1991	1987	1996	1994	1989	1999
2	2035	2041	2013	2030	2015	2024	2014	2030	2028	2012
3	2087	2098	2109	2104	2112	2108	2114	2115	2111	2127
4	2027	2025	2029	2031	2030	2030	2027	2012	2025	2015

RUN NUMBER 8456

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR F)

	1	2	3	4	5	6	7	8	9	10
1	281	264	271	260	268	266	276	275	276	293
2	395	421	338	373	339	359	342	389	386	374
3	642	778	761	767	785	775	807	837	865	1155
4	371	368	379	376	379	377	378	339	378	381

RUN NUMBER 8456
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	12996.06	6.21	6.4	2.173	2.036	76 30	81.54	62.25	101.69
2	13045.71	6.18	15.5	2.165	2.031	76.60	81.73	62.24	103.85
3	13095.45	6.16	24.6	2.156	2.018	76.90	82.25	62.24	99.48
4	13145.26	6.13	33.7	2.148	2.012	77.20	82.49	62.24	100.58
5	13195 14	6.11	42.8	2.140	2.003	77.50	82.85	62.24	99.49
6	13245.10	6.08	52.0	2.132	1.997	77.80	83.10	62.23	[illegible]
7	13295.13	6 06	61.1	2.124	1.991	78.10	83.37	62.23	[illegible]
8	13345.24	6.03	70.2	2.116	1.984	78.40	83.63	62.23	[illegible]
9	13395 42	6.00	79.3	2.108	1.983	78.70	83.76	62.23	105.09
10	13445.68	5.98	88.4	2.100	1.980	79.00	83.83	62.22	110.05

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

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RUN NUMBER 8457
MULTI-PHASE
07-10-2002
TEST FLUID IS DISTILLED WATER

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VOLUMETRIC FLOW RATE	=	3.11	GPM
MASS FLOW RATE WATER	=	25.9	LBM/MIN
MASS FLOW RATE GAS	=	.16	LBM/MIN
MASS FLUX	=	236908	LBM/(SQ.FT-HR)
FLUID VELOCITY	=	1.06	FT/S
GAS VELOCITY	=	5.49	FT/S
ROOM TEMPERATURE	=	75.27	F
INLET TEMPERATURE	=	76.16	F
OUTLET TEMPERATURE	=	79.98	F
RE NUMBER LIQUID	=	10192	
RE NUMBER GAS	=	2985	
AVERAGE PR NUMBER	=	6.06	
CURRENT TO TUBE	=	433.5	AMPS
VOLTAGE DROP IN TUBE	=	4.46	VOLTS
AVERAGE HEAT FLUX	=	2663	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	6596	BTU/HR
Q=M*C*(T2-T1)	=	5940	BTU/HR
HEAT BALANCE ERROR	=	9.94	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	88.58	89.16	89.66	90.08	90.24	90.56	90.56	90.99	91.24	91.09
2	85.25	84.55	86.98	86.37	87.47	87.32	88.08	87.50	87.99	88.44
3	80.88	80.70	81.15	81.49	81.83	82.16	82.42	82.69	82.97	82.70
4	85.30	85.53	85.80	86.12	86.49	86.94	87.37	88.58	87.93	88.39

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	87.52	88.11	88.60	89.03	89.18	89.50	89.50	89.93	90.18	90.02
2	84.15	83.44	85.90	85.27	86.38	86.23	87.00	86.40	86.90	87.36
3	79.71	79.53	79.97	80.31	80.65	80.98	81.24	81.51	81.79	81.51
4	84.20	84.43	84.70	85.02	85.39	85.84	86.28	87.50	86.84	87.30

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	11429	11509	11574	11632	11652	11696	11695	11753	11787	11766
2	10982	10888	11212	11130	11277	11256	11359	11280	11346	11407
3	10402	10379	10436	10481	10524	10567	10600	10635	10672	10636
4	10988	11019	11054	11096	11145	11205	11263	11426	11337	11400

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1825	1804	1827	1813	1828	1824	1840	1837	1829	1845
2	1898	1921	1872	1898	1877	1889	1874	1898	1892	1876
3	2025	2024	2048	2036	2046	2042	2051	2053	2044	2062
4	1897	1896	1903	1904	1902	1899	1892	1870	1894	1877

RUN NUMBER 8457

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	164	159	159	157	161	162	169	168	168	179
2	245	288	214	244	220	236	223	256	251	245
3	615	737	727	728	740	748	784	815	839	1153
4	243	247	252	253	253	250	247	219	253	247

RUN NUMBER 8457
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	9981.60	6.20	6.4	2.170	1.978	76.42	83.90	62.25	66.86
2	10028.27	6.17	15.5	2.160	1.979	76.78	83.88	62.24	70.45
3	10075.02	6.14	24.6	2.150	1.957	77.15	84.79	62.24	65.43
4	10121.85	6.10	33.7	2.140	1.954	77.52	84.91	62.24	67.61
5	10168.77	6.07	42.8	2.130	1.943	77.89	85.40	62.23	66.48
6	10215.78	6.04	52.0	2.120	1.937	78.25	85.64	62.23	67.62
7	10262.87	6.01	61.1	2.110	1.929	78.62	86.00	62.23	67.65
8	10310.05	5.98	70.2	2.101	1.921	78.99	86.33	62.22	67.96
9	10357.32	5.95	79.3	2.091	1.919	79.36	86.43	62.22	70.56
10	10404.66	5.92	88.4	2.082	1.917	79.72	86.55	62.22	73.07

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8458
MULTI-PHASE
07-10-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	4.18	GPM
MASS FLOW RATE WATER	=	34.8	LBM/MIN
MASS FLOW RATE GAS	=	.13	LBM/MIN
MASS FLUX	=	317956	LBM/(SQ.FT-HR)
FLUID VELOCITY	=	1.42	FT/S
GAS VELOCITY	=	4.39	FT/S
ROOM TEMPERATURE	=	75.61	F
INLET TEMPERATURE	=	76.15	F
OUTLET TEMPERATURE	=	78.94	F
RE NUMBER LIQUID	=	13589	
RE NUMBER GAS	=	2392	
AVERAGE PR NUMBER	=	6.10	
CURRENT TO TUBE	=	437.8	AMPS
VOLTAGE DROP IN TUBE	=	4.19	VOLTS
AVERAGE HEAT FLUX	=	2526	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	6259	BTU/HR
Q=M*C*(T2-T1)	=	5820	BTU/HR
HEAT BALANCE ERROR	=	7.02	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	85.05	84.82	84.92	85.32	85.50	85.88	85.92	86.35	86.56	86.51
2	83.16	82.67	83.94	83.64	84.34	84.39	84.80	84.51	84.76	85.15
3	79.80	80.00	80.43	80.73	81.02	81.28	81.46	81.65	81.81	81.60
4	83.19	83.18	83.32	83.61	83.82	84.16	84.36	85.16	84.87	85.10

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	83.95	83.72	83.81	84.22	84.39	84.78	84.81	85.24	85.46	85.40
2	82.04	81.55	82.83	82.52	83.23	83.27	83.69	83.39	83.64	84.04
3	78.62	78.83	79.26	79.56	79.85	80.11	80.29	80.48	80.64	80.42
4	82.07	82.06	82.30	82.49	82.70	83.04	83.34	84.05	83.75	83.99

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	14703	14663	14679	14750	14782	14849	14856	14933	14970	14961
2	14368	14281	14506	14451	14576	14584	14657	14604	14648	14719
3	13774	13809	13883	13935	13985	14031	14061	14094	14123	14085
4	14373	14371	14395	14446	14483	14543	14578	14721	14668	14710

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1898	1897	1913	1903	1911	1906	1913	1909	1904	1913
2	1928	1940	1915	1932	1921	1928	1921	1936	1935	1922
3	2034	2022	2030	2022	2027	2025	2029	2031	2027	2040
4	1927	1927	1931	1933	1934	1934	1932	1919	1932	1923

RUN NUMBER 8450

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT HR F)

	1	2	3	4	5	6	7	8	9	10
1	249	266	275	269	273	268	278	271	273	287
2	338	392	323	359	330	344	334	374	375	363
3	890	909	852	836	832	813	867	899	941	1223
4	336	353	362	361	365	360	365	329	366	367

RUN NUMBER 8458
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	13382.88	6.21	6.4	2.172	2.032	76.34	81.67	62.25	95.49
2	13428.59	6.18	15.5	2.165	2.035	76.61	81.54	62.24	103.20
3	13474.36	6.16	24.6	2.157	2.023	76.87	82.02	62.24	98.86
4	13520.20	6.14	33.7	2.150	2.019	77.14	82.20	62.24	100.71
5	13566.09	6.11	42.8	2.143	2.011	77.41	82.54	62.24	99.19
6	13612.05	6.09	52.0	2.135	2.004	77.68	82.80	62.23	99.38
7	13658.07	6.07	61.1	2.128	1.999	77.95	83.01	62.23	100.56
8	13704.15	6.05	70.2	2.121	1.993	78.22	83.29	62.23	100.26
9	13750.29	6.03	79.3	2.114	1.991	78.48	83.37	62.23	104.03
10	13796.50	6.00	88.4	2.107	1.588	78.75	83.46	62.23	107.94

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8460
MULTI-PHASE
07-10-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.32	GPM
MASS FLOW RATE WATER	=	11.0	LBM/MIN
MASS FLOW RATE GAS	=	.09	LBM/MIN
MASS FLUX	=	100749	LBM/(SQ.FT-HR)
FLUID VELOCITY	=	.45	FT/S
GAS VELOCITY	=	3.26	FT/S
ROOM TEMPERATURE	=	77.34	F
INLET TEMPERATURE	=	75.26	F
OUTLET TEMPERATURE	=	78.87	F
RE NUMBER LIQUID	=	4279	
RE NUMBER GAS	=	1781	
AVERAGE PR NUMBER	=	6.14	
CURRENT TO TUBE	=	278.1	AMPS
VOLTAGE DROP IN TUBE	=	2.94	VOLTS
AVERAGE HEAT FLUX	=	1126	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	2789	BTU/HR
Q=M*C*(T2-T1)	=	2389	BTU/HR
HEAT BALANCE ERROR	=	14.36	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	87.56	87.39	87.47	87.78	87.78	88.14	88.12	88.69	89.12	89.34
2	84.82	83.39	85.45	84.71	85.57	85.30	85.99	85.56	86.11	86.55
3	78.34	78.73	79.17	79.48	79.95	80.12	80.41	80.73	80.94	80.90
4	83.47	83.72	84.07	84.28	84.57	84.95	85.42	86.52	86.00	86.59

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	87.15	86.99	87.05	87.37	87.36	87.73	87.70	88.27	88.71	88.92
2	84.39	82.94	85.02	84.27	85.14	84.86	85.56	85.12	85.67	86.11
3	77.80	78.21	78.64	78.96	79.42	79.60	79.88	80.20	80.41	80.37
4	83.02	83.27	83.62	83.83	84.12	84.51	84.98	86.09	85.56	86.15

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	4839	4830	4834	4852	4851	4872	4870	4903	4928	4940
2	4683	4602	4719	4676	4725	4710	4749	4724	4755	4780
3	4320	4341	4365	4382	4408	4417	4433	4451	4462	4460
4	4607	4621	4640	4652	4668	4690	4716	4779	4749	4783

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	700	689	718	703	718	710	726	720	710	717
2	739	777	733	759	744	757	743	766	760	751
3	931	906	926	911	914	911	919	920	915	929
4	773	769	767	770	769	766	758	742	763	750

RUN NUMBER 8460

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	60	61	66	65	68	67	71	69	68	69
2	83	109	83	98	90	99	93	106	102	100
3	404	384	379	378	361	386	400	405	428	534
4	102	103	103	105	106	105	102	90	104	99

RUN NUMBER 8460
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	4195.63	6.28	6.4	2.195	1.997	75.50	83.09	62.25	27.13
2	4214.30	6.25	15.5	2.185	2.003	75.85	82.85	62.25	29.38
3	4233.00	6.22	24.6	2.176	1.986	76.20	83.58	62.25	27.85
4	4251.73	6.19	33.7	2.166	1.985	76.54	83.61	62.25	29.12
5	4270.49	6.16	42.8	2.157	1.975	76.89	84.01	62.24	28.88
6	4289.29	6.13	52.0	2.147	1.972	77.24	84.17	62.24	29.64
7	4308.12	6.10	61.1	2.138	1.963	77.59	84.53	62.24	29.59
8	4326.98	6.07	70.2	2.129	1.954	77.93	84.92	62.23	29.41
9	4345.88	6.04	79.3	2.119	1.950	78.28	85.09	62.23	30.17
10	4364.81	6.01	88.4	2.110	1.943	78.63	85.39	62.23	30.36

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

APPENDIX B-2

ANNULAR FLOW DATA

RUN NUMBER 8471
MULTI-PHASE
07-16-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	.95	GPM
MASS FLOW RATE WATER	=	7.9	LBM/MIN
MASS FLOW RATE GAS	=	1.49	LBM/MIN
MASS FLUX	=	72171	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.32	FT/S
GAS VELOCITY	=	51.49	FT/S
GAS VISCOSITY	=	385.37E-09	LBM-S/FT^2
INLET TEMPERATURE	=	74.70	F
OUTLET TEMPERATURE	=	82.13	F
RE NUMBER LIQUID	=	3118	
RE NUMBER GAS	=	27982	
AVERAGE PR NUMBER	=	6.03	
CURRENT TO TUBE	=	355.3	AMPS
VOLTAGE DROP IN TUBE	=	3.69	VOLTS
AVERAGE HEAT FLUX	=	1805	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	4473	BTU/HR
Q=M*C*(T2-T1)	=	4430	BTU/HR
HEAT BALANCE ERROR	=	.95	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	93.89	93.65	93.00	94.10	94.51	95.66	96.13	96.86	97.08	97.27
2	87.83	84.07	86.65	85.56	87.09	86.52	87.70	86.58	87.52	87.94
3	77.83	78.14	78.62	79.15	79.79	80.26	80.79	81.29	81.77	82.01
4	84.35	83.62	83.69	84.43	85.01	85.72	86.74	88.40	86.89	87.84

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	93.26	93.05	92.37	93.49	93.89	95.05	95.51	96.25	96.48	96.66
2	87.11	83.30	85.92	84.80	86.35	85.76	86.95	85.80	86.75	87.17
3	76.97	77.31	77.78	78.32	78.96	79.43	79.95	80.46	80.95	81.18
4	83.59	82.85	82.92	83.66	84.24	84.95	85.97	87.65	66.11	87.07

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	3718	3709	3681	3728	3745	3793	3813	3844	3854	3861
2	3465	3311	3416	3371	3434	3410	3458	3412	3450	3467
3	3062	3075	3093	3114	3139	3158	3178	3198	3217	3227
4	3322	3293	3296	3325	3349	3377	3419	3487	3424	3463

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1086	1035	1085	1053	1070	1043	1059	1048	1036	1048
2	1235	1330	1263	1311	1287	1322	1306	1350	1335	1330
3	1495	1429	1451	1434	1445	1435	1451	1445	1426	1436
4	1324	1341	1338	1340	1340	1343	1330	1304	1351	1333

RUN NUMBER 8471

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT HR-F)

	1	2	3	4	5	6	7	8	9	10
1	60	60	68	65	67	64	66	65	66	69
2	103	180	136	175	155	189	175	241	228	240
3	845	1021	1257	1464	1607	2175	3102	5640	43766	3209
4	157	193	212	212	216	217	205	175	260	245

RUN NUMBER 8471
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	2993.89	6.31	6.4	2.204	1.947	75.20	85.23	62.26	33.57
2	3021.39	6.25	15.5	2.184	1.973	75.91	84.13	62.25	40.93
3	3049.00	6.18	24.6	2.164	1.958	76.63	84.75	62.24	41.39
4	3076.70	6.12	33.7	2.144	1.951	77.34	85.07	62.24	43.47
5	3104.50	6.06	42.8	2.125	1.932	78.06	85.86	62.23	43.03
6	3132.40	6.00	52.0	2.106	1.922	78.77	86.30	62.22	44.57
7	3160.40	5.94	61.1	2.088	1.904	79.49	87.10	62.22	44.05
8	3188.50	5.88	70.2	2.069	1.894	80.20	87.54	62.21	45.65
9	3216.70	5.82	79.3	2.051	1.894	80.92	87.57	62.20	50.28
10	3244.99	5.77	88.4	2.033	1.884	81.63	88.02	62.20	52.33

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8472
MULTI-PHASE
07-16-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.73	GPM
MASS FLOW RATE WATER	=	14.4	LBM/MIN
MASS FLOW RATE GAS	=	1.54	LBM/MIN
MASS FLUX	=	131796	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.59	FT/S
GAS VELOCITY	=	52.93	FT/S
GAS VISCOSITY	=	385.46E-09	LBM-S/FT^2
INLET TEMPERATURE	=	76.18	F
OUTLET TEMPERATURE	=	81.12	F
RE NUMBER LIQUID	=	5711	
RE NUMBER GAS	=	28748	
AVERAGE PR NUMBER	=	6.01	
CURRENT TO TUBE	=	392.6	AMPS
VOLTAGE DROP IN TUBE	=	3.90	VOLTS
AVERAGE HEAT FLUX	=	2109	BTU/(SQ-FT-HR)
Q=AMP*VOLT	=	5224	BTU/HR
Q=M*C*(T2-T1)	=	4893	BTU/HR
HEAT BALANCE ERROR	=	6.34	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	88.30	90.97	89.42	90.13	90.31	91 04	91.13	91.70	92.08	91.95
2	85 64	83.76	85.23	84.49	85.57	85.31	85.92	85.18	85.84	86.13
3	79 02	79.26	79.64	80.12	80.61	80.97	81.32	81.60	81.95	82.06
4	82.83	83.46	83.24	83.83	84.26	84.70	85.24	86.39	85.56	86.07

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	87.45	90.17	88.59	89.31	89.48	90.22	90.30	90.88	91.26	91.13
2	84 76	82.83	84.33	83.57	84.66	84.39	85.01	84.25	84.92	85.21
3	78.04	78.29	78.67	79.15	79.64	80.00	80.35	80.63	80.99	81.09
4	81.91	82.53	82.31	82.90	83.34	83.77	84.32	85.48	84.63	85.15

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	6353	6556	6438	6492	6504	6560	6566	6620	6639	6628
2	6154	6013	6122	6067	6147	6127	6172	6116	6165	6187
3	5667	5685	5712	5747	5782	5808	5833	5853	5879	5887
4	5946	5991	5975	6018	6049	6081	6121	6207	6144	6182

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1462	1379	1434	1415	1410	1414	1427	1418	1406	1420
2	1517	1602	1550	1584	1566	1586	1577	1607	1599	1592
3	1700	1680	1685	1672	1679	1673	1679	1677	1667	1674
4	1589	1609	1601	1601	1599	1602	1594	1576	1607	1594

RUN NUMBER 8472

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR F)

	1	2	3	4	5	6	7	8	9	10
1	131	104	128	124	129	124	130	128	128	137
2	183	274	225	281	250	286	279	364	347	360
3	1115	1290	1400	1375	1368	1499	1699	2313	2470	5473
4	294	290	330	322	324	327	321	279	372	365

RUN NUMBER 8472
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	5559.68	6.19	6.4	2.167	1.999	76.51	83.04	62.25	62.80
2	5593.28	6.15	15.5	2.154	1.989	76.99	83.46	62.24	63.36
3	5626 96	6.11	24.6	2.141	1.988	77.46	83.48	62.24	68.12
4	5660.71	6.07	33.7	2.128	1.982	77.94	83.74	62.23	70.61
5	5694.55	6.03	42.8	2.116	1.969	78.41	84.28	62.23	69.75
6	5728.46	5.99	52.0	2.103	1.962	78.89	84.60	62.22	71.64
7	5762.46	5.95	61.1	2.091	1.952	79.36	84.99	62.22	72.60
8	5796.53	5.92	70.2	2.079	1.945	79.84	85.31	62.21	74.69
9	5830.68	5.87	79.3	2.066	1.942	80.31	85 45	62.21	79.52
10	5864 92	5 83	88.4	2.054	1.937	80.79	85.64	62.21	84.06

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

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RUN NUMBER 8473
MULTI-PHASE
07-18-2002
TEST FLUID IS DISTILLED WATER

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VOLUMETRIC FLOW RATE	=	2.24	GPM
MASS FLOW RATE WATER	=	18.7	LBM/MIN
MASS FLOW RATE GAS	=	1.47	LBM/MIN
MASS FLUX	=	170501	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.76	FT/S
GAS VELOCITY	=	50.57	FT/S
GAS VISCOSITY	=	385.30E-09	LBM-S/FT^2
INLET TEMPERATURE	=	76.33	F
OUTLET TEMPERATURE	=	80.15	F
RE NUMBER LIQUID	=	7350	
RE NUMBER GAS	=	27498	
AVERAGE PR NUMBER	=	6.04	
CURRENT TO TUBE	=	393.7	AMPS
VOLTAGE DROP IN TUBE	=	3.90	VOLTS
AVERAGE HEAT FLUX	=	2115	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5238	BTU/HR
Q=M*C*(T2-T1)	=	4733	BTU/HR
HEAT BALANCE ERROR	=	9.65	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	85.13	88.47	87.24	87.66	87.69	88.08	88.27	88.68	88.80	88.80
2	83.82	82.86	83.92	83.25	84.08	83.88	84.48	83.84	84.19	84.56
3	78.85	79.03	79.39	79.75	80.14	80.46	80.76	80.97	81.25	81.25
4	81.34	82.58	82.28	82.74	83.07	83.43	83.87	84.78	84.07	84.52

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	84.26	87.64	86.39	86.82	86.84	87.23	87.42	87.83	87.95	87.95
2	82.93	81.94	83.02	82.33	83.17	82.96	83.57	82.91	83.27	83.64
3	77.88	78.06	78.42	78.79	79.18	79.50	79.80	80.01	80.30	80.29
4	80.42	81.65	81.35	81.81	82.15	82.51	82.95	83.87	83.14	83.60

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	7913	8237	8116	8157	8160	8197	8215	8255	8267	8267
2	7788	7694	7796	7731	7810	7791	7848	7786	7820	7855
3	7318	7334	7367	7401	7437	7467	7495	7514	7541	7540
4	7552	7668	7640	7683	7714	7748	7790	7876	7808	7851

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1508	1427	1468	1455	1470	1462	1471	1464	1457	1467
2	1527	1597	1559	1586	1571	1585	1577	1601	1597	1588
3	1669	1670	1670	1658	1663	1658	1664	1662	1650	1661
4	1591	1604	1601	1599	1597	1597	1592	1577	1600	1589

RUN NUMBER 8473

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	196	133	162	159	167	166	170	168	172	182
2	240	320	273	341	307	349	330	426	427	423
3	1286	1504	1515	1505	1483	1538	1652	1953	2143	4184
4	415	341	397	387	390	391	383	335	442	428

RUN NUMBER 8473
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	7199.25	6.19	6.4	2.165	2.040	76.59	81.37	62.24	86.00
2	7232.86	6.15	15.5	2.155	2.016	76.95	82.32	62.24	76.68
3	7266.54	6.12	24.6	2.145	2.017	77.32	82.30	62.24	82.73
4	7300.27	6.09	33.7	2.135	2.013	77.69	82.44	62.23	86.61
5	7334.07	6.06	42.8	2.125	2.004	78.06	82.83	62.23	86.08
6	7367.93	6.03	52.0	2.115	1.998	78.42	83.05	62.23	88.85
7	7401.85	6.00	61.1	2.106	1.989	78.79	83.43	62.22	88.53
8	7435.83	5.97	70.2	2.096	1.984	79.16	83.66	62.22	91.35
9	7469.88	5.94	79.3	2.087	1.984	79.53	83.67	62.22	99.19
10	7503.98	5.91	88.4	2.077	1.979	79.89	83.87	62.21	103.20

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8474
MULTI-PHASE
07-18-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	.88	GPM
MASS FLOW RATE WATER	=	7.3	LBM/MIN
MASS FLOW RATE GAS	=	1.46	LBM/MIN
MASS FLUX	=	66649	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.30	FT/S
GAS VELOCITY	=	50.25	FT/S
GAS VISCOSITY	=	385.18E-09	LBM-S/FT^2
INLET TEMPERATURE	=	74.75	F
OUTLET TEMPERATURE	=	81.15	F
RE NUMBER LIQUID	=	2863	
RE NUMBER GAS	=	27347	
AVERAGE PR NUMBER	=	6.07	
CURRENT TO TUBS	=	320.0	AMPS
VOLTAGE DROP IN TUBE	=	3.30	VOLTS
AVERAGE HEAT FLUX	=	1454	BTU/(SQ.FT HR)
Q=AMP*VOLT	=	3603	BTU/HR
Q=M*C*(T2-T1)	=	3567	BTU/HR
HEAT BALANCE ERROR	=	.98	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	90.65	90.84	90.18	91.40	91.78	92.58	92.97	93.76	94.16	94.13
2	85.59	82.62	84.81	84.07	85.35	84.89	85.84	84.90	85.77	86.05
3	77.34	77.59	78.05	78.54	79.11	79.49	79.94	80.33	80.75	80.97
4	82.77	82.34	82.41	83.12	83.62	84.17	84.99	86.48	85.22	86.01

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	90.14	90.35	89.67	90.91	91.28	92.09	92.47	93.27	93.68	93.64
2	85.01	87.00	84.22	83.46	84.75	84.27	85.23	84.27	85.14	85.43
3	76.64	76.92	77.37	77.87	78.43	78.82	79.26	79.65	80.08	80.30
4	82.15	81.71	81.78	82.49	82.99	83.54	84.37	85.87	84.59	85.39

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	3314	3322	3296	3343	3358	3389	3403	3434	3450	3448
2	3121	3010	3092	3063	3111	3094	3129	3093	3126	3137
3	2816	2826	2842	2860	2880	2894	2910	2924	2940	2947
4	3015	2999	3002	3028	3046	3067	3097	3153	3105	3135

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	877	879	875	844	857	838	851	838	824	818
2	1001	1080	1023	1063	1044	1070	1058	1097	1085	1081
3	1213	1164	1181	1169	1177	1169	1181	1178	1163	1171
4	1072	1087	1084	1087	1088	1089	1079	1057	1099	1082

RUN NUMBER 8474

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT HR F)

	1	2	3	4	5	6	7	8	9	10
1	58	56	66	60	62	60	62	60	60	64
2	101	174	111	165	147	178	166	229	215	229
3	831	1038	1234	1394	1492	2096	3055	7248	-47926	-2763
4	153	183	201	199	203	206	196	165	245	231

RUN NUMBER 8474
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	2764.13	6.31	6.4	2.204	1.988	75.18	83.48	62.26	32.86
2	2786.00	6.26	15.5	2.187	2.006	75.80	82.74	62.25	39.21
3	2807.93	6.20	24.6	2.170	1.993	76.41	83.26	62.25	39.77
4	2829.94	6.15	33.7	2.153	1.983	77.03	83.68	62.24	40.91
5	2852.02	6.09	42.8	2.136	1.967	77.64	84.36	62.24	40.49
6	2874.16	6.04	52.0	2.120	1.960	78.26	84.68	62.23	42.34
7	2896.37	5.99	61.1	2.104	1.944	78.87	85.33	62.22	42.08
8	2918.65	5.94	70.2	2.088	1.934	79.49	85.76	62.22	43.28
9	2940.99	5.89	79.3	2.072	1.932	80.10	85.87	62.21	47.06
10	2963.41	5.84	88.4	2.056	1.925	80.72	86.19	62.21	49.61

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8475
MULTI-PHASE
07-18-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	.98	GPM
MASS FLOW RATE WATER	=	8.1	LBM/MIN
MASS FLOW RATE GAS	=	1.61	LBM/MIN
MASS FLUX	=	74438	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.33	FT/S
GAS VELOCITY	=	55.56	FT/S
GAS VISCOSITY	=	385.62E-09	LBM-S/FT^2
INLET TEMPERATURE	=	75.57	F
OUTLET TEMPERATURE	=	82.54	F
RE NUMBER LIQUID	=	3242	
RE NUMBER GAS	=	30137	
AVERAGE PR NUMBER	=	5.97	
CURRENT TO TUBE	=	360.0	AMPS
VOLTAGE DROP IN TUBE	=	3.62	VOLTS
AVERAGE HEAT FLUX	=	1795	BTU/(SQ FT HR)
Q=AMP*VOLT	=	4447	BTU/HR
Q=M*C*(T2-T1)	=	4325	BTU/HR
HEAT BALANCE ERROR	=	2.74	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	91.25	92.24	91.51	92.95	93.32	94.23	94.73	95.58	95.89	96.00
2	87.30	84.15	86.18	85.49	86.84	86.41	87.45	86.55	87.44	87.86
3	78.51	78.85	79.34	79.90	80.55	80.98	81.48	81.93	82.41	82.67
4	83.96	83.61	83.74	84.51	85.09	85.68	86.64	88.15	86.93	87.73

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	90.57	91.60	90.84	92.30	92.66	93.58	94.08	94.93	95.25	95.35
2	86.57	83.37	85.43	84.71	86.08	85.63	86.68	85.76	86.65	87.08
3	77.65	78.01	78.50	79.06	79.72	80.14	80.64	81.09	81.58	81.83
4	83.18	82.82	82.95	83.72	84.30	84.89	85.86	87.38	86.14	86.94

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	3720	3764	3731	3794	3809	3849	3870	3907	3921	3926
2	3551	3418	3503	3474	3530	3512	3555	3517	3554	3572
3	3185	3200	3219	3242	3268	3286	3306	3324	3344	3355
4	3410	3395	3401	3432	3456	3481	3521	3585	3533	3567

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1175	1106	1152	1117	1132	1112	1125	1112	1100	1113
2	1258	1153	1299	1343	1322	1350	1338	1377	1365	1359
3	1500	1447	1462	1450	1458	1450	1463	1460	1444	1453
4	1343	1367	1362	1368	1367	1369	1358	1337	1378	1363

RUN NUMBER 8475

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT HR F)

	1	2	3	4	5	6	7	8	9	10
1	80	74	85	78	81	78	80	78	79	83
2	119	203	161	201	179	216	202	274	259	271
3	934	1108	1309	1430	1474	1924	2540	4079	8169	-6098
4	188	223	244	241	245	249	234	201	291	279

RUN NUMBER 8475
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	3121.26	6.23	6.4	2.180	1.964	76.04	84.49	62.25	40.85
2	3147.98	6.18	15.5	2.162	1.977	76.71	83.95	62.24	47.62
3	3174.79	6.12	24.6	2.143	1.965	77.38	84.43	62.24	48.88
4	3201.70	6.06	33.7	2.125	1.953	78.05	84.95	62.23	49.92
5	3228.69	6.00	42.8	2.108	1.936	78.72	85.69	62.23	49.42
6	3255.77	5.95	52.0	2.090	1.928	79.39	86.06	62.22	51.57
7	3282.94	5.89	61.1	2.073	1.911	80.06	86.81	62.21	50.94
8	3310.20	5.84	70.2	2.056	1.900	80.73	87.29	62.21	52.41
9	3337.54	5.78	79.3	2.039	1.897	81.40	87.40	62.20	57.21
10	3364.98	5.73	88.4	2.022	1.889	82.07	87.80	62.19	59.89

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8476
MULTI-PHASE
07-18-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.47	GPM
MASS FLOW RATE WATER	=	12.3	LBM/MIN
MASS FLOW RATE GAS	=	1.62	LBM/MIN
MASS FLUX	=	112167	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.50	FT/S
GAS VELOCITY	=	56.05	FT/S
GAS VISCOSITY	=	385.70E-09	LBM-S/FT^2
INLET TEMPERATURE	=	76.62	F
OUTLET TEMPERATURE	=	81.87	F
RE NUMBER LIQUID	=	4897	
RE NUMBER GAS	=	30386	
AVERAGE PR NUMBER	=	5.96	
CURRENT TO TUBE	=	376.9	AMPS
VOLTAGE DROP IN TUBE	=	3.86	VOLTS
AVERAGE HEAT FLUX	=	2004	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	4964	BTU/HR
Q=M*C*(T2-T1)	=	4562	BTU/HR
HEAT BALANCE ERROR	=	8.10	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	87.46	90.29	89.16	90.21	90.57	91.17	91.52	92.17	92.25	92.44
2	86.02	83.99	85.37	84.80	85.88	85.61	86.34	85.59	86.17	86.56
3	79.38	79.68	80.04	80.54	81.07	81.41	81.78	82.08	82.44	82.60
4	82.75	83.45	83.40	84.14	84.60	84.95	85.65	86.74	85.88	86.56

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	86.67	89.55	88.39	89.46	89.81	90.42	90.76	91.42	91.50	91.69
2	85.22	83.14	84.54	83.96	85.04	84.76	85.50	84.73	85.32	85.71
3	78.47	78.79	79.14	79.65	80.17	80.52	80.88	81.18	81.55	81.71
4	81.90	82.59	82.55	83.29	83.75	84.09	84.80	85.90	85.02	85.71

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	5357	5540	5466	5534	5557	5596	5618	5660	5665	5677
2	5266	5136	5224	5187	5255	5237	5283	5235	5272	5297
3	4850	4869	4890	4921	4953	4974	4997	5015	5038	5047
4	5060	5102	5099	5145	5174	5196	5240	5305	5254	5297

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1365	1277	1323	1299	1310	1296	1305	1293	1288	1297
2	1378	1470	1425	1460	1444	1463	1454	1486	1477	1472
3	1572	1548	1556	1546	1553	1545	1555	1552	1539	1549
4	1462	1483	1475	1477	1477	1480	1472	1457	1484	1472

RUN NUMBER 8476

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	140	105	127	118	121	118	121	118	122	127
2	167	259	217	267	238	277	264	351	343	351
3	1048	1184	1343	1334	1315	1515	1766	2292	2855	8181
4	296	290	323	307	310	322	306	270	370	351

RUN NUMBER 8476
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	4759.39	6.15	6.4	2.154	1.998	76.97	83.07	62.24	61.97
2	4789.85	6.11	15.5	2.141	1.987	77.48	83.52	62.24	62.50
3	4820.38	6.07	24.6	2.127	1.984	77.98	83.66	62.23	66.49
4	4851.00	6.02	33.7	2.114	1.974	78.49	84.09	62.23	67.35
5	4881.68	5.98	42.8	2.100	1.959	78.99	84.69	62.22	66.12
6	4912.45	5.94	52.0	2.087	1.953	79.50	84.95	62.22	69.11
7	4943.29	5.90	61.1	2.074	1.941	80.00	85.49	62.21	68.68
8	4974.21	5.86	70.2	2.061	1.933	80.51	85.81	62.21	71.01
9	5005.20	5.82	79.3	2.049	1.933	81.01	85.85	62.20	77.79
10	5036.27	5.78	88.4	2.036	1.924	81.52	86.20	62.20	80.24

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8477
MULTI-PHASE
07-18-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.98	GPM
MASS FLOW RATE WATER	=	16.5	LBM/MIN
MASS FLOW RATE GAS	=	1.64	LBM/MIN
MASS FLUX	=	150756	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.67	FT/S
GAS VELOCITY	=	56.47	FT/S
GAS VISCOSITY	=	385.68E-09	LBM-S/FT^2
INLET TEMPERATURE	=	77.12	F
OUTLET TEMPERATURE	=	81.26	F
RE NUMBER LIQUID	=	6577	
RE NUMBER GAS	=	30617	
AVERAGE PR NUMBER	=	5.96	
CURRENT TO TUBE	=	385.6	AMPS
VOLTAGE DROP IN TUBE	=	3.95	VOLTS
AVERAGE HEAT FLUX	=	2098	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5197	BTU/HR
Q=M*C*(T2-T1)	=	4649	BTU/HR
HEAT BALANCE ERROR	=	10.55	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	84.91	88.58	87.40	88.14	88.35	88.92	88.97	89.43	89.59	89.62
2	84.55	83.54	84.51	84.03	84.90	84.80	85.27	84.61	85.09	85.38
3	79.61	79.85	80.19	80.65	81.10	81.38	81.66	81.84	82.13	82.19
4	81.78	83.06	82.90	83.57	83.95	84.23	84.68	85.53	84.95	85.38

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	84.06	87.78	86.58	87.33	87.53	88.11	88.15	88.62	88.78	88.81
2	83.71	82.66	83.65	83.15	84.03	83.92	84.39	83.72	84.20	84.50
3	78.68	78.92	79.26	79.73	80.18	80.46	80.74	80.92	81.21	81.27
4	80.90	82.17	82.01	82.68	83.06	83.34	83.80	84.65	84.06	84.50

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	6980	7295	7193	7256	7274	7323	7327	7366	7380	7382
2	6951	6863	6946	6904	6978	6969	7008	6952	6992	7017
3	6535	6555	6583	6621	6658	6681	6704	6719	6743	6748
4	6717	6823	6809	6865	6897	6920	6958	7030	6980	7017

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1465	1376	1417	1401	1412	1400	1411	1402	1396	1405
2	1452	1528	1493	1521	1508	1521	1514	1539	1532	1527
3	1601	1600	1601	1593	1597	1593	1598	1596	1587	1595
4	1523	1541	1534	1533	1532	1536	1529	1516	1536	1527

RUN NUMBER 8477

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	219	137	169	160	165	160	168	166	170	179
2	230	314	274	333	299	335	328	435	423	434
3	1245	1418	1497	1401	1347	1488	1683	2178	2523	5561
4	435	352	402	374	376	388	381	339	441	434

RUN NUMBER 8477
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	6431.26	6.12	6.4	2.143	2.028	77.40	81.84	62.24	88.89
2	6463.60	6.08	15.5	2.132	2.002	77.80	82.88	62.23	77.60
3	6496.01	6.05	24.6	2.122	2.003	78.19	82.87	62.23	84.29
4	6528.48	6.01	33.7	2.111	1.994	78.59	83.22	62.23	85.18
5	6561.02	5.98	42.8	2.101	1.983	78.99	83.70	62.22	83.73
6	6593.62	5.95	52.0	2.090	1.977	79.39	83.96	62.22	86.27
7	6626.28	5.91	61.1	2.080	1.969	79.79	84.27	62.22	87.89
8	6659.00	5.88	70.2	2.070	1.964	80.19	84.48	62.21	91.76
9	6691.79	5.85	79.3	2.059	1.962	80.58	84.56	62.21	98.86
10	6724.64	5.82	88.4	2.049	1.958	80.98	84.77	62.20	103.93

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8478
MULTI-PHASE
07-18-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	.97	GPM
MASS FLOW RATE WATER	=	8.0	LBM/MIN
MASS FLOW RATE GAS	=	1.80	LBM/MIN
MASS FLUX	=	73545	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.33	FT/S
GAS VELOCITY	=	62.33	FT/S
GAS VISCOSITY	=	386.06E-09	LBM-S/FT^2
INLET TEMPERATURE	=	76.41	F
OUTLET TEMPERATURE	=	83.87	F
RE NUMBER LIQUID	=	3246	
RE NUMBER GAS	=	33699	
AVERAGE PR NUMBER	=	5.89	
CURRENT TO TUBE	=	375.9	AMPS
VOLTAGE DROP IN TUBE	=	3.87	VOLTS
AVERAGE HEAT FLUX	=	2004	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	4964	BTU/HR
Q=M*C*(T2-T1)	=	4701	BTU/HR
HEAT BALANCE ERROR	=	5.30	

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	90.42	92.58	92.06	93.40	94.00	94.91	95.40	96.18	96.52	96.55
2	88.39	85.37	87.19	86.47	87.80	87.50	88.49	87.68	88.51	88.93
3	79.59	80.00	80.48	81.13	81.84	82.32	82.85	83.30	83.84	84.07
4	84.34	84.50	84.65	85.51	86.16	86.74	87.63	89.15	88.10	88.91

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	89.65	91.86	91.32	92.67	93.27	94.19	94.67	95.46	95.80	95.83
2	87.61	84.53	86.37	85.63	86.97	86.65	87.65	86.82	87.65	88.08
3	78.66	79.10	79.57	80.23	80.93	81.42	81.94	82.39	82.94	83.17
4	83.50	83.64	83.79	84.65	85.30	85.88	86.78	88.31	87.24	88.06

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	3636	3730	3707	3764	3789	3829	3849	3883	3898	3899
2	3551	3424	3500	3469	3525	3512	3553	3519	3553	3571
3	3187	3204	3223	3250	3278	3298	3319	3337	3359	3369
4	3382	3388	3394	3429	3456	3480	3517	3581	3536	3570

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1334	1243	1282	1250	1261	1241	1254	1243	1232	1247
2	1352	1461	1415	1459	1443	1469	1457	1494	1484	1477
3	1611	1565	1578	1564	1572	1564	1575	1573	1557	1567
4	1456	1484	1480	1484	1485	1488	1479	1457	1495	1478

RUN NUMBER 8478

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR F)

	1	2	3	4	5	6	7	8	9	10
1	104	87	98	91	93	90	93	91	93	100
2	126	211	176	222	200	238	226	305	296	313
3	921	1067	1290	1344	1364	1701	2169	3421	5338	-7800
4	221	246	271	265	269	276	266	228	325	315

RUN NUMBER 8478
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	3118.22	6.16	6.4	2.156	1.956	76.91	84.85	62.24	47.36
2	3146.60	6.10	15.5	2.137	1.957	77.63	84.78	62.24	52.54
3	3175.09	6.03	24.6	2.118	1.946	78.35	85.26	62.23	54.28
4	3203.68	5.97	33.7	2.099	1.934	79.06	85.80	62.22	55.74
5	3232.37	5.91	42.8	2.080	1.915	79.78	86.62	62.22	54.86
6	3261.16	5.86	52.0	2.062	1.906	80.50	87.04	62.21	57.34
7	3290.05	5.80	61.1	2.044	1.890	81.22	87.76	62.20	57.25
8	3319.03	5.74	70.2	2.026	1.879	81.93	88.24	62.19	59.37
9	3348.12	5.69	79.3	2.008	1.875	82.65	88.41	62.19	64.95
10	3377.31	5.63	88.4	1.991	1.867	83.37	88.78	62.18	69.04

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8479
MULTI-PHASE
07-18-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.49	GPM
MASS FLOW RATE WATER	=	12.4	LBM/MIN
MASS FLOW RATE GAS	=	1.79	LBM/MIN
MASS FLUX	=	113162	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.51	FT/S
GAS VELOCITY	=	61.69	FT/S
GAS VISCOSITY	=	385.86E-09	LBM-S/FT^2
INLET TEMPERATURE	=	76.93	F
OUTLET TEMPERATURE	=	82.36	F
RE NUMBER LIQUID	=	4965	
RE NUMBER GAS	=	33404	
AVERAGE PR NUMBER	=	5.93	
CURRENT TO TUBE	=	388.7	AMPS
VOLTAGE DROP IN TUBE	=	3.98	VOLTS
AVERAGE HEAT FLUX	=	2130	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5278	BTU/HR
Q=M*C*(T2-T1)	=	4825	BTU/HR
HEAT BALANCE ERROR	=	8.58	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	86.37	89.97	88.97	89.92	90.32	90.92	91.23	91.91	92 33	92.26
2	85.89	84.32	85.55	85.03	86.05	85.84	86.55	85.92	86.56	86.89
3	79.76	80.09	80.45	80 96	81.51	81.90	82.29	82.59	82.98	83.10
4	82.54	83.62	83.57	84 34	84.81	85.24	85.85	87.01	86.35	86.84

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	85.51	89 17	88.14	89.11	89.50	90.11	90.41	91.10	91.52	91.45
2	85.04	83.42	84.67	84.14	85.16	84.96	85.66	85.01	85.66	85.99
3	78.81	79.14	79.50	80.02	80.56	80.96	81.34	81.64	82.04	82.16
4	81.64	82.71	82.66	83 44	83.90	84.33	84.95	86.12	85.44	85.94

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	5331	5565	5499	5561	5586	5625	5645	5689	5717	5712
2	5301	5199	5278	5244	5309	5295	5340	5300	5340	5361
3	4913	4934	4956	4988	5021	5046	5070	5088	5113	5120
4	5088	5155	5152	5200	5230	5257	5295	5370	5327	5359

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1479	1383	1423	1403	1412	1400	1410	1399	1389	1401
2	1463	1554	1515	1547	1534	1552	1544	1573	1567	1559
3	1649	1636	1642	1633	1638	1631	1639	1639	1629	1636
4	1549	1572	1566	1565	1566	1568	1562	1545	1572	1561

RUN NUMBER 8479

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR F.

	1	2	3	4	5	6	7	8	9	10
1	180	121	145	137	139	137	141	137	138	148
2	169	277	239	293	265	308	295	387	374	390
3	1090	1233	1413	1414	1388	1551	1790	2362	4872	10170
4	356	321	362	342	346	354	345	299	396	395

RUN NUMBER 8479
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	4821.23	6.12	6.4	2.146	2.006	77.30	82 75	62.24	73.54
2	4853.06	6.08	15.5	2.132	1.985	77.82	83.61	62.23	69.25
3	4884.98	6.03	24.6	2.118	1 982	78.34	83.75	62.23	74.16
4	4916.98	5.99	33.7	2.104	1.972	78.86	84.17	62.22	75.45
5	4949.07	5.95	42.8	2.090	1.957	79.38	84.78	62.22	74.20
6	4981.23	5.90	52.0	2.077	1.950	79.91	85.09	62.21	77.32
7	5013.48	5.86	61.1	2.063	1.938	80.43	85.59	62.21	77.54
8	5045.81	5.82	70.2	2.050	1.930	80.95	85.97	62 20	79.75
9	5078.22	5.78	79.3	2.037	1.925	81.47	86.17	62.20	85 21
10	5110.71	5 74	88.4	2.024	1.920	81.99	86.38	62.19	91.08

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

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RUN NUMBER 8480
MULTI-PHASE
07-19-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.01	GPM
MASS FLOW RATE WATER	=	8.4	LBM/MIN
MASS FLOW RATE GAS	=	1.97	LBM/MIN
MASS FLUX	=	76943	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.34	FT/S
GAS VELOCITY	=	67.84	FT/S
GAS VISCOSITY	=	385.48E-09	LBM-S/FT^2
INLET TEMPERATURE	=	75.39	F
OUTLET TEMPERATURE	=	82.00	F
RE NUMBER LIQUID	=	3336	
RE NUMBER GAS	=	36836	
AVERAGE PR NUMBER	=	6.00	
CURRENT TO TUBE	=	366.6	AMPS
VOLTAGE DROP IN TUBE	=	3.70	VOLTS
AVERAGE HEAT FLUX	=	1868	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	4628	BTU/HR
Q=M*C*(T2-T1)	=	4406	BTU/HR
HEAT BALANCE ERROR	=	4.81	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	86.19	89.29	88.81	89.91	90.41	91.33	91.87	92.33	92.86	93.05
2	85.41	83.34	84.80	84.15	85.23	85.09	86.01	85.38	86.07	86.57
3	78.31	78.73	79.12	79.65	80.29	80.73	81.28	81.74	82 20	82.44
4	81.86	82.49	82.53	83.27	83.85	84.47	85.28	86.57	85.78	86.52

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	85.44	88.59	88.09	89 21	89.70	90.63	91.17	91.63	92.17	92.35
2	84.66	82.54	84.02	83.35	84.44	84.29	85.21	84.57	85.26	85.76
3	77.44	77.88	78.26	78.80	79.44	79.88	80.43	80.89	81.35	81.59
4	81.06	81.68	81.72	82.46	83.04	83.66	84.47	85.77	84.96	85.71

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	3621	3758	3736	3785	3807	3848	3871	3892	3916	3924
2	3588	3498	3561	3532	3579	3572	3612	3584	3614	3635
3	3284	3302	3318	3340	3367	3385	3408	3428	3447	3457
4	3435	3461	3463	3494	3519	3545	3580	3636	3601	3633

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1300	1204	1235	1209	1218	1201	1210	1207	1192	1204
2	1285	1383	1345	1382	1370	1391	1383	1411	1406	1399
3	1500	1473	1482	1470	1476	1473	1480	1477	1465	1475
4	1376	1404	1403	1405	1406	1407	1401	1380	1413	1401

RUN NUMBER 8480

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	135	99	112	105	107	103	105	106	106	111
2	145	227	194	246	226	263	248	329	324	332
3	933	1046	1280	1389	1392	1697	1904	2448	3368	43323
4	263	269	304	298	301	303	290	251	349	337

RUN NUMBER 8480
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	3217.89	6 25	6.4	2.186	2.020	75.83	82.15	62.25	56.61
2	3244.05	6 20	15 5	2.168	2.008	76.47	82.67	62.25	57.63
3	3270.30	6.14	24.6	2.151	1.999	77.11	83.02	62.24	60.35
4	3296.63	6 09	33.7	2.134	1.989	77.74	83.45	62.23	62.49
5	3323.05	6.03	42.8	2.117	1.972	78.38	84.15	62.23	61.77
6	3349.55	5 98	52.0	2.100	1.961	79.01	84.61	62.22	63.67
7	3376.13	5 93	61.1	2.083	1.945	79.65	85.32	62.22	62.06
8	3402.80	5.87	70.2	2.067	1.936	80.28	85.71	62.21	65.62
9	3429.54	5 82	79.3	2.051	1.931	80.92	85.94	62.20	70.97
10	3456.37	5 77	88.4	2.035	1.921	81.56	86.35	62.20	74.15

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8481
MULTI-PHASE
07-19-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.48	GPM
MASS FLOW RATE WATER	=	12.3	LBM/MIN
MASS FLOW RATE GAS	=	1.93	LBM/MIN
MASS FLUX	=	112735	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.50	FT/S
GAS VELOCITY	=	66.52	FT/S
GAS VISCOSITY	=	385.67E-09	LBM-S/FT^2
INLET TEMPERATURE	=	76.77	F
OUTLET TEMPERATURE	=	81.57	F
RE NUMBER LIQUID	=	4917	
RE NUMBER GAS	=	36069	
AVERAGE PR NUMBER	=	5.97	
CURRENT TO TUBE	=	370.1	AMPS
VOLTAGE DROP IN TUBE	=	3.70	VOLTS
AVERAGE HEAT FLUX	=	1886	BTU/(SQ FT-HR)
Q=AMP*VOLT	=	4672	BTU/HR
Q=M*C*(T2-T1)	=	4309	BTU/HR
HEAT BALANCE ERROR	=	7.76	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	84.26	86.47	87.48	88.09	88.46	89.08	89.34	89.89	90.18	90.35
2	84.26	83.30	84.36	83.73	84.67	84.51	85.12	84.63	85.14	85.55
3	79.26	79.57	79.90	80.31	80.79	81.12	81.48	81.79	82.12	82.28
4	81.44	82.74	82.58	83.17	83.60	83.96	84.56	85.55	84.97	85.54

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	83.48	87.74	86.73	87.35	87.72	88.34	88.60	89.15	89.45	89.61
2	83.49	82.48	83.56	82.92	83.86	83.70	84.31	83.81	84.32	84.73
3	78.40	78.73	79.04	79.46	79.94	80.27	80.63	80.94	81.27	81.43
4	80.63	81.92	81.76	82.35	82.78	83.14	83.74	84.74	84.15	84.72

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	5183	5452	5388	5428	5451	5491	5507	5543	5562	5572
2	5184	5121	5189	5148	5208	5197	5235	5204	5236	5262
3	4870	4889	4909	4934	4964	4984	5006	5025	5046	5056
4	5006	5086	5076	5113	5140	5162	5200	5262	5225	5261

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1354	1253	1289	1274	1282	1269	1279	1271	1263	1271
2	1327	1410	1375	1404	1391	1408	1400	1424	1419	1413
3	1481	1480	1483	1472	1478	1473	1479	1478	1469	1478
4	1399	1424	1420	1418	1419	1422	1415	1401	1424	1414

RUN NUMBER 8481

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR F)

	1	2	3	4	5	6	7	8	9	10
1	212	123	148	143	146	142	146	144	145	152
2	207	286	247	316	282	327	314	409	401	405
3	1130	1276	1444	1501	1483	1696	1939	2414	3025	8228
4	395	326	379	366	369	380	364	317	423	406

RUN NUMBER 8481
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	4790.77	6.14	6.4	2.151	2.036	77.09	81.50	62.24	82.49
2	4818.77	6.10	15.5	2.139	2.007	77.55	82.31	62.24	70.46
3	4846.84	6.06	24.6	2.126	2.005	78.02	82.77	62.23	76.37
4	4874.97	6.02	33.7	2.114	1.999	78.48	83.02	62.23	79.97
5	4903.17	5.98	42.8	2.102	1.986	78.94	83.57	62.22	78.34
6	4931.43	5.95	52.0	2.090	1.979	79.40	83.86	62.22	81.36
7	4959.75	5.91	61.1	2.078	1.968	79.86	84.32	62.21	81.41
8	4988.14	5.87	70.2	2.066	1.960	80.32	84.66	62.21	83.66
9	5016.59	5.83	79.3	2.054	1.957	80.79	84.80	62.21	90.38
10	5045.11	5.80	88.4	2.043	1.949	81.25	85.12	62.20	93.46

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8482
MULTI-PHASE
07-19-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	2.00	GPM
MASS FLOW RATE WATER	=	16.6	LBM/MIN
MASS FLOW RATE GAS	=	1.92	LBM/MIN
MASS FLUX	=	152162	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.68	FT/S
GAS VELOCITY	=	66.23	FT/S
GAS VISCOSITY	=	385.71E-09	LBM-S/FT^2
INLET TEMPERATURE	=	77.47	F
OUTLET TEMPERATURE	=	81.09	F
RE NUMBER LIQUID	=	6646	
RE NUMBER GAS	=	35901	
AVERAGE PR NUMBER	=	5.96	
CURRENT TO TUBE	=	367.7	AMPS
VOLTAGE DROP IN TUBE	=	3.75	VOLTS
AVERAGE HEAT FLUX	=	1899	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	4705	BTU/HR
Q=M*C*(T2-T1)	=	4183	BTU/HR
HEAT BALANCE ERROR	=	11.10	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	83.19	87.30	86.51	86.76	86.78	87.26	87.31	87.78	88.00	88.11
2	83.61	83.08	83.86	83.27	83.93	83.84	84.24	83.81	84.22	84.57
3	79.67	79.92	80.21	80.57	80.93	81.16	81.42	81.63	81.86	81.96
4	81.13	82.58	82.36	82.84	83.09	83.40	83.78	84.54	84.12	84.54

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	82.41	86.57	85.76	86.02	86.03	86.52	86.56	87.04	87.26	87.36
2	82.85	82.28	83.07	82.47	83.14	83.04	83.44	83.00	83.41	83.77
3	78.84	79.08	79.37	79.74	80.10	80.33	80.59	80.80	81.03	81.13
4	80.33	81.77	81.55	82.03	82.28	82.59	82.98	83.74	83.31	83.74

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	6906	7259	7190	7212	7213	7254	7258	7299	7318	7327
2	6943	6895	6962	6911	6967	6959	6993	6956	6991	7021
3	6609	6629	6653	6684	6713	6733	6754	6772	6791	6799
4	6733	6851	6834	6875	6896	6922	6954	7019	6982	7018

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1351	1260	1287	1280	1291	1282	1291	1283	1278	1285
2	1317	1387	1361	1384	1372	1384	1378	1398	1393	1387
3	1441	1448	1448	1438	1440	1438	1441	1440	1434	1442
4	1381	1400	1399	1395	1394	1395	1390	1379	1396	1388

RUN NUMBER 8482

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	288	148	175	176	186	181	191	186	189	197
2	256	329	292	372	340	366	378	490	477	475
3	1283	1419	1504	1466	1453	1644	1836	2226	2694	5145
4	527	377	445	426	438	444	438	384	496	480

RUN NUMBER 8482
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	6517.06	6.09	6.4	2.134	2.046	77.71	81.10	62.23	105.72
2	6545.65	6.06	15.5	2.125	2.014	78.06	82.42	62.23	82.21
3	6574.28	6.03	24.6	2.116	2.013	78.41	82.44	62.23	88.97
4	6602.97	6.00	33.7	2.107	2.010	78.76	82.56	62.22	94.14
5	6631.70	5.97	42.8	2.098	2.002	79.11	82.89	62.22	94.75
6	6660.48	5.94	52.0	2.088	1.997	79.45	83.12	62.22	97.72
7	6689.32	5.91	61.1	2.079	1.990	79.80	83.39	62.22	99.75
8	6718.20	5.88	70.2	2.071	1.984	80.15	83.64	62.21	102.44
9	6747.13	5.86	79.3	2.062	1.981	80.50	83.75	62.21	109.89
10	6776.10	5.83	88.4	2.053	1.976	80.85	84.00	62.21	113.46

NOTE; TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8483
MULTI PHASE
07-19 2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	2.02	GPM
MASS FLOW RATE WATER	=	16.8	LBM/MIN
MASS FLOW RATE GAS	=	1.78	LBM/MIN
MASS FLUX	=	151636	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.69	FT/S
GAS VELOCITY	=	61.30	FT/S
GAS VISCOSITY	=	385.45E-09	LBM-S/FT^2
INLET TEMPERATURE	=	76.70	F
OUTLET TEMPERATURE	=	80.57	F
RE NUMBER LIQUID	=	6656	
RE NUMBER GAS	=	33291	
AVERAGE PR NUMBER	=	6.01	
CURRENT TO TUBE	=	380.5	AMPS
VOLTAGE DROP IN TUBE	=	3.94	VOLTS
AVERAGE HEAT FLUX	=	2064	BTU/(SQ.FT HR)
Q=AMP*VOLT	=	5114	BTU/HR
Q=M*C*(T2-T1)	=	4465	BTU/HR
HEAT BALANCE ERROR	=	12.69	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	83.25	88.00	87.17	87.34	87.24	87.69	87.86	88.24	88.43	88.57
2	83.35	82.90	83.94	83.22	83.93	83 72	84.20	83.65	84.13	84.47
3	79.05	79.37	79.70	80.06	80.44	80.67	80.96	81.20	81.43	81.57
4	80.76	82.43	82.27	82 67	82.91	83.22	83.65	84.49	83.99	84.46

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	82.42	87.22	86.38	86.55	86.44	86.90	87.06	87.45	87.64	87.78
2	82.53	82.04	83.10	82 36	83.08	82.86	83.35	82.78	83.27	83.61
3	78 16	78.47	78.80	79 17	79.55	79.78	80.07	80 31	80.54	80.68
4	79.90	81.56	81.40	81 80	82.05	82.35	82.79	83.64	83.13	83.60

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	6974	7386	7313	7328	7318	7358	7372	7405	7422	7434
2	6983	6942	7032	6969	7030	7012	7053	7005	7046	7075
3	6616	6643	6670	6701	6732	6752	6776	6796	6816	6827
4	6762	6901	6888	6922	6942	6969	7005	7077	7034	7074

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1438	1334	1366	1358	1373	1363	1371	1365	1360	1367
2	1413	1490	1458	1483	1468	1483	1477	1499	1492	1487
3	1545	1555	1558	1545	1547	1543	1548	1545	1539	1546
4	1479	1502	1500	1497	1494	1495	1491	1477	1496	1488

RUN NUMBER 8483

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	263	134	157	160	171	168	174	173	176	183
2	253	316	270	346	317	367	355	465	448	450
3	1292	1366	1423	1417	1411	1613	1775	2085	2556	4219
4	502	355	405	401	415	423	414	363	469	452

RUN NUMBER 8483
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	6517.94	6.15	6.4	2.155	2 055	76.96	80.75	62.24	101.30
2	6548.68	6.12	15.5	2 145	2 016	77.33	82.32	62.24	76.99
3	6579.48	6.09	24 6	2.135	2.014	77.70	82 42	62.23	81.48
4	6610.33	6.06	33.7	2.125	2.012	78.08	82.47	62.23	87.36
5	6641.25	6.03	42.8	2 115	2.005	78.45	82.78	62.23	88.64
6	6672 22	5.99	52.0	2.105	2.000	78.82	82.97	62.22	92.39
7	6703 24	5.96	61.1	2.095	1.992	79.19	83.32	62.22	93.03
8	6734.33	5.93	70.2	2.086	1 987	79.57	83 54	62.22	96.39
9	6765.47	5.90	79.3	2.076	1 984	79.94	83.64	62.21	103.42
10	6796.66	5 87	88.4	2.066	1 978	80.31	83.92	62.21	106.24

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8484
MULTI-PHASE
07-19-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	2.01	GPM
MASS FLOW RATE WATER	=	16.9	LBM/MIN
MASS FLOW RATE GAS	=	1.90	LBM/MIN
MASS FLUX	=	154548	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.69	FT/S
GAS VELOCITY	=	65.36	FT/S
GAS VISCOSITY	=	385.59E-09	LBM S/FT^2
INLET TEMPERATURE	=	76.88	F
OUTLET TEMPERATURE	=	81.08	F
RE NUMBER LIQUID	=	6725	
RE NUMBER GAS	=	35463	
AVERAGE PR NUMBER	=	5.98	
CURRENT TO TUBE	=	398.0	AMPS
VOLTAGE DROP IN TUBE	=	1.98	VOLTS
AVERAGE HEAT FLUX	=	2181	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5404	BTU/HR
Q=M*C*(T2-T1)	=	4911	BTU/HR
HEAT BALANCE ERROR	=	9.11	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	83.40	87.65	86.85	87.36	87.56	88.04	88.21	88.73	88.97	89.02
2	83.82	83.18	84.07	83.60	84.42	84.29	84.78	84.26	84.78	85.11
3	79.44	79.77	80.08	80.50	80.93	81.19	81.50	81.73	81.99	82.17
4	81.08	82.63	82.48	83.09	83.48	83.75	84.25	85.17	84.61	85.07

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	82.48	86.79	85.97	86.49	86.68	87.17	87.33	87.86	88.10	88.14
2	82.92	82.24	83.15	82.66	83.49	83.35	83.85	83.31	83.84	84.17
3	78.47	78.79	79.10	79.53	79.95	80.22	80.52	80.75	81.02	81.20
4	80.14	81.68	81.53	82.15	82.54	82.81	83.31	84.19	83.67	84.13

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	7021	7392	7321	7365	7382	7425	7439	7485	7506	7510
2	7058	7000	7078	7036	7107	7095	7138	7092	7137	7165
3	6682	6709	6735	6771	6806	6829	6855	6874	6896	6911
4	6822	6953	6940	6992	7026	7048	7092	7167	7122	7162

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1583	1488	1518	1507	1518	1507	1516	1508	1502	1511
2	1547	1623	1594	1618	1606	1619	1613	1636	1629	1624
3	1684	1690	1691	1683	1688	1683	1688	1687	1681	1687
4	1617	1637	1635	1631	1630	1632	1626	1614	1633	1625

RUN NUMBER 8484

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT HR F)

	1	2	3	4	5	6	7	8	9	10
1	297	161	189	185	192	188	195	191	194	205
2	268	347	307	377	340	388	378	492	473	481
3	1291	1379	1495	1461	1435	1627	1800	2206	2692	4242
4	542	397	458	432	433	450	436	384	499	487

RUN NUMBER 8484
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	6573.40	6.14	6.4	2.149	2.049	77.16	81.00	62.24	109.41
2	6607.00	6.10	15.5	2.138	2.015	77.57	82.38	62.24	87.42
3	6640.66	6.07	24.6	2.128	2.013	77.97	82.44	62.23	94.05
4	6674.40	6.03	33.7	2.117	2.007	78.37	82.71	62.23	96.97
5	6708.20	6.00	42.8	2.106	1.996	78.78	83.17	62.22	95.71
6	6742.06	5.96	52.0	2.096	1.990	79.18	83.39	62.22	99.86
7	6776.00	5.93	61.1	2.085	1.982	79.59	83.75	62.22	100.70
8	6810.00	5.90	70.2	2.075	1.975	79.99	84.03	62.21	103.88
9	6844.07	5.87	79.3	2.064	1.972	80.39	84.16	62.21	111.46
10	6878.20	5.83	88.4	2.054	1.966	80.80	84.42	62.21	116.01

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8485
MULTI-PHASE
07-20-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	2.54	GPM
MASS FLOW RATE WATER	=	21.1	LBM/MIN
MASS FLOW RATE GAS	=	1.97	LBM/MIN
MASS FLUX	=	192836	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.86	FT/S
GAS VELOCITY	=	67.83	FT/S
GAS VISCOSITY	=	385.24E-09	LBM-S/FT^2
INLET TEMPERATURE	=	76.61	F
OUTLET TEMPERATURE	=	79.57	F
RE NUMBER LIQUID	=	8298	
RE NUMBER GAS	=	36896	
AVERAGE PR NUMBER	=	6.06	
CURRENT TO TUBE	=	368.5	AMPS
VOLTAGE DROP IN TUBE	=	3.77	VOLTS
AVERAGE HEAT FLUX	=	1913	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	4740	BTU/HR
Q=M*C*(T2-T1)	=	4224	BTU/HR
HEAT BALANCE ERROR	=	10.88	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	81.40	84.72	84.39	84.52	84.56	84.91	84.97	85.30	85.44	85.47
2	81.80	81.54	82.17	81.57	82.20	82.12	82.48	82.08	82.34	82.66
3	78.64	78.82	79.08	79.33	79.63	79.87	80.11	80.26	80.45	80.45
4	79.65	81.11	80.85	81.21	81.48	81.77	82.07	82.70	82.34	82.62

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	80.61	83.97	83.63	83.77	83.80	84.15	84.21	84.54	84.69	84.71
2	81.03	80.74	81.38	80.77	81.40	81.32	81.68	81.27	81.53	81.86
3	77.81	77.99	78.25	78.50	78.80	79.04	79.28	79.43	79.62	79.62
4	78.85	80.30	80.04	80.40	80.67	80.96	81.26	81.90	81.53	81.82

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	8562	8919	8883	8897	8901	8939	8945	8981	8996	8999
2	8606	8576	8643	8579	8646	8637	8675	8632	8660	8694
3	8269	8287	8314	8341	8372	8397	8422	8438	8458	8458
4	8377	8530	8502	8540	8569	8599	8631	8698	8660	8690

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1359	1291	1304	1298	1309	1303	1310	1305	1300	1307
2	1331	1383	1367	1387	1375	1385	1380	1397	1394	1386
3	1429	1442	1440	1430	1435	1431	1434	1433	1427	1435
4	1386	1394	1400	1396	1394	1394	1390	1381	1394	1388

RUN NUMBER 8485

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	357	187	208	212	223	220	230	227	232	244
2	315	379	341	446	398	449	436	565	569	557
3	1425	1617	1659	1706	1684	1769	1879	2279	2654	5766
4	680	434	526	509	511	510	506	445	569	567

RUN NUMBER 8485
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	8165.30	6.17	6.4	2.159	2.085	76.81	79.57	62.24	130.20
2	8194.79	6.14	15.5	2.151	2.055	77.09	80.75	62.24	98.53
3	8224.31	6.12	24.6	2.143	2.053	77.38	80.82	62.24	104.49
4	8253.88	6.09	33.7	2.136	2.053	77.66	80.86	62.24	112.61
5	8283.49	6.07	42.8	2.128	2.045	77.95	81.17	62.23	111.71
6	8313.14	6.04	52.0	2.121	2.040	78.23	81.37	62.23	114.70
7	8342.83	6.02	61.1	2.113	2.034	78.52	81.61	62.23	116.32
8	8372.57	6.00	70.2	2.106	2.029	78.80	81.79	62.22	120.47
9	8402.35	5.97	79.3	2.098	2.028	79.09	81.84	62.22	130.34
10	8432.16	5.95	88.4	2.091	2.024	79.37	82.00	62.22	136.60

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8486
MULTI-PHASE
07-20-2001
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	2.29	GPM
MASS FLOW RATE WATER	=	19.0	LBM/MIN
MASS FLOW RATE GAS	=	1.95	LBM/MIN
MASS FLUX	=	173839	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.78	FT/S
GAS VELOCITY	=	67.22	FT/S
GAS VISCOSITY	=	385.53E-09	LBM-S/FT^2
INLET TEMPERATURE	=	77.02	F
OUTLET TEMPERATURE	=	80.61	F
RE NUMBER LIQUID	=	7549	
RE NUMBER GAS	=	36489	
AVERAGE PR NUMBER	=	5.99	
CURRENT TO TUBE	=	387.0	AMPS
VOLTAGE DROP IN TUBE	=	3.85	VOLTS
AVERAGE HEAT FLUX	=	2052	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5083	BTU/HR
Q=M*C*(T2-T1)	=	4668	BTU/HR
HEAT BALANCE ERROR	=	8.17	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	82.49	86.83	86.20	86.46	86.56	86.91	87.00	87.44	87.54	87.62
2	82.88	82.69	83.49	82.90	83.68	83.52	83.93	83.42	83.77	84.11
3	79.26	79.50	79.83	80.20	80.56	80.81	81.06	81.22	81.45	81.50
4	80.56	82.25	81.99	82.47	82.80	83.02	83.44	84.20	83.71	84.11

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	81.62	86.01	85.37	85.63	85.73	86.08	86.17	86.61	86.71	86.79
2	82.03	81.80	82.62	82.02	82.80	82.63	83.05	82.53	82.88	83.22
3	78.34	78.58	78.91	79.28	79.64	79.89	80.14	80.30	80.54	80.58
4	79.67	81.36	81.09	81.58	81.91	82.13	82.55	83.32	82.82	83.22

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	7815	8239	8176	8202	8211	8245	8254	8297	8307	8315
2	7854	7832	7910	7852	7928	7912	7952	7901	7935	7968
3	7504	7526	7557	7593	7626	7650	7674	7689	7711	7716
4	7630	7790	7765	7811	7842	7863	7904	7977	7929	7968

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1499	1410	1433	1425	1437	1429	1437	1429	1425	1433
2	1468	1533	1509	1532	1519	1530	1525	1546	1541	1534
3	1582	1597	1596	1585	1590	1585	1589	1509	1581	1590
4	1528	1544	1547	1543	1541	1543	1537	1526	1542	1534

RUN NUMBER 8486

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	344	167	193	194	202	201	210	206	213	221
2	308	365	323	412	365	419	410	542	539	537
3	1461	1649	1672	1609	1594	1751	1967	2550	3080	7487
4	633	412	493	470	472	491	477	419	552	537

RUN NUMBER 8486
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	7403.15	6.13	6.4	2.147	2.064	77.26	80.42	62.24	125.05
2	7435.47	6.10	15.5	2.137	2.026	77.61	81.94	62.24	91.77
3	7467.84	6.07	24.6	2.128	2.024	77.95	82.00	62.23	98.20
4	7500.26	6.04	33.7	2.119	2.021	78.30	82.13	62.23	103.67
5	7532.74	6.01	42.8	2.110	2.011	78.64	82.52	62.23	102.40
6	7565.28	5.98	52.0	2.101	2.007	78.99	82.68	62.22	107.35
7	7597.87	5.95	61.1	2.092	2.000	79.33	82.98	62.22	108.87
8	7630.52	5.92	70.2	2.083	1.995	79.68	83.19	62.22	112.95
9	7663.22	5.90	79.3	2.074	1.994	80.02	83.24	62.21	121.36
10	7695.97	5.87	88.4	2.065	1.989	80.37	83.45	62.21	128.43

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8487
MULTI-PHASE
07-23-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	.98	GPM
MASS FLOW RATE WATER	=	8.2	LBM/MIN
MASS FLOW RATE GAS	=	1.55	LBM/MIN
MASS FLUX	=	74791	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.33	FT/S
GAS VELOCITY	=	53.40	FT/S
GAS VISCOSITY	=	385.45E-09	LBM-S/FT^2
INLET TEMPERATURE	=	74.98	F
OUTLET TEMPERATURE	=	82.25	F
RE NUMBER LIQUID	=	3239	
RE NUMBER GAS	=	29003	
AVERAGE PR NUMBER	=	6.01	
CURRENT TO TUBE	=	360.0	AMPS
VOLTAGE DROP IN TUBE	=	3.66	VOLTS
AVERAGE HEAT FLUX	=	1815	BTU/(SQ.FT HR)
Q=AMP*VOLT	=	4495	BTU/HR
Q=M*C*(T2-T1)	=	4493	BTU/HR
HEAT BALANCE ERROR	=	08	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	92.78	93.17	92.29	93.28	93.82	94.96	95.53	96.25	96.74	96.64
2	87.33	84.03	86.29	85.29	86.81	86.34	87.46	86.51	87.31	87.74
3	78.05	78.32	78.83	79.31	79.93	80.45	81.00	81.49	81.98	82.17
4	84.20	83.59	83.50	84.22	84.92	85.56	86.49	88.21	86.78	87.62

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	92.12	92.54	91.63	92.64	93.17	94.32	94.89	95.61	96.11	96.00
2	86.59	83.24	85.54	84.51	86.05	85.56	86.69	85.71	86.52	86.95
3	77.18	77.48	77.98	78.47	79.08	79.61	80.15	80.64	81.14	81.33
4	83.42	82.80	82.71	83.43	84.13	84.77	85.70	87.44	85.98	96.83

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	3804	3822	3783	3826	3849	3899	3924	3956	3978	3973
2	3569	3429	3524	3482	3546	3525	3573	3532	3566	3584
3	3181	3193	3214	3233	3258	3280	3307	3322	3342	3350
4	3436	3410	3407	3437	3466	3492	3531	3604	3543	3579

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1149	1080	1130	1102	1117	1091	1103	1095	1074	1093
2	1275	1362	1300	1344	1321	1355	1341	1381	1373	1364
3	1515	1458	1473	1458	1471	1461	1474	1471	1451	1463
4	1350	1373	1371	1371	1369	1374	1366	1338	1387	1367

RUN NUMBER 8487

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	68	65	76	73	74	71	72	73	71	76
2	114	192	149	193	169	205	191	258	251	263
3	887	1114	1324	1616	1803	2272	3026	5266	17786	3374
4	169	207	234	234	233	236	226	189	232	169

RUN NUMBER 8487
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	3113.30	6.29	6.4	2.196	1.956	75.47	84.83	62.25	36.93
2	3141.23	6.22	15.5	2.177	1.975	76.17	84.01	62.25	43.98
3	3169.25	6.16	24.6	2.157	1.965	76.87	84.46	62.24	45.39
4	3197.37	6.10	33.7	2.138	1.958	77.57	84.76	62.24	47.88
5	3225.59	6.04	42.8	2.120	1.938	78.27	85.61	62.23	46.92
6	3253.91	5.98	52.0	2.101	1.928	78.96	86.06	62.22	48.48
7	3282.33	5.92	61.1	2.083	1.910	79.66	86.86	62.22	47.83
8	3310.84	5.87	70.2	2.065	1.899	80.36	87.35	62.21	49.20
9	3339.45	5.81	79.3	2.047	1.897	81.06	87.44	62.20	53.87
10	3368.16	5.76	88.4	2.030	1.889	81.76	87.78	62.20	57.04

NOTE TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8488
MULTI-PHASE
07-23-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.35	GPM
MASS FLOW RATE WATER	=	11.2	LBM/MIN
MASS FLOW RATE GAS	=	1.60	LBM/MIN
MASS FLUX	=	102593	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.46	FT/S
GAS VELOCITY	=	55.04	FT/S
GAS VISCOSITY	=	385.70E-09	LBM-S/FT^2
INLET TEMPERATURE	=	76.27	F
OUTLET TEMPERATURE	=	82.32	F
RE NUMBER LIQUID	=	4479	
RE NUMBER GAS	=	29837	
AVERAGE PR NUMBER	=	5.96	
CURRENT TO TUBE	=	381.9	AMPS
VOLTAGE DROP IN TUBE	=	3.87	VOLTS
AVERAGE HEAT FLUX	=	2035	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5043	BTU/HR
Q=M*C*(T2-T1)	=	4782	BTU/HR
HEAT BALANCE ERROR	=	5.17	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	89.49	91.71	90.41	91.46	91.95	92.85	93.29	93.80	93.97	94.00
2	86.81	84.35	86.00	85.26	86.51	86.19	87.06	86.19	86.86	87.23
3	79.21	79.45	79.92	80.40	80.94	81.37	81.80	82.17	82.60	82.71
4	83.54	83.86	83.73	84.45	85.03	85.52	86.23	87.56	86.52	87.19

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	88.69	90.96	89.63	90.70	91.18	92.09	92.53	93.04	93.21	93.24
2	85.99	83.47	85.15	84.39	85.65	85.32	86.19	85.31	85.98	86.36
3	78.27	78.52	78.99	79.40	80.01	80.45	80.87	81.24	81.68	81.79
4	82.67	82.98	82.65	83.57	84.15	84.64	85.35	86.70	85.64	86.31

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	5017	5150	5072	5134	5163	5217	5242	5273	5281	5285
2	4860	4717	4813	4769	4841	4822	4872	4821	4860	4882
3	4424	4438	4464	4492	4521	4546	4570	4590	4615	4621
4	4671	4689	4681	4722	4755	4783	4824	4901	4840	4879

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1373	1289	1342	1315	1327	1306	1316	1309	1300	1313
2	1421	1515	1462	1501	1483	1508	1498	1532	1522	1515
3	1636	1603	1610	1599	1609	1601	1610	1607	1592	1602
4	1505	1527	1520	1522	1521	1526	1519	1497	1531	1516

RUN NUMBER 8488

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	114	94	113	106	108	104	105	105	108	115
2	152	243	199	250	221	260	246	310	321	334
3	1025	1251	1370	1467	1529	1750	2097	2812	3660	47231
4	250	266	302	293	293	298	289	248	348	337

RUN NUMBER 8488
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	4336.48	6.18	6.4	2.163	1.978	76.67	83.90	62.24	53.64
2	4368.01	6.13	15.5	2.147	1.976	77.24	83.98	62.24	57.51
3	4399.63	6.08	24.6	2.132	1.972	77.81	84.16	62.23	61.10
4	4431.35	6.03	33.7	2.116	1.963	78.39	84.53	62.23	63.00
5	4463.15	5.98	42.8	2.101	1.946	78.96	85.25	62.22	61.55
6	4495.04	5.94	52.0	2.086	1.938	79.53	85.62	62.22	63.51
7	4527.02	5.89	61.1	2.072	1.924	80.10	86.24	62.21	63.07
8	4559.09	5.84	70.2	2.057	1.916	80.68	86.57	62.21	65.57
9	4591.25	5.80	79.3	2.043	1.915	81.25	86.63	62.20	71.79
10	4623.49	5.75	88.4	2.028	1.908	81.82	86.92	62.20	75.64

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

--
RUN NUMBER 8489
MULTI-PHASE
07-23-2002
TEST FLUID IS DISTILLED WATER
--

VOLUMETRIC FLOW RATE	=	1.98	GPM
MASS FLOW RATE WATER	=	16.5	LBM/MIN
MASS FLOW RATE GAS	=	1.57	LBM/MIN
MASS FLUX	=	150704	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.67	FT/S
GAS VELOCITY	=	54.23	FT/S
GAS VISCOSITY	=	385.69E-09	LBM-S/FT^2
INLET TEMPERATURE	=	77.18	F
OUTLET TEMPERATURE	=	81.25	F
RE NUMBER LIQUID	=	6577	
RE NUMBER GAS	=	29403	
AVERAGE PR NUMBER	=	5.96	
CURRENT TO TUBE	=	378.4	AMPS
VOLTAGE DROP IN TUBE	=	3.86	VOLTS
AVERAGE HEAT FLUX	=	2012	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	4983	BTU/HR
Q=M*C*(T2-T1)	=	4547	BTU/HR
HEAT BALANCE ERROR	=	8.76	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	85.81	88.94	87.86	88.32	88.43	88.95	89.17	89.46	89.69	89.80
2	84.80	83.64	84.71	84.02	84.89	84.70	85.26	84.59	85.03	85.35
3	79.70	79.82	80.19	80.55	80.95	81.27	81.56	81.78	82.07	82.10
4	82.19	83.22	83.00	83.51	83.84	84.17	84.66	85.51	84.90	85.36

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	85.00	88.18	87.07	87.54	87.65	88.17	88.39	88.68	88.91	89.02
2	83.99	82.79	83.88	83.17	84.05	83.85	84.42	83.73	84.18	84.50
3	78.80	78.93	79.29	79.66	80.06	80.38	80.67	80.89	81.19	81.21
4	81.34	82.36	82.14	82.65	82.99	83.31	83.81	84.67	84.04	84.51

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	7057	7326	7232	7272	7281	7326	7344	7369	7389	7398
2	6972	6872	6963	6904	6977	6960	7008	6950	6988	7015
3	6543	6553	6583	6613	6646	6672	6696	6714	6739	6741
4	6751	6836	6818	6861	6888	6916	6957	7029	6977	7016

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1395	1315	1353	1339	1352	1341	1349	1344	1336	1344
2	1403	1474	1438	1466	1451	1467	1459	1483	1478	1472
3	1551	1548	1549	1538	1543	1537	1544	1541	1531	1541
4	1469	1485	1482	1479	1478	1480	1475	1459	1482	1472

RUN NUMBER 8489

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	184	127	153	150	156	153	157	158	160	167
2	214	298	255	322	288	330	316	419	411	418
3	1149	1433	1464	1489	1486	1584	1783	2213	2551	6589
4	378	328	379	367	372	379	368	326	428	416

RUN NUMBER 8489
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	6433.53	6.11	6.4	2.141	2.017	77.45	82.28	62.24	78.70
2	6465.32	6.08	15.5	2.131	1.998	77.85	83.06	62.23	72.84
3	6497.17	6.04	24.6	2.120	1.997	78.24	83.10	62.23	78.15
4	6529.09	6.01	33.7	2.110	1.993	78.63	83.26	62.23	82.02
5	6561.07	5.98	42.8	2.100	1.983	79.02	83.68	62.22	81.36
6	6593.11	5.95	52.0	2.090	1.977	79.41	83.93	62.22	83.97
7	6625.21	5.91	61.1	2.079	1.968	79.80	84.32	62.22	83.97
8	6657.38	5.88	70.2	2.069	1.964	80.19	84.49	62.21	88.21
9	6689.60	5.85	79.3	2.059	1.962	80.58	84.58	62.21	94.88
10	6721.88	5.82	88.4	2.050	1.957	80.98	84.81	62.20	98.83

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8490
MULTI-PHASE
07-23-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	2.47	GPM
MASS FLOW RATE WATER	=	20.6	LBM/MIN
MASS FLOW RATE GAS	=	1.56	LBM/MIN
MASS FLUX	=	188028	LBM/(SQ.FT HR)
LIQUID VELOCITY	=	.84	FT/S
GAS VELOCITY	=	54.00	FT/S
GAS VISCOSITY	=	385.76E-09	LBM-S/FT^2
INLET TEMPERATURE	=	77.68	F
OUTLET TEMPERATURE	=	81.10	F
RE NUMBER LIQUID	=	8223	
RE NUMBER GAS	=	29263	
AVERAGE PR NUMBER	=	5.95	
CURRENT TO TUBE	=	384.6	AMPS
VOLTAGE DROP IN TUBE	=	3.93	VOLTS
AVERAGE HEAT FLUX	=	2082	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5157	BTU/HR
Q=M*C*(T2-T1)	=	4655	BTU/HR
HEAT BALANCE ERROR	=	9.73	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	84.45	87.78	87.14	87.46	87.47	87.91	87.95	88.37	88.48	88.47
2	84.10	83.69	84.44	83.79	84.60	84.41	84 83	84.27	84.59	84.86
3	80.05	80.13	80.49	80.83	81.19	81.45	81.67	81.82	82.06	82.04
4	81.80	83.09	82.96	83.40	83.70	83.93	84.30	85.09	84.54	84.88

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	83 60	86.97	86.32	86.64	86.65	87.09	87.11	87.55	87.67	87.65
2	83.26	82.61	83.58	82.91	83.73	83.54	83.96	83.39	83.71	83 98
3	79 14	79.21	79.57	79.92	80.28	80.54	80.76	80.91	81.15	81 13
4	80 92	82.21	82.08	82.52	82.82	83.05	83 42	84.22	83.66	84 00

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	8658	9013	8944	8978	8978	9025	9029	9074	9086	9085
2	8622	8555	8656	8587	8672	8651	8696	8636	8670	8698
3	8198	8205	8242	8278	8314	8341	8364	8379	8404	8402
4	8381	8513	8500	8546	8577	8601	8640	8723	8664	8700

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1464	1389	1415	1405	1419	1409	1418	1410	1405	1413
2	1455	1515	1487	1513	1497	1511	1504	1526	1523	1515
3	1576	1585	1586	1575	1580	1574	1579	1578	1569	1578
4	1514	1525	1525	1523	1530	1523	1518	1505	1523	1514

RUN NUMBER 8490

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	257	159	182	181	191	186	195	192	197	208
2	272	346	296	376	332	379	369	480	480	486
3	1283	1636	1577	1540	1503	1598	1806	2269	2565	6106
4	502	384	434	420	423	436	428	375	488	483

RUN NUMBER 8490
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	8073.14	6.07	6.4	2.129	2 011	77.91	81 73	62.23	102.70
2	8106 54	6.04	15.5	2.120	2.006	78.24	82.75	62.23	86.95
3	8140.00	6.02	24.6	2.112	2.002	78.57	82.89	62.23	90.81
4	8173.51	5.99	33.7	2.103	2 000	78.90	83.00	62.22	95.57
5	8207 07	5.96	42.8	2.094	1.991	79.23	83.17	62.22	94.60
6	8240.69	5.93	52 0	2.086	1 986	79.55	83.55	62.22	97.97
7	8274.37	5 91	61.1	2.077	1.980	79.88	83.82	62.21	99.60
8	8308.09	5.88	70.2	2.069	1.975	80.21	84.02	62.21	102 34
9	8341 87	5.85	79.3	2.061	1.975	80.54	84.05	62.21	111.67
10	8375.71	5.83	88.4	2.052	1.971	80.87	84.19	62.21	117.81

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8491
MULTI-PHASE
07-23-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.04	GPM
MASS FLOW RATE WATER	=	8.7	LBM/MIN
MASS FLOW RATE GAS	=	1.67	LBM/MIN
MASS FLUX	=	79321	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.35	FT/S
GAS VELOCITY	=	57.87	FT/S
GAS VISCOSITY	=	386.19E 09	LBM-S/FT^2
INLET TEMPERATURE	=	76.70	F
OUTLET TEMPERATURE	=	84.23	F
RE NUMBER LIQUID	=	3515	
RE NUMBER GAS	=	31263	
AVERAGE PR NUMBER	=	5.86	
CURRENT TO TUBE	=	385.5	AMPS
VOLTAGE DROP IN TUBE	=	3.89	VOLTS
AVERAGE HEAT FLUX	=	2065	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5116	BTU/HR
Q=M*C*(T2-T1)	=	4949	BTU/HR
HEAT BALANCE ERROR	=	3.28	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	92.58	94.15	93.39	94.59	95.23	96.47	96.79	97.60	98.01	98.09
2	89.01	85.94	87.95	87.16	88.69	88.40	89.35	88.41	89.32	89.68
3	79.91	80.25	80.77	81.41	82.12	82.64	83.16	83.62	84.15	84.35
4	85.37	85.27	85.35	86.18	86.94	87.55	88.38	90.04	88.83	89.70

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	91.78	93.40	92.61	93.83	94.46	95.72	96.03	96.84	97.26	97.33
2	88.17	85.05	87.09	86.27	87.82	87.51	88.47	87.50	88.42	88.78
3	78.93	79.30	79.81	80.46	81.16	81.69	82.20	82.66	83.20	83.40
4	84.48	84.37	84.45	85.28	86.04	86.65	87.48	89.16	87.92	88.80

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	4019	4093	4057	4113	4142	4200	4215	4253	4272	4275
2	3856	3716	3807	3771	3840	3826	3869	3826	3867	3883
3	3449	3465	3487	3515	3546	3568	3591	3611	3635	3643
4	3691	3686	3690	3726	3760	3787	3825	3900	3844	3884

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1375	1295	1341	1311	1325	1298	1313	1302	1288	1302
2	1443	1545	1492	1536	1515	1545	1512	1573	1562	1557
3	1700	1651	1665	1650	1662	1653	1663	1661	1645	1655
4	1537	1562	1558	1561	1560	1567	1557	1531	1575	1556

RUN NUMBER 8491

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	94	83	96	90	92	87	90	89	90	95
2	131	217	176	222	196	211	221	301	288	307
3	986	1209	1441	1528	1569	1923	2558	4288	8100	-5067
4	211	242	268	264	262	269	262	222	319	306

RUN NUMBER 8491
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	3375.66	6.13	6.4	2.148	1.933	77.21	85.84	62.24	45.91
2	3406.60	6.07	15.5	2.129	1.940	77.93	85.53	62.23	52.01
3	3437.66	6.01	24.6	2.109	1.929	78.65	85.99	62.23	53.83
4	3468.83	5.95	33.7	2.090	1.919	79.38	86.46	62.22	55.73
5	3500.11	5.89	42.8	2.072	1.898	80.10	87.37	62.21	54.28
6	3531.50	5.83	52.0	2.053	1.887	80.83	87.89	62.21	55.82
7	3563.00	5.77	61.1	2.035	1.872	81.55	88.54	62.20	56.34
8	3594.61	5.72	70.2	2.017	1.862	82.28	89.04	62.19	58.19
9	3626.33	5.66	79.3	2.000	1.858	83.00	89.20	62.18	63.43
10	3658.15	5.61	88.4	1.982	1.850	83.72	89.58	62.18	67.24

NOTE. TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8492
MULTI-PHASE
07-23-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.37	GPM
MASS FLOW RATE WATER	=	11.4	LBM/MIN
MASS FLOW RATE GAS	=	1.67	LBM/MIN
MASS FLUX	=	103946	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.46	FT/S
GAS VELOCITY	=	57.64	FT/S
GAS VISCOSITY	=	386.29E-09	LBM-S/FT^2
INLET TEMPERATURE	=	77.38	F
OUTLET TEMPERATURE	=	84.05	F
RE NUMBER LIQUID	=	4621	
RE NUMBER GAS	=	31113	
AVERAGE PR NUMBER	=	5.84	
CURRENT TO TUBE	=	408.7	AMPS
VOLTAGE DROP IN TUBE	=	4.14	VOLTS
AVERAGE HEAT FLUX	=	2330	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5773	BTU/HR
Q=M*C*(T2-T1)	=	5455	BTU/HR
HEAT BALANCE ERROR	=	5.50	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	90.85	94.06	92.70	93.65	94.14	95.21	95.60	96.31	96.62	96.69
2	88.70	86 36	88.02	87.19	88.56	88.28	89.18	88.29	89.09	89.44
3	80.68	80.97	81.44	82.01	82.64	83.13	83.60	84.01	84.49	84.60
4	85.05	85.72	85.50	86.27	86.93	87.51	88.30	89.78	88.75	89.44

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	89.92	93.19	91.80	92.77	93.25	94.33	94.72	95.43	95.75	95.81
2	87.76	85.36	87.05	86.20	87.58	87.28	88.19	87.28	88.09	88.44
3	79.61	79.91	80.38	80.96	81.58	82.08	82.54	82.95	83.44	83.54
4	84.06	84.71	84.49	85.26	85.93	86.50	87.30	88.79	87.74	88.44

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	5156	5351	5268	5326	5355	5420	5443	5487	5506	5510
2	5028	4888	4987	4937	5018	5000	5054	5000	5048	5068
3	4558	4575	4602	4635	4670	4699	4725	4749	4777	4783
4	4813	4850	4838	4883	4921	4955	5001	5089	5027	5068

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1598	1495	1548	1524	1538	1515	1527	1517	1507	1518
2	1626	1730	1677	1718	1698	1726	1715	1753	1742	1736
3	1860	1832	1838	1824	1835	1827	1837	1835	1820	1831
4	1720	1747	1742	1742	1740	1746	1738	1714	1751	1736

RUN NUMBER 8492

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT HR F)

	1	2	3	4	5	6	7	8	9	10
1	132	101	122	117	119	113	117	115	117	124
2	163	251	211	266	236	276	263	353	339	358
3	1046	1271	1451	1515	1545	1756	2127	2896	3785	-32409
4	276	279	323	316	314	319	309	264	366	358

RUN NUMBER 8492
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	4458.45	6.08	6.4	2.131	1.944	77.83	85.34	62.23	59.15
2	4494.48	6.02	15.5	2.114	1.934	78.47	85.79	62.23	60.60
3	4530.62	5.97	24.6	2.097	1.931	79.11	85.93	62.22	65.03
4	4566.88	5.92	33.7	2.081	1.922	79.75	86.30	62.22	67.74
5	4603.24	5.86	42.8	2.064	1.905	80.39	87.08	62.21	66.23
6	4639.72	5.81	52.0	2.048	1.894	81.04	87.55	62.20	67.99
7	4676.32	5.76	61.1	2.032	1.880	81.68	88.19	62.20	68.01
8	4713.02	5.71	70.2	2.016	1.871	82.32	88.61	62.19	70.28
9	4749.84	5.66	79.3	2.001	1.868	82.96	88.75	62.18	76.30
10	4786.77	5.61	88.4	1.985	1.861	83.60	89.06	62.18	80.95

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8493
MULTI-PHASE
07-23-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.90	GPM
MASS FLOW RATE WATER	=	15.8	LBM/MIN
MASS FLOW RATE GAS	=	1.65	LBM/MIN
MASS FLUX	=	144689	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	65	FT/S
GAS VELOCITY	=	57.08	FT/S
GAS VISCOSITY	=	385.95E-09	LBM-S/FT^2
INLET TEMPERATURE	=	77.34	F
OUTLET TEMPERATURE	=	82.42	F
RE NUMBER LIQUID	=	6366	
RE NUMBER GAS	=	30887	
AVERAGE PR NUMBER	=	5.91	
CURRENT TO TUBE	=	426.2	AMPS
VOLTAGE DROP IN TUBE	=	4.27	VOLTS
AVERAGE HEAT FLUX	=	2506	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	6209	BTU/HR
Q=M*C*(T2-T1)	=	5507	BTU/HR
HEAT BALANCE ERROR	=	11.31	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	86.57	91.58	90.43	91.04	91.05	91.85	92.01	92.60	92.91	92.86
2	85.27	84.98	86.48	85.59	86.72	86.53	87.17	86.46	86.87	87.35
3	80.18	80.57	80.96	81.41	81.91	82.33	82.67	82.98	83.32	83.37
4	82.65	84.61	84.39	85.00	85.44	85.87	86.38	87.68	86.86	87.32

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	85.54	90.61	89.43	90.05	90.05	90.86	91.02	91.61	91.93	91.87
2	84.23	83.90	85.42	84.51	85.65	85.45	86.10	85.37	85.78	86.27
3	79.06	79.39	79.82	80.28	80.78	81.20	81.54	81.85	82.20	82.24
4	81.57	83.52	83.30	83.91	84.36	84.78	85.30	86.61	85.77	86.24

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	6819	7234	7137	7188	7188	7255	7268	7317	7344	7339
2	6713	6686	6809	6736	6828	6812	6864	6805	6838	6875
3	6302	6328	6362	6398	6437	6471	6498	6522	6550	6554
4	6500	6656	6638	6688	6723	6758	6799	6906	6838	6876

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1778	1674	1719	1701	1731	1704	1715	1708	1695	1709
2	1798	1876	1828	1865	1843	1864	1855	1885	1883	1871
3	1944	1960	1965	1950	1958	1951	1957	1957	1944	1955
4	1865	1885	1883	1880	1876	1881	1875	1854	1883	1872

RUN NUMBER 8493

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	226	134	159	155	165	158	164	162	164	174
2	274	327	270	347	306	349	338	441	449	446
3	1414	1610	1685	1717	1712	1808	2112	2615	3198	11967
4	479	352	405	394	397	403	400	336	450	450

RUN NUMBER 8493
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	6194.52	6.09	6.4	2.135	2.009	77.68	82.60	62.23	98.07
2	6232.67	6.05	15.5	2.122	1.967	78.17	84.15	62.23	78.03
3	6270.92	6.01	24.6	2.109	1.964	78.66	84.50	62.23	82.61
4	6309.25	5.97	33.7	2.096	1.959	79.15	84.69	62.22	86.94
5	6347.68	5.93	42.8	2.084	1.947	79.64	85.31	62.22	86.42
6	6386.20	5.89	52.0	2.071	1.939	80.12	85.58	62.21	88.34
7	6424.81	5.85	61.1	2.059	1.929	80.61	85.99	62.21	89.56
8	6463.51	5.81	70.2	2.046	1.921	81.10	86.36	62.20	91.50
9	6502.31	5.77	79.3	2.034	1.920	81.59	86.42	62.20	93.56
10	6541.19	5.73	88.4	2.022	1.914	82.08	86.66	62.19	105.02

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8494
MULTI-PHASE
07-24-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	2.46	GPM
MASS FLOW RATE WATER	=	20.5	LBM/MIN
MASS FLOW RATE GAS	=	1.67	LBM/MIN
MASS FLUX	=	187103	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.84	FT/S
GAS VELOCITY	=	57.52	FT/S
GAS VISCOSITY	=	385.84E-09	LBM-S/FT^2
INLET TEMPERATURE	=	77.64	F
OUTLET TEMPERATURE	=	81.56	F
RE NUMBER LIQUID	=	8204	
RE NUMBER GAS	=	31148	
AVERAGE PR NUMBER	=	5.93	
CURRENT TO TUBE	=	418.4	AMPS
VOLTAGE DROP IN TUBE	=	4.24	VOLTS
AVERAGE HEAT FLUX	=	2443	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	6052	BTU/HR
Q=M*C*(T2-T1)	=	5344	BTU/HR
HEAT BALANCE ERROR	=	11.70	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	84.58	89.20	88.39	88.79	88.74	89.22	89.28	89.69	89.90	89.98
2	84.14	84.15	85.24	84.52	85.41	85.26	85.73	85.15	85.48	85.84
3	80.22	80.44	80.82	81.18	81.58	81.92	82.19	82.40	82.67	82.62
4	81.84	83.79	83.56	84.07	84.40	84.76	85.13	86.05	85.47	85.85

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	83.57	88.25	87.42	87.82	87.77	88.25	88.31	88.72	88.93	89.01
2	83.14	83.11	84.22	83.48	84.38	84.23	84.70	84.11	84.44	84.80
3	79.15	79.36	79.74	80.10	80.50	80.84	81.11	81.32	81.60	81.54
4	80.80	82.75	82.51	83.03	83.36	83.72	84.09	85.02	84.43	84.81

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	8613	9103	9015	9058	9052	9104	9109	9153	9176	9184
2	8567	8565	8680	8603	8697	8681	8730	8668	8703	8741
3	8159	8180	8218	8256	8296	8331	8359	8380	8409	8403
4	8327	8527	8503	8556	8591	8628	8667	8763	8702	8742

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1736	1645	1677	1664	1682	1672	1687	1676	1668	1675
2	1733	1797	1764	1792	1774	1789	1781	1805	1802	1794
3	1849	1871	1872	1861	1866	1861	1865	1865	1855	1866
4	1792	1806	1807	1803	1800	1802	1797	1781	1802	1791

RUN NUMBER 8494

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	306	165	191	189	201	197	206	205	208	217
2	331	372	317	402	356	403	392	506	512	511
3	1483	1737	1734	1740	1713	1763	1970	2330	2732	7590
4	618	404	468	451	456	458	457	397	513	510

RUN NUMBER 8494
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	8032.77	6.07	6.4	2.129	2.032	77.90	81.67	62.23	123.39
2	8070.88	6.04	15.5	2.119	1.991	78.28	83.36	62.23	91.36
3	8109.05	6.01	24.6	2.109	1.988	78.66	83.47	62.23	96.43
4	8147.29	5.98	33.7	2.099	1.985	79.03	83.61	62.22	101.43
5	8185.61	5.95	42.8	2.090	1.976	79.41	84.00	62.22	101.06
6	8223.99	5.91	57.0	2.080	1.969	79.79	84.26	62.22	103.73
7	8262.45	5.88	61.1	2.070	1.963	80.17	84.55	62.21	105.69
8	8300.97	5.85	70.2	2.061	1.957	80.54	84.79	62.21	109.06
9	8339.57	5.82	79.3	2.051	1.956	80.92	84.85	62.20	117.87
10	8378.23	5.79	88.4	2.042	1.951	81.30	85.04	62.20	123.63

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8495
MULTI-PHASE
07-24-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.08	GPM
MASS FLOW RATE WATER	=	9.0	LBM/MIN
MASS FLOW RATE GAS	=	1.71	LBM/MIN
MASS FLUX	=	81831	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.37	FT/S
GAS VELOCITY	=	59 10	FT/S
GAS VISCOSITY	=	385.71E-09	LBM-S/FT^2
INLET TEMPERATURE	=	76.10	F
OUTLET TEMPERATURE	=	82.44	F
RE NUMBER LIQUID	=	3573	
RE NUMBER GAS	=	32040	
AVERAGE PR NUMBER	=	5.96	
CURRENT TO TUBE	=	359.5	AMPS
VOLTAGE DROP IN TUBE	=	3.68	VOLTS
AVERAGE HEAT FLUX	=	1822	BTU/(SQ.FT HR)
Q=AMP*VOLT	=	4513	BTU/HR
Q=M*C*(T2-T1)	=	4294	BTU/HR
HEAT BALANCE ERROR	=	4.85	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	89.71	91.44	90.55	91 56	92.00	92.83	93.49	93.94	94.56	94.40
2	86.96	84.22	85.80	85 01	86.27	85.94	86.86	86.03	86.83	87.18
3	78.93	79.18	79.63	80 10	80.67	81.13	81.61	82.04	82.48	82.63
4	83.49	83.53	83.44	84.12	84.70	85.23	86.06	87.45	86.47	87.13

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	89 01	90.79	89.87	90.90	91.33	92.17	92.83	93.28	93.91	93.74
2	86.24	83.44	85.05	84.24	85.51	85.16	86.05	85.24	86.05	86.40
3	78.08	78.35	78 80	79.28	79.84	80.30	80.78	81.21	81.66	81.80
4	82.72	82.74	82.66	83.34	83.92	84.44	85.28	86.68	85.68	86.34

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	4017	4099	4057	4105	4125	4165	4196	4217	4247	4239
2	3888	3761	3834	3797	3855	3839	3882	3843	3879	3896
3	3520	3533	3552	3573	3599	3619	3641	3660	3680	3687
4	3728	3729	3725	3756	3782	3806	3844	3909	3863	3893

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1200	1122	1163	1136	1150	1131	1137	1133	1116	1132
2	1247	1341	1296	1335	1317	1342	1334	1366	1360	1351
3	1474	1434	1441	1429	1438	1430	1440	1437	1424	1433
4	1336	1359	1356	1358	1357	1360	1354	1330	1369	1352

RUN NUMBER 8495

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT HR-F)

	1	2	3	4	5	6	7	8	9	10
1	96	82	95	90	92	89	89	90	89	96
2	178	212	177	227	201	240	225	307	293	308
3	949	1180	1370	1554	1644	1958	2421	3444	5586	-6841
4	215	242	276	272	274	279	265	226	320	312

RUN NUMBER 8495
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	3452.60	6.19	6.4	2.167	1.975	76.53	84.01	62.25	45.54
2	3479.38	6.14	15.5	2.150	1.980	77.14	83.83	62.24	51.30
3	3506.24	6.09	24.6	2.134	1.973	77.75	84.09	62.21	54.07
4	3533.19	6.03	33.7	2.117	1.965	78.36	84.44	62.23	56.41
5	3560.22	5 98	42.8	2 101	1.949	78.97	85.15	62.22	55.46
6	3587.33	5 93	52.0	2.085	1.940	79.57	85.52	62.22	57.64
7	3614.52	5.88	61.1	2 070	1.934	80.18	86.24	62.21	56.54
8	3641.78	5.83	70.2	2 054	1.915	80.79	86.60	62.21	58.94
9	3669.13	5.78	79.3	2.039	1.910	81.40	86.82	62.20	63.14
10	3696.56	5.74	88.4	2.024	1.905	82.01	87.07	62.19	67.61

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8496
MULTI-PHASE
07-24-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.42	GPM
MASS FLOW RATE WATER	=	11.8	LBM/MIN
MASS FLOW RATE GAS	=	1.74	LBM/MIN
MASS FLUX	=	108102	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.48	FT/S
GAS VELOCITY	=	59.96	FT/S
GAS VISCOSITY	=	386.00E-09	LBM-S/FT^2
INLET TEMPERATURE	=	77.15	F
OUTLET TEMPERATURE	=	82.85	F
RE NUMBER LIQUID	=	4764	
RE NUMBER GAS	=	32433	
AVERAGE PR NUMBER	=	5.90	
CURRENT TO TUBE	=	387.1	AMPS
VOLTAGE DROP IN TUBE	=	3.99	VOLTS
AVERAGE HEAT FLUX	=	2127	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5270	BTU/HR
Q=M*C*(T2-T1)	=	4851	BTU/HR
HEAT BALANCE ERROR	=	7.94	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	88.29	91.29	90.18	90.99	91.36	92.27	92.54	93.04	93.36	93.50
2	86.90	84.89	86.28	85.55	86.68	86.47	87.18	86.49	87.11	87.52
3	80.57	80.30	80.71	81.19	81.74	82.17	82.58	82.93	83.34	83.43
4	83.64	84.29	84.16	84.80	85.33	85.83	86.45	87.67	86.85	87.48

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	87.45	90.50	89.37	90.19	90.55	91.48	91.74	92.24	92.57	92.70
2	86.06	84.00	85.41	84.66	85.80	85.58	86.29	85.59	86.31	86.62
3	79.11	79.36	79.76	80.25	80.80	81.23	81.64	81.99	82.40	82.49
4	82.75	83.39	83.26	83.90	84.43	84.93	85.55	86.78	85.95	86.58

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	5211	5398	5328	5379	5401	5458	5475	5506	5527	5535
2	5126	5001	5087	5041	5110	5097	5140	5097	5135	5160
3	4711	4726	4750	4778	4811	4836	4860	4881	4906	4911
4	4927	4965	4957	4996	5028	5058	5095	5170	5119	5158

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1446	1353	1397	1376	1388	1369	1380	1374	1364	1374
2	1455	1547	1503	1538	1522	1545	1536	1565	1558	1551
3	1657	1635	1640	1627	1635	1629	1636	1634	1621	1632
4	1518	1563	1557	1558	1557	1561	1555	1535	1565	1552

RUN NUMBER 8496

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	145	108	130	124	128	122	126	126	128	134
2	170	261	231	280	250	291	280	371	363	373
3	1048	1283	1448	1518	1528	1704	2009	2648	3336	74486
4	295	294	336	330	331	335	326	283	386	377

RUN NUMBER 8496
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	4619.52	6.10	6.4	2.139	1.979	77.53	83.84	62.24	63.10
2	4651.49	6.06	15.5	2.125	1.968	78.08	84.31	62.23	63.89
3	4683.54	6.01	24.6	2.110	1.965	78.63	84.45	62.23	68.32
4	4715.68	5.96	33.7	2.096	1.958	79.18	84.75	62.22	71.33
5	4747.90	5.92	42.8	2.081	1.943	79.73	85.40	62.22	70.09
6	4780.21	5.87	52.0	2.067	1.934	80.27	85.80	62.21	71.84
7	4812.61	5.83	61.1	2.053	1.922	80.82	86.31	62.21	72.41
8	4845.09	5.79	70.2	2.040	1.914	81.37	86.65	62.20	75.16
9	4877.66	5.74	79.3	2.026	1.911	81.92	86.78	62.19	81.52
10	4910.31	5.70	88.4	2.013	1.904	82.47	87.10	62.19	85.54

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8497
MULTI-PHASE
07-24-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	.99	GPM
MASS FLOW RATE WATER	=	8.3	LBM/MIN
MASS FLOW RATE GAS	=	1.95	LBM/MIN
MASS FLUX	=	75154	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.34	FT/S
GAS VELOCITY	=	67.34	FT/S
GAS VISCOSITY	=	386.04E-09	LBM-S/FT^2
INLET TEMPERATURE	=	76.57	F
OUTLET TEMPERATURE	=	83.65	F
RE NUMBER LIQUID	=	3316	
RE NUMBER GAS	=	36415	
AVERAGE PR NUMBER	=	5.89	
CURRENT TO TUBE	=	371.9	AMPS
VOLTAGE DROP IN TUBE	=	3.93	VOLTS
AVERAGE HEAT FLUX	=	2013	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	4986	BTU/HR
Q=M*CP*(T2-T1)	=	4621	BTU/HR
HEAT BALANCE ERROR	=	7.33	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	88.63	91.39	90.67	91.77	92.32	93.29	93.65	94.59	94.99	95.12
2	87.64	85.08	86.46	85.79	87.02	86.85	87.65	87.01	87.79	88.22
3	79.67	80.00	80.46	81.07	81.76	82.22	82.72	83.17	83.68	83.87
4	83.75	84.06	84.08	84.88	85.53	86.12	86.88	88.34	87.47	88.18

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	87.86	90.67	89.93	91.05	91.59	92.57	92.93	93.87	94.28	94.40
2	86.88	84.26	85.66	84.97	86.21	86.02	86.83	86.17	86.95	87.39
3	78.77	79.12	79.58	80.19	80.86	81.34	81.84	82.29	82.81	82.99
4	82.93	83.22	83.24	84.04	84.69	85.28	86.05	87.52	86.63	87.35

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	3640	3760	3728	3776	3800	3842	3858	3899	3916	3922
2	3598	3488	3547	3518	3570	3562	3596	3568	3601	3620
3	3261	3276	3294	3320	3347	3367	3387	3405	3427	3435
4	3432	3445	3446	3479	3506	3531	3563	3625	3588	3618

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1331	1233	1269	1243	1254	1235	1246	1233	1222	1234
2	1318	1422	1384	1423	1408	1432	1423	1457	1449	1443
3	1560	1524	1530	1517	1524	1518	1526	1526	1512	1522
4	1417	1448	1445	1467	1447	1450	1443	1424	1458	1444

RUN NUMBER 8497

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	123	95	110	104	106	101	105	102	103	109
2	134	217	190	242	218	256	249	334	374	342
3	905	1094	1309	1372	1398	1699	2153	3190	4795	-8420
4	241	263	298	292	293	300	293	249	352	346

RUN NUMBER 8497
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	3191.86	6.15	6.4	2.152	1.973	77.05	84.11	62.24	52.07
2	3219.41	6.09	15.5	2.134	1.968	77.73	84.32	62.23	55.75
3	3247.04	6.03	24.6	2.116	1.961	78.41	84.60	62.23	59.26
4	3274.77	5.97	33.7	2.098	1.951	79.09	85.06	62.22	61.41
5	3302.60	5.92	42.8	2.080	1.933	79.77	85.84	62.22	60.44
6	3330.51	5.86	52.0	2.063	1.922	80.45	86.31	62.21	62.60
7	3358.52	5.81	61.1	2.046	1.908	81.13	86.91	62.20	63.40
8	3386.62	5.75	70.2	2.029	1.896	81.81	87.46	62.20	64.80
9	3414.81	5.70	79.3	2.012	1.892	82.49	87.67	62.19	70.70
10	3443.10	5.65	88.4	1.995	1.884	83.17	88.03	62.18	75.25

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8498
MULTI-PHASE
07-24-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.39	GPM
MASS FLOW RATE WATER	=	11.6	LBM/MIN
MASS FLOW RATE GAS	=	1.96	LBM/MIN
MASS FLUX	=	105631	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.47	FT/S
GAS VELOCITY	=	67.91	FT/S
GAS VISCOSITY	=	386.12E-09	LBM-S/FT^2
INLET TEMPERATURE	=	77.53	F
OUTLET TEMPERATURE	=	83.06	F
RE NUMBER LIQUID	=	4672	
RE NUMBER GAS	=	36704	
AVERAGE PR NUMBER	=	5.87	
CURRENT TO TUBE	=	383.0	AMPS
VOLTAGE DROP IN TUBE	=	3.94	VOLTS
AVERAGE HEAT FLUX	=	2078	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5148	BTU/HR
Q=M*C*(T2-T1)	=	4720	BTU/HR
HEAT BALANCE ERROR	=	8 32	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	86.36	90.58	89.57	90.16	90.48	91.33	91.65	92.25	92.54	92.65
2	86.12	84.87	86.04	85.27	86.32	86.23	86.90	86.24	86.82	87.20
3	80.28	80.55	80.92	81.44	81.99	82.40	82.79	83.08	83.49	83.54
4	83.01	84.18	83.96	84.61	85.12	85.58	86.19	87.35	86.66	87.19

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	85.52	89.80	88.77	89.37	89.68	90.54	90.86	91.46	91.76	91.86
2	85.30	84.00	85.19	84.40	85.46	85.36	86.03	85.36	85.94	86.32
3	79.36	79 63	80.00	80.53	81.07	81.49	81.87	82.16	82.58	82.62
4	82.14	83.30	83.08	83.73	84 24	84.70	85.31	86.48	85.78	86.31

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	4977	5232	5170	5206	5225	5277	5296	5333	5351	5357
2	4964	4887	4957	4911	4973	4967	5007	4967	5002	5024
3	4618	4633	4654	4685	4717	4740	4763	4780	4804	4807
4	4779	4846	4833	4871	4901	4928	4965	5034	4992	5024

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1444	1337	1375	1359	1371	1355	1363	1355	1346	1355
2	1420	1510	1472	1506	1491	1510	1502	1531	1525	1518
3	1600	1594	1597	1582	1589	1584	1590	1590	1578	1589
4	1499	1527	1525	1523	1522	1526	1520	1502	1529	1518

RUN NUMBER 8498

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	189	117	140	137	142	135	139	137	140	147
2	192	271	236	307	274	314	304	410	403	417
3	1101	1334	1547	1539	1523	1713	2041	2956	3735	-24566
4	353	314	370	359	361	368	360	309	422	418

RUN NUMBER 8498
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	4534.89	6.07	6.4	2.129	1.998	77.90	81.08	62.21	75 20
2	4565.25	6.03	15.5	2.115	1.971	78.43	84.18	62.23	67.73
3	4595 68	5.98	24.6	2.101	1.970	78.97	84.26	62.22	73 50
4	4626.20	5.94	33.7	2.087	1.964	79.50	84.51	62.22	77 63
5	4656.79	5.89	42.8	2.074	1.949	80.03	85.11	62.21	76.45
6	4687.47	5.85	52.0	2.060	1.940	80.56	85.52	62.21	78.[illegible]
7	4718.22	5.81	61.1	2 047	1.929	81.09	86.02	62.20	7[illegible].84
8	4749.05	5.77	70.2	2 033	1.921	81.62	86.37	62.20	81.87
9	4779.96	5.73	79.3	2 020	1.917	82.16	86.51	62.19	89.04
10	4810.95	5.68	88.4	2.007	1.911	82.69	86.79	62.19	94.73

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8499
MULTI-PHASE
07-24-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.96	GPM
MASS FLOW RATE WATER	=	16.3	LBM/MIN
MASS FLOW RATE GAS	=	1.68	LBM/MIN
MASS FLUX	=	148826	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.67	FT/S
GAS VELOCITY	=	58.04	FT/S
GAS VISCOSITY	=	386.05E-09	LBM-S/FT^2
INLET TEMPERATURE	=	77.93	F
OUTLET TEMPERATURE	=	82.33	F
RE NUMBER LIQUID	=	6569	
RE NUMBER GAS	=	31382	
AVERAGE PR NUMBER	=	5.89	
CURRENT TO TUBE	=	395.2	AMPS
VOLTAGE DROP IN TUBE	=	4.00	VOLTS
AVERAGE HEAT FLUX	=	2177	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5394	BTU/HR
Q=M*C*(T2-T1)	=	4898	BTU/HR
HEAT BALANCE ERROR	=	9.18	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	86.63	90.76	89.68	90.00	89.91	90.62	90.75	91.16	91.31	91.43
2	85.78	84.83	86.00	85.14	86.05	85.93	86.45	85.75	86.21	86.57
3	80.58	80.72	81.08	81.49	81.92	82.31	82.61	82.84	83.16	83.11
4	82.98	84.41	84.07	84.58	84.92	85.35	85.79	86.75	86.10	86.54

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	85.74	89.93	88.83	89.15	89.05	89.77	89.90	90.31	90.46	90.58
2	84.89	83.90	85.09	84.21	85.13	85.00	85.53	84.81	85.28	85.64
3	79.61	79.74	80.10	80.52	80.95	81.34	81.64	81.87	82.20	82.14
4	82.05	83.47	83.13	83.64	83.99	84.41	84.86	85.83	85.16	85.61

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	7031	7383	7290	7317	7309	7370	7380	7416	7429	7439
2	6960	6878	6976	6904	6980	6969	7013	6953	6992	7022
3	6526	6537	6567	6601	6635	6667	6692	6711	6737	6733
4	6726	6842	6814	6857	6885	6920	6957	7038	6983	7020

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1530	1432	1470	1457	1476	1462	1472	1465	1459	1466
2	1532	1612	1573	1604	1586	1603	1596	1623	1617	1609
3	1685	1690	1691	1676	1681	1676	1681	1679	1668	1680
4	1604	1623	1623	1619	1615	1618	1613	1597	1619	1610

RUN NUMBER 8499

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	203	126	150	150	161	155	161	160	164	171
2	229	307	261	340	304	344	335	447	441	446
3	1221	1544	1640	1634	1632	1675	1922	2458	2849	15829
4	419	336	399	390	397	397	394	344	455	450

RUN NUMBER 8499
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	6415.38	6.04	6.4	2.121	1.998	78.23	83.07	62.23	85.48
2	6449.46	6.01	15.5	2.110	1.969	78.65	84.26	62.23	73.86
3	6483.60	5.97	24.6	2.098	1.969	79.07	84.29	62.22	79.42
4	6517.82	5.94	33.7	2.087	1.967	79.50	84.38	62.22	84.71
5	6552.11	5.90	42.8	2.076	1.957	79.92	84.78	62.21	85.13
6	6586.47	5.87	52.0	2.066	1.949	80.34	85.13	62.21	86.35
7	6620.90	5.84	61.1	2.055	1.941	80.76	85.48	62.21	87.71
8	6655.40	5.80	70.2	2.044	1.936	81.19	85.71	62.20	91.52
9	6689.97	5.77	79.3	2.034	1.934	81.61	85.78	62.20	99.23
10	6724.61	5.73	88.4	2.023	1.929	82.03	85.99	62.19	104.34

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8500
MULTI-PHASE
07-24-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	2.49	GPM
MASS FLOW RATE WATER	=	20.7	LBM/MIN
MASS FLOW RATE GAS	=	1.71	LBM/MIN
MASS FLUX	=	189216	LBM/(SQ.FT HR)
LIQUID VELOCITY	=	.85	FT/S
GAS VELOCITY	=	59.03	FT/S
GAS VISCOSITY	=	385.83E-09	LBM-S/FT^2
INLET TEMPERATURE	=	77.68	F
OUTLET TEMPERATURE	=	81.46	F
RE NUMBER LIQUID	=	8295	
RE NUMBER GAS	=	31970	
AVERAGE PR NUMBER	=	5.93	
CURRENT TO TUBE	=	414.9	AMPS
VOLTAGE DROP IN TUBE	=	4.26	VOLTS
AVERAGE HEAT FLUX	=	2434	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	6031	BTU/HR
Q=M*C*(T2-T1)	=	5220	BTU/HR
HEAT BALANCE ERROR	=	13.44	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	84.26	89.07	88.50	88.71	88.57	88.90	89.07	89.50	89.62	89.71
2	83.77	83.97	85.14	84.35	85.17	84.99	85.53	84.93	85.16	85.58
3	80.12	80.36	80.74	81.09	81.48	81.81	82.07	82.27	82.53	82.47
4	81.68	83.70	83.47	83.91	84.21	84.50	84.92	85.81	85.22	85.57

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	83.27	88.13	87.55	87 76	87.61	87 95	88 11	88.55	88 67	88.76
2	82.78	82.95	84.13	83.33	84.16	83.97	84.52	83.90	84.13	84.56
3	79.07	79.30	79.67	80.03	80.42	80.75	81.01	81.21	81.48	81.41
4	80.66	82 67	82.44	82.88	83.19	83.47	83.90	84.80	84.19	84.55

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	8679	9195	9132	9155	9139	9175	9192	9239	9252	9262
2	8628	8645	8770	8685	8773	8753	8810	8766	8770	8815
3	8243	8266	8306	8342	8382	8417	8444	8464	8492	8485
4	8407	8617	8592	8639	8670	8701	8745	8840	8776	8814

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1708	1616	1642	1633	1651	1644	1651	1646	1638	1646
2	1708	1769	1737	1764	1747	1760	1753	1776	1775	1765
3	1815	1840	1843	1829	1834	1827	1831	1832	1821	1833
4	1762	1776	1780	1776	1772	1771	1768	1754	1774	1766

RUN NUMBER 8500

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	320	164	184	186	200	200	206	204	209	218
2	352	380	317	410	166	417	398	518	539	526
3	1598	1844	1818	1816	1778	1824	2048	2501	2867	8929
4	646	406	471	460	466	476	467	406	539	528

RUN NUMBER 8500
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	8127.46	6.07	6.4	2.129	2.038	77.93	81.44	62.23	130.00
2	8164.62	6.04	15.5	2.119	1.993	78.30	83.26	62.23	93.02
3	8201.85	6.01	24.6	2.109	1 989	78.66	83.45	62.23	95 36
4	8239.15	5.98	33 7	2.100	1.988	79.02	83.50	62.22	101 94
5	8276.51	5.95	42.8	2.090	1.979	79.39	83.84	62.22	102.39
6	8313.94	5.92	52.0	2.081	1.975	79.75	84.04	62.22	106 44
7	8351.44	5 89	61.1	2.071	1.967	80.12	84.18	62.21	106.81
8	8389.00	5.86	70.2	2.062	1.961	80.48	84.61	62.21	110.22
9	8426.63	5.83	79.3	2.053	1.961	80.84	84.62	62.21	120.62
10	8464 33	5.80	88.4	2 044	1.956	81.21	84.82	62.20	126.03

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8501
MULTI-PHASE
07-25-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	2.46	GPM
MASS FLOW RATE WATER	=	20.5	LBM/MIN
MASS FLOW RATE GAS	=	1.70	LBM/MIN
MASS FLUX	=	187406	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.84	FT/S
GAS VELOCITY	=	58.64	FT/S
GAS VISCOSITY	=	385.72E-09	LBM-S/FT^2
INLET TEMPERATURE	=	77.85	F
OUTLET TEMPERATURE	=	80.75	F
RE NUMBER LIQUID	=	8187	
RE NUMBER GAS	=	31783	
AVERAGE PR NUMBER	=	5.95	
CURRENT TO TUBE	=	359.4	AMPS
VOLTAGE DROP IN TUBE	=	3.79	VOLTS
AVERAGE HEAT FLUX	=	1876	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	4648	BTU/HR
Q=M*C*(T2-T1)	=	3968	BTU/HR
HEAT BALANCE ERROR	=	14.62	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	82.98	84.91	84.40	84.72	84.71	85.12	85.26	85.64	85.81	85.89
2	83.06	82.34	82.83	82.31	82.92	82.91	83.25	83.01	83.16	83.50
3	79.97	79.97	80.26	80.49	80.78	81.10	81.32	81.49	81.69	81.59
4	81.05	81.89	81.69	82.14	82.32	82.62	82.89	83.53	83.28	83.51

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	82.23	84.19	83.67	84.00	83.98	84.39	84.53	84.91	85.09	85.16
2	82.32	81.58	82.08	81.55	82.16	82.15	82.49	82.24	82.39	82.74
3	79.18	79.18	79.47	79.71	79.99	80.32	80.53	80.70	80.91	80.80
4	80.28	81.12	80.92	81.37	81.55	81.85	82.12	82.77	82.51	82.75

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	8488	8691	8637	8671	8669	8712	8727	8767	8785	8793
2	8497	8420	8472	8417	8481	8479	8514	8489	8504	8540
3	8175	8175	8204	8228	8258	8291	8313	8331	8351	8341
4	8287	8373	8353	8399	8418	8449	8477	8543	8517	8541

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1287	1241	1257	1248	1259	1253	1257	1252	1247	1252
2	1271	1314	1299	1319	1307	1317	1313	1327	1328	1319
3	1364	1366	1363	1356	1359	1355	1357	1358	1352	1362
4	1322	1325	1328	1323	1323	1325	1323	1313	1325	1319

RUN NUMBER 8501

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	307	211	248	244	261	252	261	254	259	271
2	297	403	374	495	435	486	474	591	627	604
3	1201	1598	1569	1647	1631	1546	1662	1920	2140	5504
4	590	473	573	531	552	548	549	473	592	601

RUN NUMBER 8501
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	8060.11	6.06	6.4	2.126	2.049	78.05	81.01	62.23	115.65
2	8088.35	6.04	15.5	2.118	2.036	78.32	81.52	62.23	107.18
3	8116.64	6.01	24.6	2.111	2.036	78.60	81.53	62.23	116.70
4	8144.96	5.99	33.7	2.103	2.033	78.88	81.65	62.22	123.34
5	8173.32	5.97	42.8	2.096	2.026	79.16	81.92	62.22	123.83
6	8201.72	5.94	52.0	2.089	2.020	79.44	82.18	62.22	124.89
7	8230.16	5.92	61.1	2.082	2.014	79.72	82.42	62.22	126.54
8	8258.64	5.90	70.2	2.074	2.008	80.00	82.66	62.21	128.48
9	8287.16	5.87	79.3	2.067	2.006	80.28	82.72	62.21	139.52
10	8315.72	5.85	88.4	2.060	2.003	80.55	82.86	62.21	148.04

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8502
MULTI-PHASE
07-25-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.92	GPM
MASS FLOW RATE WATER	=	16.0	LBM/MIN
MASS FLOW RATE GAS	=	1.66	LBM/MIN
MASS FLUX	=	146376	LBM/(SQ.FT HR)
LIQUID VELOCITY	=	.65	FT/S
GAS VELOCITY	=	57.54	FT/S
GAS VISCOSITY	=	386.03E-09	LBM S/FT^2
INLET TEMPERATURE	=	78.01	F
OUTLET TEMPERATURE	=	82.15	F
RE NUMBER LIQUID	=	6457	
RE NUMBER GAS	=	31118	
AVERAGE PR NUMBER	=	5.89	
CURRENT TO TUBE	=	382.3	AMPS
VOLTAGE DROP IN TUBE	=	3.97	VOLTS
AVERAGE HEAT FLUX	=	2089	BTU/(SQ.FT·HR)
Q=AMP*VOLT	=	5175	BTU/HR
Q=M*C*(T2-T1)	=	4538	BTU/HR
HEAT BALANCE ERROR	=	12.32	%

OUTSIDE SURFACE TEMPERATURES DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	85.61	87.50	86.68	87.24	87.38	88.00	88.16	88.66	88.95	89.08
2	85.16	83.72	84.50	84.02	84.79	84.76	85.24	84.89	85.28	85.64
3	80.63	80.72	81.06	81.45	81.85	82.22	82.53	82.78	83.07	83.09
4	82.61	83.22	83.08	83.70	83.99	84.35	84.76	85.61	85.25	85.64

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	84.80	86.70	85.86	86.43	86.56	87.19	87.35	87.85	88.14	88.27
2	84.33	82.86	83.65	83.16	83.93	83.90	84.38	84.02	84.41	84.77
3	79.72	79.82	80.16	80.56	80.95	81.33	81.64	81.88	82.18	82.19
4	81.74	82.35	82.21	82.83	83.12	83.48	83.89	84.75	84.38	84.77

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	6838	6994	6925	6971	6982	7034	7047	7089	7113	7121
2	6799	6680	6744	6704	6767	6764	6804	6774	6806	6836
3	6428	6436	6463	6495	6527	6557	6581	6601	6625	6626
4	6590	6639	6628	6678	6701	6730	6764	6834	6804	6836

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1438	1381	1410	1397	1408	1397	1404	1398	1391	1398
2	1432	1493	1468	1494	1480	1493	1468	1507	1504	1497
3	1566	1554	1553	1546	1545	1545	1548	1549	1547	1551
4	1497	1506	1504	1500	1500	1504	1500	1488	1505	1497

RUN NUMBER 8502

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	221	172	208	201	210	202	210	206	208	218
2	237	358	321	406	365	413	401	511	522	515
3	1091	1370	1442	1440	1444	1474	1616	1913	2186	4813
4	433	411	481	448	463	469	466	405	517	515

RUN NUMBER 8502
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	6314.72	6.04	6.4	2.119	2.008	78.29	82.65	62.23	88.79
2	6346.27	6.01	15.5	2.109	2.001	78.69	82.93	62.23	91.17
3	6377.87	5.97	24.6	2.098	2.000	79.08	82.97	62.22	99.53
4	6409.54	5.94	33.7	2.088	1.994	79.48	83.24	62.22	102.81
5	6441.26	5.91	42.8	2.077	1.984	79.88	83.64	62.21	102.73
6	6473.05	5.87	52.0	2.067	1.976	80.28	83.97	62.21	104.60
7	6504.90	5.84	61.1	2.057	1.968	80.68	84.31	62.21	106.21
8	6536.81	5.81	70.2	2.047	1.961	81.08	84.63	62.20	108.77
9	6568.79	5.78	79.3	2.037	1.957	81.47	84.78	62.20	116.79
10	6600.82	5.75	88.4	2.027	1.952	81.87	85.00	62.20	123.21

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8503
MULTI-PHASE
07-25-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.41	GPM
MASS FLOW RATE WATER	=	11 7	LBM/MIN
MASS FLOW RATE GAS	=	1.65	LBM/MIN
MASS FLUX	=	107018	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.48	FT/S
GAS VELOCITY	=	57.29	FT/S
GAS VISCOSITY	=	386.18E-09	LBM-S/FT^2
INLET TEMPERATURE	=	78.05	F
OUTLET TEMPERATURE	=	83.87	F
RE NUMBER LIQUID	=	4772	
RE NUMBER GAS	=	30899	
AVERAGE PR NUMBER	=	5.82	
CURRENT TO TUBE	=	394.0	AMPS
VOLTAGE DROP IN TUBE	=	3.98	VOLTS
AVERAGE HEAT FLUX	=	2160	BTU/(SQ.FT-HR)
Q-AMP*VOLT	=	5351	BTU/HR
Q-M*C*(T2-T1)	=	4871	BTU/HR
HEAT BALANCE ERROR	=	8.97	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	89.25	90.63	89.78	90.43	90.80	91.51	91.78	92.56	92.98	93.09
2	87.41	85.13	86.46	85.83	86.95	86.83	87.57	87.11	87.72	88.19
3	81.15	81.35	81.78	82.32	82.90	83.34	83.78	84.15	84.57	84.72
4	84.50	84.66	84.67	85.37	85.86	86.27	86.94	88.13	87.55	88.16

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	88.38	89 80	88.93	89.59	89.95	90.67	90.93	91.72	92.14	92.25
2	86.53	84.20	85.56	84 91	86.04	85.91	86.65	86.18	86.79	87.27
3	80.17	80 38	80.81	81 36	81.93	82.38	82.82	83.18	83.61	83.76
4	83.58	83.73	83.74	84 44	84.93	85.34	86.01	87.21	86.62	87.23

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	5215	5301	5248	5288	5310	5354	5370	5419	5445	5451
2	5103	4964	5044	5006	5073	5065	5110	5082	5119	5147
3	4726	4738	4763	4795	4829	4855	4881	4903	4928	4937
4	4926	4935	4936	4978	5007	5031	5072	5144	5108	5145

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1495	1433	1472	1457	1469	1455	1466	1456	1446	1457
2	1524	1602	1563	1594	1579	1597	1588	1615	1610	1602
3	1703	1671	1678	1665	1672	1665	1672	1672	1662	1672
4	1598	1614	1609	1606	1607	1611	1604	1588	1614	1602

RUN NUMBER 8503

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	150	132	157	153	158	154	160	155	156	166
2	188	307	260	333	294	342	327	422	415	423
3	987	1209	1342	1346	1332	1461	1646	2025	2403	6044
4	311	341	385	371	378	393	380	327	436	436

RUN NUMBER 8503
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	4625.67	6.03	6.4	2.115	1.960	78.44	84.66	62.23	66.26
2	4658.13	5.98	15.5	2 100	1.963	79.00	84.53	62.22	74.53
3	4690.67	5.93	24.6	2.086	1.958	79.56	84.76	62.22	79.21
4	4723.31	5.89	33.7	2 071	1 950	80.12	85.07	62.21	83.07
5	4756.03	5.84	42.8	2.057	1 936	80.68	85.71	62.21	81.72
6	4788.84	5.80	52 0	2.043	1.927	81.24	[illegible]	62.20	85.06
7	4821.74	5.75	61.1	2.029	1.915	81.80	86.60	62.20	85.55
8	4854.73	5.71	70 2	2.015	1.905	82.36	87.07	62.19	87.14
9	4887.81	5.67	79.3	2.002	1.900	82.92	87.29	62.18	93.91
10	4920.97	5 62	[illegible].4	1.988	1.893	83.48	87 63	62.18	98.94

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8504
MULTI-PHASE
07-25-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.00	GPM
MASS FLOW RATE WATER	=	8.4	LBM/MIN
MASS FLOW RATE GAS	=	1.71	LBM/MIN
MASS FLUX	=	76332	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.34	FT/S
GAS VELOCITY	=	59.30	FT/S
GAS VISCOSITY	=	386.56E-09	LBM-S/FT^2
INLET TEMPERATURE	=	77.90	F
OUTLET TEMPERATURE	=	84.89	F
RE NUMBER LIQUID	=	3422	
RE NUMBER GAS	=	31944	
AVERAGE PR NUMBER	=	5.78	
CURRENT TO TUBE	=	372.2	AMPS
VOLTAGE DROP IN TUBE	=	3.84	VOLTS
AVERAGE HEAT FLUX	=	1968	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	4876	BTU/HR
Q=M*C*(T2-T1)	=	4477	BTU/HR
HEAT BALANCE ERROR	=	8.19	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	91.46	91.63	90.99	92.14	92.48	93.51	93.88	94.64	95.10	95.38
2	88.71	85.60	87.15	86.65	87.84	87.77	88.61	88.06	88.84	89.34
3	81.11	81.34	81.83	82.45	83.11	83.62	84.15	84.62	85.12	85.35
4	85.45	85.00	85.15	86.02	86.57	87.14	87.93	89.26	88.57	89.31

INSIDE SURFACE TEMPERATURES DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	90.71	90.90	90.24	91.41	91.74	92.78	93.14	93.91	94.37	94.65
2	87.93	84.77	86.35	85.83	87.03	86.94	87.79	87.22	88.01	88.51
3	80.21	80.47	80.95	81.58	82.24	82.75	83.27	83.75	84.25	84.48
4	84.62	84.16	84.32	85.19	85.74	86.30	87.10	88.44	87.73	88.48

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	3820	3829	3805	3851	3866	3911	3928	3961	3982	3994
2	3700	3564	3632	3609	3661	3657	3696	3669	3703	3725
3	3372	3383	3403	3429	3457	3479	3501	3521	3542	3552
4	3558	3538	3545	3582	3606	3610	3664	3722	3691	3724

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1298	1248	1287	1263	1277	1257	1269	1260	1250	1259
2	1349	1432	1391	1427	1410	1432	1423	1453	1446	1440
3	1563	1511	1521	1511	1516	1511	1518	1527	1506	1516
4	1432	1447	1442	1443	1443	1448	1440	1422	1452	1441

RUN NUMBER 8504

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	105	105	122	114	119	113	118	116	117	123
2	141	250	209	262	236	274	264	350	339	352
3	850	1061	1229	1768	1289	1484	1743	2263	2985	26699
4	229	282	313	300	308	316	306	265	364	354

RUN NUMBER 8504
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	3296.36	6.03	6.4	2.117	1.932	78.37	85.87	62.23	49.11
2	3324.16	5.98	15.5	2.099	1.950	79.04	85.08	62.22	60.91
3	3352.05	5.92	24.6	2.082	1.941	79.71	85.46	62.22	63.89
4	3380.04	5.87	33.7	2.064	1.929	80.39	86.04	62.21	65.41
5	3408.12	5.81	42.8	2.047	1.914	81.06	86.68	62.20	65.24
6	3436.28	5.76	52.0	2.031	1.902	81.73	87.19	62.20	67.14
7	3464.54	5.71	61.1	2.014	1.888	82.40	87.85	62.19	67.60
8	3492.89	5.65	70.2	1.998	1.877	83.08	88.33	62.18	69.74
9	3521.32	5.60	79.3	1.982	1.871	83.75	88.59	62.18	75.58
10	3549.85	5.55	88.4	1.966	1.862	84.42	89.03	62.17	79.39

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8505
MULTI-PHASE
07-26-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.97	GPM
MASS FLOW RATE WATER	=	16.4	LBM/MIN
MASS FLOW RATE GAS	=	1.59	LBM/MIN
MASS FLUX	=	149505	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.67	FT/S
GAS VELOCITY	=	54.76	FT/S
GAS VISCOSITY	=	385.93E-09	LBM-S/FT^2
INLET TEMPERATURE	=	77.98	F
OUTLET TEMPERATURE	=	81.65	F
RE NUMBER LIQUID	=	6573	
RE NUMBER GAS	=	29635	
AVERAGE PR NUMBER	=	5.91	
CURRENT TO TUBE	=	361.5	AMPS
VOLTAGE DROP IN TUBE	=	3.77	VOLTS
AVERAGE HEAT FLUX	=	1877	BTU/(SQ.FT HR)
Q=AMP*VOLT	=	4649	BTU/HR
Q=M*C*(T2-T1)	=	4074	BTU/HR
HEAT BALANCE ERROR	=	12.37	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	85.20	86.96	86.03	86.44	86.50	86.99	87.19	87.68	87.81	87.93
2	84.58	83.25	83.90	83.41	84.12	84.03	84.50	84.15	84.47	84.86
3	80.32	80.46	80.77	81.11	81.48	81.78	82.05	82.27	82.51	82.56
4	82.23	82.83	82.63	83.16	83.37	83.66	84.07	84.83	84.46	84.84

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	84.46	86.25	85.30	85.72	85.77	86.27	86.46	86.96	87.09	87.20
2	83.84	82.47	83.14	82.64	83.35	83.26	83.73	83.37	83.69	84.09
3	79.51	79.65	79.97	80.31	80.68	80.98	81.25	81.47	81.71	81.76
4	81.45	82.05	81.85	82.38	82.59	82.88	83.29	84.06	83.68	84.07

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	6955	7105	7026	7061	7065	7107	7123	7165	7176	7186
2	6904	6791	6846	6804	6864	6856	6895	6865	6892	6925
3	6548	6560	6585	6613	6644	6668	6690	6708	6728	6732
4	6707	6756	6740	6784	6801	6825	6859	6922	6891	6923

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1281	1228	1257	1247	1258	1248	1255	1248	1244	1251
2	1281	1339	1315	1337	1324	1337	1332	1350	1346	1339
3	1405	1393	1391	1383	1386	1381	1386	1385	1379	1387
4	1341	1350	1347	1343	1344	1346	1342	1337	1347	1339

RUN NUMBER 8505

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT HR-F)

	1	2	3	4	5	6	7	8	9	10
1	205	160	197	194	205	199	205	199	206	215
2	228	343	312	399	356	409	393	505	509	499
3	1097	1297	1347	1350	1312	1395	1532	1795	2081	3907
4	415	389	461	433	455	466	455	396	511	503

RUN NUMBER 8505
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	6444.73	6.04	6.4	2.121	2.016	78.23	82.31	62.23	84.76
2	6473.28	6.01	15.5	2.111	2.009	78.58	82.61	62.23	86.01
3	6501.87	5.99	24.6	2.102	2.010	78.93	82.56	62.22	95.33
4	6530.52	5.96	33.7	2.093	2.005	79.29	82.76	62.22	99.55
5	6559.22	5.93	42.8	2.084	1.997	79.64	83.10	62.22	99.97
6	6587.96	5.90	52.0	2.075	1.991	79.99	83.35	62.21	103.08
7	6616.76	5.87	61.1	2.066	1.983	80.34	83.68	62.21	103.54
8	6645.60	5.84	70.2	2.057	1.977	80.70	83.96	62.21	105.82
9	6674.49	5.81	79.3	2.048	1.975	81.05	84.04	62.20	115.41
10	6703.43	5.78	88.4	2.039	1.969	81.40	84.28	62.[illegible]	130.10

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8506
MULTI-PHASE
07-26-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	2.43	GPM
MASS FLOW RATE WATER	=	20.2	LBM/MIN
MASS FLOW RATE GAS	=	1.58	LBM/MIN
MASS FLUX	=	185039	LBM/(SQ.FT HR)
LIQUID VELOCITY	=	.83	FT/S
GAS VELOCITY	=	54.62	FT/S
GAS VISCOSITY	=	386.07E-09	LBM S/FT^2
INLET TEMPERATURE	=	78.57	F
OUTLET TEMPERATURE	=	81.79	F
RE NUMBER LIQUID	=	8172	
RE NUMBER GAS	=	29530	
AVERAGE PR NUMBER	=	5.88	
CURRENT TO TUBE	=	373.5	AMPS
VOLTAGE DROP IN TUBE	=	3.91	VOLTS
AVERAGE HEAT FLUX	=	2011	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	4983	BTU/HR
Q=M*C*(T2-T1)	=	4322	BTU/HR
HEAT BALANCE ERROR	=	13.26	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	84.59	86.51	85.94	86.37	86.41	86.77	86.69	87.22	87.38	87.46
2	84.53	83.54	84.14	83.73	84.39	84.27	84.56	84.25	84.56	84.89
3	80.89	80.99	81.29	81.66	82.01	82.23	82.46	82 60	82.79	82.84
4	82.32	83.09	82.99	83.53	83.74	83.87	84.16	84.85	84.57	84.89

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	83.79	85.73	85.15	85.59	85.62	85.99	85 90	86.44	86.60	86.68
2	83.73	82.72	83 33	82 91	83.57	83.45	83.74	83.42	83.73	84.07
3	80.03	80.14	80.44	80.81	81.16	81.38	81.61	81.75	81.94	81.99
4	81.49	82.26	82.16	82 70	82.91	83.04	83 33	84.03	83.74	84.07

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	8540	8741	8681	8726	8729	8767	8758	8814	8831	8838
2	8534	8430	8492	8449	8518	8505	8535	8502	8534	8568
3	8157	8168	8198	8236	8271	8294	8317	8332	8351	8356
4	8305	8383	8373	8429	8450	8463	8493	8565	8535	8568

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1387	1336	1357	1348	1359	1350	1359	1351	1347	1354
2	1372	1423	1404	1425	1414	1424	1419	1436	1432	1426
3	1482	1477	1476	1469	1473	1466	1467	1469	1465	1472
4	1428	1434	1434	1430	1430	1434	1429	1420	1432	1426

RUN NUMBER 8506

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	277	201	236	229	242	238	258	246	252	265
2	277	393	358	447	398	457	458	542	580	572
3	1189	1422	1432	1341	1297	1399	1517	1844	2156	1519
4	527	453	520	479	495	530	531	462	578	572

RUN NUMBER 8506
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	8032.53	6.00	6 4	2.106	2.018	78.79	82.26	62.22	106.17
2	8063.61	5.97	15.5	2.098	2 007	79.10	82.71	62.22	107.33
3	8094.74	5.95	24.6	2.090	2.005	79.41	82.77	62.22	109.85
4	8125.92	5.92	33.7	2.082	2.000	79.72	83 00	62.22	112.41
5	8157.14	5.89	42.8	2.074	1.992	80.03	83.32	62.21	112.20
6	8188.41	5.87	52 0	2.066	1.988	80.33	83.46	62 21	115.47
7	8219.73	5.84	61.1	2.058	1 984	80.64	83.66	62 21	122.31
8	8251.09	5.82	70.2	2.050	1.978	80.95	83 91	62.20	121.87
9	8282.50	5.80	79 3	2.042	1.976	81.26	84.00	62.20	134.60
10	8313.96	5.77	88.4	2.035	1.973	81.57	84.20	62.20	140 44

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT-HR)

RUN NUMBER 8507
MULTI PHASE
07-26-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.37	GPM
MASS FLOW RATE WATER	=	11.4	LBM/MIN
MASS FLOW RATE GAS	=	1.98	LBM/MIN
MASS FLUX	=	104200	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.47	FT/S
GAS VELOCITY	=	68.36	FT/S
GAS VISCOSITY	=	386.31E-09	LBM-S/FT^2
INLET TEMPERATURE	=	78.16	F
OUTLET TEMPERATURE	=	83.41	F
RE NUMBER LIQUID	=	4616	
RE NUMBER GAS	=	36892	
AVERAGE PR NUMBER	=	5.83	
CURRENT TO TUBE	=	373.0	AMPS
VOLTAGE DROP IN TUBE	=	3.86	VOLTS
AVERAGE HEAT FLUX	=	1983	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	4913	BTU/HR
Q=M*C*(T2-T1)	=	4435	BTU/HR
HEAT BALANCE ERROR	=	9.72	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	85.99	88.75	87.92	88.47	88.88	89.52	89.78	90.45	90.81	90.99
2	86.16	84.53	85.34	84.83	85.80	85.75	86.35	85.94	86.50	86.93
3	80.87	81.14	81.48	81.99	82.51	82.89	83.27	83.59	83.95	84.12
4	83.21	83.78	83.71	84.40	84.86	85.22	85.81	86.78	86.40	86.92

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	85.19	88.00	87.15	87.71	88.11	88.76	89.01	89.69	90.05	90.23
2	85.38	83.71	84.53	84.01	84.98	84.92	85.53	85.11	85.67	86.10
3	80.00	80.28	80.62	81.13	81.65	82.03	82.41	82.73	83.09	83.26
4	82.39	82.94	82.88	83.57	84.03	84.39	84.98	85.96	85.57	86.09

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	4890	5055	5005	5038	5061	5100	5115	5155	5176	5187
2	4901	4804	4852	4821	4878	4875	4910	4885	4918	4943
3	4591	4607	4627	4656	4686	4708	4729	4748	4769	4778
4	4728	4760	4756	4796	4823	4843	4878	4935	4912	4943

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1381	1298	1328	1317	1325	1313	1322	1313	1306	1314
2	1345	1425	1399	1425	1413	1420	1421	1445	1440	1434
3	1511	1492	1493	1483	1488	1483	1489	1488	1482	1490
4	1421	1445	1440	1436	1437	1441	1435	1423	1442	1434

RUN NUMBER 8507

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	206	144	174	171	174	170	177	171	174	183
2	195	304	279	358	317	367	356	472	462	470
3	1018	1185	1364	1341	1331	1489	1715	2177	2732	7328
4	366	368	429	405	411	430	417	364	478	472

RUN NUMBER 8507
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	4507.90	6.02	6.4	2.113	1.994	78.51	83.24	62.23	78.10
2	4536.41	5.98	15.5	2.100	1.982	79.02	83.73	62.22	78.28
3	4564.99	5.94	24.6	2.087	1.981	79.52	83.79	62.22	86.32
4	4593.65	5.89	33.7	2.074	1.973	80.03	84.20	62.21	90.41
5	4622.37	5.85	42.8	2.061	1.959	80.53	84.69	62.21	88.54
6	4651.17	5.81	52.0	2.048	1.952	81.04	85.03	62.20	92.32
7	4680.03	5.77	61.1	2.035	1.941	81.54	85.48	62.20	93.40
8	4708.96	5.73	70.2	2.023	1.932	82.05	85.87	62.19	96.23
9	4737.97	5.69	79.3	2.010	1.927	82.55	86.10	62.19	103.78
10	4767.04	5.66	88.4	1.998	1.920	83.06	86.42	62.18	109.27

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8508
MULTI-PHASE
07-26-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	2.27	GPM
MASS FLOW RATE WATER	=	18.9	LBM/MIN
MASS FLOW RATE GAS	=	1.94	LBM/MIN
MASS FLUX	=	172597	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.77	FT/S
GAS VELOCITY	=	67.12	FT/S
GAS VISCOSITY	=	386.27E-09	LBM-S/FT^2
INLET TEMPERATURE	=	78.94	F
OUTLET TEMPERATURE	=	82.42	F
RE NUMBER LIQUID	=	7670	
RE NUMBER GAS	=	36231	
AVERAGE PR NUMBER	=	5.84	
CURRENT TO TUBE	=	379.6	AMPS
VOLTAGE DROP IN TUBE	=	3.94	VOLTS
AVERAGE HEAT FLUX	=	2060	BTU/(SQ-FT-HR)
Q=AMP*VOLT	=	5103	BTU/HR
Q=M*C*(T2-T1)	=	4489	BTU/HR
HEAT BALANCE ERROR	=	12.02	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	84.24	87.13	86.72	87.00	87.00	87.37	87.45	67.91	88.05	88.18
2	84.82	84.10	64.67	84.14	84.79	84.72	85.07	84.75	85.08	85.42
3	81.25	81.42	81.70	82.07	82.41	82.68	82.92	83.09	83.31	83.35
4	82.46	83.52	83.35	83.86	84.10	84.30	84.68	85.36	85.08	85.44

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	83.40	86.33	85.91	86.19	86.19	86.56	86.64	87.10	87.24	87.37
2	84.00	83.25	83.83	83.29	83.94	83.87	84.22	83.89	84.22	84.57
3	80.37	80.54	80.82	81.19	81.53	81.81	82.04	82.21	82.46	82.47
4	81.61	82.66	82.49	83.00	83.24	83.44	83.82	84.51	84.22	84.59

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	7929	8211	8170	8198	8197	8233	8241	8286	8299	8312
2	7986	7914	7969	7918	7980	7973	8007	7975	8007	8040
3	7640	7656	7683	7718	7751	7776	7799	7815	7836	7840
4	7758	7858	7842	7890	7913	7932	7969	8035	8007	8042

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1448	1380	1395	1388	1400	1393	1400	1393	1390	1396
2	1413	1469	1453	1475	1463	1473	1469	1485	1481	1475
3	1525	1526	1524	1514	1517	1513	1516	1517	1512	1520
4	1472	1484	1487	1482	1483	1484	1479	1470	1481	1475

RUN NUMBER 8508

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ-FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	342	202	230	230	246	243	256	249	257	269
2	292	392	364	474	426	487	483	625	624	619
3	1277	1484	1561	1491	1488	1579	1759	2177	2585	5318
4	604	470	562	524	542	572	559	491	674	614

RUN NUMBER 8508
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	7528.70	5.96	6.4	2.096	2.016	79.17	82.34	62.22	120.35
2	7560.10	5.94	15.5	2.087	1.995	79.51	83.19	62.22	103.54
3	7591.54	5.91	24.6	2.078	1.993	79.84	83.26	62.21	111.58
4	7623.04	5.88	33.7	2.070	1.989	80.18	83.42	62.21	117.64
5	7654.59	5.86	42.8	2.061	1.982	80.51	83.73	62.21	118.61
6	7686.19	5.83	52.0	2.051	1.978	80.85	83.92	62.21	124.06
7	7717.84	5.80	61.1	2.044	1.971	81.18	84.18	62.20	127.00
8	7749.54	5.78	70.2	2.036	1.965	81.52	84.43	62.20	130.77
9	7781.29	5.75	79.3	2.028	1.963	81.85	84.51	62.20	142.84
10	7813.09	5.72	88.4	2.019	1.958	82.19	84.75	62.19	144.68

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8509
MULTI-PHASE
07-26-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	2.46	GPM
MASS FLOW RATE WATER	=	20.5	LBM/MIN
MASS FLOW RATE GAS	=	1.96	LBM/MIN
MASS FLUX	=	187757	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.84	FT/S
GAS VELOCITY	=	67.73	FT/S
GAS VISCOSITY	=	386.27E-09	LBM-S/FT^2
INLET TEMPERATURE	=	79.01	F
OUTLET TEMPERATURE	=	82.36	F
RE NUMBER LIQUID	=	8322	
RE NUMBER GAS	=	36560	
AVERAGE PR NUMBER	=	5.84	
CURRENT TO TUBE	=	386.8	AMPS
VOLTAGE DROP IN TUBE	=	3.96	VOLTS
AVERAGE HEAT FLUX	=	2109	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5225	BTU/HR
Q=M*C*(T2-T1)	=	4648	BTU/HR
HEAT BALANCE ERROR	=	11.05	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	83.95	86.89	86.66	86.92	86.92	87.30	87.27	87.75	87.90	88.04
2	84.64	84.08	84.65	84.13	84.79	84.75	85.01	84.68	85.03	85.35
3	81.30	81.45	81.75	82.12	82.44	82.75	82.94	83.09	83.31	83.31
4	82.31	83.50	83.35	83.86	84.09	84.32	84.62	85.28	85.06	85.36

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	83.08	86.05	85.82	86.08	86.08	86.46	86.42	86.91	87.06	87.20
2	83.79	83.20	83.78	83.24	83.91	83.87	84.13	83.79	84.14	84.46
3	80.39	80.54	80.84	81.21	81.53	81.84	82.03	82.18	82.40	82.40
4	81.42	82.61	82.46	82.97	83.20	83.43	83.71	84.40	84.17	84.48

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	8568	8879	8854	8882	8881	8922	8918	8969	8985	9000
2	8642	8581	8641	8586	8655	8650	8678	8642	8679	8713
3	8292	8307	8338	8376	8409	8441	8460	8476	8499	8498
4	8398	8520	8504	8557	8581	8605	8636	8706	8682	8714

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1507	1441	1453	1446	1458	1451	1459	1451	1449	1453
2	1468	1523	1509	1531	1518	1528	1524	1541	1536	1530
3	1575	1581	1578	1569	1572	1567	1570	1570	1567	1575
4	1528	1537	1542	1538	1536	1539	1534	1525	1536	1530

RUN NUMBER 8509

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT HR F)

	1	2	3	4	5	6	7	8	9	10
1	392	221	244	246	262	258	277	267	276	287
2	322	418	387	503	448	506	514	670	659	656
3	1365	1616	1648	1553	1562	1571	1817	2270	2647	5939
4	698	503	598	555	573	595	598	524	651	653

RUN NUMBER 8509
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	8174.44	5.96	6.4	2.094	2.020	79.24	82.17	62.22	134.96
2	8207.24	5.93	15.5	2.086	1.997	79.56	83.10	62.22	111.83
3	8240.09	5.91	24.6	2.077	1.994	79.88	83.22	62.21	118.46
4	8272.99	5.88	33.7	2.069	1.991	80.20	83.38	62.21	124.66
5	8305.94	5.85	42.8	2.061	1.983	80.52	83.68	62.21	125.40
6	8338.95	5.83	52.0	2.053	1.978	80.85	83.90	62.21	129.56
7	8372.00	5.80	61.1	2.045	1.974	81.17	84.08	62.20	135.85
8	8405.11	5.78	70.2	2.037	1.968	81.49	84.32	62.20	139.75
9	8438.26	5.75	79.3	2.029	1.965	81.81	84.44	62.20	150.16
10	8471.47	5.73	88.4	2.021	1.961	82.13	84.63	62.19	158.06

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8510
MULTI PHASE
07-29-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	2.47	GPM
MASS FLOW RATE WATER	=	20.6	LBM/MIN
MASS FLOW RATE GAS	=	1.62	LBM/MIN
MASS FLUX	=	187919	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.84	FT/S
GAS VELOCITY	=	56.04	FT/S
GAS VISCOSITY	=	385.91E-09	LBM-S/FT^2
INLET TEMPERATURE	=	78.12	F
OUTLET TEMPERATURE	=	81.45	F
RE NUMBER LIQUID	=	8259	
RE NUMBER GAS	=	30335	
AVERAGE PR NUMBER	=	5.91	
CURRENT TO TUBE	=	386.2	AMPS
VOLTAGE DROP IN TUBE	=	3.92	VOLTS
AVERAGE HEAT FLUX	=	2085	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5165	BTU/HR
Q=M*C*(T2-T1)	=	4545	BTU/HR
HEAT BALANCE ERROR	=	12.00	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	84.32	86.68	86.15	86.38	86.28	86.60	86.77	87.20	87.40	87.48
2	83.95	83.37	84.06	83.34	83.99	83.93	84.39	84.12	84.29	84.67
3	80.51	80.52	80.89	81.13	81.44	81.84	82.12	82.30	82.58	82.38
4	81.98	82.95	82.69	83.08	83.27	83.65	83.94	84.72	84.40	84.66

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	83.46	85.85	85.31	85.55	85.44	85.76	85.93	86.36	86.57	86.64
2	83.09	82.49	83.19	82.46	83.11	83.05	83.51	83.23	83.40	83.79
3	79.60	79.60	79.98	80.22	80.53	80.93	81.21	81.39	81.68	81.47
4	81.10	82.06	81.80	82.19	82.38	82.76	83.06	83.84	83.51	83.78

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	8639	8889	8832	8857	8846	8880	8897	8943	8964	8973
2	8601	8538	8610	8534	8603	8596	8644	8615	8633	8673
3	8240	8241	8279	8304	8335	8377	8406	8424	8454	8432
4	8394	8494	8466	8507	8527	8566	8596	8678	8644	8672

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1480	1425	1444	1435	1448	1444	1450	1446	1439	1445
2	1476	1521	1502	1526	1512	1523	1518	1533	1534	1524
3	1577	1583	1579	1569	1572	1566	1569	1571	1562	1576
4	1526	1532	1537	1533	1531	1531	1529	1517	1532	1524

RUN NUMBER 8510

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	289	198	228	229	249	248	256	250	254	266
2	310	397	357	484	433	491	467	579	614	594
3	1258	1684	1592	1710	1736	1584	1656	1950	2037	6478
4	554	450	545	530	555	543	548	466	587	597

RUN NUMBER 8510
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	8112.53	6.03	6.4	2.118	2.029	78.34	81.31	62.23	113.96
2	8145.10	6.01	15.5	2.109	2.012	78.66	82.50	62.23	102.98
3	8177.73	5.98	24.6	2.101	2.010	78.98	82.57	62.22	110.20
4	8210.41	5.95	33.7	2.092	2.009	79.30	82.60	62.22	119.68
5	8243.13	5.93	42.8	2.084	2.003	79.62	82.87	62.22	121.77
6	8275.91	5.90	52.0	2.076	1.997	79.95	83.13	62.21	124.05
7	8308.74	5.88	61.1	2.068	1.989	80.27	83.43	62.21	124.81
8	8341.62	5.85	70.2	2.059	1.983	80.59	83.71	62.21	126.40
9	8374.55	5.82	79.3	2.051	1.981	80.91	83.79	62.20	136.76
10	8407.54	5.80	88.4	2.043	1.978	81.23	83.92	62.20	146.37

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

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RUN NUMBER 8511
MULTI-PHASE
07-29-2002
TEST FLUID IS DISTILLED WATER

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VOLUMETRIC FLOW RATE	=	1.94	GPM
MASS FLOW RATE WATER	=	16.1	LBM/MIN
MASS FLOW RATE GAS	=	1.63	LBM/MIN
MASS FLUX	=	147440	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.66	FT/S
GAS VELOCITY	=	56.23	FT/S
GAS VISCOSITY	=	386.00E-09	LBM-S/FT^2
INLET TEMPERATURE	=	77.99	F
OUTLET TEMPERATURE	=	82.01	F
RE NUMBER LIQUID	=	6497	
RE NUMBER GAS	=	30414	
AVERAGE PR NUMBER	=	5.90	
CURRENT TO TUBE	=	377.6	AMPS
VOLTAGE DROP IN TUBE	=	3.89	VOLTS
AVERAGE HEAT FLUX	=	2023	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5011	BTU/HR
Q=M*C*(T2-T1)	=	4422	BTU/HR
HEAT BALANCE ERROR	=	11.76	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	85.64	87.52	86.74	87.13	87.22	87.72	87.89	88.45	88.70	88.86
2	85.04	83.67	84.43	83.80	84.57	84.56	85.05	84.71	85.02	85.40
3	80.51	80.54	80.95	81.31	81.68	82.11	82.40	82.59	82.93	82.80
4	82.54	83.14	82.99	83.49	83.79	84.19	84.56	85.42	85.07	85.42

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	84.83	86.74	85.94	86.34	86.42	86.93	87.09	87.66	87.91	88.07
2	84.23	82.83	83.60	82.96	83.73	83.72	84.21	83.86	84.17	84.55
3	79.62	79.66	80.07	80.44	80.80	81.24	81.53	81.71	82.06	81.92
4	81.69	82.29	82.14	82.64	82.94	83.34	83.71	84.58	84.22	84.58

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	6890	7048	6982	7015	7022	7063	7077	7124	7145	7158
2	6841	6726	6789	6736	6800	6799	6839	6810	6836	6867
3	6467	6470	6503	6532	6562	6597	6620	6636	6664	6652
4	6634	6682	6670	6711	6735	6768	6798	6869	6840	6869

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1401	1344	1372	1360	1372	1364	1371	1364	1357	1363
2	1399	1458	1434	1460	1446	1459	1452	1471	1471	1462
3	1532	1522	1520	1509	1513	1508	1512	1514	1505	1518
4	1462	1471	1471	1468	1466	1468	1465	1453	1469	1461

RUN NUMBER 8511

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	213	166	198	196	207	202	210	203	207	215
2	234	348	314	413	368	414	400	508	522	519
3	1123	1504	1464	1484	1516	1443	1597	2023	2128	8266
4	426	404	473	455	467	466	467	402	512	515

RUN NUMBER 8511
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	6358.35	6.04	6.4	2.120	2.009	78.26	82.59	62.23	87.25
2	6389.19	6.01	15.5	2.110	2.003	78.65	82.88	62.23	89.31
3	6420.10	5.98	24.6	2.099	2.001	79.03	82.94	62.22	96.74
4	6451.06	5.94	33.7	2.089	1.997	79.42	83.09	62.22	102.79
5	6482.08	5.91	42.8	2.079	1.988	79.81	83.48	62.22	102.88
6	6513.16	5.88	52.0	2.069	1.980	80.19	83.81	62.21	104.46
7	6544.30	5.85	61.1	2.060	1.972	80.58	84.14	62.21	106.09
8	6575.49	5.82	70.2	2.050	1.965	80.97	84.45	62.20	108.16
9	6606.75	5.79	79.3	2.040	1.962	81.35	84.59	62.20	116.43
10	6638.06	5.76	88.4	2.030	1.957	81.74	84.78	62.20	123.91

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8512
MULTI-PHASE
07-29-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.39	GPM
MASS FLOW RATE WATER	=	11.6	LBM/MIN
MASS FLOW RATE GAS	=	1.62	LBM/MIN
MASS FLUX	=	105785	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.47	FT/S
GAS VELOCITY	=	56.17	FT/S
GAS VISCOSITY	=	386.15E-09	LBM-S/FT^2
INLET TEMPERATURE	=	77.71	F
OUTLET TEMPERATURE	=	83.04	F
RE NUMBER LIQUID	=	4683	
RE NUMBER GAS	=	30352	
AVERAGE PR NUMBER	=	5.87	
CURRENT TO TUBE	=	371.3	AMPS
VOLTAGE DROP IN TUBE	=	3.87	VOLTS
AVERAGE HEAT FLUX	=	1979	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	4902	BTU/HR
Q=M*C*(T2-T1)	=	4406	BTU/HR
HEAT BALANCE ERROR	=	10.12	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	88 21	89.07	88.29	89.12	89.25	89.94	90.25	90.93	91.25	91.50
2	86.70	84.31	85.44	84.86	85.78	85.76	86.43	85.99	86.47	86.92
3	80.56	80.65	81.10	81.58	82.07	82.57	82.95	83.25	83.68	83.65
4	83 64	83.71	83.71	84 41	84.77	85.31	85.84	86 91	86.40	86.91

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	87.44	88.33	87.53	88.37	88.50	89.19	89.50	90.18	90.51	90.75
2	85.92	83.49	84.64	84.04	84.97	84.94	85.62	85.16	85.64	86.10
3	79.68	79.79	80.24	80.72	81.21	81.72	82.09	82.39	82.83	82.79
4	82.82	82.88	82.88	83.59	83.95	84.49	85.02	86.10	85.57	86.09

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	5098	5152	5104	5154	5161	5203	5222	5263	5283	5298
2	5008	4865	4932	4897	4952	4950	4990	4963	4991	5018
3	4643	4649	4675	4703	4732	4761	4783	4800	4826	4824
4	4825	4829	4829	4870	4891	4923	4954	5018	4987	5018

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1324	1272	1307	1280	1301	1291	1298	1289	1281	1287
2	1343	1415	1381	1414	1399	1415	1408	1432	1429	1421
3	1519	1487	1490	1480	1484	1479	1485	1486	1475	1488
4	1421	1431	1427	1426	1425	1427	1423	1408	1431	1431

RUN NUMBER 8512

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	141	130	154	146	155	150	155	151	153	159
2	171	288	249	318	288	378	314	408	411	415
3	941	1230	1301	1323	1357	1364	1565	2019	2216	13521
4	299	332	376	358	372	370	367	317	420	417

RUN NUMBER 8512
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	4551.03	6.06	6.4	2.125	1 976	78.07	83.97	62.23	62.05
2	4580.36	6.01	15.5	2.111	1.985	78.58	83.62	62.23	72.50
3	4609.76	5.97	24.6	2.098	1.980	79.09	83.52	62.22	77.24
4	4639.23	5.93	33.7	2.085	1.971	79.61	84.18	62.22	79.83
5	4668.77	5 89	42.8	2.071	1.960	80.12	84.66	62.21	80.46
6	4698.39	5.85	52.0	2.058	1.950	80.63	85.08	62.21	81.97
7	4728 09	5 80	61.1	2.045	1.939	81.14	85.56	62.20	82.68
8	4757.85	5.76	70.2	2.033	1.930	81.66	85.96	62.20	84.76
9	4787.69	5.72	79.3	2.020	1.926	82.17	86.14	62.19	91.81
10	4817.60	5.68	88.4	2.007	1.919	82.68	86.43	62.19	97.08

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8513
MULTI-PHASE
07-29-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.05	GPM
MASS FLOW RATE WATER	=	8.7	LBM/MIN
MASS FLOW RATE GAS	=	1.66	LBM/MIN
MASS FLUX	=	79832	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.36	FT/S
GAS VELOCITY	=	57.51	FT/S
GAS VISCOSITY	=	386.34E-09	LBM-S/FT^2
INLET TEMPERATURE	=	77.24	F
OUTLET TEMPERATURE	=	84.48	F
RE NUMBER LIQUID	=	3555	
RE NUMBER GAS	=	31029	
AVERAGE PR NUMBER	=	5.83	
CURRENT TO TUBE	=	384.1	AMPS
VOLTAGE DROP IN TUBE	=	3.91	VOLTS
AVERAGE HEAT FLUX	=	2068	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5124	BTU/HR
Q=M*C*(T2-T1)	=	4775	BTU/HR
HEAT BALANCE ERROR	=	6.81	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	91.86	92.09	91.10	92.34	92.71	93.60	94.08	94.85	95.23	95.46
2	88.57	85.43	86.98	86.43	87.69	87.62	88.52	87.89	88.59	89.12
3	80.55	80.73	81.30	81.91	82.57	83.19	83.72	84.19	84.76	84.85
4	85.15	84.73	84.81	85.69	86.30	86.94	87.72	89.15	88.37	89.10

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	91.06	91.32	90.31	91.56	91.92	92.82	93.30	94.07	94.46	94.68
2	87.74	84.55	86.12	85.55	86.82	86.74	87.65	87.00	87.70	88.24
3	79.59	79.80	80.37	80.98	81.64	82.26	82.79	83.26	83.84	83.92
4	84.27	83.84	83.92	84.80	85.41	86.05	86.83	88.28	87.48	88.22

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	4012	4024	3977	4035	4051	4093	4115	4151	4169	4179
2	3861	3718	3788	3763	3820	3816	3857	3827	3859	3883
3	3500	3509	3534	3560	3589	3617	3640	3661	3686	3690
4	3705	3686	3690	3729	3756	3785	3820	3885	3849	3882

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1373	1332	1368	1342	1357	1342	1352	1343	1332	1343
2	1442	1526	1482	1520	1502	1523	1514	1546	1541	1512
3	1663	1613	1619	1609	1617	1609	1617	1616	1601	1615
4	1530	1544	1537	1539	1537	1541	1534	1514	1546	1532

RUN NUMBER 8513

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	103	102	122	114	118	115	118	117	119	125
2	144	249	211	265	238	275	263	351	349	361
3	892	1173	1300	1381	1437	1527	1832	2458	2965	-23905
4	234	285	320	306	313	318	321	266	369	362

RUN NUMBER 8513
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	3419.78	6.09	6.4	2.134	1.937	77.73	85.66	62.23	49.43
2	3449.80	6.03	15.5	2.115	1.955	78.42	84.88	62.23	60.71
3	3479.93	5.97	24.6	2.097	1.948	79.12	85.18	62.22	64.60
4	3510.16	5.91	33.7	2.079	1.935	79.82	85.72	62.22	66.22
5	3540.49	5.86	42.8	2.061	1.919	80.51	86.45	62.21	65.87
6	3570.92	5.80	52.0	2.044	1.907	81.21	86.97	62.20	67.85
7	3601.46	5.74	61.1	2.026	1.892	81.90	87.64	62.19	68.10
8	3632.10	5.69	70.2	2.009	1.881	82.60	88.15	62.19	70.34
9	3662.83	5.64	79.3	1.992	1.876	83.30	88.37	62.18	76.92
10	3693.67	5.58	88.4	1.976	1.868	83.99	88.75	62.17	81.72

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8514
MULTI-PHASE
07-29-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.97	GPM
MASS FLOW RATE WATER	=	16.4	LBM/MIN
MASS FLOW RATE GAS	=	1.64	LBM/MIN
MASS FLUX	=	149485	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.67	FT/S
GAS VELOCITY	=	56.71	FT/S
GAS VISCOSITY	=	386.22E-09	LBM-S/FT^2
INLET TEMPERATURE	=	78.35	F
OUTLET TEMPERATURE	=	82.73	F
RE NUMBER LIQUID	=	6631	
RE NUMBER GAS	=	30627	
AVERAGE PR NUMBER	=	5.85	
CURRENT TO TUBE	=	395.1	AMPS
VOLTAGE DROP IN TUBE	=	4.03	VOLTS
AVERAGE HEAT FLUX	=	2193	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5432	BTU/HR
Q=M*C*(T2-T1)	=	4880	BTU/HR
HEAT BALANCE ERROR	=	10.17	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	86.45	88.95	88.03	88.34	88.37	88.98	89.15	89.74	89.94	90.06
2	85.86	84.57	85.41	84.72	85.54	85.54	86.01	85.60	85.97	86.37
3	81.10	81.16	81.58	82.00	82.40	82.84	83.13	83.33	83.68	83.59
4	83.22	84.01	83.83	84.35	84.67	85.08	85.50	86.38	86.00	86.37

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	85.56	88.10	87.16	87.48	87.50	88.11	88.28	88.87	89.08	89.19
2	84.97	83.64	84.50	83.80	84.62	84.62	85.09	84.67	85.04	85.44
3	80.13	80.20	80.62	81.04	81.44	81.88	82.17	82.37	82.73	82.63
4	82.29	83.08	82.90	83.42	83.74	84.15	84.57	85.46	85.07	85.44

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	7047	7260	7181	7208	7209	7262	7276	7326	7343	7353
2	6997	6887	6958	6899	6968	6968	7007	6972	7003	7037
3	6598	6603	6638	6673	6705	6742	6765	6782	6811	6803
4	6775	6840	6825	6868	6895	6929	6964	7038	7006	7037

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1538	1468	1500	1490	1504	1495	1502	1493	1488	1495
2	1534	1600	1572	1599	1584	1598	1592	1613	1611	1601
3	1675	1668	1666	1653	1658	1652	1657	1658	1649	1661
4	1602	1614	1613	1609	1606	1610	1605	1593	1610	1601

RUN NUMBER 8514

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	222	162	195	196	209	203	211	205	210	221
2	242	349	313	411	369	413	406	524	532	532
3	1126	1477	1474	1455	1490	1457	1655	2128	2313	8515
4	439	402	473	458	471	473	472	412	527	532

RUN NUMBER 8514
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	6477.66	6.01	6.4	2.110	1.994	78.64	83.24	62.23	90.11
2	6511.80	5.97	15.5	2.099	1.982	79.07	83.75	62.22	88.29
3	6546.02	5.94	24.6	2.088	1.981	79.49	83.79	62.22	96.05
4	6580.30	5.90	33.7	2.077	1.977	79.91	83.93	62.21	102.70
5	6614.65	5.87	42.8	2.066	1.968	80.33	84.33	62.21	103.41
6	6649.07	5.84	52.0	2.055	1.959	80.75	84.69	62.21	104.85
7	6683.57	5.80	61.1	2.045	1.951	81.17	85.03	62.20	107.10
8	6718.13	5.77	70.2	2.034	1.944	81.59	85.34	62.20	110.09
9	6752.76	5.74	79.3	2.024	1.941	82.01	85.48	62.19	119.12
10	6787.46	5.70	88.4	2.013	1.936	82.44	85.68	62.19	127.20

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8515
MULTI-PHASE
07-29-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.43	GPM
MASS FLOW RATE WATER	=	11.9	LBM/MIN
MASS FLOW RATE GAS	=	1.64	LBM/MIN
MASS FLUX	=	108459	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.48	FT/S
GAS VELOCITY	=	56.71	FT/S
GAS VISCOSITY	=	386.37E-09	LBM-S/FT^2
INLET TEMPERATURE	=	77.88	F
OUTLET TEMPERATURE	=	83.96	F
RE NUMBER LIQUID	=	4834	
RE NUMBER GAS	=	30594	
AVERAGE PR NUMBER	=	5.82	
CURRENT TO TUBE	=	399.4	AMPS
VOLTAGE DROP IN TUBE	=	4.12	VOLTS
AVERAGE HEAT FLUX	=	2266	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5614	BTU/HR
Q=M*C*(T2-T1)	=	5138	BTU/HR
HEAT BALANCE ERROR	=	8.48	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	90.24	91.54	90.21	90.94	91.20	92.01	92.42	93.15	93.45	93.59
2	88.13	85.56	86.74	86.04	87.11	87.08	87.84	87.27	87.86	88.28
3	81.15	81.26	81.74	82.29	82.84	83.42	83.83	84.17	84.66	84.63
4	84.95	84.93	84.71	85.47	85.94	86.49	87.16	88.35	87.76	88.30

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	89.35	90.69	89.34	90.08	90.33	91.15	91.55	92.29	92.59	92.73
2	87.23	84.61	85.81	85.09	86.17	86.13	86.90	86.31	86.90	87.33
3	80.13	80.26	80.74	81.30	81.85	82.43	82.84	83.18	83.67	83.64
4	84.00	83.97	83.75	84.51	84.99	85.53	86.21	87.41	86.80	87.35

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	5345	5428	5344	5389	5405	5456	5481	5527	5546	5555
2	5214	5055	5128	5084	5150	5147	5194	5158	5194	5220
3	4787	4795	4823	4856	4889	4924	4948	4969	4998	4996
4	5018	5016	5003	5049	5078	5111	5152	5225	5188	5222

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1528	1462	1508	1491	1505	1491	1499	1489	1482	1491
2	1562	1645	1604	1639	1622	1641	1633	1662	1657	1648
3	1762	1727	1726	1713	1720	1712	1721	1720	1708	1721
4	1644	1661	1656	1653	1652	1656	1651	1634	1659	1647

RUN NUMBER 8515

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	138	123	152	148	155	150	153	150	154	162
2	174	286	252	324	292	333	320	423	420	436
3	955	1243	1344	1363	1410	1405	1654	2162	2413	20014
4	287	326	385	369	379	383	374	325	432	433

RUN NUMBER 8515
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	4678.99	6.04	6.4	2.119	1.948	78.29	85.18	62.23	61.52
2	4713.33	5.99	15.5	2.104	1.955	78.87	84.88	62.22	70.45
3	4747.77	5.94	24.6	2.088	1.954	79.46	84.91	62.22	77.58
4	4782.31	5.89	33.7	2.073	1.946	80.04	85.25	62.21	81.26
5	4816.94	5.85	42.8	2.058	1.933	80.63	85.83	62.21	81.19
6	4851.67	5.80	52.0	2.044	1.922	81.21	86.31	62.20	82.86
7	4886.50	5.75	61.1	2.029	1.909	81.80	86.87	62.20	83.19
8	4921.43	5.71	70.2	2.015	1.900	82.38	87.30	62.19	85.89
9	4956.45	5.66	79.3	2.000	1.895	82.97	87.49	62.18	93.17
10	4991.57	5.62	88.4	1.986	1.890	83.55	87.76	62.18	100.13

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8516
MULTI-PHASE
07-29-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	.99	GPM
MASS FLOW RATE WATER	=	8.2	LBM/MIN
MASS FLOW RATE GAS	=	1.64	LBM/MIN
MASS FLUX	=	75189	LBM/(SQ.FT HR)
LIQUID VELOCITY	=	.34	FT/S
GAS VELOCITY	=	56.78	FT/S
GAS VISCOSITY	=	386.49E-09	LBM S/FT^2
INLET TEMPERATURE	=	76.95	F
OUTLET TEMPERATURE	=	85.49	F
RE NUMBER LIQUID	=	3363	
RE NUMBER GAS	=	30602	
AVERAGE PR NUMBER	=	5.80	
CURRENT TO TUBE	=	411.7	AMPS
VOLTAGE DROP IN TUBE	=	4.10	VOLTS
AVERAGE HEAT FLUX	=	2325	BTU/(SQ.FT-HR)
Q-AMP*VOLT	=	5759	BTU/HR
Q=M*C*(T2-T1)	=	5356	BTU/HR
HEAT BALANCE ERROR	=	7.00	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	94.78	95.10	93.66	94.95	95.55	96.73	97.34	98.39	98.91	98,89
2	89.43	86.35	88.36	87.67	89.30	89.14	90.32	89.62	90.44	90.94
3	80.50	80.85	81.52	82.23	83.02	83.78	84.41	84.99	85.66	85.79
4	86.24	85.87	85.80	86.81	87.59	88.43	89.36	91.16	90.15	90.94

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	93.88	94.23	92.76	94.06	94.65	95.85	96.45	97.51	98.03	98.01
2	88.46	85.33	87.37	86.66	88.30	88.13	89.31	88.59	89.42	89.92
3	79.39	79.77	80.44	81.16	81.94	82.71	83.33	83.91	84.59	84.72
4	85 22	84.84	84.78	85.79	86.57	87.41	88.34	90.15	89.12	89.92

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	3901	3916	3852	3909	3935	3987	4014	4060	4084	4082
2	3667	3534	3621	3590	3660	3653	3703	3673	3708	3729
3	3288	3304	3331	3361	3393	3425	3451	3475	3503	3509
4	3530	3514	3511	3554	3587	3622	3662	3739	3695	3729

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1546	1495	1557	1529	1546	1525	1537	1525	1510	1527
2	1687	1768	1707	1751	1728	1758	1745	1785	1779	1768
3	1917	1863	1871	1858	1869	1859	1872	1872	1853	1866
4	1764	1780	1773	1773	1773	1776	1770	1745	1766	1768

RUN NUMBER 8516

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	94	94	114	108	111	107	109	107	108	116
2	153	253	208	262	230	270	254	335	334	353
3	1025	1304	1469	1588	1650	1726	2128	2930	3718	-9327
4	229	274	316	305	307	307	300	253	355	353

RUN NUMBER 8516
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	3212.69	6.10	6.4	2 140	1.912	77.52	86.74	62.24	48.98
2	3246.02	6.03	15.5	2.118	1.928	78 35	86.04	62.23	58.53
3	3279.48	5.97	24.6	2.096	1.921	79 17	86.34	62.22	62.78
4	3313.08	5.90	33.7	2 075	1.908	79 99	86.92	62.21	64.92
5	3346.82	5.83	42.8	2.054	1.887	80.81	87.87	62.21	63.71
6	3380.69	5.77	52 0	2.033	1.873	81.63	88.52	62.20	65.20
7	3414.69	5.70	61 1	2.013	1.855	82.45	89.36	62.19	65.02
8	3448.82	5.64	70.2	1.993	1.840	83.27	90 04	62.18	66.31
9	3483.09	5.58	79.3	1.973	1.835	84.09	90 29	62.17	72.36
10	3517 49	5.52	88.4	1.954	1.828	84.92	90.64	62.16	78.25

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT-HR)

RUN NUMBER 8517
MULTI-PHASE
07-30-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.33	GPM
MASS FLOW RATE WATER	=	11.1	LBM/MIN
MASS FLOW RATE GAS	=	1.58	LBM/MIN
MASS FLUX	=	101353	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.45	FT/S
GAS VELOCITY	=	54.54	FT/S
GAS VISCOSITY	=	385.88E-09	LBM-S/FT^2
INLET TEMPERATURE	=	77.12	F
OUTLET TEMPERATURE	=	82.27	F
RE NUMBER LIQUID	=	4449	
RE NUMBER GAS	=	29528	
AVERAGE PR NUMBER	=	5.92	
CURRENT TO TUBE	=	360.1	AMPS
VOLTAGE DROP IN TUBE	=	3.60	VOLTS
AVERAGE HEAT FLUX	=	1785	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	4422	BTU/HR
Q=M*C*(T2-T1)	=	4090	BTU/HR
HEAT BALANCE ERROR	=	7.52	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	88.41	88.83	87.66	88.42	88.68	89.43	89.74	90.27	90.58	90.71
2	85.84	83.48	84.61	84.07	85.07	84.99	85.64	85.16	85.70	86.10
3	79.78	79.93	80.38	80.82	81.29	81.75	82.13	82.44	82.84	82.90
4	83.38	83.10	82.97	83.64	84.02	84.50	85.08	86.14	85.57	86.07

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	87.70	88.15	86.95	87.72	87.98	88.73	89.04	89.57	89.89	90.01
2	85.10	82.70	83.86	83.30	84.31	84.22	84.87	84.38	84.92	85.33
3	78.95	79.12	79.57	80.01	80.48	80.94	81.32	81.63	82.04	82.09
4	82.61	82.32	82.19	82.86	83.24	83.72	84.30	85.37	84.79	85.30

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	4900	4925	4857	4901	4915	4959	4976	5007	5025	5033
2	4752	4617	4681	4650	4707	4702	4739	4711	4741	4764
3	4408	4418	4442	4467	4493	4518	4539	4557	4579	4582
4	4611	4595	4588	4625	4647	4674	4707	4767	4734	4763

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1221	1177	1219	1202	1213	1200	1208	1203	1194	1202
2	1274	1340	1303	1332	1316	1334	1327	1350	1345	1318
3	1441	1403	1405	1396	1401	1395	1402	1402	1393	1401
4	1337	1350	1344	1343	1343	1346	1341	1325	1349	1338

RUN NUMBER 8517

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	119	115	143	137	142	136	140	139	141	148
2	166	287	241	306	270	312	299	393	385	393
3	972	1213	1264	1315	1357	1394	1586	2010	2288	8369
4	260	309	360	343	353	356	346	298	401	396

RUN NUMBER 8517
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	4327.46	6.11	6.4	2.141	1.985	77.47	83.59	62.24	56.25
2	4354.52	6.07	15.5	2.128	1.998	77.96	83.07	62.23	67.32
3	4381.66	6.02	24.6	2.115	1.996	78.46	83.14	62.23	73.38
4	4408.85	5.98	33.7	2.102	1.988	78.95	83.47	62.22	75.99
5	4436.12	5.94	42.8	2.089	1.976	79.45	84.00	62.22	75.43
6	4463.45	5.90	52.0	2.076	1.966	79.94	84.40	62.21	76.97
7	4490.84	5.86	61.1	2.063	1.955	80.44	84.88	62.21	77.20
8	4518.30	5.82	70.2	2.051	1.947	80.93	85.24	62.20	79.69
9	4545.83	5.78	79.3	2.038	1.943	81.43	85.41	62.20	86.15
10	4573.42	5.74	88.4	2.026	1.936	81.92	85.68	62.19	91.21

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8518
MULTI-PHASE
07-30-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	.89	GPM
MASS FLOW RATE WATER	=	7.4	LBM/MIN
MASS FLOW RATE GAS	=	1.55	LBM/MIN
MASS FLUX	=	67547	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.30	FT/S
GAS VELOCITY	=	53.74	FT/S
GAS VISCOSITY	=	386.47E-09	LBM-S/FT^2
INLET TEMPERATURE	=	76.77	F
OUTLET TEMPERATURE	=	85.58	F
RE NUMBER LIQUID	=	3020	
RE NUMBER GAS	=	28969	
AVERAGE PR NUMBER	=	5.80	
CURRENT TO TUBE	=	389.9	AMPS
VOLTAGE DROP IN TUBE	=	3.94	VOLTS
AVERAGE HEAT FLUX	=	2116	BTU/(SQ.FT HR)
Q=AMP*VOLT	=	5241	BTU/HR
Q=M*C*(T2-T1)	=	5031	BTU/HR
HEAT BALANCE ERROR	=	4.20	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	95.93	94.84	93.82	95.30	95.79	96.96	97.29	98.28	99.07	99.10
2	89.93	86.10	88.41	87.83	89.41	89.21	90.28	89.44	90.59	91.04
3	80.44	80.74	81.41	82.17	82.96	83.62	84.25	84.81	85.47	85.74
4	86.76	85.74	85.87	86.98	87.70	88.43	89.37	91.06	90.09	90.92

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	95.14	94.07	93.02	94.52	95.00	96.18	96.50	97.50	98.30	98.32
2	89.06	85.18	87.53	86.92	88.54	88.30	89.38	88.51	89.67	90.12
3	79.43	79.77	80.43	81.20	81.98	82.65	83.27	83.83	84.50	84.77
4	85.04	84.02	84.95	86.06	86.78	87.51	88.45	90.16	89.16	90.00

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	3554	3512	3471	3529	3548	3595	3608	3647	3679	3680
2	3317	3170	3259	3235	3297	3288	3329	3296	3341	3358
3	2955	2968	2992	3021	3050	3074	3098	3119	3144	3154
4	3195	3156	3161	3203	3230	3258	3294	3359	3321	3354

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1355	1320	1377	1347	1365	1343	1360	1347	1329	1345
2	1506	1591	1529	1573	1549	1579	1565	1607	1596	1589
3	1753	1682	1696	1685	1695	1685	1696	1693	1679	1689
4	1587	1601	1594	1594	1594	1599	1588	1565	1609	1592

RUN NUMBER 8518

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	76	83	96	92	95	92	96	94	93	100
2	128	228	180	224	159	235	225	307	288	309
3	847	1079	1234	1302	1376	1605	2049	3124	4630	-7696
4	167	242	270	259	264	270	264	228	320	317

RUN NUMBER 8518
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	[illegible]	HU
1	2880.27	6.12	6.4	2.144	1.898	77.36	97 17	62.24	40.48
2	2911.13	6.05	15.5	2.121	1.930	78.21	85.96	62.21	52.15
3	2942.13	5.97	24.6	2.099	1.918	79.06	86.48	62.22	54.30
4	2973.26	5.90	33.7	2.077	1.901	79.90	87.17	62.21	55.59
5	3004.51	5.84	42.8	2.055	1.883	80.75	88.07	62.21	55.06
6	3035.89	5.77	52.0	2.034	1.870	81.60	88.66	62.20	57.06
7	3067.40	5.70	61.1	2.013	1.854	82.45	89.40	62.19	57.90
8	3099.04	5.64	70.2	1.993	1.841	83.29	90.5[illegible]	62.18	59.99
9	3130.80	5.57	79.3	1.972	1.833	84.14	90.41	62.17	64.15
10	3162.68	5.51	88.4	1.952	1.824	84.99	90.80	62.16	69.07

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN [illegible]/(FT*HR)

RUN NUMBER 8519
MULTI-PHASE
07-30-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.69	GPM
MASS FLOW RATE WATER	=	14.1	LBM/MIN
MASS FLOW RATE GAS	=	1.53	LBM/MIN
MASS FLUX	=	128776	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.58	FT/S
GAS VELOCITY	=	52.98	FT/S
GAS VISCOSITY	=	386.29E-09	LBM-S/FT^2
INLET TEMPERATURE	=	78.22	F
OUTLET TEMPERATURE	=	83.24	F
RE NUMBER LIQUID	=	5726	
RE NUMBER GAS	=	28596	
AVERAGE PR NUMBER	=	5.84	
CURRENT TO TUBE	=	192.5	AMPS
VOLTAGE DROP IN TUBE	=	4.01	VOLTS
AVERAGE HEAT FLUX	=	2167	BTU/(SQ.FT HR)
Q=AMP*VOLT	=	5370	BTU/HR
Q=M*C*(T2-T1)	=	4867	BTU/HR
HEAT BALANCE ERROR	=	9.37	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	88.78	90.44	89.13	89.62	89.76	90.53	90.70	91.26	91.51	91.72
2	87.13	85.01	86.04	85.41	86.35	86.33	86.86	86.33	86.88	87.27
3	81.20	81.31	81.75	82.24	82.71	83.15	83.48	83.72	84.11	84.13
4	84.21	84.54	84.33	84.99	85.35	85.79	86.30	87.27	86.76	87.26

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	87.92	89.61	88.28	88.78	88.91	89.69	89.85	90.42	90.69	90.88
2	86.25	84.09	85.14	84.50	85.45	85.42	85.95	85.41	85.96	86.35
3	80.23	80.35	80.79	81.29	81.76	82.20	82.53	82.77	83.16	83.18
4	83.29	83.61	83.41	84.07	84.43	84.87	85.38	86.36	85.84	86.34

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	6241	6165	6268	6304	6314	6371	6383	6424	6444	6458
2	6120	5965	6040	5994	6052	6060	6098	6059	6099	6128
3	5691	5699	5710	5765	5799	5830	5853	5870	5898	5899
4	5908	5931	5916	5963	5989	6020	6057	6128	6090	6127

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1487	1422	1466	1454	1468	1454	1463	1455	1449	1456
2	1513	1589	1552	1581	1565	1581	1575	1599	1593	1586
3	1682	1657	1655	1644	1649	1643	1649	1649	1639	1651
4	1588	1601	1596	1591	1591	1595	1589	1575	1596	1587

RUN NUMBER 8519

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	158	134	167	165	174	166	174	171	175	182
2	196	314	276	352	315	355	350	460	450	459
3	1006	1262	1303	1280	1299	1337	1535	1983	2204	6002
4	335	350	410	391	403	409	404	356	467	461

RUN NUMBER 8519
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	5574.18	6.02	6.4	2.112	1.966	78.56	84.42	62.23	69.70
2	5607.88	5.98	15.5	2.099	1.966	79.04	84.42	62.22	75.97
3	5641.66	5.94	24.6	2.087	1.966	79.52	84.41	62.22	83.62
4	5675.52	5.90	33.7	2.074	1.960	80.01	84.66	62.21	87.72
5	5709.46	5.86	42.8	2.062	1.949	80.49	85.14	62.21	87.79
6	5743.48	5.82	52.0	2.050	1.940	80.97	85.54	62.20	89.20
7	5777.57	5.78	61.1	2.038	1.931	81.45	85.93	62.20	91.12
8	5811.75	5.74	70.2	2.026	1.924	81.94	86.24	62.19	94.73
9	5846.00	5.70	79.3	2.014	1.920	82.42	86.41	62.19	101.98
10	5880.34	5.67	88.4	2.002	1.913	82.90	86.69	62.19	107.53

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8520
MULTI-PHASE
07-30-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	.92	GPM
MASS FLOW RATE WATER	=	7.7	LBM/MIN
MASS FLOW RATE GAS	=	1.49	LBM/MIN
MASS FLUX	=	70014	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.31	FT/S
GAS VELOCITY	=	51.53	FT/S
GAS VISCOSITY	=	386.61E-09	LBM-S/FT^2
INLET TEMPERATURE	=	77.05	F
OUTLET TEMPERATURE	=	85.99	F
RE NUMBER LIQUID	=	3143	
RE NUMBER GAS	=	27748	
AVERAGE PR NUMBER	=	5.78	
CURRENT TO TUBE	=	395.8	AMPS
VOLTAGE DROP IN TUBE	=	4.07	VOLTS
AVERAGE HEAT FLUX	=	2218	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5496	BTU/HR
Q=M*C*(T2-T1)	=	5191	BTU/HR
HEAT BALANCE ERROR	=	5.54	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	97.68	95.98	94.60	96.12	96.76	97.96	98.51	99.28	99.84	100.04
2	90.75	86.64	89.03	88.39	90.01	89.84	90.99	90.07	91.11	91.63
3	80.86	81.10	81.76	82.53	83.32	84.02	84.65	85.22	85.89	86.09
4	87.43	86.28	86.36	87.45	88.27	88.99	90.01	91.71	90.65	91.52

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	96.88	95.19	93.78	95.31	95.95	97.16	97.70	98.48	99.04	99.24
2	89.85	85.69	88.12	87.45	89.09	88.90	90.06	89.12	90.16	90.69
3	79.82	80.10	80.75	81.53	82.31	83.02	83.64	84.21	84.89	85.09
4	86.48	85.33	85.41	86.50	87.32	88.04	89.06	90.78	89.70	90.57

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	3755	3666	3628	3691	3717	3767	3789	3821	3844	3852
2	3470	3305	3401	3375	3439	3432	3478	3441	3482	3503
3	3078	3089	3114	3144	3174	3201	3225	3248	3274	3282
4	3336	3291	3294	3337	3369	3398	3439	3507	3464	3499

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1377	1352	1419	1387	1402	1380	1394	1385	1371	1384
2	1560	1644	1575	1621	1599	1628	1615	1657	1646	1638
3	1810	1735	1749	1737	1749	1739	1751	1747	1730	1743
4	1646	1654	1644	1645	1644	1650	1640	1614	1658	1641

RUN NUMBER 8520

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	71	81	98	91	94	90	93	93	94	99
2	127	229	180	224	200	234	232	304	292	309
3	835	1093	1267	1348	1431	1628	2105	3207	4745	5777
4	186	242	272	262	263	271	262	227	320	316

RUN NUMBER 8520
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	2996.16	6.09	6.4	2.136	1.879	77.65	88.24	62.24	39.36
2	3028.86	6.02	15.5	2.113	1.916	78.51	86.58	62.23	51.61
3	3061.53	5.95	24.6	2.091	1.906	79.37	87.01	62.22	54.43
4	3094.32	5.88	33.7	2.068	1.891	80.23	87.70	62.21	55.66
5	3127.24	5.81	42.8	2.047	1.870	81.09	88.67	62.20	54.65
6	3160.31	5.74	52.0	2.025	1.856	81.95	89.28	62.19	56.66
7	3193.50	5.67	61.1	2.004	1.839	82.81	90.12	62.19	56.80
8	3226.84	5.61	70.2	1.984	1.828	83.67	90.65	62.18	59.43
9	3260.30	5.54	79.3	1.963	1.821	84.53	90.95	62.17	64.53
10	3293.90	5.48	88.4	1.943	1.812	85.39	91.40	62.16	68.90

NOTE: THE K IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8521
MULTI-PHASE
07-31-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	.83	GPM
MASS FLOW RATE WATER	=	6.9	LBM/MIN
MASS FLOW RATE GAS	=	1.48	LBM/MIN
MASS FLUX	=	63298	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.28	FT/S
GAS VELOCITY	=	51.35	FT/S
GAS VISCOSITY	=	386.67E-09	LBM-S/FT^2
INLET TEMPERATURE	=	76.71	F
OUTLET TEMPERATURE	=	86.62	F
RE NUMBER LIQUID	=	2847	
RE NUMBER GAS	=	27639	
AVERAGE PR NUMBER	=	5.76	
CURRENT TO TUBE	=	400.4	AMPS
VOLTAGE DROP IN TUBE	=	3.99	VOLTS
AVERAGE HEAT FLUX	=	2200	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5450	BTU/HR
Q=M*C*(T2-T1)	=	5314	BTU/HR
HEAT BALANCE ERROR	=	2.50	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	98.60	97.27	96.04	97.75	98.44	99.53	100.23	101.26	101.78	101.84
2	90.62	86.97	89.74	89.07	90.91	90.56	91.89	90.90	92.01	92.56
3	80.61	80.93	81.67	82.50	83.36	84.14	84.83	85.48	86.24	86.46
4	87.61	86.75	86.85	88.04	88.86	89.68	90.88	92.80	91.48	92.49

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	97.79	96.48	95.21	96.94	97.62	98.71	99.41	100.45	100.96	101.03
2	89.69	86.00	88.81	88.11	89.97	89.60	90.94	89.93	91.04	91.59
3	79.54	79.90	80.63	81.47	82.32	83.11	83.79	84.44	85.21	85.43
4	86.64	85.77	85.88	87.07	87.89	88.70	89.91	91.85	90.50	91.52

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	3429	3380	3333	3397	3422	3463	3489	3529	3548	3550
2	3131	2999	3099	3074	3141	3128	3176	3140	3180	3200
3	2773	2786	2811	2840	2870	2897	2921	2944	2973	2979
4	3022	2993	2995	3037	3066	3096	3139	3209	3163	3198

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1391	1366	1435	1399	1416	1396	1411	1397	1382	1400
2	1609	1688	1612	1662	1636	1670	1655	1703	1690	1681
3	1855	1787	1805	1792	1805	1792	1808	1804	1783	1797
4	1687	1694	1686	1689	1689	1692	1681	1654	1704	1683

RUN NUMBER 8521

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	68	75	90	83	86	84	86	85	86	92
2	130	220	169	211	186	223	212	190	280	298
3	856	1139	1341	1455	1595	1855	2601	4575	8342	-3410
4	182	227	255	247	252	257	246	212	309	302

RUN NUMBER 8521
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	2699.57	6.12	6.4	2.144	1.875	77.38	88.42	62.24	18.71
2	2732.12	6.04	15.5	2.118	1.906	78.33	87.04	62.23	48.97
3	2764.82	5.96	24.6	2.093	1.892	79.28	87.63	62.22	51.03
4	2797.67	5.88	33.7	2.068	1.876	80.24	88.40	62.21	52.17
5	2830.68	5.80	42.8	2.044	1.853	81.19	89.45	62.20	51.51
6	2863.84	5.73	52.0	2.021	1.840	82.14	90.03	62.19	51.88
7	2897.14	5.65	61.1	1.997	1.820	83.09	91.01	62.18	53.65
8	2930.60	5.58	70.2	1.975	1.806	84.05	93.66	62.17	55.72
9	2964.20	5.51	79.3	1.952	1.801	85.00	91.93	62.16	61.21
10	2997.96	5.44	88.4	1.930	1.792	85.95	92.39	62.15	65.78

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8522
MULTI-PHASE
07-31-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	.96	GPM
MASS FLOW RATE WATER	=	8.0	LBM/MIN
MASS FLOW RATE GAS	=	1.79	LBM/MIN
MASS FLUX	=	73297	LBM/(SQ FT-HR)
LIQUID VELOCITY	=	.33	FT/S
GAS VELOCITY	=	61.91	FT/S
GAS VISCOSITY	=	386.05E-09	LBM-S/FT^2
INLET TEMPERATURE	=	76.30	F
OUTLET TEMPERATURE	=	83.93	F
RE NUMBER LIQUID	=	3234	
RE NUMBER GAS	=	33477	
AVERAGE PR NUMBER	=	5.89	
CURRENT TO TUBE	=	381.5	AMPS
VOLTAGE DROP IN TUBE	=	3.89	VOLTS
AVERAGE HEAT FLUX	=	2044	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5064	BTU/HR
Q=M*C*(T2-T1)	=	4788	BTU/HR
HEAT BALANCE ERROR	=	5.45	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	91.15	91.37	90.67	91.53	92.11	93.05	93.72	94.53	94.99	95.09
2	88.35	84.79	86.33	85.53	86.90	86.79	87.87	87.41	88.07	88.62
3	79.72	79.97	80.50	81.04	81.72	82.35	83.03	83.62	84.18	84.35
4	84.51	83.95	83.97	84.77	85.45	86.16	87.06	88.65	87.76	88.54

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	90.36	90.63	89.89	90.76	91.34	92.29	92.95	93.77	94.23	94.33
2	87.53	83.92	85.48	84.66	86.04	85.92	87.01	86.53	87.19	87.75
3	78.77	79.05	79.58	80.12	80.80	81.43	82.11	82.70	83.27	83.43
4	83.64	83.07	83.09	83.89	84.57	85.28	86.18	87.79	86.88	87.67

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	3654	3665	3634	3671	3695	3735	3763	3798	3818	3822
2	3536	3388	3452	3418	3475	3470	3514	3495	3522	3545
3	3181	3192	3213	3235	3262	3287	3314	3338	3351	3368
4	3376	3353	3354	3387	3414	3443	3482	3547	3509	3542

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1360	1302	1340	1319	1331	1315	1324	1318	1304	1319
2	1408	1503	1462	1503	1483	1506	1497	1527	1523	1513
3	1653	1594	1600	1587	1597	1589	1598	1598	1581	1594
4	1506	1525	1523	1520	1520	1522	1518	1495	1531	1515

RUN NUMBER 8522

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR F)

	1	2	3	4	5	6	7	8	9	10
1	103	99	115	112	114	111	112	111	112	120
2	131	235	203	265	235	276	258	333	337	349
3	846	1063	1216	1431	1521	1671	1790	2133	2703	110414
4	220	276	316	311	315	317	305	256	365	356

RUN NUMBER 8522
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	3103.80	6.17	6.4	2.159	1.950	76.81	85.08	62.24	45.90
2	3132.72	6.10	15.5	2.139	1.972	77.55	84.16	62.24	58.48
3	3161.75	6.04	24.6	2.119	1.964	78.28	84.51	62.23	62.05
4	3190.88	5.98	33.7	2.100	1.953	79.01	84.86	62.22	66.07
5	3220.11	5.92	42.8	2.081	1.936	79.75	85.69	62.22	65.01
6	3249.46	5.86	52.0	2.062	1.924	80.48	86.23	62.21	67.13
7	3278.90	5.80	61.1	2.044	1.905	81.22	87.06	62.20	65.97
8	3308.45	5.74	70.2	2.025	1.891	81.95	87.69	62.19	67.09
9	3338.10	5.68	79.3	2.007	1.867	82.68	87.89	62.19	73.94
10	3367.86	5.63	88.4	1.990	1.878	83.42	88.29	62.18	78.94

NOTE TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8523
MULTI-PHASE
07-31-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.48	GPM
MASS FLOW RATE WATER	=	12.3	LBM/MIN
MASS FLOW RATE GAS	=	1.80	LBM/MIN
MASS FLUX	=	112686	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.50	FT/S
GAS VELOCITY	=	62.12	FT/S
GAS VISCOSITY	=	386.21E-09	LBM-S/FT^2
INLET TEMPERATURE	=	77.77	F
OUTLET TEMPERATURE	=	83.29	F
RE NUMBER LIQUID	=	4998	
RE NUMBER GAS	=	33551	
AVERAGE PR NUMBER	=	5 85	
CURRENT TO TUBE	=	392.3	AMPS
VOLTAGE DROP IN TUBE	=	4.00	VOLTS
AVERAGE HEAT FLUX	=	2161	BTU/(SQ.FT HR)
Q=AMP*VOLT	=	5353	BTU/HR
Q=M*C*(T2-T1)	=	4890	BTU/HR
HEAT BALANCE ERROR	=	8.65	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	87.38	89.97	88.83	89.33	89.57	90.32	90.75	91.39	91.72	91.85
2	86.82	84.80	85.75	85.06	86.06	86.04	86.76	86.29	86.81	87.23
3	80.72	80.93	81.35	81.83	82.34	82.81	83.33	83.58	83.97	84.06
4	83.50	84.11	83.91	84.55	84.99	85.49	86.14	87.26	86.69	87.26

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	86.51	89.14	87.98	88.47	88.72	89.48	89.91	90.55	90.89	91.01
2	85.95	83 89	84.85	84.15	85.16	85.13	85.85	85.37	85.89	86 31
3	79.75	79 97	80.39	80.88	81.39	81.86	82.28	82.63	83 02	83.13
4	82.59	83.19	82.99	83 63	84.07	84.57	85.22	86.35	85.77	86.32

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	5372	5540	5465	5496	5513	5561	5589	5630	5652	5660
2	5337	5207	5267	5233	5286	5284	5330	5300	5313	5359
3	4950	4964	4990	5020	5051	5080	5106	5128	5153	5158
4	5125	5163	5150	5191	5218	5249	5290	5362	5325	5360

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1507	1424	1463	1450	1462	1450	1457	1449	1440	1450
2	1494	1581	1548	1578	1563	1580	1573	1598	1594	1586
3	1678	1656	1654	1642	1648	1643	1650	1650	1639	1650
4	1579	1599	1595	1591	1591	1594	1589	1573	1597	1586

RUN NUMBER 8523

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	180	136	166	166	172	167	169	166	167	179
2	191	303	274	357	319	364	347	455	455	467
3	1043	1273	1369	1431	1467	1541	1735	2141	2580	8726
4	355	354	421	408	418	422	407	350	472	465

RUN NUMBER 8523
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	4852.35	6.05	6.4	2.123	1.983	78.14	83.70	62.23	73.48
2	4884.71	6.01	15.5	2.109	1.975	78.67	84.05	62.33	75 95
3	4917.16	5.96	24.6	2.095	1.974	79.20	84.05	62.22	84.08
4	4949 69	5 92	33.7	2.081	1.969	79.73	84.28	62.22	89.64
5	4982.31	5 88	42.8	2.068	1.956	80.26	84.83	62.21	89.19
6	5015.01	5 83	52.0	2.054	1.946	80.80	85 26	62 21	91.26
7	5047.80	5.79	61.1	2.041	1.933	81.33	85.81	62.20	90.74
8	5080.66	5.75	70.2	2.028	1.924	81.86	86.22	62.20	93.21
9	5113.61	5.71	79.3	2.015	1.920	82.39	86.39	62.19	101.61
10	5146.65	5.67	88 4	2.002	1 913	82.92	86.69	62.18	107.84

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8524
MULTI-PHASE
07-31-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.97	GPM
MASS FLOW RATE WATER	=	16.4	LBM/MIN
MASS FLOW RATE GAS	=	1.78	LBM/MIN
MASS FLUX	=	149467	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.67	FT/S
GAS VELOCITY	=	61.53	FT/S
GAS VISCOSITY	=	386.31E-09	LBM-S/FT^2
INLET TEMPERATURE	=	78.69	F
OUTLET TEMPERATURE	=	82.84	F
RE NUMBER LIQUID	=	6649	
RE NUMBER GAS	=	33208	
AVERAGE PR NUMBER	=	5.84	
CURRENT TO TUBE	=	385.5	AMPS
VOLTAGE DROP IN TUBE	=	3.99	VOLTS
AVERAGE HEAT FLUX	=	2118	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5248	BTU/HR
Q=M*C*(T2-T1)	=	4670	BTU/HR
HEAT BALANCE ERROR	=	11.02	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	85.73	88.46	87.60	88.03	88.16	88.67	88.65	89.21	89.51	89.70
2	85.89	84.56	85.26	84.66	85.48	85.39	85.76	85.40	85.86	86.23
3	81.25	81.37	81.76	82.19	82.58	82.92	83.19	83.40	83.69	83.74
4	83.07	83.90	83.75	84.35	84.64	84.91	85.31	86.15	85.82	86.25

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	84.87	87.65	86.77	87.21	87.33	87.85	87.82	88.38	88.69	88.87
2	85.05	83.68	84.39	83.78	84.61	84.51	84.88	84.51	84.97	85.35
3	80.33	80.45	80.85	81.28	81.67	82.01	82.28	82.49	82.78	82.83
4	82.19	83.01	82.86	83.46	83.75	84.02	84.43	85.27	84.93	85.37

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	6988	7221	7147	7184	7194	7238	7236	7284	7309	7325
2	7003	6889	6948	6897	6966	6958	6989	6958	6997	7028
3	6613	6623	6656	6691	6723	6751	6773	6791	6815	6819
4	6766	6834	6821	6871	6895	6918	6951	7022	6993	7030

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1478	1403	1432	1421	1433	1422	1433	1425	1419	1425
2	1450	1520	1496	1523	1509	1522	1518	1516	1532	1526
3	1593	1585	1582	1571	1576	1569	1573	1574	1568	1578
4	1572	1537	1535	1531	1530	1535	1528	1517	1533	1525

RUN NUMBER 8524

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	250	169	204	201	211	206	221	215	217	225
2	238	352	323	421	373	429	431	558	546	547
3	1171	1460	1467	1609	1427	1497	1714	2162	2522	5888
4	472	422	496	464	480	501	499	432	553	543

RUN NUMBER 8524
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	6503.17	5.98	6.4	2.101	1.997	78.97	83.11	62.22	95.11
2	6535.56	5.95	15.5	2.091	1.983	79.37	83.70	62.22	90.96
3	6568.02	5.92	24.6	2.080	1.982	79.77	83.72	62.22	99.63
4	6600.54	5.88	33.7	2.070	1.977	80.17	83.93	6. .21	104.45
5	6633.12	5.85	42.8	2.060	1.968	80.57	84.34	62.21	104.20
6	6665.77	5.82	52.0	2.050	1.962	80.96	84.60	62.20	108.22
7	6698.48	5.79	61.1	2.040	1.956	81.36	84.85	62.20	112.65
8	6731.25	5.76	70.2	2.030	1.948	81.76	85.17	62.20	115.47
9	6764.09	5.72	79.3	2.020	1.944	82.16	85.35	62.19	123.38
10	6796.98	5.69	88.4	2.010	1.938	82.56	85.60	62.19	128.97

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8525
MULTI-PHASE
07-11-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.97	GPM
MASS FLOW RATE WATER	=	16.4	LBM/MIN
MASS FLOW RATE GAS	=	1.92	LBM/MIN
MASS FLUX	=	149987	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.67	FT/S
GAS VELOCITY	=	66.49	FT/S
GAS VISCOSITY	=	386.42E-09	LBM-S/FT^2
INLET TEMPERATURE	=	79.00	F
OUTLET TEMPERATURE	=	83.12	F
RE NUMBER LIQUID	=	6696	
RE NUMBER GAS	=	35853	
AVERAGE PR NUMBER	=	5.81	
CURRENT TO TUBE	=	385.2	AMPS
VOLTAGE DROP IN TUBE	=	4.04	VOLTS
AVERAGE HEAT FLUX	=	2141	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5310	BTU/HR
Q=M*C*(T2-T1)	=	4697	BTU/HR
HEAT BALANCE ERROR	=	11.54	%

OUTSIDE SURFACE TEMPERATURES DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	85.08	88.22	87.67	88.07	88.05	88.58	88.62	89 23	89.46	89.60
2	85.97	84.78	85.45	84.84	85.57	85.53	85.89	85.56	85.99	86.35
3	81.48	81.66	82.03	82.45	82.82	83.15	83.41	83.63	83.91	83.97
4	82.97	83.98	83.91	84.48	84.70	85.02	85.43	86.28	85.95	86.37

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	84.22	87.40	86.84	87.25	87.22	87.75	87.79	88.40	88.64	88.77
2	85.14	83.90	84.59	83.96	84.70	84.65	85.01	84.67	85.11	85.47
3	80.56	80.75	81.12	81.54	81.91	82.25	82.50	82.72	83.01	83.06
4	82 09	83.09	83 02	83.60	83.82	84.13	84.55	85.40	85.07	85.49

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	6958	7226	7178	7212	7210	7255	7258	7311	7330	7342
2	7035	6932	6989	6936	6998	6994	7025	6996	7032	7063
3	6656	6671	6701	6736	6767	6794	6815	6834	6857	6862
4	6781	6864	6858	6906	6924	6951	6985	7057	7029	7064

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1492	1411	1433	1422	1435	1426	1435	1426	1422	1428
2	1440	1513	1494	1520	1506	1518	1513	1533	1528	1522
3	1584	1579	1577	1566	1569	1565	1568	1570	1564	1573
4	1517	1533	1533	1529	1528	1532	1525	1514	1529	1522

RUN NUMBER 8525

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR F)

	1	2	3	4	5	6	7	8	9	10
1	202	182	211	209	225	219	233	224	229	240
2	245	357	330	434	392	447	450	584	574	579
3	1231	1470	1504	1452	1493	1585	1846	2333	2795	7186
4	539	448	519	488	517	532	527	451	584	574

RUN NUMBER 8525
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	6550.88	5.96	6.4	2.093	2.000	79.28	83.00	62.22	105.53
2	6583.20	5.92	15.5	2.083	1.981	79 67	83.79	62.22	95 56
3	6615.58	5.89	24.6	2.073	1.978	80.07	83.89	62.21	102.80
4	6648.03	5.86	33.7	2.062	1.974	80.47	84.09	62.21	108 46
5	6680.54	5.83	42.8	2.052	1 966	80.86	84.41	62.21	110 60
6	6713.11	5.80	52.0	2 042	1.959	81.26	84.70	62.20	114.15
7	6745.74	5.76	61.1	2 033	1.953	81.65	84.96	62.20	118.54
8	6778.43	5.71	70.2	2.023	1.945	82.05	85.30	62.19	120 65
9	6811 19	5.70	79.3	2.013	1.942	82.45	85.45	62.19	130.37
10	6844 00	5.67	88.4	2.003	1.936	82.84	85.70	62.19	137.22

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8526
MULTI-PHASE
07-31-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	.95	GPM
MASS FLOW RATE WATER	=	7 9	LBM/MIN
MASS FLOW RATE GAS	=	1.98	LBM/MIN
MASS FLUX	=	72412	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.32	FT/S
GAS VELOCITY	=	68.64	FT/S
GAS VISCOSITY	=	186.96E-09	LBM-S/FT^2
INLET TEMPERATURE	=	78.56	F
OUTLET TEMPERATURE	=	86.22	F
RE NUMBER LIQUID	=	3286	
RE NUMBER GAS	=	36867	
AVERAGE PR NUMBER	=	5.71	
CURRENT TO TUBE	=	386.4	AMPS
VOLTAGE DROP IN TUBE	=	3.94	VOLTS
AVERAGE HEAT FLUX	=	2097	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5194	BTU/HR
Q=M*C*(T2-T1)	=	4874	BTU/HR
HEAT BALANCE ERROR	=	6.18	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	90.40	92.65	91.73	92.99	93.57	94 59	94.93	95.79	96.21	96.42
2	89.85	86.87	88.13	87.62	88.93	88.89	89.71	89.13	89.98	90.49
3	81.82	82.17	82.74	83 47	84.18	84.75	85.28	85.78	86.36	86.58
4	85.60	85.80	85.89	86.92	87.56	88.17	88.97	90 37	89.73	90.48

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	89.56	91.86	90.92	92.19	92.77	93.80	94.13	95.00	95.42	95.62
2	89.02	85.98	87.26	86.73	88.05	88.00	88.82	88.23	89.08	89.60
3	80.86	81.23	81.80	82.54	83.24	83.82	84.36	84.84	85.43	85.64
4	84.71	84.90	84.99	86.07	86.66	87.27	88.07	89.48	88.91	89.59

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	3577	3672	3633	3686	3710	3753	3767	3804	3822	3830
2	3555	3430	3482	3461	3515	3513	3546	3522	3557	3578
3	3225	3239	3262	3291	3320	3343	3364	3384	3408	3417
4	3379	3386	3390	3432	3458	3483	3516	3574	3547	3578

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1452	1359	1400	1375	1386	1368	1381	1370	1362	1373
2	1426	1534	1498	1537	1521	1543	1534	1567	1558	1551
3	1672	1628	1631	1620	1627	1621	1629	1627	1615	1626
4	1535	1562	1556	1555	1556	1562	1553	1535	1564	1551

RUN NUMBER 8526

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	138	112	135	126	129	123	129	127	130	138
2	143	248	223	282	252	294	287	392	378	398
3	939	1148	1304	1295	1334	1533	1924	2664	3505	-26511
4	273	307	350	328	335	346	339	292	405	392

RUN NUMBER 8526
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	3154.76	5.97	6.4	2.098	1.928	79.08	86.04	62.22	56.95
2	3183.76	5.91	15.5	2.079	1.929	79.81	85.99	62.22	64.08
3	3212.87	5.85	24.6	2.060	1.924	80.55	86.24	62.21	69.50
4	3242.09	5.79	33.7	2.042	1.909	81.29	86.87	62.20	70.82
5	3271.41	5.74	42.8	2.024	1.891	82.02	87.68	62.19	69.87
6	3300.83	5.68	52.0	2.005	1.879	82.76	88.22	62.19	72.34
7	3330.35	5 62	61.1	1.988	1.866	83.49	88.84	62.18	73.85
8	3359.97	5.57	70.2	1.970	1.854	84.23	89.39	62.17	76.54
9	3389.70	5.51	79.3	1.953	1.848	84.97	89.69	62.16	83 52
10	3419.53	5.46	88 4	1.936	1.839	85 70	90.11	62.16	89.41

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8527
MULTI-PHASE
07-31-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.45	GPM
MASS FLOW RATE WATER	=	12.0	LBM/MIN
MASS FLOW RATE GAS	=	1.96	LBM/MIN
MASS FLUX	=	109915	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.49	FT/S
GAS VELOCITY	=	58.08	FT/S
GAS VISCOSITY	=	386.68E-09	LBM-S/FT^2)
INLET TEMPERATURE	=	78.86	F
OUTLET TEMPERATURE	=	84.56	F
RE NUMBER LIQUID	=	4946	
RE NUMBER GAS	=	36641	
AVERAGE PR NUMBER	=	5.76	
CURRENT TO TUBE	=	395.9	AMPS
VOLTAGE DROP IN TUBE	=	4.01	VOLTS
AVERAGE HEAT FLUX	=	2186	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5417	BTU/HR
Q=M*C*(T2-T1)	=	5021	BTU/HR
HEAT BALANCE ERROR	=	7.30	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	87.11	90.81	89.82	90.38	90.54	91.40	91.60	92.31	92.64	92.83
2	87.53	85.93	86.63	86.15	87.14	87.20	87.75	87.28	87.89	88.34
3	81.73	82.00	82.44	83.01	83.54	84.02	84.38	84.68	85.11	85.19
4	84.09	85.07	84.92	85.65	86.10	86.60	87.16	88.23	87.80	88.34

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	86.21	89.96	88.95	89.52	89.67	90.54	90.74	91.45	91.79	91.97
2	86.65	85.00	85.92	85.22	86.22	86.27	86.82	86.34	86.95	87.41
3	80.75	81.03	81.47	82.04	82.57	83.05	83.41	83.71	84.15	84.22
4	83.16	84.13	83.98	84.71	85.16	85.66	86.23	87.30	86.86	87.41

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	5221	5455	5392	5427	5437	5491	5503	5549	5570	5581
2	5248	5147	5203	5160	5222	5225	5259	5229	5267	5295
3	4888	4905	4932	4967	4999	5028	5050	5068	5094	5099
4	5034	5093	5084	5129	5157	5187	5222	5289	5261	5295

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1561	1459	1494	1481	1496	1482	1491	1461	1475	1483
2	1516	1607	1578	1610	1594	1610	1604	1629	1623	1616
3	1699	1686	1684	1671	1676	1672	1677	1678	1669	1680
4	1604	1630	1627	1623	1621	1625	1619	1605	1626	1616

RUN NUMBER 8527

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	224	143	173	171	181	173	181	176	180	190
2	204	308	282	371	333	375	373	500	488	500
3	1128	1366	1493	1444	1475	1561	1906	2656	3222	37993
4	409	375	447	424	434	442	438	380	502	500

RUN NUMBER 8527
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	4798.68	5.96	6.4	2.094	1.971	79.24	84.19	62.22	83.98
2	4831.46	5.91	15.5	2.080	1.951	79.79	85.03	62.22	79.33
3	4864.32	5.87	24.6	2.066	1.950	80.34	85.08	62.21	87.61
4	4897.27	5.83	33.7	2.052	1.943	80.89	85.37	62.20	92.50
5	4930.31	5.78	42.8	2.038	1.931	81.44	85.91	62.20	92.79
6	4963.43	5.74	52.0	2.024	1.920	81.98	86.38	62.19	94.29
7	4996.64	5.70	61.1	2.011	1.911	82.53	86.80	62.19	97.14
8	5029.94	5.65	70.2	1.998	1.902	83.08	87.20	62.18	100.53
9	5063.32	5.61	79.3	1.984	1.897	83.63	87.44	62.18	108.73
10	5096.79	5.57	88.4	1.971	1.890	84.18	87.75	62.17	115.76

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8528
MULTI-PHASE
07-11-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	.93	GPM
MASS FLOW RATE WATER	=	7.8	LBM/MIN
MASS FLOW RATE GAS	=	1.98	LBM/MIN
MASS FLUX	=	70902	LBM/(SQ.FT HR)
LIQUID VELOCITY	=	.32	FT/S
GAS VELOCITY	=	68.71	FT/S
GAS VISCOSITY	=	387.02E-09	LBM-S/FT^2
INLET TEMPERATURE	=	78.38	F
OUTLET TEMPERATURE	=	86.74	F
RE NUMBER LIQUID	=	3224	
RE NUMBER GAS	=	36886	
AVERAGE PR NUMBER	=	5.69	
CURRENT TO TUBE	=	398.9	AMPS
VOLTAGE DROP IN TUBE	=	4.09	VOLTS
AVERAGE HEAT FLUX	=	2247	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5566	BTU/HR
Q=M*C*(T2-T1)	=	5237	BTU/HR
HEAT BALANCE ERROR	=	5.91	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	91.58	93.85	92.92	94.13	94.65	95.76	96.16	97.06	97.59	97.72
2	90.74	87.44	88.80	88.39	89.54	89.57	90.45	89.86	90.78	91.27
3	81.92	82.78	82.89	83.68	84.45	85.09	85.67	86.20	86.84	87.04
4	86.25	86.32	86.39	87.42	88.11	88.82	89.65	91.15	90.51	91.28

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	90.69	93.01	92.06	93.28	93.80	94.92	95.31	96.22	96.75	96.87
2	89.86	86.49	87.88	87.24	88.60	88.62	89.51	88.90	89.82	90.32
3	80.89	81.28	81.88	82.68	83.45	84.09	84.67	85.20	85.85	86.04
4	85.30	85.36	85.43	86.46	87.15	87.86	88.69	90.21	89.55	90.33

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	3548	3643	3604	3654	3675	3721	3737	3775	3797	3802
2	3514	3379	3434	3409	3464	3464	3500	3475	3513	3533
3	3159	3174	3197	3229	3259	3284	3307	3328	3353	3361
4	3332	3334	3337	3378	3405	3434	3467	3528	3502	3533

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1541	1442	1485	1460	1473	1455	1468	1457	1447	1461
2	1520	1637	1599	1640	1623	1646	1637	1671	1662	1655
3	1790	1740	1743	1729	1736	1730	1738	1737	1725	1736
4	1635	1666	1661	1660	1660	1665	1657	1638	1669	1654

RUN NUMBER 8528

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT HR F)

	1	2	3	4	5	6	7	8	9	10
1	131	108	129	122	126	121	127	125	127	136
2	139	242	218	278	251	290	285	386	373	399
3	920	1138	1306	1302	1345	1531	1926	2759	3648	12657
4	257	296	340	325	332	340	336	290	399	398

RUN NUMBER 8528
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	3083.85	5.98	6.4	2.102	1.914	78.94	86.69	62.22	54.60
2	3114.83	5.92	15.5	2.081	1.917	79.75	86.54	62.22	62.20
3	3145.94	5.85	24.6	2.060	1.911	80.55	86.81	62.21	67.36
4	3177.16	5.79	33.7	2.040	1.897	81.35	87.42	62.20	69.53
5	3208.51	5.72	42.8	2.020	1.879	82.16	88.25	62.19	69.17
6	3239.97	5.66	52.0	2.001	1.865	82.96	88.87	62.18	71.25
7	3271.55	5.60	61.1	1.981	1.851	83.77	89.54	62.18	72.83
8	3303.26	5.54	70.2	1.962	1.838	84.57	90.13	62.17	75.64
9	3335.08	5.48	79.3	1.943	1.831	85.37	90.49	62.16	82.10
10	3367.01	5.42	88.4	1.925	1.822	86.18	90.89	62.15	89.11

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT-HR)

RUN NUMBER 8529
MULTI-PHASE
08-01-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	2.18	GPM
MASS FLOW RATE WATER	=	18.1	LBM/MIN
MASS FLOW RATE GAS	=	1.47	LBM/MIN
MASS FLUX	=	165605	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.74	FT/S
GAS VELOCITY	=	50.65	FT/S
GAS VISCOSITY	=	386.06E-09	LBM-S/FT^2
INLET TEMPERATURE	=	78.37	F
OUTLET TEMPERATURE	=	81.93	F
RE NUMBER LIQUID	=	7311	
RE NUMBER GAS	=	27386	
AVERAGE PR NUMBER	=	5.88	
CURRENT TO TUBE	=	368.3	AMPS
VOLTAGE DROP IN TUBE	=	3.93	VOLTS
AVERAGE HEAT FLUX	=	1993	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	4939	BTU/HR
Q=M*C*(T2-T1)	=	4292	BTU/HR
HEAT BALANCE ERROR	=	13.10	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	85.80	87.56	86.79	87.10	86.99	87.32	87.46	87.93	88.13	88.21
2	83.31	83.83	84.55	83.97	84.61	84.47	84.87	84.49	84.88	85.19
3	80.79	80.89	81.25	81.62	81.94	82.25	82.47	82.65	82.89	82.91
4	82.73	83.33	83.19	83.69	83.85	84.08	84.46	85.18	84.85	85.20

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	85.33	86.82	86.03	86.35	86.23	86.56	86.70	87.18	87.38	87.45
2	84.54	83.03	83.76	83.17	83.81	83.67	84.07	83.68	84.07	84.39
3	79.95	80.05	80.41	80.79	81.11	81.42	81.64	81.82	82.06	82.08
4	81.92	82.52	82.38	82.88	83.04	83.27	83.65	84.18	84.04	84.40

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	7757	7923	7850	7880	7869	7900	7913	7957	7976	7983
2	7712	7573	7640	7586	7645	7632	7669	7633	7669	7698
3	7293	7302	7335	7369	7398	7427	7446	7463	7485	7486
4	7472	7527	7514	7560	7574	7595	7631	7697	7666	7699

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1333	1277	1305	1296	1309	1302	1309	1301	1297	1303
2	1328	1389	1365	1389	1376	1387	1382	1400	1396	1390
3	1461	1448	1446	1436	1438	1431	1436	1436	1431	1439
4	1393	1401	1400	1396	1395	1397	1393	1383	1397	1390

RUN NUMBER 8529

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	207	162	193	193	209	208	216	210	215	226
2	223	340	305	393	358	414	405	523	512	515
3	1093	1115	1291	1245	1273	1300	1471	1764	2002	3709
4	420	393	453	430	455	473	465	409	518	513

RUN NUMBER 8529
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	7173.03	6.01	6.4	2.111	2.003	78.61	82.86	62.23	84.63
2	7203.76	5.98	15.5	2.102	1.997	78.95	83.10	62.22	86.58
3	7234.54	5.96	24.6	2.093	1.996	79.29	83.15	62.22	93.28
4	7265.37	5.93	33.7	2.084	1.992	79.64	83.30	62.22	98.15
5	7296.26	5.90	42.8	2.075	1.986	79.98	83.55	62.21	100.60
6	7327.20	5.87	52.0	2.066	1.982	80.32	83.73	62.21	105.27
7	7358.18	5.84	61.1	2.057	1.975	80.66	84.02	62.21	107.05
8	7389.22	5.82	70.2	2.049	1.969	81.01	84.26	62.20	110.13
9	7420.31	5.79	79.3	2.040	1.966	81.35	84.39	62.20	117.96
10	7451.45	5.76	88.4	2.032	1.962	81.69	84.58	62.20	124.14

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8530
MULTI-PHASE
08-01-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	2.24	GPM
MASS FLOW RATE WATER	=	18.6	LBM/MIN
MASS FLOW RATE GAS	=	1.93	LBM/MIN
MASS FLUX	=	170485	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.76	FT/S
GAS VELOCITY	=	66.87	FT/S
GAS VISCOSITY	=	386.26E-09	LBM-S/FT^2
INLET TEMPERATURE	=	78.73	F
OUTLET TEMPERATURE	=	82.58	F
RE NUMBER LIQUID	=	7574	
RE NUMBER GAS	=	36104	
AVERAGE PR NUMBER	=	5.84	
CURRENT TO TUBE	=	395.8	AMPS
VOLTAGE DROP IN TUBE	=	4.06	VOLTS
AVERAGE HEAT FLUX	=	2213	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5482	BTU/HR
Q=M*C*(T2-T1)	=	4911	BTU/HR
HEAT BALANCE ERROR	=	10.41	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	84.29	87.25	86.76	87.13	87.12	87.59	87.64	88.22	88.44	88.57
2	85.20	84.23	84.76	84.25	84.91	84.90	85.21	84.95	85.36	85.70
3	83.25	81.46	81.80	82.19	82.53	82.85	83.10	83.30	83.55	83.63
4	82.46	83.50	83.19	83.96	84.18	84.48	84.84	85.60	85.35	85.73

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	83.38	86.38	85.88	86.25	86.24	86.71	86.76	87.34	87.56	87.69
2	84.31	83.31	83.85	83.32	83.99	83.97	84.31	84.02	84.43	84.77
3	80.29	80.50	80.85	81.24	81.58	81.90	82.15	82.35	82.60	82.68
4	81.53	82.57	82.46	83.03	83.25	83.55	83.91	84.68	84.42	84.80

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	7829	8115	8067	8103	8101	8147	8151	8207	8229	8241
2	7918	7823	7874	7824	7887	7886	7917	7890	7929	7962
3	7540	7560	7591	7628	7660	7690	7714	7732	7756	7763
4	7656	7753	7742	7796	7817	7845	7880	7952	7928	7964

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1579	1505	1523	1515	1527	1519	1527	1518	1515	1521
2	1529	1595	1580	1603	1591	1601	1597	1614	1610	1604
3	1657	1654	1651	1642	1645	1641	1643	1645	1641	1648
4	1600	1614	1615	1610	1609	1612	1607	1598	1610	1604

RUN NUMBER 8530

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	360	214	247	246	264	258	275	263	270	283
2	287	404	383	497	452	511	515	662	649	654
3	1272	1446	1479	1439	1483	1546	1749	2139	2521	4620
4	628	503	592	550	579	595	595	516	652	646

RUN NUMBER 8530
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	7419.46	5.98	6.4	2.101	2.015	78.99	82.38	62.22	122.39
2	7451.74	5.95	15.5	2.091	1.995	79.36	83.19	62.22	108.35
3	7488.08	5.92	24.6	2.081	1.993	79.73	83.26	62.22	117.60
4	7522.49	5.89	33.7	2.072	1.989	80.10	83.46	62.21	123.33
5	7556.95	5.86	42.9	2.062	1.981	80.47	83.76	62.21	125.83
6	7591.48	5.83	52.0	2.053	1.975	80.84	84.03	62.21	129.75
7	7626.07	5.80	61.1	2.044	1.969	81.21	84.28	62.20	134.89
8	7660.72	5.77	70.2	2.034	1.962	81.58	84.60	62.20	137.32
9	7695.43	5.74	79.3	2.025	1.958	81.95	84.75	62.19	147.68
10	7730.20	5.71	88.4	2.016	1.952	82.32	84.99	62.19	155.27

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8531
MULTI-PHASE
08-02-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.38	GPM
MASS FLOW RATE WATER	=	11.5	LBM/MIN
MASS FLOW RATE GAS	=	1.96	LBM/MIN
MASS FLUX	=	104890	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.47	FT/S
GAS VELOCITY	=	67.64	FT/S
GAS VISCOSITY	=	385.96E-09	LBM-S/FT^2
INLET TEMPERATURE	=	77.50	F
OUTLET TEMPERATURE	=	82.30	F
RE NUMBER LIQUID	=	4616	
RE NUMBER GAS	=	36597	
AVERAGE PR NUMBER	=	5.91	
CURRENT TO TUBE	=	357.3	AMPS
VOLTAGE DROP IN TUBE	=	3.71	VOLTS
AVERAGE HEAT FLUX	=	1826	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	4523	BTU/HR
Q=M*C*(T2-T1)	=	4072	BTU/HR
HEAT BALANCE ERROR	=	9.97	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	84.82	86.77	86.12	86.66	86.87	87.56	87.87	88.47	88.81	88.98
2	85.15	83.28	83.96	83.41	84.25	84.30	84.87	84.59	85.06	85.46
3	80.05	80.24	80.62	81.01	81.45	81.87	82.26	82.55	82.91	82.98
4	82.20	82.51	82.45	83.06	83.41	83.88	84.41	85.11	85.00	85.44

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	84.09	86.07	85.41	85.96	86.16	86.86	87.16	87.77	88.11	88.28
2	84.44	82.53	83.22	82.65	83.50	83.54	84.12	83.83	84.30	84.70
3	79.25	79.45	79.83	80.23	80.66	81.09	81.47	81.76	82.13	82.19
4	81.44	81.74	81.69	82.30	82.65	83.12	83.65	84.56	84.24	84.68

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	4858	4974	4935	4968	4980	5021	5039	5075	5095	5105
2	4878	4767	4807	4775	4824	4826	4860	4843	4870	4894
3	4579	4591	4612	4635	4660	4684	4707	4723	4744	4748
4	4705	4722	4719	4754	4774	4802	4833	4885	4867	4893

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1267	1199	1221	1210	1220	1210	1216	1309	1203	1210
2	1228	1302	1282	1308	1295	1309	1303	1322	1319	1312
3	1389	1365	1363	1354	1358	1355	1359	1360	1353	1362
4	1303	1322	1321	1317	1317	1319	1315	1304	1321	1313

RUN NUMBER 8531

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	202	153	183	179	188	179	185	180	182	192
2	385	307	386	379	338	383	370	477	474	481
3	975	1170	1255	1329	1365	1418	1541	1916	2310	6311
4	359	382	449	426	442	441	430	372	485	485

RUN NUMBER 8531
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	4498.62	6.08	6.4	2.131	2.017	77.82	82.30	62.23	75.59
2	4524.77	6.04	15.5	2.119	2.013	78.28	82.45	62.23	81.29
3	4550.98	6.00	24.6	2.107	2.011	78.75	82.54	62.23	89.26
4	4577.25	5.96	33.7	2.095	2.005	79.21	82.78	62.22	94.57
5	4603.58	5.92	42.8	2.083	1.994	79.67	83.24	62.22	94.58
6	4629.97	5.89	52.0	2.071	1.984	80.13	83.65	62.21	96.00
7	4656.41	5.85	61.1	2.059	1.973	80.59	84.10	62.21	96.28
8	4682.92	5.81	70.2	2.048	1.964	81.05	84.48	62.20	98.61
9	4709.48	5.78	79.3	2.036	1.959	81.52	84.69	62.20	106.21
10	4736.11	5.74	88.4	2.025	1.953	81.98	84.96	62.19	112.97

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT-HR)

RUN NUMBER 8532
MULTI-PHASE
08-02-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	.97	GPM
MASS FLOW RATE WATER	=	8.1	LBM/MIN
MASS FLOW RATE GAS	=	1.95	LBM/MIN
MASS FLUX	=	73814	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.33	FT/S
GAS VELOCITY	=	67.34	FT/S
GAS VISCOSITY	=	386.38E-09	LBM-S/FT^2
INLET TEMPERATURE	=	77.60	F
OUTLET TEMPERATURE	=	84.30	F
RE NUMBER LIQUID	=	3291	
RE NUMBER GAS	=	36324	
AVERAGE PR NUMBER	=	5.83	
CURRENT TO TUBE	=	364.6	AMPS
VOLTAGE DROP IN TUBE	=	3.74	VOLTS
AVERAGE HEAT FLUX	=	1878	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	4652	BTU/HR
Q=M*C*(T2-T1)	=	4310	BTU/HR
HEAT BALANCE ERROR	=	7.35	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	87.97	89.38	88.81	89.80	90.19	91.11	91.52	92.30	92.70	92.94
2	87.56	84.72	85.87	85.34	86.46	86.50	87.25	86.82	87.51	88.02
3	80.64	80.88	81.42	82.00	82.62	83.14	83.64	84.07	84.59	84.78
4	83.80	83.80	84.02	84.84	85.36	85.95	86.65	87.81	87.38	88.04

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	87.22	88.57	88.08	89.08	89.47	90.40	90.80	91.59	91.99	92.23
2	86.84	83.93	85.10	84.55	85.68	85.71	86.46	86.02	86.73	87.23
3	79.79	80.05	80.59	81.17	81.79	82.31	82.81	83.24	83.77	83.95
4	83.01	83.00	83.72	84.04	84.56	85.15	85.85	87.02	86.58	87.25

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	3548	3604	3584	3626	3642	3681	3698	3732	3749	3759
2	3532	3412	3460	3438	3484	3485	3517	3498	3528	3548
3	3244	3254	3276	3300	3325	3346	3366	3384	3405	3413
4	3375	3374	3383	3417	3438	3462	3491	3540	3522	3549

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1293	1224	1253	1232	1244	1225	1238	1228	1221	1230
2	1269	1361	1333	1366	1352	1369	1362	1389	1383	1376
3	1480	1438	1442	1431	1437	1432	1439	1438	1428	1439
4	1365	1384	1380	1379	1379	1383	1378	1364	1387	1376

RUN NUMBER 8532

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT HR-F)

	1	2	3	4	5	6	7	8	9	10
1	141	123	143	135	140	134	139	136	139	146
2	144	259	231	299	267	308	299	401	392	407
3	853	1062	1155	1203	1236	1376	1611	2115	2547	14231
4	275	321	355	339	350	356	350	305	411	405

RUN NUMBER 8532
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	3174.89	6.06	6.4	2.125	1.971	78.05	84.22	62.23	57.26
2	3200.62	6.00	15.5	2.108	1.978	78.70	83.89	62.23	67.89
3	3226.43	5.95	24.6	2.091	1.970	79.34	84.25	62.22	71.78
4	3252.32	5.90	33.7	2.075	1.959	79.98	84.71	62.21	74.46
5	3278.29	5.85	42.8	2.058	1.943	80.63	85.37	62.21	74.35
6	3304.34	5.79	52.0	2.042	1.932	81.27	85.89	62.20	76.14
7	3330.48	5.74	61.1	2.026	1.918	81.92	86.48	62.19	77.01
8	3356.69	5.69	70.2	2.010	1.907	82.56	86.97	62.19	79.75
9	3382.98	5.64	79.3	1.995	1.900	83.20	87.27	62.18	86.45
10	3409.35	5.60	88.4	1.979	1.892	83.85	87.66	62.18	92.06

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8533
MULTI-PHASE
08-02-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.99	GPM
MASS FLOW RATE WATER	=	16.5	LBM/MIN
MASS FLOW RATE GAS	=	1.92	LBM/MIN
MASS FLUX	=	150976	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.67	FT/S
GAS VELOCITY	=	66.56	FT/S
GAS VISCOSITY	=	386.30E-09	LBM-S/FT^2
INLET TEMPERATURE	=	78.98	F
OUTLET TEMPERATURE	=	82.52	F
RE NUMBER LIQUID	=	6715	
RE NUMBER GAS	=	35923	
AVERAGE PR NUMBER	=	5.84	
CURRENT TO TUBE	=	362.9	AMPS
VOLTAGE DROP IN TUBE	=	3.70	VOLTS
AVERAGE HEAT FLUX	=	1849	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	4581	BTU/HR
Q=M*C*(T2-T1)	=	4060	BTU/HR
HEAT BALANCE ERROR	=	11.37	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	84.07	86.67	86.14	86.49	86.54	86.99	87.08	87.63	87.86	87.99
2	84.78	83.80	84.32	83.84	84.51	84.53	84.83	84.56	84.94	85.25
3	81.16	81.30	81.64	81.99	82.33	82.64	82.87	83.03	83.29	83.31
4	82.40	83.22	83.10	83.63	83.84	84.13	84.48	85.15	84.99	85.10

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	83.30	85.94	85.40	85.75	85.80	86.25	86.34	86.89	87.13	87.25
2	84.04	83.02	83.55	83.06	83.74	83.73	84.05	83.77	84.16	84.47
3	80.35	80.49	80.84	81.19	81.53	81.84	82.07	82.23	82.49	82.51
4	81.62	82.43	82.31	82.85	83.06	83.35	83.70	84.37	84.21	84.52

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	6927	7149	7103	7133	7137	7176	7183	7230	7250	7261
2	6988	6904	6948	6907	6961	6963	6990	6967	6999	7025
3	6682	6694	6722	6751	6779	6805	6824	6837	6859	6861
4	6787	6855	6845	6889	6906	6931	6960	7017	7003	7029

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1325	1258	1277	1269	1279	1271	1278	1269	1266	1271
2	1283	1343	1327	1349	1337	1347	1343	1359	1354	1350
3	1399	1395	1391	1383	1386	1382	1385	1386	1383	1390
4	1344	1358	1359	1354	1354	1357	1352	1344	1355	1349

RUN NUMBER 8533

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ-FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	324	197	232	230	245	238	251	239	244	255
2	266	387	363	478	423	479	481	625	612	617
3	1236	1493	1486	1456	1461	1502	1713	2210	2518	6188
4	559	472	562	519	546	559	554	485	598	603

RUN NUMBER 8533
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENB	NU
1	6589.24	5.96	6.4	2.095	2.016	79.22	82.33	62.22	112.14
2	6617.18	5.93	15.5	2.086	2.000	79.56	82.97	62.22	102.14
3	6645.17	5.91	24.6	2.077	1.999	79.90	83.03	62.21	111.50
4	6673.20	5.88	33.7	2.068	1.994	80.24	83.21	62.21	117.20
5	6701.28	5.85	42.8	2.060	1.987	80.58	83.53	62.21	118.09
6	6729.41	5.82	52.0	2.051	1.981	80.92	83.79	62.20	121.25
7	6757.56	5.80	61.1	2.042	1.975	81.26	84.04	62.20	125.27
8	6785.80	5.77	70.2	2.034	1.968	81.60	84.32	62.20	128.14
9	6814.07	5.74	79.3	2.025	1.964	81.94	84.49	62.19	136.27
10	6842.38	5.72	88.4	2.017	1.959	82.28	84.69	62.19	144.63

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8534
MULTI-PHASE
08-05-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.46	GPM
MASS FLOW RATE WATER	=	12.1	LBM/MIN
MASS FLOW RATE GAS	=	1.92	LBM/MIN
MASS FLUX	=	110914	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.50	FT/S
GAS VELOCITY	=	66.90	FT/S
GAS VISCOSITY	=	386.34E-09	LBM-S/FT^2
INLET TEMPERATURE	=	78.34	F
OUTLET TEMPERATURE	=	83.37	F
RE NUMBER LIQUID	=	4939	
RE NUMBER GAS	=	35879	
AVERAGE PR NUMBER	=	5.83	
CURRENT TO TUBE	=	374.3	AMPS
VOLTAGE DROP IN TUBE	=	3.91	VOLTS
AVERAGE HEAT FLUX	=	2015	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	4993	BTU/HR
Q=M*C*(T2-T1)	=	4448	BTU/HR
HEAT BALANCE ERROR	=	10.91	%

OUTSIDE SURFACE TEMPERATORES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	86.06	88.17	87.44	87.95	88.29	88.96	89.28	89.94	90.29	90.45
2	86.46	84.47	85.17	84.57	85.50	85.55	86.15	85.82	86.27	86.72
3	81.04	81.24	81.62	82.06	82.51	82.99	83.38	83.65	84.07	84.07
4	83.19	83.65	83.56	84.23	84.64	85.14	85.63	86.59	86.28	86.71

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	85.25	87.40	86.66	87.18	87.51	88.19	88.50	89.17	89.52	89.68
2	85.68	83.64	84.35	83.74	84.68	84.72	85.32	84.98	85.43	85.88
3	80.16	80.37	80.76	81.20	81.65	82.13	82.52	82.79	83.23	83.21
4	82.36	82.81	82.72	83.39	83.80	84.30	84.80	85.76	85.44	85.88

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	5209	5343	5297	5329	5350	5392	5412	5454	5476	5486
2	5236	5110	5154	5116	5174	5176	5214	5192	5220	5248
3	4897	4910	4933	4960	4988	5017	5041	5057	5083	5083
4	5031	5059	5053	5094	5120	5150	5181	5241	5221	5248

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1392	1319	1346	1334	1343	1333	1339	1331	1324	1332
2	1350	1430	1408	1436	1423	1436	1430	1451	1450	1441
3	1520	1497	1495	1485	1491	1486	1491	1492	1483	1495
4	1434	1451	1449	1444	1444	1447	1444	1432	1449	1441

RUN NUMBER 8534

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	211	160	191	189	194	188	193	187	189	200
2	193	319	299	397	350	396	362	497	502	506
3	1025	1234	1346	1385	1440	1437	1588	2061	2230	8536
4	389	397	471	442	452	451	449	387	500	506

RUN NUMBER 8534
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	4808.29	6.01	6.4	2.109	1.991	78.68	83.36	62.23	79.30
2	4837.39	5.97	15.5	2.096	1.986	79.16	83.56	62.22	84.46
3	4866.56	5.93	24.6	2.083	1.985	79.65	83.62	62.22	93.29
4	4895.80	5.89	33.7	2.071	1.979	80.13	83.88	62.21	98.93
5	4925.11	5.85	42.8	2.059	1.966	80.61	84.41	62.21	97.83
6	4954.48	5.81	52.0	2.047	1.956	81.10	84.84	62.20	99.14
7	4983.93	5.77	61.1	2.034	1.946	81.58	85.29	62.20	100.00
8	5013.44	5.73	70.2	2.022	1.937	82.06	85.68	62.19	102.56
9	5043.02	5.69	79.3	2.011	1.931	82.55	85.90	62.19	110.34
10	5072.67	5.66	88.4	1.999	1.925	83.03	86.16	62.18	116.26

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8535
MULTI-PHASE
08-05-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	.96	GPM
MASS FLOW RATE WATER	=	8.0	LBM/MIN
MASS FLOW RATE GAS	=	1 99	LBM/MIN
MASS FLUX	=	73332	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.33	FT/S
GAS VELOCITY	=	68 85	FT/S
GAS VISCOSITY	=	386.63E-09	LBM-S/FT^2
INLET TEMPERATURE	=	78.20	F
OUTLET TEMPERATURE	=	84.95	F
RE NUMBER LIQUID	=	3294	
RE NUMBER GAS	=	37068	
AVERAGE PR NUMBER	=	5.77	
CURRENT TO TUBE	=	365.9	AMPS
VOLTAGE DROP IN TUBE	=	3 79	VOLTS
AVERAGE HEAT FLUX	=	1910	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	4731	BTU/HR
Q=M*C*(T2-T1)	=	4342	BTU/HR
HEAT BALANCE ERROR	=	8.23	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	88.33	89 68	89.20	90.28	90.75	91.66	92.01	92.80	93.15	93.37
2	88.09	85.31	86.40	85.93	87.06	87.12	87.85	87.44	88.07	88.62
3	81.17	81 44	81.98	82.61	83.22	83.80	84.29	84.66	85.24	85.36
4	84.33	84.36	84.52	85.41	85.98	86.61	87.23	88.41	88.00	88.62

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	87.57	88.96	88.47	89.56	90.02	90.94	91.29	92.08	92.43	92.65
2	87 35	84.52	85.62	85.13	86.27	86.32	87.06	86.63	87.27	87.82
3	80.33	80.60	81.14	81.78	82.38	82.97	83.45	83.84	84.41	84.52
4	83.54	83 56	83.72	84 61	85.18	85.81	86.43	87.62	87.19	87.82

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	3540	3557	3577	3622	3642	3680	3695	3728	3743	3752
2	3530	3414	3459	3439	3486	3488	3518	3501	3527	3550
3	3244	3255	3277	3303	3327	3351	3371	3386	3410	3414
4	3374	3375	3381	3418	3441	3467	3492	3541	3524	3550

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1307	1238	1267	1245	1255	1242	1250	1241	1235	1244
2	1277	1368	1341	1376	1361	1379	1372	1398	1394	1384
3	1490	1449	1451	1441	1448	1442	1448	1448	1437	1449
4	1374	1392	1389	1389	1389	1392	1388	1373	1395	1384

RUN NUMBER 8535

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	146	128	148	139	143	137	143	139	143	152
2	146	262	236	303	271	311	304	406	407	416
3	900	1114	1219	1225	1277	1350	1597	2218	2547	50328
4	281	327	369	346	353	356	357	310	416	416

RUN NUMBER 8535
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	3178.11	6.01	6.4	2.109	1.959	78.65	84.69	62.23	58.85
2	3203.93	5.95	15.5	2.092	1.966	79.30	84.41	62 22	69.51
3	3229.84	5.90	24.6	2.076	1.958	79.95	84.74	62.21	74.33
4	3255.83	5.85	33.7	2.059	1.946	80.60	85.27	62.21	75.94
5	3281.91	5.80	42.8	2 043	1.930	81.25	85.96	62.20	75.17
6	3308.06	5.75	52.0	2.027	1.918	81.90	86.51	62.19	76 83
7	3334.29	5.69	61.1	2.011	1.905	82.55	87.06	62.19	78.52
8	3360.61	5.64	70 2	1.995	1.894	83.20	87 54	62.18	81.40
9	3387 00	5 60	79 3	1.979	1.888	83.85	87 83	62.18	88.84
10	3413.48	5.55	88 4	1.964	1.880	84.50	88 20	62.17	95.29

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8536
MULTI-PHASE
08-05-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.95	GPM
MASS FLOW RATE WATER	=	16.3	LBM/MIN
MASS FLOW RATE GAS	=	1.77	LBM/MIN
MASS FLUX	=	148557	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.66	FT/S
GAS VELOCITY	=	61.38	FT/S
GAS VISCOSITY	=	386.55E-09	LBM-S/FT^2
INLET TEMPERATURE	=	79.56	F
OUTLET TEMPERATURE	=	83.19	F
RE NUMBER LIQUID	=	6658	
RE NUMBER GAS	=	33066	
AVERAGE PR NUMBER	=	5.79	
CURRENT TO TUBE	=	364.3	AMPS
VOLTAGE DROP IN TUBE	=	3.71	VOLTS
AVERAGE HEAT FLUX	=	1861	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	4611	BTU/HR
Q=M*C*(T2-T1)	=	4059	BTU/HR
HEAT BALANCE ERROR	=	11.96	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	85.06	87.18	86.63	87.20	87.24	87.80	87.85	88.47	88.65	88.81
2	85.39	84.36	84.93	84.53	85.22	85.29	85.59	85.30	85.66	86.00
3	81.76	81.87	82.24	82.62	82.96	83.33	83.53	83.67	83.98	83.92
4	83.10	83.82	83.77	84.38	84.55	84.91	85.20	85.91	85.74	86.06

INSIDE SURFACE TEMPERATURES DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	84.29	86.44	85.88	86.46	86.49	87.06	87.10	87.73	87.95	88.07
2	84.64	83.58	84.16	83.74	84.44	84.51	84.83	84.51	84.87	85.21
3	80.94	81.06	81.43	81.81	82.15	82.52	82.72	82.86	83.17	83.11
4	82.31	83.03	82.98	83.59	83.76	84.12	84.43	85.13	84.95	85.27

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	6898	7076	7030	7078	7081	7128	7132	7184	7203	7213
2	6926	6839	6886	6852	6910	6915	6940	6916	6945	6974
3	6623	6632	6663	6694	6722	6752	6768	6780	6805	6800
4	6735	6794	6789	6840	6854	6883	6908	6967	6952	6979

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1328	1270	1291	1280	1290	1281	1288	1278	1275	1280
2	1299	1353	1337	1359	1347	1357	1353	1370	1368	1360
3	1412	1406	1403	1396	1399	1395	1398	1400	1395	1405
4	1357	1367	1366	1363	1364	1367	1363	1354	1366	1359

RUN NUMBER 8536

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	296	202	240	228	243	232	247	233	238	249
2	268	395	365	469	415	459	465	606	601	599
3	1239	1555	1514	1453	1471	1433	1697	2283	2416	8633
4	540	475	551	497	532	531	542	470	580	583

RUN NUMBER 8536
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	6531.00	5.91	6.4	2.079	1.998	79.80	83.05	62.22	108.33
2	6559.27	5.88	15.5	2.070	1.987	80.15	83.53	62.21	104.11
3	6587.59	5.86	24.6	2.062	1.985	80.50	83.61	62.21	112.90
4	6615.96	5.83	33.7	2.053	1.978	80.85	83.90	62.21	115.05
5	6644.38	5.80	42.8	2.044	1.971	81.20	84.21	62.20	116.52
6	6672.85	5.77	52.0	2.035	1.963	81.55	84.55	62.20	116.85
7	6701.36	5.75	61.1	2.027	1.958	81.90	84.76	62.20	122.48
8	6729.92	5.72	70.2	2.018	1.951	82.25	85.06	62.19	124.81
9	6758.53	5.69	79.3	2.009	1.947	82.60	85.24	62.19	132.75
10	6787.18	5.66	88.4	2.001	1.942	82.95	85.42	62.18	141.83

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR).

RUN NUMBER 8537
MULTI-PHASE
08-05-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.43	GPM
MASS FLOW RATE WATER	=	11.9	LBM/MIN
MASS FLOW RATE GAS	=	1.78	LBM/MIN
MASS FLUX	=	108617	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.49	FT/S
GAS VELOCITY	=	61.80	FT/S
GAS VISCOSITY	=	386.82E-09	LBM S/FT^2
INLET TEMPERATURE	=	79.37	F
OUTLET TEMPERATURE	=	84.71	F
RE NUMBER LIQUID	=	4909	
RE NUMBER GAS	=	33228	
AVERAGE PR NUMBER	=	5.71	
CURRENT TO TUBE	=	383.2	AMPS
VOLTAGE DROP IN TUBE	=	3.88	VOLTS
AVERAGE HEAT FLUX	=	2047	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5072	BTU/HR
Q=M*C*(T2-T1)	=	4596	BTU/HR
HEAT BALANCE ERROR	=	9.39	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	88.27	90.03	89.22	89.86	90.25	91.07	91.15	91.96	92.31	93.39
2	87.80	85.72	86.66	86.11	87.16	87.23	87.71	87.32	87.87	88.26
3	82.13	82.34	82.80	83.34	83.84	84.32	84.67	84.93	85.38	85.40
4	84.66	85.04	85.04	85.78	86.20	86.70	87.17	88.21	87.84	88.31

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	87.44	89.23	88.40	89.05	89.44	90.26	90.34	91.16	91.51	91.58
2	86.97	84.85	85.81	85.24	86.30	86.36	86.84	86.44	86.99	87.39
3	81.21	81.43	81.89	82.44	82.93	83.42	83.77	84.02	84.48	84.49
4	83.79	84.16	84.16	84.90	85.32	85.82	86.29	87.34	86.96	87.44

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	5235	5346	5295	5335	5359	5410	5415	5465	5488	5492
2	5207	5078	5136	5101	5166	5170	5199	5174	5208	5232
3	4859	4872	4900	4932	4962	4991	5012	5028	5055	5056
4	5014	5036	5036	5081	5107	5137	5166	5230	5206	5236

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1442	1375	1408	1395	1404	1391	1401	1389	1383	1392
2	1428	1506	1478	1507	1492	1508	1501	1525	1522	1513
3	1599	1573	1573	1562	1568	1564	1568	1570	1561	1572
4	1509	1523	1519	1516	1517	1521	1515	1503	1523	1512

RUN NUMBER 8537

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	187	153	184	179	183	174	186	177	180	193
2	197	327	293	380	331	372	373	492	485	501
3	1083	1327	1392	1345	1373	1410	1664	2290	2497	12673
4	372	389	446	417	429	433	436	375	490	493

RUN NUMBER 8537
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	4771.67	5.92	6.4	2.081	1.956	79.73	84.85	62.22	76.02
2	4802.21	5.88	15.5	2.068	1.954	80.25	84.93	62.21	83.25
3	4832.81	5.84	24.6	2.055	1.951	80.76	85.07	62.21	90.30
4	4863.50	5.79	33.7	2.042	1.943	81.28	85.41	62.20	94.04
5	4894.26	5.75	42.8	2.029	1.929	81.79	86.00	62.20	92.35
6	4925.09	5.71	52.0	2.016	1.919	82.31	86.47	62.19	93.38
7	4956.00	5.67	61.1	2.004	1.911	82.82	86.81	62.19	97.33
8	4986.99	5.63	70.2	1.991	1.901	83.34	87.24	62.18	99.42
9	5018.05	5.60	79.3	1.979	1.896	83.85	87.49	62.18	106.78
10	5049.19	5.56	88.4	1.967	1.890	84.37	87.73	62.17	115.48

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
HUB AND HUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8538
MULTI-PHASE
08-05-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	.94	GPM
MASS FLOW RATE WATER	=	7.8	LBM/MIN
MASS FLOW RATE GAS	=	1.81	LBM/MIN
MASS FLUX	=	71650	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.32	FT/S
GAS VELOCITY	=	62.81	FT/S
GAS VISCOSITY	=	387.02E-09	LBM-S/FT^2
INLET TEMPERATURE	=	78.76	F
OUTLET TEMPERATURE	=	86.32	F
RE NUMBER LIQUID	=	3257	
RE NUMBER GAS	=	33720	
AVERAGE PR NUMBER	=	5.70	
CURRENT TO TUBE	=	382.7	AMPS
VOLTAGE DROP IN TUBE	=	3.79	VOLTS
AVERAGE HEAT FLUX	=	1998	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	4949	BTU/HR
Q=M*C*(T2-T1)	=	4668	BTU/HR
HEAT BALANCE ERROR	=	5.68	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	92.17	92.83	91.93	93.12	93.62	94.73	95.14	95.94	96.39	96.63
2	89.84	86.67	88.10	87.58	88.92	88.98	89.81	89.23	90.07	90.60
3	81.88	82.21	87.82	83.56	84.26	84.91	85.42	85.88	86.51	86.67
4	86.09	85.90	86.01	87.05	87.66	88.33	89.10	90.45	89.88	90.62

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	91.37	92.06	91.14	92.34	92.83	93.95	94.36	95.16	95.62	95.85
2	89.02	85.80	87.25	86.71	88.06	88.11	88.94	88.34	89.19	89.72
3	80.93	81.29	81.90	82.64	83.34	83.99	84.50	84.96	85.60	85.75
4	85.21	85.01	85.13	86.17	86.78	87.45	88.22	89.58	88.99	89.74

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	3613	3642	3604	3653	3674	3720	3737	3771	3790	3800
2	3517	3387	3445	3423	3478	3480	3514	3490	3524	3546
3	3194	3208	3232	3261	3289	3315	3335	3353	3379	3385
4	3363	3355	3360	3402	3426	3453	3485	3540	3516	3547

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1384	1325	1367	1344	1357	1339	1349	1339	1332	1342
2	1421	1513	1474	1512	1494	1516	1507	1539	1531	1523
3	1648	1597	1601	1590	1597	1591	1599	1598	1586	1598
4	1517	1533	1527	1526	1527	1532	1525	1507	1536	1523

RUN NUMBER 8538

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR F)

	1	2	3	4	5	6	7	8	9	10
1	114	109	131	123	127	121	125	123	126	133
2	145	260	225	287	254	291	283	386	373	389
3	992	1235	1364	1332	1374	1461	1842	7655	3097	-35963
4	255	305	346	323	331	337	332	288	392	387

RUN NUMBER 8538
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	3129.10	5.96	6.4	2.093	1.915	79.27	86.63	62.22	52.82
2	3157.46	5.90	15.5	2.074	1.928	80.00	86.04	62.21	64.27
3	3185.91	5.84	24.6	2.056	1.921	80.72	86.35	62.21	68.94
4	3214.46	5.78	33.7	2.038	1.907	81.45	86.96	62.20	70.34
5	3243.11	5.72	42.8	2.020	1.890	82.18	87.75	62.19	69.54
6	3271.87	5.67	52.0	2.002	1.876	82.90	88.37	62.19	70.83
7	3300.71	5.61	61.1	1.984	1.862	83.63	89.00	62.18	72.08
8	3329.66	5.56	70.2	1.967	1.852	84.36	89.51	62.17	75.10
9	3358.71	5.50	79.3	1.950	1.844	85.08	89.85	62.16	81.18
10	3387.85	5.45	88.4	1.931	1.835	85.81	90.27	62.16	86.75

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8539
MULTI-PHASE
08-06-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	2.44	GPM
MASS FLOW RATE WATER	=	20.3	LBM/MIN
MASS FLOW RATE GAS	=	1.71	LBM/MIN
MASS FLUX	=	185688	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.83	FT/S
GAS VELOCITY	=	59.04	FT/S
GAS VISCOSITY	=	386.42E-09	LBM-S/FT^2
INLET TEMPERATURE	=	79.47	F
OUTLET TEMPERATURE	=	82.62	F
RE NUMBER LIQUID	=	8289	
RE NUMBER GAS	=	31838	
AVERAGE PR NUMBER	=	5.81	
CURRENT TO TUBE	=	373.3	AMPS
VOLTAGE DROP IN TUBE	=	3.77	VOLTS
AVERAGE HEAT FLUX	=	1938	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	4802	BTU/HR
Q=M*C*(T2-T1)	=	4272	BTU/HR
HEAT BALANCE ERROR	=	11.04	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	84.98	86.95	86.41	86.87	86.85	87.29	87.15	87.63	87.71	87.86
2	84.74	84.12	84.67	84.26	84.93	84.90	85.11	84.72	85.04	85.34
3	81.60	81.72	82.08	82.48	82.78	82.98	83.27	83.29	83.57	83.50
4	83.09	83.79	83.59	84.14	84.31	84.50	84.75	85.32	85.13	85.42

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	84.18	86.17	85.62	86.09	86.06	86.51	86.36	86.85	86.93	87.08
2	83.94	83.30	83.86	83.43	84.11	84.08	84.29	83.89	84.21	84.51
3	80.75	80.87	81.23	81.63	81.93	82.13	82.43	82.44	82.73	82.65
4	82.27	82.96	82.76	83.31	83.48	83.67	83.92	84.50	84.30	84.60

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	8610	8817	8760	8808	8805	8852	8837	8887	8896	8511
2	8586	8519	8577	8533	8603	8600	8621	8580	8613	8645
3	8258	8271	8308	8349	8379	8400	8430	8432	8461	8453
4	8413	8485	8464	8521	8538	8558	8584	8643	8623	8653

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1389	1341	1359	1349	1361	1352	1361	1351	1351	1355
2	1380	1422	1406	1428	1414	1424	1420	1437	1433	1427
3	1475	1474	1469	1461	1465	1462	1460	1462	1457	1467
4	1422	1431	1434	1431	1430	1434	1430	1421	1431	1425

RUN NUMBER 8539

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	309	216	254	245	263	254	280	267	280	290
2	324	429	394	502	439	494	509	688	680	677
3	1385	1670	1559	1400	1409	1558	1577	2276	2341	6003
4	550	480	580	525	552	579	590	527	651	651

RUN NUMBER 8539
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	8151.03	5.92	6.4	2.093	2.005	79.68	82.78	62.22	119.00
2	8181.67	5.90	15.5	2.075	1.992	79.98	83.32	62.21	110.46
3	8212.37	5.87	24.6	2.067	1.991	80.29	83.37	62.21	119.76
4	8243.10	5.85	33.7	2.059	1.985	80.59	83.62	62.21	121.83
5	8273.88	5.82	42.8	2.052	1.978	80.89	83.90	62.20	122.73
6	8304.71	5.80	52.0	2.044	1.973	81.20	84.10	62.20	127.05
7	8335.58	5.78	61.1	2.036	1.970	81.50	84.25	62.20	133.95
8	8366.50	5.75	70.2	2.029	1.966	81.80	84.42	62.20	140.70
9	8397.46	5.73	79.3	2.021	1.963	82.11	84.54	62.19	151.08
10	8428.46	5.71	88.4	2.014	1.959	82.41	84.71	62.19	159.92

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8540
MULTI-PHASE
08-06-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.91	GPM
MASS FLOW RATE WATER	=	16.0	LBM/MIN
MASS FLOW RATE GAS	=	1.66	LBM/MIN
MASS FLUX	=	146171	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.65	FT/S
GAS VELOCITY	=	57.56	FT/S
GAS VISCOSITY	=	386.62E-09	LBM-S/FT^2
INLET TEMPERATURE	=	79.44	F
OUTLET TEMPERATURE	=	83.67	F
RE NUMBER LIQUID	=	6566	
RE NUMBER GAS	=	30994	
AVERAGE PR NUMBER	=	5.77	
CURRENT TO TUBE	=	385.4	AMPS
VOLTAGE DROP IN TUBE	=	3.92	VOLTS
AVERAGE HEAT FLUX	=	2080	BTU/(SQ.FT HR)
Q=AMP*VOLT	=	5154	BTU/HR
Q=M*C*(T2-T1)	=	4626	BTU/HR
HEAT BALANCE ERROR	=	10.25	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	87.11	89.03	88.14	88.58	88.66	89.21	89.34	89.96	90.11	90.32
2	86.43	85.11	85 84	85.32	86 10	86.14	86.55	86.11	86.56	86.88
3	82.01	82.17	82 57	83.03	83.41	83.71	84 09	84.20	84.56	84.54
4	84.32	84.66	84 50	85.10	85.36	85.66	86.10	86.86	86.59	86.96

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	86.26	88 22	87.31	87.75	87.83	88.40	88.51	89.14	89.29	89.49
2	85.58	84 23	84 97	84.44	85.23	85.26	85.67	85.22	85.67	86.00
3	81.09	81.26	81.66	82.12	82.50	82.80	83.18	83.29	83.66	83.63
4	83.44	83.77	83.61	84.22	84.48	84.79	85.22	85.98	85.71	86.08

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	6948	7109	7034	7071	7077	7125	7133	7185	7198	7215
2	6892	6782	6842	6799	6861	6856	6900	6863	6900	6926
3	6528	6542	6574	6611	6642	6666	6697	6706	6735	6731
4	6718	6745	6732	6781	6802	6828	6862	6925	6902	6933

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1466	1405	1435	1425	1437	1427	1435	1424	1433	1426
2	1463	1523	1499	1524	1510	1520	1517	1537	1532	1527
3	1596	1581	1578	1568	1571	1569	1570	1572	1565	1574
4	1517	1535	1533	1529	1529	1532	1528	1518	1532	1525

RUN NUMBER 8540

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	224	173	212	209	221	214	226	217	225	233
2	249	371	338	436	389	434	432	580	568	584
3	1171	1405	1408	1329	1366	1501	1542	2182	2310	6414
4	408	421	498	467	489	504	500	445	562	566

RUN NUMBER 8540
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	6419.85	5.92	6.4	2.081	1.971	79.72	84.09	62.22	90.07
2	6452.30	5.89	15 5	2.071	1.967	80.11	84.37	62.21	92.83
3	6484.78	5.85	24.6	2.061	1.966	80 54	84.39	62.21	102.10
4	6517.31	5.82	33.7	2.050	1.961	80.94	84.63	62.20	106.55
5	6549.92	5 79	42.8	2.040	1.952	81 35	85.01	62.20	107.44
6	6582.58	5.76	52.0	2.030	1.945	81.76	85.37	62.20	110.40
7	6615.31	5.72	61.1	2 020	1.937	82.17	85.65	62.19	112.80
8	6648.10	5.69	70.2	2.010	1.931	82.57	85.91	62.19	117.64
9	6680.96	5.66	79.3	2.000	1.927	82.98	86.00	62.18	126.46
10	6713.88	5.63	88.4	1.990	1.922	83.39	86.30	62.18	134.52

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8541
MULTI-PHASE
08-06-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.17	GPM
MASS FLOW RATE WATER	=	11.4	LBM/MIN
MASS FLOW RATE GAS	=	1.73	LBM/MIN
MASS FLUX	=	104248	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.47	FT/S
GAS VELOCITY	=	59.83	FT/S
GAS VISCOSITY	=	386.74E-09	LBM-S/FT^2
INLET TEMPERATURE	=	78.51	F
OUTLET TEMPERATURE	=	84.80	F
RE NUMBER LIQUID	=	4700	
RE NUMBER GAS	=	32188	
AVERAGE PR NUMBER	=	5.75	
CURRENT TO TUBE	=	385.8	AMPS
VOLTAGE DROP IN TUBE	=	3.99	VOLTS
AVERAGE HEAT FLUX	=	2120	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5252	BTU/HR
Q=M*C*(T2-T1)	=	4855	BTU/HR
HEAT BALANCE ERROR	=	7.56	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	92.17	91.13	89.77	90.49	90.83	91.61	91.85	92.53	92.87	92.99
2	88.28	85.67	86.74	86.23	87.34	87.37	87.98	87.41	88.08	88.44
3	81.83	82.11	82.61	83.21	83.75	84.17	84.65	84.90	85.40	85.44
4	87.36	85.56	85.23	85.99	86.40	86.87	87.45	88.40	88.03	88.50

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	91.36	90.33	88.95	89.68	90.01	90.80	91.03	91.72	92.06	92.18
2	87.42	84.78	85.87	85.35	86.46	86.49	87.10	86.51	87.19	87.55
3	80.87	81.18	81.68	82.29	82.83	83.25	83.73	83.98	84.48	84.52
4	86.49	84.67	84.34	85.10	85.51	85.98	86.56	87.52	87.14	87.61

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	5257	5196	5113	5156	5176	5223	5237	5278	5299	5306
2	5023	4869	4932	4901	4967	4968	5004	4970	5009	5031
3	4643	4661	4690	4725	4756	4780	4808	4832	4851	4851
4	4968	4862	4843	4887	4911	4938	4973	5029	5006	5034

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1405	1374	1418	1404	1415	1402	1411	1399	1395	1402
2	1484	1519	1501	1531	1515	1510	1524	1551	1545	1538
3	1670	1606	1602	1590	1596	1593	1596	1595	1587	1597
4	1508	1542	1540	1538	1539	1543	1538	1526	1546	1536

RUN NUMBER 8541

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	116	131	166	161	167	161	169	165	167	180
2	182	313	276	352	309	351	346	478	461	488
3	1070	1226	1286	1237	1270	1432	1558	2251	2452	13839
4	210	321	394	375	390	401	398	359	468	478

RUN NUMBER 8541
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	4554.84	5.95	6.4	2.092	1.917	79.31	86.53	62.22	54.69
2	4586.97	5.91	15.5	2.078	1.947	79.87	85.24	62.21	73.50
3	4619.19	5.86	24.6	2.063	1.947	80.44	85.21	62.21	82.62
4	4651.51	5.82	33.7	2.049	1.938	81.01	85.60	62.20	85.70
5	4683.90	5.77	42.8	2.035	1.924	81.57	86.20	62.20	85.05
6	4716.39	5.73	52.0	2.021	1.915	82.14	86.63	62.19	87.69
7	4748.96	5.68	61.1	2.007	1.904	82.70	87.12	62.19	89.43
8	4781.62	5.64	70.2	1.993	1.897	83.27	87.43	62.18	94.51
9	4814.37	5.60	79.3	1.980	1.890	83.84	87.72	62.18	102.11
10	4847.20	5.55	88.4	1.966	1.885	84.40	87.97	62.17	110.31

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT-HR)

RUN NUMBER 8542
MULTI PHASE
08-06-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.02	GPM
MASS FLOW RATE WATER	=	8.5	LBM/MIN
MASS FLOW RATE GAS	=	1.73	LBM/MIN
MASS FLUX	=	77322	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.35	FT/S
GAS VELOCITY	=	59.40	FT/S
GAS VISCOSITY	=	386.96E-09	LBM-S/FT^2
INLET TEMPERATURE	=	78.71	F
OUTLET TEMPERATURE	=	86.08	F
RE NUMBER LIQUID	=	3509	
RE NUMBER GAS	=	31907	
AVERAGE PR NUMBER	=	5.71	
CURRENT TO TUBE	=	386.5	AMPS
VOLTAGE DROP IN TUBE	=	3.91	VOLTS
AVERAGE HEAT FLUX	=	2081	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5156	BTU/HR
Q=M*C*(T2-T1)	=	4766	BTU/HR
HEAT BALANCE ERROR	=	7.58	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	92.70	92.85	91.67	93.06	93.58	94.59	94.87	95.70	96.19	96.44
2	89.91	86.57	87.89	87.58	88.92	88.90	89.74	89.10	89.97	90.45
3	82.00	82.28	82.83	83.56	84.24	84.77	85.39	85.79	86.40	86.54
4	86.37	85.93	85.97	87.05	87.63	88.27	88.99	90.36	89.75	90.45

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	91.89	92.06	90.86	92.26	92.78	93.80	94.07	94.90	95.40	95.65
2	89.07	85.68	87.02	86.69	88.04	88.01	88.85	88.20	89.07	89.55
3	81.03	81.34	81.89	82.63	83.30	83.83	84.45	84.85	85.47	85.60
4	85.48	85.03	85.07	86.15	86.73	87.37	88.09	89.47	88.85	89.55

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	3922	3930	3877	3939	3962	4008	4020	4058	4080	4091
2	3798	3650	3708	3694	3753	3751	3788	3759	3798	3819
3	3451	3464	3487	3518	3547	3570	3597	3614	3641	3646
4	3641	3622	3624	3670	3695	3723	3755	3816	3788	3819

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1405	1353	1400	1376	1388	1371	1384	1372	1364	1373
2	1458	1547	1506	1541	1523	1544	1535	1568	1559	1553
3	1680	1624	1627	1619	1627	1623	1627	1627	1615	1627
4	1549	1563	1555	1555	1557	1560	1554	1535	1565	1553

RUN NUMBER 8542

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	110	111	136	125	129	124	130	127	129	136
2	147	268	235	287	253	293	284	389	371	391
3	920	1238	1284	1252	1291	1496	1637	2374	2721	87358
4	247	305	349	322	331	337	335	259	394	391

RUN NUMBER 8542
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	3374.34	5.96	6.4	2.095	1.909	79.21	86.66	62.22	51.82
2	3403.96	5.90	15.5	2.077	1.928	79.91	86.03	62.21	64.83
3	3433.88	5.85	24.6	2.058	1.924	80.62	86.23	62.21	70.87
4	3463.90	5.79	33.7	2.041	1.908	81.33	86.93	62.20	70.66
5	3494.03	5.73	42.8	2.023	1.891	82.04	87.71	62.19	69.75
6	3524.25	5.68	52.0	2.006	1.879	82.75	88.25	62.19	71.65
7	3554.58	5.63	61.1	1.989	1.865	83.46	88.87	62.18	73.05
8	3585.01	5.57	70.2	1.972	1.855	84.17	89.36	62.17	76.89
9	3615.54	5.52	79.3	1.955	1.848	84.88	89.70	62.17	81.84
10	3646.16	5.47	88.4	1.939	1.839	85.58	90.09	62.16	87.53

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8543
MULTI-PHASE
08-06-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	2.44	GPM
MASS FLOW RATE WATER	=	20.3	LBM/MIN
MASS FLOW RATE GAS	=	1.98	LBM/MIN
MASS FLUX	=	185796	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.83	FT/S
GAS VELOCITY	=	68.52	FT/S
GAS VISCOSITY	=	386.66E-09	LBM-S/FT^2
INLET TEMPERATURE	=	79.87	F
OUTLET TEMPERATURE	=	83.43	F
RE NUMBER LIQUID	=	8355	
RE NUMBER GAS	=	36886	
AVERAGE PR NUMBER	=	5.76	
CURRENT TO TUBE	=	398.5	AMPS
VOLTAGE DROP IN TUBE	=	4.00	VOLTS
AVERAGE HEAT FLUX	=	2195	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5439	BTU/HR
Q=M*C*(T2-T1)	=	4908	BTU/HR
HEAT BALANCE ERROR	=	9.75	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	84.83	87.78	87.57	87.92	87.89	88.28	88.32	88.83	89.01	89.18
2	85.56	85.00	85.58	85.08	85.75	85.74	86.05	85.66	86.05	86.36
3	82.24	82.41	82.75	83.15	83.46	83.71	84.03	84.11	84.42	84.35
4	83.27	84.41	84.29	84.84	85.05	85.31	85.65	86.31	86.13	86.42

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	83.90	86.89	86.67	87.03	86.99	87.38	87.42	87.94	88.12	88.29
2	84.65	84.06	84.65	84.14	84.82	84.80	85.11	84.71	85.11	85.42
3	81.27	81.44	81.78	82.19	82.50	82.75	83.07	83.15	83.46	83.39
4	82.33	83.47	83.34	83.90	84.11	84.37	84.71	85.37	85.19	85.48

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	8587	8897	8874	8911	8908	8949	8953	9007	9026	9043
2	8664	8603	8664	8611	8681	8680	8712	8670	8711	8744
3	8317	8334	8369	8410	8442	8468	8501	8509	8541	8533
4	8425	8542	8529	8586	8608	8634	8670	8739	8720	8750

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1603	1537	1548	1540	1552	1546	1554	1544	1543	1546
2	1563	1618	1605	1627	1614	1623	1620	1638	1634	1628
3	1670	1675	1672	1663	1666	1663	1664	1665	1661	1670
4	1622	1633	1638	1633	1632	1634	1630	1621	1632	1626

RUN NUMBER 8543

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	422	238	263	261	281	277	295	284	292	303
2	344	448	416	542	483	544	549	742	724	730
3	1434	1692	1690	1580	1637	1794	1838	2596	2713	8584
4	730	542	642	592	621	642	641	565	697	710

RUN NUMBER 8543
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	8199.06	5.89	6.4	2.072	1.999	80.11	83.04	62.21	143.39
2	8233.80	5.86	15.5	2.063	1.976	80.45	83.97	62.21	119.64
3	8268.58	5.83	24.6	2.054	1.973	80.79	84.11	62.21	126.62
4	8303.43	5.81	33.7	2.046	1.968	81.14	84.31	62.20	132.25
5	8338.33	5.78	42.8	2.037	1.961	81.48	84.60	62.20	134.43
6	8373.29	5.75	52.0	2.028	1.956	81.82	84.83	62.20	139.75
7	8408.31	5.72	61.1	2.020	1.950	82.16	85.08	62.19	144.03
8	8443.38	5.70	70.2	2.012	1.945	82.51	85.29	62.19	150.56
9	8478.51	5.67	79.3	2.003	1.941	82.85	85.47	62.19	160.13
10	8513.70	5.65	88.4	1.995	1.937	83.19	85.64	62.18	171.00

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8544
MULTI-PHASE
08-07-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	2.43	GPM
MASS FLOW RATE WATER	=	20.2	LBM/MIN
MASS FLOW RATE GAS	=	1.66	LBM/MIN
MASS FLUX	=	184708	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.83	FT/S
GAS VELOCITY	=	57.59	FT/S
GAS VISCOSITY	=	386.49E-09	LBM-S/FT^2
INLET TEMPERATURE	=	79.49	F
OUTLET TEMPERATURE	=	82.97	F
RE NUMBER LIQUID	=	8264	
RE NUMBER GAS	=	31036	
AVERAGE PR NUMBER	=	5.80	
CURRENT TO TUBE	=	392.2	AMPS
VOLTAGE DROP IN TUBE	=	4.00	VOLTS
AVERAGE HEAT FLUX	=	2160	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5352	BTU/HR
Q=M*C*(T2-T1)	=	4685	BTU/HR
HEAT BALANCE ERROR	=	12.47	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	85.44	87.78	87.26	87.54	87.49	87.89	88.08	88.55	88.77	88.88
2	85.57	84.75	85.33	84.70	85.38	85.33	85.80	85.52	85.79	86.14
3	82.04	82.11	82.43	82.71	82.99	83.29	83.72	83.88	84.15	84.03
4	83.31	84.22	84.00	84.48	84.66	85.01	85.38	86.15	85.87	86.14

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	84.55	86.92	86.39	86.68	86.62	87.02	87.21	87.68	87.91	88.01
2	84.69	83.84	84.43	83.79	84.48	84.42	84.89	84.60	84.88	85.23
3	81.10	81.17	81.49	81.78	82.06	82.36	82.79	82.95	83.22	83.09
4	82.40	83.30	83.08	83.57	83.75	84.10	84.47	85.24	84.96	85.23

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	8603	8848	8793	8823	8817	8859	8878	8928	8951	8962
2	8617	8530	8591	8525	8595	8590	8638	8608	8636	8673
3	8251	8258	8290	8319	8348	8378	8422	8438	8466	8453
4	8382	8475	8452	8502	8520	8556	8594	8674	8645	8673

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1538	1480	1498	1489	1501	1496	1502	1496	1491	1496
2	1517	1569	1552	1575	1561	1572	1568	1583	1583	1574
3	1625	1626	1622	1613	1617	1614	1613	1616	1609	1620
4	1575	1583	1586	1581	1580	1580	1579	1567	1581	1574

RUN NUMBER 8544

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR F)

	1	2	3	4	5	6	7	8	9	10
1	338	215	249	250	270	265	274	266	270	283
2	305	414	384	514	457	519	496	624	640	631
3	1181	1463	1476	1537	1629	1683	1529	1838	1966	4528
4	589	487	589	557	588	585	577	493	618	611

RUN NUMBER 8544
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	8112.25	5.92	6.4	2.081	1.995	79.72	83.18	62.22	117.68
2	8145.94	5.89	15.5	2.073	1.980	80.06	83.81	62.21	108.57
3	8179.69	5.87	24.6	2.064	1.979	80.39	83.85	62.21	117.78
4	8213.48	5.84	33.7	2.056	1.977	80.73	83.95	62.21	126.20
5	8247.33	5.81	42.8	2.047	1.970	81.06	84.22	62.20	128.65
6	8281.24	5.78	52.0	2.039	1.964	81.40	84.47	62.20	132.16
7	8315.20	5.76	61.1	2.031	1.956	81.73	84.84	62.20	130.83
8	8349.21	5.73	70.2	2.022	1.949	82.07	85.12	62.19	133.15
9	8383.28	5.71	79.3	2.014	1.947	82.40	85.34	62.19	143.16
10	8417.41	5.68	88.4	2.006	1.943	82.74	85.39	62.19	152.93

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8545
MULTI-PHASE
08-07-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.85	GPM
MASS FLOW RATE WATER	=	15.4	LBM/MIN
MASS FLOW RATE GAS	=	1.65	LBM/MIN
MASS FLUX	=	140936	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.63	FT/S
GAS VELOCITY	=	57.07	FT/S
GAS VISCOSITY	=	386.64E-09	LBM-S/FT^2
INLET TEMPERATURE	=	79.35	F
OUTLET TEMPERATURE	=	83.84	F
RE NUMBER LIQUID	=	6334	
RE NUMBER GAS	=	30728	
AVERAGE PR NUMBER	=	5.77	
CURRENT TO TUBE	=	393.1	AMPS
VOLTAGE DROP IN TUBE	=	3.96	VOLTS
AVERAGE HEAT FLUX	=	2138	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5298	BTU/HR
Q=M*C*(T2-T1)	=	4751	BTU/HR
HEAT BALANCE ERROR	=	10.32	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	87.23	89.50	88.56	88.96	89.09	89.77	89.87	90.52	90.83	90.94
2	86.76	85.35	86.13	85.50	86.36	86.38	86.84	86.44	86.94	87.26
3	82.10	82.24	82.66	83.07	83.46	83.81	84.24	84.41	84.81	84.75
4	84.13	84.80	84.63	85.21	85.54	85.95	86.37	87.25	86.97	87.32

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	86.35	88.66	87.70	88.11	88.23	88.92	89.01	89.67	89.98	90.09
2	85.88	84.44	85.23	84.59	85.46	85.47	85.93	85.52	86.02	86.35
3	81.15	81.29	81.72	82.13	82.52	82.87	83.30	83.47	83.87	83.81
4	83.22	83.88	83.71	84.29	84.62	85.03	85.46	86.34	86.05	86.41

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	6706	6890	6813	6846	6855	6910	6918	6971	6996	7004
2	6669	6555	6618	6567	6635	6636	6673	6640	6680	6706
3	6299	6310	6343	6375	6405	6433	6466	6479	6511	6506
4	6460	6512	6498	6544	6570	6602	6635	6705	6682	6711

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1518	1451	1483	1473	1485	1473	1482	1472	1468	1471
2	1511	1578	1551	1578	1563	1576	1572	1593	1589	1582
3	1650	1638	1634	1624	1629	1626	1627	1629	1622	1632
4	1578	1592	1590	1585	1584	1587	1584	1572	1588	1580

RUN NUMBER 8545

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	226	169	206	205	216	207	219	210	213	225
2	242	362	379	433	383	430	426	559	545	563
3	1103	1354	1362	1371	1430	1535	1538	2050	2135	6053
4	442	419	497	473	488	492	493	428	539	550

RUN NUMBER 8545
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	6184.31	5.93	6.4	2.083	1.972	79.65	84.15	62.22	90.58
2	6217.48	5.89	15.5	2.072	1.962	80.08	84.57	62.21	90.85
3	6250.71	5.86	24.6	2.061	1.962	80.52	84.59	62.21	99.91
4	6284.01	5.82	33.7	2.050	1.957	80.95	84.78	62.20	106.17
5	6317.37	5.79	42.8	2.039	1.947	81.38	85.21	62.20	106.26
6	6350.81	5.75	52.0	2.029	1.939	81.81	85.57	62.20	108.11
7	6384.32	5.72	61.1	2.018	1.931	82.24	85.92	62.19	110.40
8	6417.89	5.68	70.2	2.008	1.923	82.67	86.25	62.19	113.66
9	6451.54	5.65	79.3	1.997	1.918	83.11	86.48	62.18	120.32
10	6485.25	5.62	88.4	1.987	1.914	83.54	86.66	62.18	129.95

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8546
MULTI-PHASE
08-07-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.13	GPM
MASS FLOW RATE WATER	=	11.1	LBM/MIN
MASS FLOW RATE GAS	=	1.67	LBM/MIN
MASS FLUX	=	101054	LBM/(SQ.FT HR)
LIQUID VELOCITY	=	.45	FT/S
GAS VELOCITY	=	57.85	FT/S
GAS VISCOSITY	=	106.85E-09	LBM-S/FT^2
INLET TEMPERATURE	=	79.08	F
OUTLET TEMPERATURE	=	85.17	F
RE NUMBER LIQUID	=	4571	
RE NUMBER GAS	=	31095	
AVERAGE PR NUMBER	=	5.73	
CURRENT TO TUBE	=	189.4	AMPS
VOLTAGE DROP IN TUBE	=	4.01	VOLTS
AVERAGE HEAT FLUX	=	2150	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5327	BTU/HR
Q=M*C*(T2-T1)	=	4863	BTU/HR
HEAT BALANCE ERROR	=	8.72	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	90.60	91.77	90.46	91.17	91.65	92.56	92.85	93.50	93.77	94.02
2	89.10	86.26	87.33	86.79	87.95	87.96	88.60	87.96	88.67	89.06
3	82.24	82.47	82.94	83.56	84.11	84.51	85.05	85.28	85.81	85.82
4	85.58	85.62	85.52	86.32	86.80	87.35	87.99	88.99	88.56	89.12

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	89.75	90.96	89.63	90.34	90.82	91.74	92.02	92.68	92.95	93.20
2	88.25	85.36	86.45	85.89	87.06	87.06	87.70	87.05	87.76	88.15
3	81.27	81.53	82.00	82.62	83.17	83.57	84.11	84.34	84.88	84.88
4	84.67	84.71	84.61	85.41	85.97	86.44	87.08	88.09	87.65	88.22

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	5003	5073	4996	5037	5064	5118	5134	5173	5188	5203
2	4916	4752	4814	4782	4848	4849	4885	4848	4889	4911
3	4523	4537	4564	4598	4629	4651	4682	4695	4725	4725
4	4713	4715	4720	4755	4787	4813	4850	4907	4882	4915

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1460	1395	1440	1426	1437	1420	1429	1418	1415	1421
2	1476	1565	1528	1559	1541	1560	1555	1581	1575	1569
3	1675	1633	1633	1622	1630	1627	1630	1629	1619	1632
4	1566	1582	1574	1571	1571	1576	1571	1557	1578	1567

RUN NUMBER 8546

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	142	128	160	156	159	152	158	156	161	168
2	168	296	264	315	295	336	331	457	439	462
3	938	1126	1222	1177	1219	1410	1473	2168	2310	13716
4	302	341	398	377	379	391	385	345	454	453

RUN NUMBER 8546
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	4425.37	5.94	6.4	2.088	1.929	79.49	85.99	62.22	61.92
2	4457.61	5.89	15.5	2.072	1.937	80.08	85.64	62.21	72.26
3	4489.93	5.84	24.6	2.058	1.937	80.66	85.67	62.21	80.15
4	4522.35	5.80	33.7	2.043	1.928	81.25	86.07	62.20	83.26
5	4554.87	5.75	42.8	2.028	1.912	81.81	86.75	62.20	81.52
6	4587.47	5.70	52.0	2.014	1.902	82.42	87.20	62.19	83.83
7	4620.16	5.66	61.1	2.000	1.890	83.00	87.73	62.18	84.83
8	4652.94	5.62	70.2	1.985	1.883	83.59	88.04	62.16	90.03
9	4685.81	5.57	79.3	1.972	1.877	84.17	88.31	62.17	96.85
10	4718.77	5.53	88.4	1.958	1.871	84.76	88.61	62.17	103.91

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8547
MULTI-PHASE
08-07-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.04	GPM
MASS FLOW RATE WATER	=	8.6	LBM/MIN
MASS FLOW RATE GAS	=	1.67	LBM/MIN
MASS FLUX	=	79046	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.35	FT/S
GAS VELOCITY	=	58.09	FT/S
GAS VISCOSITY	=	386.84E-09	LBM-S/FT^2
INLET TEMPERATURE	=	78.36	F
OUTLET TEMPERATURE	=	85.82	F
RE NUMBER LIQUID	=	3574	
RE NUMBER GAS	=	11231	
AVERAGE PR NUMBER	=	5.73	
CURRENT TO TUBE	=	389.3	AMPS
VOLTAGE DROP IN TUBE	=	3.94	VOLTS
AVERAGE HEAT FLUX	=	2112	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5233	BTU/HR
Q=M*C*(T2-T1)	=	4886	BTU/HR
HEAT BALANCE ERROR	=	6.63	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	93.07	93.02	91.62	92.91	93.54	94.62	94.93	95.68	96.03	96.38
2	89.50	86.40	87.79	87.42	88.82	88.78	89.60	88.86	89.73	90.20
3	81.72	82.05	82.61	83.34	84.04	84.51	85.17	85.52	86.16	86.28
4	86.29	85.82	85.80	86.84	87.50	88.07	88.84	90.12	89.53	90.24

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	92.25	92.23	90.85	92.10	92.72	93.82	94.12	94.88	95.23	95.57
2	89.04	85.49	86.91	86.52	87.93	87.88	88.70	87.94	88.82	89.29
3	80.74	81.10	81.66	82.39	83.09	83.56	84.22	84.57	85.22	85.31
4	85.38	84.90	84.89	85.93	86.59	87.16	87.93	89.22	88.60	89.31

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	4026	4025	3960	4020	4048	4098	4112	4147	4163	4179
2	3881	3723	3786	3768	3831	3829	3866	3832	3871	3892
3	3515	3530	3555	3587	3617	3638	3667	3682	3711	3716
4	3718	3697	3696	3742	3772	3797	3831	3889	3862	3894

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1417	1367	1420	1397	1408	1388	1400	1389	1384	1390
2	1481	1572	1527	1562	1545	1566	1558	1592	1582	1577
3	1708	1649	1651	1642	1652	1647	1651	1650	1637	1650
4	1574	1587	1578	1577	1579	1584	1578	1559	1588	1576

RUN NUMBER 8547

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR F)

	1	2	3	4	5	6	7	8	9	10
1	105	108	135	126	128	122	127	126	130	135
2	145	266	231	283	249	288	281	392	375	397
3	912	1085	1214	1192	1218	1482	1570	2407	7661	145478
4	241	298	343	321	325	336	331	292	396	392

RUN NUMBER 8547
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	3434.62	5.99	6.4	2.104	1.910	78.86	86.85	62.22	50.42
2	3465.42	5.93	15.5	2.085	1.931	79.58	85.92	62.22	63.33
3	3496.33	5.87	24.6	2.067	1.928	80.30	86.06	62.21	69.69
4	3527.35	5.82	33.7	2.049	1.912	81.01	86.73	62.20	70.20
5	3558.48	5.76	42.8	2.031	1.893	81.73	87.58	62.20	68.62
6	3589.71	5.70	52.0	2.013	1.882	82.45	88.10	62.19	70.97
7	3621.05	5.65	61.1	1.996	1.868	83.17	88.74	62.18	71.92
8	3652.49	5.59	70.2	1.978	1.859	83.88	89.15	62.18	76.07
9	3684.04	5.54	79.3	1.961	1.852	84.60	89.47	62.17	82.23
10	3715.70	5.49	88.4	1.945	1.844	85.32	89.88	62.16	87.69

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8548
MULTI-PHASE
08-07-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.91	GPM
MASS FLOW RATE WATER	=	15.9	LBM/MIN
MASS FLOW RATE GAS	=	1.64	LBM/MIN
MASS FLUX	=	145310	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.65	FT/S
GAS VELOCITY	=	56.81	FT/S
GAS VISCOSITY	=	386.69E-09	LBM-S/FT^2
INLET TEMPERATURE	=	79.54	F
OUTLET TEMPERATURE	=	83.92	F
RE NUMBER LIQUID	=	6541	
RE NUMBER GAS	=	10574	
AVERAGE PR NUMBER	=	5.76	
CURRENT TO TUBE	=	390.2	AMPS
VOLTAGE DROP IN TUBE	=	4.01	VOLTS
AVERAGE HEAT FLUX	=	2155	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5339	BTU/HR
Q=M*C*(T2-T1)	=	4757	BTU/HR
HEAT BALANCE ERROR	=	10.90	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	87.22	89.54	88.54	88.96	89.01	89.63	89.72	90.35	90.63	90.83
2	86.92	85.46	86.17	85.60	86.45	86.47	86.87	86.41	86.96	87.26
3	82.23	82.40	82.80	83.26	83.66	83.97	84.35	84.49	84.87	84.83
4	84.23	84.89	84.72	85.36	85.63	85.97	86.41	87.22	86.96	87.34

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	86.35	88.71	87.69	88.11	88.16	88.78	88.87	89.50	89.78	89.98
2	86.05	84.56	85.28	84.70	85.56	85.57	85.97	85.50	86.05	86.36
3	81.29	81.46	81.87	82.33	82.73	83.04	83.42	83.56	83.94	83.90
4	83.33	83.98	83.81	84.45	84.72	85.06	85.50	86.32	86.05	86.44

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	6914	7107	7024	7059	7062	7114	7121	7173	7196	7213
2	6890	6768	6827	6780	6849	6850	6883	6845	6890	6915
3	6505	6520	6552	6589	6621	6646	6676	6688	6719	6715
4	6669	6722	6708	6760	6782	6809	6845	6912	6890	6921

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1507	1438	1470	1461	1474	1463	1472	1462	1458	1461
2	1493	1563	1537	1563	1547	1555	1555	1577	1572	1566
3	1635	1621	1618	1607	1612	1609	1610	1611	1606	1616
4	1562	1577	1574	1569	1568	1572	1567	1556	1572	1564

RUN NUMBER 8548

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	231	170	209	208	222	213	226	217	221	229
2	240	363	333	434	383	429	430	580	551	573
3	1126	1343	1361	1303	1332	1462	1521	2076	2174	5940
4	447	423	502	467	489	503	498	440	551	556

RUN NUMBER 8548
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	6390.66	5.91	6.4	2.079	1.970	79.83	84.25	62.21	91.30
2	6424.04	5.88	15.5	2.068	1.960	80.26	84.68	62.21	91.25
3	6457.49	5.84	24.6	2.057	1.960	80.68	84.66	62.21	101.18
4	6491.01	5.81	33.7	2.046	1.955	81.10	84.90	62.20	106.02
5	6524.59	5.78	42.8	2.036	1.945	81.52	85.29	62.20	106.80
6	6558.25	5.74	52.0	2.026	1.938	81.94	85.61	62.19	109.61
7	6591.97	5.71	61.1	2.015	1.930	82.36	85.94	62.19	112.47
8	6625.75	5.68	70.2	2.005	1.924	82.78	86.[illegible]	62.19	117.05
9	6659.61	5.64	79.3	1.995	1.919	83.20	86.46	62.18	123.70
10	6693.53	5.61	[illegible].4	1.985	1.914	83.63	86.67	62.18	132.13

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8549
MULTI-PHASE
08-08-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.43	GPM
MASS FLOW RATE WATER	=	11.9	LBM/MIN
MASS FLOW RATE GAS	=	1.61	LBM/MIN
MASS FLUX	=	108899	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.49	FT/S
GAS VELOCITY	=	55.70	FT/S
GAS VISCOSITY	=	386.39E-09	LBM S/FT^2
INLET TEMPERATURE	=	78.50	F
OUTLET TEMPERATURE	=	83.43	F
RE NUMBER LIQUID	=	4856	
RE NUMBER GAS	=	10044	
AVERAGE PR NUMBER	=	5.82	
CURRENT TO TUBE	=	361.0	AMPS
VOLTAGE DROP IN TUBE	=	3.78	VOLTS
AVERAGE HEAT FLUX	=	1879	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	4656	BTU/HR
Q=M*C*(T2-T1)	=	4168	BTU/HR
HEAT BALANCE ERROR	=	10.48	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	88.44	89.05	88.00	88.63	88.71	89.39	89.81	90.37	90.75	90.89
2	87.10	84.59	85.45	84.85	85.72	85.71	86.40	86.01	86.47	86.87
3	81.25	81.39	81.78	82.15	82.58	82.95	83.49	83.76	84.17	84.15
4	84.04	84.00	83.87	84.50	84.80	85.32	85.91	86.86	86.45	86.87

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	87.71	88.35	87.28	87.92	87.99	88.68	89.09	89.66	90.04	90.18
2	86.16	83.81	84.69	84.08	84.95	84.94	85.63	85.23	85.69	86.09
3	80.42	80.58	80.97	81.35	81.77	82.15	82.68	82.95	83.37	83.34
4	83.26	83.22	83.09	83.72	84.02	84.54	85.13	86.09	85.67	86.09

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	5265	5304	5239	5278	5282	5325	5350	5385	5409	5418
2	5182	5027	5080	5043	5096	5095	5137	5113	5141	5166
3	4824	4833	4856	4879	4904	4927	4959	4975	5000	4999
4	4994	4991	4983	5022	5040	5071	5107	5166	5140	5166

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1252	1205	1241	1225	1238	1228	1234	1221	1219	1226
2	1269	1341	1311	1339	1324	1338	1333	1354	1353	1344
3	1436	1400	1399	1390	1395	1392	1395	1396	1396	1394
4	1347	1356	1352	1348	1348	1348	1346	1333	1353	1344

RUN NUMBER 8549

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	141	133	165	159	170	164	166	163	164	173
2	268	297	267	350	313	358	337	440	441	448
3	903	1098	1174	1273	1333	1475	1384	1736	1661	5703
4	304	347	408	389	409	403	389	338	444	448

RUN NUMBER 8549
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	4729.96	5.99	6.4	2.105	1.965	78.83	84.44	62.22	61.65
2	4757.98	5.95	15.5	2.092	1.976	79.31	83.99	62.22	73.75
3	4786.07	5.91	24.6	2.080	1.975	79.78	84.01	62.22	81.66
4	4814.23	5.88	33.7	2.068	1.969	80.25	84.27	62.21	86.02
5	4842.44	5.84	47.8	2.056	1.959	80.73	84.69	62.21	87.17
6	4870.73	5.80	52.0	2.044	1.950	81.20	85.08	62.20	89.03
7	4899.07	5.76	61.1	2.032	1.937	81.68	85.64	62.20	87.08
8	4927.49	5.73	70.2	2.020	1.929	82.15	85.98	62.19	89.92
9	4955.96	5.69	79.3	2.009	1.925	82.62	86.19	62.19	96.53
10	4984.50	5.65	88.4	1.997	1.919	83.10	86.43	62.18	103.40

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8550
MULTI-PHASE
08-08-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	.95	GPM
MASS FLOW RATE WATER	=	7.9	LBM/MIN
MASS FLOW RATE GAS	=	1.61	LBM/MIN
MASS FLUX	=	72105	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.32	FT/S
GAS VELOCITY	=	55.90	FT/S
GAS VISCOSITY	=	386.77E 09	LBM-S/FT^2
INLET TEMPERATURE	=	77.66	F
OUTLET TEMPERATURE	=	86.18	F
RE NUMBER LIQUID	=	3253	
RE NUMBER GAS	=	30065	
AVERAGE PR NUMBER	=	5.74	
CURRENT TO TUBE	=	393.2	AMPS
VOLTAGE DROP IN TUBE	=	4.08	VOLTS
AVERAGE HEAT FLUX	=	2209	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5474	BTU/HR
Q=M*C*(T2-T1)	=	5150	BTU/HR
HEAT BALANCE ERROR	=	5.91	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	95.42	93.93	92.82	94.21	94.73	96.00	96.23	97.28	97.64	97.89
2	90.99	86.60	88.42	87.89	89.34	89.38	90.24	89.58	90.50	90.98
3	81.41	81.73	82.37	83.15	83.91	84.49	85.22	85.68	86.38	86.56
4	86.93	85.91	86 12	87 19	87.88	88.61	89.44	90.97	90.19	91.02

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	94.60	93.13	91.99	93.39	93.91	95.19	95.41	96.47	96.83	97.08
2	90.12	85.67	87.52	86.97	88.43	88.46	89.32	88.64	89.57	90.05
3	80.39	80.75	81.39	82.18	82.93	83.51	84.24	84.70	85.41	85.58
4	86.00	84.97	85 19	86.26	86 95	87.68	88.51	90.05	89.25	90.09

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	3771	3709	3662	3721	3742	3796	3805	3850	3865	3876
2	3584	3403	3478	3456	3515	3516	3552	3524	3562	3582
3	3192	3207	3232	3263	3293	3316	3346	3364	3393	3400
4	3416	3375	3384	3427	3455	3485	3519	3582	3549	3583

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1410	1378	1433	1405	1420	1398	1415	1400	1393	1403
2	1511	1606	1554	1596	1577	1600	1591	1628	1618	1612
3	1770	1692	1701	1690	1698	1694	1698	1698	1683	1695
4	1616	1624	1613	1614	1614	1620	1612	1592	1626	1613

RUN NUMBER 8550

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	86	97	118	110	114	108	115	111	115	122
2	127	242	203	254	227	261	257	348	338	367
3	821	995	1122	1138	1195	1432	1554	2315	2700	-74376
4	208	274	303	290	296	303	300	261	364	359

RUN NUMBER 8550
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	3108.48	6.04	6.4	2.121	1.889	78.23	87.78	62.21	43.13
2	3140.48	5 98	15.5	2 099	1.926	79.05	86.13	62.22	58.00
3	3172.61	5 91	24.6	2 078	1.917	79.87	86.52	62.21	61.69
4	3204 87	5 84	33 7	2 057	1.903	80 69	87.20	62.21	63.00
5	3237 25	5 78	42.8	2.036	1.883	81.51	88.05	62.20	62.62
6	3269.76	5.71	52 0	2 016	1.869	82.33	88.71	62.19	64.19
7	3302.40	5.65	61.1	1.996	1.855	83.15	89.37	62.18	65.77
8	3335.16	5 59	70.2	1.976	1.842	83.97	89.97	62.17	68.19
9	3368 05	5.53	79.3	1.957	1.836	84.79	90.27	62.17	74.58
10	3401.07	5 47	88.4	1.938	1 826	85 61	90.73	62 16	80.15

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8551
MULTI-PHASE
08-08-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	2.37	GPM
MASS FLOW RATE WATER	=	19.7	LBM/MIN
MASS FLOW RATE GAS	=	1.56	LBM/MIN
MASS FLUX	=	179857	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.80	FT/S
GAS VELOCITY	=	53.92	FT/S
GAS VISCOSITY	=	386.61E-09	LBM-S/FT^2
INLET TEMPERATURE	=	79.73	F
OUTLET TEMPERATURE	=	83.30	F
RE NUMBER LIQUID	=	8075	
RE NUMBER GAS	=	29036	
AVERAGE PR NUMBER	=	5.78	
CURRENT TO TUBE	=	388.9	AMPS
VOLTAGE DROP IN TUBE	=	4.02	VOLTS
AVERAGE HEAT FLUX	=	2153	BTU/(SQ.FT-HR)
Q-AMP*VOLT	=	5334	BTU/HR
Q=M*C*(T2-T1)	=	4661	BTU/HR
HEAT BALANCE ERROR	=	12.62	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	86.03	88.13	87.47	87.93	87.92	88.41	88.41	88.97	89.10	89.28
2	86.04	84.97	85.60	85.11	85.85	85.84	86.14	85.72	86.10	86.40
3	82.25	82.33	82.70	83.33	83.46	83.72	84.04	84.07	84.42	84.29
4	83.74	84.50	84.36	84.95	85.16	85.42	85.74	86.38	86.18	86.47

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	85.16	87.29	86.62	87.08	87.06	87.56	87.56	88.12	88.25	88.43
2	85.18	84.08	84.72	84.21	84.96	84.95	85.25	84.82	85.20	85.50
3	81.32	81.40	81.78	82.21	82.54	82.80	83.12	83.15	83.50	83.37
4	82.84	83.60	83.46	84.05	84.26	84.52	84.84	85.49	85.28	85.58

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	8438	8653	8585	8632	8630	8681	8680	8738	8751	8769
2	8440	8329	8394	8343	8418	8417	8447	8404	8442	8473
3	8056	8064	8101	8144	8176	8202	8234	8237	8272	8259
4	8207	8282	8268	8327	8348	8374	8406	8471	8450	8480

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1508	1452	1475	1465	1477	1468	1476	1465	1464	1467
2	1490	1545	1525	1550	1535	1545	1542	1560	1557	1550
3	1605	1600	1597	1588	1592	1589	1588	1591	1584	1595
4	1549	1557	1557	1553	1553	1556	1552	1543	1555	1548

RUN NUMBER 8551

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	290	208	247	240	258	250	267	254	264	273
2	386	410	375	482	424	474	479	638	626	634
3	1187	1466	1426	1310	1330	1424	1454	2046	2011	5170
4	539	473	555	509	532	549	551	495	606	615

RUN NUMBER 8551
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	7923.31	5.90	6.4	2.075	1.985	79.97	83.62	62.21	109.57
2	7957.03	5.87	15.5	2.066	1.973	80.31	84.09	62.21	105.95
3	7990.75	5.84	24.6	2.058	1.972	80.66	84.34	62.21	114.82
4	8024.55	5.82	33.7	2.049	1.966	81.00	84.39	62.20	118.03
5	8058.41	5.79	42.8	2.040	1.959	81.34	84.71	62.20	[illegible]
6	8092.33	5.76	52.0	2.032	1.953	81.69	84.96	62.20	122.26
7	8126.30	5.73	61.1	2.023	1.948	82.03	85.19	62.19	126.41
8	8160.32	5.71	70.2	2.015	1.943	82.37	85.39	62.19	132.26
9	8194.41	5.68	79.3	2.006	1.939	82.72	85.56	62.19	140.56
10	8228.54	5.66	88.4	1.998	1.936	83.06	85.72	62.18	150.13

NOTE. TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8552
MULTI-PHASE
08-08-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.89	GPM
MASS FLOW RATE WATER	=	15.7	LBM/MIN
MASS FLOW RATE GAS	=	1.58	LBM/MIN
MASS FLUX	=	141550	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.64	FT/S
GAS VELOCITY	=	54.72	FT/S
GAS VISCOSITY	=	386.68E-09	LBM-S/FT^2
INLET TEMPERATURE	=	79.55	F
OUTLET TEMPERATURE	=	83.85	F
RE NUMBER LIQUID	=	6459	
RE NUMBER GAS	=	29448	
AVERAGE PR NUMBER	=	5.76	
CURRENT TO TUBE	=	386.1	AMPS
VOLTAGE DROP IN TUBE	=	3.96	VOLTS
AVERAGE HEAT FLUX	=	2106	BTU/(SQ-FT-HR)
Q=AMP*VOLT	=	5217	BTU/HR
Q=M*C*(T2-T1)	=	4599	BTU/HR
HEAT BALANCE ERROR	=	11.84	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	87.62	89.47	88.51	89.03	89.06	89.65	89.75	90.34	90.54	90.71
2	87.02	85.36	86.12	85.59	86.41	86.41	86.84	86.42	86.87	87.21
3	82.25	82.37	82.76	83.21	83.59	83.92	84.32	84.46	84.85	84.76
4	84.38	84.89	84.71	85.34	65.60	85.96	86.39	87.20	86.91	87.26

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	86.77	88.65	87.68	88.20	88.23	88.82	88.92	89.51	89.71	89.88
2	86.17	84.47	85.25	84.70	85.53	85.53	85.96	85.53	85.98	86.32
3	81.32	81.45	81.84	82.30	82.68	83.01	83.41	83.55	83.94	83.85
4	83.49	84.00	83.82	84.45	84.71	85.07	85.50	86.32	86.02	86.38

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	6864	7017	6938	6980	6982	7031	7039	7087	7104	7117
2	6816	6680	6742	6698	6765	6764	6799	6764	6801	6828
3	6430	6440	6471	6507	6537	6563	6595	6606	6637	6630
4	6602	6642	6627	6678	6699	6727	6763	6828	6804	6832

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1467	1406	1438	1426	1440	1429	1438	1429	1426	1430
2	1464	1531	1505	1531	1516	1528	1523	1544	1540	1533
3	1605	1588	1585	1575	1580	1577	1578	1579	1572	1583
4	1532	1543	1541	1537	1537	1539	1535	1524	1539	1531

RUN NUMBER 8552

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT HR-F)

	1	2	3	4	5	6	7	8	9	10
1	211	167	205	200	213	206	218	210	217	226
2	231	262	328	422	375	422	418	552	543	554
3	1082	1324	1146	1792	1334	1430	1449	1940	1977	5548
4	419	412	488	456	477	486	482	425	535	544

RUN NUMBER 8552
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	6313.63	5.91	6.4	2.079	1.965	79.84	84.44	62.21	85.87
2	6346.07	5.88	15.5	2.068	1.960	80.25	84.64	62.21	89.91
3	6378.45	5.84	24.6	2.057	1.960	80.67	84.65	62.21	99.13
4	6410.95	5.81	33.7	2.047	1.954	81.08	84.91	62.20	102.87
5	6443.52	5.78	42.8	2.037	1.945	81.49	65.29	62.20	103.96
6	6476.25	5.74	52.0	2.026	1.938	81.91	85.61	62.19	106.54
7	6508.85	5.71	61.1	2.016	1.930	82.32	85.95	62.19	108.67
8	6541.61	5.68	70.2	2.006	1.924	82.73	86.23	62.19	113.78
9	6574.44	5.65	79.3	1.996	1.920	83.15	86.43	62.18	120.53
10	6607.32	5.62	88.4	1.986	1.915	83.56	86.61	62.18	139.21

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8553
MULTI-PHASE
08-08-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.27	GPM
MASS FLOW RATE WATER	=	10.6	LBM/MIN
MASS FLOW RATE GAS	=	1.60	LBM/MIN
MASS FLUX	=	96716	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.43	FT/S
GAS VELOCITY	=	55.48	FT/S
GAS VISCOSITY	=	386.87E-09	LBM-S/FT^2
INLET TEMPERATURE	=	79.04	F
OUTLET TEMPERATURE	=	85.33	F
RE NUMBER LIQUID	=	4378	
RE NUMBER GAS	=	29818	
AVERAGE PR NUMBER	=	5.72	
CURRENT TO TUBE	=	390.4	AMPS
VOLTAGE DROP IN TUBE	=	3.94	VOLTS
AVERAGE HEAT FLUX	=	2118	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5247	BTU/HR
Q=M*C*(T2-T1)	=	4808	BTU/HR
HEAT BALANCE ERROR	=	8.36	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	91.93	92.38	90.88	91.81	92.27	93.15	93.44	94.21	94.50	94.63
2	89.28	86.30	87.48	87.03	88.29	88.28	88.95	88.30	89.02	89.42
3	82.18	82.45	82.93	83.57	84.16	84.60	85.15	85.40	85.95	85.98
4	86.03	85.82	85.67	86.59	87.14	87.64	88.33	89.43	88.89	89.45

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	91.09	91.57	90.04	90.98	91.44	92.33	92.61	93.39	93.68	93.81
2	88.41	85.39	86.59	86.12	87.39	87.37	88.05	87.38	88.11	88.51
3	81.20	81.50	81.98	82.63	83.21	83.65	84.20	84.45	85.01	85.03
4	85.12	84.90	84.76	85.68	86.23	86.73	87.42	88.53	87.97	88.54

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	4862	4889	4804	4856	4881	4931	4947	4990	5007	5014
2	4714	4550	4615	4589	4659	4658	4694	4658	4698	4720
3	4325	4341	4367	4401	4432	4456	4486	4499	4529	4530
4	4535	4523	4515	4565	4595	4622	4660	4721	4690	4721

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1442	1390	1442	1424	1437	1421	1431	1418	1413	1422
2	1496	1580	1537	1569	1551	1569	1563	1593	1586	1578
3	1693	1645	1646	1636	1645	1641	1644	1644	1633	1645
4	1579	1592	1584	1580	1581	1585	1579	1564	1589	1577

RUN NUMBER 8553

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	124	120	153	146	150	144	150	146	150	159
2	167	297	259	323	281	321	315	432	416	438
3	972	1149	1259	1214	1238	1407	1482	2179	2311	13152
4	279	329	388	359	363	374	365	323	432	434

RUN NUMBER 8553
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	4233.98	5.94	6.4	2.088	1.919	79.46	86.46	62.22	57.84
2	4265.85	5.89	15.5	2.073	1.933	80.07	85.84	62.21	70.00
3	4297.80	5.84	24.6	2.057	1.933	80.67	85.84	62.21	78.08
4	4329.85	5.79	33.7	2.042	1.921	81.28	86.35	62.20	79.51
5	4362.00	5.75	42.8	2.027	1.905	81.88	87.07	62.20	77.80
6	4394.23	5.70	52.0	2.012	1.895	82.49	87.52	62.19	80.11
7	4426.56	5.65	61.1	1.997	1.883	83.09	88.07	62.18	80.96
8	4458.98	5.61	70.2	1.983	1.875	83.70	88.44	62.18	84.97
9	4491.49	5.56	79.3	1.968	1.869	84.30	88.69	62.17	91.68
10	4524.09	5.52	88.4	1.954	1.863	84.91	88.97	62.16	98.95

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8554
MULTI-PHASE
08-08-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	.95	GPM
MASS FLOW RATE WATER	=	7.9	LBM/MIN
MASS FLOW RATE GAS	=	1.54	LBM/MIN
MASS FLUX	=	72050	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.32	FT/S
GAS VELOCITY	=	53.56	FT/S
GAS VISCOSITY	=	387.12E-09	LBM-S/FT^2
INLET TEMPERATURE	=	78.67	F
OUTLET TEMPERATURE	=	86.94	F
RE NUMBER LIQUID	=	3286	
RE NUMBER GAS	=	28732	
AVERAGE PR NUMBER	=	5.67	
CURRENT TO TUBE	=	390.6	AMPS
VOLTAGE DROP IN TUBE	=	3.97	VOLTS
AVERAGE HEAT FLUX	=	2136	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5291	BTU/HR
Q=M*C*(T2-T1)	=	4947	BTU/HR
HEAT BALANCE ERROR	=	6.51	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	96.34	94.59	93.79	95.16	95.64	96.64	97.12	97.85	98.50	98.75
2	91.05	87.13	89.23	88.65	90.27	90.12	91.07	90.29	91.34	91.79
3	82.24	82.53	83.17	83.96	84.71	85.30	85.99	86.42	87.13	87.26
4	87.81	86.77	87.04	88.07	88.74	89.41	90.30	91.73	91.03	91.82

INSIDE SURFACE TEMPERATURES DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	95.54	93.80	92.97	94.36	94.83	95.84	96.31	97.05	97.71	97.95
2	90.18	86.21	88.34	87.74	89.32	89.21	90.16	89.36	90.42	90.87
3	81.24	81.57	82.20	83.00	83.74	84.34	85.02	85.45	86.17	86.29
4	86.89	85.85	86.12	87.15	87.82	88.49	89.38	90.83	90.11	90.90

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	3808	3735	3700	3758	3778	3820	3840	3871	3899	3910
2	3594	3422	3509	3484	3549	3544	3584	3551	3594	3613
3	3223	3237	3262	3293	3323	3347	3374	3392	3421	3426
4	3450	3408	3419	3460	3488	3515	3552	3611	3581	3614

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1379	1360	1411	1382	1399	1382	1394	1384	1372	1382
2	1512	1591	1537	1580	1556	1580	1571	1607	1598	1591
3	1742	1669	1683	1670	1680	1674	1680	1678	1665	1678
4	1596	1601	1593	1594	1594	1598	1591	1570	1605	1591

RUN NUMBER 8554

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	84	98	116	108	112	109	113	112	113	119
2	138	257	204	257	225	263	254	351	330	354
3	866	1081	1218	1206	1259	1477	1640	2540	2857	-18802
4	208	274	300	288	294	302	295	260	355	352

RUN NUMBER 8554
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	3144.90	5.96	6.4	2.094	1.874	79.23	88.46	62.22	43.95
2	3176.08	5.90	15.5	2.074	1.910	80.02	86.86	62.22	59.25
3	3207.39	5.83	24.6	2.054	1.897	80.82	87.41	62.21	61.38
4	3238.82	5.77	33.7	2.034	1.883	81.61	88.06	62.20	62.70
5	3270.37	5.71	42.8	2.014	1.864	82.41	88.93	62.19	61.99
6	3302.03	5.64	52.0	1.995	1.852	83.20	89.47	62.18	64.47
7	3333.82	5.58	61.1	1.976	1.836	84.00	90.22	62.17	64.87
8	3365.72	5.53	70.2	1.957	1.827	84.79	90.67	62.17	68.61
9	3397.74	5.47	79.3	1.939	1.818	85.59	91.10	62.16	73.11
10	3429.88	5.41	88.4	1.920	1.810	86.38	91.51	62.15	78.64

NOTE, TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8555
MULTI-PHASE
08-09-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	1.66	GPM
MASS FLOW RATE WATER	=	13.8	LBM/MIN
MASS FLOW RATE GAS	=	1.53	LBM/MIN
MASS FLUX	=	126251	LBM/(SQ.FT-HR)
LIQUID VELOCITY	=	.56	FT/S
GAS VELOCITY	=	53.16	FT/S
GAS VISCOSITY	=	386.52E-09	LBM-S/FT^2
INLET TEMPERATURE	=	79.09	F
OUTLET TEMPERATURE	=	83.53	F
RE NUMBER LIQUID	=	5654	
RE NUMBER GAS	=	38643	
AVERAGE PR NUMBER	=	5.79	
CURRENT TO TUBE	=	365.6	AMPS
VOLTAGE DROP IN TUBE	=	3.82	VOLTS
AVERAGE HEAT FLUX	=	1923	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	4765	BTU/HR
Q=M*C*(T2-T1)	=	4231	BTU/HR
HEAT BALANCE ERROR	=	11.21	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	88.11	89.03	87.97	88.49	88.57	89.26	89.48	90.07	90.30	90.34
2	87.01	84.86	85.67	85.09	85.92	85.96	86.48	86.02	86.46	86.77
3	83.72	81.88	82.24	82.68	83.06	83.39	83.83	83.99	84.36	84.32
4	84.17	84.35	84.19	84.83	85.11	85.51	86.01	86.80	86.48	86.80

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	87.36	88.31	87.23	87.75	87.83	88.52	88.74	89.34	89.57	89.60
2	66.25	84.07	84.84	84.30	85.13	85.17	85.69	85.22	85.66	85.98
3	80.88	81.05	81.42	81.86	82.34	82.57	83.01	83.17	83.54	83.50
4	83.37	83.55	83.39	84.03	84.31	84.71	85.21	86.01	85.68	86.01

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	6079	6147	6070	6107	6112	6162	6178	6220	6237	6240
2	6000	5846	5900	5862	5921	5924	5960	5927	5958	5981
3	5624	5636	5661	5692	5718	5741	5772	5783	5809	5806
4	5797	5810	5799	5844	5863	5891	5927	5981	5960	5983

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1295	1247	1282	1270	1282	1271	1279	1268	1264	1271
2	1307	1375	1347	1372	1358	1370	1366	1387	1384	1376
3	1458	1430	1428	1418	1423	1421	1423	1423	1416	1425
4	1379	1388	1383	1379	1378	1381	1377	1367	1363	1375

RUN NUMBER 8555

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	167	146	183	179	190	181	188	182	186	197
2	190	323	292	378	336	376	365	488	484	501
3	979	1155	1218	1191	1247	1359	1345	1800	1918	5354
4	346	371	439	410	428	433	422	376	480	495

RUN NUMBER 8555
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	5521.82	5.95	6.4	2.090	1.965	79.39	84.47	62.22	69.80
2	5551.16	5.91	15.5	2.079	1.970	79.82	84.24	62.22	79.98
3	5580.55	5.88	24.6	2.068	1.970	80.24	84.22	62.21	89.02
4	5610.01	5.84	33.7	2.057	1.964	80.67	84.49	62.21	92.70
5	5639.53	5.81	42.8	2.047	1.955	81.10	84.88	62.20	93.52
6	5669.11	5.77	52.0	2.036	1.946	81.52	85.24	62.20	95.05
7	5698.75	5.74	61.1	2.025	1.937	81.95	85.66	62.19	95.30
8	5728.45	5.71	70.2	2.015	1.931	82.38	85.93	62.19	99.36
9	5758.21	5.67	79.3	2.004	1.927	82.80	86.11	62.19	106.73
10	5788.03	5.64	88.4	1.994	1.923	83.23	86.37	62.18	116.14

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8556
MULTI-PHASE
08-09-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	.90	GPM
MASS FLOW RATE WATER	=	7.5	LBM/MIN
MASS FLOW RATE GAS	=	1.48	LBM/MIN
MASS FLUX	=	68276	LBM/(SQ.FT HR)
LIQUID VELOCITY	=	.31	FT/S
GAS VELOCITY	=	51.48	FT/S
GAS VISCOSITY	=	386.99E-09	LBM-S/FT^2
INLET TEMPERATURE	=	77.96	F
OUTLET TEMPERATURE	=	86.97	F
RE NUMBER LIQUID	=	3101	
RE NUMBER GAS	=	27643	
AVERAGE PR NUMBER	=	5.70	
CURRENT TO TUBE	=	389.7	AMPS
VOLTAGE DROP IN TUBE	=	4.11	VOLTS
AVERAGE HEAT FLUX	=	2206	BTU/(SQ.FT HR)
Q=AMP*VOLT	=	5464	BTU/HR
Q=M*C*(T2-T1)	=	5124	BTU/HR
HEAT BALANCE ERROR	=	6.22	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	97.62	95.22	93.99	95.77	96.22	97.11	97.92	98.76	99.25	99.26
2	91.45	87.08	89.25	88.84	90.41	90.24	91.38	90.43	91.51	91.97
3	81.84	82.13	82.80	83.64	84.42	85.03	85.78	86.26	86.99	87.15
4	87.91	86.71	86.91	88.13	88.85	89.46	90.53	92.06	91.19	91.93

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	96.84	94.44	93.18	94.98	95.42	96.32	97.12	97.97	98.47	98.47
2	90.58	86.16	88.37	87.93	89.52	89.33	90.48	89.51	90.59	91.06
3	80.83	81.17	81.83	82.67	83.45	84.06	84.81	85.29	86.03	86.18
4	86.99	85.79	85.99	87.21	87.93	88.54	89.62	91.16	90.27	91.02

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	3660	3565	3514	3586	3603	3639	3672	3706	3726	3726
2	3412	3241	3326	3309	3372	3364	3408	3370	3413	3431
3	3039	3052	3077	3109	3138	3161	3190	3208	3236	3242
4	3273	3227	3235	3282	3309	3333	3375	3435	3400	3429

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1345	1335	1396	1362	1381	1364	1373	1359	1350	1365
2	1506	1588	1526	1571	1548	1572	1564	1606	1594	1585
3	1751	1671	1684	1674	1684	1675	1685	1681	1666	1677
4	1597	1596	1586	1589	1588	1592	1586	1561	1602	1586

RUN NUMBER 8556

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR F)

	1	2	3	4	5	6	7	8	9	10
1	73	88	108	98	103	101	102	101	104	112
2	175	236	189	232	206	244	232	329	312	337
3	773	964	1100	1109	1188	1436	1613	2542	3121	9380
4	189	251	278	262	269	282	271	239	335	340

RUN NUMBER 8556
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	2955.74	6.02	6.4	2.112	1.867	78.57	88.81	62.23	39.47
2	2987.84	5.94	15.5	2.089	1.909	79.43	86.89	62.22	54.07
3	3020.07	5.87	24.6	2.067	1.899	80.30	87.34	62.21	57.20
4	3052.45	5.80	33.7	2.045	1.880	81.17	88.20	62.20	57.24
5	3084.95	5.73	42.8	2.023	1.861	82.03	89.08	62.19	57.10
6	3117.59	5.67	52.0	2.002	1.850	82.90	89.57	62.19	60.32
7	3150.37	5.60	61.1	1.981	1.830	83.76	90.51	62.18	59.61
8	3183.27	5.54	70.2	1.961	1.821	84.63	90.98	62.17	63.23
9	3216.31	5.47	79.3	1.941	1.813	85.50	91.34	62.16	68.68
10	3249.48	5.41	88.4	1.921	1.806	86.36	91.68	62.15	75.38

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8557
MULTI-PHASE
08-09-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	2.13	GPM
MASS FLOW RATE WATER	=	17.7	LBM/MIN
MASS FLOW RATE GAS	=	1.46	LBM/MIN
MASS FLUX	=	161949	LBM/(SQ.FT HR)
LIQUID VELOCITY	=	.72	FT/S
GAS VELOCITY	=	50.69	FT/S
GAS VISCOSITY	=	386.81E-09	LBM-S/FT^2
INLET TEMPERATURE	=	79.99	F
OUTLET TEMPERATURE	=	84.04	F
RE NUMBER LIQUID	=	7315	
RE NUMBER GAS	=	17258	
AVERAGE PR NUMBER	=	5.74	
CURRENT TO TUBE	=	393.9	AMPS
VOLTAGE DROP IN TUBE	=	4.00	VOLTS
AVERAGE HEAT FLUX	=	2170	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5376	BTU/HR
Q=M*C*(T2-T1)	=	4781	BTU/HR
HEAT BALANCE ERROR	=	11.07	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	87.75	89.62	88.63	89.14	89.21	89.78	89.82	90.45	90.60	90.70
2	87.16	85.73	86.45	85.95	86.79	86.78	87.13	86.66	87.11	87.40
3	82.71	82.85	83.22	83.70	84.05	84.34	84.72	84.79	85.16	85.06
4	84.63	85.29	85.11	85.76	86.02	86.28	86.69	87.43	87.16	87.46

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	86.86	88.77	87.76	88.27	88.34	88.91	88.95	89.59	89.74	89.83
2	86.27	84.81	85.54	85.03	85.88	85.86	86.21	85.73	86.21	86.48
3	81.75	81.90	82.27	82.76	83.10	83.39	83.77	83.84	84.22	84.11
4	83.71	84.36	84.18	84.64	85.10	85.36	85.77	86.51	86.24	86.54

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	7753	7927	7834	7882	7887	7940	7944	8002	8016	8025
2	7699	7566	7633	7586	7663	7662	7694	7650	7693	7718
3	7292	7305	7338	7381	7413	7439	7473	7479	7513	7503
4	7467	7526	7510	7569	7592	7616	7653	7721	7696	7723

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1531	1474	1506	1495	1508	1497	1506	1494	1491	1498
2	1530	1592	1566	1592	1576	1587	1584	1605	1600	1594
3	1660	1648	1645	1635	1641	1637	1637	1639	1633	1642
4	1595	1603	1600	1596	1596	1600	1595	1586	1599	1592

RUN NUMBER 8557

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	232	181	224	218	231	221	237	226	234	246
2	254	483	347	442	388	434	438	585	566	587
3	1115	1323	1340	1235	1280	1382	1393	1918	1946	4772
4	463	432	509	468	487	508	503	449	559	574

RUN NUMBER 8557
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	7160.23	5.88	6.4	2.068	1.960	80.26	84.65	62.21	93.68
2	7194.70	5.84	15.5	2.058	1.953	80.65	84.96	62.21	95.38
3	7229.24	5.81	24.6	2.048	1.954	81.04	84.94	62.20	105.14
4	7263.83	5.78	33.7	2.038	1.947	81.43	85.22	62.20	108.21
5	7298.50	5.75	42.8	2.028	1.938	81.82	85.60	62.20	108.45
6	7333.22	5.72	52.0	2.019	1.932	82.21	85.88	62.19	112.72
7	7368.01	5.69	61.1	2.009	1.925	82.60	86.18	62.19	114.64
8	7402.87	5.66	70.2	2.000	1.920	82.99	86.42	62.18	119.51
9	7437.79	5.63	79.3	1.990	1.915	83.38	86.60	62.18	127.23
10	7472.77	5.60	88.4	1.981	1.912	83.77	86.74	62.18	137.74

NOTE TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

RUN NUMBER 8558
MULTI PHASE
08-09-2002
TEST FLUID IS DISTILLED WATER

VOLUMETRIC FLOW RATE	=	.87	GPM
MASS FLOW RATE WATER	=	6.9	LBM/MIN
MASS FLOW RATE GAS	=	1.46	LBM/MIN
MASS FLUX	=	62709	LBM/(SQ.FT HR)
LIQUID VELOCITY	=	.28	FT/S
GAS VELOCITY	=	50.66	FT/S
GAS VISCOSITY	=	387.14E-09	LBM-S/FT^2
INLET TEMPERATURE	=	78.11	F
OUTLET TEMPERATURE	=	87.57	F
RE NUMBER LIQUID	=	2861	
RE NUMBER GAS	=	77173	
AVERAGE PR NUMBER	=	5.67	
CURRENT TO TUBE	=	186.5	AMPS
VOLTAGE DROP IN TUBE	=	4 05	VOLTS
AVERAGE HEAT FLUX	=	2156	BTU/(SQ.FT-HR)
Q=AMP*VOLT	=	5341	BTU/HR
Q=M*C*(T2-T1)	=	5016	BTU/HR
HEAT BALANCE ERROR	=	6 10	%

OUTSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	98.52	96 09	95.13	96.92	97.42	98 55	98.76	99.97	100.40	100.78
2	91.44	87.38	89.90	89.44	91.15	91.02	92.01	91 15	92.22	92.83
3	81.95	82.28	83 01	83.95	84.77	85.40	86.17	86 64	87.42	87.58
4	88.30	87.14	87.49	88.76	89 48	90.13	91.10	92.81	91.84	92.80

INSIDE SURFACE TEMPERATURES - DEGREES F

	1	2	3	4	5	6	7	8	9	10
1	97.76	95.34	94.34	96.15	96.64	97.78	97.98	99.20	99.64	100.01
2	90.58	86.47	89.03	88.55	90.27	90.13	91.12	90.24	91 32	91 92
3	80.95	81.33	82 05	82.99	83.81	84.44	85.21	85.68	86 47	86 62
4	87 39	86.23	86.59	87.86	88.58	89 22	90.20	91.92	90 93	91.90

REYNOLDS NUMBER AT THE INSIDE TUBE WALL

	1	2	3	4	5	6	7	8	9	10
1	3396	3306	3270	3336	3354	3397	3404	3449	3465	3479
2	3134	2988	3079	3061	3123	3118	3154	3122	3160	3182
3	2796	2809	2833	2866	2895	2917	2944	2960	2988	2993
4	3020	2979	2992	3037	3062	3085	3120	3182	3147	3181

INSIDE SURFACE HEAT FLUXES BTU/HR/FT2

	1	2	3	4	5	6	7	8	9	10
1	1303	1297	1359	1325	1344	1322	1343	1323	1314	1324
2	1495	1569	1503	1550	1525	1551	1539	1583	1572	1564
3	1729	1652	1670	1658	1669	1660	1666	1666	1648	1664
4	1575	1575	1565	1568	1568	1574	1563	1541	1581	1564

RUN NUMBER 8558

PERIPHERAL HEAT TRANSFER COEFFICIENT BTU/(SQ.FT-HR-F)

	1	2	3	4	5	6	7	8	9	10
1	68	82	98	90	94	91	97	93	96	101
2	126	230	177	219	193	227	222	309	297	313
3	783	989	1127	1091	1172	1445	1655	2937	3681	-5159
4	182	239	259	245	253	265	260	226	322	315

RUN NUMBER 8558
SUMMARY

ST	RE	PR	X/D	MUB	MUW	TB	TW	DENS	NU
1	2720.86	6.00	6.4	2.107	1.859	78.75	89.17	62.23	38.36
2	2751 65	5.93	15.5	2.083	1 899	79.66	87.34	62.22	51.63
3	2782 97	5.85	24.6	2.060	1.884	80.57	88.00	62.21	53.32
4	2814 23	5.78	33.7	2.037	1.865	81.48	88.89	62 20	53.47
5	2845.63	5.71	42 8	2.015	1.845	82.39	89 82	62.19	51.24
6	2877.16	5.64	52.0	1.992	1.833	83.29	90.39	62.18	55.74
7	2908 83	5 57	61.1	1.971	1.817	84.20	91.13	62 17	57 11
8	2940.63	5 50	70.2	1.949	1.804	85 11	91.16	62.16	59.44
9	2972.56	5 44	79.3	1.929	1.798	86.02	92.09	62 15	65 09
10	3004 62	5.37	88.4	1.908	1 787	86.93	92.62	62 14	69.44

NOTE: TBULK IS GIVEN IN DEGREES FAHRENHEIT
MUB AND MUW ARE GIVEN IN LBM/(FT*HR)

APPENDIX C

UNCERTAINTY ANALYSIS

An analysis of the probable error involved in the experimental data of the two-phase annular flow heat transfer coefficients is calculated and explained in this Appendix. Calculation of the uncertainties is based on the method proposed by Kline and McClintock (1953).

Uncertainty Analysis of Heat Transfer Coefficient

The heat transfer coefficient is defined as:

$$h = \frac{\dot{q}''}{T_{wi} - T_b} \qquad (1)$$

The percent probable error for h is given by:

$$w_h = \left[\left(\frac{d\dot{q}''}{\dot{q}''} \right)^2 + \left(\frac{d\Delta T}{\Delta T} \right)^2 \right]^{1/2} \qquad (2)$$

The heat flux is the product of the voltage drop across the test section and the current carried by the tube. Therefore, the heat flux can be written as:

$$\dot{q}'' = \frac{V_D I}{\pi D_i L} \qquad (3)$$

The uncertainty in the heat flux can then be calculated using the following equation:

$$U_{\dot{q}''} = \left[\left(\frac{dV_D}{V_D} \right)^2 + \left(\frac{dI}{I} \right)^2 + \left(\frac{dD_i}{D_i} \right)^2 + \left(\frac{dL}{L} \right)^2 \right]^{1/2} \tag{4}$$

The uncertainty of each variable was then estimated as follows:

dV_D The voltage was measured by the National Instruments Data Acquisition System and the error of the terminal block was 1%. The two-phase flow heat transfer experimental data had a voltage range of 3.3 to 4.27 volts, and it gives an average error of 0.03785 volts.

dI The amperage was also measured by the National Instruments Data Acquisition System and the error of the terminal block was 1%. The two-phase flow heat transfer experimental data had a current range of 320 to 418.4 amps, and it gives an average error of 3.731 amps.

dD_i The inside diameter of the test section was measured accurately to 0.001 inch using a caliper, and the inside diameter was 1.097 inches.

dL The heated length of the test section was 110 inches and was measured to within 0.0625 inch.

To evaluate the inside wall temperature, T_{wi}, using the appropriate boundary conditions, the heat diffusion equation was solved to render equation 5.

$$T_{wi} = T_{wo} - \left(\frac{\dot{q}}{2\pi \frac{(D_o^2 - D_i^2)}{4} kL} \right) \left[D_o^2 \ln\left(\frac{D_o}{D_i} \right) - \left(\frac{D_o^2 - D_i^2}{2} \right) \right] \tag{5}$$

The bulk temperature at the desired location x is determined by using the following equation:

$$T_b = T_{b,out} - [(T_{b,out} - T_{b,in})(L - x)]/L \tag{6}$$

The uncertainty associated with the quantity ($T_{wi} - T_b$) can be estimated from the following equation:

$$U_t = \left[\left(\frac{|dT_{wo}| + |dT_b| + |dT_2| + |dT_1|}{T_{wi} - T_b}\right)^2\right]^{1/2} \tag{7}$$

where
$$T_2 = -\left(\frac{\dot{q}}{2\pi \frac{(D_o^2 - D_i^2)}{4} kL}\right)\left[D_o^2 \ln\left(\frac{D_o}{D_i}\right) - \left(\frac{D_o^2 - D_i^2}{2}\right)\right] \tag{8}$$

$$T_1 = (T_{b,out} - T_{b,in})(L - x)/L \tag{9}$$

For this analysis, the following uncertainties of each term are as follows:

dT_{wo} The assumed error in the outside wall temperature was estimated to be 0.5 °F (0.3°C) within a range of 32 to 104 °F (0 to 40 °C), which was an ordinary temperature variation during the test run, from the calibration runs for the thermocouples.

dT_b The average bulk temperature deviation was assumed to be 0.5 °F (0.3 °C) within a range of 32 to 104 °F (0 to 40 °C), which was an ordinary temperature variation during the test run, from the calibration runs for the inlet thermal probe and the outlet thermal probe.

dT_2 The deviation ratio, dT_2/T_2 was assumed to be 0.05.

dT_1 The deviation ratio, dT_1/T_1 was assumed to be 0.05.

Applying one of the test runs for single-phase flow heat transfer (at TC station no. 7 of RN8539):

$\dot{q}$ = 4272 Btu/hr $\qquad$ $\dot{q}''$ = 1938 Btu/ft^2-hr

V_D = 3.77 volts $\qquad$ I = 373.3 amps

$T_{b,in}$ = 79.47 °F $\qquad$ $T_{b,out}$ = 82.62 °F

D_o = 1.136 inches $\qquad$ D_i = 1.097 inches

T_{wo} = 84.25 °F $\qquad$ k = 7.5798 Btu/hr-ft-°F

x = 5.92 ft (71 inches) $\qquad$ L = 9.167 ft (110 inches)

Substituting all of the above values into the proper equations, we have

$$T_1 = -0.69166 \text{ °F}$$

$$T_2 = 1.115673 \text{ °F}$$

$$(T_{wi} - T_b) = 2.054\text{°F}$$

These values result in the expected experimental uncertainties of:

$$U_t = \{[(0.5 + 0.5 + 0.05 + 0.05)/2.054]^2\}^{1/2}$$

$$= 0.146056$$

$$U_{\dot{q}''} = [(0.03785/3.77)^2 + (3.731/373.3)^2 + (0.001/1.097)^2 + (0.0625/110)^2]^{1/2}$$

$$= 0.024307$$

$$U_h = [(0.146056)^2 + (0.024307)^2]^{1/2}$$

Finally, the uncertainty for heat transfer coefficient calculations is

$$U_h = 14.8 \text{ \%}$$

From the uncertainty analysis, it can be seen that the maximum error corresponding to the experimental heat transfer coefficient is approximately 14.8 %. As shown in this analysis, the uncertainty in heat transfer coefficient is dominated by the accuracy of the measurement of temperatures.

2

VITA

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