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HEAT TRANSFER AND PRESSURE DROP IN A COMPACT PIN-FIN HEAT EXCHANGER WITH PIN ORIENTATION AT 18° TO THE FLOW DIRECTION

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Nomenclature

A = inlet manifold location
A_f = flow normal area = V_0/L
A_n = specimen normal area = $L \cdot W$
A_w = wetted wall area (total wall area exposed to fluid)
$A_{w,p}$ = wetted wall area per pin
B = outlet manifold location
Bi = Biot number = $h_w \cdot D_h/k_{ni}$
c_p = specific heat at constant pressure
d = pin diameter at braze joint
d_p = pin diameter
D_h = specimen hydraulic diameter = $4V_0/A_w$
f = friction factor
f_M = friction factor used by Metzger et al. [1982]
f_q = heat flux distribution function
G = mass flow rate per unit flow normal area = $\dot{m}/A_f$
h = heat transfer coefficient
h = enthalpy
h_w = heat transfer coefficient based on temperature of wall-fluid interface
k = thermal conductivity
k_{ni} = nickel thermal conductivity
L = heated length of specimen
$\dot{m}$ = mass flow rate
n = number of pins
N = number of rows of pins in flow direction in Metzger friction factor
Nu = Nusselt number = $h \cdot D_h/k$
Nu_m = modified Nusselt number = $Nu \cdot (T_w/T_f)^{0.55}$
Nu_w = wall Nusselt number (adjusted for finite pin conduction)
= $h_w \cdot D_h/k \cdot (T_w/T_f)^{0.55}$
P = pressure
Pr = Prandtl number = $\mu \cdot c_p/k$
q_n = local normal heat flux
Q_{px} = fraction of total heat flow on specimen added up to position x
= integration of furnace calibration function f_q, 0 to x
Q_T = total heat transfer to specimen
q_w = local heat flux (heat flow per unit area) into the cooling fluid based on total wetted-wall area of the specimen
r = recovery factor = $Pr^{1/3}$ for turbulent flow
Re = Reynolds number = $\rho V D_h/\mu$
S = pin-to-pin on-center separation
= maximum pin diameter
t = pin height
T = temperature
T_{aw} = cooling fluid adiabatic wall temperature
T_f = local bulk fluid temperature
T_w = specimen wall temperature
V = velocity
V_f = heater voltage
V_{max} = maximum velocity in specimen
V_o = open volume in specimen
$V_{o,no.p}$ = volume of hexagon of diameter S and height t

$V_{o,p}$ = open volume around each pin
$V_{s,p}$ = volume of pin between top and bottom plates
W = width of specimen
W_f = uncertainty in friction factor
W_h = uncertainty in heat transfer coefficient
W_{nu} = uncertainty in Nusselt number
W_{qt} = uncertainty in total heat transfer
W_{re} = uncertainty in Reynolds number
W_{tf} = uncertainty in fluid temperature
W_{tw} = uncertainty in wall temperature

x = position coordinate parallel to flow direction
y = position coordinate perpendicular to flow direction
z = position coordinate in vertical direction on pin; $z = 0$ at braze location on pin

β = coefficient of thermal expansion
η = pin efficiency
μ = dynamic viscosity
ρ = density

0 = location where heating begins ($x/L=0$)
1 = location where heating ends ($x/L=1$)

Heat Transfer And Pressure Drop in a Compact Pin-fin Heat Exchanger With Pin Orientation at 18° to the Flow Direction

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We have measured the heat transfer and pressure drop characteristics of a novel, compact heat exchanger in helium gas at 3.5 MPa and Reynolds numbers of 450 to 12 000. This "pin-fin" specimen consisted of pins, 0.51 mm high and spaced 2.03 mm on centers, spanning a channel through which the helium flows; the angle of the row of pins to the flow direction was 18°. The specimen was radiatively heated on the top side at heat fluxes up to 74 W/cm^2 and insulated on the back side. Correlations were developed for the friction factor and Nusselt number. The Nusselt number compares favorably to those of past studies of staggered pin-fins, when our measured temperatures are extrapolated to the temperature of the wall-fluid interface.

Key words: apparatus; compact heat exchanger; convection heat transfer; friction factor; high temperature; National Aerospace Plane; pin-fin; radiative furnace; turbulent flow; variable property effects.

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1. Introduction

This is the third report in a series of experimental studies in which we have measured heat transfer and pressure drop in compact heat exchangers. The compact heat exchangers are candidate cooling jackets for the engine struts of the National Aerospace Plane (NASP). Due to aerodynamic heating associated with the combustion of the hydrogen fuel, along with thermal radiation from the fuel combustion, the engine struts are expected to receive a normal heating load in excess of 2000 W/cm^2 [Scotti et al., 1988, Shore, 1986]. Researchers at NASA Langley plan to cool the struts by attaching a cooling jacket heat exchanger to the surface facing the high heat flux. Hydrogen gas will flow through the cooling jacket and absorb the heat before entering the engine. The anticipated conditions are that the hydrogen gas will enter the heat exchangers at 56 K and 6.9 MPa (1000 psi), and exit at 890 K and 4.8 MPa (700 psi). The heat exchangers are expected to be thin (6 mm or less) perpendicular to the flow direction to add minimal weight and thickness to the struts. Small flow passages will also produce high rates of convective heat transfer, which will reduce the temperatures of the strut. Reynolds numbers are expected to be in the range from 10 000 to 30 000, with the variation due to the flow rate and the specific design of the flow passage.

In an earlier work, we constructed an apparatus which can provide helium gas flow and a well-characterized heat flux to a heat exchanger specimen [Olson, 1989]. This apparatus was previously used to test two prototype heat exchangers for the NASP application. The first was a "tube specimen," which consisted of 20, 1 mm ID nickel tubes lying in parallel on a nickel base plate [Olson and Glover, 1990]. The second was a "channel specimen", which contained 12 rectangular channels in parallel, 3.18 mm wide by 0.56 mm high, milled in a nickel plate [Olson, 1990]. For both specimens, the Nusselt numbers we measured were in good agreement with the Nusselt numbers for flow in a single tube with well-characterized boundary conditions.

In this work we present the experimental results of a heat exchanger configuration for the NASP cooling jacket which has a much higher heat transfer coefficient than either the "tube" or "channel" specimens. The specimen tested has a "pin-fin" internal geometry, in which short cylinders (of varying diameter) span the height of the cooling passage. The centers of the pins are at the corners of equilateral triangles. This specimen was constructed and partially instrumented by NASA Langley Research Center and has internal geometry identical to that of a full-size strut, which they are developing. The pin-fins increase both the wetted heat transfer area and the flow turbulence [VanFossen, 1982].

Banks of pin-fins have been used in the gas turbine industry to cool turbine blades or vanes [Armstrong and Winstanley, 1987]. In this application, the length-to-diameter ratio of the pins varies from 1/2 to 4, and the pin diameter is constant across the span of the channel. Long pin-fins (length-to-diameter ratio of 8 or greater) have been used by the heat exchanger industry and were studied by Kays and London [1964]. There are several geometric differences between the pin-fins of this work and those of past studies in the literature, which make the accuracy of using existing correlations uncertain. Due to the manufacturing technique (explained in more detail below), the pin diameter decreases from one side of the channel to the other (length-to-diameter ratio varies from 1/4 to 1/2). In addition, the top end-wall surface (area between adjacent pins) is not smooth or flat. Pin banks of past works are often "staggered" in the flow direction to break up the flow path. The pins of the present work are also staggered, but the angle of stagger is different (18°) from that used in the past work (30° stagger). In the present use of the pin-fin specimen, high rates of heating will accelerate the flow. In the only past study with pin-fins where flow acceleration was significant, Metzger et al. [1986] used a converging channel containing pin-fins to accelerate the flow.

2. Description of experimental apparatus

The apparatus description which follows is based on that in Olson [1989] and in Olson and Glover [1990]. The apparatus was designed to test a subset of the conditions required for the NASP application. Those conditions are (1) a heating rate of 0 to 80 W/cm^2; (2) an inlet temperature of 300 K; (3) a cooling-gas pressure of up to 6.9 MPa at the inlet; and (4) an outlet temperature of 810 K or less. We used helium as the coolant gas because of the similarities in specific heat, thermal conductivity, and dynamic viscosity to the corresponding properties of hydrogen. In addition, helium does not have the explosive hazard of hydrogen. Because of the property similarities, the Reynolds number, Prandtl number, and temperature rise from specimen inlet to outlet can be matched between helium and hydrogen.

2.1. Flow apparatus

The helium flow apparatus is shown in figure 1, with the details of the specimen furnace section given in figure 2. Helium gas at 17 MPa (2500 psi) or less was supplied from a tube trailer outside the laboratory. The tube trailer contained 1100 m^3 of gas (STP). With valves 1 and 2 open, gas flowed from the trailer, through the inlet piping, and was filtered before entering the dome-loaded pressure regulator (valve 3). The regulator set the flow pressure downstream of the regulator to the value of an external control pressure, which was about 3.5 MPa (500 psi) for these experiments.

Within the furnace (fig. 2), the gas flowed into an inlet distribution manifold which directed the gas to the heat exchanger specimen. A similar distribution manifold collected the gas exiting the specimen and directed it to the outlet tubing. Gas pressure was measured at the pressure taps as shown at location 0 (start of heated zone) and at location 1 (end of heated zone). The specimen was located in the target area of the furnace (7.8 cm wide by 15.2 cm long), which delivered radiant heat to the specimen and raised the temperature of the helium as it flowed through the specimen.

The furnace consisted of a high-intensity infrared radiant heater, surrounded by highly reflective walls which reflected the heat from the heater to the specimen [Olson, 1990]. The reflective walls were made of 6.4 mm thick aluminum plates, polished on the inner surface, with a water-cooled cooling jacket soldered to the outside. The heater contained six high-temperature infrared lamps mounted in an aluminum housing. A phase-angle power controller which used 480 VAC, single phase, and 75 A at maximum voltage powered the heater.

Downstream of the furnace section, the hot gas flowed through a cooling coil immersed in a water bath. The rate of gas flow was manually adjusted at the bath outlet by valve 4, which also dropped the gas pressure to atmospheric pressure. Beyond the valve, we measured helium flow rate with a heated-tube thermal mass flow meter. After exiting the flow meter the gas was vented outside the laboratory.

2.2. 18° Pin-fin specimen

The pin-fin specimen was constructed at NASA Langley Research Center and is shown in figure 3. Heating was from the top in figure 3. The specimen consisted of an upper plate with integral pins, and a lower plate onto which the upper plate was brazed (the perspective view shows the specimen separated to view the detail of the pins). Both plates were made of commercially pure nickel (UNS 02200). The total thickness of the upper plate was 0.89 mm, with 0.51 mm high pins and 0.38 mm plate thickness above the pins. The lower plate was 1.27 mm thick. The pins were formed in the upper plate by photochemical etching. The pin diameter varied from 2.03 mm at the widest point to 1.02 mm at the point of braze to the bottom plate. The centers of the pins were at the corners of equilateral triangles. The separation between pin centers was 2.03 mm. The angle of a line drawn through the pin centers, with respect to the flow direction, was 18°. (Refer to figure 3: the angle for maximum channeling of the flow would be 0°; the angle for maximum stagger would be 30.°) The pressure taps were stainless steel tubes, 1.5 mm OD and 1.0 mm ID, brazed into holes in the specimen at locations shown in figure 4.

The top and bottom plates were brazed together in a vacuum oven using a braze alloy foil of 50 percent gold, 25 percent palladium, and 25 percent nickel (AMS-4784, 1394 K liquidus). The foil was 0.025 mm thick. Prior to brazing, the inner-facing surface of both plates was lapped to a flatness of ±0.01 mm. After brazing, the specimen was pressurized by NASA Langley to 10.3 MPa (1500 psi). This caused the top plate to deflect from the bottom plate at six spots, shown in figure 4, where the pins did not braze to the lower plate.

The assembled specimen was brazed to slots in the inlet and outlet manifolds using a braze alloy of 82 percent gold and 18 percent nickel (AMS-4787, 1223 K liquidus). The pressure tap tubes were brazed to the specimen during the same braze cycle. We pressurized the manifold and specimen to 7 MPa (1000 psi) prior to installing it into the flow apparatus, and there were no leaks. The specimen was tested with helium flow and heat transfer only up to 3.5 MPa to avoid separating the plates, since we did not know how the "disbond" areas affected the strength of the specimen at high temperature and high pressure. We painted the top side of the specimen (the upper plate side) a flat black over the 15.2 cm length to establish a uniform and highly absorptive surface over the heated area. The paint was rated to 1000 K.

2.3. Instrumentation

We measured the temperature of the gas in the inlet and outlet manifolds, gas pressure in the specimen, specimen temperatures, and the gas flow rate. The measurement technique and uncertainties, along with the gas property uncertainties, are summarized in table 1.

We determined the distribution of heat flux on the specimen by calibrating the furnace prior to installing the specimen. The heat flux distribution was defined as the local, normal (perpendicular) heat flux as a function of position over the furnace target. The heat flux was constant in the direction perpendicular to flow (y), and varied by no more than ±7 percent in the direction parallel to flow (x) except within 6 percent of the end walls.

The gas inlet and outlet temperatures were measured with platinum resistance thermometers, 4.8 mm diameter, inserted in the gas manifolds at locations A and B of figure 2. We measured the gas pressure at location 0 in the specimen with a variable-reluctance pressure transducer which had a 8.6 MPa full scale output. Difference in pressure between locations 0 and 1 in the specimen was measured with a differential pressure transducer, also a variable-reluctance type with a 1.4 MPa (200 psi) full-scale output.

We measured specimen temperatures with thermocouples made from type N wire, with a wire diameter of 0.25 mm. We spot-welded 29 thermocouples to the side opposite the radiant heat flux (insulated side). Specimen temperatures were also measured with platinum resistance thermometers (PRT) bonded to the insulated side at 4 locations. The PRTs were installed by NASA Langley. These had a nominal 1000 ohm sensing element mounted on a 2.8 mm by 6.4 mm base of alumina. Due to the large size of the sensors, the PRTs could not provide sufficient spatial resolution in specimen temperature, and were not used in calculating the heat transfer performance. We used the PRTs as a check for drift or aging of the thermocouple sensors.

The temperature of the heated side was measured at 19 locations with type N thermocouples mounted as shown in figure 5. These probes were installed at NASA Langley. Two holes, 0.33 mm diameter, were drilled in adjacent pins as close to perpendicular to the flow direction as possible (12° from perpendicular). The holes were back-drilled to within 0.13 mm of the surface with a 0.57 mm diameter drill. Each wire of the pair was spot-welded to the heated surface, with the lead extending out the hole on the insulated side. The thermocouple circuit was completed by the specimen material between the two wires. A quartz sleeve, 0.48 mm outer diameter, was inserted over the wire into the hole to electrically insulate the wire from the wall of the hole. Because a portion of the specimen was removed and replaced by wire plus quartz, each of which had a thermal conductivity lower than that of the specimen, mounting the thermocouple locally increased the specimen temperature. We estimated the magnitude of this temperature rise from a finite-element analysis as 2 to 5 K at a radiant heat flux of 50 W/cm^2. Temperatures measured with the insulated-side thermocouples were used to determine the heat transfer coefficient, as the installation technique did not disturb the specimen temperatures and conduction errors were insignificant.

All thermocouples were connected to terminals in an isothermal reference box. We measured the temperature of the reference box with a platinum resistance thermometer. Copper conductor wire connected from the terminals in the reference box to the data scanner. The reference box introduced negligible error in the temperature measurement [Olson, 1989].

All instrument signals were multiplexed through an automated scanner and measured with a digital voltmeter. The scanner and voltmeter were controlled with a personal computer through an IEEE-488 bus. Raw signals were stored on a hard disk and copied to floppy disk for backup. Signals were converted to SI units and the data analyzed at the completion of an experimental run. Some signal readings were converted immediately to SI units and displayed on the video terminal to assist in monitoring and operating the experiment. We have included the measurement uncertainties introduced by the data acquisition system in the stated uncertainties of each sensor.

3. Description of experiments and analysis techniques

3.1 Experiments conducted

A summary of the conditions for the six experiments conducted with the 18° pin-fin specimen is shown in table 2. Also listed are the values for the geometrical parameters required for the data analysis. Table 3 lists values for all the measured and calculated parameters at each data point for each experiment. Tests were conducted at a system pressure of approximately 3.5 MPa (500 psi). In experiment 1, we tested a range of helium flow rates without heating the specimen to determine the friction factor. In experiments 2 to 6, we varied the heater lamp voltage to vary the rate of specimen heating; at each heating rate a range of helium flow rates was tested up to 28 kg/h. We were not able to test a helium flow rate in these experiments as high as those which we tested the tube and channel specimens, since the pressure drop for the pin-fin specimen was much higher, on the order of 1.4 MPa (200 psi) at 28 kg/h. Operating the flow apparatus at higher inlet pressure would reduce the pressure drop, however we felt that the braze joint of the specimen was not strong enough to withstand a higher pressure during heating.

The range in Reynolds number was 450 to 12 000, while the range in normal heat flux was 0 to 74 W/cm^2 (65 Btu/(s·ft^2)). The minimum inlet gas temperature was 284 K (52 °F), while the maximum gas outlet temperature was 742 K (877 °F). The maximum specimen temperature we measured was 761 K (910 °F). Because of the high heat fluxes generated by the furnace, we followed the operating procedure described in Olson and Glover [1990] to prevent overheating the specimen during experimental set-up, run, and shut-down.

Before taking the first data point, we waited at least 15 min with the heater lamp at steady power to allow the specimen and manifolds to reach thermal steady-state. The outlet manifold had the longest time constant due to its large thermal capacitance. We scanned the sensors at least twice at each setting. After sampling all the sensors, we changed the helium flow rate by adjusting valve 4. At each new flow rate, we waited a at least 5 min to establish thermal steady-state before taking data, since a change of flow rate also affected gas, specimen, and manifold temperatures. Gas pressure, furnace heating, helium flow rate, and gas inlet pressure remained sufficiently steady while taking data to ignore thermal transients in the data analysis.

We analyzed the measured data to determine the heat transfer coefficient, h, and the friction factor, f. The heat transfer coefficient was non-dimensionalized as a Nusselt number, Nu. A modified Nusselt number, Nu_m, was calculated to include the effects of variations in thermophysical properties, which we found to be significant in the tube specimen experiments. We calculated a wall Nusselt number, Nu_w, in which we extrapolated the temperature of the insulated side to the temperature of the wall-fluid interface. This was used for comparing our results to work in the literature on pin-fin configurations. Nu, Nu_m, and Nu_w were correlated with the Reynolds number, Re. The parameters h, Re, and Nu were calculated at each location of an insulated-side thermocouple.

3.2. Friction factor

The friction factor is derived from integrating the one-dimensional momentum equation in the flow direction:

$$P_0 - P_1 = G^2(1/\rho_1 - 1/\rho_0) + (2G^2/D_h)\cdot \int_0^1 (f/\rho)dx, \qquad (1)$$

where P = pressure;
G = mass flow rate per unit flow normal area
= $\dot{m}/A_f = \rho V$;
$\dot{m}$ = mass flow rate in channel;
A_f = volume-average flow normal area = V_o/L;
ρ = density;
V = average velocity based on flow normal area;
D_h = specimen hydraulic diameter = $4V_o/A_w$;
0 = location of upstream pressure tap (x/L = 0);
1 = location of downstream pressure tap (x/L = 1).

The first term on the right hand side of the equation is the pressure decrease due to flow acceleration, and the second term is the pressure drop due to friction. Temperatures measured perpendicular to the flow direction for experiments with heating indicated that the flow was evenly distributed along the width of the specimen. Both the velocity and hydraulic diameter are based on the open volume, V_o, in the specimen, which is the method used by VanFossen [1982]. Appendix A shows how V_o is calculated.

The experiments show that f depends on Re only. Because Re does not change from the specimen inlet to outlet if the specimen is unheated, f can be removed from within the integral. For the tube and channel specimens which we tested earlier, the density change was small compared to the absolute density, and the integral could be approximated as a constant. However, for the pin-fin specimen, even with no heating, at high helium flow rate the pressure drop could be 40 percent of the inlet pressure. If we assume a linear pressure drop and density drop through the specimen, we may evaluate the integral; the resulting expression for f is

$$f = \frac{P_0 - P_1 - G^2(1/\rho_1 - 1/\rho_0)}{2 \cdot G^2 \cdot (L/D_h) \cdot \dfrac{\ln(\rho_0/\rho_1)}{(\rho_0 - \rho_1)}} \quad . \tag{2}$$

Equation (2) is valid when there is no heating, but when the specimen is heated the Reynolds number and f change with position, and f can not be calculated from eq (2). The friction factor was determined for the tests with no heating as a function of Reynolds number, where

$$Re = \rho V D_h / \mu . \tag{3}$$

Past studies in the literature in which friction factors were measured in pin-fin geometries used a different definition for f [Metzger et al., [1982]:

$$f_M = \frac{P_0 - P_1 - G^2(1/\rho_1 - 1/\rho_0)}{2 \cdot \rho \cdot V_{max}^2 \cdot N} \quad , \tag{4}$$

where V_{max} = gas velocity at minimum flow area, and
N = number of rows of pins in flow direction.

In this definition, the pressure drop is assumed to scale like the pressure drop of flow around an isolated cylinder; the rows of pins are perpendicular to the flow, and there are N rows of cylinders in the flow direction. For our pin-fin specimen, the rows are not perpendicular to the flow direction, so it is not obvious how many pins the gas circumvents as it passes through the specimen. Because the pin diameter varies with height, even if the rows were perpendicular to the flow direction it would be difficult to define a minimum area and therefore maximum velocity. The definition of f used in our work assumes a similarity of the pin-fin specimen to a channel flow, and our hydraulic diameter is defined to include the effects of the pins. In our work, specimens with different orientation of the pins to the flow, but the same pin height, diameter, and spacing will produce the same values of the geometric parameters used in the definition of f (but not necessarily the same magnitude of f).

To determine whether specimen heating had an effect on the friction factor, eq (1) was integrated in a summation form from the inlet to outlet to predict the pressure drop, $P_0 - P_1$, for the experiments with specimen heating. The integral was evaluated at each location where wall temperature was measured, with f found from the correlation of f vs Re for experiment 1 and the local density found from the gas temperature and pressure. This predicted pressure drop was compared with the measured pressure drop.

3.3. Heat transfer coefficient

The heat transfer coefficient, h, is defined through the equation

$$q_w = h \cdot (T_w - T_{aw}) , \tag{5}$$

where q_w = local heat flux (heat flow per unit area) into the cooling fluid based on total wetted-wall area of the specimen;
h = heat transfer coefficient;
T_w = specimen wall temperature;
T_{aw} = adiabatic wall temperature of the cooling fluid.

The adiabatic wall temperature is used in gas flows whenever the kinetic energy is significant compared to enthalpy changes [Rohsenow and Choi, 1961]. Friction can cause the local wall temperature to exceed the bulk fluid temperature for an adiabatic specimen, and the adiabatic wall temperature approximates this effect. It is defined as

$$T_{aw} = T_f + rV^2/(2c_p), \tag{6}$$

where T_f = local bulk fluid temperature;
r = recovery factor = $Pr^{1/3}$ for turbulent flow.

Adiabatic heating was as much as 2 K, and was greatest for high flow rate and high heating rate. The local heat flux in eq (5) is expressed in terms of the total heat transfer to the specimen, Q_T, the total wetted wall area, and the furnace calibration function, f_q [Olson, 1989], which is a dimensionless expression of the local normal heat flux:

$$q_w = (Q_T/A_n)\cdot f_q\cdot(A_n/A_w), \tag{7}$$

with A_w = wetted wall area;
A_n = specimen heated normal area = $L\cdot W$.

The function f_q is on the order of 1; if the heat flux were constant then f_q would be 1 everywhere. The wall temperature used in eq (5) was measured with the thermocouples on the insulated side of the specimen. Measured wall temperatures show that wall conduction was negligible both in the flow direction (x) (except close to the end manifolds) and perpendicular to the flow direction (y). At each position the heat incident on the specimen is all convected into the fluid.

Combining eqs (5), (6) and (7) and rearranging, we get

$$h = \frac{(Q_T/A_w)\cdot f_q}{\{T_w-[T_f+(rV^2)/(2c_p)]\}} . \tag{8}$$

The flow-direction energy equation was used to calculate Q_T (to follow). Gas temperature T_f was calculated using the flow-direction energy equation along with the furnace calibration (also to follow).

The total heat absorbed by the specimen was calculated from the temperatures of the gas inlet and outlet, the helium flow rate, and the gas pressure drop. It was not necessary to adjust for a heat leak from the specimen to the furnace wall, as the heat leak was negligible due to the low temperatures of the reflective furnace.

$$Q_T = \dot{m}(h_B - h_A), \tag{9}$$

where h = enthalpy;
A = location in inlet manifold of PRT;
B = location in outlet manifold of PRT;

We neglected kinetic energy changes from A to B since they were insignificant compared to the uncertainties of the temperature measurement. The change in enthalpy is given by

$$h_B - h_A = c_p \cdot (T_B - T_A) + \int_A^B [(1-\beta T)/\rho] dP , \tag{10}$$

where β = coefficient of thermal expansion.

The specific heat was constant for the range of conditions tested. The pressure term was included for the slight divergence from the ideal gas state for helium at these temperatures and pressures. The pressure at A and B is estimated by assuming a linear drop along the specimen and extrapolating the pressure from 0 and 1. This assumption introduces less than 0.1 percent error in Q_T. The integral was evaluated using the virial equation of state for the gas [McCarty, 1973]. Combining eqs (9) and (10) yields for Q_T:

$$Q_T = \dot{m} \cdot \{c_p \cdot (T_B - T_A) + \int_A^B [(1-\beta T)/\rho] dP\}. \tag{11}$$

The fluid temperature, T_f, was calculated by integrating the flow energy equation from the inlet manifold up to the location of interest (designated as x), now including kinetic energy:

$$T_{fx} = T_A + \frac{Q_T \cdot Q_{px}}{\dot{m} \cdot c_p} + \frac{\int_A^x [(1-\beta T)/\rho] dP}{c_p} - \frac{V_x^2}{2c_p}, \tag{12}$$

where Q_{px} = fraction of total heat flow on specimen added up to position x;
= integration of furnace calibration function f_q, 0 to x.

The fluid temperature requires the velocity at x, given by

$$V_x = \dot{m}/(A_f \rho_x), \tag{13}$$

and the density is given by the equation of state [McCarty, 1973] as

$$\rho_x = \rho_x(T_{fx}, P_x). \tag{14}$$

We assume the pressure varies linearly between locations 0 and 1:

$$P_x = P_0 - (P_0 - P_1) \cdot x/L. \tag{15}$$

The maximum error in T_f introduced by assuming a linear pressure variation was less than 0.15 K, which produces errors in h and in Nu of less than 1 percent.

With eq (15) substituted into eq (12) to evaluate the pressure term, eqs (12), (13), and (14) form a system of three equations in the unknowns of temperature, velocity, and density. They were solved by iteration. After determining T_f and V at location x, the heat transfer coefficient was calculated using eq (8). The Nusselt number, Prandtl number, and Reynolds number were then calculated, with the transport properties evaluated at the bulk fluid temperature, T_f:

$$Nu = h \cdot D_h / k, \quad Pr = \mu \cdot c_p / k. \tag{16}$$

Transport properties were calculated from the functions given in McCarty [1972]. Using Nu to evaluate the heat transfer performance assumes constant fluid properties at the location x. Temperature differences between the wall and fluid, produced by the finite heat transfer, will produce differences in fluid properties between the wall and the fluid. The wall-to-fluid temperature difference was much smaller for the pin-fin specimen than for the tube and channel specimens, due to the higher heat transfer coefficient in the pin-fin specimen. Even though property variations were small, we continued to use the temperature ratio method of Rohsenow and Hartnett [1973] to compensate for the property variations:

$$Nu_m = Nu \cdot (T_w/T_f)^{0.55}. \tag{17}$$

In the NASP application of the cooling jacket, heat fluxes would be much higher than those tested here, and the property differences between the wall and fluid would be larger due to the larger temperature difference. Nu_m was then correlated with Re.

The heat transfer coefficient, h, is <u>defined</u> in terms of the insulated wall temperature, because that temperature was measured with the least uncertainty. To predict the performance of the specimen from correlations developed in our experiments, this definition is satisfactory, and will predict the insulated wall temperature for given conditions of heat flux and gas flow rate. However, we desire to compare our results to the literature where h is defined in terms of a solid-fluid interface temperature. Because the specimen was heated from one side only and the solid thermal conductivity was finite, specimen temperatures will vary between the heated side, the insulated side, and the solid-fluid interface. For the previously tested tube and channel specimens, the fluid convection compared to the solid conduction was low enough that the temperature variations in the solid were small compared to the temperature difference between the wall and the fluid. In the pin-fin specimen, the heat transfer is much better, and the insulated wall temperature can no longer be considered the same as the solid-fluid interface temperature.

To compare our results to those of past studies where the heat transfer coefficient was defined in terms of the solid-fluid interface temperature, we computed temperature distributions in the pin with a finite element conduction analysis. Our inputs to the model were the anticipated values of the wall heat transfer coefficient, h_w, anticipated normal heat fluxes, and the adiabatic wall temperature. We assumed the heat transfer coefficient was uniform around a pin and on the top and bottom plates. Then, we calculated a pin efficiency, η, defined by

$$\eta = \frac{Q_T/A_n}{h_w \cdot (T_w - T_{aw})}. \tag{18}$$

The temperature of the insulated wall, T_w, was calculated in the analysis. The analysis was repeated for the range of h_w expected experimentally, and η was calculated for each set of conditions. η was then correlated as a function of the Biot number

$$\eta = 1.0024 + 1.5229 \cdot Bi - 0.3142 \cdot Bi^2, \tag{19}$$

with $Bi = h_w \cdot D_h / k_{ni}$.

To calculate h_w from the experimental data, we measure Q_T/A_n and T_w, and calculate T_{aw} from eqs (6) and (12). Then we use eq (18) in conjunction with eq (19) to solve for h_w. h_w is then normalized as a wall Nusselt number

$$Nu_w = h_w \cdot D_h / k \cdot (T_w/T_f)^{0.55} , \tag{20}$$

which includes the (small) effect of variable thermophysical properties between the wall and the fluid. Nu_w was also correlated with Re.

3.4 Uncertainty analysis

Uncertainties for the calculated quantities were obtained by Taylor series error propagation as described by ASME [1986]. This technique generally produces the same level of confidence in a calculated result as the level of confidence in the measurements which contribute to the result [Kline and McClintock, 1953]. A summary of the uncertainties in the data analysis parameters and in the calculated quantities is listed in table 4. Actual values at the experimental points are included in table 3. The largest contributor to the uncertainties in T_f, h, and Nu was the flow distribution uncertainty (i.e., whether or not the flow had split evenly along the specimen width), particularly near the exit of the specimen. Using an analysis similar to Olson [1990] in which transverse temperature measurements were used to predict the local gas flow, we predicted the flow distribution varied by no more than 2 percent across the width of the specimen, except close to the side edges. However, since the wall-to-fluid temperature difference was small (5 to 10 K for low heat flux and high helium flow), the small uncertainty in the flow distribution still produced a large uncertainty in h and Nu.

4. Results of experiments

4.1 Friction factor

The pressure drop in the 18° pin-fin specimen was much greater than in either the tube or channel specimens. For example, for the pin-fin specimen the pressure drop was 1296 kPa (188 psi) at $\dot{m}$ = 31.1 kg/h and P_0 = 3.4 MPa. For similar flow conditions, the pressure drop in the tube specimen was 75 kPa ($\dot{m}$ = 31.0 kg/h, P_0 = 3.4 MPa), and in the channel specimen it was 51 kPa ($\dot{m}$ = 30.6 kg/h, P_0 = 3.5 MPa). The variation of the friction factor with Reynolds number was determined in experiment 1. Figure 6 shows the variation in f with Re along with a least-squares correlation of the data (for Re > 2500). These data are correlated with

$$f = 0.8561 \cdot Re^{-0.2160} \ . \qquad (21)$$

The standard deviation of the difference between the measured and correlated values is 0.92 percent. If the points for Re > 1500 are included in the correlation, the function is

$$f = 0.9193 \cdot Re^{-0.2241} \ . \qquad (22)$$

The standard deviation of the difference between the measured and correlated values is 1.09 percent. Data points for Re < 1500 were not included because we believed the flow was laminar or in transition. The uncertainty in our measured values of f is believed to be 22 to 23 percent for Re > 450. The largest source of uncertainty for f was the uncertainty in the height of the pins, which we estimated as 0.025 mm. This could not be confirmed without sectioning the specimen, which would render it unusable for future tests. If the uncertainty in the height of the pins were half as much, or 0.013 mm, then the uncertainty in f would be 12 to 13 percent.

We can compare our measurements of friction factor to the literature results, making some assumptions about minimum flow area and number of rows which is needed for those correlations. For example, Metzger et al. [1982] used the form of eq (5) and found, for $10^3 < Re < 10^4$ and staggered circular pins,

$$f_M = 0.317 \cdot Re^{-0.132} \ . \qquad (23)$$

If the angle of the pins to the flow direction for our specimen were 30° instead of 18°, then there would be 87 rows in the flow direction. If we then use as the minimum flow area the open area along a row of pins, at Re = 8000, we calculate a pressure drop that is 23 percent lower using the Metzger correlation than what we measure. This is probably a reasonable agreement because both N and V_{max} have to be considered approximations, due to the differences in geometry between our specimen and the literature results. Metzger et al. indicate that the exponent of the Re term changes to -0.318 for $10^4 < Re < 10^5$, which makes our exponent somewhat midway between what they report.

We used the friction factor correlation developed for the tests without heat transfer to predict the pressure drop when the specimen was heated. Figure 7 compares the error between the predicted pressure drop and the measured pressure drop, plotted as a function of helium flow rate. For $Re > 2500$ we used eq (21) for f; for $666 < Re < 2500$ we used eq (22) for f. For $Re < 666$, we assumed $f \sim 1/Re$, which is the functional form for laminar flow in a tube or channel. The constant of proportionality was chosen so that f would match the measured value at $Re = 450$. The error between the measured and predicted pressure drop was less than 10 percent for most of the points, which was within the uncertainty of the measured friction factor.

4.2 Temperature distributions and heat transfer

In experiments 2 to 6 we heated the specimen to determine the heat transfer performance. A typical plot of temperatures in the helium gas and along the specimen is shown in figure 8. The data are for the lowest flow rate (11.4 kg/h) of experiment 5, which corresponded to the largest inlet-to-outlet temperature rise in the helium at that heat flux rate. The measured specimen temperatures along the y centerline ($y/W = 0.08$ for the hot side, $y/W = 0.00$ for the insulated side), are shown from the inlet to the outlet. The calculated gas temperature is also plotted (eq 12) for the locations of an insulated-side thermocouple. The gas temperature increased approximately linearly from the inlet to the outlet. The heated-side temperatures were 16 to 18 K higher than the insulated-side temperatures over most of the specimen. Specimen temperatures on both sides increased steadily from the inlet to the outlet, except that the temperature decreased near the outlet.

The temperature difference between the heated and insulated sides correlates well with the incident normal heat flux. As the heat flux increases, this temperature difference increases almost linearly. Higher coolant flow reduces the temperature difference, because higher flows reduce specimen temperatures and therefore increase the nickel thermal conductivity.

Because the temperature increased and the pressure decreased from the inlet to the outlet, other fluid properties changed significantly also. Both thermal conductivity and dynamic viscosity increase with temperature, so they increased from the inlet to the outlet. Fluid density decreased from the inlet to the outlet, due to the increase in temperature and the decrease in pressure. Because the density decreased, fluid velocity increased from the inlet to the outlet; for the conditions shown in the figure, the specimen inlet velocity was 22 m/s and the specimen outlet velocity was 61 m/s.

Temperatures at locations perpendicular to the flow direction (y-variation) for the conditions of figure 8 are shown in figure 9. Here, at each x-location we have plotted temperature on the insulated side as a function of y-position. Temperatures were much more uniform in the y-direction for the pin-fin specimen than for either the channel or tube specimen. The lowest temperatures were closest to the +y edge of the specimen; at $x/L = 0.83$, the temperature at $y/W = 0.41$ was 19 K lower than the temperature at $y/W = 0.00$. We believe temperatures were more uniform in the pin-fin specimen when compared to the tube and channel specimens because the flow was more evenly distributed along the specimen width. Except near the +y edge of the specimen, the measured temperature variations in the y-direction can be explained by nonuniformities of < 2 percent in the flow. The high pressure drop in the pin-fin specimen will cause the inlet and outlet distribution manifolds to produce more uniform flow. Also, because there are no barriers to transverse flow for the pin-fin as there were for the tube and channel specimens, the flow can readjust if it encounters a local nonuniformity in flow area (either blockage or unbonded pins). The local flow rate was not adjusted to reflect nonuniformities in wall temperature (as was done for the channel specimen in Olson [1990]), since in most cases the nonuniformities in temperature were on the same order as the uncertainties in the wall and gas temperatures.

In figure 10 we show the heat transfer coefficient and wall-to-fluid temperature difference for the same conditions as those for figure 8 (experiment 5, 11.4 kg/h helium flow). Shown are points along $y/W = 0.00$, from the inlet to the outlet. h was calculated directly from the temperature difference, with the appropriate heat flux (eq 8); to first order the trends in T_w-T_f and h are mirrored. Except near $x/L = 0$ and 1, the temperature difference was roughly constant over the entire length of the specimen. We believe the cause of the drop-off near the end walls was heat conduction through the specimen wall to the inlet and outlet manifolds. The length of this conduction region was much shorter for the pin-fin specimen when compared to the channel or tube specimens for 2 reasons: (1) the total thickness of the specimen was less; (2) the heat transfer coefficient and internal wall area were greater. Using the same technique for estimating the conduction region as described in Olson and Glover [1990], we predict the region extends from $x/L = 0$ to 0.07, and from $x/L = 0.93$ to 1.0. In these regions, h and therefore Nu cannot be calculated from eq (8), since the heat convected into the fluid was not the same as that incident on the specimen.

The wall-to-fluid temperature difference was 5 to 6 times lower for the pin-fin specimen than in the tube or channel specimen, for similar incident heat flux and helium flow rate. Because of the lower absolute temperature difference, uncertainties in the wall and fluid temperatures produced higher relative uncertainties in h, Nu, and Nu_m for the pin-fin specimen.

Figure 11 shows the variation of Re, Nu_m, and Nu with x for the same experimental conditions as above. We have plotted Nu and Nu_m along the entire heated length, although the values at $x/L = 0$ and 1 are not accurate due to conduction effects. The Reynolds number decreased from the inlet to the outlet, due to the increase in viscosity caused by the temperature increase. Nu and Nu_m also decreased from the inlet to the outlet, within the $0.07 < x/L < 0.93$ region of accuracy. Nu_m was only 1.9 to 5.8 percent greater than Nu for experiment 5, due to the small temperature difference between the wall and the fluid. (The maximum difference in the properties viscosity and thermal conductivity between the wall and the fluid was 7 percent, compared to a 26 percent difference in properties for the channel specimen [Olson, 1990]).

The trends in temperature distributions, Re, and Nu with position did not change qualitatively for the other helium flow rates for experiment 5, nor did they change for the other heat flux rates tested. Figures 8 to 11 are representative of the variations for all runs.

For experiments 2 and 4, the wall temperature reading at x = 12.69 cm and y = 1.93 cm was likely in error, since it read lower than the fluid temperature at that location. We suspect the error was caused by a short in the reference box.

Figure 12 shows the modified Nusselt number plotted against the Reynolds number for experiments 3 to 6, for data points along $y/W = 0.0$ and $0.07 < x/L < 0.93$. The data for experiment 2 were not included since they were virtually identical to the data from experiment 3. Shown as the dashed line is the correlation of VanFossen [1982] for turbulent flow past staggered, circular pins with length-to-diameter ratios of 1/2 and 2.

$$Nu = 0.153 \cdot Re^{0.685} \text{ (VanFossen [1982]).} \tag{24}$$

The solid line is the correlation for our data for Re > 5000:

$$Nu_m = 0.0198 \cdot Re^{0.928}, \tag{25}$$

or in terms of Nu,

$$Nu = 0.0198 \cdot Re^{0.928} \cdot (T_w/T_f)^{-0.55}. \tag{26}$$

The standard deviation between our data and correlation is 3.7 percent (Re > 5000). The leading coefficient and exponent on Re were calculated from a least squares fit of the data. The power on the temperature ratio term was assumed to be the same as for the tube and channel specimen data, -0.55. The uncertainty on the measured data ranged from 13.6 to 43.8 percent, with the highest uncertainty occurring near the specimen outlet for low heat flux and high helium flow (conditions of the smallest T_w-T_f).

Our data agree well with the correlation of VanFossen around Re = 5000, but are higher than his values for higher Re. The variation of Nu_m with Re is also greater for our data than for that of VanFossen. Recall, however, that in the definition of Nu_m we have used the measured, insulated side temperature as the reference wall temperature. The correlation of VanFossen is based on the pin temperature at the wall-fluid interface.

When we extrapolate our insulated temperature using eqs (18) and (19) to calculate h_w based on the temperature of the wall-fluid interface (this compensates for nonisothermal pin temperatures), we get the results shown in figure 13. The correlation for Nu_w is

$$Nu_w = 0.0357 \cdot Re^{0.837} . \tag{27}$$

Also plotted is the correlation of VanFossen. The agreement of Nu_w to the VanFossen correlation is much better, particularly at high Re. Although the exponent on Re is higher for our data, for Re > 5000 the two correlations agree to within the experimental uncertainty of our measurements.

In the NASP application, this specimen would be operated with Re > 5000. For Re < 5000, there appears to be some dependence of Nu_m and Nu_w on heat flux. For all heat fluxes $Q/A_n \geq 44$ W/cm^2, the data agree within experimental uncertainty, but the data for Q/A_n = 20 W/cm^2 seem to be systematically higher at Re = 3000. This is more evident on a log(Nu_w) vs log(Re) plot. We speculate that the higher heat transfer for the low heat flux test is related to flow acceleration. The lower heat flux will have less flow acceleration, since the increases in temperature, density, and velocity with x are less. Metzger et al. [1986] found that the heat transfer in pin-fins in a converging channel was reduced. The converging channel will produce flow acceleration. It is possible that a similar phenomenon is occurring in our test; the experiments at higher heat flux have greater temperature rise in the flow direction, greater density changes, hence more flow acceleration and reduced heat transfer.

5. Summary and conclusions

We tested a novel pin-fin specimen, with a pin angle of 18° to the flow direction, to measure the friction factor and heat transfer in helium gas. Experiments were performed in an apparatus which radiatively heated one side of the specimen at a heat flux of up to 74 W/cm^2 (65 Btu/(s·ft^2)), and cooled the specimen with helium gas at 3.5 MPa (500 psi) and Re of 450 to 12 000. Helium gas temperatures ranged from 284 K (52 °F) to 742 K (877 °F); the peak specimen temperature was 761 K (910 °F). We report the heat transfer both as a modified Nusselt number, which should be used for design purposes to predict the temperature on the insulated side of the specimen, and as a wall Nusselt number, which we used to compare the performance to past work on pin-fin configurations. Our measured wall Nusselt number agrees with the correlation of VanFossen to within experimental uncertainty for Re > 5000. Conduction to the end manifolds was important in the specimen within 7 percent of where heating begins and ends. Over most of the specimen, the non-uniformity in helium flow was less than 2 percent. At Re < 5000 (lower than the range for NASP), there appears to be some reduction in heat transfer at higher heat fluxes, possibly due to increased flow acceleration.

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APPENDIX A. Calculation of open volume, wetted-wall area, and flow area for pin-fin specimens

A.1. Open volume

The open volume was found by determining the open flow volume around each pin, then multiplying by the number of pins. We added the volume of a narrow channel next to each side edge, of width 0.64 mm and height 0.51 mm, which NASA Langley milled into the piece to prevent accumulation of braze.

The open volume per pin was found by referencing to figure (A.1). Each pin is considered to occupy a hexagon of the normal area, where the width between sides of the hexagon is S = 2.03 mm. If the pin solid were not present, for a separation between plates, t, of 0.51 mm the volume would be

$$V_{o,no.p} = (3^{1/2}/2)\cdot S^2\cdot t \ . \tag{A.1}$$

To determine the volume of the solid pin, we assumed the pin diameter varied from d at the point of the braze to S at the channel height t. With z as the vertical coordinate as in the drawing, the diameter varied with z as

$$d_p = S - 2(t^2-z^2)^{1/2} \ . \tag{A.2}$$

Performing the integration and substituting d = S - 2t, we find the solid volume of the pin as

$$V_{s,p} = \pi t/4\cdot[S^2-(\pi/4)\cdot S\cdot t+(8/3)\cdot t^2] \ . \tag{A.3}$$

The total open volume per pin is

$$V_{o,p} = V_{o,no.p} - V_{s,p}$$

$$= (3^{1/2}/2)\cdot S^2\cdot t - \pi t/4\cdot[S^2-(\pi/4)\cdot S\cdot t+(8/3)\cdot t^2] \ . \tag{A.4}$$

The total number of pins was found by dividing the normal area per pin by the total normal area, recognizing that there will be partial pins along all four edges. We found n = 3203. The total open volume was therefore n times $V_{o,p}$ plus the volume of the two channels along the edges. Substituting values for S and t we find

$$V_o = 3.856 \text{ cm}^3 \ . \tag{A.5}$$

A.2. Wetted-wall area

The wetted-wall area, A_w, was found by calculating the wetted-wall area per pin, $A_{w,p}$, then multiplying by the number of pins, n. As in the calculation of the open volume, we added the wetted-wall area of the two channels next to the side edges. The wetted-wall area per pin was composed of the wall area on the top channel, the wall area on the bottom channel, and the wall area on the side of the pins. The wall area on the side of the pins was found by integration, with reference again to figure A.1.

$$A_{w,p} = S^2\cdot(3^{1/2}/2-\pi/4) + [(3^{1/2}/2)\cdot S^2-(\pi/4)\cdot d^2] + \pi t\cdot(\pi S/2-2t) \ , \qquad (A.6)$$

where the terms on the right hand side of the equation are, respectively, the wall area on the top channel, the wall area on the bottom channel, and the wall area on the side of the pins.

Multiplying eq (A.6) by n and adding the wall area of the two side channels, we find

$$A_w = 215.8 \text{ cm}^2 \ . \qquad (A.7)$$

A.3. Flow area

The flow area was found by assuming the open volume is distributed evenly through the length of the specimen. It is an average flow area, neither the minimum or maximum. It is simply the open volume divided by the length, or

$$A_f = V_o/L, \quad = 0.2530 \text{ cm}^2 \ . \qquad (A.8)$$

Table 1. Uncertainties in experimental measurements and gas properties at a 95 percent confidence interval

Measurement or Property	Technique	Major Source of Uncertainty	Magnitude of Uncertainty
Gas Flow Rate	Thermal Mass Flow Meter	Meter Calibration	±1%
Heat Flux	Calibration of Furnace	Heat Flow Meter	±4%
Gas Inlet and Outlet Temperatures	Platinum Resistance Thermometer	Radiation	±0.5 K
Gas Pressure	Pressure Transducer	Calibration	±0.25%
Gas Differential Pressure	Pressure Transducer	Calibration	greater of ±0.5% or ±1.4 kPa
Specimen Temperature	Type N Thermocouple	Wire Calibration, Installation	greater of ±0.4% of T(C) or ±1.1 K
Gas Density	Thermodynamic Function	Function Accuracy	±0.1%
Gas Enthalpy	Thermodynamic Function	Function Accuracy	±0.2%
Gas Specific Heat	Thermodynamic Function	Function Accuracy	±5%
Gas Viscosity	Thermodynamic Function	Function Accuracy	±10%
Gas Thermal Conductivity	Thermodynamic Function	Function Accuracy	±3%

Table 2. Summary of geometrical parameters and experimental conditions for 18° pin-fin specimen

Angle of Pins to Flow Direction = 18°
Pin Height, t = 0.508 mm
Pin Spacing, S = 2.032 mm
Pin Diameter at Braze, d = 1.016 mm
Specimen Hydraulic Diameter, D_h = 0.7149 mm
Specimen Heated Length, L = 15.24 cm
Specimen Width, W = 7.85 cm
Specimen Heated Normal Area, A_n = 119.6 cm^2
Specimen Wetted Wall Area, A_w = 215.8 cm^2
Flow Normal Area, A_f = 0.2530 cm^2

Expt. #	Date	Inlet Pressure (kPa)	Heater Voltage (%)	Normal Heat Flux (W/cm^2)	Helium Flow Rate (kg/h)	Reynolds Number
1	9/18/90	3435	0.0	0.0	1.1-31.1	450-12 300
2	9/19/90	3570	24.8	20.2	4.1-15.4	900- 6 100
3	11/20/90	3500	25.5	20.4	3.7-28.3	800-11 400
4	9/19/90	3440	50.2	44.2	10.3-27.0	2400-10 800
5	11/21/90	3505	75.2	63.1	11.4-27.8	2400-11 300
6	11/23/90	3525	93.8	73.8	15.0-25.6	3300-10 400

Table 3. Data tables for all experiments

18° Pinfin Specimen
Experiment: 1
Date: 18 September 1990
Time: 14:21:10

TA	TB	M	P0	P0-P1	Vf	f	Wf
K	K	kg/h	kPa	kPa	%		%
295.13	294.57	1.12	3465.4	3.66	0.00	0.31749	44.28

Hot-side Temperatures:

X	Y	Tw	X	Y	Tw
cm	cm	K	cm	cm	K
1.332	0.485	294.81	2.549	-1.330	294.93
2.597	0.526	294.88	5.033	-1.444	294.95
2.681	0.923	294.89	7.571	-1.375	294.92
5.107	0.426	294.90	10.071	-1.476	294.90
7.626	0.498	294.87	2.465	-2.649	294.97
7.710	0.895	294.87	7.657	-2.616	294.94
10.111	0.396	294.88	12.699	-2.643	294.87
12.651	0.478	294.84	7.540	2.687	294.86
12.734	0.875	294.88	7.623	3.085	294.85
13.931	0.527	294.84			

Insulated-Side Temperatures and Calculated Data:

X	Y	Tw	Tf	P	V	RE	PR	---Uncertainties-- Wtw	Wtf	Wre
cm	cm	K	K	kPa	m/s			K	K	%
-0.038	-0.229	294.97	295.13	3465.4	2.22	445	0.665	1.10	0.50	10.69
1.293	-0.226	294.97	295.08	3465.1	2.22	445	0.665	1.10	0.50	10.69
2.527	-0.132	294.95	295.04	3464.8	2.22	445	0.665	1.10	0.50	10.69
3.802	0.056	294.94	294.99	3464.4	2.22	445	0.665	1.10	0.50	10.69
4.976	-0.008	294.90	294.95	3464.2	2.22	445	0.665	1.10	0.50	10.69
6.314	0.028	294.91	294.90	3463.8	2.22	445	0.665	1.10	0.50	10.69
7.607	0.033	294.93	294.85	3463.5	2.22	445	0.665	1.10	0.50	10.69
8.913	-0.013	294.89	294.80	3463.2	2.22	445	0.665	1.10	0.50	10.69
10.185	0.020	294.90	294.76	3462.9	2.22	445	0.665	1.10	0.50	10.69
11.453	0.066	294.87	294.71	3462.6	2.22	445	0.665	1.10	0.50	10.69
12.723	-0.033	294.88	294.66	3462.3	2.22	445	0.665	1.10	0.50	10.69
13.993	0.025	294.87	294.62	3462.0	2.22	445	0.665	1.10	0.50	10.69
15.240	-0.058	294.82	294.57	3461.7	2.22	445	0.665	1.10	0.50	10.69
2.565	-1.880	294.97	295.03	3464.7	2.22	445	0.665	1.10	0.50	10.69
5.032	-1.892	294.97	294.94	3464.1	2.22	445	0.665	1.10	0.50	10.69
7.620	-1.938	294.94	294.85	3463.5	2.22	445	0.665	1.10	0.50	10.69
10.185	-1.951	294.92	294.76	3462.9	2.22	445	0.665	1.10	0.50	10.69
12.700	-1.913	294.91	294.66	3462.3	2.22	445	0.665	1.10	0.50	10.69
2.494	1.925	294.91	295.04	3464.8	2.22	445	0.665	1.10	0.50	10.69
5.098	1.900	294.90	294.94	3464.1	2.22	445	0.665	1.10	0.50	10.69
7.620	1.852	294.92	294.85	3463.5	2.22	445	0.665	1.10	0.50	10.69
10.160	1.956	294.88	294.76	3462.9	2.22	445	0.665	1.10	0.50	10.69
12.692	1.930	293.46	294.66	3462.3	2.22	445	0.665	1.10	0.50	10.69
2.540	-3.211	294.99	295.04	3464.8	2.22	445	0.665	1.10	0.50	10.69
7.633	-3.213	294.94	294.85	3463.5	2.22	445	0.665	1.10	0.50	10.69
12.720	-3.211	294.90	294.66	3462.3	2.22	445	0.665	1.10	0.50	10.69
2.499	3.221	294.88	295.04	3464.8	2.22	445	0.665	1.10	0.50	10.69
7.620	3.454	294.88	294.85	3463.5	2.22	445	0.665	1.10	0.50	10.69
12.700	3.180	294.86	294.66	3462.3	2.22	445	0.665	1.10	0.50	10.69

Table 3 (continued)

18° Pinfin Specimen
Experiment: 1
Date: 18 September 1990
Time: 14:26:38

TA	TB	M	PO	PO-P1	Vf	f	Wf
K	K	kg/h	kPa	kPa	%		%
296.03	295.36	3.81	3445.2	24.26	0.00	0.18077	22.82

Hot-side Temperatures:

X	Y	Tw	X	Y	Tw
cm	cm	K	cm	cm	K
1.332	0.485	295.33	2.549	-1.330	295.92
2.597	0.526	295.83	5.033	-1.444	295.93
2.681	0.923	295.84	7.571	-1.375	295.93
5.107	0.426	295.86	10.071	-1.476	295.89
7.626	0.498	295.82	2.465	-2.649	295.95
7.710	0.895	295.83	7.657	-2.616	295.91
10.111	0.396	295.78	12.699	-2.643	295.89
12.651	0.478	295.78	7.540	2.687	295.79
12.734	0.875	295.83	7.623	3.085	295.77
13.931	0.527	295.81			

Insulated-Side Temperatures and Calculated Data:

X	Y	Tw	Tf	P	V	RE	PR	---Uncertainties-- Wtw	Wtf	Wre
cm	cm	K	K	kPa	m/s			K	K	%
-0.038	-0.229	295.96	296.03	3445.3	7.59	1505	0.665	1.10	0.50	10.69
1.293	-0.226	295.95	295.97	3443.2	7.59	1505	0.665	1.10	0.50	10.69
2.527	-0.132	295.95	295.92	3441.2	7.59	1505	0.665	1.10	0.50	10.69
3.802	0.056	295.96	295.86	3439.2	7.60	1506	0.665	1.10	0.50	10.69
4.976	-0.008	295.92	295.81	3437.3	7.60	1506	0.665	1.10	0.50	10.69
6.314	0.028	295.94	295.75	3435.1	7.60	1506	0.665	1.10	0.50	10.69
7.607	0.033	295.92	295.69	3433.0	7.61	1506	0.665	1.10	0.50	10.69
8.913	-0.013	295.92	295.63	3430.9	7.61	1506	0.665	1.10	0.50	10.69
10.185	0.020	295.90	295.58	3428.9	7.61	1506	0.665	1.10	0.50	10.69
11.453	0.066	295.91	295.52	3426.8	7.62	1507	0.665	1.10	0.50	10.69
12.723	-0.033	295.89	295.47	3424.8	7.62	1507	0.665	1.10	0.50	10.69
13.993	0.025	295.91	295.41	3422.8	7.62	1507	0.665	1.10	0.50	10.69
15.240	-0.058	295.89	295.36	3420.7	7.63	1507	0.665	1.10	0.50	10.69
2.565	-1.880	295.99	295.91	3441.1	7.59	1505	0.665	1.10	0.50	10.69
5.032	-1.892	295.98	295.80	3437.2	7.60	1506	0.665	1.10	0.50	10.69
7.620	-1.938	296.00	295.69	3433.0	7.61	1506	0.665	1.10	0.50	10.69
10.185	-1.951	295.98	295.58	3428.9	7.61	1506	0.665	1.10	0.50	10.69
12.700	-1.913	295.94	295.47	3424.8	7.62	1507	0.665	1.10	0.50	10.69
2.494	1.925	295.91	295.92	3441.3	7.59	1505	0.665	1.10	0.50	10.69
5.098	1.900	295.89	295.80	3437.1	7.60	1506	0.665	1.10	0.50	10.69
7.620	1.852	295.88	295.69	3433.0	7.61	1506	0.665	1.10	0.50	10.69
10.160	1.956	295.89	295.58	3428.9	7.61	1506	0.665	1.10	0.50	10.69
12.692	1.930	293.96	295.47	3424.8	7.62	1507	0.665	1.10	0.50	10.69
2.540	-3.211	296.03	295.91	3441.2	7.59	1505	0.665	1.10	0.50	10.69
7.633	-3.213	296.01	295.69	3433.0	7.61	1506	0.665	1.10	0.50	10.69
12.720	-3.211	295.98	295.47	3424.8	7.62	1507	0.665	1.10	0.50	10.69
2.499	3.221	295.82	295.92	3441.2	7.59	1505	0.665	1.10	0.50	10.69
7.620	3.454	295.84	295.69	3433.0	7.61	1506	0.665	1.10	0.50	10.69
12.700	3.180	295.83	295.47	3424.8	7.62	1507	0.665	1.10	0.50	10.69

Table 3 (continued)

18° Pinfin Specimen
Experiment: 1
Date: 18 September 1990
Time: 14:32:00

TA	TB	M	P0	P0-P1	Vf	f	Wf
K	K	kg/h	kPa	kPa	%		%
296.71	296.35	6.44	3441.9	61.07	0.00	0.15782	22.19

Hot-side Temperatures:

X	Y	Tw	X	Y	Tw
cm	cm	K	cm	cm	K
1.332	0.485	295.67	2.549	-1.330	296.63
2.597	0.526	296.58	5.033	-1.444	296.62
2.681	0.923	296.55	7.571	-1.375	296.63
5.107	0.426	296.57	10.071	-1.476	296.61
7.626	0.498	296.55	2.465	-2.649	296.64
7.710	0.895	296.55	7.657	-2.616	296.63
10.111	0.396	296.56	12.699	-2.643	296.61
12.651	0.478	296.58	7.540	2.687	296.50
12.734	0.875	296.57	7.623	3.085	296.47
13.931	0.527	296.56			

Insulated-Side Temperatures and Calculated Data:

								---Uncertainties--		
X	Y	Tw	Tf	P	V	RE	PR	Wtw	Wtf	Wre
cm	cm	K	K	kPa	m/s			K	K	%
-0.038	-0.229	296.65	296.70	3442.3	12.86	2540	0.665	1.10	0.50	10.69
1.293	-0.226	296.65	296.67	3436.9	12.88	2540	0.665	1.10	0.50	10.69
2.527	-0.132	296.61	296.64	3431.9	12.90	2540	0.665	1.10	0.50	10.69
3.802	0.056	296.63	296.61	3426.7	12.92	2540	0.665	1.10	0.50	10.69
4.976	-0.008	296.61	296.58	3422.0	12.94	2541	0.665	1.10	0.50	10.69
6.314	0.028	296.64	296.55	3416.6	12.95	2541	0.665	1.10	0.50	10.69
7.607	0.033	296.62	296.52	3411.3	12.97	2541	0.665	1.10	0.50	10.69
8.913	-0.013	296.61	296.48	3406.0	12.99	2541	0.665	1.10	0.50	10.69
10.185	0.020	296.62	296.45	3400.9	13.01	2541	0.665	1.10	0.50	10.69
11.453	0.066	296.61	296.42	3395.8	13.03	2542	0.665	1.10	0.50	10.69
12.723	-0.033	296.58	296.39	3390.6	13.05	2542	0.665	1.10	0.50	10.69
13.993	0.025	296.60	296.36	3385.5	13.06	2542	0.665	1.10	0.50	10.69
15.240	-0.058	296.63	296.33	3380.4	13.08	2542	0.665	1.10	0.50	10.69
2.565	-1.880	296.65	296.64	3431.8	12.90	2540	0.665	1.10	0.50	10.69
5.032	-1.892	296.69	296.58	3421.8	12.94	2541	0.665	1.10	0.50	10.69
7.620	-1.938	296.63	296.52	3411.3	12.97	2541	0.665	1.10	0.50	10.69
10.185	-1.951	296.65	296.45	3400.9	13.01	2541	0.665	1.10	0.50	10.69
12.700	-1.913	296.65	296.39	3390.7	13.05	2542	0.665	1.10	0.50	10.69
2.494	1.925	296.56	296.64	3432.0	12.90	2540	0.665	1.10	0.50	10.69
5.098	1.900	296.56	296.58	3421.5	12.94	2541	0.665	1.10	0.50	10.69
7.620	1.852	296.57	296.52	3411.3	12.97	2541	0.665	1.10	0.50	10.69
10.160	1.956	296.55	296.45	3401.0	13.01	2541	0.665	1.10	0.50	10.69
12.692	1.930	294.34	296.39	3390.7	13.04	2542	0.665	1.10	0.50	10.69
2.540	-3.211	296.67	296.64	3431.9	12.90	2540	0.665	1.10	0.50	10.69
7.633	-3.213	296.64	296.51	3411.2	12.97	2541	0.665	1.10	0.50	10.69
12.720	-3.211	296.63	296.39	3390.6	13.05	2542	0.665	1.10	0.50	10.69
2.499	3.221	296.49	296.64	3432.0	12.90	2540	0.665	1.10	0.50	10.69
7.620	3.454	296.49	296.52	3411.3	12.97	2541	0.665	1.10	0.50	10.69
12.700	3.180	296.49	296.39	3390.7	13.05	2542	0.665	1.10	0.50	10.69

18° Pinfin Specimen
Experiment: 1
Date: 18 September 1990
Time: 14:37:30

TA	TB	M	PO	PO-P1	Vf	f	Wf
K	K	kg/h	kPa	kPa	%		%
296.61	296.64	9.92	3433.7	132.59	0.00	0.14239	22.10

Hot-side Temperatures:

X	Y	Tw	X	Y	Tw
cm	cm	K	cm	cm	K
1.332	0.485	295.51	2.549	-1.330	296.56
2.597	0.526	296.53	5.033	-1.444	296.56
2.681	0.923	296.54	7.571	-1.375	296.56
5.107	0.426	296.54	10.071	-1.476	296.55
7.626	0.498	296.53	2.465	-2.649	296.54
7.710	0.895	296.55	7.657	-2.616	296.57
10.111	0.396	296.54	12.699	-2.643	296.57
12.651	0.478	296.55	7.540	2.687	296.51
12.734	0.875	296.57	7.623	3.085	296.52
13.931	0.527	296.55			

Insulated-Side Temperatures and Calculated Data:

								---Uncertainties--		
X	Y	Tw	Tf	P	V	RE	PR	Wtw	Wtf	Wre
cm	cm	K	K	kPa	m/s			K	K	%
-0.038	-0.229	296.54	296.58	3434.4	19.86	3914	0.665	1.10	0.50	10.69
1.293	-0.226	296.56	296.58	3422.7	19.92	3914	0.665	1.10	0.50	10.69
2.527	-0.132	296.54	296.58	3411.9	19.99	3914	0.665	1.10	0.50	10.69
3.802	0.056	296.53	296.58	3400.7	20.05	3914	0.665	1.10	0.50	10.69
4.976	-0.008	296.50	296.58	3390.3	20.11	3915	0.665	1.10	0.50	10.69
6.314	0.028	296.56	296.58	3378.6	20.18	3915	0.665	1.10	0.50	10.69
7.607	0.033	296.56	296.59	3367.2	20.25	3915	0.665	1.10	0.50	10.69
8.913	-0.013	296.57	296.59	3355.7	20.32	3915	0.665	1.10	0.50	10.69
10.185	0.020	296.55	296.59	3344.5	20.38	3915	0.665	1.10	0.50	10.69
11.453	0.066	296.57	296.59	3333.4	20.45	3915	0.665	1.10	0.50	10.69
12.723	-0.033	296.56	296.59	3322.2	20.52	3915	0.665	1.10	0.50	10.69
13.993	0.025	296.57	296.59	3311.0	20.59	3915	0.665	1.10	0.50	10.69
15.240	-0.058	296.61	296.60	3300.1	20.66	3915	0.665	1.10	0.50	10.69
2.565	-1.880	296.50	296.58	3411.5	19.99	3914	0.665	1.10	0.50	10.69
5.032	-1.892	296.54	296.58	3389.8	20.11	3915	0.665	1.10	0.50	10.69
7.620	-1.938	296.54	296.59	3367.1	20.25	3915	0.665	1.10	0.50	10.69
10.185	-1.951	296.57	296.59	3344.5	20.38	3915	0.665	1.10	0.50	10.69
12.700	-1.913	296.57	296.59	3322.4	20.52	3915	0.665	1.10	0.50	10.69
2.494	1.925	296.51	296.58	3412.2	19.99	3914	0.665	1.10	0.50	10.69
5.098	1.900	296.50	296.58	3389.3	20.12	3915	0.665	1.10	0.50	10.69
7.620	1.852	296.50	296.59	3367.1	20.25	3915	0.665	1.10	0.50	10.69
10.160	1.956	296.52	296.59	3344.7	20.38	3915	0.665	1.10	0.50	10.69
12.692	1.930	294.43	296.59	3322.5	20.52	3915	0.665	1.10	0.50	10.69
2.540	-3.211	296.50	296.58	3411.8	19.99	3914	0.665	1.10	0.50	10.69
7.633	-3.213	296.51	296.59	3367.0	20.25	3915	0.665	1.10	0.50	10.69
12.720	-3.211	296.56	296.59	3322.2	20.52	3915	0.665	1.10	0.50	10.69
2.499	3.221	296.39	296.58	3412.1	19.99	3914	0.665	1.10	0.50	10.69
7.620	3.454	296.48	296.59	3367.1	20.25	3915	0.665	1.10	0.50	10.69
12.700	3.180	296.53	296.59	3322.4	20.52	3915	0.665	1.10	0.50	10.69

Table 3 (continued)

18° Pinfin Specimen
Experiment: 1
Date: 18 September 1990
Time: 14:45:51

TA	TB	M	PO	PO-P1	Vf	f	Wf
K	K	kg/h	kPa	kPa	%		%
296.19	296.42	15.11	3416.3	294.17	0.00	0.13214	22.11

Hot-side Temperatures:

X	Y	Tw	X	Y	Tw
cm	cm	K	cm	cm	K
1.332	0.485	295.27	2.549	-1.330	296.17
2.597	0.526	296.23	5.033	-1.444	296.16
2.681	0.923	296.19	7.571	-1.375	296.19
5.107	0.426	296.26	10.071	-1.476	296.22
7.626	0.498	296.28	2.465	-2.649	296.23
7.710	0.895	296.27	7.657	-2.616	296.26
10.111	0.396	296.30	12.699	-2.643	296.29
12.651	0.478	296.30	7.540	2.687	296.20
12.734	0.875	296.32	7.623	3.085	296.27
13.931	0.527	296.32			

Insulated-Side Temperatures and Calculated Data:

								---Uncertainties--		
X	Y	Tw	Tf	P	V	RE	PR	Wtw	Wtf	Wre
cm	cm	K	K	kPa	m/s			K	K	%
-0.038	-0.229	296.22	296.12	3418.0	30.35	5970	0.665	1.10	0.50	10.69
1.293	-0.226	296.24	296.14	3392.0	30.58	5970	0.665	1.10	0.50	10.69
2.527	-0.132	296.26	296.15	3367.9	30.80	5970	0.665	1.10	0.50	10.69
3.802	0.056	296.31	296.17	3343.1	31.03	5970	0.665	1.10	0.50	10.69
4.976	-0.008	296.30	296.18	3320.2	31.24	5970	0.665	1.10	0.50	10.69
6.314	0.028	296.31	296.20	3294.1	31.48	5970	0.665	1.10	0.50	10.69
7.607	0.033	296.34	296.21	3268.8	31.72	5970	0.665	1.10	0.50	10.69
8.913	-0.013	296.35	296.23	3243.4	31.97	5970	0.665	1.10	0.50	10.69
10.185	0.020	296.36	296.24	3218.5	32.22	5970	0.665	1.10	0.50	10.69
11.453	0.066	296.37	296.26	3193.8	32.46	5970	0.665	1.10	0.50	10.69
12.723	-0.033	296.37	296.27	3169.0	32.72	5970	0.665	1.10	0.50	10.69
13.993	0.025	296.36	296.28	3144.2	32.97	5971	0.665	1.10	0.50	10.69
15.240	-0.058	296.42	296.30	3119.9	33.22	5971	0.665	1.10	0.50	10.69
2.565	-1.880	296.20	296.15	3367.2	30.81	5970	0.665	1.10	0.50	10.69
5.032	-1.892	296.17	296.18	3319.1	31.25	5970	0.665	1.10	0.50	10.69
7.620	-1.938	296.21	296.21	3268.6	31.73	5970	0.665	1.10	0.50	10.69
10.185	-1.951	296.26	296.24	3218.5	32.22	5970	0.665	1.10	0.50	10.69
12.700	-1.913	296.29	296.27	3169.5	32.71	5970	0.665	1.10	0.50	10.69
2.494	1.925	296.20	296.15	3368.6	30.79	5970	0.665	1.10	0.50	10.69
5.098	1.900	296.23	296.18	3317.8	31.26	5970	0.665	1.10	0.50	10.69
7.620	1.852	296.23	296.21	3268.6	31.73	5970	0.665	1.10	0.50	10.69
10.160	1.956	296.24	296.24	3219.0	32.21	5970	0.665	1.10	0.50	10.69
12.692	1.930	294.42	296.27	3169.6	32.71	5970	0.665	1.10	0.50	10.69
2.540	-3.211	296.27	296.15	3367.7	30.80	5970	0.665	1.10	0.50	10.69
7.633	-3.213	296.34	296.21	3268.3	31.73	5970	0.665	1.10	0.50	10.69
12.720	-3.211	296.37	296.27	3169.1	32.71	5970	0.665	1.10	0.50	10.69
2.499	3.221	296.22	296.15	3368.5	30.79	5970	0.665	1.10	0.50	10.69
7.620	3.454	296.30	296.21	3268.6	31.73	5970	0.665	1.10	0.50	10.69
12.700	3.180	296.35	296.27	3169.5	32.71	5970	0.665	1.10	0.50	10.69

18° Pinfin Specimen
Experiment: 1
Date: 18 September 1990
Time: 14:50:50

TA	TB	M	PO	PO-P1	Vf	f	Wf
K	K	kg/h	kPa	kPa	%		%
296.43	296.81	20.02	3407.8	492.73	0.00	0.12159	22.16

Hot-side Temperatures:

X	Y	Tw	X	Y	Tw
cm	cm	K	cm	cm	K
1.332	0.485	295.30	2.549	-1.330	296.44
2.597	0.526	296.40	5.033	-1.444	296.45
2.681	0.923	296.42	7.571	-1.375	296.50
5.107	0.426	296.44	10.071	-1.476	296.53
7.626	0.498	296.48	2.465	-2.649	296.40
7.710	0.895	296.48	7.657	-2.616	296.51
10.111	0.396	296.49	12.699	-2.643	296.57
12.651	0.478	296.55	7.540	2.687	296.45
12.734	0.875	296.58	7.623	3.085	296.44
13.931	0.527	296.59			

Insulated-Side Temperatures and Calculated Data:

								---Uncertainties--		
X	Y	Tw	Tf	P	V	RE	PR	Wtw	Wtf	Wre
cm	cm	K	K	kPa	m/s			K	K	%
-0.038	-0.229	296.40	296.31	3410.7	40.31	7904	0.665	1.10	0.50	10.69
1.293	-0.226	296.39	296.34	3367.2	40.83	7904	0.665	1.10	0.50	10.69
2.527	-0.132	296.43	296.36	3326.8	41.32	7904	0.665	1.10	0.50	10.69
3.802	0.056	296.45	296.38	3285.2	41.84	7905	0.665	1.10	0.50	10.69
4.976	-0.008	296.46	296.40	3246.8	42.33	7905	0.665	1.10	0.50	10.69
6.314	0.028	296.48	296.42	3203.1	42.90	7905	0.665	1.10	0.50	10.69
7.607	0.033	296.49	296.44	3160.8	43.47	7905	0.665	1.10	0.50	10.69
8.913	-0.013	296.53	296.46	3118.2	44.06	7906	0.665	1.10	0.50	10.69
10.185	0.020	296.53	296.48	3076.6	44.65	7906	0.665	1.10	0.50	10.69
11.453	0.066	296.57	296.50	3035.1	45.25	7906	0.665	1.10	0.50	10.69
12.723	-0.033	296.57	296.52	2993.6	45.87	7906	0.665	1.10	0.50	10.69
13.993	0.025	296.59	296.54	2952.1	46.51	7906	0.665	1.10	0.50	10.69
15.240	-0.058	296.63	296.56	2911.4	47.15	7907	0.665	1.10	0.50	10.69
2.565	-1.880	296.40	296.36	3325.6	41.33	7904	0.665	1.10	0.50	10.69
5.032	-1.892	296.46	296.40	3245.0	42.35	7905	0.665	1.10	0.50	10.69
7.620	-1.938	296.50	296.44	3160.4	43.47	7905	0.665	1.10	0.50	10.69
10.185	-1.951	296.56	296.48	3076.6	44.65	7906	0.665	1.10	0.50	10.69
12.700	-1.913	296.58	296.52	2994.4	45.86	7906	0.665	1.10	0.50	10.69
2.494	1.925	296.42	296.36	3327.9	41.31	7904	0.665	1.10	0.50	10.69
5.098	1.900	296.45	296.40	3242.8	42.38	7905	0.665	1.10	0.50	10.69
7.620	1.852	296.50	296.44	3160.4	43.47	7905	0.665	1.10	0.50	10.69
10.160	1.956	296.53	296.48	3077.4	44.63	7906	0.665	1.10	0.50	10.69
12.692	1.930	294.51	296.52	2994.7	45.86	7906	0.665	1.10	0.50	10.69
2.540	-3.211	296.42	296.36	3326.4	41.32	7904	0.665	1.10	0.50	10.69
7.633	-3.213	296.48	296.44	3160.0	43.48	7905	0.665	1.10	0.50	10.69
12.720	-3.211	296.58	296.52	2993.7	45.87	7906	0.665	1.10	0.50	10.69
2.499	3.221	296.38	296.36	3327.8	41.31	7904	0.665	1.10	0.50	10.69
7.620	3.454	296.45	296.44	3160.4	43.47	7905	0.665	1.10	0.50	10.69
12.700	3.180	296.56	296.52	2994.4	45.86	7906	0.665	1.10	0.50	10.69

18° Pinfin Specimen
Experiment: 1
Date: 18 September 1990
Time: 14:56:18

TA	TB	M	P0	P0-P1	Vf	f	Wf
K	K	kg/h	kPa	kPa	%		%
296.23	296.87	24.60	3415.1	748.61	0.00	0.11718	22.26

Hot-side Temperatures:

X	Y	Tw	X	Y	Tw
cm	cm	K	cm	cm	K
1.332	0.485	295.18	2.549	-1.330	296.23
2.597	0.526	296.18	5.033	-1.444	296.26
2.681	0.923	296.20	7.571	-1.375	296.32
5.107	0.426	296.19	10.071	-1.476	296.37
7.626	0.498	296.30	2.465	-2.649	296.20
7.710	0.895	296.31	7.657	-2.616	296.28
10.111	0.396	296.37	12.699	-2.643	296.41
12.651	0.478	296.43	7.540	2.687	296.27
12.734	0.875	296.42	7.623	3.085	296.27
13.931	0.527	296.44			

Insulated-Side Temperatures and Calculated Data:

X	Y	Tw	Tf	P	V	RE	PR	---Uncertainties-- Wtw	Wtf	Wre
cm	cm	K	K	kPa	m/s			K	K	%
-0.038	-0.229	296.14	296.05	3419.4	49.37	9718	0.665	1.10	0.50	10.69
1.293	-0.226	296.15	296.09	3353.3	50.33	9718	0.665	1.10	0.50	10.69
2.527	-0.132	296.16	296.12	3292.1	51.26	9718	0.665	1.10	0.50	10.69
3.802	0.056	296.22	296.16	3228.8	52.26	9719	0.665	1.10	0.50	10.69
4.976	-0.008	296.21	296.19	3170.5	53.21	9719	0.665	1.10	0.50	10.69
6.314	0.028	296.23	296.22	3104.0	54.33	9719	0.665	1.10	0.50	10.69
7.607	0.033	296.27	296.26	3039.8	55.47	9720	0.665	1.10	0.50	10.69
8.913	-0.013	296.30	296.29	2975.0	56.67	9720	0.665	1.10	0.50	10.69
10.185	0.020	296.33	296.32	2911.8	57.89	9721	0.665	1.10	0.50	10.69
11.453	0.066	296.36	296.35	2848.9	59.15	9721	0.665	1.10	0.50	10.69
12.723	-0.033	296.39	296.38	2785.8	60.48	9722	0.666	1.10	0.50	10.69
13.993	0.025	296.42	296.40	2722.8	61.87	9722	0.666	1.10	0.50	10.69
15.240	-0.058	296.49	296.43	2660.9	63.30	9723	0.666	1.10	0.50	10.69
2.565	-1.880	296.15	296.13	3290.2	51.29	9718	0.665	1.10	0.50	10.69
5.032	-1.892	296.20	296.19	3167.7	53.25	9719	0.665	1.10	0.50	10.69
7.620	-1.938	296.25	296.26	3039.2	55.48	9720	0.665	1.10	0.50	10.69
10.185	-1.951	296.35	296.32	2911.8	57.89	9721	0.665	1.10	0.50	10.69
12.700	-1.913	296.42	296.38	2787.0	60.46	9722	0.666	1.10	0.50	10.69
2.494	1.925	296.18	296.12	3293.7	51.23	9718	0.665	1.10	0.50	10.69
5.098	1.900	296.22	296.19	3164.4	53.31	9719	0.665	1.10	0.50	10.69
7.620	1.852	296.28	296.26	3039.2	55.48	9720	0.665	1.10	0.50	10.69
10.160	1.956	296.34	296.32	2913.1	57.86	9721	0.665	1.10	0.50	10.69
12.692	1.930	294.48	296.38	2787.4	60.45	9722	0.666	1.10	0.50	10.69
2.540	-3.211	296.13	296.13	3291.4	51.27	9718	0.665	1.10	0.50	10.69
7.633	-3.213	296.27	296.26	3038.5	55.49	9720	0.665	1.10	0.50	10.69
12.720	-3.211	296.37	296.38	2786.0	60.48	9722	0.666	1.10	0.50	10.69
2.499	3.221	296.13	296.12	3293.4	51.24	9718	0.665	1.10	0.50	10.69
7.620	3.454	296.25	296.26	3039.2	55.48	9720	0.665	1.10	0.50	10.69
12.700	3.180	296.37	296.38	2787.0	60.46	9722	0.666	1.10	0.50	10.69

Table 3 (continued)

18° Pinfin Specimen
Experiment: 1
Date: 18 September 1990
Time: 15:03:38

TA	TB	M	P0	P0-P1	Vf	f	Wf
K	K	kg/h	kPa	kPa	%		%
295.50	296.61	31.13	3404.8	1296.07	0.01	0.11300	22.63

Hot-side Temperatures:

X	Y	Tw	X	Y	Tw
cm	cm	K	cm	cm	K
1.332	0.485	294.95	2.549	-1.330	295.46
2.597	0.526	295.46	5.033	-1.444	295.52
2.681	0.923	295.48	7.571	-1.375	295.62
5.107	0.426	295.54	10.071	-1.476	295.72
7.626	0.498	295.62	2.465	-2.649	295.46
7.710	0.895	295.62	7.657	-2.616	295.60
10.111	0.396	295.70	12.699	-2.643	295.73
12.651	0.478	295.74	7.540	2.687	295.59
12.734	0.875	295.77	7.623	3.085	295.59
13.931	0.527	295.80			

Insulated-Side Temperatures and Calculated Data:

X	Y	Tw	Tf	P	V	RE	PR	---Uncertainties-- Wtw	Wtf	Wre
cm	cm	K	K	kPa	m/s			K	K	%
-0.038	-0.229	295.36	295.22	3412.2	62.44	12322	0.665	1.10	0.50	10.69
1.293	-0.226	295.40	295.28	3297.7	64.58	12323	0.665	1.10	0.50	10.69
2.527	-0.132	295.45	295.32	3191.7	66.71	12324	0.665	1.10	0.51	10.69
3.802	0.056	295.48	295.37	3082.1	69.05	12325	0.665	1.10	0.51	10.69
4.976	-0.008	295.50	295.41	2981.2	71.37	12326	0.665	1.10	0.51	10.69
6.314	0.028	295.56	295.45	2866.1	74.20	12328	0.665	1.10	0.51	10.69
7.607	0.033	295.58	295.48	2755.0	77.16	12329	0.666	1.10	0.51	10.69
8.913	-0.013	295.63	295.51	2642.7	80.40	12331	0.666	1.10	0.51	10.69
10.185	0.020	295.65	295.53	2533.4	83.84	12333	0.666	1.10	0.51	10.69
11.453	0.066	295.70	295.55	2424.4	87.57	12335	0.666	1.10	0.52	10.69
12.723	-0.033	295.73	295.55	2315.2	91.65	12337	0.666	1.10	0.52	10.69
13.993	0.025	295.75	295.55	2206.1	96.13	12340	0.666	1.10	0.52	10.69
15.240	-0.058	295.79	295.53	2098.9	100.99	12342	0.666	1.10	0.53	10.69
2.565	-1.880	295.42	295.33	3188.4	66.77	12324	0.665	1.10	0.51	10.69
5.032	-1.892	295.49	295.41	2976.3	71.48	12326	0.665	1.10	0.51	10.69
7.620	-1.938	295.60	295.48	2753.9	77.19	12329	0.666	1.10	0.51	10.69
10.185	-1.951	295.69	295.53	2533.4	83.84	12333	0.666	1.10	0.51	10.69
12.700	-1.913	295.73	295.55	2317.2	91.57	12337	0.666	1.10	0.52	10.69
2.494	1.925	295.44	295.32	3194.5	66.65	12324	0.665	1.10	0.51	10.69
5.098	1.900	295.52	295.41	2970.7	71.62	12326	0.665	1.10	0.51	10.69
7.620	1.852	295.56	295.48	2753.9	77.19	12329	0.666	1.10	0.51	10.69
10.160	1.956	295.65	295.53	2535.6	83.77	12333	0.666	1.10	0.51	10.69
12.692	1.930	293.94	295.55	2317.9	91.55	12337	0.666	1.10	0.52	10.69
2.540	-3.211	295.38	295.32	3190.6	66.73	12324	0.665	1.10	0.51	10.69
7.633	-3.213	295.55	295.48	2752.8	77.22	12329	0.666	1.10	0.51	10.69
12.720	-3.211	295.66	295.55	2315.5	91.64	12337	0.666	1.10	0.52	10.69
2.499	3.221	295.37	295.32	3194.1	66.66	12324	0.665	1.10	0.51	10.69
7.620	3.454	295.56	295.48	2753.9	77.19	12329	0.666	1.10	0.51	10.69
12.700	3.180	295.73	295.55	2317.2	91.57	12337	0.666	1.10	0.52	10.69

18° Pinfin Specimen
Experiment: 1
Date: 18 September 1990
Time: 15:16:05

TA	TB	M	PO	PO-P1	Vf	f	Wf
K	K	kg/h	kPa	kPa	%		%
294.91	295.31	18.08	3444.3	394.76	0.00	0.12347	22.14

Hot-side Temperatures:

X	Y	Tw	X	Y	Tw
cm	cm	K	cm	cm	K
1.332	0.485	294.86	2.549	-1.330	294.91
2.597	0.526	294.93	5.033	-1.444	294.96
2.681	0.923	294.92	7.571	-1.375	294.96
5.107	0.426	294.98	10.071	-1.476	295.01
7.626	0.498	295.01	2.465	-2.649	294.92
7.710	0.895	295.02	7.657	-2.616	294.99
10.111	0.396	295.05	12.699	-2.643	295.05
12.651	0.478	295.06	7.540	2.687	294.99
12.734	0.875	295.08	7.623	3.085	295.01
13.931	0.527	295.09			

Insulated-Side Temperatures and Calculated Data:

X	Y	Tw	Tf	P	V	RE	PR	---Uncertainties-- Wtw	Wtf	Wre
cm	cm	K	K	kPa	m/s			K	K	%
-0.038	-0.229	294.90	294.82	3446.6	35.85	7160	0.665	1.10	0.50	10.69
1.293	-0.226	294.92	294.85	3411.7	36.21	7160	0.665	1.10	0.50	10.69
2.527	-0.132	294.95	294.87	3379.4	36.56	7160	0.665	1.10	0.50	10.69
3.802	0.056	294.94	294.89	3346.0	36.92	7160	0.665	1.10	0.50	10.69
4.976	-0.008	294.96	294.92	3315.3	37.26	7160	0.665	1.10	0.50	10.69
6.314	0.028	294.99	294.95	3280.3	37.65	7160	0.665	1.10	0.50	10.69
7.607	0.033	294.99	294.97	3246.4	38.04	7160	0.665	1.10	0.50	10.69
8.913	-0.013	295.01	295.00	3212.2	38.44	7160	0.665	1.10	0.50	10.69
10.185	0.020	295.03	295.02	3178.9	38.84	7160	0.665	1.10	0.50	10.69
11.453	0.066	295.07	295.05	3145.7	39.25	7160	0.665	1.10	0.50	10.69
12.723	-0.033	295.06	295.07	3112.5	39.67	7160	0.665	1.10	0.50	10.69
13.993	0.025	295.09	295.10	3079.2	40.09	7160	0.665	1.10	0.50	10.69
15.240	-0.058	295.12	295.12	3046.6	40.52	7160	0.665	1.10	0.50	10.69
2.565	-1.880	294.89	294.87	3378.4	36.57	7160	0.665	1.10	0.50	10.69
5.032	-1.892	294.95	294.92	3313.8	37.27	7160	0.665	1.10	0.50	10.69
7.620	-1.938	294.99	294.97	3246.1	38.05	7160	0.665	1.10	0.50	10.69
10.185	-1.951	294.99	295.02	3178.9	38.84	7160	0.665	1.10	0.50	10.69
12.700	-1.913	295.05	295.07	3113.1	39.66	7160	0.665	1.10	0.50	10.69
2.494	1.925	294.90	294.87	3380.3	36.55	7160	0.665	1.10	0.50	10.69
5.098	1.900	294.92	294.92	3312.1	37.29	7160	0.665	1.10	0.50	10.69
7.620	1.852	294.98	294.97	3246.1	38.05	7160	0.665	1.10	0.50	10.69
10.160	1.956	295.00	295.02	3179.6	38.84	7160	0.665	1.10	0.50	10.69
12.692	1.930	293.60	295.07	3113.3	39.66	7160	0.665	1.10	0.50	10.69
2.540	-3.211	294.89	294.87	3379.1	36.56	7160	0.665	1.10	0.50	10.69
7.633	-3.213	294.97	294.97	3245.7	38.05	7160	0.665	1.10	0.50	10.69
12.720	-3.211	295.08	295.07	3112.6	39.67	7160	0.665	1.10	0.50	10.69
2.499	3.221	294.90	294.87	3380.1	36.55	7160	0.665	1.10	0.50	10.69
7.620	3.454	294.99	294.97	3246.1	38.05	7160	0.665	1.10	0.50	10.69
12.700	3.180	295.04	295.07	3113.1	39.66	7160	0.665	1.10	0.50	10.69

18° Pinfin Specimen
Experiment: 1
Date: 18 September 1990
Time: 15:22:35

TA	TB	M	P0	P0-P1	Vf	f	Wf
K	K	kg/h	kPa	kPa	%		%
294.74	294.89	7.45	3422.7	79.42	0.01	0.15295	22.15

Hot-side Temperatures:

X	Y	Tw	X	Y	Tw
cm	cm	K	cm	cm	K
1.332	0.485	294.90	2.549	-1.330	294.81
2.597	0.526	294.80	5.033	-1.444	294.85
2.681	0.923	294.83	7.571	-1.375	294.82
5.107	0.426	294.79	10.071	-1.476	294.84
7.626	0.498	294.82	2.465	-2.649	294.83
7.710	0.895	294.81	7.657	-2.616	294.83
10.111	0.396	294.84	12.699	-2.643	294.85
12.651	0.478	294.85	7.540	2.687	294.86
12.734	0.875	294.86	7.623	3.085	294.86
13.931	0.527	294.86			

Insulated-Side Temperatures and Calculated Data:

								---Uncertainties--		
X	Y	Tw	Tf	P	V	RE	PR	Wtw	Wtf	Wre
cm	cm	K	K	kPa	m/s			K	K	%
-0.038	-0.229	294.83	294.73	3423.1	14.87	2951	0.665	1.10	0.50	10.69
1.293	-0.226	294.82	294.74	3416.1	14.90	2951	0.665	1.10	0.50	10.69
2.527	-0.132	294.82	294.75	3409.6	14.93	2951	0.665	1.10	0.50	10.69
3.802	0.056	294.83	294.76	3402.9	14.96	2951	0.665	1.10	0.50	10.69
4.976	-0.008	294.82	294.77	3396.7	14.98	2951	0.665	1.10	0.50	10.69
6.314	0.028	294.86	294.78	3389.7	15.01	2951	0.665	1.10	0.50	10.69
7.607	0.033	294.83	294.80	3382.9	15.05	2951	0.665	1.10	0.50	10.69
8.913	-0.013	294.84	294.81	3376.0	15.07	2951	0.665	1.10	0.50	10.69
10.185	0.020	294.86	294.82	3369.3	15.10	2951	0.665	1.10	0.50	10.69
11.453	0.066	294.85	294.83	3362.6	15.14	2951	0.665	1.10	0.50	10.69
12.723	-0.033	294.85	294.84	3355.9	15.17	2951	0.665	1.10	0.50	10.69
13.993	0.025	294.87	294.85	3349.2	15.20	2951	0.665	1.10	0.50	10.69
15.240	-0.058	294.85	294.86	3342.7	15.23	2951	0.665	1.10	0.50	10.69
2.565	-1.880	294.82	294.75	3409.4	14.93	2951	0.665	1.10	0.50	10.69
5.032	-1.892	294.84	294.77	3396.4	14.98	2951	0.665	1.10	0.50	10.69
7.620	-1.938	294.85	294.80	3382.8	15.05	2951	0.665	1.10	0.50	10.69
10.185	-1.951	294.84	294.82	3369.3	15.10	2951	0.665	1.10	0.50	10.69
12.700	-1.913	294.86	294.84	3356.0	15.16	2951	0.665	1.10	0.50	10.69
2.494	1.925	294.86	294.75	3409.8	14.93	2951	0.665	1.10	0.50	10.69
5.098	1.900	294.83	294.77	3396.1	14.99	2951	0.665	1.10	0.50	10.69
7.620	1.852	294.84	294.80	3382.8	15.05	2951	0.665	1.10	0.50	10.69
10.160	1.956	294.87	294.82	3369.4	15.10	2951	0.665	1.10	0.50	10.69
12.692	1.930	293.57	294.84	3356.1	15.16	2951	0.665	1.10	0.50	10.69
2.540	-3.211	294.82	294.75	3409.5	14.93	2951	0.665	1.10	0.50	10.69
7.633	-3.213	294.84	294.80	3382.7	15.05	2951	0.665	1.10	0.50	10.69
12.720	-3.211	294.88	294.84	3355.9	15.17	2951	0.665	1.10	0.50	10.69
2.499	3.221	294.85	294.75	3409.8	14.93	2951	0.665	1.10	0.50	10.69
7.620	3.454	294.85	294.80	3382.8	15.05	2951	0.665	1.10	0.50	10.69
12.700	3.180	294.88	294.84	3356.0	15.16	2951	0.665	1.10	0.50	10.69

18° Pinfin Specimen
Experiment: 2
Date: 19 September 1990
Time: 11:32:24

TA	TB	M	PO	PO-P1	Vf	Qt	Wqt
K	K	kg/h	kPa	kPa	%	W	%
293.56	686.41	4.09	3588.3	50.47	24.83	2317.0	1.04

Hot-Side Temperatures:

X	Y	Tw	X	Y	Tw
cm	cm	K	cm	cm	K
1.332	0.485	363.71	2.549	-1.330	395.14
2.597	0.526	396.58	5.033	-1.444	458.96
2.681	0.923	400.71	7.571	-1.375	531.59
5.107	0.426	463.58	10.071	-1.476	600.51
7.626	0.498	529.86	2.465	-2.649	390.68
7.710	0.895	534.71	7.657	-2.616	533.51
10.111	0.396	599.86	12.699	-2.643	667.91
12.651	0.478	663.80	7.540	2.687	523.53
12.734	0.875	665.77	7.623	3.085	524.02
13.931	0.527	700.23			

Insulated-Side PRT Temperatures:

X	Y	Tw
cm	cm	K
-0.038	0.038	316.87
3.993	-0.224	427.57
11.648	-0.241	627.28
15.077	-1.430	703.78

Insulated-Side Thermocouple Temperatures and Calculated Data:

X	Y	Tw	Tf	Taw	P	V	RE	PR	h	NU	NUm	NUw	Wtw	Wtf	Wre	Wh	Wnu
													---------Uncertainties---------				
cm	cm	K	K	K	kPa	m/s			W/(m²·K)				K	K	%	%	%
-0.038	-0.229	314.94	293.55	293.56	3588.6	7.76	1625	0.665	0	0.00	0.00	0.00	1.10	0.50	10.69	0.00	0.00
1.293	-0.226	357.92	328.00	328.01	3584.1	8.67	1508	0.665	3921	16.87	17.70	16.67	1.10	3.05	10.69	12.39	13.91
2.527	-0.132	391.54	361.08	361.09	3580.0	9.54	1412	0.665	3494	14.09	14.73	13.94	1.10	3.28	10.69	12.98	14.44
3.802	0.056	423.72	393.03	393.04	3575.7	10.38	1333	0.665	3393	12.91	13.46	12.73	1.10	3.91	10.69	14.65	15.96
4.976	-0.008	455.78	422.72	422.73	3571.8	11.17	1268	0.666	3229	11.69	12.18	11.54	1.10	4.66	10.69	15.77	16.99
6.314	0.028	492.46	457.29	457.30	3567.3	12.09	1201	0.666	3074	10.54	10.98	10.41	1.10	5.56	10.69	17.28	18.40
7.607	0.033	527.09	490.82	490.83	3563.0	12.98	1144	0.666	2976	9.72	10.11	9.59	1.10	6.46	10.69	19.11	20.13
8.913	-0.013	562.72	524.63	524.64	3558.6	13.88	1092	0.666	2827	8.82	9.17	8.70	1.16	6.65	10.69	18.78	19.82
10.185	0.020	597.08	557.31	557.33	3554.3	14.75	1047	0.666	2666	7.97	8.28	7.87	1.30	6.95	10.69	18.85	19.88
11.453	0.066	629.01	589.08	589.10	3550.1	15.60	1008	0.666	2577	7.42	7.69	7.32	1.42	7.34	10.69	19.76	20.75
12.723	-0.033	662.83	620.52	620.54	3545.9	16.45	972	0.666	2485	6.90	7.15	6.82	1.56	7.86	10.69	19.97	20.94
13.993	0.025	696.95	654.19	654.21	3541.6	17.35	937	0.666	2708	7.24	7.50	7.12	1.70	8.57	10.69	21.32	22.24
15.240	-0.058	712.66	686.38	686.40	3537.4	18.22	906	0.666	3054	7.90	8.06	7.62	1.76	9.01	10.69	37.45	37.98
2.565	-1.880	389.25	362.05	362.06	3579.8	9.57	1410	0.665	3904	15.71	16.35	15.38	1.10	3.29	10.69	14.23	15.57
5.032	-1.892	456.44	424.16	424.17	3571.6	11.21	1265	0.666	3310	11.95	12.44	11.78	1.10	4.70	10.69	16.19	17.38
7.620	-1.938	527.94	491.16	491.17	3562.9	12.99	1143	0.666	2935	9.58	9.97	9.46	1.10	6.47	10.69	18.90	19.93
10.185	-1.951	597.60	557.31	557.33	3554.3	14.75	1047	0.666	2632	7.87	8.18	7.78	1.30	6.95	10.69	18.63	19.67
12.700	-1.913	663.12	619.94	619.96	3545.9	16.43	972	0.666	2432	6.75	7.00	6.69	1.56	7.85	10.69	19.58	20.58
2.494	1.925	387.93	360.24	360.25	3580.1	9.52	1415	0.665	3850	15.54	16.19	15.24	1.10	3.27	10.69	13.94	15.31
5.098	1.900	458.08	425.85	425.86	3571.4	11.25	1262	0.666	3319	11.96	12.45	11.78	1.10	4.74	10.69	16.34	17.52
7.620	1.852	525.31	491.16	491.17	3562.9	12.99	1143	0.666	3161	10.32	10.71	10.13	1.10	6.47	10.69	20.20	21.17
10.160	1.956	589.70	556.67	556.69	3554.4	14.73	1048	0.666	3213	9.62	9.93	9.36	1.27	6.94	10.69	22.27	23.15
12.692	1.930	424.65	619.74	619.76	3546.0	16.42	973	0.666	-538	-1.49	-1.21	7.61	1.10	7.84	10.69	7.50	9.81
2.540	-3.211	388.82	361.42	361.42	3579.9	9.55	1412	0.665	3880	15.63	16.27	15.32	1.10	3.28	10.69	14.11	15.46
7.633	-3.213	527.15	491.49	491.51	3562.9	12.99	1143	0.666	3028	9.88	10.27	9.73	1.10	6.47	10.69	19.44	20.44
12.720	-3.211	660.30	620.45	620.47	3545.9	16.44	972	0.666	2638	7.32	7.57	7.20	1.55	7.86	10.69	21.07	22.00
2.499	3.221	385.54	360.37	360.38	3580.1	9.52	1414	0.665	4234	17.09	17.74	16.62	1.10	3.27	10.69	15.07	16.34
7.620	3.454	515.14	491.16	491.17	3562.9	12.99	1143	0.666	4502	14.70	15.09	14.00	1.10	6.47	10.69	28.07	28.78
12.700	3.180	642.16	619.94	619.96	3545.9	16.43	972	0.666	4730	13.13	13.39	12.31	1.48	7.85	10.69	36.53	37.07

Table 3 (continued)

18° Pinfin Specimen
Experiment: 2
Date: 19 September 1990
Time: 11:44:21

TA	TB	M	P0	P0-P1	Vf	Qt	Wqt
K	K	kg/h	kPa	kPa	%	W	%
292.65	405.70	15.42	3547.7	360.85	24.81	2506.0	1.20

Hot-Side Temperatures:

X	Y	Tw	X	Y	Tw
cm	cm	K	cm	cm	K
1.332	0.485	317.37	2.549	-1.330	324.63
2.597	0.526	325.47	5.033	-1.444	341.81
2.681	0.923	326.95	7.571	-1.375	362.10
5.107	0.426	343.84	10.071	-1.476	381.00
7.626	0.498	359.36	2.465	-2.649	322.43
7.710	0.895	363.41	7.657	-2.616	363.27
10.111	0.396	381.02	12.699	-2.643	399.76
12.651	0.478	397.74	7.540	2.687	360.76
12.734	0.875	399.96	7.623	3.085	361.10
13.931	0.527	409.06			

Insulated-Side PRT Temperatures:

X	Y	Tw
cm	cm	K
-0.038	0.038	299.24
3.993	-0.224	330.49
11.648	-0.241	384.68
15.077	-1.430	406.96

Insulated-Side Thermocouple Temperatures and Calculated Data:

X	Y	Tw	Tf	Taw	P	V	RE	PR	h	NU	NUm	NUw	Wtw	Wtf	Wre	Wh	Wnu
													---------Uncertainties---------				
cm	cm	K	K	K	kPa	m/s			W/(m²·K)				K	K	%	%	%
-0.038	-0.229	298.42	292.60	292.67	3549.8	29.48	6136	0.665	0	0.00	0.00	0.00	1.10	0.50	10.69	0.00	0.00
1.293	-0.226	311.39	302.50	302.58	3517.9	30.73	6002	0.665	14406	65.46	66.51	56.00	1.10	0.98	10.69	17.78	18.87
2.527	-0.132	320.45	312.01	312.09	3488.4	31.94	5879	0.665	13765	61.27	62.18	52.62	1.10	1.02	10.69	19.06	20.08
3.802	0.056	329.02	321.19	321.28	3457.9	33.15	5765	0.665	14539	63.47	64.32	54.01	1.10	1.18	10.69	21.80	22.70
4.976	-0.008	337.73	329.72	329.82	3429.8	34.29	5663	0.665	14583	62.55	63.38	53.16	1.10	1.38	10.69	23.20	24.05
6.314	0.028	348.00	339.65	339.76	3397.8	35.64	5550	0.665	14185	59.64	60.44	50.83	1.10	1.63	10.69	24.69	25.49
7.607	0.033	357.37	349.29	349.40	3366.8	36.97	5446	0.665	14654	60.45	61.22	51.22	1.10	1.89	10.69	28.10	28.80
8.913	-0.013	367.05	359.00	359.13	3335.6	38.33	5345	0.666	14705	59.55	60.28	50.36	1.10	1.94	10.69	28.84	29.52
10.185	0.020	376.68	368.39	368.53	3305.1	39.68	5252	0.666	14057	55.94	56.63	47.55	1.10	2.03	10.69	28.95	29.64
11.453	0.066	385.48	377.52	377.67	3274.8	41.02	5165	0.666	14233	55.70	56.34	47.20	1.10	2.14	10.69	31.42	32.05
12.723	-0.033	394.79	386.56	386.71	3244.4	42.38	5082	0.666	14078	54.22	54.85	45.97	1.10	2.29	10.69	32.11	32.73
13.993	0.025	404.57	396.23	396.39	3214.0	43.83	4997	0.666	15301	57.94	58.61	48.51	1.10	2.50	10.69	33.92	34.51
15.240	-0.058	408.16	405.48	405.65	3184.1	45.26	4919	0.666	34522	128.69	129.16	92.62	1.10	2.63	10.69	114.23	114.40
2.565	-1.880	319.64	312.28	312.37	3487.5	31.98	5875	0.665	15784	70.21	71.12	59.10	1.10	1.03	10.69	21.64	22.54
5.032	-1.892	338.08	330.13	330.23	3428.4	34.35	5658	0.665	14713	63.05	63.88	53.51	1.10	1.39	10.69	23.47	24.31
7.620	-1.938	357.79	349.39	349.50	3366.5	36.98	5445	0.665	14091	58.12	58.88	49.52	1.10	1.89	10.69	27.10	27.83
10.185	-1.951	377.19	368.39	368.53	3305.1	39.68	5252	0.666	13241	52.69	53.38	45.18	1.10	2.03	10.69	27.35	28.07
12.700	-1.913	395.10	386.39	386.54	3244.9	42.35	5084	0.666	13272	51.13	51.76	43.72	1.10	2.29	10.69	30.35	31.00
2.494	1.925	319.61	311.76	311.85	3489.2	31.91	5882	0.665	14845	66.11	67.02	56.17	1.10	1.02	10.69	20.33	21.29
5.098	1.900	338.95	330.62	330.72	3426.9	34.42	5653	0.665	14046	60.13	60.96	51.38	1.10	1.41	10.69	22.57	23.44
7.620	1.852	357.83	349.39	349.50	3366.5	36.98	5445	0.665	14021	57.83	58.59	49.31	1.10	1.89	10.69	26.98	27.71
10.160	1.956	375.61	368.21	368.34	3305.7	39.65	5254	0.666	15789	62.85	63.54	52.52	1.10	2.02	10.69	32.32	32.93
12.692	1.930	325.62	386.33	386.48	3245.1	42.34	5084	0.666	-1865	-7.18	-6.54	47.80	1.10	2.29	10.69	7.59	9.87
2.540	-3.211	319.76	312.10	312.19	3488.1	31.96	5877	0.665	15177	67.54	68.45	57.19	1.10	1.03	10.69	20.83	21.77
7.633	-3.213	358.30	349.48	349.60	3366.2	36.99	5444	0.665	13415	55.32	56.08	47.47	1.10	1.89	10.69	25.88	26.64
12.720	-3.211	395.15	386.54	386.69	3244.4	42.37	5082	0.666	13438	51.75	52.38	44.17	1.10	2.29	10.69	30.71	31.36
2.499	3.221	319.25	311.80	311.89	3489.1	31.92	5881	0.665	15659	69.73	70.64	58.77	1.10	1.02	10.69	21.35	22.27
7.620	3.454	354.65	349.39	349.50	3366.5	36.98	5445	0.665	22689	93.58	94.35	73.84	1.10	1.89	10.69	42.92	43.39
12.700	3.180	389.70	386.39	386.54	3244.9	42.35	5084	0.666	35903	138.31	138.96	99.13	1.10	2.29	10.69	80.55	80.80

Table 3 (continued)

18° Pinfin Specimen
Experiment: 3
Date: 20 November 1990
Time: 10:43:51

TA	TB	M	PO	PO-P1	Vf	Qt	Wqt
K	K	kg/h	kPa	kPa	%	W	%
299.92	730.42	3.71	3516.2	45.29	25.47	2303.0	1.03

Hot-Side Temperatures:						Insulated-Side PRT Temperatures:		
X	Y	Tw	X	Y	Tw	X	Y	Tw
cm	cm	K	cm	cm	K	cm	cm	K
1.332	0.485	377.05	2.549	-1.330	412.13	-0.038	0.038	325.66
2.597	0.526	413.63	5.033	-1.444	482.83	3.993	-0.224	448.13
2.681	0.923	418.20	7.571	-1.375	563.16	11.648	-0.241	669.35
5.107	0.426	487.73	10.071	-1.476	639.83	15.077	-1.430	750.96
7.626	0.498	561.48	2.465	-2.649	407.39			
7.710	0.895	566.30	7.657	-2.616	564.95			
10.111	0.396	638.64	12.699	-2.643	712.87			
12.651	0.478	708.67	7.540	2.687	553.21			
12.734	0.875	710.72	7.623	3.085	553.52			
13.931	0.527	747.72						

Insulated-Side Thermocouple Temperatures and Calculated Data:

													---------Uncertainties---------				
X	Y	Tw	Tf	Taw	P	V	RE	PR	h	NU	NUm	NUw	Wtw	Wtf	Wre	Wh	Wnu
cm	cm	K	K	K	kPa	m/s			W/(m²·K)				K	K	%	%	%
-0.038	-0.229	323.75	299.92	299.93	3516.5	7.34	1453	0.665	0	0.00	0.00	0.00	1.10	0.50	10.69	0.00	0.00
1.293	-0.226	371.13	337.67	337.68	3512.5	8.26	1341	0.665	3486	14.71	15.49	14.67	1.10	3.33	10.69	12.10	13.65
2.527	-0.132	408.48	373.92	373.93	3508.8	9.14	1251	0.665	3061	12.05	12.65	12.04	1.10	3.59	10.69	12.55	14.05
3.802	0.056	444.05	408.93	408.94	3504.9	9.99	1177	0.666	2947	10.92	11.43	10.88	1.10	4.28	10.69	14.07	15.43
4.976	-0.008	479.42	441.47	441.48	3501.4	10.79	1116	0.666	2795	9.82	10.28	9.79	1.10	5.10	10.69	15.10	16.37
6.314	0.028	519.94	479.35	479.36	3497.4	11.71	1055	0.666	2648	8.79	9.19	8.77	1.10	6.09	10.69	16.47	17.64
7.607	0.033	558.24	516.09	516.10	3493.5	12.61	1002	0.666	2546	8.03	8.38	8.00	1.14	7.08	10.69	18.11	19.18
8.913	-0.013	597.64	553.14	553.15	3489.6	13.53	955	0.666	2406	7.23	7.54	7.21	1.30	7.28	10.69	17.76	18.85
10.185	0.020	635.96	588.95	588.97	3485.7	14.41	914	0.666	2242	6.45	6.73	6.44	1.45	7.61	10.69	17.64	18.73
11.453	0.066	671.30	623.77	623.79	3481.9	15.27	878	0.666	2152	5.95	6.20	5.94	1.59	8.04	10.69	18.37	19.43
12.723	-0.033	708.11	658.22	658.24	3478.1	16.12	846	0.666	2095	5.58	5.81	5.58	1.74	8.61	10.69	18.71	19.75
13.993	0.025	744.88	695.11	695.14	3474.3	17.04	814	0.666	2313	5.93	6.16	5.90	1.89	9.39	10.69	20.18	21.15
15.240	-0.058	761.09	730.39	730.41	3470.6	17.92	787	0.666	2598	6.43	6.58	6.27	1.95	9.87	10.69	35.44	36.00
2.565	-1.880	405.92	374.98	374.99	3508.6	9.16	1249	0.665	3412	13.41	14.01	13.26	1.10	3.60	10.69	13.70	15.09
5.032	-1.892	480.14	443.04	443.05	3501.2	10.82	1114	0.666	2862	10.03	10.48	9.98	1.10	5.14	10.69	15.49	16.73
7.620	-1.938	559.18	516.46	516.47	3493.5	12.62	1002	0.666	2512	7.92	8.27	7.90	1.14	7.09	10.69	17.92	19.00
10.185	-1.951	636.65	588.95	588.97	3485.7	14.41	914	0.666	2210	6.36	6.64	6.36	1.45	7.61	10.69	17.42	18.53
12.700	-1.913	708.24	657.59	657.61	3478.2	16.11	847	0.666	2061	5.49	5.72	5.50	1.74	8.60	10.69	18.44	19.49
2.494	1.925	404.16	373.00	373.01	3508.8	9.11	1253	0.665	3401	13.41	14.02	13.27	1.10	3.58	10.69	13.55	14.95
5.098	1.900	481.63	444.90	444.91	3501.0	10.87	1111	0.666	2895	10.12	10.57	10.06	1.10	5.19	10.69	15.74	16.96
7.620	1.852	555.75	516.46	516.47	3493.5	12.62	1002	0.666	2732	8.61	8.96	8.53	1.13	7.09	10.69	19.30	20.31
10.160	1.956	627.22	588.25	588.27	3485.8	14.39	915	0.666	2707	7.80	8.08	7.68	1.42	7.60	10.69	20.82	21.76
12.692	1.930	698.10	657.36	657.39	3478.2	16.10	847	0.666	2561	6.83	7.06	6.73	1.70	8.59	10.69	22.42	23.29
2.540	-3.211	405.36	374.29	374.29	3508.7	9.15	1250	0.665	3401	13.38	13.98	13.24	1.10	3.59	10.69	13.63	15.02
7.633	-3.213	557.92	516.83	516.84	3493.4	12.63	1001	0.666	2611	8.23	8.58	8.18	1.14	7.09	10.69	18.55	19.60
12.720	-3.211	704.98	658.14	658.16	3478.1	16.12	846	0.666	2231	5.94	6.17	5.91	1.73	8.61	10.69	19.78	20.77
2.499	3.221	401.19	373.14	373.15	3508.8	9.12	1253	0.665	3776	14.89	15.50	14.60	1.10	3.58	10.69	14.75	16.04
7.620	3.454	544.25	516.46	516.47	3493.5	12.62	1002	0.666	3862	12.18	12.54	11.72	1.10	7.09	10.69	26.56	27.30
12.700	3.180	684.61	657.59	657.61	3478.2	16.11	847	0.666	3864	10.30	10.53	9.82	1.65	8.60	10.69	33.03	33.63

Table 3 (continued)

18° Pinfin Specimen
Experiment: 3
Date: 20 November 1990
Time: 10:53:43

TA	TB	M	PO	PO-P1	Vf	Qt	Wqt
K	K	kg/h	kPa	kPa	%	W	%
297.85	504.46	8.40	3502.9	147.71	25.48	2501.0	1.08

Hot-Side Temperatures:

X	Y	Tw	X	Y	Tw
cm	cm	K	cm	cm	K
1.332	0.485	336.94	2.549	-1.330	351.06
2.597	0.526	352.57	5.033	-1.444	382.23
2.681	0.923	354.79	7.571	-1.375	418.61
5.107	0.426	385.66	10.071	-1.476	452.73
7.626	0.498	416.87	2.465	-2.649	348.13
7.710	0.895	421.06	7.657	-2.616	420.10
10.111	0.396	453.13	12.699	-2.643	486.04
12.651	0.478	484.14	7.540	2.687	415.95
12.734	0.875	486.62	7.623	3.085	416.44
13.931	0.527	503.35			

Insulated-Side PRT Temperatures:

X	Y	Tw
cm	cm	K
-0.038	0.038	309.30
3.993	-0.224	365.07
11.648	-0.241	463.41
15.077	-1.430	502.66

Insulated-Side Thermocouple Temperatures and Calculated Data:

													Uncertainties				
X	Y	Tw	Tf	Taw	P	V	RE	PR	h	NU	NUm	NUw	Wtw	Wtf	Wre	Wh	Wnu
cm	cm	K	K	K	kPa	m/s			W/(m²·K)				K	K	%	%	%
-0.038	-0.229	308.00	297.84	297.86	3503.8	16.56	3305	0.665	0	0.00	0.00	0.00	1.10	0.50	10.69	0.00	0.00
1.293	-0.226	330.53	315.95	315.98	3490.7	17.61	3176	0.665	8701	38.40	39.36	35.04	1.10	1.65	10.69	14.89	16.18
2.527	-0.132	347.01	333.34	333.37	3478.6	18.63	3063	0.665	8417	35.83	36.63	32.68	1.10	1.76	10.69	16.47	17.64
3.802	0.056	362.79	350.14	350.17	3466.1	19.62	2962	0.665	8905	36.67	37.39	33.14	1.10	2.08	10.69	19.70	20.69
4.976	-0.008	378.57	365.75	365.79	3454.6	20.55	2875	0.665	9012	36.03	36.72	32.47	1.10	2.47	10.69	22.06	22.95
6.314	0.028	396.92	383.93	383.97	3441.5	21.63	2781	0.666	9003	34.82	35.46	31.32	1.10	2.94	10.69	25.01	25.79
7.607	0.033	414.06	401.56	401.60	3428.9	22.70	2697	0.666	9346	35.06	35.66	31.32	1.10	3.41	10.69	29.41	30.08
8.913	-0.013	431.63	419.33	419.38	3416.1	23.78	2618	0.666	9489	34.55	35.10	30.75	1.10	3.51	10.69	30.66	31.31
10.185	0.020	449.00	436.52	436.57	3403.6	24.83	2547	0.666	9202	32.59	33.10	29.04	1.10	3.67	10.69	31.41	32.04
11.453	0.066	464.74	453.22	453.28	3391.2	25.86	2482	0.666	9682	33.42	33.88	29.53	1.10	3.87	10.69	35.66	36.21
12.723	-0.033	481.45	469.75	469.81	3378.7	26.89	2421	0.666	9748	32.83	33.28	28.93	1.10	4.15	10.69	37.40	37.93
13.993	0.025	498.78	487.45	487.52	3366.3	27.99	2360	0.666	11096	36.42	36.88	31.52	1.10	4.52	10.69	41.78	42.26
15.240	-0.058	505.84	504.37	504.44	3354.1	29.06	2305	0.666	61886	198.41	198.73	122.00	1.10	4.76	10.69	349.17	349.22
2.565	-1.880	345.35	333.85	333.88	3478.3	18.66	3059	0.665	9988	42.47	43.27	37.95	1.10	1.77	10.69	19.21	20.22
5.032	-1.892	378.59	366.51	366.54	3454.1	20.59	2871	0.665	9572	38.21	38.90	34.19	1.10	2.49	10.69	23.44	24.28
7.620	-1.938	414.20	401.73	401.78	3428.7	22.71	2696	0.666	9375	35.15	35.75	31.39	1.10	3.41	10.69	29.54	30.21
10.185	-1.951	448.92	436.52	436.57	3403.6	24.83	2547	0.666	9262	32.81	33.32	29.21	1.10	3.67	10.69	31.61	32.24
12.700	-1.913	481.26	469.45	469.51	3379.0	26.87	2422	0.666	9637	32.47	32.92	28.65	1.10	4.14	10.69	36.99	37.52
2.494	1.925	345.38	332.90	332.93	3478.9	18.60	3065	0.665	9242	39.38	40.19	35.53	1.10	1.75	10.69	17.79	18.88
5.098	1.900	380.22	367.40	367.43	3453.4	20.65	2866	0.665	9026	35.97	36.66	32.40	1.10	2.51	10.69	22.33	23.21
7.620	1.852	414.11	401.73	401.78	3428.7	22.71	2696	0.666	9446	35.42	36.02	31.61	1.10	3.41	10.69	29.75	30.41
10.160	1.956	446.23	436.18	436.23	3403.8	24.81	2548	0.666	11444	40.56	41.07	35.16	1.10	3.66	10.69	38.74	39.25
12.692	1.930	478.44	469.34	469.40	3379.0	26.86	2423	0.666	12521	42.19	42.64	35.97	1.10	4.14	10.69	47.77	48.19
2.540	-3.211	345.47	333.52	333.55	3478.5	18.64	3061	0.665	9619	40.93	41.73	36.75	1.10	1.76	10.69	18.52	19.57
7.633	-3.213	414.49	401.91	401.95	3428.6	22.72	2696	0.666	9293	34.84	35.44	31.15	1.10	3.41	10.69	29.30	29.97
12.720	-3.211	480.27	469.71	469.77	3378.8	26.89	2421	0.666	10803	36.38	36.83	31.64	1.10	4.15	10.69	41.34	41.82
2.499	3.221	344.70	332.97	333.00	3478.9	18.60	3065	0.665	9822	41.84	42.64	37.47	1.10	1.76	10.69	18.78	19.81
7.620	3.454	408.79	401.73	401.78	3428.7	22.71	2696	0.666	16609	62.28	62.88	51.40	1.10	3.41	10.69	51.53	51.92
12.700	3.180	471.93	469.45	469.51	3379.0	26.87	2422	0.666	46710	157.37	157.83	104.58	1.10	4.14	10.69	176.77	176.88

Table 3 (continued)

18° Pinfin Specimen
Experiment: 3
Date: 20 November 1990
Time: 11:01:20

TA	TB	M	PO	PO-P1	Vf	Qt	Wqt
K	K	kg/h	kPa	kPa	%	W	%
295.41	438.49	12.06	3494.0	262.64	25.49	2483.0	1.13

Hot-Side Temperatures:

X	Y	Tw	X	Y	Tw
cm	cm	K	cm	cm	K
1.332	0.485	325.15	2.549	-1.330	334.42
2.597	0.526	335.67	5.033	-1.444	356.01
2.681	0.923	337.39	7.571	-1.375	381.60
5.107	0.426	358.80	10.071	-1.476	405.47
7.626	0.498	379.46	2.465	-2.649	331.96
7.710	0.895	383.45	7.657	-2.616	383.01
10.111	0.396	405.65	12.699	-2.643	428.88
12.651	0.478	426.96	7.540	2.687	379.93
12.734	0.875	429.35	7.623	3.085	380.39
13.931	0.527	440.90			

Insulated-Side PRT Temperatures:

X	Y	Tw
cm	cm	K
-0.038	0.038	303.58
3.993	-0.224	342.92
11.648	-0.241	411.34
15.077	-1.430	438.87

Insulated-Side Thermocouple Temperatures and Calculated Data:

													---------Uncertainties---------				
X	Y	Tw	Tf	Taw	P	V	RE	PR	h	NU	NUm	NUw	Wtw	Wtf	Wre	Wh	Wnu
cm	cm	K	K	K	kPa	m/s			W/(m²·K)				K	K	%	%	%
-0.038	-0.229	302.53	295.38	295.42	3495.5	23.62	4769	0.665	0	0.00	0.00	0.00	1.10	0.50	10.69	0.00	0.00
1.293	-0.226	318.70	307.91	307.97	3472.3	24.77	4638	0.665	11710	52.59	53.60	46.27	1.10	1.19	10.69	16.24	17.43
2.527	-0.132	330.24	319.95	320.01	3450.8	25.88	4520	0.665	11146	48.78	49.64	43.06	1.10	1.26	10.69	17.49	18.60
3.802	0.056	341.14	331.58	331.64	3428.6	26.98	4412	0.665	11751	50.21	51.00	43.94	1.10	1.47	10.69	20.33	21.29
4.976	-0.008	352.15	342.39	342.46	3408.2	28.01	4317	0.665	11791	49.30	50.07	43.08	1.10	1.73	10.69	22.04	22.93
6.314	0.028	365.01	354.97	355.04	3384.9	29.22	4212	0.665	11621	47.42	48.15	41.46	1.10	2.05	10.69	24.16	24.97
7.607	0.033	376.85	367.17	367.25	3362.3	30.41	4116	0.666	12048	48.05	48.74	41.75	1.10	2.37	10.69	27.95	28.65
8.913	-0.013	389.09	379.48	379.56	3339.6	31.62	4024	0.666	12107	47.21	47.86	40.92	1.10	2.44	10.69	28.78	29.46
10.185	0.020	401.17	391.37	391.46	3317.4	32.81	3940	0.666	11708	44.70	45.31	38.86	1.10	2.55	10.69	29.30	29.98
11.453	0.066	412.18	402.93	403.03	3295.3	33.99	3863	0.666	12045	45.08	45.65	38.97	1.10	2.69	10.69	32.41	33.02
12.723	-0.033	423.84	414.37	414.48	3273.2	35.18	3789	0.666	12031	44.18	44.73	38.15	1.10	2.89	10.69	33.58	34.17
13.993	0.025	436.14	426.63	426.74	3251.1	36.45	3714	0.666	13189	47.47	48.05	40.45	1.10	3.15	10.69	35.96	36.51
15.240	-0.058	440.72	438.34	438.46	3229.4	37.69	3645	0.666	37926	133.99	134.39	93.93	1.10	3.31	10.69	154.46	154.59
2.565	-1.880	328.93	320.31	320.36	3450.2	25.91	4516	0.665	13278	58.07	58.92	50.07	1.10	1.26	10.69	20.51	21.47
5.032	-1.892	352.13	342.91	342.98	3407.2	28.06	4312	0.665	12504	52.23	53.00	45.28	1.10	1.74	10.69	23.36	24.20
7.620	-1.938	377.01	367.30	367.37	3362.1	30.42	4115	0.666	12008	47.88	48.57	41.62	1.10	2.38	10.69	27.89	28.60
10.185	-1.951	401.36	391.37	391.46	3317.4	32.81	3940	0.666	11480	43.83	44.44	38.20	1.10	2.55	10.69	28.76	29.45
12.700	-1.913	423.94	414.16	414.27	3273.6	35.16	3790	0.666	11634	42.74	43.29	37.07	1.10	2.88	10.69	32.52	33.13
2.494	1.925	329.06	319.65	319.70	3451.4	25.85	4523	0.665	12215	53.50	54.36	46.66	1.10	1.25	10.69	18.90	19.93
5.098	1.900	353.38	343.53	343.60	3406.0	28.11	4307	0.665	11714	48.87	49.64	42.74	1.10	1.76	10.69	22.10	22.99
7.620	1.852	377.08	367.30	367.37	3362.1	30.42	4115	0.666	11917	47.51	48.20	41.33	1.10	2.38	10.69	27.69	28.40
10.160	1.956	399.48	391.14	391.23	3317.9	32.79	3942	0.666	13777	52.62	53.23	44.72	1.10	2.55	10.69	34.22	34.80
12.692	1.930	421.97	414.09	414.19	3273.8	35.15	3791	0.666	14469	53.15	53.70	44.71	1.10	2.88	10.69	40.17	40.66
2.540	-3.211	329.07	320.08	320.13	3450.6	25.89	4518	0.665	12740	55.75	56.61	48.35	1.10	1.26	10.69	19.71	20.70
7.633	-3.213	377.50	367.42	367.50	3361.9	30.43	4114	0.666	11564	46.09	46.78	40.26	1.10	2.38	10.69	26.91	27.65
12.720	-3.211	423.51	414.35	414.45	3273.3	35.18	3789	0.666	12437	45.67	46.22	39.26	1.10	2.88	10.69	34.67	35.25
2.499	3.221	328.78	319.69	319.75	3451.3	25.85	4522	0.665	12643	55.37	56.23	48.07	1.10	1.25	10.69	19.50	20.50
7.620	3.454	373.20	367.30	367.37	3362.1	30.42	4115	0.666	19856	79.17	79.87	63.77	1.10	2.38	10.69	45.38	45.82
12.700	3.180	417.21	414.16	414.27	3273.6	35.16	3790	0.666	38190	140.28	140.85	98.70	1.10	2.88	10.69	104.89	105.08

Table 3 (continued)

18° Pinfin Specimen
Experiment: 3
Date: 20 November 1990
Time: 11:10:20

TA	TB	M	P0	P0-P1	Vf	Qt	Wqt
K	K	kg/h	kPa	kPa	%	W	%
292.90	397.99	16.32	3512.4	437.58	25.50	2464.0	1.22

Hot-Side Temperatures:

X	Y	Tw	X	Y	Tw
cm	cm	K	cm	cm	K
1.332	0.485	316.53	2.549	-1.330	323.48
2.597	0.526	324.02	5.033	-1.444	339.42
2.681	0.923	325.65	7.571	-1.375	358.39
5.107	0.426	341.23	10.071	-1.476	375.95
7.626	0.498	355.76	2.465	-2.649	320.99
7.710	0.895	359.56	7.657	-2.616	359.31
10.111	0.396	375.76	12.699	-2.643	393.10
12.651	0.478	391.28	7.540	2.687	357.12
12.734	0.875	393.46	7.623	3.085	357.39
13.931	0.527	401.96			

Insulated-Side PRT Temperatures:

X	Y	Tw
cm	cm	K
-0.038	0.038	299.04
3.993	-0.224	328.23
11.648	-0.241	378.92
15.077	-1.430	399.51

Insulated-Side Thermocouple Temperatures and Calculated Data:

X	Y	Tw	Tf	Taw	P	V	RE	PR	h	NU	NUm	NUw	Wtw (Uncertainties)	Wtf	Wre	Wh	Wnu
cm	cm	K	K	K	kPa	m/s			W/(m²·K)				K	K	%	%	%
-0.038	-0.229	298.20	292.83	292.92	3514.9	31.53	6491	0.665	0	0.00	0.00	0.00	1.10	0.50	10.69	0.00	0.00
1.293	-0.226	310.34	302.04	302.13	3476.2	32.86	6360	0.665	15197	69.14	70.18	58.67	1.10	0.92	10.69	18.52	19.57
2.527	-0.132	318.78	310.87	310.97	3440.4	34.15	6237	0.665	14490	64.66	65.56	55.13	1.10	0.96	10.69	19.77	20.76
3.802	0.056	326.75	319.41	319.51	3403.4	35.45	6124	0.665	15302	67.06	67.90	56.63	1.10	1.11	10.69	22.50	23.37
4.976	-0.008	334.91	327.34	327.45	3369.3	36.67	6024	0.665	15212	65.58	66.41	55.39	1.10	1.29	10.69	23.61	24.44
6.314	0.028	344.51	336.57	336.69	3330.5	38.13	5911	0.665	14708	62.23	63.03	52.77	1.10	1.52	10.69	24.83	25.62
7.607	0.033	353.20	345.52	345.65	3293.0	39.56	5807	0.666	15205	63.20	63.97	53.27	1.10	1.76	10.69	28.15	28.86
8.913	-0.013	362.24	354.55	354.69	3255.1	41.05	5706	0.666	15168	61.96	62.70	52.18	1.10	1.81	10.69	28.70	29.39
10.185	0.020	371.16	363.27	363.43	3218.2	42.52	5612	0.666	14578	58.58	59.28	49.56	1.10	1.89	10.69	28.94	29.62
11.453	0.066	379.33	371.76	371.92	3181.4	44.00	5525	0.666	14772	58.44	59.09	49.28	1.10	1.99	10.69	31.39	32.02
12.723	-0.033	387.95	380.15	380.33	3144.5	45.50	5441	0.666	14659	57.12	57.76	48.18	1.10	2.13	10.69	32.13	32.75
13.993	0.025	397.07	389.14	389.33	3107.7	47.11	5355	0.666	15904	60.99	61.67	50.80	1.10	2.33	10.69	33.82	34.41
15.240	-0.058	400.32	397.73	397.93	3071.5	48.70	5276	0.666	35675	134.79	135.27	96.46	1.10	2.45	10.69	113.13	113.31
2.565	-1.880	318.15	311.13	311.23	3439.3	34.19	6234	0.665	16305	72.72	73.62	60.91	1.10	0.97	10.69	22.08	22.97
5.032	-1.892	335.35	327.72	327.83	3367.7	36.73	6019	0.665	15121	65.13	65.96	55.06	1.10	1.30	10.69	23.55	24.38
7.620	-1.938	353.74	345.61	345.74	3292.6	39.58	5806	0.666	14360	59.68	60.45	50.73	1.10	1.76	10.69	26.69	27.43
10.185	-1.951	371.74	363.27	363.43	3218.2	42.52	5612	0.666	13560	54.49	55.18	46.59	1.10	1.89	10.69	27.02	27.75
12.700	-1.913	388.37	380.00	380.17	3145.2	45.47	5443	0.666	13623	53.09	53.73	45.26	1.10	2.13	10.69	29.96	30.62
2.494	1.925	318.26	310.65	310.74	3441.4	34.12	6240	0.665	15076	67.31	68.21	57.06	1.10	0.96	10.69	20.43	21.39
5.098	1.900	336.29	328.17	328.29	3365.8	36.80	6013	0.665	14217	61.18	62.01	52.19	1.10	1.31	10.69	22.32	23.20
7.620	1.852	353.85	345.61	345.74	3292.6	39.58	5806	0.666	14159	58.84	59.61	50.12	1.10	1.76	10.69	26.34	27.09
10.160	1.956	370.29	363.11	363.26	3218.9	42.49	5614	0.666	16040	64.47	65.17	53.77	1.10	1.89	10.69	31.67	32.30
12.692	1.930	386.81	379.94	380.12	3145.4	45.46	5443	0.666	16675	65.00	65.64	53.76	1.10	2.13	10.69	36.40	36.94
2.540	-3.211	317.99	310.96	311.06	3440.0	34.16	6236	0.665	16316	72.80	73.70	60.97	1.10	0.97	10.69	22.05	22.94
7.633	-3.213	353.93	345.70	345.83	3292.2	39.59	5805	0.666	14183	58.94	59.71	50.19	1.10	1.76	10.69	26.39	27.13
12.720	-3.211	388.06	380.13	380.31	3144.6	45.50	5442	0.666	14418	56.18	56.82	47.50	1.10	2.13	10.69	31.62	32.25
2.499	3.221	317.68	310.68	310.78	3441.2	34.12	6240	0.665	16408	73.25	74.15	61.30	1.10	0.96	10.69	22.08	22.97
7.620	3.454	350.57	345.61	345.74	3292.6	39.58	5806	0.666	23773	98.80	99.58	77.34	1.10	1.76	10.69	43.42	43.88
12.700	3.180	383.06	380.00	380.17	3145.2	45.47	5443	0.666	38718	150.90	151.57	106.51	1.10	2.13	10.69	83.45	83.69

Table 3 (continued)

18° Pinfin Specimen
Experiment: 3
Date: 20 November 1990
Time: 11:21:15

TA	TB	M	P0	P0-P1	Vf	Qt	Wqt
K	K	kg/h	kPa	kPa	%	W	%
290.46	370.39	21.45	3474.1	714.41	25.53	2454.0	1.35

Hot-Side Temperatures:

X	Y	Tw	X	Y	Tw
cm	cm	K	cm	cm	K
1.332	0.485	310.13	2.549	-1.330	314.84
2.597	0.526	315.73	5.033	-1.444	326.82
2.681	0.923	316.88	7.571	-1.375	341.50
5.107	0.426	328.90	10.071	-1.476	354.90
7.626	0.498	339.00	2.465	-2.649	312.94
7.710	0.895	342.58	7.657	-2.616	342.61
10.111	0.396	354.75	12.699	-2.643	368.24
12.651	0.478	366.15	7.540	2.687	340.41
12.734	0.875	368.19	7.623	3.085	340.96
13.931	0.527	374.57			

Insulated-Side PRT Temperatures:

X	Y	Tw
cm	cm	K
-0.038	0.038	295.28
3.993	-0.224	317.77
11.648	-0.241	356.18
15.077	-1.430	371.95

Insulated-Side Thermocouple Temperatures and Calculated Data:

													---------Uncertainties---------				
X	Y	Tw	Tf	Taw	P	V	RE	PR	h	NU	NUm	NUw	Wtw	Wtf	Wre	Wh	Wnu
cm	cm	K	K	K	kPa	m/s			W/(m²·K)				K	K	%	%	%
-0.038	-0.229	294.56	290.35	290.49	3478.2	41.53	8582	0.664	0	0.00	0.00	0.00	1.10	0.50	10.69	0.00	0.00
1.293	-0.226	304.07	297.33	297.49	3415.2	43.28	8449	0.665	18905	86.91	87.99	71.32	1.10	0.76	10.69	21.25	22.17
2.527	-0.132	310.57	304.04	304.21	3356.7	45.00	8324	0.665	17709	80.24	81.18	66.41	1.10	0.78	10.69	22.13	23.02
3.802	0.056	316.68	310.52	310.70	3296.3	46.77	8207	0.665	18435	82.37	83.27	67.67	1.10	0.88	10.69	24.38	25.19
4.976	-0.008	322.83	316.54	316.73	3240.6	48.47	8102	0.665	18537	81.77	82.66	67.08	1.10	1.01	10.69	25.29	26.07
6.314	0.028	330.13	323.54	323.75	3177.3	50.50	7983	0.666	17965	78.10	78.97	64.35	1.10	1.18	10.69	26.05	26.80
7.607	0.033	336.61	330.33	330.56	3116.0	52.54	7872	0.666	18899	81.03	81.87	66.15	1.10	1.35	10.69	29.47	30.14
8.913	-0.013	343.51	337.18	337.43	3054.1	54.69	7764	0.666	18772	79.38	80.20	64.82	1.10	1.39	10.69	29.83	30.49
10.185	0.020	350.31	343.80	344.07	2993.8	56.85	7663	0.666	18001	75.14	75.92	61.71	1.10	1.45	10.69	29.86	30.52
11.453	0.066	356.54	350.23	350.52	2933.8	59.08	7567	0.666	18108	74.65	75.39	61.19	1.10	1.53	10.69	31.99	32.60
12.723	-0.033	363.04	356.59	356.91	2873.6	61.38	7475	0.666	18171	74.00	74.73	60.58	1.10	1.64	10.69	32.87	33.47
13.993	0.025	369.86	363.40	363.74	2813.4	63.86	7380	0.666	20057	80.65	81.43	64.94	1.10	1.79	10.69	34.90	35.47
15.240	-0.058	372.19	369.91	370.28	2754.3	66.37	7291	0.666	44485	176.74	177.34	121.05	1.10	1.88	10.69	115.07	115.24
2.565	-1.880	309.76	304.24	304.41	3354.9	45.05	8321	0.665	21017	95.19	96.14	76.59	1.10	0.78	10.69	26.02	26.78
5.032	-1.892	322.84	316.83	317.02	3238.0	48.55	8097	0.665	19441	85.71	86.60	69.76	1.10	1.02	10.69	26.50	27.24
7.620	-1.938	336.86	330.40	330.63	3115.4	52.56	7871	0.666	18349	78.66	79.50	64.53	1.10	1.35	10.69	28.68	29.36
10.185	-1.951	350.63	343.80	344.07	2993.8	56.85	7663	0.666	17109	71.42	72.20	59.13	1.10	1.45	10.69	28.45	29.14
12.700	-1.913	363.24	356.47	356.79	2874.7	61.34	7477	0.666	17231	70.19	70.92	57.95	1.10	1.64	10.69	31.25	31.88
2.494	1.925	309.80	303.87	304.04	3358.2	44.95	8327	0.665	19596	88.82	89.77	72.32	1.10	0.78	10.69	24.25	25.06
5.098	1.900	323.51	317.17	317.37	3234.9	48.65	8091	0.665	18448	81.27	82.16	66.71	1.10	1.02	10.69	25.28	26.06
7.620	1.852	336.82	330.40	330.63	3115.4	52.56	7871	0.666	18485	79.24	80.08	64.92	1.10	1.35	10.69	28.88	29.56
10.160	1.956	349.35	343.67	343.94	2995.0	56.81	7664	0.666	20746	86.62	87.41	69.48	1.10	1.45	10.69	34.19	34.77
12.692	1.930	361.77	356.43	356.75	2875.1	61.32	7477	0.666	22120	90.11	90.85	71.35	1.10	1.64	10.69	39.79	40.29
2.540	-3.211	309.97	304.11	304.28	3356.1	45.02	8323	0.665	19777	89.59	90.54	72.83	1.10	0.78	10.69	24.54	25.34
7.633	-3.213	337.63	330.47	330.70	3114.8	52.58	7870	0.666	16502	70.73	71.57	59.00	1.10	1.35	10.69	25.94	26.70
12.720	-3.211	363.66	356.58	356.89	2873.7	61.38	7475	0.666	16444	66.97	67.70	55.70	1.10	1.64	10.69	29.87	30.53
2.499	3.221	309.72	303.89	304.07	3358.0	44.96	8327	0.665	19970	90.51	91.46	73.46	1.10	0.78	10.69	24.69	25.48
7.620	3.454	334.61	330.40	330.63	3115.4	52.56	7871	0.666	28764	123.30	124.16	93.33	1.10	1.35	10.69	44.31	44.76
12.700	3.180	359.01	356.47	356.79	2874.7	61.34	7477	0.666	50209	204.53	205.33	136.59	1.10	1.64	10.69	89.37	89.59

Table 3 (continued)

18° Pinfin Specimen
Experiment: 3
Date: 20 November 1990
Time: 11:35:24

TA	TB	M	P0	P0-P1	Vf	Qt	Wqt
K	K	kg/h	kPa	kPa	%	W	%
288.93	349.87	28.30	3496.0	1269.85	25.51	2446.0	1.56

Hot-Side Temperatures:

X	Y	Tw	X	Y	Tw
cm	cm	K	cm	cm	K
1.332	0.485	305.16	2.549	-1.330	308.54
2.597	0.526	309.25	5.033	-1.444	317.52
2.681	0.923	310.22	7.571	-1.375	328.81
5.107	0.426	319.32	10.071	-1.476	338.95
7.626	0.498	326.27	2.465	-2.649	306.79
7.710	0.895	329.62	7.657	-2.616	329.78
10.111	0.396	338.69	12.699	-2.643	349.03
12.651	0.478	346.99	7.540	2.687	327.89
12.734	0.875	348.90	7.623	3.085	328.41
13.931	0.527	353.60			

Insulated-Side PRT Temperatures:

X	Y	Tw
cm	cm	K
-0.038	0.038	292.61
3.993	-0.224	309.76
11.648	-0.241	338.86
15.077	-1.430	350.90

Insulated-Side Thermocouple Temperatures and Calculated Data:

X	Y	Tw	Tf	Taw	P	V	RE	PR	h	NU	NUm	NUw	Wtw	Wtf	Wre	Wh	Wnu
													---------Uncertainties---------				
cm	cm	K	K	K	kPa	m/s			W/(m²·K)				K	K	%	%	%
-0.038	-0.229	292.02	288.74	288.99	3503.2	54.11	11364	0.664	0	0.00	0.00	0.00	1.10	0.50	10.69	0.00	0.00
1.293	-0.226	299.31	294.04	294.31	3391.1	56.88	11231	0.665	24770	114.68	115.81	89.83	1.10	0.65	10.69	26.27	27.02
2.527	-0.132	304.27	299.12	299.42	3287.2	59.64	11106	0.665	23166	106.13	107.13	84.02	1.10	0.65	10.69	27.14	27.86
3.802	0.056	308.82	304.03	304.36	3179.8	62.62	10987	0.665	24620	111.62	112.58	87.33	1.10	0.71	10.69	30.05	30.71
4.976	-0.008	313.52	308.59	308.95	3080.9	65.56	10878	0.666	24662	110.72	111.69	86.56	1.10	0.80	10.69	30.46	31.11
6.314	0.028	319.14	313.89	314.29	2968.2	69.16	10756	0.666	23533	104.48	105.44	82.34	1.10	0.92	10.69	30.24	30.89
7.607	0.033	323.98	319.02	319.47	2859.4	72.92	10640	0.666	25251	110.92	111.87	86.24	1.10	1.05	10.69	34.23	34.81
8.913	-0.013	329.13	324.19	324.69	2749.4	77.01	10526	0.666	25567	111.13	112.06	86.14	1.10	1.08	10.69	35.17	35.73
10.185	0.020	334.21	329.18	329.73	2642.2	81.31	10419	0.666	24977	107.48	108.38	83.61	1.10	1.12	10.69	35.65	36.21
11.453	0.066	338.86	334.02	334.64	2535.4	85.93	10317	0.666	25748	109.73	110.60	84.81	1.10	1.19	10.69	38.89	39.40
12.723	-0.033	343.69	338.80	339.49	2428.5	90.94	10219	0.666	26452	111.68	112.56	85.84	1.10	1.27	10.69	40.57	41.06
13.993	0.025	348.89	343.90	344.69	2321.5	96.51	10117	0.666	29064	121.49	122.46	91.69	1.10	1.38	10.69	42.52	42.99
15.240	-0.058	350.67	348.77	349.65	2216.5	102.46	10022	0.666	82752	342.72	343.75	202.00	1.10	1.46	10.69	179.24	179.35
2.565	-1.880	303.68	299.27	299.57	3284.0	59.73	11102	0.665	27267	124.88	125.89	95.93	1.10	0.65	10.69	31.77	32.40
5.032	-1.892	313.61	308.81	309.17	3076.2	65.70	10873	0.666	25378	113.89	114.86	88.57	1.10	0.81	10.69	31.34	31.97
7.620	-1.938	324.23	319.07	319.52	2858.3	72.96	10639	0.666	24191	106.26	107.20	83.27	1.10	1.05	10.69	32.86	33.47
10.185	-1.951	334.71	329.18	329.73	2642.2	81.31	10419	0.666	22483	96.75	97.64	76.72	1.10	1.12	10.69	32.21	32.83
12.700	-1.913	344.24	338.71	339.40	2430.4	90.85	10221	0.666	22903	96.71	97.58	76.33	1.10	1.27	10.69	35.29	35.86
2.494	1.925	303.66	298.99	299.29	3290.0	59.57	11109	0.665	25741	117.96	118.97	91.61	1.10	0.65	10.69	29.93	30.59
5.098	1.900	314.04	309.07	309.43	3070.7	65.87	10867	0.666	24481	109.80	110.77	85.96	1.10	0.81	10.69	30.31	30.96
7.620	1.852	324.24	319.07	319.52	2858.3	72.96	10639	0.666	24118	105.93	106.87	83.05	1.10	1.05	10.69	32.77	33.37
10.160	1.956	333.66	329.08	329.64	2644.3	81.23	10421	0.666	27841	119.83	120.74	91.33	1.10	1.12	10.69	39.58	40.08
12.692	1.930	342.94	338.68	339.37	2431.1	90.82	10222	0.666	31033	131.05	131.95	97.63	1.10	1.27	10.69	47.47	47.89
2.540	-3.211	303.83	299.17	299.47	3286.1	59.67	11105	0.665	25728	117.86	118.87	91.53	1.10	0.65	10.69	30.01	30.67
7.633	-3.213	324.92	319.12	319.57	2857.2	73.00	10637	0.666	21297	93.54	94.47	74.98	1.10	1.05	10.69	29.09	29.77
12.720	-3.211	344.75	338.79	339.48	2428.7	90.93	10220	0.666	21056	88.90	89.76	71.22	1.10	1.27	10.69	32.53	33.14
2.499	3.221	303.59	299.01	299.31	3289.5	59.58	11108	0.665	26314	120.58	121.59	93.26	1.10	0.65	10.69	30.58	31.22
7.620	3.454	322.57	319.07	319.52	2858.3	72.96	10639	0.666	37362	164.11	165.10	117.95	1.10	1.05	10.69	50.21	50.61
12.700	3.180	340.90	338.71	339.40	2430.4	90.85	10221	0.666	73967	312.34	313.45	190.04	1.10	1.27	10.69	112.27	112.45

Table 3 (continued)

18° Pinfin Specimen
Experiment: 4
Date: 19 September 1990
Time: 10:45:03

TA	TB	M	P0	P0-P1	Vf	Qt	Wqt
K	K	kg/h	kPa	kPa	%	W	%
293.00	548.99	14.38	3508.5	388.78	50.19	5302.0	1.06

Hot-Side Temperatures:

X	Y	Tw	X	Y	Tw
cm	cm	K	cm	cm	K
1.332	0.485	348.16	2.549	-1.330	364.79
2.597	0.526	366.99	5.033	-1.444	403.62
2.681	0.923	370.26	7.571	-1.375	450.63
5.107	0.426	409.23	10.071	-1.476	494.15
7.626	0.498	445.97	2.465	-2.649	359.92
7.710	0.895	454.20	7.657	-2.616	453.46
10.111	0.396	494.55	12.699	-2.643	537.41
12.651	0.478	533.22	7.540	2.687	448.37
12.734	0.875	537.76	7.623	3.085	448.98
13.931	0.527	559.73			

Insulated-Side PRT Temperatures:

X	Y	Tw
cm	cm	K
-0.038	0.038	307.57
3.993	-0.224	378.32
11.648	-0.241	503.31
15.077	-1.430	553.28

Insulated-Side Thermocouple Temperatures and Calculated Data:

X	Y	Tw	Tf	Taw	P	V	RE	PR	h	NU	NUm	NUw	Wtw	Wtf	Wre	Wh	Wnu
													---------Uncertainties---------				
cm	cm	K	K	K	kPa	m/s			W/(m²·K)				K	K	%	%	%
-0.038	-0.229	305.97	292.95	293.02	3510.7	27.83	5720	0.665	0	0.00	0.00	0.00	1.10	0.50	10.69	0.00	0.00
1.293	-0.226	335.39	315.38	315.46	3476.4	30.22	5444	0.665	13467	59.51	61.56	52.18	1.10	2.01	10.69	12.99	14.45
2.527	-0.132	355.92	336.92	337.01	3444.6	32.54	5206	0.665	12873	54.41	56.08	47.72	1.10	2.16	10.69	14.27	15.60
3.802	0.056	375.84	357.72	357.82	3411.7	34.85	4998	0.665	13218	53.65	55.13	46.68	1.10	2.56	10.69	16.70	17.86
4.976	-0.008	395.73	377.05	377.17	3381.4	37.03	4822	0.666	13150	51.50	52.89	44.72	1.10	3.05	10.69	18.52	19.57
6.314	0.028	418.69	399.55	399.68	3346.9	39.61	4634	0.666	13015	48.99	50.27	42.46	1.10	3.63	10.69	20.91	21.84
7.607	0.033	440.61	421.38	421.53	3313.6	42.16	4468	0.666	12944	46.98	48.15	40.61	1.10	4.21	10.69	23.66	24.49
8.913	-0.013	462.85	443.38	443.55	3279.9	44.78	4315	0.666	12769	44.75	45.82	38.62	1.10	4.34	10.69	24.01	24.83
10.185	0.020	484.66	464.65	464.84	3247.1	47.38	4177	0.666	12240	41.54	42.51	35.94	1.10	4.53	10.69	24.35	25.15
11.453	0.066	504.87	485.33	485.54	3214.4	49.96	4054	0.666	12178	40.11	40.99	34.60	1.10	4.78	10.69	26.18	26.93
12.723	-0.033	525.98	505.79	506.02	3181.7	52.58	3939	0.666	12049	38.56	39.40	33.23	1.10	5.13	10.69	27.01	27.74
13.993	0.025	548.32	527.70	527.96	3148.9	55.40	3825	0.666	13007	40.43	41.29	34.39	1.10	5.59	10.69	28.63	29.32
15.240	-0.058	557.62	548.64	548.92	3116.8	58.17	3723	0.666	21095	63.81	64.38	49.62	1.14	5.88	10.69	70.10	70.38
2.565	-1.880	353.72	337.55	337.64	3443.6	32.61	5199	0.665	15106	63.77	65.43	54.54	1.10	2.17	10.69	16.37	17.55
5.032	-1.892	397.65	377.98	378.10	3380.0	37.13	4814	0.666	12504	48.88	50.26	42.77	1.10	3.07	10.69	17.81	18.90
7.620	-1.938	440.63	421.60	421.75	3313.3	42.18	4467	0.666	13082	47.47	48.64	40.96	1.10	4.22	10.69	23.92	24.75
10.185	-1.951	484.70	464.65	464.84	3247.1	47.38	4177	0.666	12214	41.45	42.42	35.88	1.10	4.53	10.69	24.30	25.11
12.700	-1.913	525.79	505.41	505.65	3182.3	52.53	3941	0.666	11923	38.18	39.02	32.96	1.10	5.12	10.69	26.74	27.48
2.494	1.925	353.93	336.37	336.46	3445.4	32.48	5212	0.665	13961	59.07	60.75	51.17	1.10	2.15	10.69	15.19	16.45
5.098	1.900	397.95	379.09	379.20	3378.3	37.26	4804	0.666	13057	50.94	52.32	44.27	1.10	3.10	10.69	18.62	19.66
7.620	1.852	440.97	421.60	421.75	3313.3	42.18	4467	0.666	12848	46.62	47.79	40.34	1.10	4.22	10.69	23.53	24.36
10.160	1.956	482.26	464.24	464.43	3247.8	47.33	4180	0.666	13609	46.21	47.19	39.35	1.10	4.53	10.69	26.86	27.59
12.692	1.930	362.54	505.28	505.52	3182.5	52.51	3942	0.666	-1679	-5.38	-4.48	32.78	1.10	5.12	10.69	7.30	9.65
2.540	-3.211	354.27	337.14	337.23	3444.2	32.56	5204	0.665	14270	60.29	61.96	52.04	1.10	2.16	10.69	15.55	16.79
7.633	-3.213	442.15	421.82	421.97	3312.9	42.21	4465	0.666	12234	44.37	45.53	38.68	1.10	4.22	10.69	22.49	23.36
12.720	-3.211	525.91	505.74	505.98	3181.8	52.57	3940	0.666	12065	38.62	39.46	33.28	1.10	5.13	10.69	27.04	27.77
2.499	3.221	353.52	336.45	336.54	3445.3	32.49	5211	0.665	14365	60.77	62.45	52.41	1.10	2.15	10.69	15.56	16.80
7.620	3.454	433.75	421.60	421.75	3313.3	42.18	4467	0.666	20571	74.64	75.82	59.72	1.10	4.22	10.69	36.86	37.40
12.700	3.180	515.03	505.41	505.65	3182.3	52.53	3941	0.666	25584	81.93	82.78	61.93	1.10	5.12	10.69	56.12	56.47

Table 3 (continued)

18° Pinfin Specimen
Experiment: 4
Date: 19 September 1990
Time: 10:52:53

TA	TB	M	P0	P0-P1	Vf	Qt	Wqt
K	K	kg/h	kPa	kPa	%	W	%
292.93	476.24	20.25	3477.4	681.17	50.21	5335.0	1.09

Hot-Side Temperatures:

X	Y	Tw	X	Y	Tw
cm	cm	K	cm	cm	K
1.332	0.485	335.92	2.549	-1.330	347.03
2.597	0.526	348.76	5.033	-1.444	374.49
2.681	0.923	351.28	7.571	-1.375	408.36
5.107	0.426	378.93	10.071	-1.476	439.55
7.626	0.498	402.87	2.465	-2.649	342.87
7.710	0.895	410.75	7.657	-2.616	410.97
10.111	0.396	439.38	12.699	-2.643	470.92
12.651	0.478	466.36	7.540	2.687	406.48
12.734	0.875	470.66	7.623	3.085	407.28
13.931	0.527	485.96			

Insulated-Side PRT Temperatures:

X	Y	Tw
cm	cm	K
-0.038	0.038	303.54
3.993	-0.224	354.30
11.648	-0.241	442.79
15.077	-1.430	478.79

Insulated-Side Thermocouple Temperatures and Calculated Data:

X	Y	Tw	Tf	Taw	P	V	RE	PR	h	NU	NUm	NUw	Uncertainties: Wtw	Wtf	Wre	Wh	Wnu
cm	cm	K	K	K	kPa	m/s			W/(m²·K)				K	K	%	%	%
-0.038	-0.229	302.27	292.83	292.96	3481.2	39.50	8055	0.665	0	0.00	0.00	0.00	1.10	0.50	10.69	0.00	0.00
1.293	-0.226	323.61	308.88	309.03	3421.1	42.34	7774	0.665	18522	83.02	85.18	69.12	1.10	1.47	10.69	13.98	15.35
2.527	-0.132	338.20	324.28	324.45	3365.4	45.14	7522	0.665	17816	77.29	79.10	64.48	1.10	1.57	10.69	15.30	16.55
3.802	0.056	352.34	339.15	339.35	3307.8	47.99	7297	0.665	18445	77.64	79.29	64.19	1.10	1.85	10.69	17.73	18.82
4.976	-0.008	366.44	352.98	353.19	3254.7	50.72	7102	0.666	18542	75.97	77.55	62.64	1.10	2.19	10.69	19.54	20.54
6.314	0.028	382.77	369.06	369.31	3194.3	53.99	6890	0.666	18490	73.51	75.00	60.50	1.10	2.61	10.69	21.92	22.82
7.607	0.033	398.30	384.67	384.94	3135.9	57.28	6698	0.666	18610	71.93	73.32	58.97	1.10	3.02	10.69	24.88	25.67
8.913	-0.013	414.07	400.39	400.70	3076.9	60.72	6517	0.666	18554	69.78	71.08	57.09	1.10	3.11	10.69	25.46	26.23
10.185	0.020	429.64	415.59	415.94	3019.4	64.18	6352	0.666	17815	65.32	66.53	53.67	1.10	3.25	10.69	25.81	26.57
11.453	0.066	444.12	430.37	430.75	2962.1	67.71	6202	0.666	17720	63.43	64.54	52.01	1.10	3.43	10.69	27.69	28.40
12.723	-0.033	459.28	444.98	445.41	2904.7	71.36	6061	0.666	17455	61.07	62.14	50.10	1.10	3.68	10.69	28.38	29.08
13.993	0.025	475.30	460.63	461.11	2847.4	75.32	5918	0.666	18784	64.17	65.29	51.91	1.10	4.01	10.69	29.92	30.58
15.240	-0.058	481.36	475.58	476.11	2791.0	79.30	5789	0.666	35171	117.54	118.32	83.44	1.10	4.22	10.69	84.04	84.28
2.565	-1.880	336.71	324.73	324.90	3363.6	45.23	7515	0.665	20706	89.75	91.56	72.91	1.10	1.58	10.69	17.46	18.57
5.032	-1.892	386.15	353.64	353.86	3252.2	50.85	7093	0.666	7618	31.17	32.71	29.38	1.10	2.21	10.69	9.87	11.72
7.620	-1.938	398.71	384.82	385.10	3135.3	57.31	6696	0.666	18252	70.53	71.92	58.02	1.10	3.03	10.69	24.46	25.26
10.185	-1.951	430.32	415.59	415.94	3019.4	64.18	6352	0.666	16970	62.22	63.42	51.55	1.10	3.25	10.69	24.66	25.46
12.700	-1.913	459.71	444.71	445.14	2905.8	71.29	6063	0.666	16591	58.07	59.14	48.05	1.10	3.67	10.69	27.05	27.78
2.494	1.925	336.60	323.89	324.06	3366.9	45.07	7529	0.665	19561	84.93	86.75	69.71	1.10	1.57	10.69	16.50	17.66
5.098	1.900	367.81	354.43	354.65	3249.2	51.01	7082	0.666	18709	76.44	78.01	62.92	1.10	2.23	10.69	19.90	20.88
7.620	1.852	398.44	384.82	385.10	3135.3	57.31	6696	0.666	18624	71.96	73.35	58.99	1.10	3.03	10.69	24.92	25.71
10.160	1.956	427.80	415.30	415.64	3020.5	64.12	6355	0.666	20080	73.66	74.87	59.26	1.10	3.25	10.69	28.87	29.55
12.692	1.930	345.84	444.62	445.05	2906.1	71.27	6064	0.666	-2435	-8.52	-7.42	51.61	1.10	3.67	10.69	7.40	9.74
2.540	-3.211	337.24	324.43	324.61	3364.8	45.17	7520	0.665	19371	84.01	85.82	69.06	1.10	1.57	10.69	16.44	17.61
7.633	-3.213	400.43	384.98	385.26	3134.7	57.35	6694	0.666	16374	63.25	64.63	53.00	1.10	3.03	10.69	22.12	23.00
12.720	-3.211	460.64	444.95	445.38	2904.9	71.35	6061	0.666	15859	55.48	56.55	46.25	1.10	3.67	10.69	25.92	26.68
2.499	3.221	336.47	323.95	324.12	3366.6	45.08	7528	0.665	19855	86.20	88.02	70.57	1.10	1.57	10.69	16.72	17.87
7.620	3.454	393.35	384.82	385.10	3135.3	57.31	6696	0.666	30119	116.38	117.79	87.05	1.10	3.03	10.69	39.53	40.03
12.700	3.180	451.34	444.71	445.14	2905.8	71.29	6063	0.666	38979	136.43	137.54	95.37	1.10	3.67	10.69	62.12	62.44

Table 3 (continued)

18° Pinfin Specimen
Experiment: 4
Date: 19 September 1990
Time: 11:01:03

TA	TB	M	PO	PO-P1	Vf	Qt	Wqt
K	K	kg/h	kPa	kPa	%	W	%
292.83	430.42	27.04	3431.4	1195.22	50.24	5328.0	1.14

Hot-Side Temperatures:						Insulated-Side PRT Temperatures:		
X	Y	Tw	X	Y	Tw	X	Y	Tw
cm	cm	K	cm	cm	K	cm	cm	K
1.332	0.485	327.93	2.549	-1.330	335.70	-0.038	0.038	300.87
2.597	0.526	337.10	5.033	-1.444	356.19	3.993	-0.224	339.17
2.681	0.923	339.21	7.571	-1.375	381.79	11.648	-0.241	405.29
5.107	0.426	359.88	10.071	-1.476	405.29	15.077	-1.430	432.43
7.626	0.498	376.09	2.465	-2.649	331.96			
7.710	0.895	383.52	7.657	-2.616	384.15			
10.111	0.396	404.95	12.699	-2.643	429.17			
12.651	0.478	424.60	7.540	2.687	380.24			
12.734	0.875	428.71	7.623	3.085	381.14			
13.931	0.527	439.98						

Insulated-Side Thermocouple Temperatures and Calculated Data:

													---------Uncertainties---------				
X	Y	Tw	Tf	Taw	P	V	RE	PR	h	NU	NUm	NUw	Wtw	Wtf	Wre	Wh	Wnu
cm	cm	K	K	K	kPa	m/s			W/(m²·K)				K	K	%	%	%
-0.038	-0.229	299.86	292.65	292.89	3438.2	53.37	10765	0.665	0	0.00	0.00	0.00	1.10	0.50	10.69	0.00	0.00
1.293	-0.226	316.05	304.65	304.93	3332.7	57.25	10482	0.665	24248	109.72	111.96	87.01	1.10	1.14	10.69	15.49	16.73
2.527	-0.132	326.95	316.18	316.49	3234.9	61.15	10223	0.665	23387	103.24	105.16	82.14	1.10	1.21	10.69	16.84	17.99
3.802	0.056	337.53	327.31	327.66	3133.9	65.28	9988	0.666	24257	104.64	106.43	82.50	1.10	1.41	10.69	19.18	20.20
4.976	-0.008	348.09	337.64	338.04	3040.8	69.35	9780	0.666	24427	103.21	104.95	81.15	1.10	1.66	10.69	20.77	21.72
6.314	0.028	360.35	349.66	350.13	2934.7	74.34	9551	0.666	24306	100.31	101.99	78.81	1.10	1.96	10.69	22.88	23.73
7.607	0.033	371.90	361.31	361.85	2832.2	79.54	9341	0.666	24691	99.67	101.27	77.92	1.10	2.27	10.69	25.88	26.64
8.913	-0.013	383.65	373.05	373.66	2728.7	85.17	9140	0.666	24773	97.86	99.38	76.31	1.10	2.34	10.69	26.59	27.33
10.185	0.020	395.24	384.38	385.08	2627.9	91.06	8956	0.666	23999	92.90	94.33	72.73	1.10	2.44	10.69	27.11	27.83
11.453	0.066	406.12	395.38	396.18	2527.4	97.33	8785	0.666	23801	90.39	91.73	70.73	1.10	2.58	10.69	28.91	29.60
12.723	-0.033	417.53	406.25	407.17	2426.7	104.09	8623	0.666	23329	86.98	88.30	68.21	1.10	2.76	10.69	29.39	30.06
13.993	0.025	429.52	417.87	418.92	2326.0	111.64	8458	0.666	25126	91.89	93.29	70.98	1.10	3.01	10.69	30.88	31.52
15.240	-0.058	433.69	428.95	430.16	2227.2	119.62	8308	0.666	52231	187.63	188.77	122.72	1.10	3.17	10.69	95.94	96.15
2.565	-1.880	325.89	316.52	316.83	3231.9	61.27	10216	0.665	26961	118.94	120.86	92.05	1.10	1.21	10.69	19.14	20.16
5.032	-1.892	348.24	338.14	338.55	3036.4	69.55	9770	0.666	25325	106.89	108.64	83.46	1.10	1.67	10.69	21.55	22.46
7.620	-1.938	372.45	361.43	361.96	2831.2	79.59	9339	0.666	23666	95.51	97.10	75.28	1.10	2.28	10.69	24.89	25.68
10.185	-1.951	396.24	384.38	385.08	2627.9	91.06	8956	0.666	21840	84.55	85.97	67.37	1.10	2.44	10.69	24.81	25.60
12.700	-1.913	418.31	406.05	406.96	2428.5	103.97	8626	0.666	21271	79.33	80.64	63.29	1.10	2.76	10.69	26.93	27.66
2.494	1.925	325.68	315.89	316.20	3237.5	61.04	10230	0.665	25863	114.25	116.18	89.17	1.10	1.20	10.69	18.32	19.38
5.098	1.900	349.01	338.73	339.14	3031.1	69.79	9759	0.666	24899	104.97	106.71	82.22	1.10	1.68	10.69	21.32	22.23
7.620	1.852	371.97	361.43	361.96	2831.2	79.59	9339	0.666	24798	100.08	101.67	78.17	1.10	2.28	10.69	26.01	26.77
10.160	1.956	393.97	384.16	384.86	2629.9	90.94	8959	0.666	26759	103.63	105.08	79.43	1.10	2.44	10.69	30.03	30.68
12.692	1.930	334.19	405.98	406.89	2429.1	103.92	8627	0.666	-3318	-12.38	-11.12	71.37	1.10	2.76	10.69	7.53	9.83
2.540	-3.211	326.44	316.29	316.61	3233.9	61.19	10221	0.665	24853	109.69	111.61	86.26	1.10	1.21	10.69	17.77	18.86
7.633	-3.213	374.24	361.55	362.08	2830.2	79.64	9337	0.666	20408	82.35	83.93	66.71	1.10	2.28	10.69	21.70	22.60
12.720	-3.211	419.77	406.23	407.14	2426.9	104.08	8624	0.666	19139	71.36	72.66	58.03	1.10	2.76	10.69	24.38	25.19
2.499	3.221	325.64	315.93	316.24	3237.1	61.06	10229	0.665	26066	115.13	117.06	89.71	1.10	1.21	10.69	18.46	19.51
7.620	3.454	368.25	361.43	361.96	2831.2	79.59	9339	0.666	39475	159.31	160.96	112.89	1.10	2.28	10.69	40.68	41.17
12.700	3.180	411.66	406.05	406.96	2428.5	103.97	8626	0.666	51344	191.49	192.94	126.49	1.10	2.76	10.69	63.49	63.81

Table 3 (continued)

18° Pinfin Specimen
Experiment: 4
Date: 19 September 1990
Time: 11:13:34

TA	TB	M	P0	P0-P1	Vf	Qt	Wqt
K	K	kg/h	kPa	kPa	%	W	%
293.07	641.42	10.27	3556.6	236.97	50.28	5154.0	1.04

Hot-Side Temperatures:

X	Y	Tw	X	Y	Tw
cm	cm	K	cm	cm	K
1.332	0.485	363.26	2.549	-1.330	387.39
2.597	0.526	390.05	5.033	-1.444	441.33
2.681	0.923	394.25	7.571	-1.375	505.20
5.107	0.426	448.00	10.071	-1.476	564.97
7.626	0.498	501.31	2.465	-2.649	381.67
7.710	0.895	510.09	7.657	-2.616	508.55
10.111	0.396	566.05	12.699	-2.643	624.91
12.651	0.478	620.99	7.540	2.687	502.21
12.734	0.875	623.89	7.623	3.085	502.76
13.931	0.527	655.69			

Insulated-Side PRT Temperatures:

X	Y	Tw
cm	cm	K
-0.038	0.038	312.73
3.993	-0.224	409.50
11.648	-0.241	582.18
15.077	-1.430	650.82

Insulated-Side Thermocouple Temperatures and Calculated Data:

													---------Uncertainties---------				
X	Y	Tw	Tf	Taw	P	V	RE	PR	h	NU	NUm	NUw	Wtw	Wtf	Wre	Wh	Wnu
cm	cm	K	K	K	kPa	m/s			W/(m²·K)				K	K	%	%	%
-0.038	-0.229	310.60	293.05	293.08	3557.9	19.62	4083	0.665	0	0.00	0.00	0.00	1.10	0.50	10.69	0.00	0.00
1.293	-0.226	350.27	323.59	323.63	3537.0	21.75	3820	0.665	9797	42.54	44.43	39.04	1.10	2.71	10.69	12.52	14.03
2.527	-0.132	378.75	352.91	352.96	3517.6	23.82	3602	0.665	9176	37.58	39.07	34.48	1.10	2.91	10.69	13.61	15.00
3.802	0.056	406.29	381.23	381.29	3497.6	25.85	3417	0.666	9261	35.99	37.27	32.80	1.10	3.47	10.69	15.85	17.07
4.976	-0.008	433.72	407.55	407.61	3479.1	27.75	3264	0.666	9092	33.75	34.93	30.72	1.10	4.13	10.69	17.53	18.63
6.314	0.028	465.32	438.18	438.26	3458.1	29.99	3105	0.666	8886	31.39	32.44	28.53	1.10	4.93	10.69	19.68	20.67
7.607	0.033	495.40	467.90	467.99	3437.8	32.19	2968	0.666	8760	29.58	30.52	26.81	1.10	5.73	10.69	22.17	23.05
8.913	-0.013	526.04	497.86	497.96	3417.3	34.43	2843	0.666	8530	27.59	28.44	24.98	1.10	5.90	10.69	22.24	23.12
10.185	0.020	555.90	526.83	526.94	3397.3	36.63	2734	0.666	8143	25.33	26.09	22.97	1.13	6.16	10.69	22.51	23.38
11.453	0.066	583.60	554.98	555.11	3377.3	38.79	2637	0.666	8033	24.10	24.78	21.81	1.24	6.50	10.69	24.09	24.91
12.723	-0.033	612.82	582.85	582.99	3357.4	40.96	2549	0.666	7839	22.73	23.37	20.59	1.36	6.97	10.69	24.62	25.42
13.993	0.025	643.78	612.68	612.84	3337.4	43.29	2461	0.666	8323	23.31	23.95	20.95	1.48	7.60	10.69	25.75	26.51
15.240	-0.058	658.05	641.20	641.38	3317.8	45.56	2385	0.666	10699	29.02	29.44	25.01	1.54	7.99	10.69	50.60	50.99
2.565	-1.880	375.82	353.77	353.82	3517.0	23.88	3596	0.665	10731	43.87	45.35	39.38	1.10	2.92	10.69	15.53	16.76
5.032	-1.892	433.39	408.82	408.88	3478.3	27.85	3257	0.666	9698	35.93	37.10	32.42	1.10	4.16	10.69	18.66	19.70
7.620	-1.938	495.23	468.20	468.29	3437.6	32.21	2967	0.666	8913	30.08	31.02	27.20	1.10	5.74	10.69	22.56	23.43
10.185	-1.951	555.63	526.83	526.94	3397.3	36.63	2734	0.666	8220	25.57	26.33	23.16	1.13	6.16	10.69	22.71	23.57
12.700	-1.913	612.17	582.33	582.47	3357.7	40.92	2550	0.666	7865	22.82	23.46	20.66	1.36	6.96	10.69	24.69	25.49
2.494	1.925	376.22	352.16	352.21	3518.1	23.77	3607	0.665	9875	40.50	42.00	36.80	1.10	2.90	10.69	14.37	15.70
5.098	1.900	436.99	410.32	410.38	3477.2	27.96	3249	0.666	8940	33.04	34.20	30.13	1.10	4.20	10.69	17.48	18.59
7.620	1.852	496.06	468.20	468.29	3437.6	32.21	2967	0.666	8644	29.17	30.11	26.48	1.10	5.74	10.69	21.93	22.82
10.160	1.956	552.69	526.26	526.38	3397.7	36.58	2736	0.666	8966	27.91	28.67	25.00	1.12	6.15	10.69	24.58	25.38
12.692	1.930	391.31	582.15	582.29	3357.9	40.91	2551	0.666	-1222	-3.55	-2.85	20.09	1.10	6.95	10.69	7.31	9.66
2.540	-3.211	376.43	353.20	353.25	3517.4	23.84	3599	0.665	10203	41.76	43.25	37.76	1.10	2.92	10.69	14.84	16.13
7.633	-3.213	496.60	468.50	468.58	3437.4	32.23	2965	0.666	8570	28.91	29.85	26.28	1.10	5.74	10.69	21.76	22.66
12.720	-3.211	611.27	582.78	582.92	3357.4	40.96	2549	0.666	8248	23.92	24.56	21.52	1.35	6.97	10.69	25.82	26.58
2.499	3.221	375.42	352.27	352.32	3518.1	23.78	3606	0.665	10262	42.08	43.58	38.02	1.10	2.90	10.69	14.84	16.13
7.620	3.454	486.69	468.20	468.29	3437.6	32.21	2967	0.666	13044	44.02	44.97	37.69	1.10	5.74	10.69	32.34	32.95
12.700	3.180	597.86	582.33	582.47	3357.7	40.92	2550	0.666	15175	44.03	44.67	36.21	1.30	6.96	10.69	46.43	46.85

Table 3 (continued)

18° Pinfin Specimen
Experiment: 21 November 1990
Date: 5
Time: 09:48:53

TA	TB	M	P0	P0-P1	Vf	Qt	Wqt
K	K	kg/h	kPa	kPa	%	W	%
289.43	742.35	11.40	3512.0	332.44	75.13	7437.0	1.03

Hot-Side Temperatures:

X	Y	Tw	X	Y	Tw
cm	cm	K	cm	cm	K
1.332	0.485	383.40	2.549	-1.330	414.00
2.597	0.526	418.03	5.033	-1.444	483.74
2.681	0.923	423.92	7.571	-1.375	566.81
5.107	0.426	493.28	10.071	-1.476	644.25
7.626	0.498	561.78	2.465	-2.649	406.57
7.710	0.895	573.96	7.657	-2.616	572.24
10.111	0.396	646.67	12.699	-2.643	720.67
12.651	0.478	716.13	7.540	2.687	565.14
12.734	0.875	720.05	7.623	3.085	565.11
13.931	0.527	759.47			

Insulated-Side PRT Temperatures:

X	Y	Tw
cm	cm	K
-0.038	0.038	315.57
3.993	-0.224	440.79
11.648	-0.241	664.50
15.077	-1.430	750.78

Insulated-Side Thermocouple Temperatures and Calculated Data:

													---------Uncertainties---------				
X	Y	Tw	Tf	Taw	P	V	RE	PR	h	NU	NUm	NUw	Wtw	Wtf	Wre	Wh	Wnu
cm	cm	K	K	K	kPa	m/s			W/(m²·K)				K	K	%	%	%
-0.038	-0.229	312.89	289.41	289.45	3513.9	21.77	4569	0.664	0	0.00	0.00	0.00	1.10	0.50	10.69	0.00	0.00
1.293	-0.226	364.47	329.11	329.16	3484.6	24.91	4191	0.665	10663	45.79	48.43	42.12	1.10	3.50	10.69	12.01	13.57
2.527	-0.132	401.31	367.23	367.29	3457.4	27.97	3890	0.665	10038	40.02	42.02	36.68	1.10	3.77	10.69	13.14	14.58
3.802	0.056	436.86	404.04	404.13	3429.3	30.98	3644	0.666	10206	38.12	39.79	34.56	1.10	4.50	10.69	15.48	16.72
4.976	-0.008	472.21	438.26	438.35	3403.4	33.82	3446	0.666	10116	35.74	37.24	32.26	1.10	5.36	10.69	17.33	18.45
6.314	0.028	513.09	478.08	478.20	3373.9	37.18	3245	0.666	9945	33.09	34.40	29.75	1.10	6.41	10.69	19.64	20.63
7.607	0.033	551.94	516.72	516.85	3345.4	40.49	3075	0.666	9873	31.13	32.28	27.84	1.12	7.44	10.69	22.33	23.21
8.913	-0.013	591.67	555.66	555.82	3316.6	43.88	2924	0.666	9641	28.90	29.92	25.79	1.27	7.66	10.69	22.53	23.40
10.185	0.020	630.25	593.31	593.50	3288.5	47.23	2794	0.666	9258	26.52	27.42	23.71	1.43	8.00	10.69	22.99	23.84
11.453	0.066	666.47	629.91	630.13	3260.6	50.54	2679	0.666	9086	24.96	25.75	22.31	1.57	8.45	10.69	24.48	25.29
12.723	-0.033	703.85	666.13	666.37	3232.6	53.88	2577	0.666	9002	23.78	24.51	21.29	1.72	9.05	10.69	25.38	26.16
13.993	0.025	742.85	704.90	705.18	3204.6	57.49	2477	0.666	9863	25.04	25.77	22.19	1.88	9.87	10.69	27.36	28.08
15.240	-0.058	760.41	741.97	742.28	3177.1	61.02	2389	0.666	14207	34.80	35.27	28.98	1.95	10.38	10.69	59.80	60.13
2.565	-1.880	397.22	368.35	368.41	3456.6	28.06	3882	0.665	11826	47.05	49.04	42.02	1.10	3.79	10.69	15.06	16.33
5.032	-1.892	471.65	439.91	440.01	3402.2	33.96	3437	0.666	10835	38.18	39.67	34.10	1.10	5.41	10.69	18.52	19.57
7.620	-1.938	551.42	517.10	517.24	3345.1	40.52	3074	0.666	10135	31.94	33.09	28.45	1.11	7.45	10.69	22.90	23.76
10.185	-1.951	629.71	593.31	593.50	3288.5	47.23	2794	0.666	9397	26.91	27.81	24.00	1.43	8.00	10.69	23.30	24.15
12.700	-1.913	702.67	665.46	665.70	3233.1	53.82	2579	0.666	9114	24.09	24.82	21.53	1.72	9.04	10.69	25.68	26.44
2.494	1.925	398.13	366.26	366.32	3458.1	27.89	3897	0.665	10757	42.96	44.98	38.97	1.10	3.76	10.69	13.82	15.19
5.098	1.900	477.09	441.86	441.96	3400.7	34.12	3427	0.666	9771	34.32	35.80	31.12	1.10	5.46	10.69	17.03	18.16
7.620	1.852	553.71	517.10	517.24	3345.1	40.52	3074	0.666	9500	29.94	31.09	26.92	1.12	7.45	10.69	21.58	22.49
10.160	1.956	627.83	592.58	592.77	3289.1	47.16	2796	0.666	9710	27.83	28.73	24.71	1.42	7.99	10.69	23.99	24.81
12.692	1.930	700.60	665.23	665.47	3233.3	53.80	2579	0.666	9587	25.35	26.08	22.49	1.71	9.03	10.69	26.93	27.66
2.540	-3.211	398.99	367.61	367.68	3457.1	28.00	3887	0.665	10897	43.41	45.41	39.28	1.10	3.78	10.69	14.04	15.40
7.633	-3.213	554.47	517.49	517.63	3344.8	40.55	3072	0.666	9404	29.62	30.77	26.67	1.13	7.45	10.69	21.39	22.30
12.720	-3.211	702.27	666.04	666.28	3232.7	53.88	2577	0.666	9374	24.76	25.49	22.04	1.72	9.05	10.69	26.36	27.11
2.499	3.221	397.56	366.40	366.47	3458.0	27.90	3896	0.665	11001	43.92	45.94	39.70	1.10	3.76	10.69	14.07	15.43
7.620	3.454	541.19	517.10	517.24	3345.1	40.52	3074	0.666	14465	45.58	46.74	38.37	1.10	7.45	10.69	32.07	32.68
12.700	3.180	684.90	665.46	665.70	3233.1	53.82	2579	0.666	17553	46.40	47.14	37.30	1.65	9.04	10.69	48.28	48.69

Table 3 (continued)

18° Pinfin Specimen
Experiment: 21 November 1990
Date: 5
Time: 09:57:31

TA	TB	M	P0	P0-P1	Vf	Qt	Wqt
K	K	kg/h	kPa	kPa	%	W	%
288.23	626.66	15.55	3496.2	516.55	75.18	7577.0	1.04

Hot-Side Temperatures:						Insulated-Side PRT Temperatures:		
X	Y	Tw	X	Y	Tw	X	Y	Tw
cm	cm	K	cm	cm	K	cm	cm	K
1.332	0.485	363.25	2.549	-1.330	384.59	-0.038	0.038	308.17
2.597	0.526	387.92	5.033	-1.444	435.82	3.993	-0.224	401.19
2.681	0.923	392.67	7.571	-1.375	497.57	11.648	-0.241	564.87
5.107	0.426	443.66	10.071	-1.476	554.25	15.077	-1.430	629.10
7.626	0.498	491.13	2.465	-2.649	378.10			
7.710	0.895	502.82	7.657	-2.616	502.33			
10.111	0.396	555.52	12.699	-2.643	611.42			
12.651	0.478	606.20	7.540	2.687	496.39			
12.734	0.875	610.26	7.623	3.085	496.95			
13.931	0.527	640.50						

Insulated-Side Thermocouple Temperatures and Calculated Data:

													---------Uncertainties----------				
X	Y	Tw	Tf	Taw	P	V	RE	PR	h	NU	NUm	NUw	Wtw	Wtf	Wre	Wh	Wnu
cm	cm	K	K	K	kPa	m/s			W/(m²·K)				K	K	%	%	%
-0.038	-0.229	305.96	288.18	288.26	3499.2	29.71	6252	0.664	0	0.00	0.00	0.00	1.10	0.50	10.69	0.00	0.00
1.293	-0.226	344.81	317.83	317.92	3453.6	33.13	5856	0.665	14270	62.74	65.62	55.16	1.10	2.63	10.69	12.20	13.74
2.527	-0.132	371.99	346.30	346.42	3411.3	36.49	5525	0.665	13605	56.45	58.72	49.54	1.10	2.83	10.69	13.43	14.84
3.802	0.056	398.06	373.80	373.93	3367.6	39.85	5244	0.666	14108	55.58	57.54	48.19	1.10	3.37	10.69	15.98	17.18
4.976	-0.008	424.18	399.35	399.50	3327.4	43.05	5012	0.666	14140	53.25	55.05	45.96	1.10	4.01	10.69	17.98	19.06
6.314	0.028	454.46	429.08	429.27	3281.6	46.85	4771	0.666	14035	50.32	51.94	43.26	1.10	4.79	10.69	20.47	21.43
7.607	0.033	482.99	457.93	458.15	3237.3	50.64	4562	0.666	14208	48.70	50.15	41.56	1.10	5.56	10.69	23.66	24.49
8.913	-0.013	512.06	487.01	487.26	3192.5	54.57	4372	0.666	14203	46.66	47.96	39.62	1.10	5.72	10.69	24.32	25.13
10.185	0.020	540.28	515.12	515.41	3148.9	58.48	4206	0.666	13936	44.04	45.21	37.32	1.10	5.98	10.69	25.23	26.01
11.453	0.066	566.52	542.44	542.77	3105.5	62.40	4057	0.666	14168	43.20	44.24	36.34	1.17	6.32	10.69	27.78	28.49
12.723	-0.033	593.87	569.47	569.84	3062.0	66.41	3922	0.666	14310	42.18	43.16	35.31	1.28	6.77	10.69	29.35	30.03
13.993	0.025	622.84	598.41	598.84	3018.5	70.76	3789	0.666	15771	44.91	45.91	36.93	1.40	7.38	10.69	31.87	32.49
15.240	-0.058	635.36	626.08	626.55	2975.8	75.06	3672	0.666	29769	82.14	82.81	59.24	1.45	7.76	10.69	90.55	90.77
2.565	-1.880	368.70	347.14	347.25	3410.0	36.60	5516	0.665	16187	67.05	69.31	57.12	1.10	2.84	10.69	15.53	16.77
5.032	-1.892	423.75	400.58	400.74	3325.5	43.20	5002	0.666	15177	57.03	58.82	48.64	1.10	4.05	10.69	19.25	20.26
7.620	-1.938	482.86	458.22	458.44	3236.8	50.68	4560	0.666	14453	49.52	50.97	42.14	1.10	5.57	10.69	24.07	24.88
10.185	-1.951	540.28	515.12	515.41	3148.9	58.48	4206	0.666	13940	44.06	45.23	37.34	1.10	5.98	10.69	25.24	26.02
12.700	-1.913	593.48	568.97	569.34	3062.8	66.34	3925	0.666	14222	41.95	42.93	35.16	1.28	6.76	10.69	29.18	29.86
2.494	1.925	369.45	345.58	345.69	3412.4	36.41	5532	0.665	14670	60.95	63.23	52.83	1.10	2.82	10.69	14.20	15.54
5.098	1.900	427.74	402.04	402.20	3323.2	43.39	4989	0.666	13694	51.33	53.11	44.52	1.10	4.08	10.69	17.69	18.79
7.620	1.852	484.26	458.22	458.44	3236.8	50.68	4560	0.666	13666	46.83	48.28	40.22	1.10	5.57	10.69	22.85	23.70
10.160	1.956	538.28	514.57	514.86	3149.8	58.40	4209	0.666	14809	46.84	48.02	39.30	1.10	5.97	10.69	26.68	27.42
12.692	1.930	591.50	568.80	569.17	3063.1	66.31	3926	0.666	15366	45.33	46.32	37.49	1.27	6.75	10.69	31.41	32.04
2.540	-3.211	370.18	346.59	346.70	3410.9	36.53	5521	0.665	14804	61.39	63.65	53.12	1.10	2.83	10.69	14.39	15.71
7.633	-3.213	486.01	458.51	458.73	3236.4	50.72	4558	0.666	12937	44.31	45.75	38.40	1.10	5.57	10.69	21.72	22.62
12.720	-3.211	594.10	569.41	569.78	3062.1	66.40	3923	0.666	14133	41.66	42.64	34.95	1.28	6.76	10.69	29.01	29.69
2.499	3.221	369.26	345.69	345.80	3412.3	36.42	5531	0.665	14855	61.71	63.99	53.38	1.10	2.82	10.69	14.35	15.68
7.620	3.454	475.16	458.22	458.44	3236.8	50.68	4560	0.666	21104	72.31	73.77	57.51	1.10	5.57	10.69	34.52	35.09
12.700	3.180	580.31	568.97	569.34	3062.8	66.34	3925	0.666	31300	92.32	93.33	66.38	1.23	6.76	10.69	62.93	63.24

Table 3 (continued)

18° Pinfin Specimen
Experiment: 21 November 1990
Date: 5
Time: 10:07:26

TA	TB	M	P0	P0-P1	Vf	Qt	Wqt
K	K	kg/h	kPa	kPa	%	W	%
286.72	558.93	19.34	3504.3	718.91	75.24	7573.0	1.05

Hot-Side Temperatures:

X	Y	Tw	X	Y	Tw
cm	cm	K	cm	cm	K
1.332	0.485	350.84	2.549	-1.330	367.48
2.597	0.526	370.19	5.033	-1.444	408.58
2.681	0.923	374.32	7.571	-1.375	458.75
5.107	0.426	415.23	10.071	-1.476	504.56
7.626	0.498	451.40	2.465	-2.649	361.48
7.710	0.895	462.71	7.657	-2.616	463.10
10.111	0.396	505.06	12.699	-2.643	550.85
12.651	0.478	544.89	7.540	2.687	457.11
12.734	0.875	550.03	7.623	3.085	458.03
13.931	0.527	573.11			

Insulated-Side PRT Temperatures:

X	Y	Tw
cm	cm	K
-0.038	0.038	303.11
3.993	-0.224	378.47
11.648	-0.241	509.92
15.077	-1.430	562.08

Insulated-Side Thermocouple Temperatures and Calculated Data:

X	Y	Tw	Tf	Taw	P	V	RE	PR	h	NU	NUm	NUw	Wtw	Wtf	Wre	Wh	Wnu
													---------Uncertainties---------				
cm	cm	K	K	K	kPa	m/s			W/(m²·K)				K	K	%	%	%
-0.038	-0.229	301.18	286.65	286.76	3508.4	36.66	7802	0.664	0	0.00	0.00	0.00	1.10	0.50	10.69	0.00	0.00
1.293	-0.226	332.90	310.48	310.62	3444.9	40.37	7398	0.665	17210	76.86	79.86	65.47	1.10	2.13	10.69	12.34	13.87
2.527	-0.132	354.80	333.36	333.53	3386.1	44.03	7051	0.665	16340	69.57	72.00	59.34	1.10	2.29	10.69	13.48	14.89
3.802	0.056	375.74	355.46	355.65	3325.3	47.75	6750	0.666	16937	69.05	71.19	58.24	1.10	2.72	10.69	15.90	17.11
4.976	-0.008	396.76	375.99	376.22	3269.3	51.33	6496	0.666	16977	66.63	68.63	56.00	1.10	3.23	10.69	17.76	18.85
6.314	0.028	421.26	399.89	400.15	3205.5	55.62	6228	0.666	16736	62.98	64.81	52.84	1.10	3.86	10.69	19.98	20.96
7.607	0.033	444.13	423.07	423.37	3143.9	59.94	5992	0.666	16996	61.54	63.21	51.27	1.10	4.48	10.69	23.06	23.91
8.913	-0.013	467.47	446.43	446.78	3081.6	64.48	5775	0.666	17011	59.36	60.88	49.23	1.10	4.61	10.69	23.72	24.55
10.185	0.020	490.30	469.01	469.41	3021.0	69.06	5581	0.666	16591	55.96	57.34	46.40	1.10	4.81	10.69	24.45	25.25
11.453	0.066	511.45	490.96	491.42	2960.5	73.72	5408	0.666	16786	54.86	56.11	45.20	1.10	5.08	10.69	26.71	27.45
12.723	-0.033	533.42	512.67	513.19	2899.9	78.54	5248	0.666	16981	53.86	55.05	44.14	1.10	5.44	10.69	28.16	28.87
13.993	0.025	556.64	535.91	536.50	2839.4	83.81	5089	0.666	18785	57.78	59.00	46.40	1.13	5.94	10.69	30.62	31.26
15.240	-0.058	565.71	558.11	558.78	2779.9	89.11	4948	0.666	37865	113.23	114.07	77.99	1.17	6.24	10.69	92.69	92.91
2.565	-1.880	352.11	334.03	334.20	3384.3	44.15	7041	0.665	19372	82.37	84.79	68.13	1.10	2.30	10.69	15.55	16.78
5.032	-1.892	396.59	376.99	377.21	3266.6	51.50	6485	0.666	18013	70.57	72.57	58.68	1.10	3.26	10.69	18.81	19.84
7.620	-1.938	444.41	423.30	423.61	3143.3	59.99	5990	0.666	16953	61.36	63.02	51.14	1.10	4.48	10.69	23.03	23.88
10.185	-1.951	490.91	469.01	469.41	3021.0	69.06	5581	0.666	16117	54.36	55.74	45.31	1.10	4.81	10.69	23.80	24.62
12.700	-1.913	533.78	512.27	512.79	2901.0	78.45	5251	0.666	16343	51.87	53.06	42.80	1.10	5.43	10.69	27.16	27.89
2.494	1.925	352.56	332.78	332.94	3387.7	43.94	7059	0.665	17756	75.69	78.13	63.63	1.10	2.28	10.69	14.35	15.68
5.098	1.900	399.42	378.16	378.38	3263.5	51.71	6471	0.666	16610	64.93	66.91	54.76	1.10	3.29	10.69	17.62	18.72
7.620	1.852	444.89	423.30	423.61	3143.3	59.99	5990	0.666	16576	59.99	61.65	50.19	1.10	4.48	10.69	22.56	23.43
10.160	1.956	488.32	468.57	468.97	3022.1	68.97	5585	0.666	17923	60.50	61.89	49.49	1.10	4.81	10.69	26.25	27.00
12.692	1.930	531.11	512.13	512.65	2901.4	78.42	5252	0.666	18571	58.95	60.14	47.54	1.10	5.43	10.69	30.67	31.32
2.540	-3.211	353.54	333.59	333.76	3385.5	44.07	7047	0.665	17560	74.73	77.16	62.93	1.10	2.29	10.69	14.30	15.63
7.633	-3.213	447.70	423.54	423.84	3142.6	60.03	5988	0.666	14782	53.48	55.14	45.63	1.10	4.48	10.69	20.32	21.28
12.720	-3.211	535.22	512.62	513.14	2900.1	78.53	5248	0.666	15552	49.33	50.51	41.05	1.10	5.44	10.69	25.92	26.68
2.499	3.221	352.53	332.87	333.03	3387.4	43.95	7058	0.665	17863	76.13	78.57	63.93	1.10	2.28	10.69	14.43	15.75
7.620	3.454	437.51	423.30	423.61	3143.3	59.99	5990	0.666	25378	91.86	93.54	70.96	1.10	4.48	10.69	33.78	34.37
12.700	3.180	522.13	512.27	512.79	2901.0	78.45	5251	0.666	36708	116.50	117.73	81.64	1.10	5.43	10.69	59.67	60.00

Table 3 (continued)

18° Pinfin Specimen
Experiment: 21 November 1990
Date: 5
Time: 10:15:57

TA	TB	M	P0	P0-P1	Vf	Qt	Wqt
K	K	kg/h	kPa	kPa	%	W	%
285.46	510.45	23.41	3508.5	990.38	75.24	7567.0	1.07

Hot-Side Temperatures:

X	Y	Tw	X	Y	Tw
cm	cm	K	cm	cm	K
1.332	0.485	341.54	2.549	-1.330	354.80
2.597	0.526	357.13	5.033	-1.444	388.75
2.681	0.923	360.83	7.571	-1.375	430.63
5.107	0.426	394.51	10.071	-1.476	468.65
7.626	0.498	422.60	2.465	-2.649	349.23
7.710	0.895	433.63	7.657	-2.616	434.49
10.111	0.396	468.50	12.699	-2.643	507.01
12.651	0.478	500.79	7.540	2.687	428.71
12.734	0.875	506.28	7.623	3.085	429.94
13.931	0.527	524.90			

Insulated-Side PRT Temperatures:

X	Y	Tw
cm	cm	K
-0.038	0.038	299.21
3.993	-0.224	361.81
11.648	-0.241	470.22
15.077	-1.430	513.67

Insulated-Side Thermocouple Temperatures and Calculated Data:

													---------Uncertainties----------				
X	Y	Tw	Tf	Taw	P	V	RE	PR	h	NU	NUm	NUw	Wtw	Wtf	Wre	Wh	Wnu
cm	cm	K	K	K	kPa	m/s			W/(m²·K)				K	K	%	%	%
-0.038	-0.229	297.51	285.34	285.51	3514.1	44.11	9474	0.664	0	0.00	0.00	0.00	1.10	0.50	10.69	0.00	0.00
1.293	-0.226	324.06	305.02	305.22	3426.7	48.28	9065	0.665	20338	91.93	95.04	76.01	1.10	1.78	10.69	12.64	14.13
2.527	-0.132	342.24	323.92	324.15	3345.7	52.44	8705	0.665	19202	83.37	85.93	69.21	1.10	1.90	10.69	13.68	15.07
3.802	0.056	359.41	342.16	342.43	3261.9	56.75	8387	0.666	20022	83.79	86.09	68.75	1.10	2.25	10.69	16.06	17.26
4.976	-0.008	376.83	359.11	359.42	3184.8	60.94	8116	0.666	20016	81.07	83.25	66.35	1.10	2.68	10.69	17.76	18.85
6.314	0.028	397.19	378.83	379.19	3096.9	66.04	7826	0.666	19614	76.61	78.63	62.73	1.10	3.19	10.69	19.74	20.73
7.607	0.033	416.01	397.95	398.38	3012.0	71.27	7567	0.666	19994	75.52	77.39	61.39	1.10	3.70	10.69	22.76	23.62
8.913	-0.013	435.28	417.22	417.72	2926.2	76.85	7326	0.666	20022	73.22	74.95	59.29	1.10	3.81	10.69	23.40	24.24
10.185	0.020	454.19	435.84	436.41	2842.6	82.58	7109	0.666	19476	69.13	70.72	56.05	1.10	3.98	10.69	24.04	24.86
11.453	0.066	471.77	453.93	454.59	2759.4	88.55	6913	0.666	19554	67.49	68.94	54.47	1.10	4.20	10.69	26.05	26.81
12.723	-0.033	489.91	471.82	472.57	2675.9	94.85	6731	0.666	19800	66.55	67.94	53.44	1.10	4.50	10.69	27.45	28.17
13.993	0.025	509.15	490.95	491.83	2592.5	101.81	6549	0.666	21818	71.34	72.78	56.13	1.10	4.91	10.69	29.65	30.31
15.240	-0.058	516.17	509.23	510.23	2510.6	109.00	6385	0.666	44123	140.68	141.73	94.36	1.10	5.16	10.69	89.86	90.08
2.565	-1.880	340.01	324.47	324.70	3343.2	52.57	8695	0.665	22642	98.19	100.75	79.02	1.10	1.91	10.69	15.71	16.94
5.032	-1.892	376.86	359.92	360.24	3181.1	61.15	8104	0.666	20995	84.90	87.07	68.86	1.10	2.70	10.69	18.61	19.66
7.620	-1.938	416.46	398.14	398.57	3011.1	71.32	7564	0.666	19700	74.38	76.24	60.63	1.10	3.70	10.69	22.48	23.35
10.185	-1.951	455.15	435.84	436.41	2842.6	82.58	7109	0.666	18483	65.60	67.18	53.70	1.10	3.98	10.69	22.90	23.76
12.700	-1.913	490.79	471.49	472.24	2677.5	94.73	6734	0.666	18486	62.16	63.55	50.55	1.10	4.49	10.69	25.73	26.49
2.494	1.925	340.22	323.43	323.67	3347.8	52.33	8713	0.665	21028	91.39	93.97	74.61	1.10	1.90	10.69	14.66	15.96
5.098	1.900	378.90	360.89	361.21	3176.8	61.39	8089	0.666	19739	79.68	81.84	65.37	1.10	2.72	10.69	17.73	18.82
7.620	1.852	416.45	398.14	398.57	3011.1	71.32	7564	0.666	19710	74.42	76.28	60.66	1.10	3.70	10.69	22.49	23.36
10.160	1.956	452.40	435.48	436.05	2844.3	82.46	7113	0.666	21181	75.22	76.81	60.05	1.10	3.97	10.69	25.98	26.73
12.692	1.930	487.78	471.37	472.13	2678.0	94.69	6735	0.666	21890	73.62	75.02	58.01	1.10	4.49	10.69	30.20	30.86
2.540	-3.211	341.27	324.11	324.34	3344.8	52.48	8701	0.665	20499	88.97	91.53	72.97	1.10	1.91	10.69	14.43	15.76
7.633	-3.213	419.73	398.33	398.76	3010.3	71.38	7562	0.666	16810	63.45	65.30	53.22	1.10	3.70	10.69	19.45	20.45
12.720	-3.211	492.66	471.77	472.53	2676.1	94.83	6731	0.666	17052	57.31	58.69	47.28	1.10	4.50	10.69	23.86	24.68
2.499	3.221	340.25	323.51	323.74	3347.5	52.35	8712	0.665	21075	91.58	94.16	74.74	1.10	1.90	10.69	14.69	16.00
7.620	3.454	410.44	398.14	398.57	3011.1	71.32	7564	0.666	29697	112.14	114.03	84.28	1.10	3.70	10.69	33.15	33.75
12.700	3.180	480.28	471.49	472.24	2677.5	94.73	6734	0.666	42628	143.34	144.80	97.86	1.10	4.49	10.69	57.86	58.20

Table 3 (continued)

18° Pinfin Specimen
Experiment: 21 November 1990
Date: 5
Time: 10:25:30

TA	TB	M	P0	P0-P1	Vf	Qt	Wqt
K	K	kg/h	kPa	kPa	%	W	%
284.05	473.56	27.82	3504.1	1387.91	75.30	7558.0	1.09

Hot-Side Temperatures:

X	Y	Tw	X	Y	Tw
cm	cm	K	cm	cm	K
1.332	0.485	333.75	2.549	-1.330	344.52
2.597	0.526	346.53	5.033	-1.444	372.87
2.681	0.923	349.82	7.571	-1.375	408.42
5.107	0.426	377.98	10.071	-1.476	440.39
7.626	0.498	400.05	2.465	-2.649	339.25
7.710	0.895	410.76	7.657	-2.616	411.84
10.111	0.396	439.85	12.699	-2.643	472.91
12.651	0.478	466.43	7.540	2.687	406.38
12.734	0.875	471.99	7.623	3.085	407.88
13.931	0.527	487.17			

Insulated-Side
PRT Temperatures:

X	Y	Tw
cm	cm	K
-0.038	0.038	295.73
3.993	-0.224	348.57
11.648	-0.241	439.56
15.077	-1.430	476.21

Insulated-Side Thermocouple Temperatures and Calculated Data:

													---------Uncertainties				----------
X	Y	Tw	Tf	Taw	P	V	RE	PR	h	NU	NUm	NUw	Wtw	Wtf	Wre	Wh	Wnu
cm	cm	K	K	K	kPa	m/s			W/(m²·K)				K	K	%	%	%
-0.038	-0.229	294.23	283.89	284.12	3512.0	52.20	11298	0.664	0	0.00	0.00	0.00	1.10	0.50	10.69	0.00	0.00
1.293	-0.226	316.73	300.44	300.71	3389.5	57.14	10885	0.665	23897	109.13	112.35	87.52	1.10	1.51	10.69	13.16	14.60
2.527	-0.132	332.08	316.32	316.64	3275.9	62.17	10515	0.665	22480	99.20	101.89	80.08	1.10	1.62	10.69	14.14	15.49
3.802	0.056	346.46	331.65	332.03	3158.5	67.52	10184	0.666	23540	100.64	103.09	80.25	1.10	1.91	10.69	16.51	17.68
4.976	-0.008	361.07	345.89	346.33	3050.5	72.84	9898	0.666	23616	98.15	100.50	78.05	1.10	2.26	10.69	18.15	19.22
6.314	0.028	378.27	362.45	362.98	2927.3	79.45	9589	0.666	23064	92.88	95.09	74.00	1.10	2.69	10.69	19.98	20.95
7.607	0.033	393.98	378.49	379.12	2808.3	86.40	9310	0.666	23701	92.69	94.76	73.23	1.10	3.12	10.69	23.09	23.94
8.913	-0.013	410.12	394.65	395.40	2688.1	94.04	9048	0.666	23857	90.69	92.63	71.34	1.10	3.20	10.69	23.84	24.67
10.185	0.020	425.98	410.25	411.13	2571.0	102.12	8811	0.666	23291	86.23	88.03	67.94	1.10	3.35	10.69	24.55	25.35
11.453	0.066	440.83	425.39	426.42	2454.3	110.85	8595	0.666	23298	84.15	85.82	66.08	1.10	3.54	10.69	26.48	27.22
12.723	-0.033	456.07	440.33	441.55	2337.4	120.40	8394	0.666	23610	83.28	84.90	65.08	1.10	3.79	10.69	27.88	28.59
13.993	0.025	472.30	456.29	457.74	2220.5	131.25	8191	0.666	25923	89.23	90.94	68.33	1.10	4.13	10.69	29.97	30.63
15.240	-0.058	477.87	471.49	473.21	2105.7	142.94	8008	0.666	56094	188.78	190.18	120.40	1.10	4.34	10.69	97.00	97.20
2.565	-1.880	330.22	316.79	317.11	3272.4	62.32	10504	0.665	26414	116.44	119.13	91.03	1.10	1.62	10.69	16.22	17.41
5.032	-1.892	361.25	346.58	347.02	3045.3	73.10	9885	0.666	24488	101.64	103.99	80.24	1.10	2.28	10.69	18.83	19.86
7.620	-1.938	394.58	378.66	379.29	2807.1	86.47	9308	0.666	23020	90.00	92.06	71.51	1.10	3.12	10.69	22.50	23.37
10.185	-1.951	427.18	410.25	411.13	2571.0	102.12	8811	0.666	21542	79.75	81.54	63.79	1.10	3.35	10.69	22.83	23.69
12.700	-1.913	457.12	440.05	441.27	2339.5	120.22	8398	0.666	21608	76.25	77.86	60.62	1.10	3.78	10.69	25.65	26.42
2.494	1.925	330.23	315.92	316.24	3278.9	62.03	10524	0.665	24849	109.75	112.46	86.88	1.10	1.61	10.69	15.29	16.54
5.098	1.900	362.73	347.39	347.84	3039.2	73.42	9870	0.666	23428	97.09	99.43	77.31	1.10	2.30	10.69	18.21	19.27
7.620	1.852	394.21	378.66	379.29	2807.1	86.47	9308	0.666	23582	92.20	94.26	72.91	1.10	3.12	10.69	23.01	23.86
10.160	1.956	424.42	409.95	410.82	2573.3	101.96	8816	0.666	25453	94.28	96.10	73.00	1.10	3.35	10.69	26.65	27.39
12.692	1.930	454.02	439.96	441.17	2340.2	120.15	8399	0.666	26647	94.05	95.69	71.73	1.10	3.78	10.69	31.30	31.93
2.540	-3.211	331.33	316.48	316.80	3274.7	62.22	10511	0.665	23880	105.34	108.03	84.03	1.10	1.62	10.69	14.87	16.16
7.633	-3.213	397.61	378.82	379.45	2805.9	86.55	9305	0.666	19383	75.76	77.80	62.18	1.10	3.12	10.69	19.24	20.26
12.720	-3.211	459.23	440.29	441.51	2337.6	120.38	8394	0.666	19343	68.23	69.83	55.38	1.10	3.79	10.69	23.13	23.98
2.499	3.221	330.27	315.98	316.30	3278.5	62.05	10522	0.665	24881	109.88	112.59	86.96	1.10	1.61	10.69	15.31	16.57
7.620	3.454	389.14	378.66	379.29	2807.1	86.47	9308	0.666	35724	139.67	141.78	101.26	1.10	3.12	10.69	34.13	34.71
12.700	3.180	447.66	440.05	441.27	2339.5	120.22	8398	0.666	53549	188.97	190.76	122.93	1.10	3.78	10.69	61.93	62.25

Table 3 (continued)

18° Pinfin Specimen
Experiment: 6
Date: 23 November 1990
Time: 10:47:55

TA	TB	M	P0	P0-P1	Vf	Qt	Wqt
K	K	kg/h	kPa	kPa	%	W	%
288.36	690.55	15.03	3540.5	563.65	93.30	8708.0	1.03

Hot-Side Temperatures:

X	Y	Tw	X	Y	Tw
cm	cm	K	cm	cm	K
1.332	0.485	378.65	2.549	-1.330	404.21
2.597	0.526	408.19	5.033	-1.444	465.42
2.681	0.923	414.19	7.571	-1.375	539.14
5.107	0.426	474.88	10.071	-1.476	607.04
7.626	0.498	531.98	2.465	-2.649	396.47
7.710	0.895	545.24	7.657	-2.616	545.20
10.111	0.396	608.76	12.699	-2.643	676.38
12.651	0.478	670.31	7.540	2.687	537.55
12.734	0.875	674.26	7.623	3.085	537.49
13.931	0.527	710.81			

Insulated-Side PRT Temperatures:

X	Y	Tw
cm	cm	K
-0.038	0.038	312.33
3.993	-0.224	423.51
11.648	-0.241	619.06
15.077	-1.430	695.77

Insulated-Side Thermocouple Temperatures and Calculated Data:

													---------Uncertainties---------				
X	Y	Tw	Tf	Taw	P	V	RE	PR	h	NU	NUm	NUw	Wtw	Wtf	Wre	Wh	Wnu
cm	cm	K	K	K	kPa	m/s			W/(m²·K)				K	K	%	%	%
-0.038	-0.229	310.01	288.33	288.39	3543.7	28.39	6043	0.664	0	0.00	0.00	0.00	1.10	0.50	10.69	0.00	0.00
1.293	-0.226	356.34	323.57	323.65	3493.9	32.24	5593	0.665	13490	58.59	61.78	52.27	1.10	3.11	10.69	11.77	13.36
2.527	-0.132	388.80	357.40	357.51	3447.8	36.02	5228	0.665	12778	51.89	54.35	46.16	1.10	3.35	10.69	12.90	14.37
3.802	0.056	420.23	390.08	390.21	3400.1	39.81	4925	0.666	13032	49.86	51.94	43.87	1.10	3.99	10.69	15.17	16.44
4.976	-0.008	451.38	420.44	420.60	3356.3	43.42	4678	0.666	13027	47.35	49.24	41.44	1.10	4.76	10.69	17.06	18.20
6.314	0.028	487.13	455.79	455.98	3306.2	47.73	4425	0.666	13038	44.84	46.51	38.99	1.10	5.69	10.69	19.60	20.60
7.607	0.033	521.19	490.07	490.30	3257.9	52.03	4209	0.666	13128	42.94	44.42	37.05	1.10	6.61	10.69	22.55	23.42
8.913	-0.013	555.87	524.62	524.89	3209.1	56.51	4015	0.666	13063	40.76	42.08	35.00	1.13	6.80	10.69	23.10	23.95
10.185	0.020	589.48	558.03	558.34	3161.5	60.97	3846	0.666	12794	38.25	39.42	32.78	1.26	7.11	10.69	24.00	24.82
11.453	0.066	621.17	590.50	590.86	3114.1	65.46	3698	0.666	12759	36.67	37.71	31.31	1.39	7.50	10.69	25.96	26.72
12.723	-0.033	655.02	622.63	623.04	3066.7	70.05	3564	0.666	12351	34.21	35.18	29.32	1.53	8.04	10.69	26.34	27.09
13.993	0.025	690.10	657.02	657.49	3019.2	75.05	3433	0.666	13343	35.59	36.56	30.19	1.67	8.77	10.69	28.03	28.73
15.240	-0.058	704.92	689.89	690.43	2972.6	80.01	3317	0.666	20803	53.63	54.27	41.75	1.73	9.21	10.69	66.07	66.37
2.565	-1.880	384.96	358.39	358.50	3446.4	36.13	5218	0.665	15078	61.11	63.56	52.83	1.10	3.37	10.69	14.78	16.08
5.032	-1.892	450.63	421.91	422.07	3354.2	43.60	4667	0.666	14054	50.97	52.85	44.03	1.10	4.80	10.69	18.34	19.40
7.620	-1.938	520.97	490.41	490.64	3257.4	52.08	4207	0.666	13374	43.72	45.20	37.61	1.10	6.62	10.69	22.97	23.83
10.185	-1.951	589.39	558.03	558.34	3161.5	60.97	3846	0.666	12834	38.37	39.54	32.87	1.26	7.11	10.69	24.07	24.89
12.700	-1.913	653.65	622.03	622.44	3067.5	69.97	3566	0.666	12641	35.04	36.01	29.92	1.52	8.02	10.69	26.92	27.66
2.494	1.925	385.67	356.54	356.65	3449.0	35.92	5237	0.665	13805	56.15	58.63	49.31	1.10	3.34	10.69	13.65	15.04
5.098	1.900	455.27	423.64	423.80	3351.7	43.81	4654	0.666	12774	46.19	48.06	40.53	1.10	4.85	10.69	16.98	18.12
7.620	1.852	522.48	490.41	490.64	3257.4	52.08	4207	0.666	12738	41.65	43.13	36.12	1.10	6.62	10.69	21.96	22.85
10.160	1.956	587.00	557.38	557.69	3162.5	60.88	3850	0.666	13600	40.69	41.87	34.52	1.25	7.10	10.69	25.38	26.15
12.692	1.930	651.77	621.83	622.24	3067.8	69.94	3567	0.666	13351	37.01	37.98	31.31	1.51	8.02	10.69	28.35	29.05
2.540	-3.211	387.26	357.74	357.85	3447.3	36.06	5225	0.665	13587	55.14	57.60	48.54	1.10	3.36	10.69	13.55	14.96
7.633	-3.213	525.36	490.76	490.98	3256.9	52.12	4205	0.666	11798	38.56	40.03	33.86	1.10	6.62	10.69	20.48	21.43
12.720	-3.211	655.30	622.55	622.96	3066.8	70.04	3564	0.666	12214	33.83	34.80	29.05	1.53	8.03	10.69	26.07	26.82
2.499	3.221	385.52	356.67	356.78	3448.9	35.94	5235	0.665	13934	56.66	59.14	49.68	1.10	3.34	10.69	13.76	15.14
7.620	3.454	510.77	490.41	490.64	3257.4	52.08	4207	0.666	20151	65.88	67.37	52.67	1.10	6.62	10.69	33.90	34.48
12.700	3.180	637.66	622.03	622.44	3067.5	69.97	3566	0.666	25936	71.89	72.88	53.63	1.46	8.02	10.69	53.99	54.36

Table 3 (continued)

18° Pinfin Specimen
Experiment: 6
Date: 23 November 1990
Time: 10:56:23

TA	TB	M	P0	P0-P1	Vf	Qt	Wqt
K	K	kg/h	kPa	kPa	%	W	%
287.85	610.19	19.07	3529.1	810.77	93.87	8845.0	1.04

Hot-Side Temperatures:

X	Y	Tw	X	Y	Tw
cm	cm	K	cm	cm	K
1.332	0.485	364.59	2.549	-1.330	383.92
2.597	0.526	387.44	5.033	-1.444	432.48
2.681	0.923	392.60	7.571	-1.375	491.85
5.107	0.426	440.80	10.071	-1.476	545.74
7.626	0.498	483.64	2.465	-2.649	376.85
7.710	0.895	496.62	7.657	-2.616	497.19
10.111	0.396	546.46	12.699	-2.643	601.09
12.651	0.478	594.06	7.540	2.687	489.93
12.734	0.875	598.99	7.623	3.085	490.60
13.931	0.527	628.04			

Insulated-Side PRT Temperatures:

X	Y	Tw
cm	cm	K
-0.038	0.038	307.39
3.993	-0.224	396.43
11.648	-0.241	551.77
15.077	-1.430	613.38

Insulated-Side Thermocouple Temperatures and Calculated Data:

													---------Uncertainties----------				
X	Y	Tw	Tf	Taw	P	V	RE	PR	h	NU	NUm	NUw	Wtw	Wtf	Wre	Wh	Wnu
cm	cm	K	K	K	kPa	m/s			W/(m²·K)				K	K	%	%	%
-0.038	-0.229	305.44	287.78	287.89	3533.7	36.04	7674	0.664	0	0.00	0.00	0.00	1.10	0.50	10.69	0.00	0.00
1.293	-0.226	342.77	316.00	316.14	3462.1	40.31	7210	0.665	16819	74.23	77.62	63.79	1.10	2.51	10.69	11.92	13.50
2.527	-0.132	368.59	343.10	343.27	3395.8	44.55	6819	0.665	16038	66.97	69.66	57.49	1.10	2.70	10.69	13.10	14.55
3.802	0.056	393.50	369.27	369.47	3327.2	48.87	6486	0.666	16537	65.69	68.03	55.74	1.10	3.21	10.69	15.46	16.70
4.976	-0.008	418.39	393.58	393.82	3264.1	53.04	6209	0.666	16582	63.08	65.24	53.28	1.10	3.82	10.69	17.35	18.46
6.314	0.028	447.01	421.88	422.17	3192.1	58.07	5921	0.666	16612	60.26	62.21	50.61	1.10	4.56	10.69	19.88	20.86
7.607	0.033	474.03	449.33	449.66	3122.6	63.17	5669	0.666	16911	58.75	60.50	48.92	1.10	5.30	10.69	23.05	23.90
8.913	-0.013	501.55	476.99	477.39	3052.4	68.55	5441	0.666	17010	56.71	58.30	46.93	1.10	5.45	10.69	23.83	24.66
10.185	0.020	528.39	503.73	504.19	2984.0	74.00	5239	0.666	16717	53.67	55.10	44.32	1.10	5.69	10.69	24.76	25.55
11.453	0.066	553.42	529.71	530.24	2915.8	79.58	5060	0.666	16946	52.54	53.82	43.07	1.12	6.01	10.69	27.14	27.86
12.723	-0.033	579.54	555.41	556.02	2847.5	85.40	4896	0.666	17062	51.19	52.40	41.77	1.23	6.44	10.69	28.58	29.27
13.993	0.025	607.10	582.91	583.62	2779.2	91.78	4734	0.666	18817	54.59	55.82	43.67	1.34	7.03	10.69	31.05	31.68
15.240	-0.058	618.39	609.20	610.01	2712.2	98.25	4591	0.666	36531	102.77	103.62	70.97	1.38	7.38	10.69	90.62	90.84
2.565	-1.880	365.42	343.90	344.06	3393.7	44.68	6808	0.665	18976	79.11	81.80	65.84	1.10	2.71	10.69	15.06	16.33
5.032	-1.892	417.90	394.76	395.00	3261.1	53.25	6197	0.666	17800	67.57	69.72	56.33	1.10	3.85	10.69	18.57	19.61
7.620	-1.938	474.16	449.60	449.94	3121.9	63.22	5667	0.666	17011	59.07	60.82	49.14	1.10	5.30	10.69	23.21	24.05
10.185	-1.951	528.87	503.73	504.19	2984.0	74.00	5239	0.666	16394	52.63	54.06	43.61	1.10	5.69	10.69	24.31	25.12
12.700	-1.913	579.49	554.93	555.54	2848.7	85.29	4899	0.666	16736	50.24	51.45	41.14	1.23	6.43	10.69	28.06	28.77
2.494	1.925	365.90	342.41	342.58	3397.5	44.44	6828	0.665	17446	72.94	75.65	61.68	1.10	2.69	10.69	13.94	15.31
5.098	1.900	421.27	396.15	396.39	3257.5	53.49	6182	0.666	16406	62.13	64.27	52.55	1.10	3.89	10.69	17.39	18.51
7.620	1.852	474.85	449.60	449.94	3121.9	63.22	5667	0.666	16542	57.44	59.19	48.02	1.10	5.30	10.69	22.62	23.48
10.160	1.956	526.03	503.20	503.66	2985.3	73.89	5243	0.666	18106	58.17	59.61	47.35	1.10	5.69	10.69	26.65	27.39
12.692	1.930	576.75	554.77	555.38	2849.2	85.25	4900	0.666	18738	56.26	57.48	45.12	1.21	6.43	10.69	31.25	31.88
2.540	-3.211	367.49	343.37	343.54	3395.1	44.60	6815	0.665	16947	70.73	73.42	60.12	1.10	2.70	10.69	13.70	15.09
7.633	-3.213	478.54	449.88	450.22	3121.2	63.28	5665	0.666	14548	50.50	52.24	43.18	1.10	5.30	10.69	20.11	21.08
12.720	-3.211	581.73	555.34	555.96	2847.7	85.38	4896	0.666	15564	46.70	47.91	38.74	1.23	6.44	10.69	26.21	26.96
2.499	3.221	365.85	342.52	342.68	3397.3	44.46	6827	0.665	17555	73.39	76.10	61.99	1.10	2.69	10.69	14.02	15.38
7.620	3.454	465.53	449.60	449.94	3121.9	63.22	5667	0.666	26434	91.79	93.56	70.12	1.10	5.30	10.69	35.30	35.86
12.700	3.180	565.76	554.93	555.54	2848.7	85.29	4899	0.666	39228	117.77	119.03	80.72	1.17	6.43	10.69	64.31	64.62

Table 3 (continued)

18° Pinfin Specimen
Experiment: 6
Date: 23 November 1990
Time: 11:03:40

TA	TB	M	P0	P0-P1	Vf	Qt	Wqt
K	K	kg/h	kPa	kPa	%	W	%
287.09	558.53	22.74	3515.6	1096.10	93.76	8869.0	1.05

Hot-Side Temperatures:

X	Y	Tw	X	Y	Tw
cm	cm	K	cm	cm	K
1.332	0.485	355.13	2.549	-1.330	370.84
2.597	0.526	373.86	5.033	-1.444	411.76
2.681	0.923	378.50	7.571	-1.375	462.18
5.107	0.426	418.99	10.071	-1.476	507.84
7.626	0.498	453.21	2.465	-2.649	364.21
7.710	0.895	465.90	7.657	-2.616	467.18
10.111	0.396	507.80	12.699	-2.643	554.69
12.651	0.478	546.90	7.540	2.687	460.05
12.734	0.875	552.76	7.623	3.085	461.03
13.931	0.527	575.78			

Insulated-Side PRT Temperatures:

X	Y	Tw
cm	cm	K
-0.038	0.038	303.78
3.993	-0.224	379.11
11.648	-0.241	509.79
15.077	-1.430	561.98

Insulated-Side Thermocouple Temperatures and Calculated Data:

X	Y	Tw	Tf	Taw	P	V	RE	PR	h	NU	NUm	NUw	---------Uncertainties--------- Wtw	Wtf	Wre	Wh	Wnu
cm	cm	K	K	K	kPa	m/s			W/(m²·K)				K	K	%	%	%
-0.038	-0.229	302.10	287.00	287.15	3521.8	42.99	9167	0.664	0	0.00	0.00	0.00	1.10	0.50	10.69	0.00	0.00
1.293	-0.226	333.77	310.74	310.93	3425.1	47.78	8694	0.665	19670	87.81	91.33	73.35	1.10	2.12	10.69	12.09	13.64
2.527	-0.132	355.57	333.54	333.77	3335.4	52.58	8288	0.665	18685	79.54	82.39	66.55	1.10	2.28	10.69	13.20	14.64
3.802	0.056	376.35	355.55	355.83	3242.7	57.58	7936	0.666	19417	79.17	81.68	65.43	1.10	2.71	10.69	15.57	16.80
4.976	-0.008	397.32	376.00	376.33	3157.3	62.47	7640	0.666	19461	76.40	78.75	62.90	1.10	3.22	10.69	17.37	18.49
6.314	0.028	421.51	399.79	400.19	3060.1	68.46	7326	0.666	19411	73.08	75.24	59.93	1.10	3.84	10.69	19.74	20.73
7.607	0.033	444.21	422.86	423.33	2966.1	74.63	7049	0.666	19790	71.70	73.67	58.32	1.10	4.46	10.69	22.86	23.71
8.913	-0.013	467.33	446.11	446.67	2871.1	81.27	6795	0.666	19948	69.67	71.47	56.33	1.10	4.59	10.69	23.66	24.49
10.185	0.020	490.01	468.57	469.22	2778.7	88.14	6568	0.666	19524	65.92	67.56	53.26	1.10	4.79	10.69	24.48	25.28
11.453	0.066	511.17	490.39	491.15	2686.5	95.34	6365	0.666	19674	64.38	65.87	51.71	1.10	5.06	10.69	26.64	27.38
12.723	-0.033	533.07	511.95	512.85	2594.2	103.02	6178	0.666	19901	63.21	64.63	50.48	1.10	5.42	10.69	28.08	28.78
13.993	0.025	556.16	535.03	536.07	2501.8	111.57	5992	0.666	22060	67.96	69.42	53.08	1.13	5.91	10.69	30.58	31.23
15.240	-0.058	564.95	557.05	558.28	2411.2	120.47	5827	0.666	45984	137.75	138.82	90.71	1.17	6.22	10.69	95.67	95.88
2.565	-1.880	352.86	334.21	334.44	3332.6	52.73	8277	0.665	22065	93.80	96.64	76.01	1.10	2.29	10.69	15.15	16.42
5.032	-1.892	397.16	376.99	377.32	3153.3	62.71	7626	0.666	20602	80.73	83.08	65.74	1.10	3.25	10.69	18.36	19.42
7.620	-1.938	444.72	423.10	423.57	2965.1	74.70	7047	0.666	19533	70.74	72.71	57.68	1.10	4.47	10.69	22.61	23.48
10.185	-1.951	490.95	468.57	469.22	2778.7	88.14	6568	0.666	18673	63.05	64.69	51.37	1.10	4.79	10.69	23.48	24.32
12.700	-1.913	533.58	511.56	512.45	2595.8	102.87	6182	0.666	19018	60.44	61.86	48.69	1.10	5.41	10.69	26.90	27.63
2.494	1.925	353.01	332.96	333.19	3337.8	52.45	8298	0.665	20592	87.76	90.63	72.10	1.10	2.27	10.69	14.20	15.54
5.098	1.900	399.57	378.15	378.49	3148.5	63.00	7610	0.666	19417	75.93	78.27	62.52	1.10	3.28	10.69	17.54	18.64
7.620	1.852	444.70	423.10	423.57	2965.1	74.70	7047	0.666	19547	70.80	72.77	57.72	1.10	4.47	10.69	22.62	23.49
10.160	1.956	487.73	468.13	468.78	2780.5	88.00	6573	0.666	21425	72.39	74.04	57.47	1.10	4.79	10.69	26.67	27.41
12.692	1.930	530.40	511.42	512.31	2596.4	102.82	6183	0.666	22199	70.56	71.99	55.17	1.10	5.41	10.69	31.17	31.80
2.540	-3.211	354.71	333.77	334.00	3334.4	52.63	8284	0.665	19646	83.59	86.44	69.28	1.10	2.28	10.69	13.75	15.13
7.633	-3.213	448.99	423.33	423.80	2964.2	74.76	7044	0.666	16399	59.37	61.32	49.98	1.10	4.47	10.69	19.28	20.29
12.720	-3.211	536.38	511.90	512.79	2594.4	103.00	6179	0.666	17056	54.18	55.59	44.53	1.10	5.42	10.69	24.29	25.09
2.499	3.221	352.96	333.05	333.28	3337.4	52.47	8296	0.665	20721	88.30	91.17	72.46	1.10	2.27	10.69	14.28	15.62
7.620	3.454	436.85	423.10	423.57	2965.1	74.70	7047	0.666	31104	112.65	114.65	83.60	1.10	4.47	10.69	35.17	35.73
12.700	3.180	520.88	511.56	512.45	2595.8	102.87	6182	0.666	47642	151.40	152.91	99.87	1.10	5.41	10.69	65.81	66.11

Table 3 (continued)

18° Pinfin Specimen
Experiment: 6
Date: 23 November 1990
Time: 11:11:26

TA	TB	M	P0	P0-P1	Vf	Qt	Wqt
K	K	kg/h	kPa	kPa	%	W	%
286.47	528.27	25.64	3511.5	1380.53	94.04	8899.0	1.06

Hot-Side Temperatures:

X	Y	Tw	X	Y	Tw
cm	cm	K	cm	cm	K
1.332	0.485	349.32	2.549	-1.330	363.03
2.597	0.526	365.71	5.033	-1.444	399.46
2.681	0.923	370.07	7.571	-1.375	444.73
5.107	0.426	406.07	10.071	-1.476	485.46
7.626	0.498	435.30	2.465	-2.649	356.53
7.710	0.895	447.84	7.657	-2.616	449.32
10.111	0.396	485.06	12.699	-2.643	527.26
12.651	0.478	519.36	7.540	2.687	442.46
12.734	0.875	525.60	7.623	3.085	443.62
13.931	0.527	545.81			

Insulated-Side PRT Temperatures:

X	Y	Tw
cm	cm	K
-0.038	0.038	301.45
3.993	-0.224	368.70
11.648	-0.241	484.96
15.077	-1.430	531.57

Insulated-Side Thermocouple Temperatures and Calculated Data:

X	Y	Tw	Tf	Taw	P	V	RE	PR	h	NU	NUm	NUw	Wtw	Wtf	Wre	Wh	Wnu
													---------Uncertainties----------				
cm	cm	K	K	K	kPa	m/s			W/(m²·K)				K	K	%	%	%
-0.038	-0.229	299.97	286.35	286.55	3519.4	48.41	10353	0.664	0	0.00	0.00	0.00	1.10	0.50	10.69	0.00	0.00
1.293	-0.226	328.34	307.48	307.72	3397.5	53.75	9876	0.665	21852	98.25	101.86	80.47	1.10	1.90	10.69	12.24	13.78
2.527	-0.132	347.79	327.76	328.06	3284.5	59.18	9459	0.665	20713	89.23	92.19	73.32	1.10	2.04	10.69	13.31	14.73
3.802	0.056	366.30	347.35	347.70	3167.8	64.94	9095	0.666	21498	89.07	91.71	72.33	1.10	2.41	10.69	15.60	16.83
4.976	-0.008	385.04	365.53	365.95	3060.3	70.66	8785	0.666	21470	85.94	88.43	69.61	1.10	2.87	10.69	17.27	18.39
6.314	0.028	406.73	386.69	387.20	2937.8	77.78	8454	0.666	21247	81.86	84.17	66.18	1.10	3.42	10.69	19.41	20.41
7.607	0.033	426.90	407.19	407.80	2819.4	85.26	8160	0.666	21701	80.72	82.85	64.73	1.10	3.97	10.69	22.44	23.31
8.913	-0.013	447.51	427.84	428.58	2699.8	93.47	7888	0.666	21843	78.54	80.51	62.64	1.10	4.09	10.69	23.19	24.04
10.185	0.020	467.74	447.78	448.65	2583.3	102.15	7645	0.666	21330	74.34	76.15	59.32	1.10	4.27	10.69	23.92	24.74
11.453	0.066	486.61	467.13	468.17	2467.3	111.50	7425	0.666	21437	72.57	74.22	57.61	1.10	4.51	10.69	25.95	26.71
12.723	-0.033	506.05	486.24	487.48	2351.0	121.73	7223	0.666	21748	71.62	73.21	56.52	1.10	4.83	10.69	27.41	28.13
13.993	0.025	526.63	506.66	508.15	2234.7	133.36	7020	0.666	24066	77.03	78.69	59.45	1.10	5.26	10.69	29.74	30.40
15.240	-0.058	534.04	526.11	527.91	2120.5	145.86	6839	0.666	50213	156.58	157.87	101.54	1.10	5.53	10.69	92.96	93.17
2.565	-1.880	345.37	328.36	328.65	3281.0	59.35	9448	0.665	24384	104.92	107.88	83.47	1.10	2.05	10.69	15.24	16.50
5.032	-1.892	384.93	366.41	366.83	3055.1	70.95	8770	0.666	22666	90.58	93.07	72.58	1.10	2.89	10.69	18.20	19.27
7.620	-1.938	427.45	407.40	408.01	2818.2	85.34	8158	0.666	21327	79.30	81.42	63.80	1.10	3.97	10.69	22.11	23.00
10.185	-1.951	468.79	447.78	448.65	2583.3	102.15	7645	0.666	20222	70.48	72.28	56.82	1.10	4.27	10.69	22.77	23.63
12.700	-1.913	506.83	485.89	487.13	2353.1	121.53	7226	0.666	20461	67.41	68.99	53.83	1.10	4.82	10.69	25.88	26.64
2.494	1.925	345.40	327.25	327.54	3287.5	59.03	9470	0.665	22916	98.83	101.81	79.63	1.10	2.03	10.69	14.37	15.70
5.098	1.900	386.84	367.45	367.88	3049.1	71.29	8754	0.666	21659	86.39	88.87	69.83	1.10	2.92	10.69	17.59	18.70
7.620	1.852	427.01	407.40	408.01	2818.2	85.34	8158	0.666	21814	81.11	83.24	64.97	1.10	3.97	10.69	22.58	23.45
10.160	1.956	465.38	447.39	448.27	2585.6	101.98	7650	0.666	23806	83.02	84.84	64.84	1.10	4.26	10.69	26.48	27.23
12.692	1.930	503.19	485.76	487.00	2353.8	121.47	7227	0.666	24895	82.04	83.65	63.02	1.10	4.82	10.69	31.18	31.81
2.540	-3.211	347.01	327.97	328.26	3283.3	59.24	9455	0.665	21773	93.76	96.72	76.29	1.10	2.04	10.69	13.86	15.24
7.633	-3.213	431.41	407.60	408.22	2817.0	85.42	8155	0.666	17873	66.43	68.54	55.25	1.10	3.98	10.69	18.84	19.87
12.720	-3.211	509.63	486.19	487.44	2351.2	121.70	7223	0.666	18186	59.89	61.46	48.89	1.10	4.83	10.69	23.18	24.03
2.499	3.221	345.43	327.33	327.62	3287.1	59.06	9468	0.665	22979	99.08	102.06	79.79	1.10	2.03	10.69	14.41	15.73
7.620	3.454	420.06	407.40	408.01	2818.2	85.34	8158	0.666	34405	127.93	130.10	93.18	1.10	3.97	10.69	34.79	35.36
12.700	3.180	494.91	485.89	487.13	2353.1	121.53	7226	0.666	51826	170.75	172.49	110.96	1.10	4.82	10.69	63.87	64.19

Table 4. Uncertainties in data analysis parameters and calculated quantities

Uncertainty Parameter	Major Source of Uncertainty	Magnitude of Uncertainty	Estimated or Calculated
Pin Height	Measurement	0.025 mm	Estimated
Pin Spacing	Measurement	0.050 mm	Estimated
Length of Heated Zone	Measurement	1 mm	Estimated
Location of Temperature Probe	Measurement	1 mm	Estimated
Local Flow Rate	Specimen Uniformity	2%	Estimated
Fluid Temperature	Local Flow Rate	0.5-8.6 K	Calculated
Total Heat Flow	Inlet and Outlet Temperature	1.0-1.6%	Calculated
Fluid Velocity	Local Flow Rate	8.7-8.8%	Calculated
Friction Factor	Pin Height, Pin Spacing	22-23% for Re > 500	Calculated
Heat Transfer Coefficient	Local Flow Rate	12.0-43.4%, $0.07<x/L<0.93$	Calculated
Reynolds Number	Viscosity Function, Local Flow Rate	10.7%	Calculated
Nusselt Number	Local Flow Rate	13.6-43.8%, $0.07<x/L<0.93$	Calculated

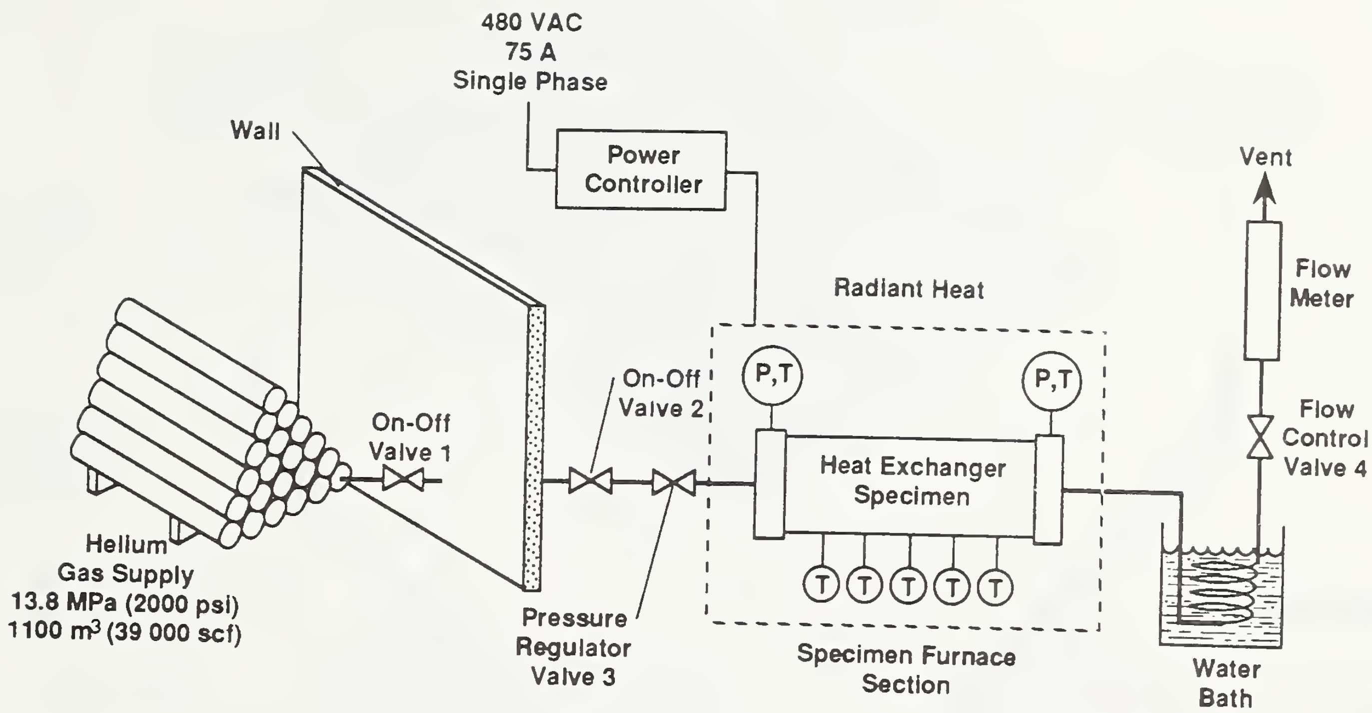


Figure 1. Helium flow apparatus.

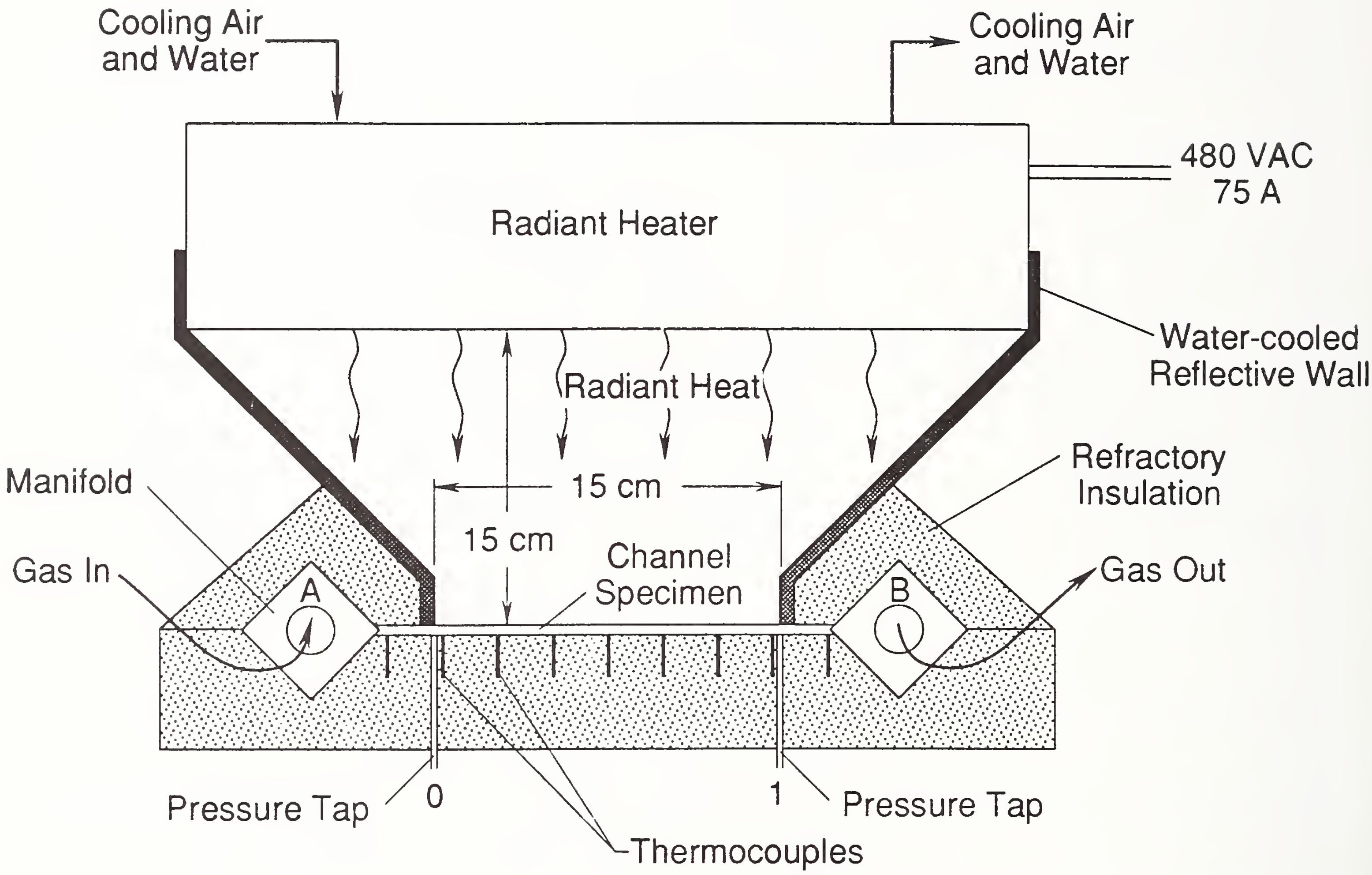
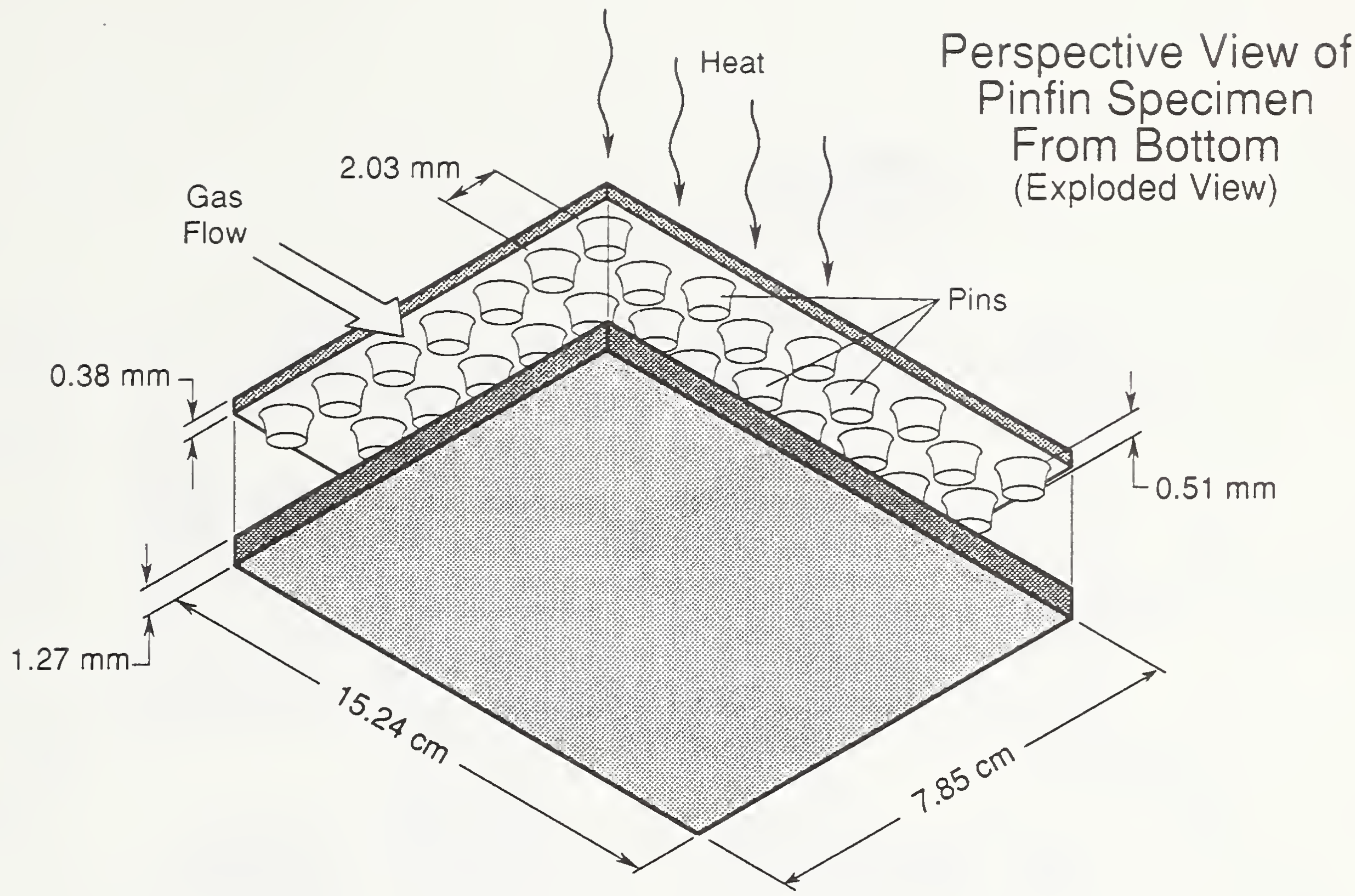


Figure 2. Specimen furnace, showing location of inlet gas temperature (A), upstream pressure (0), outlet gas temperature (B), and downstream pressure (1).



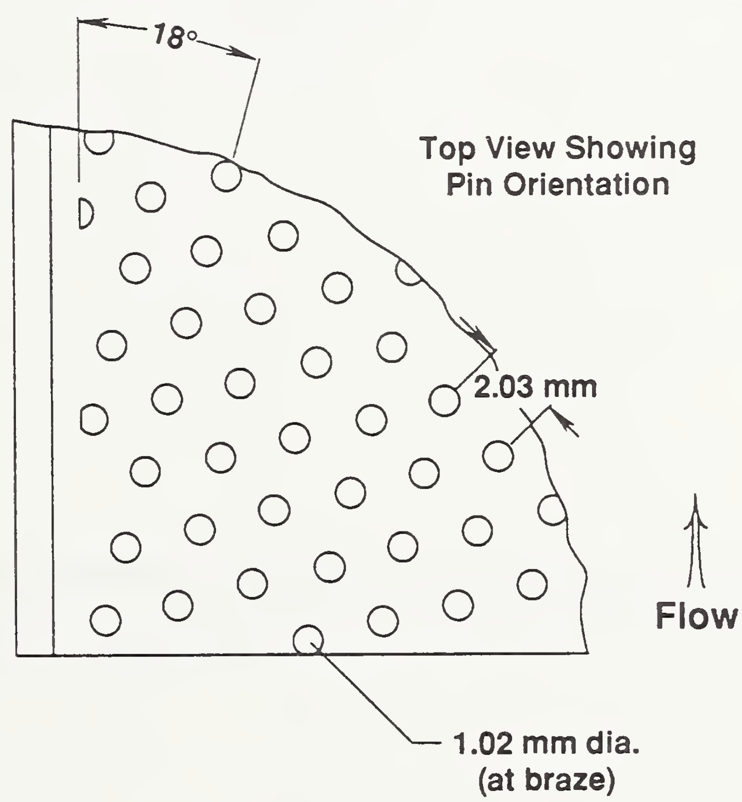


Figure 3. 18° pin-fin specimen.

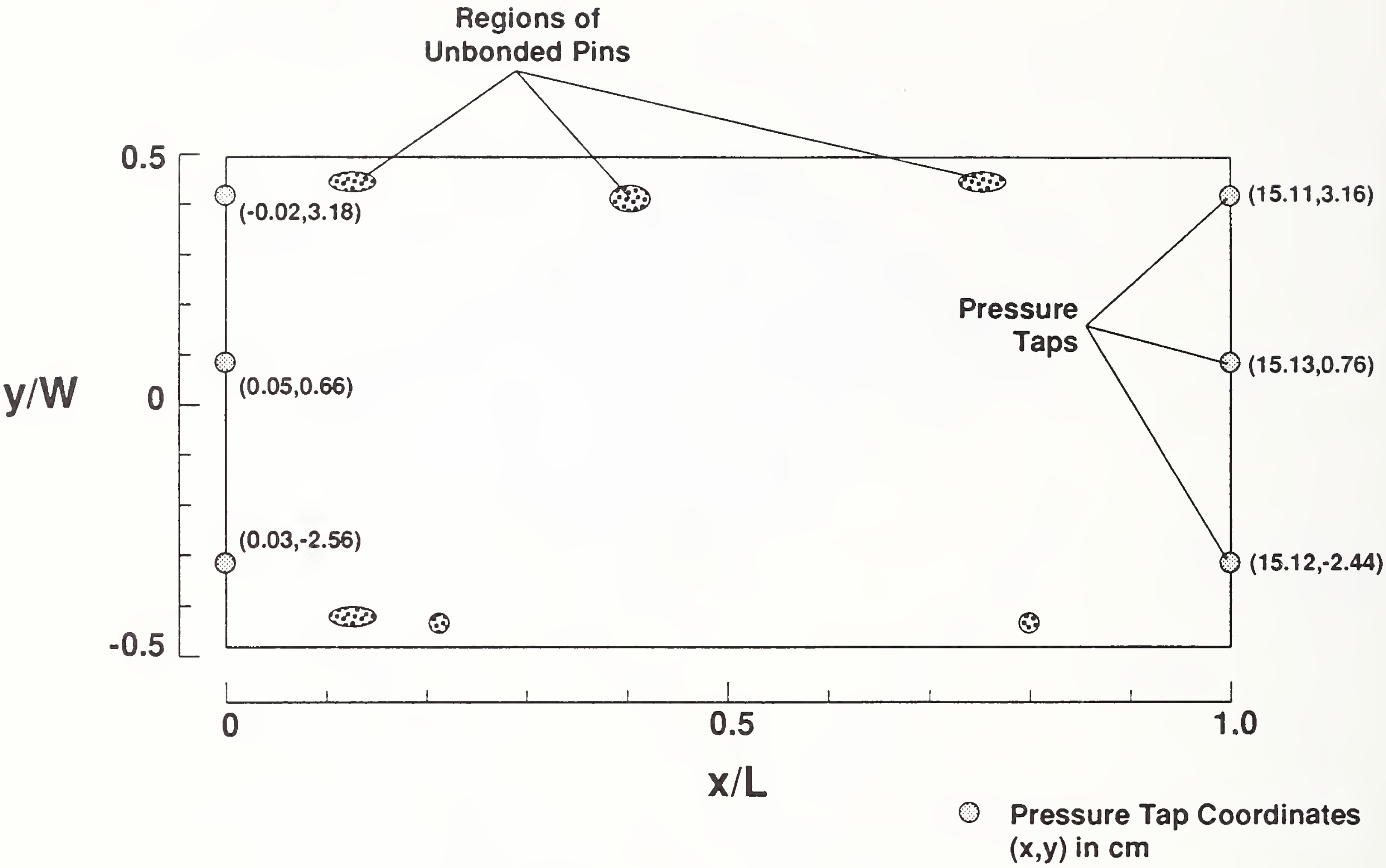


Figure 4. Top view of pin-fin specimen showing locations of unbonded pins and pressure taps.

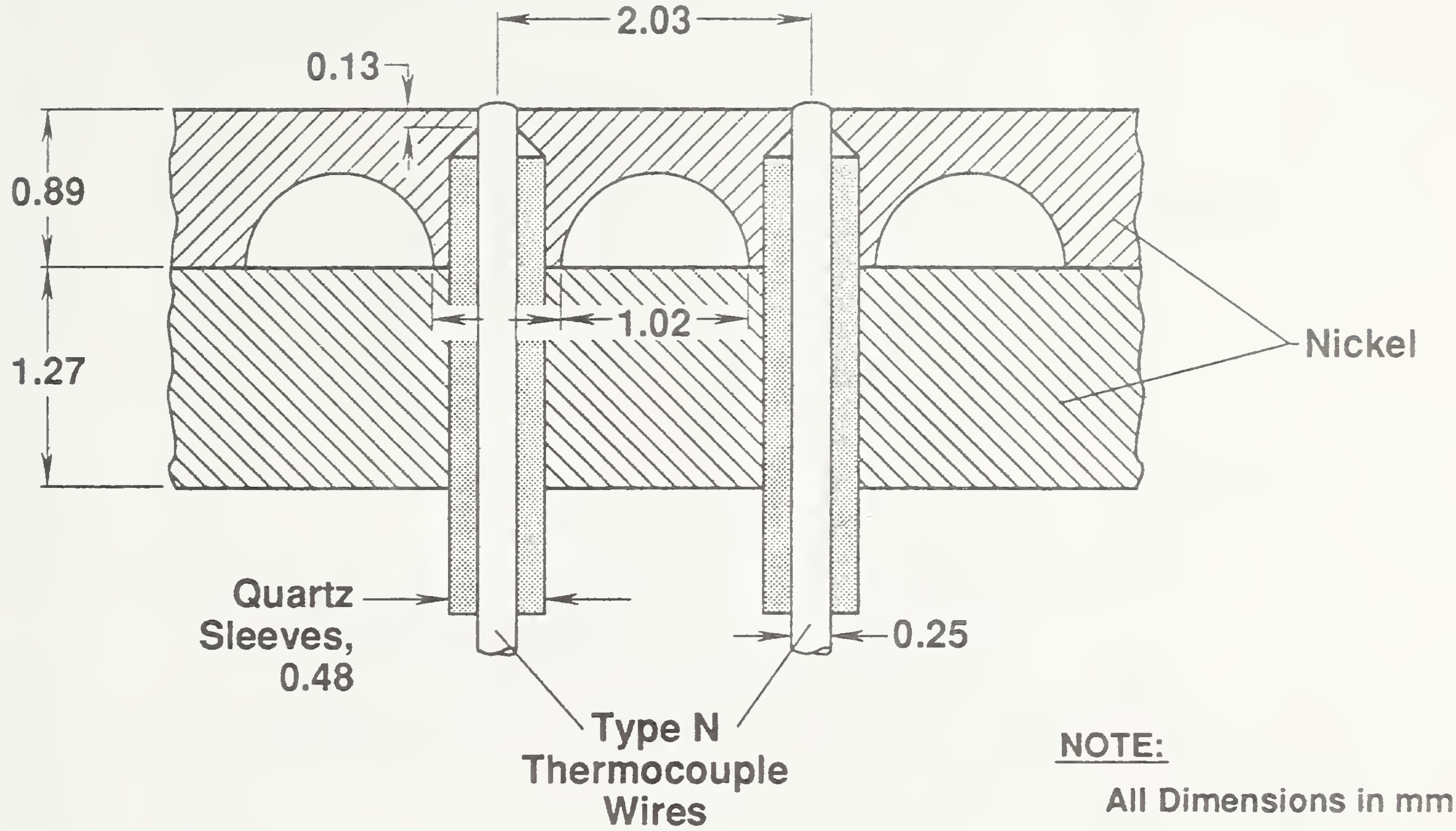


Figure 5. Method for attaching thermocouples to the heated side of the pin-fin specimen.

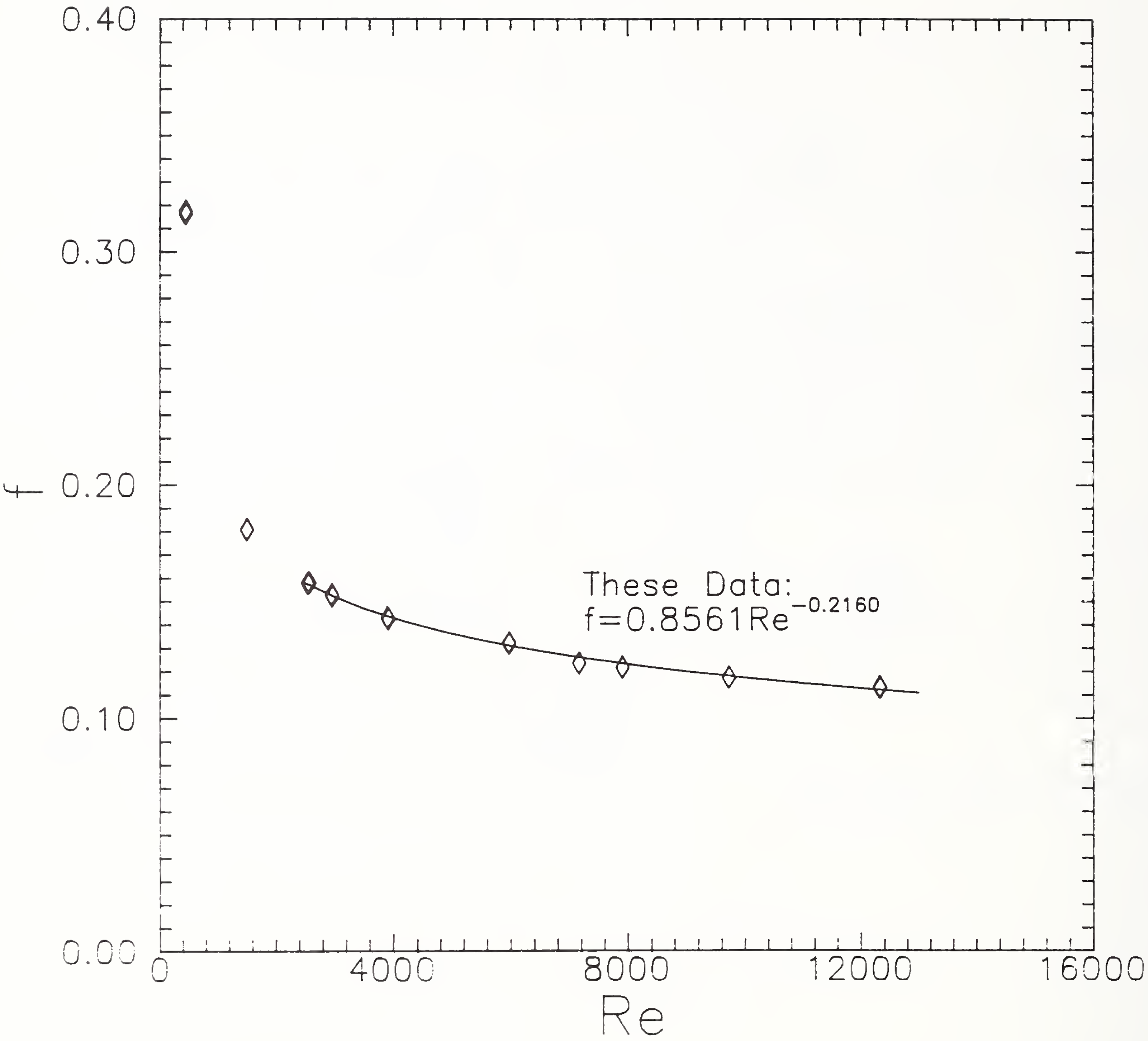


Figure 6. Friction factor (f) as a function of Reynolds number (Re) for experiment 1, no heating.

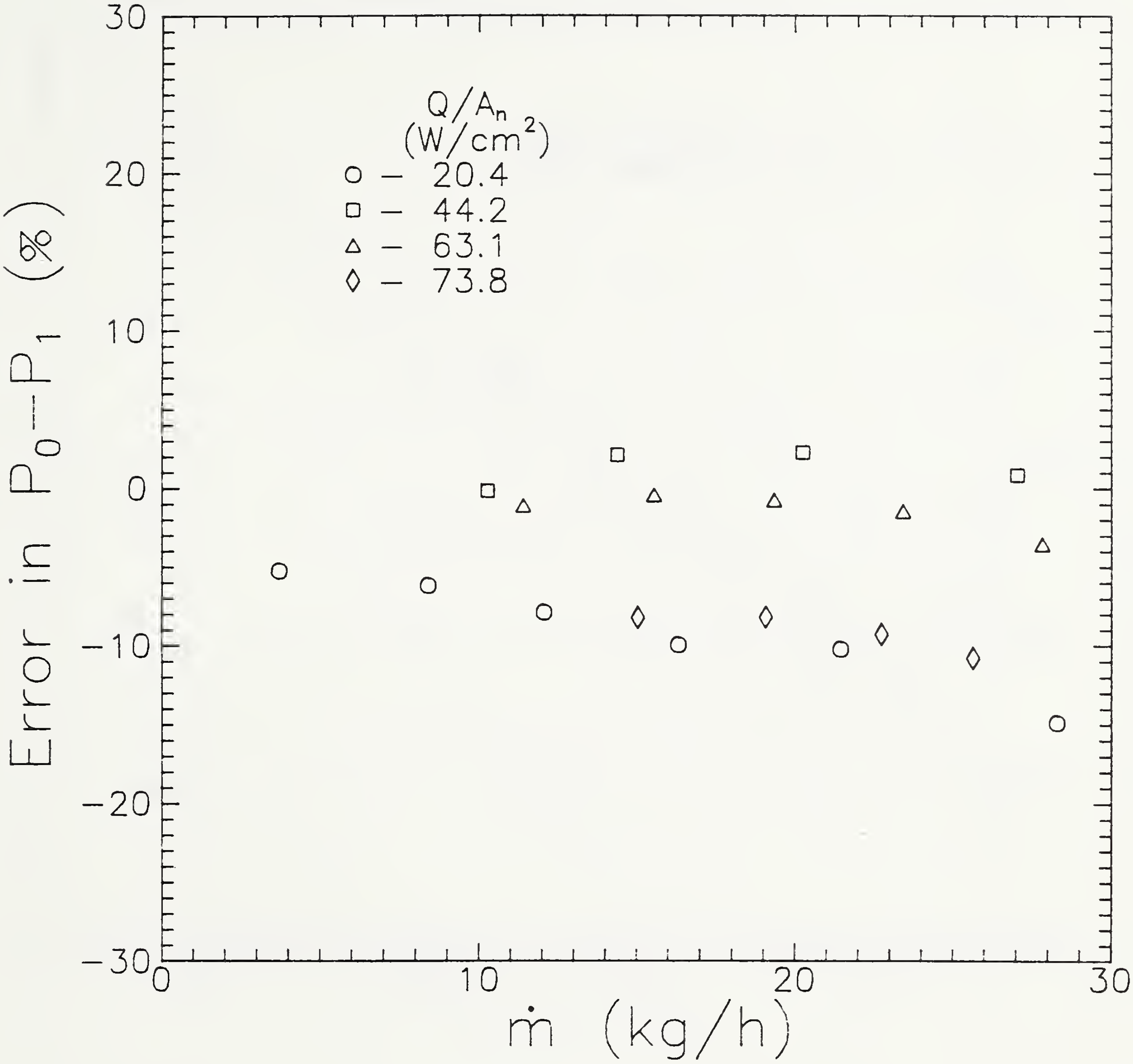


Figure 7. Percent difference between predicted and measured pressure drop (P_0-P_1) as a function of helium flow rate (ṁ) for heat transfer experiments.

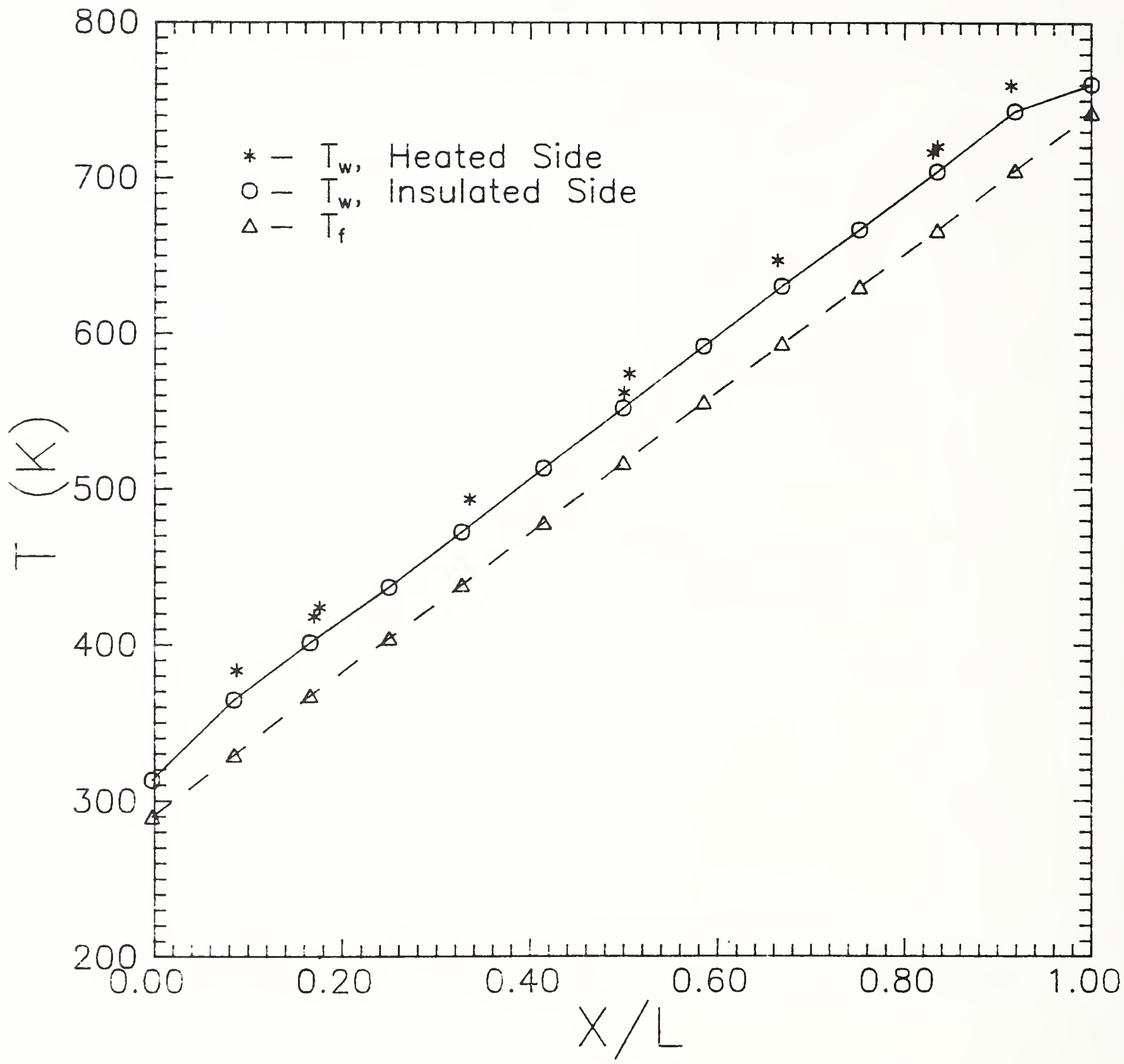


Figure 8. Wall (T_w) and gas (T_f) temperatures as a function of x/L; experiment 5, 11.4 kg/h helium flow, and y/W = 0.0.

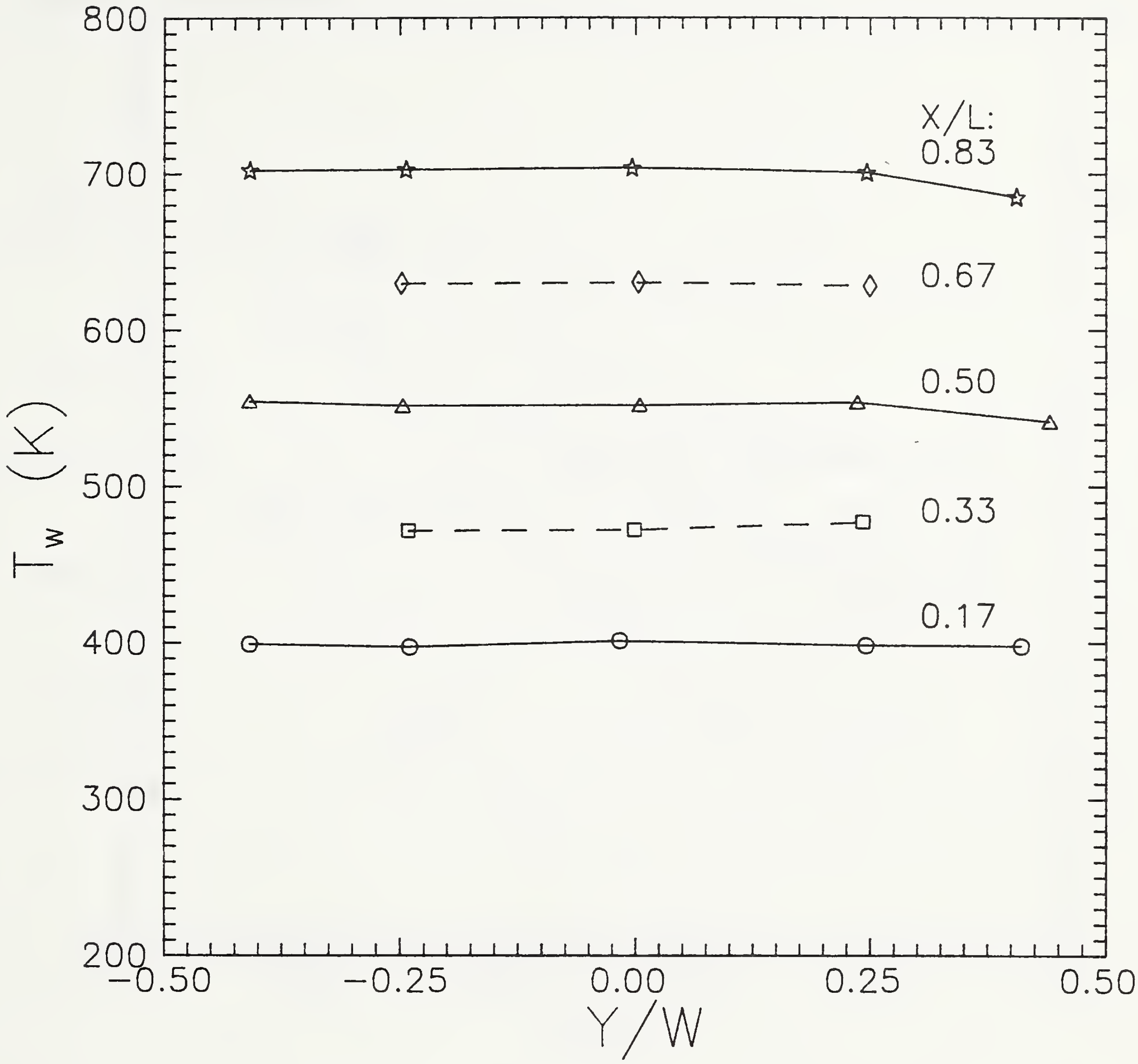


Figure 9. Wall temperature (T_w) as a function of y/W at several x/L locations; experiment 5, 11.4 kg/h helium flow.

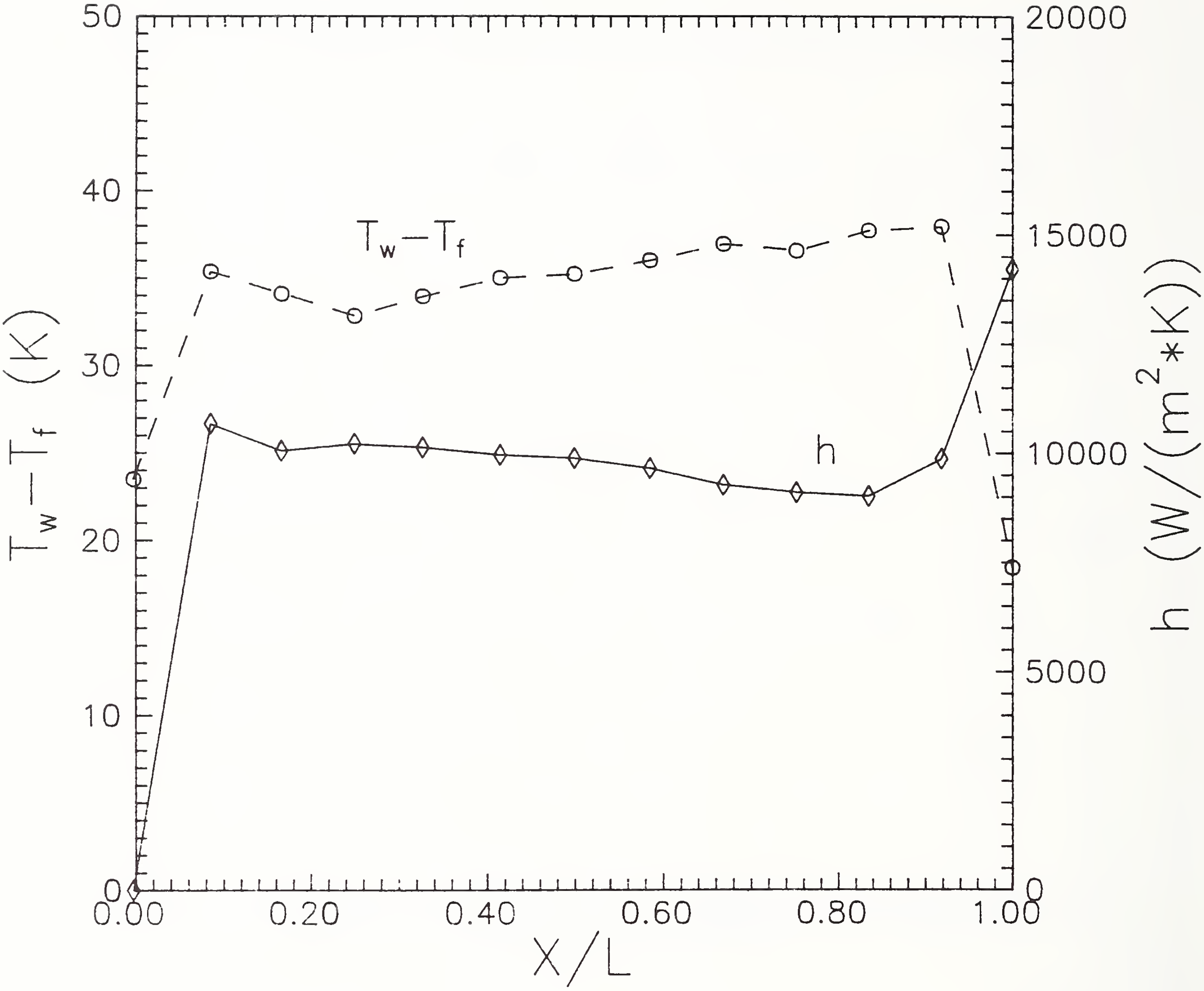


Figure 10. Wall-to-gas temperature difference (T_w-T_f) and heat transfer coefficient (h) as a function of x/L; experiment 5, 11.4 kg/h helium flow and y/W = 0.0.

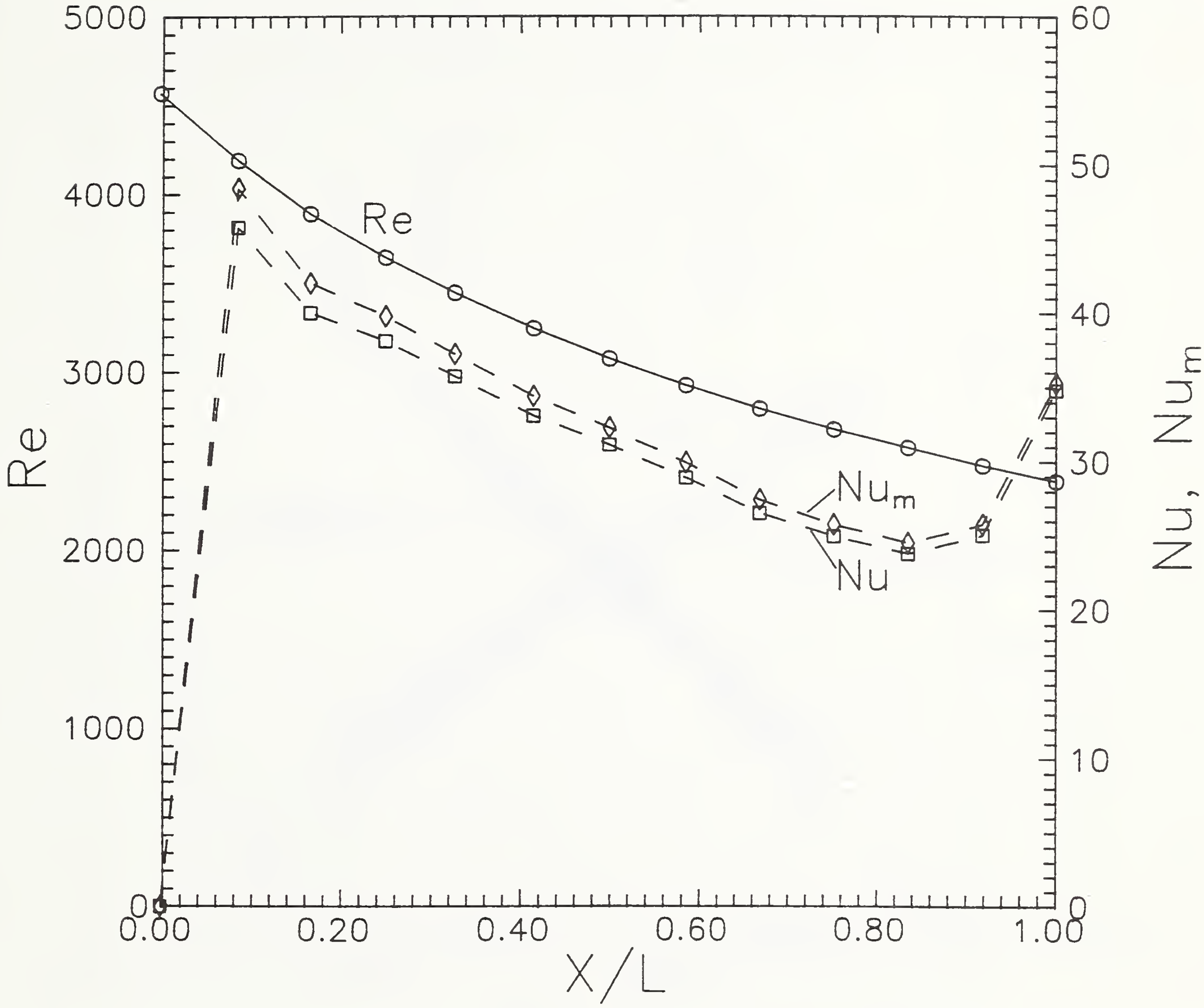


Figure 11. Reynolds number (Re), Nusselt number (Nu), and modified Nusselt number (Nu_m) as a function of x/L; experiment 5, 11.4 kg/h helium flow and y/W = 0.0.

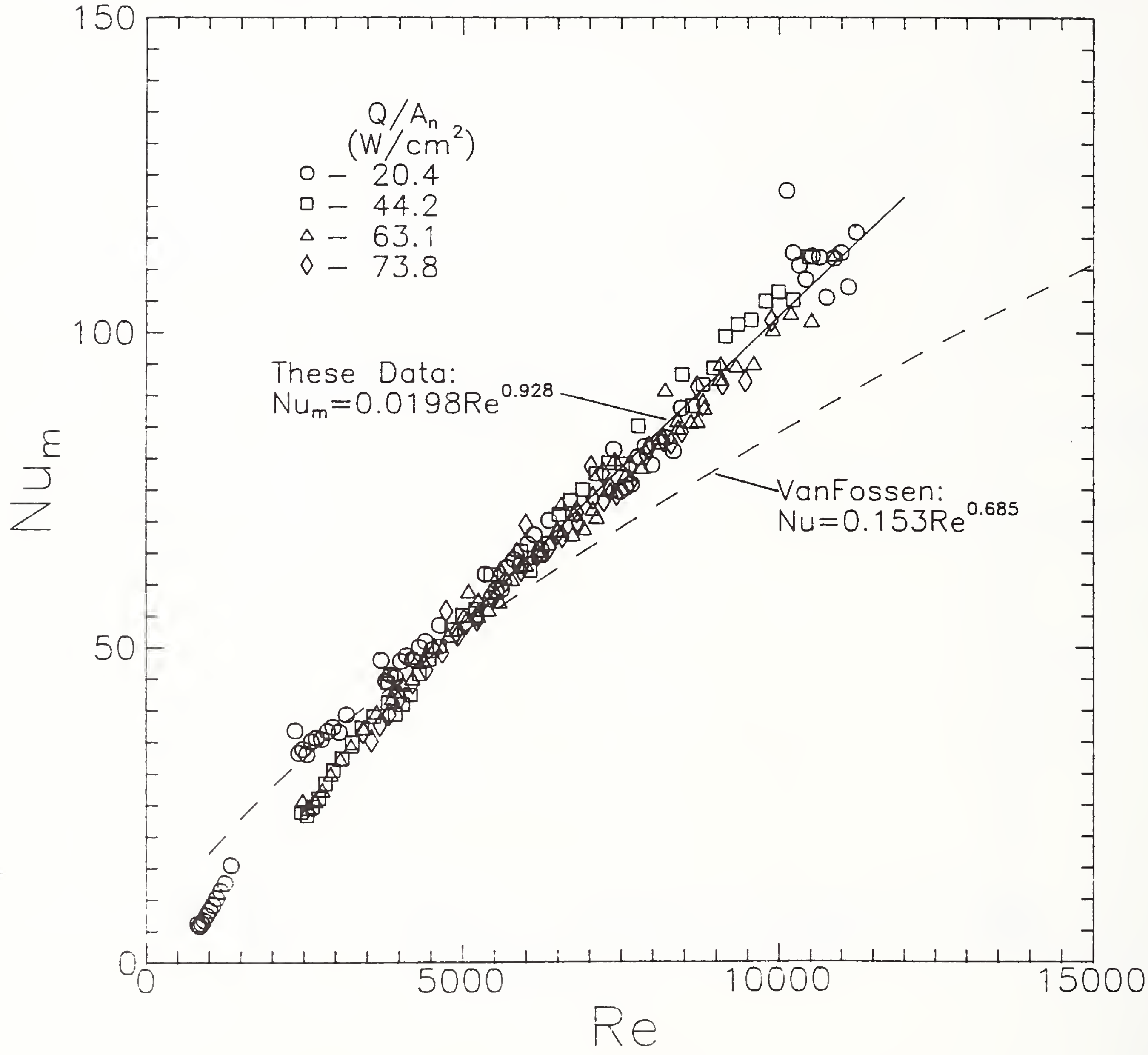


Figure 12. Modified Nusselt number (Nu_m) as a function of Reynolds number (Re); heated experiments 3-6 with $0.07 < x/L < 0.93$ and $y/W = 0.0$.

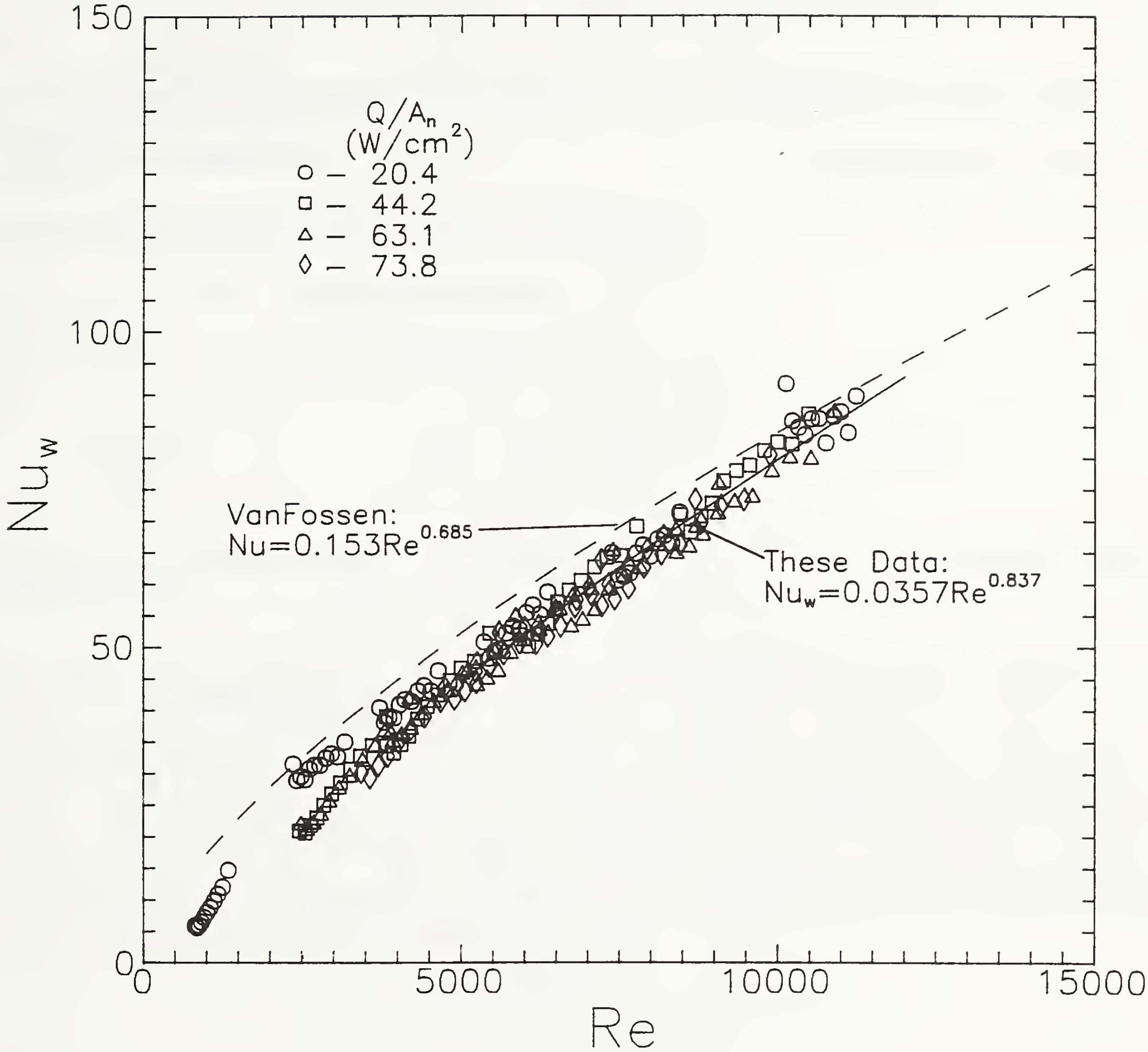
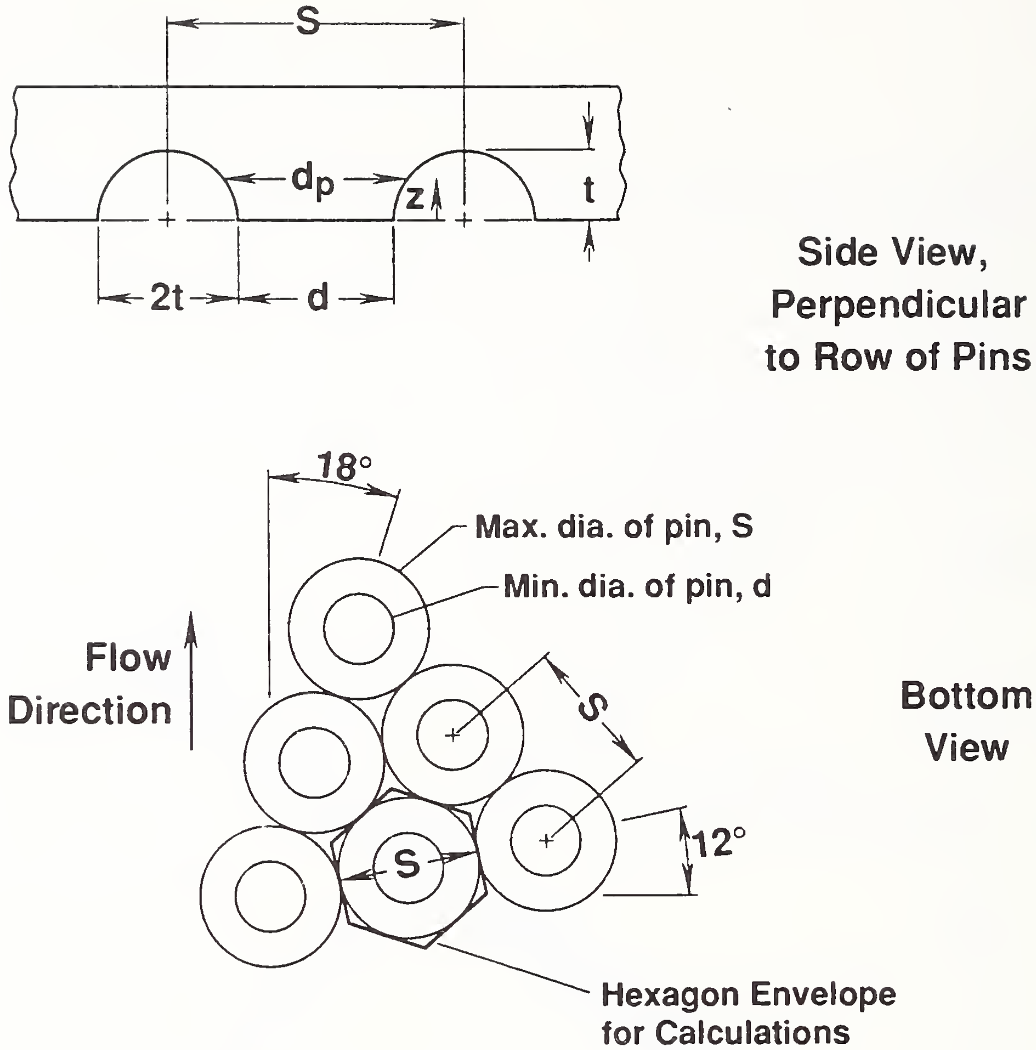


Figure 13. Wall Nusselt number (Nu_w) as a function of Reynolds number (Re); heated experiment 3-6 with 0.07 < x/L < 0.93 and y/W = 0.0.



$$d_p(z) = S - 2(t^2 - z^2)^{1/2}$$

$$d = S - 2t = 1.02\ \text{mm}$$

$$S = 2.03\ \text{mm}$$

$$t = 0.508\ \text{mm}$$

Figure A.1. Definition of pin geometry for calculating open volume, wetted-wall area, and flow area.

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AUTHOR(S)

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ABSTRACT (A 200-WORD OR LESS FACTUAL SUMMARY OF MOST SIGNIFICANT INFORMATION. IF DOCUMENT INCLUDES A SIGNIFICANT BIBLIOGRAPHY OR LITERATURE SURVEY, MENTION IT HERE.)

e have measured the heat transfer and pressure drop characteristics of a novel, compact eat exchanger in helium gas at 3.5 MPa and Reynolds numbers of 450 to 12 000. This pin-fin" specimen consisted of pins, 0.51 mm high and spaced 2.03 mm on centers, spanning channel through which the helium flows; the angle of the row of pins to the flow irection was 18°. The specimen was radiatively heated on the top side at heat fluxes) to 74 W/cm^2 and insulated on the back side. Correlations were developed for the riction factor and Nusselt number. The Nusselt number compares favorably to those of ast studies of staggered pin-fins, when our measured temperatures are extrapolated to e temperature of the wall-fluid interface.

WORDS (6 TO 12 ENTRIES; ALPHABETICAL ORDER; CAPITALIZE ONLY PROPER NAMES; AND SEPARATE KEY WORDS BY SEMICOLONS)

paratus; compact heat exchanger; convection heat transfer; friction factor; high nperature; National Aerospace Plane; pin-fin; radiative furnace; turbulent flow; riable property effects

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