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**ENHANCED BOILING HEAT TRANSFER
IN HORIZONTAL TEST BUNDLES**

Topical Report

By R. R. Trewin, M. K. Jensen, A. E. Bergles

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NOMENCLATURE

A_s	heat transfer surface area of single tube, m^2
A_{min}	minimum cross-sectional flow area, m^2
A_t	total surface area of heated tubes, m^2
c_p	specific heat at constant pressure, $J/Kg \cdot K$
D_o	tube outside diameter, m
F	maximum number of independent, intensive variables required to specify the thermodynamic state, equation (4.17)
g	gravitational constant, 9.81 m/s^2
G	mass flux, $kg/m^2 \cdot s$
h	heat transfer coefficient, $W/m^2 \cdot K$
h_n	local heat transfer coefficient at row n , $W/m^2 \cdot K$
$\bar{h}$	bundle averaged heat transfer coefficient, equation (4.30), $W/m^2 \cdot K$
i	enthalpy, J/kg
I	electrical current, A
k	fluid thermal conductivity, $W/m \cdot K$
L	tube length, m
m	number of species in mixture, equation (4.17)
$\dot{m}$	mass flow rate, kg/s
n	tube row number
Nu	Nusselt number based on tube inside diameter, hd/k
p	tube pitch, m
P	pressure, kPa
Pr	Prandtl number, $\mu c_p/k$

q''	heat flux for an individual tube, W/m ²
q''_n	heat flux for an individual tube at row n, W/m ²
Q_{1-n}	total heat transfer rate from tube s in rows 1 through n, W
Q_{tot}	total heat transfer rate, W
r	radial coordinate, m
R_{tc}	radial distance from tube axis to thermocouple location, m
Re	Reynolds number based on minimum flow area, $\dot{m}D_o/A_{\text{min}}\mu$
T_{fv}	temperature at flashing valves, °C or K
T_l	local liquid temperature, equation (3.20)
T_{sat}	saturation or bubble point temperature, K
T_{tc}	local temperature at thermocouple, °C or K
T_w	local tube surface temperature, °C or K
$T_{w,\text{ave}}$	tube average wall temperature, °C or K
ΔT_{sat}	arithmetic—mean difference between tube wall and saturated fluid temperature, K
V	electrical voltage, V
$\dot{V}$	volume flow rate, m ³ /s
x	thermodynamic quality
x_n	thermodynamic quality at tube row n
y_i^l	mass fraction in the liquid phase of component i, kg/kg
y_i^v	mass fraction in the vapor phase of component i, kg/kg
$y_{b,i}^l$	overall mass fraction of component i in the fluid, kg/kg
$\tilde{y}_i^l$	mole fraction in the liquid phase of component i, kmol/kmol
$\tilde{y}_i^v$	mole fraction in the vapor phase of component i, kmol/kmol
$\tilde{y}_{b,i}^l$	overall mole fraction of component i in the fluid, kmol/kmol

Greek Symbols

α	thermal diffusivity, $k/\rho c_p$, m^2/s
Δ	difference
μ	viscosity
ν	viscosity
ρ	density, kg/m^3
σ	surface tension,
Σ	summation
φ	number of phases

Subscripts

ave	average
f	saturated liquid or bubble point
fg	difference in property for saturated vapor and saturated liquid
fv	flashing valve
in	inlet
j	pressure tap location
L	liquid
n	tube row
sat	saturated liquid
t	tube
tc	thermocouple
v	vapor

Superscripts

'	liquid phase
"	vapor phase
~	molar property

CHAPTER 1

INTRODUCTION AND HISTORICAL REVIEW

In the United States the production of new heat exchangers is a \$1.7 billion industry (Frost and Sullivan 1992) and is a \$2.9 billion industry in Western Europe. The type of heat exchangers include shell-and-tube, coils, and plate and frame configurations, among others, with roughly half of the new heat exchangers being produced of the shell-and-tube configuration. Indeed, shell-and-tube heat exchangers represent the most widespread and commonly used heat exchanger configuration in the process industries (Bell 1986) and can be found in the chemical, petroleum, power, and air conditioning/refrigeration industries. These shell-and-tube heat exchangers commonly employ two-phase heat transfer and Hewitt (1981) estimates that at least 60% of all process industry heat exchanger equipment involves two-phase flow. It is not surprising, then, that shell-and-tube heat exchangers with shellside boiling are used extensively in a variety of applications. For example, a recent review of shellside boiling with crossflow in horizontal multitube bundles (Jensen 1989) lists, among the many applications, kettle and thermosyphon reboilers, submerged evaporators, waste heat boilers, and steam generators. In particular, horizontal shellside thermosyphon reboilers and kettle reboilers are commonly used in petroleum and chemical processing plant to vaporize process fluid mixtures and in the production of cryogenic fluids and have substantial advantages over vertical tube units (Yilmaz 1987). Additionally, the horizontal configuration is also used in waste heat boilers and in direct expansion chillers in large refrigeration systems.

Frost and Sullivan (1992) report that the heat exchanger industry is "mature, cyclic and fragmented" and that product differentiation is practically nonexistent. This is due, at least in part, to inadequately developed design techniques which, according to Palen (1983), are due to a lack of data in the open literature on multitube bundles. The present design of these heat exchangers is conservative because the boiling heat transfer and two-phase pressure drop behavior of multitube bundles is not well known when the flow is perpendicular to the tubes (Jensen 1988). Design techniques have been established which conservatively predict the average or overall performance of the tube bundle, but knowledge of what is occurring at individual tubes is ignored. Niels (1979) found that large design improvements are possible and that some design procedures result in an overdesign of kettle evaporators by 300%.

Because shellside boiling from horizontal tube bundles is commonly used, even modest improvements in the design of shell-and-tube heat exchangers with shellside boiling could result in large savings. One improvement would be to use enhanced tubes in the bundle rather than smooth tubes. There are several ways to obtain energy savings from an enhanced tube heat exchanger. Enhanced heat exchangers can make use of smaller temperature driving potentials between the heat source and the working fluid, thus lowering the operating costs. When a given temperature difference is available, the savings can result from an increase in the heat flux at the heated surface; the savings can be realized through the use of smaller heat exchangers which use less material and require less fabrication effort and which reduce shipping, installation, and maintenance costs. In addition, smaller heat exchangers can be designed so that the pumping power can be reduced resulting in a direct energy savings.

For shell—and—tube heat exchangers, enhanced boiling heat transfer surfaces present the possibility of especially large savings. The possibility exists of saving over \$300 million annually by using enhancement techniques (Robello 1986). Ragi and O'Neill (1980) report several examples of very substantial savings. Reboilers were retrofitted with tubes having sintered surfaces and the payback periods were one or two months. Arai et al. (1977) also report substantial savings when using enhanced surfaces in refrigeration applications.

In addition to financial savings, more efficient heat exchangers can help address issues concerning the environment. As demands on the world's energy resources increase and the negative impact of our present methods of energy usage on the environment becomes more and more critical, the need for methods of reducing our energy usage becomes more urgent. Strategies for reducing energy consumption that could be implemented relatively quickly include the increased usage of enhanced surfaces in shell—and—tube heat exchangers. The use of enhanced surfaces also could result in decreasing the size of heat exchangers that contain potentially damaging fluids, thus reducing the risk to the environment in the case of leaks.

The elimination of CFC's in refrigerating/air—conditioning equipment will probably result in the increased use of refrigerant mixtures as replacements. Therefore, the performance of tubes with enhanced surfaces in fluid mixtures will need to be determined in order for the cost savings mentioned above to be extended to new, environmentally benign refrigeration and air—conditioning equipment.

Before the large savings mentioned above can be widely realized, the overall performance of heat exchangers with enhanced horizontal tube bundles needs to be investigated further. Information about the flow behavior, heat transfer

characteristics, and pressure gradients at particular locations within a tube bundle is needed in order to develop better designs and more efficient heat exchangers.

Additional information on the heat transfer performance of smooth and enhanced tubes in mixtures of miscible, volatile fluids is required in order to better design the heat exchangers common in the chemical, process, and air-conditioning industries.

Therefore, this study will investigate the local heat transfer performance of individual tubes in a horizontal tube bundle in order to better understand the mechanisms involved in boiling heat transfer from horizontal tube bundles with enhanced surfaces.

Background

The information required to achieve the improved designs mentioned above can be determined once the extent of the present knowledge has been ascertained. The current knowledge regarding the parametric trends for heat transfer coefficients in tube bundles is discussed along with the information available in the open literature concerning the governing mechanisms. The available mechanistic models will be discussed. Nucleate pool boiling from single tubes is often the reference data to which the data obtained in tube bundles are compared and, therefore, will also be presented.

Kettle and full bundle reboilers (Fig. 1.1) are common types of shell-and-tube heat exchangers which incorporate shellside boiling with crossflow in horizontal multitube bundles. The full bundle reboiler is a one-pass heat exchanger where the pressure drop is imposed across the tube bundle and the flow is predominantly in one direction. In the kettle reboiler, the tube bundle occupies only

Figure 1.1. Schematics of (a) kettle and (b) full bundle reboilers.

a portion of the total cross section of the shell. The vapor and liquid mixture in the interior of the bundle flows upward but the liquid at the sides of the shell flows downwards due to the hydrostatic driving head. Therefore, a recirculating flow is established in a kettle reboiler.

Early designers of kettle reboilers based their thermal design on single-tube pool boiling correlations with correction factors to account for the influence of tube bundle dimensions and geometry (Niels 1979). However, initial investigations into heat transfer coefficients for horizontal tube bundles (Palen and Taborek 1962) showed that the heat transfer coefficient, based on inexact plant data, was smaller than that for a single tube in pool boiling. Using more accurate data, it was later found that the average heat transfer coefficient, given as a function of the heat duty and overall driving temperature difference, for a bundle of plain tubes was larger than for a single plain tube (Palen et al. 1972). Unfortunately, this overall approach to the evaluation of shellside boiling did not provide enough information to shed any light on what was actually occurring at different locations in the bundle. This lack of quantitative information prompted research into the local values for heat transfer coefficients within the tube bundle.

Boiling on Single, Smooth, Horizontal Cylinders

In order to determine the effects on a tube in a bundle due to the presence of surrounding tubes, Hwang and Yao (1984) and Wege and Jensen (1984) proposed studying a single tube in pool and forced convection boiling. In this way, different parameters could be accurately known and the effects could be separated. These separate effects could then be combined into a general design technique. In addition, nucleate pool boiling from a single, horizontal tube is frequently used as a reference

point from which to evaluate the effect of the tube bundle on the local heat transfer enhancement or as an input parameter for correlating the heat transfer coefficients of horizontal cylinders in tube bundles with crossflow. Although single tubes with enhanced boiling surfaces have been researched extensively (Bergles 1978, Webb 1981), more information is needed on the use of these tubes in bundles.

Yilmaz and Westwater (1980) investigated pool and forced convective boiling from single horizontal cylinders and found that the forced convective heat transfer coefficient increased with liquid velocity. The total forced convective heat flux could be estimated by simply adding the nucleate pool boiling heat flux and the single-phase, forced convective heat flux. Fand et al. (1976) also found an increase in the forced convective heat transfer coefficient with increasing liquid velocity.

Bitter (1972) conducted experiments in R-11 with heat flux values less than 30 kW/m^2 and found an increase in the forced convective heat transfer coefficient with increasing liquid velocity and with the addition of vapor in the upstream liquid flow. This is consistent with the results of McKee and Bell (1969) who found that the forced convective heat transfer coefficients were not significantly different from the pool boiling values except at heat fluxes lower than 30 kW/m^2 and at velocities greater than 1.64 m/s (5.4 ft/sec). Hwang and Yao (1984), who performed experiments in R-113, found similar results in that the forced convective heat transfer coefficients were not significantly different from the pool boiling values when the boiling became fully developed (at heat fluxes lower than 20 kW/m^2 for velocities less than 0.235 m/s). In addition, Hwang and Yao (1984) and Wege and Jensen (1984) found that increasing the upstream quality of a two-phase mixture increased the heat transfer coefficient significantly at low heat fluxes, but that the effect of the upstream quality decreased with increasing heat flux.

Pool Boiling from Cylinders with Enhanced Surfaces

A number of enhancement technologies are reported in the literature (Bergles 1981). In particular, some of the most common enhanced surfaces are Wieland's Gewa-T, Hitachi's Thermoexcel-E, Wolverine's Turbo-B, and Linde's High Flux shown in Fig. 1.2. Pais and Webb (1991) have compiled a literature survey of pool boiling on single tubes with enhanced surfaces that are produced by rolling the surface (see Fig. 1.2b,c,d), and by sintering small particles to the surface (see Fig. 1.2e). Pais and Webb report that the enhanced surfaces perform significantly better than smooth tubes, often by an order of magnitude.

Pool boiling heat transfer from horizontal tubes with enhanced surfaces was also reported by Yilmaz et al. (1980) who found that the heat transfer from enhanced surfaces can be an order of magnitude larger than that from smooth tubes (Fig. 1.3). The increased heat transfer possible with enhanced tubes over smooth tubes makes them a strong candidate for use in tube bundles also.

A possible disadvantage of using enhanced surfaces is the delayed onset of nucleation resulting in a boiling curve hysteresis. Pool boiling from horizontal tubes with a porous metallic coating was investigated by Bergles and Chyu (1982) who first reported a large boiling curve hysteresis for this surface in wetting fluids (Fig. 1.4). Possible explanations include the reduced tendency for vapor from the first nucleation sites to spread over the surface and activate other nucleation sites.

Shellside Boiling on Smooth, Horizontal Tube Bundles

Investigations have been performed on tube bundles in natural circulation; individual tubes in the bundle were instrumented to obtain the distribution of local heat transfer coefficients. The results from a number of investigations have shown

Enhanced boiling surfaces.

- a. Rolled-over low fins.
- b. Tunnel-and-pore arrangement.
- c. Flatened low fins.
- d. Knurled low fins (Turbo-B).
- e. Sintered porous metallic matrix surface (High Flux).

Figure 1.2. Schematic of enhanced surfaces (Bergles 1988).

Figure 1.3. Pool boiling performance for smooth and enhanced tubes (Yilmaz et al. 1980).

Figure 1.4. Boiling curve hysteresis for High Flux tubes (Bergles and Chyu 1982).

that there is generally an increase in the local heat transfer coefficient with each downstream tube as compared to a single tube in established nucleate pool boiling (Cornwell et al. 1980, Cornwell and Schuller 1982, Wallner 1971, Nakajima 1978) and that the variation in heat transfer coefficients throughout the bundle decreased with increasing heat flux (Grant et al. 1980). Unfortunately, the local quality and mass flux were not known. The difficulty in quantifying the effect of these parameters has prompted studies where a section of a tube bundle was modeled with forced convection (Polley et al. 1980, Hwang and Yao 1986, Jensen and Hsu 1987, Robinson and Katz 1951, Meyers and Katz 1953). This allowed for the mass flux and local values of quality to be calculated.

As a result of these studies and those in natural circulation, it is believed that either a thinning of the liquid film next to the heated surface (thin film vaporization), increased turbulence, or larger induced liquid velocity caused by an increase in the void fraction is responsible for the increased heat transfer coefficient as compared to pool boiling at low heat fluxes. Most of the suggested models correlate the governing heat transfer mechanism by using the nucleate pool boiling mechanism alone or by superimposing two or three of the mechanisms using various weighting factors. The methods that have been used to model tube bundles thus far superimpose (1) a nucleate pool boiling and a liquid phase convection component, (2) a thin film vaporization and a nucleate pool boiling component, or (3) a nucleate pool boiling, a liquid phase convection, and a thin film vaporization component (Nakajima 1978, Cornwell 1990, Fujita et al. 1990). These models are discussed below.

Nucleate pool boiling and single-phase convection. When nucleate pool boiling and convection are superimposed, the larger heat transfer coefficient

(relative to pool boiling) at low heat fluxes is attributed to increased convection due to the two-phase flow analogous to enhancement for single-phase convective flow at increased fluid velocities. On the other hand, at high heat fluxes, the similarity between a single tube in fully established pool boiling and a tube in a bundle is attributed to the convection effects being dominated by the nucleation effects at the tube surface. Therefore, correlations used to predict local heat transfer coefficients in a tube bundle usually incorporate a trade-off between the nucleation and the convection effects.

Many of the existing correlations for tube bundles are similar to correlations for flow inside a tube and usually fall into one of two categories. The first type calculates the heat transfer coefficients from convection and nucleation separately and then adds the contributions together. Chen (1966) proposed a correlation for flow inside a tube which has been extended to tube bundles (Palen and Yang 1983, Hwang and Yao 1986, Jensen and Hsu 1987). The second type correlates the ratio of the two-phase heat transfer coefficient to the single-phase liquid heat transfer coefficient as a function of the Martinelli parameter (to characterize convection) and the Boiling number (to characterize nucleation). However, such correlations, similar to those by Kandlikar (1990) and Shah (1982), have not been extended to tube bundles.

Nucleate pool boiling and thin film vaporization. In the case where nucleate pool boiling and thin film vaporization are superimposed, as in the model by Nakajima (1978), the nucleate pool boiling component is weighted using the void fraction as a multiplier and the thin film vaporization component is weighted using the liquid fraction as a multiplier. Nakajima's model includes an average thickness of the film between the vapor bubbles and the tube wall; an expression for the film

thickness was developed from theoretical considerations and experimental data for bubble size, velocity, and frequency. The author also gives an expression for the void fraction, but it is limited to the tube bundle used in the experiments.

Nucleate pool boiling, single-phase convection, and thin film vaporization.

Cornwell (1987) has developed a third type of model to include all of the three components mentioned above, thereby extending the ideas of Nakajima. The total heat transfer coefficient is the sum of the components due to nucleation, convection, and thin film vaporization occurring under bubbles which slide around the perimeter of the tube. He calculated the thin film vaporization component of the heat transfer and showed that nucleate boiling was much smaller than thin film vaporization for downstream tubes at low heat fluxes.

The success of the methods listed above for correlating heat transfer coefficients for smooth tubes has been limited. Polley et al. (1980) and Hwang and Yao(1988) report an ability to predict their own data to within $\pm 20\%$, but a modified Chen's method can be used as a design tool with an expected accuracy of $\pm 40\%$ (Jensen 1988). Less effort has been made to correlate local heat transfer coefficients in a tube bundle for enhanced surfaces. Müller and Hahne (1981) have developed a correlation for bundle-average heat transfer coefficients for tubes with a finned surface, but did not obtain a correlation for local values. Even less work has been done to predict local heat transfer coefficients in a bundle of tubes having sintered or knurled surfaces.

For these models, the average vapor and liquid velocities are needed in order to evaluate the component parts of the correlations. For example, Cornwell's model requires that the single-phase convection be calculated using the local liquid velocity derived from the void fraction, and Nakajima's model correlates the thin

film vaporization heat transfer coefficient as a function of the superficial vapor velocity which can be calculated knowing the void fraction. Unfortunately, data reported on local void fractions in horizontal tube bundles are limited (Schrage et al. 1987, Dowlati et al. 1988, Chan and Shoukri 1987) which seriously limits the ability to verify these correlations. Therefore, the results of these correlations must be considered to be speculative.

Shellside Boiling on Horizontal Tube Bundles with Enhanced Surfaces

There has been less research on the use of enhanced surfaces in tube bundles than for smooth tubes. The studies generally have been conducted on finned, cold-worked, and porous surfaces. The works of Meyers and Katz (1953), Danilova and Dyundin (1972), Hahne and Mueller (1983), and Yilmaz and Palen (1981) have shown that the enhanced convection due to the rising bubbles has the same effect on the performance of bundles of finned tubes as on bundles of smooth tubes. In particular, heat transfer coefficients increase with tube row at low heat fluxes, but the variation with tube row decreases with increasing heat flux.

Of more interest is the performance of tubes with formed and sintered surfaces. Stephan and Mitrovic (1981) compared the performance of tubes with finned surfaces to tubes with T-shaped fins having approximately the same surface area (the Gewa-T surface). The Gewa-T surface performed significantly better than the finned surface. The enhancement was attributed to vapor traveling around the tube perimeter before leaving at the top resulting in increased thin film vaporization in the channel. In addition, the value of the heat transfer coefficient was not found to vary with the position in the bundle.

Arai et al. (1977) investigated the heat transfer coefficients of tubes having the Thermoexcel-E surface and compared heat transfer coefficients of single tubes with those from tube bundles. In addition to determining an optimum pore size, they reported larger values of the average heat transfer coefficient for the bundle than for single tubes. This is in contradiction with the results of Yilmaz et al. (1981) who investigated the performance of the Gewa-T surface. They found that the heat transfer coefficients from tube bundles were the same or even less than those from single tubes. They attributed this decrease to a suppression of nucleate boiling. In addition, the heat transfer coefficients from the tubes with enhanced surfaces were greater than those from tubes with smooth surfaces both in a tube bundle and as single tubes.

Tubes with porous surfaces, such as Union Carbide's High Flux, have been of particular interest due to the large heat transfer coefficients obtainable (Czikk et al., 1970 and O'Neill et al., 1980). Koyama and Hashizume (1983) and Fujita et al. (1984) have reported that the heat transfer coefficients for a tube bundle were the same as for a single tube. The lack of any additional enhancement due to convective effects is the result of the nucleation-dominated heat transfer mechanism for this surface. The heat transfer process occurs in the subsurface cavities where the free stream has little effect.

Boiling on Horizontal Tubes in Fluid Mixtures

Heat transfer coefficients in pool boiling of miscible mixtures may be much lower than could be expected from the data for boiling in the individual components of the mixture. Stephan (1982) offers several explanations for this phenomenon. The vapor from the boiling process is richer in the more volatile component, leaving

the liquid next the heated surface richer in the less volatile component. The local boiling temperature increases as does the surface temperature. However, the heat transfer coefficient is based on the bubble point of the bulk fluid and does not account for the increased boiling temperature next to the heated surface. Therefore, the increased surface temperature results in a lower heat transfer coefficient.

Additional mechanisms exist to explain the decrease in the heat transfer in mixtures compared to pure fluids. According to Thome and Shock (1984), the bubble growth rate in binary mixtures is reduced, the bubble radius is increased, and the bubble frequency decreases when the difference in mole fraction between vapor and liquid composition increases (but also depends on the heat flux).

Fink et al. (1982) measured the forced convective flow boiling heat transfer coefficients in a mixture of R-113 and R-11 for various degrees of subcooling. In general, the degradation in multicomponent heat transfer coefficients was found to increase with increasing heat flux. Alpay and Balkan (1989) performed experiments on smooth and finned surfaces and found that the degradation in multicomponent heat transfer coefficients increased with the difference between the vapor and liquid composition for the most volatile component. Similar results were found by Bajorek et al. (1989).

Shellside Boiling on Tube Bundles in Fluid Mixtures

Very few investigations into boiling from horizontal tube bundles in multicomponent fluids are reported in the open literature. Montgomery and Park (1971) and Wall and Park (1978) investigated the performance of a bundle of four smooth tubes boiling in a miscible mixture. Wall and Park (1978) reported that the reduction in the heat transfer coefficients in the mixture as compared to those for

pure components is greater for larger values of wall to bulk fluid temperature differences. No reports of investigations into boiling from horizontal tube bundles with enhanced surfaces in multicomponent fluids could be found.

Conclusions

The parametric trends in the heat transfer coefficients with varying heat flux, mass flux and quality have been explored for pool boiling and boiling in tube bundles. Phenomenological models have been proposed but have not been able to satisfactorily predict the data mentioned above.

A variety of parameters have been used to predict the convection mechanism (which is the dominant mechanism at low heat fluxes and mass fluxes), e.g. convection number, single-phase heat transfer coefficient, Martinelli parameter, and thin film convection heat transfer coefficient. Likewise, boiling number and established nucleate pool boiling heat transfer coefficient have been used to characterize the nucleation component (which is the dominant component at high heat fluxes when the transfer coefficient is only slightly dependent on quality). However, because different models incorporating different parameters each are able to predict the two-phase heat transfer coefficients, at least qualitatively, the mechanisms governing the two-phase heat transfer for horizontal tube bundles in crossflow have not been established. Although nucleation has been fairly well established as the dominant mechanism at high heat fluxes (where the heat transfer coefficient is a weak function of quality), both single-phase convection and thin film vaporization are able to explain qualitatively the phenomena at low heat fluxes (where the heat transfer coefficient is a strong function of quality). Hence, the transition boundaries between the dominant mechanisms have not been established

so that there is difficulty in determining which parameters to correlate in addition to how to correlate them.

There are very few data on the performance of sintered surfaces and even fewer on knurled surfaces in tube bundles. Some researchers have found that tubes with enhanced surfaces perform better in a bundle than as single tubes while others have found just the opposite. Forced convection does not affect the heat transfer coefficients of enhanced tubes as much as smooth tubes, apparently because the heat transfer mechanisms take place in the subsurface cavities where the free stream cannot intrude. The small variation with heat flux on the heat transfer coefficient for the Turbo-B surface has not been explained.

Scope of Investigation

Based on the conclusions of the literature survey, the performance of individual, enhanced tubes in a bundle needs to be established. The purpose of this research effort is to investigate enhanced boiling heat transfer in horizontal tube bundles in pure fluids and fluid mixtures. The local heat transfer coefficients throughout the tube bundle will be determined experimentally so that detailed information can be obtained regarding the effect of important operating parameters.

The parametric trends of the heat transfer coefficients will be determined for varying pressures, mass fluxes, and heat fluxes so that their effects on the heat transfer coefficient for smooth and enhanced tube bundles can be determined. In addition, the effect of different tube bundle layouts and surface geometry on the local heat transfer coefficients will be investigated; two staggered tube bundles will be tested using smooth, Linde High Flux, and Wolverine Turbo-B surfaces.

Furthermore, the performance of both the smooth and enhanced tubes will be investigated in tube bundles and pool boiling when the working fluid is a binary mixture. The experimental results will be examined in order to establish the dominant heat transfer mechanisms and to determine important design parameters. It is hoped that this information will allow for more precise design procedures and promote the adoption of enhanced surfaces in heat exchangers with boiling on the shellside of horizontal tube bundles.

This work will determine what the important mechanisms are in two-phase heat transfer on horizontal bundles of plain and enhanced tubes in a vertical crossflow, how they interact, and what conditions are needed for one of the possible mechanisms to dominate. This information will be used to help correlate the heat transfer coefficients for these tubes. The parametric trends for different flow and operating conditions for plain and enhanced tubes will be established experimentally, and some detailed observations of the flow structure around individual tubes will be made to gain additional insight into the participating mechanisms. The necessary insight into the hydrodynamics around a tube in a bundle will be gained by visual observations of the flow and through the use of high-speed photography and video recordings.

The determination of the local phenomena will be facilitated by examining how surrounding tubes influence a tube in a tube bundle. Measuring the heat transfer coefficients for a single tube will provide a basis for comparison with the results for a tube in a bundle. In order to establish the performance of a single tube, experiments involving single tubes in pool boiling will be conducted. The pool boiling heat transfer data will then be used to select the optimum surface structure for the enhanced surfaces and it also will be used as reference values for determining

the effect of surrounding tubes on a tube in a bundle. In addition, pool boiling heat transfer characteristics are frequently used in tube bundle correlations.

In order to establish the performance of enhanced tubes in tube bundles, the parametric trends of the local heat transfer coefficients will be determined for varying operating parameters. A test chamber containing a horizontal tube bundle will be used to measure the heat transfer coefficients from individual tubes in vertical crossflow. The test chamber will allow the total mass flux and heat flux to be measured so that the local quality can be measured. Two different system pressures will be used along with two different tube bundle layouts (pitch-to-diameter ratios of 1.50 and 1.17). Pure refrigerants and refrigerant mixtures will be used in order to quantify the effect of fluid mixtures on the heat transfer coefficients. Hence, heat transfer coefficients in staggered bundles of varying pitch-to-diameter ratios, mass fluxes, heat fluxes, pressures, and qualities will be investigated for plain, cold worked and sintered surfaces.

Pool boiling experiments will provide heat transfer coefficients for single tubes in pure refrigerants and refrigerant mixtures at near atmospheric pressure. These data will provide the necessary information for selecting the optimum enhanced surfaces and for establishing the effect of the surrounding tubes in a tube bundle on the heat transfer coefficients for individual tubes.

The information described above will be used to correlate the heat transfer coefficients in bundles of enhanced tubes. The correlations thus obtained would be helpful in modeling shell-and-tube heat exchangers of the once-through cross-flow type where the horizontal components of the flow are small compared to the vertical components. Modeling the entire bundle of a shell-and-tube heat exchanger of the

kettle reboiler type is difficult with this type of analysis due to the two-dimensional nature of the recirculating flow. However, valuable insight can be gained into the phenomena occurring in much of the center of the bundle, where the flow becomes predominantly vertical.

CHAPTER 2

POOL BOILING APPARATUS AND DATA ACQUISITION/REDUCTION

In order to determine the relationship between the thermal performance of a single tube and a tube in a bundle, reference data were collected for single tubes in pool boiling. A pool boiling apparatus was used to collect pool boiling data for single, horizontal tubes having smooth or enhanced surfaces. Data were collected so that the differences in the performance between the different types of enhanced and smooth tubes could be ascertained along with insight into the mechanisms involved in the heat removal process. In addition, the precision of the pool boiling apparatus was sufficient to discern any appreciable difference in data collected from enhanced tubes differing only in the porosity of the surface.

The experimental apparatus provided a constant heat flux to instrumented tubes mounted horizontally in a pool of refrigerant or refrigerant mixtures. The apparatus permitted data to be collected in saturated fluids at near atmospheric pressure and at heat flux values up to 10^5 W/m^2 . The instrumentation allowed for the measurement of the tube wall temperatures, electric resistance heating power, the pressure at the test section, and fluid temperature so that the heat flux and wall superheats could be obtained.

Experimental Apparatus and Instrumentation

The thermal performance of single tubes having smooth and enhanced surfaces was determined in the pool boiling apparatus so that the effects of

surrounding tubes could be eliminated. The general pool boiling apparatus shown in Fig. 2.1 was designed similar to the one used by Bergles and Chyu (1982) and is described in detail by Jung and Bergles (1989). It consists of a Pyrex tank containing a water bath and a smaller Pyrex tank that contains the refrigerant and the test section. The electrically-heated cylindrical test section was mounted to a rigid, vertical supporting wall on one end and was insulated with a Plexiglas plug on the other end. Electrical connections supplying the power to the test section were inserted through the lid of the smaller Pyrex tank along with the thermocouple wires used to instrument the test section and measure the fluid temperature. A cooling coil was mounted just below the lid of the tank and had cold water circulating through it so that the refrigerant vapor condensed and refluxed back into the pool. In addition, an open reflux condenser was inserted through the lid which ensured that atmospheric pressure was maintained at the surface of the refrigerant without allowing refrigerant vapor to escape. The refrigerant in the smaller tank was insulated by surrounding it with constant temperature water in the larger tank. Water from the bath tank was recirculated through an external, temperature-controlled source that kept the water at 1 to 2° C above the saturation temperature of the refrigerant.

The test section was manufactured out of a copper cylinder 120.7 mm long with an outside diameter of 19.1 mm and an inside diameter of 6.4 mm. The test section with the High Flux surface was mounted in the same way as in the tube bundle apparatus (see Fig. 2.2). Therefore, the sealing method which was required for the tube bundle experiments also was used in the pool boiling experiments even though sealing was not required. One end of the cylinder was machined down to create a neck 19.1 mm long, with an outside diameter of 15.1 mm, which

Figure 2.1. Pool boiling apparatus (Jung and Bergles 1989).

Figure 2.2. Test section schematic for the High Flux tubes.

protruded through the mounting wall. The neck was machined with a snap-ring groove and was inserted through the mounting plate. A snap ring secured the shoulder of the test section to the mounting plate so that they were kept perpendicular to each other. The mounting plate had an o-ring groove machined in it, and an o-ring was used to provide a seal between the test section and the mounting plate.

The test sections with the smooth and Turbo-B surfaces were mounted differently than what was used for the High Flux test sections. These tubes were attached to the mounting wall using two threaded screws as shown in Fig. 2.3. The test sections were insulated from the mounting wall with a Buna-N gasket.

The test sections were instrumented with thermocouples inserted into four thermocouple wells as shown in Fig. 2.2 (a). The thermocouple wells were manufactured by drilling four holes located 90 degrees apart in the tube parallel to the axis from the end of the tube neck to a location halfway to the end of the heated surface. A relatively large hole 2.39 mm in diameter was drilled so that a sufficiently rigid drill bit could be used to provide a straight thermocouple well. Sleeves made from small copper tubing, with an outside diameter approximately equal to the diameter of the thermocouple well (to provide a snug fit), were forced into the wells as shown in Fig. 2.2 (b). The inside diameter of the sleeves was equal to 0.91 mm which provided for a snug fit between the sleeve and the 36-gage T-type (copper-constantan) thermocouple wire. T-type thermocouples were manufactured in an inert environment and were calibrated to within 0.1°C . The thermocouple beads were pressed against the bottom of the thermocouple wells, and the thermocouples were secured to the test sections with epoxy.

Figure 2.3. Test section schematic for the smooth and Turbo-B tubes in pool boiling (Jung and Bergles 1989).

Test section heating was provided by inserting a 101.6 mm long, 6.35 mm diameter, 500W electric resistance cartridge heater into the test section, and power was supplied from a 0–120V variable transformer. The cartridge heater was manufactured 0.05 mm smaller in diameter than the inside diameter of the test section to provide a snug fit and a uniform heat flux from the heater to the copper tube. Both ends of the test section were sealed to the cartridge heater with epoxy.

The current supplied to the cartridge heater was measured using a 15 A/100 mV shunt. The voltage across and current supplied to the cartridge heater were measured with a Hewlett–Packard family 9000, model 310 computer and an HP–3241A data acquisition system. In addition, the data acquisition system measured the temperature of the refrigerant, the water bath, and the four test section wall temperatures. The atmospheric pressure was determined using a precision mercury barometer, and a precision manometer was used to verify that the pressure difference between the room and the vapor space inside the apparatus was negligible.

When experiments involving refrigerant mixtures were performed, three test sections, one with each type of surface, were attached to the mounting plate 0.1254 m apart so that the tests for each surface could be completed without removing the lid and allowing the concentration to change. Tests with three smooth tubes in pure refrigerant were conducted to ensure that the multiple mounting did not affect the heat transfer coefficients.

Operating Procedure and Data Reduction

Experiments were conducted in pure R-113, pure R-11, and three mixture concentrations: 25%, 50%, and 75% of R-113 by mass. Because R-11 was the pure fluid used just prior to the mixture tests, mixture concentrations were determined by measuring the volume of R-113 added to the pool. Prior to each set of experiments for a particular concentration, a volume of refrigerant was removed and a measured volume of pure R-113 was added so that the mixture concentration could be calculated.

Prior to taking data for each test section, the pool of refrigerant was heated to the saturation temperature and degassed by heating the pool with the test section and the water jacket. The test section boiled at a heat flux of approximately 30 kW/m^2 for at least 30 minutes in order to degas the refrigerant. The removal of dissolved gas from the refrigerant was necessary to prevent early nucleation from the tube surface.

The power to the cartridge heater was then turned off and the temperature of the test section was allowed to decrease to the saturation temperature. Power was then supplied again to the test section, and the temperature of the test section and pool were allowed to come to steady state. The criterion used for steady state was a change of less than 0.1% over 30 seconds for all the voltages and temperatures measured.

After the data were taken and stored, the power to the cartridge heater was increased slightly, and the temperature of the test section again was allowed to come to steady state. This procedure was repeated for each data point until the maximum cartridge heater power was reached. The power to the cartridge heater

was then decreased slightly and the temperature of the test section and the pool were again allowed to come to steady state. In this way, data were taken at different heat flux values as the power was decreased. The experiment for a particular test section was complete when the minimum power to the cartridge heater was reached.

The values for the heat transfer coefficient are obtained by dividing the heat flux by the difference between the average tube surface temperature and the saturation temperature of the fluid:

$$h_t = q_t / (T_w - T_{\text{sat}}) \quad (2.1)$$

The heat flux was calculated by dividing the power supplied to the cartridge heater by the area of the heated surface. For the enhanced surfaces, the surface area was calculated using the radius to the outside of the enhanced surface structure. The power supplied was calculated using the voltage across and the current through the cartridge heater. Specifically,

$$q_t = (V_t I_t) / A_t \quad (2.2)$$

where

$$I_t = (1/15) V_{\text{sh}} \quad (2.3)$$

The right-hand side of equation (2.3) includes the precision resistance value (1/15) for the shunt in ohms.

The surface temperature of the test section wall was calculated using the one-dimensional conduction equation for a cylinder:

$$T_w = T_{tc} - \frac{q_t D_t}{2 k_t} \ln(D_t / d_{tc}) \quad (2.4)$$

Equation (2.4) assumes that the heat flux is uniform, which was ensured by providing a snug fit between the cartridge heater and the test section.

The saturation temperatures for the two pure fluids, R-113 and R-11, were evaluated as a function of pressure through the use of the property tables listed in ASHRAE (1985) and verified experimentally as described in Appendix D. When the working fluid was a mixture of R-113 and R-11, the bubble point was used in place of the saturation temperature. The bubble point was measured using a thermocouple placed in the bubbly flow just above the test section during the degassing process, and is described in Appendix D. The pressure at the center line of the test section was calculated by adding the hydrostatic pressure contribution (calculated using the nominal height of liquid above the test section) to the measured atmospheric pressure.

The temperature measurements as input from the data acquisition system were calibrated experimentally to 0.1° C. As seen in equation (2.4), the wall temperature is a function of the temperature at the thermocouple location, heat flux, thermal conductivity, and location of the thermocouple. A propagation-of-uncertainty analysis was performed and is given in Appendix C. The analysis shows that for uncertainties in the surface temperature were less than 0.12° C and that the uncertainty in the saturation temperature, resulting from uncertainties in the pressure measurement, were less than 0.04° C. Therefore, the

uncertainty in the wall superheat was calculated as 0.13°C . The uncertainties in the heat flux, as a result of uncertainties in surface area and voltage measurements, were less than 5%.

CHAPTER 3

EXPERIMENTAL RESULTS AND DISCUSSION

OF POOL BOILING DATA

Pool boiling experiments were performed in order to determine the thermal performance of single, horizontal tubes with different surfaces boiling in a pool of refrigerant. The results of the experiments were used as a reference for the tube bundle data and to validate the experimental tube bundle apparatus and procedure. Single tubes with plain and enhanced surfaces were tested in the pool boiling apparatus containing R-113, R-11, or mixtures of both. Heat flux and wall temperature superheat data were collected in order to determine the effect of changing heat flux and various fluids on the heat transfer coefficients.

Pure R-113 Results

The boiling curves for tubes with the smooth, knurled (Turbo-B), and sintered (medium and small porosity High Flux) surfaces in pure R-113 are shown in Fig. 3.1. The natural convection correlation curve developed by McAdams (1954) is plotted for comparison. The smooth tube results for increasing heat fluxes (from approximately 0.2 kW/m^2 up to approximately 2 kW/m^2) were predicted fairly well using the McAdams correlation, which validated the experimental apparatus and procedure.

Data from the smooth tube for heat fluxes from 2 kW/m^2 to 7 kW/m^2 deviates slightly from the natural convection line due to the presence of nucleate boiling at a few sites. The entirety of the heated surface did not nucleate until the

Figure 3.1. Boiling curves for tubes with smooth, Turbo-B, and High Flux surfaces at $P = 103 \text{ kPa}$.

heat flux was increased to approximately 8 kW/m^2 , at which time the nucleate boiling resulted in a significantly smaller wall superheat value that shifted the boiling curve to the left. Occasionally this shift in the boiling curve occurred over a range of heat fluxes, which was not repeatable. Visual observations revealed that nucleation was initiated in patches on the heated surface and that these patches grew with increasing heat flux. Similar observations were noted by Bergles and Chyu (1982).

Data taken at heat fluxes greater than 8 kW/m^2 were generally the same regardless of whether the heat flux was increased or decreased. Data obtained for decreasing heat fluxes less than 8 kW/m^2 were to the left of the data obtained for increasing heat fluxes due to the continued presence of nucleation sites, thereby creating the so-called boiling curve hysteresis.

Figure 3.1 also shows that data from the small porosity High Flux surface has the smallest wall superheat for decreasing heat fluxes greater than 1.5 kW/m^2 and so performed the best in this heat flux range. The Turbo-B surface performed better than the smooth and medium porosity High Flux surfaces for heat fluxes less than 10 kW/m^2 , but the medium porosity High Flux surface performed better than the Turbo-B and smooth surfaces for heat fluxes greater than 10 kW/m^2 . At low heat fluxes, the heat transfer coefficients for a given wall superheat are generally at least an order of magnitude better for the enhanced tubes than the smooth tubes.

At higher heat fluxes, the difference between the results for the smooth and enhanced surfaces diminishes and the boiling curves for the smooth and Turbo-B surfaces merge together. Figure 3.2 shows the boiling curve for a smooth tube up to a heat flux value of 200 kW/m^2 . The sudden shift in the boiling curve to the right indicates that the critical heat flux (CHF) has been reached which was verified by

Figure 3.2. Critical heat flux data for the smooth tube in pool boiling at $P = 103 \text{ kPa}$.

visual observations of film boiling. It appears that the CHF value for the Turbo-B and medium porosity High Flux tubes will be approximately the same as that of the smooth tube (approximately 200 kW/m^2) which indicates that the surface enhancement is ineffective when operating too close to the CHF value.

The results shown in Fig. 3.1 agree with results of other researchers. For example, the results of the smooth and small porosity High Flux surfaces are similar to those obtained by Chyu (1979), as seen in Fig. 3.3. Webb and Pais (1991) report very good agreement between heat transfer coefficients from their Turbo-B tube and values from the present study as shown in Fig. 3.4.

The small porosity High Flux surface produced the largest hysteresis in the boiling curve of approximately 10°C while the Turbo-B produced almost no overshoot. A possible explanation for the lack of a large temperature overshoot for the Turbo-B surface is that the subsurface geometry of the Turbo-B tube is connected by a spiraling channel. Figure 3.5 shows a cross section of the Turbo-B surface enlarged 20 times. Note that the subsurface channels remain open even though the pore openings are sometimes closed and the outside surface is sometimes compressed an additional amount. This channel would make it possible for vapor from just a few active nucleation sites inside the channel on the bottom of the tube to travel circumferentially around the tube and activate other extinct nucleation sites. Such a process would be less likely for tubes with the High Flux surface where the connecting subsurface channels are interrupted as shown in Fig. 3.6. Indeed, visual observations verified that the onset of nucleation for the High Flux tubes occurred in patches on the tube surface and at varying heat fluxes.

Figure 3.3. Comparison of High Flux and smooth tube pool data obtained in R-113 at $P=103$ kPa with results from Chyu (1979).

Figure 3.4.

Comparison of Turbo-B tube pool boiling data with results from Webb and Pais (1991).

Figure 3.5. Axial cross section of the Turbo-B tube (enlarged 9x).

Figure 3.6.

Cross section of the High Flux surface enlarged 100x
(Gottzmann et al. 1973).

In the fully established nucleate boiling range, the size of the pore opening has very little influence on the boiling curve for the Turbo-B surface. As reported by Jung and Bergles (1989), three boiling curves were obtained for Turbo-B tubes with surface opening sizes designated small, medium, and large, and the results were nearly identical. Subsequently, Turbo-B tubes with surface opening sizes designated "very open" and "very closed" were tested and the results are shown in Fig. 3.7. Even for these extreme pore sizes, the boiling curves show very little effect, especially for heat fluxes greater than 2000 W/m^2 . These results support the conclusion that the basis heat transfer mechanism takes place in the subsurface channel alone and that the bubble departure process at the pore has little influence.

The porosity of the High Flux surface, on the other hand, has a strong effect on the nucleate boiling heat transfer, as seen by comparing the "High Flux, small" and "High flux, medium" results shown in Fig. 3.1. Evidently, the bubble departure process is very important in the heat removal process for the High Flux surface.

It is interesting to note that while the slope of the $q'' \sim \Delta T$ boiling curves for the smooth and High Flux surfaces are steep, the slope of the boiling curve for the Turbo-B surface is approximately unity. This implies that the heat transfer coefficients for the Turbo-B tubes varied only slightly with heat flux. The heat transfer coefficients for the High Flux and smooth tubes, on the other hand, depended strongly on the heat flux so that the two enhanced surfaces performed very differently in this respect. The weak heat flux dependency on the heat transfer coefficients for the Turbo-B tubes is possibly the result of thin film vaporization and will be discussed in Chapter 5.

Figure 3.7. Comparison of very open and very closed porosity Turbo-B tube pool data in R-113 at $P = 103 \text{ kPa}$.

A "least-squares" type of linear regression was performed on the pool boiling data for the three sets of surfaces used in the tube bundle experiment. The correlation curve and fully established nucleate pool boiling data are shown in Fig. 3.8 for the smooth, Turbo-B, and medium porosity High Flux surfaces. The equation for the smooth tube data is:

$$q'' = 1.067 (\Delta T_{\text{sat}})^{4.012} \quad (3.1)$$

The correlation approximates the data to within 2.4% in the range of heat fluxes from 2.3 kW/m² to 123 kW/m². The exponent on ΔT_{sat} , which is the slope of the correlation curve, is very nearly the same as given by other researchers including Stephan and Abdelsalam (1980) who use a value of 3.92. For the Turbo-B data, the equation is:

$$q'' = 6149 (\Delta T_{\text{sat}})^{1.283} \quad (3.2)$$

which approximates the data to within 1.1% in the range of heat fluxes from 1.6 kW/m² to 152 kW/m². The exponent on ΔT_{sat} is close to unity and confirms that the heat transfer coefficient is a weak function of heat flux. For the High Flux data, the equation is:

$$q'' = 4227 (\Delta T_{\text{sat}})^{2.033} \quad (3.3)$$

which approximates the data to within 3.1% in the range of heat fluxes from 1.6 kW/m² to 43 kW/m². The value of the exponent on ΔT_{sat} is between that for the

Figure 3.8. Pool boiling correlations for smooth, Turbo-B, and High Flux tubes at $P = 103$ kPa.

smooth and Turbo-B surfaces for the applicable range of heat fluxes. Note, however, that while a linear regression appears to correlate the data for the smooth and Turbo-B surfaces fairly well, a non-linear regression would have been necessary to predict the gradually decreasing slope in the data for the High Flux surface.

Pure R-11 Results

As seen in Fig. 3.9 for the smooth tube, the pool boiling data in pure R-11 are nearly the same as in pure R-113 for fully established nucleate boiling. The performance is only slightly better in R-11 than in R-113 at low heat fluxes (less than 10 kW/m²).

The relative performance of the smooth in R-113 and R-11 can be determined by examining a model for nucleate pool boiling as described by Forster and Zuber (1955)

$$q'' = C_1 \left[\frac{i_{fg}^{1/2}}{\sigma_L^{1/2}} \frac{\rho_v^{3/8}}{T_{sat}^{3/2}} \frac{\rho_L^{1/2}}{\mu_L^{7/24}} \frac{c_p^{11/24}}{k_L^{25/24}} \right] (T_w - T_{sat})^2 \quad (3.4)$$

In general, the heat transfer coefficient in R-11 should be similar to those in R-113 due to their similar properties. For example, the vapor density and surface tension of R-113 is slightly greater than for R-11 but the thermal conductivity and heat of vaporization is slightly greater for R-11 than for R-113. At 100 kPa and a given wall superheat, equation (3.4) predicts that the heat flux for R-113 is approximately 15% larger than for R-11. Alternatively, the ratio $(T_{sat}/p_v i_{fg})^{1/2}$ used to predict the pressure effect also predicts a slightly larger heat transfer coefficient

Figure 3.9. Saturated pool boiling curve for the smooth tube in pure R-11 and pure R-113 at $P = 103$ kPa.

in R-113 than in R-11. The lack of any significant differences between the experimental data obtained in R-113 and R-11 can be attributed to experimental uncertainty.

Figure 3.10 shows that the performance of the Turbo-B tube in R-11 was better than in R-113 for heat fluxes greater than 5 kW/m^2 . The performance was poorer in R-11 than in R-113 for heat fluxes less than 1 kW/m^2 and was approximately equal for intermediate heat flux values. The performance of the small porosity High Flux surface, as shown in Fig. 3.11 was better in R-11 than in R-113 for heat flux values less than 30 kW/m^2 with the greatest increase in the performance occurring at the smallest heat flux value.

Binary Mixture Results

Figure 3.12 shows the boiling curves for the smooth tube in mixtures of R-113 and R-11. Boiling curves for the smooth tube in pure R-113 and pure R-11 are also shown for comparison. In general, the performance of the smooth surface does not change significantly with mixture concentration. The performance is only slightly better in pure R-113 than in 25% R-11 for heat flux values greater than 10 kW/m^2 . For a mixture of 50% R-11 and 50% R-113, the performance is only slightly better in the range from 1 kW/m^2 to 10 kW/m^2 than the performance in the same range of heat fluxes for a mixture with 25% R-11 and for pure R-113. The smooth tube performed better in a mixture of 75% R-11 and 25% R-113 than in pure R-11 for a range of heat flux values from 1 to 10 kW/m^2 , worse for heat flux values less than 1 kW/m^2 , and the same for heat flux values greater than 10 kW/m^2 .

Figure 3.10.

Saturated pool boiling curve for the Turbo-B tube in pure R-11 and pure R-113 at $P = 103$ kPa.

Figure 3.11. Saturated pool boiling curve for the High Flux tube in pure R-11 and pure R-113 at $P = 103$ kPa.

Figure 3.12. Saturated pool boiling curve for the smooth tube in mixtures of R-11 and R-113 at $P = 103$ kPa.

Boiling curves for the Turbo-B surface are shown in Fig. 3.13. Generally, the performance is best in pure R-11, slightly poorer for pure R-113, and as the amount of R-113 in the mixture is increased, the boiling curve is shifted to the right. The same trends were found for the small porosity High Flux tube as shown in Fig. 3.14. It is interesting to note that for the High Flux surface, the onset of fully established nucleate boiling occurred between 2 kW/m^2 and 3 kW/m^2 .

Summary

Pool boiling tests were conducted for each of the three surfaces so that reference values of the heat transfer coefficient could be obtained. Values of the heat transfer coefficient for the enhanced tubes were generally an order of magnitude larger than for the smooth tubes. Heat transfer coefficients for the porous surface were generally the largest; however, a large hysteresis in the boiling curve was found. Visual observations revealed that only patches of the High Flux surface nucleated initially and that nucleation covered more of the surface as the heat flux increased. Heat transfer coefficients for the Turbo-B tube, on the other hand, showed very little hysteresis in the boiling curve.

The pool boiling experiments conducted in pure R-11 showed that, as for the pure R-113 experiments, the enhanced tubes performed better than the smooth tubes. Indeed, the performance of the smooth and High Flux tubes in pure R-11 was approximately equal to that in pure R-113, except for heat fluxes less than 10 kW/m^2 where the performance in R-11 was slightly greater than in R-113. The performance of the Turbo-B tube was also slightly better in R-11 than in R-113.

Figure 3.13.

Saturated pool boiling curve for the Turbo-B tube in mixtures of R-11 and R-113 at $P = 103$ kPa.

Figure 3.14.

Saturated pool boiling curve for the High Flux tube in mixtures of R-11 and R-113 at $P = 103$ kPa.

Pool boiling heat transfer coefficients in fluid mixtures were less than those in pure fluids for all three surfaces. However, for a given heat flux and mixture concentration, the enhanced surfaces consistently performed better than the smooth tube. The High Flux tube performed slightly better than the Turbo-B tube, as was the case for the pure fluid experiments. The performance of all three surfaces decreased as the concentration of R-11 decreased, with the largest reduction occurring in a mixture of 25% R-11/75% R-113.

CHAPTER 4

EXPERIMENTAL TUBE BUNDLE APPARATUS AND EXPERIMENTAL PROCEDURE

An experimental tube bundle apparatus was designed to measure the thermal and hydraulic performance of tube bundles with a variety of enhanced surfaces. In particular, a need to obtain more information on the heat transfer coefficients for single tubes in pure refrigerants and refrigerant mixtures and pressure drops throughout a tube bundle guided the development of the apparatus.

In order to gain more information on the mechanisms involved in nucleate boiling in horizontal tube bundles, the experimental apparatus was designed so that measurements could be made of the mass flux, the pressure drop across the tube bundle, the power supplied to the tube bundle and individual tubes within the bundle, the fluid temperatures throughout the bundle, and the wall temperatures of individual tubes in bundles of tubes having different surface enhancements and various pitch-to-diameter ratios. The experimental apparatus permitted data to be obtained in saturated fluids at pressures from 2 to 6 bar, at heat flux values up to 80 kW/m^2 , and for mass flux values (based on the minimum flow area) up to $500 \text{ kg/m}^2\text{s}$. Using this apparatus, the fluid properties, the quality, and pressure drop could be calculated throughout the tube bundle, and the heat flux, wall superheats, and heat transfer coefficients for individual tubes were determined. Visual observations provided qualitative information, such as the distribution of nucleation sites on the surface of the tube surface and phase distribution in the main flow, so that a mechanistic interpretation of the behavior of the smooth and enhanced tubes could be formulated.

The tube bundle apparatus provided shellside boiling on horizontal tubes with flow on the tubeside in the vertical upflow direction in order to simulate the operation of kettle reboilers, submerged evaporators, waste heat boilers, and other similar heat transfer equipment. The outside tube diameter of 19.1 mm and staggered tube array were chosen as a typical of actual applications. The pitch-to-diameter ratios of 1.17 and 1.50 spanned the range of values commonly found in industry. The tube length and number of rows were sufficient to minimize the effects of the walls at the ends of the tubes and the walls on the sides of the bundle thereby approximating a predominantly one-dimensional flow around a center column of instrumented tubes.

Work by Cornwell et al. (1980) revealed that the flow through a kettle reboiler is non-uniform in general but that in the middle portion of the bundle the flow is predominantly upward. The tube bundle apparatus used in this project simulated this middle section of the bundle which is denoted by the shaded area in Fig. 4.1 for constant heat flux conditions. For the present work, the flow was forced through a section of a tube bundle with a known mass flow rate so that the inlet and local flow conditions could be quantified.

The tube bundle was designed so that the effect of lower tubes on the heat transfer coefficients of the upper tubes could be detected. Single-phase heat transfer coefficients exhibit a variation with tube row for the first three to five rows (ESDU 1973, Zukauskas 1987). However, Cornwell et al. (1980) reported a significant variation in the local two-phase heat transfer coefficients throughout a bundle of tubes in a square array with 17 rows with a constant heat flux of 20 kW/m² as shown in Fig. 4.2. A tube bundle with 15 rows was deemed large enough to detect the effect of location in the bundle on the heat transfer coefficient.

Figure 4.1. Streamlines in a tube bundle (Cornwell et al. 1980) and area simulated by experimental apparatus.

Figure 4.2.

Lines of constant heat transfer coefficients ($\text{kW/m}^2\text{K}$) at a heat flux of 20 kW/m^2 (Cornwell et al. 1980).

Description of the Refrigerant Flow Loop

A refrigerant flow loop, which used pure R-113, pure R-11, and mixtures of both, was used to provide the appropriate operating conditions for the experimental test chamber. A schematic of the refrigerant loop is shown in Fig. 4.3 and was constructed by modifying an existing loop described by Dykas (1989). The flow loop contains the test chamber, a positive displacement pump, a storage tank, preheaters, condenser, and other assorted pieces of equipment.

The refrigerant was circulated through the loop by a Wanner Engineering Hydra-Cell Model D-25 positive displacement pump. The pump had a maximum capacity of 1.6 L/s and was driven by a Fincor 5 hp, 1725 rpm electric motor. An adjustable-frequency inverter controlled the motor speed so that the pump could deliver any flowrate for the refrigerant up to the maximum. Pulsations in the flowrate at the outlet of the pump were dampened using a bladder-type Tobul accumulator. As a safety precaution with these CFC fluids, a pressure relief valve downstream of the pump allowed the refrigerant to flow into the storage tank in the event that flow through the rest of the loop was interrupted.

Refrigerant leaving the pump flowed through a Cuno model CT102 filter with filter cartridges rated at 100 microns. Downstream of the filter was a bypass branch with a bypass control needle valve which was used when the mass flow rate through the test chamber was to be reduced to very small values.

Refrigerant flow to the test section flowed through one of two flowmeters depending on the flow rate. Both were Flow Technology, Inc. turbine flowmeters. One flowmeter was calibrated to measure volume flow rates from 0.01 L/s (0.2 gpm) to 0.13 L/s (2 gpm) while the other was calibrated to measure flow rates from

Figure 4.3. Schematic of the refrigerant flow loop.

0.13 L/s (2 gpm) to 1.3 L/s (20 gpm). Immediately upstream of each flowmeter were flow straighteners which eliminated any swirl in the flow and ensured a uniform entrance condition. A thermocouple measured the temperature of the refrigerant upstream of the flowmeters so that the density could be calculated and the mass flowrate determined.

From the flowmeters the refrigerant flowed through a bank of three preheaters in parallel. Each was an Indeeco immersion-type electric heater. Two of them were rated at 20 kW each and had separate control switches so that they could be set independently either fully on or off. The voltage supplied to the third preheater was controlled by a variable transformer so that any power level from 0 to 15 kW could be obtained. Thermocouples were installed at the exit of each preheater to monitor the temperature of the refrigerant in order to prevent the flow from becoming saturated.

Slightly downstream of the bank of preheaters was a pressure gauge, a thermopile consisting of four thermocouples, and a set of flashing valves to control the pressure in the preheaters. The pressure gauge was used in conjunction with the thermocouple readings at the exit of the preheaters to ensure that the refrigerant did not reach saturation and that liquid only flowed from the preheaters. Maintaining a single-phase liquid in the preheaters permitted the straight-forward calculation of the enthalpy of the refrigerant from the temperature measurement of the liquid at the exit of the preheaters.

The refrigerant flowed through insulated stainless steel piping from the preheaters through the flashing valves to the test chamber containing the tube bundle. The test chamber was oriented vertically so that the refrigerant flowed upward. At the inlet of the tube bundle was a thermocouple to measure the

refrigerant temperature and a pressure tap connected to two bourdon—tube pressure gauges that were used to monitor the operating pressure in the test chamber. One pressure gauge was used to measure gauge pressures from 0 to 0.275 MPa (40 psi) and the other was used to measured gauge pressures up to 1.034 MPa (150 psi). At the exit of the test chamber was attached a 50.8 mm (2 in.) stainless steel pipe that continued vertically upwards to a vent used in the refrigerant degassing process.

Slightly upstream of the vent, the piping branched to a water—cooled condenser where the refrigerant vapor was condensed. Any refrigerant that was bypassed around the test chamber was mixed with the refrigerant from the test chamber at a location just upstream of the condenser. The entire flow was then cooled to approximately $15^{\circ}\text{C} \pm 5^{\circ}\text{C}$ depending on the temperature of the cooling water. Downstream of the condenser was a set of three backpressure valves used to control the pressure in test chamber and condenser.

The refrigerant then flowed through a Sporlan drier that used a desiccant to remove hydrochloric acid, hydrofluoric acid, and moisture from the refrigerant. A moisture—sensitive element that changed color when the moisture content of the refrigerant was above 20 ppm was installed downstream of the drier and was used to verify that the drier was operating properly. From the drier, the refrigerant flowed either to the pump inlet or the storage tank. The storage tank had an opening in the top under which was mounted a water—cooled condenser.

Detailed Description of the Test Chamber

The tube bundle test chamber was developed specifically for this study to produce shellside boiling over horizontal tubes where the predominant flow direction is vertically upward. The chamber consisted of five major components: shell, mounting plate, window, side—walls, and heated tubes. The shell was the main component in forming the enclosure and is shown in Fig. 4.4. The top, bottom, sides, and flanges were made of 6.35 mm (1/4 in.) thick stainless steel. A 25.4 mm (1 in.) diameter pipe was connected to the inlet of the test chamber shell so that the test chamber could be easily installed in the refrigerant flow loop. The inlet to the test chamber shell consisted of brass screens, a diverging section containing flow vanes, and a section containing a honeycomb flow straightener, as shown in Fig. 4.5. The screens were placed at the end of the inlet pipe so that any fluid entering the test chamber was evenly distributed across the flow area. The stainless steel flow vanes allowed for a smooth transition from the inlet pipe to the rectangular body of the test chamber. Any swirl in the flow was removed by the stainless steel flow straightener.

The mounting plates were constructed so that 68 heating tubes could be securely sealed in the test chamber with a precise orientation and spacing. The mounting plate also provided the means for sealing the pressure taps and thermocouple ports. The two mounting plates were built out of 12.7 mm (1/2 in.) thick 304 stainless steel. The holes used for mounting the heated tubes were spaced in an equilateral triangle of 5 columns and 15 rows with a pitch—to—diameter ratio of 1.50 on one and 1.17 on the other. The mounting plates were bolted, one at a time, to the flange of the test chamber shell and were easily interchanged. As seen

Figure 4.4. Schematic of the test chamber shell.

Figure 4.5. Cross section of the test chamber.

in Fig. 4.5, an o-ring groove was machined around the perimeter of the mounting plate next to the bolt holes. The mounting plates were sealed with a Buna-N o-ring and a soft Teflon cord.

A cross section of the holes used for mounting the heated tubes is shown in Section A-A of Fig. 4.6. The holes incorporate o-ring grooves, and Buna-N o-rings were used to seal the openings. Six pressure taps were drilled in the mounting plate between tube holes in the middle column so that the local saturation temperature and two-phase pressure drop could be measured. The pressure taps were located at the inlet, exit, and just upstream of the third, seventh, eleventh, and fifteenth tube rows. The pressure taps were connected in such a way that the pressure drop between successive taps could be measured by a Validyne pressure transducer. Thermocouple ports were constructed in the mounting plates just upstream of the bundle and at the exit so that fluid temperatures could be measured. Swagelok fittings with pipe threads to provide sealing were threaded into the mounting plate at each thermocouple port. Stainless steel 1.6 mm o.d. hypodermic tubing was inserted through the Swagelok fittings and protruded 50.8 mm (2 in.) into the flow channel. Copper-constantan thermocouples were sealed inside the tubing using epoxy such that only the bead of the thermocouple was exposed to the flow.

The window provided easy viewing of the flow so that a qualitative assessment of the hydrodynamics could be made. Lexan was used because of its chemical compatibility with R-113 and R-11, machinability, and clarity. Two layers of Lexan were used. The inner layer was made of 6.35 mm (1/4 in.) thick Lexan and was constructed with bolt holes and an o-ring groove so that the window could be sealed to the test chamber shell flange with a Buna-N o-ring and a soft

Figure 4.6.

Schematic of the test chamber mounting plate.

Teflon cord (the same as for the mounting plate). The outer layer was made of 25.4 mm (1 in.) thick Lexan to reinforce the inner layer and to prevent the window assembly from deflecting when subjected to the operating pressures.

The heated tubes were attached horizontally to the mounting plate. The middle column of tubes was instrumented with thermocouples which penetrated axially through to the midpoint of the heated surface. The construction of the instrumented tubes, regardless of the type of surface, was identical to the construction of the High Flux tubes used in the pool boiling experiment as described in Chapter 2. Those heated tubes that were not in the middle column also were constructed identically to the High Flux tubes used in the pool boiling experiment, except for the absence of thermocouple wells. The 101.6 mm (4 in.) long, 19.1 mm (3/4 in.) o.d. copper tubes were attached to the mounting plate with snap-rings, and the joints between the tubes and the mounting plate were sealed with Buna-N o-rings. The end of the tube next to the window was sealed with a Buna-N disc that was attached to the tube with epoxy.

Cartridge heaters were inserted into the end of the tube protruding through the mounting plate. The cartridge heaters were identical to those used in the pool boiling experiment and were connected to one of three variable transformers, as shown in Fig. 4.7. Each variable transformer supplied a variable voltage (up to 240 V) to a pair of bus bars and the leads from the cartridge heaters were connected electrically in parallel to one of the pairs of bus bars. Approximately one-third of the cartridge heaters were connected to each set of bus bars. Three shunts (each 50 amp — 50 mV) were used to measure the current through the bank of cartridge heaters; one shunt was used to measure the current from each variable transformer. In addition to the shunts shown in Fig. 4.7, a battery of eight shunts

CARTRIDGE HEATERS INSTRUMENTATION

Figure 4.7. Electrical power connections and instrumentation for the cartridge heaters (Dykas 1989).

(each 5 amp — 200 mV) was installed. One shunt was installed in a lead from the bus bar to each of the instrumented tubes so the current could be measured individually.

In order to minimize the effect of the outside walls, the outside two columns of heated tubes were inbedded half way into the sidewalls. Because these tubes had half of the heated surface area of the other tubes, the power supplied was reduced by half also. This was accomplished by inserting a "snubber circuits" into a lead from the bus bars to each of the cartridge heaters that were installed in the outside columns. The snubber circuits, shown in Fig. 4.8, were adjusted so that the voltage supplied to these cartridge heaters was reduced by a factor of $1/\sqrt{2}$, thereby reducing the power supplied by half.

A computer controlled data acquisition system (DAS) was used to collect and generate primary data. The DAS consisted of a Hewlett—Packard family 9000, model 310 micro—computer, a Hewlett—Packard 3497A data acquisition/control unit, a Hewlett—Packard 3457A digital multimeter, and a Kaye Instruments model K170—75C thermocouple ice point reference. A maximum of 60 thermocouple signals could be measured by the DAS. The thermocouples were connected in series with the ice point reference junction, and the voltage was measured across both the thermocouple and the reference junction by the multimeter. An additional 25 voltage signals could also be input to the DAS. The multimeter could measure the magnitude of d.c. signals, the r.m.s. values of a.c signals, or the frequencies of the signals input to these channels.

Experimental Procedure

The flow loop was filled with refrigerant by connecting storage drums containing the refrigerant to the refrigerant supply inlet shown in Fig. 4.2. The pump was turned on, and the return lines from the storage tank and dryer were closed in order to draw the liquid refrigerant into the flow loop. The pump forced the liquid through the loop and into the storage tank where air was allowed to escape through the top. The condenser in the top of the storage tank prevented refrigerant vapor from escaping through the top of the storage tank. In this way, the loop was filled with very little refrigerant being allowed to escape to the atmosphere.

Prior to taking data in pure refrigerant, any noncondensable gas dissolved in the refrigerant had to be removed. Therefore, a valve was installed at the high point in the refrigerant loop, which was directly above the test chamber, so that any dissolved air could be vented as it came out of solution. Before each day of testing, the vent was opened and refrigerant was circulated through the flow loop. The pressure at the inlet to the tube bundle was set at approximately 30 kPa (4 psi) in order to overcome the hydrostatic head necessary for liquid to fill the horizontal pipe branching to the condenser (see Fig. 4.9). The liquid was then heated to within 0.1°C of the pure refrigerant saturation temperature at the inlet to the tube bundle. As the refrigerant approached the saturation temperature, the noncondensable gas came out of solution, and its presence could easily be observed in the test chamber window. The refrigerant was pumped from the preheaters to the vent at very low mass flow rates, about 0.2 kg/s , in order to minimize the mixing of the gas and refrigerant and to aid in the detection of gas bubbles. The

Figure 4.9. Schematic of the flow loop venting apparatus.

velocity of the refrigerant was approximately 0.125 m/s through the inlet pipe, 0.0333 m/s through the tube bundle, and 0.0625 m/s through the outlet pipe.

The amount of dissolved gas in saturated R-113 was measured using an Aire-ometer. The amount of air before degassing was $46\% \pm 1\%$ by volume. After the refrigerant was heated to within 0.1°C of saturation and no bubbles were observed through the window, the amount of dissolved gas was again measured and was found to be less than 1% by volume. Therefore, the degassing process was shown to effectively remove the dissolved air.

The procedure for obtaining the desired operating conditions for pure refrigerants in the test chamber consisted of establishing the desired flowrate, test chamber inlet pressure, inlet fluid conditions, and heat flux from the bundle of heated tubes. Initially, all of the valves were opened except for the test chamber bypass valve, storage tank return valve, vent, and flow loop bypass valve. The pump was turned on and the flowrate was adjusted by changing the speed of the pump motor, using the the frequency controller. When the test chamber bypass valve was closed, all of the liquid from the pump flowed through the tube bundle. When the mass flux through the tube bundle was less than $50\text{ kg/m}^2\text{s}$ and the pressure was 600 kPa, the speed of the pump motor was too low to prevent overheating. For these operating conditions, the test chamber bypass valve was adjusted so that liquid from the pump could flow both through the tube bundle and the storage tank. This allowed for an increase in the flow from the pump without increasing the flow through the tube bundle so that pump motor speed could be increased and overheating could be prevented.

The flashing valves were then adjusted so that the pressure in the preheaters was approximately 3.4 bar (50 psi) above the intended operating pressure in the test chamber. Next, the pressure in the test chamber was increased to the desired operating pressure by adjusting the backpressure valves. An adjustment of the pump motor frequency was often necessary after changing the pressure in the preheaters or test chamber and was always necessary if the test chamber bypass valve was not closed.

The test chamber inlet fluid temperature was then increased by applying heat from the preheaters. In addition, water was circulated through the condenser so that the heat added to the refrigerant by the preheaters was removed before the refrigerant returned to the pump inlet. The number of preheaters turned on and the power level setting for the variable voltage preheater depended on the mass flow rate of the refrigerant and the desired fluid temperature at the output of the preheaters. Because the maximum power available from the variable preheater was not as large as from the other two preheaters with fixed power outputs, it was occasionally necessary to adjust the flowrate through the preheaters to a value slightly different from the desired flowrate.

After the desired flowrate, inlet pressure, and inlet fluid temperature was attained in the test chamber, the variable transformers connected to the cartridge heaters were adjusted until the desired heat flux was attained from the heated tube bundle. If the conditions were such that boiling took place on the heated tubes, then the additional volume of the refrigerant vapor resulted in a displacement of refrigerant liquid into the storage tank. During this transient, the test chamber pressure increased. The pressure in the test chamber returned to a value approximately equal to the original when the volume of liquid added to the storage

tank equaled the increase in the volume of vapor present in the test chamber and piping. Analogously, the test chamber experienced a transient decrease in pressure whenever the volume of vapor in the loop was decreased. In both cases, the final inlet pressure in the test section was slightly different from the original due to a change in the two-phase pressure drop, and the backpressure valves were adjusted to restore the original inlet pressure.

When R-113 was used as the working fluid and vapor was being generated in the flow loop, the storage tank was used to hold that amount of liquid refrigerant which was displaced by the vapor. The storage tank was connected to the inlet of the pump, and the pressure in the storage tank remained nearly at atmospheric pressure. Therefore, the pressure at the inlet to the pump remained only slightly above atmospheric pressure. However, when pure R-11 or mixtures of R-11 and R-113 were used, the inlet to the pump had to be pressurized in order to prevent the refrigerant from flashing and causing cavitation. A system pressurizer as shown in Fig. 4.10 was, therefore, installed to maintain the pressure in the loop from the backpressure valves to the pump inlet at approximately 138 kPa (20 psi). The storage tank was isolated from the rest of the loop so that as the volume of vapor in the loop increased, all of the excess refrigerant was forced into the refrigerant-side of the pressurizer and expanded the rubber bladder. A relief valve on the gas-side of the bladder allowed the nitrogen to escape so that the pressure in the pressurizer was maintained near the desired pressure for the pump inlet. As the volume of vapor in the loop decreased, the bladder contracted and liquid was forced back into the loop using compressed nitrogen. The pressure in the nitrogen-side of the pressurizer was maintained using a compressed gas regulator that was connected to the compressed nitrogen and was set slightly above the desired pump inlet pressure.

Figure 4.10. Schematic of the flow loop pressurizer.

In this way, sufficient liquid was returned to the flow loop to maintain the desired pressure at the pump inlet.

Before collecting nucleate boiling heat transfer data, single-phase heat transfer data were obtained in order to confirm the validity of the experimental apparatus. Because the single-phase heat transfer coefficients were obtained in subcooled R-113, the preheaters were set so that inlet temperature of the R-113 was between 22 and 26°C, and the backpressure valves were set so that the gage pressure in the test chamber was approximately 0.7 bar (10 psi).

After steady-state flow conditions were reached, the DAS automatically recorded the signals from the thermocouples throughout the flow loop and tube bundle, the frequency of the signal from the flowmeter, the d.c voltage from the pressure transducer, and the a.c. voltages from the shunts and bus bars. The atmospheric pressure and test chamber inlet gauge pressure were read and input to the DAS manually. The data were then reduced as described in the next section. The next set of operating conditions was achieved by adjusting the pump motor frequency, power to the cartridge heaters, and/or backpressure valves. Additional single-phase heat transfer data were collected by repeating this procedure until sufficient data were obtained to verify the validity of the experimental apparatus.

Two-phase heat transfer data were obtained first for the bundle of smooth tubes. The test chamber operating conditions were achieved by beginning with the procedure described above. In addition, the power supplied to the tube bundle was increased until the quality of the refrigerant at the exit of the tube bundle was between 65 and 80%. Data were collected after the system reached steady state. The power supplied to the tube bundle was then reduced, and the system was again allowed to come to steady state. Taking data at the largest heat flux values first

insured that nucleate boiling took place over as much of the tube surface as possible. After data were collected for all the heat flux values, the flow rate through the bundle was changed and the power supplied to the tube bundle was again increased until the output quality was between 65 and 80%. This procedure was repeated until data were collected for each value of the mass flux. The test chamber pressure was then increased, and data were collected at the full range of heat flux and mass flux values, as described above.

After data were collected for the smooth tubes mounted to the mounting plated with a pitch-to-diameter ratio of 1.50, tubes with the Turbo-B surface were installed, and data were collected using the procedure outlined above. Next, the smooth tubes were mounted to the mounting plate with a pitch-to-diameter ratio of 1.17 and more data were collected in pure R-113. This bundle of tubes was replaced with tubes having the High Flux surface, and the procedure for collecting data was repeated.

The mounting plate with a pitch-to-diameter ratio of 1.50 was then used to collect data using pure R-11. For these experiments, the tube bundle consisted of High Flux tubes in the bottom third, smooth tubes in the middle, and Turbo-B tubes in the upper third. Before the loop was filled with pure R-11, the R-113 was degassed and stored in flexible bags for use later during the tests involving refrigerant mixtures. The flow loop was then modified by installing the pressurizer shown in Fig. 4.10 before the loop was filled with pure R-11, and data were collected using the procedure outlined above.

This same bundle of tubes was used to collect data in mixtures of R-11 and R-113 for concentrations of 25, 50, and 75% by mass of R-11 in the R-113. The procedure for obtaining refrigerant mixtures involved first verifying that the pure

R-11 did not contain dissolved gas by measuring a sample of the R-11 using the Aire-ometer. Next, bags containing degassed R-113 were connected to the flow loop, and the refrigerant mixture was circulated through the loop. The flexible bags allowed the R-113 to be emptied into the flow loop without allowing air to come in contact with the refrigerant. After circulating for several hours, the concentration of the mixture was measured approximately by using hydrometers to measure the specific gravity and then using the graph shown in Fig. 4.11 to determine the mixture concentration. Pure R-113 was added to the flow loop until the desired mixture concentration was attained. Precise values (within 0.1%) of the mixture concentration were obtained using mass spectrometry. Three samples were collected for each mixture: before the experiments at 200 kPa, between the experiments at 200 and 600 kPa, and after the experiments at 600 kPa. Because the mass spectrometry analysis required several weeks, the data were collected using the values for the mixture concentration using the hydrometers. The raw data were reduced again when the mixture concentration determined using mass spectrometry was known.

Data Reduction

Heat transfer coefficients were calculated immediately after the data collection process using a computer program run on the microcomputer of the DAS. The heat transfer coefficients calculated for the two-phase experiments were defined as the ratio of the heat flux from the heated tube to the difference between the average tube wall surface temperature and the saturation temperature of the refrigerant at the local pressure just upstream of the tube; this pressure was

Figure 4.11. Specific gravity for R-11/R-113 mixtures at 20° C and 101 kPa.

obtained by linear interpolation of the pressures at the closest pressure taps. The equation for the heat transfer coefficient is given as:

$$h_n = \frac{q_n''}{T_{w,ave} - T_{sat}} \quad (4.1)$$

Single-phase heat transfer coefficients were based on the difference between the average tube wall surface temperature and the temperature of the liquid refrigerant just upstream of the heated tube:

$$h_n = \frac{q_n''}{T_{w,ave} - T_L} \quad (4.2)$$

The heat flux for an individual tube was defined as the ratio of the supplied power to the surface area exposed to the fluid. The power supplied to the heated tube was calculated as the product of the current through the cartridge heater and the voltage across the cartridge heater:

$$q_n'' = \frac{I_n V_n}{A_s} \quad (4.3)$$

where the current, I_n , was measured by the DAS for each cartridge heater and the voltage drop, V_n , was measured across those set of bus bars to which the cartridge heater was attached. The area of an individual tube was given by:

$$A_s = \pi D_o L \quad (4.4)$$

where length of the tube, L , was measured to be 0.1016 m. The diameters of the enhanced tubes were measured at the outside of the enhancement material. The enhanced tubes and the smooth tubes all had an average diameter of 19.1 mm.

The surface temperatures of the heated tubes were calculated using a one-dimensional, steady-state heat conduction equation for a cylinder:

$$T_w = T_{tc} - \frac{q_n'' D_o}{2 k_t} \ln \left[\frac{D_o}{2R_{tc}} \right] \quad (4.5)$$

where R_{tc} is the radial distance from the center of the tube to the center of the thermocouple well. The heat flux at the outside tube surface, q_n'' , is given by equation (4.3) and the temperature at the thermocouple position, T_{tc} , is measured by the DAS. The average tube wall surface temperature, $T_{w,ave}$, was then calculated as the arithmetic average of the four temperatures calculated as in equation (4.5) from the four thermocouple measurements.

The saturation temperature of the refrigerant was calculated as a function of the pressure. When pure R-113 was the working fluid, two equations given by Jensen (1980) were used for determining the saturation temperature. The expression for the saturation temperature in the range of absolute pressures from 2 bar (29.48 psi) to 4 bar (58.49 psi) was given as

$$T_{sat} = 545.741 + 2.862 P_n - 0.01423 P_n^2 \quad (4.6)$$

and in the range of absolute pressures from 4 bar (58.49 psi) to 7 bar(108.2 psi) as

$$T_{\text{sat}} = 578.073 + 1.741 P_n - 0.004424 P_n^2 \quad (4.7)$$

where P_n is the local absolute pressure (given in psia) at tube n.

The local pressure was determined by first measuring the inlet pressure to the tube bundle, P_0 , using the bourdon tube pressure gauge. Next, the pressure drops across adjacent pressure taps throughout the tube bundle, $\Delta P_{(j-1) \text{ to } j}$, were measured with the pressure transducer so that the local pressures at the pressure taps, P_j , could be calculated as

$$P_j = P_0 + \sum_{i=1}^j \Delta P_{(i-1) \text{ to } i} \quad (4.8)$$

The local pressures at the heated tubes, P_n , could then be calculated by interpolating between the pressures at the pressure taps based on the distance from the heated tube location to the nearest pressure tap locations.

The above procedure for determining the local pressures and temperatures was used during experiments when the outlet was subcooled. However, more precise values could be obtained when two-phase flow existed at the tube bundle outlet. When the refrigerant at the outlet was saturated, the outlet pressure was assumed to be the saturation pressure based on the outlet temperature. The

saturation pressure at the outlet, P_5 (kPa), was calculated from the outlet temperature, T_o (K), using an equation based on the results of Downing (1974):

$$\log(6.89 P_5) = C_1 - C_2/T_o - C_3 \log(9 T_o/5) + C_4 \quad (4.9)$$

where

$$C_1 = 33.0655$$

$$C_2 = -2406.1$$

$$C_3 = -9.2635$$

$$C_4 = 0.003697$$

The pressures at the pressure taps were then calculated using the pressure drops measured across adjacent pressure taps as

$$P_{5-j} = P_5 - \sum_{i=1}^j \Delta P_{(5-i) \text{ to } (6-i)} \quad (4.10)$$

When the inlet temperature of the refrigerant was below the saturation temperature, the refrigerant temperature was calculated using the measured inlet temperature, T_{in} . An energy balance was performed row by row through the tube bundle in order to calculate the bulk fluid temperature immediately upstream of

each row having an instrumented tube. The bulk fluid temperature of the refrigerant was calculated as:

$$T_{f,n} = T_{in} + \frac{Q_{1-n}}{\dot{m} c_p} \quad (4.11)$$

where Q_{1-n} was the heat transferred from all the tubes in rows 1 through n. The power delivered to each set of cartridge heaters through a given set of bus bars was calculated as the product of the current and voltage measured by the DAS. The power delivered by the cartridge heaters was uniform throughout a given portion of the tube bundle so that the power delivered by the tubes in rows 1 through n was assumed to be proportional to the number of tube rows.

The quality at the inlet to the tube bundle was calculated using the inlet temperature and the saturation temperature corresponding to the inlet pressure. Assuming that the refrigerant flowing through the flashing valves underwent an isenthalpic process, the inlet quality could be calculated as:

$$x_{in} = \frac{c_p(T_{fv} - T_{sat,in})}{i_{fg}} \quad (4.12)$$

where c_p is the specific heat of the pure refrigerant, T_{fv} is the temperature immediately upstream of the flashing valves, $T_{sat,in}$ is the temperature at the inlet to the tube bundle, and i_{fg} is the enthalpy of vaporization for the pure refrigerant.

The quality immediately downstream of the n^{th} tube row was calculated by performing an energy balance on the first n tube rows:

$$x_n = x_{in} + \frac{Q_{1-n}}{\dot{m} i_{fg}} \quad (4.13)$$

The mass flux was calculated using the volume flow rate measured by the turbine flowmeters and the density of the refrigerant, which was calculated as a function of temperature. The volumetric flow rate was calculated as a function of the frequency of the pulses generated by the turbine flowmeter. The total mass flow rate, $\dot{m}$, was then calculated as the product of the volumetric flow rate and the refrigerant liquid density. Finally, the mass flux, G , was calculated based on the minimum flow area between the heated tubes. The equation used to calculate the mass flux was

$$G = \frac{\dot{m}}{4(p - D_o)L} \quad (4.14)$$

where p is the tube bundle pitch and the 4 in the denominator is a result of having five heated tubes (four flow areas) in each row. Sample calculations for property evaluations and reducing the data obtained in pure R-113 can be found in Appendix B.

The procedure for reducing data taken in pure R-11 was the same as for pure R-113 except that routines for calculating the thermodynamic and physical properties of R-11 had to be substituted for those of R-113. A computer program to calculate properties of refrigerant mixtures, developed by the National Institute

of Science and Technology (National Bureau of Standards 1986) was used to calculate the properties of pure R-11. The calculated values were compared with tabulated values from ASHRAE (1985) and were all within 0.5%.

The procedure for reducing data taken in mixtures of R-11 and R-113 was generally similar to the procedure for pure refrigerants except that additional procedures for determining the properties of the mixture and for determining the mixture concentration throughout the bundle were required. Because the tube bundle used in the experiments involving refrigerant mixtures contained all three surfaces, the local mole fractions were determined so that the local quality and mixture concentration were known.

The mixture properties were calculated using the computer program developed by the National Institute of Science and Technology (National Bureau of Standards 1986) which calculates thermodynamic properties (saturation pressure, specific volume, enthalpy, specific heats, etc.) for a given temperature or saturation temperature for a given pressure. In either case, the concentration of the mixture is required. This computer program requires numerical coefficients for the pure refrigerants and the mixture. Coefficients for eleven pure refrigerants were provided including those for R-113 and R-11. Coefficients for seven mixtures were also provided, but the coefficient for the R-113/R-11 combination used in this project was not given. Therefore, a procedure was devised for obtaining the numerical coefficient from experimental pool boiling data, as discussed in Appendix E.

In order to calculate the composition throughout the tube bundle, the maximum number of independent, intensive variables required to specify the thermodynamic state was determined using Gibb's phase rule:

$$F = 2 - \varphi - m \quad (4.15)$$

where F is the maximum number of independent, intensive variables required to specify the thermodynamic state, φ is the number of phases present, and m is the number of species in the solution. For a vapor/liquid system containing two chemical species in equilibrium, the number of variables required to specify the thermodynamic state is two. The two variables normally chosen are pressure and either the temperature or the mole fraction of one of the constituents. These variables are commonly represented on two-dimensional phase diagrams where temperature is plotted as a function of the mole fraction of the most volatile component for a given pressure. An example is shown in Fig. 4.12 for a mixture of R-11 and R-113 at a pressure of 103, 202, and 606 kPa, which were generated using the mixture properties program.

Because the pressure and temperature were known at the outlet, the computer program could be used to calculate mole fractions using an iterative process. The measured outlet temperature and an estimate for the mole fraction of R-113 in the liquid phase, y_{R113}^l , was input to the computer program and the saturation pressure was calculated. This value was compared with the experimentally determined value for the outlet pressure. The mole fraction, y_{R113}^l , was adjusted until the output saturation pressure was within 0.1% of the

Figure 4.12.

Phase diagram for mixtures of R-11 and R-113.

experimental value. The mole fraction of R-11 in the liquid, $\tilde{y}_{R11}^I$, was calculated from

$$\tilde{y}_{R11}^I = 1 - \tilde{y}_{R113}^I \quad (4.16)$$

The same iterative procedure was used to determine the vapor mole fractions of R-113, $\tilde{y}_{R113}^{II}$, and R-11, $\tilde{y}_{R11}^{II}$.

Knowledge of the mole fractions also permitted the determination of the outlet quality, which could be calculated using an equation similar to that for the pure fluids:

$$x_{out} = \frac{\tilde{i}_{out} - \tilde{i}_f}{\tilde{i}_{fg}} \quad (4.17)$$

where the saturation enthalpy of the liquid mixture, $\tilde{i}_f$, and the enthalpy of vaporization for the mixture, $\tilde{i}_{fg}$, were calculated using the mixture properties program, and the enthalpy of the mixture at the outlet was calculated using:

$$\begin{aligned} \tilde{i}_{out} = & (\tilde{y}_{R113}^I \tilde{m}_L \tilde{i}_{R113} + \tilde{y}_{R11}^I \tilde{m}_L \tilde{i}_{R11} \\ & + \tilde{y}_{R113}^{II} \tilde{m}_V \tilde{i}_{R113} + \tilde{y}_{R11}^{II} \tilde{m}_V \tilde{i}_{R11}) / \tilde{m} \end{aligned} \quad (4.18)$$

In equation (4.18), the molar flowrate of the liquid, $\dot{m}_L$, was calculated by first performing a component balance on the R-113:

$$\tilde{y}'_{b,R113} = \frac{\tilde{y}'_{R113} \tilde{m}_L + \tilde{y}''_{R113} \tilde{m}_V}{\tilde{m}_L + \tilde{m}_V} \quad (4.19)$$

where the overall mole fraction of R-113 at the test chamber inlet, $\tilde{y}'_{b,R113}$, was measured experimentally using mass spectrometry. Using the relation:

$$\tilde{m} = \tilde{m}_L + \tilde{m}_V \quad (4.20)$$

Eq(4.19) becomes:

$$\tilde{m}_L = \tilde{m} \frac{\tilde{y}'_{b,R113} - \tilde{y}''_{R113}}{\tilde{y}'_{R113} - \tilde{y}''_{R113}} \quad (4.21)$$

The molar flow rate of the vapor, $\tilde{m}_V$, can easily be calculated using equation (4.20).

The outlet enthalpy as calculated from equation (4.18) was checked by comparing it with the value determined by performing an overall energy balance on the tube bundle. An energy balance performed on the entire bundle results in

$$\tilde{i}_{out} = \tilde{i}_{in} + Q_{tot}/\tilde{m} \quad (4.22)$$

where Q_{tot} is the total heat transfer from the tube bundle. Values of $\tilde{i}_{\text{out}}$ calculated using equation (4.18) were within 5% of the values of $\tilde{i}_{\text{out}}$ calculated using equation (4.22).

The inlet quality was seldom identically equal to zero. Therefore, if the inlet pressure was less than the saturation pressure as calculated from the measured inlet temperature, then a procedure similar to the one described above for calculating the outlet quality was also used to calculate the inlet quality. The measured inlet temperature and a guess for the mole fractions in the liquid were input to the mixture properties program and the calculated pressure was compared with the measured pressure. New guesses for the mole fraction were input until the calculated pressure was within 0.1% of the measured value. When the enthalpy at the inlet was known, the inlet quality was calculated as

$$x_{\text{in}} = \frac{\tilde{i}_{\text{in}} - \tilde{i}_{\text{f}}}{\tilde{i}_{\text{fg}}} \quad (4.23)$$

If the inlet is slightly subcooled (the measured inlet pressure is slightly higher than the saturation pressure) then the inlet quality is calculated as

$$x_{\text{in}} = \tilde{c}_{\text{p}}(T_{\text{in}} - T_{\text{f}})/\tilde{i}_{\text{fg}} \quad (4.24)$$

where $\tilde{c}_{\text{p}}$, T_{f} , and $\tilde{i}_{\text{fg}}$ were calculated using the mixture property program and the measured inlet pressure.

A slightly different procedure was used to determine the quality at each instrumented tube. Because the temperature of the liquid mixture was not

measured throughout the bundle, the enthalpy at a given tube row was used. The enthalpy at row n was calculated using an energy balance over the first n rows:

$$\tilde{i}_n = \tilde{i}_{in} + Q_{1-n}/\tilde{m} \quad (4.25)$$

where Q_{1-n} is an integral value of the measured heat input from the inlet to row n . The enthalpy at row n was also calculated using an equation similar to equation (4.18):

$$\begin{aligned} \tilde{i}_n = & (\tilde{y}_{R113}^I \tilde{m}_L \tilde{i}_{R113} + \tilde{y}_{R11}^I \tilde{m}_L \tilde{i}_{R11} \\ & + \tilde{y}_{R113}^{II} \tilde{m}_V \tilde{i}_{R113} + \tilde{y}_{R11}^{II} \tilde{m}_V \tilde{i}_{R11})/\tilde{m} \end{aligned} \quad (4.26)$$

where the molar enthalpies and molar flow rates were evaluated using the local values for the molar concentrations.

The procedure for determining the local molar concentrations involved iterating on the local fluid temperature until the enthalpy as calculated using equation (4.26) was within 0.1% of the value obtained using equation (4.25). The procedure began with a guess for the temperature at row n so that the mixture properties could be calculated using the mixture property program. The molar concentrations were determined for the measured pressure and guessed value for the temperature using the iterative procedure described above. The molar flow rates of the liquid and vapor were calculated as in equation (4.21) and the enthalpy was calculated as in equation (4.26). If this value did not match the value obtained in equation (4.25), then a new guess for the local temperature was made and the

process was repeated until $\tilde{i}_n$ from equation (4.26) was within 0.1% of the value from equation (4.25). Thus, the procedure for determining the local enthalpy involved a double iteration.

Once the local enthalpy was known, the quality at row n was calculated as:

$$x_n = \frac{\tilde{i}_n - \tilde{i}_f}{\tilde{i}_{fg}} \quad (4.27)$$

This procedure was repeated to find the local conditions at each tube row. After the thermodynamic state had been fixed for the 15th row, the temperature could be compared with the measured outlet temperature as an additional check. The value for the outlet temperature as computed above was generally within 0.2° C of the measured value.

The double iteration procedure described above for calculating the temperature throughout the tube bundle was found to be very time consuming. In order to reduce the number of iterations involved, values of the equilibrium ratio (K-values) were calculated. K-values for the R-113 were defined as

$$K_{R113} \equiv \tilde{y}_{R113}'' / \tilde{y}_{R113}' \quad (4.28)$$

K-values were calculated for a range of pressures and temperatures. In order to use these values in a computer program, a regression analysis was performed. The appropriate form of the equation for the regression analysis was determined using an approximate relation for the K-value:

$$K_{R113} \approx P_{sat,R113} / P \quad (4.29)$$

where the saturation pressure was approximated using the Clausius–Clapyron equation:

$$\ln (P_{sat}) = A - B/T \quad (4.30)$$

and where A and B are constants to be determined. Solving for P_{sat} and inserting it into equation (4.29):

$$K \approx \exp(A-B/T)/P \quad (4.31)$$

The regression analysis resulted in a correlation for K_{R113} in which A and B were found to be 15.352 and 3194.422 respectively. A similar procedure was used to produce a correlation for the K-values of R-11 and the constants in the correlation were found to be 15.527 and 3297.124. In this way, precise K-values could be calculated without using ideal mixture assumptions.

In order to make use of the K-values, equations (4.19) and (4.20) were combined to get

$$\tilde{y}_{R113}^I = \frac{\tilde{y}_{b,R113}^I \tilde{m}}{\tilde{m}_L + (\tilde{y}_{R113}^{II}/\tilde{y}_{R113}^I)(\tilde{m} - \tilde{m}_L)} \quad (4.32)$$

Similarly for R-11:

$$\tilde{y}_{R11}^I = \frac{\tilde{y}_{b,R11}^I \tilde{m}}{\tilde{m}_L + (\tilde{y}_{R11}^{II}/\tilde{y}_{R11}^I)(\tilde{m} - \tilde{m}_L)} \quad (4.33)$$

Substituting equations (4.32) and (4.33) into the relationship

$$\tilde{y}_{R113}^I + \tilde{y}_{R11}^I = 1 \quad (4.34)$$

we get

$$1 = \frac{\tilde{y}_{b,R113}^I \tilde{m}}{\tilde{m}_L + (\tilde{y}_{R113}^{II}/\tilde{y}_{R113}^I)(\tilde{m} - \tilde{m}_L)} + \frac{\tilde{y}_{b,R11}^I \tilde{m}}{\tilde{m}_L + (\tilde{y}_{R11}^{II}/\tilde{y}_{R11}^I)(\tilde{m} - \tilde{m}_L)} \quad (4.35)$$

K-values can now be substituted into equation (4.35) to get:

$$1 = \frac{\tilde{y}_{b,R113}^I \tilde{m}}{\tilde{m}_L + K_{R113}(\tilde{m} - \tilde{m}_L)} + \frac{\tilde{y}_{b,R11}^I \tilde{m}}{\tilde{m}_L + K_{R11}(\tilde{m} - \tilde{m}_L)} \quad (4.36)$$

The inlet conditions $\tilde{y}_{b,R113}^I$ and $\tilde{y}_{b,R11}^I$ were measured experimentally so that the only unknown in equation (4.36) is $\tilde{m}_L$. Solving equation (4.36) for $\tilde{m}_L$ results in a quadratic equation that can be solved without iterating. Therefore, equation (4.36) could be used instead of equation (4.21), and the iteration involved with solving for the local molar concentration as a function of temperature and pressure could be

avoided resulting in significant time savings. Identical results were obtained using both methods of data reduction.

Appendix C gives the uncertainty analysis for this data reduction method and lists the uncertainty in the measured parameters. The uncertainty of the heat flux was $\pm 1.0\%$. The uncertainty was 0.12°C for the thermocouple readings which led to an uncertainty of 0.15°C for the wall temperature. The pressure readings had an uncertainty of $\pm 0.5\%$ and the uncertainty for the saturation temperature 0.12°C so that the uncertainty in the wall superheat was $\pm 1.4\%$. The resulting uncertainty in the heat transfer coefficient depends on the wall superheat but is usually less than 3.5% of the absolute value. The mass flux had an uncertainty of $\pm 3.0\%$ which resulted in an uncertainty for the quality of $\pm 0.5\%$.

CHAPTER 5

SHELLSIDE BOILING EXPERIMENTAL RESULTS AND DISCUSSION

The tube-bundle test chamber was used to conduct experiments to determine the effects of flow conditions, bundle geometry, multicomponent fluids, and heated-tube surface structure on the thermal-hydraulic performance of horizontal tube bundles. Single-phase experiments were performed to establish the validity of the experimental apparatus. Two-phase heat transfer coefficients were obtained from individual tubes for a range of mass fluxes, heat fluxes, qualities, and pressures in two bundles having different pitch-to-diameter ratios. Experiments were conducted in pure R-113, pure R-11, and mixtures of both with tube-bundle inlet concentrations of approximately 25%, 50%, and 75% R-11 by mass.

Single-Phase Data and Results

Single-phase heat transfer coefficients were obtained for individually heated tubes in the tube bundle in order to establish the validity of the experimental apparatus and procedure. The heat transfer coefficients for the individual tubes obtained by experiment were compared with values predicted by a correlation developed by ESDU (1973) for smooth tubes. Figure 5.1 shows the heat transfer coefficients for individual tubes as a function of tube row. The predicted value of the heat transfer coefficient for the first row is considerably smaller than for subsequent rows. The same trend is found in the experimental values of the heat transfer coefficient for smooth tubes, although the difference between the first and subsequent rows for the experimental data is not as large as the difference between the first and subsequent rows as predicted by the ESDU correlation.

Figure 5.1. Single-phase heat transfer coefficients in the tube bundle.

Average values of the heat transfer coefficient for the tube bundle were also compared with established correlations. The average heat transfer coefficient for the tube-bundle was calculated as the arithmetic average of individual values for rows 1 through 13. The last tube row was not included in order to avoid any exit effects in the experimental data so that the experimental values for the average heat transfer coefficient could be directly compared with values given by Zukauskas (1987) and ESDU (1973).

Figure 5.2 shows experimental and predicted bundle-average values for the non-dimensional heat transfer coefficient ($Nu/Pr^{0.34}$) as a function of Reynolds number where the Reynolds number is based on the total mass flow of the fluid flowing through the minimum flow area of the bundle. The experimental heat transfer coefficients for bundles of smooth tubes and bundles of tubes with enhanced surfaces were within the experimental uncertainties of each other. This indicates that the surface roughness of the enhanced tubes is sufficiently small to have a negligible effect on the single-phase heat transfer. Values for the non-dimensional heat transfer coefficient predicted using the correlation given by Zukauskas were very close to those predicted by the ESDU correlation for the Reynolds number of interest, even though the curves for the two correlations have different slopes.

The single-phase pressure drop across the tube bundle also was measured and compared to predictions using the ESDU (1979) correlation. Figure 5.3 shows the experimental and predicted total pressure drop across the tube bundle as a function of Reynolds number. The total pressure drop was measured experimentally using the procedure outlined in Chapter 4, and the predicted values were obtained by adding the unrecoverable component of the static pressure drop given by ESDU to the hydrostatic head calculated from the bundle height and density of the R-113.

Figure 5.2. Bundle-average non-dimensional single-phase heat transfer data.

Figure 5.3. Single-phase pressure drops across the tube bundle.

The experimental values for all three surfaces are generally within the experimental uncertainty of the predicted values, which demonstrates, again, that the structured surface of the enhanced tubes is small enough to prevent a significant increase in the single-phase pressure drop. The results for both the heat transfer and pressure drop are within the experimental uncertainty of values obtained from established correlations thereby establishing the validity of the experimental apparatus and procedure.

Boiling Heat Transfer Results in Pure Refrigerants

Bundles of tubes having smooth, High Flux, and Turbo-B surfaces were used to perform bundle boiling experiments in pure R-113 and pure R-11. Two-phase heat transfer coefficients were obtained for individual tubes in the tube-bundles. Bundles having pitch-to-diameter ratios of 1.17 and 1.50 were used. The experiments were conducted for a range of pressures, mass fluxes, and heat fluxes so that the effect of these parameters on the tube-bundle performance could be ascertained.

Smooth tube results in pure R-113

Two-phase heat transfer coefficients were obtained for smooth tubes in bundles having pitch-to-diameter ratios of 1.50 and 1.17. For the bundle with a pitch-to-diameter ratio of 1.17, experiments were performed for mass fluxes ranging from 50 to 500 kg/m²s and heat fluxes ranging from 5 to 80 kg/m² at pressures of approximately 200 and 600 kPa. Experiments were performed for mass fluxes ranging from 50 to only 225 kg/m²s in the tube-bundle with a

pitch-to-diameter ratio of 1.50 due to limitations in preheater power and the requirement that the inlet flow be near saturation.

Figure 5.4 shows two-phase heat transfer coefficients as a function of tube row obtained in the bundle with a pitch-to-diameter ratio of 1.17 for a mass flux of $230 \text{ kg/m}^2\text{s}$ and a pressure of 200 kPa. Data were obtained for heat flux values ranging from 5 to 70 kW/m^2 . The heat transfer coefficients increase significantly with heat flux. For a given heat flux value, however, the heat transfer coefficients are nearly independent of tube row. Because the total mass flux, pitch-to-diameter ratio, and heat flux were constant throughout the tube-bundle, the abscissa is directly proportional to the flow quality for a given heat flux value. Therefore, Fig. 5.4 also shows that the heat transfer coefficient did not change significantly with flow quality.

Note that in Fig 5.4 for the small heat flux value of 5.1 kW/m^2 , the change in the heat transfer coefficient from the first row to the last was only $400 \text{ W/m}^2\text{K}$ but that this is 44% of the average value ($900 \text{ W/m}^2\text{K}$). At a slightly larger heat flux value of 20 kW/m^2 , the change in the heat transfer coefficient from the first row to the last was $500 \text{ W/m}^2\text{K}$ but this is only 20% of the average value. Therefore, the effect of changing quality on the heat transfer coefficient was small except for relatively small heat flux values.

Figure 5.5 shows two-phase heat transfer coefficients as a function of tube row for a heat flux of 20 kW/m^2 . Data taken at mass fluxes of approximately 50 and $500 \text{ kg/m}^2\text{s}$ are shown for pressures of approximately 200 and 600 kPa. The effect of mass flux can be seen by comparing the data at $52 \text{ kg/m}^2\text{s}$ and 200 kPa to the data taken at $506 \text{ kg/m}^2\text{s}$ and 200 kPa. The differences between the heat transfer coefficients at 52 and $500 \text{ kg/m}^2\text{s}$ are less than 20% for each tube row

Figure 5.4. Effect of heat flux and tube row/quality on the smooth tube heat transfer coefficients.

Figure 5.5. Effect of mass flux and pressure on the smooth tube heat transfer coefficients.

except the first row, even though the heat flux is relatively small (20 kW/m²). The same is true of data taken at 600 kPa. In addition, there is only a very slight increase in the heat transfer coefficient with tube row for the data taken at 200 kPa and a slight decrease for the data taken at 600 kPa. Therefore, the effect of varying the mass flux by an order of magnitude is minimal on the heat transfer coefficient for smooth tubes.

The insensitivity of the heat transfer coefficient to changes in mass flux is characteristic of heat transfer dominated by nucleate boiling. Conceivably, a balance of nucleate boiling and single-phase convection could also explain the lack of a mass flux effect if an increased mass flux resulted in a decrease in the nucleate boiling component equal to the increase in the single phase convection component.

One possible argument for a balance between nucleate boiling and single-phase convective heat transfer rests on an inverse relationship between the bubble departure diameter and the liquid velocity. Mikic and Rohsenow (1969) proposed that nucleate boiling is a function of the bubble departure diameter as follows:

$$q''_{\text{nuc}} = C_1 D_b^2 \sqrt{f} n \Delta T \quad (5.1)$$

In the presence of free stream convection, an estimate for the bubble departure diameter can be obtained by a balance between drag forces and surface tension forces:

$$F_d = F_\sigma \quad (5.2)$$

where

$$F_d = C_2 D_b^2 \rho_L u_L^2 \quad (5.3)$$

and

$$F_{\sigma} = C_3 \sigma D_b \quad (5.4)$$

After substituting equations (5.3) and (5.4) into equation (5.2) and rearranging,

$$D_b = C_4 \sigma / (\rho_L u_L^2) \quad (5.5)$$

Equation (5.5) shows that the bubble departure diameter and, therefore, the nucleate boiling heat flux decrease with increasing liquid velocity/mass flux. A correlation by ESDU (1973) gives the single-phase convective heat flux as a function of liquid velocity as

$$q_{sc}'' = C_5 \text{Re}^{0.635} \text{Pr}^{0.34} \Delta T \quad (5.6)$$

so that the heat flux increases with mass flux. If the increase in the single-phase convective heat transfer is equal to the decrease in the nucleate boiling heat transfer, then the heat transfer coefficient will not vary with mass flux.

In addition to the lack of a mass flux effect, the lack of a tube row/quality effect also might be explained using a balance between nucleation and single-phase convective heat transfer. The liquid velocity can be related to fluid properties so that regions where such a balance might occur could be identified. The velocity of the liquid changes throughout the bundle as

$$u_L = \frac{G(1-x)}{\rho_L(1-\alpha)} \quad (5.7)$$

where x and α depend on the tube row. Dowlati et al. (1988) developed a correlation for the void fraction through a tube bundle as

$$\alpha = 0.88 \left[j_g \sqrt{\rho_g / (\rho_L - \rho_g)} \sqrt{1 / g D_t} \right]^{0.57} \quad (5.8)$$

so that equations (5.7) and (5.8) can be used to calculate the liquid velocity as a function of x and $\rho_g / (\rho_L - \rho_g)$ (which is approximately equal to ρ_g / ρ_L). Kandlikar (1990) showed that the non-dimensional heat transfer coefficient (h/h_{sc}) can remain constant or even decrease for some combinations of x and ρ_g / ρ_L , as seen in Fig. 5.6.

While it is conceivable that the lack of a mass flux or tube row/quality effect on the heat transfer coefficient is a result of the fluid properties, the required balance between the nucleate boiling and single-phase convective heat transfer is highly speculative. Visual observations revealed the presence of bubble generation over nearly the entire surface of the smooth tubes, especially for heat flux values greater than 20 kW/m², as seen in Fig. 5.7. Therefore, the lack of a mass flux or tube row/quality effect on the heat transfer coefficient is a result of a heat transfer process dominated by fully established nucleate boiling.

Figure 5.5 shows that the heat transfer coefficient was sometimes smaller for the first tube row than for subsequent rows, particularly for small mass flux values. In addition, the heat transfer coefficient for the first tube row taken at 200 kPa and 52 kg/m²s was smaller than the pool boiling value at the same heat flux and approximately 100 kPa. This relatively small value for the heat transfer coefficient at the first tube row was evident even for heat flux values as large as 80 kW/m², which is much larger than the largest heat flux value required to establish fully

Figure 5.6. Non-dimensional heat transfer coefficients as a function of quality and density ratio (Kandlikar 1990).

Figure 5.7.

Nucleate boiling on the bottom of smooth tubes in a bundle.

developed nucleate boiling for pool boiling. The data obtained in the tube-bundle experiments suggest that fully established nucleate boiling is sometimes suppressed at the first tube row. This trend is more prominent in the High Flux tubes and will be discussed below in more detail.

The effect of pressure on the heat transfer coefficient can be seen by comparing the data shown in Fig. 5.5 taken at $50 \text{ kg/m}^2\text{s}$, for example. An increase in the pressure from 200 to 600 kPa increased the average heat transfer coefficient for the interior tube rows from approximately $1.8 \text{ kW/m}^2\text{K}$ to approximately $2.4 \text{ kW/m}^2\text{K}$ (approximately $600 \text{ W/m}^2\text{K}$). The increase in the average heat transfer coefficient is also $600 \text{ W/m}^2\text{K}$ for the data taken at a mass flux of $500 \text{ kg/m}^2\text{s}$. As a result, the heat transfer coefficients taken at 600 kPa were approximately 33% larger than those taken at 200 kPa, regardless of mass flux.

The effect of the pitch-to-diameter ratio on the heat transfer coefficients is shown in Fig. 5.8 where heat transfer coefficients as a function of tube row are given for a mass flux of $219 \text{ kg/m}^2\text{s}$ and a pressure of 200 kPa. Figure 5.8 shows that, even for the relatively small heat flux value of 10 kW/m^2 , the heat transfer coefficients for the bundle of smooth tubes with the pitch-to-diameter ratios of 1.17 are only slightly larger than the data from the bundle with the pitch-to-diameter ratio of 1.50. With increasing heat flux, the difference becomes even less. Figure 5.8 shows that, for the data taken at 40 kW/m^2 , the results from the two tube-bundles with different pitch-to-diameter ratios overlap. There is generally no significant difference between the data from different tube layouts for similar operating conditions at any but the lowest heat flux values.

Figure 5.8. Effect of pitch-to-diameter ratio on the smooth tube heat transfer coefficients.

High Flux tube results in pure R-113

The heat transfer coefficients for the High Flux tubes were obtained in the tube bundle with a pitch-to-diameter ratio of 1.17. Experiments in the tube bundle with a pitch-to-diameter ratio of 1.50, which would have provided a measure of the convective effects, were not performed because the pitch-to-diameter ratio was found to generally have a negligible effect on the heat transfer coefficients for smooth tubes and because the High Flux surface is even less susceptible to convective effects than the smooth surface.

Two-phase heat transfer coefficients as a function of tube row are shown in Fig. 5.9 for a mass flux of $352 \text{ kg/m}^2\text{s}$ and a pressure of 200 kPa. For a given heat flux, the heat transfer coefficient is nearly independent of tube row, except for the first two instrumented tubes. Therefore, as with the smooth tube results, the heat transfer coefficients are independent of quality because changes in tube row correspond to changes in quality. Some scatter in the data is present due to the uncertainty in the heat transfer coefficients; the uncertainty is primarily a result of the relatively small values for the wall superheats.

Figure 5.9 also shows that the heat transfer coefficient increases for the first three tube rows before attaining a constant value independent of flow quality. These results are even more dramatic than those for the first three rows of smooth tubes. Visual observations support the hypothesis that fully established nucleate boiling is somewhat suppressed in a tube bundle as compared to a single tube in pool boiling. Indeed, patches of the High Flux surface failed to nucleate even at heat flux values as high as 80 kW/m^2 and qualities as high as 0.76.

One explanation for this is associated with the possibility that the maximum heat flux attainable by the experimental apparatus was not sufficient to initiate

Figure 5.9. Effect of heat flux and tube row/quality on the High Flux tube heat transfer coefficients.

fully established nucleate boiling for the High Flux tubes, even though the data were collected for each mass flux starting with the highest heat flux value. As observed in the pool boiling experiment and reported by other researchers (Bergles and Chyu 1982), the High Flux surface does not always nucleate initially over its entire surface as the heat flux is increased. Once part of the surface nucleates, the nucleation process does not spread in the High flux surface as easily as on the smooth surface, because vapor traveling around the perimeter of a smooth tube is more likely to activate extinct nucleation sites than in the High Flux surface where the subsurface cavities are not all interconnected. However, the high conductivity, thick-walled construction of the heated tube tends to maintain the entire surface at a uniform temperature. Therefore, when one area of the heated surface nucleates, the surface area is generally large enough so that the temperature of the entire heated surface is reduced. The heat flux must then be increased sufficiently so that the required incipience superheat is achieved at the locations where nucleation has not been initiated.

In the tube bundle, the increased velocity of the free stream fluid helps to reduce the temperature of the non-nucleated portion of the heated surface below that for a tube in pool boiling so that an even larger heat flux is required to achieve the superheat necessary to initiate nucleation. This explains the areas of non-nucleating heated surface of the High Flux tubes observed in the tube bundle experiments even at the top row at heat fluxes as high as 80 kW/m^2 .

Nucleate boiling in the first rows of the High Flux tube bundle is further delayed due to a lack of vapor rising from tubes lower in the bundle. The bundle of smooth tubes does not show this effect as dramatically, because vapor from the bottom of even the first tube can more easily travel around the circumference and

activate extinct nucleation sites, thereby initiating nucleate boiling earlier than for the High Flux tubes.

The combination of the piece wise onset of nucleation and the effect of rising bubbles on the High Flux surface can be seen by observing the trends in the heat transfer coefficients as the heat flux is increased from very small values before nucleation has been initiated. Figure 5.10 shows the tube bundle results for the High Flux tubes as the heat flux is increased from 0.6 to 5.1 kW/m². For comparison, similar results are shown for the smooth tube bundle in Fig. 5.11. The heat transfer coefficients for the High Flux tubes at 5.1 kW/m² are approximately equal to the values obtained after the heat flux has been increased to the maximum value and then decreased. Large increases in the heat transfer coefficients from one heat flux to the next higher value indicate the onset of nucleation. Note that nucleation occurs in upper portions of the bundle first where the volume of vapor is the largest. Also note the relatively uniform spacing in the heat transfer coefficients for the smooth tubes indicating that nucleation was easily established and very little temperature overshoot occurred.

The heat transfer coefficients for High Flux tubes are significantly affected by changes in the heat flux. Figure 5.9 shows that the change in the average heat transfer coefficient with changing heat flux is largest at low values for the heat flux. These same data were plotted on a typical boiling curve as shown in Fig. 5.12 where each data point for tube bundle boiling was calculated using the arithmetic average of the heat flux and wall superheat for the instrumented tubes in rows 3 through 13. Recall that the pool boiling data were obtained at near atmospheric pressure and the data obtained in the tube bundle were taken at 200 kPa. The data obtained in the tube bundle result in a boiling curve which is very steep in the range of low heat

Figure 5.10. Onset of nucleate boiling for a High Flux tube bundle at $P = 200 \text{ kPa}$ and $G = 150 \text{ kg/m}^2\text{s}$.

Figure 5.11. Onset of nucleate boiling for a smooth tube bundle at $P = 200 \text{ kPa}$ and $G = 100 \text{ kg/m}^2\text{s}$.

Figure 5.12. Boiling curves tube bundles at $P = 202$ kPa, and for single tubes in pool boiling at $P = 103$ kPa.

flux. Figure 5.12 also shows that the boiling curve for High Flux tubes in pool boiling is steepest at low values of heat flux. Therefore, the trend for the two-phase heat transfer coefficient in a tube bundle is the same as for pool boiling. This coincidence strongly suggests that nucleate boiling is the predominant mechanism for heat removal throughout the bundle.

The effect of changes in mass flux on the heat transfer coefficient can be seen in Fig. 5.13 where the heat transfer coefficient is plotted versus tube row for a constant heat flux value of 20 kW/m^2 and 200 kPa and mass flux values ranging from 53 to $504 \text{ kg/m}^2\text{s}$. The large scatter in the data is a result of very low wall superheat for the High Flux surface. All the data are within the experimental uncertainty of the average value for the heat transfer coefficient. Therefore, even though the mass flux changes by an order of magnitude, the effect on the heat transfer coefficient is insignificant even for relatively small heat flux values. This is expected from the dominance of the nucleate boiling.

The effect of pressure on the heat transfer coefficient is shown in Fig. 5.14 where the heat transfer coefficient is plotted versus the tube row for a mass flux of $500 \text{ kg/m}^2\text{s}$. Data taken at heat flux values of 10 , 40 , and 80 kW/m^2 are given for pressures of 200 and 600 kPa each. Figure 5.14 shows that the heat transfer coefficients increase with pressure for a given heat flux. For example, the average heat transfer coefficient at 10 kW/m^2 is approximately $2000 \text{ W/m}^2\text{K}$ (22%) greater at 600 kPa than at 200 kPa . In addition, the pressure enhancement increases with increasing heat flux. The average heat transfer coefficient at 600 kPa and 80 kW/m^2 is $6000 \text{ W/m}^2\text{K}$ (32%) greater than at 200 kPa and 80 kW/m^2 . In general, the heat transfer coefficient was 30% greater at 600 kPa and at 200 kPa . This

Figure 5.13. Effect of mass flux on the High Flux heat transfer coefficients.

Figure 5.14. Effect of heat flux and pressure on the High Flux heat transfer coefficients.

percentage increase in the heat transfer coefficient is only slightly smaller than the smooth tube value of 33%.

The trends in the data generally suggest that the pressure effect is the result of changes in the nucleate boiling mechanism. It follows from the work of Mikic and Rohsenow (1969) that the heat transfer coefficient is a function of the number of nucleation sites and the bubble departure diameter. Using mechanical and phase equilibrium for a hemispherical bubble, the required vapor temperature in the bubble can be shown to be

$$T_v = T_{\text{sat}} + \frac{2\sigma}{r_b} \frac{T_{\text{sat}} v_{fg}}{i_{fg}} \quad (5.9)$$

Assuming a linear temperature variation normal to the heated surface in the liquid using thermal equilibrium, the required wall superheat for bubble growth can be shown to be

$$T_w - T_{\text{sat}} = \frac{2\sigma}{r_b} \frac{T_{\text{sat}} v_{fg}}{i_{fg}} + \frac{q'' r}{k_l} \quad (5.10)$$

The minimum and maximum radius for bubble growth can be determined by solving equation (5.10) for the bubble radius:

$$r = \frac{T_w - T_{\text{sat}} \pm \sqrt{(T_w - T_{\text{sat}})^2 - \frac{q'' 8 \sigma}{k_l} \frac{T_{\text{sat}} v_{fg}}{i_{fg}}}}{2 q'' r / k_l} \quad (5.11)$$

As seen in equation (5.11), the range of radii which provide for bubble growth increases with $\sqrt{(T_w - T_{\text{sat}})^2 - \frac{q'' 8 \sigma}{k_l} \frac{T_{\text{sat}} v_{fg}}{i_{fg}}}$ and so increases with decreasing values of $(T_{\text{sat}} v_{fg} / i_{fg})^{\frac{1}{2}}$. Because the number of nucleation sites should

increase with an increase in the range of radii, the number of nucleation sites, which could provide bubble growth, increases with increasing values of $(i_{fg} / T_{sat} v_{fg})^{\frac{1}{2}}$. Note that $(i_{fg} / T_{sat} v_{fg})^{\frac{1}{2}}$ is approximately equal to $(\rho_v i_{fg} / T_{sat})^{\frac{1}{2}}$.

The departure diameter given by Cole and Rohsenow (1968) is a function of $(T_{sat} / \rho_v i_{fg})$. The heat flux is a product of the number of nucleation sites and the bubble departure diameter, and so the heat flux increases with increasing values of $(T_{sat} / \rho_v i_{fg})^{\frac{1}{2}}$ which is a relatively strong function of pressure over the pressure range of interest. For example, the ratio of $(T_{sat} / \rho_v i_{fg})^{\frac{1}{2}}$ at 600 kPa to that at 200 kPa for R-113 is 1.3. This is the same value as the ratio of heat transfer coefficients at 600 kPa and 200 kPa. The pressure effect on the heat transfer coefficient is seen to be predicted reasonably using $(T_{sat} / \rho_v i_{fg})^{\frac{1}{2}}$. Therefore, bubble growth and departure are seen to be the dominant heat transfer mechanism for the High Flux surface.

Turbo-B tube results in pure R-113

Data from a tube bundle with the Turbo-B surface were collected in the bundle with the pitch-to-diameter ratio of 1.50 for a range of mass fluxes from 50 to 335 kg/m²s, heat fluxes from 5 to 80 kW/m², and pressures of 200 and 600 kPa. The upper value of the mass flux range was limited by the ability to maintain a saturated inlet condition, which was determined by the maximum preheater power. As was the case with the High Flux tube bundle, the Turbo-B surface was tested in only one bundle geometry due to the insensitivity of the Turbo-B surface to convective effects.

The heat transfer coefficients for Turbo-B tubes are shown in Fig. 5.15 where the heat transfer coefficient is plotted versus tube row for an average mass

Figure 5.15. Effect of heat flux and tube row/quality on the Turbo-B heat transfer coefficients.

flux of $217 \text{ kg/m}^2\text{s}$ and a pressure of 200 kPa. As was the case for tubes with the smooth and High Flux surfaces, the heat transfer coefficients for the Turbo-B tubes do not change significantly with tube row or quality. In general, the heat transfer coefficient for the first row is nearly the same as for the subsequent rows. Recall that the Turbo-B surface exhibited very little temperature overshoot during pool boiling. Because a lower heat transfer coefficient at the first tube row in a bundle is the result of a delay in the incipience of boiling, as postulated for the High Flux tubes, one would expect that the Turbo-B surface, which attained incipient boiling at the smallest wall superheat among all three surfaces in pool boiling, would be the surface with the least decrease at the first row in the tube bundle.

As described in Chapter 3, the early onset of nucleate boiling is attributed to the subsurface circumferential channels, which tend to keep vapor from lower nucleation sites next to the heated surface as the vapor travels around the circumference. The volume of vapor increases as it travels upward through superheated liquid and activates extinct nucleation sites along the way, which promotes the early establishment of nucleate boiling.

Figure 5.15 also shows that the heat transfer coefficients vary with heat flux, although not as much as for the smooth or High Flux tubes. The reduced effect of heat flux on the heat transfer coefficients is suggested to be a result of the large volume of vapor in the subsurface channels. This leads to a thinning of the liquid layer next to the heated surface and a suppression of nucleate boiling that promotes thin film vaporization in the upper portions of the subsurface channels. A heat transfer coefficient for thin film vaporization can be shown to be a weak function of heat flux by modeling the effect of an increased operating temperature on the heat transfer coefficient.

For turbulent flow in a thin liquid film, Collier (1981) gives the steady-state momentum equation as

$$\tau = \rho (\nu + \epsilon_m) \frac{\partial u_z}{\partial y} \quad (5.12)$$

and the steady-state energy equation as

$$q'' = -\rho c_p (\alpha + \epsilon_h) \frac{\partial T}{\partial y} \quad (5.13)$$

where conduction is in the direction normal to the heated surface only (y-direction) and fluid flow is along the heated surface in one direction only (z-direction). The velocity profile can be described using the universal velocity distribution given by White (1981):

$$u^+ = y^+ \quad \text{for } 0 < y^+ < 5 \quad (5.14)$$

$$u^+ = -3.05 + \ln(y^+) \quad \text{for } 5 < y^+ \leq 30 \quad (5.15)$$

$$u^+ = 5.5 + 2.5 \ln(y^+) \quad \text{for } y^+ > 30 \quad (5.16)$$

where $u^+ = \frac{u_z}{u^*}$ and $y^+ = \frac{u^*}{\nu} y$. Equation (5.12) can be rewritten as

$$\tau = \rho (1 + \epsilon_m/\nu) (\tau_w/\rho) \frac{\partial u^+}{\partial y^+} \quad (5.17)$$

where the wall shear stress is in the laminar sublayer so that

$$\tau_w = \mu \frac{\partial u_z}{\partial y} \quad (5.18)$$

The wall shear stress was evaluated using an expression by Hewitt and Hall–Taylor (1970) who give the velocity profile in concurrent, upward annular flow as:

$$u = 20 U y / \delta^2 \quad (5.19)$$

so that the wall shear stress becomes

$$\tau_w = 20 \mu U / \delta^2 \quad (5.20)$$

The energy equation, equation (5.13), can be rewritten as

$$q'' = -\rho c_p (\alpha + \epsilon_h) u^* / \nu \frac{\partial T}{\partial y^+} \quad (5.21)$$

and integrated to obtain:

$$\frac{T_1 - T_w}{q_w''} = \int_0^{\delta^+} \frac{\nu}{\rho c_p (\alpha + \epsilon_h) u^*} dy^+ \quad (5.22)$$

where the left hand side is equal to $1/h$. The procedure for calculating the heat transfer coefficient involves inserting the universal velocity distribution (equations 5.14 – 5.16) into equation (5.17) and solving for ϵ_m which is then assumed to be equal to ϵ_h . The expression for ϵ_h is then inserted into equation (5.21) and the integration performed to solve for the heat transfer coefficient.

In the range of $0 < y^+ < 5$, the heat transfer coefficient can be shown to be

$$h = \rho c_p u^*/F \quad (5.23)$$

where

$$F = \delta^+ Pr \quad (5.24)$$

The heat flux effect on the heat transfer coefficient can be determined heuristically by calculating the ratio of the heat transfer coefficients at different film temperatures. Combining equations (5.20), (5.23), and (5.24) and assuming a constant value for the liquid layer and mean liquid velocity, the ratio of the heat transfer coefficients is found to be:

$$h_2/h_1 = (k \sqrt{\rho/\mu})_2 / (k \sqrt{\rho/\mu})_1 \quad (5.25)$$

The heat flux effect can be seen by using equation (5.25) for a heat flux of 80 kW/m² (71° C) and a heat flux of 10 kW/m² (75° C).

$$h_{75}/h_{71} = (k \sqrt{\rho/\mu})_{75} / (k \sqrt{\rho/\mu})_{71} \quad (5.26)$$

For pure R-113 this ratio is equal to 0.99 which indicates that, for thin film vaporization, the effect of heat flux is minimal on the heat transfer coefficient. A combination of nucleate boiling in the lower regions of the subsurface channel and thin film vaporization in the upper regions would explain the small variation in the heat transfer coefficient with changes in the heat flux.

In the range of $5 < y^+ < 30$, a similar procedure can be used to show that the heat transfer coefficient can be expressed as in equation (5.23) but where the function, F , has been expanded to

$$F = 5 \text{ Pr} + 5 \ln(1 + \text{Pr}((\delta^+/5) - 1)) \quad (5.27)$$

The first term on the right hand side of equation (5.27) is the largest and, to a first approximation, equation (5.25) still holds. Finally, in the range of $y^+ > 30$, the heat transfer coefficient again can be shown to be the same as in equation (5.23) where the function, F , has been expanded to

$$F = 5 \text{ Pr} + 5 \ln(1 + 5 \text{ Pr}) + G \quad (5.28)$$

where

$$G = \frac{2.5}{H} \ln \left[\left[\frac{5\delta^+/\text{Pr} + 1 - H}{5\delta^+/\text{Pr} + 1 + H} \right] \left[\frac{150/\text{Pr} + 1 + H}{150/\text{Pr} + 1 - H} \right] \right] \quad (5.29)$$

$$H = \left[1 + \frac{10 \text{ M}}{\text{Pr} \delta^+} \right]^{\frac{1}{2}} \quad (5.30)$$

$$\text{M} = \frac{F_o \delta^+ \nu}{\tau_o u^*} \quad (5.31)$$

and

$$F_o = \frac{dP}{dz} + g \rho_l - \frac{1}{A_{cs}} \left[\frac{d(U_1 \dot{m}_1)}{dz} - U_i \frac{d\dot{m}_1}{dz} \right] \quad (5.32)$$

The expression for F_o was derived from the momentum equation where U_1 is the average liquid velocity, U_i is the velocity at the liquid-vapor interface, and $\dot{m}_1$ is the mass flow rate in the liquid layer. The largest term on the right hand side of

equation (5.28) is the first term so that, again, equation (5.25) holds to a first approximation.

The convection effects on the Turbo—B surface can be seen in Fig. 5.16 where the heat transfer coefficient is plotted versus tube row for mass flux values of 50, 100, 225, and 335 kg/m²s at a constant heat flux value of 40 kW/m² and a pressure of 200 kPa. The Turbo—B surface shows very little variation in the heat transfer coefficient with mass flux. For a given tube row, the heat transfer coefficients for each mass flux is within 15% of the average value which indicates that convective effects are not significant and justifies the use of only one bundle geometry. As for the High Flux surface, the structured surface of the Turbo—B tubes prevents the convective effects of the main stream from penetrating the subsurface where the heat transfer processes occur.

Figure 5.17 shows the heat transfer coefficients as a function of tube row for pressures of 200 and 600 kPa at heat flux values of 10, 40, and 80 kW/m² for a mass flux of 109 kg/m²s. The effect of pressure on the heat transfer coefficient can be seen by comparing heat transfer coefficients at a given mass flux. For example, the increase in the heat transfer coefficient due to pressure increase is less than 1000 W/m²K at a heat flux value of 80 kW/m² which is an increase of less than 12%. In general, the pressure effect is significantly smaller for the Turbo—B surface than for either of the other two surfaces. The pressure effect on the heat transfer coefficient can be determined by using equation (5.25) and assuming a constant value for the liquid layer and mean liquid velocity, the ratio of the heat transfer coefficients is found to be:

$$h_{600}/h_{200} = (k \sqrt{\rho/\mu})_{600}/(k \sqrt{\rho/\mu})_{200} \quad (5.33)$$

Figure 5.16. Effect of mass flux on the Turbo-B heat transfer coefficients.

Figure 5.17. Effect of pressure on the Turbo-B heat transfer coefficients.

which is equal to 0.95 for pure R-113. Again, a combination of nucleate boiling in the lower regions of the subsurface channel and thin film vaporization in the upper regions would explain the small variation in the heat transfer coefficient with changes in pressure.

Results obtained in pure R-11

Heat transfer coefficients were obtained with pure R-11 as the working fluid in tube bundles containing all three surfaces. The bundle geometry with the tube pitch-to-diameter ratio of 1.50 was used in order to facilitate visual observations even though the use of this bundle geometry restricted the mass flux to less than 350 kg/m²s due to preheater limitations. The bundle was divided into a top, middle, and bottom third with tubes having a different surface in each. Tubes with each surface occupied only a third of the bundle because of the lack of an effect of tube row on the heat transfer coefficient had been established in the tests with pure R-113. The bottom (upstream) five rows of the tube bundle contained tubes with the High Flux surface, rows six through ten contained tubes with the smooth surface, and the top five rows contained tubes with the Turbo-B surface. This arrangement for the different types of tube surfaces was selected based on information concerning the onset of nucleation for the different tube surfaces. In particular, the High Flux surface exhibited the largest hysteresis in the boiling curve and, therefore, tubes with this surface were placed in the lower portion of the tube bundle. This arrangement avoided the situation where bubbles from tubes with other surfaces, which might nucleate earlier, would flow past the tube with the High Flux surface and prematurely activate extinct nucleation sites. Because the

Turbo-B surface exhibited the least hysteresis in the boiling curve, tube with this surface were installed in the top rows.

Typical heat transfer coefficient values are shown in Fig. 5.18 for a mass flux of $110 \text{ kg/m}^2\text{s}$ and a pressure of 200 kPa at heat flux values ranging from 5 to 80 kW/m^2 . The heat transfer coefficients for the High Flux tubes are shown in rows 1 through 5 and follow the same trends as in pure R-113. For example, the heat transfer coefficients depend strongly on the heat flux as was the case in pure R-113. In addition, the heat transfer coefficients are slightly smaller in the first row than in the third and fifth rows as was the case for the pure R-113 results.

Heat transfer coefficients obtained from smooth tubes are also shown in Fig. 5.18 in rows 7 and 9. Again, a strong heat flux dependency on the heat transfer coefficient is observed, and it is similar to the trends obtained in pure R-113. The heat transfer coefficients obtained in pure R-11 were slightly smaller than those obtained in pure R-113. For example, at a mass flux of $50 \text{ kg/m}^2\text{s}$, heat flux of 60 kW/m^2 , and a pressure of 200 kPa , the average experimental value of the heat transfer coefficient for the smooth tubes is $3.9 \text{ kW/m}^2\text{K}$ in pure R-11 and $4.2 \text{ kW/m}^2\text{s}$ in pure R-113. This represents an 8% increase in the heat transfer coefficient for pure R-113 over the value in pure R-11. Fink et al. (1982) also found that the heat transfer coefficient in pure R-11 was smaller than in pure R-113. For example, at a pressure of 175 kPa and a heat flux of 57 kW/m^2 , Fink et al. (1982) report that the heat transfer coefficient in pure R-113 was 13% greater than the heat transfer coefficient in pure R-11. This is very close to the predicted difference using the model for nucleate boiling by Forster and Zuber (1955) as discussed in Chapter 2. Fink et al. attribute the difference in the heat transfer

Figure 5.18. Heat transfer coefficients for all three surfaces in pure R-11.

coefficients to a lower bubble growth rate in R-11 due to a larger enthalpy of vaporization, which results in fewer active nucleation sites.

The heat transfer coefficients shown in Fig. 5.18 for rows 11 through 15 were obtained from tubes with the Turbo-B surface. The dependency on the heat flux was less than for the High Flux tubes as seen in rows 1 through 5. Again, these results are similar to those obtained in pure R-113, including the presence of exit effects for the Turbo-B surface. When compared with the results obtained in pure R-113, the R-11 results are slightly higher. For example, the heat transfer coefficient at 60 kW/m² and 200 kPa is approximately 9.3 kW/m²K in pure R-11 and 8.3 kW/m²K in pure R-113. This represents an increase of 12% in the heat transfer coefficient in pure R-11 over that in pure R-113. This trend is the opposite of that for the smooth and High Flux surfaces. A possible explanation can be attributed to thin film vaporization as the primary mechanism for removing heat.

The mechanism of thin film vaporization, as given in equation (5.25), also predicts that the heat transfer coefficient in pure R-11 is larger than in pure R-113. For example, at a pressure of 200 kPa, the ratio:

$$h_{R11}/h_{R113} = (k \sqrt{\rho/\mu})_{R11}/(k \sqrt{\rho/\mu})_{R113} \quad (5.34)$$

is equal to 1.26 which is greater than the percentage increase of data obtained in R-11 over those in R-113 from experiments and indicates that the heat removal process in the Turbo-B surface is a mixture of nucleation and thin film vaporization.

Boiling Heat Transfer Results in Refrigerant Mixtures

Two-phase heat transfer coefficients were obtained in the same tube bundle used to collect data in pure R-11. The bundle had a tube pitch-to-diameter ratio of 1.50 and the bottom five rows of the tube bundle contained tubes with the High Flux surface, rows six through ten contained tubes with the smooth surface, and the top five rows contained tubes with the Turbo-B surface. Experiments were conducted in mixtures of R-113 and R-11 with inlet concentrations of approximately 25%, 50%, and 75% R-11 by mass. The experiments were conducted for pressures of 200 and 600 kPa, mass flux values of 50 and 225 kg/m²s, and heat flux values from 5 to 80 kW/m² so that the effect of these parameters on the tube bundle performance could be determined.

Results from the 75% R-11/25% R-113 mixture

Heat transfer coefficients for tubes with each of the three surfaces are shown in Fig. 5.19 for a mass flux of 50 kg/m²s, a pressure of 200 kPa, and heat flux values from 5 to 60 kW/m². The inlet mass concentration of R-11 in the liquid is 75.8% and decreases with increasing tube row due to evaporation of the mixture. The rate at which the concentration of R-11 in the liquid decreases depends on the mass flux and heat flux. For example, at a heat flux of 60.4 kW/m², the mass concentration of R-11 in the liquid decreased to 72.5% at the seventh tube row, which is the first row of instrumented smooth tubes. At the eleventh tube row, which is the first Turbo-B tube row, the mass concentration of R-11 in the liquid decreased to 70.4%. The mass concentration of R-11 in the liquid at the outlet of the tube bundle was 67.1%. The concentration changes throughout the bundle at

Figure 5.19. Effect of heat flux on the heat transfer coefficients for all three surfaces in a mixture of 75.8% R-11 and $G = 49 \text{ kg/m}^2\text{s}$.

different rates depending on the heat flux. At a heat flux of 10 kW/m^2 , the mass concentration of R-11 in the liquid changed by only 1.6% from the inlet to the exit of the bundle.

The heat transfer coefficients follow the same general trends as those obtained in the pure fluids. The heat transfer coefficients for the High Flux tubes in the first, third, and fifth tube rows exhibit a strong dependency on the heat flux and generally the heat transfer coefficient at the first row is the smallest. The smooth tube heat transfer coefficients were consistently smaller than those for the enhanced tubes. A significant heat flux effect was also observed for the smooth tubes. The heat transfer coefficients for the Turbo-B tubes (shown in rows 11, 13, and 15) exhibit much less variation with heat flux as was the case in the pure fluids, and some exit effects are still present.

The effect of the mass flux on the heat transfer coefficients can be seen by comparing Figs. 5.20 and 5.19; Figure 5.20 shows data at a mass flux of $225 \text{ kg/m}^2\text{s}$, while Fig. 5.19 shows data at $49 \text{ kg/m}^2\text{s}$. Heat transfer coefficients for each of the three surfaces at a given heat flux are not significantly different for the different mass flux conditions. Note that because the mass concentration of R-11 in the liquid is not an independent parameter, comparing data taken at a similar heat flux, pressure, and inlet concentration but different mass flux results in a comparison between data at different local mixture concentrations as well. For the same nominal inlet concentration and at a given tube row, the mass concentration of R-11 in the liquid is lower for the data taken at a mass flux of $49 \text{ kg/m}^2\text{s}$ than at $224 \text{ kg/m}^2\text{s}$, especially for the tubes higher in the bundle and at larger heat fluxes. For the same inlet concentrations and a heat flux of 60 kW/m^2 , the mass concentration of R-11 at the bundle exit is 73.3% when the mass flux is $49 \text{ kg/m}^2\text{s}$,

Figure 5.20. Effect of heat flux on the heat transfer coefficients for all three surfaces in a mixture of 75.8% R-11 and $G = 224 \text{ kg/m}^2\text{s}$.

which is 6.3 percentage points higher than at the bundle exit when the mass flux is $224 \text{ kg/m}^2\text{s}$. However, the mass concentration change and any changes in the free-steam convection due to a larger mass flux apparently do not appreciably affect the concentration gradient at the heated surface and so do not change the mechanisms that reduce the heat transfer.

The magnitudes of the heat transfer coefficients are, however, significantly lower in the binary mixture than in the pure fluids. For example, the heat transfer coefficient for the smooth tubes obtained in a mixture with 72.3% R-11 in the liquid at 60 kW/m^2 and 200 kPa is approximately $3.4 \text{ kW/m}^2\text{K}$. This value is 19% smaller than the value obtained for similar operating conditions in pure R-113 ($4.2 \text{ kW/m}^2\text{K}$) and 12.8% smaller than the value obtained in pure R-11 ($3.9 \text{ kW/m}^2\text{K}$). This trend has been well established and is described in detail by several researchers. Thome and Shock (1984) give some of the reasons for the lower heat transfer coefficient in mixtures: a higher concentration of the less volatile component at the heated surface causing an increased local boiling temperature and a reduced bubble growth rate; a higher enthalpy of vaporization; varying bubble departure frequencies; and reduced nucleation site density due to reduced contact angle.

The magnitudes of the heat transfer coefficients for the enhanced surfaces obtained in the binary mixture also are significantly lower than those obtained in pure fluids. The average heat transfer coefficient obtained in the binary mixture for the High Flux tubes in rows three and five at 60 kW/m^2 is approximately $10.8 \text{ kW/m}^2\text{K}$. The average value at similar operating parameters is $12.5 \text{ kW/m}^2\text{K}$ in pure R-113 and $12.2 \text{ kW/m}^2\text{K}$ in pure R-11. Therefore, the reduction in the heat transfer coefficients obtained in the mixture is approximately 13.6% and 11.5%

compared to the pure R-113 and R-11 data, respectively. The heat transfer coefficient for the Turbo-B tubes with a mass concentration of 70.0% R-11 in the liquid upstream of the eleventh tube row is $8.4 \text{ kW/m}^2\text{K}$. This value is 2.3% smaller than the value of $8.6 \text{ kW/m}^2\text{K}$ obtained in pure R-113 and 14.3% smaller than the value of $9.8 \text{ kW/m}^2\text{K}$ obtained in pure R-11. For a given heat flux larger than $30 \text{ kW/m}^2\text{K}$, the High Flux heat transfer coefficients generally were larger than those for the Turbo-B tubes. The heat transfer coefficients for the enhanced surfaces are always larger than for the smooth tubes at similar heat fluxes, pressures, and inlet mixture concentrations.

Results from the 50% R-11/50% R-113 mixture

The heat transfer coefficients obtained in a mixture with a nominal inlet mass concentration of 50% exhibited the same general trends as the data obtained in 75% R-11. Figure 5.21 shows that the High Flux tubes in rows 1, 3, and 5 performed slightly better than the Turbo-B tubes in rows 11, 13, and 15 and that both enhanced tubes performed better than the smooth tubes in rows 7 and 9. However, the variation in the mixture concentration throughout the bundle makes a direct comparison of data obtained at different tube rows difficult. Data for the Turbo-B tubes were obtained in mixtures with local liquid concentrations up to 7.6 percentage points lower in R-11 than the local mixture concentration at the High Flux tubes. The lower concentration of R-11 could account for some of the difference between the High Flux and Turbo-B tubes but lower heat transfer coefficients for the Turbo-B tubes were also found in the pure fluids, and so the variation in the liquid concentration of R-11 probably plays a minor role.

Figure 5.21. Effect of heat flux on the heat transfer coefficients for all three surfaces in a mixture of 46.5% R-11 and $G = 46 \text{ kg/m}^2\text{s}$.

The heat transfer coefficients for the Turbo-B tubes do not vary as much with heat flux as do the heat transfer coefficients for the High Flux tubes. A possible explanation is that the concentration of R-11 in the liquid at a given tube row was lower for the larger heat fluxes, and the heat transfer coefficients decrease with decreasing liquid concentrations of R-11. Therefore, the variation in the local concentration of liquid R-11 could contribute to the reduced variation with heat flux in the Turbo-B tubes. However, a similar trend was found in the data obtained in pure fluids and so, again, the variation in the liquid concentration of R-11 probably plays a minor role.

Comparisons between Fig. 5.21 and Fig. 5.19 show that the heat transfer coefficients for the 50% inlet concentration are generally smaller than those for the 75% inlet concentration by as much as 48% for the High Flux tubes, 37% for the Turbo-B tubes, but only 6% for the smooth tubes. Large reductions in the heat transfer coefficients for the enhanced tubes and smaller reductions for the smooth tube were also observed in the binary mixture pool boiling results. Similar mechanisms between pool boiling and bundle boiling appear to play significant roles in the heat transfer process.

Results from the 25% R-11/75% R-113 mixture

Data obtained in a mixture with an inlet mass concentration of 23.8% R-11 in the liquid are shown in Fig. 5.22 for a mass flux of 217 kg/m²s and a pressure of 200 kPa. At a given heat flux, the heat transfer coefficients for the High Flux tubes are larger than those for the smooth tubes but are slightly smaller than those for the Turbo-B tubes in general. The slightly larger heat transfer coefficients for the Turbo-B tubes compared to the High Flux data is contrary to the trends obtained

Figure 5.22. Effect of heat flux on the heat transfer coefficients for all three surfaces in a mixture of 23.8% R-11 and $P = 200 \text{ kPa}$.

in pure fluids and might be the result of the lower local mass concentration of R-11 in the liquid at the Turbo-B tubes.

Insight into the trends of the heat transfer coefficients for the Turbo-B tubes can be gained by comparing heat transfer coefficients obtained in a 25% R-11 mixture to those obtained in the 50% R-11 mixture. Comparing Fig. 5.22 with Fig. 5.21 shows that, at a given heat flux, the heat transfer coefficients decreased for each of the surfaces but that those for the High Flux tubes decreased the most. For example, at a heat flux of 60 kW/m^2 , the heat transfer coefficient of the High Flux tube at the third row and a liquid mass concentration of 22.7% R-11 is 13.3% smaller than the High Flux heat transfer coefficient obtained at a liquid mass concentration of 45.4% R-11. The smooth tube heat transfer coefficient at the seventh row, a heat flux of 60 kW/m^2 , and a liquid mass concentration of 20.6% R-11 was 5.9% smaller than that obtained in a mixture of 43.2% R-11 in the liquid. The heat transfer coefficient for the Turbo-B tube at the eleventh row, at a heat flux of 60 kW/m^2 , and a liquid mass concentration of 18.5% R-11 was 5.9% smaller than that obtained in a mixture of 41.1% R-11 in the liquid. The smaller decrease in the heat transfer coefficients for the Turbo-B tubes compared to the High Flux tubes could be the result of an end in the decreasing trend in the heat transfer coefficient with decreasing liquid mass concentration of R-11 or perhaps even the result of a beginning in an increasing trend in the heat transfer coefficient with decreasing liquid mass concentration of R-11.

In general, increasing the inlet pressure results in an increase in the heat transfer coefficients for all three tube surface types and at all inlet mixture concentrations. Figure 5.23 shows, for example, heat transfer coefficients as a function of tube row at a pressure of 600 kPa, a mass flux of 218 kg/m^2 , and heat

Figure 5.23. Effect of heat flux on the heat transfer coefficients for all three surfaces in a mixture of 23.1% R-11 and $p = 600 \text{ kPa}$.

fluxes ranging from 5 to 80 kg/m². The trends at 600 kPa are similar to those at 200 kPa with the heat transfer coefficients larger for the enhanced tubes than for the smooth tubes. The effect of pressure can be seen by comparing Fig. 5.23 with Fig 5.22. The heat transfer coefficients for the High Flux tubes increase with pressure but generally by only 11%. This increase in data obtained in the mixtures is significantly less than for the data obtained in pure R-113, which resulted in an average increase of approximately 30%. The smooth tube heat transfer coefficients obtained in the mixtures were approximately 33% larger at 600 kPa than at 200 kPa, which is consistent with data obtained in pure R-113. The Turbo-B heat transfer coefficients obtained at 600 kPa increased by approximately 9% over the data obtained at 200 kPa for inlet mass concentrations of 75.8% and 45.8% but increased by 23% for an inlet mass concentration of 23.1% R-11.

Examples of these data are shown in Fig. 5.24 which is a plot of the heat transfer coefficients versus the mass concentration of R-11 in the liquid for the High Flux tube at the third row, the smooth tube at the seventh row, and the Turbo-B tube at the eleventh row for an average mass flux of 204 kg/m²s, and a heat flux of 60 kW/m². The Turbo-B heat transfer coefficients obtained at a pressure of 600 kPa and a local liquid mass concentration of 20.0% R-11 are now slightly larger than for a liquid concentration of 41.5%. The heat transfer coefficients are beginning to increase with decreasing liquid mass concentration of R-11 and, apparently, the minimum heat transfer coefficients occur in mass concentrations greater than 20.0% R-11 at 600 kPa.

Figure 5.24. Effect of mixture concentration and pressure on the heat transfer coefficients for $q'' = 60 \text{ kW}/\text{m}^2$.

Comparison of results

The effect of the mass concentration of R-11 in the liquid on the heat transfer coefficient can be more easily seen in a plot such as Fig. 5.25 where heat transfer coefficients for High Flux tubes in the third tube row are plotted versus the local mass concentration of R-11 in the liquid at a pressure of 200 kPa and an average mass flux of 204 kg/m²s. Note that the mass flux is large enough so that the change in the mass concentration with heat flux is small at the third tube row, even for heat fluxes as large as 80 kW/m². Therefore, the data shown in Fig. 5.25 were taken in mixture concentrations approximately equal to the inlet concentration.

At a given heat flux, the heat transfer coefficients decrease from the values obtained in pure R-11 to minimum values obtained in the mixture with an inlet mass concentration of 23.1% R-11. Figure 5.25 shows that the heat transfer coefficients obtained in mixtures with small liquid mass concentrations of R-11 are generally smaller than those obtained in mixtures with larger liquid mass concentrations. This non-symmetric decrease in the heat transfer coefficient with liquid mass concentration of R-11 has been reported by other researchers using binary mixtures of different fluids. In a mixture of ethanol and water, for example, Stephan (1982) reports much lower heat transfer coefficients than the ideal values obtained by a linear interpolation between the pure component values. Figure 5.26 shows that the reduction below the ideal value is greatest at a liquid mole fraction of ethanol of approximately 15%.

Stephan (1982) reviewed several heat transfer coefficient correlations and noted that the decrease in the heat transfer coefficient is most pronounced when the difference between the liquid and vapor mole fractions is largest. Heat transfer

Figure 5.25.

Effect of mixture concentration and heat flux on the High Flux heat transfer coefficients.

Figure 5.26. Trends in heat transfer coefficients and the difference between the liquid and vapor mixture concentrations (Stephan 1982).

coefficients are then correlated using a wall superheat which is a function of the difference between the vapor and liquid mole fractions instead of correlating heat transfer coefficients for the pure components using only the liquid mole fraction of the least volatile component. The difference between the vapor and liquid mole fractions versus the liquid mole fraction is plotted in Fig. 5.27(a) for the R-11/R-113 mixture used in the present study. Also shown is a plot of the heat transfer coefficients versus the liquid mole fraction for all three surfaces at a heat flux of 60 kW/m² and a pressure of 200 kPa in Fig. 5.27(b). It appears that the increase in the concentration difference between vapor and liquid R-11 does follow the same trend as the decrease in the heat transfer coefficient. Therefore, the same mechanisms which reduce the heat transfer coefficients for smooth tubes also play a major role in the enhanced surfaces, and a method of correlating the enhanced surfaces similar to that used to correlate smooth tubes might be appropriate. Specifically, Stephan and Körner (1970) suggests that the heat transfer coefficient be defined as

$$h = q'' / \Delta T_a \quad (5.35)$$

where

$$\Delta T_a = \Delta T_{id} + \Delta T_e = \Delta T_{id} (1 + \theta) \quad (5.36)$$

and

$$\Delta T_{id} = \tilde{y}_{R113}^i \Delta T_{sat, R113} + \tilde{y}_{R11}^i \Delta T_{sat, R11} \quad (5.37)$$

Figure 5.27. A comparison between (a) the difference between the liquid and vapor concentrations of R-11 and (b) experimental trends in heat transfer coefficients at $q''=60$ kW/m² and $P=200$ kPa.

In equation (5.37), the terms $\Delta T_{\text{sat}, R_{113}}$ and $\Delta T_{\text{sat}, R_{11}}$ refer to the wall superheat for the pure fluids. The only unknown in equation (5.36) is θ which Stephan and Körner correlate as

$$\theta = C_{R_{113}, R_{11}} (\tilde{y}_{R_{11}}'' - \tilde{y}_{R_{113}}') \quad (5.38)$$

where $C_{R_{113}, R_{11}}$ is a positive number independent of the mole fraction. Stephan and Körner (1970) obtained values of $C_{1,2}$ for various binary mixtures but the R-11/R-113 combination was not included. Alternatively, Bier et al. (1982), recommend the following correlation:

$$h/h_{\text{id}} = 1 - D_{R_{113}, R_{11}} (\tilde{y}_{R_{11}}'' - \tilde{y}_{R_{113}}')^{0.5} \quad (5.39)$$

where

$$h_{\text{id}} = h_{R_{11}} \tilde{y}_{R_{11}}' + h_{R_{113}} (1 - \tilde{y}_{R_{11}}') \quad (5.40)$$

and $D_{R_{113}, R_{11}}$ is a function of pressure only. Again, Bier et al. (1982) did not include the R-11/R-113 combination in their study.

The correlation by Stephan and Körner was chosen as representative of the types of correlations reported in the literature. In order to determine the applicability of these types of correlations, the experimental data for the smooth tube were used to determine values of $C_{R_{113}, R_{11}}$. Generally, the values ranged from 0.5 to 2.2 with an average value of 1.5. This value was used to generate predicted heat transfer coefficients which are represented by the solid lines in Fig. 5.28. The

Figure 5.28. Comparison of experimental values for smooth tube heat transfer coefficients and predicted values using a Stephan-Körner type correlation.

experimental data for liquid mass concentrations of approximately 25% is generally overpredicted while the data for mass concentrations of approximately 75% is generally underpredicted, though the trends are followed well.

Experimental data for the enhanced surfaces was also used to determine values of $C_{R_{113}, R_{11}}$ but with little success. Values of $C_{R_{113}, R_{11}}$ for the High Flux tubes ranged from 1.1 to 18.6 which indicates that this type of correlation is not applicable for enhanced surfaces. A possible explanation is that the enhanced surfaces is conducive to more of a buildup of the less volatile component next to the heated surface than smooth tubes due to the inability of the free stream to affect the heat transfer process in the subsurface cavities.

Summary

Single-phase heat transfer and pressure drop tests were conducted in the tube bundles, and the results were found to agree with correlations given by ESDU (1973) and Zukauskas (1987). These results validated the experimental apparatus and procedure and confirmed the applicability of these correlations to the particular bundle geometry and surface types used in this study. The single-phase heat transfer coefficients for the enhanced surfaces were approximately equal to those for the smooth tubes. In addition, pressure drop values for bundles of enhanced tubes were approximately equal to those for bundles of smooth tubes. These results indicate that the surface structure of the enhanced tubes is so small as to not appreciably affect the fluid flow pattern next to the heated surface nor the surface area exposed to the main fluid flow.

Boiling heat transfer experiments conducted in the tube bundles with pure R-113 revealed that the heat transfer coefficients for the smooth tubes increased significantly with heat flux and pressure. However, the heat transfer coefficients increased only slightly with increasing mass flux and only at very low heat fluxes. The pitch-to-diameter ratio did not affect the heat transfer coefficients appreciably either, except at low heat fluxes and large mass fluxes. In addition, the heat transfer coefficients increased with tube row only at very low heat fluxes. Because the tube row is directly proportional to quality, the effect of quality changes on the heat transfer coefficients is negligible except at very low heat fluxes. Fully developed nucleate boiling was found to dominate the heat transfer process throughout the majority of the tube bundle and accounted for the small influence of mass flux, quality, and bundle geometry on the heat transfer coefficients.

The heat transfer coefficients for the enhanced surfaces were significantly larger than those for the smooth tubes and were comparable to the values obtained in pool boiling. Indeed, the increasing trend in the heat transfer coefficient obtained in the tube bundle due to increasing heat flux was comparable to the trends observed in pool boiling for all three surfaces. The effect of pressure on the heat transfer coefficients for the High Flux surface was only slightly less than that for the smooth surface and was significantly greater than that for the Turbo-B surface. The smaller pressure effect for the Turbo-B tubes in the heat transfer coefficients was attributed to thin film vaporization in the sub-surface channels. The heat transfer coefficients for the enhanced surfaces did not vary significantly with mass flux, quality, or pitch-to-diameter ratio. These results indicated that the enhanced tubes were unaffected by the convective flow in the free stream. The enhanced surface caused the boiling process to occur within the sub-surface structure, and the

external flow could not intrude into the sub-surface cavities and change the heat transfer mechanisms.

No significant variation of the heat transfer coefficient with tube row was found except at the first row in the High Flux bundle (and the last row in the Turbo-B bundle). The reduced heat transfer coefficient in the first row of the High Flux tube bundle was attributed to non-nucleating areas on the surface of the High Flux tube. Although the heat flux was increased to its maximum value before collecting data, small areas of the High Flux tubes failed to nucleate. Visual observations aided in determining that the initiation of nucleation occurred in patches for the High Flux surface, as was the case for pool boiling. In the tube bundle, however, the free-stream convection increased the heat transfer from the non-nucleating regions and prevented the wall superheat from increasing enough to initiate nucleation everywhere on the tube surface. These non-nucleating patches caused the High Flux heat transfer coefficient for tubes in the first row to sometimes be smaller than the pool boiling values. The onset of nucleation for tubes in the upper rows was aided by vapor rising from the lower tubes.

Heat transfer coefficients obtained in pure R-11 generally followed the same trends as in pure R-113. For a given heat flux and pressure, the heat transfer coefficients were slightly larger in pure R-113 than in pure R-11 for the smooth and High Flux tubes, which is consistent with models based on nucleate boiling. However, the heat transfer coefficients were slightly larger in R-11 than in R-113 for the Turbo-B tubes. The increase in the Turbo-B heat transfer coefficients in R-11 resulted from a combination of nucleate boiling and thin film vaporization in the sub-surface channels.

Heat transfer coefficients decreased significantly for all surfaces when refrigerant mixtures were used but the same trends in the mass flux, heat flux, and pressure effects generally were observed, and the enhanced surfaces consistently performed better than the smooth tubes. The reduction in the heat transfer coefficient was largest for an inlet mixture concentration of 23.8% R-11. The degradation in the smooth tube heat transfer coefficients obtained in fluid mixtures was found to depend on the difference between the molar concentration in the liquid and vapor. However, a correlation similar to the one for smooth tubes was not successful in predicting the heat transfer coefficients for enhanced tubes.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK

This investigation sought to establish the boiling heat transfer performance of individual horizontal tubes with enhanced surfaces in a tube bundle. In doing so, insight has been gained that will aid in the design of shell-and-tube heat exchangers with horizontal tube bundles. The investigation included experimental studies of single tubes in pool boiling and of tube bundles with the fluid forced through the bundle in the vertically upward direction.

The studies of two-phase flow boiling in bundles of horizontal tubes were conducted on tubes with smooth and enhanced surfaces. The enhanced surfaces tested included a knurled surface (Wolverine's Turbo-B) and a porous surface (Linde's High Flux). Tests were conducted in two staggered tube bundles consisting of fifteen rows and five columns laid out in equilateral triangular arrays with pitch-to-diameter ratios of 1.17 and 1.50. Experiments were conducted in pure refrigerant R-113, pure R-11, and mixtures of R-11 and R-113 with inlet concentrations of approximately 25, 50, and 75% of R-11 by mass in the liquid.

Conclusions

Pool boiling tests were conducted for each of the three surfaces so that reference values of the heat transfer coefficient could be obtained. Values of the heat transfer coefficient for the enhanced tubes were generally an order of magnitude larger than for the smooth tubes. Heat transfer coefficients for the porous surface were generally the largest; however, a large hysteresis in the boiling curve was

found. Visual observations revealed that only patches of the High Flux surface nucleated initially and that nucleation covered more of the surface as the heat flux increased. Heat transfer coefficients for the Turbo-B tube, on the other hand, showed very little hysteresis in the boiling curve. The difference was attributed to the sub-surface structure of the enhanced tubes and the ability of vapor generated near the bottom of the tube to travel around the perimeter and initiate boiling in extinct nucleation sites.

The pool boiling experiments conducted in pure R-11 showed that, as for the pure R-113 experiments, the enhanced tubes performed better than the smooth tubes. The performance of the smooth and High Flux tubes in pure R-11 was approximately equal to that in pure R-113, except for heat fluxes less than 10 kW/m^2 where the performance in R-11 was slightly greater than in R-113. The performance of the Turbo-B tube was also slightly better in R-11 than in R-113.

Pool boiling heat transfer coefficients in fluid mixtures were less than those in pure fluids for all three surfaces. However, for a given heat flux and mixture concentration, the enhanced surfaces consistently performed better than the smooth tube. The High Flux tube performed slightly better than the Turbo-B tube, as was the case for the pure fluid experiments. The performance of all three surfaces decreased as the concentration of R-11 decreased, with the largest performance reduction relative to the pure refrigerant performance occurring in a mixture of 25% R-11/75% R-113.

Single-phase heat transfer and pressure drop tests were conducted in the tube bundles, and the results were found to agree with correlations given by ESDU (1973) and Zukauskas (1987). These results validated the experimental apparatus and procedure and confirmed the applicability of these correlations to the particular

bundle geometry and surface types used in this study. The single-phase heat transfer coefficients for the enhanced surfaces were approximately equal to those for the smooth tubes. In addition, pressure drop values for bundles of enhanced tubes were approximately equal to those for bundles of smooth tubes. These results indicate that the surface structure of the enhanced tubes is so small as to not appreciably affect the fluid flow pattern next to the heated surface nor the surface area exposed to the main fluid flow.

Boiling heat transfer experiments in the tube bundles were conducted at pressures of 200 and 600 kPa, heat flux values from 5 to 80 kW/m², mass flux values from 50 to 500 kg/m²s, and qualities from 0% to 80%. Experiments conducted in pure R-113 revealed that the heat transfer coefficients for the smooth tubes increased significantly with heat flux and pressure. However, the heat transfer coefficients increased only slightly with increasing mass flux and only at very low heat fluxes. The pitch-to-diameter ratio did not affect the heat transfer coefficients appreciably either, except at low heat fluxes and large mass fluxes. In addition, the heat transfer coefficients increased with tube row only at very low heat fluxes. Because the tube row is directly proportional to quality, the effect of quality changes on the heat transfer coefficients is negligible except at very low heat fluxes. Fully developed nucleate boiling was found to dominate the heat transfer process throughout the majority of the tube bundle and accounted for the small influence of mass flux, quality, and bundle geometry on the heat transfer coefficients.

The heat transfer coefficients for the enhanced surfaces were significantly larger than those for the smooth tubes and were comparable to the values obtained in pool boiling. Indeed, the increasing trend in the heat transfer coefficient obtained

in the tube bundle due to with increasing heat flux was comparable to the trends observed in pool boiling for all three surfaces.

The effect of pressure on the heat transfer coefficients for the High Flux surface was only slightly less than that for the smooth surface and was significantly greater than that for the Turbo-B surface. The smaller pressure effect for the Turbo-B tubes in the heat transfer coefficients was attributed to thin film vaporization in the sub-surface channels.

The heat transfer coefficients for the enhanced surfaces did not vary significantly with mass flux, quality, or pitch-to-diameter ratio. These results indicated that the enhanced tubes were unaffected by the convective flow in the free stream. The enhanced surface caused the boiling process to occur within the sub-surface structure, and the external flow could not intrude into the sub-surface cavities and change the heat transfer mechanisms.

No significant variation of the heat transfer coefficient with tube row was found except at the first row in the High Flux bundle (and the last row in the Turbo-B bundle). The reduced heat transfer coefficient in the first row of the High Flux tube bundle was attributed to non-nucleating areas on the surface of the High Flux tube. Although the heat flux was increased to its maximum value before collecting data, small areas of the High Flux tubes failed to nucleate. Visual observations aided in determining that the initiation of nucleation occurred in patches for the High Flux surface, as was the case for pool boiling. In the tube bundle, however, the free-stream convection increased the heat transfer from the non-nucleating regions and prevented the wall superheat from increasing enough to initiate nucleation everywhere on the tube surface. These non-nucleating patches caused the High Flux heat transfer coefficient for tubes in the first row to sometimes

be smaller than the pool boiling values. The onset of nucleation for tubes in the upper rows was aided by vapor rising from the lower tubes.

Heat transfer coefficients obtained in pure R-11 generally followed the same trends as in pure R-113. For a given heat flux and pressure, the heat transfer coefficients were slightly larger in pure R-113 than in pure R-11 for the smooth and High Flux tubes. However, the heat transfer coefficients were slightly larger in R-11 than in R-113 for the Turbo-B tubes. The increase in the Turbo-B heat transfer coefficients in R-11 resulted from a combination of nucleate boiling and thin film vaporization in the sub-surface channels.

Heat transfer coefficients decreased significantly for all surfaces when refrigerant mixtures were used but the same trends in the mass flux, heat flux, and pressure effects generally were observed, and the enhanced surfaces consistently performed better than the smooth tubes. The reduction in the heat transfer coefficient was largest for an inlet mixture concentration of 23.8% R-11. The degradation in the smooth tube heat transfer coefficients due to the fluid mixtures was predicted fairly well using a correlation of the form given by Stephan and Körner (1970), which predicts the wall superheat as a function of the difference between the molar concentration in the liquid and vapor. However, experimental data for the enhanced surfaces were not well predicted using a correlation of the same form and indicates that the heat transfer process has been significantly altered by the enhanced surface structure, possibly because of the inability of the free stream to affect the heat transfer process near the heated surface.

Recommendations for Future Work

The results of this investigation have made apparent several areas which require further investigation. Perhaps the most obvious is the need to determine if a combination of nucleate boiling and single-phase convection could also account for the lack of a mass flux effect on the smooth tube heat transfer coefficients.

Although fully established nucleate boiling was found to dominate the heat transfer process in this study, the alternative possibility might apply to data obtained at low heat flux values and might explain the lack of a mass flux effect for internal flow, such as reported by Kandlikar (1990).

The invariance in the heat transfer coefficient with tube row and quality also might be explored further in light of a possible balance between nucleate boiling and single-phase convection. The explanation presented depends on a decrease in the boiling heat transfer with increasing liquid velocity, which depends on the liquid-to-vapor density ratio. This analysis could explain the density ratio effect reported by Kandlikar (1990).

The presence of thin film vaporization in the sub-surface channels of the Turbo-B tubes would be supported by verifying that liquid enters the pores near the bottom and exits as vapor through pores near the top. This could be facilitated with visual studies of the path of dye injected into the liquid.

Finally, the onset of nucleation for High Flux tubes should be investigated further. Numerical calculations could be performed to determine the maximum surface temperature variation in high conductivity, thick-walled tubes with a uniform heat flux as the inside boundary condition and a variable heat transfer coefficient as the outside boundary condition. In combination with experimental

temperature overshoot information, such a study would determine whether the temperature of small patches of non-nucleating surface area would be low enough to prevent the onset of nucleation.

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APPENDIX A

TABULATION OF EXPERIMENTAL DATA

Tables of pool boiling and bundle data are presented. The tube bundle data are presented by listing all of the heat flux data sets for each mass flux at pressures of 200 kPa and 600 kPa. An attempt was made to use a consistent set of nomenclature for the main body of text and the tabulated data headings but slight variations were unavoidable. Therefore a list of the nomenclature is presented next.

Nomenclature

ΔP	pressure drop across the bundle, kPa
G	mass flux, $\text{kg}/\text{m}^2 \cdot \text{s}$
h	heat transfer coefficient, $\text{W}/\text{m}^2 \cdot \text{K}$ or $\text{kW}/\text{m}^2 \cdot \text{K}$
p/d	pitch to diameter ratio
P	pressure, kPa
q, q''	heat flux for an individual tube, W/m^2
T	temperature, K
X	thermodynamic quality, equation (3.20a)
y'	overall mass fraction in the liquid, kg/kg

Subscripts

av	average
in	inlet
out	outlet

pool	reservoir for single—tube experiments
s	saturation
total	difference between inlet and outlet values
w	heated wall
1	top of tube (north)
2	side of tube (east)
3	bottom of tube (south)
4	side of tube (west)

Pool Boiling Data

Pure R-113 data

I	h(I)	Tav(I)-Ts	Tav(I)	T1(I)	T2(I)	T3(I)	T4(I)	Tpool(I)	q(I)
	[kW/m^2K]	[C]	[C]	[C]	[C]	[C]	[C]	[C]	[W/m^2]
1	1.033	.4	49.4	49.5	49.1	49.4	49.4	47.3	3.799E+2
2	.822	.7	49.7	49.8	49.3	49.8	49.7	47.3	5.381E+2
3	.696	1.0	50.0	50.3	49.5	50.3	50.1	47.4	7.276E+2
4	.502	2.1	51.1	51.6	50.2	51.4	51.4	47.4	1.069E+3
5	.367	4.5	53.5	54.0	52.4	53.8	53.8	47.5	1.642E+3
6	.326	7.9	56.9	57.6	55.2	57.3	57.4	47.7	2.568E+3
7	7.942	.5	49.5	49.7	49.3	49.4	49.5	47.7	3.852E+3
8	10.829	.5	49.5	49.8	49.3	49.5	49.6	47.8	5.821E+3
9	14.759	.6	49.6	49.9	49.3	49.5	49.7	47.9	9.063E+3
10	18.753	.7	49.7	50.1	49.3	49.6	49.8	48.1	1.325E+4
11	24.167	.8	49.8	50.3	49.2	49.7	50.0	48.2	1.975E+4
12	29.043	1.0	50.0	50.7	49.1	50.0	50.4	48.2	3.046E+4
13	32.465	1.4	50.4	51.3	49.1	50.5	50.8	48.3	4.630E+4
14	35.450	1.9	50.9	52.1	49.1	51.2	51.5	48.3	6.912E+4
15	29.686	1.4	50.4	51.2	49.2	50.5	50.8	48.3	4.155E+4
16	24.394	1.0	50.0	50.6	49.2	50.0	50.3	48.3	2.539E+4
17	18.315	.8	49.8	50.3	49.3	49.8	50.0	48.3	1.553E+4
18	13.779	.7	49.7	50.0	49.3	49.6	49.8	48.3	9.468E+3
19	9.828	.6	49.6	49.8	49.3	49.5	49.6	48.3	5.591E+3
20	6.988	.5	49.5	49.7	49.3	49.5	49.5	48.3	3.556E+3
21	4.920	.5	49.5	49.6	49.3	49.5	49.5	48.2	2.251E+3
22	3.625	.4	49.4	49.5	49.2	49.4	49.4	48.2	1.445E+3
23	2.452	.3	49.3	49.5	49.2	49.4	49.3	48.1	8.320E+2
24	1.563	.3	49.3	49.4	49.2	49.3	49.3	48.0	4.522E+2
25	1.156	.2	49.2	49.3	49.2	49.3	49.2	48.0	2.705E+2

The file 17FEB1989A contains 25 records.

A Hi-Flux, S tube with a surface area of 0.0060805 m², an outer diameter of 0.01905 m and a correction ratio R/r of 1.816 was tested in freon with a saturation temperature of 49 C.

I	h(I)	Tav(I)-Ts	Tav(I)	T1(I)	T2(I)	T3(I)	T4(I)	Tpool(I)	q(I)
	[kW/m^2K]	[C]	[C]	[C]	[C]	[C]	[C]	[C]	[W/m^2]
1	-.154	-0.0	48.2	48.3	48.2	48.2	48.1	48.1	1.437E+0
2	.266	1.3	49.5	49.6	49.2	49.5	49.5	48.0	3.518E+2
3	.285	2.0	50.2	50.3	49.5	50.2	50.1	48.1	5.705E+2
4	.305	3.2	51.4	51.4	50.0	51.4	51.3	48.1	9.693E+2
5	.354	4.7	52.9	52.9	50.6	53.0	52.8	48.9	1.659E+3
6	3.013	.9	49.1	49.1	48.9	49.1	49.0	48.1	2.649E+3
7	4.663	1.0	49.2	49.2	49.0	49.3	49.1	48.1	4.580E+3
8	7.020	1.1	49.3	49.2	49.1	49.5	49.3	48.1	7.848E+3
9	9.825	1.3	49.5	49.4	49.2	49.7	49.5	48.0	1.286E+4
10	13.017	1.6	49.8	49.6	49.3	50.0	49.7	48.0	2.058E+4
11	16.077	2.0	50.2	50.1	49.5	50.5	50.1	48.0	3.293E+4
12	12.923	1.6	49.8	49.7	49.4	50.1	49.7	48.0	2.097E+4
13	9.688	1.4	49.6	49.4	49.2	49.8	49.5	48.1	1.317E+4
14	7.223	1.2	49.4	49.3	49.1	49.5	49.3	48.1	8.387E+3
15	5.007	1.0	49.2	49.2	49.1	49.4	49.2	48.1	5.238E+3
16	3.142	.9	49.1	49.1	49.0	49.2	49.1	48.1	2.949E+3
17	1.747	.8	49.0	49.1	48.9	49.1	49.0	48.1	1.484E+3
18	1.066	.8	49.0	49.0	48.9	49.0	48.9	48.1	8.478E+2
19	.642	.7	48.9	49.0	48.9	48.9	48.9	48.1	4.789E+2
20	.386	.7	48.9	49.0	48.8	48.9	48.8	48.1	2.663E+2

The file 28MAY2989H contains 20 records.

A Hi-Flux, S tube with a surface area of 0.0059889 m², an outer diameter of 0.0188 m and a correction ratio R/r of 1.715 was tested in freon with a saturation temperature of 48.2 C.

I	h(I)	Tav(I)-Ts	Tav(I)	Tl(I)	T2(I)	T3(I)	T4(I)	Tpool(I)	q(I)
	[kW/m^2K]	[C]	[C]	[C]	[C]	[C]	[C]	[C]	[W/m^2]
1	-.027	-.2	48.6	48.7	48.6	48.5	48.4	48.3	5.766E+0
2	.304	.9	49.7	49.8	49.8	49.6	49.5	48.2	2.763E+2
3	.293	1.6	50.4	50.5	50.5	50.4	50.2	48.2	4.815E+2
4	.314	2.5	51.3	51.4	51.4	51.3	51.1	48.1	7.957E+2
5	2.475	.6	49.3	49.4	49.4	49.3	49.2	48.0	1.363E+3
6	3.454	.7	49.4	49.5	49.5	49.4	49.3	48.1	2.265E+3
7	4.395	.8	49.6	49.7	49.7	49.5	49.4	48.2	3.683E+3
8	5.747	1.1	49.8	50.0	50.0	49.7	49.6	48.2	6.181E+3
9	6.988	1.5	50.2	50.4	50.5	50.0	50.0	48.2	1.015E+4
10	8.026	2.0	50.8	51.0	51.1	50.5	50.5	48.2	1.616E+4
11	9.418	2.8	51.6	52.1	51.8	51.2	51.3	48.2	2.649E+4
12	8.550	2.0	50.7	51.1	51.0	50.5	50.5	48.2	1.699E+4
13	7.182	1.5	50.3	50.5	50.5	50.1	50.0	48.2	1.084E+4
14	6.017	1.2	49.9	50.1	50.1	49.8	49.7	48.2	7.025E+3
15	4.741	.9	49.7	49.8	49.8	49.6	49.5	48.2	4.318E+3
16	3.855	.8	49.5	49.7	49.6	49.5	49.4	48.2	2.956E+3
17	2.860	.7	49.4	49.5	49.5	49.4	49.3	48.2	1.893E+3
18	2.075	.6	49.3	49.4	49.4	49.3	49.2	48.2	1.219E+3
19	1.597	.5	49.3	49.4	49.3	49.3	49.1	48.2	8.311E+2
20	1.239	.5	49.2	49.3	49.3	49.2	49.1	48.1	5.881E+2
21	.834	.4	49.2	49.3	49.2	49.2	49.1	48.2	3.527E+2
22	.595	.4	49.2	49.2	49.2	49.1	49.0	48.2	2.362E+2

The file 8MAR1989 contains 22 records.

A Hi-Flux, M tube with a surface area of 0.0060837 m², an outer diameter of 0.01906 m and a correction ratio R/r of 1.745 was tested in freon with a saturation temperature of 48.76 C.

I	h(I)	Tav(I)-Ts	Tav(I)	Tl(I)	T2(I)	T3(I)	T4(I)	Tpool(I)	q(I)
	[kW/m^2K]	[C]	[C]	[C]	[C]	[C]	[C]	[C]	[W/m^2]
1	-.008	-.5	47.6	47.6	47.6	47.6	47.5	47.2	4.066E+0
2	1.977	.1	48.2	48.2	48.2	48.2	48.1	47.2	2.298E+2
3	1.214	.2	48.3	48.4	48.3	48.3	48.2	47.2	2.684E+2
4	1.135	.3	48.4	48.4	48.4	48.3	48.3	47.2	3.329E+2
5	1.247	.3	48.4	48.5	48.4	48.4	48.3	47.1	4.322E+2
6	1.414	.4	48.5	48.5	48.5	48.5	48.4	47.2	5.531E+2
7	1.628	.5	48.5	48.6	48.6	48.5	48.5	47.1	7.333E+2
8	1.904	.5	48.6	48.6	48.6	48.6	48.5	47.1	9.435E+2
9	2.183	.5	48.6	48.6	48.6	48.6	48.6	47.1	1.159E+3
10	2.503	.6	48.7	48.6	48.7	48.7	48.7	47.2	1.547E+3
11	2.755	.7	48.8	48.7	48.8	48.8	48.8	47.1	2.006E+3
12	2.944	.8	48.9	48.8	48.9	48.9	49.0	47.2	2.501E+3
13	3.219	1.0	49.1	49.0	49.1	49.1	49.2	47.3	3.250E+3
14	3.687	1.2	49.2	49.1	49.3	49.2	49.3	47.3	4.324E+3
15	4.065	1.4	49.4	49.2	49.4	49.4	49.6	47.3	5.513E+3
16	4.328	1.7	49.7	49.4	49.8	49.7	50.0	47.3	7.146E+3
17	4.919	1.9	50.0	49.6	50.1	49.9	50.3	47.3	9.375E+3
18	5.375	2.3	50.3	49.8	50.5	50.2	50.8	47.3	1.222E+4
19	5.813	2.6	50.7	50.0	51.0	50.6	51.4	47.3	1.536E+4
20	6.522	3.0	51.1	50.2	51.3	50.9	51.9	47.4	1.972E+4
21	7.284	3.5	51.5	50.4	51.8	51.3	52.6	47.3	2.521E+4
22	10.269	3.2	51.3	50.4	51.2	51.5	52.2	47.3	3.334E+4
23	11.865	3.6	51.7	50.6	51.4	52.0	52.9	47.2	4.306E+4
24	10.068	2.2	50.3	49.7	50.1	50.4	50.8	47.3	2.202E+4
25	8.009	1.5	49.5	49.2	49.4	49.7	49.8	47.4	1.174E+4
26	5.870	1.1	49.1	49.0	49.1	49.2	49.3	47.5	6.224E+3
27	4.094	.8	48.9	48.8	48.9	48.9	48.9	47.5	3.261E+3
28	2.562	.7	48.7	48.7	48.8	48.7	48.7	47.4	1.674E+3
29	1.498	.5	48.6	48.6	48.6	48.6	48.6	47.4	8.188E+2
30	.849	.5	48.6	48.6	48.6	48.5	48.5	47.4	4.087E+2

The file 6AP1989 contains 30 records.

A Hi-Flux, M tube with a surface area of 0.0060837 m², an outer diameter of 0.01906 m and a correction ratio R/r of 1.787 was tested in freon with a saturation temperature of 48.07 C.

I	h(I)	Tav(I)-Ts	Tav(I)	T1(I)	T2(I)	T3(I)	T4(I)	Tpool(I)	q(I)
	[kW/m^2K]	[C]	[C]	[C]	[C]	[C]	[C]	[C]	[W/m^2]
1	-.025	-.2	47.8	47.9	47.9	47.8	47.7	47.7	4.094E+0
2	.282	1.0	49.0	49.1	49.0	49.0	49.0	47.6	2.842E+2
3	.356	1.2	49.2	49.3	49.2	49.2	49.1	47.5	4.290E+2
4	.366	1.9	49.9	50.0	49.9	49.9	49.8	47.5	6.933E+2
5	.369	2.8	50.8	50.8	50.7	50.8	50.8	47.6	1.023E+3
6	.393	4.0	52.0	52.1	51.9	52.0	52.0	47.6	1.568E+3
7	.420	6.2	54.2	54.3	54.0	54.3	54.4	47.5	2.606E+3
8	.465	9.2	57.2	57.2	56.7	57.3	57.5	47.5	4.260E+3
9	5.325	1.3	49.3	49.2	50.1	48.7	49.1	47.5	6.858E+3
10	6.044	1.8	49.8	49.6	51.1	48.9	49.6	47.4	1.075E+4
11	6.767	2.6	50.6	50.2	52.5	49.2	50.3	47.4	1.733E+4
12	7.474	3.6	51.6	51.0	54.5	49.7	51.3	47.4	2.684E+4
13	8.123	5.1	53.1	52.3	57.1	50.5	52.6	47.4	4.157E+4
14	7.550	3.5	51.5	50.8	54.2	49.7	51.1	47.4	2.612E+4
15	4.610	.8	48.8	48.8	49.3	48.5	48.7	47.5	3.833E+3

The file 27JAN1989 contains 15 records.

A Hi-Flux, L tube with a surface area of 0 .0060805 m^2, an outer diameter of 0 .0188 m and a correction ratio R/r of 1.715 was tested in freon with a saturation temperature of 48.01 C.

I	h(I)	Tav(I)-Ts	Tav(I)	T1(I)	T2(I)	T3(I)	T4(I)	Tpool(I)	q(I)
	[kW/m^2K]	[C]	[C]	[C]	[C]	[C]	[C]	[C]	[W/m^2]
1	-.004	-.9	47.4	47.5	47.5	47.4	47.3	47.1	4.039E+0
2	2.355	.1	48.4	48.5	48.5	48.4	48.3	46.9	2.629E+2
3	1.833	.2	48.5	48.6	48.6	48.5	48.4	46.8	3.578E+2
4	1.100	.5	48.9	48.9	48.9	48.8	48.8	46.8	5.841E+2
5	.846	1.2	49.5	49.6	49.5	49.4	49.4	47.0	9.787E+2
6	.910	1.7	50.0	50.1	50.0	49.9	50.0	47.0	1.514E+3
7	1.061	2.3	50.6	50.7	50.6	50.5	50.6	47.0	2.390E+3
8	1.183	3.1	51.4	51.5	51.4	51.2	51.6	47.1	3.680E+3
9	1.379	4.1	52.4	52.4	52.3	52.1	52.9	47.2	5.661E+3
10	2.010	4.4	52.7	52.7	52.6	51.9	53.6	47.3	8.775E+3
11	3.033	4.6	53.0	53.0	52.9	51.9	53.9	47.5	1.405E+4
12	4.072	5.4	53.7	53.8	53.7	52.5	54.8	47.5	2.189E+4
13	5.711	6.0	54.3	54.7	54.1	51.9	56.7	47.6	3.434E+4
14	6.769	7.6	55.9	56.2	55.4	52.7	59.3	47.6	5.120E+4
15	6.319	5.0	53.3	53.3	53.1	51.1	55.6	47.5	3.146E+4
16	5.831	3.3	51.6	51.7	51.6	50.3	53.1	47.5	1.941E+4
17	5.296	2.3	50.6	50.6	50.6	49.6	51.4	47.5	1.199E+4
18	4.947	1.5	49.9	50.0	49.9	49.2	50.4	47.5	7.654E+3
19	4.607	1.1	49.4	49.5	49.5	49.0	49.7	47.5	4.987E+3
20	4.198	.7	49.1	49.1	49.1	48.8	49.2	47.5	3.112E+3
21	3.301	.6	48.9	49.0	48.9	48.7	49.0	47.5	1.902E+3
22	2.504	.5	48.8	48.9	48.9	48.7	48.8	47.5	1.247E+3
23	1.798	.4	48.7	48.8	48.8	48.6	48.7	47.5	7.383E+2
24	1.303	.4	48.7	48.7	48.7	48.6	48.6	47.5	4.598E+2
25	.905	.2	48.6	48.6	48.6	48.5	48.5	47.4	2.241E+2

The file 8FEB1989 contains 25 records.

A Hi-Flux, L tube with a surface area of 0 .0060805 m^2, an outer diameter of 0 .01905 m and a correction ratio R/r of 1.816 was tested in freon with a saturation temperature of 48.32 C.

I	h(I)	Tav(I)-Ts	Tav(I)	T1(I)	T2(I)	T3(I)	T4(I)	Tpool(I)	q(I)
	[kW/m^2K]	[C]	[C]	[C]	[C]	[C]	[C]	[C]	[W/m^2]
1	-.003	-.5	47.8	47.9	47.9	47.8	47.7	47.8	1.423E+0
2	.737	.4	48.6	48.7	48.7	48.6	48.5	47.7	2.639E+2
3	.968	.4	48.7	48.8	48.7	48.7	48.6	47.7	4.079E+2
4	1.287	.5	48.8	48.8	48.8	48.7	48.7	47.7	6.258E+2
5	1.671	.5	48.8	48.9	48.9	48.8	48.7	47.7	8.955E+2
6	2.192	.6	48.9	49.0	48.9	48.9	48.8	47.7	1.403E+3
7	2.881	.8	49.0	49.2	49.1	49.0	48.9	47.6	2.239E+3
8	3.770	1.0	49.2	49.4	49.2	49.2	49.1	47.6	3.646E+3
9	4.512	1.2	49.5	49.7	49.5	49.4	49.4	47.6	5.450E+3
10	5.491	1.5	49.8	50.0	49.8	49.7	49.7	47.6	8.317E+3
11	6.394	2.0	50.3	50.6	50.2	50.2	50.1	47.7	1.286E+4
12	7.108	2.8	51.1	51.6	51.0	50.9	50.9	47.7	2.003E+4
13	5.862	2.1	50.3	50.7	50.3	50.2	50.2	47.8	1.214E+4
14	4.748	1.6	49.8	50.1	49.8	49.7	49.7	47.8	7.496E+3
15	3.617	1.2	49.5	49.7	49.5	49.4	49.4	47.8	4.410E+3
16	2.873	1.0	49.3	49.4	49.3	49.2	49.1	47.8	2.819E+3
17	2.086	.8	49.0	49.2	49.1	49.0	48.9	47.8	1.607E+3
18	1.600	.6	48.9	49.0	48.9	48.8	48.7	47.8	9.342E+2
19	1.132	.5	48.8	48.8	48.8	48.7	48.7	47.7	5.446E+2
20	.717	.4	48.7	48.8	48.7	48.6	48.6	47.6	2.925E+2

The file 7JUN1989 contains 20 records.

A Turbo-B, VC tube with a surface area of 0.0060454 m², an outer diameter of 0.01894 m and a correction ratio R/r of 1.765 was tested in freon with a saturation temperature of 48.27 C.

I	h(I)	Tav(I)-Ts	Tav(I)	T1(I)	T2(I)	T3(I)	T4(I)	Tpool(I)	q(I)
	[kW/m^2K]	[C]	[C]	[C]	[C]	[C]	[C]	[C]	[W/m^2]
1	-.002	-.6	47.6	47.7	47.7	47.6	47.5	47.4	1.431E+0
2	1.153	.2	48.5	48.6	48.6	48.5	48.4	47.4	2.881E+2
3	1.401	.3	48.6	48.7	48.6	48.6	48.5	47.4	4.421E+2
4	1.868	.4	48.7	48.7	48.7	48.7	48.6	47.4	7.113E+2
5	2.143	.5	48.8	48.8	48.8	48.8	48.7	47.5	1.030E+3
6	2.474	.6	48.8	48.9	48.8	48.9	48.7	47.4	1.416E+3
7	2.879	.7	49.0	49.0	49.0	49.0	48.9	47.5	2.043E+3
8	3.184	.9	49.2	49.2	49.2	49.2	49.0	47.5	2.841E+3
9	3.737	1.1	49.4	49.5	49.4	49.5	49.2	47.5	4.171E+3
10	4.180	1.4	49.7	49.8	49.6	49.8	49.5	47.5	5.784E+3
11	4.553	1.7	50.0	50.1	50.0	50.2	49.8	47.6	7.908E+3
12	5.556	2.0	50.3	50.4	50.2	50.5	50.1	47.6	1.126E+4
13	6.230	2.6	50.8	50.8	50.8	51.1	50.6	47.6	1.591E+4
14	6.887	3.2	51.5	51.4	51.5	51.8	51.4	47.7	2.227E+4
15	8.250	3.7	52.0	51.9	52.0	52.3	51.9	47.7	3.090E+4
16	6.654	2.5	50.8	50.8	50.7	51.0	50.6	47.8	1.682E+4
17	5.168	1.7	50.0	50.1	49.9	50.2	49.8	47.8	8.990E+3
18	4.254	1.2	49.4	49.5	49.4	49.5	49.2	47.8	4.893E+3
19	3.465	.8	49.1	49.1	49.1	49.1	48.9	47.7	2.749E+3
20	2.678	.5	48.8	48.9	48.8	48.8	48.7	47.7	1.416E+3
21	2.071	.4	48.7	48.7	48.7	48.7	48.6	47.7	8.081E+2
22	1.251	.3	48.6	48.7	48.6	48.6	48.5	47.7	4.203E+2
23	.754	.3	48.6	48.6	48.6	48.6	48.5	47.7	2.373E+2

The file 8JUN1989 contains 23 records.

A Turbo-B, VO tube with a surface area of 0.0060454 m², an outer diameter of 0.01894 m and a correction ratio R/r of 1.765 was tested in freon with a saturation temperature of 48.27 C.

Pool Boiling Data

Pure R-11 data

I	h(I)	Tav(I)-Ts	Tav(I)	Tl(I)	T2(I)	T3(I)	T4(I)	Tpool(I)	q(I)
	[kW/m^2K]	[C]	[C]	[C]	[C]	[C]	[C]	[C]	[W/m^2]
1	-.007	-.4	24.0	24.1	24.1	24.0	23.9	23.8	3.096E+0
2	.278	1.3	25.7	25.8	25.8	25.7	25.6	23.8	3.524E+2
3	.289	1.7	26.2	26.3	26.3	26.1	26.1	23.8	5.052E+2
4	.276	2.8	27.3	27.4	27.3	27.2	27.2	23.8	7.846E+2
5	.278	4.5	29.0	29.2	29.0	28.9	28.9	23.9	1.261E+3
6	.294	6.7	31.1	31.3	31.2	30.9	31.1	23.8	1.960E+3
7	.361	8.7	33.1	33.4	33.1	32.8	33.1	23.8	3.121E+3
8	.460	10.9	35.3	35.8	35.3	34.7	35.5	23.7	5.002E+3
9	.587	13.6	38.0	38.6	38.0	37.3	38.2	23.7	7.963E+3
10	1.002	12.0	36.5	37.3	36.3	35.3	36.9	23.7	1.204E+4
11	1.613	11.8	36.2	36.9	36.2	35.6	36.2	23.6	1.898E+4
12	2.261	13.4	37.9	38.6	37.7	37.2	37.9	23.5	3.031E+4
13	1.571	12.1	36.5	37.1	36.4	35.9	36.6	23.5	1.895E+4
14	1.127	10.5	35.0	35.5	34.9	34.4	35.1	23.6	1.185E+4
15	.880	9.2	33.7	34.1	33.7	33.2	33.7	23.7	8.119E+3
16	.649	8.1	32.6	32.9	32.6	32.2	32.7	23.7	5.284E+3
17	.480	7.0	31.4	31.7	31.4	31.1	31.5	23.8	3.342E+3
18	.365	5.9	30.3	30.6	30.3	30.1	30.3	23.8	2.142E+3
19	.316	4.0	28.5	28.6	28.5	28.3	28.4	23.9	1.261E+3
20	.274	2.9	27.3	27.5	27.4	27.2	27.3	23.9	7.839E+2
21	.271	1.8	26.3	26.4	26.3	26.2	26.2	23.8	4.977E+2

The file PLR11 contains 21 records.

A plain tube with a surface area of 0.0060964 m², an outer diameter of 0.0191 m and a correction ratio R/r of 1.083 was tested in freon with a saturation temperature of 24.46 C.

I	h(I)	Tav(I)-Ts	Tav(I)	Tl(I)	T2(I)	T3(I)	T4(I)	Tpool(I)	q(I)
	[kW/m^2K]	[C]	[C]	[C]	[C]	[C]	[C]	[C]	[W/m^2]
1	-.008	-.4	24.1	24.2	23.9	24.1	24.0	23.9	3.321E+0
2	.375	2.5	26.9	27.0	24.0	27.0	26.8	23.9	9.325E+2
3	.418	3.5	28.0	28.0	24.0	28.1	27.9	23.8	1.485E+3
4	.447	5.5	30.0	30.0	24.1	30.1	29.8	23.9	2.471E+3
5	13.629	.3	24.8	24.8	23.9	24.9	24.7	23.7	4.151E+3
6	14.034	.3	24.8	24.8	23.9	24.9	24.7	23.6	4.478E+3
7	19.081	.4	24.8	24.7	23.8	25.0	24.8	23.6	7.175E+3
8	23.245	.5	25.0	24.8	23.7	25.2	24.9	23.5	1.168E+4
9	22.993	.8	25.3	25.1	23.7	25.6	25.2	23.6	1.848E+4
10	26.370	1.1	25.6	25.3	23.5	26.0	25.4	23.5	2.969E+4
11	23.635	.8	25.3	25.0	23.7	25.6	25.2	23.5	1.905E+4
12	20.034	.6	25.1	24.9	23.7	25.3	25.0	23.5	1.220E+4
13	17.707	.4	24.9	24.8	23.8	25.1	24.9	23.6	7.926E+3
14	13.748	.4	24.8	24.8	23.9	25.0	24.8	23.6	5.035E+3
15	10.511	.3	24.8	24.8	23.9	24.9	24.7	23.6	3.198E+3
16	9.707	.2	24.7	24.7	23.9	24.7	24.6	23.6	2.203E+3
17	6.774	.2	24.7	24.7	24.0	24.7	24.6	23.6	1.386E+3
18	4.501	.2	24.6	24.7	23.9	24.6	24.5	23.6	7.260E+2
19	2.831	.1	24.6	24.7	24.0	24.6	24.5	23.6	3.334E+2

The file HFR11 contains 19 records.

A Hi-Flux, S tube with a surface area of 0.0060805 m², an outer diameter of 0.01905 m and a correction ratio R/r of 1.816 was tested in freon with a saturation temperature of 24.46 C.

I	h(I)	Tav(I)-Ts	Tav(I)	T1(I)	T2(I)	T3(I)	T4(I)	Tpool(I)	q(I)
	[kW/m^2K]	[C]	[C]	[C]	[C]	[C]	[C]	[C]	[W/m^2]
1	-.005	-.7	23.2	23.3	23.2	23.2	23.1	23.0	3.798E+0
2	.941	.3	24.2	24.2	24.2	24.2	23.6	23.0	2.501E+2
3	1.282	.3	24.2	24.2	24.2	24.2	23.6	23.0	3.497E+2
4	1.794	.3	24.2	24.3	24.2	24.2	23.6	23.0	4.873E+2
5	2.147	.3	24.2	24.3	24.2	24.2	23.6	23.0	6.543E+2
6	2.105	.4	24.3	24.4	24.3	24.3	23.8	23.3	8.418E+2
7	2.903	.4	24.3	24.4	24.3	24.3	23.8	23.3	1.050E+3
8	3.626	.4	24.3	24.4	24.3	24.3	23.8	23.3	1.399E+3
9	3.817	.5	24.4	24.5	24.4	24.4	23.9	23.4	1.891E+3
10	4.498	.6	24.5	24.6	24.4	24.5	24.0	23.5	2.500E+3
11	4.573	.7	24.6	24.7	24.5	24.7	24.1	23.6	3.169E+3
12	4.974	.8	24.7	24.8	24.6	24.8	24.1	23.6	3.966E+3
13	5.743	.9	24.8	24.9	24.6	24.9	24.1	23.5	4.965E+3
14	6.130	1.1	25.0	25.1	24.7	25.2	24.3	23.6	6.645E+3
15	6.494	1.3	25.2	25.3	24.9	25.4	24.5	23.6	8.321E+3
16	8.025	1.4	25.3	25.4	24.9	25.7	24.7	23.6	1.101E+4
17	9.801	1.5	25.4	25.4	25.0	25.8	24.8	23.6	1.438E+4
18	15.891	1.6	25.6	25.5	25.1	26.0	24.5	23.5	2.586E+4
19	11.215	1.3	25.2	25.3	24.7	25.7	24.2	23.5	1.440E+4
20	6.920	1.0	24.9	25.0	24.6	25.1	24.1	23.6	6.778E+3
21	4.076	.8	24.8	24.8	24.6	24.8	24.0	23.6	3.312E+3
22	3.447	.5	24.5	24.5	24.4	24.5	23.9	23.5	1.860E+3
23	2.804	.4	24.3	24.4	24.3	24.3	23.8	23.5	1.031E+3
24	1.133	.3	24.3	24.3	24.3	24.2	23.8	23.5	3.575E+2
25	.005	.3	24.2	24.3	24.2	24.2	23.8	23.4	1.421E+0

The file TBR11 contains 25 records.

A Turbo-B, M tube with a surface area of 0.0061028 m², an outer diameter of 0.01912 m and a correction ratio R/r of 1.5704 was tested in freon with a saturation temperature of 23.94 C.

Pool Boiling Data

Data from the 75% R-11/25% R-113 mixture

I	h(I)	Tav(I)-Ts	Tav(I)	T1(I)	T2(I)	T3(I)	T4(I)	Tpool(I)	q(I)
	[kW/m^2K]	[C]	[C]	[C]	[C]	[C]	[C]	[C]	[W/m^2]
1	-.009	-.4	27.6	27.7	27.7	27.6	27.5	27.4	3.597E+0
2	.278	1.1	29.1	29.2	29.2	29.1	29.0	27.3	3.101E+2
3	.239	1.8	29.8	29.9	29.9	29.8	29.7	27.3	4.343E+2
4	.236	2.7	30.7	30.9	30.8	30.7	30.6	27.3	6.451E+2
5	.245	4.3	32.3	32.5	32.4	32.3	32.2	27.4	1.064E+3
6	.266	7.1	35.1	35.3	35.2	35.0	35.1	28.1	1.899E+3
7	.331	9.6	37.6	37.9	37.7	37.3	37.7	28.4	3.192E+3
8	.485	11.5	39.5	39.8	39.6	39.1	39.5	28.9	5.575E+3
9	.765	12.5	40.5	40.7	40.6	40.4	40.2	27.3	9.532E+3
10	1.397	11.3	39.3	39.9	39.3	38.7	39.2	27.6	1.573E+4
11	1.808	13.6	41.6	42.3	41.5	40.9	41.5	27.6	2.455E+4
12	1.352	10.9	38.9	39.5	39.0	38.5	38.8	27.6	1.478E+4
13	1.004	8.9	36.9	37.3	37.0	36.5	36.7	27.7	8.893E+3
14	.733	6.8	34.8	35.1	34.9	34.6	34.7	27.9	5.011E+3
15	.519	5.4	33.4	33.6	33.5	33.2	33.4	27.8	2.816E+3
16	.369	4.3	32.3	32.5	32.4	32.2	32.3	27.3	1.596E+3
17	.267	3.1	31.1	31.2	31.1	31.0	31.0	27.3	8.171E+2
18	.218	2.0	30.0	30.1	30.0	29.9	29.9	27.3	4.341E+2
19	.231	1.0	29.0	29.1	29.0	28.9	28.9	27.3	2.301E+2

The file PL2 contains 19 records.

A plain tube with a surface area of 0 .0060964 m², an outer diameter of 0 .0191 m and a correction ratio R/r of 1.083 was tested in freon with a saturation temperature of 28 C.

I	h(I)	Tav(I)-Ts	Tav(I)	T1(I)	T2(I)	T3(I)	T4(I)	Tpool(I)	q(I)
	[kW/m^2K]	[C]	[C]	[C]	[C]	[C]	[C]	[C]	[W/m^2]
1	-.007	-.6	27.4	27.5	27.5	27.4	27.3	27.2	3.935E+0
2	.261	1.3	29.3	29.4	29.2	29.3	29.2	27.3	3.374E+2
3	.245	2.6	30.6	30.7	30.3	30.6	30.5	27.3	6.321E+2
4	.249	4.4	32.4	32.4	31.9	32.3	32.3	27.3	1.084E+3
5	.240	8.2	36.2	36.2	35.3	36.2	36.2	29.9	1.975E+3
6	3.304	1.0	29.0	29.0	28.9	29.1	29.0	27.5	3.413E+3
7	4.616	1.2	29.2	29.2	28.9	29.3	29.2	27.4	5.690E+3
8	6.174	1.5	29.5	29.3	29.1	29.6	29.6	27.5	9.255E+3
9	8.200	1.9	29.9	29.7	29.4	30.0	29.9	27.5	1.530E+4
10	10.311	2.4	30.4	30.2	29.6	30.6	30.4	27.5	2.460E+4
11	12.270	3.1	31.1	30.8	29.8	31.4	31.0	27.6	3.762E+4
12	9.989	2.4	30.4	30.1	29.6	30.6	30.4	27.6	2.364E+4
13	7.596	1.9	29.9	29.7	29.4	30.0	29.9	27.6	1.412E+4
14	5.571	1.5	29.5	29.4	29.2	29.6	29.6	27.6	8.442E+3
15	3.954	1.3	29.3	29.2	29.1	29.4	29.3	27.5	5.072E+3
16	2.698	1.0	29.0	29.0	28.9	29.1	29.0	27.6	2.829E+3
17	1.803	.9	28.9	28.9	28.8	28.9	28.8	27.6	1.631E+3
18	1.120	.8	28.8	28.9	28.7	28.8	28.7	27.6	8.738E+2
19	.747	.6	28.6	28.7	28.6	28.6	28.6	27.5	4.828E+2
20	.486	.5	28.5	28.6	28.5	28.5	28.4	27.5	2.341E+2

The file HF2 contains 20 records.

A Hi-Flux, S tube with a surface area of 0 .0060805 m², an outer diameter of 0 .01905 m and a correction ratio R/r of 1.816 was tested in freon with a saturation temperature of 28 C.

I	h(I)	Tav(I)-Ts	Tav(I)	T1(I)	T2(I)	T3(I)	T4(I)	Tpool(I)	q(I)
	[kW/m^2K]	[C]	[C]	[C]	[C]	[C]	[C]	[C]	[W/m^2]
1	-.074	-0.0	27.3	27.3	27.3	27.2	27.1	27.0	3.434E+0
2	.474	.8	28.1	28.1	28.1	28.1	27.3	26.9	3.707E+2
3	.646	1.0	28.3	28.3	28.3	28.4	27.4	27.0	6.764E+2
4	.875	1.3	28.6	28.6	28.6	28.7	27.5	27.1	1.150E+3
5	1.109	1.9	29.2	29.2	29.1	29.3	27.8	27.3	2.147E+3
6	1.716	2.3	29.6	29.6	29.5	29.8	27.9	27.3	4.030E+3
7	2.809	2.9	30.2	30.1	29.9	30.5	28.4	27.4	8.137E+3
8	4.639	3.3	30.6	30.4	30.3	31.0	28.7	27.5	1.517E+4
9	10.439	3.9	31.2	31.1	30.5	31.9	28.5	27.5	4.028E+4
10	6.577	3.3	30.6	30.5	30.3	31.1	28.2	27.5	2.200E+4
11	4.164	3.0	30.3	30.2	30.0	30.7	28.1	27.3	1.249E+4
12	2.362	2.5	29.8	29.7	29.7	30.1	27.9	27.2	5.977E+3
13	1.572	2.2	29.5	29.5	29.3	29.7	27.9	27.3	3.434E+3
14	1.070	1.8	29.1	29.1	29.0	29.2	27.8	27.2	1.895E+3
15	.751	1.1	28.4	28.4	28.4	28.5	27.5	27.1	8.505E+2
16	.421	.8	28.1	28.1	28.1	28.1	27.4	27.0	3.401E+2
17	.232	.6	27.9	28.0	27.9	27.9	27.4	26.9	1.482E+2

The file TB2 contains 17 records.

A Turbo-B, M tube with a surface area of 0 .0061028 m^2, an outer diameter of 0 .01912 m and a correction ratio R/r of 1.5704 was tested in freon with a saturation temperature of 27.3 C.

Pool Boiling Data

Data from the 50% R-11/50% R-113 mixture

I	h(I)	Tav(I)-Ts	Tav(I)	T1(I)	T2(I)	T3(I)	T4(I)	Tpool(I)	q(I)
	[kW/m^2K]	[C]	[C]	[C]	[C]	[C]	[C]	[C]	[W/m^2]
1	-.029	-.1	32.1	32.2	32.2	32.1	32.0	31.8	2.989E+0
2	.219	1.7	33.9	34.0	33.9	33.8	33.8	31.7	3.703E+2
3	.198	3.5	35.7	35.8	35.7	35.7	35.6	31.7	6.943E+2
4	.203	5.7	37.9	38.0	37.9	37.8	37.8	31.8	1.155E+3
5	.231	8.7	40.9	41.1	40.9	40.8	40.8	32.1	2.012E+3
6	.288	11.3	43.5	43.7	43.5	43.2	43.4	32.0	3.241E+3
7	.400	13.6	45.8	46.3	45.8	45.2	45.9	32.1	5.446E+3
8	.688	12.4	44.6	44.8	44.7	44.5	44.4	32.3	8.546E+3
9	1.199	11.5	43.7	44.3	43.7	43.1	43.5	32.4	1.375E+4
10	1.556	13.7	45.9	46.7	45.9	45.2	45.8	32.2	2.133E+4
11	2.033	16.5	48.7	49.5	48.6	48.0	48.6	32.1	3.350E+4
12	1.525	13.6	45.8	46.6	45.8	45.2	45.7	32.4	2.072E+4
13	1.149	11.1	43.3	43.8	43.3	42.9	43.2	32.3	1.276E+4
14	.864	9.3	41.5	41.9	41.5	41.2	41.4	32.2	8.005E+3
15	.632	7.8	40.0	40.3	40.0	39.7	39.9	32.1	4.926E+3
16	.474	6.4	38.6	38.8	38.6	38.4	38.5	32.1	3.020E+3
17	.365	5.2	37.4	37.6	37.4	37.3	37.3	31.9	1.905E+3
18	.279	4.2	36.4	36.5	36.4	36.3	36.3	31.8	1.168E+3
19	.217	3.6	35.8	35.9	35.8	35.7	35.7	31.9	7.712E+2
20	.185	2.5	34.7	34.8	34.7	34.6	34.6	31.8	4.614E+2

The file PL3 contains 20 records.

A plain tube with a surface area of 0.0060964 m², an outer diameter of 0.0191 m and a correction ratio R/r of 1.083 was tested in freon with a saturation temperature of 32.2 C.

I	h(I)	Tav(I)-Ts	Tav(I)	T1(I)	T2(I)	T3(I)	T4(I)	Tpool(I)	q(I)
	[kW/m^2K]	[C]	[C]	[C]	[C]	[C]	[C]	[C]	[W/m^2]
1	-.008	-.4	31.8	31.9	31.8	31.7	31.7	31.5	3.625E+0
2	.190	1.9	34.1	34.2	34.0	34.1	34.0	31.8	3.615E+2
3	.197	3.1	35.3	35.4	35.1	35.3	35.3	31.8	6.201E+2
4	.259	4.6	36.8	36.8	35.7	36.8	36.7	31.7	1.189E+3
5	.287	7.4	39.6	39.6	37.6	39.7	39.6	32.2	2.127E+3
6	2.123	1.7	33.9	33.9	33.7	33.9	33.8	31.9	3.555E+3
7	2.971	2.0	34.2	34.2	33.9	34.3	34.2	32.1	6.011E+3
8	4.004	2.5	34.7	34.5	34.2	34.8	34.7	32.2	9.836E+3
9	5.620	3.0	35.2	35.0	34.5	35.4	35.2	32.2	1.683E+4
10	7.192	3.7	35.9	35.6	34.9	36.1	35.8	32.2	2.625E+4
11	8.720	4.5	36.7	36.4	35.2	37.0	36.7	32.2	3.932E+4
12	7.075	3.6	35.8	35.5	34.8	36.0	35.8	32.2	2.526E+4
13	5.203	2.9	35.1	34.9	34.5	35.3	35.1	32.3	1.502E+4
14	3.694	2.4	34.6	34.5	34.2	34.7	34.7	32.2	9.043E+3
15	2.639	2.1	34.3	34.2	34.0	34.4	34.3	32.2	5.559E+3
16	1.771	1.8	34.0	34.0	33.8	34.0	33.9	32.2	3.116E+3
17	1.173	1.5	33.7	33.7	33.5	33.7	33.6	32.1	1.722E+3
18	.756	1.2	33.4	33.5	33.4	33.4	33.4	32.1	9.428E+2
19	.498	1.1	33.3	33.3	33.2	33.3	33.2	32.0	5.281E+2
20	.291	.8	33.0	33.1	33.0	33.0	32.9	31.8	2.342E+2

The file HF3 contains 20 records.

A Hi-Flux, S tube with a surface area of 0.0060805 m², an outer diameter of 0.01905 m and a correction ratio R/r of 1.816 was tested in freon with a saturation temperature of 32.2 C.

I	h(I)	Tav(I)-Ts	Tav(I)	T1(I)	T2(I)	T3(I)	T4(I)	Tpool(I)	q(I)
	[kW/m^2K]	[C]	[C]	[C]	[C]	[C]	[C]	[C]	[W/m^2]
1	-.027	-.1	31.7	31.8	31.7	31.6	31.5	31.4	3.497E+0
2	.297	.5	32.3	31.7	32.4	32.3	31.4	31.4	1.557E+2
3	.373	.7	32.5	31.7	32.6	32.5	31.4	31.5	2.631E+2
4	.546	.8	32.6	31.8	32.7	32.6	31.4	31.6	4.539E+2
5	.845	1.0	32.8	31.8	32.9	32.7	31.4	31.5	8.356E+2
6	.873	1.7	33.5	31.7	33.6	33.4	31.5	31.5	1.462E+3
7	1.058	2.4	34.2	31.9	34.3	34.0	31.5	31.6	2.528E+3
8	1.526	3.2	35.0	31.8	35.2	34.7	31.5	31.6	4.829E+3
9	2.099	3.9	35.7	31.8	36.0	35.4	31.5	31.6	8.232E+3
10	2.971	4.6	36.4	31.8	36.7	36.1	31.5	31.9	1.361E+4
11	4.143	5.0	36.8	31.7	37.1	36.6	31.4	32.1	2.084E+4
12	5.565	5.5	37.3	31.6	37.5	37.0	31.3	32.1	3.043E+4
13	4.094	4.7	36.5	31.7	36.8	36.3	31.4	32.0	1.925E+4
14	2.655	4.1	35.9	31.8	36.1	35.7	31.5	31.8	1.084E+4
15	1.810	3.4	35.2	31.9	35.4	35.0	31.6	31.9	6.136E+3
16	1.275	2.6	34.4	31.9	34.6	34.3	31.6	31.7	3.330E+3
17	.966	1.8	33.6	31.9	33.7	33.5	31.6	31.6	1.735E+3
18	.755	1.2	33.0	31.9	33.1	32.9	31.6	31.6	8.914E+2
19	.519	.9	32.7	31.9	32.8	32.7	31.5	31.7	4.811E+2
20	.325	.8	32.6	31.9	32.6	32.5	31.5	31.7	2.499E+2

The file TB3A contains 20 records.

A Turbo-B, M tube with a surface area of 0.0061028 m², an outer diameter of 0.01912 m and a correction ratio R/r of 1.5704 was tested in freon with a saturation temperature of 31.8 C.

Pool Boiling Data

Data from the 25% R-11/75% R-113 mixture

I	h(I)	Tav(I)-Ts	Tav(I)	T1(I)	T2(I)	T3(I)	T4(I)	Tpool(I)	q(I)
	[kW/m^2K]	[C]	[C]	[C]	[C]	[C]	[C]	[C]	[W/m^2]
1	-.009	-.3	37.7	37.8	37.7	37.7	37.5	37.4	3.119E+0
2	.206	2.2	40.2	40.3	40.2	40.1	40.1	37.6	4.478E+2
3	.212	3.9	41.9	42.0	42.0	41.8	41.8	37.3	8.279E+2
4	.221	6.1	44.1	44.2	44.1	44.0	44.0	37.5	1.341E+3
5	.237	9.5	47.5	47.7	47.6	47.4	47.5	38.9	2.258E+3
6	.323	11.7	49.7	50.1	49.8	49.3	49.7	39.6	3.790E+3
7	.434	14.1	52.1	52.5	52.1	51.5	52.1	39.5	6.101E+3
8	.604	16.8	54.8	55.4	54.8	54.0	55.0	37.7	1.014E+4
9	1.242	12.9	50.9	51.7	50.9	50.3	50.8	38.3	1.607E+4
10	1.707	15.8	53.8	54.7	53.8	53.1	53.8	38.6	2.705E+4
11	1.951	17.0	55.0	55.8	55.0	54.3	54.9	38.4	3.318E+4
12	1.419	14.2	52.2	52.9	52.1	51.6	52.1	38.5	2.012E+4
13	1.018	11.6	49.6	50.2	49.6	49.2	49.5	38.4	1.183E+4
14	.672	9.6	47.6	47.9	47.5	47.3	47.5	38.5	6.434E+3
15	.439	7.6	45.6	45.9	45.6	45.4	45.5	38.2	3.331E+3
16	.291	5.6	43.6	43.8	43.7	43.5	43.5	37.9	1.638E+3
17	.214	4.1	42.1	42.2	42.2	42.0	42.0	37.9	8.770E+2
18	.173	2.1	40.1	40.3	40.2	40.1	40.0	37.5	3.703E+2
19	.174	1.4	39.4	39.5	39.4	39.3	39.2	37.4	2.365E+2

The file PL4 contains 19 records.

A plain tube with a surface area of 0.0060964 m², an outer diameter of 0.0191 m and a correction ratio R/r of 1.083 was tested in freon with a saturation temperature of 38 C.

I	h(I)	Tav(I)-Ts	Tav(I)	T1(I)	T2(I)	T3(I)	T4(I)	Tpool(I)	q(I)
	[kW/m^2K]	[C]	[C]	[C]	[C]	[C]	[C]	[C]	[W/m^2]
1	-.005	-.6	37.4	37.5	37.4	37.3	37.2	37.1	3.488E+0
2	.269	1.3	39.3	39.4	39.2	39.3	39.2	37.1	3.452E+2
3	.230	2.8	40.8	40.9	40.6	40.8	40.7	37.1	6.393E+2
4	.228	5.1	43.1	43.2	42.6	43.1	43.0	37.1	1.163E+3
5	.234	8.6	46.6	46.6	45.8	46.6	46.5	37.9	2.009E+3
6	1.614	2.1	40.1	40.1	39.9	40.1	40.0	37.3	3.389E+3
7	2.373	2.4	40.4	40.4	40.1	40.5	40.3	37.4	5.708E+3
8	3.254	2.9	40.9	40.7	40.4	41.0	40.8	37.7	9.279E+3
9	4.587	3.4	41.4	41.2	40.8	41.6	41.4	37.9	1.557E+4
10	6.270	4.1	42.1	42.0	41.2	42.4	42.1	38.0	2.597E+4
11	4.708	3.5	41.5	41.3	40.9	41.7	41.5	38.0	1.661E+4
12	3.303	3.0	41.0	40.9	40.6	41.2	41.0	38.0	1.003E+4
13	2.271	2.6	40.6	40.5	40.3	40.7	40.5	37.9	5.877E+3
14	1.588	2.2	40.2	40.2	39.9	40.3	40.1	37.9	3.486E+3
15	1.071	1.9	39.9	39.9	39.7	39.9	39.8	37.7	2.017E+3
16	.749	1.6	39.6	39.7	39.5	39.6	39.6	37.7	1.232E+3
17	.520	1.4	39.4	39.5	39.4	39.4	39.3	37.6	7.484E+2
18	.331	1.1	39.1	39.3	39.1	39.1	39.0	37.5	3.788E+2
19	.330	.7	38.7	38.9	38.7	38.7	38.6	37.3	2.400E+2

The file HF4 contains 19 records.

A Hi-Flux, S tube with a surface area of 0.0060805 m², an outer diameter of 0.01905 m and a correction ratio R/r of 1.816 was tested in freon with a saturation temperature of 38 C.

I	h(I)	Tav(I)-Ts	Tav(I)	T1(I)	T2(I)	T3(I)	T4(I)	Tpool(I)	q(I)
	[kW/m^2K]	[C]	[C]	[C]	[C]	[C]	[C]	[C]	[W/m^2]
1	-.006	-.2	37.8	37.8	37.8	37.7	37.7	37.5	1.410E+0
2	.204	1.3	39.3	39.5	39.3	39.2	39.3	37.5	2.698E+2
3	.402	1.8	39.8	40.0	39.8	39.7	39.8	37.5	7.416E+2
4	.514	2.6	40.6	40.8	40.5	40.4	40.6	37.6	1.325E+3
5	.589	4.0	42.0	42.2	41.8	41.7	42.1	38.0	2.327E+3
6	.783	4.8	42.8	43.1	42.6	42.4	43.0	38.2	3.758E+3
7	1.298	5.9	43.9	44.3	43.5	43.3	44.3	38.5	7.611E+3
8	1.751	6.0	44.0	44.4	43.8	43.6	44.5	38.6	1.058E+4
9	3.961	6.3	44.3	44.8	43.8	43.5	44.9	38.7	2.476E+4
10	2.231	5.8	43.8	44.1	43.6	43.4	44.2	38.8	1.302E+4
11	1.421	5.2	43.2	43.5	43.0	42.9	43.4	38.6	7.367E+3
12	.884	4.6	42.6	43.0	42.4	42.3	42.9	38.4	4.110E+3
13	.609	3.9	41.9	42.2	41.7	41.6	42.0	38.4	2.366E+3
14	.454	2.9	40.9	41.1	40.8	40.8	41.0	38.2	1.327E+3
15	.360	2.1	40.1	40.3	40.0	39.9	40.0	38.1	7.449E+2
16	.204	1.6	39.6	39.7	39.6	39.5	39.6	37.9	3.280E+2

The file TB42 contains 16 records.

A Turbo-B, M tube with a surface area of 0.0061028 m², an outer diameter of 0.01912 m and a correction ratio R/r of 1.5704 was tested in freon with a saturation temperature of 38 C.

Bundle Boiling Data

Smooth tube data in R-113 for bundle with $p/d = 1.17$

RUN NUMBER: 173
p/d = 1.17
Pin = 209.2 kPa
Xin = -.00
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 51.33 kg/s*m^2
DELTA P total = 4.48 kPa
Xout = 0.19

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	208.9	-.00	68.8	4961	74.6	859
3	208.3	0.02	69.7	4961	74.0	1160
5	207.7	0.05	69.8	5100	74.0	1213
7	207.1	0.07	69.7	5095	73.7	1271
9	206.5	0.10	69.7	4948	73.3	1343
11	205.9	0.12	69.6	5005	73.5	1299
13	205.3	0.15	69.6	4991	73.2	1372
15	204.7	0.18	69.5	5131	73.0	1399

RUN NUMBER: 170
p/d = 1.17
Pin = 210.7 kPa
Xin = -.01
SURFACE TYPE: SMOOTH

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	210.3	-.01	68.8	19709	82.6	1428
3	209.7	0.09	70.8	19894	82.1	1757
5	209.1	0.20	70.7	20391	82.2	1764
7	208.6	0.30	70.6	20448	82.0	1793
9	208.0	0.41	70.5	19880	81.3	1840
11	207.4	0.51	70.4	20233	82.4	1791
13	206.8	0.62	70.4	20456	81.8	1792
15	206.2	0.72	70.3	20807	81.2	1804

WORKING FLUID: R-113
G = 51.55 kg/s*m^2
DELTA P total = 4.48 kPa
Xout = 0.77

RUN NUMBER: 167
p/d = 1.17
Pin = 211.1 kPa
Xin = -.01
SURFACE TYPE: SMOOTH

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	210.8	-.01	69.3	29733	83.3	2126
3	210.2	0.07	70.7	30061	83.1	2429
5	209.6	0.15	70.6	30670	83.3	2425
7	209.0	0.22	70.6	30817	83.5	2390
9	208.4	0.30	70.5	30049	82.8	2450
11	207.8	0.38	70.4	29832	83.6	2371
13	207.2	0.46	70.4	30253	83.1	2473
15	206.6	0.53	70.3	30736	83.4	2337

WORKING FLUID: R-113
G = 104.27 kg/s*m^2
DELTA P total = 4.48 kPa
Xout = 0.57

RUN NUMBER: 163
p/d = 1.17
Pin = 204.1 kPa
Xin = -.00
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 52.8 kg/s*m^2
DELTA P total = 4.48 kPa
Xout = 0.39

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	203.8	-.00	68.5	10221	77.4	1155
3	203.2	0.05	69.9	10237	77.0	1438
5	202.6	0.10	69.8	10474	76.9	1465
7	202.0	0.16	69.7	10579	76.8	1495
9	201.4	0.21	69.6	10298	76.2	1550
11	200.8	0.26	69.5	10207	76.6	1430
13	200.2	0.31	69.4	10391	76.4	1486
15	199.6	0.36	69.3	10527	75.9	1589

RUN NUMBER: 169
p/d = 1.17
Pin = 207.3 kPa
Xin = 0.01
SURFACE TYPE: SMOOTH

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	207.0	0.01	69.4	9998	77.8	1197
3	206.4	0.04	68.9	10161	77.3	1203
5	205.8	0.07	68.9	10430	77.1	1271
7	205.2	0.09	69.0	10460	76.9	1330
9	204.6	0.12	69.0	10130	76.3	1392
11	204.0	0.15	69.1	10170	76.7	1329
13	203.4	0.17	69.1	10339	76.4	1419
15	202.8	0.20	69.2	10452	76.0	1341

WORKING FLUID: R-113
G = 101.24 kg/s*m^2
DELTA P total = 4.48 kPa
Xout = 0.21

RUN NUMBER: 166
p/d = 1.17
Pin = 208.6 kPa
Xin = -.01
SURFACE TYPE: SMOOTH

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	208.3	-.01	67.7	39330	84.1	2397
3	207.7	0.09	70.4	39659	84.2	2887
5	207.1	0.19	70.3	40526	84.7	2831
7	206.5	0.29	70.3	40330	84.9	2760
9	205.9	0.39	70.2	39341	84.2	2797
11	205.3	0.49	70.1	39347	85.1	2819
13	204.7	0.59	70.0	39922	84.5	2759
15	204.1	0.69	69.9	40564	85.5	2800

WORKING FLUID: R-113
G = 105.63 kg/s*m^2
DELTA P total = 4.48 kPa
Xout = 0.73

RUN NUMBER: 171
p/d = 1.17
Pin = 207.7 kPa
Xin = -.00
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 51.97 kg/s*m^2
DELTA P total = 4.48 kPa
Xout = 0.57

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	207.4	-.00	69.1	14722	80.7	1277
3	206.8	0.07	70.1	14842	79.9	1524
5	206.2	0.15	70.1	15213	79.8	1567
7	205.6	0.23	70.0	15207	79.5	1597
9	205.0	0.30	69.9	14711	79.0	1629
11	204.4	0.38	69.9	14916	79.6	1628
13	203.8	0.46	69.8	15059	79.4	1567
15	203.2	0.53	69.7	15330	78.6	1618

RUN NUMBER: 168
p/d = 1.17
Pin = 207.9 kPa
Xin = 0.00
SURFACE TYPE: SMOOTH

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	207.6	0.00	69.3	19803	81.3	1648
3	207.0	0.05	69.9	20027	80.9	1819
5	206.4	0.11	69.8	20412	80.9	1852
7	205.8	0.16	69.8	20542	80.7	1875
9	205.2	0.22	69.8	19943	80.1	1931
11	204.6	0.27	69.7	20069	80.7	1825
13	204.0	0.32	69.7	20306	80.4	1889
15	203.5	0.37	69.6	20629	79.9	2018

WORKING FLUID: R-113
G = 100.61 kg/s*m^2
DELTA P total = 4.48 kPa
Xout = 0.40

RUN NUMBER: 195
p/d = 1.17
Pin = 214.5 kPa
Xin = -.01
SURFACE TYPE: SMOOTH

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	214.1	-.01	69.2	4939	76.5	677
3	213.4	-.01	70.0	4989	76.1	813
5	212.7	-.00	70.7	5131	76.3	926
7	212.0	0.01	71.2	5113	76.1	1035
9	211.4	0.01	71.3	4971	75.8	1099
11	210.7	0.02	71.2	5010	75.9	1067
13	210.1	0.02	71.1	5042	75.8	1068
15	209.4	0.03	71.0	5144	75.6	1109

WORKING FLUID: R-113
G = 227.98 kg/s*m^2
DELTA P total = 5.12 kPa
Xout = 0.03

RUN NUMBER: 194
p/d = 1.17
Pin = 205.2 kPa
Xin = -.00
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 230.86 kg/s*m^2
DELTA P total = 5.11 kPa
Xout = 0.09

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	204.8	-.00	68.7	10070	77.8	1105
3	204.1	0.01	69.7	10150	77.4	1314
5	203.5	0.02	70.0	10511	77.5	1395
7	202.8	0.04	69.8	10468	77.2	1417
9	202.1	0.05	69.7	10179	76.5	1491
11	201.5	0.06	69.6	10195	76.3	1518
13	200.8	0.07	69.5	10315	75.9	1609
15	200.1	0.08	69.4	10492	75.9	1613

RUN NUMBER: 138
p/d = 1.17
Pin = 205 kPa
Xin = -.01
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 225.04 kg/s*m^2
DELTA P total = 4.48 kPa
Xout = 0.34

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	204.6	-.01	68.2	39857	82.9	2723
3	204.0	0.04	69.5	40193	83.2	2935
5	203.5	0.09	69.5	40974	83.4	2944
7	202.9	0.14	69.4	41765	83.7	2915
9	202.3	0.18	69.3	40824	83.0	2979
11	201.7	0.23	69.2	40494	83.3	2879
13	201.1	0.28	69.1	40750	82.2	3125
15	200.5	0.32	69.1	41402	83.2	2922

RUN NUMBER: 140
p/d = 1.17
Pin = 208.3 kPa
Xin = -.01
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 225.61 kg/s*m^2
DELTA P total = 4.48 kPa
Xout = 0.59

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	208.0	-.01	68.5	68310	85.4	4046
3	207.4	0.07	70.3	68122	86.0	4327
5	206.8	0.15	70.2	69441	85.9	4412
7	206.2	0.23	70.1	69886	86.5	4265
9	205.6	0.31	70.0	68463	85.8	4347
11	205.0	0.40	70.0	68332	86.2	4213
13	204.4	0.47	69.9	69459	85.3	4515
15	203.8	0.55	69.8	70294	87.4	4007

RUN NUMBER: 149
p/d = 1.17
Pin = 207.1 kPa
Xin = -.01
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 221.72 kg/s*m^2
DELTA P total = 4.48 kPa
Xout = 0.17

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	206.8	-.01	67.8	19788	80.1	1607
3	206.2	0.01	69.1	19882	80.3	1786
5	205.6	0.04	69.4	20337	80.3	1874
7	205.0	0.06	69.4	20331	80.0	1903
9	204.4	0.09	69.3	19684	79.3	1976
11	203.8	0.11	69.3	19815	79.6	1921
13	203.2	0.13	69.2	20177	79.3	1986
15	202.6	0.16	69.1	20420	79.0	2060

RUN NUMBER: 137
p/d = 1.17
Pin = 201.2 kPa
Xin = 0.00
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 221.45 kg/s*m^2
DELTA P total = 4.48 kPa
Xout = 0.45

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	200.9	0.00	68.3	49301	82.8	3399
3	200.3	0.06	68.7	49679	83.1	3457
5	199.7	0.12	68.7	50532	83.2	3479
7	199.1	0.18	68.7	50522	83.5	3412
9	198.5	0.24	68.6	49369	82.8	3474
11	197.9	0.30	68.6	50008	83.1	3431
13	197.3	0.36	68.5	50366	82.0	3743
15	196.7	0.42	68.5	51248	83.5	3408

RUN NUMBER: 193
p/d = 1.17
Pin = 204.6 kPa
Xin = 0.00
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 349.96 kg/s*m^2
DELTA P total = 5.12 kPa
Xout = 0.06

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	204.2	0.00	69.0	10055	77.2	1223
3	203.5	0.01	69.6	10138	77.0	1368
5	202.8	0.02	69.7	10506	77.2	1401
7	202.1	0.03	69.6	10464	76.9	1434
9	201.5	0.04	69.5	10173	76.1	1549
11	200.8	0.04	69.4	10189	75.7	1615
13	200.1	0.05	69.3	10275	75.3	1722
15	199.5	0.06	69.3	10483	75.4	1714

RUN NUMBER: 165
p/d = 1.17
Pin = 208 kPa
Xin = -.01
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 224.56 kg/s*m^2
DELTA P total = 4.48 kPa
Xout = 0.26

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	207.6	-.01	68.8	29861	82.4	2191
3	207.0	0.03	69.8	29948	82.3	2399
5	206.4	0.06	69.7	30569	82.5	2402
7	205.9	0.10	69.7	30689	82.6	2372
9	205.3	0.13	69.6	29943	81.8	2453
11	204.7	0.17	69.6	29798	82.2	2359
13	204.1	0.20	69.5	30233	81.4	2456
15	203.5	0.24	69.5	30704	81.8	2488

RUN NUMBER: 139
p/d = 1.17
Pin = 203.2 kPa
Xin = -.01
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 221.94 kg/s*m^2
DELTA P total = 4.48 kPa
Xout = 0.55

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	202.9	-.01	68.4	61815	84.4	3860
3	202.3	0.07	69.3	61857	84.9	3969
5	201.7	0.14	69.2	63256	84.9	4048
7	201.1	0.22	69.2	62813	85.3	3901
9	200.5	0.30	69.1	61533	84.6	3974
11	199.9	0.37	69.0	61829	84.9	3889
13	199.3	0.44	69.0	62501	83.9	4177
15	198.7	0.51	68.9	63447	85.8	3750

RUN NUMBER: 148
p/d = 1.17
Pin = 211.6 kPa
Xin = -.02
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 348.22 kg/s*m^2
DELTA P total = 4.51 kPa
Xout = 0.10

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	211.2	-.02	68.6	20252	80.0	1782
3	210.6	-.00	69.3	20400	79.9	1927
5	210.0	0.02	69.6	20891	80.0	2022
7	209.4	0.03	69.6	20828	79.7	2051
9	208.9	0.05	69.6	20290	78.9	2175
11	208.3	0.06	69.5	20352	79.0	2150
13	207.7	0.08	69.5	20730	78.6	2278
15	207.1	0.09	69.4	20984	78.0	2437

RUN NUMBER: 147
p/d = 1.17
Pin = 206.7 kPa
Xin = -.01
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 348.75 kg/s*m²
DELTA P total = 4.49 kPa
Xout = 0.16

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	206.4	-.01	68.6	30075	81.8	2273
3	205.8	0.01	69.2	30256	81.7	2405
5	205.2	0.04	69.2	30946	81.8	2449
7	204.6	0.06	69.1	31032	81.7	2467
9	204.0	0.08	69.1	30281	80.7	2620
11	203.4	0.11	69.1	30342	81.0	2546
13	202.8	0.13	69.0	30819	80.4	2716
15	202.2	0.15	69.0	31256	80.2	2788

RUN NUMBER: 144
p/d = 1.17
Pin = 207.7 kPa
Xin = -.01
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 346.45 kg/s*m²
DELTA P total = 4.48 kPa
Xout = 0.34

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	207.4	-.01	68.5	60704	84.9	3688
3	206.8	0.03	69.9	60535	85.6	3868
5	206.2	0.08	69.9	61867	85.6	3939
7	205.6	0.13	69.8	61358	85.9	3806
9	205.1	0.18	69.7	60011	85.0	3941
11	204.5	0.22	69.7	60165	85.5	3813
13	203.9	0.27	69.6	61142	84.5	4002
15	203.3	0.31	69.6	61905	86.0	3775

RUN NUMBER: 192
p/d = 1.17
Pin = 203.7 kPa
Xin = 0.00
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 499.24 kg/s*m²
DELTA P total = 5.15 kPa
Xout = 0.04

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	203.3	0.00	69.0	10026	76.5	1334
3	202.6	0.01	69.1	10116	76.4	1391
5	201.9	0.01	69.2	10488	76.7	1398
7	201.3	0.02	69.1	10436	76.2	1475
9	200.6	0.02	69.1	10130	75.4	1605
11	199.9	0.03	69.1	10138	75.0	1703
13	199.3	0.03	69.1	10253	74.6	1867
15	198.6	0.04	69.1	10431	74.7	1855

RUN NUMBER: 146
p/d = 1.17
Pin = 204 kPa
Xin = -.01
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 348.84 kg/s*m²
DELTA P total = 4.5 kPa
Xout = 0.22

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	203.7	-.01	68.2	40455	82.9	2752
3	203.1	0.02	69.0	40581	83.1	2879
5	202.5	0.05	68.9	41577	83.2	2919
7	201.9	0.09	68.9	41565	83.2	2895
9	201.3	0.12	68.8	40618	82.1	3069
11	200.7	0.15	68.8	40326	82.5	2943
13	200.1	0.18	68.8	40957	81.8	3141
15	199.5	0.21	68.7	41604	82.1	3110

RUN NUMBER: 143
p/d = 1.17
Pin = 203.8 kPa
Xin = -.01
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 346.87 kg/s*m²
DELTA P total = 4.51 kPa
Xout = 0.39

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	203.5	-.01	68.5	69784	85.2	4184
3	202.9	0.05	69.2	69479	85.9	4166
5	202.3	0.10	69.2	70875	85.8	4264
7	201.7	0.16	69.1	70257	86.2	4100
9	201.1	0.21	69.1	68757	85.4	4210
11	200.5	0.26	69.0	68768	85.9	4078
13	199.9	0.31	69.0	69990	85.0	4263
15	199.4	0.37	68.9	70666	86.7	3982

RUN NUMBER: 156
p/d = 1.17
Pin = 212.1 kPa
Xin = -.02
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 505.76 kg/s*m²
DELTA P total = 4.51 kPa
Xout = 0.06

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	211.8	-.02	68.4	20266	79.6	1804
3	211.2	-.01	68.8	20435	79.7	1877
5	210.6	0.00	69.0	20840	79.7	1957
7	210.0	0.01	69.1	20992	79.6	2006
9	209.4	0.03	69.1	20449	78.7	2133
11	208.8	0.04	69.1	19911	78.5	2106
13	208.2	0.05	69.0	20175	77.9	2273
15	207.6	0.06	69.0	20530	77.5	2419

RUN NUMBER: 145
p/d = 1.17
Pin = 205.4 kPa
Xin = -.01
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 346.31 kg/s*m²
DELTA P total = 4.54 kPa
Xout = 0.28

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	205.1	-.01	68.5	49879	83.9	3227
3	204.5	0.03	69.4	49883	84.4	3337
5	203.9	0.07	69.4	51051	84.4	3397
7	203.3	0.11	69.3	50760	84.6	3328
9	202.7	0.15	69.3	49606	83.4	3496
11	202.1	0.18	69.2	49344	83.9	3342
13	201.6	0.22	69.1	50138	83.0	3519
15	201.0	0.26	69.1	50921	83.9	3431

RUN NUMBER: 142
p/d = 1.17
Pin = 206 kPa
Xin = -.01
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 347.26 kg/s*m²
DELTA P total = 4.48 kPa
Xout = 0.44

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	205.7	-.01	68.5	79493	86.2	4489
3	205.1	0.05	69.8	78951	86.9	4619
5	204.5	0.11	69.7	80594	86.7	4747
7	203.9	0.17	69.7	79842	87.3	4533
9	203.3	0.23	69.6	78205	86.5	4619
11	202.7	0.29	69.5	78550	87.0	4480
13	202.1	0.35	69.4	79940	86.8	4460
15	201.5	0.41	69.3	80731	88.1	4312

RUN NUMBER: 155
p/d = 1.17
Pin = 212.4 kPa
Xin = -.02
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 506.21 kg/s*m²
DELTA P total = 4.49 kPa
Xout = 0.10

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	212.1	-.02	68.4	30111	82.0	2216
3	211.5	-.00	69.4	30377	82.0	2401
5	210.9	0.01	69.8	30971	82.2	2505
7	210.3	0.03	69.8	31265	82.2	2518
9	209.7	0.05	69.7	30508	81.1	2668
11	209.1	0.06	69.7	30056	81.3	2576
13	208.6	0.08	69.6	30610	80.6	2693
15	208.0	0.09	69.6	31019	80.5	2840

RUN NUMBER: 154
p/d = 1.17
Pin = 206.8 kPa
Xin = -.01
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 506.21 kg/s*m²
DELTA P total = 4.5 kPa
Xout = 0.15

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m ²]	Tw [C]	h [W/m ² C]
1	206.4	-.01	68.4	40525	83.1	2761
3	205.8	0.01	69.1	40825	83.3	2874
5	205.2	0.03	69.2	41739	83.3	2941
7	204.6	0.06	69.1	41607	83.4	2908
9	204.1	0.08	69.1	40634	82.3	3076
11	203.5	0.10	69.0	40214	82.7	2954
13	202.9	0.12	69.0	40822	81.8	3178
15	202.3	0.14	68.9	41444	82.1	3140

RUN NUMBER: 151
p/d = 1.17
Pin = 202 kPa
Xin = 0.01
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 498.5 kg/s*m²
DELTA P total = 4.56 kPa
Xout = 0.29

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m ²]	Tw [C]	h [W/m ² C]
1	201.6	0.01	68.7	70444	85.2	4248
3	201.0	0.04	67.9	70109	85.8	3916
5	200.5	0.08	68.0	71539	85.7	4046
7	199.9	0.12	68.1	71243	86.1	3947
9	199.3	0.16	68.2	70661	85.2	4145
11	198.7	0.19	68.2	69668	85.7	3998
13	198.1	0.23	68.3	70903	85.0	4246
15	197.5	0.27	68.4	71531	86.3	3998

RUN NUMBER: 214
p/d = 1.17
Pin = 554.6 kPa
Xin = -.01
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 47.72 kg/s*m²
DELTA P total = 4.54 kPa
Xout = 0.47

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m ²]	Tw [C]	h [W/m ² C]
1	554.3	-.01	104.1	9860	114.7	929
3	553.7	0.05	108.8	9978	114.8	1647
5	553.1	0.12	109.8	10186	115.0	1967
7	552.5	0.18	109.7	10227	115.5	1773
9	551.9	0.25	109.7	9968	115.4	1743
11	551.3	0.31	109.6	9778	115.2	1744
13	550.7	0.37	109.6	10010	115.5	1786
15	550.1	0.43	109.5	10103	115.2	1785

RUN NUMBER: 153
p/d = 1.17
Pin = 206.9 kPa
Xin = -.02
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 506.76 kg/s*m²
DELTA P total = 4.54 kPa
Xout = 0.18

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m ²]	Tw [C]	h [W/m ² C]
1	206.5	-.02	67.8	49308	84.0	3037
3	205.9	0.01	69.2	49485	84.5	3237
5	205.4	0.04	69.4	50598	84.6	3340
7	204.8	0.06	69.4	50902	84.8	3295
9	204.2	0.09	69.3	50360	83.7	3497
11	203.6	0.12	69.3	49464	84.2	3322
13	203.0	0.14	69.2	50276	83.3	3460
15	202.4	0.17	69.1	50976	84.2	3380

RUN NUMBER: 150
p/d = 1.17
Pin = 207.3 kPa
Xin = 0.00
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 497.71 kg/s*m²
DELTA P total = 4.5 kPa
Xout = 0.32

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m ²]	Tw [C]	h [W/m ² C]
1	207.0	0.00	69.4	79637	86.5	4676
3	206.4	0.04	69.4	79216	87.1	4488
5	205.8	0.09	69.4	80604	86.9	4625
7	205.2	0.13	69.4	80609	87.5	4469
9	204.6	0.17	69.4	80186	86.6	4658
11	204.0	0.22	69.4	79104	87.0	4502
13	203.4	0.26	69.4	80569	86.5	4629
15	202.8	0.30	69.4	81107	87.9	4399

RUN NUMBER: 215
p/d = 1.17
Pin = 555.8 kPa
Xin = -.02
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 53.35 kg/s*m²
DELTA P total = 4.54 kPa
Xout = 0.61

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m ²]	Tw [C]	h [W/m ² C]
1	555.5	-.02	107.0	14633	118.3	1303
3	554.9	0.06	109.9	14746	118.6	1705
5	554.3	0.15	109.9	15076	118.4	1766
7	553.7	0.23	109.8	15222	119.1	1642
9	553.1	0.32	109.8	14778	119.0	1595
11	552.5	0.41	109.7	14630	118.8	1608
13	551.9	0.49	109.7	14989	118.7	1660
15	551.3	0.57	109.6	15134	118.7	1660

RUN NUMBER: 152
p/d = 1.17
Pin = 204.9 kPa
Xin = -.01
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 507.14 kg/s*m²
DELTA P total = 4.55 kPa
Xout = 0.23

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m ²]	Tw [C]	h [W/m ² C]
1	204.6	-.01	68.2	59929	84.6	3639
3	204.0	0.02	69.2	59943	85.3	3744
5	203.4	0.05	69.2	61181	85.3	3807
7	202.8	0.09	69.1	61084	85.6	3702
9	202.2	0.12	69.0	60571	84.6	3896
11	201.7	0.15	69.0	59397	85.0	3709
13	201.1	0.18	68.9	60363	84.2	3963
15	200.5	0.21	68.9	61125	85.4	3698

RUN NUMBER: 200
p/d = 1.17
Pin = 572.2 kPa
Xin = 0.01
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 45.38 kg/s*m²
DELTA P total = 6.7 kPa
Xout = 0.26

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m ²]	Tw [C]	h [W/m ² C]
1	571.7	0.01	106.5	4946	114.3	634
3	570.7	0.04	109.8	5005	114.3	1106
5	569.9	0.08	111.1	5194	114.6	1481
7	569.0	0.11	111.0	5172	114.9	1355
9	568.2	0.15	111.0	4986	114.8	1305
11	567.4	0.18	110.9	5031	114.8	1294
13	566.5	0.21	110.8	5120	114.4	1436
15	565.6	0.25	110.8	5174	114.7	1318

RUN NUMBER: 216
p/d = 1.17
Pin = 598.7 kPa
Xin = -.06
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 51.24 kg/s*m²
DELTA P total = 4.58 kPa
Xout = 0.80

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m ²]	Tw [C]	h [W/m ² C]
1	598.3	-.06	107.4	18679	121.1	1360
3	597.8	0.05	113.3	18915	121.4	2350
5	597.2	0.17	113.3	19273	121.2	2426
7	596.6	0.28	113.2	19755	122.2	2195
9	596.0	0.40	113.2	19189	122.1	2163
11	595.4	0.52	113.1	18870	121.7	2192
13	594.8	0.63	113.1	19359	121.7	2244
15	594.2	0.74	113.0	19522	121.9	2198

RUN NUMBER: 213 WORKING FLUID: R-113
 p/d = 1.17 G = 105.86 kg/s*m^2
 Pin = 560 kPa DELTA P total = 4.52 kPa
 Xin = -.01 Xout = 0.09
 SURFACE TYPE: SMOOTH

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	559.7	-.01	107.8	4964	113.4	883
3	559.1	0.00	109.4	5024	113.3	1283
5	558.5	0.01	110.2	5127	113.5	1553
7	557.9	0.03	110.2	5184	113.8	1432
9	557.3	0.04	110.1	5062	113.8	1365
11	556.7	0.06	110.1	4868	113.9	1285
13	556.1	0.07	110.0	4985	114.7	1258
15	555.6	0.09	110.0	5028	113.9	1285

RUN NUMBER: 199 WORKING FLUID: R-113
 p/d = 1.17 G = 96.81 kg/s*m^2
 Pin = 579.5 kPa DELTA P total = 6.52 kPa
 Xin = 0.02 Xout = 0.74
 SURFACE TYPE: SMOOTH

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	579.0	0.02	109.9	29843	122.4	2392
3	578.1	0.12	111.8	30257	122.5	2810
5	577.2	0.21	111.7	30860	122.7	2800
7	576.4	0.31	111.6	30877	123.2	2661
9	575.6	0.41	111.6	29947	122.8	2672
11	574.8	0.51	111.5	29886	122.9	2619
13	573.9	0.60	111.4	30500	122.3	2799
15	573.0	0.69	111.4	30916	122.8	2711

RUN NUMBER: 204 WORKING FLUID: R-113
 p/d = 1.17 G = 232.37 kg/s*m^2
 Pin = 563.6 kPa DELTA P total = 5.11 kPa
 Xin = 0.01 Xout = 0.31
 SURFACE TYPE: SMOOTH

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	563.2	0.01	109.3	29570	119.3	2962
3	562.5	0.05	110.5	29486	119.5	3294
5	561.8	0.09	110.5	30598	119.1	3536
7	561.2	0.13	110.4	30566	120.1	3268
9	560.5	0.17	110.4	29686	119.5	3238
11	559.9	0.21	110.3	29591	119.4	3255
13	559.2	0.25	110.3	30237	119.2	3368
15	558.5	0.29	110.2	30641	119.8	3188

RUN NUMBER: 196 WORKING FLUID: R-113
 p/d = 1.17 G = 105.19 kg/s*m^2
 Pin = 589.2 kPa DELTA P total = 5.18 kPa
 Xin = 0.03 Xout = 0.25
 SURFACE TYPE: SMOOTH

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	588.8	0.03	111.6	10150	118.2	1543
3	588.1	0.06	112.5	10238	118.0	1860
5	587.4	0.09	112.5	10564	118.1	1870
7	586.8	0.12	112.4	10377	118.6	1887
9	586.1	0.15	112.4	10075	118.4	1886
11	585.4	0.18	112.3	10200	118.6	1836
13	584.8	0.21	112.3	10355	117.8	1873
15	584.1	0.24	112.2	10496	118.5	1877

RUN NUMBER: 209 WORKING FLUID: R-113
 p/d = 1.17 G = 226.99 kg/s*m^2
 Pin = 577.5 kPa DELTA P total = 5.11 kPa
 Xin = 0.00 Xout = 0.10
 SURFACE TYPE: SMOOTH

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	577.1	0.00	109.3	10042	116.9	1322
3	576.4	0.01	110.8	10105	116.9	1657
5	575.7	0.03	111.6	10398	117.0	1925
7	575.0	0.04	111.5	10422	117.5	1756
9	574.4	0.06	111.5	10158	117.5	1697
11	573.7	0.07	111.4	10057	117.6	1624
13	573.1	0.08	111.4	10251	118.1	1534
15	572.5	0.10	111.3	10400	117.7	1644

RUN NUMBER: 205 WORKING FLUID: R-113
 p/d = 1.17 G = 227.68 kg/s*m^2
 Pin = 588 kPa DELTA P total = 5.17 kPa
 Xin = -.02 Xout = 0.39
 SURFACE TYPE: SMOOTH

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	587.6	-.02	109.1	40177	121.9	3148
3	586.9	0.04	112.3	40463	122.2	4077
5	586.2	0.09	112.4	41294	121.8	4194
7	585.6	0.15	112.4	41263	123.0	3883
9	584.9	0.20	112.3	40233	122.3	4034
11	584.3	0.26	112.3	39872	122.1	4042
13	583.6	0.31	112.2	40793	122.0	4148
15	582.9	0.36	112.2	41405	122.7	3933

RUN NUMBER: 197 WORKING FLUID: R-113
 p/d = 1.17 G = 103.95 kg/s*m^2
 Pin = 594.8 kPa DELTA P total = 6.61 kPa
 Xin = -.02 Xout = 0.43
 SURFACE TYPE: SMOOTH

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	594.2	-.02	109.4	20189	120.6	1793
3	593.3	0.04	112.8	20098	120.6	2574
5	592.5	0.10	112.9	20791	120.8	2628
7	591.7	0.16	112.8	20659	121.8	2310
9	590.8	0.23	112.8	20099	121.3	2349
11	590.0	0.29	112.7	20244	121.5	2291
13	589.2	0.34	112.6	20591	121.6	2304
15	588.2	0.40	112.6	20870	121.8	2270

RUN NUMBER: 203 WORKING FLUID: R-113
 p/d = 1.17 G = 224.97 kg/s*m^2
 Pin = 571.7 kPa DELTA P total = 6.97 kPa
 Xin = -.01 Xout = 0.20
 SURFACE TYPE: SMOOTH

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	571.1	-.01	107.6	20158	118.9	1793
3	570.2	0.02	110.1	20120	118.8	2319
5	569.3	0.05	111.1	20845	118.6	2461
7	568.4	0.08	111.0	20981	119.7	2403
9	567.6	0.10	110.9	20329	119.5	2380
11	566.7	0.13	110.9	20287	119.4	2362
13	565.8	0.16	110.8	20681	119.5	2371
15	564.8	0.19	110.7	20952	119.4	2408

RUN NUMBER: 206 WORKING FLUID: R-113
 p/d = 1.17 G = 229.05 kg/s*m^2
 Pin = 590 kPa DELTA P total = 5.12 kPa
 Xin = -.01 Xout = 0.49
 SURFACE TYPE: SMOOTH

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	589.6	-.01	110.0	49694	122.8	3872
3	588.9	0.05	112.6	49810	123.2	4730
5	588.3	0.12	112.6	50911	122.7	4541
7	587.6	0.19	112.5	51103	124.0	4459
9	586.9	0.26	112.5	49892	123.1	4684
11	586.3	0.33	112.4	49622	123.0	4700
13	585.6	0.39	112.4	50634	122.9	4798
15	584.9	0.46	112.3	51345	123.6	4537

RUN NUMBER: 207 WORKING FLUID: R-113
 p/d = 1.17 G = 227.73 kg/s*m²
 Pin = 593.4 kPa DELTA P total = 5.21 kPa
 Xin = -.02 Xout = 0.59
 SURFACE TYPE: SMOOTH

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	593.0	-.02	110.1	59659	124.4	4159
3	592.3	0.07	112.9	59643	124.8	5023
5	591.6	0.15	112.8	60829	124.2	5334
7	590.9	0.23	112.8	61432	125.7	5064
9	590.3	0.31	112.7	59970	124.7	5013
11	589.6	0.40	112.7	59802	124.6	5034
13	588.9	0.48	112.6	61164	124.5	5134
15	588.3	0.56	112.6	61733	125.4	4820

RUN NUMBER: 190 WORKING FLUID: R-113
 p/d = 1.17 G = 349.37 kg/s*m²
 Pin = 605 kPa DELTA P total = 4.57 kPa
 Xin = -.00 Xout = 0.13
 SURFACE TYPE: SMOOTH

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	604.7	-.00	111.9	19910	120.0	2438
3	604.1	0.02	113.3	19944	120.7	2708
5	603.5	0.03	113.8	20544	120.6	3011
7	602.9	0.05	113.7	20689	121.0	2847
9	602.3	0.07	113.7	20146	120.7	2848
11	601.7	0.08	113.6	19911	120.9	2719
13	601.1	0.10	113.6	20364	121.2	2663
15	600.5	0.12	113.5	20656	121.0	2780

RUN NUMBER: 184 WORKING FLUID: R-113
 p/d = 1.17 G = 350.91 kg/s*m²
 Pin = 571.8 kPa DELTA P total = 4.56 kPa
 Xin = 0.02 Xout = 0.34
 SURFACE TYPE: SMOOTH

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	571.5	0.02	110.2	50152	122.5	4075
3	570.9	0.07	111.2	50118	122.7	4341
5	570.3	0.11	111.2	51180	122.3	4578
7	569.7	0.15	111.1	50766	123.3	4375
9	569.1	0.19	111.1	49630	122.4	4382
11	568.6	0.23	111.0	49306	122.3	4383
13	568.0	0.27	111.0	50429	122.2	4485
15	567.4	0.32	110.9	51043	122.9	4257

RUN NUMBER: 208 WORKING FLUID: R-113
 p/d = 1.17 G = 229.18 kg/s*m²
 Pin = 596.3 kPa DELTA P total = 5.18 kPa
 Xin = -.01 Xout = 0.69
 SURFACE TYPE: SMOOTH

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	595.9	-.01	110.4	69888	124.5	4964
3	595.2	0.08	113.1	69764	125.0	5856
5	594.5	0.18	113.1	71126	124.3	5820
7	593.8	0.27	113.0	71322	125.9	5854
9	593.2	0.37	113.0	69771	124.8	5891
11	592.5	0.46	112.9	69860	124.7	5906
13	591.9	0.56	112.9	71501	124.8	5990
15	591.2	0.65	112.8	71974	125.7	5872

RUN NUMBER: 189 WORKING FLUID: R-113
 p/d = 1.17 G = 351.35 kg/s*m²
 Pin = 604 kPa DELTA P total = 4.53 kPa
 Xin = 0.00 Xout = 0.20
 SURFACE TYPE: SMOOTH

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	603.7	0.00	112.2	30147	122.0	3068
3	603.1	0.03	113.6	30375	122.2	3546
5	602.5	0.06	113.7	31012	122.2	3656
7	601.9	0.08	113.6	30903	122.9	3528
9	601.3	0.11	113.6	30118	122.5	3388
11	600.7	0.13	113.5	30107	122.0	3552
13	600.1	0.16	113.5	30773	122.4	3472
15	599.5	0.18	113.5	31213	122.6	3411

RUN NUMBER: 187 WORKING FLUID: R-113
 p/d = 1.17 G = 350.01 kg/s*m²
 Pin = 596.5 kPa DELTA P total = 4.51 kPa
 Xin = 0.01 Xout = 0.39
 SURFACE TYPE: SMOOTH

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	596.2	0.01	112.0	60120	124.8	4696
3	595.6	0.06	113.1	59932	125.2	4965
5	595.0	0.12	113.1	61131	124.7	5255
7	594.4	0.17	113.0	60716	125.7	5208
9	593.8	0.22	113.0	59369	124.6	5113
11	593.2	0.27	113.0	59260	124.7	5068
13	592.6	0.32	112.9	60574	124.6	5181
15	592.0	0.37	112.9	61283	125.2	4984

RUN NUMBER: 191 WORKING FLUID: R-113
 p/d = 1.17 G = 350.86 kg/s*m²
 Pin = 594.1 kPa DELTA P total = 4.51 kPa
 Xin = 0.01 Xout = 0.07
 SURFACE TYPE: SMOOTH

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	593.8	0.01	111.9	10262	117.6	1788
3	593.2	0.02	112.6	10288	118.1	1896
5	592.6	0.03	112.9	10629	118.3	1962
7	592.0	0.04	112.9	10686	118.5	1891
9	591.4	0.04	112.8	10352	118.4	1867
11	590.8	0.05	112.8	10288	118.4	1823
13	590.2	0.06	112.7	10455	119.0	1811
15	589.6	0.07	112.7	10603	118.6	1806

RUN NUMBER: 188 WORKING FLUID: R-113
 p/d = 1.17 G = 350.12 kg/s*m²
 Pin = 602.8 kPa DELTA P total = 4.51 kPa
 Xin = 0.01 Xout = 0.26
 SURFACE TYPE: SMOOTH

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	602.5	0.01	112.2	39614	123.2	3585
3	601.9	0.04	113.6	39871	123.6	3990
5	601.3	0.08	113.6	40736	123.3	4187
7	600.7	0.11	113.5	40715	124.1	4060
9	600.1	0.14	113.5	39732	123.4	4009
11	599.5	0.18	113.5	39322	123.3	3983
13	598.9	0.21	113.4	40171	123.3	4043
15	598.3	0.25	113.4	40857	123.7	3942

RUN NUMBER: 186 WORKING FLUID: R-113
 p/d = 1.17 G = 349.43 kg/s*m²
 Pin = 591 kPa DELTA P total = 4.52 kPa
 Xin = 0.01 Xout = 0.46
 SURFACE TYPE: SMOOTH

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	590.7	0.01	111.6	70145	125.1	5209
3	590.1	0.08	112.7	69889	125.6	5415
5	589.5	0.14	112.7	71192	125.1	5724
7	588.9	0.20	112.6	70801	126.1	5666
9	588.3	0.25	112.6	69286	124.8	5648
11	587.7	0.31	112.5	69600	125.0	5584
13	587.1	0.37	112.5	71249	125.0	5695
15	586.5	0.43	112.4	71758	125.6	5475

RUN NUMBER: 185
p/d = 1.17
Pin = 595.8 kPa
Xin = 0.01
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 348.98 kg/s*m²
DELTA P total = 4.53 kPa
Xout = 0.52

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	595.5	0.01	111.9	80202	125.5	5906
3	594.9	0.08	113.1	79760	126.0	6171
5	594.3	0.15	113.0	81190	125.5	6527
7	593.7	0.22	113.0	81131	126.4	6538
9	593.2	0.28	113.0	79563	125.1	6548
11	592.6	0.35	112.9	80262	125.3	6457
13	592.0	0.42	112.9	81833	125.3	6563
15	591.4	0.48	112.8	82432	125.9	6293

RUN NUMBER: 179
p/d = 1.17
Pin = 546.2 kPa
Xin = 0.01
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 486.81 kg/s*m²
DELTA P total = 4.51 kPa
Xout = 0.15

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	545.8	0.01	108.4	29948	117.7	3222
3	545.2	0.03	109.1	30034	118.1	3356
5	544.6	0.05	109.1	30646	117.8	3319
7	544.1	0.07	109.0	30495	118.4	3261
9	543.5	0.08	109.0	29713	118.0	3299
11	542.9	0.10	108.9	29772	117.8	3339
13	542.3	0.12	108.9	30353	118.1	3309
15	541.7	0.14	108.8	30677	118.4	3187

RUN NUMBER: 176
p/d = 1.17
Pin = 548.7 kPa
Xin = 0.01
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 503.49 kg/s*m²
DELTA P total = 4.48 kPa
Xout = 0.27

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	548.3	0.01	108.4	60122	121.1	4723
3	547.7	0.04	109.3	59953	121.4	4959
5	547.2	0.08	109.3	61129	121.3	5082
7	546.6	0.12	109.2	61177	122.1	4767
9	546.0	0.15	109.2	59924	120.9	5118
11	545.4	0.19	109.1	59748	121.1	4982
13	544.8	0.22	109.1	61056	119.9	5151
15	544.2	0.26	109.0	61417	121.6	4880

RUN NUMBER: 183
p/d = 1.17
Pin = 534.7 kPa
Xin = 0.01
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 495.03 kg/s*m²
DELTA P total = 4.54 kPa
Xout = 0.06

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	534.4	0.01	107.6	9956	114.1	1539
3	533.8	0.02	108.0	10124	114.6	1553
5	533.2	0.02	108.1	10272	114.5	1602
7	532.6	0.03	108.1	10409	114.7	1562
9	532.1	0.04	108.0	10108	114.7	1520
11	531.5	0.04	108.0	10164	114.7	1515
13	530.9	0.05	107.9	10230	115.4	1513
15	530.3	0.05	107.9	10415	114.8	1513

RUN NUMBER: 181
p/d = 1.17
Pin = 540.4 kPa
Xin = 0.01
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 498.26 kg/s*m²
DELTA P total = 4.56 kPa
Xout = 0.19

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	540.1	0.01	108.0	39849	118.4	3833
3	539.5	0.04	108.6	40081	118.6	4032
5	538.9	0.06	108.6	40908	118.3	4092
7	538.3	0.09	108.5	41054	119.2	3847
9	537.7	0.11	108.5	39947	118.6	3967
11	537.1	0.13	108.4	39601	118.4	3991
13	536.5	0.16	108.4	40430	118.3	4001
15	535.9	0.18	108.3	40955	119.0	3847

RUN NUMBER: 178
p/d = 1.17
Pin = 550.2 kPa
Xin = 0.01
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 491.75 kg/s*m²
DELTA P total = 4.5 kPa
Xout = 0.33

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	549.8	0.01	108.7	71048	122.1	5326
3	549.3	0.06	109.4	70544	122.3	5474
5	548.7	0.10	109.4	71846	122.3	5576
7	548.1	0.14	109.4	71573	123.0	5563
9	547.5	0.18	109.3	70028	121.6	5679
11	546.9	0.22	109.3	70594	122.1	5501
13	546.3	0.27	109.2	72152	121.8	5744
15	545.7	0.31	109.2	72678	122.5	5448

RUN NUMBER: 180
p/d = 1.17
Pin = 538.2 kPa
Xin = 0.00
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 499.58 kg/s*m²
DELTA P total = 4.52 kPa
Xout = 0.09

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	537.8	0.00	107.6	20306	115.3	2631
3	537.2	0.01	108.4	20458	115.8	2740
5	536.6	0.03	108.4	20919	115.7	2773
7	536.1	0.04	108.4	20900	116.1	2701
9	535.5	0.05	108.3	20320	115.9	2675
11	534.9	0.06	108.3	20326	115.8	2705
13	534.3	0.07	108.2	20623	116.2	2582
15	533.7	0.08	108.2	20832	116.2	2575

RUN NUMBER: 182
p/d = 1.17
Pin = 539 kPa
Xin = 0.01
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 497.32 kg/s*m²
DELTA P total = 4.52 kPa
Xout = 0.23

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	538.6	0.01	107.9	49546	119.5	4277
3	538.0	0.04	108.5	49668	119.7	4452
5	537.4	0.08	108.5	50694	119.4	4633
7	536.9	0.10	108.4	50561	120.3	4458
9	536.3	0.13	108.4	49403	119.4	4465
11	535.7	0.16	108.3	49514	119.4	4472
13	535.1	0.19	108.3	50493	119.2	4632
15	534.5	0.22	108.2	51051	119.9	4358

RUN NUMBER: 174
p/d = 1.17
Pin = 549.1 kPa
Xin = -.00
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 505.33 kg/s*m²
DELTA P total = 4.51 kPa
Xout = 0.36

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	548.8	-.00	107.7	81972	121.3	6039
3	548.2	0.05	108.8	81574	121.7	6302
5	547.6	0.10	108.8	82981	121.5	6514
7	547.0	0.14	108.7	83055	122.3	6110
9	546.4	0.19	108.7	81445	120.9	6652
11	545.8	0.24	108.7	81430	121.3	6456
13	545.2	0.29	108.6	83139	119.9	6394
15	544.7	0.33	108.6	83439	122.5	6517

Bundle Boiling Data

Smooth tube data in R-113 for bundle with $p/d = 1.50$

RUN NUMBER: 389

p/d = 1.5

Pin = 206.3 kPa

Xin = -.00

SURFACE TYPE: SMOOTH

WORKING FLUID: R-113

G = 50.31 kg/s*m^2

DELTA P total = 5.64 kPa

Xout = 0.06

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	205.9	-.00	69.1	5158	74.2	1005
3	205.2	0.00	69.8	5033	73.7	1303
5	204.4	0.01	70.1	5141	74.0	1311
7	203.7	0.02	70.0	5093	73.5	1457
9	202.9	0.03	69.8	4912	73.2	1469
11	202.1	0.04	69.7	4904	73.1	1457
13	201.4	0.05	69.6	5059	72.9	1529
15	200.6	0.06	69.5	5064	72.9	1482

RUN NUMBER: 383

p/d = 1.5

Pin = 204.6 kPa

Xin = 0.01

SURFACE TYPE: SMOOTH

WORKING FLUID: R-113

G = 50.06 kg/s*m^2

DELTA P total = 5.65 kPa

Xout = 0.39

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	204.3	0.01	69.2	30889	82.7	2298
3	203.5	0.06	76.1	30153	81.4	5735
5	202.8	0.11	74.9	30722	81.2	4831
7	202.0	0.16	73.6	30790	81.0	4128
9	201.3	0.21	72.6	29777	81.2	3470
11	200.5	0.27	71.6	29831	80.6	3313
13	199.8	0.32	70.6	30571	81.8	2747
15	199.0	0.37	69.7	30601	81.8	2526

RUN NUMBER: 386

p/d = 1.5

Pin = 212.4 kPa

Xin = -.01

SURFACE TYPE: SMOOTH

WORKING FLUID: R-113

G = 50.85 kg/s*m^2

DELTA P total = 5.72 kPa

Xout = 0.76

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	212.1	-.01	70.0	61419	86.6	3699
3	211.3	0.09	71.1	59674	85.4	4182
5	210.6	0.19	71.0	60895	84.9	4382
7	209.8	0.29	70.9	61141	85.1	4319
9	209.0	0.40	70.8	59398	84.9	4218
11	208.3	0.51	70.7	59839	84.4	4377
13	207.5	0.61	70.6	61123	85.9	4008
15	206.8	0.71	70.5	61185	85.9	3987

RUN NUMBER: 388

p/d = 1.5

Pin = 205.9 kPa

Xin = -.00

SURFACE TYPE: SMOOTH

WORKING FLUID: R-113

G = 50.68 kg/s*m^2

DELTA P total = 5.67 kPa

Xout = 0.13

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	205.5	-.00	69.1	10535	76.1	1510
3	204.8	0.01	70.0	10318	75.5	1887
5	204.0	0.03	70.0	10504	75.6	1873
7	203.3	0.05	69.9	10554	75.1	2019
9	202.5	0.07	69.7	10197	75.0	1931
11	201.7	0.09	69.6	10096	74.8	1955
13	201.0	0.10	69.5	10413	75.0	1913
15	200.2	0.12	69.4	10424	75.0	1880

RUN NUMBER: 384

p/d = 1.5

Pin = 208.8 kPa

Xin = -.00

SURFACE TYPE: SMOOTH

WORKING FLUID: R-113

G = 50.85 kg/s*m^2

DELTA P total = 5.65 kPa

Xout = 0.51

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	208.5	-.00	69.5	41386	83.7	2896
3	207.7	0.06	70.6	40129	82.4	3408
5	206.9	0.13	70.5	40945	82.1	3550
7	206.2	0.20	70.4	41054	82.0	3538
9	205.4	0.27	70.3	39799	82.1	3390
11	204.7	0.34	70.2	39811	81.7	3480
13	203.9	0.41	70.1	40798	82.8	3227
15	203.1	0.48	70.0	40839	82.8	3194

RUN NUMBER: 365

p/d = 1.5

Pin = 204.7 kPa

Xin = -.00

SURFACE TYPE: SMOOTH

WORKING FLUID: R-113

G = 100.31 kg/s*m^2

DELTA P total = 5.66 kPa

Xout = 0.06

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	204.3	-.00	69.0	10322	76.6	1372
3	203.6	0.01	69.5	10083	75.8	1600
5	202.8	0.02	69.6	10328	76.1	1595
7	202.1	0.02	69.5	10327	75.7	1673
9	201.3	0.03	69.4	9940	75.5	1622
11	200.5	0.04	69.4	9970	75.3	1675
13	199.8	0.05	69.3	10079	75.5	1627
15	199.0	0.06	69.2	10089	75.5	1609

RUN NUMBER: 382

p/d = 1.5

Pin = 203.6 kPa

Xin = 0.00

SURFACE TYPE: SMOOTH

WORKING FLUID: R-113

G = 50.29 kg/s*m^2

DELTA P total = 5.65 kPa

Xout = 0.26

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	203.3	0.00	68.9	20847	80.2	1843
3	202.5	0.04	69.5	20251	79.0	2114
5	201.8	0.07	69.4	20737	78.8	2192
7	201.0	0.10	69.3	20617	78.5	2232
9	200.3	0.14	69.2	19922	78.7	2109
11	199.5	0.18	69.2	19903	78.0	2262
13	198.7	0.21	69.1	20452	78.8	2113
15	198.0	0.24	69.0	20472	78.8	2100

RUN NUMBER: 385

p/d = 1.5

Pin = 210.1 kPa

Xin = -.00

SURFACE TYPE: SMOOTH

WORKING FLUID: R-113

G = 50.53 kg/s*m^2

DELTA P total = 5.7 kPa

Xout = 0.64

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	209.7	-.00	69.8	51238	85.2	3331
3	209.0	0.08	70.6	49735	83.8	3772
5	208.2	0.16	70.5	50702	83.4	3947
7	207.5	0.25	70.5	50921	83.5	3919
9	206.7	0.34	70.4	49413	83.4	3803
11	205.9	0.43	70.3	49492	83.0	3912
13	205.2	0.51	70.2	50614	84.3	3600
15	204.4	0.60	70.1	50665	84.3	3583

RUN NUMBER: 366

p/d = 1.5

Pin = 206.7 kPa

Xin = -.01

SURFACE TYPE: SMOOTH

WORKING FLUID: R-113

G = 99.9 kg/s*m^2

DELTA P total = 5.7 kPa

Xout = 0.12

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	206.4	-.01	69.2	20624	79.6	1994
3	205.6	0.01	70.2	19999	78.5	2394
5	204.9	0.03	70.1	20453	78.4	2471
7	204.1	0.05	70.0	20456	78.2	2506
9	203.3	0.06	69.9	19753	78.4	2323
11	202.6	0.08	69.8	20047	77.9	2471
13	201.8	0.10	69.7	20314	78.6	2280
15	201.1	0.12	69.6	20334	78.6	2256

RUN NUMBER: 356 WORKING FLUID: R-113
 p/d = 1.5 G = 100.41 kg/s*m^2
 Pin = 206.8 kPa DELTA P total = 5.7 kPa
 Xin = -.01 Xout = 0.18
 SURFACE TYPE: SMOOTH

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	206.5	-.01	68.2	30704	83.1	2055
3	205.7	0.01	70.1	29820	81.2	2683
5	205.0	0.04	70.3	30462	80.7	2712
7	204.2	0.06	70.2	30795	81.2	2780
9	203.5	0.09	70.0	29773	81.5	2595
11	202.7	0.12	69.9	29895	80.9	2714
13	201.9	0.14	69.7	30555	81.9	2515
15	201.2	0.17	69.6	30585	81.9	2492

RUN NUMBER: 359 WORKING FLUID: R-113
 p/d = 1.5 G = 99.92 kg/s*m^2
 Pin = 210.7 kPa DELTA P total = 5.7 kPa
 Xin = -.01 Xout = 0.38
 SURFACE TYPE: SMOOTH

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	210.4	-.01	69.1	61276	86.7	3471
3	209.6	0.04	70.9	59612	85.2	4171
5	208.9	0.09	70.8	60951	84.9	4321
7	208.1	0.14	70.7	60815	85.2	4192
9	207.3	0.20	70.6	59055	85.2	4048
11	206.6	0.25	70.5	59492	84.4	4275
13	205.8	0.30	70.4	60565	85.9	3901
15	205.1	0.35	70.3	60626	85.9	3878

RUN NUMBER: 374 WORKING FLUID: R-113
 p/d = 1.5 G = 218.54 kg/s*m^2
 Pin = 203.7 kPa DELTA P total = 5.73 kPa
 Xin = 0.00 Xout = 0.03
 SURFACE TYPE: SMOOTH

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	203.3	0.00	68.9	10536	76.3	1436
3	202.6	0.01	69.1	10402	75.7	1589
5	201.8	0.01	69.2	10549	75.8	1601
7	201.1	0.01	69.2	10588	75.4	1700
9	200.3	0.02	69.2	10220	75.3	1663
11	199.5	0.02	69.1	10271	75.1	1721
13	198.8	0.03	69.1	10402	75.1	1706
15	198.0	0.03	69.0	10412	75.1	1694

RUN NUMBER: 357 WORKING FLUID: R-113
 p/d = 1.5 G = 100.36 kg/s*m^2
 Pin = 208.1 kPa DELTA P total = 5.72 kPa
 Xin = -.01 Xout = 0.25
 SURFACE TYPE: SMOOTH

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	207.8	-.01	68.4	41228	84.6	2555
3	207.0	0.02	70.6	40079	82.8	3285
5	206.2	0.05	70.5	40971	82.7	3360
7	205.5	0.09	70.4	41131	82.8	3308
9	204.7	0.13	70.3	39834	83.1	3106
11	204.0	0.16	70.1	39934	82.3	3282
13	203.2	0.20	70.0	40748	83.4	3033
15	202.5	0.23	69.8	40789	83.4	3000

RUN NUMBER: 360 WORKING FLUID: R-113
 p/d = 1.5 G = 100.34 kg/s*m^2
 Pin = 210.6 kPa DELTA P total = 5.7 kPa
 Xin = -.01 Xout = 0.44
 SURFACE TYPE: SMOOTH

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	210.3	-.01	69.2	72253	87.5	3957
3	209.5	0.05	70.9	70048	86.1	4614
5	208.7	0.11	70.8	71640	85.6	4829
7	208.0	0.17	70.7	71264	86.0	4643
9	207.2	0.23	70.6	69208	85.7	4557
11	206.5	0.30	70.5	70052	85.1	4794
13	205.7	0.36	70.3	71075	86.6	4372
15	205.0	0.42	70.2	71146	86.6	4347

RUN NUMBER: 367 WORKING FLUID: R-113
 p/d = 1.5 G = 218.67 kg/s*m^2
 Pin = 206 kPa DELTA P total = 5.68 kPa
 Xin = -.00 Xout = 0.05
 SURFACE TYPE: SMOOTH

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	205.7	-.00	69.2	20484	80.2	1859
3	204.9	0.00	69.8	19888	79.0	2152
5	204.2	0.01	70.0	20318	79.4	2155
7	203.4	0.02	69.9	20502	79.6	2105
9	202.7	0.03	69.8	19797	79.7	1995
11	201.9	0.04	69.6	20100	79.3	2086
13	201.2	0.04	69.5	20356	80.2	1911
15	200.4	0.05	69.4	20376	80.2	1895

RUN NUMBER: 358 WORKING FLUID: R-113
 p/d = 1.5 G = 100.1 kg/s*m^2
 Pin = 209.1 kPa DELTA P total = 5.66 kPa
 Xin = -.01 Xout = 0.31
 SURFACE TYPE: SMOOTH

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	208.7	-.01	68.9	51258	85.6	3067
3	208.0	0.03	70.6	49999	84.0	3745
5	207.2	0.07	70.5	51047	83.8	3853
7	206.5	0.12	70.4	50740	83.9	3751
9	205.7	0.16	70.3	49221	84.1	3568
11	204.9	0.21	70.2	49433	83.3	3774
13	204.2	0.25	70.1	50390	84.6	3471
15	203.4	0.29	70.0	50440	84.6	3449

RUN NUMBER: 361 WORKING FLUID: R-113
 p/d = 1.5 G = 99.97 kg/s*m^2
 Pin = 213.6 kPa DELTA P total = 5.7 kPa
 Xin = -.01 Xout = 0.51
 SURFACE TYPE: SMOOTH

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	213.3	-.01	69.4	81999	88.8	4219
3	212.5	0.06	71.4	79340	87.3	5009
5	211.8	0.12	71.3	81255	86.7	5269
7	211.0	0.19	71.2	81065	87.3	5050
9	210.3	0.27	71.1	78846	86.8	5010
11	209.5	0.34	71.0	79810	86.2	5253
13	208.8	0.41	70.9	80976	87.8	4778
15	208.0	0.47	70.8	81057	87.8	4751

RUN NUMBER: 368 WORKING FLUID: R-113
 p/d = 1.5 G = 218.21 kg/s*m^2
 Pin = 210.5 kPa DELTA P total = 5.69 kPa
 Xin = -.01 Xout = 0.08
 SURFACE TYPE: SMOOTH

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	210.1	-.01	69.5	30811	82.5	2359
3	209.4	0.00	70.5	29842	81.1	2792
5	208.6	0.01	70.7	30439	81.1	2943
7	207.9	0.03	70.6	30671	81.0	2938
9	207.1	0.04	70.5	29691	81.2	2791
11	206.3	0.05	70.4	29801	80.7	2895
13	205.6	0.06	70.3	30387	81.8	2650
15	204.8	0.07	70.2	30417	81.8	2630

RUN NUMBER: 369
p/d = 1.5
Pin = 214.6 kPa
Xin = -.01
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 217.44 kg/s*m²
DELTA P total = 5.69 kPa
Xout = 0.11

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	214.3	-.01	70.2	41518	84.8	2831
3	213.5	0.01	71.3	40224	83.3	3357
5	212.8	0.02	71.4	41070	83.1	3523
7	212.0	0.04	71.3	41103	83.2	3477
9	211.2	0.06	71.2	39796	83.2	3321
11	210.5	0.07	71.1	39887	82.6	3465
13	209.7	0.09	71.0	40690	83.9	3162
15	209.0	0.11	70.9	40731	83.9	3139

RUN NUMBER: 372
p/d = 1.5
Pin = 211.9 kPa
Xin = -.01
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 217.65 kg/s*m²
DELTA P total = 5.72 kPa
Xout = 0.20

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	211.5	-.01	69.8	71861	87.7	4012
3	210.8	0.02	71.1	69771	86.3	4582
5	210.0	0.05	71.0	71398	86.0	4750
7	209.3	0.08	70.9	71252	86.3	4607
9	208.5	0.11	70.8	69289	85.9	4562
11	207.8	0.14	70.7	69647	85.3	4765
13	207.0	0.16	70.6	70717	86.8	4349
15	206.2	0.19	70.5	70788	86.8	4326

RUN NUMBER: 376
p/d = 1.5
Pin = 206.2 kPa
Xin = -.00
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 303.89 kg/s*m²
DELTA P total = 5.65 kPa
Xout = 0.04

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	205.8	-.00	69.0	20778	79.8	1926
3	205.1	0.00	69.6	20193	79.1	2127
5	204.3	0.01	70.0	20539	79.6	2141
7	203.6	0.01	70.0	20482	79.6	2135
9	202.8	0.02	69.8	19754	79.6	2013
11	202.0	0.03	69.7	20016	79.1	2119
13	201.3	0.03	69.6	20309	79.9	1960
15	200.5	0.04	69.5	20330	79.9	1941

RUN NUMBER: 370
p/d = 1.5
Pin = 210.1 kPa
Xin = -.01
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 218.73 kg/s*m²
DELTA P total = 5.67 kPa
Xout = 0.14

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	209.8	-.01	69.1	51482	85.2	3194
3	209.0	0.01	70.5	50104	83.8	3767
5	208.3	0.03	70.7	51191	83.6	3970
7	207.5	0.05	70.6	50812	83.7	3884
9	206.8	0.07	70.5	49318	83.6	3762
11	206.0	0.09	70.4	49632	83.0	3944
13	205.3	0.11	70.3	50619	84.4	3590
15	204.5	0.13	70.2	50670	84.4	3566

RUN NUMBER: 373
p/d = 1.5
Pin = 218.2 kPa
Xin = -.01
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 217.49 kg/s*m²
DELTA P total = 5.64 kPa
Xout = 0.23

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	217.9	-.01	70.6	82471	89.6	4332
3	217.1	0.02	72.2	79735	88.3	4962
5	216.4	0.05	72.1	81634	87.8	5187
7	215.6	0.09	72.0	81521	88.3	5003
9	214.9	0.12	71.9	79154	87.8	4967
11	214.1	0.15	71.8	79374	87.1	5171
13	213.4	0.18	71.6	80617	88.7	4739
15	212.6	0.22	71.5	80697	88.7	4713

RUN NUMBER: 377
p/d = 1.5
Pin = 206.5 kPa
Xin = -.00
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 303.7 kg/s*m²
DELTA P total = 5.72 kPa
Xout = 0.06

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	206.2	-.00	69.0	30937	82.2	2344
3	205.4	0.01	69.9	30009	81.0	2684
5	204.6	0.02	70.1	30585	81.5	2704
7	203.9	0.02	70.0	30496	81.7	2612
9	203.1	0.03	69.9	29505	82.0	2446
11	202.4	0.04	69.8	29509	81.4	2530
13	201.6	0.05	69.6	30185	82.5	2356
15	200.9	0.06	69.5	30215	82.5	2338

RUN NUMBER: 371
p/d = 1.5
Pin = 209.2 kPa
Xin = -.01
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 218.29 kg/s*m²
DELTA P total = 5.72 kPa
Xout = 0.17

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	208.9	-.01	69.3	61159	86.1	3642
3	208.2	0.01	70.6	59337	84.6	4214
5	207.4	0.04	70.5	60669	84.4	4371
7	206.7	0.06	70.4	60557	84.6	4272
9	205.9	0.09	70.3	58802	84.3	4190
11	205.1	0.11	70.2	59160	83.7	4379
13	204.4	0.13	70.1	60194	85.2	3991
15	203.6	0.16	70.0	60254	85.2	3968

RUN NUMBER: 375
p/d = 1.5
Pin = 205.7 kPa
Xin = -.00
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 304.67 kg/s*m²
DELTA P total = 5.7 kPa
Xout = 0.02

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	205.4	-.00	69.2	10435	76.5	1414
3	204.6	0.00	69.4	10311	76.3	1497
5	203.9	0.00	69.7	10452	76.7	1488
7	203.1	0.01	69.8	10471	76.4	1574
9	202.4	0.01	69.7	10100	76.3	1518
11	201.6	0.01	69.6	10174	76.1	1564
13	200.9	0.02	69.5	10297	76.2	1535
15	200.1	0.02	69.4	10307	76.2	1516

RUN NUMBER: 378
p/d = 1.5
Pin = 211.1 kPa
Xin = -.00
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 305.06 kg/s*m²
DELTA P total = 5.69 kPa
Xout = 0.08

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	210.7	-.00	69.8	41048	84.3	2822
3	210.0	0.01	70.6	39760	83.0	3217
5	209.2	0.02	70.8	40616	83.1	3303
7	208.5	0.03	70.7	40829	83.5	3193
9	207.7	0.05	70.6	39548	83.7	3028
11	206.9	0.06	70.5	39724	83.1	3161
13	206.2	0.07	70.4	40584	84.5	2886
15	205.4	0.08	70.3	40625	84.5	2870

RUN NUMBER: 379
p/d = 1.5
Pin = 217.6 kPa
Xin = -.00
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 304.69 kg/s*m^2
DELTA P total = 5.66 kPa
Xout = 0.11

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	217.3	-.00	70.8	51381	86.8	3198
3	216.5	0.01	71.8	49829	85.5	3651
5	215.8	0.03	72.0	50881	85.4	3796
7	215.0	0.04	71.9	51034	85.7	3691
9	214.3	0.06	71.7	49492	85.7	3546
11	213.5	0.07	71.6	49750	85.1	3705
13	212.8	0.09	71.5	50735	86.7	3346
15	212.0	0.10	71.4	50785	86.7	3326

RUN NUMBER: 399
p/d = 1.5
Pin = 520.7 kPa
Xin = -.05
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 50.09 kg/s*m^2
DELTA P total = 4.61 kPa
Xout = 0.11

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	520.4	-.05	102.1	10371	112.7	1039
3	519.7	-.03	104.5	10227	112.5	1383
5	519.0	-.01	106.3	10290	112.9	1634
7	518.4	0.02	106.9	10388	113.8	1488
9	517.8	0.04	106.8	10056	113.5	1504
11	517.2	0.06	106.8	10623	113.6	1547
13	516.6	0.08	106.7	10384	113.4	1548
15	516.1	0.10	106.7	10347	113.4	1542

RUN NUMBER: 401
p/d = 1.5
Pin = 545.1 kPa
Xin = -.08
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 50.71 kg/s*m^2
DELTA P total = 3.51 kPa
Xout = 0.54

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	544.9	-.08	103.1	40514	121.9	2481
3	544.2	0.00	108.4	39891	120.6	3346
5	543.7	0.08	109.0	40884	120.9	3426
7	543.1	0.16	109.0	41488	122.6	3041
9	542.7	0.24	108.9	40758	122.1	3100
11	542.3	0.33	108.9	42242	122.1	3198
13	542.0	0.41	108.9	41070	121.6	3235
15	541.7	0.50	108.8	41106	121.8	3174

RUN NUMBER: 380
p/d = 1.5
Pin = 216.2 kPa
Xin = -.01
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 294.39 kg/s*m^2
DELTA P total = 5.72 kPa
Xout = 0.12

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	215.9	-.01	69.9	61494	87.6	3480
3	215.1	0.01	71.4	59647	86.2	4029
5	214.4	0.03	71.8	60897	86.0	4272
7	213.6	0.04	71.6	60663	86.2	4155
9	212.8	0.06	71.5	58912	86.1	4055
11	212.1	0.08	71.4	59620	85.5	4231
13	211.3	0.10	71.3	60514	87.0	3843
15	210.6	0.11	71.2	60575	87.0	3820

RUN NUMBER: 398
p/d = 1.5
Pin = 540.4 kPa
Xin = -.07
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 50.19 kg/s*m^2
DELTA P total = 4.4 kPa
Xout = 0.23

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	540.1	-.07	101.7	19167	116.6	1399
3	539.4	-.03	106.2	18968	116.8	2001
5	538.8	0.01	108.5	19181	117.0	2266
7	538.1	0.04	108.5	19463	118.0	2046
9	537.6	0.08	108.5	19056	118.0	1996
11	537.0	0.12	108.4	19895	118.0	2097
13	536.6	0.16	108.4	19406	117.6	2109
15	536.0	0.21	108.4	19355	117.3	2154

RUN NUMBER: 402
p/d = 1.5
Pin = 557.4 kPa
Xin = -.08
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 50.59 kg/s*m^2
DELTA P total = 3.26 kPa
Xout = 0.69

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	557.1	-.08	103.7	50552	124.5	2856
3	556.4	0.01	109.8	49974	123.1	3802
5	555.9	0.11	110.0	50910	123.0	3923
7	555.4	0.21	110.0	51179	124.8	3462
9	555.1	0.32	109.9	50149	123.8	3612
11	554.8	0.42	109.9	52353	124.2	3658
13	554.5	0.53	109.9	50740	124.0	3599
15	554.2	0.63	109.9	50955	124.2	3543

RUN NUMBER: 381
p/d = 1.5
Pin = 219.9 kPa
Xin = -.01
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 280.57 kg/s*m^2
DELTA P total = 5.69 kPa
Xout = 0.15

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	219.6	-.01	70.7	71704	88.9	3960
3	218.8	0.01	72.3	69463	87.5	4566
5	218.1	0.03	72.4	71078	87.2	4793
7	217.3	0.06	72.3	71280	87.6	4643
9	216.6	0.08	72.1	69323	87.3	4578
11	215.8	0.10	72.0	69699	86.7	4767
13	215.0	0.12	71.9	70871	88.3	4340
15	214.3	0.14	71.8	70942	88.3	4314

RUN NUMBER: 400
p/d = 1.5
Pin = 520.8 kPa
Xin = -.06
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 50.8 kg/s*m^2
DELTA P total = 3.77 kPa
Xout = 0.41

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	520.6	-.06	102.2	30875	118.0	2216
3	519.9	0.00	106.4	30398	117.1	2907
5	519.3	0.06	107.0	31074	117.4	2973
7	518.8	0.12	106.9	31581	118.9	2628
9	518.3	0.19	106.9	30849	118.6	2617
11	517.9	0.25	106.8	32009	118.8	2688
13	517.5	0.31	106.8	31188	117.7	2848
15	517.1	0.38	106.8	31108	117.8	2816

RUN NUMBER: 403
p/d = 1.5
Pin = 564.8 kPa
Xin = -.08
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 50.53 kg/s*m^2
DELTA P total = 2.67 kPa
Xout = 0.86

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	564.5	-.08	104.3	61914	126.8	3247
3	564.0	0.04	110.7	61181	125.1	4252
5	563.5	0.16	110.6	62115	124.9	4361
7	563.1	0.28	110.6	62453	126.8	3869
9	562.9	0.41	110.6	61455	125.6	4096
11	562.7	0.54	110.5	63749	127.1	3861
13	562.5	0.67	110.5	61767	127.1	3742
15	562.2	0.80	110.5	62081	127.0	3755

RUN NUMBER: 390
p/d = 1.5
Pin = 582 kPa
Xin = 0.01
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 99.46 kg/s*m²
DELTA P total = 2.53 kPa
Xout = 0.10

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	581.8	0.01	111.0	11031	116.8	1919
3	581.4	0.02	111.8	11226	117.0	2157
5	581.0	0.03	112.0	11252	117.4	2084
7	580.6	0.04	112.0	11313	117.4	2063
9	580.3	0.06	111.9	10925	117.5	1953
11	580.0	0.07	111.9	11572	118.0	1907
13	579.8	0.08	111.9	11280	117.5	2001
15	579.5	0.09	111.9	11249	117.4	2046

RUN NUMBER: 396
p/d = 1.5
Pin = 600.4 kPa
Xin = -0.00
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 102.43 kg/s*m²
DELTA P total = 1.37 kPa
Xout = 0.33

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	600.2	-0.00	113.2	40040	126.3	3039
3	599.7	0.04	113.5	40914	124.9	3566
5	599.4	0.08	113.4	41822	125.3	3527
7	599.1	0.12	113.4	42659	125.5	3543
9	599.0	0.17	113.4	41399	125.6	3410
11	599.0	0.21	113.4	43079	125.6	3538
13	599.1	0.26	113.4	41795	125.5	3459
15	599.1	0.30	113.4	41947	126.2	3275

RUN NUMBER: 393
p/d = 1.5
Pin = 605.8 kPa
Xin = -0.01
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 101.49 kg/s*m²
DELTA P total = .14 kPa
Xout = 0.55

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	605.6	-0.01	113.4	70901	128.9	4577
3	605.2	0.06	113.9	69858	127.8	5017
5	605.1	0.13	113.9	71242	128.0	5055
7	605.0	0.21	113.9	70839	127.4	5260
9	605.2	0.28	113.9	69877	127.7	5048
11	605.4	0.36	113.9	72270	128.2	5054
13	605.6	0.43	113.9	70389	127.9	5023
15	605.8	0.51	113.9	70419	128.9	4691

RUN NUMBER: 391
p/d = 1.5
Pin = 612.6 kPa
Xin = -0.01
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 98.8 kg/s*m²
DELTA P total = 2.68 kPa
Xout = 0.16

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	612.4	-0.01	112.8	20908	122.1	2251
3	611.8	0.01	114.2	21224	121.9	2749
5	611.4	0.03	114.4	21449	122.3	2696
7	610.9	0.05	114.3	21519	122.7	2570
9	610.6	0.08	114.3	21032	122.8	2490
11	610.4	0.10	114.3	22022	122.5	2697
13	610.2	0.12	114.3	21440	122.3	2675
15	609.9	0.15	114.3	21419	123.1	2432

RUN NUMBER: 395
p/d = 1.5
Pin = 592.6 kPa
Xin = 0.00
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 101.26 kg/s*m²
DELTA P total = .82 kPa
Xout = 0.41

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	592.4	0.00	112.7	51149	127.0	3567
3	591.9	0.05	112.9	50955	125.5	4045
5	591.7	0.11	112.9	51805	125.8	4010
7	591.5	0.16	112.8	52110	125.8	4015
9	591.5	0.21	112.8	51158	126.0	3896
11	591.6	0.27	112.8	53734	125.9	4112
13	591.8	0.33	112.8	52029	125.9	3997
15	591.8	0.38	112.9	52348	127.3	3628

RUN NUMBER: 392
p/d = 1.5
Pin = 591.6 kPa
Xin = -0.00
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 100.17 kg/s*m²
DELTA P total = .6 kPa
Xout = 0.64

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	591.5	-0.00	112.3	80875	128.5	4996
3	591.2	0.08	112.8	79713	127.2	5554
5	591.1	0.16	112.8	81216	127.2	5654
7	591.1	0.25	112.8	80734	127.1	5634
9	591.4	0.33	112.8	79960	127.3	5510
11	591.7	0.42	112.8	82638	127.5	5640
13	592.0	0.51	112.9	80640	127.6	5486
15	592.2	0.60	112.9	80494	129.0	5008

RUN NUMBER: 363
p/d = 1.5
Pin = 580 kPa
Xin = -0.01
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 101.6 kg/s*m²
DELTA P total = 1.81 kPa
Xout = 0.23

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	579.8	-0.01	110.3	29425	122.9	2321
3	579.3	0.02	111.9	29778	122.2	2894
5	578.9	0.05	111.8	30463	121.9	3035
7	578.6	0.08	111.8	30878	122.0	3026
9	578.4	0.11	111.8	30056	121.9	2971
11	578.3	0.15	111.8	31494	121.8	3161
13	578.4	0.18	111.8	30623	121.9	3037
15	578.2	0.21	111.8	30634	121.6	3117

RUN NUMBER: 394
p/d = 1.5
Pin = 591.2 kPa
Xin = -0.00
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 101.05 kg/s*m²
DELTA P total = .34 kPa
Xout = 0.49

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	591.0	-0.00	112.5	61527	127.8	4044
3	590.6	0.06	112.8	60895	126.1	4572
5	590.4	0.12	112.8	61882	126.2	4599
7	590.3	0.19	112.8	62224	126.6	4506
9	590.4	0.25	112.8	61228	126.5	4442
11	590.6	0.32	112.8	63225	126.3	4657
13	590.8	0.39	112.8	61295	126.4	4514
15	590.9	0.46	112.8	61590	127.8	4104

RUN NUMBER: 419
p/d = 1.5
Pin = 565.4 kPa
Xin = 0.02
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 148.74 kg/s*m²
DELTA P total = 3.91 kPa
Xout = 0.07

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	565.1	0.02	110.0	10277	115.2	2072
3	564.6	0.03	110.5	10196	115.5	2077
5	564.1	0.04	110.6	10130	115.3	2179
7	563.5	0.04	110.6	10226	115.6	2045
9	563.0	0.05	110.5	10047	115.5	2012
11	562.5	0.06	110.5	10395	115.0	2310
13	562.0	0.06	110.5	10214	115.5	2017
15	561.4	0.07	110.4	10075	115.1	2133

RUN NUMBER: 412 WORKING FLUID: R-113
 p/d = 1.5 G = 151.01 kg/s*m²
 Pin = 575.4 kPa DELTA P total = 3.97 kPa
 Xin = 0.01 Xout = 0.11
 SURFACE TYPE: SMOOTH

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	575.2	0.01	110.4	20848	119.1	2503
3	574.6	0.02	111.3	20488	119.4	2568
5	574.0	0.03	111.4	20625	118.8	2818
7	573.5	0.05	111.4	20813	119.2	2666
9	572.9	0.06	111.4	20538	119.2	2617
11	572.4	0.08	111.3	21496	118.4	3049
13	572.0	0.09	111.3	21091	119.4	2600
15	571.5	0.11	111.2	20817	119.0	2687

RUN NUMBER: 415 WORKING FLUID: R-113
 p/d = 1.5 G = 151.68 kg/s*m²
 Pin = 580.9 kPa DELTA P total = 3.43 kPa
 Xin = 0.01 Xout = 0.27
 SURFACE TYPE: SMOOTH

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	580.7	0.01	110.7	50130	125.1	3655
3	580.1	0.04	111.9	50003	125.3	3754
5	579.6	0.07	111.9	50562	124.5	4014
7	579.1	0.11	111.9	50832	124.3	4085
9	578.7	0.14	111.8	49665	124.8	3832
11	578.3	0.18	111.8	52014	123.6	4396
13	578.0	0.21	111.8	50658	124.6	3954
15	577.5	0.25	111.7	50583	124.4	4007

RUN NUMBER: 418 WORKING FLUID: R-113
 p/d = 1.5 G = 150 kg/s*m²
 Pin = 608.6 kPa DELTA P total = 3.14 kPa
 Xin = -0.00 Xout = 0.41
 SURFACE TYPE: SMOOTH

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	608.3	-0.00	112.7	80162	130.1	4822
3	607.8	0.05	114.1	78781	130.4	4849
5	607.3	0.10	114.0	79904	128.9	5386
7	606.8	0.15	114.0	80303	129.1	5353
9	606.5	0.21	114.0	79703	129.3	5213
11	606.1	0.27	114.0	82421	128.4	5694
13	605.8	0.32	113.9	80476	129.6	5165
15	605.5	0.38	113.9	80139	129.4	5180

RUN NUMBER: 413 WORKING FLUID: R-113
 p/d = 1.5 G = 149.96 kg/s*m²
 Pin = 576.2 kPa DELTA P total = 3.65 kPa
 Xin = 0.02 Xout = 0.18
 SURFACE TYPE: SMOOTH

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	576.0	0.02	110.6	30713	121.7	2897
3	575.5	0.04	111.6	30332	121.8	2955
5	574.9	0.06	111.5	30813	121.1	3227
7	574.4	0.08	111.5	31169	121.3	3171
9	573.9	0.10	111.4	30732	121.5	3060
11	573.4	0.12	111.4	31830	120.5	3498
13	573.0	0.14	111.4	31239	121.7	3040
15	572.6	0.16	111.3	30896	121.2	3128

RUN NUMBER: 416 WORKING FLUID: R-113
 p/d = 1.5 G = 152.17 kg/s*m²
 Pin = 590.5 kPa DELTA P total = 3.45 kPa
 Xin = -0.01 Xout = 0.29
 SURFACE TYPE: SMOOTH

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	590.2	-0.01	111.1	59568	126.8	4020
3	589.6	0.03	112.7	59008	126.9	4164
5	589.1	0.07	112.6	59797	125.9	4515
7	588.6	0.11	112.6	60238	126.0	4523
9	588.2	0.15	112.6	58866	126.4	4272
11	587.8	0.19	112.5	61591	125.2	4857
13	587.5	0.23	112.5	59932	126.3	4366
15	587.1	0.27	112.5	59917	126.1	4417

RUN NUMBER: 406 WORKING FLUID: R-113
 p/d = 1.5 G = 197.97 kg/s*m²
 Pin = 553.9 kPa DELTA P total = 4.78 kPa
 Xin = -0.08 Xout = 0.04
 SURFACE TYPE: SMOOTH

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	553.6	-0.08	99.8	30175	121.9	1394
3	553.0	-0.07	101.5	29725	122.8	1431
5	552.3	-0.05	103.3	30340	122.2	1643
7	551.6	-0.04	105.1	30372	122.0	1843
9	551.0	-0.02	106.9	29857	122.1	2037
11	550.4	-0.01	108.7	31090	120.8	2646
13	549.8	0.01	109.4	30479	122.0	2425
15	549.2	0.03	109.4	30283	122.1	2385

RUN NUMBER: 414 WORKING FLUID: R-113
 p/d = 1.5 G = 150.51 kg/s*m²
 Pin = 578.4 kPa DELTA P total = 3.56 kPa
 Xin = 0.00 Xout = 0.21
 SURFACE TYPE: SMOOTH

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	578.2	0.00	110.6	39831	123.7	3198
3	577.7	0.03	111.7	39745	123.8	3293
5	577.1	0.06	111.7	40338	123.1	3533
7	576.6	0.08	111.7	40596	123.0	3587
9	576.2	0.11	111.6	39681	123.3	3387
11	575.7	0.14	111.6	41623	122.3	3883
13	575.4	0.17	111.6	40743	123.4	3448
15	574.9	0.20	111.5	40537	123.0	3538

RUN NUMBER: 417 WORKING FLUID: R-113
 p/d = 1.5 G = 149.65 kg/s*m²
 Pin = 600.9 kPa DELTA P total = 3.32 kPa
 Xin = -0.01 Xout = 0.35
 SURFACE TYPE: SMOOTH

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	600.6	-0.01	112.0	70109	128.6	4439
3	600.1	0.04	113.5	69183	128.7	4560
5	599.6	0.09	113.5	70498	127.6	4977
7	599.1	0.13	113.4	70543	127.7	4963
9	598.7	0.18	113.4	69207	128.0	4749
11	598.4	0.23	113.4	72318	127.0	5316
13	598.0	0.28	113.3	70436	128.2	4780
15	597.6	0.33	113.3	70352	127.9	4822

RUN NUMBER: 407 WORKING FLUID: R-113
 p/d = 1.5 G = 196.61 kg/s*m²
 Pin = 564 kPa DELTA P total = 4.53 kPa
 Xin = -0.08 Xout = 0.08
 SURFACE TYPE: SMOOTH

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	563.7	-0.08	100.8	40024	124.4	1737
3	563.1	-0.06	103.2	39873	125.4	1840
5	562.4	-0.04	105.5	40639	124.2	2246
7	561.8	-0.02	107.9	40655	123.9	2656
9	561.2	0.00	109.8	39635	123.9	2874
11	560.6	0.02	110.4	41542	122.5	3421
13	560.1	0.04	110.3	40550	124.1	2947
15	559.6	0.07	110.3	40415	124.0	2945

RUN NUMBER: 408 WORKING FLUID: R-113
 p/d = 1.5 G = 194.48 kg/s*m^2
 Pin = 565.5 kPa DELTA P total = 4.28 kPa
 Xin = -.07 Xout = 0.13
 SURFACE TYPE: SMOOTH

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	565.3	-.07	102.2	50559	125.9	2205
3	564.6	-.05	105.2	50193	126.2	2486
5	564.0	-.02	108.2	50969	125.0	3179
7	563.4	0.00	110.1	51085	125.0	3501
9	562.8	0.03	110.6	50109	124.6	3562
11	562.3	0.06	110.5	52371	123.4	4058
13	561.9	0.09	110.5	50863	125.3	3436
15	561.4	0.11	110.4	50981	124.9	3540

RUN NUMBER: 411 WORKING FLUID: R-113
 p/d = 1.5 G = 193.79 kg/s*m^2
 Pin = 564.5 kPa DELTA P total = 3.72 kPa
 Xin = -.06 Xout = 0.25
 SURFACE TYPE: SMOOTH

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	564.3	-.06	103.6	80436	128.6	3391
3	563.6	-.02	108.3	79182	128.5	4164
5	563.1	0.02	110.6	80183	126.8	4970
7	562.5	0.06	110.5	80015	126.9	4898
9	562.1	0.10	110.5	79206	127.3	4710
11	561.7	0.15	110.5	81957	125.9	5317
13	561.3	0.19	110.4	79992	127.5	4708
15	560.9	0.23	110.4	79769	127.0	4828

RUN NUMBER: 409 WORKING FLUID: R-113
 p/d = 1.5 G = 195.87 kg/s*m^2
 Pin = 565.6 kPa DELTA P total = 4 kPa
 Xin = -.07 Xout = 0.17
 SURFACE TYPE: SMOOTH

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	565.3	-.07	103.8	60223	126.9	2719
3	564.7	-.04	107.3	59579	126.9	3194
5	564.1	-.01	109.9	60415	125.4	3997
7	563.5	0.03	110.6	60341	125.5	4059
9	563.0	0.06	110.6	59358	125.4	3996
11	562.5	0.09	110.5	61807	124.2	4529
13	562.1	0.12	110.5	60040	126.0	3894
15	561.6	0.15	110.5	60169	125.6	3992

RUN NUMBER: 410 WORKING FLUID: R-113
 p/d = 1.5 G = 196.56 kg/s*m^2
 Pin = 562.2 kPa DELTA P total = 3.85 kPa
 Xin = -.06 Xout = 0.21
 SURFACE TYPE: SMOOTH

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	561.9	-.06	104.0	70452	127.6	3136
3	561.3	-.03	108.1	69443	127.4	3803
5	560.7	0.01	110.3	70363	125.9	4545
7	560.1	0.04	110.3	70396	126.0	4511
9	559.7	0.08	110.3	69398	126.2	4379
11	559.2	0.12	110.3	72134	124.8	4963
13	558.9	0.15	110.2	70167	126.5	4345
15	558.4	0.19	110.2	70227	126.0	4454

Bundle Boiling Data

Turbo-B data in R-113 for bundle with $p/d = 1.50$

RUN NUMBER: 255 WORKING FLUID: R-113
 p/d = 1.5 G = 50.83 kg/s*m^2
 Pin = 207.4 kPa DELTA P total = 6.2 kPa
 Xin = -.00 Xout = 0.06
 SURFACE TYPE: TURBO-B

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	207.0	-.00	69.3	4887	71.6	2099
3	206.1	0.00	69.9	5006	71.6	2965
5	205.3	0.01	70.1	5113	71.5	3657
7	204.5	0.02	70.0	5091	71.5	3584
9	203.6	0.03	69.9	4918	71.3	3574
11	202.8	0.04	69.8	4884	71.3	3321
13	202.0	0.05	69.7	5045	71.2	3217
15	201.2	0.06	69.6	5091	71.1	3393

RUN NUMBER: 249 WORKING FLUID: R-113
 p/d = 1.5 G = 50.61 kg/s*m^2
 Pin = 204.7 kPa DELTA P total = 5.65 kPa
 Xin = -.00 Xout = 0.40
 SURFACE TYPE: TURBO-B

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	204.4	-.00	68.3	29821	74.4	4944
3	203.7	0.05	70.0	29632	74.8	6217
5	202.9	0.10	69.9	30024	74.9	5956
7	202.1	0.15	69.7	30175	74.8	5973
9	201.4	0.21	69.6	29753	75.0	5558
11	200.6	0.26	69.5	29796	74.6	5839
13	199.9	0.32	69.4	30602	74.8	5605
15	199.1	0.37	69.2	30711	73.0	8111

RUN NUMBER: 259 WORKING FLUID: R-113
 p/d = 1.5 G = 51.32 kg/s*m^2
 Pin = 210.4 kPa DELTA P total = 6.24 kPa
 Xin = -.01 Xout = 0.79
 SURFACE TYPE: TURBO-B

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	210.0	-.01	69.2	59304	77.5	7099
3	209.2	0.09	70.8	58556	78.6	7540
5	208.3	0.19	70.7	60087	78.8	7384
7	207.4	0.30	70.6	60033	78.6	7491
9	206.6	0.41	70.4	59349	79.0	6976
11	205.8	0.51	70.3	59333	78.6	7162
13	205.1	0.63	70.2	60735	79.0	6908
15	204.3	0.74	70.1	61069	77.3	8454

RUN NUMBER: 254 WORKING FLUID: R-113
 p/d = 1.5 G = 49.47 kg/s*m^2
 Pin = 208.7 kPa DELTA P total = 7.03 kPa
 Xin = -.01 Xout = 0.13
 SURFACE TYPE: TURBO-B

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	208.2	-.01	69.1	10085	72.3	3108
3	207.1	0.01	70.3	10317	72.6	4496
5	206.1	0.03	70.4	10528	72.3	5418
7	205.2	0.05	70.2	10511	72.2	5336
9	204.3	0.06	70.1	10188	72.1	5021
11	203.4	0.08	70.0	10236	72.2	4675
13	202.6	0.10	69.8	10567	72.2	4440
15	201.7	0.12	69.7	10638	71.6	5469

RUN NUMBER: 250 WORKING FLUID: R-113
 p/d = 1.5 G = 50.49 kg/s*m^2
 Pin = 207.3 kPa DELTA P total = 5.7 kPa
 Xin = -.00 Xout = 0.55
 SURFACE TYPE: TURBO-B

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	207.0	-.00	69.3	40077	75.6	6301
3	207.0	0.07	70.4	39746	76.1	6987
5	205.5	0.14	70.3	40396	76.3	6713
7	204.7	0.21	70.2	40165	76.3	6578
9	204.0	0.28	70.1	39830	76.6	6126
11	203.2	0.36	69.9	40076	76.2	6401
13	202.5	0.43	69.8	41100	76.5	6098
15	201.7	0.51	69.7	41259	74.1	9401

RUN NUMBER: 229 WORKING FLUID: R-113
 p/d = 1.5 G = 108.9 kg/s*m^2
 Pin = 208.7 kPa DELTA P total = 5.66 kPa
 Xin = -.00 Xout = 0.03
 SURFACE TYPE: TURBO-B

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	208.3	-.00	69.8	5006	71.5	2956
3	207.6	0.00	69.9	4904	71.6	2991
5	206.8	0.01	70.0	5010	71.4	3477
7	206.1	0.01	70.0	5060	71.4	3525
9	205.3	0.02	70.0	4922	71.3	3705
11	204.5	0.02	69.9	4866	71.2	3896
13	203.8	0.02	69.9	4940	71.0	4305
15	203.0	0.03	69.9	5000	70.8	5279

RUN NUMBER: 252 WORKING FLUID: R-113
 p/d = 1.5 G = 49.71 kg/s*m^2
 Pin = 204.1 kPa DELTA P total = 6.17 kPa
 Xin = -.00 Xout = 0.29
 SURFACE TYPE: TURBO-B

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	203.7	-.00	68.6	20964	72.9	4969
3	202.8	0.03	69.7	21382	73.4	5880
5	202.0	0.07	69.6	21788	73.6	5408
7	201.1	0.11	69.5	21732	73.1	6026
9	200.3	0.15	69.3	21213	73.1	5661
11	199.5	0.19	69.2	21303	72.9	5750
13	198.7	0.23	69.1	22012	73.1	5500
15	197.9	0.27	69.0	22067	71.8	7971

RUN NUMBER: 251 WORKING FLUID: R-113
 p/d = 1.5 G = 50.87 kg/s*m^2
 Pin = 205.4 kPa DELTA P total = 5.98 kPa
 Xin = -.01 Xout = 0.67
 SURFACE TYPE: TURBO-B

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	205.0	-.01	68.5	49897	76.0	6694
3	204.2	0.08	70.1	49634	76.9	7298
5	203.4	0.16	70.0	50663	77.1	7129
7	202.6	0.25	69.8	50358	77.0	7061
9	201.9	0.34	69.7	49914	77.3	6508
11	201.1	0.43	69.5	50001	76.9	6795
13	200.3	0.53	69.4	51148	77.3	6489
15	199.5	0.62	69.3	51400	75.2	8761

RUN NUMBER: 228 WORKING FLUID: R-113
 p/d = 1.5 G = 109.15 kg/s*m^2
 Pin = 208.3 kPa DELTA P total = 5.7 kPa
 Xin = 0.00 Xout = 0.07
 SURFACE TYPE: TURBO-B

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	208.0	0.00	69.7	10443	71.9	4633
3	207.2	0.01	70.2	10388	72.2	5061
5	206.4	0.02	70.3	10514	71.7	7247
7	205.7	0.03	70.2	10574	71.9	6313
9	204.9	0.03	70.1	10211	71.7	6384
11	204.2	0.04	70.0	10250	71.6	6522
13	203.4	0.05	70.0	10465	71.7	6086
15	202.6	0.06	69.9	10605	71.1	8421

RUN NUMBER: 226 WORKING FLUID: R-113
 p/d = 1.5 G = 108.97 kg/s*m^2
 Pin = 209.2 kPa DELTA P total = 5.7 kPa
 Xin = -.00 Xout = 0.12
 SURFACE TYPE: TURBO-B

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	208.9	-.00	69.5	20565	73.1	5686
3	208.1	0.01	70.4	20450	73.6	6440
5	207.4	0.03	70.4	20816	73.5	6925
7	206.6	0.05	70.4	20865	73.3	6979
9	205.8	0.06	70.3	20340	73.4	6529
11	205.1	0.08	70.2	20304	73.1	6964
13	204.3	0.10	70.1	20815	73.3	6436
15	203.6	0.12	70.0	20940	72.1	9995

RUN NUMBER: 221 WORKING FLUID: R-113
 p/d = 1.5 G = 109.18 kg/s*m^2
 Pin = 216.5 kPa DELTA P total = 5.68 kPa
 Xin = -.01 Xout = 0.30
 SURFACE TYPE: TURBO-B

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	216.2	-.01	70.0	49524	77.3	6811
3	215.4	0.03	71.9	49124	78.4	7616
5	214.6	0.07	71.8	50046	77.3	9129
7	213.9	0.11	71.7	49948	78.1	7751
9	213.1	0.15	71.6	49123	78.4	7175
11	212.4	0.19	71.5	49724	78.0	7600
13	211.6	0.24	71.4	50960	78.2	7385
15	210.9	0.28	71.2	51296	75.9	10988

RUN NUMBER: 225 WORKING FLUID: R-113
 p/d = 1.5 G = 109.15 kg/s*m^2
 Pin = 217.9 kPa DELTA P total = 5.67 kPa
 Xin = -.01 Xout = 0.49
 SURFACE TYPE: TURBO-B

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	217.5	-.01	70.5	79700	80.6	7865
3	216.8	0.06	72.1	78607	81.9	8019
5	216.0	0.12	72.0	80583	81.1	8850
7	215.3	0.19	71.9	80651	81.6	8326
9	214.5	0.25	71.8	79213	81.9	7808
11	213.7	0.32	71.7	79794	81.5	8142
13	213.0	0.39	71.6	81700	81.7	8058
15	212.2	0.46	71.5	82380	80.3	9351

RUN NUMBER: 227 WORKING FLUID: R-113
 p/d = 1.5 G = 108.78 kg/s*m^2
 Pin = 214.1 kPa DELTA P total = 5.7 kPa
 Xin = -.01 Xout = 0.18
 SURFACE TYPE: TURBO-B

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	213.7	-.01	70.0	30529	74.9	6206
3	213.0	0.02	71.4	30345	75.5	7473
5	212.2	0.04	71.4	30860	74.4	10002
7	211.5	0.07	71.3	31144	75.5	7391
9	210.7	0.09	71.1	30482	75.6	6827
11	209.9	0.12	71.0	30263	75.2	7278
13	209.2	0.14	70.9	31053	75.5	6846
15	208.4	0.17	70.8	31240	73.5	11483

RUN NUMBER: 223 WORKING FLUID: R-113
 p/d = 1.5 G = 109.14 kg/s*m^2
 Pin = 214 kPa DELTA P total = 5.69 kPa
 Xin = -.01 Xout = 0.37
 SURFACE TYPE: TURBO-B

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	213.7	-.01	70.1	60158	78.2	7377
3	213.0	0.04	71.5	59516	79.4	7540
5	212.2	0.09	71.4	60620	78.4	8662
7	211.4	0.14	71.3	59791	79.1	7655
9	210.7	0.19	71.1	59219	79.4	7154
11	209.9	0.24	71.0	59716	78.9	7554
13	209.2	0.29	70.9	61086	79.2	7401
15	208.4	0.34	70.8	61624	77.1	9834

RUN NUMBER: 243 WORKING FLUID: R-113
 p/d = 1.5 G = 217.22 kg/s*m^2
 Pin = 206.2 kPa DELTA P total = 5.72 kPa
 Xin = -.00 Xout = 0.03
 SURFACE TYPE: TURBO-B

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	205.9	-.00	69.0	10122	71.8	3857
3	205.1	-.00	69.5	10141	72.0	4248
5	204.4	0.00	69.9	10388	72.1	4830
7	203.6	0.01	70.0	10293	71.7	5791
9	202.9	0.01	69.8	10090	71.6	5491
11	202.1	0.02	69.7	10033	71.5	5563
13	201.4	0.02	69.6	10360	71.6	5193
15	200.6	0.03	69.5	10394	71.1	6167

RUN NUMBER: 220 WORKING FLUID: R-113
 p/d = 1.5 G = 109.09 kg/s*m^2
 Pin = 212.5 kPa DELTA P total = 5.73 kPa
 Xin = -.01 Xout = 0.25
 SURFACE TYPE: TURBO-B

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	212.2	-.01	69.9	40435	75.6	7087
3	211.4	0.03	71.2	40146	76.5	7459
5	210.7	0.06	71.1	40748	76.5	7551
7	209.9	0.09	71.0	40697	76.3	7674
9	209.2	0.13	70.9	40040	76.5	7048
11	208.4	0.16	70.8	40406	76.1	7517
13	207.6	0.19	70.7	41413	76.4	7208
15	206.9	0.23	70.6	41637	74.3	11295

RUN NUMBER: 224 WORKING FLUID: R-113
 p/d = 1.5 G = 109.06 kg/s*m^2
 Pin = 217.8 kPa DELTA P total = 5.69 kPa
 Xin = -.01 Xout = 0.43
 SURFACE TYPE: TURBO-B

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	217.5	-.01	70.4	69902	79.7	7527
3	216.7	0.05	72.1	68919	80.9	7859
5	216.0	0.10	72.0	70520	80.0	8866
7	215.2	0.16	71.9	70238	80.6	8111
9	214.4	0.22	71.8	69220	80.9	7589
11	213.7	0.28	71.7	69978	80.4	7985
13	212.9	0.34	71.6	71604	80.6	7892
15	212.2	0.40	71.5	72218	78.7	9897

RUN NUMBER: 240 WORKING FLUID: R-113
 p/d = 1.5 G = 217.6 kg/s*m^2
 Pin = 204.4 kPa DELTA P total = 5.72 kPa
 Xin = 0.00 Xout = 0.07
 SURFACE TYPE: TURBO-B

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	204.0	0.00	68.8	20297	72.2	6402
3	203.3	0.01	69.5	20192	72.6	6823
5	202.5	0.02	69.7	20542	72.4	7547
7	201.8	0.03	69.6	20656	72.3	7397
9	201.0	0.03	69.5	20249	72.4	6926
11	200.3	0.04	69.4	20146	72.1	7271
13	199.5	0.05	69.3	20851	72.3	6707
15	198.7	0.06	69.2	20857	71.3	9446

RUN NUMBER: 241 WORKING FLUID: R-113
 p/d = 1.5 G = 217.35 kg/s*m^2
 Pin = 208.3 kPa DELTA P total = 5.64 kPa
 Xin = -.00 Xout = 0.09
 SURFACE TYPE: TURBO-B

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	208.0	-.00	69.1	29994	74.0	6694
3	207.2	0.01	70.2	29952	74.3	7590
5	206.5	0.02	70.5	30424	74.5	7449
7	205.7	0.03	70.4	30296	74.2	7896
9	205.0	0.04	70.3	29805	74.3	7322
11	204.2	0.06	70.2	29932	73.9	7830
13	203.5	0.07	70.0	30778	74.3	7241
15	202.7	0.08	69.9	30919	72.8	10482

RUN NUMBER: 235 WORKING FLUID: R-113
 p/d = 1.5 G = 217.05 kg/s*m^2
 Pin = 213.2 kPa DELTA P total = 5.72 kPa
 Xin = -.01 Xout = 0.18
 SURFACE TYPE: TURBO-B

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	212.8	-.01	69.7	59922	77.7	8205
3	212.1	0.02	71.2	59614	78.4	8310
5	211.3	0.04	71.2	60697	78.3	8576
7	210.6	0.07	71.1	60793	78.5	8226
9	209.8	0.09	71.0	59980	78.6	7879
11	209.0	0.12	70.9	59934	78.0	8338
13	208.3	0.14	70.8	61315	78.2	8261
15	207.5	0.17	70.7	61744	76.2	11127

RUN NUMBER: 244 WORKING FLUID: R-113
 p/d = 1.5 G = 335.35 kg/s*m^2
 Pin = 201 kPa DELTA P total = 5.72 kPa
 Xin = -.00 Xout = 0.02
 SURFACE TYPE: TURBO-B

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	200.7	-.00	68.4	10030	71.0	3899
3	199.9	0.00	68.6	10198	71.2	3953
5	199.2	0.00	68.8	10458	71.1	4520
7	198.4	0.01	68.8	10410	70.9	4970
9	197.7	0.01	68.7	10227	70.8	4926
11	196.9	0.01	68.7	10038	70.7	4967
13	196.2	0.02	68.6	10340	70.6	5220
15	195.4	0.02	68.5	10383	70.3	5940

RUN NUMBER: 242 WORKING FLUID: R-113
 p/d = 1.5 G = 217.19 kg/s*m^2
 Pin = 207.8 kPa DELTA P total = 5.7 kPa
 Xin = -.00 Xout = 0.13
 SURFACE TYPE: TURBO-B

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	207.5	-.00	69.2	40497	75.0	7570
3	206.7	0.02	70.3	40366	75.4	7955
5	205.9	0.03	70.4	40964	75.7	7640
7	205.2	0.05	70.3	40279	75.4	7790
9	204.4	0.07	70.2	39756	75.6	7330
11	203.7	0.08	70.1	39955	75.1	7876
13	202.9	0.10	69.9	41028	75.3	7479
15	202.1	0.12	69.8	41261	73.5	10781

RUN NUMBER: 236 WORKING FLUID: R-113
 p/d = 1.5 G = 217.56 kg/s*m^2
 Pin = 212.1 kPa DELTA P total = 5.69 kPa
 Xin = -.00 Xout = 0.22
 SURFACE TYPE: TURBO-B

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	211.8	-.00	69.8	70573	78.7	8620
3	211.0	0.02	71.1	69610	79.4	8334
5	210.3	0.05	71.0	71213	79.4	8512
7	209.5	0.08	70.9	70886	79.3	8425
9	208.8	0.11	70.8	69821	79.4	8106
11	208.0	0.14	70.7	69637	78.9	8484
13	207.3	0.17	70.6	71330	78.9	8522
15	206.5	0.20	70.5	71837	77.1	10836

RUN NUMBER: 245 WORKING FLUID: R-113
 p/d = 1.5 G = 334.52 kg/s*m^2
 Pin = 205.3 kPa DELTA P total = 5.69 kPa
 Xin = -.00 Xout = 0.04
 SURFACE TYPE: TURBO-B

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	205.0	-.00	68.9	19967	72.2	5995
3	204.2	0.00	69.5	20316	72.8	6179
5	203.5	0.01	69.8	20757	72.7	7307
7	202.7	0.01	69.8	20430	72.4	7837
9	201.9	0.02	69.6	20034	72.4	7396
11	201.2	0.02	69.5	20091	72.2	7491
13	200.4	0.03	69.4	20606	72.3	7121
15	199.7	0.04	69.3	20791	71.5	9658

RUN NUMBER: 234 WORKING FLUID: R-113
 p/d = 1.5 G = 217.54 kg/s*m^2
 Pin = 212.1 kPa DELTA P total = 5.65 kPa
 Xin = -.01 Xout = 0.15
 SURFACE TYPE: TURBO-B

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	211.8	-.01	69.6	49386	76.3	8045
3	211.0	0.01	70.9	49289	76.9	8431
5	210.3	0.03	71.0	50044	76.6	8861
7	209.5	0.05	70.9	50009	76.9	8265
9	208.8	0.07	70.8	49389	77.0	7897
11	208.0	0.09	70.7	49429	76.5	8430
13	207.2	0.12	70.6	50493	76.7	8285
15	206.5	0.14	70.5	50888	74.8	11869

RUN NUMBER: 237 WORKING FLUID: R-113
 p/d = 1.5 G = 216.9 kg/s*m^2
 Pin = 214.3 kPa DELTA P total = 5.66 kPa
 Xin = -.01 Xout = 0.25
 SURFACE TYPE: TURBO-B

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	214.0	-.01	70.1	80283	80.1	8665
3	213.3	0.03	71.5	79084	80.9	8359
5	212.5	0.06	71.4	80921	80.9	8482
7	211.7	0.09	71.3	81097	80.7	8579
9	211.0	0.13	71.2	79573	80.8	8262
11	210.2	0.16	71.1	79559	80.3	8634
13	209.5	0.20	71.0	81449	80.3	8710
15	208.7	0.23	70.9	82070	78.7	10485

RUN NUMBER: 246 WORKING FLUID: R-113
 p/d = 1.5 G = 334.24 kg/s*m^2
 Pin = 209 kPa DELTA P total = 5.67 kPa
 Xin = -.01 Xout = 0.05
 SURFACE TYPE: TURBO-B

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	208.7	-.01	69.0	29754	74.1	5799
3	207.9	-.00	69.9	29843	74.5	6501
5	207.1	0.01	70.4	30429	74.3	7889
7	206.4	0.01	70.4	30282	74.1	8029
9	205.6	0.02	70.3	29851	74.2	7542
11	204.9	0.03	70.2	29733	73.9	7915
13	204.1	0.04	70.1	30548	74.1	7567
15	203.4	0.05	70.0	30787	72.9	10593

RUN NUMBER: 247

WORKING FLUID: R-113

p/d = 1.5

G = 334.83 kg/s*m²

Pin = 214.7 kPa

DELTA P total = 5.71 kPa

Xin = -.01

Xout = 0.08

SURFACE TYPE: TURBO-B

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	214.3	-.01	70.2	40063	76.4	6375
3	213.6	0.00	71.1	39719	76.7	7124
5	212.8	0.01	71.5	40400	76.4	8244
7	212.1	0.03	71.4	40223	76.5	7874
9	211.3	0.04	71.2	39848	76.6	7469
11	210.5	0.05	71.1	39823	76.1	8018
13	209.8	0.06	71.0	40850	76.3	7730
15	209.0	0.07	70.9	41099	74.9	10476

RUN NUMBER: 285

WORKING FLUID: R-113

p/d = 1.5

G = 49.94 kg/s*m²

Pin = 603.8 kPa

DELTA P total = 5.67 kPa

Xin = 0.00

Xout = 0.32

SURFACE TYPE: TURBO-B

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	603.5	0.00	103.9	20589	108.1	4830
3	602.8	0.04	105.5	20318	108.5	6776
5	602.0	0.08	105.5	20712	108.3	7205
7	601.3	0.12	105.4	20955	108.3	7192
9	600.5	0.16	105.3	20343	108.2	6969
11	599.7	0.21	105.3	20190	108.2	6864
13	599.0	0.25	105.2	20621	108.6	7084
15	598.2	0.30	105.1	20822	107.7	7974

RUN NUMBER: 282

WORKING FLUID: R-113

p/d = 1.5

G = 50.75 kg/s*m²

Pin = 604.5 kPa

DELTA P total = 5.7 kPa

Xin = 0.02

Xout = 0.78

SURFACE TYPE: TURBO-B

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	604.2	0.02	104.4	49972	111.3	7243
3	603.4	0.11	105.6	49233	111.5	8337
5	602.7	0.21	105.5	50185	111.8	7964
7	601.9	0.31	105.5	50280	112.1	7622
9	601.2	0.41	105.4	49333	112.0	7424
11	600.4	0.51	105.3	49319	112.0	7406
13	599.6	0.62	105.2	49848	112.1	7430
15	598.9	0.72	105.2	50868	110.5	9613

RUN NUMBER: 248

WORKING FLUID: R-113

p/d = 1.5

G = 335.23 kg/s*m²

Pin = 220.3 kPa

DELTA P total = 5.66 kPa

Xin = -.02

Xout = 0.08

SURFACE TYPE: TURBO-B

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	220.0	-.02	70.0	50059	78.4	5958
3	219.2	-.01	71.7	49501	78.7	7041
5	218.4	0.01	72.5	50496	78.9	7863
7	217.7	0.02	72.3	50448	78.7	7861
9	216.9	0.03	72.2	50007	78.9	7455
11	216.2	0.05	72.1	50294	78.3	8169
13	215.4	0.06	72.0	51505	78.5	7918
15	214.7	0.08	71.9	51791	76.6	10910

RUN NUMBER: 280

WORKING FLUID: R-113

p/d = 1.5

G = 50.64 kg/s*m²

Pin = 606.5 kPa

DELTA P total = 5.65 kPa

Xin = 0.00

Xout = 0.46

SURFACE TYPE: TURBO-B

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	606.2	0.00	104.0	30179	109.0	6054
3	605.4	0.06	105.8	30047	109.6	7905
5	604.7	0.12	105.7	30370	109.5	7897
7	603.9	0.18	105.6	30571	109.6	7620
9	603.1	0.24	105.6	29791	109.5	7508
11	602.4	0.30	105.5	29907	109.3	7786
13	601.6	0.37	105.4	30482	109.7	7640
15	600.9	0.43	105.4	30822	108.2	10684

RUN NUMBER: 260

WORKING FLUID: R-113

p/d = 1.5

G = 102.9 kg/s*m²

Pin = 544.8 kPa

DELTA P total = 5.73 kPa

Xin = 0.01

Xout = 0.08

SURFACE TYPE: TURBO-B

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	544.5	0.01	98.8	10255	101.8	3325
3	543.7	0.02	99.7	10385	102.2	4181
5	543.0	0.03	100.0	10635	101.7	5465
7	542.2	0.04	99.9	10616	102.0	5153
9	541.4	0.05	99.9	10230	101.9	4971
11	540.7	0.06	99.8	10184	101.9	4944
13	539.9	0.07	99.7	10451	101.8	5075
15	539.2	0.08	99.7	10538	101.4	6175

RUN NUMBER: 278

WORKING FLUID: R-113

p/d = 1.5

G = 49.07 kg/s*m²

Pin = 574.5 kPa

DELTA P total = 5.64 kPa

Xin = 0.02

Xout = 0.18

SURFACE TYPE: TURBO-B

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	574.2	0.02	102.0	10327	104.1	4872
3	573.4	0.04	102.9	10275	104.4	6755
5	572.7	0.06	102.8	10415	104.7	6628
7	571.9	0.08	102.8	10464	104.2	7216
9	571.1	0.10	102.7	10093	104.1	6904
11	570.4	0.13	102.6	10113	104.2	6566
13	569.6	0.15	102.5	10399	104.3	5879
15	568.9	0.17	102.5	10435	104.0	7000

RUN NUMBER: 281

WORKING FLUID: R-113

p/d = 1.5

G = 50.34 kg/s*m²

Pin = 605.8 kPa

DELTA P total = 5.65 kPa

Xin = 0.01

Xout = 0.63

SURFACE TYPE: TURBO-B

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	605.4	0.01	104.1	40227	110.2	6599
3	604.7	0.09	105.7	39974	110.7	7992
5	603.9	0.16	105.6	40498	110.7	7933
7	603.2	0.25	105.6	40764	111.1	7365
9	602.4	0.33	105.5	39951	111.1	7112
11	601.6	0.41	105.4	40262	111.0	7202
13	600.9	0.50	105.4	40696	111.2	7193
15	600.1	0.59	105.3	41465	109.4	10095

RUN NUMBER: 261

WORKING FLUID: R-113

p/d = 1.5

G = 102.14 kg/s*m²

Pin = 565 kPa

DELTA P total = 5.68 kPa

Xin = 0.00

Xout = 0.15

SURFACE TYPE: TURBO-B

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	564.7	0.00	100.4	20080	104.8	4572
3	564.0	0.02	101.7	20208	105.2	5788
5	563.2	0.04	101.9	20716	104.6	6933
7	562.4	0.06	101.9	20819	105.2	6292
9	561.7	0.08	101.8	20198	105.1	6156
11	560.9	0.10	101.7	20293	104.9	6480
13	560.2	0.12	101.7	20616	105.3	5714
15	559.4	0.14	101.6	20927	104.5	7184

RUN NUMBER: 262 WORKING FLUID: R-113
 p/d = 1.5 G = 101.76 kg/s*m^2
 Pin = 588.5 kPa DELTA P total = 5.66 kPa
 Xin = 0.00 Xout = 0.23
 SURFACE TYPE: TURBO-B

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	588.2	0.00	103.1	30190	107.3	7116
3	587.4	0.03	104.2	30038	107.8	8301
5	586.7	0.06	104.1	30518	107.9	8011
7	585.9	0.09	104.0	30454	107.6	8463
9	585.2	0.12	104.0	29780	107.7	7879
11	584.4	0.15	103.9	29924	107.6	8039
13	583.6	0.18	103.8	30170	107.9	7434
15	582.9	0.22	103.8	30839	106.6	10973

RUN NUMBER: 265 WORKING FLUID: R-113
 p/d = 1.5 G = 101.84 kg/s*m^2
 Pin = 580.4 kPa DELTA P total = 5.69 kPa
 Xin = 0.02 Xout = 0.47
 SURFACE TYPE: TURBO-B

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	580.0	0.02	102.5	59879	109.6	8464
3	579.3	0.08	103.4	59074	109.9	8621
5	578.5	0.13	103.4	60496	110.5	8488
7	577.8	0.19	103.3	60371	110.1	8885
9	577.0	0.25	103.2	59400	110.2	8499
11	576.2	0.31	103.2	60146	110.3	8459
13	575.5	0.38	103.1	61351	110.3	8454
15	574.7	0.44	103.0	61980	108.7	10970

RUN NUMBER: 277 WORKING FLUID: R-113
 p/d = 1.5 G = 182.99 kg/s*m^2
 Pin = 615.5 kPa DELTA P total = 5.72 kPa
 Xin = 0.00 Xout = 0.05
 SURFACE TYPE: TURBO-B

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	615.1	0.00	105.6	10379	108.2	3904
3	614.4	0.01	106.2	10301	108.5	4549
5	613.6	0.02	106.5	10495	108.0	5979
7	612.9	0.02	106.4	10651	108.2	5996
9	612.1	0.03	106.3	10275	108.1	5971
11	611.3	0.03	106.3	10275	108.1	5678
13	610.6	0.04	106.2	10533	108.3	5068
15	609.8	0.05	106.1	10569	108.0	5529

RUN NUMBER: 263 WORKING FLUID: R-113
 p/d = 1.5 G = 101.91 kg/s*m^2
 Pin = 580.4 kPa DELTA P total = 5.7 kPa
 Xin = 0.02 Xout = 0.32
 SURFACE TYPE: TURBO-B

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	580.0	0.02	102.6	40096	107.8	7707
3	579.3	0.06	103.5	39801	108.2	8403
5	578.5	0.09	103.4	40611	108.4	8020
7	577.8	0.13	103.3	40640	108.2	8248
9	577.0	0.17	103.2	40003	108.4	7788
11	576.2	0.21	103.2	40179	108.3	7764
13	575.5	0.26	103.1	40722	108.4	7647
15	574.7	0.30	103.0	41463	107.0	10500

RUN NUMBER: 266 WORKING FLUID: R-113
 p/d = 1.5 G = 101.49 kg/s*m^2
 Pin = 577.2 kPa DELTA P total = 5.69 kPa
 Xin = 0.02 Xout = 0.55
 SURFACE TYPE: TURBO-B

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	576.9	0.02	102.2	70331	110.1	8884
3	576.1	0.09	103.2	69346	110.5	9158
5	575.4	0.15	103.1	70984	111.2	8770
7	574.6	0.22	103.0	70819	110.8	9134
9	573.8	0.29	102.9	69588	110.9	8749
11	573.1	0.37	102.9	69359	110.8	8710
13	572.3	0.44	102.8	70793	110.8	8813
15	571.6	0.51	102.7	71493	109.3	10950

RUN NUMBER: 274 WORKING FLUID: R-113
 p/d = 1.5 G = 183.37 kg/s*m^2
 Pin = 624.9 kPa DELTA P total = 5.72 kPa
 Xin = 0.00 Xout = 0.09
 SURFACE TYPE: TURBO-B

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	624.6	0.00	106.1	20581	110.0	5274
3	623.8	0.01	107.0	20614	110.2	6477
5	623.1	0.02	107.3	20931	110.3	6864
7	622.3	0.03	107.2	21224	110.1	7437
9	621.6	0.05	107.1	20531	110.0	7267
11	620.8	0.06	107.1	20634	109.9	7236
13	620.1	0.07	107.0	21081	110.2	6540
15	619.3	0.08	106.9	21225	109.5	8282

RUN NUMBER: 264 WORKING FLUID: R-113
 p/d = 1.5 G = 101.68 kg/s*m^2
 Pin = 580.3 kPa DELTA P total = 5.7 kPa
 Xin = 0.02 Xout = 0.40
 SURFACE TYPE: TURBO-B

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	579.9	0.02	102.5	50043	108.8	7891
3	579.2	0.07	103.4	49497	109.2	8577
5	578.4	0.11	103.4	50621	109.6	8118
7	577.7	0.16	103.3	50556	109.3	8371
9	576.9	0.21	103.2	49802	109.5	7986
11	576.1	0.26	103.1	50342	109.5	7921
13	575.4	0.32	103.1	51248	109.6	7901
15	574.6	0.37	103.0	51956	108.0	10498

RUN NUMBER: 267 WORKING FLUID: R-113
 p/d = 1.5 G = 101.56 kg/s*m^2
 Pin = 583.6 kPa DELTA P total = 5.67 kPa
 Xin = 0.01 Xout = 0.61
 SURFACE TYPE: TURBO-B

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	583.3	0.01	102.6	79082	111.1	9374
3	582.6	0.09	103.7	78099	111.5	9904
5	581.8	0.17	103.7	79808	112.3	9255
7	581.0	0.24	103.6	80491	111.8	9832
9	580.3	0.32	103.5	78736	111.9	9415
11	579.5	0.40	103.5	78356	111.9	9308
13	578.8	0.49	103.4	80204	112.0	9352
15	578.0	0.57	103.3	80851	110.7	10923

RUN NUMBER: 276 WORKING FLUID: R-113
 p/d = 1.5 G = 183.14 kg/s*m^2
 Pin = 628.3 kPa DELTA P total = 5.64 kPa
 Xin = -.00 Xout = 0.13
 SURFACE TYPE: TURBO-B

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	628.0	-.00	106.3	30484	111.4	6008
3	627.2	0.02	107.4	30237	111.5	7475
5	626.5	0.03	107.6	30557	111.5	7707
7	625.7	0.05	107.5	30587	111.5	7711
9	624.9	0.07	107.4	29782	111.4	7517
11	624.2	0.08	107.4	29795	111.3	7609
13	623.4	0.10	107.3	30368	111.6	7003
15	622.7	0.12	107.2	30741	110.4	9715

RUN NUMBER: 269 WORKING FLUID: R-113
 p/d = 1.5 G = 179.66 kg/s*m^2
 Pin = 602.4 kPa DELTA P total = 5.7 kPa
 Xin = 0.03 Xout = 0.20
 SURFACE TYPE: TURBO-B

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	602.1	0.03	104.6	39505	110.0	7371
3	601.3	0.05	105.4	39586	110.2	8355
5	600.6	0.07	105.3	40189	110.4	8009
7	599.8	0.09	105.3	40526	110.3	8053
9	599.0	0.11	105.2	40088	110.3	7790
11	598.3	0.14	105.1	39864	110.2	7816
13	597.5	0.16	105.1	40371	110.5	7796
15	596.8	0.19	105.0	41144	108.9	10518

RUN NUMBER: 272 WORKING FLUID: R-113
 p/d = 1.5 G = 182.99 kg/s*m^2
 Pin = 629.8 kPa DELTA P total = 5.69 kPa
 Xin = -.01 Xout = 0.29
 SURFACE TYPE: TURBO-B

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	629.5	-.01	106.1	70167	115.1	7727
3	628.7	0.03	107.8	69222	114.9	9438
5	628.0	0.07	107.7	70832	115.4	9203
7	627.2	0.11	107.6	70597	115.1	9409
9	626.5	0.15	107.6	69159	115.2	9023
11	625.7	0.19	107.5	69670	115.2	9021
13	624.9	0.23	107.4	71155	115.2	9109
15	624.2	0.27	107.4	71794	113.8	11197

RUN NUMBER: 270 WORKING FLUID: R-113
 p/d = 1.5 G = 179.63 kg/s*m^2
 Pin = 603.5 kPa DELTA P total = 5.65 kPa
 Xin = 0.01 Xout = 0.23
 SURFACE TYPE: TURBO-B

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	603.2	0.01	104.5	49928	111.6	7070
3	602.4	0.04	105.5	49362	111.7	8028
5	601.7	0.07	105.4	50304	112.0	7718
7	600.9	0.10	105.4	50516	111.9	7678
9	600.2	0.12	105.3	49763	112.0	7404
11	599.4	0.15	105.2	50078	112.0	7409
13	598.6	0.18	105.2	50840	112.2	7571
15	597.9	0.21	105.1	51577	110.5	9536

RUN NUMBER: 273 WORKING FLUID: R-113
 p/d = 1.5 G = 182.74 kg/s*m^2
 Pin = 632.3 kPa DELTA P total = 5.66 kPa
 Xin = -.00 Xout = 0.34
 SURFACE TYPE: TURBO-B

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	632.0	-.00	106.3	80260	116.0	8299
3	631.2	0.04	108.0	79122	115.6	10303
5	630.4	0.08	107.9	81114	116.3	9699
7	629.7	0.13	107.8	80859	115.9	10057
9	628.9	0.17	107.8	78896	116.0	9638
11	628.2	0.22	107.7	79304	115.9	9621
13	627.4	0.26	107.6	81207	116.0	9710
15	626.7	0.31	107.6	81729	114.6	11679

RUN NUMBER: 271 WORKING FLUID: R-113
 p/d = 1.5 G = 183.43 kg/s*m^2
 Pin = 620 kPa DELTA P total = 5.72 kPa
 Xin = -.00 Xout = 0.25
 SURFACE TYPE: TURBO-B

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	619.7	-.00	105.3	60693	113.8	7094
3	618.9	0.03	106.9	59882	113.7	8865
5	618.2	0.06	106.9	61366	114.1	8427
7	617.4	0.10	106.8	61148	114.0	8449
9	616.6	0.13	106.7	60090	114.1	8143
11	615.9	0.16	106.7	60330	114.1	8144
13	615.1	0.20	106.6	61419	114.1	8130
15	614.4	0.24	106.5	62130	112.5	10431

Bundle Boiling Data

High Flux data in R-113 for bundle with $p/d = 1.17$

RUN NUMBER: 299
p/d = 1.17
Pin = 200.6 kPa
Xin = -.00
SURFACE TYPE: HIGH FLUX

WORKING FLUID: R-113
G = 52.59 kg/s*m^2
DELTA P total = 4.48 kPa
Xout = 0.18

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	200.3	-.00	67.8	5027	70.4	1979
3	199.7	0.02	69.2	4862	70.2	4829
5	199.1	0.04	69.2	4962	70.1	5099
7	198.5	0.06	69.1	5059	70.1	5046
9	197.9	0.09	69.0	4928	70.0	4686
11	197.3	0.11	68.9	4885	69.9	4896
13	196.7	0.14	68.8	4952	69.8	5007
15	196.1	0.16	68.7	4991	69.7	4830

RUN NUMBER: 302
p/d = 1.17
Pin = 205 kPa
Xin = -.00
SURFACE TYPE: HIGH FLUX

WORKING FLUID: R-113
G = 52.85 kg/s*m^2
DELTA P total = 4.5 kPa
Xout = 0.74

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	204.7	-.00	68.5	20599	72.9	4756
3	204.1	0.09	70.1	20011	72.0	10702
5	203.5	0.18	70.0	20390	71.9	10909
7	202.9	0.28	69.9	20400	71.8	10725
9	202.3	0.38	69.8	19780	71.8	10860
11	201.7	0.48	69.7	19770	71.3	11055
13	201.1	0.59	69.6	20126	71.3	11813
15	200.5	0.69	69.5	20192	71.3	11312

RUN NUMBER: 295
p/d = 1.17
Pin = 206.5 kPa
Xin = -.01
SURFACE TYPE: HIGH FLUX

WORKING FLUID: R-113
G = 101.01 kg/s*m^2
DELTA P total = 4.56 kPa
Xout = 0.38

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	206.2	-.01	68.7	20706	73.2	4560
3	205.6	0.04	70.4	20083	72.4	9715
5	205.0	0.09	70.3	20454	72.3	10044
7	204.4	0.14	70.2	20417	72.0	11177
9	203.8	0.20	70.1	19792	71.9	10827
11	203.2	0.25	70.0	19794	71.7	11573
13	202.6	0.30	69.8	20170	71.7	10785
15	202.0	0.36	69.7	20247	71.7	10329

RUN NUMBER: 300
p/d = 1.17
Pin = 203.6 kPa
Xin = -.00
SURFACE TYPE: HIGH FLUX

WORKING FLUID: R-113
G = 52.85 kg/s*m^2
DELTA P total = 4.51 kPa
Xout = 0.38

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	203.3	-.00	68.4	10588	71.6	3250
3	202.7	0.05	69.8	10235	71.2	7304
5	202.1	0.09	69.7	10455	71.1	7249
7	201.5	0.14	69.6	10503	71.1	7119
9	200.9	0.20	69.5	10237	71.0	6751
11	200.3	0.25	69.4	10154	70.7	7597
13	199.7	0.30	69.3	10304	70.7	7443
15	199.1	0.35	69.2	10369	70.6	7317

RUN NUMBER: 303
p/d = 1.17
Pin = 202.9 kPa
Xin = 0.00
SURFACE TYPE: HIGH FLUX

WORKING FLUID: R-113
G = 101.51 kg/s*m^2
DELTA P total = 4.54 kPa
Xout = 0.10

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	202.6	0.00	68.4	5198	70.7	2244
3	202.0	0.01	69.4	5012	70.4	4992
5	201.4	0.03	69.6	5114	70.3	6947
7	200.8	0.04	69.5	5100	70.3	5900
9	200.2	0.05	69.4	4959	70.3	5730
11	199.7	0.07	69.3	5018	70.2	5797
13	199.1	0.08	69.2	5082	70.2	5747
15	198.5	0.09	69.1	5128	70.1	5895

RUN NUMBER: 296
p/d = 1.17
Pin = 207.9 kPa
Xin = -.01
SURFACE TYPE: HIGH FLUX

WORKING FLUID: R-113
G = 101.98 kg/s*m^2
DELTA P total = 4.5 kPa
Xout = 0.57

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	207.6	-.01	68.4	30638	74.7	4815
3	207.0	0.06	70.5	29701	73.4	10094
5	206.4	0.14	70.4	30269	73.3	10436
7	205.8	0.21	70.3	30337	73.2	10609
9	205.2	0.29	70.2	29451	73.2	10068
11	204.6	0.37	70.1	29559	72.9	10765
13	204.0	0.45	70.1	30194	72.9	10739
15	203.4	0.53	70.0	30243	72.9	10378

RUN NUMBER: 301
p/d = 1.17
Pin = 204.8 kPa
Xin = -.00
SURFACE TYPE: HIGH FLUX

WORKING FLUID: R-113
G = 52.92 kg/s*m^2
DELTA P total = 4.49 kPa
Xout = 0.55

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	204.5	-.00	68.5	15450	72.2	4162
3	203.9	0.07	70.1	14989	71.6	10014
5	203.3	0.13	70.0	15277	71.5	10069
7	202.7	0.21	69.9	15192	71.4	9779
9	202.1	0.28	69.7	14735	71.4	9030
11	201.6	0.36	69.6	14708	71.0	10899
13	201.0	0.43	69.5	14943	70.9	10685
15	200.4	0.51	69.4	15028	70.9	10075

RUN NUMBER: 294
p/d = 1.17
Pin = 202.9 kPa
Xin = 0.00
SURFACE TYPE: HIGH FLUX

WORKING FLUID: R-113
G = 103.37 kg/s*m^2
DELTA P total = 4.55 kPa
Xout = 0.19

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	202.6	0.00	66.7	10417	71.3	2243
3	202.0	0.03	69.0	10084	70.9	5140
5	201.4	0.05	69.6	10275	70.8	8302
7	200.8	0.07	69.5	10202	70.7	8207
9	200.2	0.10	69.4	9825	70.7	7826
11	199.6	0.13	69.3	10023	70.4	8834
13	199.0	0.15	69.2	10167	70.3	8909
15	198.4	0.18	69.1	10238	70.3	8407

RUN NUMBER: 297
p/d = 1.17
Pin = 208.9 kPa
Xin = -.01
SURFACE TYPE: HIGH FLUX

WORKING FLUID: R-113
G = 101.32 kg/s*m^2
DELTA P total = 4.54 kPa
Xout = 0.77

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	208.6	-.01	68.6	41418	75.9	5675
3	208.0	0.09	70.7	40263	74.3	11053
5	207.4	0.19	70.6	41042	74.2	11359
7	206.8	0.29	70.5	40945	74.0	11538
9	206.2	0.40	70.4	39858	74.1	10842
11	205.6	0.51	70.3	39828	73.6	12030
13	205.0	0.61	70.2	40730	73.7	11677
15	204.4	0.72	70.1	40752	73.8	11223

RUN NUMBER: 286
p/d = 1.17
Pin = 200.3 kPa
Xin = 0.00
SURFACE TYPE: HIGH FLUX

WORKING FLUID: R-113
G = 225 kg/s*m²
DELTA P total = 4.54 kPa
Xout = 0.09

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	199.9	0.00	68.1	10687	74.3	1735
3	199.3	0.01	69.0	10344	70.5	6707
5	198.7	0.02	69.1	10595	70.6	7193
7	198.2	0.03	69.0	10875	70.6	6592
9	197.6	0.05	68.9	10449	70.4	6900
11	197.0	0.06	68.8	10151	70.3	7025
13	196.4	0.07	68.7	10326	70.4	6236
15	195.8	0.09	68.6	10423	70.2	6715

RUN NUMBER: 289
p/d = 1.17
Pin = 203.9 kPa
Xin = -.00
SURFACE TYPE: HIGH FLUX

WORKING FLUID: R-113
G = 224.47 kg/s*m²
DELTA P total = 4.52 kPa
Xout = 0.35

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	203.5	-.00	68.4	41217	77.6	4453
3	203.0	0.04	69.9	40058	73.7	10488
5	202.4	0.08	69.7	40965	73.5	10803
7	201.8	0.13	69.7	41191	73.7	10280
9	201.2	0.18	69.6	39632	73.3	10558
11	200.6	0.23	69.5	39809	72.8	11995
13	200.0	0.28	69.4	40694	73.3	10286
15	199.4	0.33	69.3	40839	73.0	11004

RUN NUMBER: 292
p/d = 1.17
Pin = 209.8 kPa
Xin = -.01
SURFACE TYPE: HIGH FLUX

WORKING FLUID: R-113
G = 222.45 kg/s*m²
DELTA P total = 4.51 kPa
Xout = 0.61

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	209.5	-.01	68.9	71663	79.8	6549
3	208.9	0.07	70.8	69632	76.9	11546
5	208.3	0.15	70.7	71019	76.6	12029
7	207.7	0.23	70.6	70533	76.6	11857
9	207.1	0.31	70.6	68719	76.4	11769
11	206.5	0.40	70.5	68812	76.4	11593
13	205.9	0.48	70.4	70060	76.2	12012
15	205.4	0.56	70.3	70119	76.0	12287

RUN NUMBER: 287
p/d = 1.17
Pin = 198.2 kPa
Xin = 0.00
SURFACE TYPE: HIGH FLUX

WORKING FLUID: R-113
G = 224.64 kg/s*m²
DELTA P total = 4.54 kPa
Xout = 0.18

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	197.9	0.00	67.9	20792	75.3	2797
3	197.3	0.02	68.8	20169	71.3	8181
5	196.7	0.05	68.7	20674	71.3	7981
7	196.1	0.07	68.6	20632	71.3	7642
9	195.5	0.09	68.5	19832	71.0	8036
11	194.9	0.12	68.4	20067	70.8	8671
13	194.3	0.14	68.4	20502	71.0	7689
15	193.8	0.17	68.3	20641	70.8	8279

RUN NUMBER: 290
p/d = 1.17
Pin = 206.2 kPa
Xin = -.01
SURFACE TYPE: HIGH FLUX

WORKING FLUID: R-113
G = 223.41 kg/s*m²
DELTA P total = 4.54 kPa
Xout = 0.44

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	205.8	-.01	68.7	51184	78.4	5253
3	205.3	0.05	70.3	49795	74.8	10967
5	204.6	0.10	70.2	50911	74.6	11549
7	204.1	0.16	70.1	50795	74.7	11201
9	203.5	0.22	70.0	48952	74.4	11311
11	202.9	0.28	69.9	49574	73.7	11918
13	202.3	0.35	69.8	50704	74.4	11039
15	201.7	0.41	69.7	50748	74.0	11717

RUN NUMBER: 293
p/d = 1.17
Pin = 213.1 kPa
Xin = -.01
SURFACE TYPE: HIGH FLUX

WORKING FLUID: R-113
G = 222.34 kg/s*m²
DELTA P total = 4.56 kPa
Xout = 0.69

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	212.7	-.01	69.1	82071	81.4	6658
3	212.1	0.08	71.4	79763	78.1	11866
5	211.5	0.17	71.3	81226	77.9	12367
7	211.0	0.26	71.2	81181	77.4	13186
9	210.4	0.36	71.1	79119	77.7	11987
11	209.8	0.45	71.0	79643	83.1	12612
13	209.2	0.55	70.9	80801	128.2	12411
15	208.6	0.65	70.8	81154	98.1	12974

RUN NUMBER: 288
p/d = 1.17
Pin = 200.5 kPa
Xin = 0.00
SURFACE TYPE: HIGH FLUX

WORKING FLUID: R-113
G = 224.45 kg/s*m²
DELTA P total = 4.58 kPa
Xout = 0.27

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	200.2	0.00	68.0	31046	76.6	3642
3	199.6	0.03	69.2	30200	72.3	9750
5	199.0	0.07	69.1	30908	72.3	9839
7	198.4	0.10	69.1	30925	72.4	9277
9	197.8	0.14	69.0	29713	72.0	9695
11	197.2	0.17	68.9	29938	71.7	10692
13	196.6	0.21	68.8	30593	72.1	9288
15	196.1	0.25	68.7	30727	71.7	10060

RUN NUMBER: 291
p/d = 1.17
Pin = 209.6 kPa
Xin = -.01
SURFACE TYPE: HIGH FLUX

WORKING FLUID: R-113
G = 223.05 kg/s*m²
DELTA P total = 4.53 kPa
Xout = 0.53

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	209.3	-.01	68.8	61362	79.2	5905
3	208.7	0.06	70.8	59679	76.0	11388
5	208.1	0.12	70.7	61006	76.3	10965
7	207.5	0.19	70.6	60849	75.8	11685
9	206.9	0.27	70.5	58744	75.5	11714
11	206.3	0.34	70.4	59355	74.8	11722
13	205.7	0.41	70.3	60528	75.5	11696
15	205.1	0.49	70.3	60480	75.1	12507

RUN NUMBER: 320
p/d = 1.17
Pin = 202.7 kPa
Xin = 0.01
SURFACE TYPE: HIGH FLUX

WORKING FLUID: R-113
G = 352.23 kg/s*m²
DELTA P total = 4.57 kPa
Xout = 0.06

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	202.3	0.01	68.9	10699	71.5	4153
3	201.7	0.01	69.3	10358	71.2	5495
5	201.1	0.02	69.4	10501	71.0	6559
7	200.5	0.03	69.3	10576	70.9	6749
9	200.0	0.04	69.2	10318	70.8	6485
11	199.4	0.04	69.2	10126	70.8	6533
13	198.8	0.05	69.1	10353	70.7	6569
15	198.2	0.06	69.0	10365	70.6	6787

RUN NUMBER: 319 WORKING FLUID: R-113
 p/d = 1.17 G = 351.02 kg/s*m^2
 Pin = 204.7 kPa DELTA P total = 4.49 kPa
 Xin = 0.00 Xout = 0.12
 SURFACE TYPE: HIGH FLUX

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	204.4	0.00	69.1	21010	72.8	5589
3	203.8	0.02	69.9	20405	72.3	8564
5	203.2	0.03	69.9	20793	72.0	9669
7	202.6	0.05	69.8	20699	71.9	9670
9	202.1	0.06	69.7	20217	71.9	9386
11	201.5	0.08	69.6	20149	71.8	9300
13	200.9	0.09	69.5	20567	71.6	9583
15	200.3	0.11	69.4	20641	71.5	9687

RUN NUMBER: 314 WORKING FLUID: R-113
 p/d = 1.17 G = 349.89 kg/s*m^2
 Pin = 205.4 kPa DELTA P total = 4.56 kPa
 Xin = -.00 Xout = 0.28
 SURFACE TYPE: HIGH FLUX

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	205.1	-.00	69.0	51394	76.2	7179
3	204.5	0.03	70.1	50024	74.8	10709
5	203.9	0.07	70.0	50764	74.3	11926
7	203.3	0.11	70.0	50766	74.1	12262
9	202.7	0.14	69.8	49457	74.2	11229
11	202.1	0.18	69.7	49370	73.8	11992
13	201.5	0.22	69.6	50503	74.0	11567
15	201.0	0.26	69.5	50452	73.8	11781

RUN NUMBER: 317 WORKING FLUID: R-113
 p/d = 1.17 G = 349.8 kg/s*m^2
 Pin = 206.7 kPa DELTA P total = 4.57 kPa
 Xin = 0.00 Xout = 0.45
 SURFACE TYPE: HIGH FLUX

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	206.4	0.00	69.6	81669	78.9	8782
3	205.8	0.06	70.2	79321	77.3	11194
5	205.2	0.12	70.1	80951	76.7	12429
7	204.6	0.18	70.1	80602	76.3	12989
9	204.1	0.24	70.0	78562	76.7	12806
11	203.5	0.30	70.0	78459	75.3	13702
13	202.9	0.36	69.9	79792	78.9	13777
15	202.3	0.42	69.8	79969	77.3	10597

RUN NUMBER: 318 WORKING FLUID: R-113
 p/d = 1.17 G = 351.14 kg/s*m^2
 Pin = 204.1 kPa DELTA P total = 4.54 kPa
 Xin = 0.00 Xout = 0.17
 SURFACE TYPE: HIGH FLUX

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	203.8	0.00	68.9	30694	73.7	6361
3	203.2	0.02	69.9	29820	73.0	9518
5	202.6	0.04	69.7	30347	72.6	10440
7	202.0	0.07	69.7	30474	72.5	10551
9	201.4	0.09	69.6	29766	72.6	10034
11	200.8	0.11	69.5	29768	72.5	9948
13	200.2	0.13	69.4	30373	72.3	10278
15	199.6	0.16	69.3	30423	72.2	10461

RUN NUMBER: 315 WORKING FLUID: R-113
 p/d = 1.17 G = 349.35 kg/s*m^2
 Pin = 206 kPa DELTA P total = 4.53 kPa
 Xin = -.00 Xout = 0.34
 SURFACE TYPE: HIGH FLUX

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	205.7	-.00	69.2	61291	77.1	7721
3	205.1	0.04	70.2	59715	75.7	10973
5	204.5	0.08	70.1	60643	75.1	12152
7	203.9	0.13	70.1	60609	74.9	12490
9	203.3	0.17	70.0	59157	75.1	11955
11	202.7	0.22	69.9	59107	74.5	12579
13	202.1	0.27	69.7	60403	74.8	11931
15	201.5	0.31	69.6	60291	74.6	12076

RUN NUMBER: 312 WORKING FLUID: R-113
 p/d = 1.17 G = 503.39 kg/s*m^2
 Pin = 202.5 kPa DELTA P total = 4.53 kPa
 Xin = 0.00 Xout = 0.04
 SURFACE TYPE: HIGH FLUX

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	202.2	0.00	68.9	10373	71.5	3966
3	201.6	0.01	69.2	10035	71.2	5032
5	201.0	0.01	69.3	10143	71.0	5830
7	200.4	0.02	69.2	10272	70.9	6037
9	199.8	0.02	69.2	9888	70.8	5931
11	199.2	0.03	69.1	9951	70.9	5848
13	198.6	0.03	69.1	10123	70.8	5759
15	198.0	0.04	69.0	10187	70.7	5984

RUN NUMBER: 313 WORKING FLUID: R-113
 p/d = 1.17 G = 350.72 kg/s*m^2
 Pin = 204.7 kPa DELTA P total = 4.5 kPa
 Xin = -.00 Xout = 0.22
 SURFACE TYPE: HIGH FLUX

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	204.4	-.00	68.7	40922	75.1	6380
3	203.8	0.02	70.0	39845	73.9	10383
5	203.2	0.05	69.9	40474	73.5	11412
7	202.6	0.08	69.8	40681	73.3	11510
9	202.0	0.11	69.7	39626	73.4	10773
11	201.4	0.14	69.6	39669	73.1	11274
13	200.8	0.17	69.5	40513	73.2	10935
15	200.2	0.20	69.4	40539	73.1	11038

RUN NUMBER: 316 WORKING FLUID: R-113
 p/d = 1.17 G = 349.27 kg/s*m^2
 Pin = 206.5 kPa DELTA P total = 4.51 kPa
 Xin = 0.00 Xout = 0.39
 SURFACE TYPE: HIGH FLUX

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	206.1	0.00	69.5	71630	77.6	8801
3	205.5	0.05	70.2	69776	76.1	11809
5	204.9	0.10	70.1	70892	75.5	13157
7	204.4	0.15	70.1	70805	75.2	13835
9	203.8	0.21	70.0	69100	75.5	13371
11	203.2	0.26	69.9	69202	74.8	13407
13	202.6	0.31	69.8	70746	75.1	13255
15	202.0	0.37	69.7	70668	74.9	13557

RUN NUMBER: 311 WORKING FLUID: R-113
 p/d = 1.17 G = 503.67 kg/s*m^2
 Pin = 203.6 kPa DELTA P total = 4.51 kPa
 Xin = -.00 Xout = 0.07
 SURFACE TYPE: HIGH FLUX

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	203.2	-.00	68.7	20663	72.6	5287
3	202.6	0.01	69.5	20027	71.9	8283
5	202.0	0.01	69.7	20286	71.6	10444
7	201.5	0.03	69.6	20503	71.5	10823
9	200.9	0.04	69.5	19970	71.4	10240
11	200.3	0.05	69.4	19882	71.3	10382
13	199.7	0.06	69.3	20307	71.2	10556
15	199.1	0.07	69.2	20374	71.1	10613

RUN NUMBER: 309 WORKING FLUID: R-113
 p/d = 1.17 G = 503.63 kg/s*m^2
 Pin = 201.2 kPa DELTA P total = 4.56 kPa
 Xin = 0.00 Xout = 0.12
 SURFACE TYPE: HIGH FLUX

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	200.8	0.00	68.5	31147	73.8	5917
3	200.2	0.01	69.2	30265	72.8	8514
5	199.6	0.03	69.2	30703	72.4	9440
7	199.1	0.05	69.1	30721	72.3	9628
9	198.5	0.06	69.0	29927	72.3	9684
11	197.9	0.08	68.9	29847	72.0	9879
13	197.3	0.09	68.9	30462	71.9	9925
15	196.7	0.11	68.8	30527	71.8	10208

RUN NUMBER: 306 WORKING FLUID: R-113
 p/d = 1.17 G = 502.52 kg/s*m^2
 Pin = 207.3 kPa DELTA P total = 4.5 kPa
 Xin = -.00 Xout = 0.23
 SURFACE TYPE: HIGH FLUX

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	206.9	-.00	69.6	61180	79.0	6446
3	206.4	0.03	70.4	59545	76.4	9970
5	205.8	0.05	70.3	60705	75.7	11254
7	205.2	0.09	70.2	60334	75.4	11619
9	204.6	0.12	70.2	58924	75.4	11225
11	204.0	0.15	70.1	58858	74.8	11440
13	203.4	0.18	70.0	60265	75.0	11921
15	202.8	0.21	69.9	60121	74.8	12200

RUN NUMBER: 353 WORKING FLUID: R-113
 p/d = 1.17 G = 50.04 kg/s*m^2
 Pin = 596.3 kPa DELTA P total = 5.32 kPa
 Xin = 0.00 Xout = 0.23
 SURFACE TYPE: HIGH FLUX

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	595.8	0.00	111.7	4383	114.0	1953
3	594.9	0.03	113.1	5087	113.8	7036
5	594.0	0.06	113.0	5137	113.7	7444
7	593.2	0.09	113.0	5307	113.7	6957
9	592.6	0.12	112.9	5225	113.7	6752
11	592.1	0.15	112.9	5254	113.7	6485
13	591.6	0.18	112.8	5389	113.7	6450
15	591.0	0.21	112.8	5249	113.6	6375

RUN NUMBER: 310 WORKING FLUID: R-113
 p/d = 1.17 G = 503.23 kg/s*m^2
 Pin = 202.6 kPa DELTA P total = 4.51 kPa
 Xin = 0.00 Xout = 0.16
 SURFACE TYPE: HIGH FLUX

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	202.3	0.00	68.9	40987	75.1	6661
3	201.7	0.02	69.4	39868	73.9	8879
5	201.1	0.04	69.3	40457	73.4	9880
7	200.5	0.06	69.3	40437	73.2	10214
9	199.9	0.08	69.2	39436	73.2	10082
11	199.3	0.10	69.1	39541	72.7	10968
13	198.7	0.12	69.1	40351	72.8	10865
15	198.2	0.15	69.0	40364	72.6	11194

RUN NUMBER: 307 WORKING FLUID: R-113
 p/d = 1.17 G = 501.98 kg/s*m^2
 Pin = 209.6 kPa DELTA P total = 4.53 kPa
 Xin = -.00 Xout = 0.27
 SURFACE TYPE: HIGH FLUX

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	209.3	-.00	69.9	71621	80.0	7075
3	208.7	0.03	70.6	69646	77.3	10423
5	208.1	0.07	70.6	70851	76.7	11610
7	207.5	0.10	70.5	70647	76.3	12184
9	206.9	0.14	70.4	68937	76.3	11687
11	206.3	0.18	70.4	69385	75.6	12288
13	205.7	0.21	70.3	70964	76.0	12581
15	205.1	0.25	70.2	70907	75.7	12971

RUN NUMBER: 354 WORKING FLUID: R-113
 p/d = 1.17 G = 50.35 kg/s*m^2
 Pin = 594.1 kPa DELTA P total = 5.27 kPa
 Xin = -.00 Xout = 0.44
 SURFACE TYPE: HIGH FLUX

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	593.6	-.00	111.8	9835	114.5	3679
3	592.6	0.05	112.9	10668	114.2	8074
5	591.7	0.11	112.8	11018	114.2	8385
7	590.9	0.17	112.8	11051	114.2	7788
9	590.4	0.23	112.7	10727	114.1	7764
11	589.9	0.29	112.7	10868	114.1	7569
13	589.4	0.35	112.7	10925	114.1	7734
15	588.9	0.41	112.6	10855	114.0	8115

RUN NUMBER: 305 WORKING FLUID: R-113
 p/d = 1.17 G = 504.75 kg/s*m^2
 Pin = 203.8 kPa DELTA P total = 4.52 kPa
 Xin = -.00 Xout = 0.18
 SURFACE TYPE: HIGH FLUX

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	203.4	-.00	68.9	49358	77.6	5652
3	202.8	0.02	69.8	48086	75.0	9133
5	202.3	0.04	69.7	49017	74.4	10333
7	201.7	0.07	69.6	49170	74.3	10405
9	201.1	0.09	69.5	48062	74.2	10254
11	200.5	0.12	69.4	48004	73.8	10923
13	199.9	0.14	69.3	49189	74.0	10593
15	199.3	0.17	69.2	49091	73.8	10751

RUN NUMBER: 308 WORKING FLUID: R-113
 p/d = 1.17 G = 502.49 kg/s*m^2
 Pin = 207.9 kPa DELTA P total = 4.54 kPa
 Xin = 0.01 Xout = 0.32
 SURFACE TYPE: HIGH FLUX

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	207.5	0.01	70.7	82114	79.9	8922
3	206.9	0.05	70.7	79769	77.7	11390
5	206.4	0.09	70.6	80997	77.0	12636
7	205.8	0.13	70.5	80789	76.5	13356
9	205.2	0.17	70.3	78826	76.8	12267
11	204.6	0.22	70.2	78999	75.8	13066
13	204.0	0.26	70.1	80307	76.1	13363
15	203.4	0.30	70.0	80370	75.8	13717

RUN NUMBER: 350 WORKING FLUID: R-113
 p/d = 1.17 G = 50.87 kg/s*m^2
 Pin = 590.5 kPa DELTA P total = 4.93 kPa
 Xin = -.01 Xout = 0.61
 SURFACE TYPE: HIGH FLUX

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	590.0	-.01	109.1	14342	114.9	2477
3	589.0	0.07	112.6	14880	114.3	8856
5	588.1	0.15	112.6	15308	114.3	9057
7	587.3	0.23	112.5	15514	114.3	8839
9	586.9	0.32	112.5	15117	114.1	9128
11	586.4	0.41	112.4	15290	114.1	8918
13	586.1	0.49	112.4	15377	114.2	8502
15	585.6	0.57	112.4	15296	114.2	8132

RUN NUMBER: 349 WORKING FLUID: R-113
 p/d = 1.17 G = 50.26 kg/s*m^2
 Pin = 613 kPa DELTA P total = 4.69 kPa
 Xin = 0.04 Xout = 0.91
 SURFACE TYPE: HIGH FLUX

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	612.5	0.04	111.3	20146	117.7	3129
3	611.5	0.15	114.4	20576	116.4	10294
5	610.4	0.26	114.3	21046	116.4	10197
7	609.6	0.38	114.2	21092	116.3	10076
9	609.3	0.50	114.2	20434	116.3	9699
11	609.0	0.62	114.2	20916	116.3	9783
13	608.8	0.74	114.1	20959	116.3	9810
15	608.4	0.85	114.1	20921	116.3	9578

RUN NUMBER: 346 WORKING FLUID: R-113
 p/d = 1.17 G = 103.35 kg/s*m^2
 Pin = 599.8 kPa DELTA P total = 4.96 kPa
 Xin = 0.01 Xout = 0.62
 SURFACE TYPE: HIGH FLUX

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	599.2	0.01	112.0	29069	116.3	6668
3	598.2	0.09	113.4	30129	115.7	12997
5	597.2	0.17	113.3	30572	115.6	13331
7	596.4	0.25	113.2	30286	115.5	13033
9	596.0	0.34	113.2	29911	115.4	13354
11	595.7	0.42	113.1	30692	115.6	12683
13	595.4	0.50	113.1	30769	115.6	12437
15	594.9	0.58	113.1	30683	115.6	12127

RUN NUMBER: 343 WORKING FLUID: R-113
 p/d = 1.17 G = 251.93 kg/s*m^2
 Pin = 595.1 kPa DELTA P total = 2.61 kPa
 Xin = 0.01 Xout = 0.18
 SURFACE TYPE: HIGH FLUX

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	594.6	0.01	112.4	20487	116.0	5746
3	594.0	0.03	113.0	20634	115.1	9775
5	594.4	0.05	113.0	21030	115.0	10586
7	594.5	0.08	113.0	20608	114.8	11732
9	594.1	0.10	113.0	20118	114.6	12462
11	593.6	0.12	113.0	20566	114.9	10978
13	593.0	0.15	112.9	20555	114.8	10866
15	592.5	0.17	112.9	20507	115.0	9875

RUN NUMBER: 355 WORKING FLUID: R-113
 p/d = 1.17 G = 106.81 kg/s*m^2
 Pin = 617.4 kPa DELTA P total = 5.26 kPa
 Xin = -.01 Xout = 0.20
 SURFACE TYPE: HIGH FLUX

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	616.9	-.02	113.2	10510	116.3	3371
3	616.0	0.01	114.6	10913	115.9	8316
5	615.1	0.04	114.6	11170	115.9	8578
7	614.3	0.07	114.6	11214	116.0	8035
9	613.8	0.10	114.5	10913	115.9	8189
11	613.3	0.13	114.5	11139	115.9	7711
13	612.8	0.16	114.5	11206	115.8	8095
15	612.2	0.19	114.4	11105	115.9	7718

RUN NUMBER: 345 WORKING FLUID: R-113
 p/d = 1.17 G = 108.77 kg/s*m^2
 Pin = 599.1 kPa DELTA P total = 4.92 kPa
 Xin = -.01 Xout = 0.77
 SURFACE TYPE: HIGH FLUX

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	598.5	-.01	110.3	40102	116.7	6328
3	597.5	0.09	113.3	40441	116.0	15175
5	596.5	0.19	113.2	41055	116.0	14871
7	595.7	0.29	113.2	40886	115.9	14800
9	595.4	0.40	113.1	40439	115.9	14373
11	595.0	0.51	113.1	40931	116.2	13268
13	594.7	0.62	113.1	41091	116.2	13078
15	594.2	0.72	113.0	40888	116.2	12983

RUN NUMBER: 342 WORKING FLUID: R-113
 p/d = 1.17 G = 248.19 kg/s*m^2
 Pin = 588.8 kPa DELTA P total = 6.03 kPa
 Xin = 0.02 Xout = 0.28
 SURFACE TYPE: HIGH FLUX

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	588.3	0.02	111.6	31100	117.0	5744
3	587.5	0.05	112.5	31147	115.2	11441
5	586.7	0.09	112.4	31725	114.9	12640
7	585.9	0.12	112.4	30907	115.0	11889
9	585.2	0.16	112.3	30074	114.6	12817
11	584.4	0.20	112.3	31174	114.9	11617
13	583.6	0.23	112.2	31193	115.0	11095
15	582.8	0.26	112.1	31052	114.9	11317

RUN NUMBER: 347 WORKING FLUID: R-113
 p/d = 1.17 G = 93.73 kg/s*m^2
 Pin = 595.2 kPa DELTA P total = 5.23 kPa
 Xin = -.01 Xout = 0.44
 SURFACE TYPE: HIGH FLUX

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	594.7	-.01	109.6	19402	115.3	3409
3	593.8	0.05	112.8	19822	114.8	10043
5	592.8	0.11	112.9	20245	114.8	11045
7	592.1	0.17	112.9	20260	114.8	10704
9	591.6	0.23	112.8	19614	114.6	10804
11	591.1	0.30	112.8	20423	114.7	10522
13	590.6	0.36	112.8	20535	114.8	10093
15	590.1	0.41	112.7	20435	114.9	9568

RUN NUMBER: 344 WORKING FLUID: R-113
 p/d = 1.17 G = 249.48 kg/s*m^2
 Pin = 596.5 kPa DELTA P total = 4.07 kPa
 Xin = 0.00 Xout = 0.09
 SURFACE TYPE: HIGH FLUX

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	596.0	0.00	112.4	9911	114.9	3979
3	595.2	0.01	113.0	10046	114.5	6675
5	594.6	0.02	113.1	10280	114.3	8581
7	594.1	0.03	113.0	10202	114.3	8147
9	593.7	0.05	113.0	9929	114.0	9764
11	593.3	0.06	113.0	10038	114.0	9864
13	592.8	0.07	112.9	10118	114.2	7954
15	592.5	0.08	112.9	9996	114.4	6866

RUN NUMBER: 341 WORKING FLUID: R-113
 p/d = 1.17 G = 250.89 kg/s*m^2
 Pin = 584.2 kPa DELTA P total = 6.07 kPa
 Xin = 0.00 Xout = 0.35
 SURFACE TYPE: HIGH FLUX

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	583.7	0.00	109.9	626	115.4	113
3	582.8	0.05	112.1	42323	115.2	13783
5	581.9	0.09	112.1	43102	114.9	15043
7	581.1	0.14	112.0	42853	114.9	14913
9	580.5	0.19	111.9	42145	114.7	15059
11	579.8	0.24	111.9	43120	114.8	14984
13	579.0	0.28	111.8	43214	114.9	14126
15	578.2	0.33	111.8	43070	114.7	14985

RUN NUMBER: 340 WORKING FLUID: R-113
 p/d = 1.17 G = 249.42 kg/s*m^2
 Pin = 589.9 kPa DELTA P total = 6.02 kPa
 Xin = 0.00 Xout = 0.43
 SURFACE TYPE: HIGH FLUX

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	589.4	0.00	111.2	51483	116.6	9430
3	588.6	0.06	112.6	51311	115.9	15650
5	587.8	0.11	112.5	52004	115.7	16568
7	587.1	0.17	112.5	51452	115.6	16602
9	586.3	0.23	112.4	50177	115.4	16588
11	585.5	0.29	112.4	51167	115.6	15822
13	584.8	0.35	112.3	51297	115.4	16445
15	583.9	0.40	112.2	50934	115.5	15538

RUN NUMBER: 328 WORKING FLUID: R-113
 p/d = 1.17 G = 352.36 kg/s*m^2
 Pin = 577.7 kPa DELTA P total = 4.56 kPa
 Xin = 0.01 Xout = 0.20
 SURFACE TYPE: HIGH FLUX

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	577.4	0.01	111.1	30928	114.6	8838
3	576.8	0.03	111.6	30070	114.2	11788
5	576.2	0.06	111.6	30622	113.8	13799
7	575.6	0.08	111.5	30844	113.8	13776
9	575.0	0.11	111.5	30075	113.8	13333
11	574.4	0.14	111.5	29856	113.7	13553
13	573.8	0.16	111.4	30513	113.6	13918
15	573.3	0.19	111.4	30370	113.5	14406

RUN NUMBER: 330 WORKING FLUID: R-113
 p/d = 1.17 G = 351.23 kg/s*m^2
 Pin = 595.8 kPa DELTA P total = 4.07 kPa
 Xin = 0.01 Xout = 0.36
 SURFACE TYPE: HIGH FLUX

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	595.3	0.01	112.3	59675	117.0	12660
3	594.5	0.05	113.1	59498	116.9	15547
5	593.9	0.10	113.0	60240	117.0	15275
7	593.4	0.14	113.0	59878	116.6	16514
9	593.0	0.20	113.0	59402	116.7	15850
11	592.6	0.24	112.9	59644	116.8	15300
13	592.2	0.29	112.9	59942	116.4	17184
15	591.8	0.34	112.9	59464	116.6	15861

RUN NUMBER: 325 WORKING FLUID: R-113
 p/d = 1.17 G = 346.62 kg/s*m^2
 Pin = 580.8 kPa DELTA P total = 4.54 kPa
 Xin = 0.00 Xout = 0.07
 SURFACE TYPE: HIGH FLUX

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	580.5	0.00	111.0	10733	113.3	4737
3	579.9	0.01	111.6	10444	112.8	9019
5	579.3	0.02	111.9	10573	112.6	11413
7	578.7	0.03	111.8	10731	112.8	10720
9	578.1	0.04	111.8	10463	112.8	10281
11	577.5	0.05	111.7	10360	112.7	10515
13	576.9	0.06	111.7	10595	112.9	9679
15	576.3	0.07	111.6	10598	112.9	8379

RUN NUMBER: 322 WORKING FLUID: R-113
 p/d = 1.17 G = 350.73 kg/s*m^2
 Pin = 576.9 kPa DELTA P total = 4.5 kPa
 Xin = 0.03 Xout = 0.29
 SURFACE TYPE: HIGH FLUX

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	576.6	0.03	111.2	40756	115.3	10059
3	576.0	0.06	111.5	39660	114.7	12350
5	575.4	0.10	111.5	40398	114.3	14376
7	574.8	0.13	111.4	40261	114.2	14548
9	574.2	0.17	111.4	39257	114.8	15530
11	573.6	0.20	111.4	39412	113.7	16892
13	573.0	0.24	111.3	40110	114.0	14982
15	572.4	0.27	111.3	39933	113.9	15435

RUN NUMBER: 331 WORKING FLUID: R-113
 p/d = 1.17 G = 352.56 kg/s*m^2
 Pin = 588.6 kPa DELTA P total = 4.07 kPa
 Xin = 0.01 Xout = 0.42
 SURFACE TYPE: HIGH FLUX

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	588.2	0.01	111.9	71078	117.2	13482
3	587.4	0.06	112.5	70433	117.1	15494
5	586.8	0.11	112.5	71233	116.8	16576
7	586.2	0.17	112.4	71183	116.6	17236
9	585.8	0.23	112.4	70714	116.7	16310
11	585.4	0.29	112.4	70467	116.4	17414
13	585.0	0.34	112.3	70836	116.4	17497
15	584.6	0.40	112.3	70154	116.7	16022

RUN NUMBER: 324 WORKING FLUID: R-113
 p/d = 1.17 G = 350.74 kg/s*m^2
 Pin = 589.4 kPa DELTA P total = 4.55 kPa
 Xin = 0.01 Xout = 0.14
 SURFACE TYPE: HIGH FLUX

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	589.0	0.01	111.7	20819	114.8	6641
3	588.4	0.02	112.5	20192	114.2	12120
5	587.8	0.04	112.5	20576	114.0	12932
7	587.3	0.06	112.5	20771	114.2	12306
9	586.7	0.07	112.4	20239	114.3	10772
11	586.1	0.09	112.4	20174	114.6	10017
13	585.5	0.11	112.4	20624	114.3	10818
15	584.9	0.13	112.3	20569	114.3	10466

RUN NUMBER: 329 WORKING FLUID: R-113
 p/d = 1.17 G = 356 kg/s*m^2
 Pin = 547.1 kPa DELTA P total = 4.54 kPa
 Xin = 0.03 Xout = 0.35
 SURFACE TYPE: HIGH FLUX

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	546.8	0.03	108.9	51789	113.2	11908
3	546.2	0.07	108.6	50400	112.5	12907
5	545.6	0.11	108.6	51419	112.1	14956
7	545.0	0.15	108.7	51268	112.0	15307
9	544.4	0.19	108.7	49966	112.0	15228
11	543.8	0.24	108.8	50240	111.9	15898
13	543.2	0.28	108.8	51140	111.9	16740
15	542.6	0.32	108.9	51043	111.8	17608

RUN NUMBER: 332 WORKING FLUID: R-113
 p/d = 1.17 G = 349.7 kg/s*m^2
 Pin = 591.8 kPa DELTA P total = 4.1 kPa
 Xin = -.01 Xout = 0.47
 SURFACE TYPE: HIGH FLUX

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]
1	591.3	-.01	110.5	81786	117.7	11341
3	590.6	0.05	112.8	80833	117.6	16619
5	590.0	0.11	112.7	81738	117.4	17581
7	589.4	0.18	112.7	81511	117.1	18486
9	589.0	0.25	112.7	81227	117.3	17327
11	588.6	0.32	112.6	80528	117.2	17571
13	588.2	0.38	112.6	81018	116.9	18843
15	587.8	0.44	112.6	80111	117.2	17215

RUN NUMBER: 339 WORKING FLUID: R-113
 p/d = 1.17 G = 451.52 kg/s*m^2
 Pin = 587.5 kPa DELTA P total = 4.05 kPa
 Xin = -0.00 Xout = 0.09
 SURFACE TYPE: HIGH FLUX

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	587.1	-0.00	111.6	19851	114.6	6627
3	586.3	0.01	112.3	20161	114.6	8820
5	585.7	0.02	112.4	20465	114.4	9952
7	585.1	0.04	112.3	20332	114.5	9634
9	584.7	0.05	112.3	19996	114.4	9767
11	584.3	0.06	112.3	20337	114.3	9870
13	583.9	0.07	112.2	20497	114.4	9672
15	583.5	0.09	112.2	20314	114.4	9329

RUN NUMBER: 336 WORKING FLUID: R-113
 p/d = 1.17 G = 448.42 kg/s*m^2
 Pin = 592.1 kPa DELTA P total = 4.04 kPa
 Xin = 0.00 Xout = 0.24
 SURFACE TYPE: HIGH FLUX

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	591.6	0.00	112.1	50145	116.5	11363
3	590.8	0.03	112.8	50382	116.3	14342
5	590.2	0.06	112.7	51031	116.2	14657
7	589.7	0.09	112.7	50770	115.9	15834
9	589.3	0.13	112.7	50287	116.0	14891
11	588.9	0.16	112.6	50467	116.1	14546
13	588.4	0.19	112.6	50767	115.8	15898
15	588.1	0.22	112.6	50443	116.0	14528

RUN NUMBER: 333 WORKING FLUID: R-113
 p/d = 1.17 G = 448.4 kg/s*m^2
 Pin = 591.8 kPa DELTA P total = 4.01 kPa
 Xin = -0.01 Xout = 0.37
 SURFACE TYPE: HIGH FLUX

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	591.3	-0.01	110.5	81786	117.5	11679
3	590.6	0.04	112.8	80833	117.4	17362
5	590.0	0.09	112.7	81738	117.2	18406
7	589.4	0.14	112.7	81511	116.9	19403
9	589.0	0.19	112.7	81227	116.7	19863
11	588.6	0.24	112.6	80528	117.0	18409
13	588.2	0.29	112.6	81018	116.7	19803
15	587.8	0.34	112.6	80111	117.0	18022

RUN NUMBER: 338 WORKING FLUID: R-113
 p/d = 1.17 G = 443.87 kg/s*m^2
 Pin = 590.7 kPa DELTA P total = 4.06 kPa
 Xin = 0.01 Xout = 0.15
 SURFACE TYPE: HIGH FLUX

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	590.2	0.01	112.3	29819	115.3	9832
3	589.4	0.03	112.6	30074	115.2	11920
5	588.8	0.05	112.6	30497	115.1	12300
7	588.3	0.07	112.6	30418	115.0	12584
9	587.9	0.09	112.5	30107	114.8	13109
11	587.5	0.11	112.5	30432	114.8	13565
13	587.1	0.13	112.5	30637	114.8	13527
15	586.7	0.14	112.5	30384	114.9	12455

RUN NUMBER: 335 WORKING FLUID: R-113
 p/d = 1.17 G = 449.93 kg/s*m^2
 Pin = 595.8 kPa DELTA P total = 4.09 kPa
 Xin = 0.01 Xout = 0.28
 SURFACE TYPE: HIGH FLUX

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	595.3	0.01	112.3	59675	116.8	13246
3	594.5	0.04	113.1	59498	116.7	16442
5	593.9	0.08	113.0	60240	116.8	16127
7	593.4	0.11	113.0	59878	116.4	17521
9	593.0	0.15	113.0	59402	116.5	16783
11	592.6	0.19	112.9	59644	116.6	16165
13	592.2	0.23	112.9	59942	116.3	17578
15	591.8	0.26	112.9	59464	116.4	16796

RUN NUMBER: 337 WORKING FLUID: R-113
 p/d = 1.17 G = 447.41 kg/s*m^2
 Pin = 586.5 kPa DELTA P total = 4.05 kPa
 Xin = 0.01 Xout = 0.19
 SURFACE TYPE: HIGH FLUX

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	586.0	0.01	111.9	39674	115.3	11520
3	585.2	0.03	112.3	39997	115.2	14041
5	584.6	0.05	112.3	40563	115.1	14255
7	584.1	0.08	112.2	40207	115.0	14877
9	583.7	0.11	112.2	39765	115.0	14115
11	583.3	0.13	112.2	40186	115.0	14372
13	582.8	0.16	112.2	40461	114.7	15792
15	582.5	0.18	112.1	40154	114.9	14426

RUN NUMBER: 334 WORKING FLUID: R-113
 p/d = 1.17 G = 446.03 kg/s*m^2
 Pin = 588.6 kPa DELTA P total = 4.09 kPa
 Xin = 0.01 Xout = 0.34
 SURFACE TYPE: HIGH FLUX

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	588.2	0.01	111.9	71078	117.4	12969
3	587.4	0.05	112.5	70433	117.3	14814
5	586.8	0.09	112.5	71233	117.0	15808
7	586.2	0.14	112.4	71183	116.8	16407
9	585.8	0.18	112.4	70714	116.9	15561
11	585.4	0.23	112.4	70467	116.6	16561
13	585.0	0.27	112.3	70836	116.6	16640
15	584.6	0.31	112.3	70154	116.9	15294

Bundle Boiling Data

Data obtained in pure R-11

RUN NUMBER: 437
p/d = 1.5
Pin = 202.76 kPa
Xin = 0.00

WORKING FLUID: R-11
G = 52.2 kg/s*m²
DELTA P total = 7.56 kPa
Xout = 0.05

ROW	P	Xin	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]	TYPE
1	202.1	0.00	43.7	5226	45.2	3512	H.F.
3	200.9	0.01	43.6	5295	45.1	3558	H.F.
5	200.1	0.02	43.6	5094	45.0	3763	H.F.
7	199.2	0.02	43.6	5250	47.6	1328	SM.
9	198.2	0.03	43.6	5065	47.3	1390	SM.
11	197.3	0.04	43.6	5174	44.5	5960	T.B.
13	196.3	0.04	43.6	5242	44.3	7312	T.B.
15	195.2	0.05	43.6	5162	44.2	8441	T.B.

RUN NUMBER: 431
p/d = 1.5
Pin = 206.47 kPa
Xin = -.01

WORKING FLUID: R-11
G = 50.41 kg/s*m²
DELTA P total = 10.2 kPa
Xout = 0.29

ROW	P	Xin	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]	TYPE
1	205.8	-.01	42.7	30869	47.4	6675	H.F.
3	204.3	0.03	43.7	30491	47.6	7905	H.F.
5	203.1	0.07	43.7	29909	47.4	8258	H.F.
7	201.8	0.11	43.7	30379	56.9	2304	SM.
9	200.5	0.15	43.7	29369	56.7	2263	SM.
11	199.2	0.19	43.7	30040	48.6	6156	T.B.
13	197.9	0.23	43.7	30110	47.9	7174	T.B.
15	196.3	0.27	43.7	29731	47.1	8970	T.B.

RUN NUMBER: 436
p/d = 1.5
Pin = 205.17 kPa
Xin = 0.00

WORKING FLUID: R-11
G = 56.56 kg/s*m²
DELTA P total = 9.83 kPa
Xout = 0.10

ROW	P	Xin	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]	TYPE
1	204.4	0.00	43.7	10687	45.7	5347	H.F.
3	202.9	0.02	43.6	10792	45.7	5199	H.F.
5	201.7	0.03	43.6	10386	45.5	5585	H.F.
7	200.5	0.04	43.6	10823	51.1	1450	SM.
9	199.3	0.05	43.6	10457	50.5	1518	SM.
11	198.1	0.07	43.6	10303	45.4	5681	T.B.
13	196.9	0.08	43.6	10418	45.2	6372	T.B.
15	195.3	0.09	43.6	10209	45.0	7330	T.B.

RUN NUMBER: 432
p/d = 1.5
Pin = 204.45 kPa
Xin = 0.00

WORKING FLUID: R-11
G = 50.53 kg/s*m²
DELTA P total = 9.22 kPa
Xout = 0.40

ROW	P	Xin	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]	TYPE
1	203.8	0.00	43.1	41556	47.0	10894	H.F.
3	202.5	0.05	43.6	40918	47.2	11312	H.F.
5	201.4	0.10	43.6	40243	46.8	12429	H.F.
7	200.2	0.16	43.6	41239	57.5	2966	SM.
9	199.1	0.21	43.6	39948	57.4	2893	SM.
11	197.9	0.27	43.6	40656	48.2	8740	T.B.
13	196.7	0.32	43.6	40756	48.1	9003	T.B.
15	195.2	0.37	43.6	40167	46.8	12537	T.B.

RUN NUMBER: 430
p/d = 1.5
Pin = 208.42 kPa
Xin = -.00

WORKING FLUID: R-11
G = 54.29 kg/s*m²
DELTA P total = 10.26 kPa
Xout = 0.18

ROW	P	Xin	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]	TYPE
1	207.7	-.00	43.9	20754	46.5	8030	H.F.
3	206.2	0.02	44.0	20511	46.7	7633	H.F.
5	205.0	0.04	44.0	20138	46.5	8066	H.F.
7	203.8	0.07	44.0	20586	54.7	1927	SM.
9	202.5	0.09	44.0	19847	54.3	1928	SM.
11	201.2	0.12	44.0	20494	46.5	8368	T.B.
13	199.9	0.14	44.0	20546	46.6	8198	T.B.
15	198.2	0.17	44.0	20278	46.0	10180	T.B.

RUN NUMBER: 433
p/d = 1.5
Pin = 208.17 kPa
Xin = -.01

WORKING FLUID: R-11
G = 51.25 kg/s*m²
DELTA P total = 9.62 kPa
Xout = 0.48

ROW	P	Xin	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]	TYPE
1	207.5	-.01	43.9	51344	48.4	11464	H.F.
3	206.0	0.05	44.1	50549	48.6	11376	H.F.
5	204.9	0.12	44.1	49695	48.1	12627	H.F.
7	203.7	0.18	44.1	50686	59.9	3228	SM.
9	202.4	0.25	44.1	49207	59.8	3138	SM.
11	201.2	0.32	44.1	50329	49.7	9014	T.B.
13	200.0	0.38	44.1	50348	49.7	9104	T.B.
15	198.6	0.44	44.1	49906	48.2	12362	T.B.

RUN NUMBER: 434
p/d = 1.5
Pin = 214.7 kPa
Xin = -.01

WORKING FLUID: R-11
G = 60.05 kg/s*m²
DELTA P total = 9.82 kPa
Xout = 0.49

ROW	P	Xin	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]	TYPE
1	214.0	-.01	44.2	61922	49.5	11763	H.F.
3	212.5	0.05	45.2	60833	49.7	13442	H.F.
5	211.3	0.12	45.2	59902	49.1	15182	H.F.
7	210.2	0.19	45.2	61313	60.6	3971	SM.
9	209.0	0.26	45.2	59603	60.6	3862	SM.
11	207.7	0.33	45.2	60364	51.6	9348	T.B.
13	206.5	0.39	45.2	60410	51.7	9294	T.B.
15	204.9	0.46	45.2	60002	50.2	11968	T.B.

RUN NUMBER: 427
p/d = 1.5
Pin = 192.29 kPa
Xin = -.00

WORKING FLUID: R-11
G = 110.68 kg/s*m²
DELTA P total = 1.16 kPa
Xout = 0.05

ROW	P	Xin	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]	TYPE
1	192.2	-.00	42.8	10538	46.2	3088	H.F.
3	192.0	0.01	43.2	10490	46.2	3529	H.F.
5	191.9	0.01	43.2	10293	45.9	3777	H.F.
7	191.7	0.02	43.1	10633	51.5	1280	SM.
9	191.6	0.02	43.1	10254	50.8	1329	SM.
11	191.5	0.03	43.1	10454	45.6	4165	T.B.
13	191.3	0.04	43.1	10486	45.7	4051	T.B.
15	191.1	0.04	43.0	10338	45.4	4347	T.B.

RUN NUMBER: 435
p/d = 1.5
Pin = 224.45 kPa
Xin = -.02

WORKING FLUID: R-11
G = 57.56 kg/s*m²
DELTA P total = 11.1 kPa
Xout = 0.58

ROW	P	Xin	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]	TYPE
1	223.6	-.02	44.4	71705	51.6	9821	H.F.
3	221.9	0.06	46.5	70519	51.9	13006	H.F.
5	220.5	0.14	46.5	69261	51.2	14654	H.F.
7	219.2	0.22	46.5	70391	62.8	4322	SM.
9	217.8	0.31	46.5	68463	62.8	4189	SM.
11	216.4	0.39	46.5	67714	54.8	8173	T.B.
13	215.1	0.47	46.5	67837	54.3	8671	T.B.
15	213.4	0.54	46.5	67566	52.8	10677	T.B.

RUN NUMBER: 426
p/d = 1.5
Pin = 191.68 kPa
Xin = -.00

WORKING FLUID: R-11
G = 109.93 kg/s*m²
DELTA P total = 1.18 kPa
Xout = 0.09

ROW	P	Xin	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]	TYPE
1	191.6	-.00	42.3	20823	46.2	5414	H.F.
3	191.4	0.01	43.1	20573	46.1	6922	H.F.
5	191.3	0.02	43.1	20193	45.8	7269	H.F.
7	191.1	0.04	43.0	20724	54.5	1808	SM.
9	191.0	0.05	43.0	20015	54.0	1822	SM.
11	190.8	0.06	43.0	20547	46.1	6691	T.B.
13	190.7	0.07	43.0	20608	46.0	6816	T.B.
15	190.5	0.09	42.9	20337	45.5	7821	T.B.

RUN NUMBER: 428
p/d = 1.5
Pin = 193 kPa
Xin = 0.00

WORKING FLUID: R-11
G = 110.35 kg/s*m²
DELTA P total = 1.17 kPa
Xout = 0.02

ROW	P	Xin	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]	TYPE
1	192.9	0.00	42.9	5172	45.0	2548	H.F.
3	192.8	0.01	43.2	5173	45.0	2945	H.F.
5	192.6	0.01	43.3	5055	44.9	3193	H.F.
7	192.5	0.01	43.3	5191	47.2	1309	SM.
9	192.3	0.01	43.2	5005	46.9	1370	SM.
11	192.2	0.02	43.2	5103	44.5	4013	T.B.
13	192.0	0.02	43.2	5117	44.2	5165	T.B.
15	191.8	0.02	43.2	5035	44.0	5940	T.B.

RUN NUMBER: 420
p/d = 1.5
Pin = 206.76 kPa
Xin = -.01

WORKING FLUID: R-11
G = 103.86 kg/s*m²
DELTA P total = 8.39 kPa
Xout = 0.13

ROW	P	Xin	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]	TYPE
1	206.2	-.01	43.1	30568	47.9	6346	H.F.
3	205.1	0.01	44.1	30106	47.5	8751	H.F.
5	204.1	0.03	44.1	29700	47.3	9426	H.F.
7	203.1	0.04	44.1	30478	56.0	2560	SM.
9	202.1	0.06	44.1	29527	55.8	2524	SM.
11	201.0	0.08	44.1	30466	47.2	9733	T.B.
13	199.8	0.10	44.1	30267	47.1	9994	T.B.
15	198.4	0.12	44.1	30009	46.5	12450	T.B.

RUN NUMBER: 421
p/d = 1.5
Pin = 210.27 kPa
Xin = -.01

WORKING FLUID: R-11
G = 105.17 kg/s*m^2
DELTA P total = 1.15 kPa
Xout = 0.18

ROW	P	Xin	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]	TYPE
1	210.2	-.01	44.3	41234	49.3	8131	H.F.
3	210.0	0.01	46.1	40498	48.9	14660	H.F.
5	209.9	0.04	46.1	39953	48.4	17241	H.F.
7	209.7	0.07	46.1	40539	58.1	3367	SM.
9	209.6	0.09	46.1	39337	58.0	3305	SM.
11	209.4	0.12	46.0	40474	49.5	11749	T.B.
13	209.3	0.14	46.0	40171	49.1	12944	T.B.
15	209.1	0.17	46.0	39959	48.2	18168	T.B.

RUN NUMBER: 424
p/d = 1.5
Pin = 201.24 kPa
Xin = 0.01

WORKING FLUID: R-11
G = 100.61 kg/s*m^2
DELTA P total = 1.21 kPa
Xout = 0.36

ROW	P	Xin	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]	TYPE
1	201.2	0.01	44.3	72211	49.8	13104	H.F.
3	201.0	0.06	44.7	70957	49.5	14819	H.F.
5	200.8	0.10	44.7	69821	48.6	17599	H.F.
7	200.7	0.15	44.6	71373	60.5	4490	SM.
9	200.5	0.20	44.6	69377	60.4	4395	SM.
11	200.4	0.25	44.6	70929	51.7	9905	T.B.
13	200.2	0.29	44.6	70997	51.2	10668	T.B.
15	200.0	0.34	44.5	70548	49.9	13069	T.B.

RUN NUMBER: 422
p/d = 1.5
Pin = 204 kPa
Xin = -.00

WORKING FLUID: R-11
G = 103.34 kg/s*m^2
DELTA P total = 1.18 kPa
Xout = 0.24

ROW	P	Xin	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]	TYPE
1	203.9	-.00	44.2	51534	48.9	10834	H.F.
3	203.8	0.03	45.1	50581	48.5	15061	H.F.
5	203.6	0.06	45.1	49849	48.0	17301	H.F.
7	203.5	0.09	45.1	51052	58.6	3769	SM.
9	203.3	0.13	45.1	49628	58.4	3713	SM.
11	203.1	0.16	45.0	50807	49.6	11017	T.B.
13	203.0	0.19	45.0	50487	49.3	11762	T.B.
15	202.8	0.22	45.0	50307	48.1	16273	T.B.

RUN NUMBER: 425
p/d = 1.5
Pin = 203.1 kPa
Xin = 0.00

WORKING FLUID: R-11
G = 101.29 kg/s*m^2
DELTA P total = 1.17 kPa
Xout = 0.40

ROW	P	Xin	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]	TYPE
1	203.0	0.00	44.1	82016	50.1	13755	H.F.
3	202.9	0.05	45.0	80810	49.7	17170	H.F.
5	202.7	0.11	45.0	79300	48.8	20612	H.F.
7	202.5	0.16	44.9	81255	61.1	5030	SM.
9	202.4	0.21	44.9	78954	60.9	4936	SM.
11	202.2	0.27	44.9	80266	52.3	10845	T.B.
13	202.1	0.32	44.9	80522	51.8	11578	T.B.
15	201.9	0.37	44.8	79807	50.5	14117	T.B.

RUN NUMBER: 423
p/d = 1.5
Pin = 202.45 kPa
Xin = 0.01

WORKING FLUID: R-11
G = 96.5 kg/s*m^2
DELTA P total = 1.15 kPa
Xout = 0.32

ROW	P	Xin	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]	TYPE
1	202.4	0.01	44.2	61508	49.4	11881	H.F.
3	202.2	0.05	44.9	60324	49.0	14573	H.F.
5	202.1	0.09	44.9	59449	48.4	16722	H.F.
7	201.9	0.13	44.8	61120	59.7	4127	SM.
9	201.8	0.17	44.8	59453	59.5	4056	SM.
11	201.6	0.21	44.8	60420	50.7	10230	T.B.
13	201.5	0.26	44.8	60259	50.3	10852	T.B.
15	201.3	0.30	44.7	60001	49.0	14024	T.B.

RUN NUMBER: 446
p/d = 1.5
Pin = 199.89 kPa
Xin = -.00

WORKING FLUID: R-11
G = 228.92 kg/s*m^2
DELTA P total = 6.01 kPa
Xout = 0.01

ROW	P	Xin	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]	TYPE
1	199.5	-.00	43.4	5058	45.7	2166	H.F.
3	198.7	-.00	43.4	5076	45.6	2305	H.F.
5	197.9	0.00	43.4	4919	45.5	2396	H.F.
7	197.1	0.00	43.4	5079	47.6	1214	SM.
9	196.3	0.00	43.4	4899	47.4	1235	SM.
11	195.5	0.00	43.4	4999	45.0	3134	T.B.
13	194.7	0.01	43.4	5038	44.9	3458	T.B.
15	193.9	0.01	43.4	4937	44.7	3813	T.B.

RUN NUMBER: 445
p/d = 1.5
Pin = 197.67 kPa
Xin = -.00

WORKING FLUID: R-11
G = 227.78 kg/s*m^2
DELTA P total = 6.12 kPa
Xout = 0.02

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	197.3	-.00	42.9	10573	45.7	3789	H.F.
3	196.5	0.00	43.0	10612	45.6	4131	H.F.
5	195.6	0.01	43.0	10287	45.4	4374	H.F.
7	194.8	0.01	43.0	10630	50.5	1424	SM.
9	194.0	0.01	43.0	10265	50.1	1452	SM.
11	193.2	0.02	43.0	10383	44.3	8104	T.B.
13	192.4	0.02	43.0	10466	45.1	5128	T.B.
15	191.6	0.02	43.0	10212	44.9	5593	T.B.

RUN NUMBER: 440
p/d = 1.5
Pin = 206.84 kPa
Xin = -.00

WORKING FLUID: R-11
G = 228.6 kg/s*m^2
DELTA P total = 6.2 kPa
Xout = 0.08

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	206.5	-.00	44.1	41118	49.1	8209	H.F.
3	205.6	0.01	44.6	40577	48.8	9570	H.F.
5	204.8	0.02	44.6	39738	48.1	11140	H.F.
7	203.9	0.03	44.6	40783	58.2	2988	SM.
9	203.1	0.04	44.6	39518	58.2	2897	SM.
11	202.3	0.06	44.6	40166	49.0	8971	T.B.
13	201.5	0.07	44.6	40249	48.9	9349	T.B.
15	200.6	0.08	44.6	39782	48.0	11722	T.B.

RUN NUMBER: 438
p/d = 1.5
Pin = 199.77 kPa
Xin = -.00

WORKING FLUID: R-11
G = 231.91 kg/s*m^2
DELTA P total = -.72 kPa
Xout = 0.04

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	200.0	-.00	43.8	20827	48.2	4730	H.F.
3	200.3	0.01	44.7	20818	48.1	6238	H.F.
5	200.2	0.01	44.7	20276	47.5	7383	H.F.
7	200.2	0.02	44.7	20778	54.8	2054	SM.
9	200.1	0.02	44.7	20095	54.6	2023	SM.
11	200.0	0.03	44.7	20415	47.1	8545	T.B.
13	200.0	0.04	44.7	20575	47.2	8404	T.B.
15	200.5	0.04	44.7	20268	46.8	9904	T.B.

RUN NUMBER: 441
p/d = 1.5
Pin = 208.31 kPa
Xin = -.00

WORKING FLUID: R-11
G = 229.38 kg/s*m^2
DELTA P total = 6.21 kPa
Xout = 0.11

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	207.9	-.00	44.3	51628	49.7	9548	H.F.
3	207.1	0.01	44.8	50827	49.6	10698	H.F.
5	206.3	0.03	44.8	49869	48.8	12401	H.F.
7	205.4	0.04	44.8	51127	59.6	3464	SM.
9	204.6	0.06	44.8	49655	59.6	3364	SM.
11	203.8	0.07	44.8	50850	50.4	9143	T.B.
13	203.0	0.09	44.8	50834	50.0	9747	T.B.
15	202.1	0.10	44.8	50522	48.9	12443	T.B.

RUN NUMBER: 439
p/d = 1.5
Pin = 207.85 kPa
Xin = -.00

WORKING FLUID: R-11
G = 229.85 kg/s*m^2
DELTA P total = 6.18 kPa
Xout = 0.06

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	207.5	-.00	44.1	30990	48.7	6653	H.F.
3	206.6	0.00	44.7	30654	48.5	8208	H.F.
5	205.8	0.01	44.7	29883	47.8	9641	H.F.
7	205.0	0.02	44.7	30586	56.9	2523	SM.
9	204.2	0.03	44.7	29635	56.8	2461	SM.
11	203.4	0.04	44.7	30321	48.2	8614	T.B.
13	202.6	0.05	44.7	30470	48.0	9203	T.B.
15	201.7	0.06	44.7	30052	47.4	11416	T.B.

RUN NUMBER: 442
p/d = 1.5
Pin = 207.78 kPa
Xin = -.00

WORKING FLUID: R-11
G = 228.85 kg/s*m^2
DELTA P total = 6.18 kPa
Xout = 0.13

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	207.4	-.00	44.1	60731	50.0	10314	H.F.
3	206.5	0.01	44.7	59583	49.7	11940	H.F.
5	205.7	0.03	44.7	58662	48.9	13909	H.F.
7	204.9	0.05	44.7	59870	60.2	3874	SM.
9	204.1	0.07	44.7	58180	60.2	3766	SM.
11	203.3	0.08	44.7	59482	50.8	9842	T.B.
13	202.5	0.10	44.7	59505	50.5	10266	T.B.
15	201.6	0.12	44.7	59312	49.3	12980	T.B.

RUN NUMBER: 443
p/d = 1.5
Pin = 213.97 kPa
Xin = -.01

WORKING FLUID: R-11
G = 225.38 kg/s*m²
DELTA P total = 6.2 kPa
Xout = 0.15

ROW	P	Xin	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]	TYPE
1	213.6	-.01	44.5	72317	51.5	10379	H.F.
3	212.7	0.01	45.7	71136	51.3	12680	H.F.
5	211.9	0.03	45.7	69894	50.3	15135	H.F.
7	211.1	0.05	45.7	71318	61.9	4410	SM.
9	210.2	0.07	45.7	69328	61.9	4295	SM.
11	209.4	0.10	45.7	70473	52.7	10037	T.B.
13	208.6	0.12	45.7	70671	52.5	10438	T.B.
15	207.8	0.14	45.7	70195	51.2	12828	T.B.

RUN NUMBER: 454
p/d = 1.5
Pin = 202.92 kPa
Xin = 0.01

WORKING FLUID: R-11
G = 354.79 kg/s*m²
DELTA P total = 6.64 kPa
Xout = 0.02

ROW	P	Xin	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]	TYPE
1	202.5	0.01	44.1	10707	46.1	5519	H.F.
3	201.5	0.01	43.8	10875	46.0	4997	H.F.
5	200.7	0.01	43.8	10625	45.8	5334	H.F.
7	199.8	0.01	43.8	10883	50.6	1595	SM.
9	198.9	0.01	43.8	10509	50.2	1640	SM.
11	198.1	0.02	43.8	10846	45.5	6506	T.B.
13	197.2	0.02	43.8	10880	45.5	6604	T.B.
15	196.3	0.02	43.8	10727	45.3	7295	T.B.

RUN NUMBER: 444
p/d = 1.5
Pin = 214.39 kPa
Xin = -.01

WORKING FLUID: R-11
G = 224.21 kg/s*m²
DELTA P total = 6.31 kPa
Xout = 0.17

ROW	P	Xin	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]	TYPE
1	214.0	-.01	44.7	82241	51.9	11425	H.F.
3	213.1	0.01	45.8	81006	51.7	13512	H.F.
5	212.3	0.04	45.8	79541	50.7	16110	H.F.
7	211.5	0.06	45.8	80550	62.5	4827	SM.
9	210.6	0.09	45.8	78261	62.4	4705	SM.
11	209.8	0.11	45.8	80476	53.6	10240	T.B.
13	209.0	0.14	45.8	80893	53.2	10826	T.B.
15	208.1	0.16	45.8	80032	52.0	12861	T.B.

RUN NUMBER: 447
p/d = 1.5
Pin = 204.47 kPa
Xin = 0.00

WORKING FLUID: R-11
G = 353.28 kg/s*m²
DELTA P total = 7.25 kPa
Xout = 0.02

ROW	P	Xin	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]	TYPE
1	204.0	0.00	44.0	20669	46.7	7815	H.F.
3	202.9	0.01	44.0	20521	46.6	7714	H.F.
5	202.0	0.01	44.0	20047	46.3	8644	H.F.
7	201.1	0.01	44.0	20460	54.0	2041	SM.
9	200.1	0.01	44.0	19762	53.6	2045	SM.
11	199.2	0.02	44.0	20322	46.6	7708	T.B.
13	198.3	0.02	44.0	20447	46.3	8654	T.B.
15	197.2	0.02	44.0	20066	46.0	9906	T.B.

RUN NUMBER: 455
p/d = 1.5
Pin = 202.48 kPa
Xin = 0.01

WORKING FLUID: R-11
G = 355.79 kg/s*m²
DELTA P total = 6.77 kPa
Xout = 0.01

ROW	P	Xin	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]	TYPE
1	202.0	0.01	44.1	5292	45.7	3175	H.F.
3	201.0	0.01	43.7	5347	45.6	2771	H.F.
5	200.2	0.01	43.7	5217	45.5	2907	H.F.
7	199.3	0.01	43.7	5417	47.7	1350	SM.
9	198.4	0.01	43.7	5215	47.5	1377	SM.
11	197.5	0.01	43.7	5234	45.0	3957	T.B.
13	196.7	0.01	43.7	5249	44.9	4331	T.B.
15	195.7	0.01	43.7	5168	44.8	4857	T.B.

RUN NUMBER: 448
p/d = 1.5
Pin = 209.68 kPa
Xin = 0.00

WORKING FLUID: R-11
G = 351.06 kg/s*m²
DELTA P total = 7.09 kPa
Xout = 0.03

ROW	P	Xin	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]	TYPE
1	209.2	0.00	44.7	30752	48.2	8763	H.F.
3	208.2	0.01	44.9	30462	48.2	9195	H.F.
5	207.3	0.01	44.9	29761	47.7	10397	H.F.
7	206.4	0.02	44.9	30715	57.3	2471	SM.
9	205.4	0.02	44.9	29715	57.2	2414	SM.
11	204.5	0.02	44.9	30208	48.4	8539	T.B.
13	203.6	0.02	44.9	30388	48.2	9147	T.B.
15	202.6	0.03	44.9	29853	47.6	10795	T.B.

RUN NUMBER: 449
p/d = 1.5
Pin = 214.88 kPa
Xin = -.00

WORKING FLUID: R-11
G = 350.69 kg/s*m²
DELTA P total = 6.87 kPa
Xout = 0.04

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m ²]	Tw [C]	h [W/m ² C]	SURF TYPE
1	214.4	-.00	45.2	41295	49.4	9641	H.F.
3	213.5	0.00	45.7	40777	49.4	11085	H.F.
5	212.6	0.01	45.7	40039	48.9	12803	H.F.
7	211.7	0.02	45.7	40736	59.3	3007	SM.
9	210.8	0.02	45.7	39439	59.3	2917	SM.
11	209.9	0.02	45.7	40348	49.9	9704	T.B.
13	209.0	0.03	45.7	40485	49.7	10326	T.B.
15	208.0	0.03	45.7	39940	48.9	12540	T.B.

RUN NUMBER: 452
p/d = 1.5
Pin = 239.95 kPa
Xin = -.01

WORKING FLUID: R-11
G = 344.16 kg/s*m²
DELTA P total = 4.99 kPa
Xout = 0.07

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m ²]	Tw [C]	h [W/m ² C]	SURF TYPE
1	239.7	-.01	48.9	71934	55.6	10762	H.F.
3	239.0	0.01	49.9	70814	55.6	12365	H.F.
5	238.3	0.02	49.9	69583	54.8	14286	H.F.
7	237.7	0.03	49.9	70918	65.3	4597	SM.
9	237.0	0.03	49.9	68886	65.3	4457	SM.
11	236.3	0.04	49.9	70071	56.7	10293	T.B.
13	235.6	0.05	49.9	70332	56.6	10581	T.B.
15	235.0	0.06	49.9	69893	55.6	12179	T.B.

RUN NUMBER: 450
p/d = 1.5
Pin = 221.23 kPa
Xin = -.00

WORKING FLUID: R-11
G = 348.67 kg/s*m²
DELTA P total = 6.37 kPa
Xout = 0.05

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m ²]	Tw [C]	h [W/m ² C]	SURF TYPE
1	220.8	-.00	46.2	51624	51.3	10014	H.F.
3	220.0	0.01	46.8	50808	51.3	11307	H.F.
5	219.1	0.02	46.8	49942	50.7	12930	H.F.
7	218.3	0.02	46.8	50922	61.5	3474	SM.
9	217.4	0.02	46.8	49357	61.5	3360	SM.
11	216.6	0.03	46.8	50357	52.0	9694	T.B.
13	215.8	0.03	46.8	50513	51.8	10165	T.B.
15	214.9	0.04	46.8	50100	51.0	12097	T.B.

RUN NUMBER: 453
p/d = 1.5
Pin = 251.67 kPa
Xin = -.00

WORKING FLUID: R-11
G = 344.96 kg/s*m²
DELTA P total = 4.53 kPa
Xout = 0.08

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m ²]	Tw [C]	h [W/m ² C]	SURF TYPE
1	251.4	-.00	50.8	82009	57.6	12058	H.F.
3	250.8	0.01	51.6	80868	57.7	13391	H.F.
5	250.1	0.03	51.6	79405	56.7	15629	H.F.
7	249.5	0.04	51.6	80813	67.1	5234	SM.
9	248.9	0.04	51.6	78512	67.1	5093	SM.
11	248.3	0.05	51.6	80150	59.1	10726	T.B.
13	247.7	0.06	51.6	80626	58.8	11215	T.B.
15	247.1	0.07	51.6	79905	57.9	12729	T.B.

RUN NUMBER: 451
p/d = 1.5
Pin = 229.51 kPa
Xin = -.01

WORKING FLUID: R-11
G = 346.24 kg/s*m²
DELTA P total = 6.06 kPa
Xout = 0.05

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m ²]	Tw [C]	h [W/m ² C]	SURF TYPE
1	229.1	-.01	47.1	62196	53.3	10006	H.F.
3	228.3	0.00	48.1	61184	53.3	11766	H.F.
5	227.5	0.02	48.2	60195	52.6	13523	H.F.
7	226.7	0.02	48.2	61470	63.4	4023	SM.
9	225.9	0.02	48.2	59708	63.5	3900	SM.
11	225.1	0.03	48.2	60782	54.3	9863	T.B.
13	224.3	0.04	48.2	60949	54.1	10226	T.B.
15	223.5	0.05	48.2	60607	53.2	12090	T.B.

RUN NUMBER: 475
p/d = 1.5
Pin = 535.23 kPa
Xin = 0.08

WORKING FLUID: R-11
G = 52.04 kg/s*m²
DELTA P total = 6.1 kPa
Xout = 0.13

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m ²]	Tw [C]	h [W/m ² C]	SURF TYPE
1	534.8	0.08	80.3	5298	86.6	845	H.F.
3	533.9	0.08	80.6	5273	86.6	878	H.F.
5	533.1	0.09	80.6	5133	86.1	945	H.F.
7	532.2	0.10	80.6	5349	87.2	817	SM.
9	531.4	0.11	80.6	5203	87.1	801	SM.
11	530.6	0.11	80.6	5239	84.8	1248	T.B.
13	529.9	0.12	80.6	5261	84.7	1293	T.B.
15	529.1	0.13	80.6	5140	84.6	1293	T.B.

RUN NUMBER: 484
p/d = 1.5
Pin = 600.67 kPa
Xin = 0.01

WORKING FLUID: R-11
G = 51.89 kg/s*m²
DELTA P total = 7.32 kPa
Xout = 0.11

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m ²]	Tw [C]	h [W/m ² C]	SURF TYPE
1	600.2	0.01	84.8	10437	86.7	5528	H.F.
3	599.0	0.02	85.9	10386	86.9	9929	H.F.
5	598.1	0.03	85.8	10155	86.8	10077	H.F.
7	597.1	0.05	85.8	10469	89.7	2625	SM.
9	596.1	0.06	85.7	10079	89.7	2522	SM.
11	595.2	0.08	85.6	10182	87.3	5984	T.B.
13	594.3	0.09	85.6	10228	87.1	6812	T.B.
15	593.4	0.11	85.5	10039	86.8	8084	T.B.

RUN NUMBER: 480
p/d = 1.5
Pin = 603.16 kPa
Xin = -.01

WORKING FLUID: R-11
G = 54.05 kg/s*m²
DELTA P total = 7.38 kPa
Xout = 0.45

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m ²]	Tw [C]	h [W/m ² C]	SURF TYPE
1	602.7	-.01	83.6	43696	88.3	9307	H.F.
3	601.6	0.05	86.1	43236	89.7	12083	H.F.
5	600.7	0.11	86.0	42450	89.4	12702	H.F.
7	599.7	0.17	86.0	43231	94.6	4987	SM.
9	598.7	0.23	85.9	41866	94.8	4712	SM.
11	597.8	0.30	85.8	43092	90.4	9380	T.B.
13	596.8	0.36	85.8	43308	90.3	9488	T.B.
15	595.8	0.42	85.7	42673	90.0	9989	T.B.

RUN NUMBER: 482
p/d = 1.5
Pin = 609.43 kPa
Xin = -.00

WORKING FLUID: R-11
G = 52.07 kg/s*m²
DELTA P total = 7.25 kPa
Xout = 0.24

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m ²]	Tw [C]	h [W/m ² C]	SURF TYPE
1	608.9	-.00	84.9	21901	88.2	6679	H.F.
3	607.8	0.03	86.5	21791	88.7	10231	H.F.
5	606.9	0.06	86.5	21327	88.6	10084	H.F.
7	605.9	0.09	86.4	21744	92.5	3537	SM.
9	604.9	0.13	86.3	20952	92.5	3378	SM.
11	604.0	0.16	86.3	21114	88.7	8541	T.B.
13	603.1	0.19	86.2	21222	88.6	8753	T.B.
15	602.2	0.22	86.1	20851	88.3	9862	T.B.

RUN NUMBER: 479
p/d = 1.5
Pin = 611.59 kPa
Xin = 0.00

WORKING FLUID: R-11
G = 50.42 kg/s*m²
DELTA P total = 6.92 kPa
Xout = 0.55

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m ²]	Tw [C]	h [W/m ² C]	SURF TYPE
1	611.0	0.00	86.3	51428	92.0	8939	H.F.
3	609.9	0.08	86.6	50483	90.8	11817	H.F.
5	608.8	0.15	86.5	49731	90.4	12625	H.F.
7	607.9	0.22	86.5	50575	96.1	5248	SM.
9	607.1	0.30	86.4	49991	96.0	5214	SM.
11	606.3	0.37	86.4	49680	91.7	9356	T.B.
13	605.5	0.44	86.4	49822	91.6	9474	T.B.
15	604.7	0.51	86.3	49604	90.8	10985	T.B.

RUN NUMBER: 481
p/d = 1.5
Pin = 587.75 kPa
Xin = 0.90

WORKING FLUID: R-11
G = 53.74 kg/s*m²
DELTA P total = 7.92 kPa
Xout = 1.20

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m ²]	Tw [C]	h [W/m ² C]	SURF TYPE
1	587.2	0.90	84.0	30360	87.8	8059	H.F.
3	586.0	0.94	84.9	30020	87.9	10062	H.F.
5	585.0	0.98	84.9	29403	87.6	10754	H.F.
7	583.9	1.02	84.8	30064	91.5	4516	SM.
9	582.9	1.06	84.7	29070	91.5	4314	SM.
11	581.9	1.10	84.7	29831	88.2	8364	T.B.
13	581.0	1.14	84.6	29973	88.2	8338	T.B.
15	579.8	1.18	84.5	29540	87.7	9216	T.B.

RUN NUMBER: 478
p/d = 1.5
Pin = 577.78 kPa
Xin = 0.02

WORKING FLUID: R-11
G = 48.21 kg/s*m²
DELTA P total = 7.25 kPa
Xout = 0.69

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m ²]	Tw [C]	h [W/m ² C]	SURF TYPE
1	577.2	0.02	83.4	61139	88.9	11111	H.F.
3	576.0	0.11	84.2	60149	89.1	12365	H.F.
5	574.9	0.19	84.1	59184	88.6	13353	H.F.
7	573.9	0.29	84.1	60417	94.2	5951	SM.
9	573.0	0.38	84.0	59744	94.2	5888	SM.
11	572.2	0.47	83.9	59465	90.2	9447	T.B.
13	571.4	0.56	83.9	59762	90.1	9575	T.B.
15	570.5	0.65	83.8	59326	89.1	11184	T.B.

RUN NUMBER: 464
p/d = 1.5
Pin = 590.19 kPa
Xin = 0.01

WORKING FLUID: R-11
G = 98.53 kg/s*m²
DELTA P total = 6.07 kPa
Xout = 0.07

ROW	P	Xin	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]	TYPE
1	589.8	0.01	84.1	10746	85.9	6017	H.F.
3	588.9	0.01	84.8	10694	85.8	10504	H.F.
5	588.1	0.02	84.8	10456	85.8	10564	H.F.
7	587.3	0.03	84.8	10778	88.8	2698	SM.
9	586.5	0.04	84.8	10376	88.9	2542	SM.
11	585.7	0.05	84.8	10483	86.5	6085	T.B.
13	584.9	0.05	84.8	10530	86.2	7520	T.B.
15	584.1	0.06	84.8	10335	86.1	8133	T.B.

RUN NUMBER: 477
p/d = 1.5
Pin = 585.91 kPa
Xin = 0.00

WORKING FLUID: R-11
G = 52.86 kg/s*m²
DELTA P total = 7.62 kPa
Xout = 0.72

ROW	P	Xin	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]	TYPE
1	585.4	0.00	83.4	71738	89.8	11218	H.F.
3	584.2	0.10	84.8	70662	90.1	13399	H.F.
5	583.2	0.19	84.8	69393	89.7	14112	H.F.
7	582.2	0.29	84.7	70763	95.5	6563	SM.
9	581.2	0.39	84.6	68696	94.9	6653	SM.
11	580.3	0.49	84.5	69915	91.4	10153	T.B.
13	579.3	0.58	84.5	70337	91.3	10258	T.B.
15	578.3	0.68	84.4	69741	90.5	11492	T.B.

RUN NUMBER: 463
p/d = 1.5
Pin = 598.6 kPa
Xin = -.00

WORKING FLUID: R-11
G = 98.87 kg/s*m²
DELTA P total = 7.27 kPa
Xout = 0.11

ROW	P	Xin	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]	TYPE
1	598.1	-.00	84.1	20652	87.3	6472	H.F.
3	597.0	0.01	85.3	20548	87.3	10230	H.F.
5	596.0	0.03	85.3	20110	87.2	10723	H.F.
7	595.0	0.04	85.3	20508	91.0	3608	SM.
9	594.1	0.06	85.3	19761	91.0	3492	SM.
11	593.1	0.08	85.3	19913	88.2	7046	T.B.
13	592.3	0.09	85.3	20015	87.8	8021	T.B.
15	591.3	0.11	85.3	19666	87.4	9370	T.B.

RUN NUMBER: 476
p/d = 1.5
Pin = 600.4 kPa
Xin = 0.00

WORKING FLUID: R-11
G = 52.15 kg/s*m²
DELTA P total = 7.48 kPa
Xout = 0.83

ROW	P	Xin	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]	TYPE
1	599.9	0.00	84.2	81198	91.5	11231	H.F.
3	598.7	0.10	85.9	80337	91.8	13663	H.F.
5	597.7	0.19	85.8	78679	91.3	14303	H.F.
7	596.6	0.29	85.7	80366	97.1	7057	SM.
9	595.6	0.40	85.7	79450	97.0	7008	SM.
11	594.7	0.50	85.6	79508	93.8	9732	T.B.
13	593.9	0.60	85.5	80092	93.5	10063	T.B.
15	592.9	0.69	85.5	79034	92.1	11902	T.B.

RUN NUMBER: 457
p/d = 1.5
Pin = 577.41 kPa
Xin = 0.01

WORKING FLUID: R-11
G = 102.03 kg/s*m²
DELTA P total = 7.95 kPa
Xout = 0.17

ROW	P	Xin	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]	TYPE
1	576.9	0.01	83.2	31262	87.9	6703	H.F.
3	575.7	0.03	83.7	30912	86.8	10128	H.F.
5	574.6	0.05	83.7	30277	86.5	10999	H.F.
7	573.6	0.07	83.7	30956	90.4	4602	SM.
9	572.6	0.10	83.7	29932	90.6	4357	SM.
11	571.6	0.12	83.7	30716	87.4	8397	T.B.
13	570.6	0.14	83.7	30862	87.3	8501	T.B.
15	569.5	0.16	83.7	30417	86.9	9403	T.B.

RUN NUMBER: 456
p/d = 1.5
Pin = 591.5 kPa
Xin = 0.01

WORKING FLUID: R-11
G = 98 kg/s*m²
DELTA P total = 5.98 kPa
Xout = 0.04

ROW	P	Xin	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]	TYPE
1	591.1	0.01	84.5	5331	86.0	3753	H.F.
3	590.2	0.01	84.9	5308	85.8	5909	H.F.
5	589.4	0.02	84.9	5185	85.8	5597	H.F.
7	588.6	0.02	84.9	5338	88.0	1725	SM.
9	587.8	0.03	84.9	5138	88.0	1652	SM.
11	587.1	0.03	84.9	5244	85.8	5740	T.B.
13	586.3	0.03	84.9	5266	85.8	6276	T.B.
15	585.5	0.04	84.9	5165	85.6	7239	T.B.

RUN NUMBER: 458
p/d = 1.5
Pin = 592.43 kPa
Xin = -.01

WORKING FLUID: R-11
G = 102.63 kg/s*m²
DELTA P total = 7.41 kPa
Xout = 0.21

ROW	P	Xin	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]	TYPE
1	591.9	-.01	82.8	41193	88.1	7823	H.F.
3	590.8	0.02	85.2	40759	88.4	12571	H.F.
5	589.9	0.04	85.2	40019	88.4	12912	H.F.
7	589.0	0.07	85.2	40750	93.4	4990	SM.
9	588.0	0.10	85.1	39464	93.2	4871	SM.
11	587.0	0.13	85.0	40617	89.3	9456	T.B.
13	586.1	0.16	85.0	40821	89.2	9584	T.B.
15	585.0	0.19	84.9	40222	88.6	10989	T.B.

RUN NUMBER: 461
p/d = 1.5
Pin = 575.56 kPa
Xin = 0.00

WORKING FLUID: R-11
G = 100.37 kg/s*m²
DELTA P total = 7.64 kPa
Xout = 0.39

ROW	P	Xin	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]	TYPE
1	575.0	0.00	82.6	71756	89.0	11273	H.F.
3	573.9	0.05	84.1	70679	89.3	13460	H.F.
5	572.8	0.10	84.0	69409	88.9	14258	H.F.
7	571.8	0.16	83.9	70791	94.5	6688	SM.
9	570.8	0.21	83.8	68722	94.4	6483	SM.
11	569.9	0.26	83.8	69945	90.6	10266	T.B.
13	569.0	0.32	83.7	70368	90.5	10379	T.B.
15	567.9	0.36	83.6	69770	89.5	11886	T.B.

RUN NUMBER: 460
p/d = 1.5
Pin = 600.63 kPa
Xin = 0.00

WORKING FLUID: R-11
G = 95.73 kg/s*m²
DELTA P total = 6.94 kPa
Xout = 0.30

ROW	P	Xin	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]	TYPE
1	600.1	0.00	85.5	51437	91.2	8907	H.F.
3	598.9	0.04	85.7	50492	90.0	11922	H.F.
5	597.9	0.08	85.7	49740	89.7	12511	H.F.
7	596.9	0.12	85.7	50587	95.1	5359	SM.
9	596.1	0.16	85.6	50003	95.2	5232	SM.
11	595.3	0.20	85.6	49692	90.8	9527	T.B.
13	594.5	0.24	85.6	49835	90.7	9623	T.B.
15	593.7	0.28	85.5	49616	90.0	11037	T.B.

RUN NUMBER: 462
p/d = 1.5
Pin = 585.26 kPa
Xin = 0.00

WORKING FLUID: R-11
G = 99.02 kg/s*m²
DELTA P total = 6.13 kPa
Xout = 0.45

ROW	P	Xin	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]	TYPE
1	584.9	0.00	83.3	81220	90.5	11370	H.F.
3	584.0	0.06	84.4	80358	90.3	13720	H.F.
5	583.2	0.12	84.4	78700	89.9	14475	H.F.
7	582.3	0.18	84.4	80403	95.6	7188	SM.
9	581.5	0.24	84.4	79487	95.8	7025	SM.
11	580.7	0.30	84.4	79550	92.6	9740	T.B.
13	579.9	0.36	84.4	80134	92.4	10081	T.B.
15	579.1	0.42	84.4	79075	91.1	11913	T.B.

RUN NUMBER: 465
p/d = 1.5
Pin = 566.55 kPa
Xin = 0.02

WORKING FLUID: R-11
G = 98.13 kg/s*m²
DELTA P total = 6.04 kPa
Xout = 0.36

ROW	P	Xin	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]	TYPE
1	566.1	0.02	82.6	61152	88.0	11318	H.F.
3	565.2	0.06	83.1	60161	87.9	12440	H.F.
5	564.4	0.11	83.1	59196	87.5	13409	H.F.
7	563.6	0.15	83.1	60436	93.0	6053	SM.
9	562.8	0.20	83.1	59762	93.2	5890	SM.
11	562.0	0.25	83.1	59485	89.6	9108	T.B.
13	561.3	0.29	83.1	59782	89.7	9065	T.B.
15	560.5	0.33	83.1	59346	88.3	11234	T.B.

RUN NUMBER: 474
p/d = 1.5
Pin = 585.84 kPa
Xin = 0.00

WORKING FLUID: R-11
G = 217.02 kg/s*m²
DELTA P total = 7.06 kPa
Xout = 0.01

ROW	P	Xin	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]	TYPE
1	585.4	0.00	84.0	5223	85.1	4666	H.F.
3	584.3	0.00	84.2	5199	85.0	6703	H.F.
5	583.3	0.00	84.5	5061	85.2	6648	H.F.
7	582.4	0.01	84.6	5260	87.6	1791	SM.
9	581.5	0.01	84.6	5121	87.6	1703	SM.
11	580.6	0.01	84.5	5160	85.4	6030	T.B.
13	579.7	0.01	84.5	5183	85.3	6517	T.B.
15	578.8	0.01	84.4	5064	85.2	7057	T.B.

RUN NUMBER: 466
p/d = 1.5
Pin = 567.8 kPa
Xin = 0.01

WORKING FLUID: R-11
G = 210.79 kg/s*m²
DELTA P total = 7.55 kPa
Xout = 0.03

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m ²]	Tw [C]	h [W/m ² C]	SURF TYPE
1	567.2	0.01	82.8	10819	84.6	5838	H.F.
3	566.0	0.02	83.2	10765	84.3	10033	H.F.
5	565.0	0.02	83.3	10580	84.4	10231	H.F.
7	563.9	0.02	83.3	10775	87.2	2760	SM.
9	563.1	0.02	83.2	10583	87.1	2732	SM.
11	562.2	0.03	83.2	10615	84.5	7876	T.B.
13	561.3	0.03	83.1	10646	84.4	8311	T.B.
15	560.3	0.03	83.0	10527	84.1	9745	T.B.

RUN NUMBER: 467
p/d = 1.5
Pin = 564.48 kPa
Xin = 0.00

WORKING FLUID: R-11
G = 203.33 kg/s*m²
DELTA P total = 8.41 kPa
Xout = 0.04

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m ²]	Tw [C]	h [W/m ² C]	SURF TYPE
1	563.9	0.00	82.6	20972	85.7	6797	H.F.
3	562.6	0.01	83.0	20722	84.9	10808	H.F.
5	561.5	0.02	83.0	20410	85.0	10334	H.F.
7	560.4	0.02	82.9	20824	88.0	4088	SM.
9	559.3	0.02	82.9	20419	88.1	3920	SM.
11	558.3	0.03	82.8	20500	85.1	9067	T.B.
13	557.3	0.03	82.8	20556	84.9	9480	T.B.
15	556.1	0.04	82.7	20215	84.8	9941	T.B.

RUN NUMBER: 468
p/d = 1.5
Pin = 562.41 kPa
Xin = 0.01

WORKING FLUID: R-11
G = 212.23 kg/s*m²
DELTA P total = 7.5 kPa
Xout = 0.06

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m ²]	Tw [C]	h [W/m ² C]	SURF TYPE
1	561.8	0.01	82.3	30817	86.1	8134	H.F.
3	560.6	0.02	83.0	30399	85.6	11926	H.F.
5	559.5	0.03	83.0	29968	85.5	11931	H.F.
7	558.5	0.03	82.9	30656	89.2	4892	SM.
9	557.6	0.04	82.8	30179	88.9	4936	SM.
11	556.7	0.04	82.8	30237	86.0	9283	T.B.
13	555.9	0.05	82.7	30300	85.9	9525	T.B.
15	554.9	0.06	82.6	29855	85.4	10940	T.B.

RUN NUMBER: 469
p/d = 1.5
Pin = 572.56 kPa
Xin = 0.00

WORKING FLUID: R-11
G = 216.85 kg/s*m²
DELTA P total = 7.62 kPa
Xout = 0.11

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m ²]	Tw [C]	h [W/m ² C]	SURF TYPE
1	572.0	0.00	82.6	41211	87.4	8469	H.F.
3	570.9	0.02	83.7	40468	86.8	12986	H.F.
5	569.9	0.03	83.8	39891	86.8	13020	H.F.
7	568.9	0.05	83.7	40993	91.7	5080	SM.
9	567.8	0.06	83.6	40522	91.8	4971	SM.
11	566.9	0.07	83.5	40172	87.8	9488	T.B.
13	566.0	0.09	83.5	40221	87.6	9717	T.B.
15	564.9	0.10	83.4	39973	87.4	10087	T.B.

RUN NUMBER: 470
p/d = 1.5
Pin = 575.98 kPa
Xin = 0.00

WORKING FLUID: R-11
G = 211.32 kg/s*m²
DELTA P total = 7.58 kPa
Xout = 0.11

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m ²]	Tw [C]	h [W/m ² C]	SURF TYPE
1	575.4	0.00	82.7	51113	88.6	8746	H.F.
3	574.3	0.02	84.1	50165	87.9	13180	H.F.
5	573.2	0.04	84.0	49457	87.8	13022	H.F.
7	572.2	0.05	83.9	50685	93.1	5523	SM.
9	571.3	0.06	83.9	50148	93.5	5217	SM.
11	570.4	0.07	83.8	49809	89.0	9592	T.B.
13	569.5	0.09	83.7	49913	88.8	9801	T.B.
15	568.4	0.10	83.7	49675	88.2	11090	T.B.

RUN NUMBER: 471
p/d = 1.5
Pin = 543.13 kPa
Xin = -.00

WORKING FLUID: R-11
G = 203.14 kg/s*m²
DELTA P total = 8.6 kPa
Xout = 0.13

ROW #	P [kPa]	Xin [-]	Tf [C]	q'' [W/m ²]	Tw [C]	h [W/m ² C]	SURF TYPE
1	542.5	-.00	80.9	62328	88.1	8663	H.F.
3	541.1	0.02	81.0	61246	85.9	12691	H.F.
5	540.0	0.04	81.0	60254	85.5	13644	H.F.
7	538.9	0.06	81.0	61440	92.2	5526	SM.
9	537.8	0.07	81.0	60829	92.2	5445	SM.
11	536.8	0.08	81.0	60555	87.3	9645	T.B.
13	535.7	0.10	81.0	60897	87.2	9930	T.B.
15	534.5	0.12	81.0	60500	86.6	10851	T.B.

RUN NUMBER: 472 WORKING FLUID: R-11
 p/d = 1.5 G = 218.99 kg/s*m^2
 Pin = 602.59 kPa DELTA P total = 5.9 kPa
 Xin = 0.03 Xout = 0.20

ROW	P	Xin	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]	TYPE
1	602.2	0.03	82.8	71763	90.9	8777	H.F.
3	601.4	0.05	85.7	70665	90.8	13912	H.F.
5	600.5	0.07	85.7	69442	90.5	14670	H.F.
7	599.8	0.10	85.7	71106	95.7	7147	SM.
9	599.0	0.12	85.7	70401	95.8	6986	SM.
11	598.2	0.14	85.7	70131	92.5	10339	T.B.
13	597.5	0.17	85.7	70608	92.5	10477	T.B.
15	596.7	0.19	85.7	69817	91.3	12497	T.B.

RUN NUMBER: 473 WORKING FLUID: R-11
 p/d = 1.5 G = 204.9 kg/s*m^2
 Pin = 545.75 kPa DELTA P total = 6.27 kPa
 Xin = 0.01 Xout = 0.23

ROW	P	Xin	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]	TYPE
1	545.3	0.01	81.1	82475	88.0	12063	H.F.
3	544.4	0.04	81.8	81446	87.6	14025	H.F.
5	543.5	0.07	81.8	79864	87.2	14644	H.F.
7	542.6	0.10	81.7	82028	93.0	7232	SM.
9	541.8	0.13	81.6	81103	93.2	7015	SM.
11	541.0	0.16	81.6	81150	89.9	9751	T.B.
13	540.3	0.19	81.5	81791	89.3	10511	T.B.
15	539.5	0.21	81.5	80513	87.8	12640	T.B.

Bundle Boiling Data

Data from the 25% R-11/75% R-113 mixture

RUN NUMBER: 654 y'in = 23.8 % R-11 / 76.2 % R-113
 p/d = 1.5 G = 49.87 kg/s*m^2
 Pin = 205.51 kPa DELTA P total = 6.82 kPa
 Xin = -.00 Xout = 0.05

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	205.1	-.00	0.238	52.4	5277	59.9	705	H.F.
3	204.0	0.00	0.238	53.6	5218	59.6	865	H.F.
5	203.1	0.01	0.237	54.5	5118	59.5	1024	H.F.
7	202.2	0.02	0.237	55.1	5179	61.1	864	SM.
9	201.3	0.03	0.236	55.6	5049	61.5	861	SM.
11	200.5	0.03	0.236	56.1	5117	59.6	1462	T.B.
13	199.6	0.04	0.235	56.5	5115	59.5	1722	T.B.
15	198.7	0.05	0.235	57.0	5035	59.2	2244	T.B.

RUN NUMBER: 653 y'in = 23.8 % R-11 / 76.2 % R-113
 p/d = 1.5 G = 49.66 kg/s*m^2
 Pin = 202.07 kPa DELTA P total = 6.56 kPa
 Xin = -.00 Xout = 0.12

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	201.6	-.00	0.238	53.0	10781	60.7	1403	H.F.
3	200.6	0.01	0.237	53.8	10662	60.7	1556	H.F.
5	199.6	0.03	0.236	54.4	10470	60.7	1663	H.F.
7	198.7	0.04	0.235	54.9	10561	64.7	1075	SM.
9	197.9	0.06	0.234	55.5	10373	64.5	1154	SM.
11	197.1	0.08	0.233	56.0	10466	60.6	2301	T.B.
13	196.3	0.09	0.232	56.6	10459	60.4	2691	T.B.
15	195.5	0.11	0.232	57.1	10307	60.0	3598	T.B.

RUN NUMBER: 657 y'in = 23.8 % R-11 / 76.2 % R-113
 p/d = 1.5 G = 49.97 kg/s*m^2
 Pin = 199.31 kPa DELTA P total = 6.51 kPa
 Xin = 0.00 Xout = 0.23

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	198.8	0.00	0.238	53.2	20858	62.1	2360	H.F.
3	197.8	0.03	0.236	54.0	20619	62.4	2482	H.F.
5	196.8	0.06	0.234	54.6	20244	62.2	2680	H.F.
7	195.9	0.09	0.233	55.1	20735	68.9	1513	SM.
9	195.0	0.12	0.231	55.7	20362	68.6	1580	SM.
11	194.3	0.15	0.229	56.3	20543	62.9	3071	T.B.
13	193.5	0.19	0.227	56.8	20543	62.9	3360	T.B.
15	192.8	0.22	0.226	57.4	20254	61.9	4486	T.B.

RUN NUMBER: 658 y'in = 23.8 % R-11 / 76.2 % R-113
 p/d = 1.5 G = 49.98 kg/s*m^2
 Pin = 200 kPa DELTA P total = 6.55 kPa
 Xin = -.00 Xout = 0.34

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	199.5	-.00	0.238	53.6	31079	63.5	3155	H.F.
3	198.4	0.04	0.235	54.5	30693	64.0	3244	H.F.
5	197.4	0.09	0.233	55.1	30057	63.6	3532	H.F.
7	196.5	0.13	0.230	55.8	30698	70.9	2032	SM.
9	195.7	0.18	0.227	56.4	30168	70.8	2099	SM.
11	194.9	0.23	0.225	57.0	30265	65.1	3752	T.B.
13	194.2	0.27	0.222	57.6	30284	65.0	4083	T.B.
15	193.4	0.32	0.220	58.2	29825	63.5	5677	T.B.

RUN NUMBER: 644 y'in = 23.8 % R-11 / 76.2 % R-113
 p/d = 1.5 G = 49.63 kg/s*m^2
 Pin = 200 kPa DELTA P total = 5.51 kPa
 Xin = 0.00 Xout = 0.46

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	199.6	0.00	0.238	54.3	41206	65.2	3785	H.F.
3	198.6	0.06	0.234	55.2	40587	65.8	3833	H.F.
5	197.7	0.12	0.231	55.8	39877	65.6	4086	H.F.
7	196.9	0.18	0.227	56.4	40615	72.3	2558	SM.
9	196.2	0.25	0.224	57.0	39903	72.2	2630	SM.
11	195.5	0.31	0.220	57.6	39932	66.9	4279	T.B.
13	195.0	0.37	0.217	58.2	39882	67.0	4520	T.B.
15	194.5	0.43	0.214	58.7	39474	65.2	6099	T.B.

RUN NUMBER: 660 y'in = 23.8 % R-11 / 76.2 % R-113
 p/d = 1.5 G = 49.97 kg/s*m^2
 Pin = 203.44 kPa DELTA P total = 6.85 kPa
 Xin = -.00 Xout = 0.57

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	202.9	-.00	0.238	53.4	51421	66.3	4003	H.F.
3	201.8	0.07	0.234	54.8	50597	67.0	4154	H.F.
5	200.7	0.14	0.229	55.6	49771	66.5	4580	H.F.
7	199.7	0.22	0.225	56.5	50773	74.4	2840	SM.
9	198.9	0.30	0.220	57.4	50008	74.3	2958	SM.
11	198.1	0.38	0.216	58.3	50164	69.4	4520	T.B.
13	197.4	0.45	0.211	59.2	50214	69.4	4925	T.B.
15	196.6	0.53	0.207	60.1	49769	67.6	6609	T.B.

RUN NUMBER: 661 y'in = 23.8 % R-11 / 76.2 % R-113
 p/d = 1.5 G = 50.07 kg/s*m^2
 Pin = 203.44 kPa DELTA P total = 6.82 kPa
 Xin = -.00 Xout = 0.68

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	202.9	-.00	0.238	53.4	61820	67.4	4430	H.F.
3	201.8	0.08	0.233	54.8	60798	67.9	4639	H.F.
5	200.7	0.17	0.227	55.7	59785	67.5	5086	H.F.
7	199.7	0.26	0.222	56.6	61098	75.9	3176	SM.
9	198.9	0.36	0.217	57.5	60256	75.8	3296	SM.
11	198.1	0.46	0.211	58.5	60482	71.0	4826	T.B.
13	197.4	0.55	0.206	59.4	60718	71.1	5172	T.B.
15	196.6	0.64	0.201	60.3	60217	69.8	6351	T.B.

RUN NUMBER: 656 y'in = 23.8 % R-11 / 76.2 % R-113
 p/d = 1.5 G = 99.78 kg/s*m^2
 Pin = 199.31 kPa DELTA P total = 6.6 kPa
 Xin = 0.00 Xout = 0.12

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	198.8	0.00	0.238	52.8	11053	60.2	1515	H.F.
3	197.8	0.02	0.237	53.6	10927	60.0	1696	H.F.
5	196.9	0.03	0.236	54.1	10731	60.0	1802	H.F.
7	195.9	0.05	0.235	54.6	10742	64.7	1057	SM.
9	195.1	0.06	0.234	55.1	10545	64.4	1128	SM.
11	194.3	0.08	0.233	55.6	10693	60.2	2290	T.B.
13	193.5	0.10	0.232	56.1	10687	60.0	2686	T.B.
15	192.7	0.11	0.232	56.6	10526	59.4	3684	T.B.

RUN NUMBER: 647 y'in = 23.8 % R-11 / 76.2 % R-113
 p/d = 1.5 G = 49.64 kg/s*m^2
 Pin = 202.75 kPa DELTA P total = 6.68 kPa
 Xin = -.00 Xout = 0.82

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	202.2	-.00	0.238	53.6	72712	68.6	4854	H.F.
3	201.1	0.10	0.232	55.1	71652	69.0	5146	H.F.
5	200.1	0.21	0.226	56.1	70370	68.5	5678	H.F.
7	199.1	0.32	0.219	57.1	72433	77.2	3603	SM.
9	198.3	0.43	0.213	58.1	71431	77.2	3729	SM.
11	197.5	0.55	0.207	59.0	71474	72.4	5362	T.B.
13	196.8	0.66	0.200	60.0	71757	72.8	5596	T.B.
15	196.1	0.76	0.194	61.0	70979	72.3	6275	T.B.

RUN NUMBER: 652 y'in = 23.8 % R-11 / 76.2 % R-113
 p/d = 1.5 G = 99.07 kg/s*m^2
 Pin = 200.69 kPa DELTA P total = 6.57 kPa
 Xin = -.00 Xout = 0.23

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	200.2	-.00	0.238	53.4	20950	62.3	2363	H.F.
3	199.2	0.03	0.236	54.2	20684	62.6	2471	H.F.
5	198.2	0.06	0.234	54.8	20327	62.4	2689	H.F.
7	197.3	0.09	0.232	55.4	20884	68.2	1636	SM.
9	196.4	0.12	0.231	56.0	20512	67.9	1719	SM.
11	195.6	0.16	0.229	56.6	20559	62.9	3236	T.B.
13	194.9	0.19	0.227	57.2	20552	62.9	3593	T.B.
15	194.1	0.22	0.225	57.7	20289	61.9	4880	T.B.

RUN NUMBER: 655 y'in = 23.8 % R-11 / 76.2 % R-113
 p/d = 1.5 G = 99.88 kg/s*m^2
 Pin = 202.75 kPa DELTA P total = 6.68 kPa
 Xin = -.00 Xout = 0.06

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	202.3	-.00	0.238	52.4	5275	59.3	762	H.F.
3	201.3	0.01	0.238	53.5	5218	59.0	946	H.F.
5	200.4	0.01	0.237	54.2	5120	58.9	1085	H.F.
7	199.5	0.02	0.237	54.6	5180	60.7	856	SM.
9	198.7	0.03	0.236	55.1	5050	60.9	861	SM.
11	197.8	0.04	0.236	55.5	5129	59.0	1488	T.B.
13	197.0	0.04	0.235	55.9	5126	58.8	1790	T.B.
15	196.1	0.05	0.235	56.4	5049	58.5	2339	T.B.

RUN NUMBER: 651 y'in = 23.8 % R-11 / 76.2 % R-113
 p/d = 1.5 G = 99.52 kg/s*m^2
 Pin = 199.31 kPa DELTA P total = 6.41 kPa
 Xin = 0.00 Xout = 0.35

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	198.8	0.00	0.238	53.5	31118	63.6	3099	H.F.
3	197.7	0.05	0.235	54.4	30589	64.0	3195	H.F.
5	196.7	0.09	0.233	55.0	30031	63.7	3472	H.F.
7	195.8	0.14	0.230	55.6	31083	70.3	2117	SM.
9	195.0	0.19	0.227	56.2	30546	70.2	2187	SM.
11	194.2	0.23	0.224	56.8	30653	64.9	3792	T.B.
13	193.5	0.28	0.222	57.4	30599	64.8	4138	T.B.
15	192.9	0.33	0.219	58.0	30321	63.4	5604	T.B.

RUN NUMBER: 650
 p/d = 1.5
 Pin = 197.93 kPa
 Xin = 0.00

y'in = 23.8 % R-11 / 76.2 % R-113
 G = 99.49 kg/s*m²
 DELTA P total = 6.51 kPa
 Xout = 0.46

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m ²]	Tw [C]	h [W/m ² C]	SURF TYPE
1	197.4	0.00	0.238	54.2	41077	64.5	4024	H.F.
3	196.3	0.06	0.234	55.1	40485	65.0	4055	H.F.
5	195.3	0.12	0.231	55.6	39680	64.6	4422	H.F.
7	194.4	0.18	0.227	56.1	40637	71.9	2587	SM.
9	193.7	0.25	0.224	56.7	39989	71.8	2656	SM.
11	193.0	0.31	0.220	57.2	40633	66.5	4360	T.B.
13	192.2	0.37	0.217	57.8	40581	66.7	4571	T.B.
15	191.4	0.43	0.213	58.3	40243	65.0	6073	T.B.

RUN NUMBER: 663
 p/d = 1.5
 Pin = 202.07 kPa
 Xin = -.00

y'in = 23.8 % R-11 / 76.2 % R-113
 G = 212.23 kg/s*m²
 DELTA P total = 6.69 kPa
 Xout = 0.38

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m ²]	Tw [C]	h [W/m ² C]	SURF TYPE
1	201.6	-.00	0.238	53.0	72634	67.0	5207	H.F.
3	200.5	0.05	0.235	54.2	71550	67.3	5437	H.F.
5	199.4	0.10	0.232	54.9	70231	66.6	5992	H.F.
7	198.4	0.15	0.229	55.7	71660	75.3	3646	SM.
9	197.6	0.20	0.226	56.4	70866	75.3	3760	SM.
11	196.9	0.25	0.222	57.2	70789	69.8	5610	T.B.
13	196.1	0.30	0.219	57.9	71280	69.7	6053	T.B.
15	195.4	0.35	0.216	58.7	70591	68.3	7304	T.B.

RUN NUMBER: 649
 p/d = 1.5
 Pin = 199.31 kPa
 Xin = 0.00

y'in = 23.8 % R-11 / 76.2 % R-113
 G = 98.84 kg/s*m²
 DELTA P total = 6.81 kPa
 Xout = 0.58

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m ²]	Tw [C]	h [W/m ² C]	SURF TYPE
1	198.8	0.00	0.238	54.1	51154	65.7	4395	H.F.
3	197.7	0.08	0.234	55.1	50332	66.4	4456	H.F.
5	196.6	0.15	0.229	55.8	49472	65.9	4877	H.F.
7	195.7	0.23	0.225	56.5	50881	73.8	2945	SM.
9	194.8	0.31	0.220	57.2	50078	73.7	3030	SM.
11	194.0	0.39	0.216	57.9	50119	68.5	4692	T.B.
13	193.3	0.47	0.212	58.6	50126	68.6	4974	T.B.
15	192.5	0.54	0.207	59.3	49764	67.1	6367	T.B.

RUN NUMBER: 664
 p/d = 1.5
 Pin = 204.82 kPa
 Xin = -.01

y'in = 23.8 % R-11 / 76.2 % R-113
 G = 208.38 kg/s*m²
 DELTA P total = 6.86 kPa
 Xout = 0.43

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m ²]	Tw [C]	h [W/m ² C]	SURF TYPE
1	204.3	-.01	0.238	52.7	82197	68.3	5276	H.F.
3	203.2	0.05	0.234	54.6	81235	68.7	5773	H.F.
5	202.1	0.11	0.231	55.5	79700	68.0	6358	H.F.
7	201.2	0.17	0.227	56.3	81364	77.0	3926	SM.
9	200.3	0.23	0.224	57.1	80402	76.9	4049	SM.
11	199.5	0.29	0.220	57.9	80496	71.6	5853	T.B.
13	198.8	0.35	0.217	58.7	81189	71.5	6334	T.B.
15	198.0	0.40	0.213	59.5	80101	70.4	7318	T.B.

RUN NUMBER: 648
 p/d = 1.5
 Pin = 201.38 kPa
 Xin = 0.00

y'in = 23.8 % R-11 / 76.2 % R-113
 G = 99.33 kg/s*m²
 DELTA P total = 6.72 kPa
 Xout = 0.70

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m ²]	Tw [C]	h [W/m ² C]	SURF TYPE
1	200.9	0.00	0.238	53.6	62262	67.3	4526	H.F.
3	199.7	0.09	0.233	54.9	61271	67.9	4715	H.F.
5	198.7	0.18	0.227	55.7	60172	67.4	5182	H.F.
7	197.7	0.27	0.222	56.6	61775	75.6	3249	SM.
9	196.9	0.37	0.217	57.5	60844	75.6	3363	SM.
11	196.1	0.47	0.211	58.4	60373	70.5	4958	T.B.
13	195.4	0.56	0.206	59.2	60503	70.7	5263	T.B.
15	194.7	0.65	0.201	60.1	60095	69.4	6435	T.B.

RUN NUMBER: 682
 p/d = 1.5
 Pin = 546.2 kPa
 Xin = 0.00

y'in = 23.1 % R-11 / 76.9 % R-113
 G = 49.11 kg/s*m²
 DELTA P total = 7.15 kPa
 Xout = 0.06

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m ²]	Tw [C]	h [W/m ² C]	SURF TYPE
1	545.7	0.00	0.231	82.0	4669	88.0	775	H.F.
3	544.6	0.01	0.231	82.5	4630	87.9	869	H.F.
5	543.7	0.02	0.231	83.0	4455	87.7	950	H.F.
7	542.7	0.02	0.230	83.6	4758	89.2	853	SM.
9	541.8	0.03	0.230	84.0	4669	89.1	919	SM.
11	540.9	0.04	0.230	84.3	4448	87.3	1486	T.B.
13	540.0	0.05	0.230	84.5	4456	87.2	1649	T.B.
15	539.1	0.05	0.229	84.8	4393	87.1	1935	T.B.

RUN NUMBER: 680
p/d = 1.5
Pin = 546.2 kPa
Xin = -.00

y'in = 23.1 % R-11 / 76.9 % R-113
G = 48.89 kg/s*m^2
DELTA P total = 6.98 kPa
Xout = 0.13

ROW	P	Xin	y'	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	R-11	[C]	[W/m^2]	[C]	[W/m^2 C]	TYPE
1	545.7	-.01	0.231	82.0	10739	90.0	1326	H.F.
3	544.7	0.01	0.230	83.2	10651	89.7	1616	H.F.
5	543.7	0.03	0.230	84.0	10241	89.5	1848	H.F.
7	542.8	0.05	0.229	84.5	10688	92.4	1346	SM.
9	541.9	0.06	0.229	85.0	10412	92.5	1380	SM.
11	541.0	0.08	0.228	85.4	10318	89.8	2359	T.B.
13	540.2	0.10	0.228	85.9	10336	89.8	2653	T.B.
15	539.2	0.12	0.227	86.4	10198	89.3	3448	T.B.

RUN NUMBER: 675
p/d = 1.5
Pin = 546.2 kPa
Xin = -.00

y'in = 23.1 % R-11 / 76.9 % R-113
G = 49.04 kg/s*m^2
DELTA P total = 6.43 kPa
Xout = 0.50

ROW	P	Xin	y'	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	R-11	[C]	[W/m^2]	[C]	[W/m^2 C]	TYPE
1	545.7	-.01	0.231	82.4	40976	93.6	3639	H.F.
3	544.7	0.06	0.229	83.7	40597	93.8	4035	H.F.
5	543.8	0.12	0.227	84.3	39680	93.5	4316	H.F.
7	542.9	0.19	0.225	84.9	40555	98.2	3070	SM.
9	542.1	0.26	0.223	85.6	40019	98.2	3160	SM.
11	541.3	0.33	0.221	86.2	40265	95.1	4525	T.B.
13	540.6	0.40	0.218	86.8	40388	95.1	4858	T.B.
15	539.8	0.47	0.216	87.4	40054	93.9	6139	T.B.

RUN NUMBER: 679
p/d = 1.5
Pin = 546.2 kPa
Xin = -.00

y'in = 23.1 % R-11 / 76.9 % R-113
G = 48.97 kg/s*m^2
DELTA P total = 6.95 kPa
Xout = 0.25

ROW	P	Xin	y'	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	R-11	[C]	[W/m^2]	[C]	[W/m^2 C]	TYPE
1	545.7	-.00	0.231	82.1	21050	91.7	2187	H.F.
3	544.6	0.03	0.230	83.6	20898	91.7	2601	H.F.
5	543.6	0.06	0.229	84.2	20094	91.3	2850	H.F.
7	542.7	0.10	0.228	84.8	20776	95.3	1981	SM.
9	541.8	0.13	0.227	85.4	20298	95.4	2036	SM.
11	541.0	0.17	0.226	86.0	20505	92.1	3351	T.B.
13	540.1	0.20	0.225	86.5	20530	92.0	3720	T.B.
15	539.3	0.24	0.224	87.1	20257	91.3	4793	T.B.

RUN NUMBER: 673
p/d = 1.5
Pin = 549.65 kPa
Xin = -.00

y'in = 23.1 % R-11 / 76.9 % R-113
G = 48.73 kg/s*m^2
DELTA P total = 6.59 kPa
Xout = 0.63

ROW	P	Xin	y'	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	R-11	[C]	[W/m^2]	[C]	[W/m^2 C]	TYPE
1	549.1	-.00	0.231	82.6	51265	95.5	3970	H.F.
3	548.1	0.08	0.228	84.1	50713	95.8	4348	H.F.
5	547.1	0.16	0.226	84.8	49446	95.5	4628	H.F.
7	546.3	0.25	0.223	85.5	50611	100.2	3440	SM.
9	545.5	0.34	0.221	86.1	50047	100.3	3546	SM.
11	544.7	0.42	0.218	86.8	50216	97.4	4766	T.B.
13	543.9	0.51	0.215	87.5	50390	97.4	5078	T.B.
15	543.1	0.59	0.213	88.2	50062	96.2	6224	T.B.

RUN NUMBER: 677
p/d = 1.5
Pin = 546.2 kPa
Xin = 0.07

y'in = 23.1 % R-11 / 76.9 % R-113
G = 49.12 kg/s*m^2
DELTA P total = 6.77 kPa
Xout = 0.53

ROW	P	Xin	y'	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	R-11	[C]	[W/m^2]	[C]	[W/m^2 C]	TYPE
1	545.7	0.14	0.231	82.1	31429	92.7	2951	H.F.
3	544.6	0.19	0.229	83.7	31161	92.8	3423	H.F.
5	543.6	0.24	0.228	84.3	30041	92.5	3643	H.F.
7	542.7	0.29	0.226	84.9	31136	96.9	2585	SM.
9	541.8	0.35	0.225	85.5	30592	97.0	2670	SM.
11	541.0	0.40	0.223	86.1	30689	93.7	4044	T.B.
13	540.3	0.45	0.221	86.7	30758	93.8	4344	T.B.
15	539.4	0.50	0.220	87.3	30446	92.7	5573	T.B.

RUN NUMBER: 670
p/d = 1.5
Pin = 549.65 kPa
Xin = -.00

y'in = 23.1 % R-11 / 76.9 % R-113
G = 48.83 kg/s*m^2
DELTA P total = 6.87 kPa
Xout = 0.77

ROW	P	Xin	y'	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	R-11	[C]	[W/m^2]	[C]	[W/m^2 C]	TYPE
1	549.1	-.00	0.231	82.9	62639	95.9	4826	H.F.
3	548.0	0.10	0.228	84.2	62010	96.2	5141	H.F.
5	546.9	0.19	0.225	84.8	60501	95.8	5508	H.F.
7	546.0	0.29	0.221	85.5	61792	100.8	4053	SM.
9	545.1	0.39	0.218	86.2	61064	100.9	4162	SM.
11	544.3	0.49	0.215	86.9	60789	98.0	5476	T.B.
13	543.6	0.58	0.212	87.6	61120	98.0	5857	T.B.
15	542.8	0.67	0.209	88.3	60565	96.8	7098	T.B.

RUN NUMBER: 683 y'in = 23.1 % R-11 / 76.9 % R-113
 p/d = 1.5 G = 196.51 kg/s*m^2
 Pin = 542.76 kPa DELTA P total = 7.14 kPa
 Xin = -.00 Xout = 0.03

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	542.3	-.00	0.231	81.5	5028	88.0	781	H.F.
3	541.2	0.00	0.231	82.1	4985	87.8	874	H.F.
5	540.2	0.01	0.231	82.6	4795	87.6	958	H.F.
7	539.3	0.01	0.231	83.2	5202	89.2	872	SM.
9	538.4	0.01	0.230	83.7	5104	89.2	932	SM.
11	537.5	0.02	0.230	84.0	4819	87.2	1484	T.B.
13	536.6	0.02	0.230	84.2	4825	87.2	1633	T.B.
15	535.6	0.03	0.230	84.5	4759	87.0	1878	T.B.

RUN NUMBER: 676 y'in = 23.1 % R-11 / 76.9 % R-113
 p/d = 1.5 G = 196.07 kg/s*m^2
 Pin = 546.2 kPa DELTA P total = 6.64 kPa
 Xin = 0.07 Xout = 0.26

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	545.7	0.07	0.231	82.1	31242	92.5	2981	H.F.
3	544.6	0.10	0.230	83.7	30977	92.5	3501	H.F.
5	543.7	0.12	0.229	84.3	29840	92.3	3730	H.F.
7	542.7	0.15	0.229	84.9	30890	96.7	2607	SM.
9	541.9	0.17	0.228	85.5	30396	96.8	2691	SM.
11	541.1	0.20	0.227	86.1	30512	93.4	4196	T.B.
13	540.4	0.23	0.226	86.7	30573	93.5	4505	T.B.
15	539.6	0.25	0.226	87.3	30267	92.5	5798	T.B.

RUN NUMBER: 681 y'in = 23.1 % R-11 / 76.9 % R-113
 p/d = 1.5 G = 196.19 kg/s*m^2
 Pin = 546.2 kPa DELTA P total = 7.02 kPa
 Xin = -.00 Xout = 0.06

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	545.7	-.00	0.231	82.0	10808	90.0	1350	H.F.
3	544.7	0.01	0.231	83.2	10719	89.6	1655	H.F.
5	543.7	0.01	0.230	84.0	10304	89.5	1889	H.F.
7	542.8	0.02	0.230	84.5	10763	92.4	1356	SM.
9	541.9	0.03	0.230	85.0	10517	92.5	1390	SM.
11	541.0	0.04	0.230	85.4	10397	89.7	2428	T.B.
13	540.1	0.05	0.229	85.9	10411	89.6	2803	T.B.
15	539.2	0.06	0.229	86.4	10271	89.2	3655	T.B.

RUN NUMBER: 674 y'in = 23.1 % R-11 / 76.9 % R-113
 p/d = 1.5 G = 196.67 kg/s*m^2
 Pin = 546.2 kPa DELTA P total = 6.81 kPa
 Xin = -.00 Xout = 0.25

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	545.7	-.00	0.231	82.4	41003	93.4	3703	H.F.
3	544.6	0.03	0.230	83.7	40645	93.6	4100	H.F.
5	543.6	0.06	0.229	84.3	39589	93.4	4384	H.F.
7	542.6	0.10	0.228	84.9	40639	98.0	3122	SM.
9	541.8	0.13	0.227	85.6	40115	98.0	3222	SM.
11	541.0	0.17	0.226	86.2	40327	94.9	4615	T.B.
13	540.2	0.20	0.225	86.8	40463	95.0	4940	T.B.
15	539.4	0.23	0.224	87.4	40114	93.8	6245	T.B.

RUN NUMBER: 678 y'in = 23.1 % R-11 / 76.9 % R-113
 p/d = 1.5 G = 197.06 kg/s*m^2
 Pin = 546.2 kPa DELTA P total = 6.9 kPa
 Xin = -.00 Xout = 0.13

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	545.7	-.00	0.231	82.1	21045	91.6	2209	H.F.
3	544.6	0.01	0.230	83.6	20901	91.5	2654	H.F.
5	543.7	0.03	0.230	84.2	20096	91.4	2808	H.F.
7	542.7	0.05	0.229	84.8	20775	95.3	1976	SM.
9	541.8	0.07	0.229	85.4	20369	95.4	2043	SM.
11	541.0	0.08	0.228	86.0	20504	91.9	3477	T.B.
13	540.2	0.10	0.228	86.5	20538	92.0	3730	T.B.
15	539.3	0.12	0.227	87.1	20299	91.5	4612	T.B.

RUN NUMBER: 672 y'in = 23.1 % R-11 / 76.9 % R-113
 p/d = 1.5 G = 195.47 kg/s*m^2
 Pin = 549.65 kPa DELTA P total = 6.68 kPa
 Xin = -.00 Xout = 0.32

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	549.1	-.00	0.231	82.6	51441	94.9	4194	H.F.
3	548.0	0.04	0.230	84.1	50939	95.1	4642	H.F.
5	547.0	0.08	0.228	84.8	49657	94.8	4974	H.F.
7	546.0	0.12	0.227	85.5	50780	99.6	3594	SM.
9	545.2	0.17	0.226	86.1	50172	99.7	3712	SM.
11	544.5	0.21	0.224	86.8	50307	96.7	5089	T.B.
13	543.7	0.25	0.223	87.5	50525	96.8	5432	T.B.
15	543.0	0.30	0.222	88.2	50147	95.6	6774	T.B.

RUN NUMBER: 671 y'in = 23.1 % R-11 / 76.9 % R-113
 p/d = 1.5 G = 195.1 kg/s*m^2
 Pin = 549.65 kPa DELTA P total = 6.91 kPa
 Xin = -.00 Xout = 0.38

ROW	P	Xin	y'	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	R-11	[C]	[W/m^2]	[C]	[W/m^2 C]	TYPE
1	549.1	-.00	0.231	82.9	62254	95.8	4839	H.F.
3	548.0	0.05	0.229	84.2	61574	96.1	5149	H.F.
5	547.0	0.10	0.228	84.8	60016	95.7	5516	H.F.
7	546.0	0.15	0.226	85.5	61407	100.7	4052	SM.
9	545.1	0.20	0.225	86.2	60589	100.7	4183	SM.
11	544.3	0.26	0.223	86.9	60368	97.9	5492	T.B.
13	543.6	0.31	0.222	87.6	60700	97.9	5885	T.B.
15	542.7	0.36	0.220	88.3	60170	96.6	7202	T.B.

RUN NUMBER: 668 y'in = 23.1 % R-11 / 76.9 % R-113
 p/d = 1.5 G = 195.54 kg/s*m^2
 Pin = 549.65 kPa DELTA P total = 6.81 kPa
 Xin = -.00 Xout = 0.46

ROW	P	Xin	y'	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	R-11	[C]	[W/m^2]	[C]	[W/m^2 C]	TYPE
1	549.1	-.00	0.231	83.0	74179	96.7	5416	H.F.
3	548.0	0.06	0.229	84.2	73567	97.1	5733	H.F.
5	547.0	0.12	0.227	85.0	71878	96.6	6181	H.F.
7	546.0	0.18	0.225	85.7	73458	101.8	4560	SM.
9	545.1	0.24	0.223	86.4	72619	101.8	4723	SM.
11	544.3	0.31	0.222	87.1	72088	99.0	6062	T.B.
13	543.6	0.37	0.220	87.9	72560	99.0	6494	T.B.
15	542.8	0.43	0.218	88.6	71650	98.0	7648	T.B.

RUN NUMBER: 666 y'in = 23.1 % R-11 / 76.9 % R-113
 p/d = 1.5 G = 196.21 kg/s*m^2
 Pin = 549.65 kPa DELTA P total = 6.8 kPa
 Xin = -.00 Xout = 0.50

ROW	P	Xin	y'	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	R-11	[C]	[W/m^2]	[C]	[W/m^2 C]	TYPE
1	549.1	-.00	0.231	82.5	81568	97.0	5649	H.F.
3	548.0	0.06	0.229	84.2	80940	97.4	6153	H.F.
5	546.9	0.12	0.227	85.0	78932	96.8	6660	H.F.
7	545.9	0.19	0.225	85.7	80535	102.2	4883	SM.
9	545.2	0.25	0.223	86.4	79412	102.1	5054	SM.
11	544.4	0.32	0.221	87.2	79926	99.7	6400	T.B.
13	543.7	0.38	0.218	87.9	80512	99.7	6820	T.B.
15	542.9	0.45	0.217	88.6	79258	98.7	7904	T.B.

Bundle Boiling Data

Data from the 50% R-11/50% R-113 mixture

RUN NUMBER: 563 y'in = 46.5 % R-11 / 53.5 % R-113
 p/d = 1.5 G = 43.57 kg/s*m^2
 Pin = 200.03 kPa DELTA P total = 6.25 kPa
 Xin = 0.01 Xout = 0.05

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	199.6	0.01	0.465	52.6	5213	55.7	1707	H.F.
3	198.8	0.01	0.465	52.7	5155	55.6	1802	H.F.
5	197.9	0.02	0.464	52.8	5050	55.5	1918	H.F.
7	197.1	0.03	0.464	53.0	5233	57.5	1142	SM.
9	196.3	0.03	0.463	53.1	5096	57.3	1196	SM.
11	195.5	0.03	0.463	53.2	5104	55.1	2762	T.B.
13	194.7	0.04	0.462	53.3	5095	54.8	3396	T.B.
15	193.8	0.05	0.462	53.5	5039	54.5	4701	T.B.

RUN NUMBER: 559 y'in = 46.5 % R-11 / 53.5 % R-113
 p/d = 1.5 G = 51.59 kg/s*m^2
 Pin = 202.79 kPa DELTA P total = 5.89 kPa
 Xin = 0.00 Xout = 0.23

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	202.7	0.00	0.465	53.4	30867	60.8	4142	H.F.
3	202.4	0.04	0.462	53.6	30455	61.1	4092	H.F.
5	201.9	0.09	0.460	54.1	29882	60.5	4678	H.F.
7	201.2	0.11	0.457	54.5	30824	67.3	2407	SM.
9	200.2	0.12	0.454	55.0	30221	67.1	2488	SM.
11	199.2	0.13	0.451	55.4	30041	61.5	4943	T.B.
13	198.1	0.17	0.449	55.9	30002	61.5	5343	T.B.
15	196.9	0.21	0.446	56.4	29671	60.1	7945	T.B.

RUN NUMBER: 561 y'in = 46.5 % R-11 / 53.5 % R-113
 p/d = 1.5 G = 49.38 kg/s*m^2
 Pin = 200.03 kPa DELTA P total = 6.43 kPa
 Xin = 0.00 Xout = 0.08

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	199.6	0.00	0.465	52.3	10351	57.1	2172	H.F.
3	198.8	0.02	0.464	52.4	10222	57.0	2210	H.F.
5	198.0	0.03	0.463	52.5	10024	56.7	2356	H.F.
7	197.1	0.04	0.462	52.6	10229	60.7	1261	SM.
9	196.3	0.05	0.461	52.7	9948	60.4	1297	SM.
11	195.4	0.05	0.460	52.8	10160	56.6	2707	T.B.
13	194.6	0.06	0.459	52.9	10139	56.4	2880	T.B.
15	193.6	0.08	0.459	53.0	10029	55.9	3480	T.B.

RUN NUMBER: 558 y'in = 46.5 % R-11 / 53.5 % R-113
 p/d = 1.5 G = 48.68 kg/s*m^2
 Pin = 202.1 kPa DELTA P total = 6.79 kPa
 Xin = 0.00 Xout = 0.32

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	201.7	0.00	0.465	53.3	40732	62.1	4663	H.F.
3	200.7	0.06	0.461	53.5	40113	62.3	4561	H.F.
5	199.8	0.12	0.458	53.8	39367	61.6	5037	H.F.
7	198.9	0.16	0.454	54.1	40729	69.1	2718	SM.
9	198.0	0.17	0.450	54.5	40090	69.1	2748	SM.
11	197.2	0.19	0.447	54.8	39997	63.5	4581	T.B.
13	196.3	0.24	0.443	55.1	39917	63.7	4682	T.B.
15	195.3	0.30	0.440	55.5	39667	61.9	6139	T.B.

RUN NUMBER: 550 y'in = 46.5 % R-11 / 53.5 % R-113
 p/d = 1.5 G = 52.37 kg/s*m^2
 Pin = 198.65 kPa DELTA P total = 7.19 kPa
 Xin = -.00 Xout = 0.21

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	198.2	-.00	0.465	51.9	20125	57.8	3365	H.F.
3	197.2	0.02	0.463	52.0	19826	58.4	3109	H.F.
5	196.3	0.05	0.461	52.2	19466	57.8	3482	H.F.
7	195.4	0.08	0.460	52.3	20086	63.5	1793	SM.
9	194.5	0.11	0.458	52.5	19684	63.1	1840	SM.
11	193.5	0.14	0.456	52.6	19789	57.5	4074	T.B.
13	192.5	0.17	0.454	52.7	19725	57.4	4244	T.B.
15	191.5	0.19	0.453	52.9	19537	56.4	5463	T.B.

RUN NUMBER: 557 y'in = 46.5 % R-11 / 53.5 % R-113
 p/d = 1.5 G = 50.81 kg/s*m^2
 Pin = 204.86 kPa DELTA P total = 6.9 kPa
 Xin = -.01 Xout = 0.38

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	204.4	-.01	0.465	52.6	51194	63.4	4748	H.F.
3	203.4	0.07	0.460	53.1	50355	63.8	4744	H.F.
5	202.6	0.14	0.456	53.4	49492	63.1	5079	H.F.
7	201.7	0.18	0.451	53.6	50931	71.0	2927	SM.
9	200.8	0.19	0.447	53.8	50222	70.9	2928	SM.
11	199.9	0.22	0.442	54.0	49932	65.8	4230	T.B.
13	199.0	0.27	0.438	54.2	49855	65.9	4259	T.B.
15	198.0	0.34	0.434	54.4	49646	64.2	5078	T.B.

RUN NUMBER: 556 y'in = 46.5 % R-11 / 53.5 % R-113
 p/d = 1.5 G = 51.18 kg/s*m^2
 Pin = 202.1 kPa DELTA P total = 7.87 kPa
 Xin = 0.00 Xout = 0.46

ROW	P	Xin	y'	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	R-11	[C]	[W/m^2]	[C]	[W/m^2 C]	TYPE
1	201.6	0.00	0.465	53.7	61480	64.4	5772	H.F.
3	200.4	0.09	0.460	54.0	60472	64.9	5566	H.F.
5	199.4	0.17	0.454	54.5	59536	64.1	6183	H.F.
7	198.4	0.22	0.448	54.9	61132	72.4	3514	SM.
9	197.4	0.24	0.443	55.4	60358	72.3	3574	SM.
11	196.4	0.27	0.438	55.9	60000	67.4	5232	T.B.
13	195.4	0.33	0.432	56.4	60104	67.8	5287	T.B.
15	194.2	0.42	0.427	56.9	59716	66.4	6266	T.B.

RUN NUMBER: 551 y'in = 46.5 % R-11 / 53.5 % R-113
 p/d = 1.5 G = 92.48 kg/s*m^2
 Pin = 198.65 kPa DELTA P total = 7.25 kPa
 Xin = 0.00 Xout = 0.09

ROW	P	Xin	y'	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	R-11	[C]	[W/m^2]	[C]	[W/m^2 C]	TYPE
1	198.2	0.00	0.465	53.7	21166	59.4	3693	H.F.
3	197.2	0.02	0.464	53.9	20803	59.8	3535	H.F.
5	196.3	0.03	0.463	54.4	20426	59.5	4011	H.F.
7	195.3	0.04	0.462	54.9	20990	65.1	2045	SM.
9	194.4	0.05	0.461	55.3	20574	64.9	2161	SM.
11	193.4	0.05	0.460	55.8	20638	59.4	5710	T.B.
13	192.4	0.07	0.459	56.3	20555	59.3	6762	T.B.
15	191.4	0.08	0.459	56.8	20357	58.3	13423	T.B.

RUN NUMBER: 562 y'in = 46.5 % R-11 / 53.5 % R-113
 p/d = 1.5 G = 91.65 kg/s*m^2
 Pin = 202.1 kPa DELTA P total = 6.64 kPa
 Xin = -.01 Xout = 0.02

ROW	P	Xin	y'	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	R-11	[C]	[W/m^2]	[C]	[W/m^2 C]	TYPE
1	201.7	-.00	0.465	50.6	5192	56.0	947	H.F.
3	200.7	0.00	0.465	51.8	5134	55.9	1247	H.F.
5	199.9	0.00	0.465	52.5	5032	55.8	1493	H.F.
7	199.0	0.01	0.464	52.5	5210	57.8	975	SM.
9	198.1	0.01	0.464	52.5	5074	57.6	985	SM.
11	197.2	0.01	0.464	52.5	5093	55.4	1756	T.B.
13	196.4	0.01	0.464	52.4	5084	55.2	1871	T.B.
15	195.5	0.02	0.463	52.4	5025	54.9	2048	T.B.

RUN NUMBER: 552 y'in = 46.5 % R-11 / 53.5 % R-113
 p/d = 1.5 G = 97.21 kg/s*m^2
 Pin = 202.1 kPa DELTA P total = 7.47 kPa
 Xin = 0.00 Xout = 0.12

ROW	P	Xin	y'	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	R-11	[C]	[W/m^2]	[C]	[W/m^2 C]	TYPE
1	201.6	0.00	0.465	53.1	31313	60.3	4362	H.F.
3	200.5	0.02	0.464	53.3	30934	60.7	4182	H.F.
5	199.6	0.05	0.462	53.6	30100	60.1	4582	H.F.
7	198.6	0.06	0.461	53.8	31065	66.6	2442	SM.
9	197.6	0.06	0.459	54.1	30575	66.5	2474	SM.
11	196.7	0.07	0.458	54.4	30518	60.8	4727	T.B.
13	195.7	0.09	0.457	54.6	30411	60.9	4851	T.B.
15	194.6	0.11	0.455	54.9	30143	59.6	6466	T.B.

RUN NUMBER: 560 y'in = 46.5 % R-11 / 53.5 % R-113
 p/d = 1.5 G = 98.44 kg/s*m^2
 Pin = 199.34 kPa DELTA P total = 6.1 kPa
 Xin = 0.02 Xout = 0.05

ROW	P	Xin	y'	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	R-11	[C]	[W/m^2]	[C]	[W/m^2 C]	TYPE
1	199.0	0.01	0.465	53.0	10289	56.7	2803	H.F.
3	198.2	0.01	0.465	53.1	10165	56.6	2900	H.F.
5	197.4	0.02	0.464	53.3	9966	56.4	3220	H.F.
7	196.6	0.03	0.464	53.5	10173	60.3	1495	SM.
9	195.8	0.03	0.463	53.6	9887	59.9	1569	SM.
11	194.9	0.03	0.463	53.8	10096	56.1	4363	T.B.
13	194.1	0.04	0.462	54.0	10077	56.0	5126	T.B.
15	193.3	0.04	0.462	54.2	9968	55.4	7929	T.B.

RUN NUMBER: 553 y'in = 46.5 % R-11 / 53.5 % R-113
 p/d = 1.5 G = 100.76 kg/s*m^2
 Pin = 202.1 kPa DELTA P total = 5.87 kPa
 Xin = 0.00 Xout = 0.16

ROW	P	Xin	y'	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	R-11	[C]	[W/m^2]	[C]	[W/m^2 C]	TYPE
1	201.7	0.00	0.465	52.6	41572	61.8	4552	H.F.
3	200.9	0.03	0.463	52.7	41051	62.1	4362	H.F.
5	200.2	0.06	0.461	52.8	40380	61.4	4676	H.F.
7	199.4	0.08	0.459	52.9	41119	68.5	2630	SM.
9	198.6	0.08	0.458	53.0	40484	68.4	2615	SM.
11	197.8	0.09	0.456	53.1	40246	63.0	4036	T.B.
13	197.0	0.11	0.454	53.1	40078	63.1	4050	T.B.
15	196.2	0.14	0.452	53.2	39821	61.7	4733	T.B.

RUN NUMBER: 554
p/d = 1.5
Pin = 202.1 kPa
Xin = 0.01

y'in = 46.5 % R-11 / 53.5 % R-113
G = 101.26 kg/s*m²
DELTA P total = 6.49 kPa
Xout = 0.20

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m ²]	Tw [C]	h [W/m ² C]	SURF TYPE
1	201.7	0.00	0.465	53.1	51856	63.2	5149	H.F.
3	200.8	0.04	0.463	53.3	51041	63.6	4933	H.F.
5	199.9	0.08	0.460	53.5	50121	62.9	5373	H.F.
7	199.1	0.10	0.458	53.8	51293	70.4	3084	SM.
9	198.2	0.10	0.456	54.1	50633	70.4	3096	SM.
11	197.4	0.12	0.454	54.3	50739	65.3	4620	T.B.
13	196.5	0.15	0.451	54.6	50686	65.4	4683	T.B.
15	195.6	0.18	0.449	54.8	50327	63.8	5649	T.B.

RUN NUMBER: 581
p/d = 1.5
Pin = 589.06 kPa
Xin = -.00

y'in = 46.1 % R-11 / 53.9 % R-113
G = 49.13 kg/s*m²
DELTA P total = 6.8 kPa
Xout = 0.04

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m ²]	Tw [C]	h [W/m ² C]	SURF TYPE
1	588.6	-.00	0.461	91.3	5251	97.1	906	H.F.
3	587.5	0.00	0.461	91.9	5220	97.0	1014	H.F.
5	586.5	0.01	0.461	92.4	5126	97.1	1111	H.F.
7	585.6	0.01	0.460	93.0	5539	99.3	881	SM.
9	584.7	0.02	0.460	93.5	5467	99.3	941	SM.
11	583.8	0.03	0.460	93.8	5072	97.2	1454	T.B.
13	582.9	0.03	0.460	94.0	5152	97.2	1601	T.B.
15	581.9	0.04	0.460	94.3	5084	97.0	1841	T.B.

RUN NUMBER: 555
p/d = 1.5
Pin = 202.1 kPa
Xin = 0.00

y'in = 46.5 % R-11 / 53.5 % R-113
G = 102.59 kg/s*m²
DELTA P total = 7.39 kPa
Xout = 0.23

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m ²]	Tw [C]	h [W/m ² C]	SURF TYPE
1	201.6	0.00	0.465	53.3	61471	64.5	5509	H.F.
3	200.5	0.04	0.462	53.5	60510	64.9	5308	H.F.
5	199.6	0.09	0.460	53.8	59483	64.0	5818	H.F.
7	198.6	0.11	0.457	54.1	61187	72.2	3383	SM.
9	197.7	0.12	0.454	54.5	60378	72.2	3406	SM.
11	196.7	0.13	0.451	54.8	60091	67.3	4792	T.B.
13	195.8	0.17	0.449	55.1	60198	67.5	4871	T.B.
15	194.7	0.21	0.446	55.5	59763	66.0	5665	T.B.

RUN NUMBER: 580
p/d = 1.5
Pin = 592.5 kPa
Xin = -.00

y'in = 46.1 % R-11 / 53.9 % R-113
G = 48.89 kg/s*m²
DELTA P total = 6 kPa
Xout = 0.09

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m ²]	Tw [C]	h [W/m ² C]	SURF TYPE
1	592.0	-.00	0.461	91.8	11027	99.0	1539	H.F.
3	591.0	0.01	0.461	93.0	10973	98.9	1874	H.F.
5	590.0	0.02	0.460	93.9	10545	98.8	2143	H.F.
7	589.1	0.03	0.460	94.3	10961	102.4	1359	SM.
9	588.2	0.05	0.459	94.8	10781	102.6	1394	SM.
11	587.3	0.06	0.459	95.3	10693	99.9	2312	T.B.
13	586.5	0.07	0.458	95.8	10556	99.8	2600	T.B.
15	585.5	0.08	0.458	96.3	10527	99.4	3379	T.B.

RUN NUMBER: 564
p/d = 1.5
Pin = 202.07 kPa
Xin = -.00

y'in = 46.5 % R-11 / 53.5 % R-113
G = 106.11 kg/s*m²
DELTA P total = 6.69 kPa
Xout = 0.19

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m ²]	Tw [C]	h [W/m ² C]	SURF TYPE
1	201.6	-.00	0.465	52.1	72634	66.1	5728	H.F.
3	200.5	0.02	0.462	53.3	71550	66.4	5981	H.F.
5	199.4	0.05	0.459	54.0	70231	65.7	6591	H.F.
7	198.4	0.07	0.455	54.8	71660	74.4	4011	SM.
9	197.6	0.10	0.452	55.5	70866	74.4	4136	SM.
11	196.9	0.13	0.449	56.3	70789	68.9	6170	T.B.
13	196.1	0.15	0.446	57.0	71280	68.8	6659	T.B.
15	195.4	0.18	0.443	57.8	70591	67.4	8035	T.B.

RUN NUMBER: 579
p/d = 1.5
Pin = 592.5 kPa
Xin = -.00

y'in = 46.1 % R-11 / 53.9 % R-113
G = 49.27 kg/s*m²
DELTA P total = 6.04 kPa
Xout = 0.18

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m ²]	Tw [C]	h [W/m ² C]	SURF TYPE
1	592.0	-.00	0.461	91.9	21351	100.3	2562	H.F.
3	590.9	0.02	0.460	93.4	21161	100.3	3079	H.F.
5	590.0	0.04	0.459	94.1	20478	100.4	3257	H.F.
7	589.0	0.07	0.458	94.6	21080	105.2	1995	SM.
9	588.1	0.09	0.458	95.2	20641	105.2	2063	SM.
11	587.3	0.12	0.457	95.8	20865	101.9	3407	T.B.
13	586.5	0.14	0.456	96.4	20797	102.0	3656	T.B.
15	585.6	0.17	0.455	96.9	20590	101.5	4520	T.B.

RUN NUMBER: 578 y'in = 46.1 % R-11 / 53.9 % R-113
 p/d = 1.5 G = 49.12 kg/s*m^2
 Pin = 592.5 kPa DELTA P total = 6.23 kPa
 Xin = 0.07 Xout = 0.38

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	592.0	0.10	0.461	91.9	31744	101.2	3423	H.F.
3	590.9	0.14	0.460	93.5	31446	101.4	3971	H.F.
5	589.9	0.17	0.458	94.1	30301	101.3	4226	H.F.
7	589.0	0.21	0.457	94.7	31506	106.8	2611	SM.
9	588.1	0.25	0.456	95.3	30878	106.8	2697	SM.
11	587.3	0.29	0.455	95.9	30902	103.7	3963	T.B.
13	586.6	0.33	0.453	96.5	31007	103.8	4258	T.B.
15	585.7	0.36	0.452	97.1	30705	102.7	5462	T.B.

RUN NUMBER: 575 y'in = 46.1 % R-11 / 53.9 % R-113
 p/d = 1.5 G = 48.78 kg/s*m^2
 Pin = 595.95 kPa DELTA P total = 6.53 kPa
 Xin = -.00 Xout = 0.55

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	595.4	-.00	0.461	92.7	62502	103.9	5613	H.F.
3	594.3	0.07	0.458	94.0	61924	104.3	5973	H.F.
5	593.3	0.14	0.456	94.6	60385	104.1	6398	H.F.
7	592.3	0.22	0.453	95.3	61797	110.4	4093	SM.
9	591.4	0.29	0.451	96.0	60799	110.4	4225	SM.
11	590.6	0.37	0.448	96.7	60712	108.0	5382	T.B.
13	589.9	0.44	0.446	97.4	61053	108.0	5767	T.B.
15	589.0	0.52	0.443	98.1	60399	106.6	7057	T.B.

RUN NUMBER: 577 y'in = 46.1 % R-11 / 53.9 % R-113
 p/d = 1.5 G = 49.17 kg/s*m^2
 Pin = 592.5 kPa DELTA P total = 6.33 kPa
 Xin = -.00 Xout = 0.36

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	592.0	-.00	0.461	92.2	41245	101.8	4296	H.F.
3	590.9	0.04	0.459	93.6	41000	102.2	4756	H.F.
5	589.9	0.09	0.458	94.2	39971	102.0	5085	H.F.
7	588.9	0.14	0.456	94.8	40876	107.8	3153	SM.
9	588.1	0.19	0.454	95.4	40488	107.8	3254	SM.
11	587.3	0.24	0.453	96.0	40550	105.0	4523	T.B.
13	586.5	0.29	0.451	96.6	40680	105.0	4841	T.B.
15	585.7	0.34	0.449	97.2	40423	103.8	6120	T.B.

RUN NUMBER: 589 y'in = 46.1 % R-11 / 53.9 % R-113
 p/d = 1.5 G = 196.45 kg/s*m^2
 Pin = 592.5 kPa DELTA P total = 6.81 kPa
 Xin = 0.00 Xout = 0.03

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	592.0	0.00	0.461	91.8	4892	97.3	898	H.F.
3	590.9	0.00	0.461	92.3	4865	97.2	1008	H.F.
5	590.0	0.01	0.461	92.8	4786	97.2	1102	H.F.
7	589.0	0.01	0.461	93.4	5095	99.3	862	SM.
9	588.1	0.01	0.461	93.8	5032	99.2	928	SM.
11	587.2	0.02	0.461	94.1	4701	97.3	1457	T.B.
13	586.3	0.02	0.460	94.3	4783	97.3	1616	T.B.
15	585.4	0.02	0.460	94.6	4719	97.1	1897	T.B.

RUN NUMBER: 576 y'in = 46.1 % R-11 / 53.9 % R-113
 p/d = 1.5 G = 48.73 kg/s*m^2
 Pin = 595.95 kPa DELTA P total = 6.43 kPa
 Xin = -.00 Xout = 0.46

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	595.4	-.00	0.461	92.5	51636	103.7	4606	H.F.
3	594.4	0.06	0.459	94.0	51054	104.1	5044	H.F.
5	593.4	0.12	0.457	94.7	49809	103.9	5369	H.F.
7	592.6	0.18	0.455	95.3	50919	110.0	3475	SM.
9	591.8	0.24	0.453	96.0	50400	110.1	3581	SM.
11	591.0	0.30	0.451	96.7	50539	107.5	4670	T.B.
13	590.2	0.37	0.448	97.3	50605	107.5	4976	T.B.
15	589.4	0.43	0.446	98.0	50408	106.3	6099	T.B.

RUN NUMBER: 588 y'in = 46.1 % R-11 / 53.9 % R-113
 p/d = 1.5 G = 196.19 kg/s*m^2
 Pin = 592.5 kPa DELTA P total = 6.04 kPa
 Xin = -.00 Xout = 0.06

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	592.0	-.00	0.461	91.8	11096	98.9	1565	H.F.
3	591.0	0.01	0.461	93.0	11041	98.8	1920	H.F.
5	590.0	0.01	0.461	93.9	10608	98.7	2191	H.F.
7	589.1	0.02	0.460	94.3	11036	102.4	1369	SM.
9	588.2	0.03	0.460	94.8	10886	102.6	1404	SM.
11	587.3	0.04	0.460	95.3	10771	99.8	2380	T.B.
13	586.4	0.05	0.460	95.8	10631	99.6	2747	T.B.
15	585.5	0.05	0.460	96.3	10600	99.2	3582	T.B.

RUN NUMBER: 587
p/d = 1.5
Pin = 592.5 kPa
Xin = -.00

y'in = 46.1 % R-11 / 53.9 % R-113
G = 195.9 kg/s*m^2
DELTA P total = 6.09 kPa
Xout = 0.11

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	592.0	-.00	0.461	91.9	21356	100.3	2537	H.F.
3	590.9	0.01	0.461	93.4	21158	100.5	3017	H.F.
5	589.9	0.03	0.460	94.1	20476	100.3	3306	H.F.
7	589.0	0.04	0.460	94.6	21081	105.2	2001	SM.
9	588.1	0.06	0.459	95.2	20569	105.2	2056	SM.
11	587.3	0.08	0.459	95.8	20865	102.1	3284	T.B.
13	586.4	0.09	0.458	96.4	20789	102.1	3646	T.B.
15	585.6	0.11	0.458	96.9	20548	101.3	4697	T.B.

RUN NUMBER: 584
p/d = 1.5
Pin = 595.95 kPa
Xin = -.00

y'in = 46.1 % R-11 / 53.9 % R-113
G = 195.47 kg/s*m^2
DELTA P total = 6.52 kPa
Xout = 0.28

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	595.4	-.00	0.461	92.5	51812	103.1	4865	H.F.
3	594.3	0.04	0.460	94.0	51280	103.5	5384	H.F.
5	593.3	0.07	0.459	94.7	50019	103.3	5770	H.F.
7	592.3	0.11	0.458	95.3	51088	109.4	3630	SM.
9	591.5	0.15	0.457	96.0	50526	109.5	3749	SM.
11	590.7	0.19	0.456	96.7	50631	106.8	4987	T.B.
13	590.0	0.23	0.455	97.3	50740	106.9	5323	T.B.
15	589.3	0.27	0.454	98.0	50492	105.6	6639	T.B.

RUN NUMBER: 586
p/d = 1.5
Pin = 592.5 kPa
Xin = 0.07

y'in = 46.1 % R-11 / 53.9 % R-113
G = 196.07 kg/s*m^2
DELTA P total = 6.1 kPa
Xout = 0.24

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	592.0	0.06	0.461	91.9	31558	101.0	3458	H.F.
3	590.9	0.09	0.460	93.5	31261	101.2	4061	H.F.
5	590.0	0.11	0.460	94.1	30100	101.1	4326	H.F.
7	589.0	0.13	0.459	94.7	31259	106.6	2633	SM.
9	588.2	0.16	0.458	95.3	30682	106.6	2718	SM.
11	587.4	0.18	0.458	95.9	30725	103.4	4112	T.B.
13	586.7	0.20	0.457	96.5	30821	103.5	4415	T.B.
15	585.9	0.23	0.457	97.1	30526	102.5	5682	T.B.

RUN NUMBER: 583
p/d = 1.5
Pin = 595.95 kPa
Xin = -.00

y'in = 46.1 % R-11 / 53.9 % R-113
G = 195.33 kg/s*m^2
DELTA P total = 5.9 kPa
Xout = 0.35

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	595.4	-.00	0.461	92.8	62855	104.1	5598	H.F.
3	594.3	0.04	0.460	94.1	62320	104.5	5964	H.F.
5	593.2	0.09	0.458	94.7	60740	104.3	6389	H.F.
7	592.3	0.13	0.457	95.4	62101	110.6	4093	SM.
9	591.4	0.18	0.456	96.1	61300	110.7	4204	SM.
11	590.6	0.22	0.455	96.8	61146	108.2	5367	T.B.
13	589.9	0.26	0.453	97.5	61477	108.2	5739	T.B.
15	589.1	0.30	0.452	98.2	60888	106.9	6956	T.B.

RUN NUMBER: 585
p/d = 1.5
Pin = 592.5 kPa
Xin = -.00

y'in = 46.1 % R-11 / 53.9 % R-113
G = 196.16 kg/s*m^2
DELTA P total = 5.95 kPa
Xout = 0.22

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	592.0	-.00	0.461	92.2	41218	102.0	4221	H.F.
3	591.0	0.03	0.460	93.6	40952	102.3	4681	H.F.
5	590.1	0.06	0.459	94.2	40062	102.2	5006	H.F.
7	589.2	0.09	0.458	94.8	40792	108.0	3101	SM.
9	588.4	0.12	0.458	95.4	40392	108.1	3192	SM.
11	587.7	0.15	0.457	96.0	40488	105.1	4435	T.B.
13	586.9	0.18	0.456	96.6	40605	105.2	4760	T.B.
15	586.1	0.21	0.455	97.2	40363	103.9	6017	T.B.

RUN NUMBER: 582
p/d = 1.5
Pin = 595.95 kPa
Xin = -.00

y'in = 46.1 % R-11 / 53.9 % R-113
G = 195.54 kg/s*m^2
DELTA P total = 6.43 kPa
Xout = 0.41

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	595.4	-.00	0.461	92.8	74427	104.6	6282	H.F.
3	594.3	0.05	0.459	94.0	73917	105.1	6651	H.F.
5	593.3	0.10	0.458	94.8	72247	104.8	7170	H.F.
7	592.3	0.16	0.456	95.5	73847	111.5	4606	SM.
9	591.4	0.22	0.455	96.2	72829	111.5	4770	SM.
11	590.6	0.28	0.453	96.9	72431	109.1	5941	T.B.
13	589.9	0.33	0.452	97.7	72913	109.1	6364	T.B.
15	589.1	0.38	0.451	98.4	71880	108.0	7495	T.B.

Bundle Boiling Data

Data from the 75% R-11/25% R-113 mixture

RUN NUMBER: 509 y'in = 75.8 % R-11 / 24.2 % R-113
 p/d = 1.5 G = 48.58 kg/s*m^2
 Pin = 209.33 kPa DELTA P total = 6.26 kPa
 Xin = -.00 Xout = 0.05

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	208.9	-.00	0.758	48.2	5343	50.0	2908	H.F.
3	208.1	0.01	0.758	49.1	5288	49.9	2991	H.F.
5	207.3	0.01	0.757	49.0	5137	49.8	3223	H.F.
7	206.4	0.02	0.757	48.8	5212	52.3	1474	SM.
9	205.6	0.03	0.757	48.6	5106	52.0	1481	SM.
11	204.8	0.04	0.756	48.4	5078	49.4	4806	T.B.
13	203.9	0.04	0.756	48.2	5086	49.2	4812	T.B.
15	203.1	0.05	0.756	48.0	4990	49.1	4768	T.B.

RUN NUMBER: 507 y'in = 75.8 % R-11 / 24.2 % R-113
 p/d = 1.5 G = 48.75 kg/s*m^2
 Pin = 201.83 kPa DELTA P total = 7.15 kPa
 Xin = 0.00 Xout = 0.33

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	201.3	0.00	0.758	46.5	31221	51.1	5525	H.F.
3	200.3	0.04	0.756	46.0	30747	51.6	5477	H.F.
5	199.3	0.09	0.754	46.1	30126	51.1	5968	H.F.
7	198.3	0.13	0.752	46.2	31017	60.7	2142	SM.
9	197.4	0.18	0.750	46.2	30400	60.6	2111	SM.
11	196.5	0.22	0.747	46.3	30523	51.9	5429	T.B.
13	195.7	0.27	0.745	46.4	30525	52.0	5431	T.B.
15	194.7	0.31	0.743	46.4	30092	50.9	6694	T.B.

RUN NUMBER: 508 y'in = 75.8 % R-11 / 24.2 % R-113
 p/d = 1.5 G = 48.65 kg/s*m^2
 Pin = 201.02 kPa DELTA P total = 6.26 kPa
 Xin = 0.00 Xout = 0.12

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	200.6	0.00	0.758	46.9	10604	49.2	4745	H.F.
3	199.8	0.02	0.757	47.6	10487	49.2	3754	H.F.
5	199.0	0.03	0.757	47.5	10185	48.9	3943	H.F.
7	198.1	0.05	0.756	47.3	10718	54.1	1580	SM.
9	197.3	0.06	0.755	47.1	10478	53.5	1636	SM.
11	196.4	0.08	0.754	46.9	10540	48.8	5558	T.B.
13	195.6	0.10	0.754	46.8	10551	48.7	5565	T.B.
15	194.8	0.11	0.753	46.6	10336	48.2	6402	T.B.

RUN NUMBER: 504 y'in = 75.8 % R-11 / 24.2 % R-113
 p/d = 1.5 G = 49.04 kg/s*m^2
 Pin = 203.65 kPa DELTA P total = 6.8 kPa
 Xin = 0.00 Xout = 0.43

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	203.2	0.00	0.758	46.7	41245	51.8	7671	H.F.
3	202.2	0.06	0.755	47.5	40902	53.0	7867	H.F.
5	201.3	0.11	0.752	47.4	40030	52.5	7854	H.F.
7	200.5	0.17	0.750	47.3	40572	61.2	2933	SM.
9	199.6	0.23	0.747	47.2	39868	61.4	2805	SM.
11	198.7	0.29	0.744	47.1	40056	53.1	6755	T.B.
13	197.8	0.35	0.741	47.0	40182	53.2	6902	T.B.
15	196.9	0.40	0.739	46.9	39577	52.0	7836	T.B.

RUN NUMBER: 510 y'in = 75.8 % R-11 / 24.2 % R-113
 p/d = 1.5 G = 50.52 kg/s*m^2
 Pin = 229.62 kPa DELTA P total = 6.41 kPa
 Xin = -.02 Xout = 0.18

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	229.3	-.02	0.758	46.7	20603	51.4	4374	H.F.
3	228.5	0.01	0.757	48.9	20256	52.4	5836	H.F.
5	227.6	0.04	0.755	48.8	19786	53.4	5791	H.F.
7	226.8	0.06	0.754	48.7	20116	59.3	1891	SM.
9	225.9	0.09	0.753	48.6	19666	59.3	1836	SM.
11	225.0	0.12	0.751	48.4	20261	52.0	5685	T.B.
13	224.2	0.14	0.750	48.3	20288	51.9	5689	T.B.
15	223.2	0.17	0.748	48.2	19907	51.2	6656	T.B.

RUN NUMBER: 511 y'in = 75.8 % R-11 / 24.2 % R-113
 p/d = 1.5 G = 50.19 kg/s*m^2
 Pin = 234.86 kPa DELTA P total = 6.16 kPa
 Xin = -.02 Xout = 0.48

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	234.5	-.02	0.758	47.0	51141	54.1	7259	H.F.
3	233.6	0.05	0.755	49.7	50382	55.1	9282	H.F.
5	232.8	0.11	0.751	49.6	49580	55.0	9141	H.F.
7	232.0	0.18	0.748	49.5	50594	64.0	3478	SM.
9	231.2	0.25	0.744	49.4	49813	64.5	3282	SM.
11	230.4	0.32	0.741	49.3	50139	56.4	6986	T.B.
13	229.6	0.39	0.737	49.1	50133	56.6	6756	T.B.
15	228.7	0.45	0.734	49.0	49779	55.1	8256	T.B.

RUN NUMBER: 506
p/d = 1.5
Pin = 219.45 kPa
Xin = -.01
y'in = 75.8 % R-11 / 24.2 % R-113
G = 48.52 kg/s*m^2
DELTA P total = 6.25 kPa
Xout = 0.64

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	219.1	-.01	0.758	48.2	61638	54.1	9105	H.F.
3	218.2	0.07	0.754	50.4	60689	54.9	10420	H.F.
5	217.4	0.16	0.750	50.2	59663	54.2	11221	H.F.
7	216.6	0.24	0.745	50.1	60985	64.5	4238	SM.
9	215.7	0.34	0.741	50.0	60207	65.1	3985	SM.
11	214.9	0.43	0.737	49.9	60078	56.7	8809	T.B.
13	214.1	0.51	0.733	49.7	60219	56.9	8418	T.B.
15	213.2	0.59	0.729	49.6	59784	55.5	10115	T.B.

RUN NUMBER: 501
p/d = 1.5
Pin = 201.27 kPa
Xin = 0.00
y'in = 75.8 % R-11 / 24.2 % R-113
G = 194.42 kg/s*m^2
DELTA P total = 6.68 kPa
Xout = 0.11

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	200.8	0.00	0.758	46.5	21480	50.3	4949	H.F.
3	199.8	0.02	0.757	46.4	21300	51.6	5096	H.F.
5	198.9	0.03	0.757	46.4	20680	51.9	4939	H.F.
7	198.0	0.05	0.756	46.4	20886	58.2	1773	SM.
9	197.3	0.06	0.755	46.4	20117	57.8	1759	SM.
11	196.5	0.08	0.755	46.4	20053	50.6	4779	T.B.
13	195.6	0.09	0.754	46.4	20120	50.5	4951	T.B.
15	194.6	0.11	0.753	46.5	19670	49.8	5849	T.B.

RUN NUMBER: 516
p/d = 1.5
Pin = 209.17 kPa
Xin = -.00
y'in = 75.8 % R-11 / 24.2 % R-113
G = 204.03 kg/s*m^2
DELTA P total = 5.63 kPa
Xout = 0.03

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	208.8	-.00	0.758	48.4	5343	50.2	2908	H.F.
3	207.9	0.00	0.758	49.5	5288	51.3	2972	H.F.
5	207.1	0.01	0.758	49.6	5137	51.2	3204	H.F.
7	206.3	0.01	0.757	49.6	5212	52.7	1663	SM.
9	205.4	0.02	0.757	49.6	5106	52.7	1670	SM.
11	204.6	0.02	0.757	49.6	5078	50.6	5298	T.B.
13	203.8	0.02	0.757	49.7	5086	50.6	5304	T.B.
15	202.9	0.03	0.757	49.6	4990	50.6	5260	T.B.

RUN NUMBER: 503
p/d = 1.5
Pin = 207.52 kPa
Xin = -.00
y'in = 75.8 % R-11 / 24.2 % R-113
G = 196.87 kg/s*m^2
DELTA P total = 6.52 kPa
Xout = 0.16

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	207.1	-.00	0.758	47.5	30602	52.1	5511	H.F.
3	206.2	0.02	0.757	48.0	30411	53.4	5582	H.F.
5	205.3	0.04	0.756	47.9	29457	53.1	5614	H.F.
7	204.5	0.06	0.755	47.8	30338	60.7	2360	SM.
9	203.6	0.09	0.754	47.8	29267	60.7	2273	SM.
11	202.7	0.11	0.753	47.7	30283	53.0	5753	T.B.
13	201.9	0.13	0.752	47.7	30372	53.0	5737	T.B.
15	201.0	0.15	0.751	47.6	29791	51.9	6890	T.B.

RUN NUMBER: 502
p/d = 1.5
Pin = 200.86 kPa
Xin = 0.00
y'in = 75.8 % R-11 / 24.2 % R-113
G = 204.34 kg/s*m^2
DELTA P total = 5.63 kPa
Xout = 0.07

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	200.5	0.00	0.758	47.1	10604	49.4	4745	H.F.
3	199.6	0.01	0.758	48.1	10487	50.8	3835	H.F.
5	198.8	0.02	0.757	48.1	10185	50.6	4024	H.F.
7	198.0	0.03	0.757	48.1	10718	54.2	1769	SM.
9	197.1	0.04	0.757	48.2	10478	53.9	1825	SM.
11	196.3	0.04	0.756	48.2	10540	50.0	6050	T.B.
13	195.5	0.05	0.756	48.3	10551	50.0	6057	T.B.
15	194.6	0.06	0.756	48.2	10336	49.7	6894	T.B.

RUN NUMBER: 515
p/d = 1.5
Pin = 203.49 kPa
Xin = 0.00
y'in = 75.8 % R-11 / 24.2 % R-113
G = 205.96 kg/s*m^2
DELTA P total = 6.12 kPa
Xout = 0.24

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	203.0	0.00	0.758	46.9	41245	52.3	7671	H.F.
3	202.0	0.03	0.757	48.0	40902	53.0	8048	H.F.
5	201.2	0.06	0.755	48.0	40030	53.0	8035	H.F.
7	200.3	0.10	0.754	48.1	40572	61.1	3120	SM.
9	199.4	0.13	0.752	48.3	39868	61.6	2992	SM.
11	198.5	0.16	0.751	48.4	40056	54.2	6947	T.B.
13	197.6	0.19	0.750	48.5	40182	54.2	7094	T.B.
15	196.7	0.22	0.748	48.5	39577	53.5	8028	T.B.

RUN NUMBER: 505 y'in = 75.8 % R-11 / 24.2 % R-113
 p/d = 1.5 G = 205.8 kg/s*m^2
 Pin = 234.67 kPa DELTA P total = 6.77 kPa
 Xin = -.02 Xout = 0.24

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	234.3	-.01	0.758	46.8	51141	53.9	7259	H.F.
3	233.4	0.02	0.756	49.3	50382	54.6	9471	H.F.
5	232.6	0.06	0.755	49.0	49580	54.3	9330	H.F.
7	231.8	0.09	0.753	48.7	50594	62.5	3656	SM.
9	231.0	0.13	0.751	48.3	49813	62.7	3460	SM.
11	230.2	0.16	0.749	48.0	50139	55.0	7192	T.B.
13	229.4	0.19	0.748	47.7	50133	54.9	6962	T.B.
15	228.5	0.23	0.746	47.4	49779	53.3	8462	T.B.

RUN NUMBER: 543 y'in = 75.1 % R-11 / 24.9 % R-113
 p/d = 1.5 G = 51.44 kg/s*m^2
 Pin = 575.96 kPa DELTA P total = 6.8 kPa
 Xin = -.00 Xout = 0.04

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	575.5	-.00	0.751	90.0	5346	93.1	1734	H.F.
3	574.4	0.00	0.751	90.5	5309	93.2	1941	H.F.
5	573.4	0.01	0.751	90.9	5167	93.4	2127	H.F.
7	572.5	0.01	0.750	91.4	5577	97.5	916	SM.
9	571.6	0.02	0.750	91.8	5491	97.4	978	SM.
11	570.7	0.02	0.750	92.0	5151	94.2	2300	T.B.
13	569.8	0.03	0.750	92.1	5195	94.2	2532	T.B.
15	568.8	0.03	0.750	92.3	5127	94.0	2911	T.B.

RUN NUMBER: 514 y'in = 75.8 % R-11 / 24.2 % R-113
 p/d = 1.5 G = 203.79 kg/s*m^2
 Pin = 219.29 kPa DELTA P total = 5.62 kPa
 Xin = -.01 Xout = 0.35

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	218.9	-.01	0.758	48.4	61638	54.2	10605	H.F.
3	218.0	0.04	0.756	50.8	60689	55.4	13129	H.F.
5	217.2	0.09	0.754	50.9	59663	54.8	14930	H.F.
7	216.4	0.14	0.752	50.9	60985	64.7	4427	SM.
9	215.6	0.19	0.750	51.1	60207	65.5	4174	SM.
11	214.7	0.24	0.748	51.1	60078	57.6	9301	T.B.
13	213.9	0.28	0.746	51.2	60219	58.0	8910	T.B.
15	213.0	0.33	0.744	51.2	59784	56.9	10607	T.B.

RUN NUMBER: 542 y'in = 75.1 % R-11 / 24.9 % R-113
 p/d = 1.5 G = 51.19 kg/s*m^2
 Pin = 579.4 kPa DELTA P total = 6 kPa
 Xin = -.00 Xout = 0.08

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	578.9	-.00	0.751	90.5	11089	94.3	2944	H.F.
3	577.9	0.01	0.751	91.6	11018	94.7	3587	H.F.
5	576.9	0.02	0.750	92.4	10599	95.0	4102	H.F.
7	576.0	0.03	0.750	92.7	11031	100.6	1413	SM.
9	575.1	0.04	0.749	93.1	10803	100.6	1449	SM.
11	574.2	0.05	0.749	93.5	10712	96.4	3657	T.B.
13	573.4	0.06	0.748	93.9	10652	96.5	4112	T.B.
15	572.4	0.08	0.748	94.3	10568	96.2	5344	T.B.

RUN NUMBER: 513 y'in = 75.8 % R-11 / 24.2 % R-113
 p/d = 1.5 G = 203.79 kg/s*m^2
 Pin = 219.29 kPa DELTA P total = 5.62 kPa
 Xin = -.01 Xout = 0.35

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	218.9	-.01	0.758	48.4	72117	54.4	12102	H.F.
3	218.0	0.04	0.756	50.8	71006	55.6	14917	H.F.
5	217.2	0.09	0.753	50.9	69806	55.0	16718	H.F.
7	216.4	0.14	0.751	50.9	71352	67.0	4427	SM.
9	215.6	0.19	0.748	51.1	70442	67.9	4174	SM.
11	214.7	0.24	0.746	51.1	70292	58.7	9301	T.B.
13	213.9	0.28	0.743	51.2	70456	59.1	8910	T.B.
15	213.0	0.33	0.741	51.2	69948	57.8	10607	T.B.

RUN NUMBER: 541 y'in = 75.1 % R-11 / 24.9 % R-113
 p/d = 1.5 G = 51.59 kg/s*m^2
 Pin = 579.4 kPa DELTA P total = 6.36 kPa
 Xin = -.00 Xout = 0.16

ROW #	P [kPa]	Xin [-]	y' R-11	Tf [C]	q'' [W/m^2]	Tw [C]	h [W/m^2 C]	SURF TYPE
1	578.9	-.00	0.751	90.6	21409	95.0	4903	H.F.
3	577.8	0.02	0.750	92.1	21249	95.7	5893	H.F.
5	576.9	0.04	0.749	92.6	20432	95.9	6233	H.F.
7	575.9	0.06	0.748	93.0	21165	103.2	2074	SM.
9	575.0	0.09	0.748	93.5	20718	103.2	2145	SM.
11	574.2	0.11	0.747	94.0	20817	97.9	5389	T.B.
13	573.4	0.13	0.746	94.5	20868	98.1	5782	T.B.
15	572.5	0.15	0.745	94.9	20635	97.8	7149	T.B.

RUN NUMBER: 540
p/d = 1.5
Pin = 579.4 kPa
Xin = 0.07

y'in = 75.1 % R-11 / 24.9 % R-113
G = 51.44 kg/s*m²
DELTA P total = 6.29 kPa
Xout = 0.34

ROW	P	Xin	y'	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	R-11	[C]	[W/m ²]	[C]	[W/m ² C]	TYPE
1	578.9	0.09	0.751	90.6	31756	95.5	6552	H.F.
3	577.8	0.13	0.750	92.2	31545	96.3	7599	H.F.
5	576.8	0.16	0.748	92.7	30438	96.4	8088	H.F.
7	575.9	0.19	0.747	93.2	31461	104.7	2715	SM.
9	575.0	0.23	0.746	93.6	30984	104.7	2804	SM.
11	574.2	0.26	0.744	94.1	31006	99.1	6268	T.B.
13	573.5	0.29	0.743	94.6	31073	99.3	6734	T.B.
15	572.6	0.33	0.742	95.1	30806	98.7	8638	T.B.

RUN NUMBER: 537
p/d = 1.5
Pin = 582.85 kPa
Xin = -0.00

y'in = 75.1 % R-11 / 24.9 % R-113
G = 51.07 kg/s*m²
DELTA P total = 6.53 kPa
Xout = 0.50

ROW	P	Xin	y'	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	R-11	[C]	[W/m ²]	[C]	[W/m ² C]	TYPE
1	582.3	-0.00	0.751	91.4	62584	97.3	10743	H.F.
3	581.2	0.06	0.748	92.6	61955	98.0	11431	H.F.
5	580.2	0.13	0.746	93.1	60406	98.1	12245	H.F.
7	579.2	0.20	0.743	93.7	61808	108.3	4255	SM.
9	578.3	0.27	0.741	94.3	60900	108.2	4392	SM.
11	577.5	0.33	0.738	94.9	60746	102.0	8512	T.B.
13	576.8	0.40	0.735	95.5	61083	102.2	9122	T.B.
15	575.9	0.47	0.733	96.1	60490	101.5	11162	T.B.

RUN NUMBER: 539
p/d = 1.5
Pin = 579.4 kPa
Xin = -0.00

y'in = 75.1 % R-11 / 24.9 % R-113
G = 51.48 kg/s*m²
DELTA P total = 6.65 kPa
Xout = 0.32

ROW	P	Xin	y'	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	R-11	[C]	[W/m ²]	[C]	[W/m ² C]	TYPE
1	578.9	-0.00	0.751	90.9	41395	96.0	8222	H.F.
3	577.8	0.04	0.749	92.2	41021	96.7	9102	H.F.
5	576.8	0.08	0.748	92.7	39977	96.8	9732	H.F.
7	575.8	0.12	0.746	93.2	40999	105.7	3278	SM.
9	575.0	0.17	0.744	93.7	40497	105.7	3383	SM.
11	574.2	0.22	0.742	94.2	40695	99.9	7153	T.B.
13	573.4	0.26	0.741	94.7	40776	100.1	7656	T.B.
15	572.6	0.30	0.739	95.2	40493	99.4	9679	T.B.

RUN NUMBER: 531
p/d = 1.5
Pin = 579.4 kPa
Xin = 0.00

y'in = 75.1 % R-11 / 24.9 % R-113
G = 217.08 kg/s*m²
DELTA P total = 6.81 kPa
Xout = 0.02

ROW	P	Xin	y'	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	R-11	[C]	[W/m ²]	[C]	[W/m ² C]	TYPE
1	578.9	0.00	0.751	90.6	4892	93.5	1720	H.F.
3	577.8	0.00	0.751	91.1	4865	93.7	1929	H.F.
5	576.9	0.01	0.751	91.6	4786	93.9	2110	H.F.
7	575.9	0.01	0.751	92.2	5095	97.9	896	SM.
9	575.0	0.01	0.751	92.6	5032	97.8	965	SM.
11	574.1	0.02	0.751	92.9	4701	94.9	2304	T.B.
13	573.2	0.02	0.750	93.1	4783	95.0	2557	T.B.
15	572.3	0.02	0.750	93.4	4719	95.0	3000	T.B.

RUN NUMBER: 538
p/d = 1.5
Pin = 582.85 kPa
Xin = -0.00

y'in = 75.1 % R-11 / 24.9 % R-113
G = 51.03 kg/s*m²
DELTA P total = 5.62 kPa
Xout = 0.41

ROW	P	Xin	y'	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	R-11	[C]	[W/m ²]	[C]	[W/m ² C]	TYPE
1	582.3	-0.00	0.751	91.2	51579	97.1	8814	H.F.
3	581.3	0.05	0.749	92.6	51074	97.9	9653	H.F.
5	580.3	0.11	0.747	93.2	49772	98.0	10275	H.F.
7	579.5	0.16	0.744	93.8	50971	107.9	3612	SM.
9	578.7	0.22	0.742	94.3	50371	107.9	3723	SM.
11	577.9	0.28	0.740	94.9	50600	101.8	7387	T.B.
13	577.1	0.33	0.738	95.5	50775	101.9	7871	T.B.
15	576.3	0.38	0.736	96.1	50429	101.3	9647	T.B.

RUN NUMBER: 530
p/d = 1.5
Pin = 579.4 kPa
Xin = -0.00

y'in = 75.1 % R-11 / 24.9 % R-113
G = 216.79 kg/s*m²
DELTA P total = 6.04 kPa
Xout = 0.05

ROW	P	Xin	y'	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	R-11	[C]	[W/m ²]	[C]	[W/m ² C]	TYPE
1	578.9	-0.00	0.751	90.6	11096	94.3	2996	H.F.
3	577.9	0.00	0.751	91.8	11041	94.8	3675	H.F.
5	576.9	0.01	0.751	92.7	10608	95.2	4192	H.F.
7	576.0	0.02	0.750	93.1	11036	100.9	1424	SM.
9	575.1	0.03	0.750	93.6	10886	101.1	1459	SM.
11	574.2	0.03	0.750	94.1	10771	97.0	3764	T.B.
13	573.3	0.04	0.750	94.6	10631	97.0	4345	T.B.
15	572.4	0.05	0.749	95.1	10600	96.9	5666	T.B.

RUN NUMBER: 529 y'in = 75.1 % R-11 / 24.9 % R-113
 p/d = 1.5 G = 216.47 kg/s*m^2
 Pin = 579.4 kPa DELTA P total = 6.61 kPa
 Xin = -.00 Xout = 0.10

ROW	P	Xin	y'	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	R-11	[C]	[W/m^2]	[C]	[W/m^2 C]	TYPE
1	578.9	-.00	0.751	90.5	21273	94.9	4856	H.F.
3	577.8	0.01	0.751	91.8	21133	95.5	5774	H.F.
5	576.8	0.02	0.750	92.2	20425	95.5	6326	H.F.
7	575.9	0.04	0.750	92.6	21113	102.8	2080	SM.
9	575.0	0.05	0.749	93.0	20661	102.7	2138	SM.
11	574.2	0.07	0.749	93.4	20758	97.4	5194	T.B.
13	573.3	0.08	0.748	93.7	20858	97.4	5766	T.B.
15	572.5	0.09	0.748	94.1	20583	96.9	7429	T.B.

RUN NUMBER: 526 y'in = 75.1 % R-11 / 24.9 % R-113
 p/d = 1.5 G = 216 kg/s*m^2
 Pin = 582.85 kPa DELTA P total = 6.14 kPa
 Xin = -.00 Xout = 0.25

ROW	P	Xin	y'	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	R-11	[C]	[W/m^2]	[C]	[W/m^2 C]	TYPE
1	582.3	-.00	0.751	91.1	51757	96.6	9311	H.F.
3	581.2	0.03	0.750	92.4	51223	97.3	10304	H.F.
5	580.2	0.06	0.749	92.8	49917	97.4	11042	H.F.
7	579.2	0.10	0.748	93.3	51150	106.9	3774	SM.
9	578.4	0.13	0.747	93.8	50458	106.7	3898	SM.
11	577.7	0.17	0.746	94.2	50521	100.6	7888	T.B.
13	576.9	0.20	0.745	94.7	50774	100.7	8419	T.B.
15	576.2	0.24	0.743	95.2	50406	100.0	10500	T.B.

RUN NUMBER: 528 y'in = 75.1 % R-11 / 24.9 % R-113
 p/d = 1.5 G = 216.66 kg/s*m^2
 Pin = 579.4 kPa DELTA P total = 5.67 kPa
 Xin = 0.07 Xout = 0.21

ROW	P	Xin	y'	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	R-11	[C]	[W/m^2]	[C]	[W/m^2 C]	TYPE
1	578.9	0.06	0.751	90.5	31530	95.3	6618	H.F.
3	577.8	0.08	0.750	92.0	31299	96.0	7772	H.F.
5	576.9	0.10	0.750	92.4	30144	96.0	8280	H.F.
7	575.9	0.12	0.749	92.8	31163	104.1	2738	SM.
9	575.1	0.14	0.748	93.2	30766	104.1	2826	SM.
11	574.3	0.16	0.748	93.5	30886	98.3	6504	T.B.
13	573.6	0.18	0.747	94.0	30793	98.4	6983	T.B.
15	572.8	0.20	0.746	94.4	30596	97.8	8986	T.B.

RUN NUMBER: 525 y'in = 75.1 % R-11 / 24.9 % R-113
 p/d = 1.5 G = 215.84 kg/s*m^2
 Pin = 582.85 kPa DELTA P total = 6.4 kPa
 Xin = -.00 Xout = 0.31

ROW	P	Xin	y'	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	R-11	[C]	[W/m^2]	[C]	[W/m^2 C]	TYPE
1	582.3	-.00	0.751	91.4	62881	97.3	10713	H.F.
3	581.2	0.04	0.750	92.4	62366	97.9	11413	H.F.
5	580.1	0.08	0.748	92.9	60883	97.9	12227	H.F.
7	579.2	0.12	0.747	93.4	62029	108.0	4255	SM.
9	578.3	0.16	0.746	93.9	61437	107.9	4370	SM.
11	577.5	0.20	0.744	94.4	61012	101.5	8488	T.B.
13	576.8	0.23	0.743	94.8	61337	101.6	9078	T.B.
15	576.0	0.27	0.742	95.3	60874	100.9	11002	T.B.

RUN NUMBER: 527 y'in = 75.1 % R-11 / 24.9 % R-113
 p/d = 1.5 G = 216.76 kg/s*m^2
 Pin = 579.4 kPa DELTA P total = 5.56 kPa
 Xin = -.00 Xout = 0.20

ROW	P	Xin	y'	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	R-11	[C]	[W/m^2]	[C]	[W/m^2 C]	TYPE
1	578.9	-.00	0.751	90.8	41282	95.9	8078	H.F.
3	577.9	0.02	0.750	91.9	40857	96.5	8959	H.F.
5	577.0	0.05	0.749	92.4	40062	96.5	9581	H.F.
7	576.1	0.08	0.748	92.8	40860	105.4	3223	SM.
9	575.3	0.10	0.748	93.2	40291	105.3	3318	SM.
11	574.6	0.13	0.747	93.6	40626	99.4	7014	T.B.
13	573.8	0.16	0.746	94.0	40647	99.4	7529	T.B.
15	573.0	0.19	0.745	94.4	40345	98.6	9516	T.B.

RUN NUMBER: 536 y'in = 75.1 % R-11 / 24.9 % R-113
 p/d = 1.5 G = 207.12 kg/s*m^2
 Pin = 582.85 kPa DELTA P total = 6.46 kPa
 Xin = -.00 Xout = 0.40

ROW	P	Xin	y'	Tf	q''	Tw	h	SURF
#	[kPa]	[-]	R-11	[C]	[W/m^2]	[C]	[W/m^2 C]	TYPE
1	582.3	-.00	0.751	91.2	73952	97.5	11866	H.F.
3	581.2	0.06	0.749	91.7	73323	92.3	6894	H.F.
5	580.1	0.11	0.748	92.0	71492	88.4	5359	H.F.
7	579.1	0.17	0.746	92.4	73279	107.8	1861	SM.
9	578.3	0.23	0.745	91.8	72465	107.4	1590	SM.
11	577.5	0.29	0.743	92.0	72073	88.4	2165	T.B.
13	576.8	0.35	0.742	92.5	72605	85.9	1939	T.B.
15	576.1	0.40	0.740	92.8	71701	82.8	1750	T.B.

Single-Phase Data

RUN NUMBER: 6
p/d = 1.5
Pin = 115.9 kPa
Xin = -.24
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 101.84 kg/s*m²
DELTA P total = 6.28 kPa
Xout = -.20

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	115.5	-.24	24.5	4684	43.5	250
3	114.6	-.24	25.0	4762	43.1	267
5	113.8	-.23	25.6	4597	43.7	257
7	113.0	-.23	26.1	5670	44.2	317
9	112.1	-.22	26.6	5460	44.1	316
11	111.3	-.22	27.1	4939	45.3	280
13	110.5	-.21	28.2	5170	46.0	298
15	109.6	-.21	29.2	5291	46.6	314

RUN NUMBER: 9
p/d = 1.5
Pin = 146.8 kPa
Xin = -.32
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 297.27 kg/s*m²
DELTA P total = 6.43 kPa
Xout = -.29

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	146.5	-.32	23.1	13397	44.8	621
3	145.6	-.32	23.4	13621	44.3	660
5	144.8	-.32	23.8	13148	44.9	628
7	143.9	-.31	24.2	13835	46.4	629
9	143.1	-.31	24.5	13324	46.0	625
11	142.3	-.31	24.9	13295	47.1	611
13	141.5	-.30	25.6	13917	47.0	662
15	140.6	-.30	26.4	14244	47.6	682

RUN NUMBER: 12
p/d = 1.5
Pin = 171 kPa
Xin = -.37
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 393.46 kg/s*m²
DELTA P total = 7.08 kPa
Xout = -.35

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	170.6	-.37	23.1	11269	39.5	693
3	169.7	-.37	23.4	11457	39.1	734
5	168.9	-.37	23.6	11060	39.1	720
7	168.1	-.36	23.9	11718	40.3	718
9	167.2	-.36	24.1	11285	40.1	711
11	166.4	-.36	24.4	11268	41.0	688
13	165.6	-.36	24.9	11795	40.7	757
15	164.7	-.35	25.4	12072	41.0	784

RUN NUMBER: 7
p/d = 1.5
Pin = 119.3 kPa
Xin = -.23
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 81.55 kg/s*m²
DELTA P total = 6.6 kPa
Xout = -.20

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	118.9	-.23	26.0	3827	42.8	232
3	118.0	-.23	26.5	3891	42.9	241
5	117.2	-.23	27.0	3756	43.5	232
7	116.4	-.22	27.5	4522	43.8	282
9	115.5	-.22	28.0	4355	43.6	283
11	114.7	-.21	28.5	3928	44.8	250
13	113.9	-.21	29.6	4112	45.9	261
15	113.0	-.20	30.6	4209	46.4	275

RUN NUMBER: 10
p/d = 1.5
Pin = 115.8 kPa
Xin = -.24
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 99.74 kg/s*m²
DELTA P total = 6.91 kPa
Xout = -.20

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	115.4	-.24	24.9	6223	43.6	337
3	114.6	-.23	25.4	6327	43.5	356
5	113.7	-.23	25.9	6107	43.9	344
7	112.9	-.22	26.4	6433	44.4	363
9	112.1	-.22	26.9	6196	44.3	363
11	111.3	-.21	27.4	6168	45.5	352
13	110.4	-.21	28.4	6457	46.3	372
15	109.6	-.20	29.5	6609	46.8	393

RUN NUMBER: 13
p/d = 1.5
Pin = 160.6 kPa
Xin = -.34
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 354.63 kg/s*m²
DELTA P total = 6.01 kPa
Xout = -.32

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	160.3	-.34	23.7	10045	42.1	550
3	159.5	-.34	24.0	10213	41.5	587
5	158.8	-.34	24.3	9859	41.9	565
7	158.0	-.34	24.6	11777	42.8	653
9	157.2	-.33	24.9	11342	42.3	656
11	156.4	-.33	25.2	10300	43.4	576
13	155.7	-.33	25.8	10782	43.3	626
15	154.9	-.32	26.4	11036	43.9	641

RUN NUMBER: 8
p/d = 1.5
Pin = 119.3 kPa
Xin = -.26
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 198.08 kg/s*m²
DELTA P total = 6.37 kPa
Xout = -.24

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	118.9	-.26	23.1	6852	37.5	483
3	118.0	-.26	23.4	6966	37.0	517
5	117.2	-.25	23.7	6725	37.5	493
7	116.4	-.25	24.0	7147	38.4	501
9	115.5	-.25	24.3	6883	38.4	492
11	114.7	-.25	24.6	6839	39.0	485
13	113.9	-.24	25.2	7159	39.1	524
15	113.0	-.24	25.8	7328	39.5	545

RUN NUMBER: 11
p/d = 1.5
Pin = 112.4 kPa
Xin = -.21
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 50 kg/s*m²
DELTA P total = 6.94 kPa
Xout = -.16

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	112.0	-.21	26.4	3868	41.5	262
3	111.1	-.21	27.0	3933	42.0	267
5	110.3	-.20	27.6	3796	42.2	266
7	109.5	-.20	28.2	4015	43.1	275
9	108.6	-.19	28.8	3867	43.7	265
11	107.8	-.18	29.4	3839	45.0	258
13	107.0	-.18	30.7	4019	46.0	275
15	106.1	-.17	31.9	4113	46.6	294

RUN NUMBER: 14
p/d = 1.5
Pin = 186.8 kPa
Xin = -.30
SURFACE TYPE: SMOOTH

WORKING FLUID: R-113
G = 47.62 kg/s*m²
DELTA P total = 6.34 kPa
Xout = -.19

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	186.5	-.30	22.7	9182	56.9	273
3	185.7	-.29	24.9	9467	54.1	330
5	185.0	-.28	27.0	9016	56.1	316
7	184.2	-.26	29.3	10167	57.9	362
9	183.4	-.24	31.6	10125	61.1	351
11	182.7	-.23	34.0	9727	63.4	337
13	181.9	-.21	36.3	9806	65.4	344
15	181.1	-.19	38.7	10069	67.2	361

RUN NUMBER: 16 WORKING FLUID: R-113
 p/d = 1.5 G = 49.05 kg/s*m²
 Pin = 202 kPa DELTA P total = 5.59 kPa
 Xin = -.33 Xout = -.22
 SURFACE TYPE: SMOOTH

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	201.6	-.33	22.6	8657	55.7	265
3	200.9	-.31	24.5	8926	53.4	315
5	200.2	-.30	26.5	8501	55.0	303
7	199.4	-.29	28.6	8643	56.6	314
9	198.6	-.27	30.8	8656	59.6	307
11	197.9	-.26	33.0	8601	61.9	304
13	197.1	-.24	35.3	8670	64.0	308
15	196.4	-.23	37.5	8902	65.7	323

RUN NUMBER: 19 WORKING FLUID: R-113
 p/d = 1.5 G = 125.43 kg/s*m²
 Pin = 115.8 kPa DELTA P total = 5.77 kPa
 Xin = -.20 Xout = -.15
 SURFACE TYPE: TURBO-B

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	115.5	-.20	21.1	8982	44.8	379
3	114.7	-.20	22.0	9080	41.9	457
5	113.9	-.19	23.0	9279	45.1	419
7	113.2	-.18	23.9	9315	45.1	439
9	112.4	-.18	25.0	9110	45.8	437
11	111.6	-.17	26.0	9019	46.6	438
13	110.8	-.16	27.0	9145	47.3	450
15	110.1	-.16	28.1	9270	47.8	470

RUN NUMBER: 22 WORKING FLUID: R-113
 p/d = 1.5 G = 227.03 kg/s*m²
 Pin = 126.2 kPa DELTA P total = 5.75 kPa
 Xin = -.22 Xout = -.19
 SURFACE TYPE: TURBO-B

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	125.8	-.22	21.3	10263	39.9	553
3	125.0	-.21	22.0	10271	34.9	794
5	124.2	-.21	22.6	10516	38.1	636
7	123.5	-.21	23.2	10424	38.4	685
9	122.7	-.20	23.9	10128	38.7	681
11	121.9	-.20	24.6	10342	39.6	685
13	121.2	-.19	25.2	10561	40.1	712
15	120.4	-.19	25.9	10628	40.3	738

RUN NUMBER: 17 WORKING FLUID: R-113
 p/d = 1.5 G = 151.74 kg/s*m²
 Pin = 188.2 kPa DELTA P total = 5.66 kPa
 Xin = -.31 Xout = -.27
 SURFACE TYPE: SMOOTH

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	187.9	-.31	21.7	11585	50.4	408
3	187.1	-.31	22.7	11945	49.0	458
5	186.4	-.30	23.7	11376	50.2	432
7	185.6	-.30	24.7	11479	50.9	442
9	184.8	-.29	25.7	11497	51.2	455
11	184.1	-.28	26.7	11485	52.6	447
13	183.3	-.28	27.8	11577	53.3	458
15	182.6	-.27	28.8	11887	53.8	480

RUN NUMBER: 20 WORKING FLUID: R-113
 p/d = 1.5 G = 49.71 kg/s*m²
 Pin = 112.4 kPa DELTA P total = 5.74 kPa
 Xin = -.20 Xout = -.12
 SURFACE TYPE: TURBO-B

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	112.0	-.20	20.9	5472	41.9	261
3	111.3	-.19	22.4	5551	40.1	313
5	110.5	-.18	23.8	5654	43.9	281
7	109.7	-.17	25.3	5624	44.2	296
9	109.0	-.16	26.8	5483	45.9	287
11	108.2	-.15	28.4	5438	47.3	287
13	107.4	-.14	30.0	5512	48.9	291
15	106.6	-.13	31.6	5581	49.6	309

RUN NUMBER: 23 WORKING FLUID: R-113
 p/d = 1.5 G = 227.72 kg/s*m²
 Pin = 126.2 kPa DELTA P total = 5.67 kPa
 Xin = -.22 Xout = -.18
 SURFACE TYPE: TURBO-B

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	125.8	-.22	21.4	13091	44.4	569
3	125.1	-.21	22.2	13119	38.6	802
5	124.3	-.21	23.0	13413	43.5	655
7	123.5	-.20	23.8	13343	42.9	698
9	122.8	-.20	24.7	12979	43.4	691
11	122.0	-.19	25.5	13145	44.4	697
13	121.3	-.19	26.4	13435	44.9	723
15	120.5	-.18	27.2	13535	45.2	752

RUN NUMBER: 18 WORKING FLUID: R-113
 p/d = 1.5 G = 99.64 kg/s*m²
 Pin = 126.2 kPa DELTA P total = 6.26 kPa
 Xin = -.26 Xout = -.22
 SURFACE TYPE: SMOOTH

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	125.8	-.26	14.7	3570	33.6	190
3	124.9	-.26	15.5	3554	32.4	212
5	124.1	-.25	16.3	3611	34.8	197
7	123.3	-.25	17.1	3588	35.9	192
9	122.4	-.24	17.9	3520	36.1	196
11	121.6	-.23	18.8	3687	36.9	206
13	120.8	-.23	19.6	3600	37.8	200
15	119.9	-.22	20.5	3591	38.2	206

RUN NUMBER: 21 WORKING FLUID: R-113
 p/d = 1.5 G = 347.73 kg/s*m²
 Pin = 164.1 kPa DELTA P total = 5.93 kPa
 Xin = -.28 Xout = -.25
 SURFACE TYPE: TURBO-B

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	163.7	-.28	22.2	15926	41.7	816
3	162.9	-.27	22.8	15949	36.5	1169
5	162.1	-.27	23.5	16310	40.9	937
7	161.3	-.26	24.1	16113	40.4	993
9	160.5	-.26	24.8	15728	40.9	981
11	159.7	-.26	25.5	15858	41.3	1008
13	159.0	-.25	26.2	16233	41.8	1042
15	158.2	-.25	26.9	16372	41.8	1104

RUN NUMBER: 24 WORKING FLUID: R-113
 p/d = 1.5 G = 442.32 kg/s*m²
 Pin = 202 kPa DELTA P total = 5.78 kPa
 Xin = -.33 Xout = -.30
 SURFACE TYPE: TURBO-B

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m ²]	[C]	[W/m ² C]
1	201.7	-.33	22.9	20181	42.9	1010
3	200.9	-.32	23.5	20583	37.9	1437
5	200.1	-.32	24.2	20961	42.2	1164
7	199.3	-.32	24.8	20761	41.7	1229
9	198.5	-.31	25.5	20289	42.3	1204
11	197.8	-.31	26.2	20574	42.7	1245
13	197.0	-.30	26.9	21100	43.2	1287
15	196.2	-.30	27.6	21254	43.1	1363

RUN NUMBER: 25 WORKING FLUID: R-113
 p/d = 1.5 G = 451.46 kg/s*m^2
 Pin = 208.9 kPa DELTA P total = 5.76 kPa
 Xin = -.33 Xout = -.28
 SURFACE TYPE: TURBO-B

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	208.5	-.33	24.3	31485	53.3	1084
3	207.7	-.32	25.2	32036	46.4	1516
5	207.0	-.32	26.2	32541	50.8	1323
7	206.2	-.31	27.2	32395	51.9	1313
9	205.4	-.30	28.2	31880	53.0	1290
11	204.7	-.30	29.3	32119	53.3	1336
13	203.9	-.29	30.4	32942	54.2	1383
15	203.1	-.28	31.4	33079	53.8	1480

RUN NUMBER: 29 WORKING FLUID: R-113
 p/d = 1.17 G = 250.67 kg/s*m^2
 Pin = 166.9 kPa DELTA P total = 4.48 kPa
 Xin = -.29 Xout = -.23
 SURFACE TYPE: HIGH FLUX

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	166.5	-.29	20.7	8200	35.6	550
3	165.9	-.28	21.7	7927	32.7	722
5	165.3	-.28	22.8	7962	33.2	765
7	164.8	-.27	23.9	8101	35.3	712
9	164.2	-.26	25.1	7898	36.3	704
11	163.6	-.25	26.3	7788	37.8	678
13	163.0	-.24	27.4	7945	38.2	739
15	162.4	-.23	28.6	7966	39.1	757

RUN NUMBER: 27 WORKING FLUID: R-113
 p/d = 1.17 G = 46.83 kg/s*m^2
 Pin = 156.5 kPa DELTA P total = 4.48 kPa
 Xin = -.28 Xout = -.13
 SURFACE TYPE: HIGH FLUX

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	156.2	-.28	20.5	3677	36.8	226
3	155.6	-.26	23.1	3565	37.8	242
5	155.0	-.24	25.7	3584	40.3	245
7	154.4	-.22	28.6	3695	43.9	241
9	153.8	-.20	31.7	3600	46.8	239
11	153.2	-.18	34.8	3578	49.8	239
13	152.6	-.16	37.8	3615	51.5	265
15	152.0	-.14	40.8	3639	52.5	312

RUN NUMBER: 30 WORKING FLUID: R-113
 p/d = 1.17 G = 502.75 kg/s*m^2
 Pin = 146.2 kPa DELTA P total = 4.48 kPa
 Xin = -.25 Xout = -.20
 SURFACE TYPE: HIGH FLUX

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	145.8	-.25	21.2	13745	37.1	865
3	145.2	-.25	22.0	13300	34.5	1063
5	144.7	-.24	22.8	13438	34.8	1116
7	144.1	-.24	23.6	13611	36.8	1029
9	143.5	-.23	24.4	13255	37.8	992
11	142.9	-.22	25.3	13133	39.2	944
13	142.3	-.21	26.1	13395	39.3	1020
15	141.7	-.21	27.0	13411	40.1	1023

RUN NUMBER: 28 WORKING FLUID: R-113
 p/d = 1.17 G = 103.84 kg/s*m^2
 Pin = 153.1 kPa DELTA P total = 4.48 kPa
 Xin = -.27 Xout = -.20
 SURFACE TYPE: HIGH FLUX

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	152.7	-.27	20.7	3722	32.9	303
3	152.1	-.26	21.9	3601	31.1	392
5	151.6	-.25	23.1	3625	32.0	407
7	151.0	-.24	24.4	3734	34.2	382
9	150.4	-.24	25.9	3641	35.4	384
11	149.8	-.23	27.3	3616	37.0	372
13	149.2	-.22	28.8	3655	37.8	405
15	148.6	-.21	30.1	3679	39.0	414

RUN NUMBER: 31 WORKING FLUID: R-113
 p/d = 1.17 G = 350.22 kg/s*m^2
 Pin = 164.8 kPa DELTA P total = 5.28 kPa
 Xin = -.28 Xout = -.19
 SURFACE TYPE: HIGH FLUX

ROW	P	Xin	Tf	q''	Tw	h
#	[kPa]	[-]	[C]	[W/m^2]	[C]	[W/m^2 C]
1	164.3	-.28	22.1	15717	46.6	639
3	163.6	-.27	23.8	15740	41.9	865
5	162.9	-.26	25.4	16100	43.2	908
7	162.2	-.24	27.2	15964	45.8	859
9	161.5	-.23	29.0	15578	47.7	833
11	160.8	-.22	30.8	15707	49.7	831
13	160.2	-.21	32.7	16083	51.4	858
15	159.5	-.19	34.6	16223	53.0	878

APPENDIX B

SAMPLE CALCULATIONS

A sample of calculations performed in the tube bundle data reduction programs is presented below. Two sample calculations are presented. The first is a sample of the data reduction process for data obtained in pure R-113 and includes calculations for the heat transfer coefficients, pressure drop, quality, and mass flow rate. The second shows the additional steps required to determine the local concentration and quality of the refrigerant mixtures.

NOMENCLATURE

A_s	heat transfer surface area of single tube, m^2
c_p	specific heat at constant pressure, $J/Kg \cdot K$
D_o	tube outside diameter, m
G	mass flux, $kg/m^2 \cdot s$
h	heat transfer coefficient, $W/m^2 \cdot K$
h_n	local heat transfer coefficient at row n , $W/m^2 \cdot K$
i	enthalpy, J/kg
I	electrical current, A
k_t	copper thermal conductivity, $W/m \cdot K$
L	tube length, m
$\dot{m}$	mass flow rate, kg/s
n	tube row number
p	tube pitch, m

P	pressure, kPa
q''	heat flux for an individual tube, W/m ²
q''_n	heat flux for an individual tube at row n , W/m ²
Q_{1-n}	total heat transfer rate from tube s in rows 1 through n , W
R_{tc}	radial distance from tube axis to thermocouple location, m
T_{fv}	temperature at flashing valves, °C or K
T_{sat}	saturation or bubble point temperature, K
T_{tc}	local temperature at thermocouple, °C or K
T_w	local tube surface temperature, °C or K
$T_{w,ave}$	tube average wall temperature, °C or K
V	electrical voltage, V
$\dot{V}$	volume flow rate, m ³ /s
x	thermodynamic quality
x_n	thermodynamic quality at tube row n
$\tilde{y}'_i$	mole fraction in the liquid phase of component i , kmol/kmol
$\tilde{y}''_i$	mole fraction in the vapor phase of component i , kmol/kmol
$\tilde{y}^b_{b,i}$	overall mole fraction of component i in the fluid, kmol/kmol

Greek Symbols

Δ	difference
ρ	density, kg/m ³

Subscripts

ave	average
f	saturated liquid or bubble point
fg	difference in property for saturated vapor and saturated liquid
fv	flashing valve
in	inlet
j	pressure tap location
L	liquid
n	tube row
o	inlet
sat	saturated liquid
tc	thermocouple

Superscripts

'	liquid phase
"	vapor phase
~	molar property

Data Reduction for Pure R-113

Raw data collected as run number 138 was obtained in pure R-113 in a bundle of smooth tubes. The pertinent bundle geometry information is as follows:

$$p/D_o = 1.17$$

$$D_o = 0.01905 \text{ m}$$

$$R_{tc} = 5.6 \text{ mm}$$

$$A_s = 0.00608 \text{ m}^2$$

and the properties of the copper tube and refrigerant were as follows:

$$k_t = 386 \text{ W/m K}$$

$$i_{fg} = 138.9 \text{ kJ/kg}$$

$$c_p = 1003.7 \text{ J/kg K}$$

Information recorded by the DAS included

$$P_o = 206.46 \text{ kPa}$$

$$\dot{V} = 0.186 \text{ L/s}$$

$$\Delta P_{0-1} = 0.59 \text{ kPa}$$

$$\Delta P_{1-2} = 1.16 \text{ kPa}$$

$$\Delta P_{2-3} = 1.05 \text{ kPa}$$

$$\Delta P_{3-4} = 1.15 \text{ kPa}$$

$$\Delta P_{4-5} = 0.54 \text{ kPa}$$

$$T_o = 69.67 \text{ }^\circ\text{C}$$

$$T_{fv} = 69.28 \text{ }^\circ\text{C}$$

and for the third tube row,

$$V_3 = 133.54 \text{ V}$$

$$I_3 = 1.866 \text{ A}$$

$$T_{tc1} = 83.80 \text{ }^\circ\text{C}$$

$$T_{tc2} = 83.61 \text{ }^\circ\text{C}$$

$$T_{tc3} = 83.33 \text{ }^\circ\text{C}$$

$$T_{tc4} = 83.67 \text{ }^\circ\text{C}$$

The heat transfer coefficients calculated for the two-phase experiments were defined as the ratio of the heat flux from the heated tube to the difference between the average tube wall surface temperature and the saturation temperature of the

refrigerant at the local pressure just upstream of the tube; this pressure was obtained by linear interpolation of the pressures at the closest pressure taps.

Because the refrigerant at the outlet was saturated, the outlet pressure was assumed to be the saturation pressure based on the outlet temperature. The saturation pressure at the outlet, P_5 (kPa), was calculated using an equation based on the results of Downing (1974):

$$\log(6.89 P_5) = C_1 - C_2/T_o - C_3 \log(9 T_o/5) + C_4 \quad (\text{B.1})$$

where

$$C_1 = 33.0655$$

$$C_2 = -2406.1$$

$$C_3 = -9.2635$$

$$C_4 = 0.003697$$

so that $P_5 = 201.45$ kPa

The pressures at the pressure taps were then calculated using the pressure drops measured across adjacent pressure taps as

$$P_{5-j} = P_5 - \sum_{i=1}^j \Delta P_{(5-i) \text{ to } (6-i)} \quad (\text{B.2})$$

so that $P_4 = 205.85$, $P_3 = 204.69$, $P_2 = 203.64$, $P_1 = 202.49$, and $P_0 = 201.95$ kPa.

the total pressure drop was the difference between P_5 and P_0 , or 4.51 kPa.

The saturation temperature of the refrigerant was calculated as a function of the pressure. For example, the pressure at the third tube row was calculated as 205.54 kPa by interpolation and the saturation temperature was

$$T_{\text{sat}} = 545.741 + 2.862 P_n - 0.01423 P_n^2 \quad (\text{B.3})$$

$$T_{\text{sat}} = 70.3 \text{ } ^\circ\text{C}$$

The heat flux for an individual tube was defined as the ratio of the supplied power to the surface area exposed to the fluid. The power supplied to the heated tube was calculated as the product of the current through the cartridge heater and the voltage across the cartridge heater:

$$q_n'' = \frac{I_n V_n}{A_s} = 40970 \text{ W/m}^2 \quad (\text{B.4})$$

The surface temperatures of the heated tubes were then calculated using a one-dimensional, steady-state heat conduction equation for a cylinder:

$$T_w = T_{tc} - \frac{q_n'' D_o}{2 k_t} \ln \left[\frac{D_o}{2 R_{tc}} \right] \quad (\text{B.5})$$

for the third tube row, which resulted in tube wall temperatures of $T_{w1} = 83.57 \text{ } ^\circ\text{C}$, $T_{w2} = 83.38 \text{ } ^\circ\text{C}$, $T_{w3} = 83.10 \text{ } ^\circ\text{C}$, and $T_{w4} = 83.44 \text{ } ^\circ\text{C}$. The average tube wall surface temperature, $T_{w,\text{ave}}$, was then calculated as the arithmetic average of the four temperatures calculated as $83.21 \text{ } ^\circ\text{C}$.

The heat transfer coefficient at the third tube could then be calculated as:

$$h_n = \frac{q_n''}{T_{w,ave} - T_{sat}} \quad (B.6)$$

$$h_n = 3127 \text{ W/m}^2$$

The mass flux was calculated using the volume flow rate measured by the turbine flowmeters and the density of the refrigerant. The volumetric flow rate, $\dot{V}$, was calculated as a function of the frequency of the pulses generated by the turbine flowmeter. The total mass flow rate, $\dot{m}$, was then calculated as the product of the volumetric flow rate and the refrigerant liquid density. The mass flux, G , was calculated based on the minimum flow area between the heated tubes. The equation used to calculate the mass flux was

$$G = \frac{\dot{V} \rho_L}{4 (p - D_o) L} \quad (B.7)$$

where p is the tube bundle pitch and the 4 in the denominator is a result of having five heated tubes (four flow areas) in each row. For this case, $G = 225.1 \text{ kg/m}^2\text{s}$.

The quality at the inlet to the tube bundle was calculated using the inlet temperature and the saturation temperature corresponding to the inlet pressure. Assuming that the refrigerant flowing through the flashing valves underwent an

isenthalpic process, the inlet quality could be calculated as:

$$x_{\text{in}} = \frac{c_p(T_{\text{fv}} - T_{\text{sat,in}})}{i_{\text{fg}}} \quad (\text{B.8})$$

where c_p is the specific heat of the pure refrigerant, T_{fv} is the temperature immediately upstream of the flashing valves, $T_{\text{sat,in}}$ is the saturation temperature corresponding to the tube bundle inlet pressure, and i_{fg} is the enthalpy of vaporization for the pure refrigerant. The quality immediately downstream of the 3th tube row was calculated by performing an energy balance on the first 3 tube rows:

$$x_3 = x_{\text{in}} + \frac{Q_{1-3}}{\dot{m} i_{\text{fg}}} \quad (\text{B.9})$$

so that

$$x_3 = 0.0865$$

The procedure for reducing data taken in pure R-11 was the same as for pure R-113 except that routines for calculating the thermodynamic and physical properties of R-11 had to be substituted for those of R-113. A computer program to calculate properties of refrigerant mixtures, developed by the National Institute of Science and Technology (National Bureau of Standards 1986) was used to calculate the properties of pure R-11.

Data Reduction in Refrigerant Mixtures

The procedure for reducing data taken in mixtures of R-11 and R-113 was generally similar to the procedure for pure refrigerants except that additional procedures for determining the properties of the mixture and for determining the mixture concentration throughout the bundle were required. Because the tube bundle used in the experiments involving refrigerant mixtures contained all three surfaces, the local mole fractions were determined so that the local quality and mixture concentration were known.

Raw data stored as run number 506 was obtained in a mixture of 75.8% R-11 and 24.2% R-113 by mass. Additional values for the fluid were as follows:

$$\bar{y}'_{b,R-113} = 0.305$$

$$\bar{y}'_{b,R-11} = 0.695$$

$$\dot{m} = 0.188 \text{ kg/s}$$

The mixture properties were calculated using the computer program developed by the National Institute of Science and Technology (National Bureau of Standards 1986) which calculates thermodynamic properties (saturation pressure, specific volume, enthalpy, specific heats, etc.) for a given temperature or saturation temperature for a given pressure. In either case, the concentration of the mixture is required.

The inlet was slightly subcooled, therefore the inlet quality was calculated as

$$x_{\text{in}} = \tilde{c}_p(T_{\text{in}} - T_f)/\tilde{i}_{fg} \quad (\text{B.10})$$

$$x_{\text{in}} = -0.01$$

where $\tilde{c}_p$, T_f , and $\tilde{i}_{fg}$ were calculated using the mixture property program and the measured inlet pressure.

The procedure for calculating the local temperature and mass concentration in the mixture began with a guess for the temperature so that the mixture properties could be calculated using the mixture property program.

The estimated value of outlet temperature and an estimate for the mole fraction of R-113 in the liquid phase, $\tilde{y}_{R113}^l$, were input to the computer program and the saturation pressure was calculated. This value was compared with the experimentally determined value for the outlet pressure. The mole fraction, $\tilde{y}_{R113}^l$, was adjusted until the output saturation pressure was within 0.1% of the experimental value. The mole fraction of R-11 in the liquid, $\tilde{y}_{R11}^l$, was calculated from

$$\tilde{y}_{R11}^l = 1 - \tilde{y}_{R113}^l \quad (\text{B.11})$$

The same iterative procedure was used to determine the vapor mole fractions of R-113, $\tilde{y}_{R113}^v$, and R-11, $\tilde{y}_{R11}^v$.

The same values of pressure and estimated temperature were used to calculate K-values as

$$K \approx \exp(A-B/T)/P \quad (\text{B.12})$$

These K-values could then be used to calculate $\tilde{m}_L$ from

$$1 = \frac{\tilde{y}'_{b,R113} \tilde{m}}{\tilde{m}_L + K_{R113}(\tilde{m} - \tilde{m}_L)} + \frac{\tilde{y}'_{b,R11} \tilde{m}}{\tilde{m}_L + K_{R11}(\tilde{m} - \tilde{m}_L)} \quad (\text{B.13})$$

The mixture enthalpy could then be calculated as

$$\begin{aligned} \tilde{i}_n = & (\tilde{y}'_{R113} \tilde{m}_L \tilde{i}_{R113} + \tilde{y}'_{R11} \tilde{m}_L \tilde{i}_{R11} \\ & + \tilde{y}''_{R113} \tilde{m}_V \tilde{i}_{R113} + \tilde{y}''_{R11} \tilde{m}_V \tilde{i}_{R11}) / \tilde{m} \end{aligned} \quad (\text{B.14})$$

where the molar enthalpies and molar flow rates were evaluated using the local values for the molar concentrations.

The procedure for determining the local molar concentrations involved iterating on the local fluid temperature until the enthalpy as calculated using equation (4.26) was within 0.1% of the value obtained by performing an energy balance on the portion of the tube bundle:

$$\tilde{i}_n = \tilde{i}_{in} + Q_{1-n} / \tilde{m} \quad (\text{B.15})$$

where Q_{1-n} is an integral value of the measured heat input from the inlet to row n . A new guess for the local temperature was made and the process was repeated until $\tilde{i}_n$ from equation (4.26) was within 0.1% of the value from equation (4.25). The enthalpy at the third tube row was calculated using the above procedure and found to be 111.8 kJ/kmol.

Once the local enthalpy was known, the quality at row n was calculated as:

$$x_n = \frac{\tilde{i}_n - \tilde{i}_f}{\tilde{i}_{fg}} \quad (\text{B.16})$$

At the third tube row, the quality was $x_3 = 0.07$. This procedure was repeated to find the local conditions at each tube row. After the thermodynamic state had been fixed for the 15th row, the temperature could be compared with the measured outlet temperature as an additional check. The value for the outlet temperature as computed above was generally within 0.2° C of the measured value.

APPENDIX C

PROPAGATION OF UNCERTAINTY

An uncertainty analysis was performed on the experimental data using the method given by Kline and McClintock (1953). The uncertainty, W , of variable R is given as

$$W_R = \left\{ \left[\frac{\partial R}{\partial v_1} W_{v_1} \right]^2 + \left[\frac{\partial R}{\partial v_2} W_{v_2} \right]^2 + \cdots + \left[\frac{\partial R}{\partial v_n} W_{v_n} \right]^2 \right\} \quad (C.1)$$

where

$$R = R(v_1, v_2, \dots, v_n) \quad (C.2)$$

The equation for the heat transfer coefficient is given as

$$h = \frac{q''}{T_w - T_s} \quad (C.3)$$

Therefore, the uncertainty in the heat transfer coefficient can be expressed as

$$W_h = \left\{ \left[\frac{1}{T_w - T_s} W_{q''} \right]^2 + \left[\frac{-q''}{(T_w - T_s)^2} W_{T_w} \right]^2 + \left[\frac{q''}{(T_w - T_s)^2} W_{T_s} \right]^2 \right\}^{\frac{1}{2}} \quad (C.4)$$

From equation (C.4) we find that the expression for W_h is a function of $W_{q_t''}$, W_{T_w} , and W_{T_s} . Beginning with the $W_{q_t''}$ term we require the following expression for the heat flux

$$q_t'' = \frac{I_t V_t}{A_t} \quad (C.5)$$

Therefore

$$W_{q_t''} = \left\{ \left[\frac{V_t}{A_t} W_{I_t} \right]^2 + \left[\frac{I_t}{A_t} W_{V_t} \right]^2 + \left[\frac{-I_t V_t}{[A_t]^2} W_{A_t} \right]^2 \right\}^{\frac{1}{2}} \quad (C.6)$$

The uncertainty in the current supplied to each instrumented tube was determined from the calibration of the shunts. Each shunt was calibrated using a digital voltmeter having an accuracy of ± 0.001 mV so that the voltage readings could be considered negligible. The maximum difference between the actual voltage drop measured across the shunt and the value obtained from the calibration curve was 0.0003 V. The resulting uncertainty in the current measurements for the 5 amp/200 mV shunts was then 0.0075 amps. The shunts themselves had an inherent uncertainty of 0.25% of full scale which caused an additional uncertainty of 0.0125 amps. Thus, the total uncertainty in the instrumented tube current measurements was $W_{I_t} = 0.02$ amps.

The uncertainty in the instrumented tube voltage measurements was determined from the calibration of the data acquisition system voltage

measurements. By determining the maximum difference between the measured voltage supplied to the instrumented tubes and the voltage obtained from the calibration curve, the uncertainty was calculated to be $W_{V_t} = 0.3 \text{ V}$.

The uncertainty in the surface area of the instrumented tubes was determined using the equation for the surface area

$$A_t = \pi D L_t \quad (C.7)$$

Therefore, the uncertainty is

$$W_{A_t} = \pi \left\{ \left[L_t W_D \right]^2 + \left[D W_{L_t} \right]^2 \right\}^{\frac{1}{2}} \quad (C.8)$$

The lengths of the instrumented tubes were measured to be within 0.15 mm of the design length of 0.1016 m. The diameters of the enhanced tubes were measured at the outside of the enhancement material. The diameters of the enhanced tubes and the smooth tubes were all within 0.08 mm of the average value of 0.01906 m. The uncertainty in the surface area was calculated to be $W_{A_t} = 27.07 \text{ mm}^2$.

Values for W_{I_t} , W_{V_t} , and W_{A_t} can be inserted into equation (C.6) and $W_{q_t''}$ is found to be less than 1.0% of q_t''

In order to calculate the term involving W_{T_w} from equation (C.4), we begin with the expression for T_w ,

$$T_w = T_{tc} - \frac{q_t''}{2} \frac{D}{k_t} \ell \approx \left[\frac{D}{d} \right] \quad (C.9)$$

The uncertainty can then be expressed as

$$\begin{aligned} W_{T_w} = & \left\{ \left[W_{T_{tc}} \right]^2 + \left[\frac{-q_t''}{2 k_t} \left[\ell \approx \left[\frac{D}{d} \right] + 1 \right] W_D \right]^2 + \left[\frac{q_t''}{2 k_t} \frac{D}{d} W_d \right]^2 \right. \\ & \left. + \left[\frac{-D}{2 k_t} \ell \approx \left[\frac{D}{d} \right] W_{q_t''} \right]^2 + \left[\frac{q_t''}{2 k_t} \frac{D}{d} \ell \approx \left[\frac{D}{d} \right] W_{k_t} \right]^2 \right\}^{\frac{1}{2}} \quad (C.10) \end{aligned}$$

The uncertainty of the temperature inside the tube wall at the thermocouple location, $W_{T_{tc}}$, was determined by calibrating the thermocouples in boiling water. The agreement between the values for the temperatures as calculated by the data acquisition system was checked so that the random errors associated with the impurities in the wire, the quality of the bead, the electrical connections between the thermocouple, ice point and voltmeter, the electrical noise, and the voltage-to-temperature calibration curve errors were all accounted for. The uncertainty in the temperature measurements at the thermocouple location was calculated to be $W_{T_{tc}} = 0.12^\circ\text{C}$.

The uncertainty in the thermal conductivity of the tube material was determined by calculating the difference between the values for the conductivity of

copper at the extreme values of the temperature range. The uncertainty in the thermal conductivity was found to be $W_{k_t} = 8 \text{ W/m K}$.

The uncertainty in the thermocouple location was calculated by assuming that the distance between the wall of the thermocouple well and the inside tube wall was the maximum possible error. This is reasonable because the thermocouple well never broke through the inside tube surface. The uncertainty of the thermocouple location was measured to be $W_d = 1.0 \text{ mm}$. Values for W_{tc} , W_D , W_{q_t} , and W_{k_t} can be inserted into equation (C.10) in order to calculate a value for W_{T_w} of 0.15°C .

The final term in equation (C.4) involving the uncertainty of the saturation temperature, W_{T_s} , was calculated using the expression for the saturation temperature. The expression for the saturation pressure in the low pressure range ($29.48 \text{ psi} < P < 58.49 \text{ psi}$) was given as

$$T_s = 545.741 + 2.862 P_n - 0.01423 P_n^2 \quad (\text{C.11})$$

and at the high pressures ($58.49 \text{ psi} < P < 108.2 \text{ psi}$) as

$$T_s = 578.073 + 1.741 P_n - 0.004424 P_n^2 \quad (\text{C.12})$$

where P_n is the local pressure at tube n. The uncertainty in the saturation

temperature could be calculated for both pressure ranges as

$$W_{T_s} = \left\{ \left[\frac{\partial T_s}{\partial P_n} W_{P_n} \right]^2 \right\}^{\frac{1}{2}}$$

or

$$W_{T_s} = \frac{dT_s}{dP_n} W_{P_n} \quad (C.13)$$

Differentiating the expression for the saturation temperature at low pressures

$$\frac{dT_s}{dP_n} = 2.862 - 0.02846 P_n \quad (C.14)$$

and at high pressures

$$\frac{dT_s}{dP_n} = 1.741 - 0.008848 P_n \quad (C.15)$$

The local pressure is calculated using the saturation pressure at the outlet (which is a function of the measured outlet temperature, T_o) and the measured pressure drops throughout the bundle, ΔP_i . The pressure at the n^{th} tube location is expressed as

$$P_n = P_s + \sum_{i=1}^n \Delta P_i \quad (C.16)$$

Assuming that the uncertainty for each pressure drop is equal to ΔP_i , the uncertainty in the local pressure is

$$W_{P_n} = \left\{ \left[W_{P_{s_o}} \right]^2 + \left[i W_{\Delta P_i} \right]^2 \right\}^{\frac{1}{2}} \quad (C.17)$$

where i is the number of ΔP 's used to calculate P_n . The pressure drop is given by

$$\Delta P_i = \Delta P_t + L_p \rho_{R-113} g \quad (C.18)$$

where ΔP_t is the pressure transducer measurement. Assuming that the uncertainty in the density the R-113, the distance between pressure taps, and the gravitational constant to be negligible, the uncertainty in the pressure drop is $W_{\Delta P_i} = W_{\Delta P_t}$.

The pressure transducer was calibrated and the uncertainty was estimated to be $W_{\Delta P_t} = 0.05 \text{ in.H}_2\text{O}$. The saturation pressure is calculated as

$$P_{s,o} = 10^{(33.0655 - 4330.98/T_o - 9.2635 \log(T_o) + 20539 \cdot 10^{-4} T_o)} \quad (C.19)$$

Therefore, the uncertainty in the saturation pressure can be expressed as

$$W_{P_{s,o}} = \frac{dP}{dT_o} W_{T_o} \quad (C.20)$$

where

$$\frac{dP}{dT} = P_{s,o} \left\{ \left[\frac{4330.98}{T_o^2} + 0.00020539 \right] \ln(10) - \frac{9.2635}{T_o} \right\} \quad (C.21)$$

Inserting equation (C.20) and the value for ΔP_i into equation (C.17) allows for the uncertainty of the local pressure to be calculated as within 0.5% of the local pressure. Equation (C.17) and either equation (C.14) or (C.15) can be inserted into the equation for the saturation temperature uncertainty given by equation (C.13) and the uncertainty is found to be 0.12 °C. The uncertainty in the heat transfer coefficient can now be calculated by inserting equations (C.6), (C.10), and (C.13) into equation (C.4). The uncertainty is usually found to be less than 3.5% of the absolute value, although uncertainties as large as 12.9% occur when the corresponding wall superheat is less than 1 °C.

The uncertainty in the mass flux readings is obtained from the equation for the mass flux,

$$G = \rho \dot{V} / A_{\min} \quad (C.22)$$

where $\dot{V}$ is the volume flow rate measured by the flow meter and $A_{\min}$ is the minimum flow area between the tubes. Hence, the uncertainty in the mass flux is

$$W_G = \left\{ \left[\left[\frac{\dot{V}}{A_{\min}} \right] W_\rho \right]^2 + \left[\left[\frac{\rho}{A_{\min}} \right] W_{\dot{V}} \right]^2 + \left[\left[\frac{-\rho \dot{V}}{A_{\min}^2} \right] W_{A_{\min}} \right]^2 \right\}^{\frac{1}{2}} \quad (C.23)$$

The volumetric flow rate was measured by the turbine flow meter which had an accuracy of $\pm 0.5\%$. The minimum flow area was calculated from

$$A_{\min} = (p - D_o) L_t \quad (\text{C.24})$$

so that the uncertainty in the minimum flow area is

$$W_{A_{\min}} = \left[\left[L_t W_p \right]^2 + \left[-L_t W_{D_o} \right]^2 + \left[(p - D_o) W_{L_t} \right]^2 \right]^{\frac{1}{2}} \quad (\text{C.25})$$

The liquid density of R-113 was calculated from

$$\rho = 103.555 - 0.07126 T - 6.36 \cdot 10^{-5} T^2 \quad (\text{C.26})$$

so the uncertainty is

$$W_{\rho} = (-0.07126 - 1.272 \cdot 10^{-4} T) W_T \quad (\text{C.27})$$

The resulting uncertainty in the mass flux is $\pm 3.0\%$.

The quality was calculated from

$$x = \frac{c_p (T_{fv} - T_s)}{h_{fg}} \quad (\text{C.28})$$

so the uncertainty is

$$W_x = \left\{ \left[\left[\frac{T_{fv} - T_s}{i_{fg}} \right] W_{c_p} \right]^2 + \left[\left[\frac{c_p}{i_{fg}} \right] W_{T_{fv}} \right]^2 + \left[\left[\frac{-c_p}{i_{fg}} \right] W_{T_s} \right]^2 + \left[\left[\frac{-c_p(T_{fv} - T_s)}{i_{fg}^2} \right] W_{i_{fg}} \right]^2 \right\}^{\frac{1}{2}} \quad (C.29)$$

Values of W_{c_p} and $W_{i_{fg}}$ were approximated as 0.04% and 0.05%, respectively, so that the uncertainty on the quality was usually less than 0.5%.

APPENDIX D

SATURATION TEMPERATURE DETERMINATION

An experimental apparatus was used to measure the saturation temperature of R-113 at atmospheric pressure so that a comparison could be made with the correlation used in the data reduction program. For this experiment, the saturation temperature was defined as the refrigerant temperature corresponding to the minimum heated surface temperature for which boiling could be maintained.

The design of the experimental apparatus was guided by the concern that commercially available R-113 is not strictly pure but contains small amounts of other refrigerants. In this case, the concentration of the least volatile component would decrease in the liquid as the fluid is vaporized unless the vapor is condensed and put back into the liquid.

Minimizing the wall superheat accomplished several goals. First, the vapor generation was minimized so that any concentration gradients in the liquid and vapor was minimized. Second, the low wall temperature minimized the temperature gradients that might arise even in pure fluids.

The wall superheat was minimized through the use of boiling chips. The boiling chips provided a range of nucleation site sizes so that the optimum size was available.

The experimental apparatus was a modification of the design suggested in ASTM D1120-83 and is shown in Fig. D.1. A round-bottom, short-neck, heat resistant glass flask with a side-entering tube contained the refrigerant and boiling chips. A water-cooled reflux condenser was connected to the flask neck in order to condense vapors back to the pool. Two thermocouples were inserted into the flask

Figure D.1. Experimental apparatus for measuring the boiling point.

through the side neck, one to monitor the vapor temperature and the other to monitor the liquid temperature.

An important improvement over the design suggested in ASTM D1120-83 was the use of a water bath connected to a constant-temperature recirculating bath for heating instead of using a bunsen burner or electric heater. A third thermocouple, placed next to the external wall of the flask, was used to monitor the bath temperature.

Prior to measuring the boiling the point, the bath temperature was increased to approximately 5° C above the minimal boiling point of the fluid, as shown in Fig. D.2. This caused vigorous boiling in the flask, which was maintained for approximately 30 minutes in order to degass the fluid. Once degassing was complete, the bath temperature was lowered to approximately 2° C higher than the liquid temperature measured during degassing as shown in Fig. D.3. Lowering the bath temperature reduced the superheat in the liquid and provided a better approximation for the boiling point than the tabulated values. Once the bath temperature reached steady state, the bath temperature was slowly decreased, maintaining quasi-steady state, until boiling stopped. The arithmetic average of the vapor and liquid temperatures last recorded when boiling on the chips stopped was the experimental value of the boiling point.

The experimental values were 47.8° C for the liquid R-113 and 47.6° C for the vapor. as shown in Fig. D.4. Boiling stopped when the bath temperature was 48.4° C. The experimental value of 47.7° C agreed well with the value of 47.56 reported by ASHRAE (1989) and correlated by Jensen (1980). The predicted values were used in the data reduction program so that a consistent set of data at various pressures could be utilized.

Figure D.2. Bath temperature is increased to about 5°C above the minimal boiling point of the fluid.

Figure D.3. Bath temperature is lowered to about 2°C below liquid temperature during degassing.

Figure D.4. Experimental values for saturation temperature of liquid and vapor R-113.