LIQUID PHASE HEAT TRANSFER IN
HELICALLY COILED TUBES

By

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PREFACE

Heat transfer when distilled water and Dowtherm G flow through a helically coiled tube was studied. A Reynolds number range from 6 to 46,000 was investigated for two helical coils 9.99 and 20.64 inches in diameter. The tubes were 0.625 inches o.d. x 0.495 inches i.d. Type 304 seamless stainless steel. For both helically coiled tubes, an axial length of 10 feet was heated electrically by passing DC current through the tube wall.

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NOMENCLATURE

A	heat transfer surface area, ft^2
A_x	cross-sectional area of the tube based on the tube inside diameter, ft^2
AAD	average absolute deviation
AAPD	average absolute percent deviation
APD	average percent difference
C_p	specific heat of the fluid, BTU/lb-°F
D_c	helical coil diameter, measured from tube center-to-tube center, inches or feet
De	Dean number, $Re\sqrt{d_i/D_c}$
d_i	inside diameter of the tube, inches or feet
d_i/D_c	helical coil curvature ratio
d_o	straight tube outside diameter, inches
emf	electromotive force, millivolts
f	Fanning friction factor, dimensionless
g	gravitational acceleration, ft/hr^2 or ft/sec^2
G	mass velocity of the fluid, $lb/hr\text{-}ft^2$
g_c	conversion factor, $lb_m\text{-}ft/lb_f\text{-}sec^2$
Gr	Grashof number, $d_i^3\rho^2 g\beta\Delta t/\mu^2$
Gz	Graetz number, WC_p/kL
h	local heat transfer coefficient, $BTU/hr\text{-}ft^2\text{-}°F$
H	height of the pressure tap above a reference plane, ft
h_i	average heat transfer coefficient based on the tube inside diameter, $BTU/hr\text{-}ft^2\text{-}°F$

k	thermal conductivity, BTU/hr-ft-°F
l	length of conduit between the pressure taps, ft
L	axial length along the helical coil from the inlet electrode, ft
Nu	Nusselt number, $h_i d_i/k$ or hd_i/k
P	measured fluid pressure, psig or lb_f/ft^2
P'	total fluid pressure, $P+\rho\frac{g}{g_c}H$, lb_f/ft^2
Pr	Prandtl number, $C_p\mu/k$
Q	heat flow rate, BTU/hr
Q/A	heat flux, $BTU/hr\text{-}ft^2$
(r', θ', z')	cylindrical coordinates with the origin at the center of the tube cross-section
Ra	Rayleigh number, Gr·Pr
Re	Reynolds number, d_iG/μ
T	fluid temperature, °F or °C
t_b	bulk fluid temperature, °F
t_w	inside wall temperature, °F
T_w	dimensionless inside wall temperature
v	fluid velocity, ft/sec
W	mass flow rate of fluid, lb/hr
z	dimensionless axial distance from the inlet electrode

Greek Letters

β	coefficient of volume expansion of the fluid, 1/°F
ΔH	fluid heat loss for flow in pipes, ft
ΔQ	difference between the imput rate of thermal energy and the rate of increase of the thermal energy of the fluid in passing through the helical coil, BTU/hr
Δt	temperature drop between the wall and the fluid, °F
μ	fluid viscosity, centipoise or $lb_m/ft\text{-}hr$

ρ fluid density, gm/ml or lb/ft^3

Subscripts

avg.	average
b	bulk fluid
c	helical coil
cr	critical
f	film conditions
hc	helical coil
i	inside of tube
in	coil inlet
L	point located at a distance L from the initial measuring point
o	outside of tube
out	coil exit
s	straight tube
T	temperature
w	wall
x	cross-section
0	initial measuring point

CHAPTER I

INTRODUCTION

When a fluid flows through a straight tube, the fluid velocity is maximum at the tube center, zero at the tube wall and symmetrically distributed about the axis. However, when a fluid flows through a curved tube, the primary velocity profile indicated above is distorted by the addition of a secondary flow pattern. The secondary flow is generated by centrifugal action and acts in a plane perpendicular to the primary flow.

Since the velocity is maximum at the tube center the fluid at the center is subjected to the maximum centrifugal action which pushes the fluid towards the outer wall. The fluid at the outer wall moves inward along the tube wall to replace the fluid ejected outwards. This results in the formation of two vortices symmetrical about a horizontal plane through the tube center. Figure 1 is a sketch of the secondary flow pattern.

Due to the existence of the superimposed secondary flow, the heat and mass transfer rates (and the fluid pressure drop) are higher in a curved tube than in an equivalent straight tube at the same flow rate and the transfer mechanisms are more complicated.

The objective of the research program was to obtain a better and more quantitative insight into the heat transfer process that occurs when a fluid flows in a helically coiled tube.

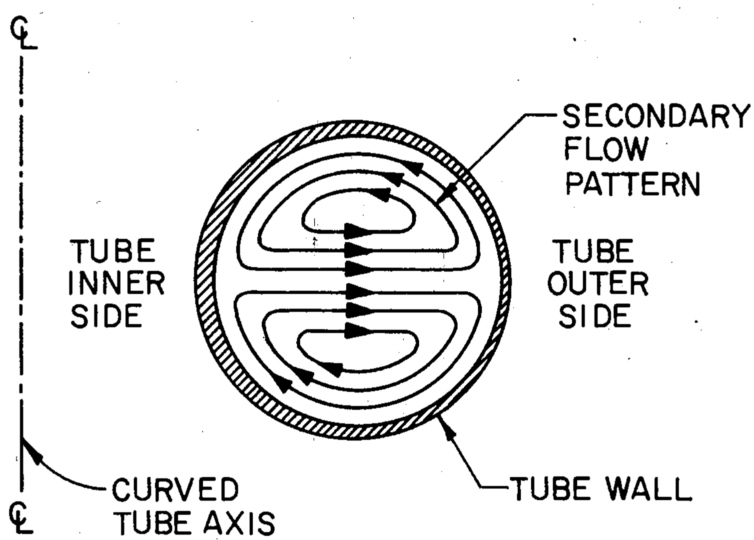

Figure 1. Sketch of the Secondary Flow Pattern in a Curved Tube

Sensible heat transfer to liquids flowing in helically coiled tubes (hereafter also referred to as helical coils) was experimentally evaluated. The study covered the fluid flow range extending from laminar flow (Re = 6) through transition to high turbulent flow (Re = 46,000). Experimental data were gathered for two liquids: distilled water and Dowtherm G. Dowtherm G is Dow Chemical Company's tradename for an organic heat transfer fluid intended for use in low pressure heating systems. Both fluids were studied in two different diameter (9.99 and 20.64 inches) helical cols. The inside diameter and the wall thickness of the initially straight tube were 0.495 and 0.065 inches, respectively. Both coils were fabricated of Type 304 seamless stainless steel tube.

Helical coils are extensively employed for heat transfer applications in the process and power industries. Some of their applications are:

1. Helical coils are used for transferring heat in chemical reactors and agitated vessels because heat transfer coefficients are higher in helical coils. This is especially important when chemical reactions having high heats of reaction are carried out and the heat generated (or consumed) has to be transferred rapidly to maintain the temperature of the reaction. Also, because helical coils have a compact configuration, more heat transfer surface can be provided per unit of space than by the use of straight tubes.

2. Because of the compact configuration of the helical coils, they can be very readily used in heat transfer applications with space limitations as, for example, in steam generators for marine and industrial applications.

3. The helically-coiled tube is eminently suited for studying the characteristics of a plug flow reactor in reaction kinetics studies, because the secondary motion present in a helical coil destroys the radial concentration gradients.

4. The existence of the self-induced radial acceleration field in helical coils makes helical coils most desirable for heat transfer and fluid flow applications in the absence of a gravity field, such as for spaceships in outer space.

5. Helically-coiled tubes have recently been studied for possible applications in bio-engineering. Weissman and Mockros (42) recently studied the use of helical coils to augment mass transfer in membrane blood-oxygenators. Their study demonstrated, both theoretically and experimentally, that by coiling a membrane tube into a helical coil, they could substantially increase the mass transfer rate of oxygen and carbon dioxide to and from the blood flowing inside the tube.

6. Helically-coiled tubes have been and are used extensively in the cryogenic industry for the liquefaction of gases. The Single Pressure Mixed Refrigerant (SPMR) Process for the liquefaction of natural gas is a current example of the application of helically-coiled tubes in the cryogenic industry. Coiled tube heat exchangers can economically satisfy the severe size and operating conditions required by the SPMR Process. Recent emphasis on the increased production of liquefied natural gas will call for an increased use of coiled tube heat exchangers.

CHAPTER II

LITERATURE REVIEW

Fluid flow in curved channels has been studied since 1876. The first paper on heat transfer in helical coils was published in 1919. Koutsky and Adler (22) compiled a chronological list of important papers on fluid flow in helical coils and curved channels dating from 1876 to 1964. More recently Srinivasan et al. (39) critically examined the various published correlations for determining the pressure drop and heat transfer in helical and spiral coils.

Fluid Flow Literature

White (43) reported the results of experiments performed using helical coils of curvature ratios, d_i/D_c, of 1/15, 1/50 and 1/2050. The experiments were performed using water, lubricating oil and mixtures of lubricating oil and lamp oil. Based on the experimental data he had gathered, White proposed the following empirical correlation for calculating the friction head loss for the laminar flow of fluids in helical coils:

$$\Delta H = (C)\left(\frac{8\mu}{\rho v d_i}\right)\left(\frac{4 l v^2}{g d_i}\right) \qquad (2.1)$$

where $C^{-1} = 1-[1-(11.6/De)^{0.45}]^{1/0.45}$ for $11.6 < De \leq 2{,}000$

and $C = 1$ for $De \leq 11.6$.

In a later paper, White (44) proposed another empirical correlation for determining the Fanning friction factor for liquids flowing in helical coils in the fully developed turbulent flow regime. The correlation is:

$$f_c = 0.08(Re)^{-0.25} + 0.012(d_i/D_c)^{0.5} \quad (2.2)$$

for $15{,}000 \leq Re \leq 100{,}000$.

Adler (1) theoretically calculated the velocity profile and the pressure drop for flow in curved pipes based on the Prandtl boundary layer model. Adler derived the following equation to determine the friction factor in curved pipes:

$$\frac{f_c}{f_s} = 0.1064(De)^{0.5} \quad (2.3)$$

He also experimentally measured the pressure drop and velocity profiles for flow in curved tubes with d_i/D_c of 1/50, 1/100 and 1/200. His equation asymptotically approaches the experimental results for high Dean numbers in the laminar flow regime.

Barua (4) theoretically derived a power series solution for the resistance coefficient for high Dean number flow in stationary curved pipes. His correlation, expressed as the first two terms of the power series, is:

$$\frac{f_c}{f_s} = 0.509 + 0.0918(De)^{0.5} \quad (2.4)$$

Barua in his paper did not indicate the effective range for his correlation. However, he stated that his correlation is similar to Hasson's (16) correlation which Barua indicated is in good agreement with experimentally observed results for $30 < De < 2{,}000$. Hence, it may be concluded that Barua's correlation is also valid over the same Dean number range.

Prandtl (30) suggested the following equation for determining the Fanning friction factor for flow in curved tubes:

$$\frac{f_c}{f_s} = 0.37(De/2)^{0.36} \tag{2.5}$$

The above equation is valid in the range 40 < De < 2,000.

Mori and Nakayama (25) theoretically analyzed the high Dean number fully developed laminar flow regime using the approximate boundary layer theory. Their analysis resulted in a power series solution for the friction factor for flow in curved tubes. Their equations for the friction factor, for the first and second approximation of the power series, are:

$$\left(\frac{f_c}{f_s}\right)_I = 0.1080(De)^{0.5} \tag{2.6}$$

and

$$\left(\frac{f_c}{f_s}\right)_{II} = \left(\frac{f_c}{f_s}\right)_I \left[\frac{1}{1-3.253(De)^{-0.5}}\right] \tag{2.7}$$

where the subscripts I and II on the (f_c/f_s) ratio indicate the first and second approximations, respectively.

Mori and Nakayama also performed an experimental study using air flowing in a curved pipe with a d_i/D_c ratio of 1/40. They report that their experimental results were in good agreement with their theoretical analysis. They further report that over a wide range of Dean numbers, their second approximation, Equation (2.7), gave friction factors that agreed fairly well with Ito's empirical correlation for friction factors for laminar flow in curved pipes.

In a second paper, Mori and Nakayama (26) reported the results of their analysis of the turbulent flow regime in curved pipes. They theoretically derived the relationship for the Fanning friction factor for turbulent flow in curved pipes based on the following assumptions:

1. A thin boundary layer exists along the pipe wall.

2. Fanning friction factors for turbulent flow in straight pipes are given by the following empirical correlation:

$$f_s = \alpha(Re)^{-1/m} \tag{2.8}$$

where

$\alpha = 0.079$ for $m = 4$;

$\alpha = 0.046$ for $m = 5$.

The value of m is commonly chosen to be 4 or 5. With $m = 4$, Equation (2.8) is the Blasius resistance formula for turbulent flow in straight tubes.

Mori and Nakayama (26) developed the following equations to determine the Fanning friction factor for turbulent flow in curved pipes:

$$\text{For } m = 4: \quad f_c(d_i/D_c)^{-0.5} = \frac{0.075}{[Re(d_i/D_c^{2}]^{0.2}} \left\{1 + \frac{0.112}{[Re(d_i/D_c)^2]^{0.2}}\right\} \tag{2.9}$$

$$\text{For } m = 5: \quad f_c(d_i/D_c)^{-0.5} = \frac{0.048}{[Re(d_i/D_c)^{2.5}]^{1/6}} \left\{1 + \frac{0.068}{[Re(d_i/D_c)^{2.5}]^{1/6}}\right\} \tag{2.10}$$

They reported that Equation (2.9) gave values for the friction factor that agreed with the values calculated by using Ito's empirical correlation for turbulent flow friction factors in curved pipes.

Ito performed an extensive experimental program to study the friction factors for laminar and turbulent flow of water through curved pipes. He evaluated five curved pipes ranging in d_i/D_c ratio from 1/16.4 to 1/648 for both the laminar and the turbulent fluid flow regime. Ito (17) correlated his laminar flow data with the following empirical equation:

$$\frac{f_c}{f_s} = \frac{21.5(De)}{[1.56 + \log_{10}(De)]^{5.73}} \tag{2.11}$$

The above equation is valid in the range $13.5 < De < 2{,}000$.

Ito (18) proposed the following empirical correlation for calculating the Fanning friction factor in the turbulent flow regime:

$$f_c(d_i/D_c)^{-0.5} = 0.00725 + 0.076[Re(d_i/D_c)^2]^{-0.25} \tag{2.12}$$

for $0.034 < Re(d_i/D_c)^2 < 300$,

and

$$f_c = f_s = 0.079(Re)^{-1/4} \tag{2.13}$$

for $Re(d_i/D_c)^2 < 0.034$.

Ito (18) also proposed the following empirical correlation for determining the critical Reynolds number for fluid flow in curved pipes in the range $15 < D_c/d_i < (8.6)\ (10^2)$:

$$Re_{critical} = 20{,}000(d_i/D_c)^{0.32} \tag{2.14}$$

For $D_c/d_i > (8.6)\ (10^2)$, the critical Reynolds number for curved pipes is taken to be the same as for a straight pipe, namely 2,100.

Kubair and Varrier (24) proposed that friction factors for turbulent flow in helical coils can be calculated from the following equation:

$$f_c = 0.003538(Re)^{0.09} \exp[(1.887)\ (d_i/D_c)] \tag{2.15}$$

The above equation is valid for $9{,}000 < Re < 25{,}000$ and $0.037 < d_i/D_c < 0.097$.

Schmidt (35) proposed the following empirical correlations for evaluating the Fanning friction factor for flow in helically-coiled tubes:

For $10^2 < Re < Re_{cr}$:

$$f_c = \left\{1 + 0.14(d_i/D_c)^{0.97} (Re)^{\left[1 - 0.644(d_i/D_c)^{0.312}\right]}\right\}\left(\frac{16}{Re}\right) \tag{2.16}$$

For $Re_{cr} < Re < (2.2)(10^4)$:

$$f_c = \left[1 + \frac{(2.88)(10^4)}{Re}\left(\frac{d_i}{D_c}\right)^{0.62}\right]\left[\frac{0.0791}{Re^{0.25}}\right] \tag{2.17}$$

For $(2.0)(10^4) < Re < (1.5)(10^5)$:

$$f_c = \left[1 + 0.0823\left\{1 + \left(\frac{d_i}{D_c}\right)\right\}\left\{\frac{d_i}{D_c}\right\}^{0.53}\left\{Re\right\}^{0.25}\right]\left[\frac{0.0791}{Re^{0.25}}\right] \tag{2.18}$$

Further details regarding Schmidt's experimental work are presented in the Heat Transfer Literature section of this chapter.

Truesdell and Adler (40) numerically calculated the fully developed axial and secondary velocities for laminar flow in helically-coiled tubes for both circular and elliptical cross-sections having diametral ratios of 0.5, 0.685, 1.46 and 2.0.

Most of the literature correlations mentioned above for determining the Fanning friction factor for fluid flow in a helically-coiled tube are plotted in Figure 2 for ease of comparison. The Hagen-Poiseuille law for the laminar flow regime and the Blasius resistance formula for the turbulent flow regime are also shown in Figure 2.

Heat Transfer Literature

Richter (32) reported in 1919 that he used a coaxial double pipe heat exchanger to cool acid liquors. He reported that under the same

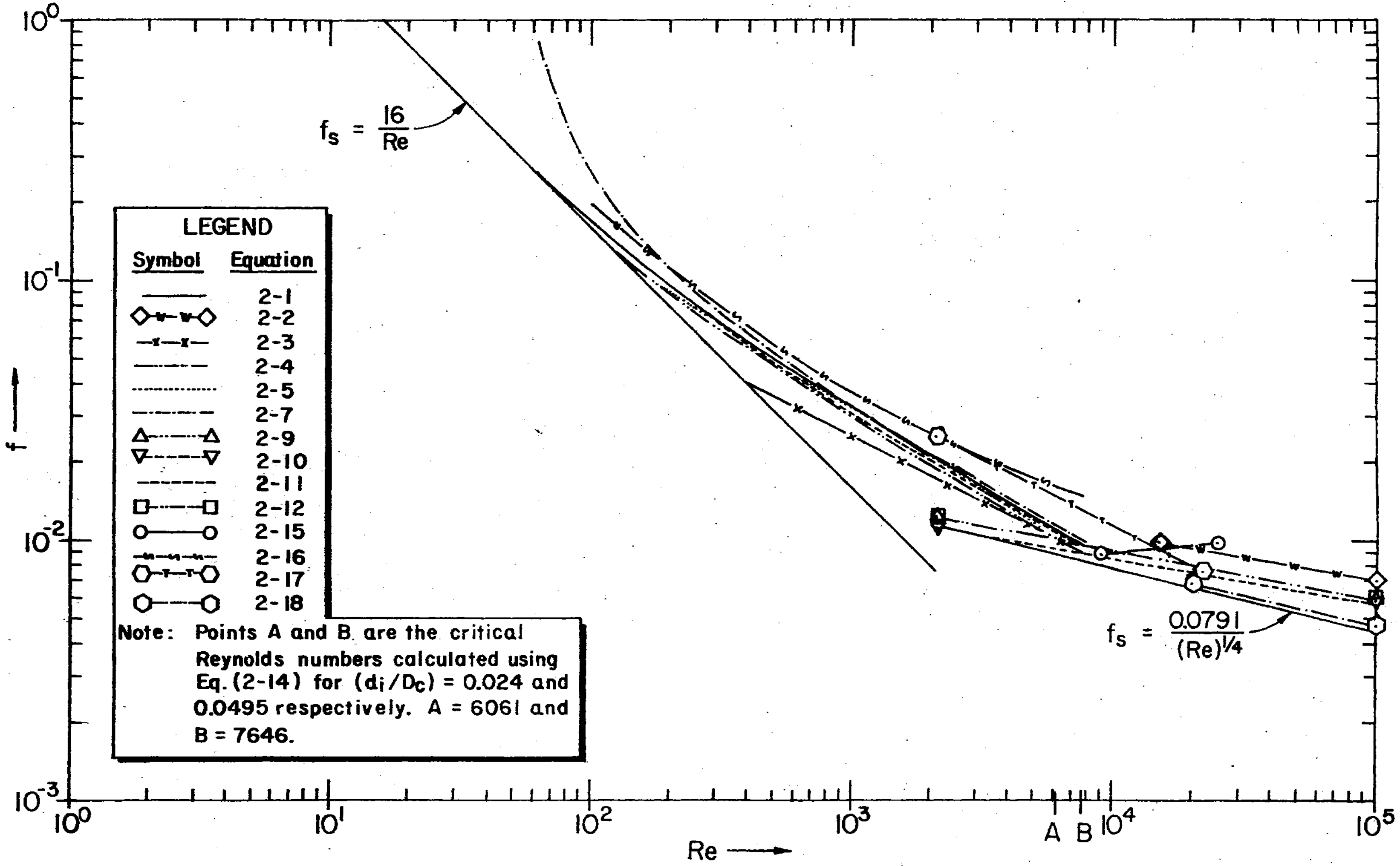

Figure 2. Plot of the Literature Correlations for Determining the Fanning Friction Factor for Fluid Flow in a Helically-Coiled Tube

operating conditions, a coiled double pipe heat exchanger gave higher heat transfer coefficients than a straight pipe exchanger.

Jeschke (19) evaluated the cooling of air in the turbulent flow regime in two helical coils. The helical coils had a D_c/d_i of 6.1 and 18.2 and the Reynolds numbers evaluated extended to 150,000. He proposed the following empirical correlation:

$$Nu = 0.045 \left[1 + \frac{3.54}{(D_c/d_i)}\right] (Re)^{0.76} (Pr)^{0.4} \qquad (2.19)$$

The above equation was obtained from Rogers and Mayhew's (33) paper.

Berg and Bonilla (5) experimentally studied heat transfer to air, water and Essolube 30 lubricating oil in helical coils. They studied the laminar flow regime and proposed the following correlation:

$$\frac{h_i d_i}{c_p f} = [0.0000229 + 0.000636 (d_i/D_c)] Re_f^{1.29} \qquad (2.20)$$

Berg and Bonilla reported that coiling the pipe did not result in a significant improvement in the heat transfer over that occurring in a straight pipe, except at higher fluid velocities.

Kirpikov (21) experimentally tested helical coils with D_c/d_i of 10, 13 and 18. Water was used as the test fluid in the coils. Kirpikov proposed the following correlation for $10^4 < Re < (4.5)(10^4)$:

$$(Nu)(Pr)^{-0.4} = 0.0456(Re)^{0.8} (d_i/D_c)^{0.21} \qquad (2.21)$$

Information regarding Kirpikov's correlation was obtained from Rogers and Mayhew's (33) paper.

Seban and McLaughlin (36) experimentally evaluated the laminar and the turbulent flow regimes for fluids flowing in helical coils. They evaluated two helical coils having a D_c/d_i ratio of 17 and 104 for

Reynolds numbers ranging from 12 to 65,000. They used a medium heavy Freezene oil to study the laminar flow regime and water for the turbulent flow regime. The coils were heated by passing AC current through the tube wall of the helical coils.

Seban and McLaughlin proposed the following empirical correlation for the peripheral average heat transfer coefficient for helical coils: For the laminar flow regime: $12 \leq Re \leq 5{,}600$:

$$Nu = (0.13)\left[\frac{f_c}{8}(Re)^2\right]^{1/3} \tag{2.22}$$

where f_c is calculated from White's (43) equation, namely:

$$\frac{f_c}{f_s} = \left[1 - \left\{1 - \left(\frac{11.6}{Re\sqrt{d_i/D_c}}\right)^{0.45}\right\}^{2.22}\right]^{-1}$$

and $$f_s = \frac{64}{Re}.$$

For the turbulent flow regime: $6{,}000 \leq Re \leq 65{,}000$:

$$Nu = 0.023(Re)^{0.85}(d_i/D_c)^{0.1}(Pr)^{0.4} \tag{2.23}$$

Seban and McLaughlin evaluated their fluid properties at the film temperature which they defined to be the arithmetic average of the mixed bulk fluid and the inside wall temperature.

Rogers and Mayhew (33) also proposed an empirical correlation for evaluating the average heat transfer coefficient for helical coils for the turbulent flow regime, based on their experimental data. They studied three coils having D_c/d_i ratios of 10.726, 13.234 and 20.075. Reynolds numbers ranging from $(3.0)(10^3)$ to $(5.0)(10^4)$ were evaluated using water as the test fluid. The coils were heated by steam. Rogers and Mayhew's correlation is similar to Seban and McLaughlin's turbulent flow correlation, Equation (2.23), except that the constant 0.023 is replaced by 0.021.

Mori and Nakayama (27), as part of their theoretical study of the fluid flow and heat transfer processes occurring in curved pipes, developed the following equations for evaluating the Nusselt number:
In the laminar flow regime:

$$Nu = \frac{0.864}{A} \{De\}^{1/2} \left\{1 + \frac{2.35}{(De)^{1/2}}\right\} \tag{2.24}$$

where

$$A = \left[\frac{2}{11}\right]\left[1 + \left\{1 + \frac{77}{4(Pr)^2}\right\}^{0.5}\right]$$

The range for Equation (2.24) is stated to be $De > 30 \sim 60$.
In the turbulent flow regime:

$$Nu = \left[\frac{Pr^{0.4}}{41.0}\right]\left[(Re)^{5/6}\right]\left[\left(\frac{d_i}{D_c}\right)^{1/12}\right]\left[1 + \frac{0.061}{\{Re(d_i/D_c)^{2.5}\}^{1/6}}\right] \tag{2.25}$$

Equation (2.25) is stated to be applicable for $Pr > 1$ and $Re(d_i/D_c)^{2.5} > 0.4$.

To support their theoretically obtained equations, Mori and Nakayama also experimentally measured the velocity and temperature distributions for air flowing through curved pipes. For the laminar flow regime they studied the flow of air through a helical coil having a D_c/d_i ratio of 40, while for the turbulent flow regime they studied two coils having D_c/d_i ratios of 40 and 18.7. Heat was supplied by passing AC current through nichrome wire wound around the coils. They reported that their experimental results were in good agreement with the results of their theoretical analysis.

Kubair and Kuloor (23) gathered experimental data on heat transfer to aqueous glycerol solutions flowing through helical coils, in the laminar flow regime. They evaluated four helical coils having d_i/D_c ratios of 0.037, 0.056, 0.074 and 0.097. Reynolds numbers ranging from 60 to 5,100 were evaluated. The coils were heated by steam. Kubair and Kuloor proposed the following empirical correlation:

$$Nu = [1.98 + 1.8(d_i/D_c)] [(Gz)^{0.7}] \tag{2.26}$$

for $80 < Re < 6{,}000$; $20 < Pr < 100$; and, $10 < Gz < 1{,}000$.

Schmidt (35) experimentally evaluated the heat transfer and the pressure drop for fluid flow in helical coils. He evaluated five coils having D_c/d_i ratios of 4.914, 10.171, 20.288, 40.967, and 81.103. Reynolds numbers ranging from 100 to 100,000 were evaluated using air, water and Shell Voluta Oil 919 as the test fluids. The coils were heated in a steam bath.

Schmidt reported the following correlations for determining the Nusselt number for heat transfer in helically coiled tubes:

For $10^2 < Re < Re_{cr}$:

$$Nu = 3.65 + 0.08 [1 + (0.08) (d_i/D_c)^{0.9}](Re)^{\beta} (Pr)^{1/3} \tag{2.27}$$

where $\beta = 0.5 + (0.2903) (d_i/D_c)^{0.194}$.

For $Re_{cr} < Re < (2.2) (10^4)$:

$$Nu = 0.023 \left[1 + 14.8 \left\{1 + \left(\frac{d_i}{D_c}\right)\right\} \left(\frac{d_i}{D_c}\right)^{1/3}\right] (Re)^{\gamma} (Pr)^{1/3} \tag{2.28}$$

where $\gamma = 0.8 - (0.22) (d_i/D_c)^{0.1}$.

For $(2.0) (10^4) < Re < (1.5) (10^5)$:

$$Nu = 0.023 \left[1 + 3.6 \left\{1 - \left(\frac{d_i}{D_c}\right)\right\} \left(\frac{d_i}{D_c}\right)^{0.8}\right] (Re)^{0.8} (Pr)^{1/3} \tag{2.29}$$

Shchukin (37) proposed the following empirical correlation for laminar flow heat transfer in helical coils:

For $26 < De < 7{,}000$ and $6.2 < D_c/d_i < 62.5$:

$$Nu = 0.0575\ (Re)^{0.33}\ (De)^{0.42}\ (Pr)^{0.43} \left(\frac{Pr}{Pr_w}\right)^{0.25} \qquad (2.30)$$

For the turbulent flow regime, Shchukin proposed the following correlation:

For $Re_{cr} < Re < 67{,}000$ and $6.2 < D_c/d_i < 104$:

$$Nu = 0.0266 \left[Re^{0.85} \left(\frac{d_i}{D_c}\right)^{0.15} + 0.225 \left(\frac{D_c}{d_i}\right)^{1.55} \right] (Pr)^{0.4} \qquad (2.31)$$

Dravid et al. (13) experimentally and numerically evaluated the effect of secondary fluid motion on heat transfer in the laminar flow regime. They experimentally tested five fluids covering a Prandtl number range from 5 to 175. The Prandtl numbers and other physical properties were evaluated at the average of the inlet and outlet temperatures of the fluids from the coil. One helical coil was used for all the fluids. Their helical coil had a d_i/D_c ratio of 0.0537. The coil was electrically heated by passing AC current through a teflon-insulated nichrome wire wound around the tube in a helically cut groove with a spacing of 0.2 in.

Dravid et al. proposed the following correlation for the fully-developed Nusselt number:

$$Nu = (0.76 + 0.65\ \sqrt{De})\ (Pr)^{0.175} \qquad (2.32)$$

Equation (2.32) is stated to be valid for $50 < De < 2{,}000$ and $5 < Pr < 175$.

In addition to the aforementioned experimental studies on heat transfer in helical coils, several theoretical and numerical studies have also been reported in the literature.

Ozisik and Topakoglu (29) evaluated the heat transfer for hydrodynamically and thermally fully developed laminar flow in a curved pipe by a series expansion method applied to the Navier-Stokes and energy equations. They report that, based on their solution, the heat transfer in a curved pipe depends on the Reynolds and Prandtl number and the curvature of the pipe.

Akiyama and Cheng (2) evaluated the laminar forced convection heat transfer in curved pipes by using the boundary vorticity method. In their paper they pointed out the deficiencies of the pertubation and the boundary layer approximation methods proposed by earlier workers in the field. They also developed a new parameter, De^2Pr, to account for the Prandtl number effect on heat transfer in curved pipes.

Kalb and Seader (20) recently published their results of a theoretical and numerical study of the heat transfer to steady viscous flow in curved tubes of circular cross-section. They presented numerical results for Dean numbers ranging from 1 to 1,200, Prandtl numbers ranging from 0.005 to 1,600 and D_c/d_i values ranging from 10 to 100. They also proposed the following correlation, based on their numerical study, to calculate the Nusselt number for laminar flow heat transfer in curved pipes:

$$Nu = 0.913(De)^{0.476}\,(Pr)^{0.200}. \tag{2.33}$$

The above equation is stated to be valid for $80 \leq De \leq 1{,}200$ and $0.7 \leq Pr \leq 5$.

CHAPTER III

EXPERIMENTAL EQUIPMENT

Liquid phase heat transfer was studied in two helically coiled tubes using distilled water and Dowtherm G. A sketch of the experimental set-up is shown in Figure 3. Figure 4 is a photograph of the general layout of the experimental equipment.

Description of Individual Units

Helical Coils

Two helical coils 9.99 and 20.64 inches in diameter were used. The coils were fabricated from initially-straight Type 304 seamless stainless steel tubing 5/8-inch o.d. x 0.065-inch wall thickness. The axial (and heated) length of the helically coiled tube was 10 feet for both the small and the large diameter coil. Straight tube sections were provided at the inlet and the exit of both the coils. Dimensions of the two helical coils are summarized in Table I.

Some flattening of the tube resulted during the formation of the helical coils. Hence, the longitudinal and the lateral outer tube diameters were measured at one-foot intervals starting from the inlet electrode, except that the tenth measurement was made at an interval of 3/4-foot from the ninth measurement. These measurements are presented in Table II. The measurement intervals were selected to

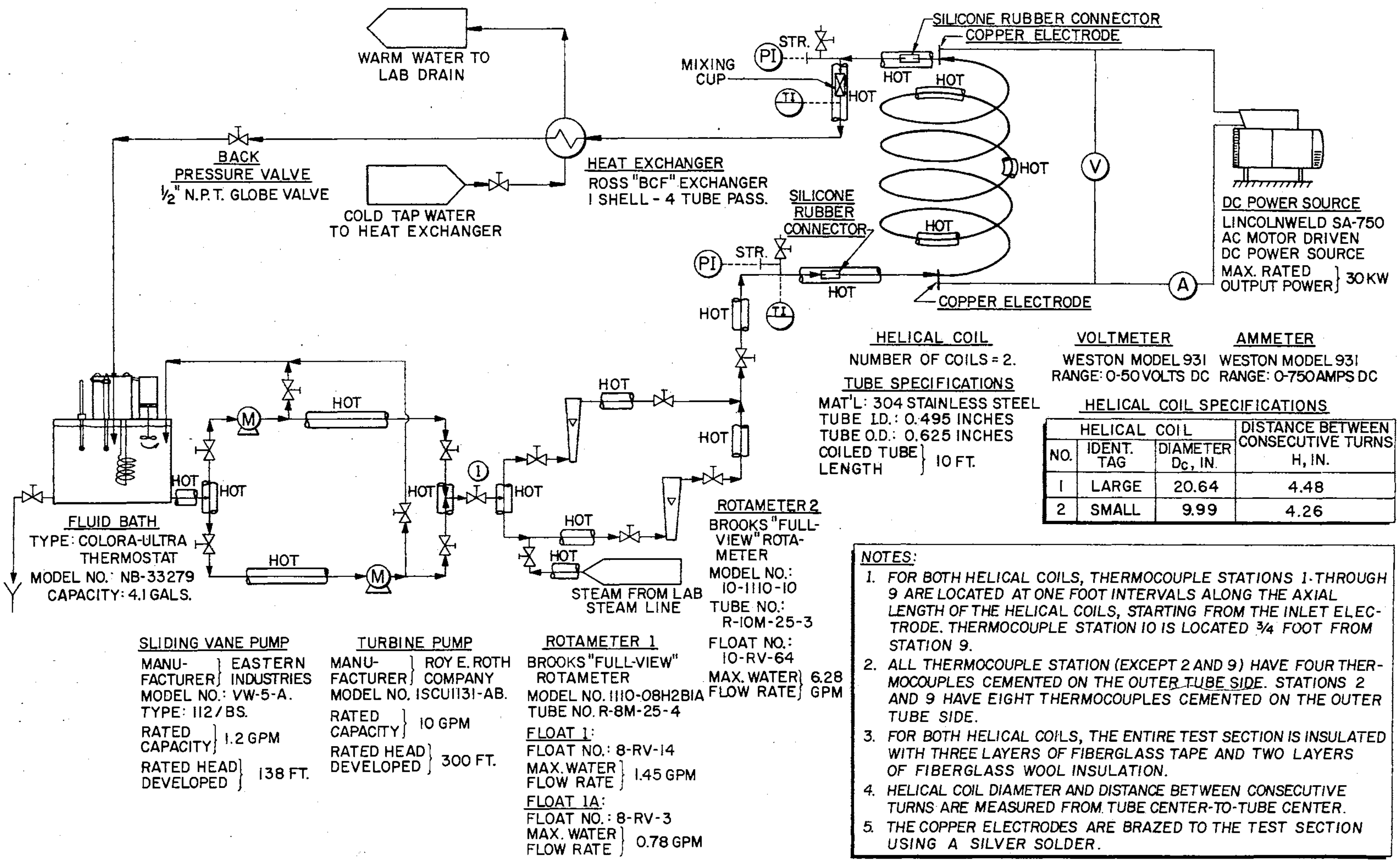

Figure 3. Diagrammatic Sketch of the Experimental Equipment

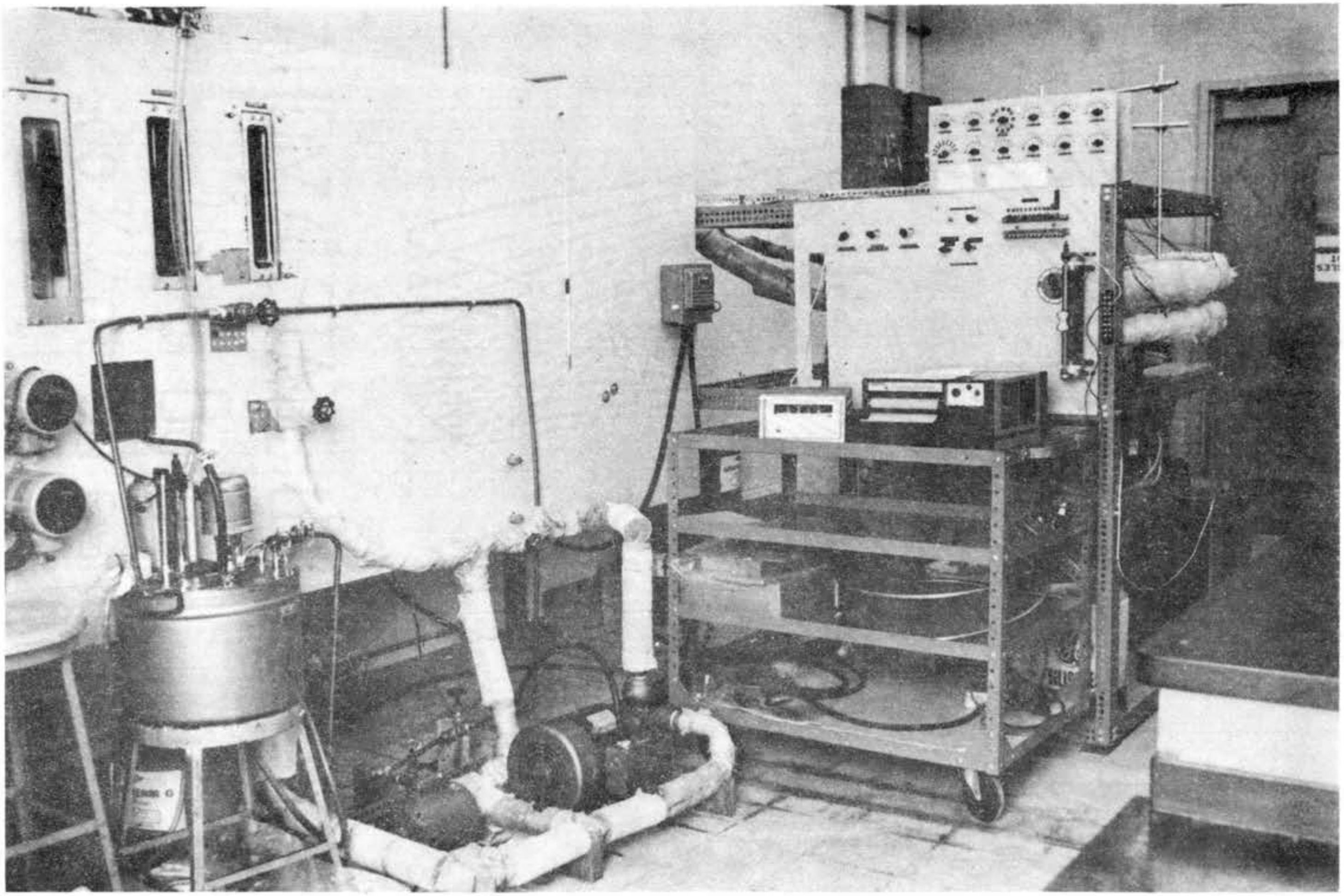

Figure 4. General Layout of the Experimental Equipment

TABLE I

PHYSICAL DIMENSIONS OF THE TWO HELICAL COILS (9)

Item	Small Coil	Large Coil
Coil diameter, tube-center-to-tube-center, D_c, inches	9.99	20.64
Straight tube outside diameter, d_o, inches	0.625	0.625
Straight tube inside diameter, d_i, inches	0.495	0.495
Approximate number of turns in helical coil	3.8	1.8
Ratio of coil diameter to straight tube inside diameter, D_c/d_i	20.18	41.70
Curvature ratio, d_i/D_c	0.0495	0.0240
Axial and heated length of helical coil, feet	10.0	10.0
Coil pitch, tube-center-to-tube-center, inches	4.26	4.48
Length of straight tube preceding the inlet electrode, inches	12.0	11.0
Length of straight tube following the exit electrode, inches	3.0	4.0

TABLE II

MEASURED OUTSIDE TUBE DIAMETERS AFTER FORMATION OF HELICAL COILS (9)

Station Number	Axial Distance from Inlet Electrode feet	Coiled Tube Outside Diameters, Inches			
		Small Coil		Large Coil	
		Longitudinal	Lateral	Longitudinal	Lateral
1	1.0	0.637	0.614	0.630	0.626
2	2.0	0.637	0.613	0.631	0.625
3	3.0	0.637	0.614	0.630	0.626
4	4.0	0.635	0.616	0.631	0.625
5	5.0	0.634	0.617	0.630	0.625
6	6.0	0.636	0.618	0.631	0.625
7	7.0	0.635	0.618	0.630	0.625
8	8.0	0.635	0.618	0.631	0.626
9	9.0	0.635	0.618	0.631	0.625
10	9.75	0.635	0.618	0.630	0.625
	Average Values	0.6356	0.6164	0.6305	0.6253

correspond to the intended thermocouple station locations on the two helical coils.

A copper bar electrode was silver-soldered at each end of the heated length.

Experiments were performed with the axis of both coils in the vertical direction. The fluid entered the coils at the bottom and exited at the top.

Fluid Bath

A "Colora" type "Ultra-Thermostat" vessel was used as the fluid bath. The bath has a capacity of 4.1 gallons and is equipped with a thermostat, a 500 and 1,000 watt immersion type electric heater, a centrifugal pump and an impeller mounted on a common shaft and driven by an electric motor. The model number of the bath is NB-33279. The temperature of the bath fluid was controlled by adjusting the set point on the thermostat and the bath temperature was measured by means of a Brooklyn P-M mercury-in-glass thermometer having a range from 20 to 300°F and graduated in 2°F intervals.

Pumps

A sliding vane pump and a turbine pump were used to pump the fluid through the experimental loop depending upon the fluid flow rate that was to be investigated.

The sliding vane pump was manufactured by Eastern Industries, Inc. The pump model number is VW-5-A. The pump is a positive displacement pump having a rated maximum capacity of 1.2 gpm of water and capable of developing a head of 138 feet.

The turbine pump was manufactured by Roy E. Roth Co. The pump model number is 1SCU1131-AB. The pump has a rated capacity of 10 gpm of water and is capable of developing a head of 300 feet.

DC Power Source

A Lincolnweld SA-750 AC motor driven DC generator was used to generate the DC current, which was fed to the helically-coiled tube through two copper bars silver-soldered to the tube. Resistance heating, due to the passage of the DC current through the tube wall, provided the heat to the fluid. All the experimental runs were conducted under approximately constant wall heat flux conditions. The DC power generator has a maximum rated output power of 30 kilowatts.

DC resistance heating was chosen over AC resistance heating because:

1. Complex AC induction and skin effects are avoided.

2. AC heating may cause cyclic temperature variations in the test section whereas DC heating provides a constant heat source.

3. Possible thermal stresses in the test section caused by the cyclic nature of the AC current are avoided.

4. The cyclic nature of the electrical forces in AC may induce vibrations in the test section. These vibrations do not exist when DC is used.

5. AC, because of its cyclic nature, may induce spurious emfs in the thermocouple wires resulting in erroneous readings.

A motor-generator was used as opposed to a rectifier because:

1. It was available.

2. Its power output is relatively smooth and free from large magnitude superimposed sine waves.

3. It is more resistant to overload than rectifiers.

4. It is not as susceptible to transient voltage peaks that occur in switching the unit on and off as are rectifiers.

Heat Exchanger

A standard pressure 1 shell-4 tube pass heat exchanger was used to cool the test fluid from the helical coil. The heat exchanger is a size 502, 'BCF' type exchanger manufactured by the Kewanee-Ross Corporation (34).

Measuring Devices

Thermocouples

Two different types of thermocouples were used to measure temperatures in the experiment:

1. Conax "Con-o-clad" thermocouples to measure the bulk fluid temperature.

2. Insulated wire thermocouples to measure the outside wall temperature of the helically coiled tube.

Conax "Con-o-clad" Thermocouples

Two Iron-Constantan type ungrounded "Con-o-clad" thermocouples, manufactured by the Conax Corporation, were used to measure the bulk fluid temperature at the inlet and the exit of the coil. Ungrounded thermocouples are manufactured such that the thermocouple is sealed inside a metal sheath (usually 316 stainless steel) but does not contact the metal sheath. Sheathed ungrounded thermocouples were used to measure the bulk fluid temperature because:

1. The sheath protects the thermocouple from corrosion due to the nature of the fluid.

2. Unlike grounded thermocouples, the ungrounded thermocouple indicates the bulk temperature of the fluid and is relatively unaffected by the tube wall temperature.

3. The ungrounded thermocouples are immune to any stray emfs that may be produced by the DC heating current.

The abovementioned thermocouples will hereafter be referred to as the 'Conax thermocouples'.

For distilled water flow rates less than 1.0 gpm and for all the Dowtherm G experimental runs, the Conax thermocouples were placed immediately downstream of the inlet and exit mixing cups to measure the mixed average bulk fluid temperature. Mixing cups were not used for flow rates higher than 1.0 gpm because:

1. The fluid was adjudged to be sufficiently well mixed to preclude the need of mixing cups.

2. At higher fluid flow rates the mixing cups produced a considerable pressure drop across the system thereby decreasing the maximum fluid flow rate that could be attained.

The Conax thermocouples were first calibrated against a reference thermometer by using a constant temperature bath. Later, the Conax thermocouples were also calibrated in-situ by using low pressure saturated steam. Details of the calibration procedure are presented in Chapter IV.

Insulated Wire Thermocouples

The outside wall temperatures of the helically coiled tube were measured using thermocouples made from fiberglass insulated, 30 B&S gauge Iron-Constantan thermocouple wire. The thermocouples were fabricated in the laboratory by using the thermocouple welder. These thermocouples will hereafter be referred to simply as "thermocouples".

Thermocouples were placed at ten stations on the helically-coiled tube. The stations were located at one-foot intervals along the axial length of the tube starting from the inlet electrode; except that thermocouple station 10 was located 3/4-foot from thermocouple station 9. Four thermocouples were placed 90 degrees apart on the tube cross-section at stations 1, 3 through 8, and 10. Eight thermocouples were placed 45 degrees apart on the tube cross-section at stations 2 and 9. Figure 5 is a sketch of the thermocouple layout for the two schemes mentioned above.

The thermocouple beads were fixed on the tube surface with Sauereisen cement. In order to electrically insulate the thermocouple beads from the heating current, a thin layer of Sauereisen cement was first placed at the intended thermocouple location and allowed to set before cementing the thermocouple bead to its intended location. The thermocouple wires from the thermocouple beads were held in place about 1/2-inch from the thermocouple beads by means of a layer of asbestos paper tape and a flexible hose clamp. The asbestos paper tape was placed between the clamp and the thermocouple wires to prevent any accidental short-circuiting of the thermocouple wires due to the sharp edges of the metal hose clamp. The thermocouple wires were then placed

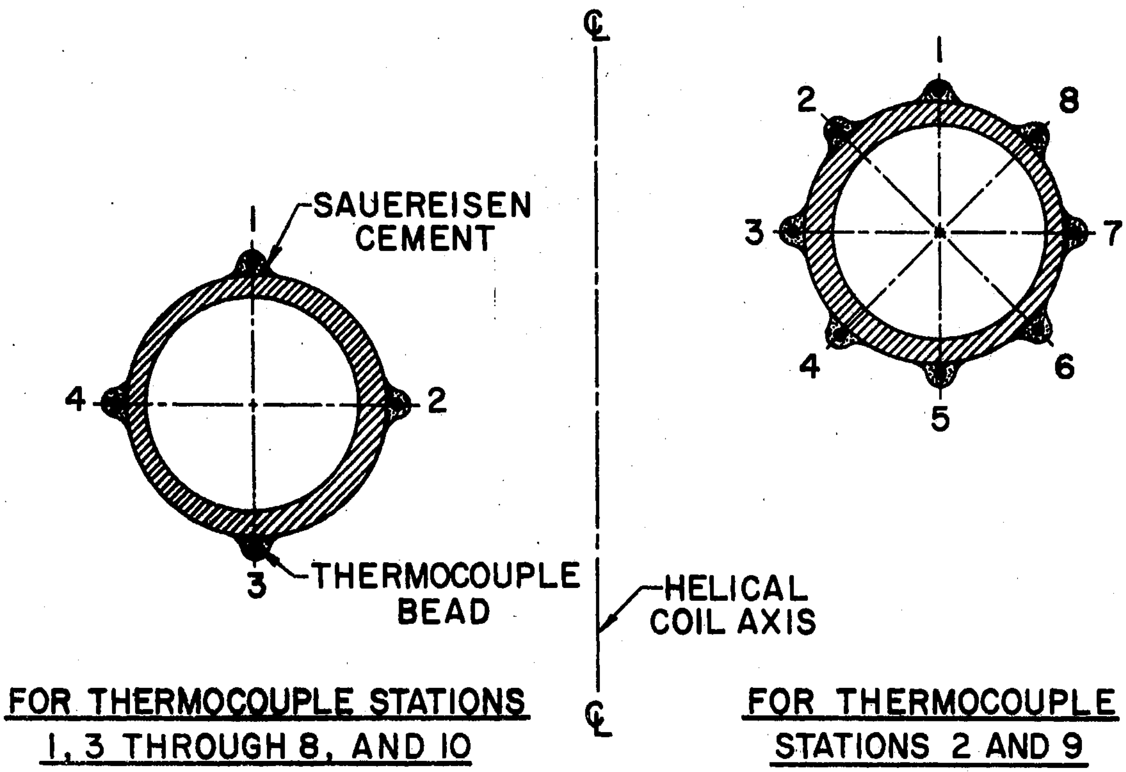

Figure 5. Layout of the Thermocouples on the Tube Cross-Section of the Helical Coil

along the helical coil for about two inches and clamped again to the tube before being lead-off to the thermocouple selector switchboard.

Each thermocouple was tagged with two numbers: the first, running from 1 to 10, indicated the thermocouple station number; the second running from 1 through 4 (1 through 8 for thermocouple stations 2 and 9) indicated the thermocouple location on the tube periphery. Location 1 was at the top of the tube and the others followed clockwise, facing the tube cross-section; that is, thermocouple 2 (3 for stations 2 and 9) was closest to the coil axis. Thus, for example, a thermocouple tagged '9-5' indicates the thermocouple at station 9 and located 180 degrees from the top of the tube periphery, i.e., at the bottom of the tube at station 9.

Each thermocouple emf was measured individually on a "Numatron"--a voltmeter with a digital readout.

For both helical coils, the thermocouples were calibrated in-situ by bleeding low pressure saturated steam through the coil. Details of the calibration procedure are given in Chapter IV.

Rotameters

Two Brooks "Full-View" rotameters were used to indicate and meter the fluid flow rate. The rotameter specifications are given in Table III.

Two floats were used interchangeably in Rotameter 1 in order that low fluid flow rates could be evaluated. Type "RV" floats were used in the rotameters because of their immunity to viscosity variations of the fluid being metered. However, for the Dowtherm G runs, the viscosity

TABLE III

ROTAMETER SPECIFICATIONS

Item	Rotameter 1	Rotameter 2
Rotameter model number	1110-08H2B1A	10-1110-10
Rotameter tube number	R-8M-25-4	R-10M-25-3
Float number	8-RV-14; 8-RV-3	10-RV-64
Maximum water flow rate, gpm	1.45; 0.78	6.28

immunity ceiling of these floats were exceeded for the flow rates encountered; hence, the fluid flow rate was measured for each data run. The viscosity immunity ceiling was determined from Brooks Instrument Division's Technical Bulletin Number T-022 Rev. A (7).

Pressure Transducers

Two unbonded type strain gauge pressure transducers were used to monitor the fluid pressure at the inlet and the exit of the helical coil. The pressure transducers were manufactured by the Transducer Division, Consolidated Electrodynamics Corporation. Specifications for the pressure transducers are given in Table IV.

A Hewlett-Packard Bench Series Model 6214A regulated DC voltage supply unit was used to provide the rated electrical excitation to the two pressure transducers. The voltage supply unit has a range of 0 to 10 volts and 0 to 1.0 amperes DC.

Figure 6 shows the circuit diagram used to connect the pressure transducers. The pressure transducer output was measured on the

TABLE IV

PRESSURE TRANSDUCER SPECIFICATIONS (8)

Item	Inlet Pressure Transducer	Exit Pressure Transducer
Pressure transducer type	4-316-0001	4-312-0001
Pressure range, psig	0-50	0-50
Compensated temperature range, °F	+77 to +600	-65 to +250
Operable temperature range, °F	-320 to +650	-320 to +300
Rated electrical excitation, volts DC	5.0	5.0
Input resistance (from calibration record), ohms	341	357
Output resistance (from calibration record), ohms	341	357
Transducer output range, millivolts DC	0-20	0-20

Numatron. However, the transducer output was monitored on the oscillograph to determine if the fluid flow was steady.

The pressure transducers were calibrated using a Budenberg Dead Weight Tester and a Crosby Bourdon Tube pressure gauge. The calibration procedure is presented in Chapter IV.

Oscillograph

A Consolidated Electrodynamics Corporation (CEC) Model 5-124 Recording Oscillograph was used to monitor the fluid pressure measured by the pressure transducers.

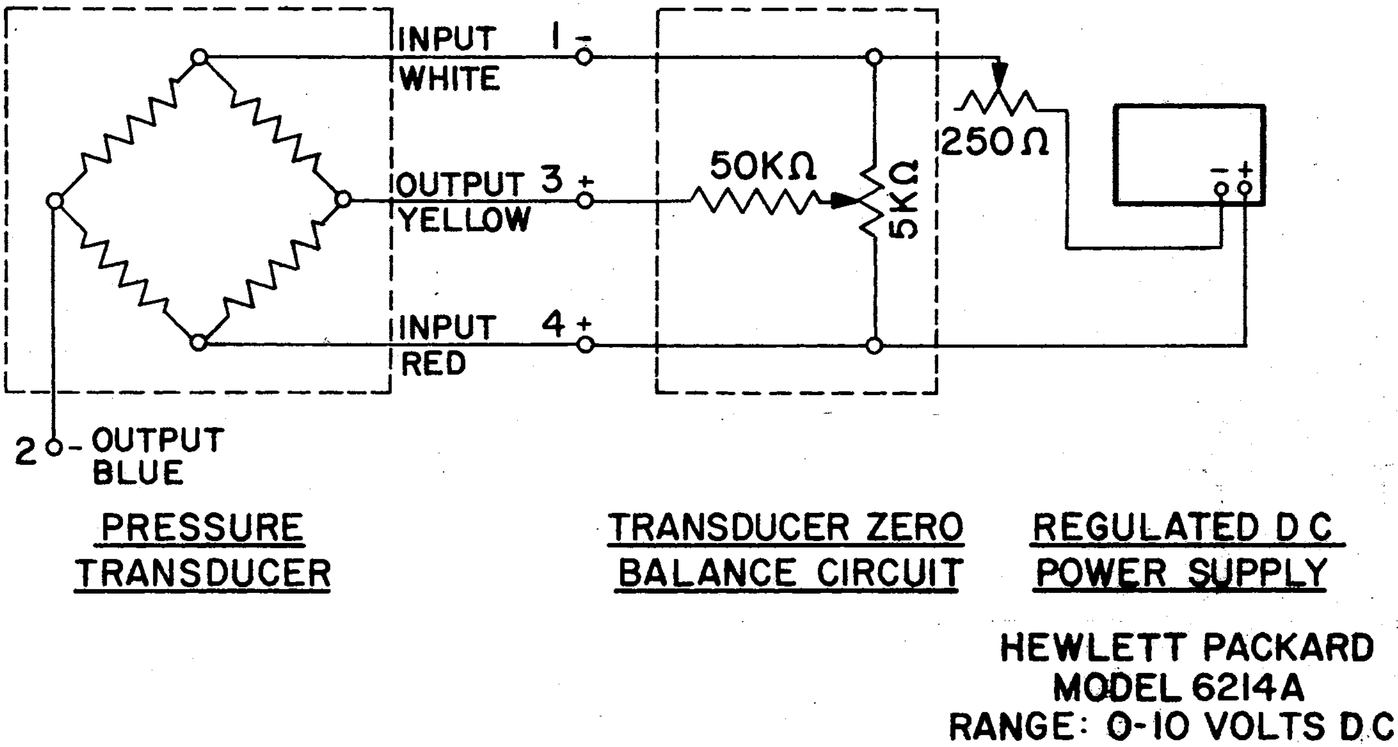

Figure 6. Circuit Diagram for Connecting the Pressure Transducer

For each experimental run, the fluid pressure at the inlet and the exit of the helical coil, as indicated by the pressure transducers, was recorded on the oscillograph to determine the steadiness of the fluid flow.

Two D'Arsonval mirror type galvanometers, one for the inlet and the other for the exit pressure transducer, were used in the oscillograph. The galvanometers used were CEC Type 7-351 and 7-339. Table V lists the characteristics of the two galvanometers.

TABLE V

CHARACTERISTICS OF THE GALVANOMETERS (14)

Item	CEC Galvanometer	
	Type 7-351	Type 7-339
External damping resistance required, ohms	350	350
Undamped natural frequency, Hz	20	50
Terminal resistance ($\pm$10%), ohms	33	30
System voltage sensitivity at 11.5 inch optical arm, in./mv	0.982	0.572
Maximum safe current, milliamps	15	15

DC Ammeter and Voltmeter

The power input to the coil was measured by the DC ammeter and the voltmeter.

The current flowing through the coil was measured by a Weston model 931 DC ammeter in conjunction with a 50 millivolt shunt. The ammeter has a 0-750 amperes range.

The 50 millivolt shunt was connected in the line carrying the current to the coil. The ammeter was connected across the shunt.

The voltage drop across the coil was measured by a Weston model 931 DC voltmeter. The voltmeter has a 0-50 volts range. The voltmeter was connected to the two copper bars.

The ammeter and the voltmeter were calibrated by the manufacturer and were guaranteed to be accurate to within one percent of their full range, that is ±7.5 amperes and ±0.5 volts, respectively.

Mercury-in-glass Thermometers

Mercury-in-glass thermometers were used to measure the bath fluid temperature and the room temperature. A Brooklyn "P-M" 20 to 300°F thermometer was used to measure the bath fluid temperature. The thermometer was graduated in 2°F intervals. A 23-inch long, 65 to 90°F ASTM Calorimeter Thermometer was used to measure the room temperature. In addition, another 20 to 300°F Brooklyn "P-M" thermometer was also used to measure the room temperature, especially when the room temperature was higher than 90.25°F, the upper indicated limit of the ASTM Calorimeter Thermometer.

Numatron

The thermocouple and the pressure transducer outputs were measured on the Numatron. The Numatron is Leeds and Northrup Company's tradename for a voltmeter with a digital readout. Hereafter, in this dissertation, the word 'Numatron' will be used to denote the voltmeter with a digital readout. The Numatron is also equipped with the circuitry that converts a thermocouple emf fed to the instrument into its corresponding temperature reading. The reading is displayed directly in degrees Fahrenheit on the digital readout panel in the Numatron.

The Numatron has the following stated accuracies: ±0.26°F for the 0 to 300°F temperature range; 10 microvolts ±1 Digit for the 0.01 volt range; and, 1 millivolt ±1 Digit for the 10 volt range. Further details regarding the Numatron may be obtained from the Numatron Operations Manual (28).

The Numatron was acquired in April 1971. Prior to that, the thermocouple and pressure transducer outputs were measured using a Leeds and Northrup model 8690 potentiometer. Experimental data for runs 217 to 262 were obtained using the 8690 potentiometer.

Auxiliary Equipment

Auxiliary equipment was used for the calibration of the measuring devices. All measuring devices were calibrated except the DC ammeter and voltmeter and the oscillograph per se. The description of the auxiliary equipment is classified into the following sections based upon the measuring device(s) calibrated:

1. Thermocouple and thermometer calibration equipment.
2. Pressure transducer calibration equipment.
3. Rotameter calibration and fluid flow rate measurement equipment.
4. Numatron calibration equipment.

Thermocouple and Thermometer Calibration

Equipment

The Conax thermocouples and the Brooklyn "P-M" thermometers were calibrated by recording the temperatures indicated by them when inserted in a preset constant temperature bath.

The constant temperature bath used was a "Lo-Temptrol" model 154 Circulating System manufactured by the Precision Scientific Company. The bath set-point temperature could be varied continuously from 14°F (-10°C) to 212°F (100°C). The circulating system has a guaranteed accuracy for maintaining the bath temperature to within ±0.108°F (±0.06°C) of the set-point temperature (31).

The emfs generated by the Conax thermocouples were measured on an 8690 potentiometer. The reference junction was inserted in a Dewar flask filled with crushed ice and distilled water mixture. The potentiometer has a stated accuracy of ±(0.05% of reading + 40 microvolts) (11).

Pressure Transducer Calibration Equipment

The pressure transducers were calibrated using a Budenberg Dead Weight Tester and a 0-60 psi Bourdon Tube pressure gauge manufactured by the Crosby Gage and Valve Company. The Budenberg Dead Weight Tester is accurate to 0.05%.

Rotameter Calibration and Fluid Flow Rate Measurement Equipment

The rotameter calibration and fluid flow rate measurement equipment consisted of the following:

1. Stop Watch: A 60 minute stop watch with a main dial range of 60 seconds was used to time the fluid flow rate. The stop watch has an accuracy of 0.2 seconds.

2. Weighing Equipment: A 5 kilogram capacity Ohaus Pan Balance was used to weigh the amount of fluid collected for fluid flow rates below 1.0 gpm. The balance has a sensitivity of 0.5 grams. A set of calibrated weights was used in conjunction with the balance.

For fluid flow rates greater than 1.0 gpm, a single-beam platform weighing scale was used to weigh the amount of fluid collected. The weighing scale has a capacity of 300 lbs and an accuracy of 0.125 lb. The beam is graduated in pounds and ounces. The scale was calibrated against a set of "bullion" weights.

3. Fluid Collecting Vessels: The fluid collecting vessels consisted of various capacity beakers and cylindrical jars. The vessels were used to collect the fluid for a given time interval, so that the mass flow rate could be determined. Also, 500 and 1,000 ml volumetric flasks were used to calibrate both floats in Rotameter 1.

Numatron Calibration Equipment

A Leeds and Northrup model 8687 volt potentiometer was used for the calibration of the Numatron. The potentiometer used has a maximum stated accuracy of $\pm$(0.03% of reading + 30 microvolts) (10).

CHAPTER IV

EXPERIMENTAL PROCEDURE

The experimental procedure is subdivided into three sections: (1) Calibration procedure; (2) Start-up procedure; (3) Data gathering procedure.

Calibration Procedure

Thermocouple and Thermometer Calibration

The two Conax thermocouples were first calibrated from 32°F (0°C) to 212°F (100°C) by inserting the thermocouples in a preset constant temperature bath and measuring the emfs generated by the thermocouples. The bath temperature was varied from 32°F (0°C) to 212°F (100°C) in 10°C increments. Distilled water was used as the bath fluid; for calibration at 32°F (0°C), a mixture of methanol and distilled water was used as the bath fluid.

The thermocouples were immersed to a depth of approximately three inches in the bath fluid. The 'Micro-Set Thermoregulator' switch was adjusted to the desired temperature and the system was set into operation to bring the bath fluid temperature up to the set-point temperature. The system was then operated for about one hour to insure that steady state had been achieved. Following this step, thermocouple outputs were measured four times at fifteen minute intervals. The thermoregulator switch was then adjusted for a new temperature and the entire procedure was repeated. Figures 18 and 19 in Appendix B are the calibration curves for the two thermocouples.

The Brooklyn P-M thermometers were likewise calibrated from 59°F (15°C) to 122°F (50°C) at 5°C increments. However, for the calibration of the thermometers, three readings were taken at fifteen minute intervals at each set-point temperature of the bath. The calibration curves for the thermometers are given in Figures 20 and 21 in Appendix B.

The Conax thermocouples and the insulated wire thermocouples, used to measure the outer tube wall temperature on the helical coils, were calibrated in-situ by bleeding low pressure saturated steam through the coils.

After the helical coils were installed in the fluid flow circuit and prepared for obtaining experimental data (see Start-up Procedure), the fluid flow circuit downstream of the helical coil was altered slightly to facilitate the collection of the steam condensate from the coil during the calibration process. The alteration involved is indicated in Figure 7.

Low pressure saturated steam was bled through the fluid flow circuit. The system was allowed to achieve steady state. Thermocouple readings, inlet and exit steam pressure, room temperature and the atmospheric pressure in the room were recorded after 3, 6 and 12 hours of operation. In addition, the steam condensate flow rate was also measured at the abovementioned time intervals.

Knowing the absolute pressure of the saturated steam at the inlet and exit of the coil, the steam temperature was determined from steam

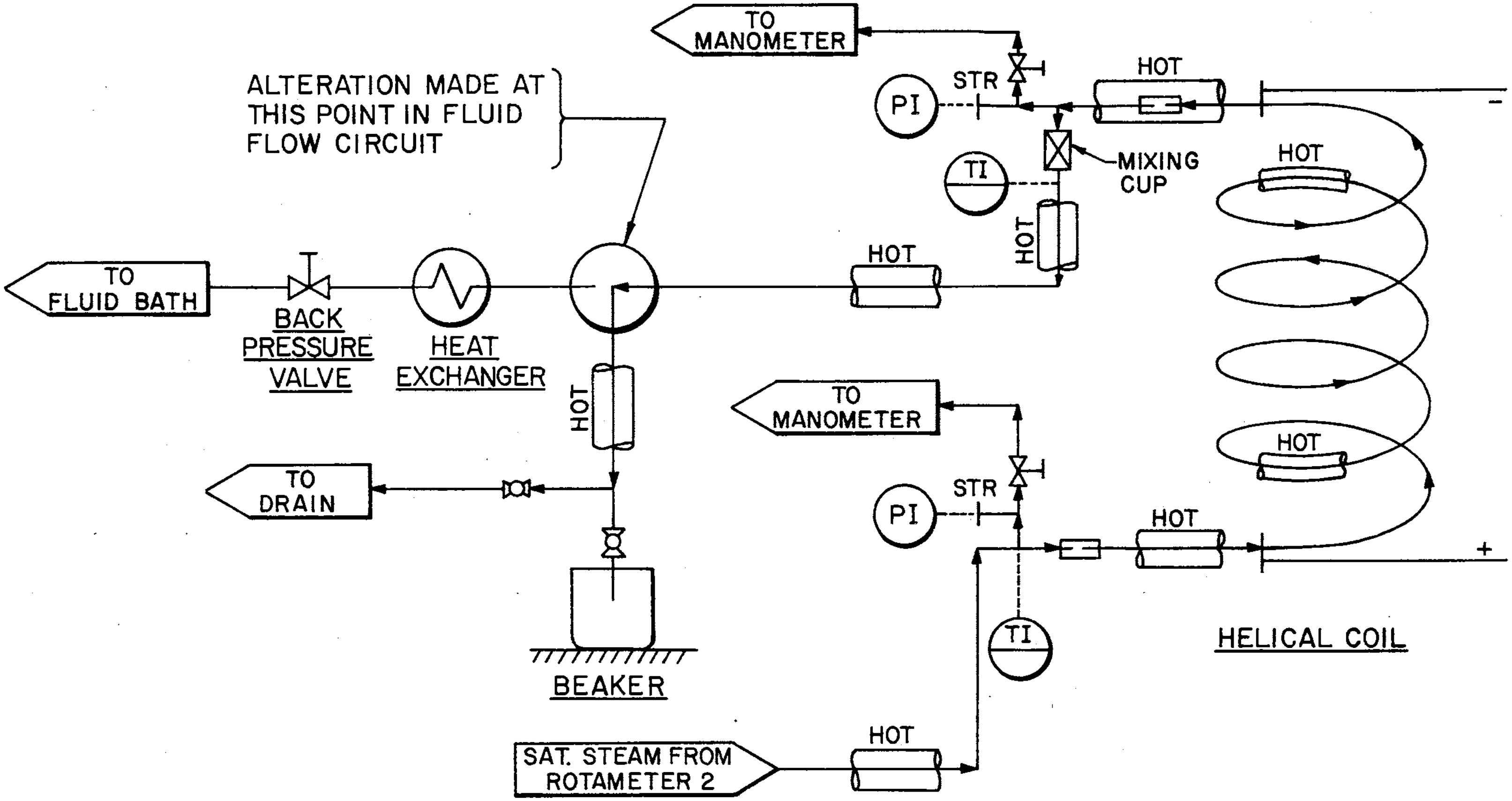

Figure 7. Sketch of the Experimental Set-up for the In-Situ Calibration of the Insulated Wire and Conax Thermocouples

tables and hence the deviation indicated by the thermocouples was determined. The steam temperature was assumed to drop linearly along the length of the helical coil. Knowing the condensated flow rate, the steam temperature in the coil, the room temperature and the total outer surface area of the coil, the average heat loss flux and the heat loss at the calibration conditions was determined. Thermocouple calibration data are presented in Appendix B.

The thermocouple calibrations and the heat loss information obtained were incorporated into the computer programs for calculating the heat balance and the inside wall temperatures.

Pressure Transducer Calibration

The two pressure transducers were calibrated from 0 to 50 psig using a Budenberg Dead Weight Tester and a Crosby 0-60 psig Bourdon tube type pressure gauge. Since test pressures on the Budenberg Dead Weight Tester could be incremented in steps of 10 psi only, the Crosby pressure gauge was first calibrated from 0 to 50 psig. The two pressure transducers were then calibrated at 5 psi increments from 0 to 50 psig using the calibrated Crosby pressure gauge as the reference standard. The Budenberg Dead Weight Tester was used to provide the fluid pressure to all three instruments simultaneously. Pressure transducer outputs were measured individually on the Numatron. Calibrations for the two pressure transducers are presented in Table XIII in Appendix B.

Rotameter Calibration

Both rotameters used in the course of the experiments were calibrated for distilled water. Rotameter 1 was calibrated from 10 percent to 100 percent of maximum flow in 10 percent increments for both floats. Rotameter 2 was calibrated from 1.0 to 5.0 gpm in 0.5 gpm increments. Both the rotameters were calibrated with the flow rate increasing upto the maximum and then decreasing to the minimum flow rate.

The calibration procedure consisted of the following steps:

1. The fluid flow rate was adjusted to the desired float setting on the rotameter.

2. After operating for some time at the desired float setting, the fluid flowing in the system was collected in a previously weighed empty container for a predetermined interval of time. The time interval ranged from 30 seconds up to three minutes, depending upon the flow rate being calibrated.

3. The bath fluid temperature was recorded and taken to be the temperature of the fluid in the rotameter.

4. The vessel containing the fluid collected was weighed to determine the weight of the fluid collected.

The abovementioned procedure was repeated three times for each float setting on the rotameter.

Rotameter 1 was also calibrated for both floats with Dowtherm G as the working fluid using the abovementioned procedure. However, since the viscosity immunity ceiling for both floats was exceeded for Dowtherm G, the rotameters were used as guides to set the flow rate and the mass flow rate was measured (by the procedure outlined above) at the time of execution of the data run.

Calibration data for Rotameters 1 and 2 are presented in Table XIV through Table XV in Appendix B. Dowtherm G mass flow rates measured during the execution of the data runs are presented in Table XVI through Table XIX in Appendix B.

Numatron Calibration

The Numatron was calibrated periodically. The calibration procedure is detailed in section 14 of the Numatron Operations Manual (28).

Start-up Procedure

Experimental data were obtained for two different diameter (9.99 and 20.64 inches) helical coils.

After one of the helical coils was installed in the fluid flow circuit and the thermocouple wires were connected to the switches on the thermocouple selector switchboard, the fluid flow circuit was tested for possible leaks by flowing fluid at the anticipated maximum flow rate through the circuit. Any leaks detected were eliminated. The fluid flow circuit was then insulated with fiberglass tape and fiberglass wool insulation and prepared for obtaining experimental data.

The above operation was performed every time the helical coil was changed.

The start-up procedure was followed every time the experimental set-up was activated to gather experimental data. The start-up procedure consisted of the following steps:

1. The impeller and the heater in the fluid bath were activated and the fluid in the bath was brought to the desired operating temperature (72°F or 90°F).

2. The Numatron, the oscillograph and the DC power supply for the pressure transducers were switched on and the mercury vapor lamp in the oscillograph was activated.

3. The pump was started and the fluid was allowed to circulate in the by-pass line.

4. The input voltage to the pressure transducers was adjusted to 5 volts by adjusting the potentiometer on the voltage supply unit.

5. Cooling water was started to the heat exchanger located downstream of the helical coil.

6. The flow control valve located upstream of the rotameter (Item 1 in Figure 3) was opened and the fluid was allowed to flow through the test section.

7. The DC ammeter and Voltmeter zero were checked and adjusted, if necessary.

8. The DC generator was started, with the polarity switch in the "Off" position, and allowed to warm-up for about 15 minutes.

9. After the warm-up period the polarity switch was thrown to the "Electrode Negative" position thereby causing the DC current to flow through the test section.

Data Gathering Procedure

The data gathering procedure consisted of the following steps:

1. The fluid flow rate was adjusted to the desired value by means of the flow control valve.

2. The DC current was adjusted to the desired value by varying the output control switch on the control box of the generator. Fine

control of the current was accomplished by adjusting the external rheostat connected to the generator.

3. The cooling water flow rate to the heat exchanger was adjusted so that the bath fluid temperature remained constant.

4. The exit fluid pressure from the coil was monitored on the Numatron. If the transducer output was negative, the back pressure valve was partially closed and the fluid flow rate was adjusted to create a positive transducer output at the desired flow rate.

5. The experimental set-up was then operated for at least one and a half hours to allow the system to achieve steady state. Minor adjustments were made to the current, the fluid flow rate and the cooling water flow rate, as was deemed necessary.

6. After about two hours of operation, the following experimental data were measured:

a. The helical coil surface temperatures (indicated by the insulated wire thermocouples cemented on the coil).

b. The inlet and exit bulk fluid temperatures (indicated by the Conax thermocouples).

c. The fluid flow rate indicated by the rotameter.

d. The DC current flowing through the coil and the voltage drop across the coil.

e. The room and the bath fluid temperature.

f. The coil inlet and exit fluid pressure, as indicated by the pressure transducers.

All the thermocouple and pressure transducer outputs were measured on the Numatron. During the measurement of the transducer outputs on the

Numatron, the transducer outputs were also alternately switched to the oscillograph to monitor the steadiness of the fluid flow.

7. The entire set of data, as indicated in Step 6 above, was measured again to ascertain if steady state had been achieved. The time span between the two sets of measurements was approximately half an hour.

8. Steady state was deemed to have been achieved if the two sets of temperature and pressure measurements agreed within $\pm$0.3°F for temperature measurements and within $\pm$0.1 millivolt for the pressure transducer measurements.

If steady state had not been achieved, Steps 6 and 7 were repeated after about one hour of continued operation.

Except for a few data cases, steady state was achieved when data were measured after about two hours of operation for a given set of fluid flow rate and current settings.

The fluid flow rate and/or the current was changed to a new set of conditions and the entire Data Gathering Procedure was repeated for the new set of input conditions.

For the Dowtherm G runs, the mass flow rate of the fluid was measured, after obtaining the temperature and pressure data as indicated in Steps 6 and 7 of the Data Gathering Procedure section, before proceeding to a new set of input conditions.

The distilled water used in the experiments was changed frequently to minimize the solids content of the water.

CHAPTER V

DATA REDUCTION

Experimental data were gathered for two helical coils using distilled water and Dowtherm G. In all, 158 data runs were made using water and 112 runs were made using Dowtherm G as the working fluid. The raw experimental data are presented in Appendix A. Computer programs were written to reduce the experimental data using the IBM 360/65 computer. Computer program flowcharts and listings are given in Appendix F.

The physical quantities measured for each data run are listed under item 6 in the Data Gathering Procedure in Chapter IV. The outer surface temperatures were measured at 48 locations along the length of the coil. Details regarding the locations of the thermocouples are given in Chapter III.

The physical properties of the fluid were evaluated at the average bulk fluid temperature at each thermocouple station. The bulk fluid temperature was assumed to increase linearly along the axial length of the coil, starting from the inlet electrode.

Average temperatures for the entire coil, for each data run, were taken to be the temperatures at thermocouple station 5 located midway up the helical coil. To correct for wall effects, the fluid viscosity was also determined at the average inside wall temperature so that the viscosity correction factor may be evaluated.

Physical properties of the fluid were also evaluated at the average film temperature so that correlations presented by some earlier workers in the field may be tested for their effectiveness.

Regression correlations were developed to evaluate the physical properties of the fluids at the appropriate temperatures. These correlations are presented in Appendix C and are incorporated into the computer programs used for the data reduction.

Data reduction consisted of the following steps:

1. Calculation of the overall heat balance.

2. Calculation of the local inside wall temperature and the inside wall radial heat flux.

3. Calculation of the local heat transfer coefficient.

4. Calculation of the dimensionless axial distance and the dimensionless inside wall temperature.

5. Calculation of the relevant dimensionless numbers.

6. Calculation of the Fanning friction factor.

Details regarding the above mentioned steps follow.

Calculation of the Overall Heat Balance

The overall heat balance for each data run was calculated as follows:

Heat input rate, BTU/hr = Q_{input}

$$Q_{input} = \text{(Current in coil) (Voltage drop across coil) (3.4128)} \tag{5.1}$$

Heat output rate, BTU/hr = Q_{output}

$$Q_{output} = (W)\ (C_p)\ [(t_b)_{out} - (t_b)_{in}] \tag{5.2}$$

where

W = mass flow rate of fluid flowing through the coil, lb/hr;

C_p = specific heat of the fluid at the average bulk fluid temperature in the coil, BTU/lb-°F;

$(t_b)_{out}$ = bulk fluid temperature at the coil exit, °F;

$(t_b)_{in}$ = bulk fluid temperature at the coil inlet, °F;

$\Delta Q = Q_{input} - Q_{output}$;

$$\text{Percent error in heat balance} = \left\{\frac{\Delta Q}{Q_{input}}\right\}\{100\}.$$

The inlet and the exit fluid temperatures were measured by the Conax thermocouples. These temperatures were corrected based on the thermocouple calibrations given in Table X in Appendix B before being used in Equation (5.2).

Calculation of the Local Inside Wall Temperature and the Inside Wall Radial Heat Flux

Crain (9) developed a computer program to numerically calculate the inside wall temperature from the measured outside wall temperature. This computer program was used to determine the inside wall temperatures from the measured outside wall temperatures. The computer program was modified to correct the measured outside wall temperatures, based on the surface thermocouple calibrations. The calibration data for the surface thermocouples on the two helical coils are given in Table XI and XII in Appendix B.

Briefly, the modified computer program corrects the outside wall temperatures and then, using the corrected outside wall temperatures, computes the inside wall temperatures by a trial-and-error solution.

The program also computes the inside wall radial heat flux at each thermocouple location on the helical coil. Details regarding the computer program are given in Reference (9). A flowchart and a listing of the modified computer program, called SPNS01, are given in Appendix F of this thesis.

Calculation of the Local Heat Transfer Coefficient

Knowing the inside wall temperature, the inside wall radial heat flux and the bulk fluid temperature, the local heat transfer coefficient was calculated as follows:

$$h = \frac{(Q/A)_i}{[(t_w)_i - t_b]} \qquad (5.3)$$

where

h = local inside heat transfer coefficient, BTU/hr-ft^2-°F;

$(Q/A)_i$ = local inside wall heat flux, BTU/hr-ft^2;

$(t_w)_i$ = local inside wall temperature, °F;

t_b = bulk fluid temperature at the thermocouple station, °F.

The local heat transfer coefficient calculated above (and used in this study) is the "apparent" local heat transfer coefficient and not the "true" heat transfer coefficient. It is the apparent heat transfer coefficient because in determining the value of the local heat transfer a computed average bulk fluid temperature for the thermocouple station was used rather than an experimentally measured bulk fluid temperature at the thermocouple station. This was done because it was not feasible (due to system limitations) to measure the fluid temperature at each thermocouple station without interfering with the fluid flow pattern.

The average bulk fluid temperature at the thermocouple station was obtained by measuring the "mixing-cup" bulk fluid temperature at the coil inlet and exit and by assuming that the fluid temperature rise was linear along the length of the helical coil.

Calculation of the Dimensionless Axial Distance and the Dimensionless Inside Wall Temperature

The dimensionless axial distance and the dimensionless inside wall temperatures were calculated for each thermocouple for each data run:

1. To get the temperature profiles across the coil for each thermocouple location on a common basis for ease of comparison.

2. To facilitate a comparison of the experimental data with the results presented by Dravid et al. (13).

The dimensionless axial distance and the dimensionless wall temperatures were defined exactly as Dravid et al. (13) defined them, namely:

$$\text{Dimensionless axial distance} = z = \frac{\text{Axial distance along helical coil from inlet electrode, ft.}}{\text{Tube inside radius, ft.}} \tag{5.4}$$

and

$$\text{Dimensionless wall temperature} = T_w = \frac{[t_w - (t_b)_{inlet}]}{dt_b/dz} \tag{5.5}$$

where

$$\frac{dt_b}{dz} = \frac{[(t_b)_{exit} - (t_b)_{inlet}]}{\dfrac{\text{Total heated length, ft.}}{\text{Tube inside radius, ft.}}} \tag{5.6}$$

Calculation of the Relevant Dimensionless Numbers

The dimensionless numbers calculated at the average bulk fluid temperature at each station were the Reynolds, Prandtl, Dean and Graetz number. The Nusselt number was also calculated for each thermocouple position at each station. In addition, the Grashof and Rayleigh numbers were calculated for each station using the circumferentially-averaged inside wall temperature and the average bulk fluid temperature at the station. The definition of the dimensionless numbers evaluated are given in Table VI.

Calculation of the Fanning Friction Factor

The Fanning friction factor for fluid flow in a helically-coiled tube was calculated as follows:

From page 182 of Reference (6):

$$f = \left\{\frac{1}{4}\right\} \left\{\frac{d_i}{L}\right\} \left\{\frac{P_0' - P_L'}{\frac{1}{2}\rho V_{avg.}^2}\right\} (g_c) \tag{5.7}$$

where

$P_0' - P_L'$ = the frictional pressure loss due to fluid flow between the measuring points 0 and L.

$$= \left[(P_0 - P_L) + \rho\frac{g}{g_c}(H_0 - H_L)\right]$$

where

$P_0 - P_L$ = the measured fluid pressure drop between the measuring points 0 and L,

and

$H_0 - H_L$ = the difference in elevation between the points 0 and L.

For the helical coil, $H_L > H_0$

$\therefore$ $H_0 - H_L$ is negative.

$\therefore$ Equation (5.7) may be written as:

TABLE VI

DEFINITION OF THE DIMENSIONLESS NUMBERS EVALUATED

Dimensionless Number	Symbol	Definition
Reynolds	Re	$\frac{(d_i)(G)}{\mu}$
Prandtl	Pr	$\frac{(C_p)(\mu)}{k}$
Dean	De	$(Re)(\sqrt{d_i/D_c})$
Graetz	Gz	$\frac{(W)(C_p)}{(k)(L)}$
Nusselt	Nu	$\frac{(h)(d_i)}{(k)}$
Grashof	Gr	$\frac{(d_i^3)(\rho^2)(g)(\beta)(\Delta t)}{\mu^2}$
Rayleigh	Ra	$(Gr)(Pr)$

$$f = \left(\frac{1}{2}\right)\left(\frac{d_i}{L}\right)\left[\frac{1}{v_{avg.}^2}\left\{\frac{(P_0 - P_L)}{\rho} - \frac{g}{g_c}(H_L - H_0)\right\}\right](g_c) \qquad (5.8)$$

or, for the measured pressure drop, $P_0 - P_L$, in lb_f/in^2:

$$f = \left(\frac{1}{2}\right)\left(\frac{d_i}{L}\right)\left[\frac{1}{v_{avg.}^2}\left\{\frac{(P_0 - P_L)(144)(g_c)}{\rho_b} - g(H_L - H_0)\right\}\right] \qquad (5.9)$$

The friction factor obtained from Equation (5.9) was corrected for wall viscosity effects by applying the viscosity correction factor. The viscosity correction factor is given by the following equation:

$$\text{viscosity correction factor} = \left(\frac{\mu_b}{\mu_w}\right)^{0.14} \qquad (5.10)$$

∴ corrected $f = f_c = (f)$ (viscosity correction factor)

where

f_c = Fanning friction factor for isothermal fluid flow in a helically-coiled tube.

All the experimental data gathered was reduced using the above procedures. Sample calculations for one data run are given in Appendix D.

To understand the mechanism of the heat transfer process in a helical coil, the inside wall heat transfer coefficients were calculated for each thermocouple location on the coil and the Nusselt number profile for each thermocouple station was digitally plotted for four thermocouple locations on the tube periphery for each data run. The four thermocouple positions selected were the top, bottom, inner and outer side of the tube periphery. These positions are shown in Figure 9 in Chapter VI.

CHAPTER VI

RESULTS AND DISCUSSION OF RESULTS

Experimental data were gathered for Reynolds numbers ranging from 6 to 46,000 using water and Dowtherm G for two helically coiled tubes 9.99 and 20.64 inches in diameter. Results of this study together with a discussion of the results are presented in this chapter.

The critical Reynolds number for fluid flow in the two helical coils was determined by using the correlation given by Ito (18):

$$Re_{cr} = 2 \times 10^4 (d_i/D_c)^{0.32} \qquad (6.1)$$

The critical Reynolds number for the 20.64-in. coil was calculated to be 6061 while that for the 9.99-in. coil was 7646. A study of the experimental data gathered indicated that the critical Reynolds number for the 20.64-in. coil was between 5449 and 6385, while that for the 9.99-in. coil was between 7410 and 8439. Since the demarcation was not distinct, the calculated critical Reynolds numbers (calculated using Equation (6.1)) were used in the analysis of the data.

The experimental results and the discussion of the results are subdivided into two sections:

1. Fluid flow friction factor results.
2. Heat transfer results.

Fluid Flow Friction Factor Results

Fanning friction factors were calculated from the experimentally measured fluid pressures for each data run according to the procedure given in Chapter V. Figure 8 shows the Fanning friction factors plotted against the average Reynolds number for fluid flow in the two helical coils studied. The Hagen-Poiseuille law for the laminar flow regime and the Blasius resistance formula for the turbulent flow regime for the straight tube are also shown in Figure 8.

From Figure 8 the following observations are made:

1. For Reynolds numbers greater than approximately 150, for similar fluid flow conditions, the friction factor for flow in the helical coils is higher than the friction factor for flow in an equivalent straight tube.

2. For Reynolds numbers less than approximately 150, the friction factor for the helical coil becomes identical with the friction factor for the straight tube.

3. In the laminar flow regime, the difference between the helical coil and the straight tube friction factors increases as the Reynolds number increases.

4. In the turbulent flow regime, the helical coil friction factors are generally greater than those for an equivalent straight tube, under similar fluid flow conditions.

The increase in the friction factor for fluid flow in helically coiled tubes is due to the presence of the superimposed secondary flow pattern that occurs when fluids flow in curved tubes.

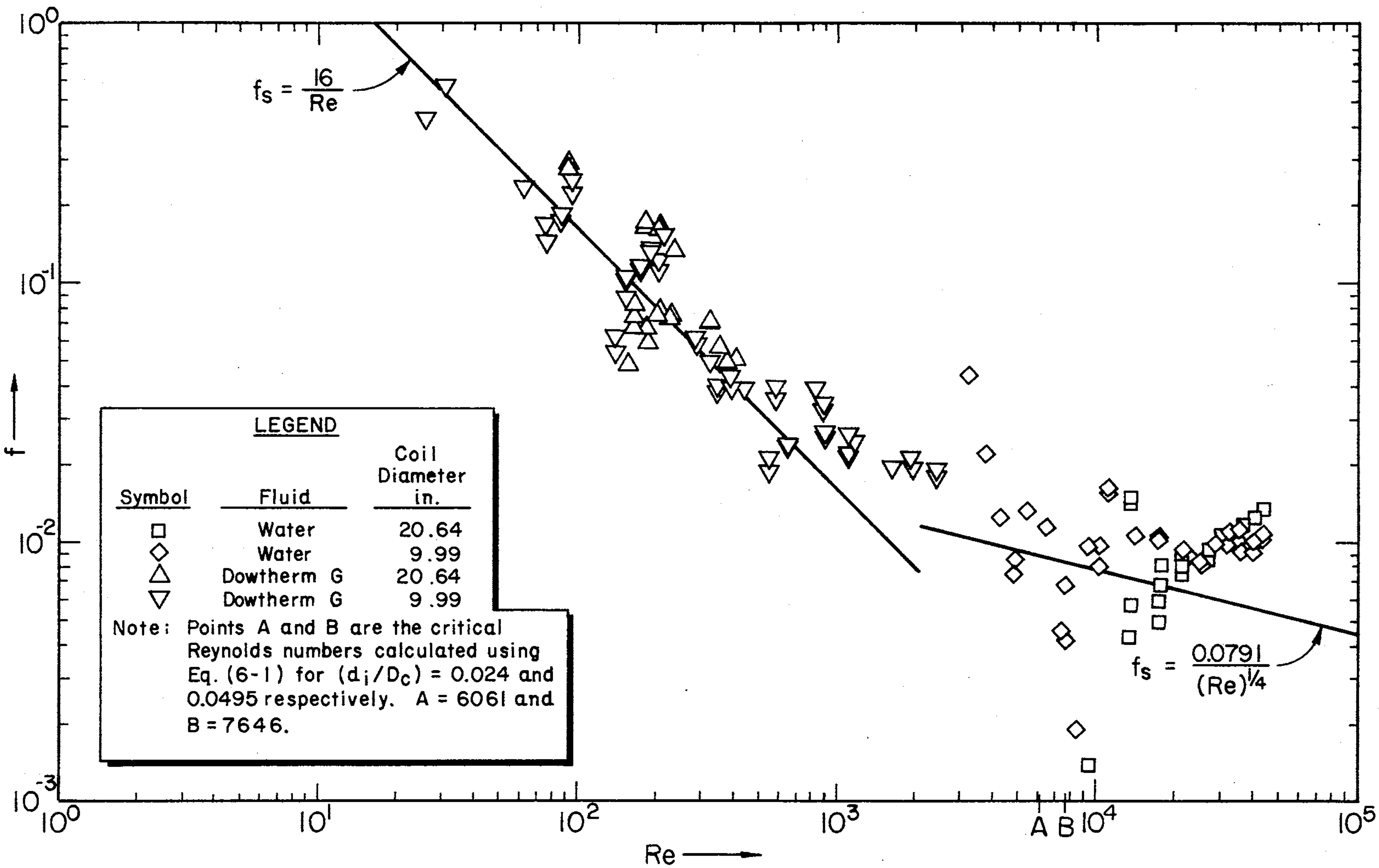

Figure 8. Experimental Fanning Friction Factors for Fluid Flow in the Helical Coils Evaluated

Figure 2 in Chapter II shows the plot of several literature correlations plotted on axes similar to those of Figure 8. A comparison between the two figures indicates that the experimental values follow the trend and agree reasonably well with the values predicted by the literature correlations over the Reynolds number range studied. The agreement between the values is better in the laminar flow regime than in the turbulent flow regime.

Even though the experimental values agree reasonably well with the literature correlations, no correlation of the data was attempted because:

1. Most of the pressure drop data were measured at the low end of the 0-50 psig pressure transducers used to measure the fluid pressure at the inlet and the exit of the helical coil.

2. The accuracy of the data was not of the quality that could justify the development of a correlation (or correlations) based on the experimental data.

Heat Transfer Results

General Discussion

Values of the Reynolds, Dean and Prandtl numbers and the average values of the heat flux, the heat transfer coefficient and the Nusselt number for the inside wall were computed for each thermocouple station for each data run. These values are summarized in Appendix E for all the experimental data runs.

The average heat flux and the average heat transfer coefficient at a thermocouple station were defined as follows:

$$\text{Average heat flux} = \frac{1}{8}\sum_{i=1}^{8} (Q/A)_i , \tag{6.2}$$

$$\text{Average heat transfer coefficient} = \frac{1}{8}\sum_{i=1}^{8} \frac{(Q/A)_i}{(t_w)_i - t_b} \tag{6.3}$$

where i indicates the peripheral location on the tube cross section at a thermocouple station. The average heat transfer coefficient obtained from Equation (6.3) was then used to determine the average Nusselt number for the thermocouple station. The physical properties of the fluid used in the determination of the Reynolds, Prandtl and Nusselt number were evaluated at the average bulk fluid temperature at the thermocouple station, t_b.

As anticipated, higher heat transfer coefficients were obtained for fluid flow in a helically-coiled tube than in an equivalent straight tube under similar fluid flow conditions. This fact has been known historically and has been indicated by earlier workers in the field (Seban and McLaughlin (36), Schmidt (35) and Dravid et al. (13), to mention a few). It has been attributed to the presence of the superimposed secondary flow due to centrifugal action. For example, in the laminar flow regime the helical coil Nusselt numbers were, on the average, about two to three times the straight tube value; in several data runs, the helical coil values were about five times the straight tube value. In the turbulent flow regime the ratio of the helical coil to the straight tube Nusselt number was about 1.2. The decrease in the ratio for the turbulent flow regime (when compared to the values obtained in the laminar flow regime) may be due to the increased mixing of the fluid due to turbulent flow. The increased mixing results in higher heat transfer coefficients for both the helical coil and the straight tube and tends to dampen the beneficial effect of the secondary flow. The straight tube Nusselt numbers were computed by using the Hausen (15) correlation for the laminar regime and the Sieder-Tate (38) correlation for the turbulent regime.

Also, in general, the experimental results indicated that the heat transfer coefficient was the highest at position 7 and lowest at position 3 on the tube periphery. Locations of the positions on the tube periphery for a thermocouple station are given in Figure 9.

For example, in the laminar flow regime, for an average Reynolds number of 3402, the heat transfer coefficient at position 7 was 3.6 times the value at position 3, while the heat transfer coefficients at positions 1 and 5 were comparable and intermediate between the values at 3 and 7. This was attributed to the presence of the secondary flow caused by centrifugal action. The fluid flow pattern postulated to be responsible for the above behavior is sketched in Figure 9. Referring to Figure 9, the secondary flow causes the fluid to sweep position 7 thereby increasing the heat transfer coefficient at 7, but the recirculating fluid tends to accumulate at position 3 thereby decreasing the heat transfer coefficient at 3. Also, the fact that the heat transfer coefficients at positions 1 and 5 were comparable suggests that the secondary flow pattern was symmetrical about a horizontal plane through the tube center. The Nusselt number profile across the tube periphery for the above case is plotted in Figure 11 to indicate the Nusselt number variation around the tube periphery.

In the turbulent flow regime, although the fluid velocity was higher, the effect of the superimposed secondary flow was diminished possibly because of increased fluid mixing. For example, for an average

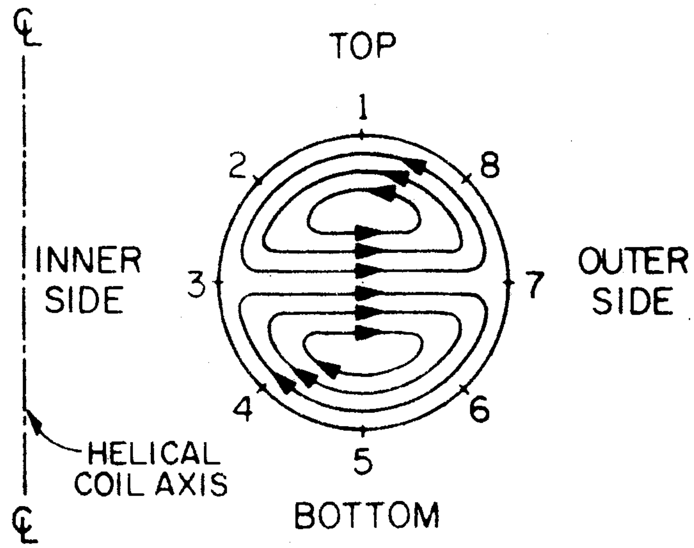

Figure 9. Postulated Fluid Flow Pattern in a Helically-Coiled Tube at High Reynolds Number Flow

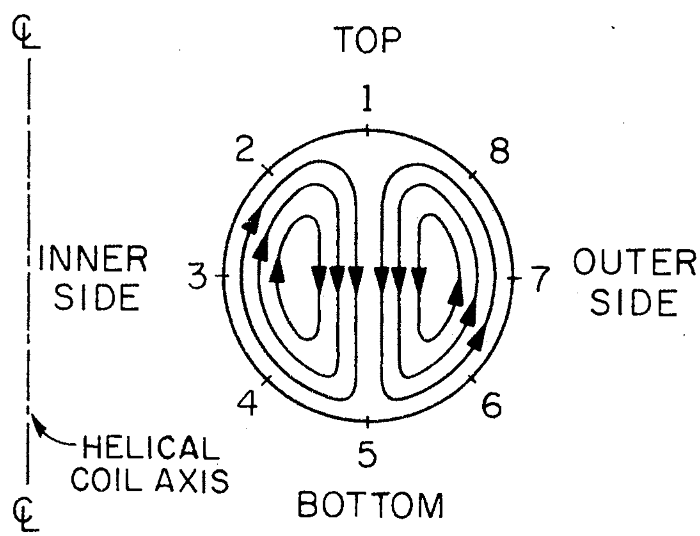

Figure 10. Postulated Fluid Flow Pattern in a Helically-Coiled Tube for Heat Transfer at Low Reynolds Number Flow

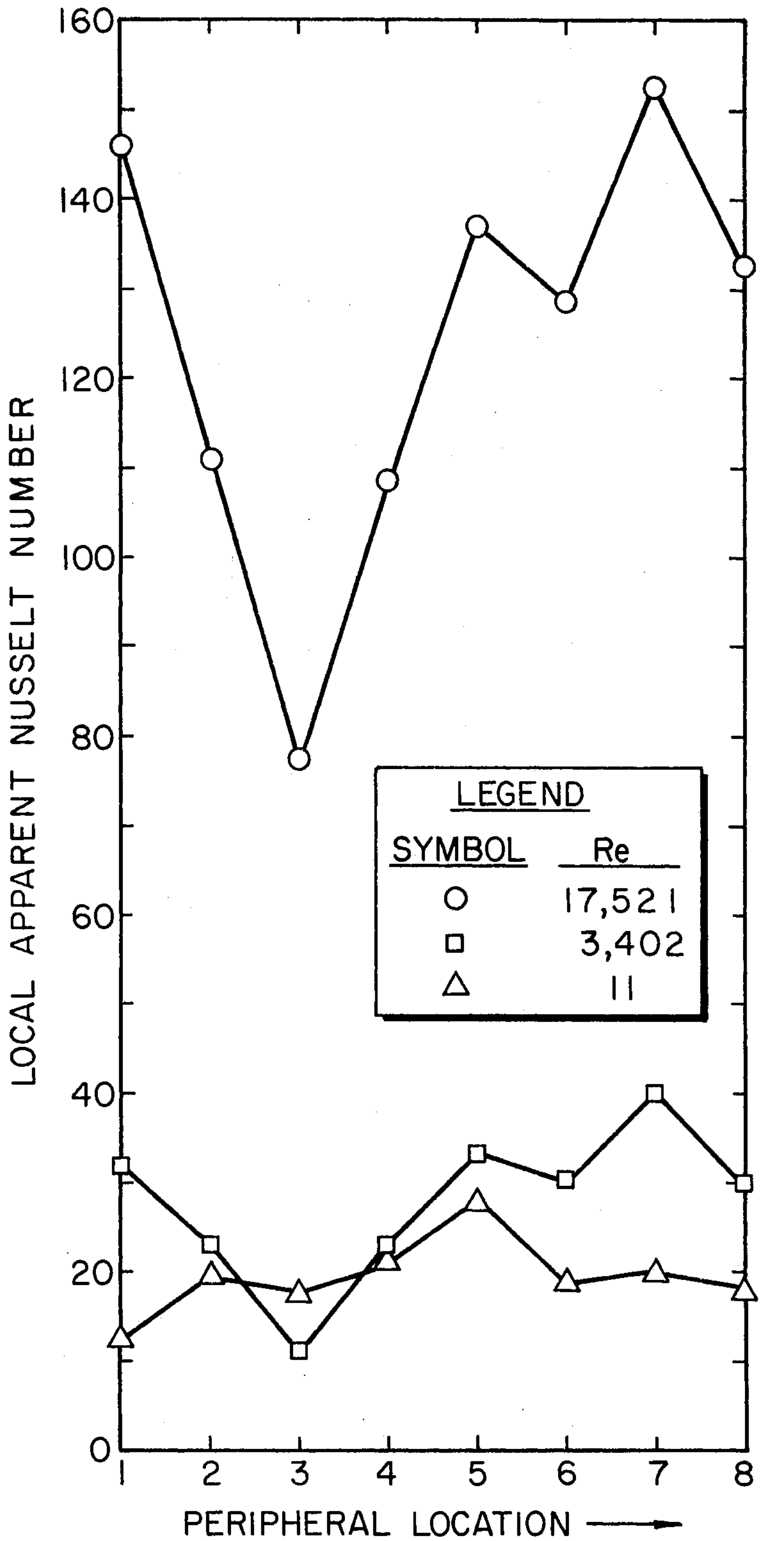

Figure 11. Typical Local Apparent Nusselt Number Profiles

Reynolds number of 17,521, the ratio of the heat transfer coefficient at position 7 to that at position 3 was 1.98. The Nusselt number profile across the tube periphery for a Reynolds number of 17,521 is plotted in Figure 11.

During the course of the heat transfer studies it was observed that as the fluid velocity through the helical coil was decreased below approximately 0.25 ft/sec, the highest heat transfer coefficient moved from position 7 to position 5 and the lowest heat transfer coefficient moved to position 1 from position 3, while the heat transfer coefficients at positions 3 and 7 were comparable and intermediate between the values at 5 and 1. For example, for an average Reynolds number of 11, the ratio of the heat transfer coefficients at positions 5 and 1 was 2.11. Figure 11 shows the Nusselt number profile for the above case. The peripheral average Nusselt number for this case was calculated to be 19.68, which is about 4.5 times as large as the asymptotic Nusselt number for pure forced convection in a straight tube under constant heat flux conditions, namely 4.36.

The fact that the experimental Nusselt number for flow in the helically-coiled tube was several times the straight tube asymptotic Nusselt number indicated that forced convection alone, due only to the axial flow of the fluid, could not be responsible for the experimentally obtained Nusselt number but that some other mode or modes of heat transfer were also present to augment the heat transfer coefficient. As indicated earlier, secondary flow due to centrifugal action could be one of these other modes of heat transfer. However, since the fluid velocity was below 0.25 ft/sec for the runs where the above phenomenon was observed, enhancement of the heat transfer coefficient due to secondary flow caused by centrifugal action would tend to be small. Also, the fact that the heat transfer coefficients were highest at position 5 and lowest at position 1 strongly indicated that a secondary flow pattern due to natural convection may well be the other mode of heat transfer that was instrumental in causing the higher heat transfer coefficients for the low Reynolds number runs. The fluid flow pattern postulated to be existing in the helically-coiled tube for heat transfer to the fluid at low Reynolds number is shown in Figure 10.

The flow patterns depicted in Figures 9 and 10 are idealized flow patterns. In actuality, the flow patterns may be skewed.

Empirical correlations have been developed to fit the experimental data in the laminar and turbulent flow regime. The correlations and details regarding their development are presented later in this chapter.

Testing of Literature Correlations

Available literature correlations in the laminar and turbulent flow regime were tested against the experimental results to determine how well the two agreed. The average absolute deviation (AAD), the average percent difference (APD) and the average absolute percent deviation (AAPD) were used as measures to determine the degree of fit of the literature correlations to the experimental data. Results of the tests are given in Tables VII and IX for the turbulent and the laminar flow regime, respectively.

The AAD, APD and AAPD are defined as follows:

$$\text{AAD} = \frac{\sum_{i=1}^{n} \left[\left| \begin{pmatrix}\text{Calculated} \\ \text{value}\end{pmatrix} - \begin{pmatrix}\text{Experimental} \\ \text{value}\end{pmatrix} \right| \right]_i}{n}$$

$$\text{APD} = \frac{\sum_{i=1}^{n}\left[\left\{\frac{\begin{pmatrix}\text{Calculated}\\ \text{value}\end{pmatrix} - \begin{pmatrix}\text{Experimental}\\ \text{value}\end{pmatrix}}{(\text{Experimental value})}\right\}\left\{100\right\}\right]_i}{n}$$

$$\text{AAPD} = \frac{\sum_{i=1}^{n}\left[\left|\text{APD}\right|\right]_i}{n}$$

where n is the total number of data runs evaluated and the summation is performed over all the data runs evaluated.

Further discussion of the heat transfer results is subdivided into three sections depending upon the fluid flow regime. Reynolds number is used as the criterion to determine the flow regime. The three flow regimes and the Reynolds number range for each regime are:

1. Turbulent flow regime: $Re \geq 10{,}000$;
2. Transition flow regime: $Re_{cr} \leq Re < 10{,}000$;
3. Laminar flow regime: $Re < Re_{cr}$;

where Re_{cr} is the critical Reynolds number. Re_{cr} values for the two coils were calculated using Equation (6.1). For the 9.99-in. coil Re_{cr} was calculated to be 7646, while for the 20.64-in. coil Re_{cr} was 6061.

Turbulent Flow Regime

Experimental data in the turbulent flow regime were gathered using water; 32 data runs were made using the 20.64-in. diameter coil and 24 data runs were made using the 9.99-in. diameter coil. In all 574 data points were obtained in the turbulent flow regime since temperatures were measured at ten stations along the coil for each data run.

Literature correlations were tested against the experimental results to determine how well the two agreed. Test results are given in Table VII for the two helical coils. It may be noted from Table VII that Schmidt's (35) correlation gave the best fit of the data for the 9.99-in. coil while Mori and Nakayama's (27) correlation gave the best fit for the 20.64-in. coil.

All of the literature correlations tested have two drawbacks:

1. The correlations do not predict the experimental data for both coils very well.

2. The correlations break down when extended to the straight tube case, i.e., when D_c tends to infinity.

Jeschke's (19) and Schmidt's (35) correlations do not suffer from the second drawback; however, they do not fit the data very well.

To overcome these drawbacks an empirical correlation was developed to calculate the average Nusselt number for fluid flow in a helical coil. The correlation was developed based on the data at station 5, located midway up the helical coil. This correlation was then tested to see how well it fit the data for the other thermocouple stations. Test results of the fit of the developed correlation to all the experimental data in the turbulent flow regime are given in Table VII.

Development of Correlation

As mentioned above, a correlation was developed based on the data at station 5. Station 5 data were selected because it was felt that the data represented the average conditions in the coil.

The correlation was developed as follows:

The ratio (Nu_{hc}/Nu_s) was plotted versus the curved tube factor, $(1 + Re \sqrt{d_i/D_c})$, for both coils. Nu_{hc} is the calculated Nusselt number for fluid flow in a helical coil and was calculated from the experimental data. Nu_s is the Nusselt number for an equivalent straight tube

TABLE VII

TEST RESULTS OF LITERATURE CORRELATIONS FITTED TO EXPERIMENTAL DATA FOR THE TURBULENT FLOW REGIME

Investigator(s)	Reference	Stated Range of Applicability	For 9.99-in. Coil			For 20.64-in. Coil		
			AAD	APD %	AAPD %	AAD	APD %	AAPD %
Jeschke	19	$Re_{cr}<Re<1.5x10^5$	57.3	44.1	44.1	32.0	29.7	29.7
Kirpikov	21	$10^4 \leq Re \leq 4.5x10^4$	12.9	-4.7	6.4	44.1	-23.6	23.6
Seban and McLaughlin	36	$6x10^3 \leq Re \leq 6.56x10^4$ $2.9 \leq Pr \leq 5.7$	19.1	16.6	16.6	6.9	6.2	8.8
Rogers and Mayhew	33	$10^4<Re<10^5$	7.8	5.0	6.0	17.5	-8.6	9.6
Mori and Nakayama	27	$Re(d_i/D_c)^{2.5}>0.4$ $Pr>1$	12.5	10.8	11.1	8.9	3.0	8.4
Schmidt	35	$2x10^4<Re<1.5x10^5$	11.5	5.3	5.9	21.3	-9.7	9.7
Shchukin	37	$Re_{cr}<Re<6.7x10^4$	16.0	13.0	13.1	11.0	1.1	9.2
Present Work	-	$10^4 \leq Re \leq 4.6x10^4$ $3.8 \leq Pr \leq 6.4$	5.5	-2.7	3.1	3.9	-0.09	2.2

calculated at the corresponding fluid conditions existing in the helical coil by using the Sieder-Tate (38) correlation:

$$Nu_s = 0.023(Re)^{0.8}(Pr)^{1/3}(\mu_b/\mu_w)^{0.14} \tag{6.4}$$

The curved tube factor was chosen as the abscissa to facilitate the development of a correlation that would reduce to the straight tube correlation when D_c tends to infinity. Figure 12 shows the data plotted on the above coordinates.

Linear regressions were performed to determine the best fitting straight lines to the points plotted. The best fitting lines are drawn on Figure 12. The slope and the intercept of the best fitting line for the 9.99-in. coil were 0.1126 and 0.4534 respectively. For the 20.64-in. coil the slope and the intercept were 0.06466 and 0.7576 respectively.

The slopes of the two lines mentioned above were correlated as a linear function of the helical coil curvature ratio, d_i/D_c. The resulting correlation is:

$$\text{Slope} = 0.0197 + 1.875(d_i/D_c) \tag{6.5}$$

The intercepts of the two lines were also correlated as a function of d_i/D_c. The intercepts were correlated using the functional relation shown below.

$$\text{Intercept} = e^{-c_1(d_i/D_c)}[1 + c_2(d_i/D_c)] \tag{6.6}$$

The reason for choosing a relationship such as Equation (6.6) was that the final correlation should be such that it may be capable of being extended to cover d_i/D_c values ranging between 0 and 1.

Equation (6.6) was solved by trial-and-error for the two constants c_1 and c_2. The values of c_1 and c_2 were computed to be 34.72 and 30.94, respectively.

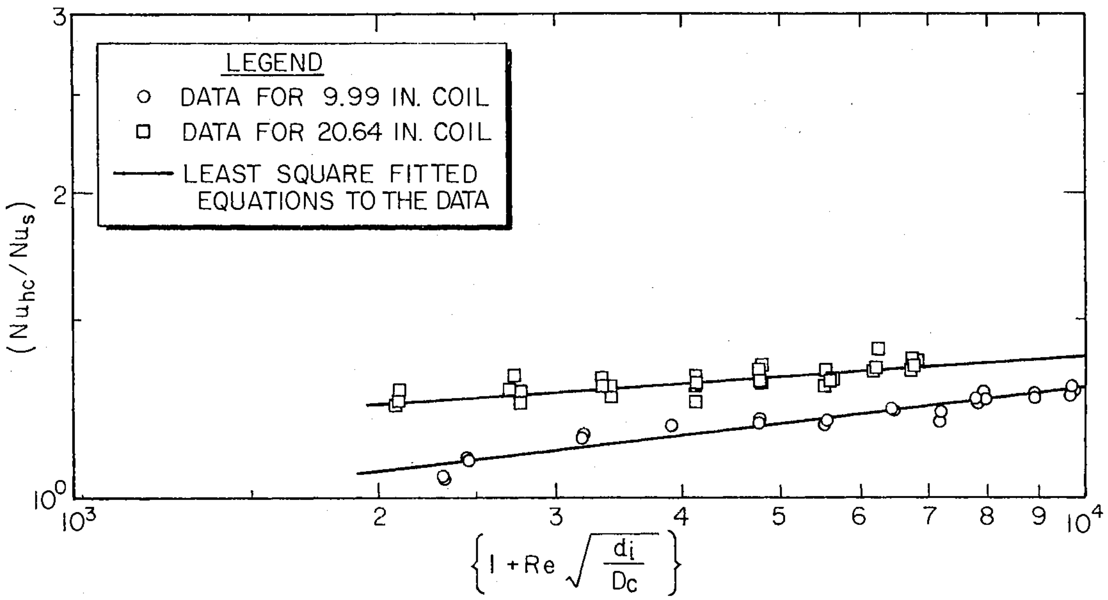

Figure 12. Experimental Turbulent Flow Regime Data for Thermocouple Station 5

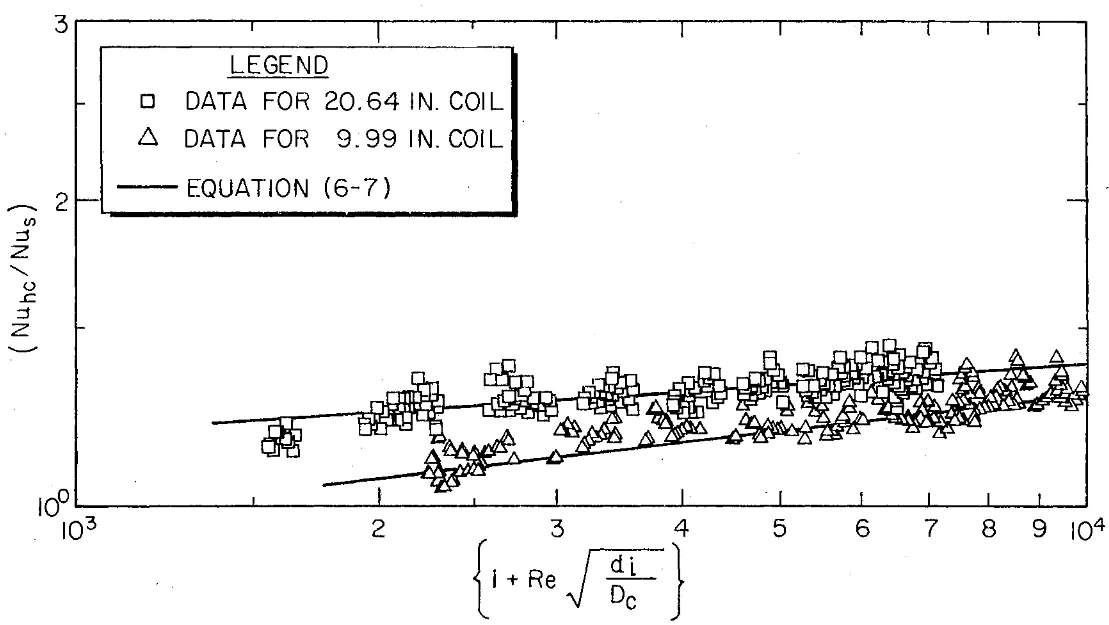

Figure 13. Experimental Turbulent Flow Regime Data for All the Thermocouple Stations

Hence, the final correlation may be written as:

$$Nu_{hc} = Nu_s \left\{ e^{-34.72(d_i/D_c)} \left[1 + 30.94\left(\frac{d_i}{D_c}\right) \right] \right\} \left\{ 1 + Re\sqrt{\frac{d_i}{D_c}} \right\}^{\delta} \quad (6.7)$$

where

$$Nu_s = 0.023(Re)^{0.8}(Pr)^{1/3}(\mu_b/\mu_w)^{0.14}$$

and

$$\delta = 0.0197 + 1.875(d_i/D_c).$$

Physical properties of the fluid used in Equation (6.7) and (6.4) were evaluated at the bulk fluid temperature except μ_w which was evaluated at the wall temperature.

As mentioned earlier, Equation (6.7) was developed to fit the data for station 5. This correlation was tested to see how well it fit the data for all the thermocouple stations. Test results of the fit to all the turbulent flow regime experimental data are given in Table VII. Figure 13 shows the plot of all the data and Equation (6.7).

From Figure 13 the following observations are made:

1. Higher heat transfer coefficients are obtained for fluid flow in a helically coiled tube than in an equivalent straight tube under similar fluid flow conditions.

2. Higher Nusselt numbers were obtained for flow in the 20.64-in. coil than in the 9.99-in. coil over the range of curved tube factors evaluated.

3. Data for the 9.99-in. coil have a greater slope than the data for the 20.64-in. coil.

One would expect that the data taken using the 9.99-in. coil would show a higher value of the Nu_{hc}/Nu_s ratio than the data taken using the

20.64-in. coil because of greater centrifugal action. However, the experimental data do not support this viewpoint. No satisfactory explanation could be developed to explain the experimental findings other than the fact that the two curvature ratios evaluated are too close to each other to make a definite statement. It is felt that more experimental data need to be gathered on helical coils with curvature ratios varying by at least an order of magnitude before any definite conclusions can be made.

Equation (6.7) was developed to fit the experimental data for Reynolds numbers ranging from 10,000 to 46,000; for Prandtl numbers ranging between 3.8 and 6.4 and for d_i/D_c ratios of 0.0240 and 0.0495. However, it is felt that Equation (6.7) may be capable of predicting Nusselt numbers for helical-coil flow for Reynolds and Prandtl numbers within the range of the Sieder-Tate turbulent flow correlation for the straight tube (Equation (6.4)).

Equation (6.7) is also limited with regard to the curvature ratio. The limiting curvature ratio is defined here as that value of d_i/D_c for which Equation (6.7) yields a value of $Nu_{hc} \leq Nu_s$. Two such limiting values of d_i/D_c exist: the lower limit and the upper limit.

The lower limit is d_i/D_c tending to zero. For d_i/D_c tending to zero (the straight tube case), Equation (6.7) reduces to Equation (6.4) which is the Sieder-Tate correlation for the straight tube.

The upper limit of d_i/D_c is dependent upon the Reynolds number of the fluid flowing through the helical coil. For a Reynolds number of 10,000, for example, the upper limit is 0.0595.

Transition Flow Regime

Of the experimental data gathered, 4 runs on the 9.99-in. coil and 12 runs on the 20.64-in. coil fell in the transition regime. In all 166 data points fell in the transition regime.

In most practical applications, operation in the transition regime is avoided. However, should it be necessary, the Nusselt number for transition regime fluid flow may be determined by extending the laminar and the turbulent flow regime correlations into the transition regime and interpolating between the values obtained from the laminar and the turbulent flow regime correlations at the Reynolds number in the transition regime.

Attempts were made to correlate the data in the transition regime but no satisfactory correlation could be developed that would: 1) fit the data satisfactorily, and 2) mesh with the values obtained from the laminar and the turbulent flow regime correlations at the extremities of the transition regime. Hence, the empirical correlations developed for the turbulent and the laminar flow regime were extended to calculate the Nusselt number in the transition regime. Test results indicating how well the values obtained from the above correlations agree with the experimentally obtained Nusselt numbers in the transition regime are given in Table VIII.

Laminar Flow Regime

Experimental data in the laminar flow regime were gathered using water and Dowtherm G. In all 1960 data points were obtained in the laminar flow regime. Of these 1162 data points were obtained on the 9.99-in. coil while 798 data points were obtained on the 20.64-in. coil.

TABLE VIII

TEST RESULTS OF EXTENDING THE LAMINAR AND THE TURBULENT FLOW REGIME CORRELATIONS TO CALCULATE NUSSELT NUMBERS IN THE TRANSITION REGIME

Correlation	For 9.99-in. Coil			For 20.64-in. Coil		
	AAD	APD %	AAPD %	AAD	APD %	AAPD %
Turbulent Flow Regime Correlation	1.9	1.3	3.0	11.1	20.9	20.9
Laminar Flow Regime Correlation	4.7	-7.4	7.4	10.4	-17.7	17.7

Literature correlations were tested against the experimental results to determine how well the two agreed. Test results are presented in Table IX for the two helical coils studied. It may be noted from Table IX that Schmidt's (35) correlation comes closest to fitting the experimental data. Here again, the literature correlations break down when extended to the straight tube case.

To fit the experimental data better than the existing correlations, a new correlation was developed. Details regarding the development of the correlation are presented later in this section.

As indicated earlier in this chapter, higher heat transfer coefficients were obtained for fluid flow in helical coils. The heat transfer coefficients were about two to three times the value for the straight tube under otherwise similar operating conditions. Up to now, workers in the field have attributed the higher heat transfer coefficients to the presence of a superimposed secondary flow due to centrifugal action. However, the present experimental study has revealed that secondary flow due to centrifugal action may not be the only cause of the higher heat transfer coefficients but that natural convection may also play an important role in causing the higher heat transfer coefficients. In actuality, it is felt that some combination of these two factors causes the higher heat transfer coefficients. Also, it is felt that the fluid flow parameters and the temperature difference between the heating surface and the fluid determine which of the two factors may be the controlling factor in accounting for the higher heat transfer coefficients.

To get a better understanding of the relationship between the above two factors and to facilitate the development of a correlation to fit

TABLE IX

TEST RESULTS OF LITERATURE CORRELATIONS FITTED TO EXPERIMENTAL DATA FOR THE LAMINAR FLOW REGIME

Investigator(s)	Reference	Stated Range of Applicability	For 9.99-in. Coil AAD	For 9.99-in. Coil APD %	For 9.99-in. Coil AAPD %	For 20.64-in Coil AAD	For 20.64-in Coil APD %	For 20.64-in Coil AAPD %
Berg and Bonilla	5	$Re<Re_{cr}$	20.6	-50.1	56.8	21.1	-76.4	76.4
Seban and McLaughlin	36	$12\leq Re\leq 5,600$ $100\leq Pr\leq 657$	23.3	-68.7	68.7	19.5	-66.7	66.7
Mori and Nakayama	27	$De>30$ $Pr>1$	18.9	23.4	51.7	17.1	36.0	57.0
Kubair and Kuloor*	23	$80<Re<6,000$ $20<Pr<100$	107.2	231.8	235.8	63.6	206.8	211.4
Schmidt	35	$100<Re<Re_{cr}$	6.6	-10.9	18.2	6.0	-16.4	20.9
Kalb and Seader	20	$80\leq De\leq 1,200$ $0.7\leq Pr\leq 5$	4.7	-20.3	20.3	5.5	-23.0	23.0
Shchukin	37	$26<De<7,000$	8.0	-17.6	22.7	7.4	-26.0	26.6
Dravid, et al.	13	$50<De<2,000$ $5<Pr<175$	19.9	-40.9	40.9	12.0	-33.6	33.6
Present Work	-	$1\leq De\leq 1,700$ $2.3<Pr<250$	4.3	3.1	11.8	2.9	-1.9	10.1

* = Test results using Kubair and Kuloor's Correlation are presented here merely for completeness. The data values used to test the correlation fall outside the stated range of applicability, hence the poor results.

the experimental data, the data were subdivided into four groups based on the ratio of the local heat transfer coefficients for thermocouple positions 1 and 5 located on the tube periphery (see Figure 9 for the thermocouple locations). The four groups are defined as follows:

$\frac{h_1}{h_5} \geq 0.9$ natural convection is negligible.

$0.9 > \frac{h_1}{h_5} \geq 0.7$ natural convection exists but is not significant.

$0.7 > \frac{h_1}{h_5} \geq 0.5$ natural convection is becoming significant.

$0.5 > \frac{h_1}{h_5}$ natural convection is significant if not predominant.

Figure 14 shows some typical Nusselt number profiles at station 5 for the 9.99-in. coil plotted as a function of the peripheral location. The following observations may be made from Figure 14:

1. At the higher Reynolds numbers, the Nusselt number is highest at position 7 and lowest at position 3 while the Nusselt numbers at stations 1 and 5 are almost identical. This indicates that at higher Reynolds numbers, secondary flow due to centrifugal action tends to predominate and there is negligible natural convection.

2. At the lower Reynolds numbers, the Nusselt number is highest at position 5 and lowest at position 1 while the Nusselt numbers at positions 3 and 7 are comparable. This strongly indicates that the secondary flow pattern may now be due to the existence of natural convection rather than due to centrifugal action.

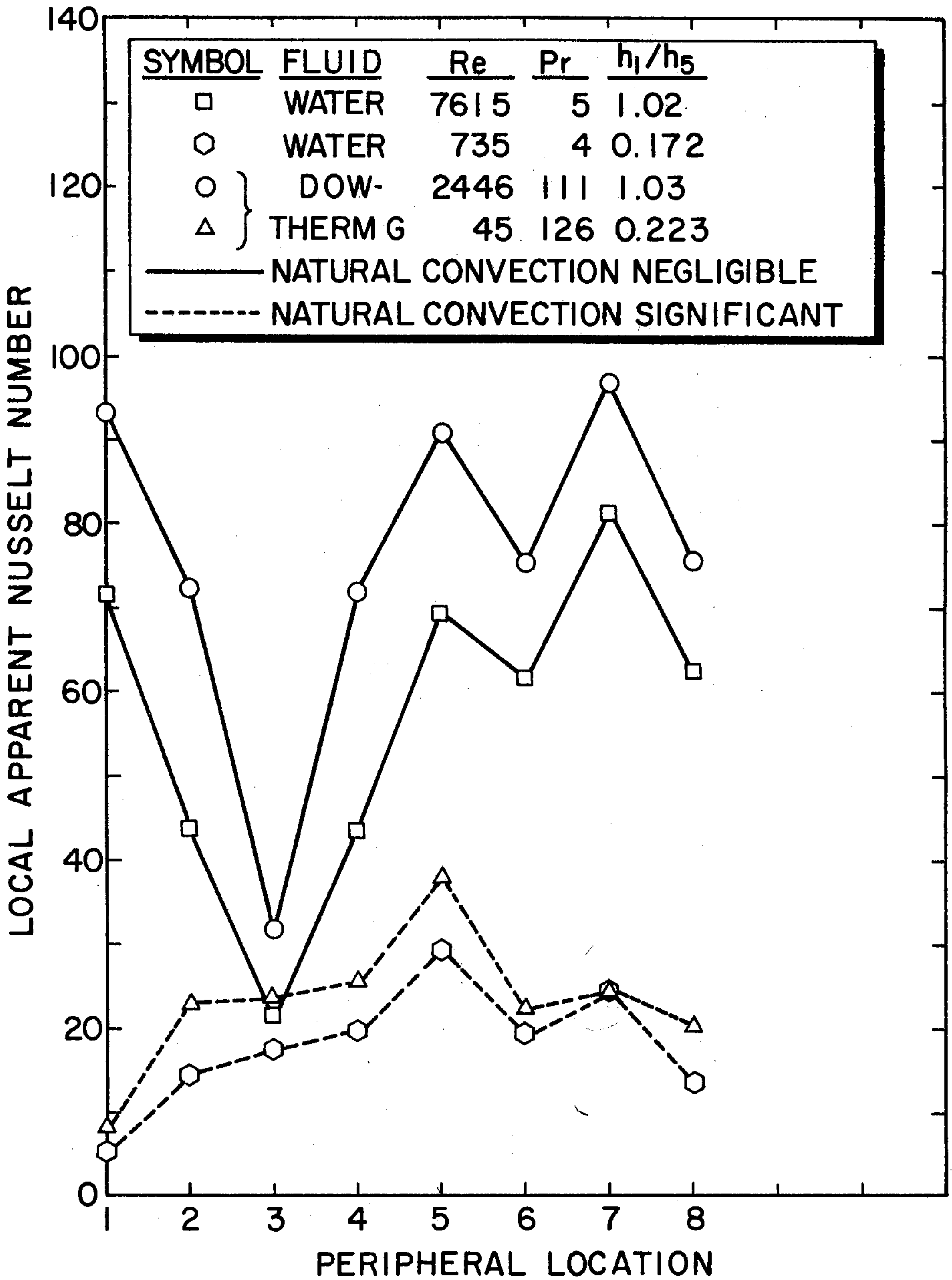

Figure 14. Typical Local Apparent Nusselt Number Profiles in the Laminar Flow Regime

The h_1/h_5 ratio is also indicated for the typical results shown in Figure 14. Note that the values are in accord with the subdivision of the data mentioned above.

To demonstrate that higher heat transfer coefficients were obtained for fluid flow in a helically-coiled tube than in an equivalent straight tube and to aid in the development of the correlation, the peripheral average Nusselt numbers were plotted versus the Graetz number for several data runs in the laminar flow regime. Figure 15 shows some typical experimental results plotted on the above coordinates. The Hausen (15) and the Sieder-Tate (38) correlations for laminar flow in a straight tube are also shown in the above plot.

The following observations may be made from Figure 15:

1. Substantially higher Nusselt numbers are obtained for fluid flow in a helically-coiled tube than in an equivalent straight tube.

2. The peripheral average Nusselt number is practically independent of length for relatively high Reynolds number flow (for example, Re = 2448) and it tends to increase with length for low Reynolds number flow (for example, Re = 10).

Observation 2 above seemed to indicate an anomalous length dependence of the peripheral average Nusselt number. A detailed examination of the data gathered at low Graetz numbers indicated the existence of substantial natural convection effects. It was not possible to determine conclusively from the data gathered whether the length dependence was associated with the natural convection effect or whether it was associated with the forced convection effect and merely surfaced with the natural convection effect. Nonetheless, the data do show a definite dependence upon the length of the fluid flow path.

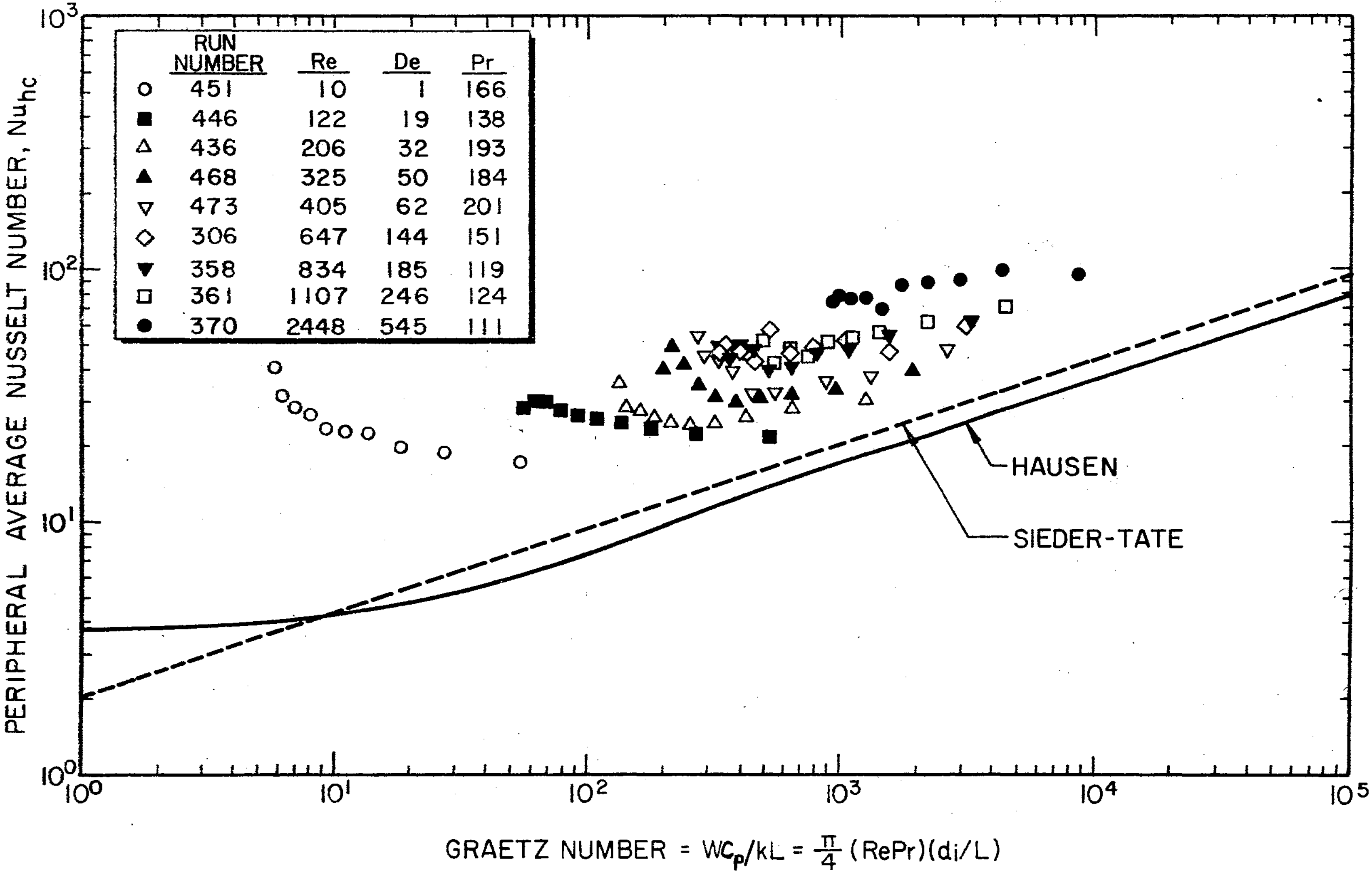

Figure 15. Peripheral Average Nusselt Number - Graetz Number Plots for Some Typical Experimental Runs in the Laminar Flow Regime

Attempts were made to correlate the data using the curved tube factor, $(1 + Re\sqrt{(d_i/D_c)})$, with the goal that the correlation developed would reduce to the known straight tube correlation when D_c tended to infinity. However, the correlation developed was unable to fit all the experimental data points satisfactorily. The data set appeared to show the anomalous length dependence discussed above.

To resolve the question regarding the length dependence, it became apparent that experimental data were needed at very low Reynolds and Grashof numbers. These data were not available in the present experimental data set. Hence, the above plan of attack was abandoned and another approach was taken to develop a correlation to fit the experimental data in the laminar flow regime. Details regarding the development of the correlation follow.

Development of Correlation

The correlation to predict the Nusselt number for fluid flow in a helically-coiled tube in the laminar flow regime was premised to be of the following form:

$$Nu_{hc} = \begin{bmatrix}\text{forced convection}\\ \text{contribution}\end{bmatrix} \begin{bmatrix}\text{natural convection}\\ \text{contribution}\end{bmatrix} \qquad (6.8)$$

Forced Convection Contribution. The forced convection contribution was evaluated by considering only those data points having h_1/h_5 ratios greater than or equal to 0.9. As mentioned earlier, points having $h_1/h_5 \geq 0.9$ showed a negligible natural convection contribution; hence these points were selected to develop the correlation for the forced convection contribution.

The above condensed data set was plotted using the coordinates shown in Figure 16. The physical property effect in the data appeared to be satisfactorily correlated by $(Pr)^{1/3}$ rather than $(Pr)^{0.175}$, as indicated by Dravid, et al. (13). Hence, $(Pr)^{1/3}$ was used in the ordinate. The Sieder-Tate viscosity correction factor was also incorporated into the ordinate (and the proposed correlation) to allow for the distortion of the velocity profile due to heating at the wall.

The extent of the Reynolds number and the helical coil curvature ratio contribution to the forced convection contribution was determined from Figure 16. The following conclusions were derived from Figure 16:

1. The data set seemed to be generally proportional to approximately the 0.5-power of the Reynolds number.

2. The condensed data set showed a small dependence upon the coil curvature ratio.

Hence, the forced convection contribution was correlated as:

$$Nu^{*}_{hc} = \left[0.224 + 1.369 \left(\frac{d_i}{D_c}\right)\right] [Re^{m}] [Pr^{1/3}] \left[\left(\frac{\mu_b}{\mu_w}\right)^{0.14}\right] \quad (6.9)$$

where

Nu^{*}_{hc} = the forced convection contribution to the Nusselt number for flow in a helically-coiled tube in the laminar flow regime;

and

$$m = 0.501 + 0.318\, (d_i/D_c). \quad (6.10)$$

Natural Convection Contribution. The natural convection contribution was evaluated by considering only those data points having h_1/h_5 ratios less than 0.5. As indicated earlier, these points showed significant if not predominant natural convection effects.

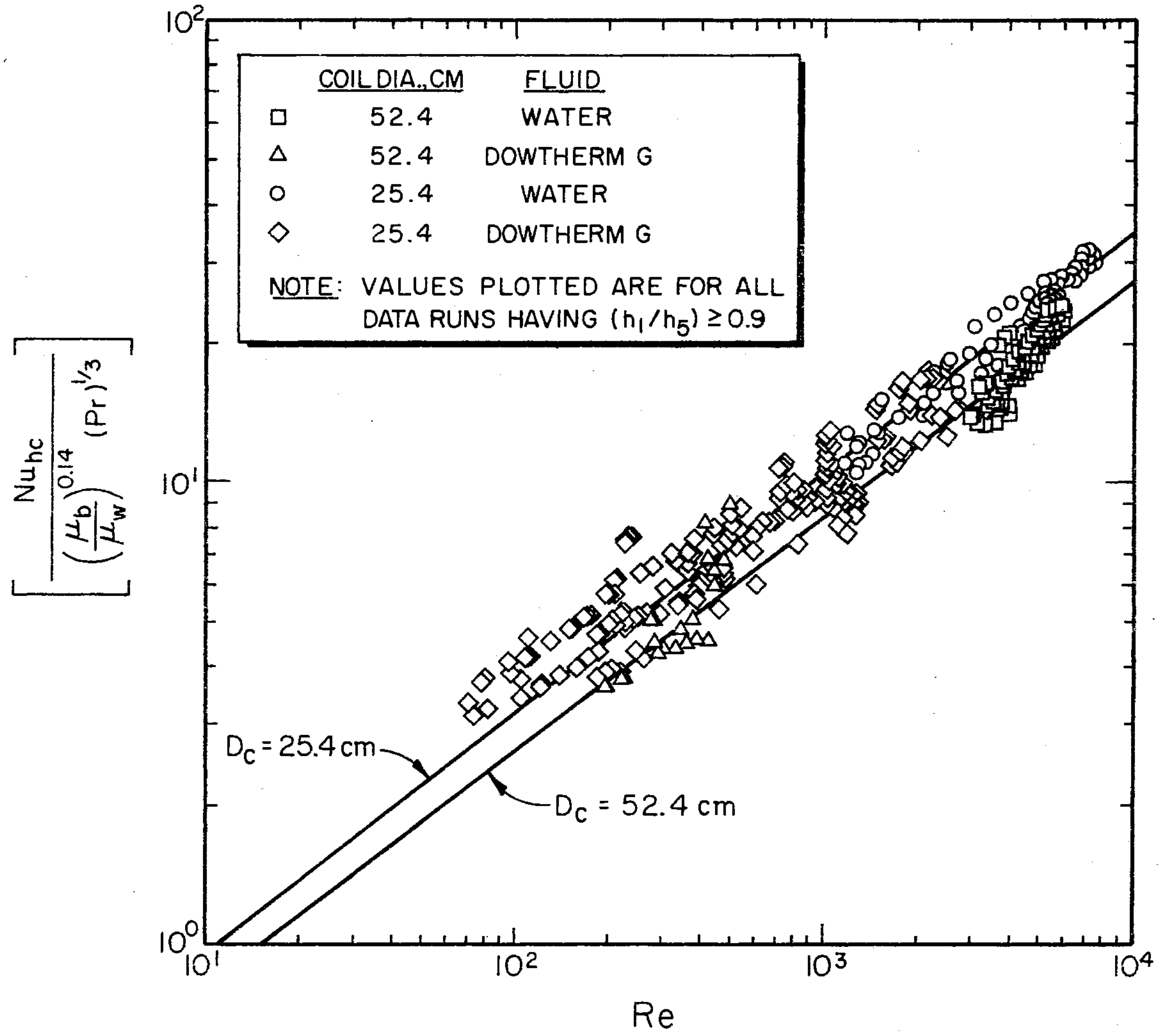

Figure 16. Correlation of Data for All Runs Presumed to Have Negligible Natural Convection Effects

A detailed examination of the experimental data (and Equation (6.8)) indicated that the natural convection contribution part of Equation (6.8) should satisfy the following criteria:

1. The contribution should be large (> 1) for data points having $h_1/h_5 < 0.5$ but should tend to unity for data points where $h_1/h_5 \geq 0.9$.

2. The contribution should traverse the h_1/h_5 range as a continuous function.

3. The factor should be made up of some combination of the dimensionless groups that reflect the magnitude of the natural convection effect and the degree to which it might be suppressed by the forced convection flow.

Of the dimensionless groups available, (Gr/Re^2) was arrived at as the combination of the dimensionless groups that would be used to develop the natural convection contribution because:

1. It is used to determine, qualitatively, the significance of natural convection heat transfer in problems involving forced and natural convection heat transfer.

2. It is the combination of the dimensionless groups that satisfies criterion 3 above.

3. When tested, it seemed to best fit the experimental data.

In addition, when tested, the data indicated a definite dependence on the coil-to-tube diameter ratio.

Figure 17 shows the plot of $((Nu_{hc}/Nu_{hc}^*) - 1)$ plotted versus $((Gr/Re^2)(D_c/d_i))$ for all the data points having $h_1/h_5 < 0.5$. $((Nu_{hc}/Nu_{hc}^*) - 1)$ was selected as the ordinate in Figure 17 so that the natural convection contribution could be incorporated in Equation (6.8) as a positive multiplier having a numerical value equal to or greater

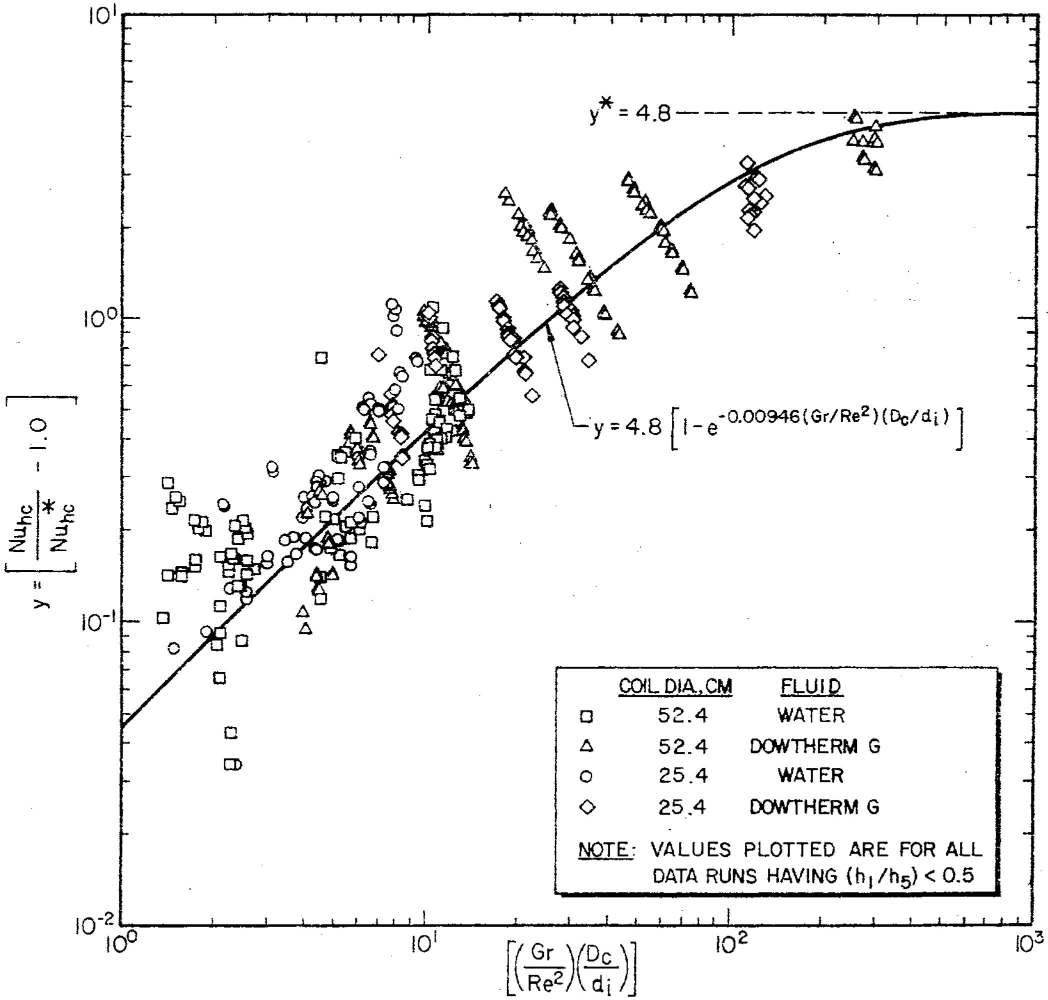

Figure 17. Correlation of Data for All Runs Presumed to Have Significant Natural Convection Effects

than unity, depending upon the extent of the natural convection present and the degree to which it is suppressed by the forced convection flow. $((Gr/Re^2)(D_c/d_i))$ was chosen as the abscissa because tests revealed that it seemed to correlate the natural convection and the coil-to-tube diameter ratio effects better than (Gr/Re^2) by itself.

The data points in Figure 17 were fitted with an equation of the form:

$$\frac{y}{y^*} = \left[1 - e^{-c_1 (Gr/Re^2)(D_c/d_i)}\right] \qquad (6.11)$$

where $y = \left[\frac{Nu_{hc}}{Nu^*_{hc}} - 1\right]$

and $y^* = \left[\frac{Nu_{hc}}{Nu^*_{hc}} - 1\right]$ for $\left(\frac{Gr}{Re^2}\right)\left(\frac{D_c}{d_i}\right) \geq 10^3$.

Various values of y^* and c_1 (in Equation (6.11)) were tried to determine the values that resulted in the equation that best fit the data plotted in Figure 17. The equation that best fit the data is:

$$y = 4.8\left[1 - e^{-0.00946 (Gr/Re^2)(D_c/d_i)}\right] \qquad (6.12)$$

Equation (6.12) has been drawn in Figure 17. As can be seen from Figure 17, Equation (6.12) seems to correlate the data reasonably well. Note also that the data shown in Figure 17 exhibit the length dependence discussed earlier.

Hence, the final correlation to predict the Nusselt number for fluid flow in a helically coiled tube in the laminar flow regime may be written as:

$$Nu_{hc} = \left\{0.224 + 1.369(d_i/D_c)\right\} \left\{Re^{[0.501 + 0.318(d_i/D_c)]}\right\}$$

$$\left\{1 + 4.8 \left[1 - e^{-0.00946(Gr/Re^2)(D_c/d_i)}\right]\right\}$$

$$x \left\{Pr^{1/3}\right\}\left\{\left(\frac{\mu_b}{\mu_w}\right)^{0.14}\right\} \tag{6.13}$$

The physical properties of the fluid used in Equation (6.13) were evaluated at the bulk fluid temperature except μ_w which was evaluated at the average inside wall temperature at the thermocouple station.

Equation (6.13) is valid for:

$6 \leq Re \leq Re_{cr}$

$1 \leq De \leq 1.7 \times 10^3$

$2.3 < Pr < 250$

$241 < Gr < 9.22 \times 10^5$.

Test results of the fit of Equation (6.13) to the total laminar regime experimental data set are given in Table IX.

The limiting cases of Equation (6.13) are as follows (regarding the curvature ratio):

1. For the lower limiting case of d_i/D_c tending to zero, Equation (6.13) reduces to:

$$Nu_{hc} = 1.30(Re)^{0.501} (Pr)^{1/3} (\mu_b/\mu_w)^{0.14} \tag{6.14}$$

2. For the upper limiting case of d_i/D_c tending to 1, Equation (6.13) reduces to:

$$Nu_{hc} = 1.59(Re)^{0.819} \left\{1 + 4.8 \left[1 - e^{-0.00946(Gr/Re^2)}\right]\right\}$$

$$(Pr)^{1/3} \left\{\left(\frac{\mu_b}{\mu_w}\right)^{0.14}\right\} \tag{6.15}$$

When (Gr/Re^2) tends to zero, that is, for negligible natural convection, Equation (6.13) reduces to Equation (6.9), the equation developed for the forced convection contribution. On the other hand, if (Gr/Re^2) tends to infinity, Equation (6.13) reduces to the following equation:

$$Nu_{hc} = 5.8 \left\{0.224 + 1.369\left(\frac{d_i}{D_c}\right)\right\} \left\{Re^{[0.501 + 0.318(d_i/D_c)]}\right\}$$

$$(Pr)^{1/3} \left\{\left(\frac{\mu_b}{\mu_w}\right)^{0.14}\right\} \tag{6.16}$$

$$= 5.8 \text{ [forced convection contribution]}.$$

As can be readily noted, Equation (6.16) implies that the natural convection contribution to the Nusselt number has an upper bound. The experimental data gathered tends to support this viewpoint.

From Tables VII and IX, it may be noted that the turbulent and the laminar regime correlations developed (Equations (6.7) and (6.13), respectively) best fit the present experimental data.

Also, the turbulent flow regime correlations reduces to give a valid equation for the straight tube case when D_c tends to infinity. However, the laminar flow regime correlation, when extended to the straight tube case, results in an equation (Equation (6.14) above) that is independent of the length, unlike any known straight tube correlations. Equation (6.14) generally predicts higher Nusselt numbers for the straight tube than those calculated from either the Hausen (15) or the Sieder-Tate (38) correlation for the straight tube.

Several gaps still exist in fully understanding the mechanism of heat transfer in a helically-coiled tube. For example, in the laminar regime, the dependence of the Nusselt number upon the length needs to be evaluated. It is felt that more experimental data are needed at low Reynolds numbers and low heat flux values to understand how the length affects the Nusselt number for flow in a helical coil.

The curvature ratio dependence indicated in the correlations was developed on data gathered on two coils with the curvature ratio of one being approximately twice the other. The curvature ratio dependence may be refined if more data could be obtained on coils that cover a much wider curvature ratio range than that covered in the present study.

Lastly, it would be useful if the correlations developed could be tested against the experimental data of other workers in the field to determine the fitness of the correlations.

CHAPTER VII

CONCLUSIONS AND RECOMMENDATIONS

An experimental study of the heat transfer processes occurring when a single phase fluid flows through a helical coil has been conducted. Two fluids, water and Dowtherm G, were studied using two helical coils 9.99 and 20.64 inches in diameter. The entire fluid flow regime from laminar through transition to turbulent flow was investigated. The fluids were heated by passing DC current through the tube. In the course of the study, available literature correlations were tested to determine how well they could predict the experimental results.

The following conclusions were arrived at as a result of the total study:

1. Higher heat transfer coefficients were obtained for fluids flowing in the helical coils, for both the laminar and turbulent flow regime, than in the same length of straight tube under similar fluid flow conditions. The ratio of the heat transfer coefficient for the helical coil to that for the straight tube was higher in the laminar flow regime than in the turbulent flow regime. This is understandable in view of the fact that greater random mixing in the turbulent flow regime diminishes the augmentation of the heat transfer coefficient due to the superimposed secondary flow. The secondary flow results from the centrifugal action that a fluid is subjected to when flowing in a curved path.

2. Higher friction factors were obtained for fluid flow in the helical coils than in an equivalent straight tube under similar flow conditions. This too may be attributed to the presence of the superimposed secondary flow.

3. Greater insight into the nature of the secondary flow when fluids are heated in helical coils was obtained because the wall temperatures were measured at several peripheral locations at various points along the length of the helical coil. In the laminar flow regime, the definite existence of natural convection effects was established. It was determined that the higher heat transfer coefficients obtained for flow in a helical coil may be due not only to the presence of the superimposed secondary flow due to centrifugal action, but also may be due to the existence of natural convection currents. It was established that natural convection effects were substantial, if not predominant, at low Reynolds numbers but diminished in intensity as the Reynolds number increased. A measure of the extent to which the natural convection effects contributed to the increase of the average heat transfer coefficient has been incorporated into the empirical correlation developed to predict the average Nusselt number for fluid flow in the laminar flow regime (Equation (6.13)).

4. An anomalous dependence of the Nusselt number upon the length was noted. The length dependence was noticed to be associated with low Graetz number runs. However, it was not possible to determine from the experimental data whether the length dependence was actually associated with the natural convection contribution or whether it was associated with the forced convection contribution and only surfaces with the natural convection correlation.

5. Dravid et al. (13) report that the Nusselt number for fluid flow in a helical coil varies as the 0.175-power of the Prandtl number of the fluid. This dependence appears to be erroneous. Results of the present experimental study indicate that the Nusselt number varies approximately as the more conventional one-third power of the Prandtl number of the fluid.

6. Correlations have been developed to predict the average Nusselt number for fluids flowing in a helically-coiled tube for the turbulent and the laminar flow regime. The correlations are Equations (6.7) and (6.13) in Chapter VI. These correlations fit the experimental results better than any of the literature correlations tested.

7. The correlation developed for the turbulent flow regime is of the form that when the coil diameter tends to infinity (the straight tube case), the correlation reduces to give the Sieder-Tate (38) correlation for the straight tube. This is a feature that is lacking in most of the literature correlations.

8. The laminar flow regime correlation is of the form that, when the coil diameter tends to infinity, results in a viable equation. However, the resulting equation for the straight tube predicts higher Nusselt numbers than either the Hausen (15) or the Sieder-Tate (38) correlation.

Several gaps still exist in the complete understanding of the mechanism of heat transfer in a helical coil. The following recommendations are made, based on the results of this study, for future research in the area:

1. Equations (6.7) and (6.13) were developed for the case when a fluid is heated in a helically coiled tube. It is felt that the same

correlations should apply when a fluid is cooled in a helically-coiled tube. However, it is recommended that experimental studies be performed to establish the validity of this premise.

2. Fluid pressure drops should be measured using pressure measuring devices having an appropriate range so that friction factor correlations for fluid flow in a helical coil in the laminar and turbulent flow regime can be established.

3. More experimental data is needed at low Reynolds and Grashof numbers in order to evaluate the nature and the magnitude of the dependence of the Nusselt number upon the length factor.

4. Further research needs to be performed using helical coils with widely varying curvature ratios (at least covering one order of magnitude) to refine the dependence of the average Nusselt number on the curvature ratio of the helical coil.

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APPENDIX A

EXPERIMENTAL DATA

THERMCCOUPLE NUMBER	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F
1-1	90.3	90.3	93.7	92.3	94.3	94.0	97.0	96.5	99.3	99.7
1-2	97.0	97.3	102.0	101.0	104.0	103.3	108.0	108.0	112.7	112.7
1-3	90.3	90.7	93.0	92.7	94.0	93.7	96.5	96.0	99.0	99.0
1-4	87.7	87.7	90.0	89.3	90.3	90.3	92.7	92.3	94.7	94.7
2-1	91.7	91.7	94.7	94.0	96.0	95.7	99.0	99.0	102.0	102.0
2-2	96.5	96.0	100.7	99.3	102.0	102.0	106.5	106.5	112.7	112.0
2-3	98.7	98.7	103.7	102.3	105.3	105.7	111.0	111.0	116.3	116.3
2-4	95.0	95.0	99.3	98.3	100.3	100.0	104.3	103.7	108.0	108.0
2-5	91.7	91.3	94.7	93.7	94.7	94.7	98.0	98.0	101.0	101.0
2-6	89.3	89.3	92.0	91.0	92.0	92.0	94.7	94.7	98.0	97.7
2-7	88.3	88.3	90.7	90.0	90.7	91.0	93.3	93.3	95.7	96.0
2-8	89.0	89.0	91.7	91.0	92.0	92.0	95.0	94.3	97.3	97.7
3-1	92.3	92.3	95.3	94.7	97.0	97.0	100.3	100.0	103.0	104.0
3-2	100.0	100.0	104.0	103.3	107.0	107.0	112.3	112.3	117.7	118.3
3-3	93.0	92.7	95.7	95.0	97.3	97.3	100.7	100.3	103.0	103.7
3-4	89.3	89.0	92.0	91.3	92.7	92.7	95.7	95.3	98.0	98.7
4-1	93.3	92.7	96.5	95.3	97.7	97.7	101.0	100.7	104.0	105.0
4-2	101.7	101.0	106.0	105.0	108.7	108.7	114.7	113.7	118.7	120.0
4-3	95.0	94.7	98.3	97.3	99.3	99.3	103.0	102.7	105.7	107.0
4-4	91.0	90.3	93.7	92.7	94.0	94.0	97.7	97.3	99.7	101.0
5-1	94.7	94.0	98.0	97.0	99.0	99.3	103.0	103.0	106.0	107.7
5-2	103.0	102.3	107.3	106.0	109.7	110.0	115.7	115.7	121.0	122.3
5-3	96.5	95.7	99.7	98.7	100.7	100.7	105.3	105.0	107.7	109.0
5-4	92.3	91.7	95.0	94.3	96.0	96.0	99.7	99.7	102.0	103.3
6-1	95.7	95.3	98.7	97.3	100.7	100.3	105.0	104.7	108.7	109.7
6-2	103.3	103.3	108.0	106.5	111.7	111.0	117.7	117.3	123.3	124.0
6-3	97.3	97.3	100.7	99.7	103.0	102.7	107.7	107.7	111.0	112.0
6-4	93.3	93.0	95.7	94.7	97.7	97.7	101.7	101.7	104.7	105.7
7-1	96.5	96.5	100.3	99.3	102.7	102.7	107.7	107.7	111.7	112.3
7-2	104.0	103.7	108.7	107.7	112.3	112.3	118.7	118.7	125.3	125.7
7-3	98.0	98.0	101.3	100.7	103.7	103.7	109.0	109.3	112.7	113.3
7-4	94.3	94.3	97.3	96.5	99.3	99.3	104.0	104.0	107.3	108.7
8-1	98.7	98.7	102.0	101.7	105.0	105.0	110.3	110.7	115.0	116.3
8-2	105.3	105.3	109.7	109.0	114.0	114.0	121.0	121.0	126.3	128.0
8-3	99.0	99.3	102.0	101.7	105.3	105.0	111.0	110.7	114.7	115.7
8-4	95.7	95.7	98.7	98.0	101.3	101.3	106.0	106.0	110.0	111.3
9-1	99.3	99.0	102.0	101.7	105.3	105.3	110.7	111.0	115.3	116.7
9-2	103.3	103.0	107.0	106.5	111.0	110.7	117.3	117.3	123.7	124.7
9-3	107.3	107.3	111.0	110.7	115.3	115.3	123.0	123.0	128.7	130.0
9-4	105.3	105.3	109.0	108.7	113.3	113.0	120.3	120.0	125.3	126.7
9-5	101.7	101.3	104.3	104.0	108.0	108.0	113.7	113.7	117.7	120.0
9-6	99.0	98.7	101.0	101.0	104.3	104.3	110.0	110.0	113.3	114.7
9-7	97.3	97.3	99.7	99.3	102.7	102.3	108.0	108.0	111.3	113.0
9-8	97.7	97.3	99.7	99.3	103.0	102.7	108.3	108.0	111.7	113.3
10-1	100.7	100.7	103.7	103.0	107.3	107.7	113.3	113.3	117.7	119.0
10-2	108.3	108.0	112.0	111.3	116.3	116.3	124.0	124.3	130.0	131.3
10-3	102.7	102.3	105.7	105.0	109.3	109.3	115.0	115.0	119.5	121.0
10-4	98.7	98.3	101.0	100.7	103.7	104.0	109.7	109.7	113.7	115.3
INLET FLUID TEMPERATURE, F	72.7	72.7	72.7	72.5	72.3	72.3	72.5	72.5	72.2	72.5
EXIT FLUID TEMPERATURE, F	87.3	87.3	89.6	89.2	90.9	91.4	94.8	95.0	99.0	99.5
BATH FLUID TEMPERATURE, F	72.0	72.0	72.0	72.0	72.0	72.0	72.0	72.0	72.0	72.0
AMMETER READING,I, AMPS	200.0	200.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0
VOLTMETER READING,V, VOLTS	8.90	8.90	8.90	8.90	8.90	8.90	8.90	8.90	8.90	8.90
FLUID FLOW RATE, LB/HR	623.00	623.00	548.80	548.80	480.50	480.50	410.30	410.30	342.50	342.50
INLET PRES. TRDCR. OUTPUT,MV	1.210	1.210	0.910	0.880	0.610	0.610	0.410	0.420	0.230	0.240
EXIT PRES. TRDCR. OUTPUT,MV	1.080	1.080	0.830	0.780	0.570	0.580	0.420	0.420	0.310	0.320
INLET FLUID PRESSURE, PSIG	3.57	3.57	2.80	2.72	1.98	1.98	1.40	1.42	0.80	0.83
EXIT FLUID PRESSURE, PSIG	3.48	3.48	2.82	2.68	2.06	2.07	1.57	1.57	1.23	1.25
RCCM TEMPERATURE, F	84.0	84.0	85.0	85.0	86.0	86.0	86.0	87.0	88.0	88.0
RUN NUMBER	217	218	219	220	221	222	223	224	225	226

THERMOCOUPLE NUMBER	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F
1-1	100.0	100.0	103.7	103.7	97.7	97.7	104.7	105.0	125.0	124.7
1-2	113.0	113.0	118.7	118.7	109.7	109.7	114.3	115.0	120.0	120.0
1-3	99.7	99.7	103.7	103.7	96.0	96.0	100.0	100.0	107.0	107.3
1-4	95.3	95.3	99.0	99.0	93.0	92.7	94.7	95.0	104.7	104.7
2-1	101.7	102.0	107.7	108.0	102.0	102.0	110.0	110.0	135.7	135.7
2-2	111.7	112.3	120.0	120.3	112.0	112.0	118.7	118.7	132.3	132.7
2-3	115.3	116.0	122.7	122.7	112.7	112.7	116.0	116.0	124.7	125.3
2-4	107.3	107.7	102.3	102.7	104.3	104.3	108.0	108.0	117.0	117.0
2-5	100.3	100.7	104.7	104.7	98.0	98.3	101.7	101.7	112.7	112.7
2-6	97.0	97.3	101.0	101.0	94.7	94.7	98.0	98.3	110.3	110.3
2-7	95.3	96.0	99.3	99.3	93.7	93.7	97.0	97.0	112.3	112.7
2-8	97.0	97.7	101.0	101.3	95.3	95.7	100.0	99.7	122.7	123.7
3-1	103.3	104.0	109.7	109.7	102.7	103.0	116.0	115.7	143.0	142.7
3-2	117.3	119.0	125.7	125.7	115.0	115.3	123.0	123.0	132.3	132.0
3-3	103.0	103.7	108.7	108.3	100.7	101.0	109.7	109.7	119.3	119.3
3-4	98.0	99.0	102.3	102.3	95.0	95.0	103.7	103.7	120.3	120.0
4-1	103.7	104.7	110.7	110.7	107.0	106.5	114.3	114.3	149.0	148.7
4-2	119.3	120.3	129.0	129.0	120.0	120.3	126.3	126.3	140.3	140.3
4-3	106.0	107.3	112.3	112.3	106.0	106.0	111.3	111.3	126.7	126.7
4-4	100.3	101.0	105.0	105.0	100.7	100.7	103.7	103.7	125.3	125.7
5-1	107.0	107.7	113.7	114.0	110.3	110.3	120.7	120.3	153.0	154.0
5-2	122.3	123.0	131.7	132.0	123.3	123.7	130.3	130.3	146.7	147.3
5-3	109.0	109.7	114.7	115.0	109.7	109.7	116.3	116.3	133.0	134.0
5-4	103.0	103.7	108.0	108.3	105.3	105.3	111.0	111.0	133.0	134.0
6-1	109.7	109.7	117.0	116.7	113.0	113.3	125.7	125.3	159.7	159.3
6-2	124.0	124.7	134.0	133.3	125.7	125.7	133.3	133.0	151.0	151.0
6-3	111.7	112.3	119.0	119.0	113.0	113.0	121.0	121.0	142.0	142.0
6-4	105.3	105.7	112.0	112.0	109.0	109.0	116.0	116.0	141.7	141.7
7-1	112.7	112.7	121.3	121.0	118.3	118.0	131.0	130.7	169.3	169.3
7-2	126.0	126.3	135.3	135.7	128.0	128.0	136.0	136.0	156.3	156.3
7-3	113.7	114.0	121.3	121.3	115.0	115.3	124.3	124.0	149.7	150.0
7-4	108.3	108.7	115.3	115.7	112.3	112.3	120.3	120.0	151.0	151.0
8-1	116.0	116.3	125.7	125.7	122.0	122.3	138.0	137.7	180.0	180.3
8-2	128.0	128.0	137.7	137.7	129.3	129.7	139.3	139.0	163.7	163.7
8-3	116.0	116.0	124.3	124.0	116.3	116.3	127.3	127.3	156.0	156.3
8-4	111.3	111.3	119.0	118.7	111.7	112.3	125.3	125.0	161.0	161.3
9-1	116.7	116.7	126.0	126.3	120.7	121.0	139.7	139.0	171.7	173.0
9-2	125.0	125.0	136.0	136.0	133.0	133.7	149.7	149.7	175.7	176.0
9-3	130.0	130.7	141.0	141.0	132.0	132.7	144.0	143.7	170.7	171.0
9-4	126.7	127.0	136.0	136.0	126.3	126.7	138.5	138.0	166.0	165.7
9-5	119.5	120.0	128.3	128.3	118.7	119.5	132.0	131.7	161.7	162.3
9-6	115.0	115.3	123.7	124.0	114.3	114.7	128.7	128.7	160.3	160.7
9-7	113.0	113.3	121.0	121.3	112.3	113.0	128.0	128.0	161.7	161.7
9-8	113.3	113.7	122.0	122.0	114.3	114.7	131.0	130.7	165.3	166.3
10-1	119.0	120.0	129.3	129.7	123.3	124.0	143.7	143.3	188.3	188.7
10-2	132.0	131.7	142.3	142.7	133.7	134.0	147.0	147.0	180.0	179.7
10-3	121.3	121.3	130.3	130.7	121.0	121.0	134.3	134.3	170.7	169.7
10-4	115.0	115.3	124.3	124.3	114.7	114.7	131.3	131.0	170.3	169.0
INLET FLUID TEMPERATURE, F	72.5	72.5	72.7	72.7	72.7	72.7	72.7	72.7	73.4	73.4
EXIT FLUID TEMPERATURE, F	99.5	99.5	106.7	106.7	104.0	104.7	116.6	116.4	154.4	150.1
BATH FLUID TEMPERATURE, F	72.0	72.0	72.0	72.0	72.0	72.0	72.0	72.0	72.0	72.0
AMMETER READING,I, AMPS	300.0	300.0	300.0	300.0	250.0	250.0	250.0	250.0	250.0	250.0
VOLTMETER READING,V, VOLTS	8.90	8.90	8.90	8.90	7.40	7.40	7.40	7.40	7.50	7.50
FLUID FLOW RATE, LB/HR	342.50	342.50	275.20	275.20	207.10	207.10	144.60	144.60	82.10	82.10
INLET PRES. TRDCR. OUTPUT,MV	0.240	0.250	0.130	0.150	0.0	0.0	0.0	0.0	0.180	0.500
EXIT PRES. TRDCR. OUTPUT,MV	0.270	0.290	0.160	0.170	0.040	0.040	0.020	0.020	0.370	0.640
INLET FLUID PRESSURE, PSIG	0.83	0.88	0.47	0.54	0.0	0.0	0.0	0.0	0.65	1.65
EXIT FLUID PRESSURE, PSIG	1.08	1.15	0.69	0.71	0.15	0.15	0.05	0.05	1.42	2.26
RCCM TEMPERATURE, F	84.0	86.0	88.0	88.0	88.0	88.0	85.0	86.0	88.0	88.0
RUN NUMBER	227	228	229	230	231	232	233	234	235	236

THERMOCOUPLE NUMBER	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F
1-1	84.7	84.3	85.7	85.7	86.0	86.0	87.7	87.7	89.7	89.7
1-2	90.7	90.3	92.3	92.3	93.3	93.3	95.0	95.0	98.3	98.0
1-3	84.7	84.7	85.3	85.3	86.5	86.5	88.0	88.0	89.3	89.3
1-4	83.0	83.0	83.7	83.7	83.7	84.0	85.3	85.3	86.5	86.0
2-1	85.7	85.3	87.3	87.3	88.3	88.3	90.0	90.0	92.0	91.7
2-2	90.0	89.7	91.7	91.7	93.7	93.3	96.0	96.0	99.0	98.7
2-3	91.7	91.3	94.0	94.0	95.7	95.3	97.7	98.7	100.3	100.0
2-4	89.7	89.3	90.0	90.0	91.3	91.3	92.3	93.0	95.0	94.7
2-5	85.3	85.7	86.5	86.5	87.3	87.3	88.3	88.7	90.3	90.0
2-6	83.7	83.7	84.7	85.0	85.3	85.3	85.7	86.5	88.3	88.3
2-7	83.3	83.0	84.3	84.0	84.7	84.7	85.3	85.3	87.3	87.3
2-8	83.7	83.7	84.7	84.7	85.0	85.0	86.0	86.0	88.7	88.3
3-1	86.5	86.0	88.0	88.0	89.0	89.0	90.7	91.0	92.3	92.3
3-2	93.0	92.7	95.0	95.0	97.3	97.3	100.3	100.3	101.3	101.3
3-3	87.0	86.5	88.0	88.0	88.7	89.0	90.7	90.7	91.7	92.0
3-4	84.3	84.0	85.0	85.0	85.3	85.3	87.3	87.3	86.0	88.0
4-1	87.0	87.0	88.3	88.3	89.3	89.3	91.3	91.3	94.0	94.0
4-2	94.0	93.7	96.5	96.0	99.0	99.0	101.3	101.7	104.0	104.0
4-3	88.3	88.0	89.7	89.7	90.7	90.3	92.0	92.3	95.3	95.3
4-4	85.3	85.3	86.5	86.5	87.0	87.0	87.7	88.0	91.3	91.3
5-1	88.3	88.0	90.0	89.7	90.7	90.7	93.0	93.7	97.7	97.7
5-2	94.7	94.3	97.7	97.3	100.3	100.0	103.0	103.3	107.3	107.3
5-3	89.0	89.0	90.7	90.7	91.7	91.3	93.7	94.0	98.0	97.7
5-4	86.5	86.0	88.0	87.7	88.3	88.3	90.7	91.0	95.3	95.0
6-1	89.0	88.3	90.7	90.7	91.7	91.7	95.3	94.7	99.7	99.3
6-2	95.7	95.3	98.3	98.3	101.3	101.3	104.3	104.3	108.7	108.7
6-3	90.3	90.0	92.0	92.0	93.0	93.0	95.3	95.3	100.0	100.0
6-4	87.7	87.0	88.7	89.0	89.3	89.3	92.0	91.7	97.3	97.3
7-1	90.7	90.3	92.0	92.3	93.7	93.7	97.3	97.3	103.0	103.0
7-2	97.0	97.0	99.3	99.3	102.7	102.3	106.0	107.0	110.3	110.3
7-3	91.3	90.7	92.7	92.7	94.3	94.3	98.0	98.0	101.7	101.7
7-4	89.0	88.7	90.3	90.7	91.0	91.3	96.0	96.0	100.7	100.7
8-1	92.0	91.3	93.7	93.7	95.7	95.7	101.0	100.7	104.3	104.0
8-2	98.0	97.3	100.3	100.3	103.3	103.3	108.3	108.3	111.7	111.7
8-3	91.7	91.7	93.3	93.7	95.0	95.0	99.0	99.0	103.0	103.0
8-4	90.0	89.7	91.3	91.3	92.3	92.3	97.7	97.7	100.7	100.7
9-1	92.0	91.7	94.0	93.7	96.0	96.0	101.0	100.7	104.7	104.3
9-2	95.3	95.3	98.0	98.0	101.3	101.3	108.0	107.3	112.3	112.3
9-3	98.3	98.3	101.0	101.0	104.7	104.3	110.7	110.3	114.0	114.0
9-4	97.0	96.5	99.3	99.0	102.0	102.0	107.7	107.3	111.0	111.0
9-5	93.3	93.0	95.3	95.3	97.3	97.3	102.7	102.3	106.0	106.0
9-6	91.3	91.3	93.3	93.3	94.7	94.7	101.0	100.3	103.7	103.7
9-7	90.3	90.3	92.0	92.0	93.3	93.3	100.3	100.0	102.7	102.7
9-8	90.7	90.3	92.3	92.0	93.7	93.7	100.0	99.7	102.3	102.0
10-1	93.3	93.0	95.0	95.0	98.0	97.7	103.7	103.3	107.7	107.7
10-2	99.3	99.0	102.0	102.0	105.3	105.7	111.7	111.7	115.7	115.7
10-3	94.3	93.7	96.0	96.0	98.3	98.3	103.0	103.0	107.3	107.3
10-4	91.7	91.0	93.3	93.3	94.7	95.0	100.7	100.7	104.7	104.7
INLET FLUID TEMPERATURE, F	72.7	72.5	72.7	72.7	72.5	72.7	72.7	72.7	73.0	73.0
EXIT FLUID TEMPERATURE, F	83.8	83.5	85.1	84.9	86.4	86.4	89.1	88.5	92.1	92.1
BATH FLUID TEMPERATURE, F	72.0	72.0	72.0	72.0	72.0	72.0	72.0	72.0	72.0	72.0
AMMETER READING,I, AMPS	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
VOLTMETER READING,V, VOLTS	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80
FLUID FLOW RATE, LB/HR	363.50	363.50	330.60	330.60	290.10	290.10	252.50	252.50	215.20	215.20
INLET PRES. TRDCR. OUTPUT,MV	0.340	0.340	0.250	0.250	0.170	0.170	0.090	0.090	0.050	0.050
EXIT PRES. TRDCR. OUTPUT,MV	0.340	0.340	0.260	0.270	0.180	0.180	0.150	0.150	0.080	0.080
INLET FLUID PRESSURE, PSIG	1.15	1.15	0.88	0.88	0.60	0.60	0.33	0.33	0.18	0.18
EXIT FLUID PRESSURE, PSIG	1.32	1.32	1.05	1.08	0.75	0.75	0.64	0.64	0.35	0.35
ROOM TEMPERATURE, F	86.0	86.0	87.0	87.0	84.0	85.0	86.0	86.0	87.0	88.0
RUN NUMBER	237	238	239	240	241	242	243	244	245	246

THERMOCOUPLE NUMBER	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F
1-1	107.0	107.0	109.7	109.7	114.3	114.3	108.0	108.0	117.0	117.0
1-2	114.7	114.3	116.7	116.7	119.0	119.0	110.0	110.0	112.3	112.3
1-3	106.5	106.5	107.7	107.3	109.0	109.3	103.3	103.3	107.0	107.0
1-4	104.0	103.7	104.7	104.3	105.7	106.0	101.3	101.7	108.0	108.0
2-1	110.3	110.0	113.7	113.0	118.3	118.7	111.7	112.0	123.7	123.7
2-2	116.7	116.3	120.0	119.5	123.0	123.7	113.7	113.7	120.7	120.7
2-3	117.0	116.7	118.7	118.7	120.3	120.7	111.7	111.7	116.3	116.3
2-4	111.7	111.7	113.0	113.0	114.7	115.3	108.3	108.3	113.0	113.0
2-5	107.7	107.3	108.7	108.7	110.7	111.0	106.0	105.7	111.3	111.3
2-6	105.0	104.7	106.5	106.0	108.3	109.0	105.0	104.7	111.7	111.7
2-7	104.3	104.3	105.3	105.3	108.0	108.3	105.0	104.7	114.3	114.7
2-8	105.7	105.7	107.3	107.3	110.3	111.0	107.0	107.0	120.0	120.0
3-1	110.7	111.0	115.7	115.3	123.0	123.0	115.0	114.7	130.0	129.7
3-2	118.7	118.7	122.0	122.0	125.3	125.3	115.3	115.3	122.3	122.3
3-3	109.0	109.3	112.7	112.7	115.7	115.7	109.7	109.7	116.0	116.0
3-4	105.3	105.3	109.0	109.0	112.7	112.7	108.0	108.3	119.5	120.0
4-1	113.0	113.0	118.0	118.3	124.3	124.7	116.0	116.0	135.3	135.7
4-2	121.7	122.0	126.0	126.0	128.7	128.7	117.7	117.7	129.0	129.0
4-3	112.0	112.7	116.3	116.3	118.0	118.0	111.3	111.3	122.0	122.0
4-4	109.0	109.0	113.0	113.3	115.7	115.7	110.3	110.3	123.7	124.0
5-1	115.0	115.3	120.0	120.0	127.0	127.3	118.0	117.7	139.3	139.7
5-2	124.3	124.3	127.7	127.7	132.3	132.3	121.0	120.7	134.7	134.7
5-3	115.0	115.0	117.7	118.0	122.3	122.7	114.3	114.3	128.3	128.3
5-4	112.0	112.3	115.0	115.3	119.0	119.0	112.7	112.7	128.7	129.3
6-1	118.3	118.7	123.7	123.7	131.7	131.7	122.0	122.0	145.0	145.0
6-2	126.3	126.7	130.0	130.0	135.0	135.0	123.3	123.3	138.5	138.5
6-3	117.7	117.7	121.3	121.3	126.7	126.3	117.7	117.3	133.7	133.7
6-4	115.0	115.3	117.7	117.7	124.0	123.7	116.3	116.3	135.3	135.3
7-1	122.7	123.0	126.3	126.0	137.3	137.3	126.0	126.0	151.3	151.3
7-2	128.3	128.3	131.7	131.0	138.0	138.5	126.0	125.3	143.7	143.7
7-3	119.0	119.5	123.0	123.0	130.3	130.3	120.7	120.7	140.0	140.0
7-4	117.7	118.0	120.0	120.0	129.0	129.0	120.0	119.5	141.7	142.3
8-1	124.0	124.3	130.7	130.7	142.3	142.3	129.7	129.7	157.3	157.7
8-2	129.3	129.7	133.3	133.3	141.7	141.3	128.0	128.0	149.0	149.3
8-3	120.0	120.3	124.7	124.7	133.7	133.3	123.0	123.0	145.0	145.0
8-4	117.0	117.0	123.0	123.3	131.7	131.7	122.7	122.3	148.3	149.0
9-1	124.3	124.7	131.7	132.3	144.0	144.0	132.0	131.7	162.7	162.3
9-2	132.3	132.3	139.7	140.0	150.3	150.3	135.3	135.0	161.7	162.0
9-3	131.7	131.7	136.7	137.0	145.3	145.7	131.7	131.3	155.3	155.7
9-4	128.0	128.0	133.0	133.0	141.7	141.7	129.3	129.3	152.0	153.3
9-5	123.3	123.3	128.0	128.3	137.3	137.3	126.7	126.7	149.3	150.7
9-6	120.0	120.0	125.7	125.7	135.3	135.7	125.3	125.3	148.7	149.7
9-7	118.3	118.3	125.3	125.3	135.0	135.0	125.0	125.0	150.0	151.0
9-8	120.0	120.3	127.0	127.0	137.0	137.3	127.0	126.7	156.0	156.3
10-1	126.3	126.7	135.0	135.0	147.7	148.0	134.0	134.0	165.3	167.7
10-2	133.3	133.3	139.0	139.7	148.3	148.3	134.3	134.0	159.7	161.0
10-3	124.7	124.7	130.3	130.3	139.7	140.0	129.0	129.0	153.7	155.0
10-4	120.7	120.7	127.7	127.7	138.0	138.0	127.3	127.7	154.3	156.0
INLET FLUID TEMPERATURE, F	89.6	89.6	89.6	89.6	89.6	89.6	89.6	89.6	89.2	89.2
EXIT FLUID TEMPERATURE, F	112.5	112.5	118.0	118.0	127.9	127.9	120.0	120.0	147.2	150.1
BATH FLUID TEMPERATURE, F	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0
AMMETER READING, I, AMPS	200.0	200.0	200.0	200.0	200.0	200.0	150.0	150.0	150.0	150.0
VOLTMETER READING, V, VOLTS	5.90	5.90	5.90	5.90	5.90	5.90	4.50	4.50	4.50	4.50
FLUID FLOW RATE, LB/HR	179.70	179.70	142.50	142.50	110.00	110.00	77.00	77.00	40.00	40.00
INLET PRES. TRDCR. OUTPUT, MV	0.040	0.040	0.010	0.0	0.0	0.0	0.0	0.0	0.140	0.380
EXIT PRES. TRDCR. OUTPUT, MV	0.090	0.090	0.060	0.060	0.060	0.060	0.050	0.050	0.260	0.500
INLET FLUID PRESSURE, PSIG	0.14	0.14	0.03	0.0	0.0	0.0	0.0	0.0	0.50	1.32
EXIT FLUID PRESSURE, PSIG	0.37	0.37	0.25	0.25	0.25	0.25	0.20	0.20	1.05	1.85
ROOM TEMPERATURE, F	86.0	86.0	87.0	87.0	85.0	86.0	86.0	86.0	86.0	86.0
RUN NUMBER	247	248	249	250	251	252	253	254	255	256

THERMOCOUPLE NUMBER	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F
1-1	91.0	91.0	103.3	103.0	84.7	84.3	116.4	116.6	107.4	107.6
1-2	94.3	94.3	98.7	98.7	90.7	90.3	127.0	127.1	113.5	113.6
1-3	87.3	87.7	92.7	92.7	84.7	84.7	114.8	115.2	107.1	107.3
1-4	85.3	85.3	92.7	92.7	83.0	82.7	111.6	111.8	105.0	105.2
2-1	95.7	95.7	110.3	110.3	85.7	85.3	118.5	118.9	109.5	109.7
2-2	98.0	98.7	107.7	107.3	90.0	89.7	125.4	125.5	113.4	113.7
2-3	96.5	97.0	103.3	103.3	91.7	91.7	128.8	128.8	116.2	116.5
2-4	93.0	93.0	100.0	99.7	88.3	88.3	122.9	123.0	112.4	112.6
2-5	90.7	90.7	98.0	97.7	85.0	85.0	116.6	116.6	108.3	108.4
2-6	89.7	89.7	97.3	97.3	83.7	83.7	113.3	113.5	106.4	106.6
2-7	89.3	89.7	100.3	100.3	83.0	83.0	112.6	112.7	106.1	106.2
2-8	91.3	91.3	105.7	105.3	83.7	83.7	114.4	114.4	107.0	107.2
3-1	99.7	100.0	116.3	116.0	86.0	86.0	120.3	120.5	110.9	111.0
3-2	100.7	100.7	109.0	109.0	92.3	92.3	131.2	131.2	118.0	118.1
3-3	94.7	94.7	102.7	102.7	86.5	86.5	119.0	119.2	110.1	110.1
3-4	93.0	93.3	105.7	105.7	84.0	84.0	114.8	114.9	107.3	107.6
4-1	101.0	101.0	122.0	122.0	87.0	86.5	121.5	121.7	111.5	111.8
4-2	103.3	103.7	115.3	115.3	93.7	93.3	133.3	133.6	119.6	119.7
4-3	97.0	97.3	109.0	109.0	88.3	88.3	122.4	122.4	112.1	112.2
4-4	95.0	95.0	109.7	109.7	85.0	85.0	117.2	117.2	108.8	108.9
5-1	103.3	103.3	126.0	126.0	88.0	88.0	123.5	123.7	112.8	113.0
5-2	106.0	106.0	121.7	121.7	94.3	94.7	135.3	135.5	121.0	121.1
5-3	99.7	99.7	114.7	114.7	89.0	88.7	124.7	124.8	113.8	113.9
5-4	98.3	98.0	115.0	115.0	86.5	86.0	119.6	119.5	110.4	110.5
6-1	107.7	107.0	131.3	131.3	88.7	88.7	125.9	125.7	114.4	114.6
6-2	109.3	108.3	125.0	125.0	95.7	95.3	137.7	137.6	122.7	122.9
6-3	103.0	102.7	120.3	120.3	90.3	90.3	127.6	127.4	115.7	115.9
6-4	101.7	101.3	121.3	121.3	87.3	87.3	121.8	121.8	111.9	112.1
7-1	112.3	110.3	137.3	137.7	90.3	90.0	128.4	128.4	116.0	116.4
7-2	112.7	111.0	129.3	129.7	96.5	96.0	138.9	138.9	123.4	123.7
7-3	107.0	106.0	126.0	126.0	90.7	91.0	128.7	128.8	116.3	116.8
7-4	106.0	105.0	128.0	128.0	88.7	88.7	124.5	124.6	113.5	113.9
8-1	116.0	114.7	143.7	143.7	91.7	91.7	131.8	132.0	118.3	118.7
8-2	114.3	113.3	135.0	135.0	97.3	97.0	141.3	141.5	125.2	125.5
8-3	109.0	108.3	130.7	131.0	91.0	91.3	130.9	131.0	117.8	118.2
8-4	108.7	107.7	134.0	134.0	89.3	89.3	127.0	127.3	115.3	115.6
9-1	118.3	117.0	150.3	150.3	91.3	91.3	132.9	133.0	119.0	119.2
9-2	121.7	120.7	149.0	148.3	95.0	95.0	139.2	139.5	123.3	123.6
9-3	118.0	117.3	143.0	141.7	98.0	98.0	144.1	144.2	127.2	127.3
9-4	115.7	115.0	140.3	139.3	96.5	96.5	141.2	141.5	125.2	125.3
9-5	113.0	112.0	138.0	136.7	93.0	93.0	134.8	134.6	120.7	120.8
9-6	112.0	110.7	137.3	136.0	91.0	91.3	130.9	130.9	118.1	118.2
9-7	111.7	110.7	139.3	138.0	90.3	90.3	129.2	129.2	116.8	116.9
9-8	113.3	112.3	145.7	144.3	90.3	90.3	129.6	129.8	117.1	117.3
10-1	121.7	119.5	155.7	154.3	94.7	94.3	135.1	135.5	120.6	120.8
10-2	121.3	120.3	148.7	147.7	99.3	99.3	145.4	146.2	128.1	128.1
10-3	115.3	114.3	142.3	141.7	94.3	94.3	136.3	136.3	121.7	121.7
10-4	114.3	112.7	143.3	142.7	91.0	91.7	131.0	130.8	118.0	118.2
INLET FLUID TEMPERATURE, F	72.7	72.7	74.7	74.7	73.7	73.7	91.6	91.6	91.4	91.4
EXIT FLUID TEMPERATURE, F	106.3	104.9	134.6	134.1	84.3	84.3	118.4	118.1	108.6	108.6
BATH FLUID TEMPERATURE, F	72.0	72.0	72.0	72.0	72.0	72.0	91.0	91.0	91.0	91.0
AMMETER READING, I, AMPS	150.0	150.0	150.0	150.0	200.0	200.0	352.0	350.0	350.0	350.0
VOLTMETER READING, V, VOLTS	4.50	4.50	4.50	4.50	5.80	5.80	10.50	10.50	10.40	10.40
FLUID FLOW RATE, LB/HR	72.59	75.07	39.05	38.90	363.50	363.50	477.00	477.00	728.00	728.00
INLET PRES. TRDCR. OUTPUT, MV	0.420	0.520	0.760	0.760	0.460	0.450	0.168	0.170	0.562	0.598
EXIT PRES. TRDCR. OUTPUT, MV	0.420	0.520	0.760	0.760	0.380	0.360	0.0	0.0	0.149	0.168
INLET FLUID PRESSURE, PSIG	1.43	1.72	2.40	2.40	1.55	1.51	0.59	0.60	1.87	1.94
EXIT FLUID PRESSURE, PSIG	1.57	1.91	2.62	2.62	1.43	1.40	0.0	0.0	0.61	0.70
ROOM TEMPERATURE, F	81.0	81.0	83.0	83.0	83.0	84.0	89.0	90.0	87.0	88.0
RUN NUMBER	257	258	259	260	261	262	263	264	265	266

THERMOCOUPLE NUMBER	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F
1-1	105.3	105.3	103.6	103.5	103.8	103.8	102.8	102.8	109.4	109.1
1-2	110.0	110.0	107.5	107.4	108.1	108.1	105.8	105.7	113.1	112.9
1-3	105.1	105.2	103.5	103.4	103.7	103.8	103.4	103.4	110.2	110.0
1-4	103.6	103.7	102.2	102.2	102.2	102.3	101.5	101.5	107.6	107.4
2-1	107.1	107.3	105.1	105.1	105.5	105.6	104.6	104.6	111.9	111.7
2-2	110.0	110.2	107.5	107.5	108.2	108.3	107.2	107.1	115.3	115.2
2-3	112.1	112.5	109.2	109.3	110.1	110.2	108.3	108.3	116.9	116.8
2-4	109.0	109.3	106.5	106.5	106.9	106.9	105.2	105.2	112.5	112.5
2-5	105.9	106.2	104.1	104.1	104.2	104.2	103.1	103.1	109.6	109.6
2-6	104.7	104.9	103.1	103.0	103.1	103.1	102.2	102.2	108.4	108.2
2-7	104.4	104.6	102.9	102.8	102.9	103.0	102.1	102.2	108.4	108.1
2-8	105.2	105.4	103.6	103.6	103.8	103.8	103.0	103.0	109.5	109.4
3-1	108.0	108.3	105.9	105.9	106.1	106.2	105.0	105.0	112.2	112.0
3-2	113.7	113.9	110.6	110.6	111.4	111.6	109.7	109.7	119.0	118.7
3-3	107.4	107.6	105.4	105.4	105.6	105.6	104.6	104.6	111.8	111.6
3-4	105.3	105.6	103.7	103.6	103.6	103.6	102.7	102.7	109.2	109.0
4-1	108.7	108.9	106.4	106.3	106.7	106.6	105.4	105.3	112.8	112.7
4-2	115.1	115.3	111.6	111.7	112.7	112.7	110.8	110.6	120.1	120.1
4-3	109.1	109.3	106.7	106.8	107.1	107.0	105.9	105.8	113.1	113.2
4-4	106.5	106.8	104.5	104.6	104.6	104.5	103.5	103.4	109.8	109.8
5-1	109.7	109.9	107.1	107.2	107.5	107.4	106.2	106.1	113.7	113.7
5-2	116.2	116.5	112.5	112.6	113.7	113.7	111.7	111.5	121.4	121.4
5-3	110.4	110.8	107.7	107.8	108.3	108.3	106.8	106.7	114.6	114.5
5-4	107.8	108.1	105.4	105.6	105.7	105.7	104.4	104.3	111.3	111.2
6-1	110.9	111.1	108.0	108.0	108.4	108.4	107.0	106.9	114.7	114.7
6-2	117.7	118.0	113.6	113.6	114.9	114.9	112.7	112.6	122.9	122.7
6-3	112.1	112.3	108.9	108.9	109.6	109.6	108.0	107.9	116.3	116.2
6-4	109.2	109.4	106.3	106.4	106.7	106.6	105.3	105.2	112.4	112.3
7-1	112.4	112.6	109.0	109.1	109.7	109.5	107.5	107.5	115.8	116.0
7-2	118.3	118.7	114.1	114.1	115.5	115.3	113.1	113.0	123.4	123.3
7-3	112.7	113.0	109.3	109.4	110.1	110.0	108.1	108.0	116.5	116.5
7-4	110.5	110.6	107.4	107.4	107.9	107.8	106.2	106.1	113.8	113.7
8-1	114.1	114.3	110.5	110.5	111.3	111.1	109.5	109.2	118.2	118.0
8-2	119.6	119.9	115.3	115.2	116.6	116.5	114.2	114.0	124.9	124.6
8-3	113.8	114.0	110.3	110.2	110.9	110.9	109.0	108.9	117.8	117.6
8-4	111.6	111.9	108.5	108.4	108.9	108.8	107.1	107.0	115.2	115.1
9-1	114.5	114.8	110.9	110.8	111.5	111.4	109.6	109.5	118.4	118.4
9-2	117.8	118.2	113.8	113.5	114.6	114.6	112.4	112.3	122.3	122.3
9-3	121.2	121.5	116.5	116.3	117.8	117.8	115.3	115.3	126.5	126.4
9-4	119.5	119.7	115.0	114.8	116.2	116.1	113.8	113.8	124.4	124.3
9-5	116.0	116.1	112.1	111.9	113.0	112.9	110.8	110.8	120.2	120.1
9-6	113.8	113.9	110.4	110.0	111.0	110.9	109.0	109.0	117.7	117.7
9-7	112.7	112.9	109.5	109.1	109.8	109.8	108.0	108.0	116.2	116.1
9-8	113.0	113.1	109.6	109.3	110.0	109.9	108.1	108.1	116.5	116.3
10-1	115.5	115.8	111.8	111.4	112.3	112.3	110.2	110.2	119.5	119.4
10-2	121.7	122.0	117.0	116.7	118.3	118.3	115.7	115.7	127.2	127.0
10-3	116.5	116.7	112.6	112.3	113.4	113.4	111.3	111.2	121.0	120.9
10-4	113.5	113.9	110.1	109.9	110.6	110.6	108.6	108.6	117.3	117.2
INLET FLUID TEMPERATURE, F	92.4	92.5	92.5	92.5	90.8	90.9	91.2	91.3	92.4	92.3
EXIT FLUID TEMPERATURE, F	105.4	105.6	102.7	102.7	102.1	102.1	100.8	100.8	105.6	105.5
BATH FLUID TEMPERATURE, F	92.0	92.0	91.8	91.8	90.0	90.0	90.0	90.0	91.0	91.0
AMMETER READING,I, AMPS	350.0	350.0	350.0	350.0	400.0	400.0	400.0	400.0	500.0	500.0
VOLTMETER READING,V, VOLTS	10.40	10.40	10.40	10.40	11.80	11.80	11.80	11.80	14.90	14.90
FLUID FLOW RATE, LB/HR	969.00	969.00	1205.00	1205.00	1475.00	1475.00	1729.00	1729.00	1962.00	1962.00
INLET PRES. TRDCR. OUTPUT,MV	1.093	1.131	1.867	1.903	2.704	2.717	3.860	3.869	4.915	4.906
EXIT PRES. TRDCR. OUTPUT,MV	0.595	0.587	1.128	1.133	1.722	1.726	2.425	2.413	3.046	3.048
INLET FLUID PRESSURE, PSIG	3.27	3.36	5.23	5.32	7.21	7.23	9.97	9.98	12.51	12.49
EXIT FLUID PRESSURE, PSIG	2.14	2.12	3.58	3.60	5.03	5.05	6.73	6.69	8.20	8.21
ROOM TEMPERATURE, F	91.0	91.5	92.0	92.0	89.0	90.0	94.0	94.0	95.0	96.0
RUN NUMBER	267	268	269	270	271	272	273	274	275	276

THERMOCOUPLE NUMBER	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F
1-1	107.3	107.5	107.5	107.5	107.3	107.4	108.1	108.6	102.5	102.5
1-2	110.0	110.3	109.7	109.7	110.0	110.0	111.8	112.3	105.5	105.4
1-3	108.2	108.4	107.1	107.1	108.3	108.3	108.7	109.4	103.0	103.0
1-4	105.6	105.9	105.9	105.9	105.6	105.6	106.2	106.8	101.2	101.2
2-1	109.2	109.5	108.3	108.3	109.4	109.4	110.5	111.2	104.4	104.4
2-2	112.3	112.6	110.7	110.8	112.5	112.4	114.0	114.4	106.8	106.8
2-3	113.7	114.0	112.5	112.6	113.9	113.9	115.5	116.0	108.0	108.0
2-4	110.1	110.3	109.7	109.7	110.0	110.0	111.3	111.9	104.9	104.9
2-5	107.5	107.7	107.1	107.1	107.5	107.5	108.5	109.1	102.9	102.9
2-6	106.3	106.5	105.7	105.8	106.3	106.3	107.2	107.8	102.0	102.0
2-7	106.3	106.4	105.6	105.7	106.2	106.2	107.2	107.7	101.9	101.9
2-8	107.4	107.6	106.6	106.6	107.3	107.3	108.4	108.9	102.8	102.8
3-1	109.7	110.0	109.0	109.0	109.8	109.6	111.1	111.6	104.8	104.7
3-2	115.8	116.0	114.6	114.5	115.8	115.7	117.8	118.2	109.6	109.4
3-3	109.4	109.4	108.5	108.4	109.4	109.3	110.7	111.2	104.5	104.3
3-4	107.0	107.1	106.3	106.1	106.9	106.9	108.1	108.7	102.7	102.4
4-1	110.2	110.5	109.4	109.4	110.2	110.3	111.8	112.3	105.2	105.1
4-2	117.0	117.3	115.6	115.6	117.1	117.1	119.3	119.8	110.6	110.4
4-3	110.6	110.9	109.7	109.7	110.7	110.8	112.3	112.8	105.6	105.4
4-4	107.6	107.9	106.8	106.8	107.6	107.7	109.0	109.6	103.3	103.2
5-1	111.1	111.3	110.0	110.0	111.2	111.2	112.8	113.4	106.0	105.8
5-2	118.2	118.4	116.5	116.6	118.1	118.1	120.4	121.0	111.4	111.2
5-3	111.9	112.1	110.9	110.9	111.9	111.8	113.6	114.1	106.5	106.4
5-4	108.9	109.1	107.9	107.9	108.8	108.8	110.4	110.9	104.2	104.1
6-1	112.1	112.5	110.9	110.9	112.0	112.0	113.8	114.3	106.8	106.7
6-2	119.6	119.9	117.8	117.8	119.4	119.4	121.8	122.3	112.6	112.4
6-3	113.5	113.9	112.1	112.2	113.4	113.4	115.2	115.8	107.8	107.6
6-4	109.9	110.3	108.7	108.8	109.9	109.9	111.5	112.0	105.1	105.1
7-1	113.2	113.6	111.7	111.7	112.8	113.1	115.0	115.6	107.7	107.4
7-2	119.9	120.2	118.0	118.1	120.0	119.9	122.4	122.8	112.9	112.8
7-3	113.9	114.2	112.2	112.3	113.7	113.7	115.6	116.1	108.1	108.0
7-4	111.2	111.5	109.8	109.9	111.1	111.1	112.8	113.3	106.1	106.0
8-1	115.1	115.4	113.4	113.6	115.0	115.0	117.0	117.4	109.2	109.1
8-2	121.2	121.4	119.1	119.2	121.2	121.1	123.6	124.0	113.9	113.9
8-3	114.8	115.0	113.1	113.2	114.8	114.7	116.7	117.0	108.8	108.8
8-4	112.4	112.7	110.9	111.0	112.4	112.3	114.2	114.6	107.0	107.0
9-1	115.3	115.5	113.6	113.8	115.2	115.3	117.6	117.6	109.3	109.4
9-2	118.9	119.0	117.0	117.0	118.8	118.8	121.4	121.5	112.1	112.1
9-3	122.8	122.8	120.5	120.5	122.6	122.6	125.4	125.5	115.1	115.0
9-4	120.8	120.9	118.7	118.7	120.7	120.7	123.3	123.4	113.6	113.6
9-5	117.1	117.2	115.3	115.3	116.9	117.0	119.3	119.3	110.6	110.6
9-6	114.7	114.8	113.0	113.0	114.6	114.6	116.7	116.8	108.7	108.8
9-7	113.4	113.3	111.8	111.8	113.3	113.1	115.3	115.4	107.8	107.8
9-8	113.5	113.5	111.9	111.9	113.4	113.3	115.4	115.5	108.0	107.9
10-1	116.3	116.1	114.3	114.5	116.2	116.0	118.4	118.6	110.2	110.1
10-2	123.2	123.1	120.9	121.0	123.2	123.1	126.0	126.1	115.6	115.5
10-3	117.7	117.6	115.7	115.8	117.6	117.5	119.9	120.0	111.1	111.0
10-4	114.3	114.1	112.5	112.7	114.2	114.1	116.3	116.4	108.6	108.5
INLET FLUID TEMPERATURE, F	91.9	91.7	91.6	91.7	91.6	91.5	91.6	91.8	91.1	91.0
EXIT FLUID TEMPERATURE, F	103.5	103.3	102.0	102.1	103.1	103.1	104.8	104.9	100.5	100.6
BATH FLUID TEMPERATURE, F	90.0	90.0	90.0	90.0	90.0	90.0	90.0	91.0	90.0	90.0
AMMETER READING, I, AMPS	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0	400.0	400.0
VOLTMETER READING, V, VOLTS	14.70	14.70	14.70	14.70	14.70	14.70	14.70	14.70	11.70	11.70
FLUID FLOW RATE, LB/HR	2208.00	2208.00	2417.00	2417.00	2208.00	2208.00	1962.00	1962.00	1729.00	1729.00
INLET PRES. TRDCR. OUTPUT, MV	6.510	6.522	8.062	8.077	6.506	6.548	4.906	4.828	3.856	3.853
EXIT PRES. TRDCR. OUTPUT, MV	4.030	4.076	5.071	5.065	4.095	4.084	3.085	3.140	2.436	2.446
INLET FLUID PRESSURE, PSIG	16.50	16.55	20.30	20.38	16.50	16.60	12.50	12.30	9.97	9.96
EXIT FLUID PRESSURE, PSIG	10.58	10.68	13.08	13.06	10.74	10.71	8.30	8.44	6.76	6.77
ROOM TEMPERATURE, F	92.0	93.0	98.0	98.0	96.0	97.0	92.0	93.0	92.5	93.0
RUN NUMBER	277	278	279	280	281	282	283	284	285	286

THERMOCOUPLE NUMBER	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F
1-1	104.0	103.9	102.0	101.9	103.5	103.5	106.8	106.9	115.8	115.6
1-2	108.4	108.3	105.9	105.8	108.2	108.4	112.9	113.1	126.3	126.2
1-3	103.9	103.8	101.9	101.7	103.3	103.5	106.4	106.6	114.3	114.2
1-4	102.5	102.4	100.5	100.4	101.8	102.0	104.3	104.4	110.9	110.6
2-1	105.8	105.6	103.4	103.3	105.3	105.6	109.2	109.2	117.9	117.8
2-2	108.5	108.2	105.8	105.7	108.2	108.5	113.3	113.3	124.6	124.6
2-3	110.6	110.2	107.6	107.6	110.4	110.7	116.1	116.1	128.3	128.3
2-4	107.5	107.1	104.9	104.9	107.2	107.5	112.2	112.1	122.3	122.1
2-5	104.6	104.4	102.4	102.3	104.0	104.3	107.8	107.8	115.6	115.6
2-6	103.5	103.2	101.3	101.3	102.7	103.0	106.0	106.0	112.6	112.6
2-7	103.4	103.1	101.2	101.1	102.5	102.8	105.6	105.6	111.7	111.7
2-8	104.3	103.9	101.9	101.8	103.3	103.5	106.6	106.5	113.3	113.4
3-1	106.6	106.5	104.0	104.1	106.2	106.5	110.5	110.5	119.4	119.5
3-2	112.0	111.7	108.8	108.8	111.9	112.1	117.7	117.7	129.8	129.9
3-3	106.0	105.7	103.5	103.5	105.6	105.8	109.7	109.6	118.1	118.2
3-4	104.1	103.9	101.9	101.8	103.6	103.8	107.0	107.0	113.9	113.8
4-1	107.1	106.9	104.5	104.5	106.8	106.9	111.3	111.2	120.4	120.4
4-2	113.2	112.9	109.8	109.8	113.1	113.2	119.4	119.4	132.2	132.2
4-3	107.6	107.3	104.9	104.9	107.1	107.3	111.9	111.9	121.4	121.2
4-4	105.0	104.8	102.7	102.7	104.6	104.7	108.5	108.5	116.2	116.2
5-1	108.0	107.8	105.3	105.3	107.8	107.9	112.6	112.6	122.4	122.4
5-2	114.2	113.9	110.8	110.7	114.4	114.4	121.0	121.0	134.1	134.1
5-3	108.7	108.4	105.9	105.9	108.7	108.6	113.6	113.6	123.4	123.5
5-4	106.1	105.8	103.7	103.7	106.1	106.0	110.0	110.0	118.5	118.5
6-1	108.9	108.7	106.2	106.2	109.4	109.2	114.1	114.4	124.6	124.6
6-2	115.3	115.1	111.8	111.9	116.2	115.9	122.6	122.8	136.5	136.5
6-3	110.0	109.9	107.1	107.1	110.5	110.2	115.5	115.6	126.4	126.3
6-4	107.1	106.9	104.6	104.6	107.6	107.3	111.7	111.8	120.9	120.8
7-1	109.7	109.8	107.2	107.2	110.1	110.4	115.9	115.9	127.3	127.3
7-2	115.8	115.6	112.3	112.3	116.8	116.5	123.5	123.6	137.7	137.7
7-3	110.2	110.2	107.5	107.5	111.2	110.9	116.3	116.3	127.7	127.7
7-4	108.2	108.1	105.6	105.6	109.0	108.6	113.4	113.5	123.3	123.4
8-1	111.7	111.5	108.7	108.7	112.6	112.4	118.2	118.3	130.8	130.8
8-2	116.9	116.8	113.4	113.5	118.3	118.0	125.2	125.3	140.2	140.2
8-3	111.2	111.0	108.4	108.4	112.3	112.0	117.8	117.8	129.7	129.8
8-4	109.2	109.1	106.7	106.7	110.2	110.0	115.2	115.2	126.0	126.0
9-1	111.8	111.8	109.1	109.1	113.2	112.8	119.2	119.2	131.5	131.7
9-2	114.9	114.9	111.9	111.9	116.6	116.3	123.6	123.5	137.7	137.9
9-3	118.0	118.1	114.7	114.8	119.8	119.6	127.4	127.4	142.6	142.6
9-4	116.4	116.4	113.3	113.3	118.1	117.9	125.2	125.3	139.9	139.9
9-5	113.0	113.0	110.2	110.2	114.5	114.3	120.6	120.7	133.4	133.6
9-6	111.0	111.1	108.4	108.4	112.4	112.2	118.0	118.0	129.6	129.7
9-7	109.9	110.1	107.5	107.5	111.4	111.1	116.7	116.7	127.8	127.8
9-8	110.1	110.2	107.7	107.7	111.5	111.2	116.9	116.9	128.3	128.5
10-1	112.6	112.7	110.0	109.9	114.2	113.9	120.6	120.7	133.8	133.9
10-2	118.5	118.6	115.2	115.2	120.4	120.2	128.3	128.3	143.8	144.0
10-3	113.5	113.6	110.7	110.7	115.2	114.9	121.6	121.6	134.8	135.0
10-4	110.7	110.9	108.3	108.3	112.2	112.0	118.0	118.1	129.7	129.8
INLET FLUID TEMPERATURE, F	91.1	91.2	90.9	90.7	91.1	90.6	90.5	90.5	90.7	90.7
EXIT FLUID TEMPERATURE, F	102.1	102.3	101.0	100.9	103.8	103.5	108.0	108.0	116.8	117.0
BATH FLUID TEMPERATURE, F	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0
AMMETER READING, I, AMPS	400.0	400.0	350.0	350.0	350.0	350.0	350.0	350.0	350.0	350.0
VOLTMETER READING, V, VOLTS	11.70	11.70	10.20	10.20	10.40	10.40	10.40	10.40	10.50	10.50
FLUID FLOW RATE, LB/HR	1475.00	1475.00	1205.00	1205.00	969.00	969.00	728.00	728.00	477.00	477.00
INLET PRES. TRDCR. OUTPUT, MV	2.757	2.745	1.846	1.849	1.123	1.100	0.596	0.568	0.161	0.153
EXIT PRES. TRDCR. OUTPUT, MV	1.741	1.729	1.132	1.156	0.649	0.651	0.270	0.276	0.006	0.008
INLET FLUID PRESSURE, PSIG	7.35	7.30	5.16	5.17	3.34	3.28	1.95	1.87	0.57	0.56
EXIT FLUID PRESSURE, PSIG	5.08	5.05	3.60	3.66	2.29	2.31	1.07	1.10	0.0	0.0
ROOM TEMPERATURE, F	94.0	94.0	93.0	93.0	88.0	88.0	90.0	90.0	92.0	92.0
RUN NUMBER	287	288	289	290	291	292	293	294	295	296

THERMOCOUPLE NUMBER	TEMP., F	TEMP., F
1-1	108.1	107.9
1-2	110.4	110.2
1-3	107.6	107.4
1-4	106.4	106.2
2-1	108.7	108.5
2-2	111.3	111.2
2-3	113.1	112.8
2-4	110.1	109.9
2-5	107.5	107.4
2-6	106.3	106.2
2-7	106.2	106.0
2-8	107.1	107.0
3-1	109.4	109.3
3-2	114.8	114.8
3-3	108.8	108.7
3-4	106.7	106.6
4-1	109.8	109.7
4-2	116.0	116.0
4-3	110.1	110.0
4-4	107.2	107.1
5-1	110.4	110.3
5-2	117.1	117.0
5-3	111.4	111.2
5-4	108.3	108.3
6-1	111.4	111.4
6-2	118.2	118.3
6-3	112.7	112.6
6-4	109.3	109.2
7-1	112.5	112.3
7-2	118.7	118.6
7-3	113.1	112.9
7-4	110.6	110.4
8-1	114.2	114.0
8-2	119.8	119.6
8-3	114.0	113.7
8-4	111.7	111.4
9-1	114.3	114.0
9-2	117.6	117.3
9-3	121.2	120.9
9-4	119.4	119.1
9-5	116.0	115.8
9-6	113.8	113.4
9-7	112.5	112.2
9-8	112.6	112.3
10-1	115.2	114.8
10-2	121.6	121.4
10-3	116.5	116.2
10-4	113.2	113.0
INLET FLUID TEMPERATURE, F	92.2	91.8
EXIT FLUID TEMPERATURE, F	102.6	102.2
BATH FLUID TEMPERATURE, F	90.5	90.0
AMMETER READING,I, AMPS	500.0	500.0
VOLTMETER READING,V, VOLTS	14.75	14.75
FLUID FLOW RATE, LB/HR	2417.00	2417.00
INLET PRES. TRDCR. OUTPUT,MV	8.037	8.059
EXIT PRES. TRDCR. OUTPUT,MV	5.063	5.091
INLET FLUID PRESSURE, PSIG	20.25	20.30
EXIT FLUID PRESSURE, PSIG	13.06	13.14
ROOM TEMPERATURE, F	96.0	97.0
RUN NUMBER	297	298

THERMOCOUPLE NUMBER	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F
1-1	81.4	81.4	82.3	82.2	83.1	83.1	82.2	82.2	83.2	83.1
1-2	91.0	90.9	92.2	92.2	93.7	93.6	92.2	92.2	93.8	93.6
1-3	82.0	82.1	82.9	83.0	84.0	83.9	82.9	82.9	84.1	84.0
1-4	79.3	79.2	79.9	80.0	80.6	80.6	79.9	79.9	80.7	80.6
2-1	81.8	81.7	82.5	82.7	83.5	83.6	82.5	82.6	83.5	83.4
2-2	88.1	88.0	89.1	89.2	90.4	90.5	89.1	89.2	90.4	90.3
2-3	91.5	91.3	92.5	92.6	93.8	93.9	92.5	92.6	93.9	93.8
2-4	86.8	86.8	87.9	88.0	88.9	89.1	87.8	88.0	89.2	89.1
2-5	82.6	82.6	83.6	83.6	84.4	84.5	83.6	83.6	84.5	84.5
2-6	81.3	81.2	82.1	82.1	82.8	82.9	81.9	82.1	82.8	82.8
2-7	79.9	79.9	80.5	80.7	81.3	81.3	80.5	80.6	81.2	81.2
2-8	80.2	80.3	80.9	81.0	81.8	81.8	80.9	80.9	81.7	81.7
3-1	83.0	83.3	84.1	84.3	85.9	86.1	84.4	84.4	86.0	86.1
3-2	93.0	93.4	94.5	94.6	96.6	96.6	95.0	94.8	96.6	96.6
3-3	83.3	83.5	84.7	84.6	86.4	86.5	84.8	84.8	86.3	86.5
3-4	80.9	81.1	82.1	82.0	83.9	83.9	82.0	82.1	83.7	83.8
4-1	84.0	84.0	85.7	85.7	87.9	88.0	86.0	85.9	87.9	87.8
4-2	94.1	94.2	95.9	95.9	98.4	98.4	96.3	96.0	98.3	98.1
4-3	85.1	85.1	86.8	86.7	89.2	89.1	87.0	86.9	89.0	88.9
4-4	82.6	82.6	84.4	84.3	86.9	86.8	84.4	84.4	86.7	86.7
5-1	86.4	86.4	88.2	88.2	90.2	90.3	88.3	88.2	90.3	90.1
5-2	95.3	95.3	97.1	97.2	99.7	99.6	97.3	97.3	99.9	99.5
5-3	86.3	86.2	87.9	88.0	90.7	90.7	88.2	88.3	90.8	90.6
5-4	84.0	83.8	85.7	85.7	88.5	88.6	85.9	86.0	88.6	88.5
6-1	86.8	86.7	88.6	88.5	92.4	92.3	88.8	88.8	92.3	92.2
6-2	96.5	96.4	98.6	98.4	102.2	101.9	98.8	98.7	101.9	101.8
6-3	87.5	87.4	89.3	89.1	92.8	92.6	89.2	89.2	92.6	92.5
6-4	85.1	85.0	86.6	86.6	91.3	91.1	86.7	86.7	91.0	91.0
7-1	87.8	87.8	89.5	89.4	93.7	93.6	89.6	89.5	93.5	93.6
7-2	97.2	97.3	99.1	99.0	103.3	103.0	99.2	99.2	102.9	103.0
7-3	88.1	88.1	89.6	89.5	93.8	93.7	89.7	89.7	93.6	93.8
7-4	86.0	85.8	87.5	87.3	92.4	92.4	87.5	87.5	92.3	92.3
8-1	89.0	88.9	90.7	90.6	94.8	94.7	90.7	90.9	94.6	94.7
8-2	98.4	98.3	100.4	100.3	104.2	104.2	100.5	100.5	104.0	104.1
8-3	89.2	89.1	90.8	90.8	94.7	94.7	90.9	90.9	94.5	94.7
8-4	87.2	87.1	88.9	88.7	93.3	93.4	88.9	88.8	93.1	93.1
9-1	90.2	90.0	92.3	92.1	96.3	96.3	92.3	92.1	96.2	96.1
9-2	94.3	94.1	96.7	96.5	100.6	100.8	96.7	96.5	100.6	100.5
9-3	98.8	98.7	101.2	101.1	105.0	105.2	101.2	101.0	104.9	104.9
9-4	94.9	94.8	97.0	97.0	100.8	101.0	97.1	97.0	100.8	100.8
9-5	90.8	90.7	92.5	92.5	96.6	96.8	92.7	92.7	96.4	96.5
9-6	88.7	88.6	90.3	90.3	94.7	94.8	90.3	90.3	94.7	94.7
9-7	88.1	88.1	89.8	89.8	94.4	94.4	89.8	89.8	94.0	94.3
9-8	88.7	88.6	90.4	90.3	95.1	95.0	90.5	90.3	94.8	94.9
10-1	91.2	91.2	93.3	93.2	97.7	97.7	93.4	93.2	97.4	97.4
10-2	100.0	100.0	102.5	102.3	106.5	106.3	102.3	102.2	106.3	106.2
10-3	91.3	91.2	93.4	93.3	97.3	97.3	93.4	93.2	97.2	97.1
10-4	88.8	88.7	90.8	90.6	95.2	95.2	90.6	90.5	95.3	95.2
INLET FLUID TEMPERATURE, F	72.4	72.3	72.4	72.4	72.5	72.5	72.3	72.3	72.5	72.4
EXIT FLUID TEMPERATURE, F	83.5	83.5	85.0	85.0	87.1	87.1	85.0	85.0	87.1	87.0
BATH FLUID TEMPERATURE, F	72.0	72.0	72.0	72.0	72.0	72.0	72.0	72.0	72.0	72.0
AMMETER READING,I, AMPS	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
VOLTMETER READING,V, VOLTS	5.90	5.90	5.90	5.90	6.00	6.00	6.00	6.00	6.00	6.00
FLUID FLOW RATE, LB/HR	374.30	374.30	329.20	329.20	288.20	288.20	329.20	329.20	288.20	288.20
INLET PRES. TRDCR. OUTPUT,MV	0.298	0.297	0.199	0.199	0.091	0.090	1.281	1.282	0.969	0.968
EXIT PRES. TRDCR. OUTPUT,MV	0.036	0.037	0.0	0.0	0.0	0.0	0.886	0.889	0.598	0.598
INLET FLUID PRESSURE, PSIG	1.00	1.00	0.70	0.70	0.35	0.35	3.76	3.76	2.94	2.94
EXIT FLUID PRESSURE, PSIG	0.12	0.12	0.0	0.0	0.0	0.0	2.96	2.97	2.13	2.13
ROOM TEMPERATURE, F	86.0	87.0	86.0	87.0	86.0	87.0	85.0	85.5	86.5	87.0
RUN NUMBER	101	102	103	104	105	106	107	108	109	110

THERMOCOUPLE NUMBER	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F
1-1	83.9	84.0	84.8	84.8	86.2	86.2	88.1	88.2	90.6	90.6
1-2	94.7	94.9	96.0	95.9	97.6	97.6	99.5	99.6	101.7	101.6
1-3	84.8	84.8	85.6	85.6	87.0	87.0	88.7	88.8	90.7	90.7
1-4	81.2	81.2	81.7	81.8	82.6	82.7	83.9	84.0	85.6	85.5
2-1	84.5	84.5	85.7	85.8	88.2	88.1	92.5	92.5	97.2	97.0
2-2	91.7	91.7	93.0	93.1	95.8	95.8	100.2	100.4	106.0	105.9
2-3	94.9	95.0	96.1	96.1	98.3	98.3	101.4	101.5	105.5	105.4
2-4	90.1	90.2	91.2	91.3	93.4	93.4	96.6	96.6	100.9	100.8
2-5	85.4	85.5	86.5	86.5	88.7	88.7	92.0	92.2	96.9	96.7
2-6	83.6	83.8	84.6	84.6	86.8	86.8	90.5	90.6	95.3	95.2
2-7	81.9	82.1	82.9	82.9	85.2	85.3	89.4	89.4	94.0	93.9
2-8	82.5	82.5	83.5	83.6	86.0	86.1	90.2	90.3	94.4	94.3
3-1	88.3	88.4	91.0	91.2	93.2	93.4	95.8	95.8	101.1	100.9
3-2	98.5	98.7	100.8	100.9	103.6	103.6	106.2	106.3	110.0	109.9
3-3	88.4	88.6	90.6	90.6	93.0	93.1	95.5	95.5	99.3	99.1
3-4	86.5	86.5	89.1	89.2	91.3	91.3	93.1	93.2	96.7	96.5
4-1	89.4	89.5	91.6	91.6	94.9	94.9	97.9	97.9	102.5	102.2
4-2	100.2	100.3	101.9	101.8	104.8	104.9	109.0	109.0	113.6	113.6
4-3	90.7	90.9	92.0	92.0	94.4	94.3	99.0	99.0	104.2	104.1
4-4	88.3	88.5	90.0	89.9	92.7	92.7	96.8	96.8	100.6	100.8
5-1	92.6	92.5	96.5	96.4	99.5	99.3	102.2	102.2	110.9	110.6
5-2	102.0	101.8	104.6	104.5	107.8	107.8	112.0	111.9	117.3	117.0
5-3	93.0	92.9	94.9	94.8	97.9	97.9	102.6	102.6	107.2	106.9
5-4	91.3	91.1	94.0	94.0	97.0	97.0	99.7	99.7	104.7	104.6
6-1	95.2	95.2	96.8	96.9	100.5	100.5	103.3	103.4	111.1	111.1
6-2	104.6	104.6	106.8	107.0	110.2	110.1	114.3	114.3	120.1	120.2
6-3	95.1	95.1	97.3	97.4	100.4	100.3	103.9	103.9	110.0	109.8
6-4	94.2	94.2	95.9	96.0	99.1	99.0	100.1	99.9	106.6	106.6
7-1	95.4	95.4	98.4	98.5	103.8	103.7	108.3	108.3	115.4	115.4
7-2	105.6	105.6	108.2	108.4	112.8	112.6	117.2	117.2	123.8	123.7
7-3	96.5	96.5	98.7	98.9	102.3	102.2	106.3	106.3	113.6	113.6
7-4	95.0	95.2	97.4	97.5	101.9	101.8	104.6	104.7	110.9	110.9
8-1	97.6	97.7	101.3	101.5	104.4	104.3	112.4	112.4	119.8	119.7
8-2	107.2	107.2	109.9	110.1	114.0	113.9	120.1	119.8	126.4	126.4
8-3	97.9	97.9	99.9	100.0	103.9	103.9	109.8	109.5	116.3	116.4
8-4	96.9	96.8	99.2	99.3	102.6	102.6	109.0	108.9	114.9	114.9
9-1	99.5	99.5	102.1	102.4	107.2	107.2	114.0	114.1	123.1	122.9
9-2	104.0	104.0	107.3	107.6	112.8	112.9	120.6	120.7	130.6	130.5
9-3	108.4	108.4	111.3	111.6	115.9	116.0	121.8	121.8	129.7	129.7
9-4	104.2	104.2	106.9	107.2	111.1	111.2	116.1	116.3	124.5	124.5
9-5	100.2	100.2	103.0	103.2	107.3	107.3	111.9	111.9	120.9	120.9
9-6	98.8	98.7	101.4	101.5	105.8	105.8	109.9	110.1	118.4	118.2
9-7	99.0	98.9	101.1	101.0	106.0	106.0	110.1	110.2	117.9	117.8
9-8	98.8	98.7	100.8	100.8	106.2	106.3	111.7	111.4	119.5	119.4
10-1	101.2	101.2	103.9	103.9	110.1	110.3	116.7	116.7	127.5	127.5
10-2	109.9	109.8	112.8	112.9	118.0	118.0	123.8	123.8	133.0	132.9
10-3	100.9	100.9	104.0	104.0	108.2	108.2	113.4	113.4	124.0	124.0
10-4	100.0	100.0	102.5	102.5	106.8	106.8	112.2	112.1	122.4	122.6
INLET FLUID TEMPERATURE, F	72.5	72.5	72.5	72.6	72.6	72.5	72.8	72.8	72.6	72.6
EXIT FLUID TEMPERATURE, F	89.3	89.3	91.7	91.8	95.9	95.8	102.1	102.1	111.6	111.7
BATH FLUID TEMPERATURE, F	72.0	72.0	72.0	72.0	72.0	72.0	72.0	72.0	72.0	72.0
AMMETER READING,I, AMPS	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
VOLTMETER READING,V, VOLTS	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
FLUID FLOW RATE, LB/HR	252.50	252.50	217.20	217.20	180.10	180.10	145.80	145.80	108.30	108.30
INLET PRES. TRDCR. OUTPUT,MV	0.701	0.701	0.495	0.496	1.214	1.217	0.767	0.768	0.927	0.925
EXIT PRES. TRDCR. OUTPUT,MV	0.356	0.358	0.177	0.176	0.898	0.899	0.472	0.476	0.688	0.690
INLET FLUID PRESSURE, PSIG	2.25	2.25	1.64	1.64	3.57	3.58	2.41	2.41	2.84	2.84
EXIT FLUID PRESSURE, PSIG	1.41	1.41	0.74	0.74	2.98	2.98	1.74	1.75	2.41	2.42
ROOM TEMPERATURE, F	88.0	88.0	87.0	87.0	88.0	88.0	88.5	88.0	86.0	86.0
RUN NUMBER	111	112	113	114	115	116	117	118	119	120

THERMOCOUPLE NUMBER	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F
1-1	85.9	85.9	99.8	99.8	109.3	109.3	91.4	91.4	87.1	87.1
1-2	92.8	92.7	98.5	98.6	105.5	105.7	92.9	92.8	100.1	100.2
1-3	85.7	85.6	91.7	91.8	97.0	97.2	87.5	87.5	88.6	88.7
1-4	82.3	82.2	90.0	90.0	95.5	95.6	85.6	85.6	84.3	84.3
2-1	91.5	91.4	105.6	105.6	118.6	119.0	96.3	96.3	87.8	87.7
2-2	97.3	97.1	108.0	107.8	119.0	119.3	99.5	99.4	96.0	96.0
2-3	97.0	96.6	103.1	103.0	111.1	111.3	96.7	96.7	102.1	102.0
2-4	94.0	93.7	99.8	99.7	106.8	106.9	94.0	94.0	95.3	95.2
2-5	91.2	91.2	97.3	97.2	104.0	104.0	91.4	91.3	89.9	89.8
2-6	90.4	90.2	96.6	96.4	103.8	103.8	90.1	90.1	87.7	87.7
2-7	89.3	89.2	96.5	96.6	106.7	106.8	89.2	89.2	85.2	85.2
2-8	89.7	89.6	100.2	100.3	112.0	111.9	91.3	91.4	85.8	85.8
3-1	93.6	93.6	113.6	113.4	126.8	126.6	101.0	101.0	89.6	89.6
3-2	100.4	100.3	110.2	110.3	120.3	120.1	101.4	101.4	104.5	104.5
3-3	93.9	93.9	104.4	104.5	113.1	112.9	96.6	96.5	91.1	90.9
3-4	91.1	91.1	105.8	105.8	116.0	115.9	95.6	95.5	87.0	86.8
4-1	97.7	97.7	119.7	119.8	134.7	134.5	105.4	105.4	90.6	90.4
4-2	102.7	102.6	117.2	117.3	128.7	128.5	106.0	106.0	105.3	105.1
4-3	96.1	96.0	112.7	112.7	124.0	124.0	101.2	101.2	92.2	92.2
4-4	94.7	94.7	112.2	112.0	125.4	125.4	100.3	100.3	88.5	88.4
5-1	101.4	101.4	128.6	128.4	148.1	148.0	111.2	111.0	93.2	93.0
5-2	106.0	105.7	123.9	123.7	139.7	139.7	110.4	110.4	106.2	106.2
5-3	98.8	98.7	118.1	118.0	132.5	132.4	105.9	105.8	93.9	93.8
5-4	97.0	97.1	119.0	119.2	135.3	135.4	104.6	104.7	90.1	90.2
6-1	103.6	103.7	133.4	133.5	154.9	154.7	114.9	114.9	93.9	93.8
6-2	109.2	109.4	130.3	130.3	148.3	148.4	114.8	114.8	107.9	107.8
6-3	103.0	103.2	125.1	124.9	142.4	142.4	110.2	110.5	95.4	95.1
6-4	100.4	100.5	125.1	124.1	143.8	143.9	109.3	109.4	91.6	91.4
7-1	107.3	107.5	141.1	139.9	164.4	164.7	119.9	120.2	95.5	95.3
7-2	111.6	111.8	136.7	136.7	156.3	156.6	119.2	119.3	108.3	107.9
7-3	104.7	104.7	132.2	132.4	150.7	151.2	114.5	114.7	96.1	96.0
7-4	103.4	103.6	132.7	132.7	153.5	153.9	114.1	114.4	92.9	92.9
8-1	111.3	111.3	147.7	147.7	174.1	174.0	124.1	124.5	96.7	96.7
8-2	115.1	115.0	142.8	142.9	165.5	165.2	123.4	123.7	109.3	109.3
8-3	108.6	108.6	137.7	137.9	159.0	158.4	119.3	119.5	97.2	97.3
8-4	108.0	107.9	139.2	139.3	161.5	161.4	118.6	119.0	94.2	94.2
9-1	115.0	114.7	154.5	154.6	182.1	181.7	129.3	129.8	98.0	98.1
9-2	119.7	119.7	154.8	154.9	180.9	180.4	131.0	131.3	103.0	103.3
9-3	118.2	118.0	149.3	149.5	172.7	172.3	127.9	128.1	109.1	109.4
9-4	114.7	114.6	146.7	146.7	168.8	168.6	125.4	125.8	103.9	104.0
9-5	112.3	112.2	146.3	146.3	168.2	168.2	124.4	124.7	98.8	98.8
9-6	111.0	110.9	146.2	146.3	169.9	169.6	123.5	123.8	95.8	95.8
9-7	110.9	110.8	147.0	147.2	171.9	172.0	123.6	123.9	94.9	95.1
9-8	112.2	112.3	150.6	150.6	177.7	177.9	125.7	125.9	95.7	96.0
10-1	118.0	117.8	160.9	160.9	191.9	191.8	133.6	134.1	99.4	99.6
10-2	120.4	120.3	154.9	155.0	182.3	182.3	131.4	131.8	110.5	110.7
10-3	114.4	114.2	150.3	150.2	176.9	176.8	127.5	128.0	99.6	99.9
10-4	113.2	113.3	152.0	152.2	180.8	180.8	127.4	127.8	96.1	96.3
INLET FLUID TEMPERATURE, F	72.9	72.9	73.3	73.4	73.5	73.5	73.7	73.7	71.9	71.9
EXIT FLUID TEMPERATURE, F	106.1	106.0	142.4	142.5	170.0	170.1	120.4	120.9	87.1	87.2
BATH FLUID TEMPERATURE, F	72.0	72.0	72.0	72.0	72.0	72.0	72.0	72.0	72.0	72.0
AMMETER READING,I, AMPS	150.0	150.0	150.0	150.0	180.0	180.0	130.0	130.0	300.0	300.0
VOLTMETER READING,V, VOLTS	4.60	4.60	4.60	4.60	5.50	5.50	3.90	3.90	9.20	9.20
FLUID FLOW RATE, LB/HR	76.20	76.20	36.20	36.20	36.20	36.20	36.20	36.20	636.70	636.70
INLET PRES. TRDCR. OUTPUT,MV	0.715	0.722	0.588	0.610	0.847	0.994	0.661	0.665	1.184	1.192
EXIT PRES. TRDCR. OUTPUT,MV	0.478	0.482	0.483	0.507	0.701	0.849	0.402	0.409	0.706	0.705
INLET FLUID PRESSURE, PSIG	2.29	2.30	1.93	1.98	2.62	3.00	2.13	2.14	3.51	3.52
EXIT FLUID PRESSURE, PSIG	1.74	1.75	1.75	1.86	2.71	2.86	1.55	1.56	2.46	2.46
ROOM TEMPERATURE, F	86.0	86.0	86.0	87.0	88.0	88.0	86.0	86.0	88.1	88.3
RUN NUMBER	121	122	123	124	125	126	127	128	129	130

THERMOCOUPLE NUMBER	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F
1-1	89.0	89.0	90.6	90.6	92.0	92.1	94.2	94.2	97.0	97.0
1-2	104.4	104.3	108.2	108.2	111.6	111.6	115.4	115.4	119.2	119.1
1-3	90.5	90.5	92.1	92.2	93.6	93.7	96.1	95.9	98.5	98.5
1-4	85.6	85.7	86.9	86.9	88.0	88.0	89.6	89.6	91.3	91.2
2-1	89.7	89.8	91.3	91.5	92.9	93.0	95.3	95.1	97.9	98.0
2-2	99.4	99.4	102.5	102.6	105.4	105.4	109.3	109.2	113.5	113.5
2-3	106.1	106.1	109.6	109.7	112.6	112.6	116.1	115.9	118.9	119.0
2-4	98.0	98.1	100.5	100.7	103.0	103.0	105.9	105.9	108.8	108.8
2-5	91.7	91.7	93.3	93.4	95.1	95.1	97.3	97.4	99.8	99.9
2-6	89.4	89.4	90.7	90.9	92.2	92.2	94.0	94.2	96.2	96.3
2-7	86.7	86.7	88.0	88.0	89.3	89.3	90.9	90.9	92.8	92.9
2-8	87.2	87.3	86.6	88.7	90.0	90.0	91.6	91.6	93.9	94.0
3-1	91.7	91.6	93.5	93.7	95.8	95.7	98.8	98.8	104.0	104.2
3-2	109.3	109.3	113.4	113.4	117.0	116.9	120.9	121.0	125.4	125.9
3-3	92.9	92.9	94.9	95.0	96.9	96.9	99.8	99.7	104.1	104.3
3-4	88.5	88.6	90.1	90.1	91.7	91.7	94.0	94.0	98.6	98.9
4-1	92.6	92.7	94.9	94.9	97.3	97.3	101.0	101.2	106.9	107.1
4-2	109.7	109.7	114.2	114.4	118.2	118.2	123.1	123.2	129.3	129.6
4-3	94.5	94.6	97.1	97.0	99.4	99.4	103.2	103.3	109.1	109.4
4-4	90.3	90.3	92.3	92.3	94.2	94.1	97.6	97.7	103.9	104.0
5-1	95.5	95.6	98.5	98.4	101.3	101.3	106.0	106.0	111.9	111.9
5-2	110.8	110.9	116.0	116.0	120.0	119.9	125.2	125.4	131.8	131.9
5-3	96.3	96.3	99.0	99.0	101.7	101.6	105.8	105.7	112.5	112.5
5-4	92.1	92.2	94.3	94.4	96.7	96.6	100.7	100.5	106.7	106.8
6-1	96.4	96.6	99.5	99.6	102.7	102.6	107.3	107.3	117.3	117.4
6-2	112.8	112.8	118.5	118.6	122.9	122.7	128.7	128.7	137.0	137.1
6-3	98.0	98.1	101.2	101.2	104.3	104.2	108.4	108.3	117.0	117.0
6-4	93.7	93.7	96.3	96.3	98.9	98.9	103.0	102.9	113.6	113.8
7-1	98.1	98.3	101.4	101.4	105.0	104.8	109.9	109.6	121.4	121.5
7-2	113.4	113.5	119.5	119.6	124.4	124.1	130.5	130.4	140.4	140.6
7-3	98.9	99.0	102.2	102.2	105.7	105.6	110.2	110.1	119.9	119.9
7-4	95.4	95.5	98.1	98.1	101.2	101.1	105.5	105.5	117.7	117.8
8-1	99.8	99.9	103.3	103.3	107.1	107.1	112.6	112.5	122.8	122.8
8-2	115.0	115.1	121.3	121.3	126.3	126.4	132.6	132.6	142.2	142.3
8-3	100.4	100.7	104.1	104.0	107.7	107.8	112.8	112.8	123.0	123.1
8-4	97.0	97.2	100.1	100.1	103.5	103.5	108.0	108.1	119.4	119.7
9-1	101.6	101.8	105.5	105.5	109.7	109.8	115.1	115.3	124.2	124.5
9-2	107.6	107.9	112.8	112.8	118.1	118.2	124.7	124.9	135.7	136.1
9-3	115.1	115.2	121.6	121.6	127.3	127.4	133.6	133.6	144.0	144.5
9-4	108.8	109.0	113.9	113.9	119.0	119.0	124.6	124.7	135.1	135.5
9-5	102.7	102.9	106.8	106.6	110.9	111.0	116.3	116.3	127.4	127.8
9-6	99.4	99.5	102.8	102.7	106.7	106.7	111.7	111.6	123.5	123.5
9-7	98.4	98.4	101.6	101.6	105.4	105.4	110.2	110.3	121.4	121.6
9-8	99.2	99.3	102.5	102.5	106.5	106.5	111.3	111.5	121.3	121.5
10-1	103.3	103.5	107.4	107.3	112.0	112.0	117.6	117.8	132.5	132.7
10-2	116.8	116.9	123.4	123.4	129.4	129.5	135.8	136.0	148.2	148.4
10-3	103.6	103.7	107.7	107.6	112.1	112.2	117.5	117.8	129.8	129.9
10-4	99.5	99.6	102.9	102.9	106.9	106.9	111.5	111.5	127.8	127.7
INLET FLUID TEMPERATURE, F	72.3	72.4	72.2	72.3	72.4	72.4	72.4	72.4	72.4	72.4
EXIT FLUID TEMPERATURE, F	89.9	90.0	92.4	92.4	95.7	95.8	100.0	100.1	106.9	106.9
BATH FLUID TEMPERATURE, F	72.0	72.0	72.0	72.0	72.0	72.0	72.0	72.0	72.0	72.0
AMMETER READING,I, AMPS	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0
VOLTMETER READING,V, VOLTS	9.20	9.20	9.20	9.20	9.20	9.20	9.20	9.20	9.20	9.20
FLUID FLOW RATE, LB/HR	559.30	559.30	484.60	484.60	414.90	414.90	344.80	344.80	277.70	277.70
INLET PRES. TRDCR. OUTPUT,MV	0.874	0.875	0.614	0.616	0.402	0.401	2.579	2.577	1.803	1.795
EXIT PRES. TRDCR. OUTPUT,MV	0.519	0.521	0.301	0.302	0.118	0.122	2.201	2.209	1.480	1.474
INLET FLUID PRESSURE, PSIG	2.70	2.70	2.01	2.01	1.40	1.40	6.90	6.90	5.07	5.04
EXIT FLUID PRESSURE, PSIG	1.93	1.93	1.20	1.20	0.51	0.51	6.21	6.23	4.44	4.43
ROOM TEMPERATURE, F	88.2	88.7	89.7	89.8	90.0	91.0	86.7	86.9	89.3	89.6
RUN NUMBER	131	132	133	134	135	136	137	138	139	140

THERMOCOUPLE NUMBER	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F
1-1	92.0	92.0	96.5	96.5	110.3	110.2	84.9	84.9	94.7	94.6
1-2	108.4	108.5	112.8	112.8	119.2	119.1	92.0	92.1	104.4	104.3
1-3	92.9	93.1	96.9	96.9	104.3	104.6	85.0	85.0	93.3	93.2
1-4	87.1	87.2	90.1	90.1	97.7	97.9	81.6	81.6	88.2	88.0
2-1	93.3	93.3	103.0	103.0	120.1	120.4	89.7	89.8	101.5	101.4
2-2	104.9	105.1	115.6	115.5	132.2	131.9	95.4	95.5	111.8	111.6
2-3	108.4	108.5	115.1	115.1	124.3	124.0	95.6	95.6	109.5	109.3
2-4	101.2	101.3	107.9	107.9	116.9	117.0	92.6	92.8	104.8	104.7
2-5	94.4	94.6	101.7	101.7	111.0	110.9	90.1	90.2	100.5	100.5
2-6	91.7	91.9	99.4	99.2	108.5	108.5	89.0	89.1	98.4	98.4
2-7	89.2	89.4	97.7	97.6	106.7	106.8	88.0	88.0	96.2	96.3
2-8	90.0	90.2	99.1	99.2	109.9	110.1	92.3	88.1	97.3	97.3
3-1	101.7	101.8	107.6	107.5	128.0	128.3	92.3	92.4	106.2	105.8
3-2	115.9	116.0	122.1	122.2	132.2	131.8	98.7	98.7	114.1	113.9
3-3	100.1	100.3	105.9	106.0	118.4	118.0	92.2	92.3	103.0	103.1
3-4	98.0	98.3	101.3	101.2	114.7	114.5	90.3	90.4	99.4	99.1
4-1	102.0	102.2	110.5	110.5	135.0	135.1	94.4	94.4	110.9	110.8
4-2	117.7	117.7	125.6	125.6	140.0	140.3	101.3	101.5	117.8	117.7
4-3	102.3	102.3	110.9	110.9	127.7	128.0	95.0	95.0	107.6	107.5
4-4	98.7	98.7	106.6	106.8	124.8	124.5	92.8	93.0	105.7	105.7
5-1	109.9	110.0	118.5	118.4	148.7	148.7	98.4	98.5	118.6	118.3
5-2	121.1	121.1	130.4	130.4	147.1	147.4	104.2	104.4	122.5	122.4
5-3	106.0	106.0	116.6	116.5	134.7	135.0	98.2	98.3	112.9	112.9
5-4	104.5	104.4	112.0	112.0	134.0	134.0	95.1	95.3	111.0	110.9
6-1	110.4	110.3	120.6	120.6	151.5	151.8	101.2	101.3	121.6	121.5
6-2	124.5	124.4	132.9	132.9	153.1	153.4	106.7	106.9	127.4	127.3
6-3	110.1	110.1	116.9	117.0	141.4	141.8	100.7	100.7	117.9	117.8
6-4	108.0	108.0	113.4	113.4	140.4	140.8	98.9	99.0	115.5	115.4
7-1	115.1	115.1	125.1	124.9	156.6	156.9	103.0	103.0	127.1	126.9
7-2	127.9	128.0	137.0	136.9	158.2	158.4	109.5	109.7	132.2	132.0
7-3	112.2	112.2	120.9	121.1	146.8	146.9	103.4	103.4	122.3	122.1
7-4	111.0	110.9	118.2	118.4	145.8	145.6	101.3	101.1	120.6	120.3
8-1	114.8	114.9	129.3	129.5	163.3	163.4	106.5	106.9	131.6	131.4
8-2	128.0	128.0	140.2	140.4	163.1	163.3	111.4	111.5	135.6	135.4
8-3	112.4	112.5	125.9	126.0	151.5	151.9	105.1	105.0	126.4	126.4
8-4	110.0	110.2	122.8	122.9	152.8	152.6	103.5	103.5	125.1	125.3
9-1	119.9	120.0	135.4	135.5	172.6	172.6	109.6	109.5	137.5	137.4
9-2	128.3	128.4	145.5	145.8	179.3	179.4	114.1	114.1	144.2	144.2
9-3	131.4	131.5	144.3	144.7	170.8	170.8	113.9	114.1	140.5	140.3
9-4	123.7	123.9	136.6	136.9	164.5	164.2	110.7	111.0	135.5	135.4
9-5	118.1	118.3	131.0	131.4	162.1	162.2	108.5	108.8	132.4	132.2
9-6	115.9	116.0	128.1	128.1	160.8	161.1	107.0	107.2	130.6	130.4
9-7	116.1	116.1	127.6	127.7	161.4	161.7	106.7	106.6	130.4	130.2
9-8	117.2	117.3	130.2	130.3	165.3	165.1	107.0	107.0	132.9	132.6
10-1	122.3	122.5	140.9	141.1	180.9	181.3	111.8	112.0	142.4	142.1
10-2	134.3	134.5	147.8	148.1	177.0	177.2	116.0	116.3	144.1	143.8
10-3	120.7	120.7	134.1	134.4	167.1	167.2	110.2	110.6	135.7	135.6
10-4	117.6	117.6	132.7	132.8	167.8	168.1	108.3	108.9	134.7	134.5
INLET FLUID TEMPERATURE, F	72.4	72.5	72.6	72.6	72.9	72.9	72.9	72.9	72.9	72.9
EXIT FLUID TEMPERATURE, F	103.6	103.6	117.5	117.5	150.0	150.1	101.3	101.5	123.2	123.0
BATH FLUID TEMPERATURE, F	72.0	72.0	72.0	72.0	72.0	72.0	72.0	72.0	72.0	72.0
AMMETER READING, I, AMPS	250.0	250.0	250.0	250.0	250.0	250.0	150.0	150.0	200.0	200.0
VOLTMETER READING, V, VOLTS	7.50	7.50	7.50	7.50	7.60	7.60	4.60	4.60	6.00	6.00
FLUID FLOW RATE, LB/HR	212.30	212.30	147.80	147.80	84.40	84.40	84.40	84.40	84.40	84.40
INLET PRES. TRDCR. OUTPUT, MV	1.008	1.010	0.460	0.462	1.548	1.646	1.232	1.233	1.522	1.538
EXIT PRES. TRDCR. OUTPUT, MV	0.713	0.713	0.227	0.223	1.390	1.470	0.928	0.926	1.254	1.267
INLET FLUID PRESSURE, PSIG	3.06	3.06	1.55	1.55	4.42	4.66	3.62	3.62	4.36	4.40
EXIT FLUID PRESSURE, PSIG	2.48	2.48	0.93	0.91	4.23	4.42	3.07	3.07	3.92	3.94
ROOM TEMPERATURE, F	87.6	87.5	87.8	87.7	89.7	89.8	87.1	87.3	87.8	87.8
RUN NUMBER	141	142	143	144	145	146	147	148	149	150

THERMOCOUPLE NUMBER	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F
1-1	86.5	86.6	90.8	90.9	87.6	87.6	85.3	85.3	87.0	87.0
1-2	97.2	97.2	103.9	103.9	96.6	96.3	92.2	92.1	94.6	94.5
1-3	87.9	88.0	91.3	91.6	88.1	88.0	85.6	85.6	87.3	87.3
1-4	83.9	83.9	86.9	87.1	84.6	84.6	82.9	82.8	84.2	84.4
2-1	86.9	87.0	91.2	91.3	87.8	87.8	85.4	85.3	87.0	87.0
2-2	93.7	93.7	100.0	100.1	94.0	93.9	90.3	90.3	92.3	92.3
2-3	98.7	98.7	106.4	106.5	98.6	98.4	93.7	93.7	96.1	96.1
2-4	93.3	93.3	99.1	99.3	93.6	93.5	90.0	89.9	91.9	91.9
2-5	88.8	88.8	92.4	92.7	88.9	88.9	86.3	86.3	88.0	88.1
2-6	86.9	86.9	90.0	90.2	87.1	87.0	84.8	84.8	86.4	86.4
2-7	84.7	84.7	87.7	87.9	85.2	85.1	83.3	83.2	84.6	84.7
2-8	85.1	85.1	88.3	88.5	85.8	85.8	83.7	83.7	85.2	85.2
3-1	88.3	88.4	92.8	93.1	88.9	89.0	86.5	86.4	88.1	88.1
3-2	100.5	100.6	109.5	109.6	100.1	100.3	95.5	95.4	98.2	98.0
3-3	89.7	89.7	93.9	94.1	89.9	89.9	87.4	87.3	89.3	89.3
3-4	86.1	86.1	89.5	89.8	86.3	86.4	84.5	84.5	86.0	86.0
4-1	89.3	89.3	94.1	94.4	89.8	89.8	87.2	87.2	89.0	88.9
4-2	100.9	100.9	109.6	109.7	100.4	100.6	95.8	95.8	98.4	98.4
4-3	90.9	90.9	95.9	96.0	91.2	91.4	88.6	88.5	90.5	90.5
4-4	87.6	87.7	91.6	91.9	88.2	88.2	85.9	85.8	87.6	87.6
5-1	91.5	91.6	97.3	97.4	92.2	92.2	89.1	89.1	91.0	90.9
5-2	101.8	101.9	110.8	110.8	101.7	101.7	96.7	96.6	99.2	99.1
5-3	92.2	92.3	97.5	97.8	92.5	92.6	89.5	89.5	91.6	91.5
5-4	89.0	89.1	93.6	93.8	89.6	89.6	87.0	87.0	88.9	88.9
6-1	92.4	92.3	98.1	98.5	92.9	93.0	89.7	89.8	91.6	91.7
6-2	103.3	103.2	112.8	112.9	103.1	103.3	97.8	97.9	100.5	100.6
6-3	93.7	93.7	99.6	99.8	94.0	94.1	90.7	90.7	92.6	92.9
6-4	90.4	90.5	95.2	95.5	90.8	90.8	88.1	88.1	89.8	90.0
7-1	93.6	93.6	99.8	100.0	94.3	94.4	90.8	90.9	92.8	92.8
7-2	103.6	103.8	113.1	113.4	103.8	103.9	98.6	98.6	101.2	101.2
7-3	94.2	94.3	100.4	100.5	94.7	94.7	91.2	91.2	93.4	93.4
7-4	91.5	91.6	96.9	97.0	92.1	92.2	89.1	89.2	91.1	91.1
8-1	94.8	94.9	101.6	101.7	95.6	95.6	91.9	91.9	94.1	94.1
8-2	105.2	105.2	114.9	115.0	105.3	105.4	99.7	99.6	102.5	102.4
8-3	95.4	95.5	102.0	102.1	95.8	95.9	92.1	92.1	94.4	94.4
8-4	92.8	92.9	98.5	98.8	93.4	93.4	90.2	90.2	92.2	92.2
9-1	96.2	96.3	103.4	103.7	97.1	97.1	93.1	93.1	95.4	95.3
9-2	100.5	100.5	108.9	109.2	101.1	101.2	96.4	96.3	98.7	98.7
9-3	105.6	105.5	115.2	115.6	105.7	105.7	100.1	100.1	102.8	102.8
9-4	101.3	101.2	109.7	110.0	101.7	101.8	96.7	96.7	99.1	99.3
9-5	97.2	97.2	104.1	104.5	97.6	97.7	93.5	93.4	95.6	95.8
9-6	94.6	94.6	101.1	101.2	95.2	95.2	91.4	91.4	93.4	93.7
9-7	93.8	93.9	100.1	100.3	94.5	94.3	90.9	90.9	92.9	93.1
9-8	94.6	94.5	101.2	101.3	95.2	95.1	91.6	91.6	93.7	93.8
10-1	97.7	97.7	105.5	105.5	98.4	98.4	94.1	94.2	95.6	96.6
10-2	106.8	106.8	117.2	117.3	107.2	107.1	101.2	101.2	104.3	104.3
10-3	97.8	97.8	105.5	105.5	98.3	98.3	94.1	94.0	96.5	96.5
10-4	94.7	94.7	101.3	101.5	95.4	95.4	91.7	91.7	93.9	93.9
INLET FLUID TEMPERATURE, F	72.7	72.7	72.5	72.7	72.8	72.8	72.8	72.8	72.6	72.6
EXIT FLUID TEMPERATURE, F	86.2	86.3	90.6	90.7	86.4	86.3	83.6	83.6	84.3	84.3
BATH FLUID TEMPERATURE, F	72.0	72.0	72.0	72.1	72.0	72.0	72.0	72.0	72.0	72.0
AMMETER READING, I, AMPS	300.0	300.0	350.0	350.0	350.0	350.0	350.0	350.0	400.0	400.0
VOLTMETER READING, V, VOLTS	9.20	9.20	10.50	10.50	10.50	10.50	10.50	10.50	12.10	12.10
FLUID FLOW RATE, LB/HR	707.10	707.10	728.00	728.00	969.00	969.00	1205.00	1205.00	1475.00	1475.00
INLET PRES. TRDCR. OUTPUT, MV	1.539	1.536	0.619	0.607	1.261	1.250	2.052	2.051	3.010	3.007
EXIT PRES. TRDCR. OUTPUT, MV	1.004	1.016	0.127	0.130	0.590	0.586	1.149	1.152	1.893	1.899
INLET FLUID PRESSURE, PSIG	4.41	4.39	2.01	1.99	3.71	3.68	5.65	5.65	7.94	7.94
EXIT FLUID PRESSURE, PSIG	3.27	3.32	0.54	0.55	2.12	2.09	3.64	3.66	5.44	5.46
ROOM TEMPERATURE, F	88.6	88.9	86.4	86.5	88.5	88.7	88.9	89.2	90.2	90.3
RUN NUMBER	151	152	153	154	155	156	157	158	159	160

THERMOCOUPLE NUMBER	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F
1-1	85.7	85.7	91.2	91.2	90.1	90.0	88.7	88.9	96.3	96.3
1-2	92.3	92.2	100.1	100.1	98.2	98.2	96.2	96.5	118.1	118.3
1-3	85.9	85.9	91.8	91.9	90.8	90.7	89.4	89.6	97.6	97.8
1-4	83.3	83.3	88.1	88.1	87.3	87.1	86.0	86.2	91.1	91.4
2-1	85.6	85.6	91.4	91.4	90.2	90.1	89.0	89.0	97.6	97.8
2-2	90.3	90.3	97.6	97.7	95.8	95.8	94.1	94.2	112.1	112.3
2-3	93.6	93.6	101.9	102.1	99.9	99.8	98.0	98.2	121.0	121.3
2-4	90.1	90.1	97.3	97.4	95.7	95.6	94.0	94.1	109.1	109.4
2-5	86.6	86.6	92.7	92.8	91.5	91.3	90.1	90.3	99.2	99.6
2-6	85.2	85.2	90.6	90.7	89.6	89.5	88.3	88.6	95.8	96.1
2-7	83.5	83.6	88.4	88.5	87.5	87.3	86.4	86.5	92.6	92.9
2-8	84.1	84.1	89.1	89.2	88.2	88.0	86.9	87.0	93.6	93.8
3-1	86.5	86.5	92.5	92.6	91.3	91.2	90.0	90.0	100.4	100.8
3-2	95.3	95.1	104.2	104.3	102.1	102.0	99.9	99.9	125.6	126.1
3-3	87.6	87.4	93.9	94.0	92.7	92.6	91.1	91.2	101.3	101.6
3-4	84.7	84.6	90.0	90.0	89.0	88.8	87.6	87.7	95.2	95.5
4-1	87.4	87.3	93.6	93.7	92.3	92.1	90.7	90.7	102.2	102.5
4-2	95.6	95.5	104.7	104.8	102.4	102.3	100.2	100.3	127.0	127.4
4-3	88.6	88.7	95.5	95.7	94.0	94.0	92.4	92.4	104.3	104.7
4-4	86.0	86.0	92.0	92.0	90.8	90.8	89.3	89.4	98.2	98.6
5-1	89.1	89.2	95.8	95.9	94.6	94.3	92.7	92.8	107.0	107.1
5-2	96.4	96.5	105.6	105.8	103.5	103.3	101.0	101.1	129.6	129.5
5-3	89.7	89.7	96.7	96.9	95.3	95.2	93.4	93.4	107.3	107.3
5-4	87.3	87.3	93.4	93.5	92.1	92.0	90.4	90.5	101.4	101.4
6-1	89.8	89.9	96.8	96.9	95.2	95.0	93.3	93.4	108.4	108.4
6-2	97.7	97.9	107.4	107.4	104.8	104.8	102.3	102.4	132.5	132.6
6-3	90.9	91.0	98.3	98.5	96.5	96.4	94.6	94.7	110.0	110.1
6-4	88.4	88.4	94.8	94.9	93.4	93.1	91.7	91.6	103.8	104.0
7-1	90.9	90.9	98.3	98.4	96.3	96.4	94.5	94.5	110.9	111.0
7-2	98.1	98.2	108.3	108.3	105.4	105.4	102.9	102.9	133.6	133.7
7-3	91.2	91.2	98.9	99.1	97.0	97.0	95.1	95.1	111.3	111.4
7-4	89.3	89.3	96.1	96.1	94.4	94.5	92.7	92.8	106.3	106.4
8-1	91.8	91.9	99.6	99.8	97.6	97.7	95.8	95.8	113.5	113.5
8-2	99.1	99.3	109.7	109.8	106.7	106.9	104.1	104.1	135.7	135.8
8-3	91.9	92.1	100.1	100.3	97.9	98.1	95.9	95.9	113.9	113.9
8-4	90.0	90.2	97.4	97.6	95.4	95.6	93.6	93.7	108.8	108.9
9-1	92.7	93.0	101.3	101.5	99.0	99.3	96.7	96.9	116.3	116.4
9-2	95.8	96.0	105.3	105.5	102.6	102.9	100.1	100.2	125.7	125.5
9-3	99.4	99.6	110.1	110.4	107.1	107.3	104.2	104.3	136.2	136.3
9-4	96.2	96.4	105.9	106.1	103.0	103.3	100.4	100.6	126.6	126.7
9-5	93.1	93.4	101.7	102.0	99.3	99.4	97.0	97.2	117.4	117.4
9-6	91.3	91.5	99.0	99.3	96.9	97.0	94.8	95.0	112.4	112.4
9-7	90.8	91.0	98.3	98.6	96.3	96.4	94.3	94.3	110.9	111.1
9-8	91.5	91.6	99.1	99.4	97.1	97.2	95.1	95.1	112.2	112.2
10-1	94.0	94.1	102.6	102.8	100.2	100.4	98.0	98.1	118.7	118.8
10-2	100.8	100.9	111.7	111.9	108.5	108.8	105.6	105.8	137.8	137.9
10-3	93.9	94.0	102.4	102.5	100.0	100.2	97.8	97.8	118.6	118.6
10-4	91.6	91.7	99.3	99.4	97.0	97.4	95.1	95.1	112.9	112.8
INLET FLUID TEMPERATURE, F	72.6	72.8	72.8	72.8	72.7	72.8	72.8	72.8	72.4	72.4
EXIT FLUID TEMPERATURE, F	82.7	82.8	86.4	86.6	84.9	85.1	83.5	83.6	99.4	99.4
BATH FLUID TEMPERATURE, F	72.0	72.0	72.0	72.0	72.0	72.0	72.0	72.0	72.0	72.0
AMMETER READING,I, AMPS	400.0	400.0	500.0	500.0	500.0	500.0	500.0	500.0	350.0	350.0
VOLTMETER READING,V, VOLTS	12.20	12.20	15.20	15.20	15.20	15.20	15.20	15.20	10.60	10.60
FLUID FLOW RATE, LB/HR	1729.00	1729.00	1962.00	1962.00	2208.00	2208.00	2417.00	2417.00	477.00	477.00
INLET PRES. TRDCR. OUTPUT,MV	4.120	4.096	5.365	5.368	6.745	6.773	8.587	8.568	0.760	0.771
EXIT PRES. TRDCR. OUTPUT,MV	2.721	2.737	3.636	3.649	4.683	4.652	5.880	5.862	0.427	0.413
INLET FLUID PRESSURE, PSIG	10.33	10.33	13.60	13.61	17.00	17.12	21.45	21.40	2.40	2.42
EXIT FLUID PRESSURE, PSIG	7.43	7.46	9.63	9.65	12.14	12.10	15.20	15.12	1.60	1.57
ROOM TEMPERATURE, F	92.3	92.6	88.4	88.4	91.2	91.2	90.6	91.4	89.8	90.4
RUN NUMBER	161	162	163	164	165	166	167	168	169	170

THERMOCOUPLE NUMBER	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F
1-1	106.2	106.3	107.0	107.0	108.0	108.1
1-2	113.3	113.3	114.6	114.5	116.1	116.4
1-3	106.5	106.5	107.3	107.3	108.2	108.4
1-4	103.3	103.4	104.0	104.0	104.8	104.9
2-1	106.2	106.2	107.0	107.1	108.1	108.3
2-2	111.2	111.2	112.3	112.3	113.8	114.0
2-3	114.9	114.8	116.3	116.3	118.1	118.2
2-4	110.8	110.8	111.9	112.0	113.4	113.4
2-5	107.2	107.2	108.0	108.0	109.1	109.2
2-6	105.6	105.6	106.3	106.3	107.2	107.4
2-7	103.8	103.7	104.3	104.4	105.2	105.3
2-8	104.2	104.2	104.9	104.9	105.8	105.9
3-1	107.2	107.2	108.2	108.1	109.3	109.4
3-2	116.8	116.9	118.5	118.3	120.3	120.6
3-3	108.3	108.4	109.3	109.3	110.4	110.6
3-4	105.1	105.1	105.8	105.8	106.7	106.9
4-1	108.1	108.1	109.0	109.0	110.3	110.4
4-2	117.3	117.3	118.9	118.7	120.9	121.1
4-3	109.7	109.7	110.7	110.7	112.0	112.3
4-4	106.7	106.8	107.6	107.6	108.7	108.9
5-1	109.9	110.0	111.2	111.1	112.6	112.8
5-2	118.1	118.2	119.9	119.9	122.0	122.2
5-3	110.6	110.8	112.0	111.9	113.3	113.5
5-4	107.9	108.0	109.0	109.0	110.2	110.4
6-1	110.8	110.8	112.1	112.1	113.5	113.7
6-2	119.6	119.7	121.5	121.4	123.7	124.0
6-3	111.9	111.9	113.3	113.2	114.7	115.0
6-4	109.1	109.1	110.1	110.1	111.5	111.8
7-1	111.6	111.7	113.0	113.0	114.6	114.9
7-2	120.0	120.0	122.0	121.9	124.2	124.7
7-3	112.3	112.4	113.8	113.8	115.4	115.7
7-4	110.1	110.1	111.4	111.4	112.7	113.1
8-1	113.0	113.0	114.4	114.4	116.2	116.5
8-2	121.1	121.1	123.2	123.1	125.6	125.9
8-3	113.4	113.3	114.8	114.8	116.5	116.8
8-4	111.2	111.2	112.5	112.6	114.1	114.3
9-1	114.2	114.3	116.0	115.9	117.7	118.1
9-2	117.6	117.5	119.5	119.4	121.6	122.0
9-3	121.7	121.7	124.0	123.8	126.4	126.8
9-4	117.9	117.8	119.9	119.8	122.0	122.4
9-5	114.6	114.6	116.3	116.2	118.1	118.5
9-6	112.5	112.4	114.0	114.0	115.7	116.0
9-7	112.0	111.9	113.5	113.4	115.1	115.3
9-8	112.7	112.6	114.1	114.0	115.8	116.1
10-1	115.3	115.3	117.0	117.0	119.2	119.4
10-2	123.1	123.0	125.3	125.2	128.0	128.3
10-3	115.2	115.1	116.9	116.9	118.9	119.2
10-4	112.6	112.6	114.2	114.1	116.0	116.1
INLET FLUID TEMPERATURE, F	91.1	91.1	91.1	91.1	91.0	91.1
EXIT FLUID TEMPERATURE, F	102.1	102.0	103.1	103.1	104.5	104.6
BATH FLUID TEMPERATURE, F	90.0	90.0	90.0	90.0	90.0	90.0
AMMETER READING, I, AMPS	500.0	500.0	500.0	500.0	500.0	500.0
VOLTMETER READING, V, VOLTS	15.20	15.20	15.20	15.20	15.20	15.20
FLUID FLOW RATE, LB/HR	2417.00	2417.00	2208.00	2208.00	1962.00	1962.00
INLET PRES. TRDCR. OUTPUT, MV	8.228	8.170	6.484	6.602	5.317	5.419
EXIT PRES. TRDCR. OUTPUT, MV	5.601	5.603	4.527	4.565	3.654	3.657
INLET FLUID PRESSURE, PSIG	20.60	20.45	16.40	16.75	13.47	13.75
EXIT FLUID PRESSURE, PSIG	14.40	14.40	11.77	11.86	9.67	9.69
ROOM TEMPERATURE, F	88.0	88.2	87.6	88.4	87.9	88.3
RUN NUMBER	171	172	173	174	175	176

THERMOCOUPLE NUMBER	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F
1-1	129.1	129.1	133.4	132.9	134.9	134.6	141.6	141.1	144.1	144.5
1-2	136.7	136.7	140.5	139.9	141.1	141.5	146.1	145.7	147.5	147.8
1-3	127.4	127.4	131.1	130.6	132.2	132.4	137.0	136.8	138.8	139.2
1-4	122.1	122.2	126.0	125.5	127.6	127.6	133.1	132.9	135.7	136.0
2-1	139.0	139.2	143.4	142.6	143.7	143.7	148.1	147.9	150.8	151.2
2-2	143.1	143.2	147.4	146.5	147.5	147.4	151.6	151.4	153.5	153.8
2-3	143.3	143.4	147.1	146.3	146.8	146.6	150.0	149.9	151.2	151.4
2-4	139.6	139.7	143.1	142.6	142.9	142.8	145.6	145.6	146.4	146.6
2-5	134.6	134.8	138.2	137.7	138.2	138.2	140.7	140.8	141.6	141.8
2-6	131.8	131.9	135.3	135.0	135.6	135.3	138.0	138.2	139.2	139.2
2-7	131.3	131.4	135.0	134.6	135.4	135.0	137.8	138.1	139.4	139.5
2-8	133.9	134.0	137.8	137.5	138.4	137.9	141.2	141.8	144.0	144.1
3-1	141.9	142.1	147.0	146.6	148.9	148.2	155.4	156.3	159.4	159.4
3-2	148.7	149.0	153.3	152.9	154.1	153.2	157.1	157.3	158.9	158.9
3-3	140.4	140.7	144.8	144.5	145.9	146.1	148.7	149.0	150.3	150.3
3-4	135.1	135.4	139.3	139.2	141.0	140.8	145.3	145.5	148.8	148.8
4-1	147.5	147.4	152.1	151.9	153.4	153.8	160.9	160.6	161.1	161.3
4-2	154.4	154.3	158.2	157.8	157.5	157.9	162.1	161.6	161.7	161.9
4-3	147.0	146.9	150.8	150.3	150.1	150.2	153.4	152.9	152.6	152.7
4-4	141.7	141.6	145.7	145.2	146.0	145.8	150.7	150.2	150.1	150.2
5-1	152.1	152.7	157.2	157.3	158.9	158.8	160.4	160.7	165.3	165.1
5-2	157.8	158.4	161.8	161.9	161.8	161.8	163.3	163.4	168.3	168.1
5-3	149.2	149.8	152.8	152.9	152.6	152.7	153.4	153.4	160.3	160.0
5-4	145.6	146.1	149.3	149.4	149.7	150.1	150.6	150.5	156.2	155.8
6-1	157.5	157.6	160.7	160.2	159.9	159.7	159.7	159.7	167.2	167.0
6-2	162.1	162.2	164.4	163.9	163.4	163.3	164.4	164.3	168.3	168.6
6-3	153.0	153.0	155.1	154.8	154.4	154.4	154.0	154.0	161.3	160.8
6-4	149.6	149.5	151.4	151.2	150.6	150.6	149.5	149.6	157.2	156.8
7-1	159.0	159.4	160.1	160.1	159.9	159.6	160.9	161.1	168.5	168.5
7-2	163.6	164.1	164.3	164.3	163.3	163.0	166.4	166.9	170.1	170.1
7-3	154.6	154.9	154.9	154.9	154.2	154.1	156.2	156.3	162.9	162.8
7-4	151.3	151.6	151.4	151.4	151.3	151.2	151.8	152.0	160.0	159.8
8-1	153.3	153.7	160.1	160.2	161.6	161.9	164.7	164.7	172.8	172.3
8-2	158.5	158.7	162.4	162.4	163.3	163.6	167.1	166.9	173.1	172.8
8-3	149.8	150.0	154.4	154.5	155.7	156.0	158.4	158.1	167.2	167.0
8-4	145.7	146.1	152.3	152.3	153.8	154.1	155.8	155.2	164.5	164.0
9-1	148.9	149.8	159.4	159.3	161.8	162.0	170.7	170.2	175.6	175.6
9-2	157.1	157.7	164.5	164.4	166.9	167.1	175.7	175.8	181.0	180.8
9-3	159.3	159.6	164.1	164.0	166.3	166.4	174.0	173.7	179.2	178.8
9-4	156.8	156.9	161.3	161.1	163.5	163.5	170.8	170.9	176.4	176.0
9-5	150.6	150.7	156.6	156.5	159.1	158.9	166.3	166.3	173.4	172.9
9-6	145.1	145.2	153.2	153.0	155.7	155.5	163.1	163.0	171.0	170.5
9-7	142.5	142.7	152.4	152.2	155.0	154.6	162.6	162.4	169.0	168.5
9-8	143.5	143.8	154.2	153.8	156.7	156.3	164.8	164.7	169.0	168.6
10-1	156.9	156.9	152.0	152.1	155.7	155.5	169.4	169.5	178.8	178.6
10-2	164.7	164.7	160.6	160.6	162.0	162.1	175.0	175.0	180.2	180.1
10-3	157.0	157.0	149.7	149.7	152.4	152.6	167.4	167.4	174.6	174.5
10-4	148.6	148.6	143.1	142.9	147.7	147.5	162.1	161.9	172.1	172.2
INLET FLUID TEMPERATURE, F	90.2	90.3	90.7	90.7	90.5	90.5	90.4	90.3	90.3	90.3
EXIT FLUID TEMPERATURE, F	111.7	111.9	116.2	116.1	119.8	120.0	124.8	124.5	128.3	128.1
BATH FLUID TEMPERATURE, F	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0
AMMETER READING,I, AMPS	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0
VOLTMETER READING,V, VOLTS	4.60	4.60	4.60	4.60	4.60	4.60	4.60	4.60	4.60	4.60
FLUID FLOW RATE, LB/HR	283.97	283.97	245.14	245.14	212.08	212.08	181.99	181.99	164.98	164.98
INLET PRES. TRDCR. OUTPUT,MV	0.730	0.726	0.577	0.577	0.487	0.489	0.334	0.336	0.281	0.280
EXIT PRES. TRDCR. OUTPUT,MV	0.326	0.331	0.239	0.243	0.191	0.185	0.085	0.091	0.060	0.060
INLET FLUID PRESSURE, PSIG	2.32	2.32	1.90	1.90	1.61	1.61	1.13	1.14	0.97	0.97
EXIT FLUID PRESSURE, PSIG	1.27	1.28	0.95	0.96	0.80	0.77	0.33	0.36	0.25	0.25
ROOM TEMPERATURE, F	81.6	81.6	82.8	82.9	84.7	84.3	83.4	83.5	82.4	82.8
RUN NUMBER	433	434	435	436	437	438	439	440	441	442

THERMOCOUPLE NUMBER	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F
1-1	151.9	151.9	159.2	159.6	125.7	125.9	130.4	130.0	101.0	101.3
1-2	152.0	152.1	156.0	156.4	124.9	125.1	127.8	127.4	100.3	100.5
1-3	143.9	143.9	148.9	149.1	121.6	121.7	124.5	124.2	99.2	99.5
1-4	142.8	142.9	149.9	150.2	121.8	122.0	126.2	125.9	100.1	100.3
2-1	160.2	160.3	167.2	167.6	130.7	130.8	135.7	136.0	106.4	106.7
2-2	160.3	160.4	165.5	165.8	130.1	130.1	134.2	133.9	106.1	106.4
2-3	156.4	156.6	160.7	161.0	128.1	128.1	131.4	131.3	105.5	105.7
2-4	151.6	151.8	155.9	156.1	125.8	125.7	128.8	128.9	104.9	105.0
2-5	147.7	147.9	153.0	153.2	124.2	124.1	127.5	127.7	104.5	104.7
2-6	146.4	146.6	152.9	153.1	124.1	123.9	128.1	128.3	104.7	104.8
2-7	148.3	148.7	156.5	156.6	125.7	125.4	130.6	130.8	105.5	105.6
2-8	154.1	154.5	162.8	163.0	128.6	128.2	134.0	134.1	106.3	106.5
3-1	163.9	164.4	171.9	172.3	133.2	132.8	139.9	139.9	112.0	112.2
3-2	160.8	161.4	164.8	165.3	130.6	130.2	135.6	135.0	111.2	111.4
3-3	152.2	152.7	156.4	156.8	126.5	126.3	131.4	131.0	110.2	110.3
3-4	152.9	153.3	160.4	160.9	127.8	127.7	134.3	133.8	110.7	110.9
4-1	167.4	166.7	177.4	177.5	136.4	136.6	145.5	145.4	116.8	116.9
4-2	164.5	164.1	169.5	169.7	133.2	133.4	140.9	140.8	115.8	115.7
4-3	155.4	155.3	160.6	160.9	129.1	129.3	136.4	136.3	114.9	114.8
4-4	155.7	155.7	165.1	165.4	130.9	131.0	139.0	138.6	115.5	115.4
5-1	170.6	170.9	180.4	180.2	137.7	137.6	148.8	148.8	122.5	122.5
5-2	168.0	168.1	173.3	172.8	134.9	134.7	145.0	145.1	121.8	121.7
5-3	158.2	158.2	163.8	164.2	130.5	130.2	140.3	140.5	120.6	120.5
5-4	159.8	159.8	169.0	169.5	132.7	132.5	142.8	143.1	121.2	121.1
6-1	176.4	176.5	186.4	185.9	141.9	141.9	155.0	154.9	128.4	128.6
6-2	171.7	171.7	177.0	176.8	138.1	138.0	150.4	150.2	127.3	127.5
6-3	165.2	165.2	169.7	169.4	134.6	134.5	146.4	146.3	126.3	126.4
6-4	168.9	169.2	176.0	176.0	137.5	137.3	149.6	149.6	127.1	127.3
7-1	180.5	180.8	191.7	191.6	144.4	144.8	160.1	160.4	132.8	133.3
7-2	178.8	179.1	183.1	182.9	140.7	141.3	155.5	155.1	131.7	132.0
7-3	170.3	169.9	175.0	174.9	137.1	137.8	151.3	151.1	131.1	131.2
7-4	170.8	170.9	181.3	181.1	139.7	140.4	154.4	154.2	131.6	131.8
8-1	180.8	181.2	195.3	195.3	147.0	146.9	164.3	164.4	137.5	137.5
8-2	175.6	175.4	185.4	185.1	142.9	142.8	159.5	159.6	136.6	136.6
8-3	170.5	170.3	179.4	179.0	140.5	140.3	156.3	156.4	136.0	135.9
8-4	172.8	172.2	186.2	186.0	143.4	143.3	160.0	160.0	136.8	136.7
9-1	181.0	180.8	201.2	201.6	149.9	149.9	169.4	169.2	141.9	141.9
9-2	182.8	182.6	200.5	200.5	149.7	149.5	168.7	168.3	141.9	141.8
9-3	177.0	176.7	193.0	193.0	146.6	146.4	165.3	165.0	141.3	141.1
9-4	172.9	172.6	188.3	188.0	144.6	144.3	163.1	162.9	140.8	140.6
9-5	172.4	172.0	186.1	185.8	143.7	144.1	161.7	161.6	140.7	140.4
9-6	172.2	171.8	186.9	186.6	143.8	144.1	161.6	161.4	140.3	140.0
9-7	172.1	171.8	190.2	189.8	145.5	145.7	164.0	163.7	140.9	140.5
9-8	174.6	174.4	195.6	195.1	148.0	148.1	167.4	167.2	141.6	141.2
10-1	188.6	188.8	205.4	206.0	152.2	152.6	173.6	173.1	143.7	143.5
10-2	186.7	186.4	199.4	199.5	149.3	149.5	169.9	169.3	143.1	142.9
10-3	176.6	176.5	191.6	191.9	145.6	145.8	165.6	164.9	142.1	141.9
10-4	175.6	175.2	194.2	194.5	147.5	147.8	168.0	168.1	142.5	142.3
INLET FLUID TEMPERATURE, F	90.3	90.3	90.2	90.3	89.7	89.7	89.1	89.1	84.9	85.1
EXIT FLUID TEMPERATURE, F	136.7	136.7	149.4	149.3	126.9	126.6	151.1	150.9	136.7	136.4
BATH FLUID TEMPERATURE, F	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0
AMMETER READING,I, AMPS	150.0	150.0	150.0	150.0	100.0	100.0	100.0	100.0	50.0	50.0
VOLTMETER READING,V, VOLTS	4.60	4.60	4.60	4.60	3.00	3.00	3.00	3.00	1.40	1.40
FLUID FLOW RATE, LB/HR	132.53	132.53	102.82	102.82	76.76	76.76	44.56	44.56	10.48	10.48
INLET PRES. TRDCR. OUTPUT,MV	0.228	0.227	0.216	0.221	0.353	0.361	0.568	0.565	0.762	0.771
EXIT PRES. TRDCR. OUTPUT,MV	0.043	0.040	0.078	0.089	0.142	0.146	0.433	0.427	0.601	0.605
INLET FLUID PRESSURE, PSIG	0.78	0.78	0.78	0.78	1.22	1.25	1.87	1.87	2.41	2.40
EXIT FLUID PRESSURE, PSIG	0.16	0.16	0.32	0.36	0.60	0.61	1.64	1.63	2.17	2.18
ROOM TEMPERATURE, F	83.6	83.5	83.2	83.2	82.0	82.1	82.5	82.8	81.3	81.6
RUN NUMBER	443	444	445	446	447	448	449	450	451	452

THERMOCOUPLE NUMBER	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F
1-1	100.3	100.3	131.2	131.4	120.3	120.5	142.9	142.6	139.3	139.4
1-2	100.2	100.2	128.1	128.3	121.7	121.9	147.0	146.7	144.9	144.9
1-3	99.5	99.4	124.7	124.9	118.0	118.1	138.1	137.8	135.7	135.7
1-4	99.7	99.6	126.9	127.1	116.8	117.0	134.6	134.3	131.4	131.4
2-1	102.7	102.5	137.4	137.7	124.5	124.7	149.5	149.2	147.3	147.4
2-2	102.5	102.3	135.8	136.1	125.4	125.6	152.8	152.5	151.0	151.3
2-3	102.0	101.8	132.9	133.3	124.2	124.3	150.7	150.6	149.9	150.1
2-4	101.4	101.2	130.1	130.5	121.9	122.1	146.1	146.1	145.9	146.2
2-5	101.1	100.9	128.9	129.3	119.8	119.9	141.2	141.2	140.8	141.0
2-6	101.1	100.9	129.6	130.0	118.8	119.0	138.6	138.6	138.2	138.4
2-7	101.7	101.4	132.4	132.9	119.3	119.5	138.6	138.6	138.0	138.2
2-8	102.4	102.2	136.0	136.4	121.5	121.8	142.5	142.5	141.2	141.5
3-1	104.1	103.8	143.2	143.8	126.8	127.1	157.9	157.9	153.7	153.8
3-2	103.4	103.1	139.0	139.5	127.0	127.2	158.8	158.8	157.5	157.4
3-3	102.4	102.1	134.7	135.2	123.0	123.1	150.5	150.5	149.2	148.9
3-4	102.9	102.5	137.7	138.3	122.3	122.4	147.8	147.8	144.5	144.4
4-1	105.5	105.6	150.5	150.7	130.5	130.5	162.0	162.1	159.2	159.3
4-2	104.5	104.7	145.9	146.1	129.9	130.0	162.3	162.2	161.7	161.7
4-3	103.5	103.7	141.5	141.8	126.7	126.3	153.4	153.3	153.5	153.5
4-4	104.1	104.2	144.0	144.3	126.6	126.0	150.8	150.7	149.9	150.0
5-1	107.3	106.8	156.3	156.8	133.5	133.7	161.2	161.1	162.0	161.5
5-2	106.5	106.1	152.5	152.9	133.1	133.4	164.7	164.4	164.8	164.4
5-3	105.3	104.9	147.6	147.9	128.9	129.2	153.8	153.5	154.8	154.6
5-4	105.9	105.4	150.2	150.5	129.3	129.6	150.1	149.8	151.8	151.7
6-1	109.3	108.5	164.1	164.3	135.7	135.9	160.5	160.1	161.6	161.1
6-2	108.3	107.6	159.3	159.5	135.0	135.2	167.6	167.0	164.9	164.4
6-3	107.3	106.6	155.2	155.3	131.9	132.1	157.4	156.9	155.6	155.2
6-4	108.2	107.4	158.5	158.7	131.8	132.1	150.2	149.7	152.2	151.9
7-1	110.8	110.3	170.5	170.5	134.4	134.5	161.6	161.6	163.5	163.2
7-2	109.8	109.3	165.9	165.8	134.8	134.9	168.6	168.5	166.6	166.3
7-3	109.0	108.4	161.7	161.5	130.4	130.6	159.5	159.5	157.2	156.9
7-4	109.6	109.0	164.8	164.5	130.0	130.1	152.8	152.6	154.6	154.3
8-1	112.2	111.7	176.4	176.1	137.1	137.5	167.3	166.8	165.3	165.0
8-2	111.3	110.8	171.6	172.1	136.8	137.3	171.4	170.9	166.6	166.3
8-3	110.5	109.9	168.3	168.9	134.4	134.8	163.6	163.2	158.8	158.5
8-4	111.3	110.7	172.1	172.6	134.3	134.8	158.6	158.1	157.1	156.7
9-1	113.8	114.0	183.0	183.6	139.6	140.0	172.9	172.2	167.4	167.1
9-2	113.7	113.9	182.1	181.7	141.2	141.5	178.2	177.4	172.5	172.1
9-3	113.0	113.0	178.8	178.4	139.9	140.2	177.1	176.5	171.2	170.9
9-4	112.5	112.7	176.6	177.1	138.5	138.7	174.7	174.0	168.3	167.9
9-5	112.2	112.4	175.2	175.7	137.4	137.6	171.4	170.8	163.9	163.5
9-6	112.0	112.3	174.9	175.3	136.6	136.8	167.5	167.1	160.8	160.4
9-7	112.6	112.7	177.3	177.7	136.3	136.5	165.8	165.2	160.2	159.7
9-8	113.3	113.4	180.9	181.3	137.2	137.4	167.3	166.5	162.0	161.6
10-1	114.0	114.0	187.4	187.8	140.6	140.5	173.3	174.0	162.8	162.9
10-2	113.3	113.2	183.7	184.0	141.4	141.3	177.7	178.1	168.5	168.7
10-3	112.3	112.1	179.2	179.6	138.9	138.8	171.5	171.7	159.6	159.8
10-4	112.8	112.5	181.6	182.0	137.8	137.7	167.1	167.1	154.7	154.8
INLET FLUID TEMPERATURE, F	88.2	88.4	88.6	88.6	90.4	90.5	90.5	90.5	90.7	90.7
EXIT FLUID TEMPERATURE, F	106.0	106.1	164.8	165.2	115.4	115.6	128.0	128.2	121.6	121.7
BATH FLUID TEMPERATURE, F	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0
AMMETER READING,I, AMPS	50.0	50.0	100.0	100.0	100.0	100.0	150.0	150.0	150.0	150.0
VOLTMETER READING,V, VOLTS	1.40	1.40	3.00	3.00	3.00	3.00	4.60	4.60	4.60	4.60
FLUID FLOW RATE, LB/HR	33.23	33.23	33.23	33.23	109.90	109.90	173.15	173.15	204.37	204.37
INLET PRES. TRDCR. OUTPUT,MV	0.498	0.502	0.350	0.355	0.538	0.534	0.508	0.508	0.628	0.630
EXIT PRES. TRDCR. OUTPUT,MV	0.202	0.208	0.211	0.209	0.222	0.220	0.219	0.222	0.216	0.213
INLET FLUID PRESSURE, PSIG	1.64	1.66	1.20	1.22	1.78	1.77	1.70	1.70	2.01	2.02
EXIT FLUID PRESSURE, PSIG	0.86	0.88	0.88	0.88	0.90	0.90	0.90	0.90	0.89	0.88
ROOM TEMPERATURE, F	80.1	80.2	81.1	81.2	81.7	81.9	82.8	82.9	82.7	82.4
RUN NUMBER	453	454	455	456	457	458	459	460	461	462

THERMOCOUPLE NUMBER	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F
1-1	133.1	133.2	128.5	128.8	146.4	146.1	144.4	143.9	140.8	140.5
1-2	140.2	140.3	136.1	136.5	158.3	158.2	156.9	156.2	153.3	153.1
1-3	130.9	130.9	126.9	127.1	143.7	143.5	141.9	141.6	138.9	138.6
1-4	125.7	125.8	121.6	121.6	135.8	135.6	134.0	133.8	131.3	131.0
2-1	142.9	142.9	138.3	138.8	162.8	162.9	159.3	159.3	155.1	155.3
2-2	146.8	146.8	142.4	142.9	169.5	169.7	166.0	165.6	161.7	161.9
2-3	146.6	146.6	142.8	143.1	169.5	169.7	166.4	166.2	162.5	162.8
2-4	142.8	142.7	139.1	139.4	163.3	163.3	160.0	160.1	157.0	156.9
2-5	137.7	137.7	134.0	134.3	155.4	155.5	152.2	152.4	148.8	149.1
2-6	134.9	134.9	131.2	131.5	151.3	151.3	148.2	148.5	144.9	145.2
2-7	134.5	134.4	130.7	131.0	150.9	150.9	147.5	147.1	144.5	144.7
2-8	137.4	137.3	133.2	133.5	154.8	154.7	151.1	150.7	147.8	148.0
3-1	146.3	146.2	140.9	141.3	166.6	166.5	161.7	161.3	157.5	157.5
3-2	152.6	152.6	147.8	148.2	177.6	177.5	173.5	173.1	169.8	169.6
3-3	144.2	144.2	139.6	139.9	163.9	163.8	160.0	159.7	156.6	156.7
3-4	138.8	138.9	134.4	134.7	156.4	156.4	152.6	152.3	149.1	149.3
4-1	152.0	152.1	146.5	146.2	171.3	171.3	168.4	168.0	164.1	163.7
4-2	158.1	158.1	153.5	153.3	184.0	184.4	181.8	181.2	177.2	176.7
4-3	150.6	151.2	146.7	146.7	172.5	172.6	170.2	169.7	165.7	165.5
4-4	145.5	145.4	140.9	141.0	163.5	163.4	161.6	161.1	157.6	157.3
5-1	156.9	157.1	151.4	151.8	179.7	180.0	176.7	176.3	172.1	171.6
5-2	161.6	161.7	157.3	157.6	188.9	189.3	185.9	185.3	181.3	180.8
5-3	152.7	152.8	148.7	149.1	175.2	175.5	171.5	171.4	166.5	166.1
5-4	149.1	149.3	145.0	145.3	168.8	169.2	166.3	165.8	161.9	161.6
6-1	160.5	160.7	156.3	156.2	180.3	180.2	178.1	177.8	174.1	174.1
6-2	164.5	164.5	161.2	161.2	189.3	188.9	187.7	187.6	184.7	185.0
6-3	155.3	155.4	152.2	152.2	174.0	173.5	172.5	172.3	170.5	170.8
6-4	151.8	151.8	148.7	148.8	167.6	167.3	166.9	166.8	164.9	165.2
7-1	160.0	159.9	158.5	158.8	175.2	175.0	161.7	161.9	154.0	153.8
7-2	164.3	164.2	163.4	163.6	183.6	183.5	174.5	174.8	171.1	171.1
7-3	155.0	155.0	154.5	154.6	169.8	169.8	158.3	157.9	153.9	154.2
7-4	151.5	151.5	151.3	151.6	165.0	165.1	151.7	151.3	144.8	144.8
8-1	159.4	159.8	152.8	152.8	169.6	169.6	166.0	165.8	168.8	168.7
8-2	161.7	162.0	159.3	159.1	177.4	177.7	179.0	178.8	178.8	178.4
8-3	153.6	153.8	150.7	150.5	161.6	161.8	161.6	161.6	165.1	165.1
8-4	151.3	151.5	145.8	145.7	157.0	157.0	152.2	152.2	158.0	158.2
9-1	157.6	157.3	148.7	148.5	160.7	160.8	168.8	168.8	157.6	157.5
9-2	162.8	162.5	157.4	157.1	173.7	173.8	179.0	178.6	168.8	168.4
9-3	162.5	162.2	160.1	159.9	176.9	176.9	181.2	180.7	170.8	170.2
9-4	159.8	159.4	157.6	157.3	172.6	172.5	177.5	177.2	165.9	165.3
9-5	155.2	155.6	151.1	151.0	162.7	162.6	168.5	168.5	155.6	155.1
9-6	151.9	152.1	144.9	144.8	154.9	154.9	161.0	161.0	148.1	147.9
9-7	151.2	151.1	141.7	141.6	151.3	151.4	158.5	158.6	145.0	144.9
9-8	153.1	152.8	142.3	142.2	152.5	152.5	160.6	160.7	148.1	148.0
10-1	152.1	152.2	159.0	158.9	175.7	175.3	172.4	172.2	164.7	164.3
10-2	161.1	161.0	164.8	165.1	184.5	184.4	182.9	182.6	174.3	173.9
10-3	150.0	150.0	157.9	158.1	171.6	171.5	168.6	168.4	162.1	161.9
10-4	142.9	142.9	151.7	151.5	163.7	163.5	161.5	161.4	155.6	155.4
INLET FLUID TEMPERATURE, F	90.8	90.8	90.7	90.7	91.1	91.0	90.9	90.8	90.7	90.7
EXIT FLUID TEMPERATURE, F	115.7	115.5	110.9	110.9	120.5	120.4	117.0	116.8	114.2	114.3
BATH FLUID TEMPERATURE, F	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0
AMMETER READING, I, AMPS	150.0	150.0	150.0	150.0	200.0	200.0	200.0	200.0	200.0	200.0
VOLTMETER READING, V, VOLTS	4.60	4.60	4.60	4.60	6.10	6.10	6.10	6.10	6.10	6.10
FLUID FLOW RATE, LB/HR	248.05	248.05	295.09	295.09	366.09	366.09	411.62	411.62	455.46	455.46
INLET PRES. TRDCR. OUTPUT, MV	0.677	0.671	0.763	0.761	0.959	0.957	1.179	1.182	1.422	1.423
EXIT PRES. TRDCR. OUTPUT, MV	0.206	0.205	0.245	0.248	0.448	0.443	0.632	0.631	0.828	0.826
INLET FLUID PRESSURE, PSIG	2.18	2.16	2.41	2.41	2.94	2.93	3.50	3.50	4.12	4.12
EXIT FLUID PRESSURE, PSIG	0.86	0.86	0.96	0.97	1.67	1.65	2.23	2.23	2.81	2.81
ROOM TEMPERATURE, F	82.7	82.8	83.5	83.6	84.0	84.0	84.3	84.5	85.0	85.1
RUN NUMBER	463	464	465	466	467	468	469	470	471	472

THERMCCOUPLE NUMBER	TEMP., F	TEMP., F
1-1	138.6	138.6
1-2	151.3	151.2
1-3	137.0	136.9
1-4	129.4	129.5
2-1	151.8	151.6
2-2	158.3	158.1
2-3	159.5	159.2
2-4	153.6	153.4
2-5	145.8	145.7
2-6	142.2	142.1
2-7	141.8	141.6
2-8	144.9	144.7
3-1	153.9	153.6
3-2	166.4	166.1
3-3	153.4	153.3
3-4	146.0	145.8
4-1	161.3	161.3
4-2	174.0	174.0
4-3	162.7	162.7
4-4	155.2	155.3
5-1	168.0	168.2
5-2	177.5	177.8
5-3	162.8	163.0
5-4	158.5	158.6
6-1	168.7	169.3
6-2	181.4	181.7
6-3	168.8	169.0
6-4	162.4	162.6
7-1	156.8	156.7
7-2	175.0	174.8
7-3	159.0	158.6
7-4	148.3	148.0
8-1	160.4	160.8
8-2	167.1	167.5
8-3	154.0	154.2
8-4	150.1	150.2
9-1	158.9	158.9
9-2	169.2	169.3
9-3	171.6	171.9
9-4	167.7	167.9
9-5	158.7	158.4
9-6	151.4	151.1
9-7	149.0	148.7
9-8	151.4	151.0
10-1	147.7	147.7
10-2	162.6	162.5
10-3	149.1	149.0
10-4	139.6	139.6
INLET FLUID TEMPERATURE, F	90.8	90.9
EXIT FLUID TEMPERATURE, F	111.8	111.8
BATH FLUID TEMPERATURE, F	90.0	90.0
AMMETER READING,I, AMPS	200.0	200.0
VOLTMETER READING,V, VOLTS	6.10	6.10
FLUID FLCW RATE, LB/HR	501.39	501.39
INLET PRES. TRDCR. OUTPUT,MV	1.681	1.676
EXIT PRES. TRDCR. OUTPUT,MV	1.002	1.003
INLET FLUID PRESSURE, PSIG	4.78	4.76
EXIT FLUID PRESSURE, PSIG	3.28	3.28
RCCM TEMPERATURE, F	85.2	85.3
RUN NUMBER	473	474

THERMOCOUPLE NUMBER	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F
1-1	131.4	131.4	179.9	179.9	171.2	171.2	128.4	128.6	131.2	131.1
1-2	147.4	147.4	212.6	212.8	203.5	203.5	144.0	144.3	147.0	146.8
1-3	132.9	132.9	181.8	182.2	173.9	173.9	129.9	130.1	132.7	132.6
1-4	123.9	123.9	164.8	165.2	157.2	157.2	121.3	121.5	123.8	123.7
2-1	144.5	144.6	212.1	212.4	201.2	201.1	141.3	141.6	144.3	144.1
2-2	155.2	155.3	236.4	236.6	223.1	223.1	151.5	151.8	154.9	154.6
2-3	159.1	159.1	239.5	239.9	228.3	228.2	154.8	155.1	158.7	158.4
2-4	153.3	153.3	225.3	225.6	213.1	213.1	148.6	148.8	152.8	152.5
2-5	145.2	145.2	209.6	209.9	196.2	196.1	140.5	140.6	144.9	144.5
2-6	141.7	141.7	203.1	203.3	189.8	189.8	137.3	137.4	141.4	141.1
2-7	139.0	139.1	198.7	198.9	186.2	186.2	135.2	135.2	138.9	138.4
2-8	141.8	141.9	205.4	205.6	193.7	193.7	138.3	138.4	141.6	141.3
3-1	153.2	153.4	225.7	225.7	188.5	188.6	145.7	145.7	152.4	152.3
3-2	165.1	165.3	245.8	246.1	227.9	227.8	158.4	158.4	164.0	164.0
3-3	148.5	148.8	210.8	210.8	197.6	197.8	142.1	142.1	147.4	147.5
3-4	144.8	145.0	205.5	205.7	180.5	180.7	137.3	137.3	143.7	143.8
4-1	152.5	152.9	204.4	204.6	196.1	196.0	143.2	143.1	151.0	151.2
4-2	165.3	165.6	235.6	235.9	243.1	243.0	159.0	158.9	164.1	164.2
4-3	149.2	149.2	202.6	202.9	211.0	211.1	147.2	147.1	148.7	148.7
4-4	144.8	144.9	192.4	192.8	190.2	190.2	140.5	140.6	144.1	144.1
5-1	149.8	149.6	203.3	203.2	217.6	217.6	139.4	139.4	148.8	148.8
5-2	162.9	162.8	238.6	238.7	238.0	237.7	159.3	159.3	162.6	162.7
5-3	149.0	148.9	200.9	200.7	210.3	210.2	145.1	145.1	149.0	149.0
5-4	143.5	143.1	185.5	185.4	203.8	203.7	134.3	134.2	143.1	143.1
6-1	148.5	148.7	247.5	247.3	194.2	194.2	151.7	151.8	147.8	147.8
6-2	163.9	164.3	278.9	278.8	234.7	234.9	172.5	172.5	164.4	164.4
6-3	152.1	152.4	252.2	252.2	203.5	203.4	163.5	163.4	152.7	152.9
6-4	144.8	144.9	236.1	236.4	182.5	182.8	152.2	152.1	144.8	144.9
7-1	149.9	149.8	235.0	235.1	238.1	238.5	144.8	144.6	147.7	147.8
7-2	162.0	161.8	249.3	249.2	262.1	262.0	162.5	162.3	161.3	161.4
7-3	150.4	150.5	217.6	217.4	226.8	226.9	152.8	152.7	149.9	149.9
7-4	146.0	146.1	212.0	212.1	218.8	218.9	144.1	144.1	144.8	144.5
8-1	148.7	148.8	237.1	237.2	227.2	227.1	140.3	139.8	146.3	146.2
8-2	162.0	161.7	258.6	258.6	251.0	250.4	160.6	160.2	160.4	160.5
8-3	148.6	148.6	225.4	225.2	222.4	222.5	145.7	145.5	146.7	146.3
8-4	144.6	144.6	219.9	219.6	214.5	214.2	134.7	134.5	142.4	142.2
9-1	160.1	160.2	236.6	236.2	224.9	224.9	150.2	150.3	157.8	157.8
9-2	167.4	167.7	260.4	260.5	244.7	244.6	160.5	160.5	164.8	164.6
9-3	172.1	172.4	275.5	272.4	256.3	256.1	166.8	166.5	170.5	170.4
9-4	167.8	167.8	266.3	266.2	244.1	244.0	162.5	162.1	166.7	166.6
9-5	161.2	161.0	251.2	251.3	229.2	229.0	154.1	154.1	160.5	160.3
9-6	156.0	156.0	236.2	236.0	216.9	216.5	146.4	146.4	155.1	154.8
9-7	154.2	153.9	227.0	226.9	211.3	211.4	143.5	143.4	153.0	152.8
9-8	156.1	156.1	226.2	226.1	214.1	214.2	144.8	144.9	154.4	154.1
10-1	164.6	165.2	258.1	258.4	245.2	245.2	156.1	155.9	163.4	163.4
10-2	178.4	178.6	277.3	277.8	266.9	267.0	169.3	169.0	177.3	177.3
10-3	166.9	166.9	243.8	244.1	234.0	234.4	153.0	152.7	166.3	166.3
10-4	159.1	159.2	234.3	234.7	222.1	221.9	145.7	145.6	158.2	158.1
INLET FLUID TEMPERATURE, F	90.3	90.3	91.3	91.3	93.5	93.5	90.6	90.6	90.2	90.3
EXIT FLUID TEMPERATURE, F	112.6	112.9	146.6	146.7	137.1	137.4	109.9	109.7	112.5	112.4
BATH FLUID TEMPERATURE, F	90.0	90.0	91.0	91.0	93.0	93.0	90.0	90.0	90.0	90.0
AMMETER READING, I, AMPS	200.0	200.0	300.0	300.0	300.0	300.0	200.0	200.0	200.0	200.0
VOLTMETER READING, V, VOLTS	6.10	6.10	9.75	9.75	9.70	9.70	6.10	6.10	6.10	6.10
FLUID FLOW RATE, LB/HR	479.53	479.53	468.10	468.10	595.89	595.89	558.61	558.61	486.47	486.47
INLET PRES. TRDCR. OUTPUT, MV	1.530	1.527	1.289	1.275	1.886	1.864	2.014	2.016	1.553	1.555
EXIT PRES. TRDCR. OUTPUT, MV	0.874	0.870	0.786	0.785	1.227	1.211	1.268	1.268	0.916	0.914
INLET FLUID PRESSURE, PSIG	4.38	4.38	3.77	3.73	5.26	5.22	5.57	5.57	4.46	4.46
EXIT FLUID PRESSURE, PSIG	2.93	2.92	2.68	2.68	3.83	3.80	3.93	3.93	3.04	3.04
ROOM TEMPERATURE, F	83.4	83.6	84.5	84.6	85.2	85.6	85.7	85.9	86.5	86.5
RUN NUMBER	302	303	304	305	306	307	308	309	310	311

THERMOCOUPLE NUMBER	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F
1-1	134.1	134.0	136.0	136.0	140.8	140.6	124.6	124.6	129.8	129.9
1-2	149.8	149.7	151.8	151.9	156.5	156.4	134.5	134.7	139.6	139.5
1-3	135.5	135.3	137.3	137.5	141.8	141.6	125.4	125.5	130.0	130.1
1-4	126.2	126.1	127.9	128.0	131.7	131.5	118.5	118.7	123.0	123.1
2-1	147.4	147.2	149.6	149.7	154.9	154.8	134.1	134.3	140.7	140.7
2-2	158.3	158.1	160.8	161.0	167.0	167.0	141.5	141.7	148.5	148.5
2-3	162.5	162.2	165.1	165.3	171.0	171.0	144.1	144.3	150.3	150.3
2-4	156.8	156.6	159.7	159.7	165.3	165.3	140.8	140.9	146.7	146.7
2-5	148.6	148.4	151.4	151.4	156.7	156.7	135.3	135.4	141.2	141.2
2-6	144.8	144.6	147.4	147.3	152.3	152.3	132.3	132.3	138.1	138.1
2-7	141.7	141.6	143.9	144.0	148.5	148.5	129.7	129.7	135.2	135.2
2-8	144.6	144.4	146.8	146.9	151.7	151.7	131.9	132.0	138.0	138.0
3-1	158.0	158.0	161.1	161.3	167.9	167.9	143.4	143.4	150.6	150.7
3-2	170.8	170.8	175.1	175.2	182.4	182.4	152.1	152.0	158.9	158.9
3-3	155.4	155.4	159.9	160.1	167.4	167.2	142.6	142.5	149.1	149.1
3-4	150.8	150.8	154.5	154.5	160.9	160.8	138.3	138.1	144.7	144.6
4-1	163.1	163.1	169.1	169.1	176.7	176.6	149.1	148.9	157.0	156.8
4-2	175.0	175.0	182.3	182.3	190.7	190.6	157.4	157.2	164.3	164.1
4-3	159.6	159.6	167.1	167.2	175.2	175.1	147.5	147.3	154.2	154.0
4-4	156.2	156.1	162.7	162.8	170.0	169.9	144.0	143.9	150.7	150.4
5-1	161.5	161.4	171.8	172.0	178.1	178.5	154.0	153.9	160.4	160.2
5-2	172.0	171.9	181.7	181.9	187.4	187.7	160.0	159.9	166.3	166.0
5-3	155.7	155.8	164.4	164.5	170.9	171.2	150.7	150.7	157.4	157.1
5-4	151.7	151.7	160.4	160.6	167.2	167.7	147.9	147.9	153.2	152.8
6-1	154.9	154.7	154.3	154.3	167.2	167.2	153.1	153.1	151.6	151.7
6-2	168.4	168.3	169.6	169.9	181.9	182.0	162.8	162.8	165.6	165.8
6-3	154.1	154.0	153.7	154.0	165.2	165.5	155.1	155.1	154.7	154.8
6-4	147.4	147.3	145.9	146.0	157.0	157.0	148.3	148.2	144.9	144.9
7-1	151.8	151.7	150.5	150.5	160.3	160.0	143.4	143.2	158.8	158.5
7-2	166.1	166.2	166.1	166.4	175.0	175.2	157.2	157.0	165.5	166.0
7-3	150.1	150.6	147.7	148.1	156.9	156.5	145.1	145.0	156.3	156.8
7-4	144.2	144.4	141.8	142.1	150.0	149.7	138.0	137.9	153.5	154.1
8-1	157.3	157.6	160.8	161.2	166.7	166.8	146.9	147.0	160.3	160.5
8-2	169.2	169.5	171.6	172.1	180.4	180.6	154.2	154.3	167.4	167.6
8-3	152.4	152.7	155.7	155.6	166.8	167.1	144.3	144.6	158.8	159.0
8-4	147.6	147.8	152.7	152.5	159.3	159.5	142.0	142.3	153.6	153.7
9-1	164.8	164.5	171.2	171.8	173.3	173.3	153.5	153.6	150.7	150.6
9-2	173.9	173.4	179.8	180.3	183.8	183.9	158.8	158.9	159.7	159.6
9-3	178.5	178.0	182.2	182.0	189.0	189.2	159.8	159.9	162.2	162.1
9-4	173.2	173.5	175.7	175.4	184.6	184.7	156.1	156.1	157.7	157.7
9-5	165.7	165.2	168.8	169.3	177.9	178.0	151.8	151.8	151.0	151.0
9-6	159.9	160.2	164.1	164.6	171.1	171.3	148.2	148.3	145.4	145.4
9-7	157.7	158.0	162.7	163.0	167.4	167.8	147.3	147.3	143.4	143.3
9-8	159.8	160.0	165.6	165.9	168.5	168.9	149.6	149.6	145.3	145.2
10-1	168.2	167.9	177.4	177.3	185.0	185.2	158.3	158.4	153.2	153.0
10-2	184.9	185.1	188.0	187.8	194.3	194.4	164.7	164.8	163.4	163.2
10-3	173.1	173.4	173.4	173.1	179.5	179.6	156.3	156.3	152.8	152.6
10-4	161.9	161.6	168.5	168.9	174.7	174.8	152.2	152.2	145.9	145.6
INLET FLUID TEMPERATURE, F	90.2	90.2	90.3	90.3	90.1	90.0	90.0	90.0	90.0	90.0
EXIT FLUID TEMPERATURE, F	115.9	115.8	118.6	118.8	125.0	125.2	115.9	116.2	124.3	124.2
BATH FLUID TEMPERATURE, F	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0
AMMETER READING,I, AMPS	200.0	200.0	200.0	200.0	200.0	200.0	150.0	150.0	150.0	150.0
VOLTMETER READING,V, VOLTS	6.10	6.10	6.10	6.10	6.20	6.20	4.75	4.75	4.75	4.75
FLUID FLOW RATE, LB/HR	415.42	415.42	376.41	376.41	309.41	309.41	246.56	246.56	190.28	190.28
INLET PRES. TRDCR. OUTPUT,MV	1.209	1.216	0.998	0.988	0.690	0.686	0.510	0.504	0.461	0.459
EXIT PRES. TRDCR. OUTPUT,MV	0.651	0.657	0.471	0.467	0.255	0.250	0.101	0.096	0.105	0.105
INLET FLUID PRESSURE, PSIG	3.57	3.59	3.00	2.98	2.20	2.19	1.71	1.69	1.55	1.55
EXIT FLUID PRESSURE, PSIG	2.31	2.34	1.74	1.72	1.04	1.00	0.46	0.40	0.47	0.47
ROOM TEMPERATURE, F	86.5	86.6	84.6	84.8	86.1	86.2	86.3	86.3	85.9	86.1
RUN NUMBER	312	313	314	315	316	317	318	319	320	321

THERMOCOUPLE NUMBER	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F
1-1	134.3	134.4	115.4	115.4	132.9	132.8	102.0	101.8	123.4	123.6
1-2	143.2	143.5	119.3	119.2	130.3	130.2	102.2	102.0	133.5	133.6
1-3	133.4	133.7	114.8	114.8	126.4	126.4	101.1	101.0	124.2	124.3
1-4	126.5	126.8	111.7	111.7	127.4	127.4	100.8	100.7	117.4	117.5
2-1	145.9	146.2	122.3	122.2	139.3	139.3	104.0	104.0	132.8	132.9
2-2	154.0	154.2	125.1	125.0	138.4	138.6	104.2	104.2	140.2	140.3
2-3	154.5	154.6	124.8	124.7	134.8	134.9	103.7	103.7	143.0	143.1
2-4	150.8	150.8	122.9	122.8	132.2	132.4	103.1	103.1	139.7	139.9
2-5	145.2	145.4	120.5	120.3	130.8	130.9	102.5	102.5	134.0	134.2
2-6	142.0	142.5	119.4	119.3	130.9	130.9	102.3	102.3	131.0	131.2
2-7	139.4	139.9	118.9	118.7	133.0	133.1	102.7	102.7	128.4	128.5
2-8	142.7	143.1	120.6	120.5	136.2	136.2	103.4	103.4	130.6	130.7
3-1	154.6	154.9	126.6	126.3	145.1	145.0	105.4	105.4	141.9	142.0
3-2	162.5	162.9	129.1	128.8	141.1	141.3	105.1	105.2	150.8	151.0
3-3	152.9	153.0	124.5	124.2	136.7	137.1	103.9	103.9	141.2	141.4
3-4	147.8	147.9	123.0	122.7	139.6	139.8	104.1	104.2	136.8	137.1
4-1	160.9	161.0	130.2	129.9	151.3	151.3	106.7	106.9	147.5	147.8
4-2	167.6	167.7	132.8	132.7	147.7	147.6	106.5	106.6	156.0	156.3
4-3	157.4	157.5	128.3	128.2	143.4	143.2	105.4	105.5	146.0	146.4
4-4	153.8	153.9	126.9	126.7	145.9	145.6	105.7	105.8	142.5	142.8
5-1	164.2	164.4	132.8	132.5	158.4	158.1	108.5	108.6	152.7	152.9
5-2	167.9	167.9	134.4	134.1	154.7	154.6	108.1	108.1	158.7	158.9
5-3	158.8	158.7	129.6	129.4	150.1	150.0	107.0	107.1	149.1	149.3
5-4	156.2	156.1	128.7	128.5	153.3	153.2	107.5	107.6	146.6	146.7
6-1	155.0	155.1	133.5	133.1	166.0	165.7	110.5	110.5	153.0	153.1
6-2	166.7	166.7	135.5	135.0	161.8	161.7	110.0	110.1	161.4	161.4
6-3	153.8	153.8	131.1	130.7	157.5	157.4	109.0	109.0	153.6	153.6
6-4	146.1	146.3	129.7	129.3	159.9	159.9	109.3	109.3	148.3	148.1
7-1	165.6	165.7	131.4	131.5	171.9	171.7	111.9	111.9	144.0	143.7
7-2	171.7	171.8	135.7	135.3	168.2	168.1	111.6	111.6	157.5	157.1
7-3	162.3	162.5	131.6	131.5	164.1	164.0	110.7	110.8	145.9	145.6
7-4	159.6	159.7	127.7	127.8	166.8	166.7	111.0	111.0	138.4	138.2
8-1	160.8	160.8	131.8	131.2	179.4	179.3	113.9	113.9	141.3	141.3
8-2	169.3	169.4	135.9	135.4	174.5	174.5	113.3	113.4	150.5	150.3
8-3	160.7	160.7	131.3	130.8	171.0	171.0	112.5	112.5	139.5	139.3
8-4	154.4	154.3	129.1	129.2	173.2	173.3	112.6	112.6	135.8	135.8
9-1	173.1	173.0	138.7	138.2	186.2	186.4	115.6	115.5	150.7	150.5
9-2	178.5	178.5	141.2	140.6	185.3	185.5	115.6	115.7	155.4	155.1
9-3	178.4	178.5	141.1	140.5	181.2	181.3	114.8	114.9	156.6	156.6
9-4	174.3	174.5	139.2	139.6	178.5	178.6	114.3	114.2	153.0	153.1
9-5	170.2	170.2	137.5	137.7	177.7	177.8	114.0	114.1	149.1	149.2
9-6	166.9	166.8	136.0	136.3	178.4	178.6	114.1	114.1	145.7	145.8
9-7	165.3	165.7	135.0	134.6	179.6	179.8	114.0	114.1	144.6	144.7
9-8	166.7	166.7	136.3	135.9	183.6	183.8	114.8	114.9	146.6	146.8
10-1	180.2	180.6	142.1	141.6	190.9	191.0	116.5	116.7	152.9	153.0
10-2	184.5	185.1	144.5	144.0	186.5	186.7	116.1	116.2	160.5	160.6
10-3	176.9	177.2	140.9	140.5	182.7	182.8	115.3	115.3	152.9	153.0
10-4	173.9	174.1	138.7	138.2	185.7	185.8	115.5	115.6	148.3	148.2
INLET FLUID TEMPERATURE, F	89.8	89.8	89.8	89.9	89.2	89.2	89.1	89.1	90.1	90.1
EXIT FLUID TEMPERATURE, F	130.1	130.1	114.9	115.0	159.8	160.1	106.3	106.1	114.3	114.4
BATH FLUID TEMPERATURE, F	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0
AMMETER READING,I, AMPS	150.0	150.0	100.0	100.0	100.0	100.0	50.0	50.0	150.0	150.0
VOLTMETER READING,V, VOLTS	4.75	4.75	3.00	3.00	3.00	3.00	1.50	1.50	4.70	4.70
FLUID FLOW RATE, LB/HR	162.36	162.36	105.19	105.19	34.92	34.92	35.69	35.69	264.07	264.07
INLET PRES. TRDCR. OUTPUT,MV	0.563	0.566	0.563	0.565	0.596	0.614	0.651	0.680	0.495	0.489
EXIT PRES. TRDCR. OUTPUT,MV	0.224	0.228	0.220	0.221	0.384	0.402	0.339	0.366	0.025	0.020
INLET FLUID PRESSURE, PSIG	1.84	1.85	1.84	1.85	1.93	1.99	2.12	2.19	1.63	1.62
EXIT FLUID PRESSURE, PSIG	0.90	0.91	0.91	0.91	1.46	1.55	1.29	1.42	0.05	0.04
ROOM TEMPERATURE, F	85.3	85.5	86.1	86.2	87.0	87.0	86.8	86.7	84.8	85.0
RUN NUMBER	322	323	324	325	326	327	328	329	330	331

THERMOCOUPLE NUMBER	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F
1-1	126.4	126.4	129.6	129.7	133.4	133.5	139.8	139.4	113.3	113.3
1-2	136.4	136.4	139.4	139.4	142.6	142.6	147.4	147.0	117.4	117.4
1-3	127.1	127.0	129.9	129.9	132.9	132.9	137.4	137.1	113.1	113.1
1-4	120.2	120.0	122.9	122.8	126.0	126.0	130.9	130.7	109.9	109.9
2-1	136.8	136.3	140.6	140.5	145.0	144.9	152.3	152.0	120.2	120.2
2-2	144.6	144.0	148.5	148.4	153.0	152.9	159.3	158.9	123.2	123.1
2-3	147.1	147.2	150.3	150.2	153.6	153.6	157.8	157.3	123.3	123.3
2-4	143.6	143.8	146.7	146.5	149.8	149.8	153.8	153.3	121.5	121.5
2-5	137.9	138.1	141.0	140.9	144.3	144.3	148.9	148.4	119.0	119.0
2-6	134.8	135.0	137.9	137.8	141.3	141.3	146.4	145.9	117.7	117.8
2-7	132.1	132.3	135.1	135.0	138.6	138.6	144.2	143.8	117.0	117.0
2-8	134.5	134.3	137.9	137.8	141.6	141.8	148.3	147.9	118.6	118.6
3-1	146.3	146.6	150.4	150.3	154.0	154.1	157.9	157.4	124.3	124.4
3-2	154.7	155.0	158.4	158.4	161.8	161.8	165.0	164.5	127.2	127.3
3-3	144.8	144.3	148.6	148.6	152.0	152.1	155.0	154.7	122.6	122.8
3-4	140.3	140.0	144.1	144.1	147.2	147.3	148.1	147.9	120.8	121.1
4-1	151.8	151.5	156.4	156.4	160.0	160.2	158.6	158.6	127.4	127.7
4-2	159.8	159.6	163.8	163.8	166.6	166.9	167.2	167.0	130.7	130.9
4-3	149.8	149.6	153.6	153.7	156.5	156.7	154.7	154.6	126.3	126.5
4-4	146.3	146.0	150.1	150.2	152.8	153.1	149.7	149.7	124.7	124.9
5-1	156.6	156.2	159.9	160.0	162.9	163.2	165.0	164.7	131.2	131.4
5-2	162.6	162.2	165.9	166.0	167.2	167.5	169.0	168.6	133.3	133.4
5-3	153.5	153.1	156.9	157.0	158.2	158.4	158.9	158.5	128.9	129.0
5-4	150.1	149.9	152.6	152.6	154.9	155.1	155.7	155.4	127.8	127.9
6-1	152.8	152.7	151.5	151.4	153.4	153.4	163.2	163.3	133.7	133.7
6-2	165.0	164.9	165.6	165.5	165.4	165.2	171.9	171.8	136.2	136.1
6-3	156.6	156.5	154.7	154.6	152.5	152.4	162.4	162.4	132.3	132.1
6-4	147.3	147.2	144.7	144.6	145.1	145.1	154.0	154.0	130.2	130.2
7-1	146.7	146.7	158.4	158.1	164.5	164.6	168.1	168.0	131.4	131.3
7-2	158.3	158.3	165.2	165.0	170.8	170.8	173.3	173.1	136.6	136.3
7-3	146.4	146.4	156.0	155.6	161.5	161.4	164.1	164.0	132.3	132.0
7-4	141.1	141.2	153.3	152.9	158.4	158.4	162.6	162.7	127.9	127.5
8-1	156.5	156.5	160.1	159.9	159.3	159.4	172.4	172.6	129.2	128.9
8-2	162.7	162.6	167.3	167.0	168.3	168.3	177.2	177.4	134.9	134.5
8-3	153.9	153.9	158.6	158.3	159.2	159.2	169.4	169.5	129.5	129.3
8-4	151.0	151.0	153.1	152.8	152.1	152.0	166.8	166.9	126.0	125.6
9-1	157.2	157.4	150.5	150.8	162.6	162.7	184.4	184.6	135.8	135.4
9-2	163.0	163.3	159.7	160.0	168.6	168.6	189.5	189.8	138.0	137.6
9-3	163.6	163.9	162.2	162.4	168.8	168.8	187.5	187.6	137.8	137.5
9-4	159.5	159.6	157.7	157.8	164.4	164.4	183.6	183.7	135.9	135.6
9-5	155.2	155.2	150.9	151.0	159.9	160.1	181.3	181.4	134.1	133.8
9-6	151.1	151.1	145.3	145.3	156.4	156.7	179.8	180.1	132.6	132.4
9-7	149.6	149.7	143.2	143.3	155.5	155.8	178.2	178.5	131.8	131.7
9-8	152.3	152.4	145.1	145.2	158.2	158.5	179.3	179.7	133.2	133.0
10-1	160.2	160.2	152.6	152.5	175.5	175.6	190.3	190.7	137.6	137.6
10-2	166.5	166.5	163.1	163.0	180.7	180.7	192.7	192.6	140.1	140.1
10-3	158.1	158.1	152.3	152.2	171.8	172.2	185.9	186.1	136.1	136.2
10-4	152.9	152.8	145.4	145.1	168.1	167.9	184.4	184.8	134.0	134.0
INLET FLUID TEMPERATURE, F	89.8	89.9	89.9	89.9	90.0	90.0	89.9	89.8	89.4	89.4
EXIT FLUID TEMPERATURE, F	117.7	117.8	123.6	123.6	128.6	128.4	136.3	136.5	112.5	112.4
BATH FLUID TEMPERATURE, F	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0
AMMETER READING, I, AMPS	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	100.0	100.0
VOLTMETER READING, V, VOLTS	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	3.00	3.00
FLUID FLOW RATE, LB/HR	222.60	222.60	192.35	192.35	163.00	163.00	135.21	135.21	118.56	118.56
INLET PRES. TRDCR. OUTPUT, MV	0.549	0.548	0.562	0.562	0.575	0.576	0.549	0.548	0.553	0.549
EXIT PRES. TRDCR. OUTPUT, MV	0.134	0.130	0.183	0.181	0.225	0.230	0.236	0.240	0.191	0.185
INLET FLUID PRESSURE, PSIG	1.79	1.79	1.85	1.85	1.88	1.88	1.79	1.79	1.83	1.79
EXIT FLUID PRESSURE, PSIG	0.56	0.55	0.77	0.77	0.90	0.91	0.93	0.94	0.79	0.78
ROOM TEMPERATURE, F	86.6	86.8	87.6	87.9	88.1	88.1	87.8	87.8	84.6	84.8
RUN NUMBER	332	333	334	335	336	337	338	339	340	341

THERMOCOUPLE NUMBER	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F
1-1	118.2	118.6	125.0	125.0	131.0	130.9	100.1	100.3	103.7	103.9
1-2	121.2	121.5	125.4	125.4	129.0	128.9	100.6	100.8	102.9	103.0
1-3	116.8	117.0	121.3	121.3	125.1	125.0	99.5	99.7	101.7	101.9
1-4	114.2	114.5	120.1	120.1	125.6	125.5	99.1	99.2	102.3	102.4
2-1	124.1	124.3	129.4	129.6	136.5	136.2	101.8	102.0	108.9	109.1
2-2	126.6	126.8	130.7	131.0	136.0	135.7	102.3	102.6	108.6	109.0
2-3	125.7	125.9	128.5	128.9	132.8	132.4	101.9	102.2	107.9	108.1
2-4	123.7	123.9	126.4	126.7	130.4	130.0	101.3	101.5	107.1	107.4
2-5	121.4	121.5	124.4	124.7	128.8	128.4	100.7	100.9	106.7	107.0
2-6	120.4	120.5	123.6	123.9	128.7	128.3	100.5	100.6	106.6	107.0
2-7	120.2	120.2	124.2	124.5	130.7	130.2	100.5	100.6	107.2	107.6
2-8	122.2	122.3	126.8	127.1	133.6	133.2	101.2	101.3	108.1	108.4
3-1	126.6	126.7	132.4	132.7	141.2	141.4	103.0	102.9	113.9	114.3
3-2	129.5	129.5	131.6	131.8	137.3	137.5	103.2	103.2	113.1	113.4
3-3	124.6	124.6	127.1	127.3	132.9	133.2	102.0	101.9	111.9	112.3
3-4	122.5	122.6	127.7	127.8	135.7	135.8	101.9	101.8	112.6	112.9
4-1	128.3	128.2	136.0	136.2	146.0	146.1	104.2	104.2	118.8	119.2
4-2	132.6	132.7	135.1	135.2	142.4	142.7	104.5	104.4	118.2	118.6
4-3	128.4	128.3	131.0	131.0	138.3	138.7	103.5	103.3	117.1	117.5
4-4	125.2	125.1	132.3	132.4	140.7	141.1	103.6	103.2	117.7	118.0
5-1	128.0	127.8	140.4	140.5	151.3	150.8	106.2	105.9	123.9	124.4
5-2	131.8	131.6	138.8	138.8	147.8	148.1	106.2	105.8	123.3	123.8
5-3	125.9	125.7	135.4	135.3	143.3	143.0	105.0	104.7	122.0	122.4
5-4	123.5	123.3	136.9	136.9	146.5	146.2	105.2	105.0	122.9	123.3
6-1	132.6	132.7	143.1	143.1	157.5	157.6	107.9	107.6	129.4	129.8
6-2	136.4	136.6	143.3	143.4	153.5	153.8	107.9	107.6	128.7	129.1
6-3	132.9	132.9	138.7	139.1	149.2	149.5	106.9	106.8	127.7	128.0
6-4	130.2	130.2	138.5	138.7	151.8	152.0	106.9	106.7	128.1	128.4
7-1	136.5	136.6	145.8	145.9	162.2	162.3	109.0	108.8	133.6	133.9
7-2	139.0	139.0	145.1	145.1	158.6	158.6	109.1	108.9	133.2	133.4
7-3	134.9	135.1	142.2	142.3	154.5	154.7	108.3	108.0	132.2	132.4
7-4	133.5	133.7	143.1	143.3	157.3	157.5	108.2	108.0	132.8	133.0
8-1	141.7	141.8	150.2	150.4	168.2	168.3	110.6	110.5	139.2	139.6
8-2	143.0	143.1	148.7	148.8	163.5	163.8	110.6	110.4	138.2	138.5
8-3	139.8	139.8	145.8	145.9	160.0	160.3	109.8	109.7	137.4	137.7
8-4	138.3	138.4	146.2	146.4	162.2	162.6	109.6	109.4	137.6	137.9
9-1	145.8	145.8	155.6	155.8	173.5	173.2	112.0	111.9	144.0	144.4
9-2	148.0	148.0	156.3	156.5	172.8	172.6	112.4	112.2	143.8	144.2
9-3	146.8	146.8	153.3	153.6	168.6	168.5	111.8	111.7	143.0	143.3
9-4	145.0	145.0	150.9	151.1	165.8	165.7	111.2	111.2	142.3	142.5
9-5	144.0	144.1	150.1	150.2	165.1	165.1	111.0	110.9	142.2	142.4
9-6	143.1	143.1	150.6	150.7	166.0	166.2	111.0	110.8	142.3	142.6
9-7	141.9	142.0	150.6	150.8	167.2	167.2	110.8	110.7	142.2	142.4
9-8	143.3	143.3	152.9	153.1	170.8	170.9	111.4	111.3	143.4	143.6
10-1	148.9	148.9	156.1	155.8	177.0	177.1	113.1	113.0	146.9	147.0
10-2	149.9	149.8	156.3	156.5	172.8	172.9	113.0	112.7	146.2	146.4
10-3	146.8	146.6	152.6	152.9	169.0	169.2	112.1	111.9	145.4	145.7
10-4	144.9	144.7	151.1	150.9	171.9	172.1	112.1	111.9	145.8	146.1
INLET FLUID TEMPERATURE, F	89.4	89.4	89.4	89.3	89.0	88.9	88.7	88.7	86.9	86.9
EXIT FLUID TEMPERATURE, F	118.7	118.8	127.7	127.8	147.9	147.7	102.6	102.5	135.7	135.9
BATH FLUID TEMPERATURE, F	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0
AMMETER READING,I, AMPS	100.0	100.0	100.0	100.0	100.0	100.0	50.0	50.0	50.0	50.0
VOLTMETER READING,V, VOLTS	3.00	3.00	3.00	3.00	3.00	3.00	1.40	1.40	1.40	1.40
FLUID FLOW RATE, LB/HR	88.59	88.59	66.59	66.59	43.13	43.13	43.22	43.22	11.54	11.54
INLET PRES. TRDCR. OUTPUT,MV	0.587	0.592	0.457	0.459	0.542	0.548	0.602	0.603	0.574	0.568
EXIT PRES. TRDCR. OUTPUT,MV	0.255	0.256	0.160	0.160	0.280	0.292	0.277	0.276	0.310	0.309
INLET FLUID PRESSURE, PSIG	1.92	1.93	1.55	1.55	1.78	1.79	1.98	1.98	1.87	1.85
EXIT FLUID PRESSURE, PSIG	1.05	1.05	0.69	0.69	1.12	1.15	1.11	1.11	1.23	1.23
ROOM TEMPERATURE, F	85.8	85.8	86.3	86.3	86.4	86.3	85.8	85.7	85.6	85.6
RUN NUMBER	342	343	344	345	346	347	348	349	350	351

THERMOCOUPLE NUMBER	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F
1-1	136.4	136.4	148.0	148.3	143.9	143.9	153.1	153.0	149.0	149.0
1-2	151.7	151.8	170.5	170.6	165.9	165.9	169.7	169.4	164.6	164.7
1-3	137.7	137.9	150.8	151.0	146.4	146.4	155.1	154.9	150.2	150.3
1-4	129.2	129.2	138.7	138.8	135.0	134.9	145.9	145.7	141.8	141.8
2-1	143.5	143.6	155.1	155.0	148.9	148.6	158.2	157.9	153.0	153.1
2-2	153.5	153.8	170.0	169.9	162.8	162.5	170.1	170.0	163.2	163.2
2-3	157.8	158.1	177.4	177.4	169.1	168.7	176.1	176.1	168.3	168.2
2-4	152.4	152.3	169.7	169.8	160.8	160.4	170.7	170.7	163.2	162.9
2-5	143.7	144.4	157.7	157.8	149.3	149.0	161.4	161.5	155.2	154.9
2-6	139.9	139.8	152.2	152.7	144.6	144.1	156.3	156.5	151.5	151.2
2-7	137.2	137.4	147.3	147.5	140.1	140.4	151.5	151.9	148.0	147.9
2-8	140.4	140.5	151.2	151.3	144.5	144.5	154.9	154.9	150.5	150.5
3-1	144.8	144.5	158.1	158.1	154.3	153.9	164.5	164.2	160.3	160.1
3-2	160.6	161.0	181.3	181.1	175.0	174.7	181.9	181.6	173.8	173.4
3-3	146.5	146.9	160.1	160.5	154.2	153.8	168.1	167.7	158.7	158.4
3-4	139.1	139.4	150.6	150.7	145.5	145.6	159.7	159.4	154.3	154.1
4-1	147.0	147.2	161.7	161.4	154.0	154.0	165.4	165.2	160.1	160.1
4-2	163.6	163.6	186.1	186.2	177.1	177.2	185.9	185.6	175.8	175.5
4-3	150.3	150.2	166.9	166.8	159.1	159.2	173.2	173.5	162.9	162.6
4-4	142.9	143.3	156.4	156.6	150.1	149.9	163.2	163.2	157.2	157.1
5-1	151.3	151.6	169.8	170.1	159.4	159.2	177.8	177.7	163.3	163.0
5-2	166.0	166.0	189.2	189.4	180.5	180.7	192.4	192.9	180.2	179.5
5-3	152.5	152.7	169.4	170.2	162.2	162.4	179.3	179.8	168.0	167.4
5-4	145.7	145.5	160.6	161.5	152.7	152.6	173.4	173.9	160.3	160.1
6-1	153.5	153.0	172.8	172.7	166.1	166.3	183.1	183.4	171.8	171.7
6-2	168.8	168.5	192.6	192.4	186.3	186.1	194.6	194.9	186.1	186.0
6-3	154.7	154.8	172.2	172.5	166.6	166.4	179.9	180.0	173.3	173.1
6-4	147.1	147.1	163.8	164.3	158.7	158.9	176.1	176.1	168.4	168.1
7-1	154.5	154.4	173.2	173.5	166.9	166.4	172.2	172.3	172.7	172.4
7-2	169.3	169.1	195.1	195.2	186.0	185.9	195.0	194.8	186.5	186.3
7-3	154.5	154.9	177.6	177.3	164.6	164.6	180.1	179.9	172.6	172.7
7-4	147.9	148.0	169.2	169.1	158.4	158.5	166.7	166.4	167.4	167.1
8-1	155.3	155.1	176.3	176.1	169.8	169.9	175.0	175.1	178.5	178.9
8-2	170.0	170.1	197.4	197.6	188.7	188.9	192.3	192.7	191.3	191.5
8-3	156.2	156.5	178.4	178.2	169.4	169.4	178.2	178.6	178.4	178.6
8-4	149.5	149.6	169.5	169.3	162.7	162.4	170.3	170.3	174.1	174.4
9-1	157.4	157.5	180.3	180.1	169.8	169.7	186.6	186.7	167.9	167.8
9-2	166.5	166.9	191.5	191.2	181.4	181.2	194.9	194.9	178.3	178.5
9-3	172.0	172.3	200.1	199.9	190.5	189.8	196.8	197.0	187.6	187.6
9-4	167.1	167.2	193.5	193.2	184.6	184.4	189.3	189.7	184.6	184.5
9-5	159.9	160.3	182.9	183.3	174.5	174.1	181.5	181.8	177.2	177.5
9-6	153.8	153.8	175.1	175.3	166.7	166.2	176.5	176.6	168.6	168.5
9-7	151.5	151.7	172.0	172.1	162.8	162.6	175.8	175.9	163.8	163.6
9-8	153.7	153.7	173.9	174.2	163.9	163.9	180.1	180.2	164.0	164.0
10-1	160.2	160.3	180.3	180.3	172.6	172.1	184.5	184.3	176.1	176.0
10-2	173.3	173.1	200.2	200.1	188.8	188.6	195.8	195.7	191.3	191.0
10-3	160.9	160.9	181.9	182.2	169.2	169.3	180.4	180.4	179.7	179.6
10-4	152.6	152.4	171.4	171.4	162.7	162.9	174.5	174.5	172.4	172.2
INLET FLUID TEMPERATURE, F	101.2	101.2	104.2	104.2	104.7	104.6	118.6	118.7	119.1	119.0
EXIT FLUID TEMPERATURE, F	118.7	118.8	123.6	123.6	119.6	119.6	136.7	136.9	132.2	132.0
BATH FLUID TEMPERATURE, F	98.5	98.5	101.0	101.0	101.0	101.0	119.0	119.5	120.0	120.0
AMMETER READING, I, AMPS	200.0	200.0	250.0	250.0	250.0	250.0	200.0	200.0	200.0	200.0
VOLTMETER READING, V, VOLTS	6.10	6.10	7.70	7.70	7.70	7.70	6.10	6.10	6.10	6.10
FLUID FLOW RATE, LB/HR	600.48	600.48	864.72	864.72	1120.32	1120.32	594.72	594.72	824.76	824.76
INLET PRES. TRDCR. OUTPUT, MV	1.511	1.522	2.489	2.479	3.489	3.529	1.175	1.179	1.893	1.895
EXIT PRES. TRDCR. OUTPUT, MV	0.744	0.786	1.506	1.518	2.284	2.286	0.472	0.478	0.980	0.982
INLET FLUID PRESSURE, PSIG	4.35	4.37	6.69	6.66	9.07	9.17	3.49	3.51	5.72	5.27
EXIT FLUID PRESSURE, PSIG	2.56	2.69	4.52	4.55	6.38	6.40	1.74	1.76	3.22	3.22
ROOM TEMPERATURE, F	82.6	83.1	85.3	85.4	86.0	86.1	83.9	84.2	84.4	84.3
RUN NUMBER	352	353	354	355	356	357	358	359	360	361

THERMOCOUPLE NUMBER	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F	TEMP., F
1-1	155.3	155.3	150.8	150.9	160.6	160.9	158.1	158.3	169.7	169.7
1-2	171.4	171.4	166.2	166.4	183.9	184.1	180.8	181.1	200.6	200.8
1-3	157.1	157.1	152.5	152.6	163.2	163.4	160.4	160.6	172.7	172.8
1-4	148.1	148.0	144.2	144.3	151.8	151.9	149.9	150.0	159.6	159.6
2-1	160.3	160.4	153.7	154.0	161.5	161.7	158.3	158.4	170.2	170.2
2-2	171.6	171.6	163.7	163.8	176.8	177.1	173.2	173.5	190.7	190.8
2-3	177.1	176.8	168.9	169.3	184.4	184.6	180.9	181.1	201.1	201.2
2-4	171.4	171.4	164.0	164.3	175.2	175.6	171.6	171.7	187.9	187.9
2-5	162.7	162.7	155.9	156.0	165.8	166.1	159.4	159.6	171.6	171.7
2-6	158.5	158.1	152.2	152.3	157.4	157.7	154.4	154.5	165.0	165.0
2-7	154.4	154.3	149.0	149.0	153.1	153.4	150.5	150.6	159.9	160.0
2-8	157.4	157.4	151.4	151.5	157.8	157.6	154.4	154.5	165.1	165.1
3-1	164.1	164.0	159.6	159.6	171.7	172.0	165.1	165.3	175.9	176.2
3-2	180.1	180.1	174.2	174.2	192.2	192.0	187.1	187.5	206.7	206.8
3-3	165.5	165.3	159.5	159.5	171.5	171.6	163.2	163.4	176.6	176.7
3-4	157.6	157.7	153.7	153.6	164.5	164.7	155.1	155.4	165.9	165.9
4-1	166.8	166.6	160.8	160.2	171.4	171.5	167.0	167.1	175.2	175.1
4-2	184.4	184.4	177.0	176.5	193.7	193.9	190.6	190.5	208.4	208.4
4-3	170.2	170.6	164.0	163.9	171.6	171.7	167.5	167.5	180.8	180.8
4-4	162.2	161.9	158.2	158.0	164.8	164.8	159.2	159.2	169.5	169.3
5-1	173.1	173.5	164.5	164.7	181.6	181.7	174.9	175.1	188.6	188.6
5-2	187.3	187.4	179.4	180.0	199.1	198.9	193.2	193.4	214.5	214.5
5-3	173.0	173.2	166.8	167.1	180.3	180.3	169.2	169.4	188.7	188.9
5-4	167.9	167.7	160.6	160.7	174.1	174.0	162.6	162.7	179.7	179.8
6-1	175.6	175.8	170.2	170.2	182.9	183.1	181.4	181.8	195.1	195.3
6-2	189.9	190.2	183.9	184.0	205.1	205.1	199.9	200.3	225.1	225.1
6-3	175.4	175.9	170.3	170.2	185.5	185.4	178.3	178.5	198.2	198.2
6-4	168.2	168.2	166.0	165.9	175.7	175.9	172.0	172.3	186.1	186.2
7-1	174.7	174.7	171.4	171.5	185.9	185.9	178.3	178.1	188.5	188.5
7-2	191.2	191.2	184.9	185.3	206.3	206.2	195.9	195.7	221.8	222.3
7-3	178.1	177.9	171.1	171.5	188.0	188.0	176.9	177.0	193.7	194.1
7-4	170.3	170.5	166.9	166.9	180.8	180.7	171.3	171.5	179.8	180.1
8-1	177.6	177.8	174.6	174.5	183.6	183.8	185.5	185.8	193.7	194.1
8-2	192.7	192.7	188.9	188.4	205.8	205.5	201.4	201.2	222.5	222.4
8-3	179.6	179.4	175.7	175.7	186.9	186.4	180.9	180.6	192.2	191.9
8-4	171.9	172.1	170.8	170.9	176.6	176.5	174.6	174.4	182.2	182.2
9-1	182.4	182.6	174.0	174.4	184.6	184.6	172.9	172.8	194.9	194.9
9-2	190.2	190.4	182.9	183.2	197.8	197.5	183.6	183.9	212.8	212.6
9-3	194.9	195.0	189.6	190.0	207.9	207.5	196.0	196.3	224.2	224.1
9-4	189.8	189.9	185.4	185.5	202.8	202.6	191.1	191.5	212.2	212.1
9-5	182.1	182.6	178.8	179.0	192.7	192.5	182.6	182.5	196.9	197.1
9-6	176.4	176.5	173.1	173.4	183.3	183.4	173.6	173.8	186.0	185.9
9-7	173.9	173.7	169.7	170.0	178.6	178.8	167.3	167.2	182.9	183.1
9-8	178.1	178.1	170.4	170.5	179.0	179.0	169.1	169.0	186.1	185.7
10-1	183.0	183.1	178.3	178.4	187.3	187.1	175.8	175.7	201.3	201.2
10-2	196.1	196.2	191.3	191.3	205.9	206.0	200.7	200.6	225.0	224.7
10-3	182.6	182.5	179.3	179.6	181.9	181.8	183.1	183.1	197.8	197.6
10-4	175.2	175.2	173.2	173.4	175.8	176.0	167.7	167.6	185.6	185.9
INLET FLUID TEMPERATURE, F	121.4	121.4	121.7	121.9	121.8	122.1	122.8	122.8	123.3	123.2
EXIT FLUID TEMPERATURE, F	139.1	139.0	134.6	134.7	137.2	137.6	135.3	135.2	138.6	138.6
BATH FLUID TEMPERATURE, F	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0
AMMETER READING, I, AMPS	200.0	200.0	200.0	200.0	250.0	250.0	250.0	250.0	300.0	300.0
VOLTMETER READING, V, VOLTS	6.10	6.10	6.10	6.10	7.75	7.75	7.75	7.75	9.50	9.50
FLUID FLOW RATE, LB/HR	604.44	604.44	823.32	823.32	1113.12	1113.12	1361.16	1361.16	1633.68	1633.68
INLET PRES. TRDCR. OUTPUT, MV	1.206	1.219	2.011	2.012	3.088	3.083	4.363	4.340	5.954	5.716
EXIT PRES. TRDCR. OUTPUT, MV	0.527	0.518	1.140	1.134	1.963	1.954	2.849	2.742	4.106	3.894
INLET FLUID PRESSURE, PSIG	3.57	3.59	5.56	5.56	8.12	8.11	11.18	11.11	15.18	14.44
EXIT FLUID PRESSURE, PSIG	1.93	1.91	3.61	3.59	5.62	5.60	7.72	7.46	10.76	10.24
ROOM TEMPERATURE, F	86.9	87.0	87.6	87.8	87.6	87.9	89.6	89.7	90.1	90.5
RUN NUMBER	362	363	364	365	366	367	368	369	370	371

APPENDIX B

CALIBRATION DATA

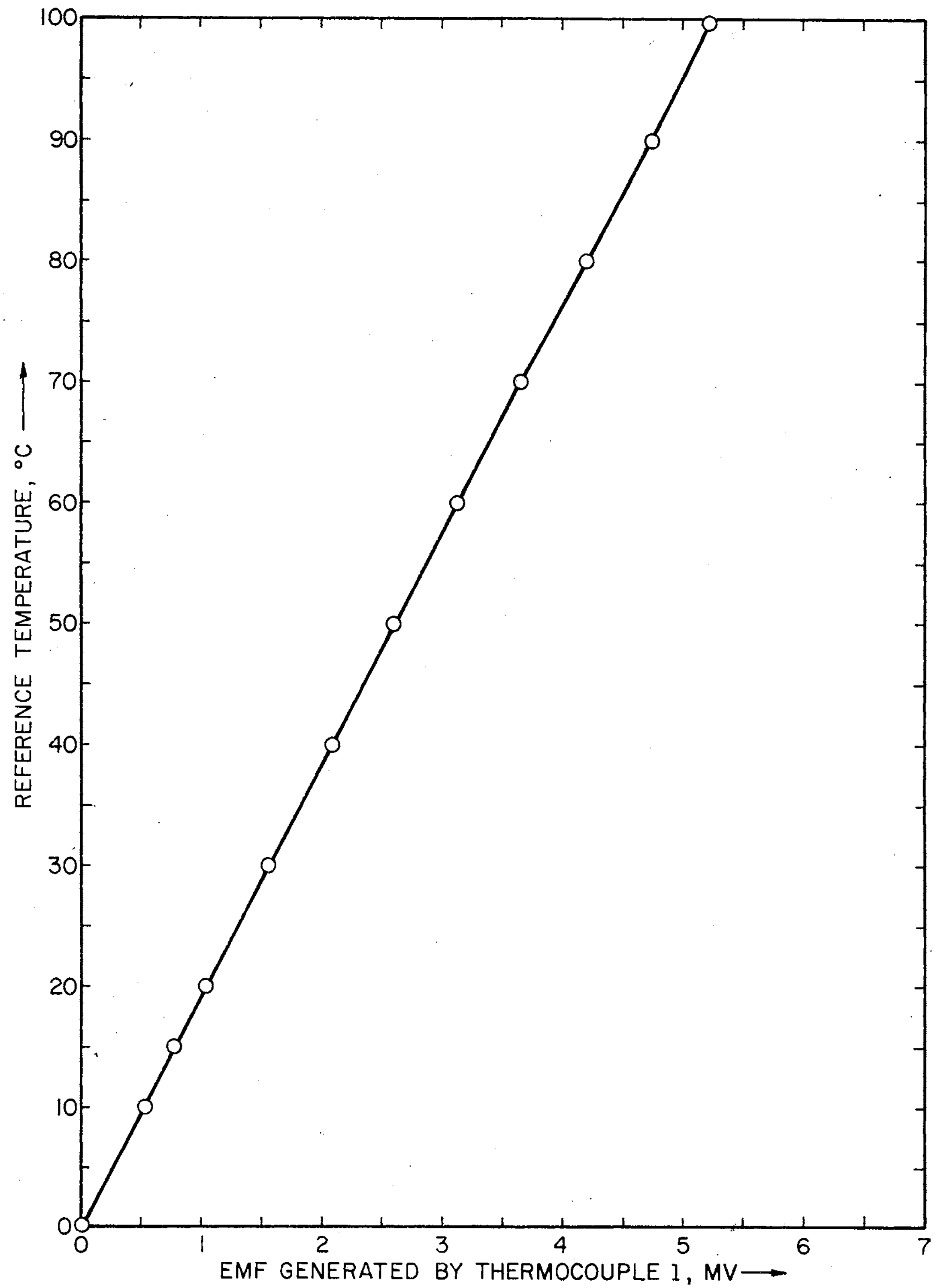


Figure 18. Calibration Curve for the Conax Thermocouple Used to Measure the Temperature of the Inlet Fluid to the Helical Coil

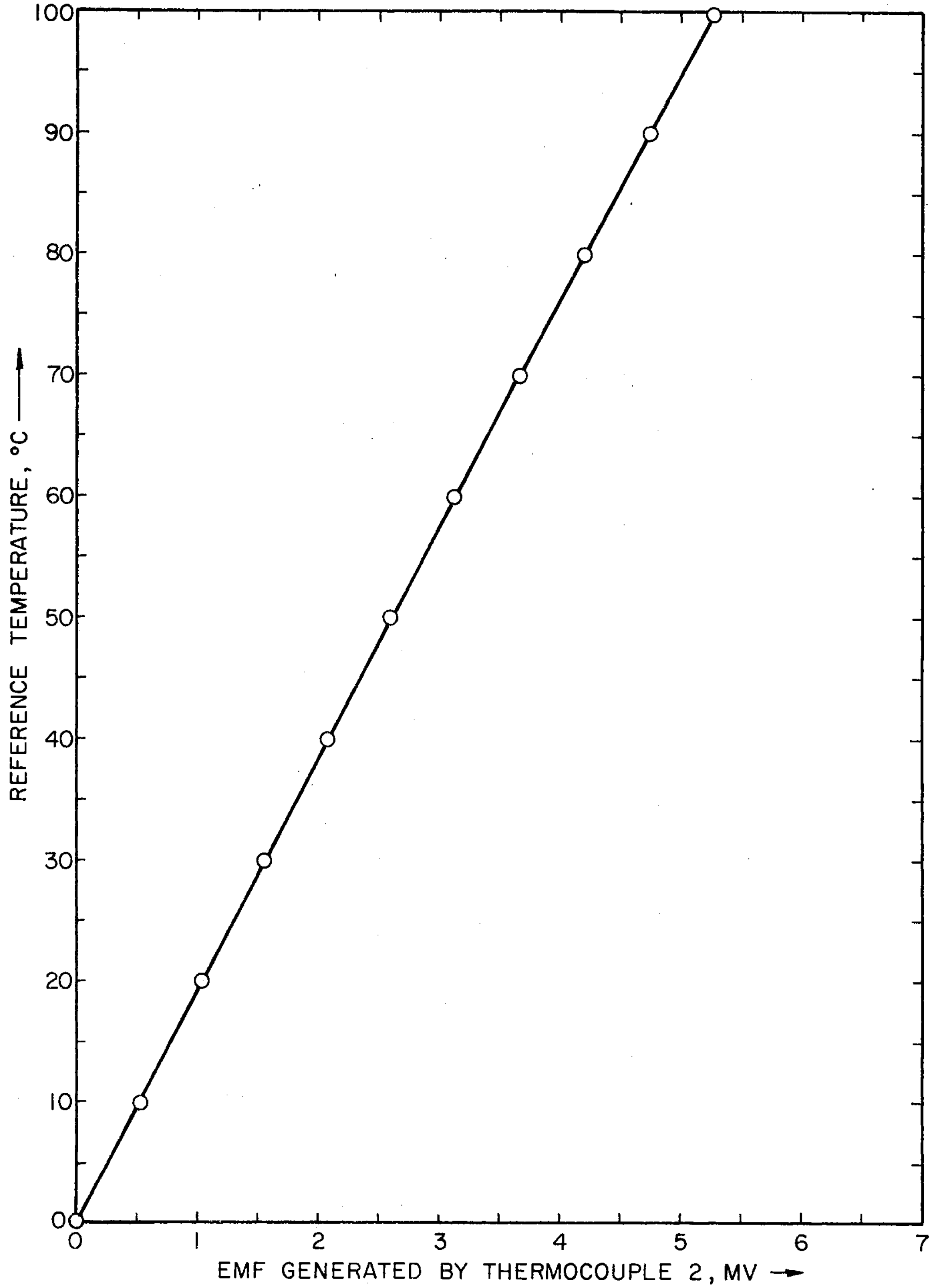


Figure 19. Calibration Curve for the Conax Thermocouple Used to Measure the Temperature of the Exit Fluid From the Helical Coil

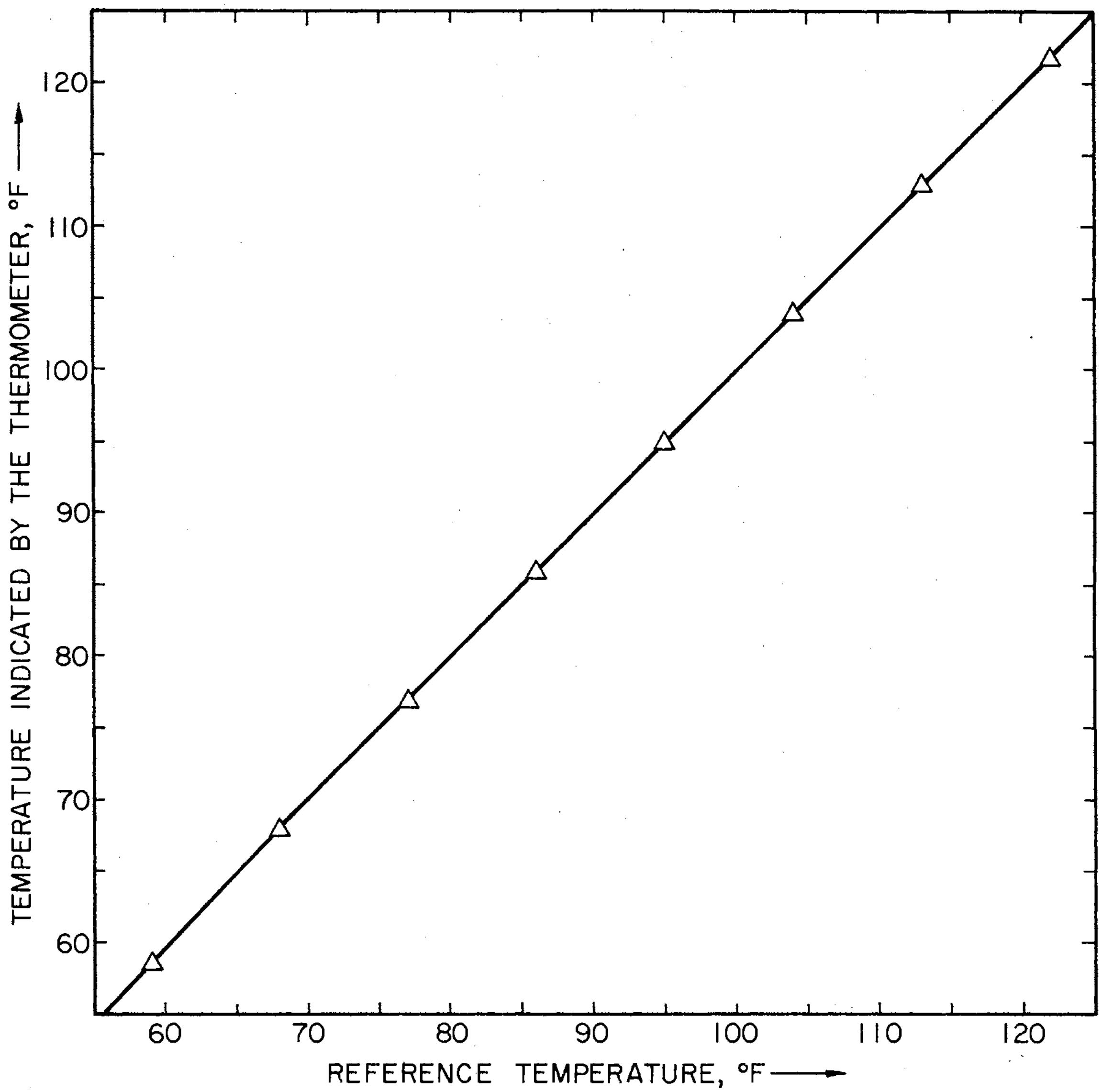


Figure 20. Calibration Curve for the Brooklyn "P-M" Thermometer Used to Measure the Room Temperature

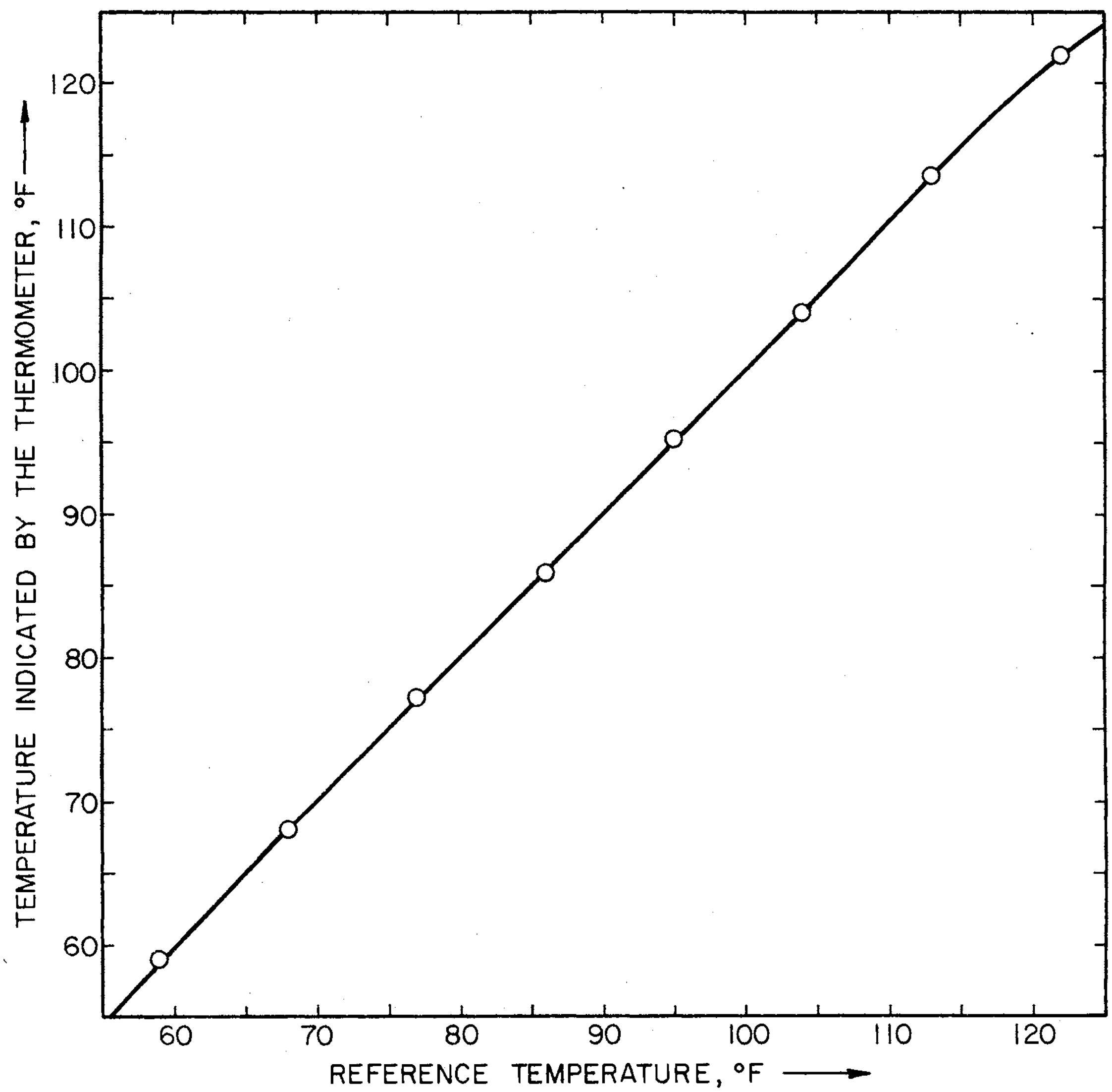


Figure 21. Calibration Curve for the Brooklyn "P-M" Thermometer Used to Measure the Bath Fluid Temperature

TABLE X

CALIBRATION DATA FOR CONAX THERMOCOUPLES OBTAINED DURING IN-SITU CALIBRATION OF SURFACE THERMOCOUPLES ON HELICAL COILS

Helical Coil Diameter In.	Thermocouple Location	Saturated Steam Temperature °F	Thermocouple Correction °F	Average Room Temperature °F
9.99	Inlet	210.6	-0.550	75.58
	Exit	210.4	-0.548	
20.64	Inlet	210.4	-0.543	76.35
	Exit	210.1	-0.522	

Note:

1. For the 9.99-inch coil, the inlet thermocouple was located 32 in. upstream from the inlet electrode and the exit thermocouple was located 10 in. downstream from the exit electrode.

2. For the 20.64-inch coil, the inlet thermocouple was located 31 in. upstream from the inlet electrode and the exit thermocouple was located 11 in. downstream from the exit electrode.

3. The saturated steam temperature was determined from the Steam Tables (3) at the absolute pressure of steam at the indicated location.

4. The thermocouple corrections given above are the average calculated values and should not be construed to indicate the precision of the temperature measurement. The temperatures were measured with a precision of 0.1°F.

5. The temperature corrections given above were the corrections required to be added to the temperature indicated by the thermocouples when low pressure saturated steam was bled through the coil.

TABLE XI

CALIBRATION DATA FOR SURFACE THERMOCOUPLES
ON THE 9.99 INCH DIAMETER COIL

Thermocouple Station Number	Temperature Correction, °F							
	Peripheral Location							
	1	2	3	4	5	6	7	8
1	0.3968		0.0635		0.5135		0.3302	
2	-0.2730	0.6770	-0.0730	0.1937	0.5103	1.3103	-0.0897	0.2937
3	-0.0262		-0.1095		0.3905		0.2738	
4	0.4373		-0.0293		0.7540		0.7207	
5	0.2842		0.5008		0.8342		0.1508	
6	-0.3023		-0.4857		0.1310		0.3810	
7	1.1945		0.2778		0.3117		0.4945	
8	0.5247		0.2247		-0.2070		0.5913	
9	-0.0952	0.0048	0.3715	0.5548	0.0882	0.1548	0.3215	1.0215
10	0.7393		0.3727		0.0393		0.5893	

Note:

1. The temperature corrections indicated above were the corrections required to be added to the temperature indicated by the thermocouples when low pressure saturated steam was bled through the coil.

2. The temperature corrections are the computed arithmetic average of the corrections after 3, 6 and 12 hours of continuous operation.

3. Temperatures were measured with a precision of 0.1°F. The precision of the temperature corrections given above results from the calculation of the corrections and should not be construed to indicate the precision of the temperature measurement.

TABLE XII

CALIBRATION DATA FOR SURFACE THERMOCOUPLES
ON THE 20.64 INCH DIAMETER COIL

Thermocouple Station Number	Temperature Correction, °F — Peripheral Location 1	2	3	4	5	6	7	8
1	1.1172		0.6338		0.8505		0.6505	
2	1.0777	0.6110	0.5943	0.5277	1.1777	1.3110	0.6277	0.8943
3	1.1048		0.4548		0.4215		1.6215	
4	0.4653		1.1653		0.9302		0.3987	
5	1.1258		1.0925		1.6592		0.9092	
6	0.5197		1.2967		1.4197		0.9030	
7	0.0802		1.0635		0.5468		0.8968	
8	1.1907		0.7407		0.6740		0.5073	
9	1.0678	0.7178	0.9678	1.1345	0.7512	1.5678	1.1012	0.9178
10	1.4843		0.9510		1.7010		1.5343	

Note: Same as for Table XI.

TABLE XIII

CALIBRATION DATA FOR PRESSURE TRANSDUCERS

Reference Pressure psig	Average Emf Generated, mv — Pressure Transducer 4-316-001 Inlet	Average Emf Generated, mv — Pressure Transducer 4-312-0001 Exit
0.0	0.0	0.0
4.8	1.699	1.650
9.5	3.659	3.544
14.3	5.778	5.595
19.2	7.807	7.550
24.3	9.847	9.515
29.5	11.883	11.524
34.5	13.946	13.527
40.0	16.177	15.675
45.2	18.207	17.697
50.5	20.415	19.855

TABLE XIV

CALIBRATION DATA FOR ROTAMETER 1
FOR DISTILLED WATER

Rotameter Setting % Maximum Flow	Mass Flow Rate, lbs/hour	
	Float Number	
	8-RV-3	8-RV-14
10.0	40.0	82.1
20.0	77.0	144.6
30.0	110.0	207.1
40.0	142.5	275.2
50.0	179.7	342.5
60.0	215.2	410.3
70.0	252.5	480.5
80.0	290.1	548.8
90.0	330.6	623.0
100.0	363.5	694.0

TABLE XV

CALIBRATION DATA FOR ROTAMETER 2
FOR DISTILLED WATER

Rotameter Setting gpm	Average Mass Flow Rate lbs/hour
1.0	477.0
1.5	728.0
2.0	969.0
2.5	1205.0
3.0	1475.0
3.5	1729.0
4.0	1962.0
4.5	2208.0
5.0	2417.0

TABLE XVI

MASS FLOW RATE OF DOWTHERM G MEASURED DURING THE EXECUTION OF THE DATA RUNS USING THE 20.64 INCH DIAMETER COIL

Rotameter: 1

Rotameter Setting % Maximum Flow	Float: 8-RV-3		Float: 8-RV-14	
	Data Run Number	Average Mass Flow Rate lbs/hour	Data Run Number	Average Mass Flow Rate lbs/hour
10.0	451-452	10.48	453-456	33.23
20.0	449-450	44.56	457-458	109.90
30.0	447-448	76.76	459-460	173.15
40.0	445-446	102.82	461-462	204.37
50.0	443-444	132.53	463-464	248.05
60.0	441-442	164.98	465-466	295.09
70.0	439-440	181.99	467-468	366.09
80.0	437-438	212.08	469-470	411.62
90.0	435-436	245.14	471-472	455.46
100.0	433-434	283.97	473-474	501.39

TABLE XVII

MASS FLOW RATE OF DOWTHERM G MEASURED DURING THE EXECUTION OF DATA RUNS 302 TO 329 USING THE 9.99 INCH DIAMETER COIL

Rotameter: 1
Float: 8-RV-14

Data Run Number	Rotameter Setting % Maximum Flow	Average Mass Flow Rate lbs/hour
302-303	100.0	479.53
304-305	100.0	468.10
306-307	100.0	595.89
308-309	100.0	558.61
310-311	90.0	486.47
312-313	80.0	415.42
314-315	70.0	376.41
316-317	60.0	309.41
318-319	50.0	246.56
320-321	40.0	190.28
322-323	30.0	162.36
324-325	20.0	105.19
326-327	10.0	34.92
328-329	10.0	35.68

TABLE XVIII

MASS FLOW RATE OF DOWTHERM G MEASURED DURING THE EXECUTION OF DATA RUNS 330 TO 351 USING THE 9.99 INCH DIAMETER COIL

Rotameter: 1
Float: 8-RV-3

Data Run Number	Rotameter Setting % Maximum Flow	Average Mass Flow Rate lbs/hour
330-331	100.0	264.07
332-333	90.0	222.60
334-335	80.0	192.35
336-337	70.0	163.00
338-339	60.0	132.51
340-341	50.0	118.56
342-343	40.0	88.59
344-345	30.0	66.59
346-347	20.0	43.13
348-349	20.0	43.22
350-351	10.0	11.54

TABLE XIX

MASS FLOW RATE OF DOWTHERM G MEASURED DURING THE EXECUTION OF DATA RUNS 352 TO 371 USING THE 9.99 INCH DIAMETER COIL

Rotameter: 2
Float: 10-RV-64

Data Run Number	Rotameter Setting gpm (On Water Scale)	Average Mass Flow Rate lbs/hour
352-353	1.0	600.48
354-355	1.5	864.72
356-357	2.0	1120.32
358-359	1.0	594.72
360-361	1.4	824.76
362-363	1.0	604.44
364-365	1.4	823.32
366-367	2.0	1113.12
368-369	2.5	1361.16
370-371	3.0	1633.68

APPENDIX C

REGRESSION CORRELATIONS FOR ESTIMATING THE PHYSICAL PROPERTIES OF WATER AND DOWTHERM G

Regression correlations were developed to compute the physical properties of water and Dowtherm G at the experimentally obtained bulk fluid and wall temperatures. The density, viscosity, specific heat and the thermal conductivity were the physical properties correlated.

Physical property data on water were obtained from the CRC Handbook of Chemistry and Physics (41). Page numbers in the Handbook from which the data were obtained are given along with the correlation. Physical property data for Dowtherm G were obtained from the Dowtherm G sales pamphlet (12) and from the Dow Chemical Company.

The correlations are given below together with:

1. The range of temperatures over which the correlation is applicable.

2. The average absolute deviation (AAD) and the average absolute percent deviation (AAPD) of the calculated values (using the correlation) from the reported data values.

For water the correlations are:

Density in gm/ml: Data taken from page F-5 of Reference (41);

$$\rho = 0.999986 + (0.1890)\,(10^{-4})\,(T,°C) - (0.5886)\,(10^{-5})\,(T,°C)^2 + (0.1548)\,(10^{-7})\,(T,°C)^3$$

Range: 0°C(32°F) to 100°C(212°F)

AAD: 0.00006

AAPD: 0.00637%.

Viscosity in centipoise:

$$\log_{10} \frac{\mu_T}{\mu_{20}} = \frac{1.3272(20-T) - 0.001053(T-20)^2}{T + 105}$$

where T = water temperature, °C

and μ_{20} = viscosity of water at 20°C = 1.002 cp.

The above correlation and the viscosity data on water are reported on page F-36 in Reference (41).

Range: 20°C(68°F) to 100°C(212°F)

AAD: 0.00001

AAPD: 0.00338%.

Specific heat in BTU/lb-°F: Data taken from page D-128 of Reference (41);

$$C_p = 1.01881 - (0.4802)\,(10^{-3})\,(T,°F) + (0.3274)\,(10^{-5})\,(T,°F)^2 - 0.604\,(10^{-8})\,(T,°F)^3$$

Range: 32°F to 212°F

AAD: 0.00045

AAPD: 0.04455%.

Thermal conductivity in BTU/hr-ft-°F: Data taken from page E-11 of Reference (41).

$$k = 0.30289 + (0.7029)\,(10^{-3})\,(T,°F) - (0.1178)\,(10^{-5})\,(T,°F)^2 - (0.550)\,(10^{-9})\,(T,°F)^3$$

Range: 44°F to 206°F

AAD: 0.00016

AAPD: 0.04404%.

For Dowtherm G the correlations are:

Density in lb/ft^3:

$$\rho = 70.70705 - (0.25338)\,(10^{-1})\,(T,°F) - (0.3095)\,(10^{-4})\,(T,°F)^2 + (0.8890)\,(10^{-7})\,(T,°F)^3$$

Range: 0°F to 300°F

AAD: 0.05452

AAPD: 0.08286%.

Viscosity in centipoise:

$$\mu = 1.05786\ (10^{2}) - (1.6867)\ (T,°F) + (0.1058)\ (10^{-1})\ (T,°F)^{2} - (0.29936)\ (10^{-4})\ (T,°F)^{3} + (0.31814)\ (10^{-7})\ (T,°F)^{4}$$

Range: 90°F to 200°F

AAD: 0.09492

AAPD: 1.71597%.

Specific heat in BTU/lb-°F:

$$C_p = 0.369356 + (0.20216)\ (10^{-3})\ (T,°F) + (0.8285)\ (10^{-6})\ (T,°F)^{2} - (0.19987)\ (10^{-8})\ (T,°F)^{3}$$

Range: 0°F to 300°F

AAD: 0.00128

AAPD: 0.31433%.

Thermal conductivity in BTU/hr-ft-°F:

$$k = 241.90848\ [(3.149499)\ (10^{-4}) - (0.93)\ (10^{-7})\ (T,°C)]$$

Range: 0°F to 300°F

AAD: 0.00025

AAPD: 0.33892%.

APPENDIX D

SAMPLE CALCULATIONS

Calculations for experimental data run 297 are presented as a sample calculation. Experimental data values for run 297 are presented on page 105 in Appendix A. The sample calculations given below follow the steps outlined on page 48 in Chapter V. Computer programs have been written to perform the calculations for all the data runs on the IBM 360/65 computer.

Calculation of the Overall Heat Balance

Heat input rate, BTU/hr = Q_{input}

$$Q_{input} = \begin{Bmatrix}\text{Current}\\ \text{in coil}\end{Bmatrix} \begin{Bmatrix}\text{Voltage drop}\\ \text{across coil}\end{Bmatrix} (3.4128)$$

$$= (500.0)\ (14.75)\ (3.4128)$$

$$= 25{,}169.40 \text{ BTU/hr.}$$

Heat output rate, BTU/hr = Q_{output}

$$Q_{output} = (W)\ (C_p)\ [(t_b)_{out} - (t_b)_{in}]$$

The inlet and exit bulk fluid temperatures measured by the Conax thermocouples were corrected, based on their calibration. Calibration data for these thermocouples are given in Table X in Appendix B.

$$\therefore \begin{matrix}\text{corrected inlet}\\ \text{fluid temperature}\end{matrix} = 92.20 + \frac{(-0.543)}{(210.4 - 76.4)} \{92.2 - 76.4\}$$

$$= 92.14°F$$

and

$$\begin{matrix}\text{corrected exit}\\ \text{fluid temperature}\end{matrix} = 102.60 + \frac{(-0.522)}{(210.1 - 76.4)} \{102.6 - 76.4\}$$

$$= 102.5°F.$$

$$\begin{matrix}\text{Average fluid temperature}\\ \text{in the helical coil for}\\ \text{data run 297}\end{matrix} = \frac{92.14 + 102.5}{2} = 97.32°F.$$

From Appendix C,

$$C_p \text{ for water} = 1.01881 - (0.4802)(10^{-3})(T) + (0.3274)(10^{-5})(T^2) - (0.604)(10^{-8})(T^3)$$

at T = 97.32°F,

$$C_p = 1.01881 - (0.4802)(10^{-3})(97.32) + (0.3274)(10^{-5})(97.32)^2 - (0.604)(10^{-8})(97.32)^3$$

$$= 0.998 \text{ BTU/lb-°F.}$$

$$Q_{output} = (2417.0)(0.998)(102.5 - 92.14)$$

$$= 24{,}990 \text{ BTU/hr.}$$

$$\therefore \Delta Q = Q_{input} - Q_{output}$$

$$= (25{,}169.4 - 24{,}990.0) = 179.4 \text{ BTU/hr}$$

$$\therefore \text{percent error in heat balance} = \frac{\Delta Q}{Q_{input}} = \left[\frac{179.4}{25169.4}\right](100) = 0.071\%.$$

Calculation of the Local Inside Wall Temperature and the Inside Wall Radial Heat Flux

As indicated in Chapter V, a numerical solution developed by Crain (9) was used to compute the inside wall temperatures from the measured outside wall temperatures and the inside wall radial heat flux at each thermocouple location. The trial-and-error solution is complex and hence a sample calculation will not be given here; however, Tables XX to XXIII give the uncorrected outside surface temperatures, the corrected outside wall temperatures, the computed inside wall temperatures and the inside wall radial heat fluxes for every thermocouple located on the helical coil. The aforementioned values are for experimental data run 297.

TABLE XX

UNCORRECTED OUTSIDE SURFACE TEMPERATURES FOR RUN 297

Thermocouple Station Number	Uncorrected Outside Surface Temperatures, °F — Peripheral Location							
	1	2	3	4	5	6	7	8
1	108.1		110.4		107.6		106.4	
2	108.7	111.3	113.1	110.1	107.5	106.3	106.2	107.1
3	109.4		114.8		108.8		106.7	
4	109.8		116.0		110.1		107.2	
5	110.4		117.1		111.4		108.3	
6	111.4		118.2		112.7		109.3	
7	112.5		118.7		113.1		110.6	
8	114.2		119.8		114.0		111.7	
9	114.3	117.6	121.2	119.4	116.0	113.8	112.5	112.6
10	115.2		121.6		116.5		113.2	

TABLE XXI

CORRECTED OUTSIDE SURFACE TEMPERATURES FOR RUN 297

Thermocouple Station Number	Corrected Outside Surface Temperatures, °F							
	Peripheral Location							
	1	2	3	4	5	6	7	8
1	108.36		110.56		107.80		106.55	
2	108.96	111.46	113.26	110.23	107.77	106.59	106.34	107.31
3	109.67		114.93		108.90		107.07	
4	109.92		116.35		110.33		107.29	
5	110.69		117.43		111.83		108.52	
6	111.54		118.60		113.09		109.52	
7	112.52		119.04		113.25		110.83	
8	114.54		120.04		114.19		111.83	
9	114.60	117.82	121.52	119.76	116.22	114.24	112.80	112.85
10	115.63		121.92		117.01		113.62	

TABLE XXII

CORRECTED INSIDE WALL TEMPERATURES
FOR RUN 297

Thermocouple Station Number	Inside Wall Temperatures, °F Peripheral Location							
	1	2	3	4	5	6	7	8
1	102.29		103.90		101.69		101.03	
2	102.85	104.93	106.72	103.64	101.64	100.92	100.83	101.65
3	103.54		108.42		102.73		101.51	
4	103.75		109.86		104.19		101.71	
5	104.50		110.94		105.70		102.93	
6	105.33		112.11		106.95		103.93	
7	106.32		112.54		107.08		105.27	
8	108.38		113.52		108.01		106.25	
9	108.44	111.21	114.99	113.26	110.05	108.56	107.25	107.12
10	109.43		115.39		110.88		108.02	

TABLE XXIII

RADIAL HEAT FLUX FOR INSIDE SURFACE
FOR RUN 297

Thermocouple Station Number	Radial Heat Flux for Inside Surface, MBTU/hr-ft^2							
	Peripheral Location							
	1	2	3	4	5	6	7	8
1	19.54		20.80		19.65		18.24	
2	19.66	20.59	20.42	20.81	19.74	18.59	18.21	18.55
3	19.76		20.30		19.89		18.38	
4	19.87		20.22		19.81		18.50	
5	19.95		20.25		19.77		18.50	
6	20.00		20.25		19.77		18.52	
7	20.00		20.29		19.89		18.42	
8	19.86		20.39		19.92		18.52	
9	19.89	20.92	20.44	20.55	19.91	18.65	18.37	18.83
10	20.01		20.43		19.80		18.57	

Calculation of the Local Heat Transfer Coefficient

For thermocouple 5-1:

$$\text{local heat transfer coefficient} = h = \frac{Q_i}{[(t_w)_i - (t_b)_5]}$$

$$\frac{(Q/A)_i}{[(t_w)_i - (t_b)_5]}$$

$$(t_b)_5 = 92.14 + \left[\frac{(102.5 - 92.14)}{10.0}\right](5.0)$$

$$= 92.14 + 5.18 = 97.32°F$$

$$h = \frac{(19.95)\,(10^3)}{(104.50 - 97.32)} = (2.779)\,(10^3)\ \text{BTU/hr-ft}^2\text{-°F}$$

Calculation of the Dimensionless Axial Distance and the Dimensionless Inside Wall Temperature

By definition:

$$\text{Dimensionless axial distance} = z = \frac{\text{Axial distance along helical coil from inlet electrode, ft.}}{\text{Tube inside radius, ft.}}$$

and

$$\text{Dimensionless wall temperature} = T_w = \frac{[t_w - (t_b)_{inlet}]}{dt_b/dz}$$

where

$$dt_b/dz = \frac{[(t_b)_{exit} - (t_b)_{inlet}]}{\dfrac{\text{Total heated length, ft.}}{\text{Tube inside radius, ft.}}}$$

For thermocouple 5-1:

$$z = \frac{5.0}{0.495/[(2.0)\,(12.0)]} = \frac{5.0}{0.020625} = 242.4$$

$$\frac{dt_b}{dz} = \frac{102.5 - 92.14}{\dfrac{10.0}{0.020625}} = \frac{10.36}{484.848} = 0.02137$$

$$\therefore T_w = \frac{104.5 - 92.14}{0.02137} = \frac{12.36}{0.02137} = 578.4$$

Similar calculations were performed for the other thermocouples. Table XXIV gives the results for run number 297.

Calculation of the Relevant Dimensionless Numbers

Table VI in Chapter V gives the definition of the dimensionless numbers evaluated.

For data run 297 and thermocouple station 5 the dimensionless numbers are:

Reynolds Number: Re

$$Re = \frac{(d_i)\ (G)}{(\mu)}$$

From page 141 in Appendix C,

$$\log_{10}\left[\frac{\mu_T}{\mu_{20}}\right] \approx \frac{1.3272(20 - T) - 0.001053(T - 20)^2}{T + 105} \quad (D.1)$$

where T is measured in °C and $\mu_{20} = 1.002$ cp.

At $(t_b)_5 = 97.32°F = 36.29°C$:

$$\log_{10}\left[\frac{\mu_T}{1.002}\right] = \frac{1.3272(20 - 36.29) - 0.001053(36.29 - 20)^2}{(36.29 + 105)}$$

$$\log_{10}\left[\frac{\mu_T}{1.002}\right] = \frac{1.3272(-16.29) - 0.001053(16.29)^2}{141.29}$$

or, $\mu_T = (0.6998)\ (1.002) = 0.7012$ cp

or, $\mu_T = (0.7012)\ (2.42) = 1.697\ lb_m/ft\text{-}hr$ (D.2)

$$\therefore Re = \left[\frac{0.495}{12}\right]\left[\frac{2417.0}{(3.1416/4.0)\ (0.495/12)^2}\right]\left[\frac{1}{1.697}\right]$$

$$= [0.04125]\left[\frac{2417.0}{(0.7854)\ (1.7016)\ (10^{-3})}\right]\left[\frac{1}{1.697}\right]$$

$$= (43.9613)\ (10^3) = 43,961$$

TABLE XXIV

DIMENSIONLESS AXIAL DISTANCE AND INSIDE WALL TEMPERATURES FOR RUN 297

Dimensionless Axial Distance z	Dimensionless Inside Wall Temperatures, T_W — Peripheral Location 1	2	3	4	5	6	7	8
48.5	475.0		550.3		447.1		416.1	
97.0	501.3	598.7	682.2	538.2	444.6	411.1	406.9	445.1
145.5	533.4		761.9		495.5		438.7	
193.9	543.4		829.4		563.8		447.8	
242.4	578.4		880.0		634.6		505.1	
290.9	617.5		934.5		693.3		551.9	
339.4	663.7		954.6		699.3		614.5	
387.9	760.1		1000.4		742.9		660.3	
436.4	762.7	892.5	1069.2	988.6	838.4	768.6	707.3	701.1
472.7	809.3		1087.9		876.8		743.4	

Dean Number: De

$$De = (Re)\,(\sqrt{d_i/D_c})$$

$$De = (43{,}961)\,(\sqrt{(0.495/20.64)}) = 6807.9$$

$\therefore$ De = 6808

Prandtl Number: Pr

$$Pr = \frac{(C_p)\,(\mu)}{k}$$

At $(t_b)_5 = 97.32°F$:

$$C_p = 1.01881 - (0.4802)\,(10^{-3})\,(T) + (0.3274)\,(10^{-5})\,(T^2) - (0.604)\,(10^{-8})\,(T^3)$$

$$= 1.01881 - (0.4802)\,(10^{-3})\,(97.32) + (0.3274)\,(10^{-5})\,(97.32)^2 - (0.604)\,(10^{-8})\,(97.32)^3$$

$$= 0.998 \text{ BTU/lb-°F.}$$

$$k = 0.30289 + (0.7029)\,(10^{-3})\,(T) - (0.1178)\,(10^{-5})\,(T^2) - (0.550)\,(10^{-9})\,(T^3)$$

$$= 0.30289 + (0.7029)\,(10^{-3})\,(97.32) - (0.1178)\,(10^{-5})\,(97.32)^2 - (0.550)\,(10^{-9})\,(97.32)^3$$

$$= 0.3596 \text{ BTU/hr-ft-°F}$$

$\mu = 1.697\ lb_m/ft\text{-}hr$ [from Equation (D.2)]

$$\therefore Pr = \frac{(0.998)\,(1.697)}{0.3596} = 4.707$$

Graetz Number: Gz

$$Gz = \frac{(W)\,(C_p)}{(k)\,(L)}$$

$$= \frac{(2417.0)\ (0.998)}{(0.3596)\ (5.0)} = 1341.6$$

$$= 1342$$

Nusselt Number: Nu

The Nusselt number is calculated for thermocouple location 5-1.

$$\mathrm{Nu} = \frac{(h)\ (d_i)}{(k)}$$

$$\mathrm{Nu} = \frac{(2.779)\ (10^3)\ (0.495/12.0)}{(0.3956)} = (0.31878)\ (10^3)$$

3596

$$= 318.8$$

Grashof Number: Gr

$$\mathrm{Gr} = \frac{(d_i^3)\ (\rho^2)\ (g)\ (\beta)\ (\Delta t)}{\mu^2}$$

From page 141 in Appendix C:

$$\rho,\ \mathrm{gm/ml} = 0.999986 + (0.1890)\ (10^{-4})\ (T) - (0.5886)\ (10^{-5})\ (T^2) + (0.1548)\ (10^{-7})\ (T^3)$$

$$\rho,\ \mathrm{lb_m/ft^3} = (62.43)\ (\rho,\ \mathrm{gm/ml})$$

At $(t_b)_5 = 97.32°F = 36.29°C$:

$$\rho_b = 62.43\ [0.999986 + (0.1890)\ (10^{-4})\ (36.29) - (0.5886)\ (10^{-5})\ (36.29)^2 + (0.1548)\ (10^{-7})\ (36.29)^3]$$

$$= 62.03\ \mathrm{lb_m/ft^3}$$

From Table XXII:

Circumferentially-averaged wall temp. for station 5 $= (t_w)_{avg.} = \frac{104.50+110.94+105.70+102.93}{4.0}$

or, $(t_w)_{avg.} = 106.02°F = 41.12°C$

$$\therefore (\rho_w) = 62.43 \, [0.999986 + (0.1890)\,(10^{-4})\,(41.12) - (0.5886)\,(10^{-5})\,(41.12)^2 + (0.1548)\,(10^{-7})\,(41.12)^3]$$

$$= 61.92 \; lb_m/ft^3$$

$$(\rho_{avg.})_5 = (62.03 + 61.92)/2.0$$

$$= 61.98 \; lb_m/ft^3$$

$$\Delta t = 106.02 - 97.32 = 8.7°F$$

$$\beta = \frac{(\rho_b - \rho_w)}{(\rho_{avg.})_5 \, (\Delta t)} = \frac{(62.03 - 61.92)}{(61.98)\,(8.7)}$$

$$\beta = (2.040)\,(10^{-4}) \; °F^{-1}$$

$$g = 32.174 \; ft/sec^2 = (4.17)\,(10^8) \; ft/hr^2$$

$$\mu = 1.697 \; lb_m/ft\text{-}hr \qquad \text{[from Equation (D.2)]}$$

$$\therefore Gr = \frac{(d_i^3)\,(\rho^2)\,(g)\,(\beta)\,(\Delta t)}{\mu^2}$$

$$= \left[\frac{0.495}{12.0}\right]^3 [62.03]^2 \, [(4.17)\,(10^8)] \, [(2.040)\,(10^{-4})] \times [8.7] \left[\frac{1}{(1.697)^2}\right]$$

$$= (6.941)\,(10^4) = 69{,}410$$

Rayleigh Number: Ra

$$Ra = (Gr)\,(Pr)$$

$$= (69410)\,(4.707)$$

$$= (3.267)\,(10^5)$$

Calculation of the Fanning Friction Factor

Using Equation (5.9):

$$f = \left(\frac{1}{2}\right) \left(\frac{d_i}{L}\right)\left[\frac{1}{v_{avg.}^2}\left\{\frac{(P_0 - P_L)\ (144)\ (g_c)}{\rho_b} - g(H_L - H_0)\right\}\right] \quad (D.3)$$

For data run 297, the calculations are as follows:

$\rho_b = 62.03\ lb_m/ft^3$

$(P_0 - P_L) = (20.25 - 13.06) = 7.19$ psi

$(H_L - H_0) = 16.0$ inches $= 1.333$ ft.

$g_c = 32.174\ (lb_m\text{-}ft)/(lb_f\text{-}sec^2)$

$g = 32.174\ ft/sec^2$

$d_i = 0.495$ inches

$L =$ distance between the pressure taps $= 12$ ft.

$W = 2417.0$ lb/hr

tube cross-sectional area $= A_x = (\pi/4)\ (d_i^2)$

$$= \left[\frac{3.1416}{4.0}\right]\left[\frac{(0.495)^2}{144.0}\right] = 0.001336\ ft^2$$

$$v_{avg.} = \frac{W}{(\rho_b)\ (A_x)\ (3600.0)}$$

$$= \frac{2417.0}{(62.03)\ (1.336)\ (10^{-3})\ (3.6)\ (10^3)}$$

$= 8.102$ ft/sec

Substituting in Equation (D.3),

$$f = \left(\frac{1}{2}\right)\left[\frac{0.495}{(12)\ (12)}\right]\left[\frac{1}{(8.102)^2}\left\{\frac{(7.19)\ (144)\ (32.174)}{62.03} - (32.174)\ (1.333)\right\}\right]$$

$$= \left(\frac{1}{2}\right)(0.003438)\left[\frac{1}{65.642}\{537.025 - 42.883\}\right]$$

$\therefore$ f = 0.01294

Correcting for wall viscosity effects:

$$\text{viscosity correction factor} = \left(\frac{\mu_b}{\mu_w}\right)^{0.14}$$

μ_b = 1.697 lb_m/ft-hr [from Equation (D.2)]

Using Equation (D.1),

μ_w (at 106.02°F) = 1.547 lb_m/ft-hr

$$\therefore \text{viscosity correction factor} = \left[\frac{1.697}{1.547}\right]^{0.14} = 1.013$$

$\therefore$ corrected f = (f) (viscosity correction factor)

= (0.01294) (1.013)

or, f_c = 0.01312

where f_c = Fanning friction factor for isothermal fluid flow in a helically-coiled tube.

APPENDIX E

CALCULATED RESULTS

THERMOCOUPLE STATION : 1

FLUID : WATER
COIL DIAMETER = 20.64 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.023983

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
217	8605	1332	6.407	6996	479.82	56.82
218	8605	1332	6.407	6997	475.17	56.27
219	7603	1177	6.386	7022	401.86	47.57
220	7582	1174	6.405	7014	416.21	49.29
221	6637	1027	6.406	7026	379.90	44.99
222	6642	1028	6.402	7023	385.88	45.69
223	5709	884	6.354	7054	341.05	40.35
224	5711	884	6.352	7044	348.11	41.19
225	4775	739	6.340	7070	305.65	36.18
226	4795	742	6.311	7071	308.90	36.52
227	4795	742	6.311	7101	303.19	35.85
228	4795	742	6.311	7089	302.57	35.78
229	3896	603	6.231	7119	267.24	31.56
230	3896	603	6.231	7119	267.24	31.56
231	2922	452	6.255	4914	240.85	28.45
232	2925	453	6.249	4913	243.10	28.72
233	2073	321	6.144	4970	216.43	25.52
234	2072	321	6.146	4967	213.64	25.19
235	1243	192	5.778	5051	176.30	20.66
236	1236	191	5.813	5052	173.03	20.29
237	4998	774	6.440	3078	293.14	34.73
238	4985	772	6.459	3076	291.60	34.56
239	4553	705	6.428	3079	274.04	32.46
240	4552	705	6.429	3079	273.54	32.41
241	3993	618	6.431	3102	263.34	31.20
242	4002	619	6.416	3097	264.11	31.28
243	3495	541	6.390	3102	238.49	28.24
244	3493	540	6.396	3102	237.36	28.10
245	3001	464	6.338	3111	220.77	26.12
246	3001	464	6.338	3103	223.90	26.49
247	3074	476	5.040	3256	224.24	25.90
248	3074	476	5.040	3255	226.58	26.17
249	2453	379	5.005	3262	211.47	24.41
250	2453	379	5.005	3260	215.57	24.88
251	1915	296	4.943	3293	202.12	23.30
252	1915	296	4.943	3288	198.75	22.91
253	1328	205	4.992	1875	162.98	18.81
254	1328	205	4.992	1875	160.20	18.49
255	708	109	4.848	1917	132.31	15.22
256	710	110	4.830	1917	135.11	15.54
257	1027	159	6.235	1787	150.42	17.76
258	1061	164	6.247	1788	147.07	17.37

THERMOCOUPLE STATION : 1

FLUID : WATER
COIL DIAMETER = 20.64 INCHES TUBE-TO-COIL DIAMETER RATIO = 0.023983

RUN NUMBER	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION: REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	AVERAGE VALUES FOR THE THERMOCOUPLE STATION: HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
259	586	90	5.843	1831	129.67	15.21
260	583	90	5.847	1830	129.22	15.16
261	5060	783	6.352	3096	325.87	38.56
262	5060	783	6.352	3088	334.36	39.56
263	8383	1298	4.891	9887	510.43	58.78
264	8380	1297	4.893	9774	496.26	57.15
265	12629	1955	4.963	9685	811.57	93.60
266	12629	1955	4.963	9681	798.01	92.04
267	16919	2620	4.927	9634	1040.47	119.91
268	16940	2623	4.920	9632	1045.79	120.51
269	20998	3251	4.938	9607	1247.04	143.75
270	20998	3251	4.938	9607	1258.51	145.07
271	25248	3910	5.038	12545	1456.63	168.26
272	25274	3914	5.032	12541	1460.97	168.74
273	29673	4595	5.023	12501	1681.45	194.17
274	29703	4600	5.017	12500	1706.59	197.05
275	34265	5306	4.926	19601	1879.18	216.57
276	34230	5301	4.931	19589	1902.79	219.31
277	38281	5928	4.966	19578	2224.56	256.59
278	38194	5914	4.979	19578	2113.67	243.86
279	41707	6458	4.993	19539	2158.27	249.08
280	41754	6466	4.986	19539	2182.55	251.85
281	38147	5907	4.986	19555	2136.78	246.56
282	38109	5901	4.991	19550	2108.18	243.29
283	33962	5259	4.975	19595	1995.80	230.24
284	34035	5270	4.963	19598	1917.97	221.21
285	29633	4589	5.031	12506	1732.22	200.07
286	29606	4584	5.036	12501	1716.16	198.23
287	25325	3922	5.021	12517	1454.05	167.91
288	25357	3926	5.014	12516	1491.40	172.19
289	20621	3193	5.039	9582	1249.26	144.31
290	20577	3186	5.051	9580	1238.59	143.12
291	16669	2581	5.010	9632	1101.00	127.11
292	16579	2567	5.040	9634	1025.22	118.43
293	12506	1936	5.017	9658	794.42	91.73
294	12506	1936	5.017	9660	785.18	90.66
295	8292	1284	4.951	9751	493.01	56.85
296	8294	1284	4.950	9749	498.68	57.50
297	41989	6502	4.955	19561	2170.44	250.29
298	41801	6473	4.980	19551	2121.18	244.74

THERMOCOUPLE STATION : 1

FLUID : WATER
COIL DIAMETER = 9.99 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.049550

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
101	5127	1141	6.468	3050	396.15	46.96
102	5121	1139	6.476	3043	391.38	46.40
103	4517	1005	6.454	3056	363.90	43.13
104	4517	1005	6.454	3050	361.20	42.81
105	3970	883	6.426	3063	339.96	40.27
106	3970	883	6.426	3057	340.22	40.30
107	4512	1004	6.462	3062	361.84	42.89
108	4512	1004	6.462	3059	361.37	42.83
109	3970	883	6.426	3061	335.53	39.75
110	3965	882	6.435	3057	335.19	39.71
111	3488	776	6.405	3057	319.46	37.83
112	3488	776	6.405	3057	318.20	37.68
113	3010	670	6.383	3069	304.36	36.03
114	3014	670	6.374	3069	306.29	36.25
115	2512	559	6.336	3073	283.98	33.59
116	2509	558	6.346	3073	279.82	33.10
117	2054	457	6.264	3083	264.18	31.21
118	2054	457	6.264	3086	262.06	30.96
119	1541	343	6.196	3114	239.66	28.28
120	1541	343	6.195	3114	240.95	28.44
121	1080	240	6.220	1728	197.07	23.27
122	1080	240	6.221	1728	198.73	23.46
123	539	120	5.882	1789	139.08	16.33
124	540	120	5.874	1785	139.32	16.35
125	559	124	5.650	2595	162.51	19.00
126	559	124	5.650	2596	161.08	18.83
127	527	117	6.034	1319	135.51	15.95
128	527	117	6.030	1319	136.39	16.05
129	8711	1939	6.476	6943	526.35	62.40
130	8712	1939	6.475	6943	525.36	62.28
131	7715	1717	6.417	6964	480.60	56.92
132	7725	1719	6.407	6960	482.70	57.16
133	6698	1491	6.402	6972	433.75	51.36
134	6706	1492	6.393	6972	435.68	51.58
135	5773	1285	6.355	6987	409.71	48.48
136	5773	1285	6.354	6981	408.12	48.29
137	4824	1073	6.316	7030	372.61	44.06
138	4824	1074	6.315	7028	373.76	44.20
139	3919	872	6.254	7039	341.39	40.33
140	3919	872	6.254	7037	342.13	40.42
141	2984	664	6.283	4864	306.77	36.26
142	2987	665	6.275	4865	306.74	36.25

THERMOCOUPLE STATION : 1

FLUID : WATER
COIL DIAMETER = 9.99 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.049550

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
143	2119	471	6.144	4896	269.44	31.77
144	2119	471	6.144	4897	269.49	31.78
145	1264	281	5.850	4965	208.99	24.52
146	1264	281	5.849	4965	207.61	24.36
147	1189	264	6.263	1716	203.00	23.98
148	1189	264	6.261	1715	203.27	24.02
149	1223	272	6.072	3126	213.63	25.16
150	1222	272	6.074	3126	215.68	25.40
151	9753	2171	6.417	6932	590.79	69.98
152	9754	2171	6.416	6930	588.30	69.68
153	10075	2242	6.393	9497	641.84	75.99
154	10100	2248	6.376	9498	642.36	76.03
155	13385	2979	6.407	9444	822.75	97.43
156	13383	2979	6.408	9441	826.22	97.85
157	16585	3691	6.433	9412	1016.30	120.41
158	16585	3691	6.433	9410	1021.54	121.03
159	20272	4512	6.444	12314	1204.15	142.69
160	20272	4512	6.444	12314	1197.01	141.84
161	23713	5278	6.459	12283	1361.91	161.42
162	23772	5291	6.441	12280	1394.49	165.23
163	27101	6032	6.407	19330	1583.64	187.54
164	27108	6034	6.405	19331	1583.03	187.47
165	30405	6768	6.430	19294	1702.71	201.72
166	30448	6777	6.419	19292	1739.17	206.00
167	33262	7404	6.434	19273	1953.69	231.47
168	33266	7405	6.433	19271	1911.67	226.49
169	6668	1484	6.321	9552	471.72	55.79
170	6668	1484	6.321	9551	466.97	55.22
171	41499	9237	5.021	19585	2222.43	256.63
172	41494	9236	5.021	19583	2203.54	254.46
173	37953	8448	5.014	19602	2045.85	236.21
174	37953	8448	5.014	19596	2047.78	236.43
175	33744	7511	5.011	19617	1858.92	214.61
176	33782	7519	5.005	19617	1849.11	213.45

THERMOCOUPLE STATION : 1

FLUID : DOWTHERM G
COIL DIAMETER = 20.64 INCHES TUBE-TO-COIL DIAMETER RATIO = 0.023983

RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
433	190	29	240.027	2069	59.44	32.50
434	190	29	239.498	2069	59.56	32.57
435	167	25	235.744	2090	55.17	30.17
436	166	25	236.645	2086	55.52	30.36
437	145	22	234.899	2088	53.40	29.21
438	145	22	235.229	2091	53.34	29.17
439	125	19	233.405	2137	48.20	26.36
440	125	19	233.545	2134	48.42	26.48
441	114	17	231.775	2159	46.73	25.56
442	114	17	231.868	2159	46.35	25.35
443	93	14	227.915	2198	42.58	23.30
444	93	14	227.915	2199	42.56	23.28
445	74	11	222.591	2245	39.88	21.82
446	74	11	222.229	2247	39.76	21.76
447	52	8	234.918	1050	35.32	19.31
448	52	8	235.060	1051	35.10	19.20
449	31	4	226.253	1073	34.12	18.66
450	31	4	226.343	1069	34.33	18.78
451	6	1	251.092	315	31.56	17.25
452	6	1	250.381	315	31.17	17.04
453	21	3	251.624	321	32.20	17.60
454	21	3	250.671	320	32.92	18.00
455	24	3	222.131	1085	35.07	19.19
456	24	3	221.952	1086	34.91	19.10
457	74	11	237.400	1022	39.42	21.56
458	74	11	236.877	1022	39.32	21.50
459	120	18	231.078	2150	47.64	26.06
460	120	18	230.986	2147	47.93	26.22
461	141	21	233.213	2129	49.95	27.32
462	141	21	233.166	2131	49.99	27.34
463	169	26	235.551	2089	55.60	30.41
464	169	26	235.645	2089	55.45	30.33
465	199	30	238.249	2053	60.57	33.13
466	199	30	238.249	2054	60.34	33.00
467	254	39	232.041	3571	72.39	39.60
468	253	39	232.507	3570	72.53	39.67
469	282	43	234.518	3555	74.04	40.49
470	282	43	235.036	3551	74.29	40.63
471	310	48	236.687	3525	77.70	42.49
472	310	48	236.640	3522	78.16	42.75
473	340	52	237.395	3507	80.63	44.10
474	340	52	236.967	3506	80.77	44.17

THERMOCOUPLE STATION : 1

FLUID : DOWTHERM G
COIL DIAMETER = 9.99 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.049550

RUN NUMBER	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION: REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	AVERAGE VALUES FOR THE THERMOCOUPLE STATION: HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
302	322	71	239.167	3455	89.87	49.14
303	323	71	239.024	3453	89.90	49.16
304	344	76	219.432	7905	96.41	52.76
305	344	76	219.388	7907	96.11	52.60
306	448	99	214.947	7816	107.55	58.86
307	448	99	214.817	7813	107.56	58.87
308	376	83	239.162	3417	96.22	52.61
309	375	83	239.258	3418	95.60	52.28
310	326	72	239.647	3434	89.48	48.93
311	327	72	239.263	3433	89.91	49.16
312	281	62	238.024	3455	84.78	46.36
313	281	62	238.072	3454	84.98	46.47
314	256	57	236.317	3482	82.46	45.09
315	256	57	236.227	3481	82.29	45.01
316	212	47	234.160	3507	75.99	41.56
317	212	47	234.489	3505	76.16	41.65
318	166	36	238.885	2001	64.01	35.00
319	166	37	238.746	2002	63.84	34.91
320	130	29	234.913	2038	57.83	31.63
321	130	29	234.961	2037	57.65	31.53
322	112	25	233.044	2069	53.56	29.30
323	112	25	233.044	2069	53.22	29.11
324	70	15	240.229	958	43.08	23.56
325	70	15	239.748	957	43.26	23.66
326	25	5	221.987	1050	32.55	17.81
327	25	5	221.853	1050	32.61	17.84
328	23	5	247.481	286	26.91	14.71
329	23	5	247.580	286	27.18	14.86
330	177	39	239.220	2002	66.38	36.30
331	177	39	239.172	2002	66.11	36.15
332	150	33	238.890	2012	60.90	33.30
333	150	33	238.411	2010	61.25	33.49
334	131	29	235.669	2027	57.45	31.42
335	131	29	235.669	2025	57.43	31.41
336	112	25	232.904	2047	53.89	29.48
337	112	25	232.993	2047	53.83	29.44
338	94	21	229.759	2086	49.09	26.85
339	94	21	230.082	2084	49.29	26.96
340	78	17	243.128	955	45.54	24.90
341	78	17	243.177	953	45.46	24.86
342	59	13	240.142	976	39.64	21.67
343	59	13	240.094	978	39.27	21.47

THERMOCOUPLE STATION : 1

FLUID : DOWTHERM G
COIL DIAMETER = 9.99 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.049550

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
344	45	10	235.863	1010	34.64	18.95
345	45	10	236.241	1010	34.55	18.89
346	30	6	228.125	1043	32.49	17.77
347	30	6	228.630	1043	32.48	17.77
348	27	6	251.067	281	29.12	15.92
349	27	6	251.117	283	28.77	15.73
350	7	1	242.787	301	28.13	15.38
351	7	1	242.695	302	27.89	15.25
352	503	112	194.034	3500	106.22	58.19
353	503	112	193.995	3497	105.99	58.06
354	775	172	181.988	5378	129.24	70.84
355	775	172	181.988	5379	128.69	70.53
356	1005	223	181.797	5337	142.82	78.27
357	1003	223	182.129	5336	142.61	78.16
358	718	160	136.774	3628	111.65	61.34
359	720	160	136.477	3625	112.58	61.85
360	996	221	136.770	3590	128.28	70.47
361	994	221	137.068	3591	127.66	70.13
362	773	172	129.527	3627	113.83	62.56
363	773	172	129.553	3626	113.93	62.62
364	1049	233	129.982	3587	130.04	71.47
365	1053	234	129.496	3587	130.45	71.70
366	1429	318	129.091	5481	147.66	81.16
367	1438	320	128.305	5480	148.19	81.45
368	1773	394	127.295	5446	160.54	88.25
369	1773	394	127.321	5447	159.72	87.80
370	2163	481	125.365	7783	173.14	95.19
371	2159	480	125.586	7781	172.59	94.89

THERMOCOUPLE STATION : 2

FLUID : WATER
COIL DIAMETER = 20.64 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.023983

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
217	8768	1357	6.274	7007	498.24	58.88
218	8768	1357	6.274	7006	501.28	59.24
219	7769	1203	6.233	7034	419.64	49.56
220	7746	1199	6.254	7024	436.84	51.60
221	6797	1052	6.238	7035	407.55	48.13
222	6806	1054	6.229	7034	409.59	48.37
223	5874	909	6.155	7070	361.14	42.59
224	5877	910	6.151	7062	365.06	43.05
225	4940	765	6.103	7093	320.29	37.74
226	4961	768	6.074	7092	324.39	38.21
227	4961	768	6.074	7111	335.95	39.57
228	4961	768	6.074	7104	327.14	38.53
229	4066	629	5.940	7129	317.90	37.36
230	4066	629	5.940	7130	314.80	36.99
231	3039	470	5.985	4933	264.31	31.08
232	3045	471	5.973	4934	264.55	31.10
233	2189	339	5.780	4994	246.01	28.83
234	2188	338	5.783	4987	245.15	28.73
235	1368	211	5.190	5114	193.14	22.38
236	1355	209	5.248	5117	185.22	21.49
237	5070	785	6.337	3083	311.27	36.82
238	5056	783	6.357	3082	307.71	36.41
239	4626	716	6.314	3087	284.99	33.70
240	4624	716	6.317	3087	284.21	33.61
241	4065	629	6.304	3113	272.31	32.19
242	4073	630	6.290	3106	275.98	32.62
243	3570	552	6.242	3109	266.54	31.48
244	3564	552	6.252	3112	257.51	30.42
245	3075	476	6.168	3123	234.86	27.70
246	3075	476	6.168	3115	237.87	28.06
247	3154	488	4.897	3268	248.12	28.58
248	3154	488	4.897	3266	251.21	28.93
249	2532	392	4.831	3276	241.86	27.82
250	2532	392	4.831	3274	244.48	28.12
251	1997	309	4.715	3310	235.86	27.06
252	1997	309	4.715	3308	226.87	26.03
253	1374	212	4.807	1896	165.56	19.03
254	1374	212	4.807	1896	168.45	19.36
255	754	116	4.519	1957	145.87	16.66
256	759	117	4.488	1957	152.15	17.36
257	1071	165	5.947	1814	149.62	17.58
258	1104	171	5.970	1815	144.70	17.01

THERMOCOUPLE STATION : 2

FLUID : WATER
COIL DIAMETER = 20.64 INCHES TUBE-TO-COIL DIAMETER RATIO = 0.023983

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
259	630	97	5.390	1876	136.09	15.83
260	626	96	5.398	1874	136.53	15.88
261	5129	794	6.256	3100	355.04	41.94
262	5129	794	6.256	3093	356.98	42.17
263	8634	1337	4.732	9905	552.38	63.39
264	8628	1336	4.736	9790	539.13	61.88
265	12874	1993	4.857	9703	837.89	96.42
266	12874	1993	4.857	9700	824.04	94.83
267	17165	2658	4.848	9649	1065.23	122.56
268	17188	2661	4.841	9649	1051.22	120.93
269	21238	3289	4.876	9620	1267.08	145.87
270	21238	3289	4.876	9621	1273.28	146.58
271	25571	3960	4.966	12559	1488.81	171.72
272	25594	3963	4.961	12555	1494.97	172.42
273	29995	4645	4.963	12514	1711.15	197.36
274	30022	4649	4.958	12514	1727.89	199.27
275	34772	5384	4.846	19624	1918.76	220.75
276	34737	5379	4.851	19617	1926.55	221.67
277	38780	6005	4.895	19602	2267.56	261.15
278	38693	5992	4.907	19598	2160.50	248.89
279	42196	6534	4.928	19549	2309.12	266.13
280	42243	6541	4.922	19550	2323.60	267.76
281	38642	5984	4.914	19577	2177.01	250.83
282	38607	5978	4.919	19570	2156.86	248.53
283	34467	5337	4.894	19621	2006.62	231.10
284	34536	5348	4.883	19626	1927.32	221.91
285	29949	4638	4.971	12520	1735.96	200.25
286	29928	4634	4.975	12517	1720.01	198.43
287	25640	3970	4.951	12534	1446.65	166.81
288	25675	3976	4.944	12531	1524.09	175.71
289	20857	3230	4.975	9593	1280.49	147.72
290	20815	3223	4.987	9593	1260.72	145.48
291	16908	2618	4.931	9646	1138.20	131.18
292	16821	2605	4.959	9649	1041.61	120.13
293	12754	1975	4.908	9681	801.54	92.34
294	12754	1975	4.908	9681	803.29	92.54
295	8536	1321	4.793	9767	537.04	61.72
296	8540	1322	4.791	9767	538.51	61.88
297	42480	6578	4.891	19571	2338.30	269.28
298	42290	6549	4.916	19562	2265.93	261.08

THERMOCOUPLE STATION : 2

FLUID : WATER
COIL DIAMETER = 9.99 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.049550

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
101	5200	1157	6.365	3054	439.37	52.00
102	5195	1156	6.372	3047	433.35	51.29
103	4591	1022	6.337	3060	410.32	48.54
104	4591	1022	6.337	3055	401.89	47.54
105	4045	900	6.292	3067	389.65	46.06
106	4045	900	6.292	3061	385.66	45.59
107	4587	1021	6.345	3066	408.09	48.28
108	4587	1021	6.345	3064	402.71	47.64
109	4045	900	6.292	3064	390.46	46.15
110	4040	899	6.301	3061	385.75	45.60
111	3564	793	6.253	3062	368.98	43.59
112	3564	793	6.253	3062	364.13	43.01
113	3084	686	6.210	3076	343.76	40.58
114	3088	687	6.201	3077	346.25	40.87
115	2587	576	6.129	3089	293.05	34.55
116	2584	575	6.138	3089	289.28	34.11
117	2132	474	6.010	3116	234.91	27.64
118	2132	474	6.010	3120	233.97	27.53
119	1618	360	5.867	3169	195.10	22.90
120	1618	360	5.865	3168	197.03	23.12
121	1126	250	5.937	1772	151.93	17.65
122	1126	250	5.938	1771	153.25	18.01
123	586	130	5.360	1832	156.22	18.16
124	586	130	5.353	1827	157.75	18.34
125	625	139	4.983	2663	185.99	21.46
126	625	139	4.982	2663	185.63	21.42
127	558	124	5.659	1346	155.25	18.15
128	559	124	5.651	1346	157.19	18.38
129	8884	1977	6.335	6954	555.57	65.72
130	8886	1978	6.333	6952	558.36	66.05
131	7891	1756	6.256	6974	515.77	60.93
132	7901	1758	6.247	6971	517.76	61.16
133	6874	1530	6.219	6982	472.29	55.76
134	6881	1531	6.212	6983	471.17	55.62
135	5946	1323	6.147	6999	447.76	52.80
136	5948	1324	6.145	6993	447.24	52.74
137	4995	1112	6.073	7042	417.53	49.17
138	4997	1112	6.071	7040	418.11	49.24
139	4093	911	5.957	7051	393.34	46.23
140	4093	911	5.957	7050	390.94	45.95
141	3103	690	6.012	4877	346.93	40.82
142	3106	691	6.005	4879	345.04	40.59

THERMOCOUPLE STATION : 2

FLUID : WATER
COIL DIAMETER = 9.99 INCHES TUBE-TO-COIL DIAMETER RATIO = 0.049550

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
143	2240	498	5.772	4951	248.01	29.06
144	2240	498	5.772	4951	248.47	29.11
145	1386	308	5.277	5038	212.66	24.68
146	1386	308	5.275	5038	212.24	24.63
147	1233	274	6.017	1760	155.83	18.34
148	1233	274	6.013	1754	156.71	18.44
149	1301	289	5.665	3185	188.24	22.01
150	1300	289	5.668	3185	187.79	21.96
151	9924	2209	6.294	6939	631.53	74.65
152	9926	2209	6.292	6938	631.33	74.63
153	10311	2295	6.229	9508	698.83	82.52
154	10334	2300	6.213	9509	698.33	82.44
155	13620	3031	6.283	9452	887.31	104.87
156	13617	3031	6.285	9450	890.02	105.19
157	16817	3743	6.334	9419	1097.62	129.83
158	16817	3743	6.334	9417	1103.70	130.55
159	20579	4580	6.336	12321	1304.52	154.31
160	20579	4580	6.336	12320	1299.33	153.70
161	24024	5347	6.365	12289	1475.21	174.59
162	24080	5360	6.348	12287	1505.81	178.16
163	27578	6138	6.283	19342	1704.83	201.49
164	27592	6142	6.279	19344	1697.49	200.61
165	30885	6875	6.317	19305	1834.78	216.97
166	30933	6885	6.306	19302	1885.75	222.96
167	33723	7506	6.335	19285	2074.13	245.35
168	33732	7508	6.334	19281	2048.85	242.35
169	6900	1536	6.083	9571	512.01	60.31
170	6900	1536	6.083	9570	503.70	59.33
171	42015	9352	4.952	19594	2420.14	279.06
172	42006	9350	4.953	19593	2421.43	279.22
173	38468	8563	4.939	19610	2252.01	259.61
174	38468	8563	4.939	19607	2237.58	257.94
175	34258	7625	4.927	19628	2032.16	234.20
176	34297	7634	4.921	19630	2025.72	233.43

THERMOCOUPLE STATION : 2

FLUID : DOWTHERM G
COIL DIAMETER = 20.64 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.023983

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
433	199	30	229.930	2130	51.69	28.28
434	199	30	229.375	2131	51.71	28.29
435	176	27	224.016	2151	49.21	26.93
436	176	27	224.829	2146	49.43	27.05
437	154	23	221.515	2140	49.34	27.00
438	154	23	221.692	2141	49.61	27.14
439	135	20	217.817	2171	47.93	26.23
440	134	20	218.080	2171	47.65	26.08
441	124	19	214.774	2189	47.46	25.97
442	124	19	214.947	2188	47.25	25.86
443	103	16	207.652	2238	43.13	23.61
444	103	16	207.652	2241	42.96	23.52
445	84	13	197.627	2289	41.15	22.54
446	84	13	197.380	2291	41.08	22.50
447	56	8	218.053	1075	36.59	20.02
448	56	8	218.317	1073	36.66	20.06
449	36	5	199.763	1101	38.11	20.87
450	36	5	199.925	1100	37.90	20.75
451	7	1	226.426	350	34.40	18.82
452	7	1	225.998	349	34.11	18.66
453	22	3	242.861	333	33.16	18.13
454	22	3	241.987	332	34.34	18.78
455	28	4	190.582	1121	39.94	21.88
456	28	4	190.275	1123	39.54	21.66
457	78	12	225.816	1040	40.16	21.97
458	78	12	225.273	1040	40.05	21.91
459	130	20	214.342	2181	48.16	26.36
460	130	20	214.169	2180	48.20	26.38
461	150	23	219.217	2175	47.60	26.05
462	150	23	219.128	2178	47.46	25.97
463	178	27	224.097	2148	49.65	27.16
464	178	27	224.277	2147	49.64	27.16
465	208	32	228.815	2114	52.40	28.66
466	208	32	228.815	2116	52.02	28.46
467	270	41	218.766	3684	60.98	33.37
468	270	41	219.207	3684	60.86	33.31
469	298	46	222.579	3655	63.16	34.56
470	298	46	223.116	3652	63.09	34.52
471	325	50	225.816	3621	65.65	35.92
472	325	50	225.725	3622	65.43	35.80
473	355	55	227.631	3595	68.40	37.42
474	356	55	227.264	3593	68.68	37.57

THERMOCOUPLE STATION : 2

FLUID : DOWTHERM G
COIL DIAMETER = 9.99 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.049550

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
302	338	75	228.740	3565	71.02	38.85
303	338	75	228.465	3564	71.00	38.84
304	387	86	196.353	8240	75.97	41.61
305	387	86	196.274	8242	75.82	41.53
306	491	109	196.910	8104	84.28	46.16
307	492	109	196.672	8101	84.34	46.19
308	391	87	230.115	3519	75.66	41.40
309	391	87	230.300	3519	75.38	41.23
310	342	76	229.201	3544	70.78	38.72
311	342	76	228.924	3541	71.31	39.01
312	296	66	226.099	3570	67.78	37.08
313	296	66	226.190	3568	67.94	37.17
314	272	60	223.305	3601	66.09	36.16
315	272	60	223.134	3601	66.05	36.14
316	229	51	218.352	3633	62.09	33.98
317	228	50	218.528	3633	62.07	33.97
318	175	39	226.826	2077	52.90	28.94
319	175	39	226.562	2078	52.88	28.93
320	140	31	219.323	2123	48.68	26.64
321	140	31	219.411	2121	48.63	26.61
322	122	27	214.965	2158	45.90	25.12
323	122	27	214.965	2160	45.60	24.96
324	74	16	228.474	1002	38.05	20.81
325	74	16	228.015	1000	38.35	20.98
326	29	6	192.619	1085	36.18	19.82
327	29	6	192.385	1086	36.16	19.81
328	24	5	239.134	297	28.12	15.38
329	24	5	239.326	298	28.07	15.35
330	186	41	227.924	2077	54.38	29.75
331	187	41	227.832	2077	54.20	29.65
332	159	35	225.926	2094	50.25	27.49
333	159	35	225.472	2092	50.37	27.56
334	141	31	220.296	2111	48.31	26.43
335	141	31	220.296	2109	48.36	26.46
336	122	27	215.573	2135	46.11	25.23
337	122	27	215.737	2135	46.09	25.22
338	104	23	209.342	2178	43.19	23.64
339	104	23	209.512	2175	43.46	23.79
340	82	18	232.166	999	39.40	21.55
341	82	18	232.260	998	39.31	21.50
342	63	14	226.481	1012	37.34	20.43
343	63	14	226.389	1013	37.25	20.38

THERMOCOUPLE STATION : 2

FLUID : DOWTHERM G
COIL DIAMETER = 9.99 INCHES TUBE-TO-COIL DIAMETER RATIO = 0.049550

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
344	49	10	218.449	1035	35.79	19.59
345	49	10	218.713	1037	35.41	19.38
346	34	7	202.690	1073	35.30	19.33
347	34	7	203.181	1071	35.58	19.48
348	28	6	244.216	290	30.13	16.48
349	28	6	244.313	292	29.71	16.24
350	8	1	220.207	333	30.82	16.87
351	8	1	220.038	335	30.25	16.55
352	522	116	187.319	3558	92.07	50.45
353	522	116	187.244	3556	91.59	50.19
354	807	179	175.019	5451	114.05	62.53
355	807	179	175.019	5451	113.77	62.37
356	1037	230	176.426	5379	132.27	72.51
357	1035	230	176.710	5377	132.36	72.56
358	746	166	131.973	3677	100.36	55.15
359	748	166	131.659	3676	100.42	55.18
360	1024	228	133.274	3632	113.11	62.15
361	1021	227	133.591	3632	113.03	62.11
362	802	178	125.111	3675	101.78	55.96
363	801	178	125.160	3674	101.82	55.98
364	1077	239	126.734	3619	119.36	65.61
365	1081	240	126.286	3619	119.54	65.72
366	1475	328	125.254	5494	148.98	81.91
367	1485	330	124.471	5494	149.37	82.13
368	1819	405	124.222	5449	166.25	91.41
369	1819	404	124.272	5450	165.53	91.01
370	2232	496	121.684	7788	179.09	98.48
371	2228	496	121.873	7785	178.48	98.15

THERMOCOUPLE STATION : 3

FLUID : WATER
COIL DIAMETER = 20.64 INCHES TUBE-TO-COIL DIAMETER RATIO = 0.023983

RUN NUMBER	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	AVERAGE VALUES FOR THE THERMOCOUPLE STATION HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
217	8932	1383	6.145	7019	507.92	59.89
218	8932	1383	6.145	7017	515.15	60.75
219	7936	1229	6.085	7044	435.68	51.32
220	7911	1225	6.107	7037	447.44	52.73
221	6959	1077	6.076	7054	401.94	47.34
222	6972	1079	6.063	7054	405.57	47.76
223	6040	935	5.965	7092	358.90	42.19
224	6044	936	5.960	7082	366.13	43.04
225	5107	791	5.879	7110	330.99	38.85
226	5130	794	5.850	7118	324.77	38.10
227	5130	794	5.850	7136	337.57	39.60
228	5130	794	5.850	7133	322.88	37.88
229	4239	656	5.670	7172	291.95	34.14
230	4239	656	5.670	7171	293.26	34.29
231	3159	489	5.732	4950	279.90	32.77
232	3167	490	5.716	4953	281.05	32.89
233	2307	357	5.449	5059	211.70	24.65
234	2306	357	5.453	5052	211.23	24.60
235	1498	232	4.690	5187	196.14	22.49
236	1477	228	4.764	5184	187.64	21.55
237	5142	796	6.237	3093	307.04	36.26
238	5128	794	6.257	3089	312.68	36.94
239	4700	727	6.203	3096	286.32	33.79
240	4697	727	6.208	3096	284.65	33.60
241	4138	640	6.180	3123	276.78	32.66
242	4145	641	6.169	3117	277.75	32.76
243	3644	564	6.098	3127	251.99	29.69
244	3636	563	6.114	3128	246.63	29.07
245	3149	487	6.004	3129	254.10	29.89
246	3149	487	6.004	3123	251.91	29.63
247	3235	501	4.761	3278	267.32	30.70
248	3235	501	4.761	3279	264.26	30.35
249	2612	404	4.666	3304	224.55	25.73
250	2612	404	4.666	3303	225.64	25.86
251	2081	322	4.503	3352	212.44	24.25
252	2081	322	4.503	3345	212.01	24.21
253	1420	220	4.632	1922	159.40	18.25
254	1420	220	4.632	1922	158.03	18.10
255	801	124	4.224	1998	154.12	17.48
256	808	125	4.182	1998	164.63	18.65
257	1116	172	5.679	1844	142.87	16.71
258	1149	177	5.711	1845	136.54	15.98

THERMOCOUPLE STATION : 5

FLUID : WATER
COIL DIAMETER = 20.64 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.023983

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
259	674	104	4.991	1917	143.43	16.55
260	670	103	5.000	1917	141.77	16.36
261	5198	805	6.162	3108	357.01	42.11
262	5198	805	6.162	3101	356.12	42.01
263	8888	1376	4.581	9933	559.00	63.94
264	6880	1375	4.586	9818	543.94	62.22
265	13120	2031	4.756	9724	838.85	96.32
266	13120	2031	4.756	9719	826.99	94.96
267	17413	2696	4.771	9664	1065.63	122.40
268	17438	2700	4.763	9665	1049.38	120.51
269	21479	3326	4.814	9632	1245.70	143.22
270	21479	3326	4.814	9634	1252.20	143.97
271	25896	4010	4.897	12574	1495.47	172.24
272	25917	4013	4.893	12570	1498.65	172.59
273	30319	4695	4.904	12528	1690.05	194.68
274	30342	4698	4.899	12528	1706.99	196.61
275	35282	5463	4.767	19651	1887.32	216.77
276	35246	5458	4.773	19641	1908.74	219.25
277	39281	6083	4.825	19625	2219.99	255.29
278	39194	6069	4.837	19620	2133.99	245.47
279	42687	6610	4.865	19571	2251.61	259.15
280	42734	6618	4.858	19570	2310.89	265.94
281	39139	6061	4.845	19601	2133.72	245.48
282	39108	6056	4.849	19592	2136.40	245.81
283	34974	5416	4.814	19649	1953.13	224.55
284	35040	5426	4.804	19653	1882.91	216.43
285	30265	4687	4.913	12535	1676.03	193.10
286	30252	4684	4.916	12531	1716.59	197.79
287	25957	4019	4.884	12549	1439.66	165.77
288	25995	4025	4.876	12547	1502.19	172.94
289	21094	3266	4.913	9605	1282.56	147.77
290	21054	3260	4.923	9604	1254.85	144.61
291	17149	2655	4.853	9663	1117.06	128.54
292	17065	2642	4.880	9665	1033.77	119.02
293	13004	2013	4.803	9700	802.88	92.28
294	13004	2013	4.803	9700	804.81	92.51
295	8782	1360	4.643	9792	544.67	62.38
296	8788	1361	4.640	9793	545.97	62.53
297	42972	6654	4.828	19590	2326.21	267.53
298	42782	6625	4.852	19584	2237.47	257.45

THERMOCOUPLE STATION : 3

FLUID : WATER
COIL DIAMETER = 9.99 INCHES TUBE-TO-COIL DIAMETER RATIO = 0.049550

RUN NUMBER	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION: REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	AVERAGE VALUES FOR THE THERMOCOUPLE STATION: HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
101	5275	1174	6.264	3062	441.71	52.19
102	5270	1173	6.270	3058	420.20	49.65
103	4666	1038	6.224	3072	393.48	46.46
104	4666	1038	6.224	3066	392.92	46.39
105	4121	917	6.163	3086	342.89	40.44
106	4121	917	6.163	3081	338.63	39.94
107	4662	1037	6.230	3079	386.13	45.60
108	4662	1037	6.230	3076	383.66	45.30
109	4121	917	6.163	3083	345.69	40.78
110	4116	916	6.171	3080	336.20	39.66
111	3641	810	6.105	3092	285.99	33.70
112	3641	810	6.105	3093	283.31	33.39
113	3160	703	6.044	3118	246.06	28.97
114	3164	704	6.036	3119	246.19	28.98
115	2664	593	5.933	3130	228.70	26.87
116	2661	592	5.941	3131	225.45	26.49
117	2210	492	5.772	3145	224.57	26.31
118	2210	492	5.772	3149	224.18	26.26
119	1696	377	5.564	3193	206.37	24.09
120	1697	377	5.562	3192	209.42	24.44
121	1173	261	5.673	1787	169.11	19.78
122	1172	261	5.675	1787	168.70	19.73
123	634	141	4.907	1890	146.37	16.86
124	635	141	4.901	1885	146.56	16.88
125	694	154	4.432	2732	193.20	22.02
126	695	154	4.430	2731	196.16	22.36
127	590	131	5.318	1385	139.57	16.21
128	591	131	5.308	1384	142.97	16.61
129	9057	2016	6.199	6972	544.04	64.21
130	9061	2016	6.196	6970	551.23	65.06
131	8069	1796	6.102	6994	510.08	60.10
132	8079	1798	6.093	6991	513.53	60.50
133	7051	1569	6.044	7006	466.13	54.87
134	7057	1570	6.038	7006	465.58	54.80
135	6122	1362	5.949	7026	439.72	51.68
136	6124	1363	5.947	7019	441.13	51.84
137	5169	1150	5.844	7075	403.30	47.31
138	5171	1151	5.842	7074	404.53	47.45
139	4269	950	5.681	7106	347.95	40.70
140	4269	950	5.681	7107	343.3	40.16
141	3225	717	5.758	4946	258.23	30.25
142	3228	718	5.753	4948	256.55	30.05

THERMOCOUPLE STATION : 3

FLUID : WATER
COIL DIAMETER = 9.99 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.049550

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
143	2364	526	5.435	4989	251.94	29.33
144	2364	526	5.435	4989	252.38	29.38
145	1512	336	4.787	5108	211.02	24.25
146	1512	336	4.785	5105	213.33	24.51
147	1276	284	5.785	1772	164.42	19.27
148	1277	284	5.780	1771	163.78	19.19
149	1380	307	5.299	3212	208.64	24.23
150	1379	307	5.303	3210	210.52	24.45
151	10095	2247	6.174	6953	629.88	74.31
152	10099	2248	6.171	6952	629.20	74.23
153	10549	2348	6.072	9530	694.49	81.79
154	10571	2353	6.057	9533	689.49	81.18
155	13857	3084	6.162	9465	905.38	106.79
156	13852	3083	6.165	9465	894.64	105.53
157	17050	3795	6.236	9434	1074.76	126.93
158	17050	3795	6.236	9431	1082.69	127.86
159	20888	4649	6.230	12339	1273.45	150.38
160	20888	4649	6.230	12338	1276.03	150.68
161	24337	5417	6.273	12303	1457.28	172.21
162	24390	5429	6.258	12299	1509.41	178.32
163	28058	6245	6.162	19369	1688.00	199.11
164	28080	6250	6.157	19369	1687.39	199.02
165	31369	6982	6.208	19328	1801.59	212.67
166	31421	6994	6.197	19327	1850.25	218.37
167	34187	7609	6.239	19307	2034.48	240.28
168	34200	7612	6.236	19301	2026.82	239.36
169	7135	1588	5.859	9604	509.21	59.75
170	7135	1588	5.859	9605	499.26	58.58
171	42533	9467	4.884	19617	2358.62	271.58
172	42519	9464	4.886	19615	2339.00	269.33
173	38986	8678	4.866	19637	2174.16	250.24
174	38986	8678	4.866	19631	2186.02	251.61
175	34776	7741	4.845	19656	1996.76	229.72
176	34814	7749	4.839	19657	1979.23	227.67

THERMOCOUPLE STATION : 3

FLUID : DOWTHERM G
COIL DIAMETER = 20.64 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.023983

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
433	208	32	220.233	2163	49.55	27.11
434	209	32	219.658	2165	49.42	27.05
435	186	28	212.843	2189	47.07	25.77
436	185	28	213.574	2187	47.10	25.78
437	164	25	208.858	2188	46.49	25.45
438	164	25	208.900	2188	46.75	25.59
439	145	22	203.226	2228	44.72	24.49
440	145	22	203.596	2230	44.39	24.31
441	134	20	198.974	2255	43.81	23.99
442	134	20	199.215	2253	43.71	23.94
443	114	17	189.138	2272	43.73	23.96
444	114	17	189.138	2276	43.40	23.78
445	95	14	175.419	2320	43.16	23.66
446	95	14	175.267	2323	42.90	23.52
447	61	9	202.351	1091	38.88	21.29
448	61	9	202.718	1089	39.00	21.36
449	41	6	176.319	1128	42.16	23.11
450	41	6	176.533	1124	42.64	23.38
451	8	1	204.065	385	36.35	19.90
452	8	1	203.876	385	35.88	19.65
453	22	3	234.381	342	35.56	19.45
454	22	3	233.583	339	37.19	20.34
455	33	5	163.489	1160	43.96	24.11
456	33	5	163.093	1163	43.40	23.80
457	82	12	214.770	1060	40.01	21.90
458	83	12	214.207	1060	39.98	21.88
459	141	21	198.772	2248	44.16	24.19
460	141	21	198.532	2247	44.20	24.21
461	160	24	206.024	2229	44.48	24.36
462	160	24	205.899	2230	44.65	24.44
463	188	29	213.174	2186	47.53	26.02
464	188	29	213.431	2185	47.43	25.96
465	217	33	219.734	2145	50.21	27.47
466	217	33	219.734	2147	49.86	27.28
467	287	44	206.219	3737	58.24	31.89
468	287	44	206.636	3737	58.20	31.86
469	315	48	211.219	3701	60.48	33.11
470	314	48	211.773	3697	60.63	33.19
471	342	52	215.420	3667	62.72	34.33
472	342	53	215.290	3666	62.65	34.29
473	371	57	218.247	3638	65.22	35.69
474	372	57	217.939	3636	65.51	35.85

THERMOCOUPLE STATION : 3

FLUID : DOWTHERM G
COIL DIAMETER = 9.99 INCHES TUBE-TO-COIL DIAMETER RATIO = 0.049550

RUN NUMBER	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION: REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	AVERAGE VALUES FOR THE THERMOCOUPLE STATION: HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
302	354	78	218.745	3610	67.45	36.91
303	355	79	218.348	3610	67.28	36.82
304	435	96	175.668	8305	76.17	41.76
305	435	96	175.561	8305	76.13	41.74
306	539	120	180.362	8045	93.88	51.46
307	540	120	180.035	8044	93.80	51.42
308	407	90	221.390	3538	75.32	41.22
309	407	90	221.657	3537	75.20	41.15
310	358	79	219.185	3582	68.12	37.28
311	359	79	219.009	3583	68.12	37.28
312	313	69	214.740	3638	62.07	33.97
313	312	69	214.869	3637	62.03	33.95
314	289	64	210.975	3681	59.77	32.72
315	289	64	210.734	3681	59.70	32.68
316	246	54	203.568	3727	55.82	30.57
317	246	54	203.609	3725	55.87	30.59
318	185	41	215.347	2136	47.58	26.04
319	185	41	214.969	2135	47.77	26.14
320	150	33	204.721	2186	44.55	24.39
321	150	33	204.846	2185	44.50	24.37
322	133	29	198.236	2216	43.39	23.76
323	133	29	198.236	2216	43.24	23.68
324	78	17	217.264	1029	36.90	20.19
325	78	17	216.827	1026	37.34	20.43
326	34	7	167.103	1127	38.54	21.14
327	34	7	166.800	1128	38.34	21.03
328	24	5	231.050	306	29.85	16.33
329	24	5	231.329	307	29.64	16.21
330	196	43	217.133	2134	48.70	26.65
331	196	43	217.002	2134	48.50	26.54
332	168	37	213.630	2151	45.91	25.13
333	169	37	213.199	2148	46.12	25.24
334	151	33	205.832	2172	44.43	24.32
335	151	33	205.882	2170	44.41	24.31
336	132	29	199.481	2193	43.28	23.70
337	132	29	199.712	2194	43.16	23.64
338	115	25	190.687	2213	43.55	23.86
339	115	25	190.725	2210	43.77	23.98
340	86	19	221.671	1024	38.24	20.93
341	85	19	221.804	1024	37.91	20.74
342	67	14	213.557	1030	38.26	20.94
343	67	14	213.428	1030	38.24	20.93

THERMOCOUPLE STATION : 3

FLUID : DOWTHERM G
COIL DIAMETER = 9.99 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.049550

RUN NUMBER	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION: REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	AVERAGE VALUES FOR THE THERMOCOUPLE STATION: HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
344	53	11	202.268	1056	37.90	20.53
345	53	11	202.433	1057	37.24	20.39
346	39	8	180.028	1105	37.99	20.82
347	38	8	180.502	1107	37.60	20.61
348	29	6	237.538	298	31.25	17.09
349	29	6	237.681	298	31.43	17.19
350	9	2	199.638	366	32.69	17.90
351	9	2	199.409	368	32.06	17.56
352	541	120	180.837	3572	92.42	50.66
353	542	120	180.728	3571	92.09	50.48
354	841	187	168.321	5474	112.83	61.88
355	841	187	168.321	5474	112.53	61.71
356	1070	238	171.214	5423	122.57	67.21
357	1068	237	171.457	5421	122.89	67.39
358	774	172	127.361	3730	89.23	49.05
359	776	172	127.035	3726	90.13	49.54
360	1052	234	129.880	3676	101.00	55.51
361	1049	233	130.213	3675	101.29	55.67
362	831	185	120.872	3698	98.96	54.42
363	831	185	120.943	3697	98.97	54.43
364	1106	246	123.579	3655	108.54	59.68
365	1110	247	123.168	3653	109.19	60.04
366	1522	338	121.551	5577	123.87	68.12
367	1532	341	120.771	5576	124.30	68.36
368	1866	415	121.235	5492	150.29	82.65
369	1865	415	121.307	5494	149.14	82.02
370	2302	512	118.130	7840	164.98	90.75
371	2299	511	118.290	7839	164.27	90.36

THERMOCOUPLE STATION : 4

FLUID : WATER
COIL DIAMETER = 20.64 INCHES . TUBE-TO-COIL DIAMETER RATIO = 0.023983

RUN NUMBER	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	AVERAGE VALUES FOR THE THERMOCOUPLE STATION HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
217	9097	1408	6.020	7035	505.77	59.51
218	9097	1408	6.020	7029	528.59	62.20
219	8105	1255	5.943	7063	434.42	51.05
220	8078	1251	5.966	7052	456.82	53.70
221	7121	1102	5.920	7069	416.58	48.93
222	7139	1105	5.904	7069	421.83	49.54
223	6208	961	5.784	7111	370.31	43.39
224	6214	962	5.778	7099	379.63	44.48
225	5277	817	5.668	7127	349.50	40.87
226	5301	821	5.639	7140	335.58	39.22
227	5301	821	5.639	7155	353.16	41.28
228	5301	821	5.639	7153	336.24	39.30
229	4414	683	5.418	7199	305.56	35.56
230	4414	683	5.418	7199	305.56	35.56
231	3279	507	5.496	4997	250.91	29.25
232	3290	509	5.475	4996	256.16	29.85
233	2428	376	5.146	5064	260.59	30.17
234	2426	375	5.151	5057	259.03	29.99
235	1632	252	4.262	5245	212.95	24.17
236	1603	248	4.348	5245	196.74	22.38
237	5215	807	6.140	3100	314.45	37.08
238	5200	805	6.160	3099	309.69	36.53
239	4774	739	6.095	3106	288.60	34.00
240	4769	738	6.102	3105	287.27	33.85
241	4211	652	6.060	3134	278.22	32.76
242	4217	653	6.050	3127	283.04	33.32
243	3720	576	5.960	3133	275.93	32.43
244	3709	574	5.980	3135	264.31	31.08
245	3225	499	5.847	3152	235.94	27.68
246	3225	499	5.847	3146	235.42	27.62
247	3317	513	4.630	3302	252.03	28.86
248	3317	513	4.630	3304	248.13	28.41
249	2693	417	4.510	3332	216.77	24.75
250	2693	417	4.510	3333	214.00	24.44
251	2166	335	4.306	3371	234.76	26.68
252	2166	335	4.306	3366	233.49	26.53
253	1467	227	4.467	1935	178.92	20.41
254	1467	227	4.467	1935	178.92	20.41
255	849	131	3.958	2036	159.67	17.99
256	859	133	3.908	2038	175.32	19.72
257	1162	180	5.429	1858	161.32	18.78
258	1194	184	5.470	1859	151.92	17.70

THERMOCOUPLE STATION : 4

FLUID : WATER
COIL DIAMETER = 20.64 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.023983

RUN NUMBER	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	AVERAGE VALUES FOR THE THERMOCOUPLE STATION HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
259	720	111	4.636	1956	151.60	17.36
260	715	110	4.647	1956	149.14	17.08
261	5268	815	6.071	3118	352.61	41.53
262	5268	815	6.071	3110	359.35	42.32
263	9145	1416	4.438	9960	576.36	65.70
264	9133	1414	4.444	9845	561.60	64.03
265	13368	2070	4.657	9739	871.59	99.86
266	13368	2070	4.657	9735	858.38	98.35
267	17662	2735	4.696	9679	1086.95	124.64
268	17689	2739	4.688	9678	1073.95	123.13
269	21721	3363	4.754	9643	1285.04	147.55
270	21721	3363	4.754	9645	1277.05	146.63
271	26223	4061	4.829	12588	1524.28	175.30
272	26240	4063	4.825	12583	1552.88	178.58
273	30643	4745	4.845	12540	1734.54	199.55
274	30664	4748	4.842	12537	1779.16	204.67
275	35794	5543	4.691	19665	2005.91	230.00
276	35757	5537	4.697	19659	1984.65	227.59
277	39785	6161	4.757	19638	2349.40	269.77
278	39698	6147	4.768	19638	2206.90	253.47
279	43180	6687	4.802	19585	2370.65	272.49
280	43228	6694	4.796	19585	2401.72	276.02
281	39638	6138	4.776	19615	2236.27	256.89
282	39612	6134	4.780	19611	2194.88	252.16
283	35485	5495	4.737	19669	2021.60	232.03
284	35547	5504	4.728	19673	1940.42	222.67
285	30583	4736	4.856	12546	1749.04	201.27
286	30577	4735	4.857	12540	1778.09	204.62
287	26275	4069	4.818	12563	1469.65	168.98
288	26316	4075	4.810	12560	1541.01	177.15
289	21332	3303	4.851	9615	1316.89	151.52
290	21295	3297	4.861	9615	1286.95	148.11
291	17391	2693	4.778	9675	1160.57	133.33
292	17310	2680	4.803	9676	1085.29	124.74
293	13255	2052	4.701	9718	826.67	94.81
294	13255	2052	4.701	9717	828.65	95.03
295	9031	1398	4.500	9818	561.82	64.14
296	9039	1399	4.496	9818	566.15	64.63
297	43467	6731	4.767	19605	2438.25	280.04
298	43275	6701	4.791	19596	2339.40	268.82

THERMOCOUPLE STATION : 4

FLUID : WATER
COIL DIAMETER = 9.99 INCHES TUBE-TO-COIL DIAMETER RATIO = 0.049550

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
101	5350	1190	6.166	3074	415.99	49.07
102	5346	1190	6.171	3068	411.06	48.49
103	4741	1055	6.114	3088	357.08	42.08
104	4741	1055	6.114	3081	358.95	42.30
105	4197	934	6.037	3107	303.49	35.72
106	4197	934	6.037	3101	303.60	35.73
107	4737	1054	6.119	3096	348.20	41.04
108	4737	1054	6.119	3091	350.71	41.34
109	4197	934	6.037	3103	307.09	36.15
110	4192	933	6.046	3099	305.70	35.99
111	3718	827	5.964	3106	285.30	33.54
112	3718	827	5.964	3108	281.00	33.03
113	3236	720	5.885	3126	266.47	31.28
114	3240	721	5.877	3126	269.82	31.67
115	2741	610	5.746	3142	244.36	28.62
116	2738	609	5.754	3142	242.88	28.45
117	2289	509	5.548	3171	222.61	25.97
118	2289	509	5.548	3173	222.83	26.00
119	1776	395	5.285	3222	213.30	24.76
120	1777	395	5.282	3221	214.72	24.93
121	1220	271	5.426	1811	171.69	19.99
122	1220	271	5.429	1811	171.68	19.99
123	683	152	4.511	1941	144.82	16.54
124	684	152	4.506	1936	146.08	16.68
125	766	170	3.972	2805	194.07	21.87
126	767	170	3.970	2804	195.48	22.03
127	622	138	5.009	1417	142.31	16.43
128	624	138	4.997	1417	145.36	16.78
129	9232	2055	6.067	6984	557.75	65.68
130	9237	2056	6.064	6982	565.15	66.55
131	8248	1836	5.954	7007	523.82	61.57
132	8258	1838	5.945	7005	525.44	61.75
133	7230	1609	5.877	7024	469.78	55.14
134	7235	1610	5.872	7024	472.35	55.44
135	6300	1402	5.761	7047	444.65	52.08
136	6303	1403	5.758	7040	446.62	52.31
137	5345	1189	5.629	7106	395.30	46.19
138	5348	1190	5.626	7106	393.09	45.93
139	4449	990	5.425	7152	331.41	38.58
140	4449	990	5.425	7152	328.23	38.21
141	3348	745	5.521	4956	289.47	33.76
142	3351	745	5.517	4957	289.56	33.77

THERMOCOUPLE STATION : 4

FLUID : WATER
COIL DIAMETER = 9.99 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.049550

RUN NUMBER	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION: REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	AVERAGE VALUES FOR THE THERMOCOUPLE STATION: HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
143	2490	554	5.127	5029	252.74	29.25
144	2490	554	5.127	5030	251.84	29.14
145	1642	365	4.365	5188	200.90	22.86
146	1642	365	4.363	5188	200.89	22.86
147	1321	294	5.567	1790	171.18	19.98
148	1322	294	5.561	1789	171.00	19.96
149	1462	325	4.969	3254	206.75	23.85
150	1461	325	4.974	3253	206.48	23.82
151	10268	2285	6.057	6965	638.25	75.15
152	10273	2286	6.054	6963	638.28	75.15
153	10789	2401	5.920	9549	698.64	82.07
154	10811	2406	5.907	9551	694.45	81.56
155	14096	3137	6.045	9480	907.10	106.78
156	14089	3136	6.049	9480	897.17	105.62
157	17285	3847	6.141	9446	1078.11	127.12
158	17285	3847	6.141	9443	1085.35	127.98
159	21199	4719	6.128	12354	1273.00	150.07
160	21199	4719	6.128	12353	1277.36	150.58
161	24651	5487	6.184	12316	1454.58	171.63
162	24701	5498	6.169	12314	1487.73	175.50
163	28542	6353	6.045	19394	1667.98	196.36
164	28571	6359	6.039	19395	1666.36	196.14
165	31855	7090	6.102	19349	1789.41	210.85
166	31911	7103	6.090	19348	1828.29	215.39
167	34653	7713	6.145	19325	2013.39	237.42
168	34670	7717	6.141	19321	2011.54	237.18
169	7374	1641	5.647	9633	511.91	59.84
170	7374	1641	5.647	9634	501.00	58.56
171	43054	9583	4.818	19637	2301.27	264.60
172	43035	9579	4.821	19637	2280.70	262.25
173	39505	8793	4.794	19658	2142.19	246.18
174	39505	8793	4.794	19653	2146.73	246.70
175	35296	7856	4.765	19680	1957.65	224.83
176	35335	7865	4.759	19682	1939.00	222.66

THERMOCOUPLE STATION : 4

FLUID : DOWTHERM G
COIL DIAMETER = 20.64 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.023983

RUN NUMBER	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION: REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	AVERAGE VALUES FOR THE THERMOCOUPLE STATION: HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
433	218	33	210.928	2208	46.34	25.36
434	218	33	210.334	2207	46.56	25.49
435	196	30	202.208	2231	44.92	24.60
436	196	30	202.862	2227	45.08	24.69
437	175	27	196.902	2219	45.79	25.08
438	175	27	196.822	2223	45.81	25.09
439	156	24	189.590	2265	44.08	24.15
440	155	24	190.051	2261	44.31	24.28
441	145	22	184.314	2268	45.87	25.14
442	145	22	184.612	2267	45.65	25.02
443	125	19	172.270	2294	45.52	24.96
444	125	19	172.270	2293	45.65	25.03
445	108	16	155.750	2354	44.93	24.66
446	108	16	155.674	2355	44.76	24.56
447	66	10	187.753	1110	40.90	22.41
448	66	10	188.207	1111	40.48	22.18
449	47	7	155.669	1162	45.34	24.88
450	46	7	155.919	1159	45.42	24.92
451	9	1	183.860	415	40.88	22.40
452	9	1	183.868	413	40.95	22.44
453	23	3	226.180	350	38.82	21.24
454	23	3	225.454	350	38.84	21.25
455	39	6	140.396	1205	47.17	25.91
456	39	6	139.949	1206	47.00	25.81
457	87	13	204.242	1085	39.15	21.44
458	87	13	203.666	1082	39.69	21.73
459	153	23	184.314	2271	45.25	24.80
460	153	23	184.016	2270	45.37	24.86
461	171	26	193.603	2264	43.69	23.94
462	171	26	193.447	2266	43.73	23.95
463	198	30	202.764	2230	44.93	24.61
464	198	30	203.092	2231	44.75	24.50
465	226	35	210.997	2191	46.68	25.55
466	226	35	210.997	2189	46.71	25.57
467	306	47	194.372	3791	55.87	30.60
468	305	47	194.764	3792	55.77	30.55
469	333	51	200.418	3770	56.22	30.79
470	332	51	200.986	3765	56.43	30.90
471	359	55	205.484	3731	58.29	31.91
472	359	55	205.318	3728	58.57	32.07
473	388	60	209.234	3706	59.65	32.65
474	388	60	208.981	3706	59.66	32.66

THERMOCOUPLE STATION : 4

FLUID : DOWTHERM G
COIL DIAMETER = 9.99 INCHES TUBE-TO-COIL DIAMETER RATIO = 0.049550

RUN NUMBER	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	AVERAGE VALUES FOR THE THERMOCOUPLE STATION HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT. F H	NUSSELT NUMBER NU
302	371	82	209.165	3612	70.05	38.35
303	372	82	208.660	3612	69.99	38.32
304	489	108	157.198	8165	90.38	49.59
305	489	108	157.072	8167	90.13	49.46
306	590	131	165.219	8163	88.86	48.74
307	592	131	164.819	8161	88.96	48.80
308	424	94	212.980	3555	75.46	41.31
309	423	94	213.325	3554	75.37	41.25
310	376	83	209.588	3585	70.62	38.66
311	376	83	209.504	3586	70.56	38.63
312	330	73	203.929	3679	60.18	32.95
313	330	73	204.095	3678	60.16	32.94
314	306	68	199.303	3745	56.07	30.71
315	307	68	198.998	3745	56.07	30.71
316	265	59	189.759	3798	52.64	28.84
317	265	59	189.683	3797	52.71	28.88
318	195	43	204.424	2176	45.39	24.85
319	196	43	203.946	2175	45.63	24.99
320	162	36	191.068	2230	43.16	23.64
321	161	36	191.222	2227	43.27	23.70
322	144	32	182.785	2258	42.74	23.43
323	144	32	182.785	2257	42.65	23.38
324	82	18	206.581	1055	35.99	19.70
325	82	18	206.165	1053	36.27	19.86
326	39	8	145.075	1171	40.50	22.24
327	39	8	144.727	1170	40.89	22.45
328	25	5	223.224	316	31.32	17.13
329	25	5	223.584	317	30.85	16.88
330	207	46	206.833	2175	46.27	25.33
331	207	46	206.665	2176	46.01	25.19
332	178	39	201.979	2192	44.03	24.11
333	179	39	201.572	2189	44.29	24.25
334	162	36	192.385	2215	43.08	23.60
335	162	36	192.385	2213	42.99	23.55
336	143	32	184.568	2234	42.66	23.38
337	143	31	184.852	2235	42.43	23.25
338	127	28	173.681	2221	46.97	25.75
339	127	28	173.611	2221	47.02	25.78
340	90	20	211.628	1049	37.16	20.34
341	90	20	211.798	1049	36.82	20.15
342	71	15	201.344	1049	38.91	21.31
343	71	15	201.182	1048	39.06	21.39

THERMOCOUPLE STATION : 4

FLUID : DOWTHERM G
COIL DIAMETER = 9.99 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.049550

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATICN			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	CEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
344	57	12	187.259	1084	38.08	20.86
345	57	12	187.335	1085	37.97	20.80
346	44	9	159.924	1140	39.91	21.90
347	44	9	160.376	1142	39.32	21.57
348	30	6	231.031	308	31.79	17.39
349	30	6	231.217	307	32.24	17.63
350	10	2	180.954	398	34.54	18.93
351	10	2	180.676	401	33.86	18.56
352	562	125	174.581	3600	89.14	48.87
353	562	125	174.440	3599	88.77	48.67
354	876	195	161.889	5525	105.82	58.05
355	876	195	161.889	5524	105.92	58.10
356	1104	245	166.162	5453	118.47	64.98
357	1103	245	166.363	5453	118.39	64.93
358	803	178	122.934	3759	86.89	47.78
359	806	179	122.600	3757	87.19	47.95
360	1081	240	126.584	3697	98.26	54.02
361	1078	239	126.933	3696	98.23	54.00
362	862	191	116.803	3733	93.45	51.41
363	861	191	116.893	3732	93.52	51.44
364	1136	252	120.517	3685	102.26	56.24
365	1140	253	120.142	3681	103.61	56.98
366	1570	349	117.976	5581	127.20	69.97
367	1581	352	117.201	5580	127.97	70.40
368	1914	426	118.333	5526	140.98	77.54
369	1913	425	118.426	5526	140.73	77.41
370	2374	528	114.701	7868	161.71	88.97
371	2371	527	114.832	7865	161.79	89.02

THERMOCOUPLE STATION : 5

FLUID : WATER
COIL DIAMETER = 20.64 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.023983

RUN NUMBER	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	AVERAGE VALUES FOR THE THERMOCOUPLE STATION HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
217	9263	1434	5.899	7050	507.17	59.55
218	9263	1434	5.899	7043	534.32	62.74
219	8276	1281	5.806	7078	441.59	51.77
220	8246	1277	5.830	7068	459.78	53.92
221	7286	1128	5.770	7085	422.53	49.50
222	7308	1131	5.751	7086	426.22	49.92
223	6378	987	5.612	7131	374.05	43.70
224	6385	988	5.604	7124	377.10	44.05
225	5449	843	5.468	7150	358.12	41.72
226	5475	847	5.439	7165	340.44	39.64
227	5475	847	5.439	7187	347.36	40.45
228	5475	847	5.439	7182	334.95	39.00
229	4592	711	5.183	7229	312.44	36.20
230	4592	711	5.183	7232	308.29	35.72
231	3402	526	5.274	5032	240.28	27.89
232	3416	529	5.250	5033	244.26	28.34
233	2551	395	4.869	5118	234.96	27.05
234	2548	394	4.875	5111	234.29	26.97
235	1770	274	3.894	5303	225.24	25.33
236	1733	268	3.987	5312	197.79	22.30
237	5288	819	6.045	3109	314.83	37.06
238	5272	816	6.065	3106	317.13	37.35
239	4849	750	5.990	3117	283.02	33.29
240	4843	750	5.998	3116	286.58	33.71
241	4284	663	5.944	3144	280.84	33.00
242	4289	664	5.936	3137	285.74	33.57
243	3796	587	5.826	3151	260.02	30.49
244	3782	585	5.850	3154	244.99	28.74
245	3301	511	5.696	3181	209.68	24.53
246	3301	511	5.696	3173	211.98	24.80
247	3399	526	4.505	3325	241.96	27.63
248	3399	526	4.505	3326	238.39	27.22
249	2774	429	4.362	3347	231.20	26.31
250	2774	429	4.362	3349	227.70	25.91
251	2253	348	4.122	3401	238.07	26.93
252	2253	348	4.122	3396	234.95	26.58
253	1515	234	4.312	1955	185.17	21.05
254	1515	234	4.312	1954	186.33	21.18
255	898	139	3.719	2076	161.30	18.05
256	911	141	3.663	2078	179.16	20.02
257	1208	187	5.197	1879	168.15	19.49
258	1240	192	5.244	1878	159.69	18.52

THERMOCOUPLE STATION : 5

FLUID : WATER
COIL DIAMETER = 20.64 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.023983

RUN NUMBER	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION: REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	AVERAGE VALUES FOR THE THERMOCOUPLE STATION: HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
259	768	118	4.319	1996	157.21	17.87
260	762	118	4.332	1996	153.97	17.51
261	5338	826	5.981	3126	349.38	41.08
262	5338	826	5.981	3119	358.65	42.17
263	9404	1456	4.302	9988	586.96	66.70
264	9390	1454	4.309	9872	571.66	64.97
265	13617	2108	4.562	9759	877.10	100.28
266	13617	2108	4.562	9754	865.77	98.98
267	17913	2774	4.622	9694	1084.19	124.12
268	17942	2778	4.614	9694	1065.49	121.96
269	21964	3401	4.696	9654	1291.22	148.07
270	21964	3401	4.696	9657	1266.84	145.27
271	26551	4111	4.762	12604	1520.64	174.63
272	26565	4114	4.759	12598	1534.74	176.24
273	30969	4796	4.788	12552	1727.43	198.49
274	30986	4798	4.785	12551	1769.11	203.27
275	36309	5622	4.617	19690	1976.07	226.20
276	36272	5617	4.622	19683	1967.61	225.26
277	40291	6239	4.690	19662	2303.25	264.08
278	40203	6226	4.701	19660	2192.16	251.41
279	43675	6763	4.742	19604	2353.52	270.16
280	43723	6771	4.736	19604	2380.50	273.22
281	40140	6216	4.710	19636	2207.52	253.22
282	40118	6212	4.713	19631	2198.69	252.22
283	35997	5574	4.661	19693	2009.44	230.25
284	36056	5583	4.653	19695	1927.43	220.81
285	30903	4785	4.800	12558	1739.95	199.98
286	30903	4785	4.800	12553	1775.08	204.02
287	26595	4118	4.753	12578	1459.88	167.62
288	26639	4125	4.744	12575	1539.76	176.76
289	21571	3340	4.791	9627	1308.18	150.33
290	21536	3335	4.800	9627	1282.52	147.41
291	17634	2730	4.704	9692	1129.67	129.57
292	17557	2718	4.727	9692	1080.74	124.02
293	13509	2092	4.603	9738	835.63	95.63
294	13509	2092	4.603	9738	835.63	95.63
295	9282	1437	4.365	9845	573.94	65.31
296	9292	1439	4.360	9845	576.68	65.62
297	43963	6808	4.707	19623	2405.37	275.90
298	43771	6778	4.730	19616	2308.14	264.88

THERMOCOUPLE STATION : 5

FLUID : WATER
COIL DIAMETER = 9.99 INCHES TUBE-TO-COIL DIAMETER RATIO = 0.049550

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
101	5425	1207	6.070	3086	387.59	45.65
102	5421	1206	6.074	3079	389.91	45.92
103	4816	1072	6.007	3100	344.12	40.48
104	4816	1072	6.007	3094	341.96	40.23
105	4274	951	5.916	3120	295.05	34.66
106	4274	951	5.916	3115	292.65	34.37
107	4813	1071	6.011	3108	335.02	39.42
108	4813	1071	6.011	3105	333.14	39.19
109	4274	951	5.916	3118	291.72	34.26
110	4269	950	5.924	3114	293.44	34.47
111	3795	844	5.827	3128	259.35	30.41
112	3795	844	5.827	3127	262.41	30.77
113	3313	737	5.732	3156	230.17	26.95
114	3317	738	5.724	3156	233.13	27.29
115	2819	627	5.568	3174	217.14	25.34
116	2816	626	5.575	3174	216.39	25.26
117	2370	527	5.337	3198	215.02	24.99
118	2370	527	5.337	3201	215.34	25.02
119	1857	413	5.027	3261	202.93	23.44
120	1858	413	5.024	3258	206.45	23.84
121	1268	282	5.197	1831	183.76	21.30
122	1267	282	5.200	1831	182.96	21.20
123	734	163	4.164	1991	155.05	17.56
124	735	163	4.160	1986	156.16	17.68
125	840	187	3.584	2885	198.76	22.16
126	841	187	3.582	2885	199.85	22.28
127	655	146	4.727	1450	147.04	16.87
128	657	146	4.713	1450	151.08	17.33
129	9408	2094	5.940	7002	542.57	63.76
130	9414	2095	5.936	7000	546.73	64.24
131	8428	1876	5.811	7028	511.64	59.98
132	8439	1878	5.803	7025	512.41	60.07
133	7410	1649	5.716	7048	457.47	53.54
134	7415	1650	5.712	7048	458.61	53.67
135	6479	1442	5.583	7075	430.90	50.31
136	6483	1443	5.579	7067	433.93	50.66
137	5524	1229	5.425	7140	380.96	44.35
138	5527	1230	5.422	7137	384.22	44.72
139	4631	1030	5.187	7187	330.77	38.32
140	4631	1030	5.187	7185	329.94	38.23
141	3473	773	5.299	5005	254.95	29.60
142	3475	773	5.295	5006	255.84	29.71

THERMOCOUPLE STATION : 5

FLUID : WATER
COIL DIAMETER = 9.99 INCHES TUBE-TO-COIL DIAMETER RATIO = 0.049550

RUN NUMBER	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
143	2619	583	4.845	5083	235.52	27.10
144	2619	583	4.845	5083	236.13	27.17
145	1776	395	4.000	5274	196.23	22.13
146	1777	395	3.998	5275	195.43	22.04
147	1366	304	5.361	1811	170.15	19.78
148	1368	304	5.354	1811	169.19	19.67
149	1545	344	4.670	3300	201.38	23.08
150	1544	343	4.676	3299	201.26	23.07
151	10442	2324	5.944	6980	626.07	73.57
152	10449	2325	5.940	6980	622.93	73.20
153	11031	2455	5.775	9573	680.51	79.73
154	11052	2460	5.763	9574	678.86	79.52
155	14337	3191	5.932	9498	882.27	103.66
156	14328	3189	5.936	9497	875.53	102.87
157	17521	3900	6.049	9460	1055.98	124.32
158	17521	3900	6.049	9457	1057.02	124.44
159	21512	4788	6.028	12372	1243.36	146.33
160	21512	4788	6.028	12370	1251.93	147.33
161	24966	5557	6.096	12333	1404.11	165.43
162	25014	5568	6.083	12332	1422.39	167.55
163	29029	6461	5.932	19418	1644.86	193.26
164	29065	6469	5.924	19420	1639.56	192.60
165	32345	7199	5.998	19375	1732.35	203.77
166	32405	7213	5.986	19372	1785.83	210.01
167	35121	7818	6.053	19345	1963.79	231.21
168	35143	7822	6.049	19342	1957.71	230.48
169	7615	1695	5.447	9674	489.23	56.97
170	7615	1695	5.447	9670	488.39	56.88
171	43577	9700	4.753	19659	2262.97	259.83
172	43553	9694	4.756	19660	2215.84	254.44
173	40028	8910	4.724	19685	2060.63	236.45
174	40028	8910	4.724	19679	2071.78	237.73
175	35820	7973	4.687	19708	1904.85	218.39
176	35859	7982	4.682	19708	1885.38	216.13

THERMOCOUPLE STATION : 5

FLUID : DOWTHERM G
COIL DIAMETER = 20.64 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.023983

RUN NUMBER	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION: REYNOLDS NUMBER RE	CEAN NUMBER DE	PRANDTL NUMBER PR	AVERAGE VALUES FOR THE THERMOCOUPLE STATION: HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
433	228	35	202.004	2236	45.29	24.80
434	228	35	201.393	2240	45.00	24.64
435	207	32	192.090	2259	44.37	24.30
436	206	32	192.674	2259	44.15	24.19
437	186	28	185.620	2251	45.36	24.86
438	186	28	185.431	2254	45.31	24.83
439	168	26	176.864	2267	46.98	25.75
440	167	25	177.401	2267	46.81	25.66
441	158	24	170.738	2315	44.20	24.24
442	157	24	171.084	2311	44.29	24.29
443	138	21	156.940	2322	46.88	25.73
444	138	21	156.940	2323	46.86	25.72
445	122	19	138.411	2382	47.32	25.99
446	122	19	138.396	2383	47.16	25.90
447	72	11	174.205	1122	44.51	24.40
448	71	11	174.732	1120	44.59	24.45
449	53	8	137.574	1189	50.44	27.71
450	53	8	137.847	1188	49.77	27.34
451	10	1	165.662	453	41.40	22.71
452	10	1	165.830	451	41.33	22.67
453	24	3	218.251	362	39.39	21.55
454	24	3	217.592	359	41.71	22.83
455	45	7	120.870	1248	51.03	28.07
456	45	7	120.400	1250	50.83	27.95
457	92	14	194.218	1105	39.32	21.54
458	92	14	193.630	1105	39.15	21.45
459	165	25	170.910	2274	48.65	26.68
460	166	25	170.566	2271	49.00	26.87
461	183	28	181.922	2282	44.70	24.50
462	183	28	181.739	2282	44.95	24.64
463	209	32	192.849	2258	44.35	24.29
464	208	32	193.240	2259	44.13	24.17
465	236	36	202.596	2220	45.37	24.84
466	236	36	202.596	2222	45.08	24.68
467	325	50	183.197	3838	54.30	29.76
468	325	50	183.566	3841	53.99	29.59
469	352	54	190.158	3812	54.85	30.05
470	351	54	190.736	3807	54.96	30.11
471	377	58	195.993	3769	56.85	31.14
472	378	58	195.795	3765	57.18	31.32
473	405	62	200.580	3737	58.66	32.13
474	406	62	200.377	3738	58.56	32.07

THERMOCOUPLE STATION : 5

FLUID : DOWTHERM G
COIL DIAMETER = 9.99 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.049550

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
344	62	13	173.361	1113	38.43	21.07
345	62	13	173.361	1113	38.46	21.09
346	50	11	142.172	1176	41.94	23.03
347	49	11	142.598	1174	41.94	23.03
348	31	6	224.692	319	31.97	17.49
349	31	6	224.919	318	32.66	17.87
350	11	2	164.034	430	36.68	20.12
351	11	2	163.719	433	35.88	19.68
352	583	129	168.546	3624	86.96	47.69
353	583	129	168.376	3621	86.86	47.64
354	912	203	155.712	5567	101.05	55.45
355	912	203	155.712	5572	99.94	54.84
356	1139	253	161.263	5485	113.82	62.44
357	1138	253	161.426	5484	113.77	62.41
358	834	185	118.691	3834	74.92	41.21
359	836	186	118.345	3835	74.70	41.09
360	1110	247	123.386	3726	93.21	51.25
361	1107	246	123.749	3724	93.66	51.50
362	893	198	112.897	3771	87,62	48.21
363	892	198	113.005	3771	87.29	48.03
364	1166	259	117.545	3707	98.57	54.22
365	1170	260	117.203	3708	98.40	54.13
366	1620	360	114.528	5662	109.97	60.50
367	1632	363	113.758	5660	110.74	60.93
368	1964	437	115.515	5563	132.69	73.00
369	1962	436	115.627	5563	132.03	72.63
370	2448	545	111.393	7971	138.38	76.16
371	2446	544	111.499	7969	138.00	75.95

THERMOCOUPLE STATION : 5

FLUID : DOWTHERM G
COIL DIAMETER = 9.99 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.049550

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
302	389	86	199.994	3599	75.31	41.24
303	390	86	199.388	3596	75.86	41.54
304	548	122	140.774	8135	100.13	54.99
305	549	122	140.634	8133	100.32	55.10
306	647	144	151.394	8262	83.97	46.09
307	649	144	150.939	8258	84.14	46.19
308	442	98	204.879	3524	86.03	47.10
309	441	98	205.293	3523	85.86	47.01
310	394	87	200.399	3576	75.38	41.28
311	394	87	200.399	3576	75.36	41.27
312	348	77	193.650	3651	66.40	36.38
313	348	77	193.846	3650	66.33	36.33
314	325	72	188.265	3737	59.49	32.60
315	326	72	187.904	3737	59.43	32.56
316	285	63	176.883	3780	57.05	31.28
317	285	63	176.703	3783	56.80	31.14
318	206	45	194.041	2204	44.87	24.58
319	207	46	193.474	2203	45.03	24.67
320	174	38	178.318	2250	44.09	24.17
321	174	38	178.498	2246	44.25	24.26
322	157	35	168.546	2273	44.79	24.56
323	157	35	168.546	2272	44.79	24.57
324	87	19	196.409	1067	37.38	20.48
325	87	19	196.013	1065	37.75	20.67
326	45	10	126.186	1218	42.15	23.17
327	46	10	125.816	1216	42.51	23.37
328	26	5	215.650	326	32.47	17.77
329	26	5	216.085	328	32.04	17.54
330	217	48	197.006	2203	45.46	24.90
331	218	48	196.807	2203	45.35	24.84
332	189	42	190.948	2220	43.66	23.92
333	190	42	190.563	2216	43.96	24.08
334	174	38	179.765	2236	43.92	24.07
335	174	38	179.765	2234	43.83	24.03
336	156	34	170.772	2248	44.61	24.46
337	155	34	171.100	2250	44.35	24.32
338	140	31	158.224	2258	47.32	25.97
339	140	31	158.063	2256	47.67	26.16
340	95	21	202.024	1069	36.95	20.23
341	95	21	202.228	1069	36.72	20.11
342	75	16	189.813	1039	46.37	25.41
343	76	16	189.621	1037	46.84	25.66

THERMOCOUPLE STATION : 6

FLUID : WATER
COIL DIAMETER = 20.64 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.023983

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
217	9430	1460	5.782	7059	531.93	62.33
218	9430	1460	5.782	7056	541.60	63.46
219	8447	1308	5.674	7086	471.30	55.12
220	8415	1303	5.698	7073	500.50	58.56
221	7452	1154	5.627	7104	424.13	49.56
222	7479	1158	5.604	7101	439.19	51.30
223	6549	1014	5.448	7152	378.68	44.10
224	6558	1015	5.439	7144	383.46	44.65
225	5622	870	5.279	7179	357.62	41.51
226	5650	875	5.250	7188	347.87	40.36
227	5650	875	5.250	7211	353.41	41.00
228	5650	875	5.250	7203	346.51	40.20
229	4773	739	4.964	7266	309.28	35.67
230	4773	739	4.964	7263	311.09	35.88
231	3527	546	5.067	5060	240.69	27.82
232	3543	548	5.040	5061	244.83	28.28
233	2677	414	4.615	5160	232.88	26.66
234	2673	414	4.621	5152	232.24	26.59
235	1911	296	3.575	5371	228.42	25.46
236	1866	289	3.672	5370	205.12	22.93
237	5362	830	5.952	3117	317.85	37.36
238	5345	827	5.973	3113	329.15	38.70
239	4924	762	5.887	3124	295.53	34.69
240	4917	761	5.897	3125	288.70	33.90
241	4358	674	5.831	3153	290.93	34.12
242	4362	675	5.825	3146	292.45	34.29
243	3872	599	5.697	3164	261.16	30.56
244	3855	597	5.725	3162	259.41	30.37
245	3377	523	5.552	3196	210.28	24.54
246	3377	523	5.552	3189	211.48	24.68
247	3482	539	4.385	3348	232.97	26.53
248	3482	539	4.385	3349	228.96	26.07
249	2857	442	4.221	3372	228.75	25.94
250	2857	442	4.221	3372	228.75	25.94
251	2341	362	3.950	3436	227.93	25.67
252	2341	362	3.950	3428	231.57	26.08
253	1562	242	4.164	1980	179.98	20.38
254	1562	242	4.164	1979	182.25	20.64
255	948	146	3.502	2117	167.05	18.58
256	964	149	3.441	2117	195.29	21.68
257	1255	194	4.979	1905	168.35	19.42
258	1286	199	5.032	1901	162.47	18.76

THERMOCOUPLE STATION : 6

FLUID : WATER
COIL DIAMETER = 20.64 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.023983

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
259	816	126	4.036	2035	166.48	18.79
260	809	125	4.049	2035	162.30	18.33
261	5409	837	5.894	3134	356.38	41.84
262	5409	837	5.894	3127	356.79	41.89
263	9666	1497	4.172	10017	600.01	67.96
264	9648	1494	4.180	9898	588.95	66.72
265	13869	2147	4.470	9778	889.56	101.48
266	13869	2147	4.470	9774	871.92	99.47
267	18164	2813	4.551	9711	1075.96	122.98
268	18196	2817	4.542	9710	1069.22	122.19
269	22209	3439	4.638	9666	1305.96	149.56
270	22209	3439	4.638	9667	1298.99	148.77
271	26880	4162	4.697	12617	1544.15	177.07
272	26892	4164	4.694	12612	1559.01	178.77
273	31297	4846	4.732	12565	1741.57	199.87
274	31310	4848	4.730	12563	1778.37	204.08
275	36827	5703	4.544	19713	2004.54	229.08
276	36789	5697	4.550	19705	1999.86	228.57
277	40800	6318	4.625	19682	2315.13	265.06
278	40711	6304	4.636	19682	2153.47	246.61
279	44173	6840	4.682	19620	2390.46	274.03
280	44221	6848	4.676	19623	2402.87	275.42
281	40644	6294	4.644	19656	2228.18	255.22
282	40626	6291	4.647	19650	2215.72	253.80
283	36513	5654	4.588	19713	2045.15	233.95
284	36568	5663	4.580	19716	1961.35	224.33
285	31223	4835	4.745	12572	1737.67	199.48
286	31230	4836	4.744	12567	1766.19	202.75
287	26916	4168	4.690	12592	1477.77	169.44
288	26963	4175	4.681	12591	1542.86	176.86
289	21811	3377	4.732	9639	1322.78	151.81
290	21778	3372	4.741	9639	1294.30	148.57
291	17878	2768	4.632	9711	1088.90	124.69
292	17804	2757	4.654	9707	1074.70	123.12
293	13764	2131	4.508	9757	846.13	96.62
294	13764	2131	4.508	9758	833.42	95.16
295	9536	1476	4.235	9874	582.06	66.03
296	9548	1478	4.229	9873	588.78	66.78
297	44462	6885	4.648	19642	2410.57	276.13
298	44269	6855	4.671	19636	2302.58	263.89

THERMOCOUPLE STATION : 6

FLUID : WATER
COIL DIAMETER = 9.99 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.049550

RUN NUMBER	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION: REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	AVERAGE VALUES FOR THE THERMOCOUPLE STATION: HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
101	5501	1224	5.977	3094	399.92	47.02
102	5498	1223	5.980	3087	402.26	47.30
103	4892	1088	5.903	3107	361.13	42.41
104	4892	1088	5.903	3100	364.28	42.78
105	4351	968	5.798	3139	272.83	31.98
106	4351	968	5.798	3132	276.48	32.41
107	4889	1088	5.906	3114	356.56	41.87
108	4889	1088	5.906	3111	356.28	41.84
109	4351	968	5.798	3134	277.57	32.53
110	4346	967	5.806	3131	276.40	32.40
111	3874	862	5.695	3148	244.16	28.56
112	3874	862	5.695	3148	244.16	28.56
113	3390	754	5.585	3169	237.81	27.77
114	3395	755	5.578	3170	237.75	27.76
115	2898	645	5.398	3189	225.58	26.24
116	2895	644	5.405	3188	225.01	26.18
117	2452	545	5.138	3205	251.84	29.15
118	2452	545	5.138	3208	253.26	29.32
119	1939	431	4.789	3274	236.16	27.14
120	1941	432	4.785	3274	238.14	27.36
121	1317	293	4.982	1854	185.95	21.45
122	1316	293	4.985	1856	182.34	21.04
123	786	175	3.858	2033	166.19	18.67
124	787	175	3.854	2025	173.86	19.53
125	917	204	3.255	2949	214.72	23.71
126	918	204	3.253	2948	215.04	23.74
127	689	153	4.470	1480	154.94	17.68
128	691	153	4.454	1481	157.70	17.98
129	9586	2133	5.817	7015	557.41	65.36
130	9593	2135	5.812	7012	569.25	66.74
131	8611	1916	5.673	7042	528.61	61.82
132	8621	1919	5.665	7039	528.97	61.85
133	7592	1690	5.563	7066	468.67	54.70
134	7596	1690	5.560	7066	468.79	54.71
135	6661	1482	5.412	7096	440.88	51.31
136	6666	1483	5.408	7089	444.06	51.68
137	5704	1269	5.233	7162	397.96	46.15
138	5708	1270	5.229	7160	400.91	46.49
139	4816	1072	4.964	7243	302.07	34.84
140	4816	1072	4.964	7243	300.69	34.68
141	3600	801	5.090	5030	260.56	30.13
142	3602	801	5.087	5030	261.68	30.26

THERMOCOUPLE STATION : 6

FLUID : WATER
COIL DIAMETER = 9.99 INCHES TUBE-TO-COIL DIAMETER RATIO = 0.049550

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
143	2750	612	4.587	5095	281.47	32.20
144	2750	612	4.587	5096	280.99	32.14
145	1913	425	3.682	5322	213.59	23.88
146	1914	426	3.680	5325	210.99	23.59
147	1412	314	5.167	1833	168.84	19.55
148	1414	314	5.160	1833	169.35	19.61
149	1631	363	4.399	3333	212.62	24.22
150	1628	362	4.405	3333	212.28	24.18
151	10617	2363	5.834	6993	634.21	74.39
152	10625	2365	5.829	6991	637.88	74.81
153	11276	2510	5.635	9591	700.36	81.85
154	11295	2514	5.624	9593	692.30	80.89
155	14579	3245	5.821	9511	907.05	106.36
156	14568	3242	5.826	9512	894.78	104.93
157	17758	3952	5.958	9470	1075.79	126.45
158	17758	3952	5.958	9468	1070.19	125.79
159	21827	4858	5.931	12382	1290.94	151.67
160	21827	4858	5.931	12384	1265.63	148.70
161	25284	5628	6.010	12345	1410.47	165.94
162	25328	5638	5.998	12345	1420.61	167.10
163	29519	6570	5.821	19441	1654.51	194.01
164	29562	6580	5.812	19443	1655.97	194.15
165	32837	7309	5.898	19393	1770.51	207.89
166	32902	7323	5.885	19391	1830.10	214.84
167	35593	7922	5.963	19364	1979.92	232.75
168	35619	7928	5.958	19358	1983.73	233.18
169	7859	1749	5.258	9699	506.41	58.76
170	7859	1749	5.258	9696	503.03	58.37
171	44103	9817	4.690	19678	2276.45	261.01
172	44074	9810	4.694	19676	2256.20	258.71
173	40553	9027	4.656	19703	2100.68	240.68
174	40553	9027	4.656	19697	2107.88	241.50
175	36346	8090	4.612	19729	1949.69	223.15
176	36385	8099	4.606	19730	1915.94	219.26

THERMOCOUPLE STATION : 6

FLUID : DOWTHERM G
COIL DIAMETER = 20.64 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.023983

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
433	238	36	193.447	2268	44.09	24.15
434	239	37	192.822	2268	44.24	24.23
435	219	33	182.475	2277	44.86	24.59
436	218	33	182.993	2274	44.96	24.64
437	198	30	174.984	2259	47.19	25.87
438	198	30	174.701	2261	47.36	25.96
439	180	27	165.006	2265	51.00	27.98
440	180	27	165.606	2264	50.74	27.83
441	171	26	158.188	2322	46.93	25.75
442	170	26	158.570	2318	47.00	25.79
443	152	23	143.048	2371	45.84	25.17
444	152	23	143.048	2373	45.78	25.14
445	138	21	123.200	2425	48.39	26.61
446	138	21	123.234	2423	48.55	26.70
447	77	12	161.654	1150	44.95	24.66
448	77	12	162.241	1149	44.79	24.57
449	60	9	121.802	1231	52.29	28.75
450	60	9	122.089	1228	52.13	28.67
451	11	1	149.331	490	42.57	23.37
452	11	1	149.624	490	41.55	22.81
453	25	3	210.589	375	39.74	21.75
454	25	3	209.995	370	43.21	23.65
455	53	8	104.496	1301	53.08	29.23
456	53	8	104.024	1301	53.28	29.34
457	96	15	184.679	1121	39.92	21.88
458	97	15	184.083	1121	39.83	21.83
459	179	27	158.506	2282	51.78	28.41
460	179	27	158.125	2278	52.43	28.77
461	195	30	170.951	2283	47.35	25.96
462	195	30	170.745	2282	47.77	26.20
463	220	34	183.415	2279	44.49	24.38
464	219	34	183.860	2279	44.33	24.29
465	246	38	194.521	2249	44.29	24.26
466	246	38	194.521	2248	44.27	24.25
467	346	53	172.666	3834	57.27	31.40
468	345	53	173.016	3831	57.44	31.49
469	372	57	180.421	3820	56.37	30.89
470	371	57	181.006	3817	56.34	30.88
471	396	61	186.934	3793	56.66	31.05
472	397	61	186.708	3794	56.54	30.98
473	424	65	192.277	3766	57.76	31.64
474	424	65	192.122	3768	57.53	31.52

THERMOCOUPLE STATION : 6

FLUID : DOWTHERM G
COIL DIAMETER = 9.99 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.049550

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
302	408	90	191.215	3606	77.88	42.66
303	409	91	190.521	3606	77.84	42.64
304	615	136	126.232	8650	69.62	38.27
305	616	137	126.083	8649	69.63	38.28
306	709	157	138.806	8092	105.48	57.94
307	711	158	138.310	8091	105.57	57.99
308	460	102	197.077	3652	66.80	36.59
309	459	102	197.555	3650	66.63	36.50
310	413	91	191.601	3587	77.37	42.39
311	412	91	191.679	3588	77.21	42.30
312	368	81	183.882	3616	75.13	41.17
313	367	81	184.106	3614	75.20	41.21
314	345	76	177.836	3622	79.28	43.46
315	346	77	177.426	3622	79.24	43.44
316	307	68	164.892	3707	68.90	37.79
317	307	68	164.627	3707	68.88	37.78
318	218	48	184.180	2212	46.37	25.41
319	219	48	183.533	2211	46.57	25.52
320	187	41	166.430	2203	53.96	29.60
321	187	41	166.631	2202	53.79	29.50
322	171	38	155.449	2215	57.27	31.43
323	171	38	155.449	2215	57.08	31.32
324	91	20	186.730	1073	39.76	21.79
325	91	20	186.352	1070	40.41	22.14
326	52	11	110.107	1264	44.06	24.25
327	53	11	109.729	1263	44.45	24.47
328	27	6	208.323	338	33.35	18.26
329	27	6	208.828	338	32.94	18.03
330	229	51	187.638	2217	46.11	25.27
331	229	51	187.411	2216	46.18	25.30
332	201	44	180.515	2211	47.32	25.94
333	201	44	180.152	2209	47.48	26.03
334	187	41	167.982	2191	53.24	29.20
335	187	41	167.982	2189	53.31	29.24
336	169	37	158.035	2189	57.21	31.39
337	168	37	158.398	2189	57.08	31.32
338	154	34	144.214	2257	52.48	28.82
339	154	34	143.982	2257	52.57	28.87
340	100	22	192.845	1086	37.14	20.34
341	99	22	193.079	1085	37.10	20.32
342	80	17	178.939	1078	42.36	23.22
343	80	18	178.723	1078	42.38	23.23

THERMOCOUPLE STATION : 6

FLUID : DOWTHERM G
COIL DIAMETER = 9.99 INCHES TUBE-TO-COIL DIAMETER RATIO = 0.049550

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
344	68	15	160.517	1129	40.52	22.23
345	68	15	160.452	1130	40.27	22.09
346	56	12	126.570	1212	43.91	24.14
347	56	12	126.969	1214	43.32	23.81
348	31	7	218.520	329	32.15	17.59
349	31	7	218.784	328	32.55	17.81
350	12	2	148.757	464	38.20	20.97
351	12	2	148.418	466	37.65	20.67
352	605	134	162.726	3638	87.31	47.90
353	605	134	162.529	3633	87.64	48.08
354	950	211	149.787	5592	99.94	54.86
355	950	211	149.787	5593	99.58	54.66
356	1175	261	156.516	5535	105.83	58.08
357	1174	261	156.643	5535	105.63	57.97
358	865	192	114.620	3854	74.36	40.91
359	867	193	114.267	3853	74.37	40.92
360	1140	253	120.281	3783	82.60	45.43
361	1136	253	120.657	3782	82.63	45.44
362	925	206	109.153	3782	88.60	48.77
363	924	205	109.278	3783	88.05	48.47
364	1197	266	114.659	3745	91.36	50.26
365	1200	267	114.352	3743	91.75	50.48
366	1671	372	111.202	5686	108.26	59.58
367	1683	374	110.439	5686	108.78	59.87
368	2014	448	112.777	5635	114.94	63.25
369	2011	447	112.909	5638	114.13	62.80
370	2524	561	108.202	8049	126.84	69.82
371	2522	561	108.284	8047	126.53	69.65

THERMOCOUPLE STATION : 7

FLUID : WATER
COIL DIAMETER = 20.64 INCHES TUBE-TO-COIL DIAMETER RATIO = 0.023983

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
217	9599	1486	5.668	7066	561.97	65.72
218	9599	1486	5.668	7066	563.59	65.90
219	8621	1335	5.546	7097	487.88	56.92
220	8586	1329	5.572	7088	505.26	58.98
221	7619	1179	5.488	7116	438.90	51.15
222	7651	1184	5.463	7116	449.05	52.31
223	6722	1041	5.290	7170	384.66	44.66
224	6733	1042	5.281	7165	385.80	44.78
225	5798	898	5.100	7202	364.54	42.16
226	5827	902	5.071	7210	356.33	41.19
227	5827	902	5.071	7237	356.40	41.20
228	5827	902	5.071	7227	351.12	40.59
229	4956	767	4.759	7294	314.99	36.17
230	4956	767	4.759	7295	313.40	35.99
231	3653	565	4.871	5089	240.67	27.70
232	3673	568	4.842	5089	246.30	28.33
233	2804	434	4.381	5195	239.78	27.30
234	2800	433	4.388	5187	240.88	27.43
235	2057	318	3.296	5445	235.15	26.00
236	2002	310	3.395	5446	206.29	22.88
237	5436	841	5.861	3127	312.05	36.62
238	5418	839	5.883	3125	315.52	37.04
239	4999	774	5.788	3133	297.10	34.82
240	4991	772	5.799	3135	286.64	33.60
241	4432	686	5.721	3166	284.99	33.36
242	4435	686	5.717	3160	283.13	33.14
243	3949	611	5.573	3185	237.38	27.71
244	3930	608	5.604	3187	228.89	26.73
245	3455	535	5.413	3216	201.39	23.44
246	3455	535	5.413	3210	200.94	23.39
247	3566	552	4.271	3368	231.08	26.24
248	3566	552	4.271	3370	225.72	25.63
249	2940	455	4.088	3388	243.92	27.57
250	2940	455	4.088	3387	245.91	27.79
251	2429	376	3.790	3470	223.10	25.02
252	2429	376	3.790	3465	221.82	24.88
253	1611	249	4.025	2004	178.05	20.09
254	1611	249	4.025	2002	182.89	20.64
255	999	154	3.306	2161	168.47	18.63
256	1017	157	3.241	2162	198.74	21.93
257	1303	201	4.776	1935	160.24	18.41
258	1334	206	4.833	1925	162.76	18.72

THERMOCOUPLE STATION : 7

FLUID : WATER
COIL DIAMETER = 20.64 INCHES TUBE-TO-COIL DIAMETER RATIO = 0.023983

RUN NUMBER	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	AVERAGE VALUES FOR THE THERMOCOUPLE STATION HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
259	865	134	3.781	2077	175.40	19.67
260	858	132	3.796	2078	168.67	18.92
261	5479	848	5.808	3143	353.54	41.45
262	5479	848	5.808	3136	354.98	41.62
263	9931	1537	4.048	10038	627.93	70.90
264	9910	1534	4.058	9922	608.27	68.70
265	14121	2186	4.380	9790	939.30	106.93
266	14121	2186	4.380	9789	900.97	102.57
267	18417	2852	4.481	9722	1112.63	126.97
268	18451	2857	4.472	9720	1106.88	126.28
269	22454	3477	4.581	9674	1356.82	155.19
270	22454	3477	4.581	9676	1346.88	154.05
271	27211	4214	4.633	12629	1588.71	181.93
272	27220	4215	4.631	12622	1623.74	185.93
273	31625	4897	4.678	12571	1877.55	215.22
274	31635	4899	4.676	12569	1907.99	218.70
275	37347	5783	4.474	19725	2113.71	241.16
276	37309	5777	4.479	19719	2087.16	238.16
277	41311	6397	4.561	19695	2410.40	275.57
278	41222	6383	4.572	19694	2254.96	257.86
279	44672	6918	4.623	19629	2534.76	290.20
280	44721	6925	4.618	19630	2544.76	291.30
281	41150	6372	4.581	19667	2349.49	268.73
282	41137	6370	4.582	19661	2316.74	264.99
283	37032	5734	4.516	19729	2146.63	245.16
284	37083	5742	4.509	19731	2054.49	234.60
285	31545	4885	4.691	12580	1814.02	207.99
286	31559	4887	4.689	12575	1868.78	214.26
287	27238	4218	4.628	12600	1565.54	179.25
288	27288	4225	4.618	12600	1607.50	184.02
289	22052	3415	4.675	9646	1379.78	158.15
290	22021	3410	4.682	9646	1353.22	155.13
291	18123	2806	4.562	9720	1145.36	130.95
292	18053	2795	4.582	9718	1117.28	127.79
293	14020	2171	4.416	9771	880.42	100.31
294	14020	2171	4.416	9772	876.48	99.87
295	9793	1516	4.112	9895	606.71	68.62
296	9806	1518	4.105	9895	610.72	69.06
297	44963	6963	4.590	19656	2468.61	282.41
298	44769	6933	4.612	19646	2399.10	274.60

THERMOCOUPLE STATION : 7

FLUID : WATER
COIL DIAMETER = 9.99 INCHES TUBE-TO-COIL DIAMETER RATIO = 0.049550

RUN NUMBER	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION: REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	AVERAGE VALUES FOR THE THERMOCOUPLE STATION: HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
101	5577	1241	5.885	3101	413.26	48.51
102	5575	1240	5.888	3094	415.13	48.74
103	4968	1105	5.801	3113	384.97	45.13
104	4968	1105	5.801	3106	391.36	45.88
105	4429	986	5.684	3149	279.81	32.73
106	4429	986	5.684	3142	281.23	32.90
107	4966	1105	5.803	3120	381.33	44.70
108	4966	1105	5.803	3117	382.29	44.81
109	4429	986	5.684	3144	284.13	33.24
110	4424	984	5.691	3142	278.61	32.59
111	3953	880	5.567	3155	261.17	30.48
112	3953	880	5.567	3156	259.92	30.34
113	3469	772	5.444	3182	244.72	28.50
114	3473	773	5.437	3183	244.06	28.42
115	2978	662	5.236	3211	220.32	25.55
116	2974	662	5.243	3210	220.37	25.56
117	2534	564	4.951	3237	232.77	26.84
118	2534	564	4.951	3241	232.42	26.80
119	2023	450	4.568	3307	233.15	26.66
120	2025	450	4.564	3307	234.49	26.81
121	1366	304	4.780	1875	198.69	22.83
122	1365	304	4.784	1876	194.47	22.34
123	840	187	3.587	2088	164.63	18.36
124	841	187	3.583	2081	165.35	18.44
125	996	221	2.973	3022	233.57	25.56
126	996	221	2.971	3024	227.16	24.86
127	723	161	4.234	1513	158.04	17.93
128	726	161	4.217	1515	160.28	18.17
129	9765	2173	5.697	7027	570.57	66.76
130	9773	2175	5.692	7024	579.65	67.81
131	8794	1957	5.540	7056	539.35	62.92
132	8805	1960	5.533	7055	537.80	62.73
133	7776	1731	5.415	7083	480.72	55.95
134	7779	1731	5.413	7082	481.58	56.05
135	6845	1523	5.250	7117	447.19	51.88
136	6850	1524	5.245	7110	453.11	52.56
137	5887	1310	5.051	7186	406.66	46.99
138	5892	1311	5.047	7184	411.28	47.52
139	5003	1113	4.757	7283	298.18	34.24
140	5003	1113	4.757	7282	297.18	34.13
141	3729	830	4.894	5061	258.76	29.80
142	3730	830	4.892	5061	259.56	29.89

THERMOCOUPLE STATION : 7

FLUID : WATER
COIL DIAMETER = 9.99 INCHES TUBE-TO-COIL DIAMETER RATIO = 0.049550

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
143	2884	642	4.351	5137	281.89	32.07
144	2884	642	4.351	5138	280.29	31.89
145	2054	457	3.403	5373	236.69	26.25
146	2056	457	3.401	5373	237.08	26.29
147	1458	324	4.984	1851	176.69	20.39
148	1460	325	4.976	1849	179.97	20.76
149	1717	382	4.152	3375	214.56	24.29
150	1715	381	4.159	3373	215.87	24.44
151	10794	2402	5.728	7002	657.66	76.99
152	10803	2404	5.722	7001	656.87	76.89
153	11522	2564	5.500	9606	720.48	83.99
154	11540	2568	5.490	9607	719.71	83.88
155	14822	3299	5.714	9525	922.75	108.00
156	14809	3296	5.720	9524	909.12	106.41
157	17996	4006	5.870	9480	1093.56	128.34
158	17996	4006	5.870	9480	1084.98	127.34
159	22144	4929	5.835	12397	1294.01	151.78
160	22144	4929	5.835	12397	1293.90	151.76
161	25603	5699	5.926	12357	1444.55	169.70
162	25644	5708	5.916	12355	1465.35	172.12
163	30012	6680	5.714	19462	1673.50	195.86
164	30063	6692	5.703	19463	1682.45	196.87
165	33332	7419	5.799	19408	1817.91	213.09
166	33402	7435	5.786	19409	1837.73	215.36
167	36066	8028	5.875	19379	2001.55	234.93
168	36097	8035	5.870	19375	2009.01	235.78
169	8106	1804	5.079	9724	520.35	60.16
170	8106	1804	5.079	9721	517.11	59.78
171	44630	9934	4.628	19692	2338.36	267.74
172	44597	9927	4.632	19692	2301.73	263.57
173	41080	9144	4.589	19720	2135.81	244.33
174	41080	9144	4.589	19715	2137.58	244.54
175	36875	8208	4.538	19747	1993.28	227.76
176	36914	8217	4.532	19752	1940.34	221.68

THERMOCOUPLE STATION : 7

FLUID : DOWTHERM G
COIL DIAMETER = 20.64 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.023983

RUN NUMBER	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION: REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	AVERAGE VALUES FOR THE THERMOCOUPLE STATION: HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
433	249	38	185.248	2278	44.94	24.63
434	250	38	184.612	2281	44.85	24.58
435	231	35	173.345	2274	47.58	26.09
436	230	35	173.800	2274	47.44	26.01
437	210	32	164.969	2259	50.28	27.58
438	211	32	164.603	2260	50.62	27.76
439	194	30	153.973	2278	53.23	29.21
440	193	29	154.624	2279	52.75	28.95
441	185	28	146.610	2335	49.13	26.97
442	184	28	147.021	2332	49.02	26.91
443	168	26	130.499	2400	46.85	25.75
444	168	26	130.499	2401	46.89	25.77
445	156	24	109.924	2463	49.87	27.45
446	156	24	109.993	2462	49.96	27.50
447	84	13	150.048	1166	48.31	26.52
448	83	12	150.682	1169	46.77	25.67
449	68	10	108.132	1263	57.28	31.53
450	68	10	108.420	1260	57.35	31.57
451	12	1	134.727	518	48.12	26.44
452	12	1	135.117	518	46.44	25.52
453	26	4	203.185	384	42.14	23.07
454	26	4	202.653	380	45.13	24.71
455	61	9	90.883	1343	58.10	32.03
456	62	9	90.428	1341	59.25	32.67
457	102	15	175.610	1111	46.21	25.33
458	102	15	175.008	1110	46.25	25.36
459	193	30	147.050	2294	54.39	29.86
460	194	30	146.639	2293	54.68	30.02
461	208	32	160.659	2296	48.96	26.86
462	209	32	160.434	2295	49.35	27.08
463	232	35	174.443	2275	47.23	25.90
464	231	35	174.938	2274	47.10	25.82
465	257	39	186.764	2265	44.47	24.37
466	257	39	186.764	2265	44.29	24.27
467	368	57	162.756	3797	63.57	34.87
468	368	56	163.084	3796	63.47	34.82
469	393	60	171.187	3695	74.48	40.84
470	391	60	171.776	3693	74.51	40.86
471	417	64	178.293	3643	80.43	44.09
472	417	64	178.040	3643	80.50	44.13
473	443	68	184.314	3673	72.33	39.64
474	443	68	184.202	3670	72.70	39.84

THERMOCOUPLE STATION : 7

FLUID : DOWTHERM G
COIL DIAMETER = 9.99 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.049550

RUN NUMBER	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	AVERAGE VALUES FOR THE THERMOCOUPLE STATION HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
302	427	95	182.818	3610	80.94	44.36
303	429	95	182.044	3609	81.28	44.55
304	688	153	113.411	8383	89.16	49.06
305	689	153	113.258	8382	89.24	49.11
306	776	172	127.373	8460	78.58	43.19
307	779	173	126.848	8459	78.61	43.21
308	479	106	189.568	3585	80.15	43.91
309	478	106	190.105	3582	80.06	43.86
310	433	96	183.189	3581	82.43	45.18
311	432	96	183.336	3580	82.45	45.18
312	388	86	174.610	3592	84.60	46.38
313	388	86	174.856	3593	84.06	46.09
314	366	81	167.993	3589	93.32	51.18
315	367	81	167.542	3590	93.03	51.02
316	330	73	153.747	3651	84.70	46.49
317	331	73	153.407	3649	85.48	46.92
318	230	51	174.821	2144	60.42	33.13
319	231	51	174.105	2143	60.98	33.43
320	201	44	155.362	2246	51.56	28.30
321	200	44	155.581	2247	51.11	28.05
322	186	41	143.431	2295	50.08	27.50
323	186	41	143.431	2295	49.93	27.42
324	96	21	177.527	1066	45.20	24.78
325	96	21	177.168	1066	45.37	24.87
326	60	13	96.514	1309	45.95	25.32
327	61	13	96.143	1309	46.44	25.59
328	28	6	201.237	349	34.29	18.78
329	28	6	201.807	350	33.78	18.50
330	241	53	178.715	2157	58.05	31.82
331	241	53	178.462	2154	58.49	32.06
332	213	47	170.658	2160	58.49	32.07
333	213	47	170.315	2159	58.56	32.11
334	201	44	156.995	2233	51.00	27.99
335	201	44	156.995	2229	51.32	28.16
336	183	40	146.299	2270	49.56	27.21
337	183	40	146.689	2270	49.42	27.13
338	170	37	131.553	2298	52.44	28.82
339	170	37	131.266	2297	52.63	28.92
340	104	23	184.080	1078	41.88	22.95
341	104	23	184.340	1075	42.14	23.09
342	85	19	168.695	1100	42.69	23.41
343	86	19	168.458	1101	42.59	23.36

THERMOCOUPLE STATION : 7

FLUID : DOWTHERM G
COIL DIAMETER = 9.99 INCHES TUBE-TO-COIL DIAMETER RATIO = 0.049550

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
344	73	16	148.671	1155	41.77	22.93
345	73	16	148.552	1156	41.71	22.90
346	63	14	112.926	1249	45.87	25.24
347	63	14	113.295	1251	45.41	24.98
348	32	7	212.509	338	32.97	18.05
349	32	7	212.809	337	33.42	18.29
350	14	3	135.011	494	41.16	22.61
351	14	3	134.654	495	41.01	22.53
352	627	139	157.115	3645	89.33	49.02
353	628	139	156.895	3643	89.19	48.94
354	989	220	144.104	5630	96.84	53.18
355	989	220	144.104	5630	96.84	53.17
356	1213	270	151.918	5534	109.21	59.94
357	1212	269	152.009	5533	109.35	60.02
358	897	199	110.720	3807	87.31	48.05
359	900	200	110.360	3803	87.88	48.37
360	1171	260	117.271	3784	84.64	46.56
361	1167	259	117.659	3783	84.63	46.55
362	958	213	105.562	3797	88.96	48.98
363	957	213	105.703	3797	88.77	48.87
364	1228	273	111.862	3755	91.38	50.29
365	1231	274	111.584	3755	91.26	50.22
366	1723	383	107.996	5722	104.09	57.30
367	1736	386	107.240	5720	104.85	57.72
368	2065	459	110.121	5622	121.32	66.77
369	2062	459	110.269	5622	121.05	66.62
370	2602	579	105.127	7996	141.48	77.90
371	2600	578	105.186	7997	140.78	77.52

THERMOCOUPLE STATION : 8

FLUID : WATER
COIL DIAMETER = 20.64 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.023983

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
217	9769	1512	5.557	7082	559.46	65.29
218	9769	1512	5.557	7082	556.20	64.91
219	8795	1362	5.423	7109	502.92	58.54
220	8758	1356	5.449	7105	507.95	59.16
221	7787	1206	5.355	7136	436.43	50.74
222	7824	1211	5.327	7136	450.08	52.29
223	6897	1068	5.140	7194	385.69	44.65
224	6910	1070	5.130	7188	388.19	44.93
225	5976	925	4.930	7226	367.58	42.37
226	6007	930	4.902	7240	353.17	40.68
227	6007	930	4.902	7265	354.60	40.84
228	6007	930	4.902	7253	352.53	40.61
229	5142	796	4.567	7331	313.19	35.81
230	5142	796	4.567	7329	316.00	36.13
231	3780	585	4.688	5102	270.77	31.04
232	3803	589	4.656	5105	273.98	31.39
233	2934	454	4.166	5238	241.04	27.30
234	2929	453	4.173	5230	241.03	27.30
235	2206	341	3.051	5527	241.32	26.47
236	2142	331	3.152	5529	206.61	22.74
237	5510	853	5.772	3135	318.20	37.28
238	5491	850	5.794	3132	320.78	37.60
239	5075	786	5.691	3142	301.71	35.30
240	5065	784	5.703	3143	293.86	34.39
241	4507	698	5.615	3175	288.05	33.65
242	4509	698	5.612	3169	288.44	33.69
243	4027	623	5.452	3203	230.19	26.81
244	4004	620	5.487	3202	223.35	26.03
245	3533	547	5.279	3224	216.02	25.08
246	3533	547	5.279	3217	216.60	25.14
247	3650	565	4.161	3373	269.74	30.54
248	3650	565	4.161	3375	266.26	30.15
249	3025	468	3.962	3411	248.40	27.98
250	3025	468	3.962	3412	245.99	27.71
251	2519	390	3.640	3501	233.27	26.05
252	2519	390	3.640	3493	235.81	26.34
253	1660	257	3.893	2024	188.26	21.17
254	1660	257	3.893	2024	191.36	21.52
255	1051	162	3.127	2204	175.62	19.31
256	1072	166	3.060	2207	213.64	23.44
257	1351	209	4.585	1954	176.43	20.18
258	1381	213	4.647	1947	172.51	19.76

THERMOCOUPLE STATION : 8

FLUID : WATER
COIL DIAMETER = 20.64 INCHES TUBE-TO-COIL DIAMETER RATIO = 0.023983

RUN NUMBER	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION: REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	AVERAGE VALUES FOR THE THERMOCOUPLE STATION: HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
259	915	141	3.552	2119	190.43	21.21
260	907	140	3.567	2120	180.93	20.16
261	5551	859	5.725	3149	367.02	42.96
262	5551	859	5.725	3143	363.57	42.56
263	10198	1579	3.931	10070	629.12	70.82
264	10174	1575	3.941	9955	602.52	67.84
265	14376	2226	4.294	9813	924.61	105.04
266	14376	2226	4.294	9811	892.86	101.44
267	18672	2891	4.413	9737	1111.88	126.68
268	18707	2897	4.404	9737	1102.24	125.55
269	22700	3515	4.526	9688	1318.20	150.58
270	22700	3515	4.526	9688	1332.97	152.27
271	27544	4265	4.570	12644	1585.65	181.32
272	27550	4266	4.569	12638	1609.37	184.03
273	31955	4948	4.624	12587	1798.77	205.94
274	31962	4949	4.623	12584	1848.35	211.61
275	37870	5864	4.405	19754	2030.09	231.25
276	37831	5858	4.410	19745	2045.16	232.99
277	41824	6477	4.498	19718	2350.73	268.36
278	41735	6463	4.509	19717	2219.88	253.48
279	45174	6995	4.566	19652	2467.11	282.08
280	45222	7003	4.561	19653	2459.52	281.18
281	41658	6451	4.518	19694	2244.92	256.40
282	41649	6450	4.519	19685	2258.31	257.93
283	37553	5815	4.446	19752	2104.10	239.91
284	37600	5822	4.440	19754	2044.79	233.12
285	31868	4935	4.638	12594	1785.89	204.53
286	31888	4938	4.634	12590	1807.63	207.00
287	27562	4268	4.567	12617	1525.19	174.39
288	27615	4276	4.557	12616	1592.24	182.02
289	22294	3452	4.618	9661	1345.29	154.00
290	22265	3448	4.625	9661	1319.83	151.11
291	18370	2844	4.494	9738	1100.74	125.65
292	18304	2834	4.512	9736	1087.25	124.16
293	14279	2211	4.327	9793	870.74	99.00
294	14279	2211	4.327	9794	867.95	98.68
295	10051	1556	3.994	9927	602.86	67.98
296	10067	1559	3.987	9928	608.08	68.55
297	45465	7040	4.533	19676	2403.82	274.64
298	45271	7010	4.555	19665	2360.18	269.79

THERMOCOUPLE STATION : 8

FLUID : WATER
COIL DIAMETER = 9.99 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.049550

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
101	5653	1258	5.796	3110	412.20	48.31
102	5652	1258	5.798	3103	415.94	48.75
103	5045	1123	5.702	3124	386.54	45.23
104	5045	1123	5.702	3116	391.33	45.79
105	4508	1003	5.573	3156	295.36	34.48
106	4508	1003	5.573	3150	294.64	34.39
107	5043	1122	5.704	3130	384.79	45.03
108	5043	1122	5.704	3127	383.39	44.86
109	4508	1003	5.573	3151	300.80	35.11
110	4502	1002	5.581	3149	294.66	34.40
111	4032	897	5.444	3169	260.03	30.28
112	4032	897	5.444	3169	259.95	30.27
113	3548	789	5.309	3196	246.96	28.68
114	3552	790	5.302	3197	246.37	28.61
115	3058	680	5.082	3218	244.80	28.30
116	3055	680	5.089	3218	243.55	28.16
117	2618	582	4.775	3268	220.04	25.28
118	2618	582	4.775	3270	222.79	25.59
119	2108	469	4.362	3335	242.89	27.64
120	2110	469	4.358	3335	244.06	27.77
121	1417	315	4.592	1905	185.85	21.26
122	1415	315	4.596	1904	185.11	21.18
123	894	199	3.346	2132	183.40	20.31
124	895	199	3.343	2128	182.28	20.18
125	1077	239	2.730	3087	269.08	29.20
126	1077	239	2.728	3084	282.66	30.67
127	758	168	4.017	1544	164.41	18.55
128	761	169	4.000	1546	166.36	18.76
129	9945	2213	5.582	7039	590.40	68.93
130	9954	2215	5.576	7037	593.14	69.24
131	8979	1998	5.412	7072	549.96	64.00
132	8990	2001	5.405	7071	545.53	63.48
133	7962	1772	5.274	7102	487.03	56.53
134	7964	1772	5.273	7101	488.67	56.72
135	7030	1564	5.095	7138	456.26	52.77
136	7037	1566	5.090	7132	457.32	52.88
137	6072	1351	4.879	7211	414.79	47.76
138	6078	1353	4.875	7210	416.47	47.94
139	5194	1156	4.562	7303	319.43	36.52
140	5194	1156	4.562	7302	317.40	36.29
141	3859	859	4.709	5057	319.81	36.68
142	3860	859	4.708	5058	317.54	36.42

THERMOCOUPLE STATION : 8

FLUID : WATER
COIL DIAMETER = 9.99 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.049550

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
143	3020	672	4.133	5176	284.33	32.17
144	3020	672	4.133	5177	282.33	31.95
145	2199	489	3.157	5427	264.87	29.16
146	2200	489	3.155	5427	263.90	29.05
147	1505	335	4.811	1868	188.20	21.64
148	1507	335	4.802	1867	189.98	21.84
149	1806	402	3.927	3408	230.01	25.89
150	1803	401	3.934	3408	227.15	25.57
151	10971	2442	5.624	7015	666.79	77.91
152	10982	2444	5.618	7014	665.84	77.79
153	11771	2620	5.370	9625	733.04	85.24
154	11788	2623	5.361	9626	729.87	84.86
155	15067	3354	5.610	9539	937.15	109.47
156	15053	3350	5.616	9538	925.64	108.14
157	18236	4059	5.783	9493	1103.96	129.37
158	18236	4059	5.783	9491	1104.97	129.48
159	22462	5000	5.743	12412	1303.14	152.60
160	22462	5000	5.743	12411	1304.64	152.77
161	25923	5770	5.844	12366	1491.63	174.98
162	25961	5779	5.834	12367	1481.73	173.79
163	30508	6791	5.610	19482	1694.36	197.93
164	30567	6804	5.598	19486	1690.41	197.42
165	33830	7530	5.704	19427	1849.70	216.44
166	33904	7547	5.690	19430	1851.63	216.61
167	36542	8134	5.790	19397	2021.86	236.95
168	36578	8142	5.783	19393	2031.66	238.08
169	8356	1860	4.909	9752	529.16	60.96
170	8356	1860	4.909	9749	527.52	60.77
171	45160	10052	4.568	19711	2338.64	267.40
172	45122	10044	4.572	19708	2323.17	265.66
173	41610	9262	4.524	19740	2165.38	247.35
174	41610	9262	4.524	19735	2159.51	246.68
175	37407	8326	4.466	19770	2008.44	229.11
176	37446	8335	4.460	19771	1972.74	225.01

THERMOCOUPLE STATION : 8

FLUID : DOWTHERM G
COIL DIAMETER = 20.64 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.023983

RUN NUMBER	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION: REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	AVERAGE VALUES FOR THE THERMOCOUPLE STATION: HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
433	261	40	177.398	2239	51.85	28.42
434	262	40	176.753	2241	51.72	28.35
435	243	37	164.680	2274	50.26	27.57
436	243	37	165.079	2273	50.06	27.46
437	224	34	155.550	2271	51.92	28.49
438	224	34	155.112	2276	51.83	28.45
439	208	32	143.725	2300	54.17	29.75
440	207	32	144.415	2297	54.27	29.80
441	200	31	135.949	2366	49.36	27.12
442	200	30	136.382	2361	49.47	27.18
443	185	28	119.196	2403	51.49	28.32
444	185	28	119.196	2402	51.77	28.47
445	175	27	98.394	2493	52.61	28.98
446	175	27	98.489	2492	52.86	29.12
447	90	14	139.338	1187	50.48	27.73
448	90	14	140.005	1185	50.20	27.57
449	77	12	96.348	1297	62.63	34.51
450	77	12	96.631	1295	61.84	34.07
451	14	2	121.716	551	52.02	28.60
452	14	2	122.178	548	51.15	28.13
453	27	4	196.037	394	44.35	24.29
454	27	4	195.561	390	47.57	26.06
455	70	10	79.657	1387	63.04	34.80
456	71	11	79.231	1389	62.66	34.59
457	107	16	166.995	1134	45.15	24.76
458	108	16	166.390	1136	44.73	24.54
459	209	32	136.489	2330	53.52	29.40
460	210	32	136.056	2326	54.22	29.79
461	222	34	151.018	2309	50.63	27.79
462	223	34	150.776	2308	51.10	28.05
463	244	37	165.920	2268	50.67	27.79
464	244	37	166.457	2269	50.24	27.56
465	268	41	179.316	2229	50.65	27.76
466	268	41	179.316	2228	50.75	27.82
467	392	60	153.438	3739	75.85	41.63
468	391	60	153.747	3740	75.57	41.48
469	415	64	162.437	3720	75.27	41.29
470	413	64	163.028	3718	75.02	41.15
471	438	67	170.057	3743	66.90	36.69
472	438	67	169.782	3742	66.96	36.72
473	463	71	176.682	3664	75.73	41.52
474	463	71	176.611	3665	75.44	41.36

THERMOCOUPLE STATION : 8

FLUID : DOWTHERM G
COIL DIAMETER = 9.99 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.049550

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
302	448	99	174.793	3598	88.13	48.32
303	450	100	173.947	3597	88.61	48.58
304	768	171	102.158	8453	88.95	48.99
305	769	171	102.006	8452	89.15	49.10
306	848	188	117.019	8379	87.04	47.88
307	852	189	116.477	8374	87.35	48.05
308	499	111	182.342	3529	98.88	54.19
309	497	110	182.934	3525	99.19	54.36
310	453	101	175.147	3562	91.84	50.35
311	453	100	175.359	3561	92.16	50.52
312	410	91	165.813	3620	83.64	45.88
313	409	91	166.081	3622	83.01	45.53
314	389	86	158.711	3664	81.34	44.63
315	390	86	158.227	3663	81.53	44.74
316	355	79	143.403	3717	77.37	42.49
317	356	79	143.002	3718	77.29	42.45
318	243	54	165.948	2158	61.93	33.97
319	244	54	165.172	2159	61.97	33.99
320	216	48	145.075	2254	54.59	29.98
321	215	48	145.307	2254	54.27	29.80
322	203	45	132.426	2265	59.94	32.94
323	203	45	132.426	2264	59.96	32.95
324	102	22	168.784	1070	49.61	27.21
325	102	22	168.444	1067	50.50	27.70
326	69	15	85.110	1354	48.43	26.72
327	69	15	84.755	1354	48.82	26.93
328	29	6	194.387	360	35.45	19.42
329	29	6	195.017	360	34.89	19.11
330	253	56	170.221	2127	69.46	38.09
331	254	56	169.947	2126	69.76	38.26
332	226	50	161.354	2223	51.93	28.49
333	226	50	161.030	2222	52.04	28.55
334	215	48	146.768	2241	53.92	29.60
335	215	48	146.768	2237	54.19	29.75
336	198	44	135.506	2235	60.17	33.06
337	198	44	135.916	2235	59.95	32.94
338	187	41	120.147	2329	53.49	29.42
339	187	41	119.819	2330	53.51	29.43
340	110	24	175.713	1062	50.40	27.63
341	110	24	175.998	1059	50.84	27.87
342	91	20	159.056	1132	41.12	22.56
343	91	20	158.801	1132	41.15	22.58

THERMOCOUPLE STATION : 8

FLUID : DOWTHERM G
COIL DIAMETER = 9.99 INCHES TUBE-TO-COIL DIAMETER RATIO = 0.049550

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
344	79	17	137.765	1178	43.18	23.72
345	79	17	137.601	1179	43.10	23.68
346	71	15	101.055	1284	48.55	26.74
347	71	15	101.394	1286	47.75	26.30
348	33	7	206.658	347	33.71	18.46
349	33	7	206.991	347	33.91	18.57
350	15	3	122.680	525	43.33	23.83
351	15	3	122.318	527	42.94	23.61
352	651	144	151.710	3654	90.87	49.88
353	652	145	151.467	3652	90.83	49.86
354	1030	229	138.657	5641	98.21	53.95
355	1030	229	138.657	5639	98.47	54.09
356	1251	278	147.463	5568	105.13	57.72
357	1250	278	147.522	5567	105.18	57.75
358	930	207	106.985	3815	88.02	48.46
359	933	207	106.620	3815	88.05	48.48
360	1202	267	114.352	3831	77.85	42.83
361	1198	266	114.749	3834	77.17	42.46
362	992	220	102.124	3811	89.35	49.21
363	991	220	102.276	3810	89.01	49.02
364	1260	280	109.149	3785	86.99	47.88
365	1263	281	108.899	3784	87.28	48.04
366	1777	395	104.906	5697	112.57	61.99
367	1790	398	104.158	5694	113.68	62.60
368	2117	471	107.542	5664	114.15	62.84
369	2113	470	107.705	5662	114.20	62.87
370	2681	596	102.162	8014	141.09	77.71
371	2680	596	102.200	8011	140.96	77.64

THERMOCOUPLE STATION : 9

FLUID : WATER
COIL DIAMETER = 20.64 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.023983

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
217	9940	1539	5.450	7099	556.36	64.80
218	9940	1539	5.450	7097	567.60	66.10
219	8971	1389	5.304	7121	536.13	62.26
220	8931	1383	5.331	7117	533.01	61.93
221	7957	1232	5.227	7151	454.36	52.69
222	7999	1238	5.197	7150	474.70	55.01
223	7074	1095	4.997	7212	400.15	46.18
224	7089	1097	4.985	7206	404.71	46.70
225	6156	953	4.770	7244	396.77	45.57
226	6189	958	4.741	7260	373.18	42.84
227	6189	958	4.741	7286	374.47	42.98
228	6189	958	4.741	7276	367.98	42.24
229	5330	825	4.388	7357	333.68	37.99
230	5330	825	4.388	7358	331.09	37.70
231	3910	605	4.515	5114	317.65	36.28
232	3936	609	4.481	5118	320.05	36.52
233	3066	474	3.967	5272	257.19	28.98
234	3060	473	3.975	5263	257.08	28.97
235	2358	365	2.836	5537	307.68	33.51
236	2285	353	2.936	5541	246.76	26.97
237	5585	864	5.686	3140	340.73	39.86
238	5565	861	5.708	3138	336.80	39.41
239	5152	797	5.596	3150	314.16	36.69
240	5141	796	5.610	3149	312.40	36.49
241	4583	709	5.511	3185	299.27	34.89
242	4584	709	5.510	3179	299.29	34.90
243	4105	635	5.336	3222	222.18	25.82
244	4080	631	5.374	3219	219.71	25.55
245	3611	559	5.150	3241	219.68	25.43
246	3611	559	5.150	3233	221.63	25.66
247	3735	578	4.055	3389	287.15	32.43
248	3735	578	4.055	3390	284.58	32.14
249	3110	481	3.841	3434	257.55	28.92
250	3110	481	3.841	3435	255.33	28.67
251	2611	404	3.500	3527	247.15	27.49
252	2611	404	3.500	3522	243.78	27.12
253	1709	264	3.768	2047	191.87	21.50
254	1709	264	3.768	2046	193.62	21.70
255	1104	170	2.963	2235	211.15	23.10
256	1128	174	2.894	2240	251.92	27.49
257	1400	216	4.406	1978	179.01	20.39
258	1430	221	4.472	1971	174.56	19.91

THERMOCOUPLE STATION : 9

FLUID : WATER
COIL DIAMETER = 20.64 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.023983

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
259	966	149	3.345	2170	179.86	19.91
260	958	148	3.360	2162	193.79	21.47
261	5622	870	5.643	3156	382.23	44.68
262	5622	870	5.643	3150	379.00	44.30
263	10467	1621	3.818	10100	650.11	72.96
264	10440	1616	3.829	9984	626.36	70.32
265	14632	2266	4.210	9834	935.88	106.10
266	14632	2266	4.210	9830	920.84	104.40
267	18927	2931	4.347	9753	1130.28	128.57
268	18965	2937	4.337	9752	1130.41	128.56
269	22947	3553	4.472	9702	1320.77	150.68
270	22947	3553	4.472	9699	1378.74	157.30
271	27878	4317	4.509	12660	1620.16	185.00
272	27881	4317	4.509	12654	1636.31	186.85
273	32286	4999	4.571	12599	1829.04	209.15
274	32289	5000	4.570	12599	1838.45	210.22
275	38396	5946	4.338	19778	2080.29	236.59
276	38356	5940	4.343	19769	2075.51	236.07
277	42339	6556	4.437	19741	2391.29	272.60
278	42250	6543	4.448	19735	2314.73	263.94
279	45678	7073	4.510	19671	2493.68	284.75
280	45726	7081	4.505	19672	2517.96	287.49
281	42169	6530	4.457	19712	2302.80	262.64
282	42165	6529	4.458	19705	2310.02	263.46
283	38076	5896	4.378	19780	2123.55	241.74
284	38120	5903	4.373	19775	2130.73	242.53
285	32192	4985	4.586	12607	1815.99	207.73
286	32220	4989	4.581	12604	1836.71	210.08
287	27887	4318	4.508	12630	1590.70	181.63
288	27943	4327	4.498	12630	1614.16	184.27
289	22537	3490	4.562	9673	1361.17	155.62
290	22511	3486	4.569	9673	1338.13	153.01
291	18618	2883	4.427	9754	1106.93	126.16
292	18555	2873	4.444	9752	1101.41	125.58
293	14539	2251	4.240	9815	880.19	99.87
294	14539	2251	4.240	9815	879.40	99.78
295	10312	1597	3.882	9953	631.98	71.05
296	10331	1599	3.874	9955	634.52	71.32
297	45970	7119	4.478	19694	2462.27	280.96
298	45775	7088	4.499	19685	2428.65	277.26

THERMOCOUPLE STATION : 9

FLUID : WATER
COIL DIAMETER = 9.99 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.049550

RUN NUMBER	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION: REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	AVERAGE VALUES FOR THE THERMOCOUPLE STATION: HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
101	5730	1275	5.709	3116	423.70	49.58
102	5729	1275	5.710	3110	428.28	50.12
103	5122	1140	5.606	3131	398.68	46.57
104	5122	1140	5.606	3125	401.03	46.84
105	4586	1021	5.466	3166	302.02	35.18
106	4586	1021	5.466	3160	299.52	34.89
107	5121	1140	5.607	3138	396.53	46.32
108	5121	1140	5.607	3134	400.55	46.79
109	4586	1021	5.466	3161	306.94	35.76
110	4581	1019	5.473	3158	301.48	35.13
111	4113	915	5.325	3183	257.74	29.94
112	4113	915	5.325	3183	258.71	30.06
113	3627	807	5.178	3209	252.08	29.20
114	3631	808	5.172	3210	251.38	29.12
115	3140	699	4.935	3242	235.01	27.09
116	3136	698	4.941	3242	232.78	26.84
117	2702	601	4.608	3280	246.86	28.25
118	2702	601	4.608	3283	245.99	28.15
119	2194	488	4.172	3363	255.22	28.91
120	2196	489	4.167	3362	259.37	29.38
121	1467	326	4.414	1928	190.24	21.68
122	1466	326	4.419	1928	190.48	21.70
123	950	211	3.130	2187	175.52	19.30
124	951	211	3.127	2183	175.34	19.28
125	1159	258	2.518	3159	296.79	31.97
126	1160	258	2.516	3158	304.10	32.75
127	794	176	3.818	1578	164.91	18.51
128	797	177	3.800	1580	167.82	18.82
129	10126	2254	5.470	7045	638.75	74.42
130	10137	2256	5.463	7045	635.53	74.03
131	9166	2040	5.289	7084	573.68	66.60
132	9177	2042	5.282	7082	572.24	66.43
133	8149	1814	5.138	7115	508.87	58.90
134	8150	1814	5.138	7114	510.99	59.15
135	7217	1606	4.947	7157	470.10	54.20
136	7225	1608	4.942	7151	471.54	54.36
137	6260	1393	4.717	7231	434.87	49.89
138	6266	1394	4.711	7231	434.91	49.89
139	5387	1199	4.380	7324	341.64	38.89
140	5387	1199	4.380	7325	337.62	38.44
141	3991	888	4.536	5103	282.05	32.23
142	3992	888	4.535	5105	280.50	32.05

THERMOCOUPLE STATION : 9

FLUID : WATER
COIL DIAMETER = 9.99 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.049550

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
143	3158	703	3.932	5221	281.10	31.64
144	3158	703	3.932	5223	278.71	31.38
145	2346	522	2.940	5510	251.49	27.49
146	2348	522	2.937	5510	251.99	27.54
147	1552	345	4.647	1889	188.05	21.54
148	1555	346	4.637	1888	189.71	21.73
149	1895	422	3.720	3452	226.61	25.36
150	1892	421	3.728	3451	226.70	25.38
151	11149	2481	5.523	7025	690.84	80.57
152	11161	2484	5.516	7023	696.43	81.21
153	12021	2676	5.244	9640	759.62	88.12
154	12037	2679	5.237	9642	752.54	87.28
155	15314	3408	5.509	9551	967.34	112.79
156	15297	3405	5.516	9550	960.88	112.05
157	18477	4112	5.699	9501	1147.92	134.31
158	18477	4112	5.699	9499	1150.64	134.63
159	22782	5071	5.652	12421	1374.64	160.70
160	22782	5071	5.652	12422	1353.64	158.25
161	26245	5842	5.764	12376	1551.35	181.73
162	26280	5850	5.755	12376	1530.31	179.24
163	31008	6902	5.509	19499	1761.28	205.35
164	31074	6917	5.496	19503	1747.21	203.66
165	34331	7642	5.610	19441	1925.56	224.94
166	34410	7659	5.596	19443	1930.01	225.39
167	37021	8240	5.706	19405	2145.04	251.01
168	37061	8249	5.699	19401	2136.17	249.94
169	8609	1916	4.748	9773	553.70	63.57
170	8609	1916	4.748	9770	551.59	63.32
171	45693	10171	4.508	19723	2443.19	278.98
172	45649	10161	4.513	19721	2430.61	277.57
173	42143	9380	4.460	19756	2224.55	253.73
174	42143	9380	4.460	19750	2246.13	256.19
175	37941	8445	4.396	19786	2091.04	238.14
176	37981	8454	4.390	19789	2038.24	232.10

THERMOCOUPLE STATION : 9

FLUID : DOWTHERM G
COIL DIAMETER = 20.64 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.023983

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
433	273	42	169.884	2226	57.53	31.55
434	274	42	169.234	2228	57.43	31.49
435	257	39	156.466	2279	52.42	28.76
436	256	39	156.812	2277	52.49	28.81
437	238	36	146.700	2285	53.46	29.35
438	239	37	146.202	2287	53.98	29.64
439	224	34	134.219	2351	51.03	28.04
440	223	34	134.940	2350	50.85	27.94
441	217	33	126.153	2401	49.14	27.01
442	216	33	126.600	2396	49.27	27.08
443	203	31	109.048	2407	56.44	31.07
444	203	31	109.048	2406	56.82	31.27
445	196	30	88.434	2538	53.09	29.28
446	196	30	88.544	2536	53.31	29.40
447	98	15	129.471	1207	52.64	28.93
448	97	15	130.162	1207	51.86	28.50
449	87	13	86.249	1331	67.35	37.15
450	87	13	86.521	1328	67.29	37.12
451	15	2	110.172	580	57.81	31.82
452	15	2	110.682	576	57.59	31.70
453	28	4	189.134	405	46.23	25.33
454	28	4	188.715	405	46.02	25.21
455	80	12	70.472	1432	67.93	37.55
456	81	12	70.082	1433	68.32	37.77
457	113	17	158.816	1152	45.50	24.97
458	114	17	158.210	1153	45.45	24.94
459	226	35	126.773	2380	50.98	28.02
460	227	35	126.326	2375	51.78	28.47
461	237	36	141.996	2336	50.46	27.71
462	237	36	141.741	2335	50.98	28.00
463	258	39	157.829	2269	53.35	29.27
464	257	39	158.401	2268	53.18	29.18
465	280	43	172.168	2213	56.92	31.21
466	280	43	172.168	2211	57.06	31.29
467	417	64	144.689	3708	89.18	48.97
468	416	64	144.979	3708	88.91	48.82
469	438	67	154.155	3759	72.22	39.64
470	437	67	154.744	3757	71.91	39.46
471	460	71	162.212	3655	87.90	48.22
472	461	71	161.918	3652	88.48	48.54
473	484	75	169.371	3674	78.21	42.89
474	484	75	169.336	3673	78.60	43.11

THERMOCOUPLE STATION : 9

FLUID : DOWTHERM G
COIL DIAMETER = 9.99 INCHES TUBE-TO-COIL DIAMETER RATIO = 0.049550

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
302	469	104	167.127	3683	74.33	40.76
303	472	105	166.218	3681	74.76	41.01
304	854	190	92.325	8573	85.98	47.39
305	856	190	92.177	8572	86.20	47.52
306	925	206	107.668	8381	91.25	50.23
307	930	207	107.119	8377	91.55	50.40
308	520	115	175.394	3595	84.64	46.40
309	518	115	176.033	3593	84.25	46.19
310	475	105	167.464	3653	75.82	41.58
311	474	105	167.735	3651	75.96	41.66
312	433	96	157.477	3699	72.56	39.81
313	432	96	157.761	3698	72.42	39.74
314	413	91	149.970	3749	70.33	38.60
315	414	92	149.456	3751	70.13	38.50
316	382	85	133.820	3783	71.52	39.30
317	383	85	133.369	3784	71.50	39.29
318	257	57	157.540	2201	57.16	31.36
319	258	57	156.714	2201	57.50	31.55
320	232	51	135.529	2186	77.68	42.68
321	231	51	135.770	2184	77.53	42.60
322	220	49	122.374	2340	52.94	29.11
323	220	49	122.374	2339	52.83	29.05
324	107	23	160.485	1110	44.04	24.16
325	107	23	160.162	1108	44.46	24.39
326	78	17	75.608	1398	50.68	27.99
327	79	17	75.276	1400	50.96	28.15
328	30	6	187.767	369	37.05	20.30
329	30	6	188.451	370	36.33	19.91
330	267	59	162.142	2190	59.01	32.37
331	267	59	161.849	2189	59.05	32.39
332	239	53	152.580	2221	55.56	30.50
333	240	53	152.275	2221	55.56	30.50
334	231	51	137.262	2174	75.92	41.71
335	231	51	137.262	2174	75.59	41.53
336	215	47	125.603	2251	63.34	34.82
337	214	47	126.026	2253	62.70	34.47
338	205	45	109.903	2412	47.92	26.38
339	206	45	109.546	2413	47.90	26.37
340	115	25	167.735	1098	45.43	24.92
341	115	25	168.039	1095	45.60	25.01
342	97	21	149.997	1157	40.56	22.27
343	97	21	149.727	1158	40.64	22.31

THERMOCOUPLE STATION : 9

FLUID : DOWTHERM G
COIL DIAMETER = 9.99 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.049550

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
344	86	19	127.747	1209	43.13	23.70
345	86	19	127.546	1210	43.01	23.64
346	80	17	90.779	1318	51.33	28.30
347	79	17	91.087	1319	51.03	28.13
348	34	7	200.961	355	34.92	19.12
349	34	7	201.327	355	34.93	19.13
350	17	3	111.661	555	46.16	25.40
351	17	3	111.295	557	45.97	25.30
352	675	150	146.504	3672	90.04	49.44
353	676	150	146.240	3670	89.87	49.34
354	1072	238	133.437	5668	96.70	53.13
355	1072	238	133.437	5667	96.57	53.06
356	1291	287	143.151	5578	105.97	58.20
357	1290	287	143.179	5575	106.36	58.41
358	963	214	103.407	3864	80.91	44.56
359	967	215	103.040	3864	80.95	44.58
360	1234	274	111.520	3768	95.08	52.33
361	1230	273	111.926	3768	94.76	52.15
362	1027	228	98.831	3833	87.56	48.24
363	1025	228	98.995	3833	87.20	48.04
364	1293	287	106.519	3785	89.45	49.24
365	1296	288	106.297	3786	89.14	49.08
366	1831	407	101.929	5717	111.69	61.52
367	1845	410	101.190	5715	112.53	61.98
368	2170	483	105.038	5604	135.36	74.53
369	2166	482	105.218	5604	135.05	74.36
370	2762	614	99.306	8027	142.03	78.24
371	2762	614	99.325	8024	142.05	78.25

THERMOCOUPLE STATION : 10

FLUID : WATER
COIL DIAMETER = 20.64 INCHES TUBE-TO-COIL DIAMETER RATIO = 0.023983

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
217	10069	1559	5.372	7113	540.62	62.87
218	10069	1559	5.372	7110	552.45	64.24
219	9103	1409	5.218	7137	517.48	60.00
220	9062	1403	5.245	7131	523.20	60.69
221	8086	1252	5.134	7167	448.07	51.86
222	8131	1259	5.102	7168	455.85	52.73
223	7208	1116	4.893	7231	391.41	45.08
224	7223	1118	4.881	7226	394.71	45.45
225	6292	974	4.654	7267	384.72	44.08
226	6326	979	4.626	7282	365.59	41.86
227	6326	979	4.626	7308	366.92	42.01
228	6326	979	4.626	7299	359.30	41.14
229	5473	847	4.260	7385	324.72	36.86
230	5473	847	4.260	7387	321.28	36.47
231	4008	620	4.392	5134	306.63	34.92
232	4036	625	4.357	5135	318.41	36.23
233	3166	490	3.827	5301	253.69	28.48
234	3160	489	3.835	5292	253.13	28.42
235	2475	383	2.690	5641	252.75	27.39
236	2394	370	2.790	5635	218.77	23.79
237	5641	873	5.622	3150	321.61	37.58
238	5621	870	5.645	3146	329.38	38.50
239	5209	806	5.527	3159	306.12	35.70
240	5197	804	5.541	3159	300.19	35.02
241	4640	718	5.435	3197	282.50	32.89
242	4640	718	5.435	3191	279.86	32.58
243	4165	645	5.251	3230	222.80	25.85
244	4136	640	5.291	3230	215.39	25.01
245	3671	568	5.057	3257	206.94	23.91
246	3671	568	5.057	3251	206.51	23.86
247	3800	588	3.979	3405	270.62	30.50
248	3800	588	3.979	3405	268.99	30.32
249	3174	491	3.755	3454	243.48	27.28
250	3174	491	3.755	3455	242.42	27.16
251	2680	415	3.400	3553	238.60	26.46
252	2680	415	3.400	3548	236.00	26.17
253	1747	270	3.679	2064	186.13	20.81
254	1747	270	3.679	2065	183.65	20.53
255	1144	177	2.850	2268	204.08	22.24
256	1170	181	2.780	2279	236.21	25.68
257	1438	222	4.279	2000	173.16	19.67
258	1466	227	4.347	1989	172.86	19.66

THERMOCOUPLE STATION : 10

FLUID : WATER
COIL DIAMETER = 20.64 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.023983

RUN NUMBER	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
259	1005	155	3.202	2205	176.04	19.40
260	996	154	3.217	2199	178.54	19.69
261	5676	879	5.583	3170	341.11	39.83
262	5676	879	5.583	3164	331.97	38.76
263	10671	1652	3.737	10124	639.32	71.59
264	10641	1647	3.749	10009	614.45	68.83
265	14825	2295	4.149	9850	913.35	103.39
266	14825	2295	4.149	9845	900.69	101.96
267	19120	2961	4.298	9763	1123.44	127.64
268	19159	2967	4.288	9764	1106.90	125.73
269	23133	3582	4.431	9711	1298.77	148.04
270	23133	3582	4.431	9708	1354.47	154.38
271	28129	4356	4.464	12671	1601.39	182.67
272	28130	4356	4.464	12665	1600.72	182.59
273	32535	5038	4.532	12610	1801.35	205.80
274	32536	5038	4.531	12609	1807.92	206.55
275	38792	6007	4.288	19798	2009.89	228.31
276	38752	6001	4.293	19790	2010.98	228.46
277	42728	6617	4.392	19757	2307.47	262.77
278	42638	6603	4.403	19749	2296.48	261.58
279	46057	7132	4.468	19683	2448.28	279.30
280	46106	7140	4.463	19688	2426.74	276.81
281	42554	6590	4.412	19732	2218.30	252.73
282	42553	6589	4.412	19723	2250.61	256.41
283	38471	5957	4.328	19797	2075.25	235.96
284	38512	5964	4.323	19793	2067.71	235.07
285	32436	5023	4.547	12618	1743.29	199.24
286	32469	5028	4.542	12613	1793.56	204.96
287	28132	4356	4.464	12641	1560.31	177.98
288	28191	4365	4.454	12644	1572.45	179.32
289	22720	3518	4.521	9683	1320.35	150.81
290	22695	3514	4.527	9682	1306.19	149.21
291	18805	2912	4.378	9766	1087.90	123.84
292	18745	2902	4.394	9763	1080.79	123.08
293	14735	2282	4.177	9832	860.28	97.46
294	14735	2282	4.177	9832	855.10	96.87
295	10510	1627	3.801	9977	620.21	69.57
296	10530	1630	3.793	9979	622.80	69.85
297	46350	7177	4.437	19711	2395.34	273.06
298	46154	7147	4.458	19698	2356.88	268.81

THERMOCOUPLE STATION : 10

FLUID : WATER
COIL DIAMETER = 9.99 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.049550

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
101	5788	1288	5.645	3125	415.62	48.58
102	5788	1288	5.645	3118	418.68	48.94
103	5180	1153	5.535	3142	382.82	44.66
104	5180	1153	5.535	3134	389.49	45.43
105	4646	1034	5.387	3175	300.10	34.91
106	4646	1034	5.387	3169	299.76	34.87
107	5180	1153	5.536	3147	387.31	45.18
108	5180	1153	5.536	3143	394.77	46.05
109	4646	1034	5.387	3171	302.36	35.17
110	4641	1033	5.394	3168	301.08	35.03
111	4173	929	5.239	3195	255.67	29.65
112	4173	929	5.239	3194	255.81	29.67
113	3687	820	5.084	3223	248.65	28.75
114	3692	821	5.077	3223	250.50	28.96
115	3201	712	4.829	3255	236.58	27.21
116	3198	711	4.835	3256	234.00	26.92
117	2767	615	4.489	3298	247.11	28.20
118	2767	615	4.489	3301	248.07	28.31
119	2260	503	4.037	3396	233.56	26.36
120	2262	503	4.033	3396	234.18	26.43
121	1506	335	4.289	1947	191.32	21.73
122	1504	335	4.293	1946	190.78	21.67
123	993	221	2.983	2225	181.30	19.85
124	993	221	2.980	2221	182.04	19.92
125	1223	272	2.377	3229	250.68	26.86
126	1224	272	2.376	3228	253.99	27.22
127	821	182	3.679	1605	163.65	18.30
128	825	183	3.660	1608	164.69	18.40
129	10263	2284	5.388	7060	615.94	71.65
130	10275	2287	5.381	7062	608.57	70.78
131	9307	2071	5.199	7101	557.96	64.67
132	9318	2074	5.193	7100	556.50	64.49
133	8291	1845	5.040	7135	495.09	57.19
134	8291	1845	5.040	7134	497.09	57.42
135	7359	1638	4.841	7179	457.81	52.66
136	7367	1640	4.835	7174	459.53	52.86
137	6401	1425	4.600	7254	433.33	49.58
138	6408	1426	4.595	7254	432.32	49.46
139	5533	1231	4.251	7385	294.54	33.43
140	5533	1231	4.251	7384	293.63	33.32
141	4091	910	4.412	5125	280.51	31.96
142	4091	910	4.412	5127	279.59	31.85

THERMOCOUPLE STATION : 10

FLUID : WATER
COIL DIAMETER = 9.99 INCHES TUBE-TO-COIL DIAMETER RATIO = 0.049550

RUN NUMBER	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION: REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	AVERAGE VALUES FOR THE THERMOCOUPLE STATION: HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
143	3263	726	3.792	5263	263.92	29.60
144	3263	726	3.792	5265	261.12	29.29
145	2459	547	2.792	5571	246.63	26.82
146	2461	547	2.790	5573	245.42	26.69
147	1588	353	4.530	1904	190.59	21.77
148	1591	354	4.520	1905	186.02	21.25
149	1964	437	3.577	3487	222.44	24.80
150	1960	436	3.584	3485	222.25	24.78
151	11284	2511	5.449	7038	672.49	78.32
152	11297	2514	5.442	7037	679.06	79.07
153	12211	2718	5.154	9662	729.51	84.47
154	12225	2721	5.147	9663	730.33	84.55
155	15500	3450	5.435	9567	940.76	109.53
156	15482	3446	5.442	9565	931.94	108.52
157	18658	4153	5.637	9514	1111.77	129.93
158	18658	4153	5.637	9512	1111.55	129.91
159	23024	5125	5.586	12439	1303.54	152.20
160	23024	5125	5.586	12439	1303.42	152.19
161	26487	5896	5.705	12392	1468.32	171.82
162	26520	5903	5.697	12390	1468.52	171.82
163	31384	6986	5.435	19523	1701.01	198.05
164	31457	7002	5.421	19526	1710.10	199.05
165	34709	7726	5.542	19463	1865.90	217.69
166	34791	7744	5.527	19467	1850.87	215.88
167	37381	8321	5.644	19429	2034.95	237.86
168	37425	8330	5.637	19424	2044.06	238.89
169	8800	1958	4.633	9802	538.99	61.72
170	8800	1958	4.633	9798	539.10	61.73
171	46093	10260	4.464	19744	2355.05	268.64
172	46046	10249	4.470	19741	2337.63	266.69
173	42544	9470	4.413	19777	2154.63	245.48
174	42544	9470	4.413	19772	2164.85	246.65
175	38344	8535	4.344	19812	1993.67	226.77
176	38384	8544	4.339	19813	1971.57	224.23

THERMOCOUPLE STATION : 10

FLUID : DOWTHERM G
COIL DIAMETER = 20.64 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.023983

	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
433	282	43	164.466	2277	51.32	28.15
434	284	44	163.812	2277	51.55	28.28
435	267	41	150.591	2228	65.39	35.89
436	267	41	150.902	2227	65.32	35.85
437	249	38	140.424	2241	65.30	35.87
438	250	38	139.885	2243	65.87	36.18
439	236	36	127.557	2354	53.52	29.42
440	235	36	128.294	2353	53.22	29.25
441	230	35	119.342	2422	49.36	27.15
442	229	35	119.794	2419	49.15	27.03
443	217	33	102.142	2453	54.14	29.82
444	217	33	102.142	2453	54.41	29.97
445	213	32	81.889	2577	52.42	28.93
446	212	32	82.009	2579	52.08	28.74
447	104	16	122.595	1224	54.08	29.74
448	103	16	123.298	1225	52.86	29.07
449	95	14	79.661	1361	69.14	38.17
450	94	14	79.924	1357	69.87	38.57
451	17	2	102.398	592	73.73	40.61
452	17	2	102.933	589	72.62	39.99
453	29	4	184.117	407	52.41	28.72
454	29	4	183.737	405	54.21	29.71
455	88	13	64.730	1464	72.48	40.10
456	88	13	64.366	1466	72.61	40.18
457	118	18	152.961	1163	46.30	25.41
458	118	18	152.356	1161	46.78	25.68
459	240	37	120.010	2388	52.91	29.10
460	240	37	119.557	2390	52.87	29.08
461	249	38	135.619	2305	58.03	31.88
462	249	38	135.356	2308	58.04	31.89
463	268	41	152.034	2230	64.47	35.39
464	267	41	152.631	2229	64.06	35.16
465	289	44	166.999	2278	48.22	26.45
466	289	44	166.999	2278	48.24	26.46
467	436	67	138.486	3804	72.61	39.89
468	435	67	138.763	3803	72.73	39.95
469	457	70	148.240	3781	71.07	39.01
470	455	70	148.827	3778	70.97	38.96
471	477	73	156.577	3719	75.75	41.57
472	478	74	156.270	3716	76.26	41.85
473	500	77	164.093	3597	100.24	54.98
474	500	77	164.085	3596	100.30	55.02

THERMOCOUPLE STATION : 10

FLUID : DOWTHERM G
COIL DIAMETER = 9.99 INCHES TUBE-TO-COIL DIAMETER RATIO = 0.049550

RUN NUMBER	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	AVERAGE VALUES FOR THE THERMOCOUPLE STATION HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
302	486	108	161.605	3728	69.91	38.35
303	489	109	160.655	3728	70.01	38.41
304	923	205	85.799	8657	83.82	46.24
305	924	205	85.654	8660	83.64	46.14
306	987	219	101.269	8522	84.37	46.47
307	992	221	100.719	8518	84.54	46.56
308	536	119	170.361	3619	82.46	45.22
309	534	118	171.033	3616	82.39	45.18
310	492	109	161.932	3701	70.52	38.68
311	491	109	162.242	3701	70.43	38.64
312	451	100	151.516	3743	68.90	37.82
313	450	100	151.812	3742	68.91	37.82
314	431	96	143.754	3798	66.60	36.57
315	433	96	143.224	3797	66.81	36.69
316	403	89	127.105	3842	67.02	36.84
317	405	90	126.625	3842	67.11	36.89
318	267	59	151.531	2238	53.85	29.56
319	269	59	150.674	2238	54.19	29.74
320	244	54	128.831	2205	77.85	42.79
321	244	54	129.079	2202	78.16	42.96
322	234	52	115.423	2399	48.96	26.93
323	234	52	115.423	2400	48.65	26.76
324	111	24	154.543	1135	42.13	23.12
325	112	24	154.232	1131	42.90	23.54
326	85	19	69.566	1435	51.72	28.59
327	86	19	69.255	1435	52.05	28.78
328	31	7	182.949	377	37.80	20.72
329	31	7	183.672	379	36.91	20.23
330	277	61	156.348	2217	56.95	31.25
331	278	61	156.041	2216	57.02	31.29
332	250	55	146.337	2246	54.49	29.92
333	251	55	146.044	2245	54.64	30.00
334	244	54	130.584	2191	76.86	42.24
335	244	54	130.584	2188	77.30	42.48
336	228	50	118.727	2344	51.69	28.43
337	227	50	119.155	2344	51.40	28.27
338	220	49	102.929	2455	46.68	25.71
339	221	49	102.557	2457	46.67	25.70
340	120	26	161.997	1113	45.22	24.81
341	119	26	162.315	1112	44.95	24.66
342	101	22	143.567	1178	40.10	22.02
343	101	22	143.288	1177	40.40	22.19

THERMOCOUPLE STATION : 10

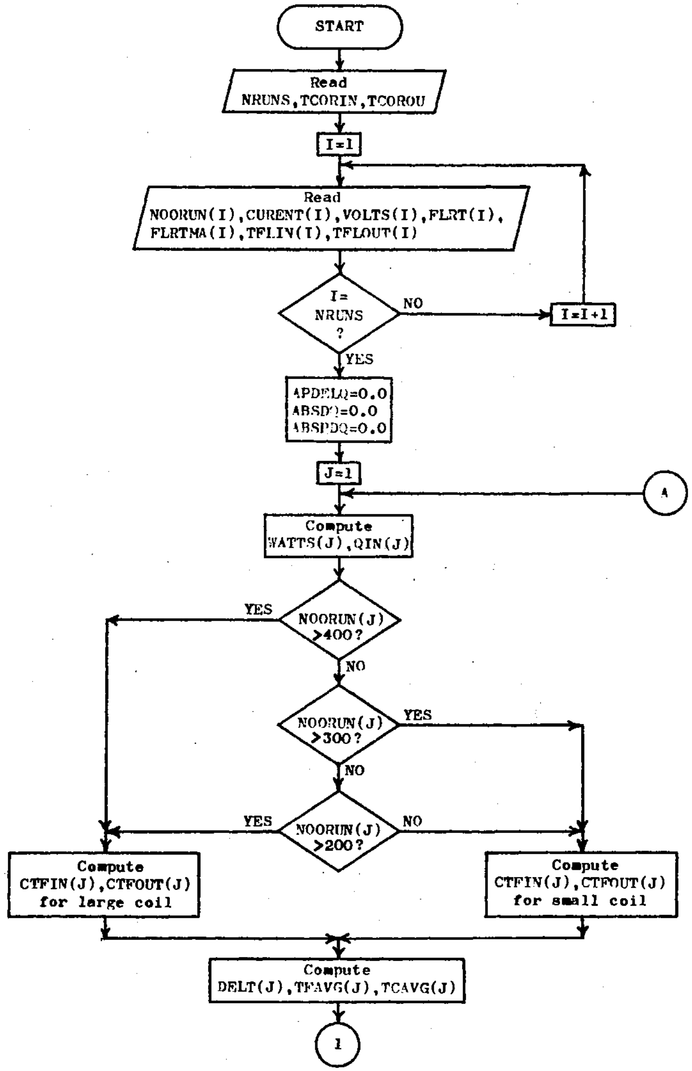
FLUID : DOWTHERM G
COIL DIAMETER = 9.99 INCHES   TUBE-TO-COIL DIAMETER RATIO = 0.049550

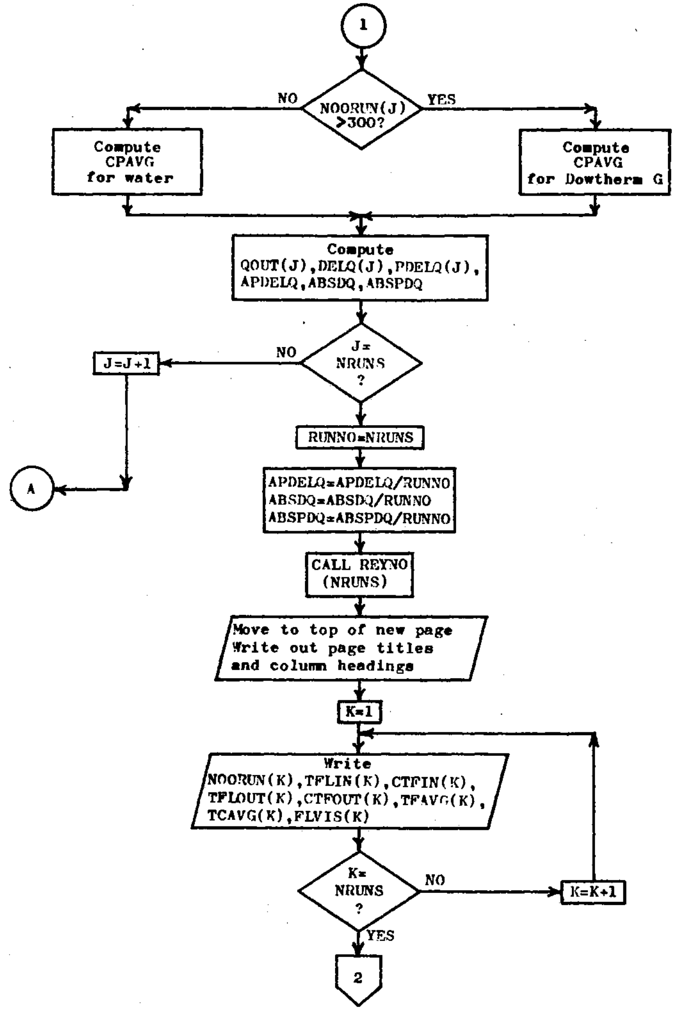
	AT THE AVERAGE BULK FLUID TEMPERATURE AT THE THERMOCOUPLE STATION			AVERAGE VALUES FOR THE THERMOCOUPLE STATION		
RUN NUMBER	REYNOLDS NUMBER RE	DEAN NUMBER DE	PRANDTL NUMBER PR	HEAT FLUX, BTU/HR-SQ.FT. Q/A	HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT.-F H	NUSSELT NUMBER NU
344	91	20	120.784	1217	45.26	24.89
345	91	20	120.561	1217	45.39	24.96
346	86	19	84.016	1346	52.75	29.10
347	86	19	84.301	1348	52.06	28.72
348	35	7	196.791	363	35.12	19.23
349	35	7	197.179	362	35.45	19.41
350	18	4	104.193	576	49.26	27.12
351	18	4	103.830	578	49.16	27.07
352	694	154	142.728	3687	89.26	49.02
353	695	154	142.449	3683	89.55	49.18
354	1105	246	129.670	5669	99.14	54.49
355	1105	246	129.670	5669	99.02	54.42
356	1321	294	140.007	5575	109.04	59.89
357	1321	294	140.014	5574	109.10	59.93
358	989	220	100.827	3857	85.08	46.86
359	993	221	100.457	3854	85.50	47.09
360	1259	280	109.453	3824	82.97	45.67
361	1254	279	109.866	3824	82.88	45.61
362	1053	234	96.453	3842	88.33	48.68
363	1052	234	96.625	3841	88.11	48.55
364	1318	293	104.597	3811	85.59	47.13
365	1321	294	104.394	3811	85.45	47.05
366	1873	416	99.769	5693	120.65	66.46
367	1887	420	99.038	5691	121.66	67.02
368	2210	492	103.210	5623	132.52	72.98
369	2206	491	103.399	5622	132.43	72.93
370	2824	628	97.235	8067	135.89	74.87
371	2824	628	97.238	8065	135.79	74.82

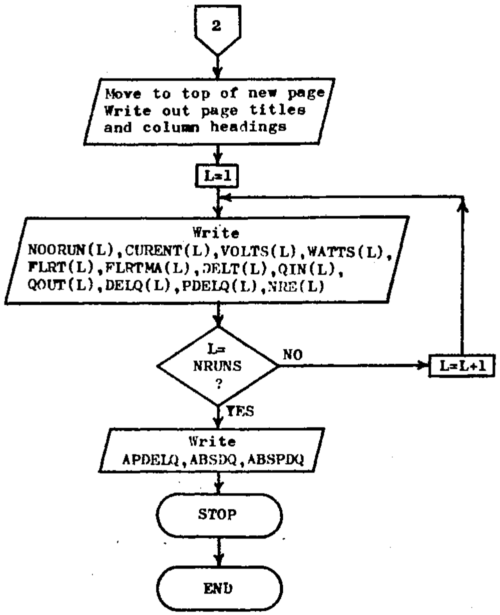
Figure 22. Flowchart for Computer Program SPNSOO

APPENDIX F

COMPUTER PROGRAM LISTINGS


START
Read
NRUNS,TCORIN,TCOROU
I=1
Read
NOORUN(I),CURENT(I),VOLTS(I),FLRT(I),
FLRTMA(I),TFLIN(I),TFLOUT(I)
I=
NRUNS
?
NO
I=I+1
YES
APDELQ=0.0
ABSDQ=0.0
ABSPDQ=0.0
J=1
A
Compute
WATTS(J),QIN(J)
YES
NOORUN(J)
>400?
NO
NOORUN(J)
>300?
YES
NO
YES
NOORUN(J)
>200?
NO
Compute
CTFIN(J),CTFOUT(J)
for large coil
Compute
CTFIN(J),CTFOUT(J)
for small coil
Compute
DELT(J),TFAVG(J),TCAVG(J)
1


1
NO
NOORUN(J)
>300?
YES
Compute
CPAVG
for water
Compute
CPAVG
for Dowtherm G
Compute
QOUT(J),DELQ(J),PDELQ(J),
APDELQ,ABSDQ,ABSPDQ
J=J+1
NO
J=
NRUNS
?
A
RUNNO=NRUNS
APDELQ=APDELQ/RUNNO
ABSDQ=ABSDQ/RUNNO
ABSPDQ=ABSPDQ/RUNNO
CALL REYNO
(NRUNS)
Move to top of new page
Write out page titles
and column headings
K=1
Write
NOORUN(K),TFLIN(K),CTFIN(K),
TFLOUT(K),CTFOUT(K),TFAVG(K),
TCAVG(K),FLVIS(K)
K=
NRUNS
?
NO
K=K+1
YES
2



SUBROUTINE REYNO:

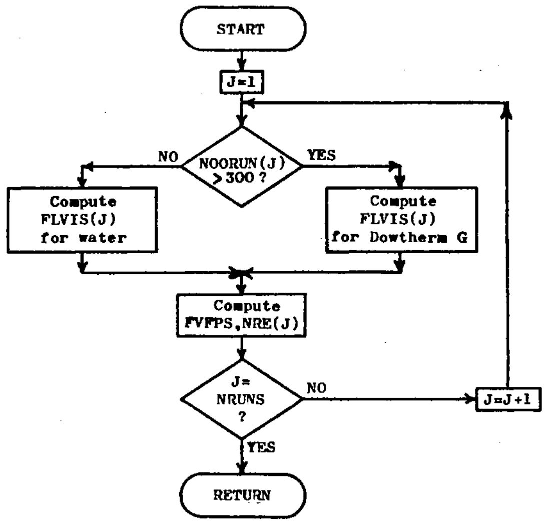
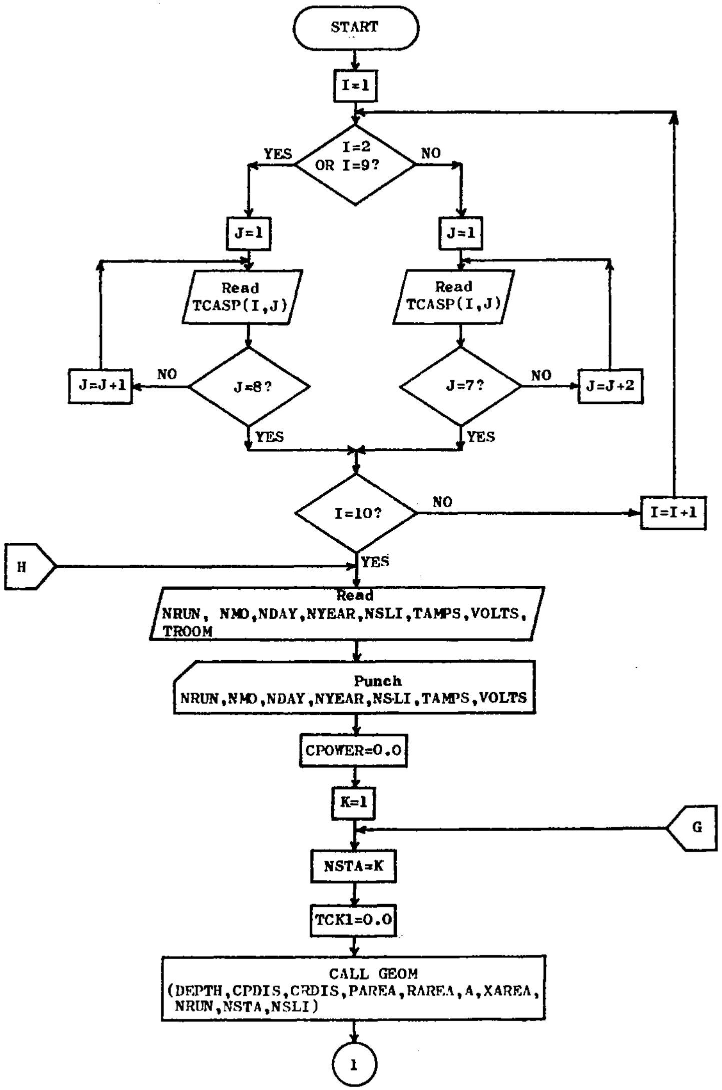


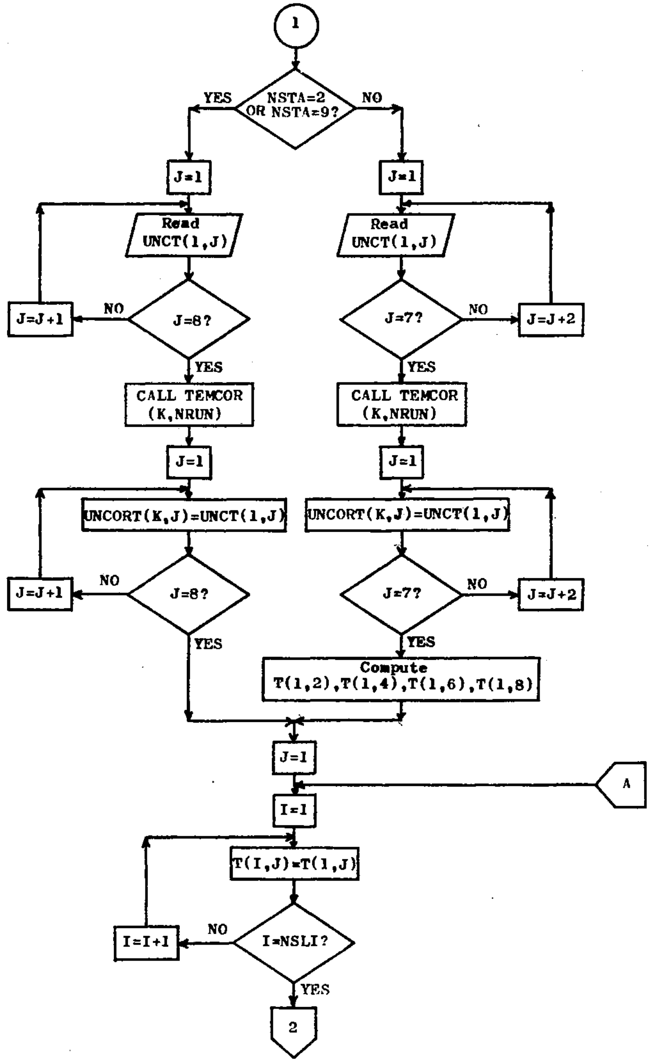
Figure 23. 80/80 Listing of Computer Program SPNSOO

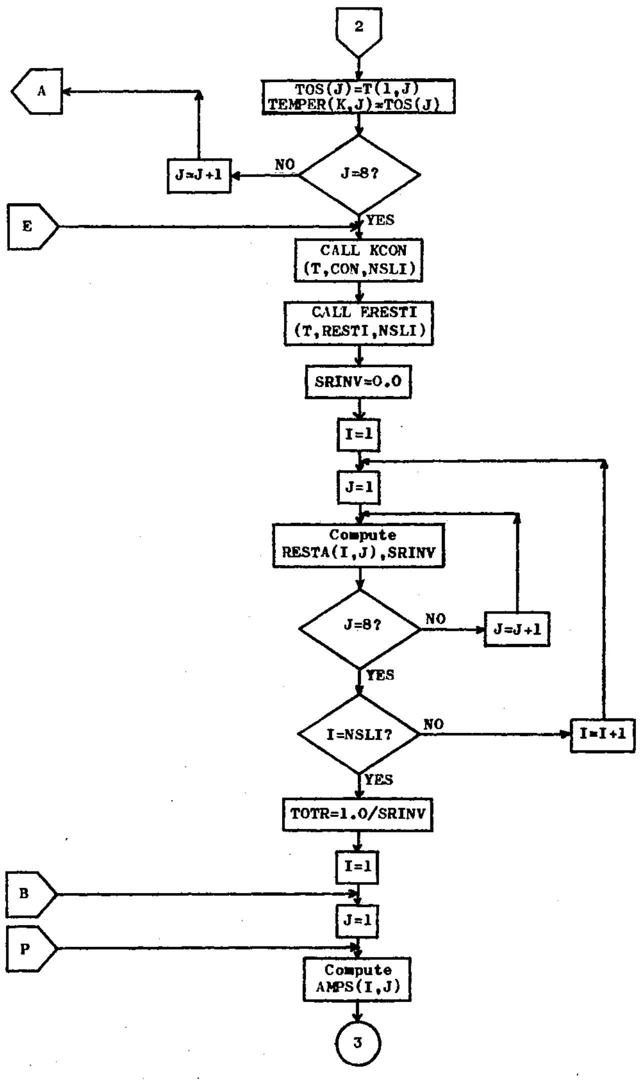
```
C
C @%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*
C
C COMPUTER PROGRAM: SPNS00.
C
C PROGRAM TO PERFORM HEAT BALANCE CALCULATIONS FOR EXPERIMENTAL DATA RUNS.   BY
C SUMAN P.N. SINGH.
C
C @%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*
C
      DIMENSION CURENT(30),VOLTS(30),FLRT(30),TFLIN(30),TFLOUT(30),WATTS
     1(30),QIN(30),QOUT(30),CTFIN(30),CTFOUT(30),PDELQ(30),DELQ(30),DELT
     2(30)
      COMMON/FLDPRP/TFAVG(30),TCAVG(30),FLRTMA(30),NRE(30),FLVIS(30),NOO
     1RUN(30)
      READ(5,100) NRUNS,TCORIN,TCOROU
  100 FORMAT(I2,2F10.5)
      READ(5,101)(NOORUN(I),CURENT(I),VOLTS(I),FLRT(I),FLRTMA(I),TFLIN(I
     1),TFLOUT(I),I=1,NRUNS)
  101 FORMAT(I3,F7.1,5F10.2)
      APDELQ=0.0
      ABSDQ=0.0
      ABSPDQ=0.0
      DO 1 J=1,NRUNS
      WATTS(J)=CURENT(J)*VOLTS(J)
      QIN(J)=WATTS(J)*3.4128
      IF(NOORUN(J).GT.400) GO TO 5
      IF(NOORUN(J).GT.300) GO TO 4
      IF(NOORUN(J).GT.200) GO TO 5
    4 CTFIN(J)=TFLIN(J)+((TCORIN/(210.583-75.58))*(TFLIN(J)-75.58))
      CTFOUT(J)=TFLOUT(J)+((TCOROU/(210.385-75.58))*(TFLOUT(J)-75.58))
      GO TO 6
    5 CTFIN(J)=TFLIN(J)+((TCORIN/(210.357-76.35))*(TFLIN(J)-76.35))
      CTFOUT(J)=TFLOUT(J)+((TCOROU/(210.128-76.35))*(TFLOUT(J)-76.35))
    6 DELT(J)=CTFOUT(J)-CTFIN(J)
      TFAVG(J)=(CTFOUT(J)+CTFIN(J))/2.0
      TCAVG(J)=((TFAVG(J)-32.0)*5.0)/9.0
      IF(NOORUN(J).GT.300) GO TO 7
      CPAVG=1.01881-0.4802E-03*TFAVG(J)+0.3274E-05*TFAVG(J)*TFAVG(J)-0.6
     104E-08*TFAVG(J)*TFAVG(J)*TFAVG(J)
      GO TO 8
    7 CPAVG=0.369356+0.20216E-03*TFAVG(J)+0.8285E-06*TFAVG(J)*TFAVG(J)-0
     1.19987E-08*TFAVG(J)*TFAVG(J)*TFAVG(J)
    8 QOUT(J)=FLRTMA(J)*CPAVG*DELT(J)
      DELQ(J)=QIN(J)-QOUT(J)
      PDELQ(J)=(DELQ(J)/QIN(J))*100.00
      APDELQ=APDELQ+PDELQ(J)
      ABSDQ=ABSDQ+ABS(DELQ(J))
      ABSPDQ=ABSPDQ+ABS(PDELQ(J))
    1 CONTINUE
      RUNNO=NRUNS
      APDELQ=APDELQ/RUNNO
      ABSDQ=ABSDQ/RUNNO
      ABSPDQ=ABSPDQ/RUNNO
      CALL REYNO(NRUNS)
      WRITE(6,200)
  200 FORMAT(1H1,///,5X,48HHEAT BALANCE CALCULATIONS FOR EXPERIMENTAL RU
     1NS.,15X,17HSUMAN P.N. SINGH.,//)
      WRITE(6,201)
  201 FORMAT(5X,49HCOIL USED :SMALL. DIAMETER OF COIL:  9.99 INCHES.,/)
      WRITE(6,202)
  202 FORMAT(5X,23HFLUID USED :DOWTHERM G.,/)
      WRITE(6,203)
  203 FORMAT(5X,20HROTAMETER USED : 2 .,//)
      WRITE(6,204)
  204 FORMAT(5X,6H  RUN ,5X,27HINLET FLUID TEMPERATURE, F ,5X,27HEXIT FL
     1UID TEMPERATURE, F  ,5X,23H AVG. FLUID TEMPERATURE,5X,15HFLUID VIS
     2COSITY)
      WRITE(6,205)
  205 FORMAT(5X,6HNUMBER,5X,12HEXPERIMENTAL,5X,10HCORRECTED ,5X,12HEXPER
     1IMENTAL,5X,10HCORRECTED ,9X,1HF,13X,1HC,16X,2HCP,//)
      DO 2 K=1,NRUNS
      WRITE(6,206) NOORUN(K),TFLIN(K),CTFIN(K),TFLOUT(K),CTFOUT(K),TFAVG
     1(K),TCAVG(K),FLVIS(K)
  206 FORMAT(7X,I3,4(9X,F7.2),6X,F7.2,7X,F7.2,11X,F7.4)
    2 CONTINUE
      WRITE(6,200)
      WRITE(6,202)
      WRITE(6,203)
      WRITE(6,215)
  215 FORMAT(5X,58HNOTE: GPMWS= GALLONS/MINUTE ON WATER SCALE ON ROTAMET
     1ER 2.,//)
      WRITE(6,207)
  207 FORMAT(59X,10H DELTA  T  ,27X,8HDELTA Q=,12X,6HRE AT )
      WRITE(6,208)
  208 FORMAT(59X,10H TOUT-TIN ,3X,8H   QIN  ,3X,10H   QOUT   ,3X,8HQIN-Q
     1OUT,12X,6H AVG. )
      WRITE(6,209)
  209 FORMAT(3X,3HRUN,3X,5H  I  ,3X,5H  V  ,3X,7H   W   ,3X,21H  FLOW RA
     1TE OF FLUID ,3X,10H CONAX TCS,3X,8HW*3.4128,3X,10HMCPDELTA T,3X,8H
     2   DQ   ,3X,6HDQ/QIN,3X,6HFLUID )
      WRITE(6,210)
  210 FORMAT(3X,3HNO.,3X,5H AMPS,3X,5HVOLTS,3X,7H WATTS ,3X,10H   GPMWS
     1 ,3X,8H  LB/HR ,3X,10H     F     ,3X,8H BTU/HR ,3X,10H  BTU/HR  ,3X
     2,8H BTU/HR ,3X,6H  %   ,3X,6HTEMP. ,/)
      DO 3 L=1,NRUNS
      WRITE(6,211) NOORUN(L),CURENT(L),VOLTS(L),WATTS(L),FLRT(L),FLRTMA(
     1L),DELT(L),QIN(L),QOUT(L),DELQ(L),PDELQ(L),NRE(L)
  211 FORMAT(3X,I3,3X,F5.1,3X,F5.2,3X,F7.1,3X,F6.1,6X,F8.2,6X,F6.2,4X,F8
     1.2,4X,F8.2,4X,F8.2,3X,F6.2,3X,I6)
    3 CONTINUE
      WRITE(6,212) APDELQ
  212 FORMAT(//,5X,29HAVERAGE PERCENT DIFFERENCE = ,F6.2,3H %.)
      WRITE(6,213) ABSDQ
  213 FORMAT(/,5X,28HAVERAGE ABSOLUTE DEVIATION =,F10.3,8H BTU/HR.)
      WRITE(6,214) ABSPDQ
  214 FORMAT(/,5X,36HAVERAGE ABSOLUTE PERCENT DEVIATION =,F6.2,3H %.)
      STOP
```

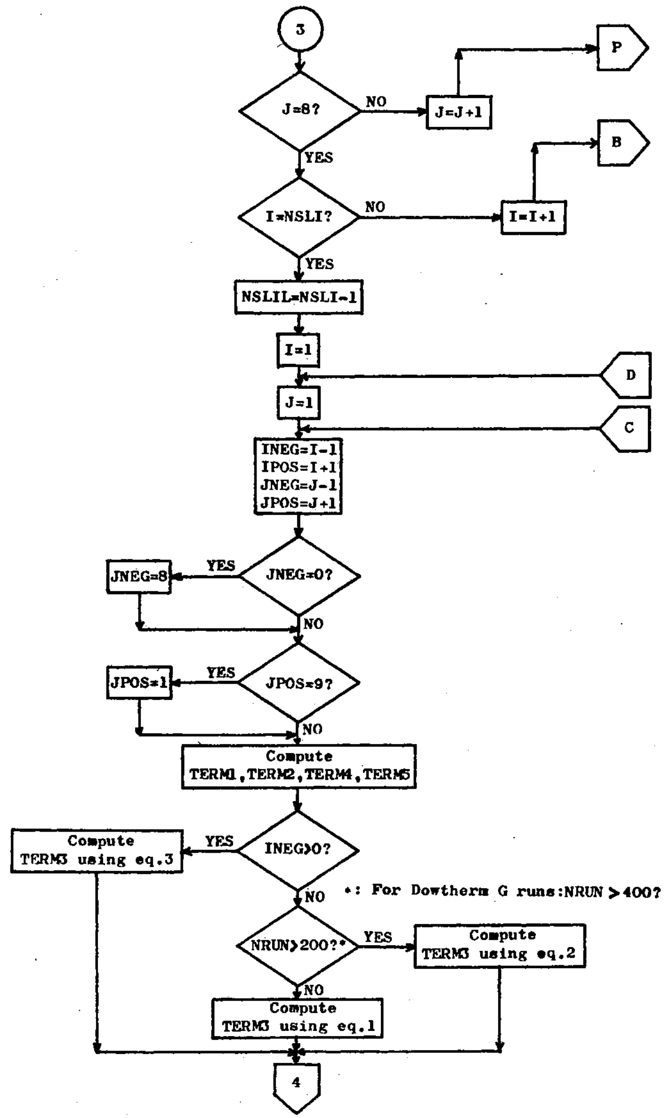
```
      END


      SUBROUTINE REYNO(NRUNS)
C
      COMMON/FLDPRP/TFAVG(30),TCAVG(30),FLRTMA(30),NRE(30),FLVIS(30),NDO
     1RUN(30)
      DO 1 J=1,NRUNS
      IF(NDORUN(J).GT.300) GO TO 2
      RHSVR=((1.3272*(20.0-TCAVG(J)))-(0.001053*(TCAVG(J)-20.0)*(TCAVG(J
     1)-20.0)))/(TCAVG(J)+105.0)
      RHSLN=2.303*RHSVR
      FLVIS(J)=1.002*EXP(RHSLN)
      GO TO 3
    2 FLVIS(J)=0.105786E+03-0.16867E+01*TFAVG(J)+0.1058E-01*TFAVG(J)*TFA
     1VG(J)-0.29936E-04*TFAVG(J)*TFAVG(J)*TFAVG(J)+0.31814E-07*TFAVG(J)*
     2TFAVG(J)*TFAVG(J)*TFAVG(J)
    3 FVFPS=2.42*FLVIS(J)
      DMLSRE=((0.495/12.0)*FLRTMA(J))/((3.1416/4.0)*(0.495*0.495/144.0)*
     1FVFPS)
      NRE(J)=DMLSRE
    1 CONTINUE
      RETURN
      END
```

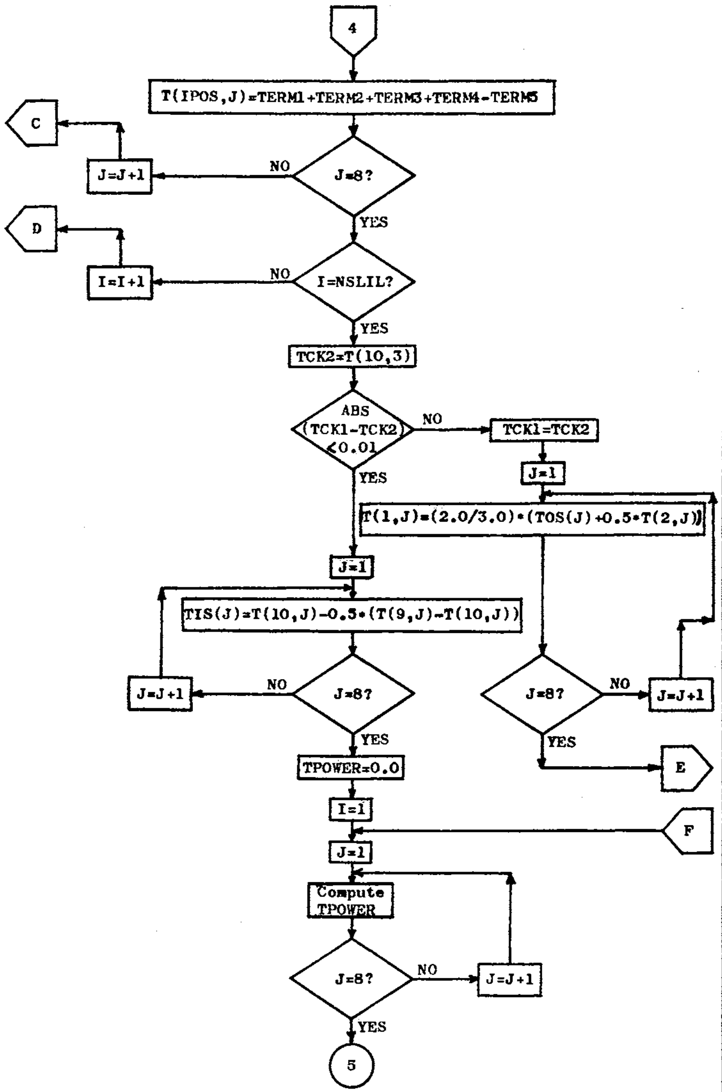
Figure 24. Flowchart for Computer Program SPNS01

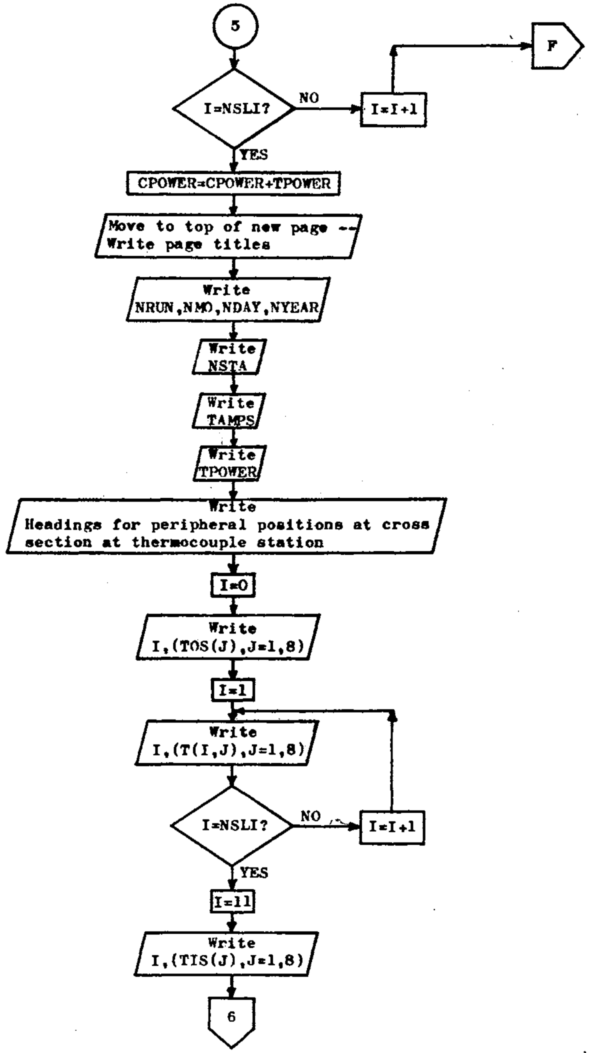

START
I=1
I=2 OR I=9?
YES
NO
J=1
J=1
Read TCASP(I,J)
Read TCASP(I,J)
J=8?
J=7?
NO
NO
J=J+1
J=J+2
YES
YES
I=10?
NO
I=I+1
YES
H
Read NRUN, NMO,NDAY,NYEAR,NSLI,TAMPS,VOLTS, TROOM
Punch NRUN,NMO,NDAY,NYEAR,NSLI,TAMPS,VOLTS
CPOWER=0.0
K=1
G
NSTA=K
TCK1=0.0
CALL GEOM (DEPTH,CPDIS,CRDIS,PAREA,RAREA,A,XAREA, NRUN,NSTA,NSLI)
1

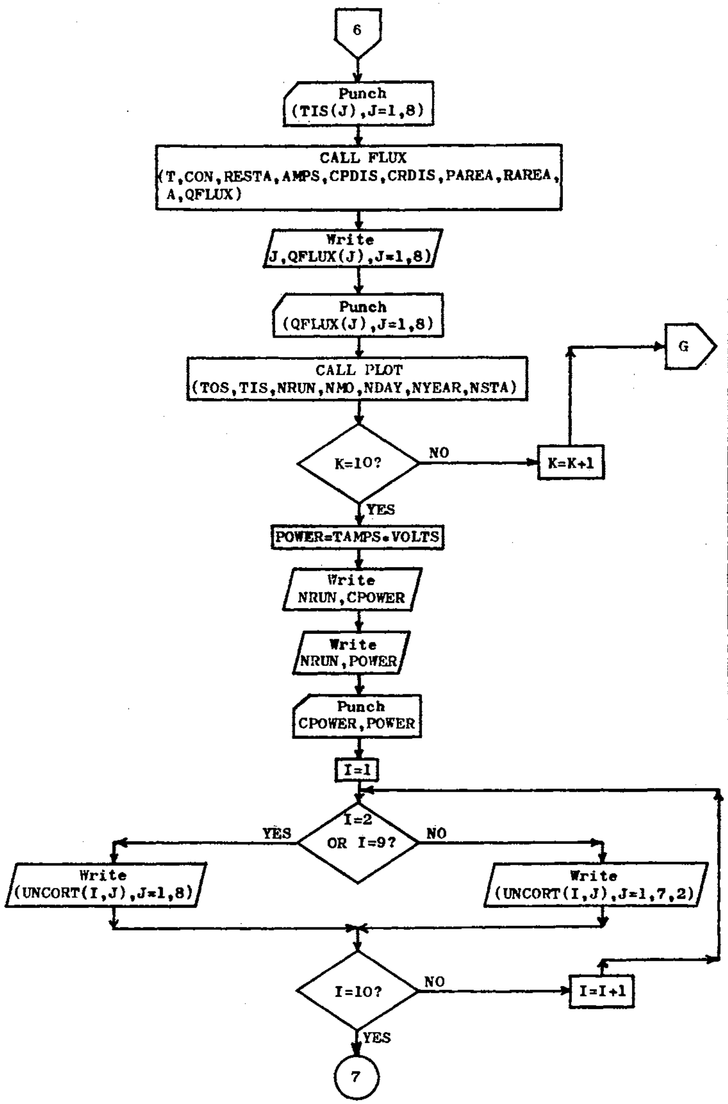

1
NSTA=2 OR NSTA=9?
YES
NO
J=1
J=1
Read UNCT(1,J)
Read UNCT(1,J)
J=8?
J=7?
NO
NO
J=J+1
J=J+2
YES
YES
CALL TEMCOR (K,NRUN)
CALL TEMCOR (K,NRUN)
J=1
J=1
UNCORT(K,J)=UNCT(1,J)
UNCORT(K,J)=UNCT(1,J)
J=8?
J=7?
NO
NO
J=J+1
J=J+2
YES
YES
Compute T(1,2),T(1,4),T(1,6),T(1,8)
J=1
A
I=1
T(I,J)=T(1,J)
I=NSLI?
NO
I=I+1
YES
2

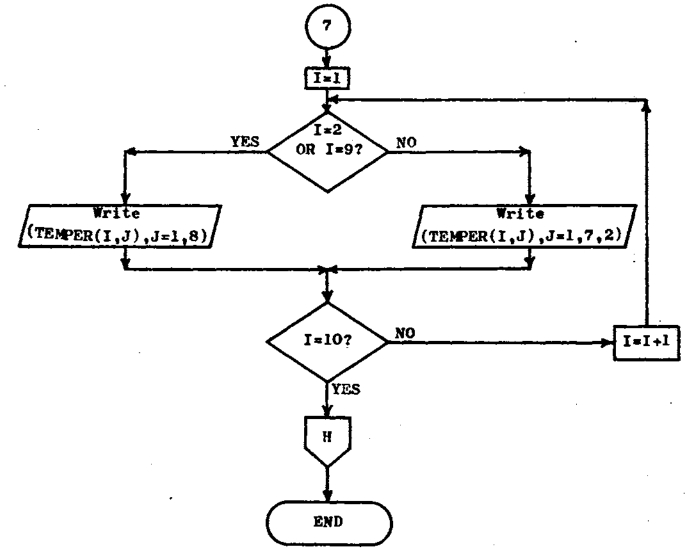

2
TOS(J)=T(1,J)
TEMPER(K,J)=TOS(J)
J=8?
NO
J=J+1
A
YES
E
CALL KCON
(T,CON,NSLI)
CALL ERESTI
(T,RESTI,NSLI)
SRINV=0.0
I=1
J=1
Compute
RESTA(I,J),SRINV
J=8?
NO
J=J+1
YES
I=NSLI?
NO
I=I+1
YES
TOTR=1.0/SRINV
I=1
B
J=1
P
Compute
AMPS(I,J)
3


3
J=8?
NO
J=J+1
P
YES
I=NSLI?
NO
I=I+1
B
YES
NSLIL=NSLI-1
I=1
D
J=1
C
INEG=I-1
IPOS=I+1
JNEG=J-1
JPOS=J+1
JNEG=0?
YES
JNEG=8
NO
JPOS=9?
YES
JPOS=1
NO
Compute
TERM1,TERM2,TERM4,TERM5
INEG>0?
YES
Compute
TERM3 using eq.3
NO
*: For Dowtherm G runs:NRUN >400?
NRUN>200?*
YES
Compute
TERM3 using eq.2
NO
Compute
TERM3 using eq.1
4

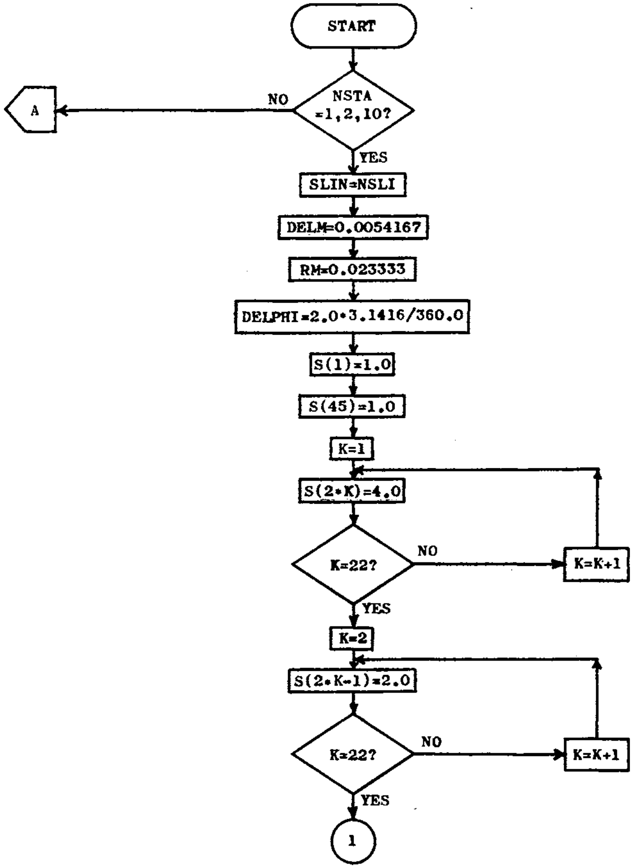

4
T(IPOS,J)=TERM1+TERM2+TERM3+TERM4-TERM5
J=8?
NO
J=J+1
C
YES
I=NSLIL?
NO
I=I+1
D
YES
TCK2=T(10,3)
ABS
(TCK1-TCK2)
<0.01
NO
TCK1=TCK2
J=1
T(1,J)=(2.0/3.0)*(TOS(J)+0.5*T(2,J))
J=8?
NO
J=J+1
YES
E
YES
J=1
TIS(J)=T(10,J)-0.5*(T(9,J)-T(10,J))
J=8?
NO
J=J+1
YES
TPOWER=0.0
I=1
F
J=1
Compute
TPOWER
J=8?
NO
J=J+1
YES
5

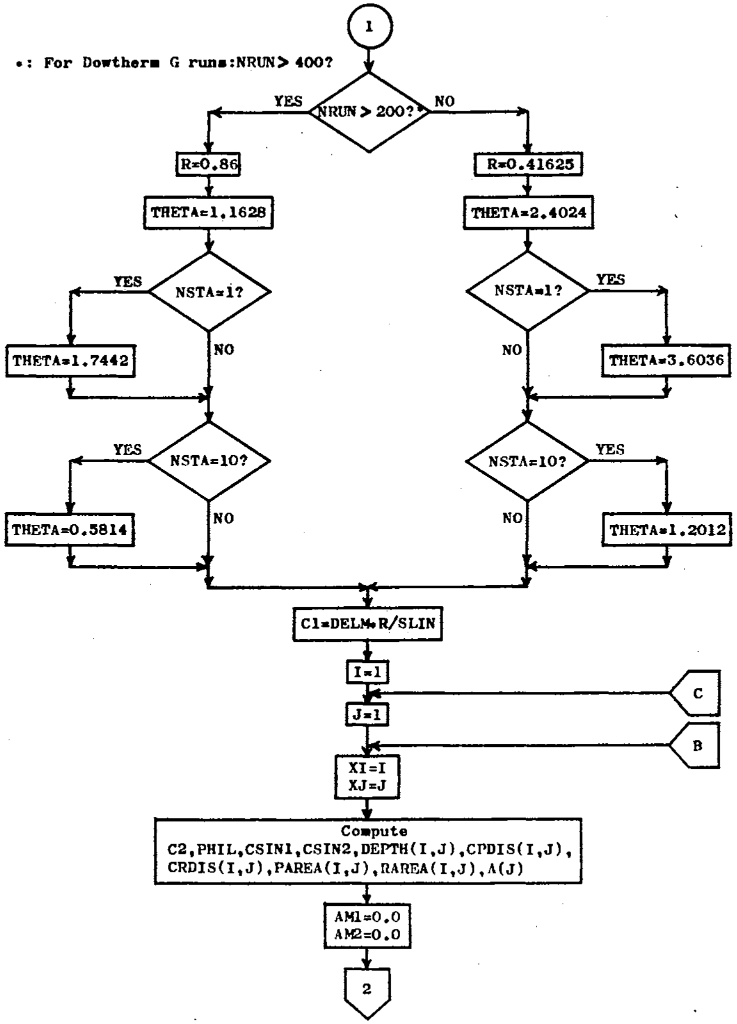

5
I=NSLI?
NO
I=I+1
F
YES
CPOWER=CPOWER+TPOWER
Move to top of new page --
Write page titles
Write
NRUN,NMO,NDAY,NYEAR
Write
NSTA
Write
TAMPS
Write
TPOWER
Write
Headings for peripheral positions at cross
section at thermocouple station
I=0
Write
I,(TOS(J),J=1,8)
I=1
Write
I,(T(I,J),J=1,8)
I=NSLI?
NO
I=I+1
YES
I=11
Write
I,(TIS(J),J=1,8)
6

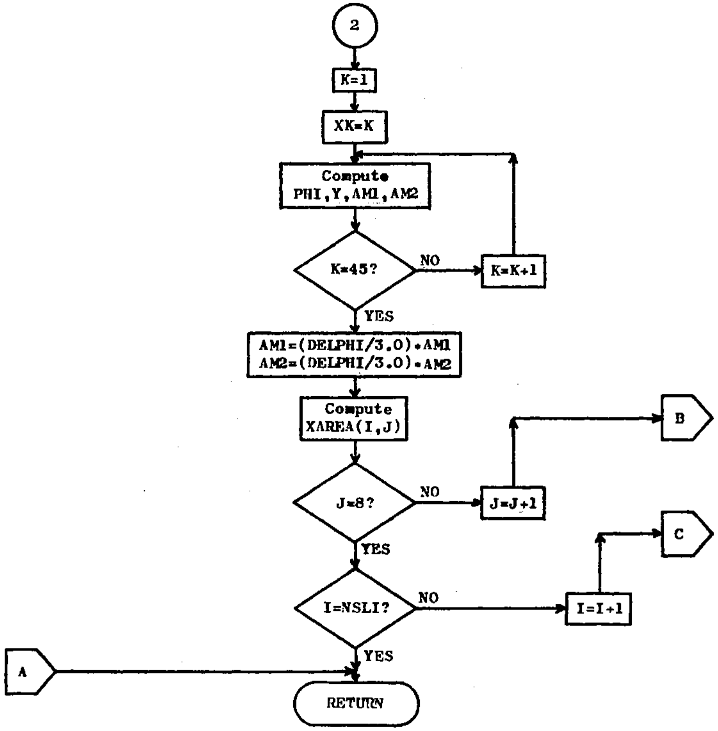

6
Punch
(TIS(J),J=1,8)
CALL FLUX
(T,CON,RESTA,AMPS,CPDIS,CRDIS,PAREA,RAREA,
A,QFLUX)
Write
J,QFLUX(J),J=1,8)
Punch
(QFLUX(J),J=1,8)
CALL PLOT
(TOS,TIS,NRUN,NMO,NDAY,NYEAR,NSTA)
K=10?
NO
K=K+1
G
YES
POWER=TAMPS*VOLTS
Write
NRUN,CPOWER
Write
NRUN,POWER
Punch
CPOWER,POWER
I=1
I=2
OR I=9?
YES
NO
Write
(UNCORT(I,J),J=1,8)
Write
(UNCORT(I,J),J=1,7,2)
I=10?
NO
I=I+1
YES
7


7
I=1
I=2
OR I=9?
YES
NO
Write
(TEMPER(I,J),J=1,8)
Write
(TEMPER(I,J),J=1,7,2)
I=10?
NO
I=I+1
YES
H
END

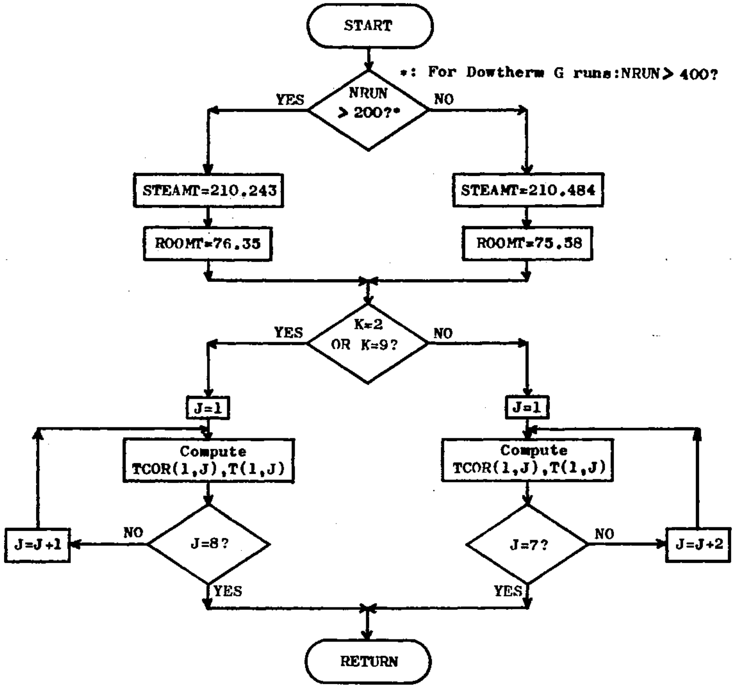
SUBROUTINE GEOM:



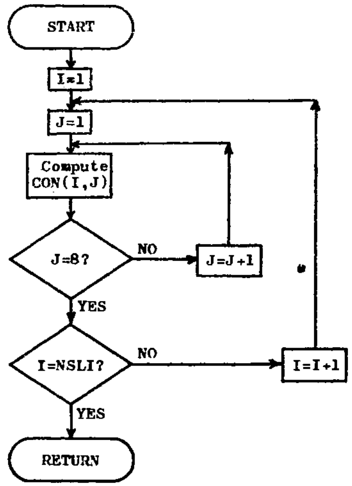




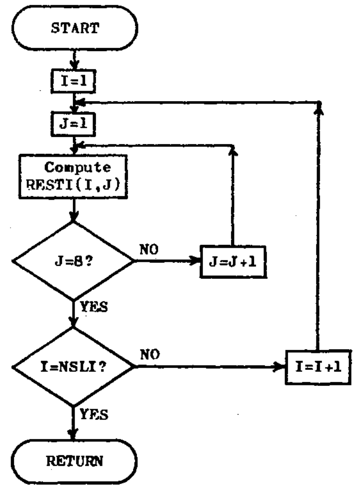
SUBROUTINE TEMCOR:



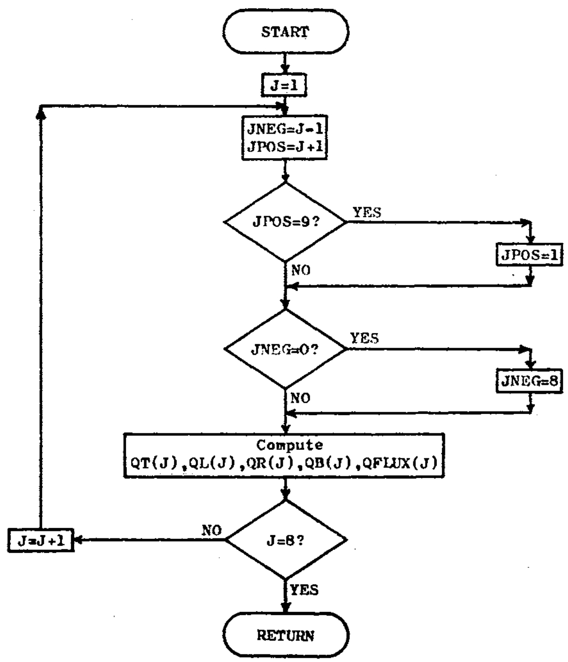
SUBROUTINE KCON:



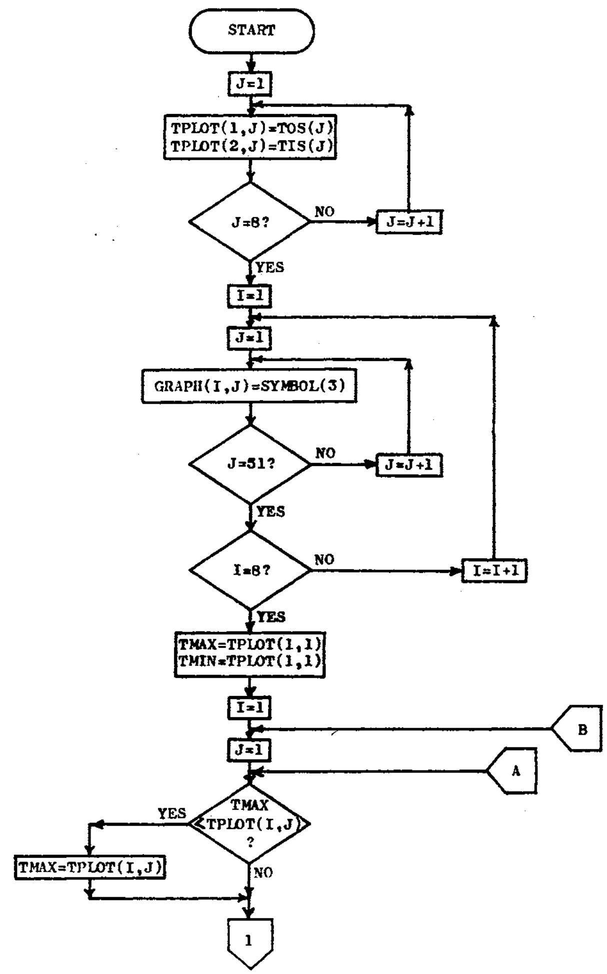
SUBROUTINE ERESTI:

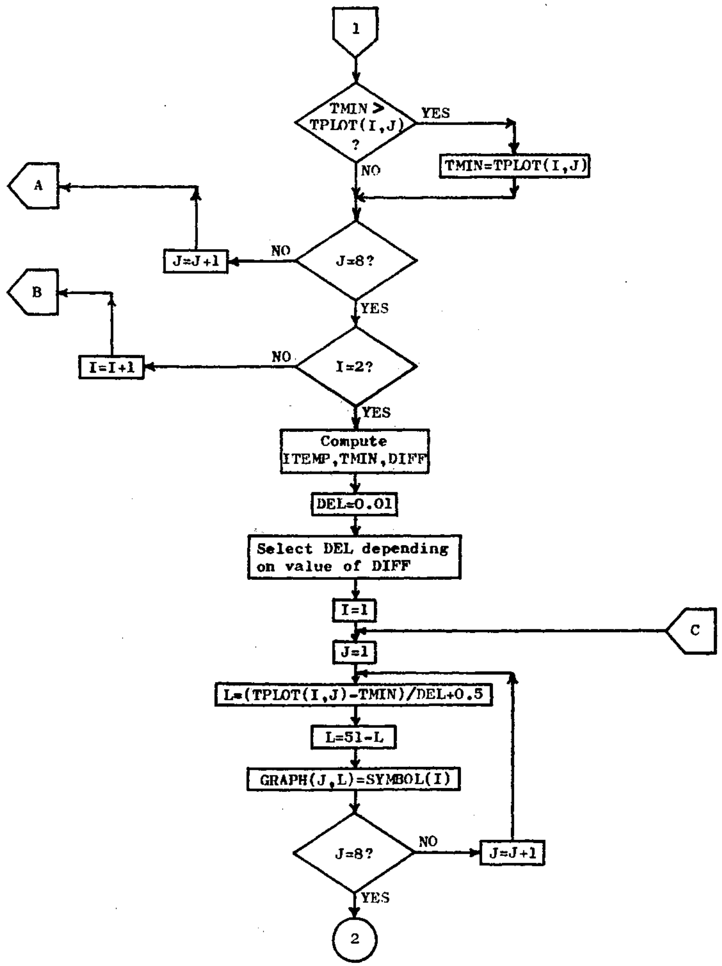


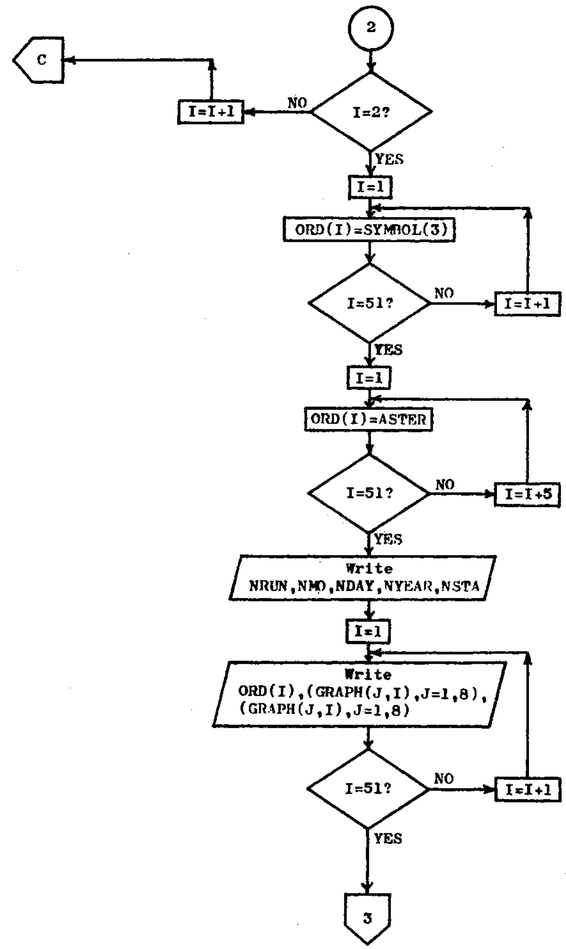
SUBROUTINE FLUX:



SUBROUTINE PLOT:




1
TMIN > TPLOT(I,J) ?
YES
TMIN=TPLOT(I,J)
NO
A
J=J+1
NO
J=8?
YES
B
I=I+1
NO
I=2?
YES
Compute ITEMP,TMIN,DIFF
DEL=0.01
Select DEL depending on value of DIFF
I=1
C
J=1
L=(TPLOT(I,J)-TMIN)/DEL+0.5
L=51-L
GRAPH(J,L)=SYMBOL(I)
J=8?
NO
J=J+1
YES
2


2
C
I=I+1
NO
I=2?
YES
I=1
ORD(I)=SYMBOL(3)
I=51?
NO
I=I+1
YES
I=1
ORD(I)=ASTER
I=51?
NO
I=I+5
YES
Write NRUN,NMO,NDAY,NYEAR,NSTA
I=1
Write ORD(I),(GRAPH(J,I),J=1,8), (GRAPH(J,I),J=1,8)
I=51?
NO
I=I+1
YES
3

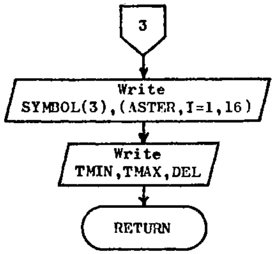

3
Write
SYMBOL(3),(ASTER,I=1,16)
Write
TMIN,TMAX,DEL
RETURN

Figure 25. 80/80 Listing of Computer Program SPNS01

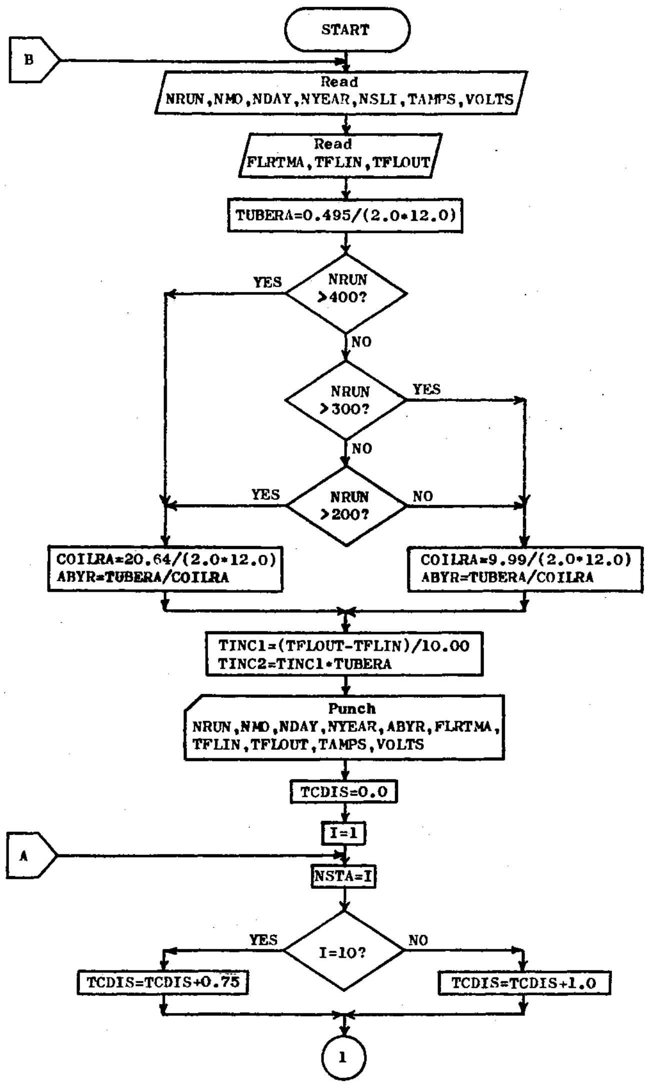
```
C
C a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*
C
C COMPUTER PROGRAM: SPNS01.
C
C PROGRAM TO COMPUTE THE INSIDE WALL TEMPERATURE FROM THE EXPERIMENTALLY
C MEASURED OUTSIDE WALL TEMPERATURES FOR LIQUID PHASE HEAT TRANSFER STUDIES IN
C HELICALLY COILED TUBES.   BY SUMAN P.N. SINGH.
C
C a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*
C
      DIMENSION T(10,8),TOS(8),TIS(8),CON(10,8),RESTI(10,8),RESTA(10,8),
     1AMPS(10,8),DEPTH(10,8),CPDIS(10,8),CRDIS(10,8),PAREA(10,8),RAREA(1
     20,8),A(8),XAREA(10,8),QFLUX(8),TCASP(10,8),UNCT(1,8),TEMPER(10,8),
     3UNCORT(10,8)
      COMMON/CORDAT/UNCT,TCASP,T
  100 FORMAT(5I5,3F10.2)
  101 FORMAT(4F10.5)
  102 FORMAT(8F10.5)
  103 FORMAT(4F10.1)
  104 FORMAT(8F10.1)
  200 FORMAT(1H1,49HCALCULATION OF INSIDE TEMPERATURES     SUMAN SINGH)
  201 FORMAT(1X,12HRUN NUMBER =,I4,I10,1H/,I3,1H/,I3)
  202 FORMAT(1X,16HSTATION NUMBER =,I3)
  203 FORMAT(1X,17HCURRENT IN COIL =,F6.1,5H AMPS)
  204 FORMAT(1X,39HTOTAL POWER GENERATED IN THIS SEGMENT =,F8.2,6H WATTS
     1/)
  205 FORMAT(3X,1H1,5X,1H0,8X,2H45,7X,2H90,7X,3H135,6X,3H180,6X,3H225,6X
     1,3H270,6X,3H315/)
  206 FORMAT(1X,I3,8F9.2)
  207 FORMAT(1H )
  208 FORMAT(1X,6HQFLUX(,I1,3H) =,E14.7,27H BTU PER SQUARE FOOT PER HR)
  209 FORMAT(1H1,35HCALCULATED POWER GENERATION FOR RUN,I4,2H =,F9.2,6H
     1WATTS/)
  210 FORMAT(1X,31HACTUAL POWER GENERATION FOR RUN,I4,2H =,F9.2,6H WATTS
     1)
  300 FORMAT(5I5,2E20.7)
  301 FORMAT(4E20.7)
  302 FORMAT(2E20.7)
      DO 2 I=1,10
      IF(I.EQ.2.OR.I.EQ.9) GO TO 1
      READ(5,101)(TCASP(I,J),J=1,7,2)
      GO TO 2
    1 READ(5,102)(TCASP(I,J),J=1,8)
    2 CONTINUE
   10 READ(5,100)NRUN,NMO,NDAY,NYEAR,NSLI,TAMPS,VOLTS,TROOM
      WRITE(7,300)NRUN,NMO,NDAY,NYEAR,NSLI,TAMPS,VOLTS
      CPOWER=0.0
      DO 27 K=1,10
      NSTA=K
      TCK1=0.0
      CALL GEOM(DEPTH,CPDIS,CRDIS,PAREA,RAREA,A,XAREA,NRUN,NSTA,NSLI)
      IF(NSTA.EQ.2.OR.NSTA.EQ.9)GO TO 12
      READ(5,103)(UNCT(1,J),J=1,7,2)
      CALL TEMCOR(K,NRUN)
      DO 3 J=1,7,2
      UNCORT(K,J)=UNCT(1,J)
    3 CONTINUE
      T(1,2)=(T(1,1)+T(1,3))/2.0
      T(1,4)=(T(1,3)+T(1,5))/2.0
      T(1,6)=(T(1,5)+T(1,7))/2.0
      T(1,8)=(T(1,7)+T(1,1))/2.0
      GO TO 13
   12 READ(5,104)(UNCT(1,J),J=1,8)
      CALL TEMCOR(K,NRUN)
      DO 4 J=1,8
      UNCORT(K,J)=UNCT(1,J)
    4 CONTINUE
   13 CONTINUE
      DO 15 J=1,8
      DO 14 I=1,NSLI
      T(I,J)=T(1,J)
   14 CONTINUE
      TOS(J)=T(1,J)
      TEMPER(K,J)=TOS(J)
   15 CONTINUE
   16 CALL KCON(T,CON,NSLI)
      CALL ERESTI(T,RESTI,NSLI)
      SRINV=0.0
      DO 17 I=1,NSLI
      DO 17 J=1,8
      RESTA(I,J)=RESTI(I,J)*DEPTH(I,J)/XAREA(I,J)
      SRINV=SRINV+1.0/RESTA(I,J)
   17 CONTINUE
      TOTR=1.0/SRINV
      DO 18 I=1,NSLI
      DO 18 J=1,8
      AMPS(I,J)=TAMPS*TOTR/RESTA(I,J)
   18 CONTINUE
      NSLIL=NSLI-1
      DO 21 I=1,NSLIL
      DO 21 J=1,8
      INEG=I-1
      IPOS=I+1
      JNEG=J-1
      JPOS=J+1
      IF(JNEG.EQ.0)JNEG=8
      IF(JPOS.EQ.9)JPOS=1
      TERM1=(PAREA(I,J)/RAREA(IPOS,J))*(CRDIS(IPOS,J)/CPDIS(I,J))*((CON(
     1I,J)+CON(I,JNEG))/(CON(I,J)+CON(IPOS,J)))*(T(I,J)-T(I,JNEG))
      TERM2=(PAREA(I,JPOS)/RAREA(IPOS,J))*(CRDIS(IPOS,J)/CPDIS(I,JPOS))*
     1((CON(I,J)+CON(I,JPOS))/(CON(I,J)+CON(IPOS,J)))*(T(I,J)-T(I,JPOS))
      TERM4=T(I,J)
      TERM5=2.0*CRDIS(IPOS,J)*(DEPTH(I,J)/(XAREA(I,J)*RAREA(IPOS,J)))*3.
     14128*RESTI(I,J)*AMPS(I,J)*AMPS(I,J)/(CON(I,J)+CON(IPOS,J))
      IF(INEG.GT.0)GO TO 19
      IF(NRUN.GT.400) GO TO 9
      IF(NRUN.GT.300) GO TO 28
```

```
      IF(NRUN.GT.200) GO TO 9
28    TERM3=-1321.87*RAREA(I,J)*CRDIS(IPOS,J)*(TOS(J)-TROOM)/(134.9*RARE
     1A(IPOS,J)*(CON(I,J)+CON(IPOS,J)))
      GO TO 20
 9    TERM3=-1334.42*RAREA(I,J)*CRDIS(IPOS,J)*(TOS(J)-TROOM)/(133.89*RAR
     1EA(IPOS,J)*(CON(I,J)+CON(IPOS,J)))
      GO TO 20
19    TERM3=(RAREA(I,J)/RAREA(IPOS,J))*(CRDIS(IPOS,J)/CRDIS(I,J))*((CON(
     1I,J)+CON(INEG,J))/(CON(I,J)+CON(IPOS,J)))*(T(I,J)-T(INEG,J))
20    T(IPOS,J)=TERM1+TERM2+TERM3+TERM4-TERM5
21    CONTINUE
      TCK2=T(10,3)
      IF(ABS(TCK1-TCK2).LT.0.01)GO TO 23
      TCK1=TCK2
      DO 22 J=1,8
      T(1,J)=(2.0/3.0)*(TOS(J)+0.5*T(2,J))
22    CONTINUE
      GO TO 16
23    DO 24 J=1,8
      TIS(J)=T(10,J)-0.5*(T(9,J)-T(10,J))
24    CONTINUE
      TPOWER=0.0
      DO 25 I=1,NSLI
      DO 25 J=1,8
      TPOWER=TPOWER+RESTA(I,J)*AMPS(I,J)*AMPS(I,J)
25    CONTINUE
      CPOWER=CPOWER+TPOWER
      WRITE(6,200)
      WRITE(6,201)NRUN,NMO,NDAY,NYEAR
      WRITE(6,202)NSTA
      WRITE(6,203)TAMPS
      WRITE(6,204)TPOWER
      WRITE(6,205)
      I=0
      WRITE(6,206)I,(TOS(J),J=1,8)
      WRITE(6,207)
      DO 26 I=1,NSLI
      WRITE(6,206)I,(T(I,J),J=1,8)
26    CONTINUE
      WRITE(6,207)
      I=11
      WRITE(6,206)I,(TIS(J),J=1,8)
      WRITE(7,301)(TIS(J),J=1,8)
      CALL FLUX(T,CON,RESTA,AMPS,CPDIS,CRDIS,PAREA,RAREA,A,QFLUX)
      WRITE(6,207)
      WRITE(6,208)(J,QFLUX(J),J=1,8)
      WRITE(7,301)(QFLUX(J),J=1,8)
      CALL PLOT(TOS,TIS,NRUN,NMO,NDAY,NYEAR,NSTA)
27    CONTINUE
      POWER=TAMPS*VOLTS
      WRITE(6,209)NRUN,CPOWER
      WRITE(6,210)NRUN,POWER
      WRITE(7,302)CPOWER,POWER
      WRITE(6,211)
211   FORMAT(/////,5X,57HTEMPERATURE RECORDED BY THE THERMOCOUPLES ON TH
     1E COIL, F.,//)
      DO 6 I=1,10
      IF(I.EQ.2.OR.I.EQ.9) GO TO 5
      WRITE(6,212)(UNCORT(I,J),J=1,7,2)
212   FORMAT(5X,4(F10.2,14X))
      GO TO 6
 5    WRITE(6,213)(UNCORT(I,J),J=1,8)
213   FORMAT(5X,8(F10.2,2X))
 6    CONTINUE
      WRITE(6,214)
214   FORMAT(////,5X,87HCORRECTED OUTSIDE SURFACE TEMPERATURES AS RECORD
     1ED BY THE THERMOCOUPLES ON THE COIL, F.,//)
      DO 8 I=1,10
      IF(I.EQ.2.OR.I.EQ.9) GO TO 7
      WRITE(6,212)(TEMPER(I,J),J=1,7,2)
      GO TO 8
 7    WRITE(6,213)(TEMPER(I,J),J=1,8)
 8    CONTINUE
      GO TO 10
      END


      SUBROUTINE GEOM(DEPTH,CPDIS,CRDIS,PAREA,RAREA,A,XAREA,NRUN,NSTA,NS
     1LI)
C
      DIMENSION DEPTH(10,8),CPDIS(10,8),CRDIS(10,8),PAREA(10,8),RAREA(10
     1,8),A(8),XAREA(10,8),S(45)
      IF(NSTA.EQ.3.OR.NSTA.EQ.4.OR.NSTA.EQ.5.OR.NSTA.EQ.6.OR.NSTA.EQ.7.O
     1R.NSTA.EQ.8.OR.NSTA.EQ.9)GO TO 16
      SLIN=NSLI
      DELM=0.0054167
      RM=0.023333
      DELPHI=2.0*3.1416/360.0
      S(1)=1.0
      S(45)=1.0
      DO 10 K=1,22
      S(2*K)=4.0
10    CONTINUE
      DO 11 K=2,22
      S(2*K-1)=2.0
11    CONTINUE
      IF(NRUN.GT.400)GO TO 12
      IF(NRUN.GT.300) GO TO 9
      IF(NRUN.GT.200) GO TO 12
 9    R=0.41625
      THETA=2.4024
      IF(NSTA.EQ.1)THETA=3.6036
      IF(NSTA.EQ.10)THETA=1.2012
      GO TO 13
12    R=0.86
```

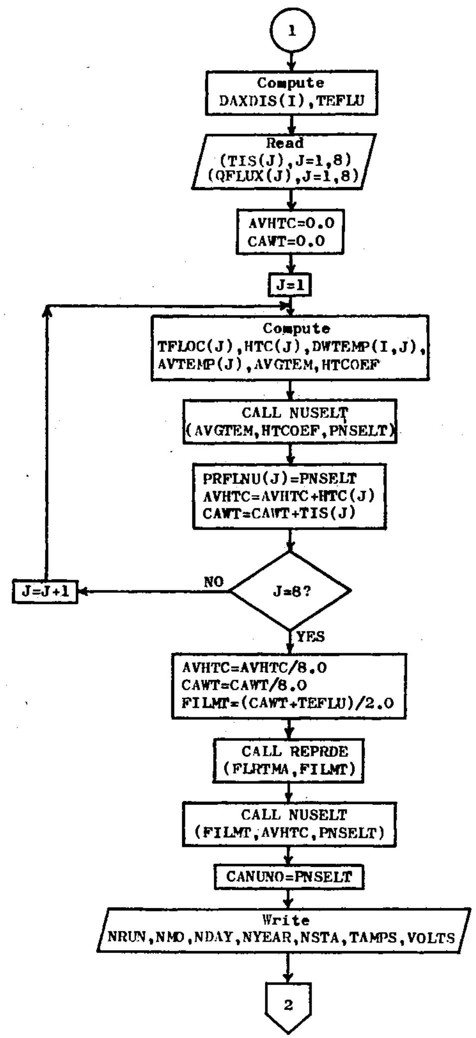
```
      THETA=1.1628
      IF(NSTA.EQ.1)THETA=1.7442
      IF(NSTA.EQ.10)THETA=0.5814
   13 CONTINUE
      C1=DELM*R/SLIN
      DO 15 I=1,NSLI
      DO 15 J=1,8
      XI=I
      XJ=J
      C2=(SLIN-2.0*XI+1.0)/2.0
      PHIL=(2.0*XJ-3.0)*3.1416/8.0
      CSIN1=SIN((XJ-1.0)*3.1416/4.0)
      CSIN2=SIN(PHIL)
      DEPTH(I,J)=(R-RM*CSIN1-(DELM/2.0)*((SLIN-2.0*XI+1.0)/SLIN)*(R*CSIN
     11/(R-RM*CSIN1)))*THETA
      CPDIS(I,J)=(3.1416/4.0)*(RM+(DELM/2.0)*((SLIN-2.0*XI+1.0)/SLIN)*(R
     1/(R-RM*CSIN2)))
      CRDIS(I,J)=(DELM/SLIN)*(R/(R-RM*CSIN1))
      PAREA(I,J)=(DELM*THETA/SLIN)*(R/(R-RM*CSIN2))*(R-RM*CSIN2-(DELM/2.
     10)*((SLIN-2.0*XI+1.0)/2.0)*(R*CSIN2/(R-RM*CSIN2)))
      RAREA(I,J)=(3.1416*THETA/4.0)*(R-RM*CSIN1-(DELM/2.0)*((SLIN-2.0*XI
     1+2.0)/SLIN)*(R*CSIN1/(R-RM*CSIN1)))*(RM+(DELM/2.0)*((SLIN-2.0*XI+2
     2.0)/SLIN)*(R/(R-RM*CSIN1)))
      A(J)=(3.1416*THETA/4.0)*(R-RM*CSIN1-(DELM/2.0)*((SLIN-20.0)/SLIN)*
     1(R*CSIN1/(R-RM*CSIN1)))*(RM+(DELM/2.0)*((SLIN-20.0)/SLIN)*(R/(R-RM
     2*CSIN1)))
      AM1=0.0
      AM2=0.0
      DO 14 K=1,45
      XK=K
      PHI=PHIL+(XK-1.0)*DELPHI
      Y=R-RM*SIN(PHI)
      AM1=AM1+S(K)*1.0/Y
      AM2=AM2+S(K)*1.0/(Y*Y)
   14 CONTINUE
      AM1=(DELPHI/3.0)*AM1
      AM2=(DELPHI/3.0)*AM2
      XAREA(I,J)=RM*C1*AM1+C2*C1*C1*AM2
   15 CONTINUE
   16 RETURN
      END


      SUBROUTINE TEMCOR(K,NRUN)
C
      DIMENSION UNCT(1,8),TCASP(10,8),T(10,8),TCOR(1,8)
      COMMON/CORDAT/UNCT,TCASP,T
      IF(NRUN.GT.400) GO TO 1
      IF(NRUN.GT.300) GO TO 7
      IF(NRUN.GT.200) GO TO 1
    7 STEAMT=210.484
      ROOMT=75.58
      GO TO 2
    1 STEAMT=210.243
      ROOMT=76.35
    2 CONTINUE
      IF(K.EQ.2.OR.K.EQ.9) GO TO 4
      DO 3 J=1,7,2
      TCOR(1,J)=TCASP(K,J)*((UNCT(1,J)-ROOMT)/(STEAMT-ROOMT))
      T(1,J)=UNCT(1,J)+TCOR(1,J)
    3 CONTINUE
      GO TO 6
    4 DO 5 J=1,8
      TCOR(1,J)=TCASP(K,J)*((UNCT(1,J)-ROOMT)/(STEAMT-ROOMT))
      T(1,J)=UNCT(1,J)+TCOR(1,J)
    5 CONTINUE
    6 CONTINUE
      RETURN
      END


      SUBROUTINE KCON(T,CON,NSLI)
C
      DIMENSION T(10,8),CON(10,8)
      DO 10 I=1,NSLI
      DO 10 J=1,8
      CON(I,J)=7.8034+0.51691E-02*T(I,J)-0.88501E-06*T(I,J)*T(I,J)
   10 CONTINUE
      RETURN
      END


      SUBROUTINE ERESTI(T,RESTI,NSLI)
C
      DIMENSION T(10,8),RESTI(10,8)
      DO 10 I=1,NSLI
      DO 10 J=1,8
      RESTI(I,J)=0.21675E-05+0.11492E-08*T(I,J)+0.70965E-12*T(I,J)*T(I,J
     1)-0.84327E-17*T(I,J)*T(I,J)*T(I,J)
   10 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE FLUX(T,CON,RESTA,AMPS,CPDIS,CRDIS,PAREA,RAREA,A,QFLUX)
C
      DIMENSION T(10,8),CON(10,8),RESTA(10,8),AMPS(10,8),CPDIS(10,8),CRD
     1IS(10,8),PAREA(10,8),RAREA(10,8),A(8),QFLUX(8),QT(8),QL(8),QR(8),Q
     2B(8)
      DO 10 J=1,8
      JNEG=J-1
      JPOS=J+1
      IF(JPOS.EQ.9)JPOS=1
      IF(JNEG.EQ.0)JNEG=8
      QT(J)=((CON(10,J)+CON(9,J))/2.0)*(RAREA(10,J)/CRDIS(10,J))*(T(9,J)
     1-T(10,J))
      QL(J)=((CON(10,J)+CON(10,JNEG))/2.0)*(PAREA(10,J)/CPDIS(10,J))*(T(
     110,JNEG)-T(10,J))
      QR(J)=((CON(10,J)+CON(10,JPOS))/2.0)*(PAREA(10,JPOS)/CPDIS(10,JPOS
     1))*(T(10,JPOS)-T(10,J))
      QB(J)=-QT(J)-QL(J)-QR(J)-3.4128*RESTA(10,J)*AMPS(10,J)*AMPS(10,J)
      QFLUX(J)=-QB(J)/A(J)
   10 CONTINUE
      RETURN
      END


      SUBROUTINE PLOT(TOS,TIS,NRUN,NMO,NDAY,NYEAR,NSTA)
C
      DIMENSION TOS(8),TIS(8),TPLOT(2,8),GRAPH(8,51),SYMBOL(3),ORD(51)
  200 FORMAT(1H1,12HRUN NUMBER =,I4,I10,1H/,I3,1H/,I3,5X,16HSTATION NUMB
     1ER =,I3//)
  201 FORMAT(17(4X,1A1))
  202 FORMAT(//1X,23HBASE LINE TEMPERATURE =,F7.2)
  203 FORMAT(1X,21HMAXIMUM TEMPERATURE =,F7.2)
  204 FORMAT(1X,23HTEMPERATURE INCREMENT =,F6.2)
      DATA SYMBOL/1HO,1HI,1H /
      DATA ASTER/1H*/
      DO 10 J=1,8
      TPLOT(1,J)=TOS(J)
      TPLOT(2,J)=TIS(J)
   10 CONTINUE
      DO 11 I=1,8
      DO 11 J=1,51
      GRAPH(I,J)=SYMBOL(3)
   11 CONTINUE
      TMAX=TPLOT(1,1)
      TMIN=TPLOT(1,1)
      DO 12 I=1,2
      DO 12 J=1,8
      IF(TMAX.LT.TPLOT(I,J))TMAX=TPLOT(I,J)
      IF(TMIN.GT.TPLOT(I,J))TMIN=TPLOT(I,J)
   12 CONTINUE
      ITEMP=TMIN/5.0
      TMIN=5*ITEMP
      DIFF=TMAX-TMIN
      DEL=0.01
      IF(DIFF.GT.0.5)DEL=0.05
      IF(DIFF.GT.2.5)DEL=0.1
      IF(DIFF.GT.5.0)DEL=0.2
      IF(DIFF.GT.10.0)DEL=0.4
      IF(DIFF.GT.20.0)DEL=0.6
      IF(DIFF.GT.30.0)DEL=0.8
      IF(DIFF.GT.40.0)DEL=1.0
      IF(DIFF.GT.50.0)DEL=2.0
      IF(DIFF.GT.100.0)DEL=3.0
      IF(DIFF.GT.150.0)DEL=4.0
      IF(DIFF.GT.200.0)DEL=5.0
      IF(DIFF.GT.250.0)DEL=6.0
      IF(DIFF.GT.300.0)DEL=7.0
      IF(DIFF.GT.350.0)DEL=8.0
      IF(DIFF.GT.400.0)DEL=9.0
      IF(DIFF.GT.450.0)DEL=10.0
      IF(DIFF.GT.500.0)DEL=20.0
      IF(DIFF.GT.1000.0)DEL=40.0
      DO 13 I=1,2
      DO 13 J=1,8
      L=(TPLOT(I,J)-TMIN)/DEL+0.5
      L=51-L
   13 GRAPH(J,L)=SYMBOL(I)
      DO 14 I=1,51
      ORD(I)=SYMBOL(3)
   14 CONTINUE
      DO 15 I=1,51,5
      ORD(I)=ASTER
   15 CONTINUE
      WRITE(6,200)NRUN,NMO,NDAY,NYEAR,NSTA
      DO 16 I=1,51
      WRITE(6,201)ORD(I),(GRAPH(J,I),J=1,8),(GRAPH(J,I),J=1,8)
   16 CONTINUE
      WRITE(6,201)SYMBOL(3),(ASTER,I=1,16)
      WRITE(6,202)TMIN
      WRITE(6,203)TMAX
      WRITE(6,204)DEL
      RETURN
      END
```

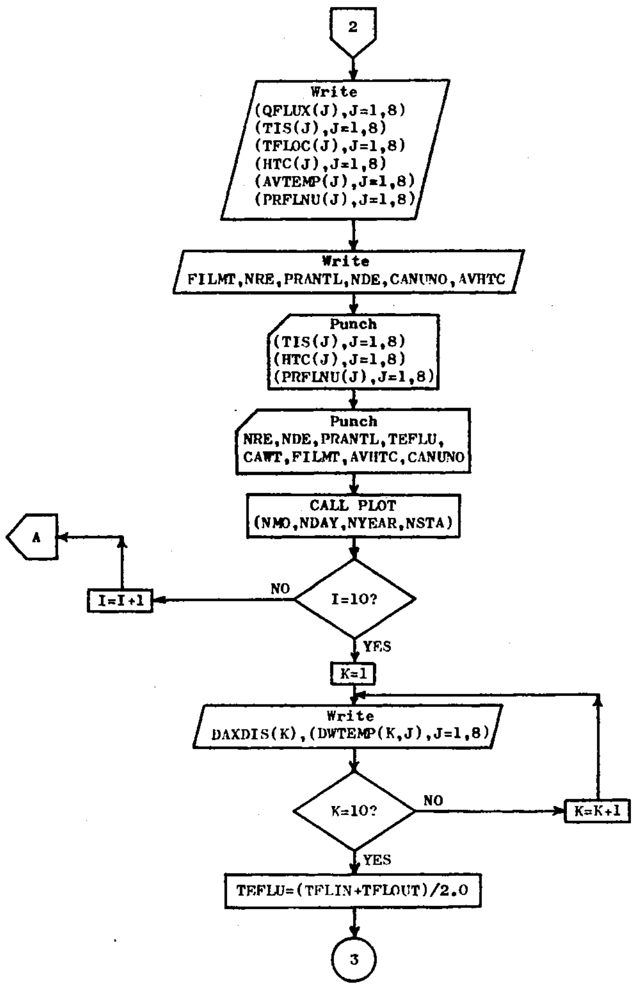
Figure 26. Flowchart for Computer Program SPNS02

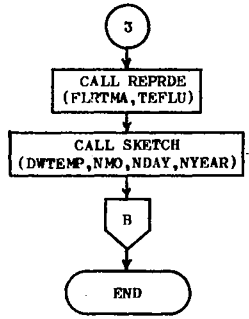


START
B
Read
NRUN,NMO,NDAY,NYEAR,NSLI,TAMPS,VOLTS
Read
FLRTMA,TFLIN,TFLOUT
TUBERA=0.495/(2.0*12.0)
NRUN >400?
YES
NO
NRUN >300?
YES
NO
NRUN >200?
YES
NO
COILRA=20.64/(2.0*12.0)
ABYR=TUBERA/COILRA
COILRA=9.99/(2.0*12.0)
ABYR=TUBERA/COILRA
TINC1=(TFLOUT-TFLIN)/10.00
TINC2=TINC1*TUBERA
Punch
NRUN,NMO,NDAY,NYEAR,ABYR,FLRTMA,
TFLIN,TFLOUT,TAMPS,VOLTS
TCDIS=0.0
I=1
A
NSTA=I
I=10?
YES
NO
TCDIS=TCDIS+0.75
TCDIS=TCDIS+1.0
1

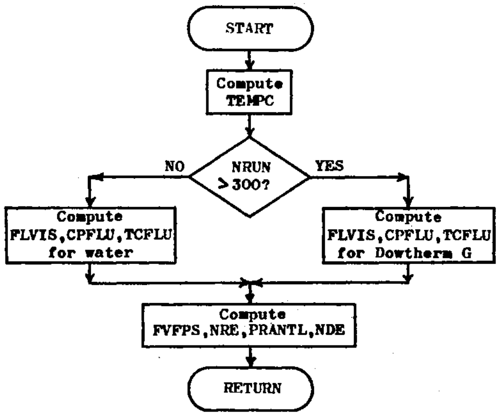


1
Compute
DAXDIS(I),TEFLU
Read
(TIS(J),J=1,8)
(QFLUX(J),J=1,8)
AVHTC=0.0
CAWT=0.0
J=1
Compute
TFLOC(J),HTC(J),DWTEMP(I,J),
AVTEMP(J),AVGTEM,HTCOEF
CALL NUSELT
(AVGTEM,HTCOEF,PNSELT)
PRFLNU(J)=PNSELT
AVHTC=AVHTC+HTC(J)
CAWT=CAWT+TIS(J)
J=8?
NO
J=J+1
YES
AVHTC=AVHTC/8.0
CAWT=CAWT/8.0
FILMT=(CAWT+TEFLU)/2.0
CALL REPRDE
(FLRTMA,FILMT)
CALL NUSELT
(FILMT,AVHTC,PNSELT)
CANUNO=PNSELT
Write
NRUN,NMO,NDAY,NYEAR,NSTA,TAMPS,VOLTS
2

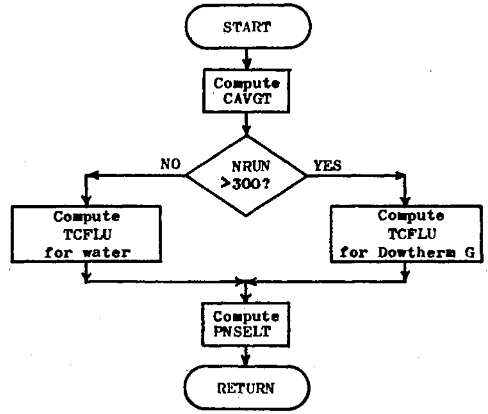

2
Write
(QFLUX(J),J=1,8)
(TIS(J),J=1,8)
(TFLOC(J),J=1,8)
(HTC(J),J=1,8)
(AVTEMP(J),J=1,8)
(PRFLNU(J),J=1,8)
Write
FILMT,NRE,PRANTL,NDE,CANUNO,AVHTC
Punch
(TIS(J),J=1,8)
(HTC(J),J=1,8)
(PRFLNU(J),J=1,8)
Punch
NRE,NDE,PRANTL,TEFLU,
CAWT,FILMT,AVHTC,CANUNO
CALL PLOT
(NMO,NDAY,NYEAR,NSTA)
A
I=I+1
NO
I=10?
YES
K=1
Write
DAXDIS(K),(DWTEMP(K,J),J=1,8)
K=10?
NO
K=K+1
YES
TEFLU=(TFLIN+TFLOUT)/2.0
3


3
CALL REPRDE
(FLRTMA,TEFLU)
CALL SKETCH
(DWTEMP,NMO,NDAY,NYEAR)
B
END

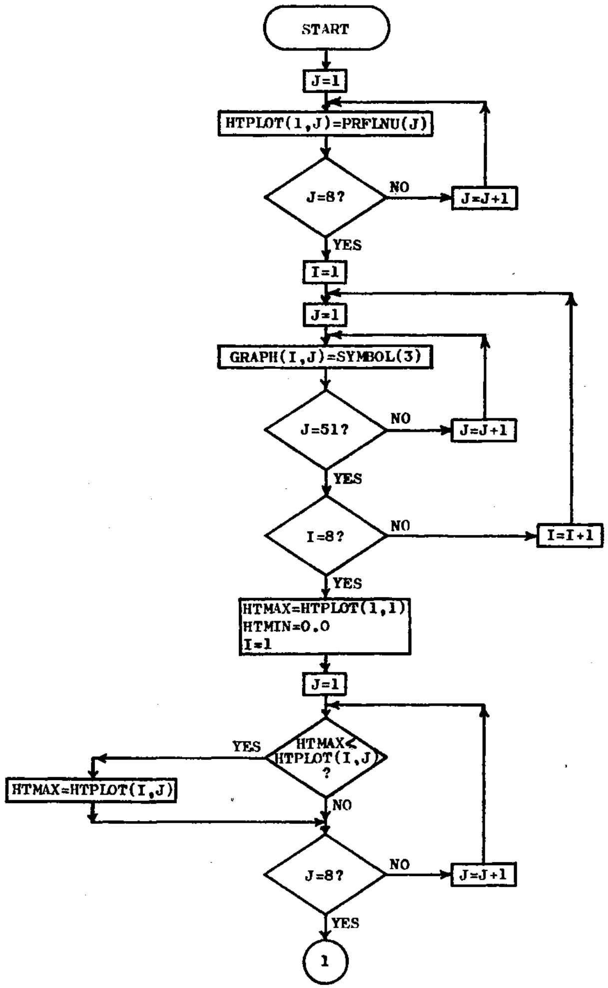
SUBROUTINE REPRDE:

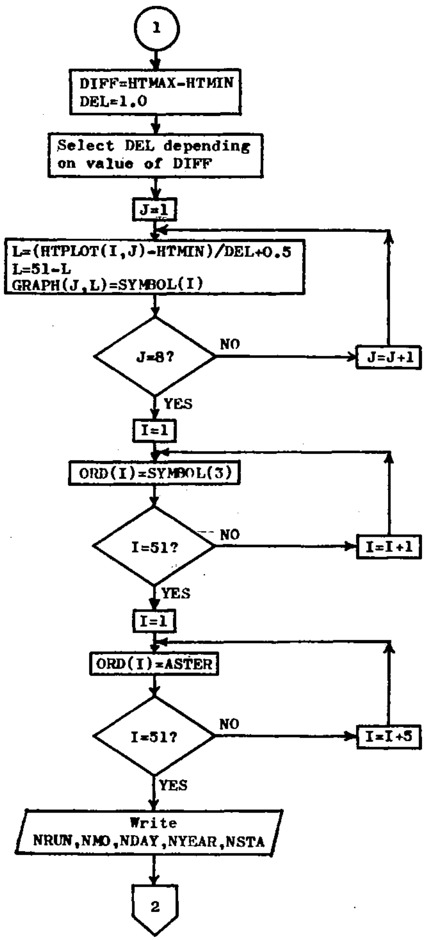


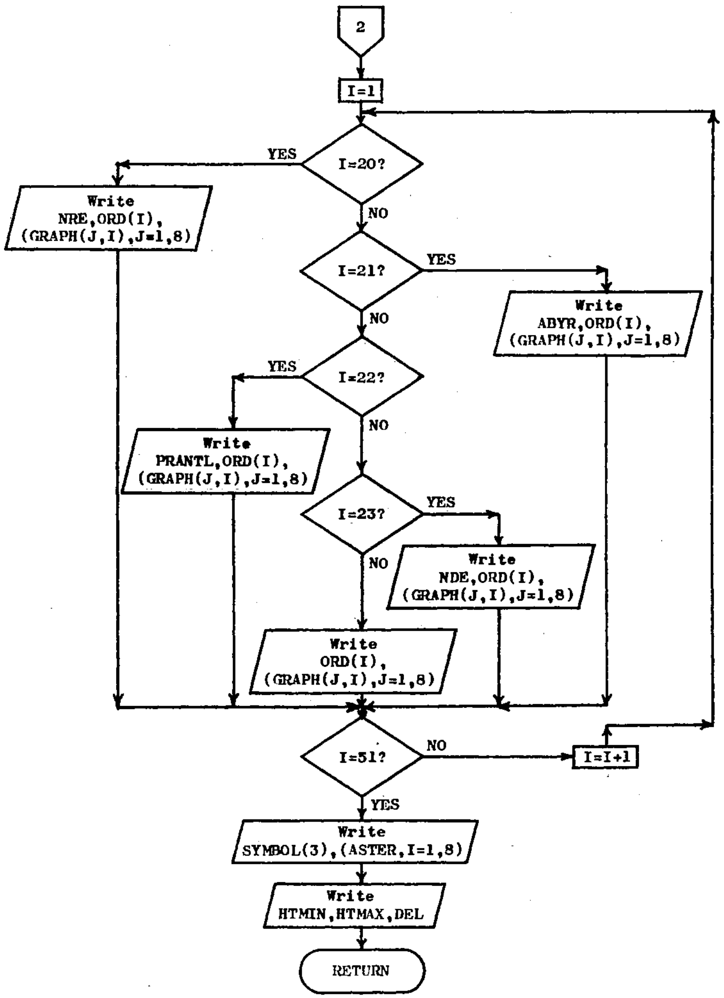
SUBROUTINE NUSELT:



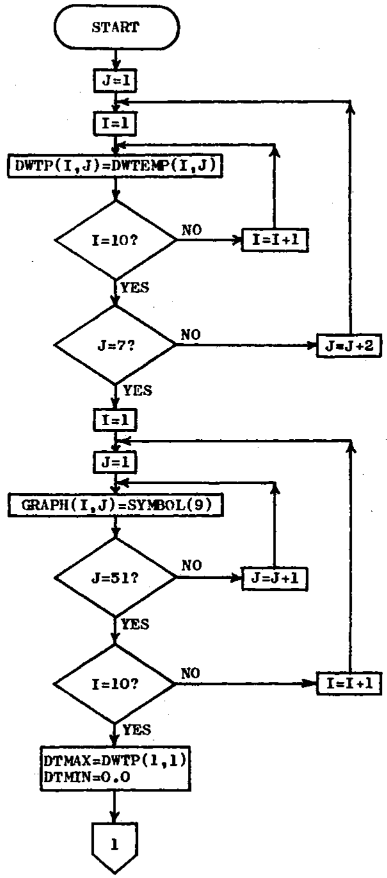
SUBROUTINE PLOT:

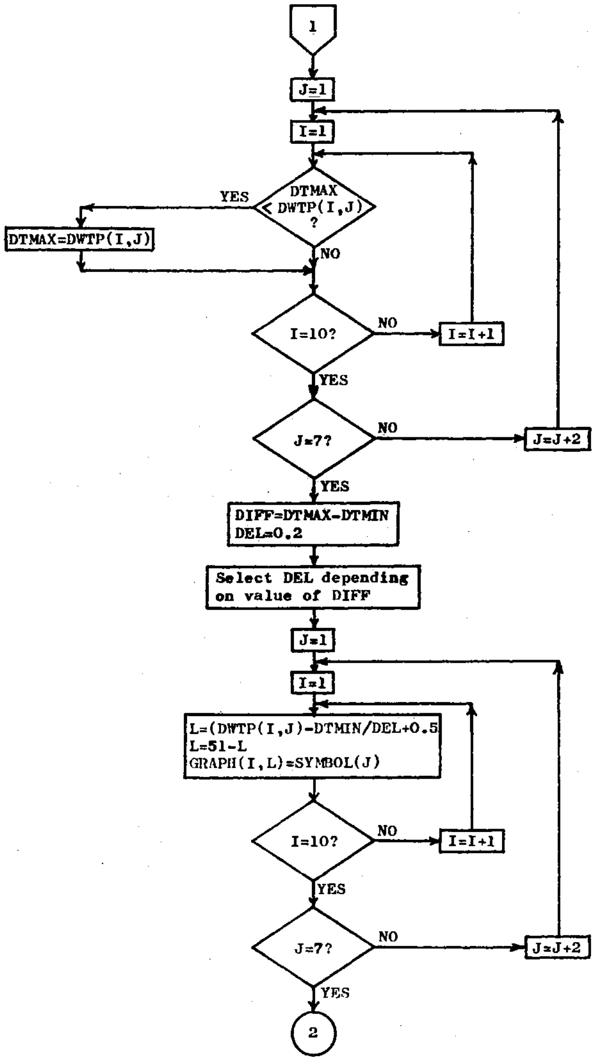


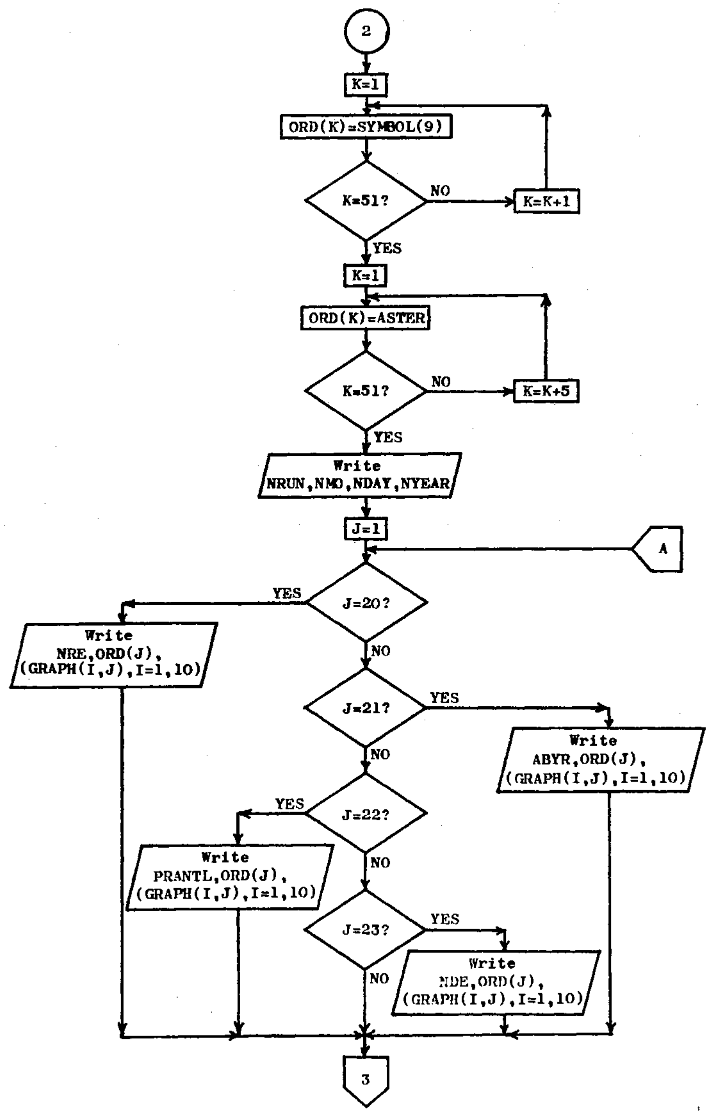




SUBROUTINE SKETCH:




1
J=1
I=1
DTMAX < DWTP(I,J) ?
YES
DTMAX=DWTP(I,J)
NO
I=10?
NO
I=I+1
YES
J=7?
NO
J=J+2
YES
DIFF=DTMAX-DTMIN
DEL=0.2
Select DEL depending on value of DIFF
J=1
I=1
L=(DWTP(I,J)-DTMIN/DEL+0.5
L=51-L
GRAPH(I,L)=SYMBOL(J)
I=10?
NO
I=I+1
YES
J=7?
NO
J=J+2
YES
2


2
K=1
ORD(K)=SYMBOL(9)
K=51?
NO
K=K+1
YES
K=1
ORD(K)=ASTER
K=51?
NO
K=K+5
YES
Write NRUN,NMO,NDAY,NYEAR
J=1
A
J=20?
YES
Write NRE,ORD(J), (GRAPH(I,J),I=1,10)
NO
J=21?
YES
Write ABYR,ORD(J), (GRAPH(I,J),I=1,10)
NO
J=22?
YES
Write PRANTL,ORD(J), (GRAPH(I,J),I=1,10)
NO
J=23?
YES
Write NDE,ORD(J), (GRAPH(I,J),I=1,10)
NO
3

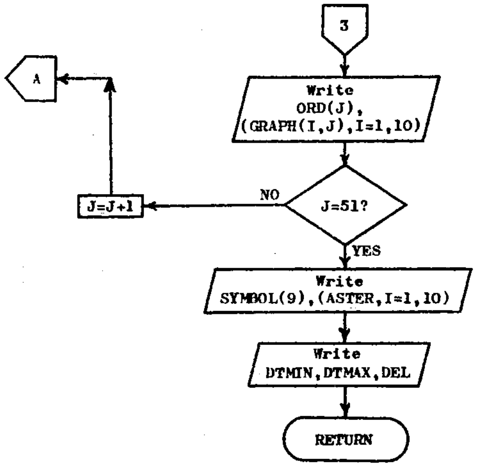

3
A
Write
ORD(J),
(GRAPH(I,J),I=1,10)
NO
J=51?
J=J+1
YES
Write
SYMBOL(9),(ASTER,I=1,10)
Write
DTMIN,DTMAX,DEL
RETURN

Figure 27. 80/80 Listing of Computer Program SPNS02

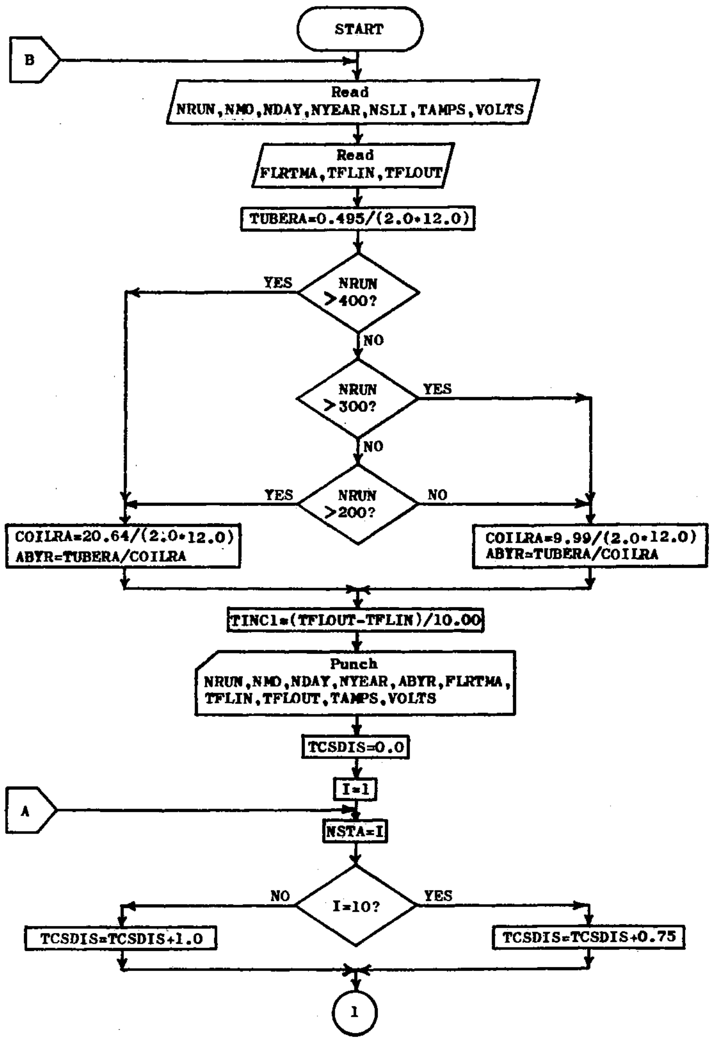
```
C
C @%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*
C
C COMPUTER PROGRAM: SPNS02.
C
C PROGRAM TO COMPUTE:
C  1. HEAT TRANSFER COEFFICIENTS
C  2. PERTINENT FLUID FLOW AND HEAT TRANSFER DIMENSIONLESS NUMBERS, AND
C  3. DIMENSIONLESS WALL TEMPERATURES AND AXIAL DISTANCES ALONG THE HELICAL COIL
C FOR LIQUID PHASE HEAT TRANSFER STUDIES IN HELICALLY COILED TUBES.   BY SUMAN
C P.N. SINGH.
C
C @%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*
C
C *** NOTE:1. FLUID PROPERTIES ARE EVALUATED AT THE AVERAGE LOCAL FILM
C             TEMPERATURE(=T(F,L)) AT EACH THERMOCOUPLE STATION.
C          2. T(F,L)=(T(WALL)+T(BULK FLUID))/2.0.
C          3. LOCAL H(AVG.)=(1/N)E((Q/A)/(T(WALL)-T(BULK FLUID))).
C
      DIMENSION QFLUX(8),TIS(8),TFLOC(8),HTC(8),AVTEMP(8),DAXDIS(10),DWT
     1EMP(10,8)
      COMMON/DLSNOS/NRE,ABYR,NDE,PRANTL,PRFLNU(8),NRUN
    1 READ(5,100) NRUN,NMO,NDAY,NYEAR,NSLI,TAMPS,VOLTS
  100 FORMAT(5I5,2E20.7)
      READ(5,101) FLRTMA,TFLIN,TFLOUT
  101 FORMAT(3F10.2)
      TUBERA=0.495/(2.0*12.0)
      IF(NRUN.GT.400) GO TO 2
      IF(NRUN.GT.300) GO TO 9
      IF(NRUN.GT.200) GO TO 2
    9 COILRA=9.99/(2.0*12.0)
      ABYR=TUBERA/COILRA
      GO TO 3
    2 COILRA=20.64/(2.0*12.0)
      ABYR=TUBERA/COILRA
    3 CONTINUE
      TINC1=(TFLOUT-TFLIN)/10.00
      TINC2=TINC1*TUBERA
      WRITE(7,300)NRUN,NMO,NDAY,NYEAR,ABYR,FLRTMA,TFLIN,TFLOUT,TAMPS,VOL
     1TS
  300 FORMAT(4I5,F10.6,5F10.2)
      TCDIS=0.0
      DO 7 I=1,10
      NSTA=I
      IF(I.EQ.10) GO TO 4
      TCDIS=TCDIS+1.0
      GO TO 5
    4 TCDIS=TCDIS+0.75
    5 CONTINUE
      DAXDIS(I)=TCDIS/TUBERA
      TEFLU=TFLIN+(TINC1*TCDIS)
      READ(5,102)(TIS(J),J=1,8)
  102 FORMAT(4E20.7)
      READ(5,102)(QFLUX(J),J=1,8)
      AVHTC=0.0
      CAWT=0.0
      DO 6 J=1,8
      TFLOC(J)=TEFLU
      HTC(J)=QFLUX(J)/(TIS(J)-TEFLU)
      DWTEMP(I,J)=(TIS(J)-TFLIN)/TINC2
      AVTEMP(J)=(TIS(J)+TFLOC(J))/2.0
      AVGTEM=AVTEMP(J)
      HTCOEF=HTC(J)
      CALL NUSELT(AVGTEM,HTCOEF,PNSELT)
      PRFLNU(J)=PNSELT
      AVHTC=AVHTC+HTC(J)
      CAWT=CAWT+TIS(J)
    6 CONTINUE
      AVHTC=AVHTC/8.0
      CAWT=CAWT/8.0
      FILMT=(CAWT+TEFLU)/2.0
      CALL REPRDE(FLRTMA,FILMT)
      CALL NUSELT(FILMT,AVHTC,PNSELT)
      CANUNO=PNSELT
      WRITE(6,200)
  200 FORMAT(1H1,2X,80HCALCULATION OF HEAT TRANSFER COEFFECIENTS IN A HE
     1LICAL COIL BY SUMAN P.N. SINGH.)
      WRITE(6,201)NRUN,NMO,NDAY,NYEAR
  201 FORMAT(2X,12HRUN NUMBER =,I4,I10,1H-,I2,1H-,I2)
      WRITE(6,202)NSTA
  202 FORMAT(2X,16HSTATION NUMBER =,I3)
      WRITE(6,203)TAMPS,VOLTS
  203 FORMAT(2X,17HCURRENT IN COIL =,F6.1,5H AMPS,10X,26HVOLTAGE DROP AC
     1ROSS COIL =,F7.2,6H VOLTS)
      WRITE(6,204)
  204 FORMAT(//,2X,20HPERIPHERAL LOCATION ,14X,10H    1     ,2X,10H    2
     1     ,2X,10H    3     ,2X,10H    4     ,2X,10H    5     ,2X,10H
     2 6     ,2X,10H    7     ,2X,10H    8     ,/2X,30HDEGREES CLOCKWISE
     3 FROM NORTH  ,4X,10H    0     ,2X,10H   45     ,2X,10H   90     ,2
     4X,10H  135     ,2X,10H  180     ,2X,10H  225     ,2X,10H  270
     5,2X,10H  315     ,//)
      WRITE(6,205)(QFLUX(J),J=1,8)
  205 FORMAT(2X,30HHEAT FLUX, Q , BTU/HR-SQ.FT. =,2X,8(F10.3,2X))
      WRITE(6,206)(TIS(J),J=1,8)
  206 FORMAT(/,2X,30HINSIDE WALL TEMPERATURE,TW, F=,2X,8(F10.3,2X))
      WRITE(6,207)
  207 FORMAT(//,2X,54HFOR FLUID TEMPERATURES MEASURED BY CONAX THERMOCOU
     1PLES)
      WRITE(6,208)(TFLOC(J),J=1,8)
  208 FORMAT(/,2X,30HLOCAL FLUID TEMPERATURE,TF, F=,2X,8(F10.3,2X))
      WRITE(6,209)(HTC(J),J=1,8)
  209 FORMAT(/,2X,30HH(LOCAL), BTU/HR-SQ.FT.-F    =,2X,8(F10.3,2X))
      WRITE(6,216)(AVTEMP(J),J=1,8)
  216 FORMAT(/,2X,30HAVG. LOCAL TEMP.,(TF+TW)/2, F=,2X,8(F10.3,2X))
      WRITE(6,217)(PRFLNU(J),J=1,8)
  217 FORMAT(/,2X,30HPERIPHERAL NUSSELT NUMBER, NU=,2X,8(F10.3,2X))
      WRITE(6,218) FILMT
  218 FORMAT(//,2X,61HAT THE LOCAL (CIRCUMFERENTIALLY AVERAGED) FILM TEM
```

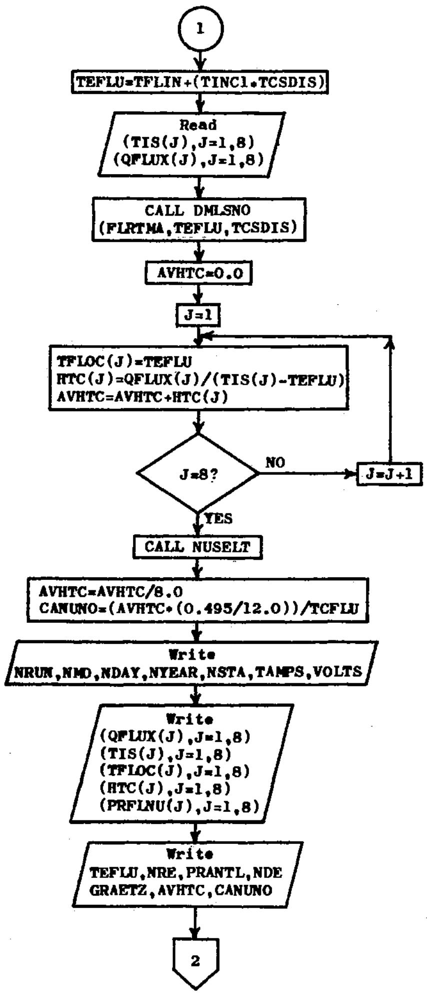
```
     1PERATURE OF,F10.3,4H F :)
      WRITE(6,219) NRE
  219 FORMAT(/,2X,23HREYNOLDS NUMBER = RE = ,I7)
      WRITE(6,220) PRANTL
  220 FORMAT(/,2X,23HPRANDTL  NUMBER = PR = ,F7.2)
      WRITE(6,221) NDE
  221 FORMAT(/,2X,23HDEAN     NUMBER = DE = ,I7)
      WRITE(6,222) CANUNO
  222 FORMAT(/,2X,23HNUSSELT  NUMBER = NU = ,F10.3)
      WRITE(6,223) AVHTC
  223 FORMAT(//,2X,35HAVERAGE H(LOCAL) FOR THIS STATION =,F10.3,16H BTU/
     1HR-SQ.FT.-F)
      WRITE(7,301)(TIS(J),J=1,8)
  301 FORMAT(8F10.3)
      WRITE(7,301)(HTC(J),J=1,8)
      WRITE(7,301)(PRFLNU(J),J=1,8)
      WRITE(7,302)NRE,NDE,PRANTL,TEFLU,CAWT,FILMT,AVHTC,CANUNO
  302 FORMAT(2I10,6F10.3)
      CALL PLOT(NMO,NDAY,NYEAR,NSTA)
    7 CONTINUE
      WRITE(6,213)
  213 FORMAT(1H1,2X,90HDIMENSIONLESS AXIAL DISTANCE AND WALL TEMPERATURE
     1 VALUES FOR VARIOUS PERIPHERAL LOCATIONS.,///)
      WRITE(6,214)
  214 FORMAT(2X,14HDIMENSIONLESS ,24X,58HDIMENSIONLESS WALL TEMPERATURE,
     1(T(WALL)-T(INLET))/(DTB/DZ),/2X,14HAXIAL DISTANCE,5X,10H    1
     2,2X,10H    2     ,2X,10H    3     ,2X,10H    4     ,2X,10H    5
     3    ,2X,10H    6     ,2X,10H    7     ,2X,10H    8     ,/8X,1HZ,12X,
     410H    0     ,2X,10H   45     ,2X,10H   90     ,2X,10H  135     ,2
     5X,10H  180     ,2X,10H  225     ,2X,10H  270     ,2X,10H  315
     6,//)
      DO 8 K=1,10
      WRITE(6,215)DAXDIS(K),(DWTEMP(K,J),J=1,8)
  215 FORMAT(2X,F10.3,7X,8(F10.3,2X))
    8 CONTINUE
      TEFLU=(TFLIN+TFLOUT)/2.0
      CALL REPRDE(FLRTMA,TEFLU)
      CALL SKETCH(DWTEMP,NMO,NDAY,NYEAR)
      GO TO 1
      END


      SUBROUTINE REPRDE(FLRTMA,TEFLU)
C
      COMMON/DLSNOS/NRE,ABYR,NDE,PRANTL,PRFLNU(8),NRUN
      TEMPC=((TEFLU-32.0)*5.0)/9.0
      IF(NRUN.GT.300) GO TO 1
      RHSVR=((1.3272*(20.0-TEMPC))-(0.001053*(TEMPC-20.0)*(TEMPC-20.0)))
     1/(TEMPC+105.0)
      RHSLN=2.303*RHSVR
      FLVIS=1.002*EXP(RHSLN)
      CPFLU=1.01881-0.4802E-03*TEFLU+0.3274E-05*TEFLU*TEFLU-0.604E-08*TE
     1FLU*TEFLU*TEFLU
      TCFLU=0.30289+0.7029E-03*TEFLU-0.1178E-05*TEFLU*TEFLU-0.550E-09*TE
     1FLU*TEFLU*TEFLU
      GO TO 2
    1 FLVIS=0.105786E+03-0.16867E+01*TEFLU+0.1058E-01*TEFLU*TEFLU-0.2993
     16E-04*TEFLU*TEFLU*TEFLU+0.31814E-07*TEFLU*TEFLU*TEFLU*TEFLU
      CPFLU=0.369356+0.20216E-03*TEFLU+0.8285E-06*TEFLU*TEFLU-0.19987E-0
     18*TEFLU*TEFLU*TEFLU
      TCFLU=241.90848*(3.149499E-04-(0.93E-07*TEMPC))
    2 FVFPS=2.42*FLVIS
      RENO=((0.495/12.0)*FLRTMA)/((3.1416/4.0)*(0.495*0.495/144.0)*FVFPS
     1)
      NRE=RENO
      PRANTL=(CPFLU*FVFPS)/TCFLU
      DENO=RENO*(SQRT(ABYR))
      NDE=DENO
      RETURN
      END


      SUBROUTINE NUSELT(AVGTEM,HTC,PNSELT)
C
      COMMON/DLSNOS/NRE,ABYR,NDE,PRANTL,PRFLNU(8),NRUN
      CAVGT=((AVGTEM-32.0)*5.0)/9.0
      IF(NRUN.GT.300) GO TO 1
      TCFLU=0.30289+0.7029E-03*AVGTEM-0.1178E-05*AVGTEM*AVGTEM-0.550E-09
     1*AVGTEM*AVGTEM*AVGTEM
      GO TO 2
    1 TCFLU=241.90848*(3.149499E-04-(0.93E-07*CAVGT))
    2 PNSELT=(HTC*(0.495/12.0))/TCFLU
      RETURN
      END


      SUBROUTINE PLOT(NMO,NDAY,NYEAR,NSTA)
C
      DIMENSION HTPLOT(2,8),GRAPH(8,51),SYMBOL(3),ORD(51)
      COMMON/DLSNOS/NRE,ABYR,NDE,PRANTL,PRFLNU(8),NRUN
      DATA SYMBOL/1HC,1HA,1H /
      DATA ASTER/1H*/
      DO 1 J=1,8
      HTPLOT(1,J)=PRFLNU(J)
    1 CONTINUE
      DO 2 I=1,8
      DO 2 J=1,51
      GRAPH(I,J)=SYMBOL(3)
    2 CONTINUE
```

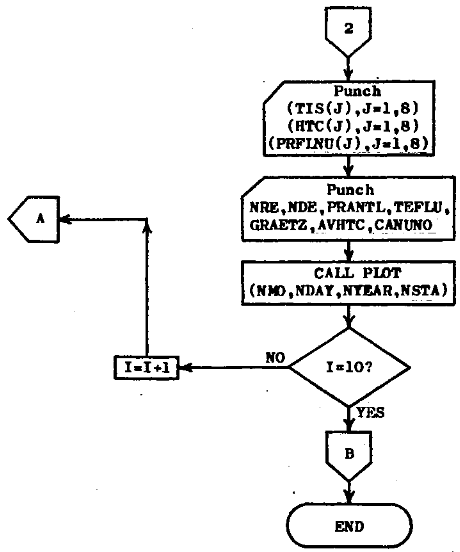
```
      HTMAX=HTPLOT(1,1)
      HTMIN=0.0
      I=1
      DO 3 J=1,8
      IF(HTMAX.LT.HTPLOT(I,J))HTMAX=HTPLOT(I,J)
    3 CONTINUE
      DIFF=HTMAX-HTMIN
      DEL=1.0
      IF(DIFF.GT.50.0)DEL=2.0
      IF(DIFF.GT.100.0)DEL=5.0
      IF(DIFF.GT.200.0)DEL=10.0
      IF(DIFF.GT.500.0)DEL=20.0
      IF(DIFF.GT.1000.0)DEL=50.0
      IF(DIFF.GT.2000.0)DEL=100.0
      IF(DIFF.GT.5000.0)DEL=200.0
      IF(DIFF.GT.10000.0)DEL=500.0
      DO 4 J=1,8
      L=(HTPLOT(I,J)-HTMIN)/DEL+0.5
      L=51-L
    4 GRAPH(J,L)=SYMBOL(I)
      DO 5 I=1,51
      ORD(I)=SYMBOL(3)
    5 CONTINUE
      DO 6 I=1,51,5
      ORD(I)=ASTER
    6 CONTINUE
      WRITE(6,200)NRUN,NMO,NDAY,NYEAR,NSTA
  200 FORMAT(1H1,2X,12HRUN NUMBER =,I4,I10,1H-,I2,1H-,I2,5X,16HSTATION N
     1UMBER =,I3,//)
      DO 11 I=1,51
      IF(I.EQ.20) GO TO 7
      IF(I.EQ.21) GO TO 8
      IF(I.EQ.22) GO TO 9
      IF(I.EQ.23) GO TO 10
      WRITE(6,201) ORD(I),(GRAPH(J,I),J=1,8)
  201 FORMAT(50X,9(4X,1A1))
      GO TO 11
    7 WRITE(6,202) NRE,ORD(I),(GRAPH(J,I),J=1,8)
  202 FORMAT(10X,23HREYNOLDS NUMBER = RE = ,I7,10X,9(4X,1A1))
      GO TO 11
    8 WRITE(6,203) ABYR,ORD(I),(GRAPH(J,I),J=1,8)
  203 FORMAT(10X,23HTUBE/COIL RADIUS= A/R= ,F7.4,10X,9(4X,1A1))
      GO TO 11
    9 WRITE(6,204) PRANTL,ORD(I),(GRAPH(J,I),J=1,8)
  204 FORMAT(10X,23HPRANDTL  NUMBER = PR = ,F7.2,10X,9(4X,1A1))
      GO TO 11
   10 WRITE(6,205) NDE,ORD(I),(GRAPH(J,I),J=1,8)
  205 FORMAT(10X,23HDEAN     NUMBER = DE = ,I7,10X,9(4X,1A1))
   11 CONTINUE
      WRITE(6,201)SYMBOL(3),(ASTER,I=1,8)
      WRITE(6,206)
  206 FORMAT(59X,1H1,4X,1H2,4X,1H3,4X,1H4,4X,1H5,4X,1H6,4X,1H7,4X,1H8,/5
     16X,40HPERIPHERAL LOCATION,CLKWISE. FROM NORTH ,/)
      WRITE(6,207)HTMIN,HTMAX
  207 FORMAT(2X,27HBASE LINE NUSSELT NUMBER = ,F5.1,10X,25HMAXIMUM NUSSE
     1LT NUMBER = ,F10.3)
      WRITE(6,208) DEL
  208 FORMAT(2X,10HDELTA NU =,F10.1)
      RETURN
      END


      SUBROUTINE SKETCH(DWTEMP,NMO,NDAY,NYEAR)
C
      DIMENSION DWTEMP(10,8),DWTP(10,8),GRAPH(10,51),SYMBOL(9),ORD(51)
      COMMON/DLSNOS/NRE,ABYR,NDE,PRANTL,PRFLNU(8),NRUN
      DATA SYMBOL/1H1,1H2,1H3,1H4,1H5,1H6,1H7,1H8,1H /
      DATA ASTER/1H*/
      DO 1 J=1,7,2
      DO 1 I=1,10
      DWTP(I,J)=DWTEMP(I,J)
    1 CONTINUE
      DO 2 I=1,10
      DO 2 J=1,51
      GRAPH(I,J)=SYMBOL(9)
    2 CONTINUE
      DTMAX=DWTP(1,1)
      DTMIN=0.0
      DO 3 J=1,7,2
      DO 3 I=1,10
      IF(DTMAX.LT.DWTP(I,J))DTMAX=DWTP(I,J)
    3 CONTINUE
      DIFF=DTMAX-DTMIN
      DEL=0.2
      IF(DIFF.GT.10.0)DEL=0.5
      IF(DIFF.GT.25.0)DEL=1.0
      IF(DIFF.GT.50.0)DEL=2.0
      IF(DIFF.GT.100.0)DEL=5.0
      IF(DIFF.GT.250.0)DEL=10.0
      IF(DIFF.GT.500.0)DEL=20.0
      IF(DIFF.GT.1000.0)DEL=50.0
      IF(DIFF.GT.2500.0)DEL=100.0
      IF(DIFF.GT.5000.0)DEL=200.0
      IF(DIFF.GT.10000.0)DEL=500.0
      DO 4 J=1,7,2
      DO 4 I=1,10
      L=(DWTP(I,J)-DTMIN)/DEL+0.5
      L=51-L
    4 GRAPH(I,L)=SYMBOL(J)
      DO 5 K=1,51
      ORD(K)=SYMBOL(9)
    5 CONTINUE
      DO 6 K=1,51,5
      ORD(K)=ASTER
    6 CONTINUE
```

```
      WRITE(6,200)NRUN,NMO,NDAY,NYEAR
  200 FORMAT(1H1,2X,12HRUN NUMBER =,I4,I10,1H-,I2,1H-,I2,//)
      DO 11 J=1,51
      IF(J.EQ.20) GO TO 7
      IF(J.EQ.21) GO TO 8
      IF(J.EQ.22) GO TO 9
      IF(J.EQ.23) GO TO 10
      WRITE(6,201)ORD(J),(GRAPH(I,J),I=1,10)
  201 FORMAT(50X,11(4X,1A1))
      GO TO 11
    7 WRITE(6,202)NRE,ORD(J),(GRAPH(I,J),I=1,10)
  202 FORMAT(10X,23HREYNOLDS NUMBER = RE = ,I7,10X,11(4X,1A1))
      GO TO 11
    8 WRITE(6,203)ABYR,ORD(J),(GRAPH(I,J),I=1,10)
  203 FORMAT(10X,23HTUBE/COIL RADIUS= A/R= ,F7.4,10X,11(4X,1A1))
      GO TO 11
    9 WRITE(6,204)PRANTL,ORD(J),(GRAPH(I,J),I=1,10)
  204 FORMAT(10X,23HPRANDTL  NUMBER = PR = ,F7.2,10X,11(4X,1A1))
      GO TO 11
   10 WRITE(6,205)NDE,ORD(J),(GRAPH(I,J),I=1,10)
  205 FORMAT(10X,23HDEAN     NUMBER = DE = ,I7,10X,11(4X,1A1))
   11 CONTINUE
      WRITE(6,201)SYMBOL(9),(ASTER,I=1,10)
      WRITE(6,206)
  206 FORMAT(59X,1H1,4X,1H2,4X,1H3,4X,1H4,4X,1H5,4X,1H6,4X,1H7,4X,1H8,4X
     1,1H9,4X,2H10,/59X,44HSTATION NUMBER,STARTING FROM INLET ELECTRODE,
     2/)
      WRITE(6,207)DTMIN,DTMAX
  207 FORMAT(2X,42HBASE LINE DIMENSIONLESS WALL TEMPERATURE=,F5.0,10X,39
     1HMAXIMUM DIMENSIONLESS WALL TEMPERATURE=,F10.3)
      WRITE(6,208)DEL
  208 FORMAT(2X,10HDELTA DWT=,F10.2)
      RETURN
      END
```

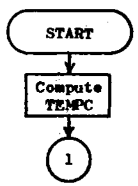
Figure 28. Flowchart for Computer Program SPNS04

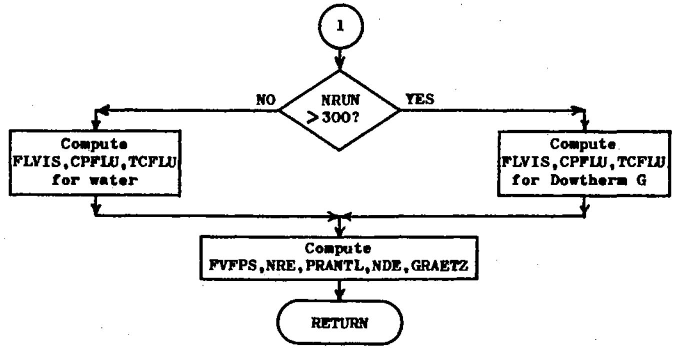

START
B
Read
NRUN,NMO,NDAY,NYEAR,NSLI,TAMPS,VOLTS
Read
FLRTMA,TFLIN,TFLOUT
TUBERA=0.495/(2.0*12.0)
NRUN >400?
YES
NO
NRUN >300?
YES
NO
NRUN >200?
YES
NO
COILRA=20.64/(2.0*12.0)
ABYR=TUBERA/COILRA
COILRA=9.99/(2.0*12.0)
ABYR=TUBERA/COILRA
TINC1=(TFLOUT-TFLIN)/10.00
Punch
NRUN,NMO,NDAY,NYEAR,ABYR,FLRTMA,
TFLIN,TFLOUT,TAMPS,VOLTS
TCSDIS=0.0
I=1
A
NSTA=I
I=10?
NO
YES
TCSDIS=TCSDIS+1.0
TCSDIS=TCSDIS+0.75
1


1
TEFLU=TFLIN+(TINC1*TCSDIS)
Read
(TIS(J),J=1,8)
(QFLUX(J),J=1,8)
CALL DMLSNO
(FLRTMA,TEFLU,TCSDIS)
AVHTC=0.0
J=1
TFLOC(J)=TEFLU
HTC(J)=QFLUX(J)/(TIS(J)-TEFLU)
AVHTC=AVHTC+HTC(J)
J=8?
NO
J=J+1
YES
CALL NUSELT
AVHTC=AVHTC/8.0
CANUNO=(AVHTC*(0.495/12.0))/TCFLU
Write
NRUN,NMO,NDAY,NYEAR,NSTA,TAMPS,VOLTS
Write
(QFLUX(J),J=1,8)
(TIS(J),J=1,8)
(TFLOC(J),J=1,8)
(HTC(J),J=1,8)
(PRFLNU(J),J=1,8)
Write
TEFLU,NRE,PRANTL,NDE
GRAETZ,AVHTC,CANUNO
2

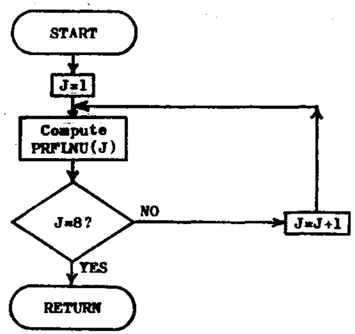


SUBROUTINE DMLSNO:





SUBROUTINE NUSELT:



SUBROUTINE PLOT: Same as for SPNSO2.

Figure 29. 80/80 Listing of Computer Program SPNS04

```
C
C a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*
C
C COMPUTER PROGRAM: SPNS04.
C
C PROGRAM TO COMPUTE:
C  1. HEAT TRANSFER COEFFICIENTS, AND
C  2. PERTINENT FLUID FLOW AND HEAT TRANSFER DIMENSIONLESS NUMBERS
C FOR LIQUID PHASE HEAT TRANSFER STUDIES IN HELICALLY COILED TUBES.    BY SUMAN
C P.N. SINGH.
C
C a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*
C
C *** NOTE:1. FLUID PROPERTIES ARE EVALUATED AT THE LOCAL BULK FLUID TEMPERATURE
C             AT EACH THERMOCOUPLE STATION.
C          2. LOCAL H(AVG.)=(1/N)E((Q/A)/(T(WALL)-T(BULK FLUID))).
C
      DIMENSION QFLUX(8),TIS(8),TFLOC(8)
      COMMON/DLSNOS/NRE,ABYR,NDE,PRANTL,CANUNO,GRAETZ
      COMMON/INVALU/HTC(8),PRFLNU(8),TCFLU,NRUN
    1 READ(5,100) NRUN,NMO,NDAY,NYEAR,NSLI,TAMPS,VOLTS
  100 FORMAT(5I5,2E20.7)
      READ(5,101) FLRTMA,TFLIN,TFLOUT
  101 FORMAT(3F10.2)
      TUBERA=0.495/(2.0*12.0)
      IF(NRUN.GT.400) GO TO 2
      IF(NRUN.GT.300) GO TO 8
      IF(NRUN.GT.200) GO TO 2
    8 COILRA=9.99/(2.0*12.0)
      ABYR=TUBERA/COILRA
      GO TO 3
    2 COILRA=20.64/(2.0*12.0)
      ABYR=TUBERA/COILRA
    3 CONTINUE
      TINC1=(TFLOUT-TFLIN)/10.00
      WRITE(7,300)NRUN,NMO,NDAY,NYEAR,ABYR,FLRTMA,TFLIN,TFLOUT,TAMPS,VOL
     1TS
  300 FORMAT(I3,2X,3I5,F10.6,5F10.2)
      TCSDIS=0.0
      DO 7 I=1,10
      NSTA=I
      IF(I.EQ.10) GO TO 4
      TCSDIS=TCSDIS+1.0
      GO TO 5
    4 TCSDIS=TCSDIS+0.75
    5 CONTINUE
      TEFLU=TFLIN+(TINC1*TCSDIS)
      READ(5,102)(TIS(J),J=1,8)
  102 FORMAT(4E20.7)
      READ(5,102)(QFLUX(J),J=1,8)
      CALL DMLSNO(FLRTMA,TEFLU,TCSDIS)
      AVHTC=0.0
      DO 6 J=1,8
      TFLOC(J)=TEFLU
      HTC(J)=QFLUX(J)/(TIS(J)-TEFLU)
      AVHTC=AVHTC+HTC(J)
    6 CONTINUE
      CALL NUSELT
      AVHTC=AVHTC/8.0
      CANUNO=(AVHTC*(0.495/12.0))/TCFLU
      WRITE(6,200)
  200 FORMAT(1H1,2X,80HCALCULATION OF HEAT TRANSFER COEFFECIENTS IN A HE
     1LICAL COIL BY SUMAN P.N. SINGH.)
      WRITE(6,201)NRUN,NMO,NDAY,NYEAR
  201 FORMAT(2X,12HRUN NUMBER =,I4,I10,1H-,I2,1H-,I2)
      WRITE(6,202)NSTA
  202 FORMAT(2X,16HSTATION NUMBER =,I3)
      WRITE(6,203)TAMPS,VOLTS
  203 FORMAT(2X,17HCURRENT IN COIL =,F6.1,5H AMPS,10X,26HVOLTAGE DROP AC
     1ROSS COIL =,F7.2,6H VOLTS)
      WRITE(6,204)
  204 FORMAT(//,2X,20HPERIPHERAL LOCATION ,14X,10H     1     ,2X,10H     2
     1     ,2X,10H     3     ,2X,10H     4     ,2X,10H     5     ,2X,10H
     2 6     ,2X,10H     7     ,2X,10H     8     ,/2X,30HDEGREES CLOCKWISE
     3 FROM NORTH   ,4X,10H     0     ,2X,10H    45     ,2X,10H    90     ,2
     4X,10H   135     ,2X,10H   180     ,2X,10H   225     ,2X,10H   270
     5,2X,10H   315     ,//)
      WRITE(6,205)(QFLUX(J),J=1,8)
  205 FORMAT(2X,30HHEAT FLUX, Q , BTU/HR-SQ.FT. =,2X,8(F10.3,2X))
      WRITE(6,206)(TIS(J),J=1,8)
  206 FORMAT(/,2X,30HINSIDE WALL TEMPERATURE,TW, F=,2X,8(F10.3,2X))
      WRITE(6,207)
  207 FORMAT(//,2X,54HFOR FLUID TEMPERATURES MEASURED BY CONAX THERMOCOU
     1PLES)
      WRITE(6,208)(TFLOC(J),J=1,8)
  208 FORMAT(/,2X,30HLOCAL FLUID TEMPERATURE,TF, F=,2X,8(F10.3,2X))
      WRITE(6,209)(HTC(J),J=1,8)
  209 FORMAT(/,2X,30HH(LOCAL), BTU/HR-SQ.FT.-F     =,2X,8(F10.3,2X))
      WRITE(6,217)(PRFLNU(J),J=1,8)
  217 FORMAT(/,2X,30HPERIPHERAL NUSSELT NUMBER, NJ=,2X,8(F10.3,2X))
      WRITE(6,218) TEFLU
  218 FORMAT(//,2X,33HAT THE LOCAL FLUID TEMPERATURE OF,F10.3,4H F :)
      WRITE(6,219) NRE
  219 FORMAT(/,2X,23HREYNOLDS NUMBER = RE = ,I10)
      WRITE(6,220) PRANTL
  220 FORMAT(/,2X,23HPRANDTL  NUMBER = PR = ,F10.3)
      WRITE(6,221) NDE
  221 FORMAT(/,2X,23HDEAN     NUMBER = DE = ,I10)
      WRITE(6,222) GRAETZ
  222 FORMAT(/,2X,23HGRAETZ   NUMBER = GZ = ,F10.3)
      WRITE(6,223) AVHTC
  223 FORMAT(//,2X,35HAVERAGE H(LOCAL) FOR THIS STATION =,F10.3,16H BTU/
     1HR-SQ.FT.-F)
      WRITE(6,224) CANUNO
  224 FORMAT(/,2X,46HAVERAGE NUSSELT NUMBER(=NU) FOR THIS STATION =,F10.
     13)
      WRITE(7,301)(TIS(J),J=1,8)
  301 FORMAT(8F10.3)
```

```
      WRITE(7,301)(HTC(J),J=1,8)
      WRITE(7,301)(PRFLNU(J),J=1,8)
      WRITE(7,302)NRE,NDE,PRANTL,TEFLU,GRAETZ,AVHTC,CANUNO
  302 FORMAT(2X,I10,1X,I10,2X,F10.3,1X,F10.3,2X,2(F10.3,1X),F10.3)
      CALL PLOT(NMO,NDAY,NYEAR,NSTA)
    7 CONTINUE
      GO TO 1
      END
```

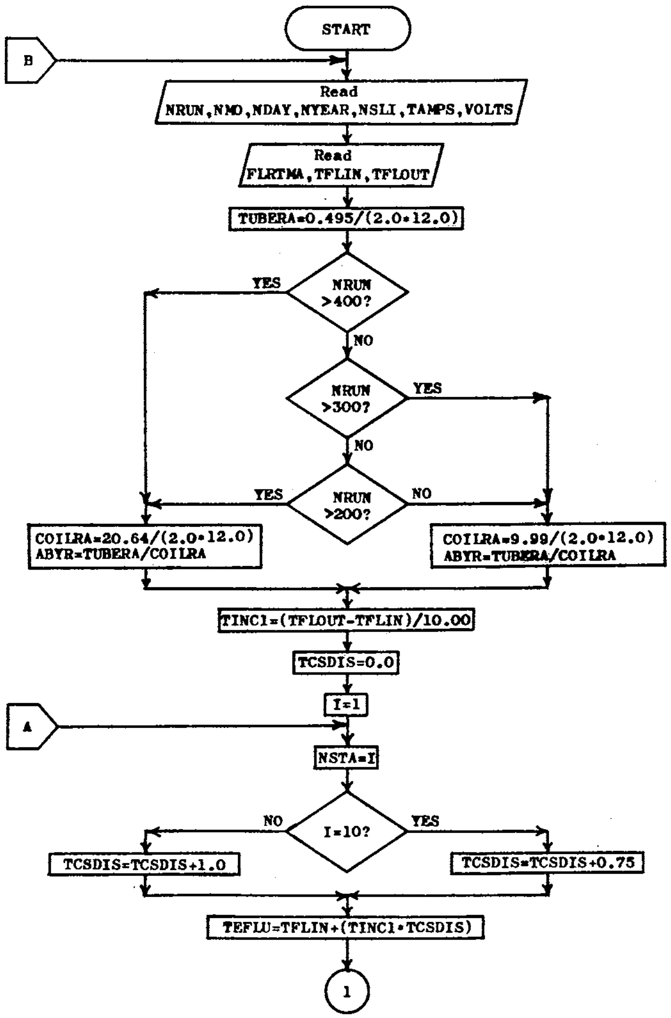
```
      SUBROUTINE DMLSNO(FLRTMA,TEFLU,TCSDIS)
C
      COMMON/DLSNOS/NRE,ABYR,NDE,PRANTL,CANUNO,GRAETZ
      COMMON/INVALU/HTC(8),PRFLNU(8),TCFLU,NRUN
      TEMPC=((TEFLU-32.0)*5.0)/9.0
      IF(NRUN.GT.300) GO TO 1
      RHSVR=((1.3272*(20.0-TEMPC))-(0.001053*(TEMPC-20.0)*(TEMPC-20.0)))
     1/(TEMPC+105.0)
      RHSLN=2.303*RHSVR
      FLVIS=1.002*EXP(RHSLN)
      CPFLU=1.01881-0.4802E-03*TEFLU+0.3274E-05*TEFLU*TEFLU-0.604E-08*TE
     1FLU*TEFLU*TEFLU
      TCFLU=0.30289+0.7029E-03*TEFLU-0.1178E-05*TEFLU*TEFLU-0.550E-09*TE
     1FLU*TEFLU*TEFLU
      GO TO 2
    1 FLVIS=0.105786E+03-0.16867E+01*TEFLU+0.1058E-01*TEFLU*TEFLU-0.2993
     16E-04*TEFLU*TEFLU*TEFLU+0.31814E-07*TEFLU*TEFLU*TEFLU*TEFLU
      CPFLU=0.369356+0.20216E-03*TEFLU+0.8285E-06*TEFLU*TEFLU-0.19987E-0
     18*TEFLU*TEFLU*TEFLU
      TCFLU=241.90848*(3.149499E-04-(0.93E-07*TEMPC))
    2 FVFPS=2.42*FLVIS
      RENO=((0.495/12.0)*FLRTMA)/((3.1416/4.0)*(0.495*0.495/144.0)*FVFPS
     1)
      NRE=RENO
      PRANTL=(CPFLU*FVFPS)/TCFLU
      DENO=RENO*(SQRT(ABYR))
      NDE=DENO
      GRAETZ=(FLRTMA*CPFLU)/(TCFLU*TCSDIS)
      RETURN
      END
```

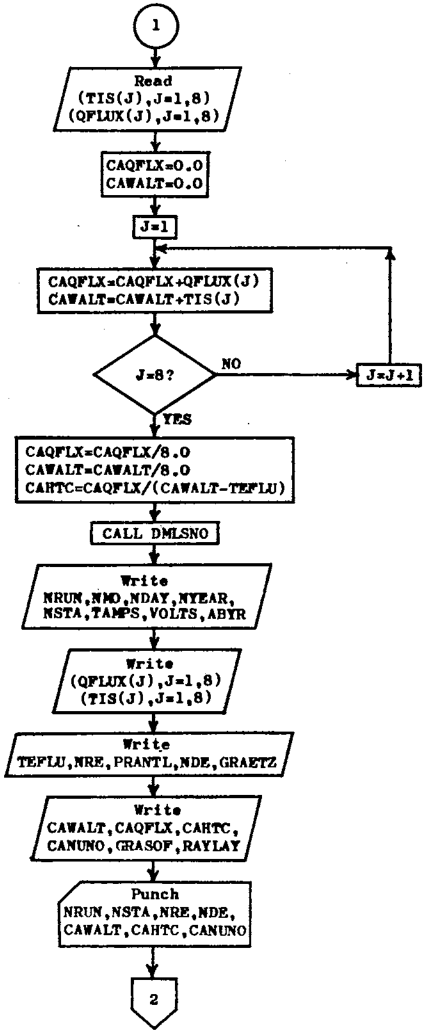
```
      SUBROUTINE NUSELT
C
      COMMON/INVALU/HTC(8),PRFLNU(8),TCFLU,NRUN
      DO 1 J=1,8
      PRFLNU(J)=(HTC(J)*(0.495/12.0))/TCFLU
    1 CONTINUE
      RETURN
      END
```

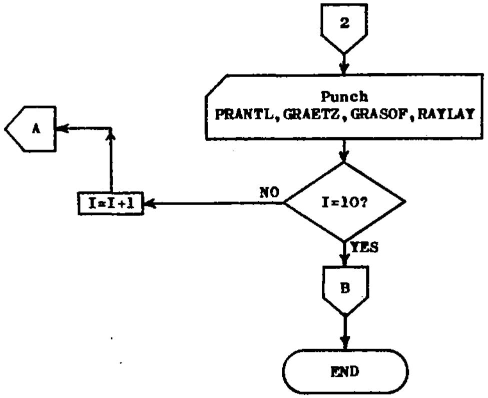
```
      SUBROUTINE PLOT(NMO,NDAY,NYEAR,NSTA)
C
      DIMENSION HTPLOT(2,8),GRAPH(8,51),SYMBOL(3),ORD(51)
      COMMON/DLSNOS/NRE,ABYR,NDE,PRANTL,CANUNO,GRAETZ
      COMMON/INVALU/HTC(8),PRFLNU(8),TCFLU,NRUN
      DATA SYMBOL/1HC,1HA,1H /
      DATA ASTER/1H*/
      DO 1 J=1,8
      HTPLOT(1,J)=PRFLNU(J)
    1 CONTINUE
      DO 2 I=1,8
      DO 2 J=1,51
      GRAPH(I,J)=SYMBOL(3)
    2 CONTINUE
      HTMAX=HTPLOT(1,1)
      HTMIN=0.0
      I=1
      DO 3 J=1,8
      IF(HTMAX.LT.HTPLOT(I,J))HTMAX=HTPLOT(I,J)
    3 CONTINUE
      DIFF=HTMAX-HTMIN
      DEL=1.0
      IF(DIFF.GT.50.0)DEL=2.0
      IF(DIFF.GT.100.0)DEL=5.0
      IF(DIFF.GT.200.0)DEL=10.0
      IF(DIFF.GT.500.0)DEL=20.0
      IF(DIFF.GT.1000.0)DEL=50.0
      IF(DIFF.GT.2000.0)DEL=100.0
      IF(DIFF.GT.5000.0)DEL=200.0
      IF(DIFF.GT.10000.0)DEL=500.0
      DO 4 J=1,8
      L=(HTPLOT(I,J)-HTMIN)/DEL+0.5
      L=51-L
    4 GRAPH(J,L)=SYMBOL(I)
      DO 5 I=1,51
      ORD(I)=SYMBOL(3)
    5 CONTINUE
      DO 6 I=1,51,5
      ORD(I)=ASTER
    6 CONTINUE
      WRITE(6,200)NRUN,NMO,NDAY,NYEAR,NSTA
  200 FORMAT(1H1,2X,12HRUN NUMBER =,I4,I10,1H-,I2,1H-,I2,5X,16HSTATION N
     1UMBER =,I3,//)
      DO 11 I=1,51
      IF(I.EQ.20) GO TO 7
      IF(I.EQ.21) GO TO 8
      IF(I.EQ.22) GO TO 9
```

```
      IF(I.EQ.23) GO TO 10
      WRITE(6,201) ORD(I),(GRAPH(J,I),J=1,8)
  201 FORMAT(50X,9(4X,1A1))
      GO TO 11
    7 WRITE(6,202) NRE,ORD(I),(GRAPH(J,I),J=1,8)
  202 FORMAT(10X,23HREYNOLDS NUMBER = RE = ,I7,10X,9(4X,1A1))
      GO TO 11
    8 WRITE(6,203) ABYR,ORD(I),(GRAPH(J,I),J=1,8)
  203 FORMAT(10X,23HTUBE/COIL RADIUS= A/R= ,F7.4,10X,9(4X,1A1))
      GO TO 11
    9 WRITE(6,204) PRANTL,ORD(I),(GRAPH(J,I),J=1,8)
  204 FORMAT(10X,23HPRANDTL  NUMBER = PR = ,F7.2,10X,9(4X,1A1))
      GO TO 11
   10 WRITE(6,205) NDE,ORD(I),(GRAPH(J,I),J=1,8)
  205 FORMAT(10X,23HDEAN      NUMBER = DE = ,I7,10X,9(4X,1A1))
   11 CONTINUE
      WRITE(6,201)SYMBOL(3),(ASTER,I=1,8)
      WRITE(6,206)
  206 FORMAT(59X,1H1,4X,1H2,4X,1H3,4X,1H4,4X,1H5,4X,1H6,4X,1H7,4X,1H8,/5
     16X,40HPERIPHERAL LOCATION,CLKWISE. FROM NORTH ,/)
      WRITE(6,207)HTMIN,HTMAX
  207 FORMAT(2X,27HBASE LINE NUSSELT NUMBER = ,F5.1,10X,25HMAXIMUM NUSSE
     1LT NUMBER = ,F10.3)
      WRITE(6,208) DEL
  208 FORMAT(2X,10HDELTA NU =,F10.1)
      RETURN
      END
```

Figure 30. Flowchart for Computer Program SPNS06


START
B
Read
NRUN,NMO,NDAY,NYEAR,NSLI,TAMPS,VOLTS
Read
FLRTMA,TFLIN,TFLOUT
TUBERA=0.495/(2.0*12.0)
NRUN >400?
YES
NO
NRUN >300?
YES
NO
NRUN >200?
YES
NO
COILRA=20.64/(2.0*12.0)
ABYR=TUBERA/COILRA
COILRA=9.99/(2.0*12.0)
ABYR=TUBERA/COILRA
TINC1=(TFLOUT-TFLIN)/10.00
TCSDIS=0.0
I=1
A
NSTA=I
I=10?
NO
YES
TCSDIS=TCSDIS+1.0
TCSDIS=TCSDIS+0.75
TEFLU=TFLIN+(TINC1*TCSDIS)
1


1
Read
(TIS(J),J=1,8)
(QFLUX(J),J=1,8)
CAQFLX=0.0
CAWALT=0.0
J=1
CAQFLX=CAQFLX+QFLUX(J)
CAWALT=CAWALT+TIS(J)
J=8?
NO
J=J+1
YES
CAQFLX=CAQFLX/8.0
CAWALT=CAWALT/8.0
CAHTC=CAQFLX/(CAWALT-TEFLU)
CALL DMLSNO
Write
NRUN,NMO,NDAY,NYEAR,
NSTA,TAMPS,VOLTS,ABYR
Write
(QFLUX(J),J=1,8)
(TIS(J),J=1,8)
Write
TEFLU,NRE,PRANTL,NDE,GRAETZ
Write
CAWALT,CAQFLX,CAHTC,
CANUNO,GRASOF,RAYLAY
Punch
NRUN,NSTA,NRE,NDE,
CAWALT,CAHTC,CANUNO
2



SUBROUTINE DMLSNO:

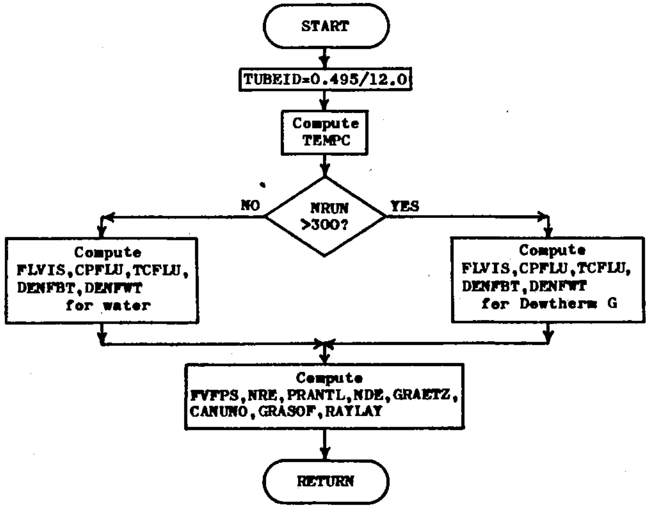
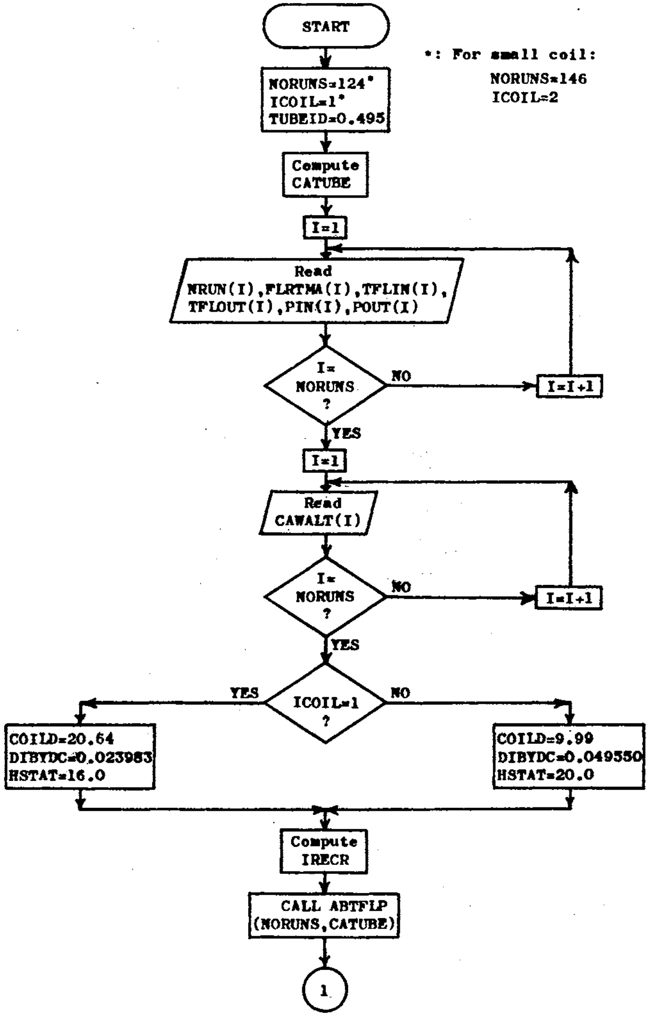


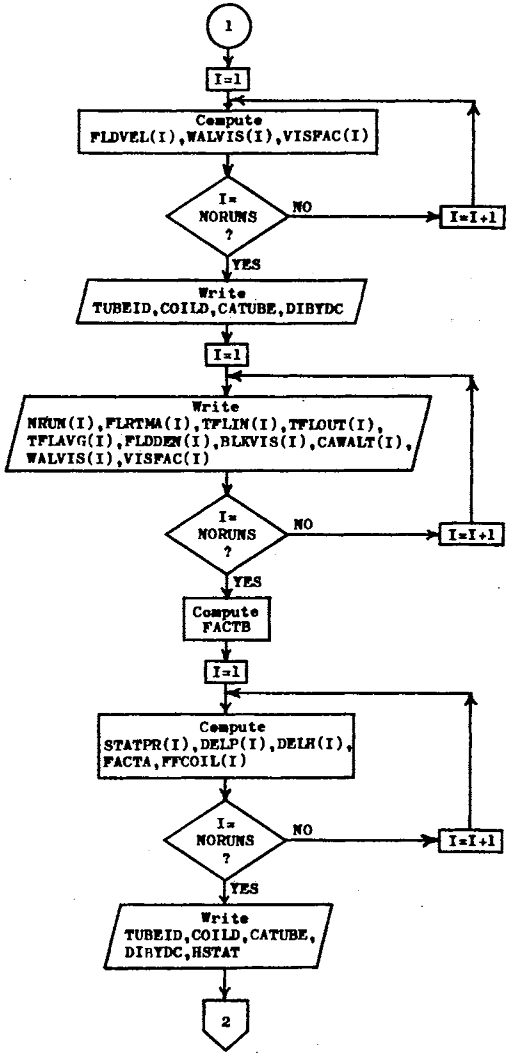
Figure 31. 80/80 Listing of Computer Program SPNS06

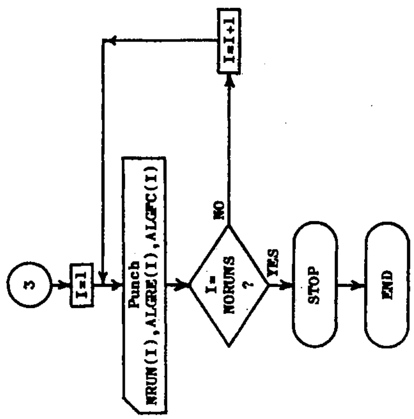
```
C
C a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*
C
C COMPUTER PROGRAM: SPNS06.
C
C PROGRAM TO COMPUTE:
C  1. HEAT TRANSFER COEFFICIENTS, AND
C  2. PERTINENT FLUID FLOW AND HEAT TRANSFER DIMENSIONLESS NUMBERS
C FOR LIQUID PHASE HEAT TRANSFER STUDIES IN HELICALLY COILED TUBES.   BY SUMAN
C P.N. SINGH.
C
C a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*a%*
C
C *** NOTE:1. FLUID PROPERTIES ARE EVALUATED AT THE LOCAL BULK FLUID TEMPERATURE
C             AT EACH THERMOCOUPLE STATION.
C          2. LOCAL H(AVG.)=((1/N)E(Q/A))/((1/N)E(T(WALL))-T(BULK FLUID)).
C
      DIMENSION QFLUX(8),TIS(8)
      COMMON/INVALU/FLRTMA,TEFLU,TCSDIS,CAWALT,CAHTC,NRUN
      COMMON/DLSNOS/NRE,ABYR,NDE,PRANTL,GRAETZ,GRASOF,RAYLAY,CANUNO
    1 READ(5,100) NRUN,NMO,NDAY,NYEAR,NSLI,TAMPS,VOLTS
  100 FORMAT(5I5,2E20.7)
      READ(5,101) FLRTMA,TFLIN,TFLOUT
  101 FORMAT(3F10.2)
      TUBERA=0.495/(2.0*12.0)
      IF(NRUN.GT.400) GO TO 2
      IF(NRUN.GT.300) GO TO 8
      IF(NRUN.GT.200) GO TO 2
    8 COILRA=9.99/(2.0*12.0)
      ABYR=TUBERA/COILRA
      GO TO 3
    2 COILRA=20.64/(2.0*12.0)
      ABYR=TUBERA/COILRA
    3 CONTINUE
      TINC1=(TFLOUT-TFLIN)/10.00
      TCSDIS=0.0
      DO 7 I=1,10
      NSTA=I
      IF(I.EQ.10) GO TO 4
      TCSDIS=TCSDIS+1.0
      GO TO 5
    4 TCSDIS=TCSDIS+0.75
    5 CONTINUE
      TEFLU=TFLIN+(TINC1*TCSDIS)
      READ(5,102)(TIS(J),J=1,8)
  102 FORMAT(4E20.7)
      READ(5,102)(QFLUX(J),J=1,8)
      CAQFLX=0.0
      CAWALT=0.0
      DO 6 J=1,8
      CAQFLX=CAQFLX+QFLUX(J)
      CAWALT=CAWALT+TIS(J)
    6 CONTINUE
      CAQFLX=CAQFLX/8.0
      CAWALT=CAWALT/8.0
      CAHTC=CAQFLX/(CAWALT-TEFLU)
      CALL DMLSNO
      WRITE(6,200)
  200 FORMAT(1H1,2X,80HCALCULATION OF HEAT TRANSFER COEFFECIENTS IN A HE
     1LICAL COIL BY SUMAN P.N. SINGH.)
      WRITE(6,201)NRUN,NMO,NCAY,NYEAR
  201 FORMAT(2X,12HRUN NUMBER =,I4,I10,1H-,I2,1H-,I2)
      WRITE(6,202)NSTA
  202 FORMAT(2X,16HSTATION NUMBER =,I3)
      WRITE(6,203)TAMPS,VOLTS
  203 FORMAT(2X,17HCURRENT IN COIL =,F6.1,5H AMPS,10X,26HVOLTAGE DROP AC
     1ROSS COIL =,F7.2,6H VOLTS)
      WRITE(6,208) ABYR
  208 FORMAT(2X,29HTUBE-TO-COIL DIAMETER RATIO =,F10.6)
      WRITE(6,204)
  204 FORMAT(//,2X,20HPERIPHERAL LOCATION ,14X,10H     1    ,2X,10H    2
     1    ,2X,10H    3    ,2X,10H    4    ,2X,10H    5    ,2X,10H
     2 6    ,2X,10H    7    ,2X,10H    8    ,/2X,30HDEGREES CLOCKWISE
     3 FROM NORTH ,4X,10H    0    ,2X,10H   45    ,2X,10H   90    ,2
     4X,10H  135    ,2X,10H  180    ,2X,10H  225    ,2X,10H  270
     5,2X,10H  315    ,//)
      WRITE(6,205)(QFLUX(J),J=1,8)
  205 FORMAT(2X,30HHEAT FLUX, Q , BTU/HR-SQ.FT. =,2X,8(F10.3,2X))
      WRITE(6,206)(TIS(J),J=1,8)
  206 FORMAT(/,2X,30HINSIDE WALL TEMPERATURE,TW, F=,2X,8(F10.3,2X))
      WRITE(6,207)
  207 FORMAT(//,2X,54HFOR FLUID TEMPERATURES MEASURED BY CONAX THERMOCOU
     1PLES)
      WRITE(6,218) TEFLU
  218 FORMAT(//,2X,33HAT THE LOCAL FLUID TEMPERATURE OF,F10.3,4H F :)
      WRITE(6,219) NRE
  219 FORMAT(/,2X,23HREYNOLDS NUMBER = RE = ,I10)
      WRITE(6,220) PRANTL
  220 FORMAT(/,2X,23HPRANDTL  NUMBER = PR = ,F10.3)
      WRITE(6,221) NDE
  221 FORMAT(/,2X,23HDEAN     NUMBER = DE = ,I10)
      WRITE(6,222) GRAETZ
  222 FORMAT(/,2X,23HGRAETZ   NUMBER = GZ = ,F10.3)
      WRITE(6,223)
  223 FORMAT(///,2X,64HTHE FOLLOWING ARE PERIPHERALLY AVERAGED VALUES FO
     1R THIS STATION:,//)
      WRITE(6,224) CAWALT
  224 FORMAT(2X,26HAVERAGE WALL TEMPERATURE =,F10.3,2H F)
      WRITE(6,225) CAQFLX
  225 FORMAT(/,2X,19HAVERAGE HEAT FLUX =,F10.3,14H BTU/HR-SQ.FT.)
      WRITE(6,226) CAHTC
  226 FORMAT(/,2X,35HAVERAGE HEAT TRANSFER COEFFICIENT =,F10.3,16H BTU/H
     1R-SQ.FT.-F)
      WRITE(6,227) CANUNO
  227 FORMAT(//,2X,23HNUSSELT  NUMBER = NU = ,F10.3)
      WRITE(6,228) GRASOF
  228 FORMAT(/,2X,23HGRASHOF  NUMBER = GR = ,E20.9)
      WRITE(6,229) RAYLAY
```

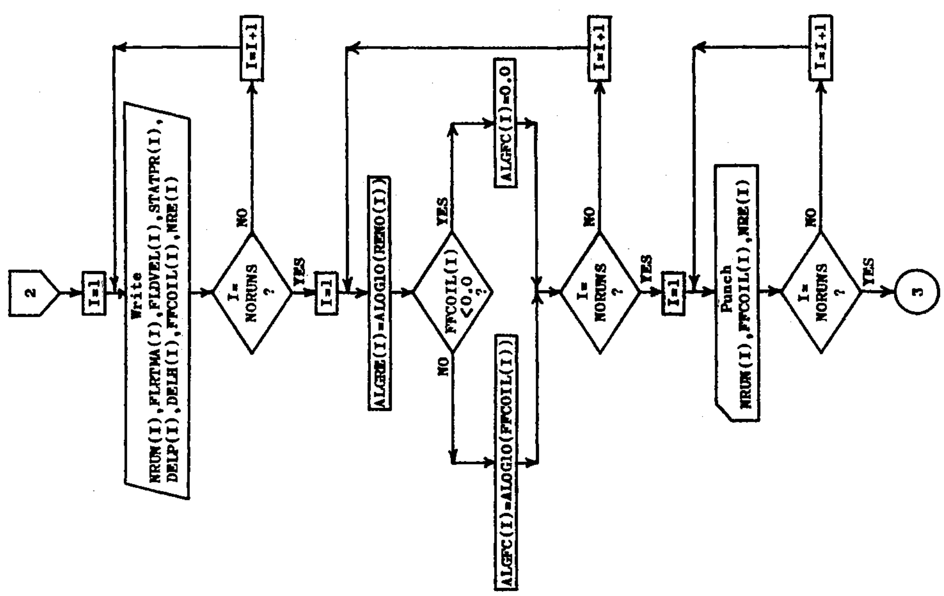
```
229 FORMAT(/,2X,23HRAYLEIGH NUMBER = RA = ,E20.9)
    WRITE(7,300) NRUN,NSTA,NRE,NDE,CAWALT,CAHTC,CANUNO
300 FORMAT(I3,1H-,I2,4X,I10,5X,I10,3(5X,F10.3))
    WRITE(7,301)  PRANTL,GRAETZ,GRASOF,RAYLAY
301 FORMAT(F10.3,6X,F10.3,7X,E20.9,7X,E20.9)
  7 CONTINUE
    GO TO 1
    END



    SUBROUTINE DMLSNO
C
    COMMON/INVALU/FLRTMA,TEFLU,TCSDIS,CAWALT,CAHTC,NRUN
    COMMON/DLSNOS/NRE,ABYR,NDE,PRANTL,GRAETZ,GRASOF,RAYLAY,CANUNO
    TUBEID=0.495/12.0
    TEMPC=((TEFLU-32.0)*5.0)/9.0
    IF(NRUN.GT.300) GO TO 1
    RHSVR=((1.3272*(20.0-TEMPC))-(0.001053*(TEMPC-20.0)*(TEMPC-20.0)))
   1/(TEMPC+105.0)
    RHSLN=2.303*RHSVR
    FLVIS=1.002*EXP(RHSLN)
    CPFLU=1.01881-0.4802E-03*TEFLU+0.3274E-05*TEFLU*TEFLU-0.604E-08*TE
   1FLU*TEFLU*TEFLU
    TCFLU=0.30289+0.7029E-03*TEFLU-0.1178E-05*TEFLU*TEFLU-0.550E-09*TE
   1FLU*TEFLU*TEFLU
    ROEFBT=0.999986+0.1890E-04*TEMPC-0.5886E-05*TEMPC*TEMPC+0.1548E-07
   1*TEMPC*TEMPC*TEMPC
    DENFBT=62.43*ROEFBT
    CAWTC=((CAWALT-32.0)*5.0)/9.0
    ROEFWT=0.999986+0.1890E-04*CAWTC-0.5886E-05*CAWTC*CAWTC+0.1548E-07
   1*CAWTC*CAWTC*CAWTC
    DENFWT=62.43*ROEFWT
    GO TO 2
  1 FLVIS=0.105786E+03-0.16867E+01*TEFLU+0.1058E-01*TEFLU*TEFLU-0.2993
   16E-04*TEFLU*TEFLU*TEFLU+0.31814E-07*TEFLU*TEFLU*TEFLU*TEFLU
    CPFLU=0.369356+0.20216E-03*TEFLU+0.8285E-06*TEFLU*TEFLU-0.19987E-0
   18*TEFLU*TEFLU*TEFLU
    TCFLU=241.90848*(3.149499E-04-(0.93E-07*TEMPC))
    DENFWT=70.70705-0.25338E-01*CAWALT-0.3095E-04*CAWALT*CAWALT+0.8890
   1E-07*CAWALT*CAWALT*CAWALT
    DENFBT=70.70705-0.25338E-01*TEFLU-0.3095E-04*TEFLU*TEFLU+0.8890E-0
   17*TEFLU*TEFLU*TEFLU
  2 FVFPS=2.42*FLVIS
    RENO=((0.495/12.0)*FLRTMA)/((3.1416/4.0)*(0.495*0.495/144.0)*FVFPS
   1)
    NRE=RENO
    PRANTL=(CPFLU*FVFPS)/TCFLU
    DENO=RENO*(SQRT(ABYR))
    NDE=DENO
    GRAETZ=(FLRTMA*CPFLU)/(TCFLU*TCSDIS)
    CANUNO=(CAHTC*TUBEID)/TCFLU
    AVDENF=(DENFBT+DENFWT)/2.0
    DELTAT=CAWALT-TEFLU
    BETA=(DENFBT-DENFWT)/(DELTAT*AVDENF)
    GRAVTY=4.17E+08
    GRASOF=(TUBEID*TUBEID*TUBEID*GRAVTY*DENFBT*DENFBT*BETA*DELTAT)/(FV
   1FPS*FVFPS)
    RAYLAY=GRASOF*PRANTL
    RETURN
    END
```

Figure 32. Flowchart for Computer Program SPNS10

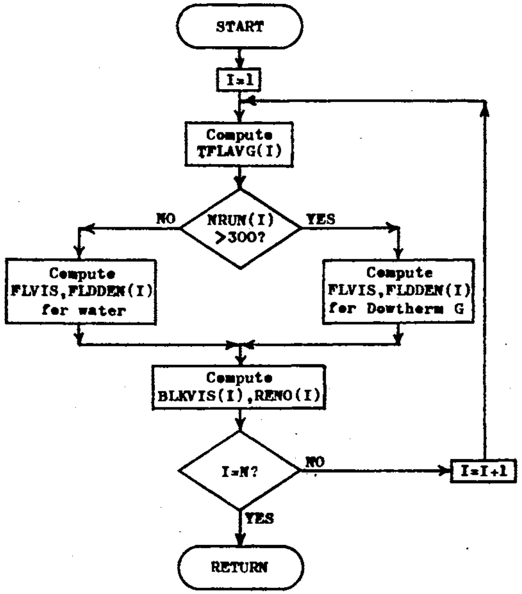

START
NORUNS=124*
ICOIL=1*
TUBEID=0.495
*: For small coil:
NORUNS=146
ICOIL=2
Compute CATUBE
I=1
Read
NRUN(I),FLRTMA(I),TFLIN(I),
TFLOUT(I),PIN(I),POUT(I)
I=NORUNS ?
NO
I=I+1
YES
I=1
Read CAWALT(I)
I=NORUNS ?
NO
I=I+1
YES
ICOIL=1 ?
YES
NO
COILD=20.64
DIBYDC=0.023983
HSTAT=16.0
COILD=9.99
DIBYDC=0.049550
HSTAT=20.0
Compute IRECR
CALL ABTFLP
(NORUNS,CATUBE)
1


1
I=1
Compute
FLDVEL(I),WALVIS(I),VISFAC(I)
I=NORUNS ?
NO
I=I+1
YES
Write
TUBEID,COILD,CATUBE,DIBYDC
I=1
Write
NRUN(I),FLRTMA(I),TFLIN(I),TFLOUT(I),
TFLAVG(I),FLDDEN(I),BLKVIS(I),CAWALT(I),
WALVIS(I),VISFAC(I)
I=NORUNS ?
NO
I=I+1
YES
Compute FACTB
I=1
Compute
STATPR(I),DELP(I),DELH(I),
FACTA,FFCOIL(I)
I=NORUNS ?
NO
I=I+1
YES
Write
TUBEID,COILD,CATUBE,
DIBYDC,HSTAT
2


3
I=1
Punch
NRUN(I),ALGRE(I),ALGFC(I)
I=
NORUNS
?
NO
I=I+1
YES
STOP
END


2
I=1
Write
NRUN(I),FLRTMA(I),FLDVEL(I),STATPR(I),
DELP(I),DELH(I),FFCOIL(I),NRE(I)
I=
NORUNS
?
NO
I=I+1
YES
I=1
ALGRE(I)=ALOG10(RENO(I))
FFCOIL(I)
<0.0
?
YES
ALGFC(I)=0.0
NO
ALGFC(I)=ALOG10(FFCOIL(I))
I=
NORUNS
?
NO
I=I+1
YES
I=1
Punch
NRUN(I),FFCOIL(I),NRE(I)
I=
NORUNS
?
NO
I=I+1
YES
3

SUBROUTINE ABTFLP:



FUNCTION VISC:

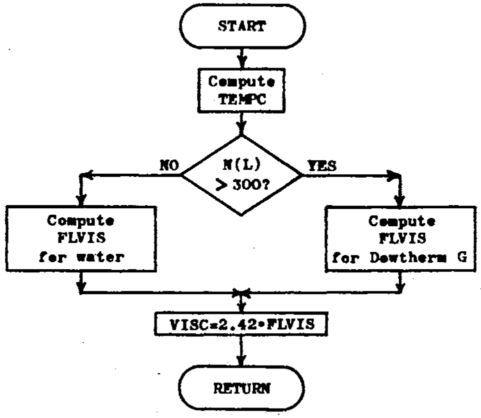


Figure 33. 80/80 Listing of Computer Program SPNS10

```
C
C @%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*
C
C COMPUTER PROGRAM: SPNS10.
C
C PROGRAM TO COMPUTE THE FRICTIONAL HEAD LOSS AND FANNING FRICTION FACTOR FOR
C FLUID FLOW THROUGH A HELICALLY COILED TUBE.   BY SUMAN P.N. SINGH.
C
C @%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*@%*
C
      DIMENSION PIN(200),POUT(200),STATPR(200),FLDVEL(200),DELP(200),DEL
     1H(200),FFCOIL(200),NRE(200),CAWALT(200),WALVIS(200),VISFAC(200),AL
     2GRE(200),ALGFC(200)
      COMMON/FLDPRP/BLKVIS(200),FLDDEN(200),RENO(200),NRUN(200),FLRTMA(2
     100),TFLIN(200),TFLOUT(200),TFLAVG(200)
      NORUNS=124
      ICOIL=1
      TUBEID=0.495
      CATUBE=(3.1416/4.0)*((TUBEID*TUBEID)/144.0)
      GC=32.174
      DO 1 I=1,NORUNS
      READ(5,101) NRUN(I),FLRTMA(I),TFLIN(I),TFLOUT(I),PIN(I),POUT(I)
  101 FORMAT(I5,5F10.2)
    1 CONTINUE
      DO 14 I=1,NORUNS
      READ(5,102) CAWALT(I)
  102 FORMAT(40X,F10.3)
   14 CONTINUE
      IF(ICOIL.EQ.1) GO TO 15
      COILD=9.99
      DIBYDC=0.049550
      HSTAT=20.0
      GO TO 16
   15 COILD=20.64
      DIBYDC=0.023983
      HSTAT=16.0
   16 CONTINUE
      IRECR=20000.0*(DIBYDC**0.32)
      CALL ABTFLP(NORUNS,CATUBE)
      DO 2 I=1,NORUNS
      NRE(I)=RENO(I)
      FLDVEL(I)=FLRTMA(I)/(FLDDEN(I)*CATUBE*3600.0)
      WALVIS(I)=VISC(NRUN,I,CAWALT)
      VISFAC(I)=(BLKVIS(I)/WALVIS(I))**0.14
    2 CONTINUE
      WRITE(6,200)
  200 FORMAT(1H1,//,2X,77HFLUID FLOW PARAMETERS FOR FLOW IN HELICALLY CO
     1ILED TUBES.    SUMAN P.N. SINGH.)
      WRITE(6,201) TUBEID,COILD,CATUBE,DIBYDC
  201 FORMAT(//,2X,29HHELICAL COIL: TUBE I.D.,INS.=,F6.3,3X,15HCOIL DIA.
     1,INS.=,F7.2,3X,33HTUBE CROSS-SECTIONAL AREA,SQ.FT.=,F10.6,3X,7HDIB
     2YDC=,F10.6)
      WRITE(6,202)
  202 FORMAT(//,2X,7HRUN NO.,2X,10H   W,LB/HR,2X,10H  TFLIN, F,2X,10H TF
     1LOUT, F,2X,10H TFLAVG, F,2X,10H FLD. DEN.,2X,10HFLD. VISC.,2X,10H
     2CAWALT, F,2X,10HWALL VISC.,2X,10HVISC. FACT,//)
      DO 3 I=1,NORUNS
      WRITE(6,203) NRUN(I),FLRTMA(I),TFLIN(I),TFLOUT(I),TFLAVG(I),FLDDEN
     1(I),BLKVIS(I),CAWALT(I),WALVIS(I),VISFAC(I)
  203 FORMAT(4X,I3,4X,9(F10.3,2X))
    3 CONTINUE
    5 FACTB=32.174*(HSTAT/12.0)
      DO 6 I=1,NORUNS
      STATPR(I)=FLDDEN(I)*(HSTAT/12.0)*(1.0/144.0)
      DELP(I)=(PIN(I)-POUT(I))-STATPR(I)
      DELH(I)=DELP(I)/0.433
      FACTA=((PIN(I)-POUT(I))*144.0*GC)/FLDDEN(I)
      FFCOIL(I)=(1.0/2.0)*(TUBEID/(12.0*12.0))*(1.0/(FLDVEL(I)*FLDVEL(I)
     1))*(FACTA-FACTB)*VISFAC(I)
    6 CONTINUE
      WRITE(6,200)
      WRITE(6,201) TUBEID,COILD,CATUBE,DIBYDC
      WRITE(6,204) HSTAT
  204 FORMAT(//,2X,23HSTATIC FLUID HEAD,INS.=,F5.1)
      WRITE(6,205)
  205 FORMAT(//,2X,6H RUN  ,3X,22H    FLUID  FLOW  RATE ,3X,13HSTATIC PR
     1ESS.,3X,24H    COIL  PRESSURE  DROP,3X,12HFRICT. FACT.,4X,10H    RE
     2. NO.)
      WRITE(6,206)
  206 FORMAT(2X,6HNUMBER,3X,10H    LB/HR ,2X,10H   FT/SEC.,8X,3HPSI,8X,1
     10H      PSI ,2X,12HFT. OF WATER,9X,4HF(C),//)
      DO 7 I=1,NORUNS
      WRITE(6,207)NRUN(I),FLRTMA(I),FLDVEL(I),STATPR(I),DELP(I),DELH(I),
     1FFCOIL(I),NRE(I)
  207 FORMAT(3X,I3,5X,F10.2,2X,F10.5,6X,F5.2,8X,F10.2,2X,F12.6,3X,F12.6,
     12X,I10)
    7 CONTINUE
      DO 13 I=1,NORUNS
      ALGRE(I)=ALOG10(RENO(I))
      IF(FFCOIL(I).LT.0.0) GO TO 12
      ALGFC(I)=ALOG10(FFCOIL(I))
      GO TO 13
   12 ALGFC(I)=0.0
   13 CONTINUE
   10 DO 9 I=1,NORUNS
      WRITE(7,301) NRUN(I),FFCOIL(I),NRE(I)
  301 FORMAT(I3,F12.6,I10)
    9 CONTINUE
      WRITE(7,302)(NRUN(I),ALGRE(I),ALGFC(I),I=1,NORUNS)
  302 FORMAT(I5,2F10.4)
      STOP
      END
```

```
      SUBROUTINE ABTFLP(N,CSAREA)
C
      COMMON/FLDPRP/BLKVIS(200),FLDDEN(200),RENO(200),NRUN(200),FLRTMA(2
     100),TFLIN(200),TFLOUT(200),TFLAVG(200)
      DO 3  I=1,N
      TFLAVG(I)=(TFLIN(I)+TFLOUT(I))/2.0
      TEFLU=TFLAVG(I)
      IF(NRUN(I).GT.300) GO TO 1
      TEMPC=((TEFLU-32.0)*5.0)/9.0
      RHSVR=((1.3272*(20.0-TEMPC))-(0.001053*(TEMPC-20.0)*(TEMPC-20.0)))
     1/(TEMPC+105.0)
      RHSLN=2.303*RHSVR
      FLVIS=1.002*EXP(RHSLN)
      ROEFBT=0.999986+0.1890E-04*TEMPC-0.5886E-05*TEMPC*TEMPC+0.1548E-07
     1*TEMPC*TEMPC*TEMPC
      FLDDEN(I)=62.43*ROEFBT
      GO TO 2
    1 FLVIS=0.105786E+03-0.16867E+01*TEFLU+0.1058E-01*TEFLU*TEFLU-0.2993
     16E-04*TEFLU*TEFLU*TEFLU+0.31814E-07*TEFLU*TEFLU*TEFLU*TEFLU
      FLDDEN(I)=70.70705-0.25338E-01*TEFLU-0.3095E-04*TEFLU*TEFLU+0.8890
     1E-07*TEFLU*TEFLU*TEFLU
    2 BLKVIS(I)=2.42*FLVIS
      RENO(I)=(0.495*FLRTMA(I))/(12.0*CSAREA*BLKVIS(I))
    3 CONTINUE
      RETURN
      END
```

```
      FUNCTION VISC(N,L,TT)
C
      DIMENSION N(200),TT(200)
      TEMP=TT(L)
      TEMPC=((TEMP-32.0)*5.0)/9.0
      IF(N(L).GT.300) GO TO 2
    1 RHSVR=((1.3272*(20.0-TEMPC))-(0.001053*(TEMPC-20.0)*(TEMPC-20.0)))
     1/(TEMPC+105.0)
      RHSLN=2.303*RHSVR
      FLVIS=1.002*EXP(RHSLN)
      GO TO 3
    2 FLVIS=0.105786E+03-0.16867E+01*TEMP+0.1058E-01*TEMP*TEMP-0.29936E-
     104*TEMP*TEMP*TEMP+0.31814E-07*TEMP*TEMP*TEMP*TEMP
    3 VISC=2.42*FLVIS
      RETURN
      END
```

NOMENCLATURE FOR COMPUTER PROGRAMS

A = Cross-sectional area of the innermost segment of a tube slice normal to the r'-direction

ABSDQ = Average absolute deviation in the heat balance

ABSPDQ = Average absloute percent deviation in the heat balance

ABTFLP = Name of the subroutine that computes the bulk fluid viscosity, density and the Reynolds number

ABYR = Tube radius/coil radius

ALGFC = Log_{10}(Fanning friction factor for helical coil flow)

ALGRE = Log_{10}(Reynolds number)

AMPS = Fraction of the total current flowing through each segment of each slice of the tube wall, amps

AM1 = Result of the numerical integration of one of the terms used to compute XAREA

AM2 = Result of the numerical integration of the other term used to compute XAREA

APDELQ = Average percent difference in the heat balance

AVDENF = Average fluid density at a thermocouple station, lb/ft^3

AVGTEM = Arithmetic average of the inside wall temperature and the bulk fluid temperature at a peripheral location on the tube cross-section for a thermocouple station, °F

AVHTC = Average heat transfer coefficient for a thermocouple station, BTU/hr-ft^2-°F

AVTEMP = Same as for AVGTEM

BETA = Coefficient of the volume expansion of the fluid at a thermocouple station, 1/°F

BLKVIS = Fluid viscosity at the average bulk fluid temperature, lb_m/ft-hr

C1 = One of the integration constants used to compute XAREA

C2 = Another integration constant used to compute XAREA

CAHTC = Circumferentially-averaged heat transfer coefficient at a thermocouple station on the helical coil, BTU/hr-ft^2-°F

CANUNO = Circumferentially-averaged Nusselt number at the average fluid temperature for a thermocouple station

CAQFLX = Circumferentially-averaged heat flux at a thermocouple station, BTU/ft^2-hr

CATUBE = Cross-sectional area of the tube based on the inside tube diameter, ft^2

CAVGT = Average fluid temperature, °C

CAWALT = Circumferentially-averaged wall temperature at a thermocouple station, °F

CAWT = Same as for CAWALT

CAWTC = Circumferentially-averaged wall temperature at a thermocouple station, °C

COILD = Helical coil diameter, inches

COILRA = Helical coil radius, feet

CON = Thermal conductivity of one segment of one slice, BTU/hr-ft-°F

CPAVG = Specific heat of the fluid at the average temperature of the fluid, BTU/lb-°F

CPDIS = Arc length in the θ'-direction

CPFLU = Specific heat of the fluid, BTU/lb-°F

CPOWER = Calculated electric power input to the helical coil, watts

CRDIS = Length in the r'-direction

CTFIN = Corrected inlet temperature of the fluid,°F

CTFOUT = Corrected exit temperature of the fluid from the helical coil, °F

CURENT = Magnitude of the DC current flowing through the helical coil for the experimental run, amps

DAXDIS = Dimensionless axial distance of the thermocouple station from the inlet electrode

DEL = Increment used for the plot in the PLOT and SKETCH subroutines

DELH = Fluid head loss ude to flow in the helical coil, feet of water

DELM = Thickness of the wall at $\theta'=0$, feet

DELP = Fluid pressure drop due to flow in the helical coil, psi

DELPHI = Integration interval for the numerical integration of the integrands used to compute XAREA, degree

DELQ = The difference between the thermal energy input (by the electric heating of the coil) and the increase in the thermal energy of the fluid (in passing through the helical coil), BTU/hr

DELT = Temperature difference of the bulk fluid between the coil inlet and the coil exit, °F

DELTAT = Difference between the circumferentially-averaged wall temperature and the local bulk fluid temperature, °F

DENFBT = Fluid density at the local bulk fluid temperature at a thermocouple station, lb/ft^3

DENFWT = Fluid density at the circumferentially-averaged wall temperature at a thermocouple station, lb/ft^3

DENO = Dean number of the fluid

DEPTH = Arc length of an element of a tube slice in the θ-direction, feet

DIBYDC = Inside tube diameter/coil diameter

DIFF = Difference between the highest and the lowest value of a parameter to be plotted. DIFF is used to select the plot increment DEL

DMLSNO = Name of the subroutine that computes the density, specific heat, viscosity and the thermal conductivity and several dimensionless numbers for a thermocouple station

DMLSRE = Calculated value of the Reynolds number at the average bulk fluid temperature

DTMAX = Highest value of the dimensionless wall temperature to be plotted for a particular experimental data run

DTMIN = Lowest dimensionless wall temperature to be plotted for a particular experimental data run = 0.0

DWTEMP = Dimensionless wall temperature at a peripheral location on the tube cross-section for a thermocouple station

DWTP = Dummy variable. Assigned the value of the dimensionless wall temperature at a thermocouple station for a particular experimental data run

ERESTI = Name of the subroutine that computes the electrical resistivity of each segment of each slice for all the segments and slices for a thermocouple station

FFCOIL = The Fanning friction factor for fluid flow in a helical coil

FILMT = Average fluid film temperature for a thermocouple station, °F

FLDDEN = Fluid density at the average bulk fluid temperature, lb/ft^3

FLDVEL = Fluid velocity in the helical coil, ft/sec

FLRT = Fluid flow rate as indicated on the rotameter, % maximum flow or gpm

FLRTMA = Mass flow rate of fluid, lb/hr

FLUX = Name of the subroutine that computes the heat flux entering the fluid across each segment of the tube cross-section for a thermocouple station

FLVIS = Fluid viscosity at the average bulk fluid temperature, centipoise

FVFPS = Fluid viscosity at the average bulk fluid temperature, lb/ft-hr

GC = Conversion factor, $lb_m\text{-}ft/lb_f\text{-}sec^2$

GEOM = Name of the subroutine that computes the geometric dimensions of the segments of the coil

GRAETZ = Graetz number for the fluid computed at the local bulk fluid temperature at a thermocouple station

GRAPH = Variable name used to digitally plot the parameter to be plotted in the PLOT and SKETCH subroutines

GRASOF = Grashof number of the fluid for a thermocouple station

GRAVTY = Gravitational acceleration, ft/hr^2

HSTAT = Static head of fluid between the inlet and the exit pressure taps, inches

HTC = Heat transfer coefficient for heat transferred radially to the fluid across a segment of the tube cross-section for a thermocouple station, $BTU/hr\text{-}ft^2\text{-}^\circ F$

HTCOEF = Same as for HTC

HTMAX = The highest value of the Nusselt number to be plotted for a particular thermocouple station

HTMIN = The lowest value of the Nusselt number to be plotted for a particular thermocouple station

HTPLOT = Dummy variable. Assigned the value of the Nusselt number for each peripheral thermocouple location for a particular thermocouple station

ICOIL = Coil identification number: I=1 for the large coil; I=2 for the small coil

IRECR = Critical Reynolds number for flow in helically coiled tubes

ITEMP = Truncated value of the lowest temperature to be plotted for a thermocouple station, °F

KCON = Name of the subroutine that computes the thermal conductivity of each segment of each slice for a thermocouple station

NDAY = The day when the experimental run was performed

NDE = Dean number

NMO = The month when the experimental run was performed

NOORUN = Experimental run identification number

NORUNS = Number of experimental runs evaluated

NRE = Reynolds number

NRUN = Same as for NOORUN

NRUNS = Total number of the experimental data runs to be computed by the computer program

NSLI = Number of concentric slices into which the tube wall is divided for the numerical solution

NSTA = Thermocouple station number

NUSELT = Name of the subroutine that computes the Nusselt number

NYEAR = The year when the experimental run was performed

ORD = Variable name used to denote the ordinate in subroutines PLOT and SKETCH

PAREA = Cross-sectional area of a segment of a tube slice normal to the θ'-direction

PDELQ = Percent difference in the heat balance for the experimental data run

PIN = Fluid pressure at the coil inlet, psig

PLOT = Name of the subroutine that digitally plots either the wall temperatures or the Nusselt numbers for a thermocouple station

PNSELT = Nusselt number at the average film temperature at a thermocouple location

POUT = Fluid pressure at the coil exit, psig

POWER = Total electrical power input to the helical coil, watts

PRANTL = Prandtl number

PRFLNU = Same as for PNSELT

QB = Heat flux in the (-r')-direction for one segment of the innermost slice of the tube wall at a thermocouple station, BTU/hr-ft^2

QFLUX = Heat flux entering the fluid radially across one segment of the tube element for a thermocouple station, BTU/hr-ft^2

QIN = Rate of input of thermal energy to the helical coil, BTU/hr

QL = Heat flux in the $(-\theta')$-direction for one segment of the innermost slice of the tube wall at a thermocouple station, BTU/hr-ft^2

QOUT = Rate of increase of the thermal energy of the fluid in passing through the helical coil, BTU/hr

QR = Heat flux in the θ'-direction for one segment of the innermost slice of the tube wall at a thermocouple station, BTU/hr-ft^2

QT = Heat flux in the r'-direction for one segment of the innermost slice of the tube wall at a thermocouple station, BTU/hr-ft^2

R = Distance of the tube center from the helical coil axis, feet

RAREA = Cross-sectional area of a segment of a tube slice normal to the r'-direction

RAYLAY = Rayleigh number

RENO = Reynolds number

REPRDE = Name of the subroutine that computes the Reynolds, Prandtl and Dean number for the fluid at the average fluid film temperature at a thermocouple station

RESTA = Electrical resistance of one segment of one slice of the helically coiled tube at a thermocouple location, ohms

RESTI = Electrical resistivity of one segment of one slice of the helically coiled tube at a thermocouple location, ohms/ft

REYNO = Name of the subroutine that computes the Reynolds number for the fluid at the average bulk fluid temperature

RHSLN = Log_e(RHSVR)

RHSVR = Calculated value of the right hand side of the viscosity relation for water

RM = Radius of the mid-point of the tube wall from the center of the tube cross-section, feet

ROEFBT = Fluid density at the local bulk fluid temperature at a thermocouple station, gm/ml

ROEFWT = Fluid density at the circumferentially-averaged wall temperature at a thermocouple station, gm/ml

ROOMT = Average room temperature prevalent during the calibration of the surface thermocouples, °F

RUNNO = Floating point value of NRUNS

S = Coefficient used in the numerical integration formula for computing XAREA

SKETCH = Name of the subroutine that digitally plots the dimensionless wall temperature versus the dimensionless axial distance for an experimental data run

SRINV = Sum of the inverse electrical resistances of all the segments of all the slices of the tube wall for a thermocouple station, $ohms^{-1}$

STATPR = Static head of fluid between the coil inlet and exit pressure taps, psig

STEAMT = Average temperature of low pressure steam in the helical coil during the calibration of the surface thermocouples, °F

SYMBOL = Variable name used to select symbol to be plotted to indicate the value of the variable plotted for a thermocouple location

T = Corrected temperature reading of the node in a segment of a tube slice, °F

TAMPS = Same as for CURENT

TCASP = Average temperature correction for the surface thermocouples when low pressure steam is passed through the helical coil, °F

TCAVG = Average bulk temperature of the fluid in the helical coil, °C

TCDIS = Axial distance of the thermocouple station from the inlet electrode, feet

TCFLU = Thermal conductivity of the fluid, BTU/hr-ft-°F

TCK1 = Temperature set-point to check the convergence of the numerical solution, °F

TCK2 = Computed temperature of one segment of one slice of the tube wall. Used to check the convergence of the numerical solution, °F

TCOR = Temperature correction for the surface thermocouples at the experimental conditions, °F

TCORIN = Temperature correction for the inlet fluid thermocouple reading at the steam temperature, °F

TCOROU = Temperature correction for the exit fluid thermocouple reading at the steam temperature, °F

TCSDIS = Same as for TCDIS

TEFLU = Local average bulk fluid temperature at a thermocouple station, °F

TEMCOR = Name of the subroutine that corrects the experimental temperature readings of the surface thermocouples based on their calibration at the steam point

TEMPC = Fluid temperature, °C

TEMPER = Corrected surface thermocouple temperature, °F

TFAVG = Average temperature of the bulk fluid in the helical coil, °F

TFLAVG = Same as for TFAVG

TFLIN = Inlet fluid temperature to the helical coil, °F

TFLOC = Same as for TEFLU

TFLOUT = Exit fluid temperature from the helical coil, °F

THETA = The angle at the helical coil axis that describes an arc in the z'-direction, radians

TINC1 = Bulk fluid temperature increment per axial foot of the helically coiled tube, °F/ft

TINC2 = Bulk fluid temperature increment per unit length of the dimensionless axial distance along the helical coil, °F

TIS = Inside wall temperature at a peripheral location on the tube cross-section for a thermocouple station, °F

TMAX = Highest temperature to be plotted for a thermocouple station, °F

TMIN = Lowest temperature to be plotted for a thermocouple station, °F

TOS = Same as for TEMPER

TOTR = Total electrical resistance of the tube wall for a thermocouple station, ohms

TPLOT = Variable name which is assigned the outside and the inside tube wall temperatures for each segment of the tube wall for a thermocouple station, °F

TPOWER = The computed electrical power dissipated at a thermocouple station, watts

TROOM = Room temperature during the execution of the data run, °F

TUBEID = Inside tube diameter, feet

TUBERA = Inside tube radius, feet

UNCORT = Uncorrected surface thermocouple temperature reading, °F

UNCT = Same as for UNCORT

VISC = Name of the function subroutine that computes the viscosity of the fluid

VISFAC = Viscosity correction factor

VOLTS = Voltage drop across the helical coil for an experimental data run, volts

WALVIS = Fluid viscosity at the circumferentially-averaged wall temperature, lb_m/ft-hr

WATTS = Electrical power input to the helical coil, watts

XAREA = Cross-sectional area of a segment of a tube slice normal to the z'-direction

APPENDIX G

ERROR ANALYSIS

An analysis was performed to determine the error in the calculated heat transfer coefficients. The analysis is as follows:

From Appendix D:

$$h = \frac{Q/A}{(t_w)_i - t_b} = \phi(Q/A,\ t_w,\ t_b) \tag{G.1}$$

or

$$dh = \frac{\partial\phi}{\partial(Q/A)} \cdot d(Q/A) + \frac{\partial\phi}{\partial t_w} \cdot dt_w + \frac{\partial\phi}{\partial t_b} \cdot dt_b \tag{G.2}$$

From Equation (G.1)

$$\frac{\partial\phi}{\partial(Q/A)} = \frac{1}{(t_w - t_b)}\ ;\ \frac{\partial\phi}{\partial t_w} = -\frac{(Q/A)}{(t_w - t_b)^2}\ ;\ \frac{\partial\phi}{\partial t_b} = \frac{(Q/A)}{(t_w - t_b)^2}$$

Substituting in Equation (G.2)

$$dh = \frac{1}{(t_w - t_b)} \cdot d(Q/A) - \frac{(Q/A)}{(t_w - t_b)^2} \cdot dt_w + \frac{(Q/A)}{(t_w - t_b)^2}\, dt_b$$

or

$$\frac{dh}{h} = \frac{d(Q/A)}{(Q/A)} - \frac{dt_w}{(t_w - t_b)} + \frac{dt_b}{(t_w - t_b)} \tag{G.3}$$

To estimate the error in h, the error in the measurements of (Q/A), t_w and t_b will be estimated.

The error in the heat flux, Q/A, depends upon the error associated with the primary measurements used to determine the heat flux. These measurements together with an estimate of their error are:

1. Coil current--1%.
2. Coil voltage--1%.
3. Coil dimensions--0.1%.
4. Inside wall temperature--1.0%.
5. Room temperature--0.5%.

If all of the above mentioned measurements were in error to the extent indicated and in the same direction, the maximum error in the heat flux would be 3.6%.

From Appendix B, the calibration data on the bulk fluid and the wall thermocouples indicate that at an average temperature of 210°F:

1. The bulk fluid thermocouples had an average correction of -0.5°F.

2. The surface thermocouples on the 9.99-inch diameter coil had an average correction of +0.3°F.

3. The surface thermocouples on the 20.64-inch diameter coil had an average correction of +0.9°F.

The calibrations were performed using the Numatron to measure the thermocouple outputs. The Numatron had a stated accuracy of ±0.26°F over the 0 to 300°F range. Since the calibrations were made in-situ, the above mentioned corrections reflect the inaccuracies of the Numatron and the associated thermocouple wires.

Based on the above information, the average error in the bulk fluid temperature, the surface temperature on the 9.99-inch diameter coil and the surface temperature on the 20.64-inch diameter coil was estimated to be 0.3, 0.2 and 0.5 percent, respectively.

Now, since the inside wall temperature was determined by a numerical solution, the average error in the wall temperature would be affected by the errors in the coil dimensions, the room temperature, the flow rate and any computational errors. Taking all the errors into account, the combined total error in the inside wall temperature was estimated to be 1 percent.

Rewriting Equation (G.3),

$$\frac{dh}{h} = \frac{d(Q/A)}{(Q/A)} - \frac{(dt_w)/t_w}{(1 - (t_b/t_w))} + \frac{(dt_b)/t_b}{((t_w/t_b) - 1)}$$

The average bulk fluid and inside wall temperature were estimated to be 100°F and 120°F, respectively.

The maximum error in the heat transfer coefficient would occur when the errors in the independent variables are all additive.

Therefore,

$$\frac{dh}{h} = 0.036 + \frac{0.01}{(1 - (100/120))} + \frac{0.003}{((120/100) - 1)}$$

$$= 0.036 + 0.059 + 0.015$$

$$= 0.110 = 11\%.$$

In addition, a heat balance was made around the coil for each experimental data run. For the 158 runs made on the two coils using water, the average percent error and the absolute average percent error in the heat balance was 1.64% and 2.01%, respectively. For the 112 runs made using Dowtherm G, the above mentioned errors in the heat balance were 2.72% and 3.9%, respectively. The Dowtherm G runs indicated a greater error in the heat balance because most of the data were taken in the low flow rate regime with lower heat input rates than for the water data runs.

VITA

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