EXPERIMENTAL INVESTIGATION OF LAMINAR HEAT TRANSFER IN THE THERMAL ENTRANCE REGION OF INTERNALLY FINNED TUBES

BY

Ibrahim Mahmoud Rustum

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ABSTRACT

The pressure drop and heat transfer performance in the thermal entry region of six horizontally oriented copper tubes has been thoroughly investigated. Five tubes were internally finned and one was smooth. A uniform heat flux axially and circumferentially was supplied using resistance wires wrapped tightly around the tube. For each tested tube the heated section was preceded by a hydrodynamic entry section. Water was used as the working fluid.

Pressure drop measurements were first performed under isothermal conditions to define the friction factor and the critical Reynolds number. These results compared favourably with the predictions of previous analytical models. Further pressure drop measurements are reported with heat addition and the effects of free convection and geometry on the diabatic friction factor are discussed.

Heat transfer measurements were taken locally at several axial positions along the heated section. Results of the local Nusselt number are presented and the effects of Reynolds number and Rayleigh number are studied thoroughly. The circumferential variation of wall temperatures was also investigated for each tube at different values of Rayleigh number. The results of the fully developed Nusselt number for the smooth tube are compared with other results showing a very good agreement. A correlation between Rayleigh number and the fully developed Nusselt number was developed for each finned tube separately. From these correlations it was possible to discuss the effect of tube geometry on the degree of enhancement due to free convection.

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NOMENCLATURE

English Symbols

A_c = Actual surface area per unit length [m^2/m]

A_{fl} = Actual flow area [m^2]

A_s = Nominal inside surface area = π $D_i L$ [m^2]

A_w = Wall cross-sectional area [m^2]

c_p = Specific heat of the fluid [J/Kg . K]

D_{ft} = Fin-tip diameter [m]

D_h = Hydraulic diameter = 4 A_{fl}/A_c [m]

D_i = Inside diameter [m]

D_{os} = Outside diameter [m]

f = Fanning friction factor defined by equation (4.2)

g = Gravitational acceleration [m/s^2]

H = Relative fin height = l/R_i

k_c = Copper thermal conductivity [W/m . K]

k_f = Fluid thermal conductivity [W/m . K]

L = Heated length [m]

L_p = Distance between pressure taps [m]

l = Fin height [m]

M = Number of fins

$\dot{m}$ = Mass flow rate of Fluid [Kg/s]

P = Pressure [Pa]

Q_e = Rate of electrical heat input [W]

Q_f = Rate of heat gained by the fluid [W]

R_i = Inside radius = $D_i/2$ [m]

T_b = Local bulk temperature [°C]

T_m = Mean bulk temperature [°C]

T_w = Wall temperature [°C]

$\bar{T}_w$ = Average of top and bottom wall temperatures [°C]

x = Axial distance from the beginning of heating [m]

X^+ = Reduced length = $x/(R_i Re Pr)$

Dimensionless Quantities

Gr = Grashof number = $g\ \beta\rho^2 D_i^3\ (T_w - T_b)/\mu^2$

Gr* = Modified Grashof number = GrNu

Nu = Nusselt number = $Q_f/(\pi\ L\ (T_w - T_b) k_f)$

Pr = Prandtl number = $\mu\ c_p/k_f$

Ra = Rayleigh number = GrPr

Ra* = Modified Rayleigh number = $g\beta\ D_i^3 Q_f \rho^2 c_p/(\mu\ k_f^2 \pi\ L)$

Re = Reynolds number = $(\dot{m}\ D_i/(\mu\ A_{fl})$

Greek Symbols

α = Helix angle

γ = Half-fin angle

β = Fluid thermal expansion coefficient [1/K]

Θ_w = Dimensionless wall temperature defined by equation (4.6)

ρ = Fluid density [Kg/m^3]

μ = Fluid viscosity [N.s/m^2]

Δ = Difference when used as a prefix

Subscripts

cr	=	Critical (at laminar-turbulent transition)
dia	=	Diabatic
fd	=	Fully developed
i	=	Based on the inside diameter
iso	=	Isothermal
m	=	Mean (evaluated at mean bulk temperature)
w	=	Wall
x	=	local value

Chapter I

INTRODUCTION

During the past few decades a great amount of research has been directed towards the development of compact and more efficient heat exchangers. Energy conservation and improved energy utilization have been the major driving forces behind this research. For some applications, such as those in the area of transportation, it is desirable to decrease the weight and size of heat exchangers while maintaining the same heat duty and pumping power. For some other applications, such as those encountered in the power and process industries, weight and size are not of major concern but increased heat duty for the same pumping power or decreased pumping power for the same heat duty has obvious economical benefits.

The development of techniques for enhancing the standard heat transfer performance of smooth tubes is, of course, a necessary requirement for manufacturing compact heat exchangers. Some of these enhancement techniques are: surface promoters, vortex generators, tube vibration, fluid vibration, electrostatic fields, and fluid additives. Among these techniques, tube vibration, fluid vibration and electrostatic fields are not widely used because they require an external source of power and hence are considered uneconomical. Fluid additives are used in a limited number of applications since it is necessary in most applications to maintain the purity of the working fluids. On the other hand, surface promoters gained a lot of interest due to simplicity and suitability to a wide range of engineering applications. This thesis deals with one type of surface promoters (internally finned tubes) which involves the addition of a certain number of identical fins evenly distributed on the inner surface of the tube, as shown in Figure 1.1. These tubes are presently available in different diameters, different numbers of fins, different fin heights and different fin types (straight and spiral).

Before using any enhanced surface in the design of compact heat exchangers, the heat transfer and pressure drop characteristics of this surface must be studied under different operating conditions. Due to the initial success of internally finned tubes as enhanced surfaces, a number of research efforts (analytical and experimental) exploring the performance of these tubes were reported during the past ten years. Both laminar and turbulent flow conditions were studied. On the analytical side, the mathematical models were limited to pure forced convection in the fully developed region which exists at some distance away from the entrance of the tube. While these studies are useful in explaining the fluid flow and heat transfer mechanisms involved, a designer needs detailed information on the thermal performance in the entrance region. This is particularly true for compact heat exchangers where small tube lengths are used. In the meantime, almost all the experimental data of heat transfer in internally finned tubes are average values corresponding to a certain tube length.

The objective of this investigation is to study experimentally the heat transfer characteristics in the thermal entrance region of horizontal internally finned tubes. Finned tubes with different configurations

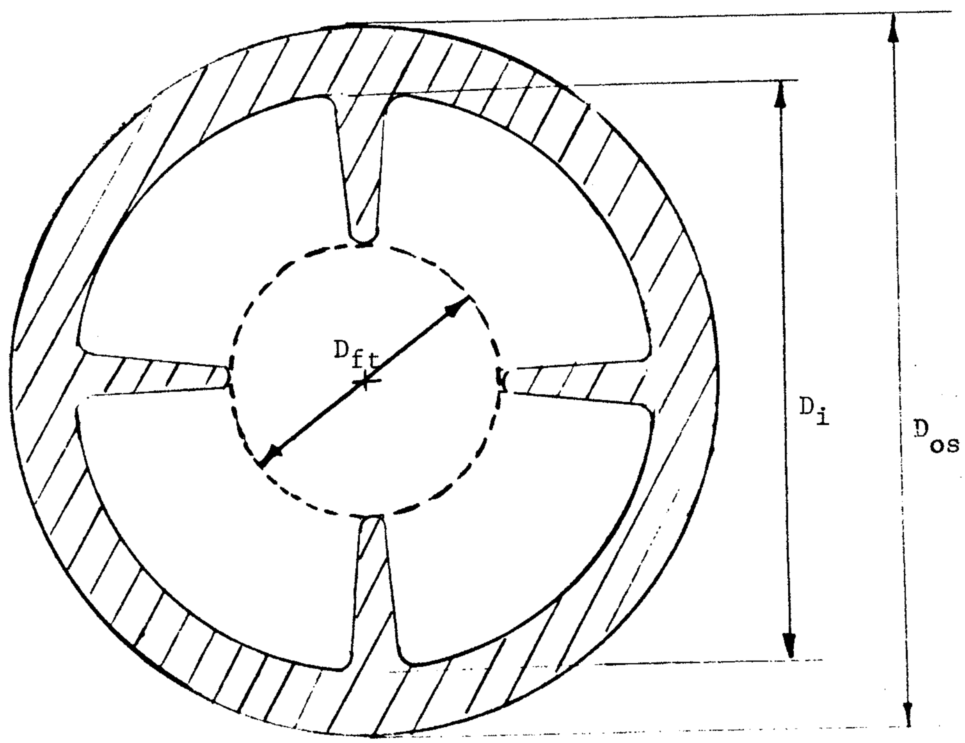


Figure 1.1 Schematic diagram of an internally finned tube

(number of fins, fin height and angle of twist), as well as a smooth tube, will be used. Distilled water is used as the test fluid. The flow is laminar, and a provision of establishing fully developed fluid flow is imposed before the beginning of heating. The boundary condition of uniform heat input axially is selected for this study. No similar results were reported yet in the literature (either analytically or experimentally) and hence the present results should be of some value to the designer. On the other hand, the chances of comparison between the present results and other experiments or analysis are limited.

Chapter II

LITERATURE REVIEW

Since the present study is concerned with the laminar heat transfer characteristics of internally finned tubes, an exhaustive review of the research efforts done in this area is presented here. However, due to the relatively small size of this literature, this review was extended to include some studies dealing with smooth tubes. These two groups of studies share many similarities in the experimental procedure, methods of data reduction and presentation, and trends in the results. Both analytical and experimental studies are included; however, the review is limited to the laminar flow condition. Two limiting thermal boundary conditions are normally used; these are uniform wall temperature axially or uniform heat input axially. Studies pertaining to both boundary conditions are included in the case of internally finned tubes, but the review is limited to the boundary condition of uniform heat input axially in the case of smooth tubes.

One important feature of laminar flow inside horizontal ducts is the presence of free convective currents superimposed over the main mechanism of forced convection. The difference in temperature between the tube wall and the fluid causes density gradients within the flow cross-section which act as the driving force for secondary flow in planes perpendicular to the main stream. The dimensionless groups which were found to be indicative of the strength of these secondary flows are the Grashaf number, Gr, or Rayleigh number, Ra. Normally, for a smooth tube free convection can be ignored for $Ra \leqslant 10^4$. For higher values of Ra, the influence of free convection on the pressure drop and heat transfer characteristics cannot be ignored. As will be seen later, the influence of free convection is much more pronounced on the heat transfer than on the pressure drop.

Horizontal, vertical and inclined tube orientations were covered in the literature. However, since the horizontal orientation was used in the present experiment, mainly studies using this orientation are covered in this review.

2.1 Smooth Tubes

These studies started almost around the turn of the twentieth century. Hundreds of papers have been published since that time. In this review only a few selected papers with widely known recognition will be reviewed.

Petukhov and Polyakov [1,2] conducted an experimental investigation of local heat transfer in a stainless steel tube with an inside diameter of 18.8 mm, wall thickness of 0.36 mm, and a heated length of 99 diameters. In their experimental set up they passed an alternating current through the tube to provide a constant input heat flux both axially and circumferentially. Distilled water was used as the working fluid. A length of 96 diameters was used before the heated section for developing the velocity profile. The experiment covered the ranges of 50 to 2400 for Reynolds number and 2×10^5 to 4×10^7 for the modified Rayleigh number, Ra*. The axial variation of wall temperature at both the top and the bottom was shown at $Ra^* = (1.8 - 3.0) \times 10^7$, and Re =

(1400 - 1700). The difference between the wall top and bottom temperatures was found to increase along the tube until it reached 27°C at the end of the tube for the above mentioned values of Re and Ra*. The local-average Nusselt number was shown as a function of the reduced length X^+ at different values of Ra* for the range $300 < Re < 800$. The results were compared with the pure forced convection solution for smooth tubes. The agreement was excellent at the early part of the thermal entry region for all values of Ra*. However, the experimental results deviated from the forced convection solution showing the effect of free convection as the fully developed region was approached. The critical value of Ra* at which the fully developed Nusselt number deviated from the theoretical pure forced convection value was found to be 1.8×10^4. Based on their results, the following formula for the fully developed Nusselt number was developed:

$$Nu_{fd} = 4.36\ [1 + (Ra^*/1.8 \times 10^4)^4]^{0.045} \qquad (2.1)$$

with the properties evaluated at the average bulk temperature. This correlation fitted their experimental data with a maximum deviation of ±5%. This correlation will be used in this experimental investigation for comparison with the fully-developed-Nusselt-number results of a smooth tube. No pressure-drop measurements were reported in [1,2].

Ede [3] conducted an experiment similar to that in [1,2] using aluminum and brass tubes with inside diameters ranging from 12.7 to 50 mm. Reynolds number ranged from 300 to 100,000, and Grashof numbers of up to 10^7 were used. Air and water were used as the working fluids and the boundary condition of uniform heat input axially and circumferentially was imposed by passing electric currents through the wall of the tube. The investigation was mostly in the turbulent flow region, however, in the laminar flow portion similar results to those in [1,2] were presented in terms of circumferential variation of wall temperature and axial distribution of local Nusselt number. In the fully developed region, Nusselt number was correlated for water as a function of Grashof number as follows:

$$Nu_{fd} = 4.364\ (1 + 0.06\ Gr^{0.3}) \tag{2.2}$$

with the properties evaluated at the mean bulk temperature. By using the cited average value of Prandtl number (Pr = 8), equation (2.2) can be written in the form,

$$Nu_{fd} = 4.364\ (1 + 0.0322\ Ra^{0.3}) \tag{2.3}$$

Expressing equation (2.3) in terms of the modified Rayleigh number, Ra*, instead of Rayleigh number, Ra, we get:

$$Nu_{fd} = 4.364\ [1 + 0.0322\ (Ra^*/Nu_{fd})^{0.3}] \tag{2.4}$$

Equation (2.4) will be compared with the relevant portion of the present experimental results. No mention was made of pressure-drop measurements or specifications of heated length or hydrodynamic entry region.

Newell and Bergles [4] analytically investigated the effect of free convection on the heat transfer and pressure drop characteristics in the fully developed region of horizontal smooth tubes. The finite difference technique was used in this analysis. This analysis was carried out for two limiting cases of zero and infinite wall conductance, with water as the working fluid. The results showed that the free convection augmented both Nusselt number and the product of the friction factor and Reynolds number. Infinite conductive tubes showed higher increases in heat transfer and pressure drop than the zero conductive tubes at any given value of Grashof number. For the infinite conductivity case, at a Grashof number of 10^6, Nusselt number showed an increase of 500% over the asymptotic value of pure forced convection. The zero-wall-conductivity tubes showed a significant circumferential variation of wall temperature.

Bergles and Simonds [5] tested a glass tube with water as the working fluid and constant heat flux axially and circumferentially as the boundary condition. The tube was 0.762-m long and 11.0-mm inside diameter. A copper tube with the same inside diameter and 0.914-m length was used to develop the velocity profile ahead of the heated section. The experiment was carried out within the Reynolds number range of 300 to 800, and Rayleigh numbers of up to 10^6. Local average values of Nusselt number were presented against the reduced length X^+, however, no significant variation was evident along X^+ indicating that all the recorded data were in the fully developed region. These data were compared with the predictions of [4] for the zero conductivity case. It was found that at any Rayleigh number, the experimental values of Nusselt number were higher than the analytical predictions. Wall temperature differences between the top and bottom were shown to be generally higher than those reported in [1,3]. The high wall temperature difference between the top and the bottom was related to the low thermal conductivity of the glass tube. The experimental values of Nusselt number in the fully developed region were plotted against Rayleigh number along with the three empirical correlations reported in [1] for a stainless steel tube, [3] for aluminum and brass tubes, and another correlation for a stainless steel tube developed by Petukhov et al. The data and the empirical correlations occupied a narrow band, and they all fell mostly within the predictions of the two limiting cases reported in [4]. This agreement led Bergles and Simonds to conclude that wall conductance has no significant contribution to the average fully developed Nusselt number. No pressure drop measurements were reported.

Morcos and Bergles [6] extended the work of Bergles and Simonds [5] to include a stainless steel tube in addition to the glass tube, and ethylene glycol as well as water as the working fluids. Their objective was to study the effects of wall conductance and fluid properties on the pressure drop and heat transfer performance during laminar, mixed convection. A uniform input power axially and circumferentially was ensured by heating the tubes electrically. The glass tube had 11.0-mm inside diameter, 1.2-mm wall thickness, and 1.13 m heated length. A 1.9-m long stainless steel tube of similar inside diameter was used to develop the velocity profile ahead of the heated section. The stainless steel test section had 1.22-m heated length, 2.0-m hydrodynamic entry length ahead of the heated section, inside diameter of 10-mm, and a wall thickness of 0.5-mm. Four sets of data for the fully developed Nusselt number of the glass tube and the metal tube with both water and ethylene glycol were plotted against Rayleigh number up to $Ra = 10^6$. These results were in close agreement with each other up to $Ra = 10^5$, however, for higher values of Rayleigh number the effects of wall conductance and Prandtl number became noticeable. Consequently, they developed the following correlation:

$$Nu_{fd} = [(4.36)^2 + [0.145 (Gr^*Pr^{1.35}K^{*-0.25})^{0.265}]^{1/2} \qquad (2.5)$$

knowing that $Ra^* = Gr^*Pr$, then equation (2.5) becomes

$$Nu_{fd} = [(4.36)^2 + [0.145(Ra^*Pr^{0.35}K^{*-0.25})^{0.265}]^{1/2} \qquad (2.6)$$

where $K^* = k_f D_i / k_w t$ and t is the wall thickness. All properties needed in equations (2.5) and (2.6) are to be evaluated at the mean film temperature. Equation (2.6) was recommended for the following range of parameters:

$$3 \times 10^5 < Ra^* < 10^7,\ 4 < Pr < 175,\ \text{and}\ 0.2 < K^* < 7$$

Equation (2.6) will not be used for comparison with the present results since the value of K^* used for this experiment ($K^* = 0.005$) is much below the recommended range. The increase in the average friction factor due to heating over the isothermal value was presented as a function Rayleigh number only for the Reynolds number range of 20 to 400. Data corresponding to the glass and metal tubes with ethylene glycol as the working fluid was used. The diabatic friction factor showed an enhancement of 50% over the isothermal friction factor at Rayleigh number of 10^6. The effect of wall conductance on the enhancement of the friction factor was shown to be negligible. In comparing the experimental data with the predictions corresponding to the two limiting cases presented in [4], it was shown that all the experimental data fell within the two limits. The following empirical correlation was reported for the ratio of the average diabatic friction factor and the fully developed isothermal friction factor:

$$\bar{f}_{dia}/f_{iso,fd} = [1 + (0.195\ Ra^{0.15})^{15}]^{1/15} \qquad (2.7)$$

The properties in correlation (2.7) are to be evaluated at the mean film temperature. This correlation will be used for comparison with the present experimental results.

2.2 Internally Finned Tubes

Since the internally finned tubes have been introduced only recently, a limited number of studies have been conducted to test these tubes in terms of heat transfer and pressure drop performance. Analytical studies were limited to the fully developed, forced convection situation, and no analysis is available yet for the case of mixed convection in the horizontal orientation. Experimental results were obtained for internally finned tubes of different geometries, and using different thermal boundary conditions. The following is a review of most published work concerning the internally finned tubes in the laminar flow region.

2.2.1 Experimental Studies

Hilding and Coogan [7] tested ten internally finned tubes with different geometries, and one smooth tube. All tubes were made of copper. The fins were longitudinal and straight with a rectangular cross-section. The relative fin height H ranged from 0.36 to 1.0. Number of fins M ranged from 2 to 8. All tested tubes had 14.0-mm inside diameter and a length of 0.46-m. In their experimental set-up, no provision was made for separating the flow domain into developing and fully developed parts. Thus, the reported values for the friction factor and Nusselt number were average values for the whole tube length. A steam jacket was used as the source of heat to ensure a constant wall temperature circumferentially and axially and air was used as the working fluid. Values of the isothermal and diabatic friction factors were reported for Reynolds numbers ranging from 1000 to 100,000 based on the hydraulic diameter. All properties were taken at the average bulk temperature between the inlet and outlet. The internally finned tubes showed higher values of ($\bar{f}_{dia}/\bar{f}_{iso}$) than the smooth tube. The increase in the average friction factor due to heating was more noticeable in the turbulent flow region. The Nusselt number based on the hydraulic diameter for the finned tubes showed an enhancement over the smooth tube in the laminar and transition flow regions. However, this trend was reversed in the turbulent region. The final conclusion of this work was that the presence of fins enhanced the heat transfer in the tubes by a factor of 200 to 300%. However, an accompanied increase in the pressure drop was also noted, which was seen to be very high in the turbulent region.

Heeren and Wegscheider [8] studied the possibility of using internally finned tubes instead of smooth tubes in the design of condensers for power plants. They reported that after six years of testing they came up with the optimum configuration for the finned tube which they did not specify clearly probably due to patent rights. In this reference [8] the authors commented briefly on the heat transfer performance of a condenser constructed with this optimum finned tubes. They showed that the increase in the overall heat transfer coefficient over the smooth tube design depended on the velocity of flow. This increase was about 100% at a velocity of 4.6 m/s and decreased to about 40% as the velocity increased to 13.7 m/s. No significant change was noted in the percentage increase in the overall heat transfer coefficient beyond the velocity of 13.7 m/s. Using this internally finned tube, Heeren and Wegscheider reported that it was possible to construct a condenser carrying the same duty of the conventional smooth tube design but with only 59% of the external surface area. This finding is quite interesting in illustrating the fact that internally finned tubes can be a useful tool in constructing compact heat exchangers.

Watkinson et al. [9] conducted an extensive experimental investigation of the laminar heat transfer and pressure drop performances of internally finned tubes. Eighteen internally finned tubes with straight and spiral fins as well as two smooth tubes were tested. The relative fin height H ranged from 0.05 to 0.31, and the number of fins M ranged from 6 to 50. The velocity profile was developed using a 0.61-m long tube prior to the 2.44-m long heated section. Oil was used as the working fluid providing a Prandtl number range of 180 to 250. The operational range of Reynolds number was 50 - 3000 based on the inside diameter. A steam jacket was used as the heat source to ensure the constant wall temperature boundary condition. Similar to [7], the measured values of Nusselt number were average values over the whole tube length encompassing the thermal entry region and the fully developed region. The Nusselt number results for all finned tubes showed an enhancement over the smooth tubes. The degree of this enhancement was different from one finned tube to another depending on the geometry. At Reynolds number of 500 based on the inside diameter, the enhancement of Nusselt number for the different finned tubes over the smooth tubes varied from 8 to 224%. For the case of straight fins the enhancement of Nusselt number decreased with the increase in number of fins, but increased by increasing the relative fin height. A correlation for the average Nusselt number was developed as a function of Pr, (D_h/L), M, Re, Gr, and

(μ_m/μ_w). Their correlation fitted all of their data with a standard deviation of ±17%. The average friction factor was measured isothermally and with heat addition, however, only the isothermal results were reported. At the same Reynolds number, the internally finned tubes showed a consistent increase in the isothermal friction factor over the smooth tube. At a Reynolds number of 500 based on the inside diameter, the isothermal friction factor for different internally finned tubes increased by 18 to 131% over the smooth tube depending on the geometry. In an attempt to correlate the friction factor with the tube geometry, no simple relation was found. However, the friction factor at given values of Reynolds number was found to increase strongly with the ratio of hydraulic diameter to inside diameter. The critical Reynolds number at the laminar-turbulent flow transition for all the tubes was correlated against the ratio of fin height to hydraulic diameter. It was shown that the critical Reynolds number based on hydraulic diameter is higher for tubes with lower fin height to hydraulic ratio. The critical Reynolds number was approaching the critical value for the smooth tube of 2100 as the ratio of fin height to hydraulic diameter approached zero. However, there was a considerable scatter in the data which indicate that the ratio of fin height to hydraulic diameter is not the only parameter on which the critical Reynolds number depends.

Marner and Bergles [10] conducted an experimental investigation using many tubes with different augmentation techniques. Two sets of tests were carried out at two different boundary conditions; one was constant heat flux axially and circumferentially, and the other was constant wall temperature axially and circumferentially. In the first set of tests, a single internally finned tube was used. This tube had straight fins, 0.92-m heated length, 14.2-mm inside diameter, 0.83-mm wall thickness, number of fins M = 10, and relative fin height of 0.22. No mention was made of hydrodynamic entry length. Water and ethylene glycol were used as the last fluids. Local values of Nusselt number were plotted versus the reduced length X^+. The local Nusselt number showed an increase as compared with the smooth tube condition. The dependence of the local Nusselt number on Prandtl number was investigated, however no solid conclusion was possible from their limited data. The average friction factor was presented under isothermal conditions and compared with the standard values for smooth tubes. The finned tube showed a consistent increase in the isothermal friction factor over the smooth tube. Surprisingly, no mention was made of the range of Grashof or Rayleigh number used. In the second set of testing, where the constant wall temperature was imposed, a spiral finned tube was tested among other tubes with different augmentation techniques. The internally finned tube was made of copper with 2.31-m heated length, 25.1-mm inside diameter, 0.71-mm wall thickness, 16 fins, and relative fin height of 0.168. No mention of a hydrodynamic entry region was made. A steam jacket was used as the heat source. Average values of Nusselt number over the whole tube length were presented during heating. A second set of average Nusselt number values were reported during cooling. In the case of cooling, the fluid was pumped hot in the test section, while cooling water was used in the outer jacket. Average Nusselt number values were plotted against Reynolds number based on the inside diameter, during both heating and cooling of ethylene glycol. The enhancement of the average Nusselt number over the smooth tube was higher during heating than cooling. The average friction factor was reported during both heating and cooling of ethylene glycol, and during isothermal conditions. At the same Reynolds number based on the inside diameter, the friction factor during cooling was the highest, followed by the friction factor during heating and then the isothermal value.

2.2.2 Analytical Studies

Nandakumar and Masliyah [11] solved the momentum equation for fully developed, laminar flow in tubes with straight internal fins using the finite element technique. The fins were chosen to be of triangular shape with parameters as shown in Figure 2.1. The independent parameters which define the geometry of the tube are: the relative fin height H, the number of fins M, and the half-fin angle, γ. Nandakumar and Masliyah discussed the influence of these geometrical parameters on the axial velocity distribution within the flow cross-section. They also reported tabulated values for the product ($f_{iso,fd}$ Re) based on the hydraulic diameter covering the range: $0.1 \leq H \leq 0.2$, $6 \leq M \leq 24$ and $3° \leq \gamma \leq 12°$. These values were also correlated by,

$$(f_{iso,fd} \times Re)_h = -0.5077+16.287\,(D_h/D_i)^{1.2}-0.049\,[1-EXP[20SH/(S+H)] \quad (2.8)$$

This correlation fitted their numerical values with an average error of 2.0% and a maximum error of 4%. A part of the present experimental results will be compared with the predictions of equation (2.8).

Masliyah and Nandakumar [12] extended their previous work [11] to include the solution of the energy equation using the same technique,

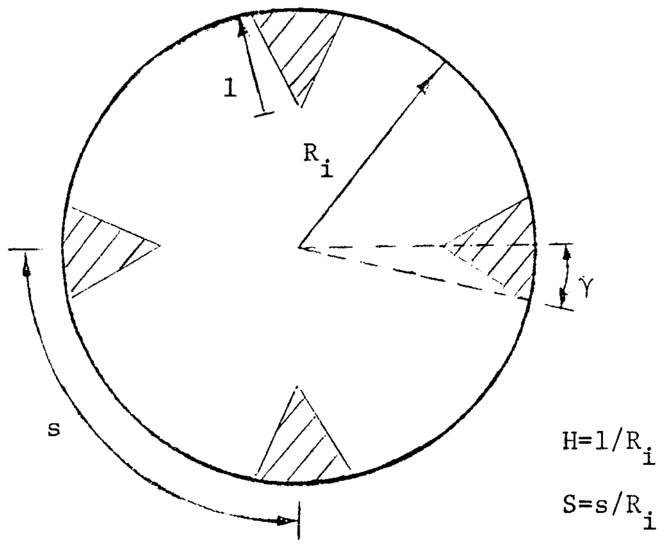


Figure 2.1 Finned tube geometry used in Ref. [11,12]

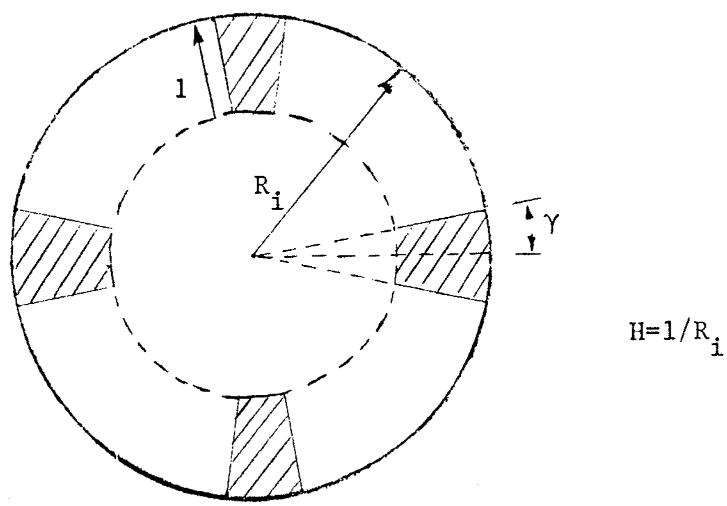


Figure 2.2 Finned tube geometry used in Ref. [13,14]

and the same fin shape shown in Figure 2.1. A uniform input heat flux axially and uniform wall temperature peripherally were imposed. A fully developed, laminar, forced convection was also assumed. The fully developed Nusselt number based on the inside diameter was presented in graphical and tabular forms for the following ranges of geometrical parameters: ($4 \leq M \leq 24$, $0 \leq \gamma \leq 3°$ and $0.2 \leq H \leq 0.8$). It was shown that the fully developed Nusselt number depends strongly on H, M and . A high relative fin height leads to a high Nusselt number for any values of M and γ. Zero half-fin angle gave the highest values of Nusselt number for any combination of M and H. Finally, it was shown that for any combination of H and γ, the value of Nusselt number starts increasing as M increases up to a certain value of M beyond which a further increase in M causes a decrease in Nusselt number.

Soliman and Feingold [13] obtained an analytical solution for the momentum equation in the form of an infinite series. The assumed geometry with its relevant parameters is shown in Figure 2.2. This geometry resembles closely the actual geometry of the internally finned tubes, and the series solution allows more accuracy than the finite difference or finite element solutions. The product ($f_{iso,fd}$ Re) based on the inside diameter was developed for the range: ($4 \leq M \leq 32$, $0.05 \leq H \leq 1$ and $0 \leq \gamma \leq 3.0°$). The present experimental results will be compared with the predictions of this analysis.

Soliman and Feingold [14] extended their previous analysis [13] to include the energy equation. Again, the solution was in the form of an infinite series using the geometry in Figure 2.2. Laminar, forced convection, fully developed flow with a uniform heat flux axially and uniform wall temperature peripherally was assumed. Results of the fully developed Nusselt number based on the inside diameter were presented for a range of geometrical parameters similar to that in [13]. The effects of H, M and γ on Nu had similar trends as those reported in [12].

The influence of the thermal boundary condition on the heat transfer performance of internally finned tubes was investigated by Soliman et al. [15]. In this study a uniform wall temperature axially and circumferentially was imposed. The geometrical parameters used in the previous works [13,14] were adopted. The momentum and energy equations were solved numerically using the finite difference technique. Values of Nusselt number based on the inside diameter were tabulated for wide ranges of H and M with $\gamma = 3°$. It was shown that for any combination of H and M, the value of Nusselt number corresponding to the uniform wall temperature boundary condition is lower than Nusselt number for the other limiting boundary conditions used in [14]. The effect of the finite conductance along the fins, which would result in a non uniform temperature there, was investigated in [15,16]. It was shown that the fin conductance can have serious effects on the overall heat transfer performance of tubes with long fins ($H > 0.4$).

All the above analyses were concerned with situations where pure forced convection is assumed to exist. As of yet, there is no published work in which the case of mixed convection in horizontal internally finned tubes has been considered, mainly due to the complexity of the problem. However, the following three references dealt with a simplified form of the problem. The simplification was done by changing the orientation from horizontal to vertical thus providing axial symmetry

[17], or by considering a shrouded fin array in which a two-dimensional computational module was possible [18] or by limiting the number of internal fins to two [19].

Prakash and Patankar [17] analytically investigated the effect of free convection on the heat transfer and pressure drop characteristics of vertical internally finned tubes. Uniform heat flux axially and uniform wall temperature circumferentially were assumed. Fully developed, laminar flow was considered. The finite difference technique was used in solving the relevant momentum and energy equations. The analysis was carried out for a Rayleigh number range of 0 to 10^5, and the geometrical parameters range of $0 \leq H \leq 0.8$, $0 \leq M \leq 32$, and $\gamma = 0$. The increase in Nu and fRe due to free convection were found to be strongly dependent on the geometry. Generally speaking, the percentage increases in Nu and fRe corresponding to any value of Ra were highest for the smooth tube (H = 0) and decreased monotonically as H increased. This influence of H was particularly noticeable at small values of M (e.g. M = 6). However, at high values of M (e.g. M = 16), the influence of H on the percentage increase in Nu due to free convection became almost negligible. For any combination of H, M, and Ra, the percentage increase in fRe was higher than the percentage increase in Nu. This is attributed to the vertical orientation, since an opposite trend was reported by many investigators for the horizontal orientation. The critical value of Ra at which significant changes in Nu and fRe began to take effect was found to depend on the geometry. This critical Rayleigh number increased as H increased.

Acharya and Patankar [18] analyzed the problem of laminar, fully developed, mixed convection in a shrouded fin array using the finite difference method. Two cases were considered; a hot fin and base with a cold fluid, or a cold fin and base with hot fluid. In the first case, which is more relevant to the present investigation, the solution was carried out for Grashof number range of 10^4 to 10^7. The ratio of fin height to space between fins was fixed at 0.5, while the ratio of the fin tip clearance to fin height (C) was assigned the values of 0, 0.4, and 1.0. The increases in Nu and fRe due to free convections were found to be strongly dependent on C. Longer fins (i.e. smaller c) delayed the effect of Gr on Nu and fRe. In the second case, for C = 0 and 0.4 (long fins) the effect of free convection was not significant on either Nu or fRe until Gr reached 10^5; while for C = 1 (short fins), the effect of free convection was significant from Gr = 10^4. Higher values of C (shorter fins) produced larger increases in Nu and fRe at any value of Gr. Generally for all the geometrical cases, the percentage increase in Nu due to free convection was higher than the percentage increase in fRe (contrary to what was reported in [17] for the vertical orientation).

Mirza [19] conducted an analytical investigation of the heat transfer and pressure drop performance of a horizontal tube with two vertical straight internal fins of zero thickness. In this investigation of mixed convection, laminar and fully developed flow was considered. Uniform heat input axially and uniform wall temperature circumferentially were assumed. Results were obtained for Pr = 0.7 (air) and the finite difference method was used. The relative fin height H was varied from 0 to 1.0 and the computations were carried out for a Grashof number range of 0 to 10^6. The percentage increase in Nu due to free convection was found to be a function of the relative fin height H. An increase in H was shown to have the effect of suppressing free convection. At H = 0 (smooth tube) the effect of free convection was shown to be significant for $Gr \geq 10^4$, but at H = 1.0 this effect was delayed to $Gr \geq 10^5$. At any value of Gr, the percentage increase in Nu was higher for lower values of H. However, at $Gr > 10^5$ the tubes with longer fins showed a higher rate of increase in Nu with Gr than those with shorter fins. Similar trends were also noted for fRe.

From the above review of analytical and experimental research efforts on the pressure drop and heat transfer characteristics of internally finned tubes, the following observations can be drawn:

1. All analytical investigations assume fully developed conditions; a situation which is expected to exist some distance away from the entrance of the tube.

2. The effect of free convection has not been included in any analysis concerning the internally finned tubes in horizontal orientation, except for the simplified geometry considered in [19].

3. Almost all the available experimental data provide average values of Nusselt number for a specific length of tube. Only very limited local measurement has been reported corresponding to one tube [10].

The present investigation was carried out due to the above apparent deficiencies. For the design of compact heat exchangers where tube lengths are normally small, it is very important to know the detailed performance in the thermal entrance region and to know the effects of tube geometry and free convection on this performance.

Chapter III

EXPERIMENTAL INVESTIGATION

The objective of this experiment is to investigate the laminar heat transfer and pressure drop characteristics in the thermal entry region of internally finned tubes. In this investigation, uniform heat input axially is chosen as the thermal boundary condition. Distilled water was selected as the working fluid because of its wide use in practical applications. The following main features will be studied thoroughly for each tube:

1. The isothermal, fully developed, friction factor and the critical Reynolds number at which transition to turbulent flow starts.

2. The variation of the local-average Nusselt number axially along the heated section at different Reynolds and Rayleigh numbers.

3. The diabatic friction factor across the heated section at different Reynolds and Rayleigh numbers.

4. The circumferential variation of wall temperature under the effect of free convection.

5. The effect of both geometry and free convection on the fully developed Nusselt number.

Five copper internally finned tubes with different geometries are to be tested along with a smooth copper tube. The smooth tube is used in this investigation for the following reasons:

1. To provide a base for comparison with the internally finned tubes.

2. To test the technique of heat supply and wall temperature measurement by comparing the present-smooth-tube results with other experimental results.

The finned tubes were supplied by Noranda Metal industries, Inc.. The numbers assigned to these tubes by the manufacturer are used here, while the smooth tube is referred to as tube No. 1. All dimensions are used as they were supplied by the manufacturer, except for tube No. 20 where significant deviations were noted between different research papers. Dimensions of tube No. 20 are used as reported by Watkinson et al. [9], which were based on actual measurements. All dimensions used in this investigation are listed in Table 1.

3.1 General Description of the Experimental Set-up

A schematic diagram of the experimental set-up is shown in Figure 3.1. A tank of 200-litres capacity is used for collecting the test fluid. The tank is insulated by a 25-mm layer of fiber glass. A 3/4 horsepower centrifugal pump is used to circulate the water in the system. The water is pumped from the tank and passed through a filter to prevent any solid impurities from being circulated into the system. A by-pass line controlled by two values (valves) is used to adjust the water flow rate and pressure level in the system.

For each test tube, the test section consisted of a hydrodynamic entry length followed (without any discontinuity) by a heated section in which all pressure drop and heat transfer measurements were taken. The total length for all finned-tubes test sections was 3.20-m, of which 2.2-m was used as a hydrodynamic entry length. Pressure drop measure-

Table 1 Detailed Dimensions of Test Tubes

Tube Number	1	9	10	13	14	20
Tube outside diameter, D_{os}-mm	21.3	12.7	9.53	9.53	15.9	12.7
Tube inside diameter, D_i-mm	15.9	10.3	8.00	7.04	13.9	10.7
Fin-tip diameter, D_{ft}-mm	-	7.75	5.46	4.75	10.9	7.66
Number of fins, M	-	10	16	10	10	16
Relative fin height, H	-	0.248	0.318	0.325	0.216	0.284
Helix angle, α -degrees	-	0	0	0	0	5.4
Actual flow area, A_{fl}-mm^2	198.6	73.6	40.6	29.9	137	76.6
Actual surface area, A_c-mm^2/mm	50.0	54.0	60.0	35.2	67.3	71.6
Hydraulic diameter, D_h-mm	15.9	5.45	2.71	3.39	8.15	4.47

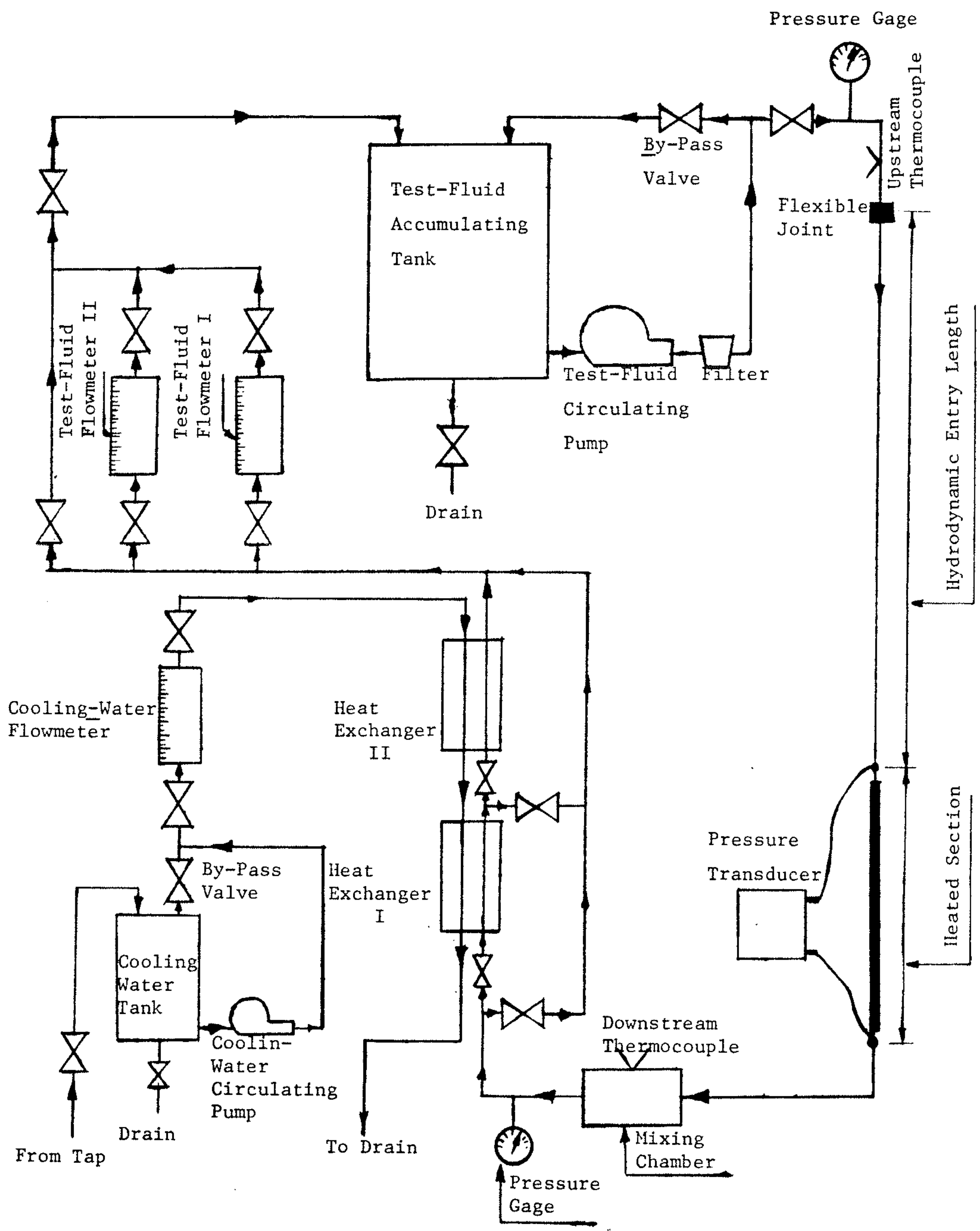


Figure 3.1 Schematic diagram of the experimental set-up

were taken across a length of 1.0-m of which 0.875-m constituted the heated section. For the smooth tube, the total length of the test section was 5.65-m, of which 3.40-m was used as a hydrodynamic entry length, followed by a 2.25-m heated section. A thermocouple was used to measure the upstream bulk temperature immediately ahead of the hydrodynamic entry section.

After passing through the test section, the water flows into a mixing chamber (to be described in Section 3.2.2) forcing the fluid to mix properly before the downstream bulk temperature is taken. The water is then introduced to two heat exchangers to be cooled to the initial temperature (for detailed description of the heat exchangers, see Section 3.2.3). After the fluid is cooled it passes through a flowmeter measurement station where two variable area rotameters made by Fisher and Porter are used. The two flowmeters are connected in parallel so that one or both can be used depending on the flowrate. The small flowmeter has a maximum capacity of 18 cm^3/s, while the other has a maximum capacity of 70 cm^3/s. Both flowmeters were calibrated before the beginning of the experiment. If flowrate measurement is not required, both flowmeters can be bypassed. After flow measurement, the working fluid then flows back to the accumulating tank.

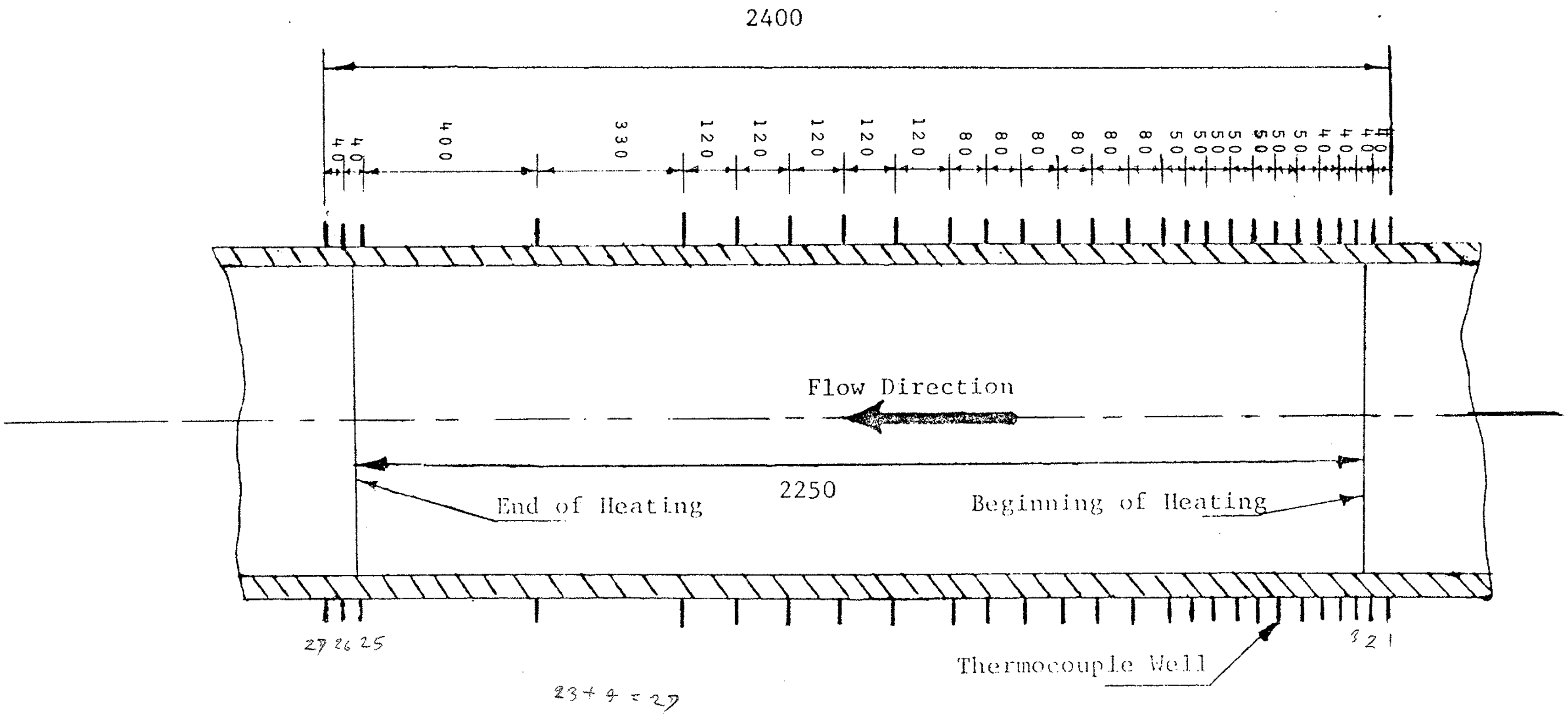
An open-loop cooling water system was used with a 100 litres accumulating tank to ensure a steady flowrate. A 1/4 horsepower centrifugal pump was used to circulate the water with a by-pass line to control the flowrate in the cooling system. The water is then passed through a flowmeter of variable area type made by Fisher and Porter with a maximum capacity of 300 cm^3/s. The water is then passed through the heat exchangers, and then down to the drain.

3.2 Detailed Description of the Main Components

3.2.1 Heated Sections

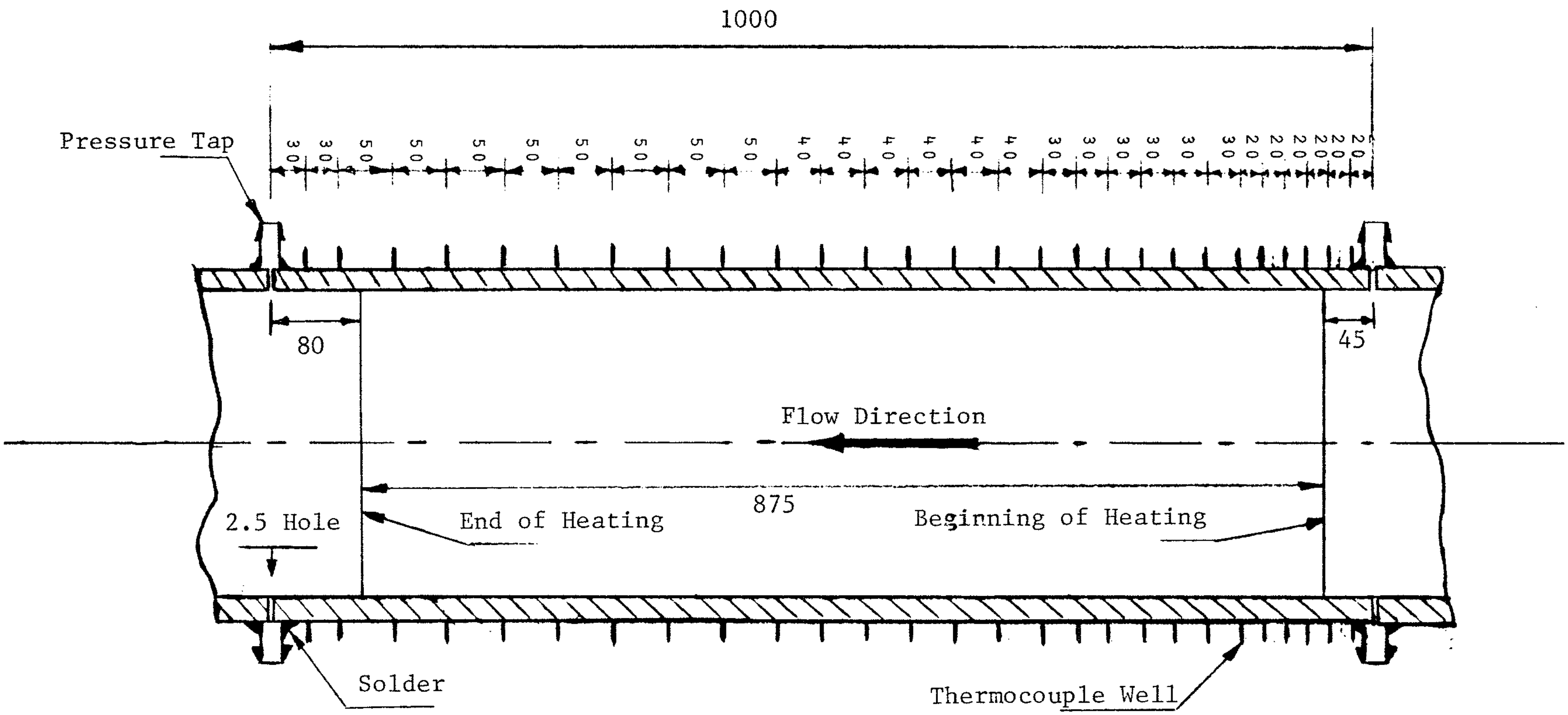
Figures 3.2(a) and 3.2(b) show the detailed dimensions of the smooth tube and finned-tubes heated sections, respectively. For the finned tubes, two pressure stations, 1.0-m apart are used to measure the pressure drop across the heated section with two pressure taps at each station. Lead lines from the pressure stations are connected to a pressure transducer with adjustable span of 0-50.8-mm of water up to 0-152.4-mm of water. The transducer is manufactured by Rosemount Inc., model No. 1151DP, and excited by a D.C. power supply with a 0-100 mA and 0-120 V ranges. The transducer output in mA is measured by a digital multimeter.

For all tubes, the wall temperature was measured at 27 axial stations along the heated section. At each station two, 24 gage, copper-constantan thermocouples were attached to the wall at the top and bottom. The thermocouples were installed in a small copper well, 2.5-mm in diameter, filled with a high thermally conductive paste (k = 125 W/mk) made by Omega Engineering, Inc. The well is then sealed with solid epoxy to keep the paste always in contact with the tube wall, as shown in Figure 3.3. Two wall-temperature measurement stations are located before the beginning of heating, and another two stations are located after the end of heating. These measurements are used in calculating the temperature gradient in the tube-wall, so that the bulk temperature can be evaluated at the beginning and end of heating as will be



All dimensions in mm

Figure 3.2(a) Details of the heated section for the smooth tube



All dimensions in mm

Figure 3.2(b) Details of the heated section for finned tubes

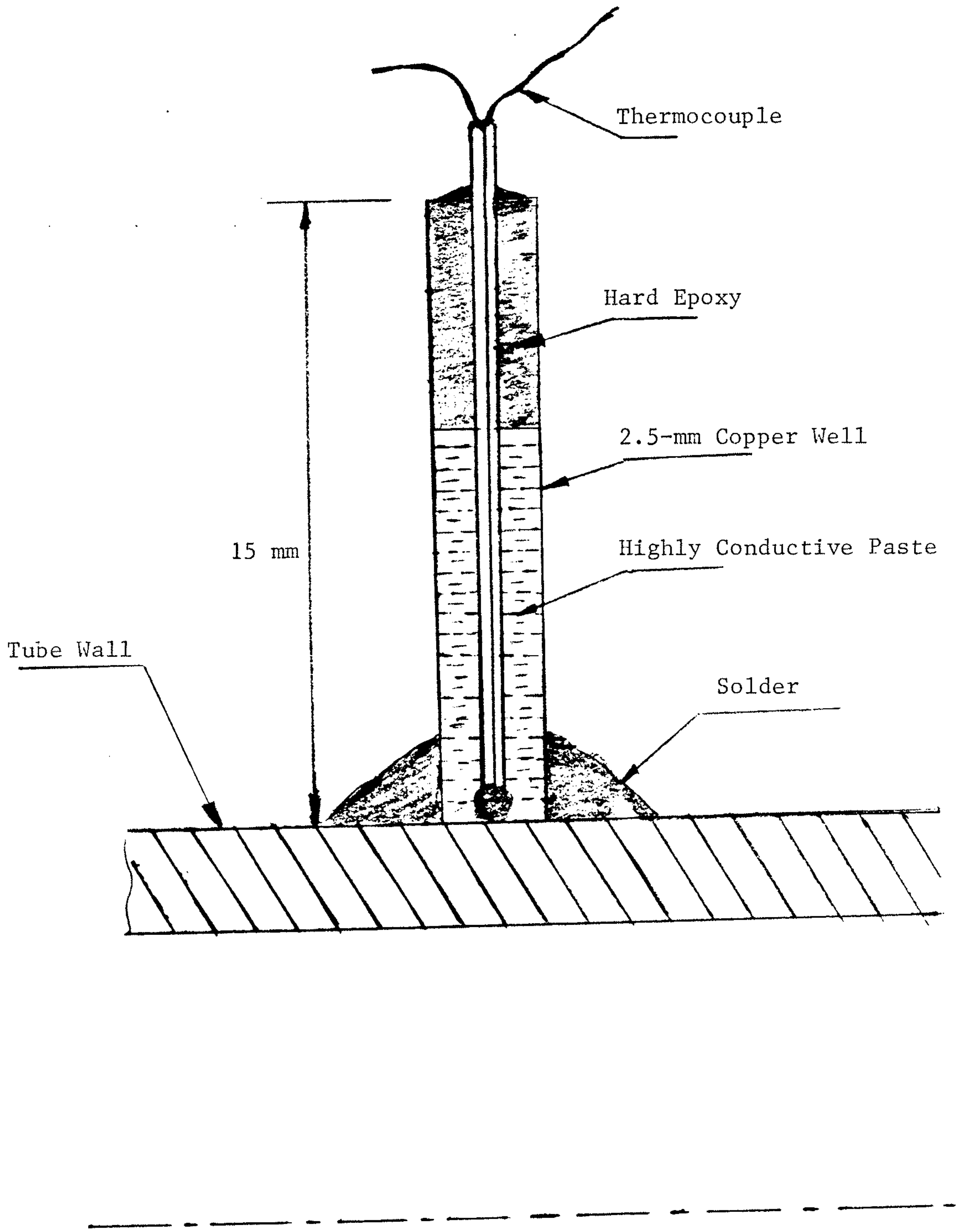


Figure 3.3 The arrangement used for attaching wall thermocouples

shown in a later section. Within the heated section, the wall temperature measuring stations are less distant from each other at the beginning in order to detect the expected rapid rise in wall temperature there, while they are more distant towards the end where the variation in wall-temperature is expected to be linear. Details of the dimensions and distances between stations are shown in Figure 3.2.

An insulated heating wire of 0.81-mm in diameter and 2.08 ohms/m is used for heating. Two parallel lines were wrapped tightly around the tube in order to decrease the overall resistance. No gaps were left between the wires (except around the thermocouple wells) in order to ensure a uniform wall heat flux. A 2000 V.A. isolation transformer (Hammond, model EQSP), and a power variac were used to control the power supply to the heating wire. This impact power was measured by a digital Watt-meter (Electro industries, model W100) with a range of 0 to 2.0 kW. A schematic diagram of the power circuit is shown in Figure 3.4. All thermocouple outputs were measured by a digital potentiometer in °C or °F (Leads and Northrup, model 938 Numatron). All test sections were covered by a 25-mm layer of fiber glass insulation to largely eliminate heat losses from the test section. A specially designed bed was used for supporting the test section and the horizontality of the tube over this bed was checked by a surveying level.

3.2.2 Mixing Chamber

The purpose of having the mixing chamber is to mix the working fluid properly at the exit of the heated section. As shown in Figure 3.5, the chamber has a diameter of 60 mm, and a length of 200 mm. A

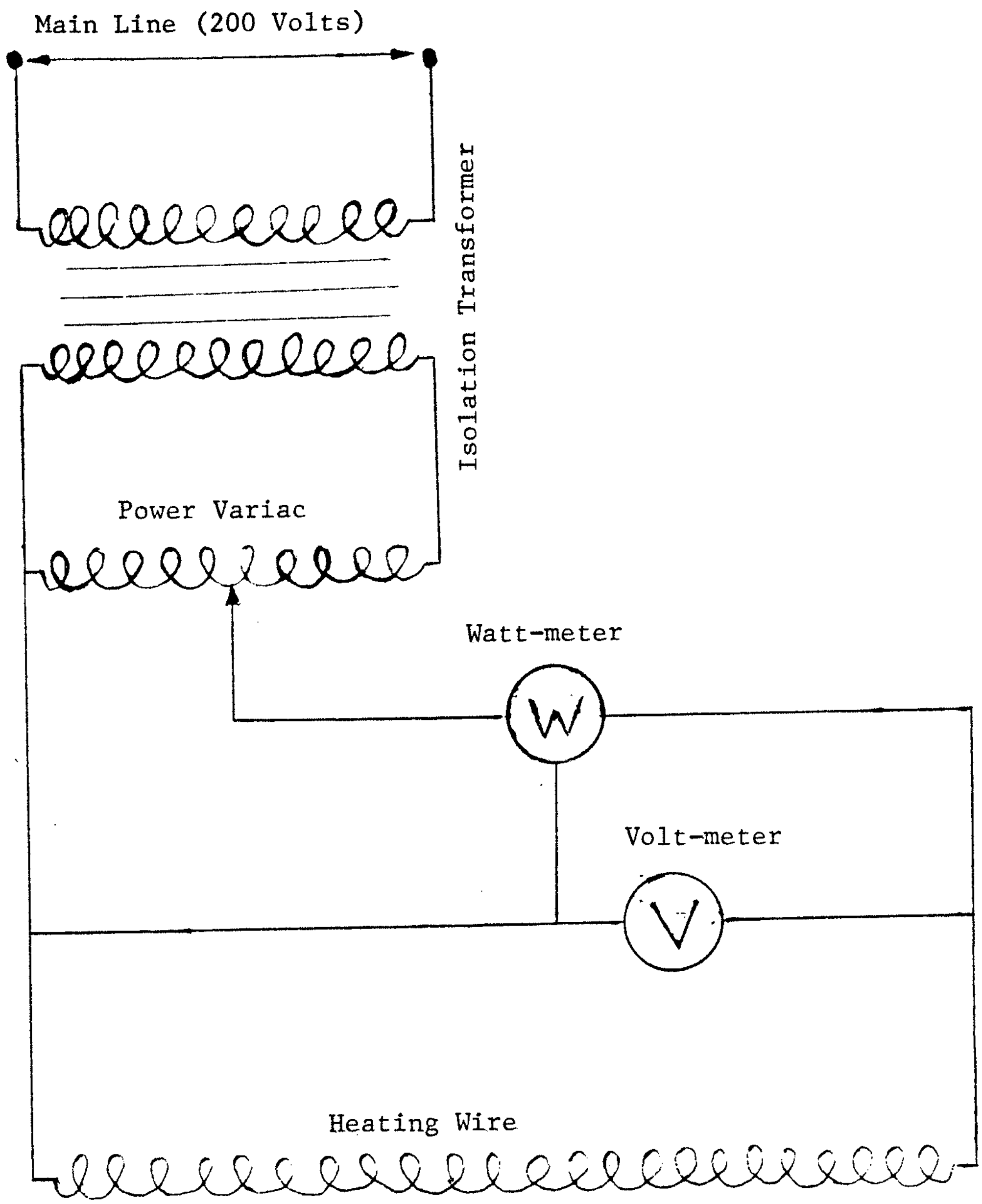


Figure 3.4 Electrical circuit used for heating

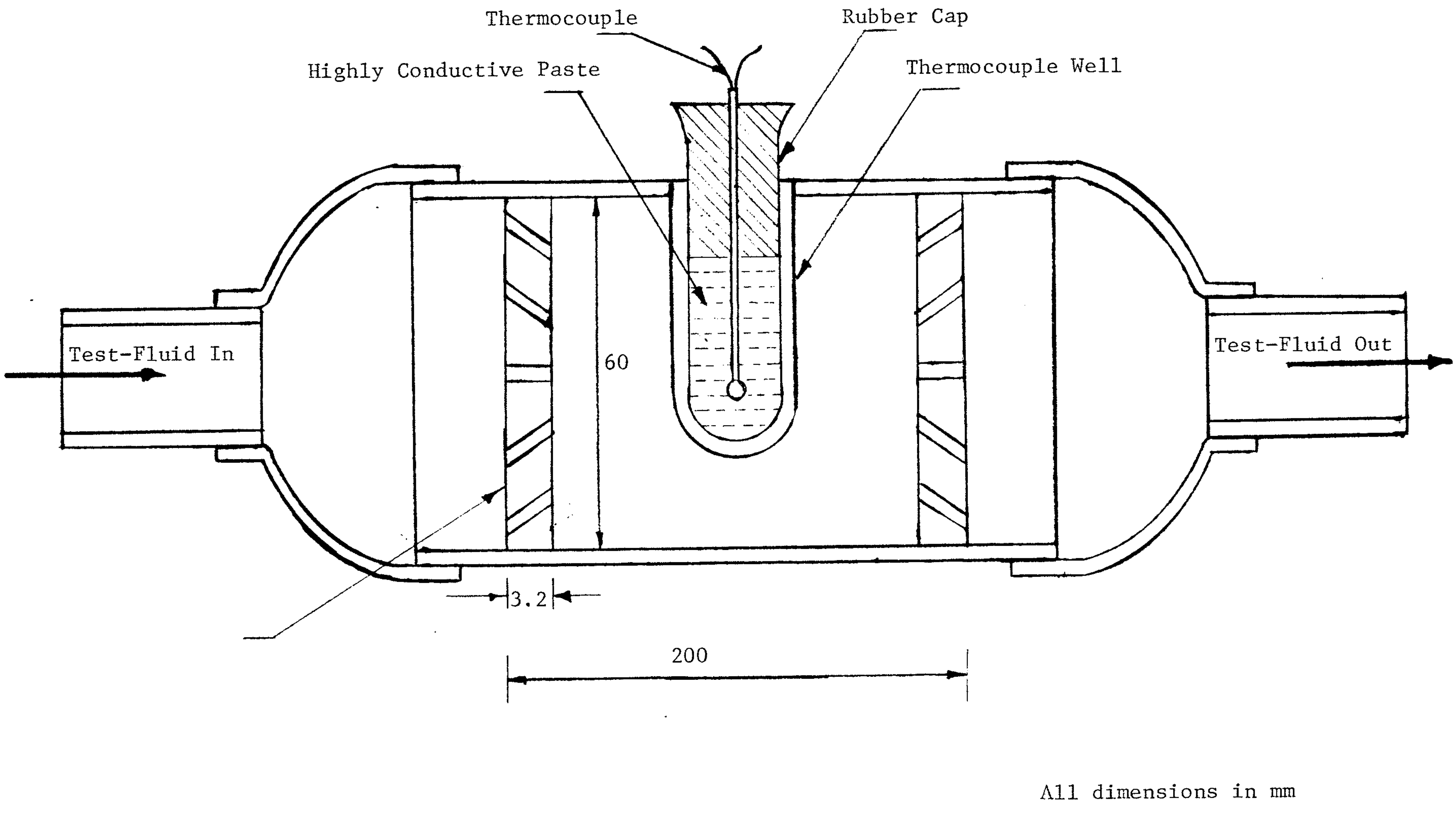


Figure 3.5 The mixing chamber

thermocouple well filled with high thermally conductive paste (k = 125 W/mk) is used to measure the downstream bulk temperature using a 24 gage copper constantan thermocouple. Two grids are fixed at both ends of the chamber with several inclined holes to create a vortex in the chamber. This vortex mixes the fluid thoroughly so that a uniform temperature is reached around the thermocouple well. The mixing chamber performed very well for most test runs.

Since the vorticity generated within the mixing chamber depends upon the water velocity, at very low flowrates the mixing chamber showed ineffectiveness and the downstream thermocouple reading kept rising very slowly with time. This problem was overcome by installing a thermocouple just upstream of the mixing chamber. At very low flowrates it is expected that the water temperature becomes uniform by the time it reaches there. Heat balance calculations have shown that this measurement was quite accurate.

3.2.3 Heat Exchangers

Two, 1.5-m long, counter-current, double-pipe heat exchangers were used to cool the test fluid back to the initial temperature. The inner tube has an inside diameter of 12.7-mm and an outer diameter of 15.9-mm. The outer tube is 19.0-mm inside diameter, and 22.2-mm outside diameter. The test fluid is flowing in the annulus and the cooling fluid is flowing in the inner tube. The heat exchangers are connected in series by a set of valves. Depending on the settings of these valves, the flow can be directed to only one or both exchangers depending on the required heat duty. These heat exchangers are essential for the establishment of steady-state conditions in the system.

3.3 Experimental Procedure

3.3.1 Isothermal Pressure-Drop Measurements and Determination of Laminar-Turbulent Transition

All internally finned tubes were tested isothermally to evaluate the friction factor and the critical Reynolds number, Re_{cr}, at which the flow starts the transition to turbulent flow. The following procedure was followed for each tube:

1. The test fluid flowrate was adjusted to its lowest possible value of 1.3 cm^3/s.

2. Downstream and upstream bulk temperatures were recorded (both readings were always the same since no heat was added).

3. The pressure transducer output was recorded when steady state conditions were reached. The last two steps were repeated after increasing the flowrate by a precalculated amount that gives a small increase in Reynolds number, so that any change in the trend of the pressure drop with Reynolds number can be detected. The process was continued until Reynolds number based on the inside diameter reached about 2500. The isothermal friction factor and the corresponding Reynolds number were then calculated for each run based on the inside diameter with fluid properties evaluated at the bulk temperature.

3.3.2 Calibration of Wall Thermocouples

To detect any errors in the wall thermocouples readings due to the method of attaching the thermocouples to the wall, all thermocouples were calibrated after being attached to the wall. The following procedure was followed for each of the six test sections:

1. The flowmeters and heat exchangers were isolated from the system by adjusting their by-pass lines.

2. The by-pass line of the test-fluid circulating pump was closed completely, thus forcing the maximum flowrate to be circulated in the system.

3. No heat was added in the test section. Thus, it was possible to assume that the upstream and downstream bulk temperatures, as well as all wall temperatures were equal since the heat losses from the test section were minimized by the insulation.

4. The water was heated in the test-fluid accumulating tank using an external heater of 1500 W capacity controlled by a power variac until the water temperature reached 82°C.

5. Operation continued until steady state was reached, which was indicated by the constancy of all thermocouples readings.

6. The upstream and downstream bulk temperatures along with all wall thermocouples readings were recorded. Steps No. 4, 5, and 6 were repeated for water temperatures of 60, 38, and 16°C to cover all the range expected during testing.

During these calibration runs, the maximum difference between the upstream and downstream bulk temperatures was 0.1°C. The average bulk temperature was assumed to be the actual temperature to which all wall thermocouples readings should be corrected. The wall thermocouples readings deviated slightly from the bulk temperature. At the bulk temperature of 82°C, the wall thermocouples readings were within the range 80-82°C, while at the bulk temperature of 16°C, the wall thermocouples readings were within ±0.2°C of the bulk temperature. The four readings at each wall thermocouple and the corresponding bulk temperatures were used to generate a calibration formula which was used to correct the readings of that particular thermocouple during the heat transfer tests.

3.3.3 Heat Transfer Tests

A similar procedure was followed for each of the six test sections. Two or three flowrates were selected within the laminar flow range for each finned tube. A higher number of flowrates was used for the smooth tube. At each flowrate, several test runs were conducted corresponding to different input powers in the heated section. The amount of change in the power supply from one run to another depended on the flowrate. High input powers were needed for high flowrates in order to achieve a reasonable increase in the bulk temperature.

For each run, corresponding to a certain flowrate and a certain power input, operation continued until steady state conditions were achieved as indicated by the constancy of all thermocouples, flowmeters and pressure-transducer readings. Then, the following data were recorded.

i - Upstream and downstream bulk temperatures

ii - All wall thermocouples readings

iii - Electrical input power in Watts

iv - Pressure-transducer reading

v - Test-fluid flowrate

3.3.4 Data Reduction

The recorded data were fed to a digital computer to be reduced. A FORTRAN IV computer program was prepared for this purpose. A listing of this program is provided in Appendix A. The following briefly outlines the steps performed by the program. For details of calculations, a sample run is presented in Appendix B.

1. All wall thermocouples were corrected according to the formula developed for each one by the calibration process.

2. The rate of heat gained by the fluid was calculated as:

$$Q_f = mcp\ (T_{out} - T_{in}) \tag{3.1}$$

3. The percentage deviation between the electrical power supplied and the rate of heat gained by the water was calculated as:

$$E = [(Q_e - Q_f)/Q_e] \times 100 \tag{3.2}$$

Runs with more than 10.5% heat balance error were rejected. In fact, 90% of the recorded runs have values of E within ±5%.

4. The two wall temperature measurements before the beginning of heating and the first one in the heated section were used to fit a second degree polynomial, from which the axial gradient of wall temperature was evaluated at the beginning of heating.

5. The above step was performed at the end of heating using the two wall temperature measurements outside the heated section and the last station in the heated section.

6. Knowing the wall cross-sectional area and the wall thermal conductivity, the rate of heat conducted axially at both ends of the heated section was calculated.

7. The inlet bulk temperature at the beginning of the heated

section was evaluated by adding the amount of increase in the bulk temperature due to the axial heat conduction to the upstream bulk temperature.

8. The outlet bulk temperature was evaluated as in the above step, except that the bulk temperature difference due to the axial heat conduction in the wall was subtracted from the downstream bulk temperature.

9. After the inlet and outlet bulk temperatures were evaluated, a straight line was fitted between them and the local bulk temperature was evaluated at each wall-temperature-measurement station.

10. At each station the difference between the average wall temperature and the bulk temperature was evaluated and used to calculate the local Nusselt number.

$$Nu_x = Q_f/[(\pi L)(\bar{T}_w - T_b)k_f] \qquad (3.3)$$

11. Local Reynolds, Rayleigh, and Prandtl numbers were evaluated at each station based on the local bulk temperature.

12. The reduced length, X^+, was evaluated at each station.

13. Mean values of Reynolds, Rayleigh, and Prandtl numbers were evaluated at the average bulk temperature.

14. The average, diabatic friction factor was calculated as

$$f_{dia} = [\Delta P \; D_i \; \rho \; A_{fl}{}^2]/[2L_p \dot{m}^2] \qquad (3.4)$$

A detailed listing of all the reduced data of all the test runs performed in this investigation is provided in Appendix C.

Chapter IV

RESULTS AND DISCUSSION

In this chapter, the results of pressure drop with and without heat transfer, local and fully-developed Nusselt number, and the circumferential variation of wall temperature will be presented and discussed thoroughly for each tested tube. Comparisons with other results available in the literature are made whenever possible. Isothermal pressure drop measurements are presented for the five internally finned tubes only, since the pressure drop in the smooth tube was too small to measure accurately with the available facility. Also, diabatic pressure drop measurements were not recorded for tube No. 9 because of technical difficulties during the testing of that tube. The ranges of operating conditions for each of the tested tubes are listed in Table 2.

4.1 Pressure Drop Results

This section is divided into two subsections. In the first subsection the isothermal pressure drop measurements will be presented and discussed to show the effect of tube geometry on the friction factor and the critical Reynolds number at which the transition to turbulent flow starts. In the second subsection, the influence of heating on the friction factor will be presented and discussed.

4.1.1 Isothermal Runs

The experimental procedure during the isothermal pressure drop

Table 2 Ranges of Operating Conditions

$Re = \frac{\rho V D}{\mu}$

Tube Number	Mean Flowrate, m (Kg/hr)	Input Power, Q_e, Watts	Mean Reynolds number, Re_m	Mean Rayleigh Number, Ra_m* 10^6	Prandtl Number, Pr_m	Number of Test Runs
1	4.71 - 42.7	50 - 2000	325 - 1600	1.88 - 74.8	3.4 - 6.0	45
9	4.71 - 15.3	50 - 700	215 - 920	0.61 - 16.6	4.3 - 6.2	21
10	4.71 - 11.8	50 - 300	360 - 940	0.47 - 4.26	3.4 - 4.8	12
13	4.71 - 6.04	50 - 250	420 - 720	0.27 - 2.52	3.5 - 4.9	9
14	8.23 - 30.3	50 - 1200	280 - 1360	1.70 - 73.5	4.0 - 5.6	15
20	4.71 - 18.9	50 - 400	230 - 920	1.20 - 13.8	3.7 - 4.8	11

runs was given in detail in the previous chapter. The friction factor and Reynolds number were calculated based on the inside diameter as follows:

$$Re_i = (\dot{m}D_i)/(\mu A_{fl}) \quad (4.1)$$

$$(f_{iso,fd})_i = (\Delta P D_i \ \rho \ A_{fl}^2)/(2L_p \ \dot{m}^2) \quad (4.2)$$

The friction factor and Reynolds number calculated from equations (4.1) and (4.2) are plotted on a log-log scale for each tube in Figures 4.1 to 4.5 along with the two analytical predictions reported in [11,13]. In these figures, the experimental friction factor is seen to vary linearly with Reynolds number in the laminar flow region as expected. The sharp deviation from that linear behaviour indicates the start of the transition to turbulent flow. Reynolds number corresponding to this transition is called the critical Reynolds number (Re_{cr}). The experimental friction factor in the laminar region shows good agreement with the analytical predictions as can be easily seen in Figures 4.1 to 4.5. The values of $(f_{iso,fd}\ Re)_i$ for all the finned tubes are listed with the two analytical predictions in Table 3. Notice must be directed to the fact that the experimental results for tube No. 20, which is a spirally finned tube, has been compared with the analytical results of [11,13] which were developed for tubes with straight internal fins. It is assumed that this comparison is valid based on the analytical results of Ivanovic [20] which show that the spiralling of the fins in tube No. 20 will affect the heat transfer and pressure drop performance only for $(\tan\alpha)\ Re_h > 1000$. For $\alpha = 5.4°$, this criteria reduces to $Re_h >$ 10,000, which is beyond the present experimental range.

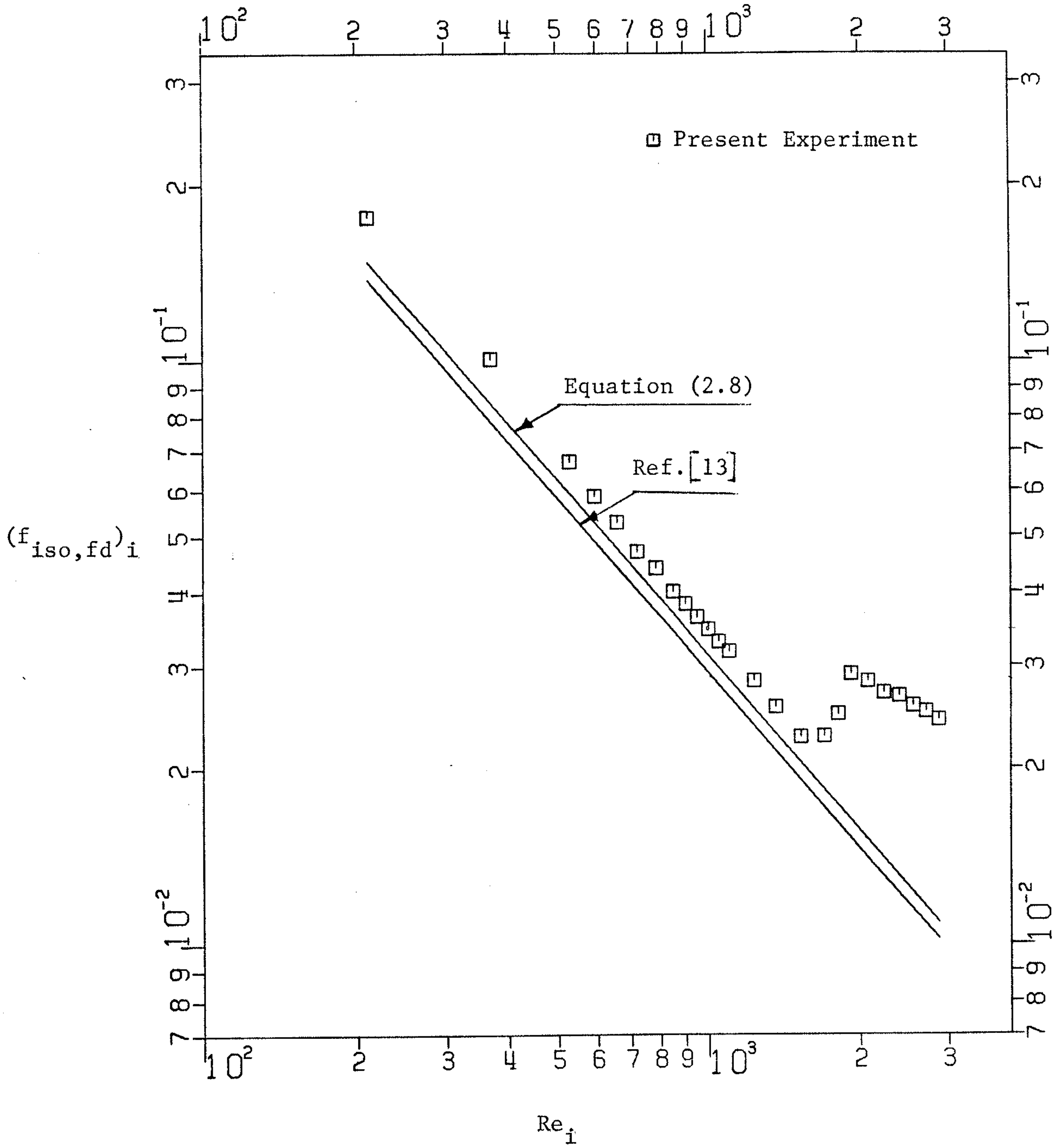


Figure 4.1 Isothermal friction factor for test tube No.9

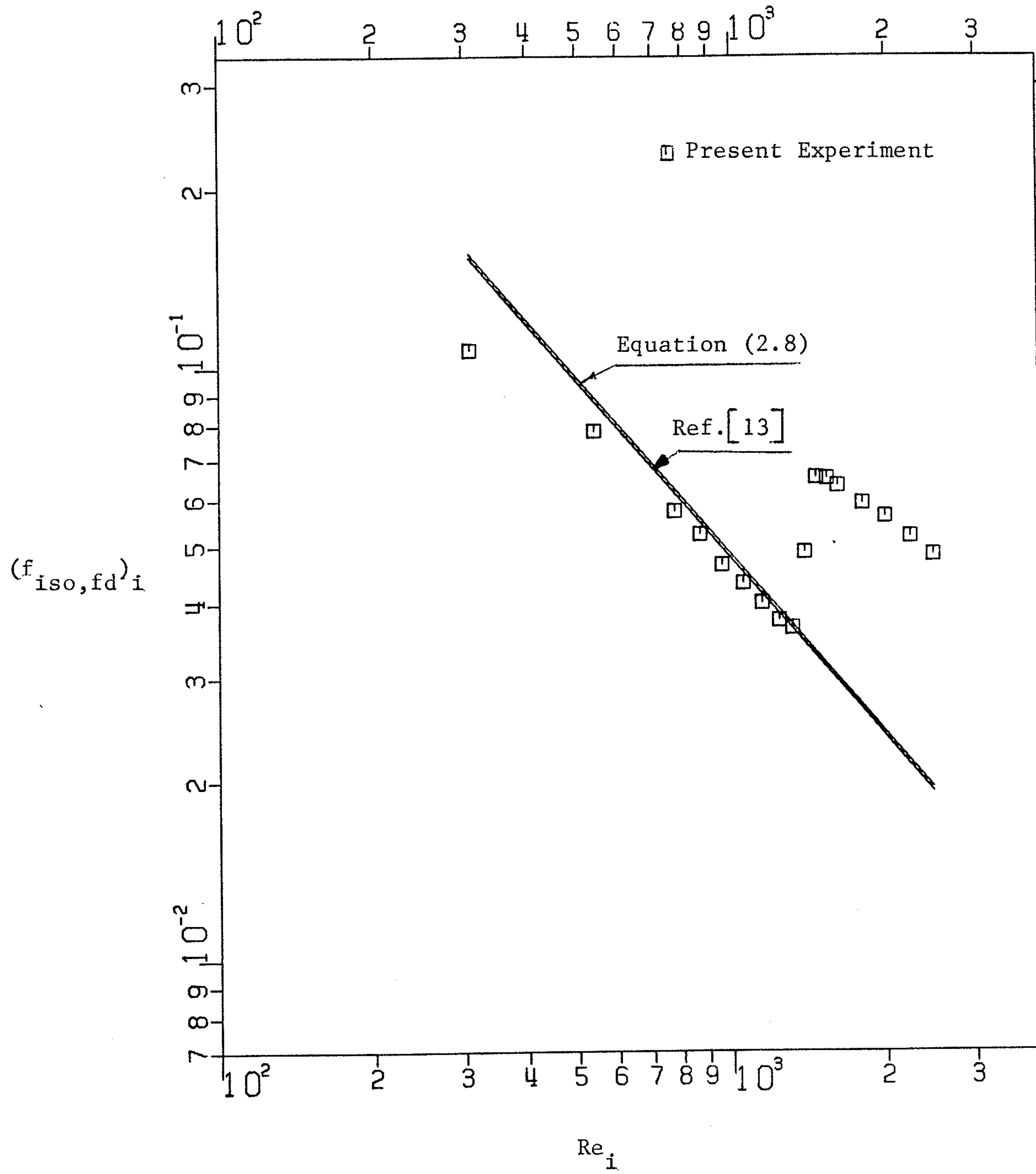


Figure 4.2 Isothermal friction factor for test tube No.10

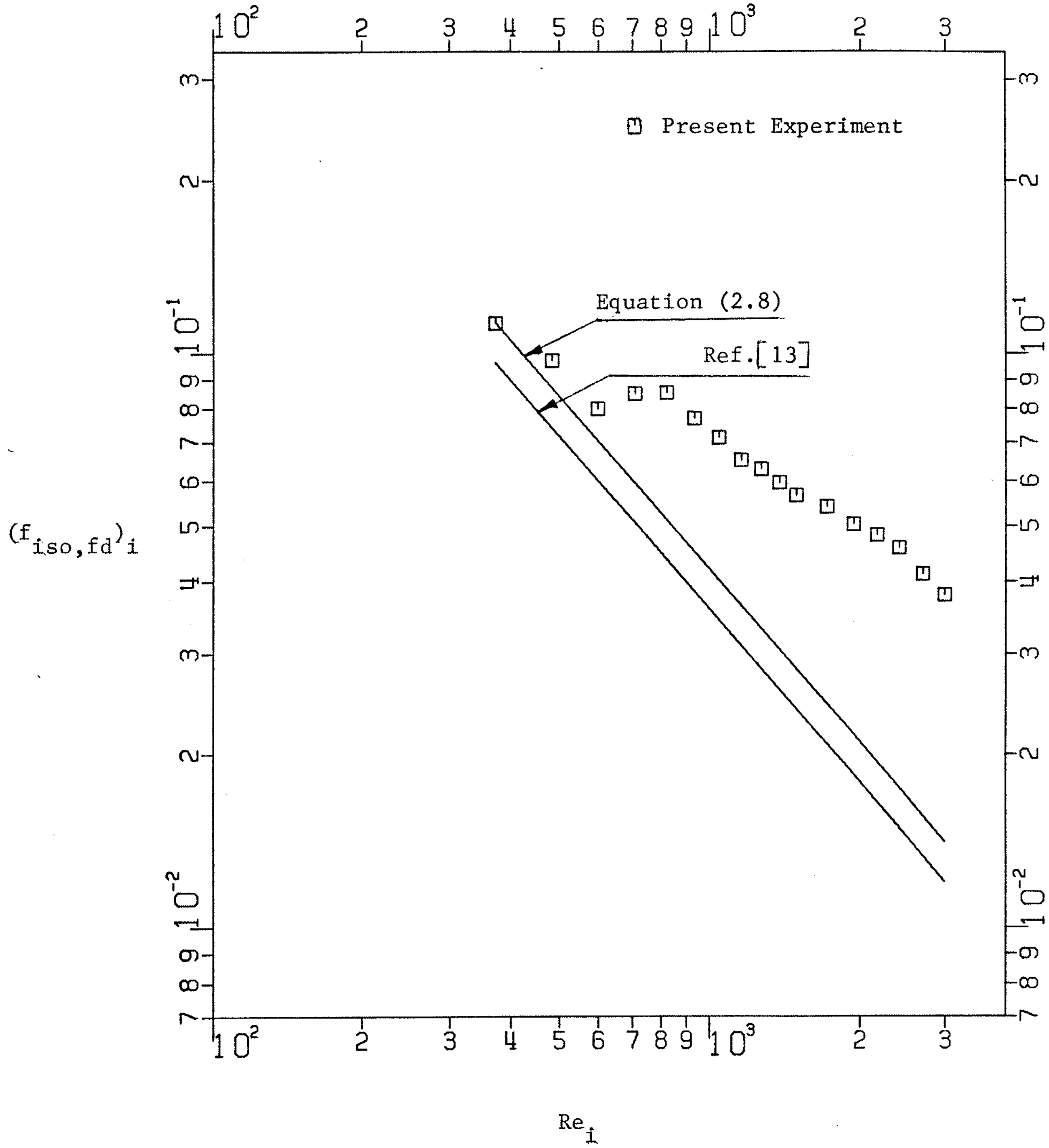


Figure 4.3 Isothermal friction factor for test tube No.13

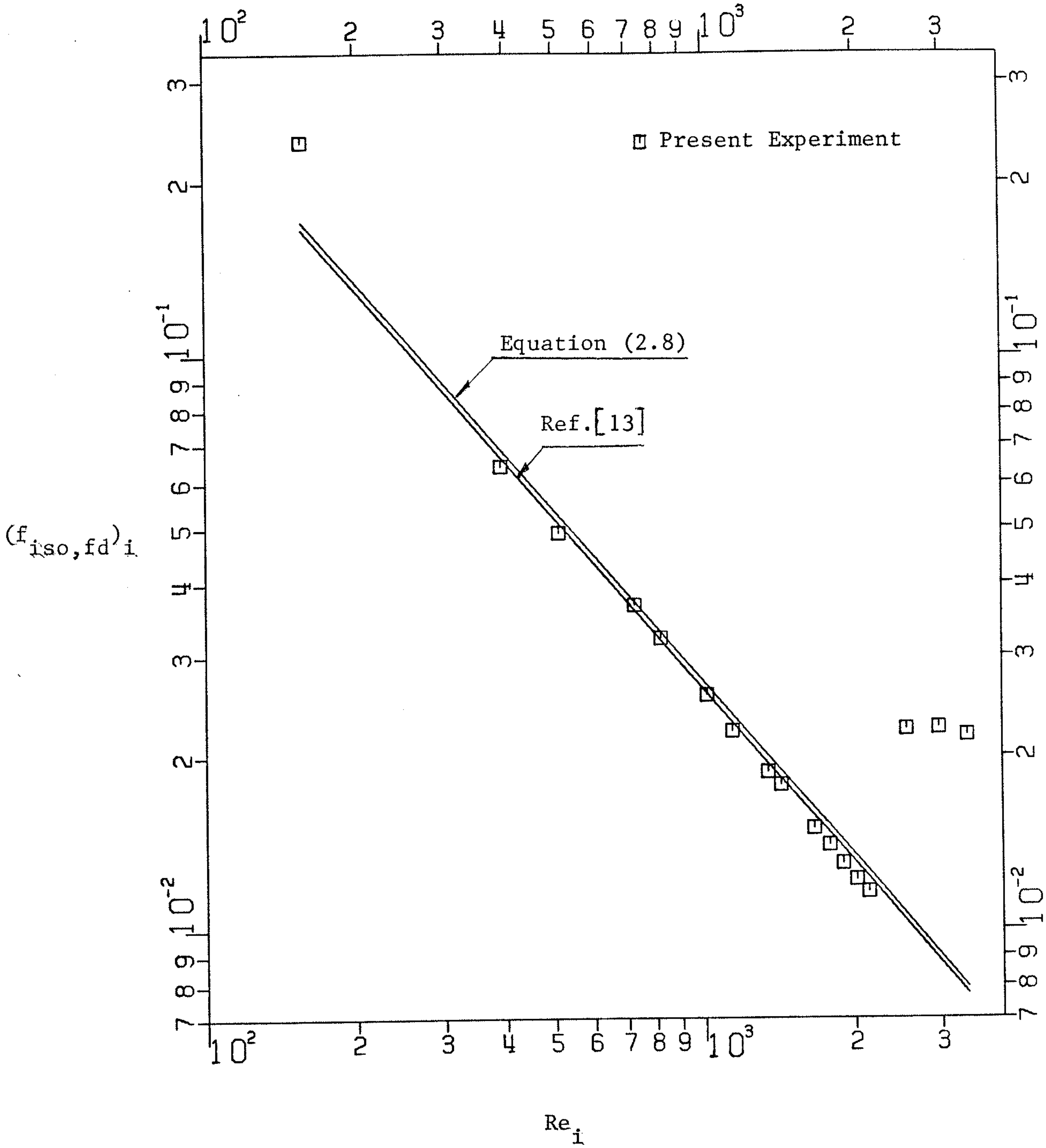


Figure 4.4 Isothermal friction factor for test tube No.14

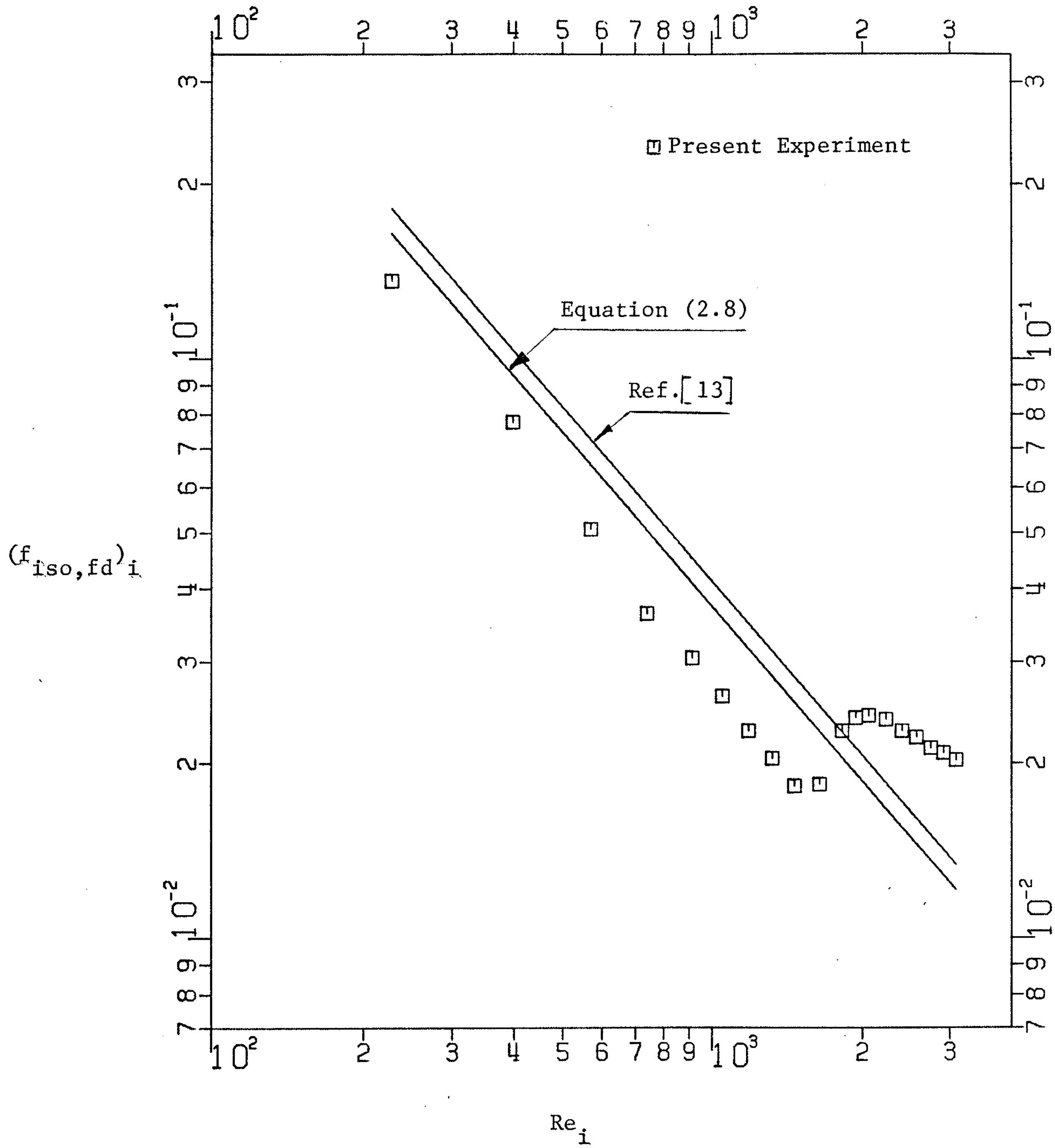


Figure 4.5 Isothermal friction factor for test tube No.20

Table 3 Comparison of $(f_{iso,fd}\ Re)_i$ - Values With Two Analytical Predictions

Tube Number	Present Experiment	Ref. [11] Equation (2.8)	Ref. [13] With γ = 3°
9	34.6	31.2	29.1
10	45.6	48.2	47.5
13	47.4	42.1	35.9
14	25.3	26.9	26.1
20	27.4	37.4	41.3

The critical Reynolds number for all the five internally finned tubes was calculated based on both the inside and hydraulic diameters and listed in Table 4. It can be seen from these results that the critical Reynolds number decreases as H increases while M has an opposite effect. The data is limited however and does not permit development of a reasonably accurate correlation. In an earlier investigation, Watkinson et al. [9] reported similar data for 18 internally finned tubes with different geometries. Their results were presented along with a straight line that passes through the data, on a log-log plot using the critical Reynolds number based on the hydraulic diameter. This plot was reproduced along with the present results in Figure 4.6. The correlation line is seen to be mostly influenced by the data of the spirally finned tubes, while the points corresponding to straight fins are all falling above that line. The scattering in the plot suggests that the critical Reynolds number is influenced by other parameters such as the number of fins. The present results are shown to be mostly above the correlation line where all the data of straight fins are.

4.1.2 Runs With Heat Addition

During the heat transfer runs, the pressure drop across the whole heated section was recorded. The diabatic friction factor (as an average over the heated section) was calculated by equation (4.2), and Reynolds number was calculated by equation (4.1). The modified Rayleigh number was calculated as follows:

$$Ra^* = [g \beta D_i^3 Q_f \rho^2 Cp] / [\mu K_f^2 \pi L] \qquad (4.3)$$

Table 4 Critical Reynolds Number Based on the Inside and Hydraulic Diameters

Tube Number	H	M	$(Re_{cr})_i$	$(Re_{cr})_h$
9	0.248	10	1530	810
10	0.318	16	1300	440
13	0.325	10	600	289
14	0.216	10	2130	1249
20	0.288	16	1465	612

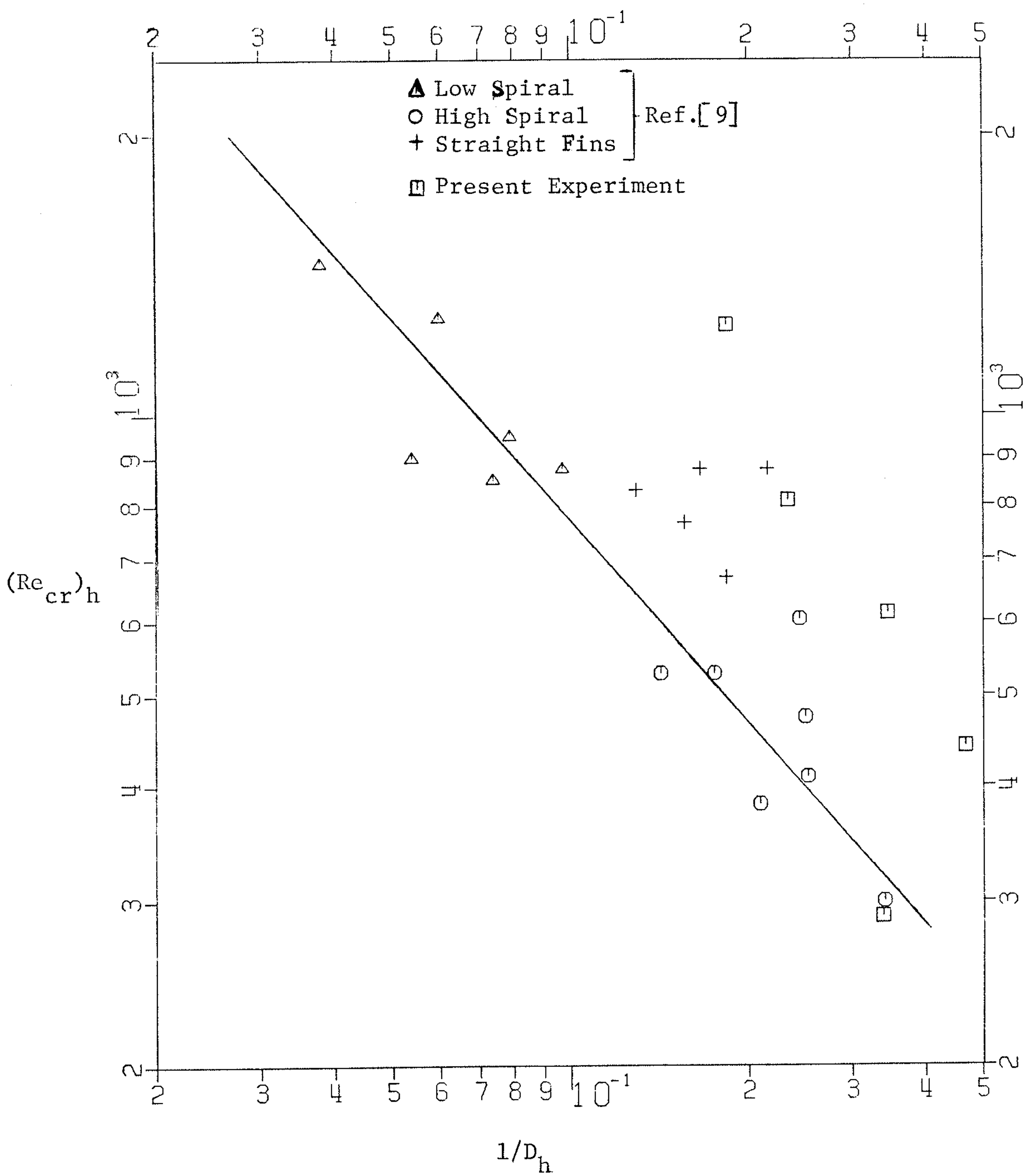


Figure 4.6 Correlation of the critical Reynolds number

In order to show the effect of heating on the pressure drop, without the interference of any property effects, all properties were evaluated at the inlet bulk temperature. By evaluating all fluid properties at the inlet bulk temperature, the ratio $(\bar{f}_{dia}/f_{iso,fd})$ represents the ratio of pressure drops for two identical tubes with the same flowrates and the same inlet temperatures with heat being supplied to one of the tubes while the other is kept adiabatic. The ratio $(\bar{f}_{dia}/f_{iso,fd})$ was plotted against R_a^* for each tube separately and the results are shown in Figures 4.7 to 4.10. The plotted data is seen to be strongly dependent on Reynolds number. For each tube, two or three sets of data corresponding to different Reynolds numbers are shown. From Figures 4.7 to 4.10 it can be noted that the value of $(\bar{f}_{dia}/f_{iso,fd})$ decreases with increasing R_a^* for all sets of runs of tubes 10 and 13. For tube No. 14, the ratio $(f_{dia}/f_{iso,fd})$ increases with increasing R_a^* for all sets of runs. For tube No. 20, $(\bar{f}_{dia}/f_{iso,fd})$ increses with R_a^* for one set of runs, while for the other set, the ratio $(\bar{f}_{dia}/f_{iso,fd})$ shows a decrease with R_a^* up to a certain value of R_a^* and then it starts increasing. From these results it is clear that there are two factors responsible for this behaviour. One is the fluid viscosity, and the other is the free convection. At low values of R_a^*, the free convection effect is not strong, and the heat supplied causes a drop in the fluid viscosity which consequently causes a decrease in the pressure drop. This seems to be the case for tubes No. 10 and 13 where most of the data correspond to $R_a^* < 10^6$. At high values of R_a^*, the free convection effect on the pressure drop is strong enough to overcome the viscosity effect, and an increase in the pressure drop results as reflected by the

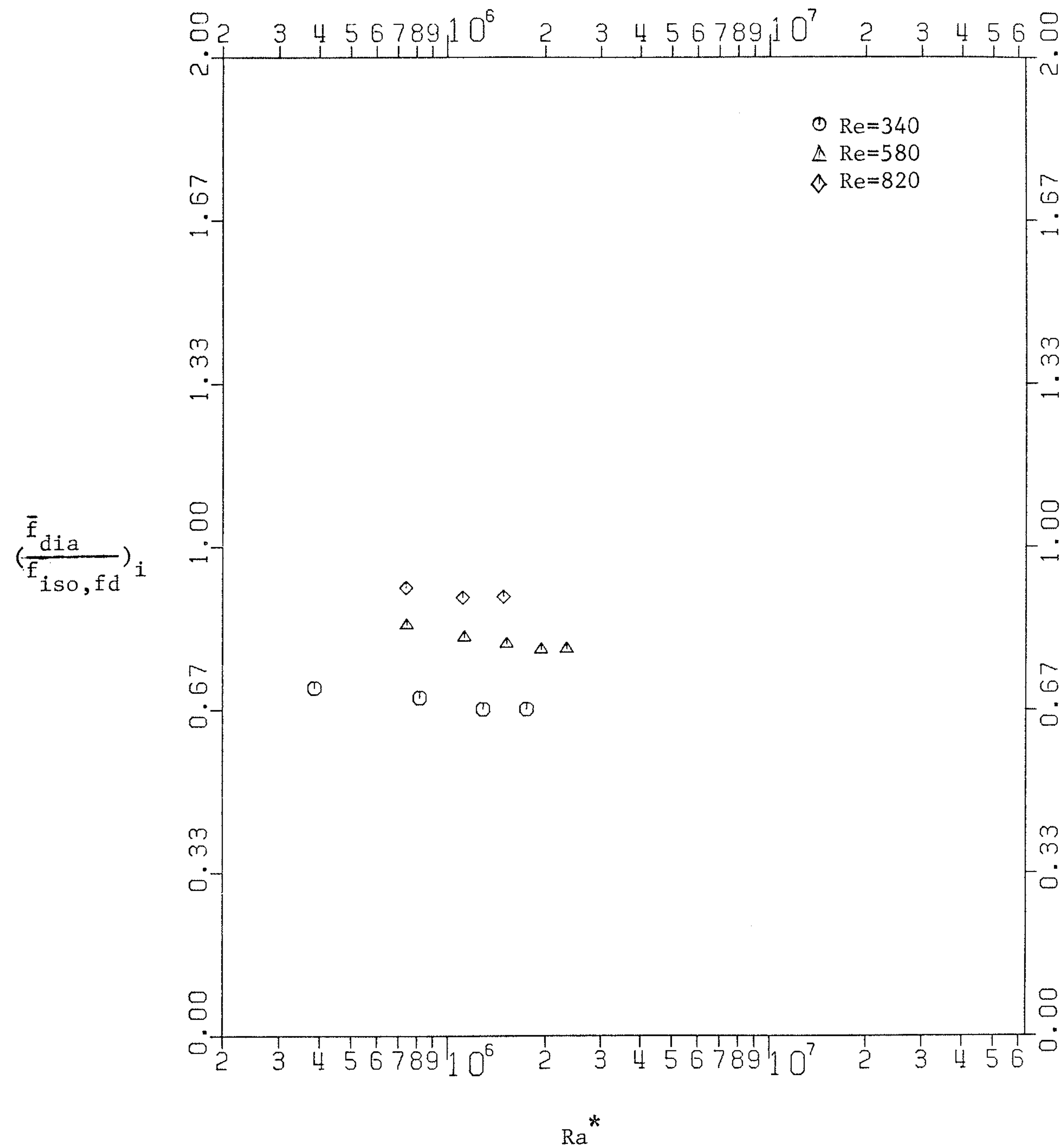


Figure 4.7 The effect of heating on the friction factor for tube No.10

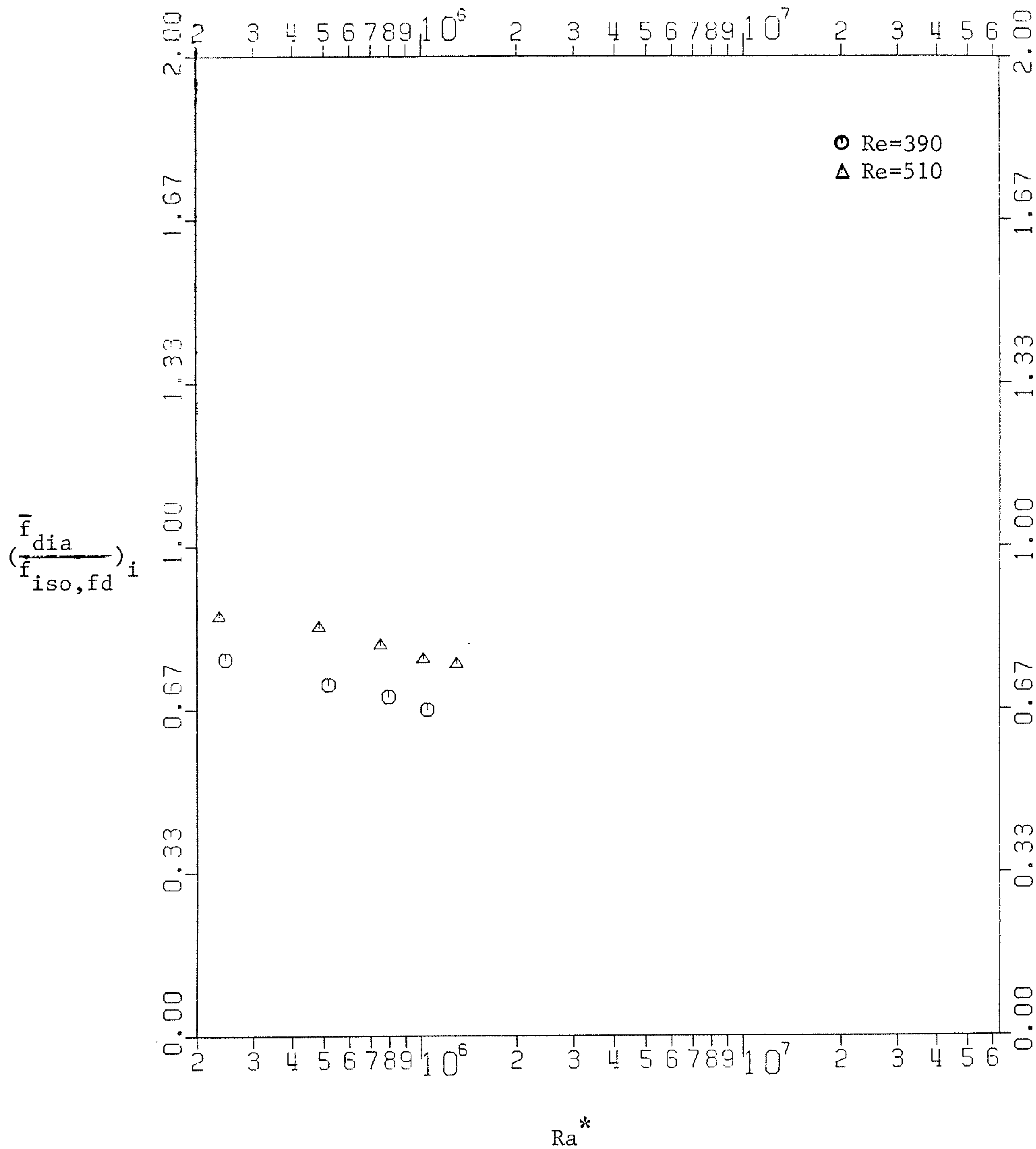


Figure 4.8 The effect of heating on the friction factor for tube No.13

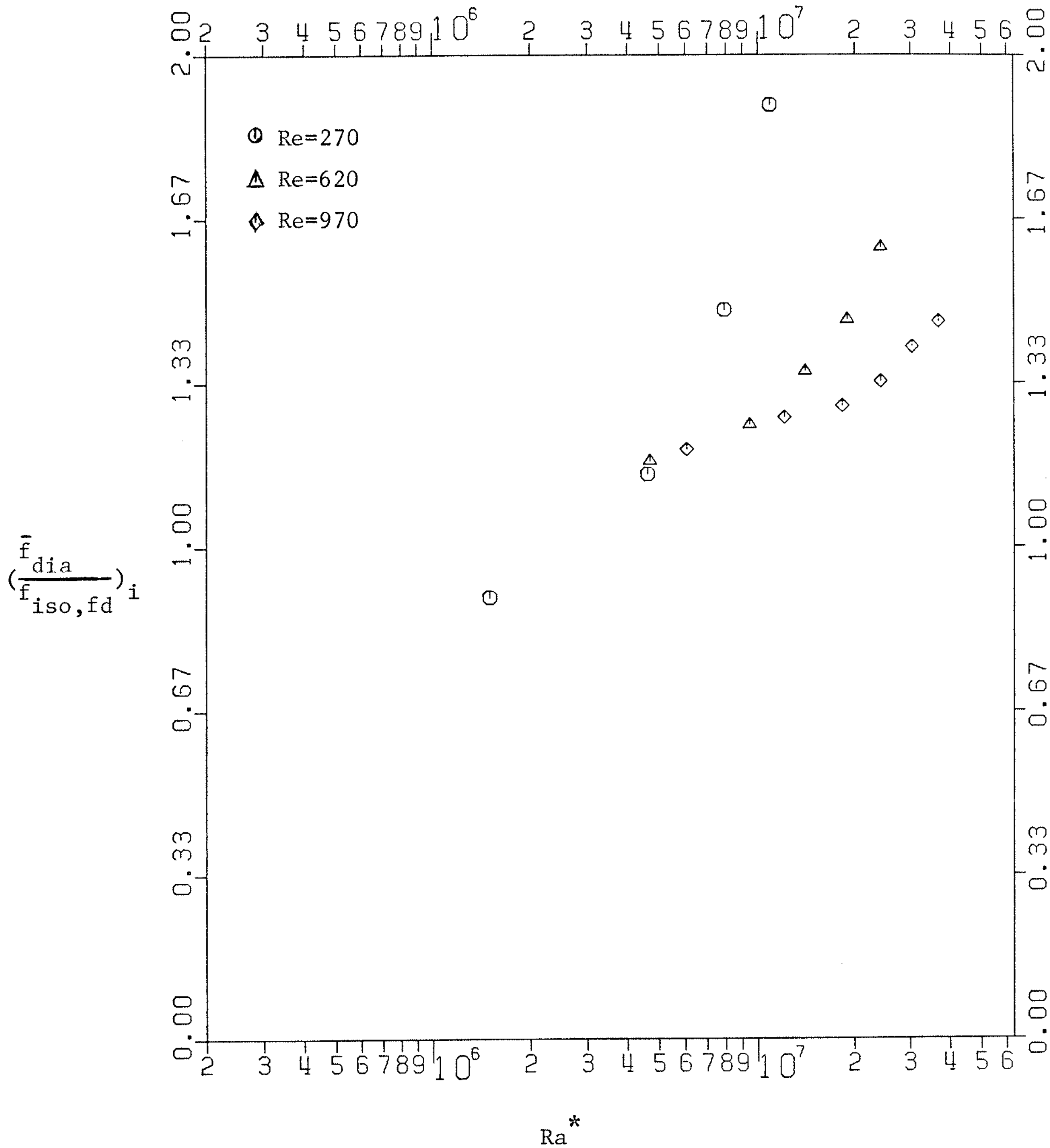


Figure 4.9 The effect of heating on the friction factor for tube No.14

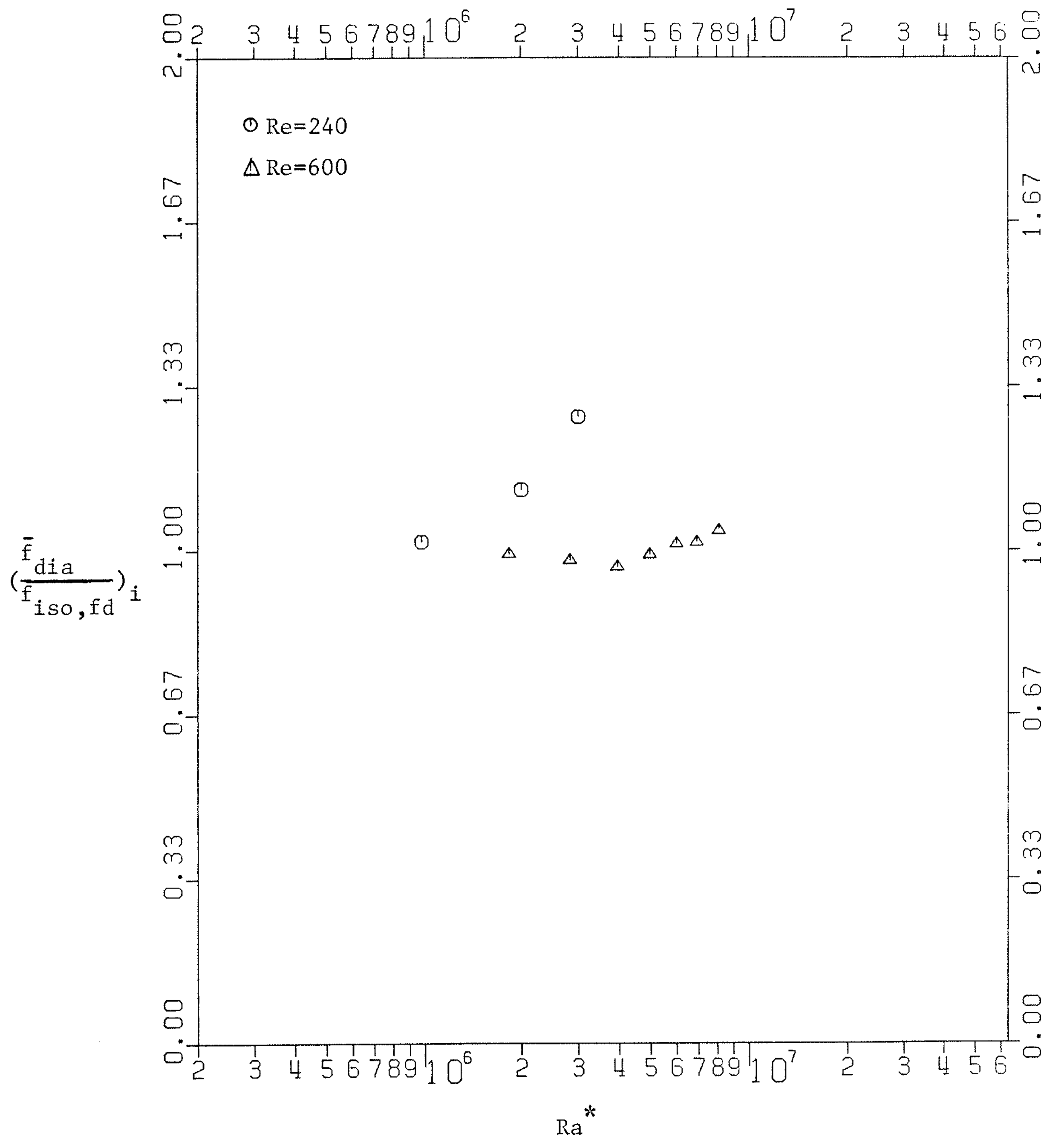


Figure 4.10 The effect of heating on the friction factor for tube No.20

values of $(\bar{f}_{dia}/f_{iso,fd})$. This is the case for tube No. 14 where the data correspond to $R_a^* > 10^6$. Tube No. 20 for which the data has a medium range of R_a^*, shows a continuous increase in the pressure drop for one set of runs, while the other set shows a decrease and then an increase with increasing R_a^*. The results in Figure 4.7 to 4.10 suggest that there is a critical value of R_a^* at which the effect of free convection becomes stronger than the viscosity drop. This critical R_a^* seems to depend on Reynolds number and tube geometry.

Another important trend displayed by Figures 4.7 to 4.10 is the effect of Reynolds number on the value of $(f_{dia}/f_{iso,fd})$. At low values of R_a^*, lower Reynolds numbers corresponds to lower values of $(\bar{f}_{dia}/f_{iso,fd})$ as in tubes 10 and 13, while the trend is reversed at higher values of R_a^* as in tubes No. 14 and 20. At low values of R_a^*, where the effect of free convection is not strong, the pressure drop decreases as Re decreases at the same R_a^* because smaller Re results in higher rise in bulk temperature and consequently a lower average viscosity in the heated section. At high values of R_a^*, the free convective currents are aided by this decrease in viscosity and thus the pressure drop increases as Re decreases at the same R_a^*. It must be pointed out that the above Reynolds number effect, is not discussed in almost all analytical investigations since it is a common practice to assume constant properties.

A comparison was also made between the experimental data and the predictions of empirical equation (2.7) reported in [6] for smooth tubes. Values of f_{dia} and Ra were calculated with all properties evaluated at the film temperature at the middle of the heated section as recommended in [6]. The results are shown for each tube separately along with equation (2.7) in Figures 4.11 to 4.14. According to the trends reported in [18,19], it is expected that all the experimental values would fall below the line of equation (2.7). This empirical equation was limited in [6] to $Ra \leq 10^6$, however, it was extended by a dotted line in Figure 4.11 to 4.14 to cover the range occupied by the experimental data. Tubes No. 10 and 13 show values of $(\bar{f}_{dia}/f_{iso,fd})$ lower than the empirical equation confirming the expectation that the effect of free convection was suppressed by the presence of the fins. Tubes No. 14 and 20 crossed the empirical line to higher values of $(\bar{f}_{dia}/f_{iso,fd})$. Most of the experimental data that crossed the empirical line correspond to values of Ra higher than 10^6, which is outside the recommended range of the empirical equation.

To show the effect of geometry on $(\bar{f}_{dia}/f_{iso,fd})$ two plots are presented in Figure 4.15 and 4.16. Each plot contains data for tubes No. 10, 13, 14 and 20 at the same range of Re_m, with equation (2.7) for comparison. Figures 4.15 and 4.16 show that tubes No. 10 and 13 with higher values of H exhibited lower values of $(\bar{f}_{dia}/f_{iso,fd})$ than the other finned tubes and the empirical prediction for smooth tubes. Tubes No. 14 and 20 with lower values of H exhibited a sharp increase in $(\bar{f}_{dia}/f_{iso,fd})$ at high values of Ra and exceeded the empirical predictions for smooth tubes. However, this occurred mainly at $Ra > 10^6$ where equation (2.7) may not be valid. Generally, the presence of the fins seems to suppress the effect of free convection on the values of $(\bar{f}_{dia}/f_{iso,fd})$. By comparing the results of tubes No. 10 and 13 which have almost the same value of H but different values of M, we find a clear trend in Figures 4.15 and 4.16 indicating that a larger M results in less free convection effect on the diabatic friction factor.

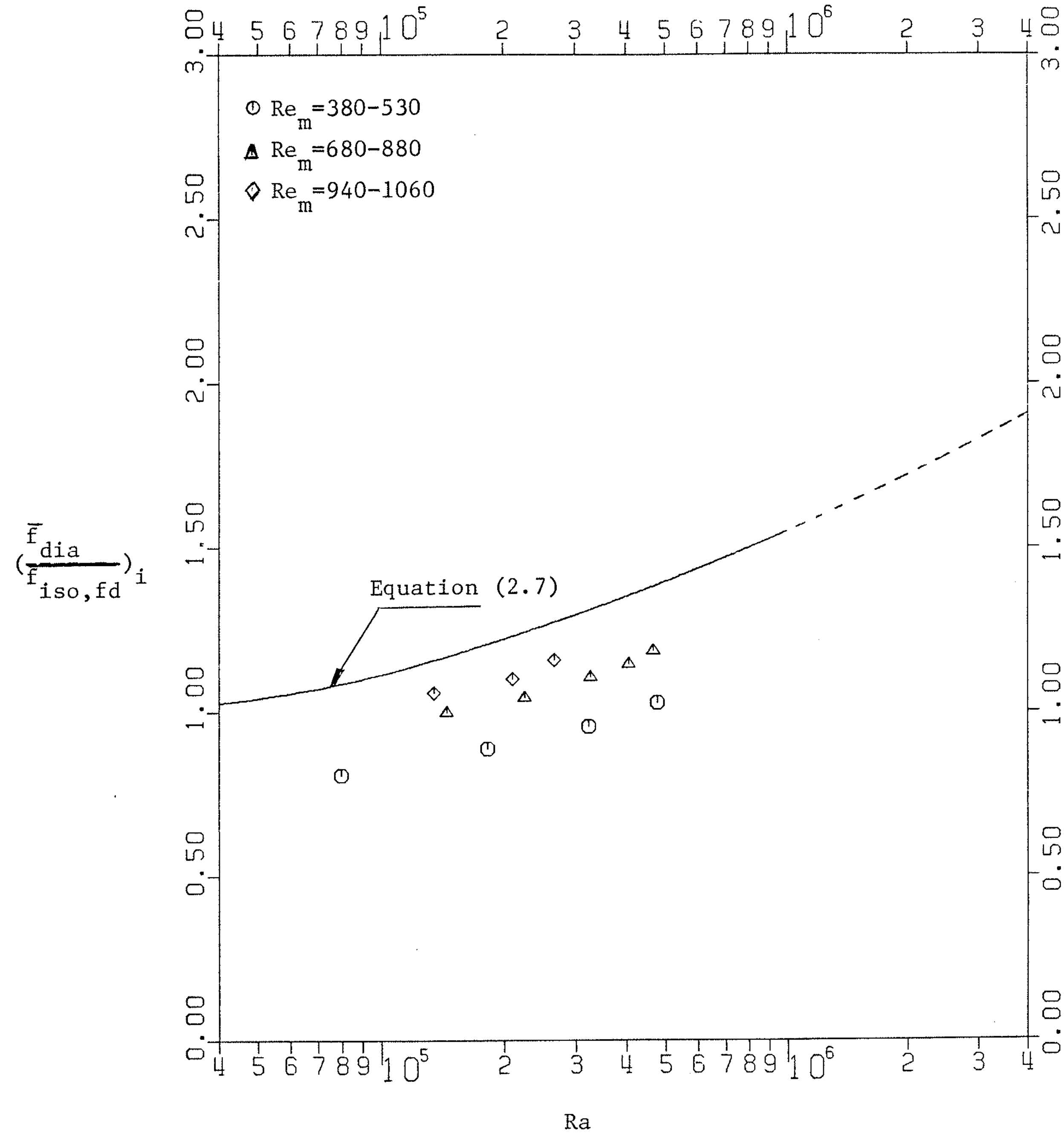


Figure 4.11 Comparison between the present diabatic friction factor data for tube No.10 and equation(2.7) reported in[6]

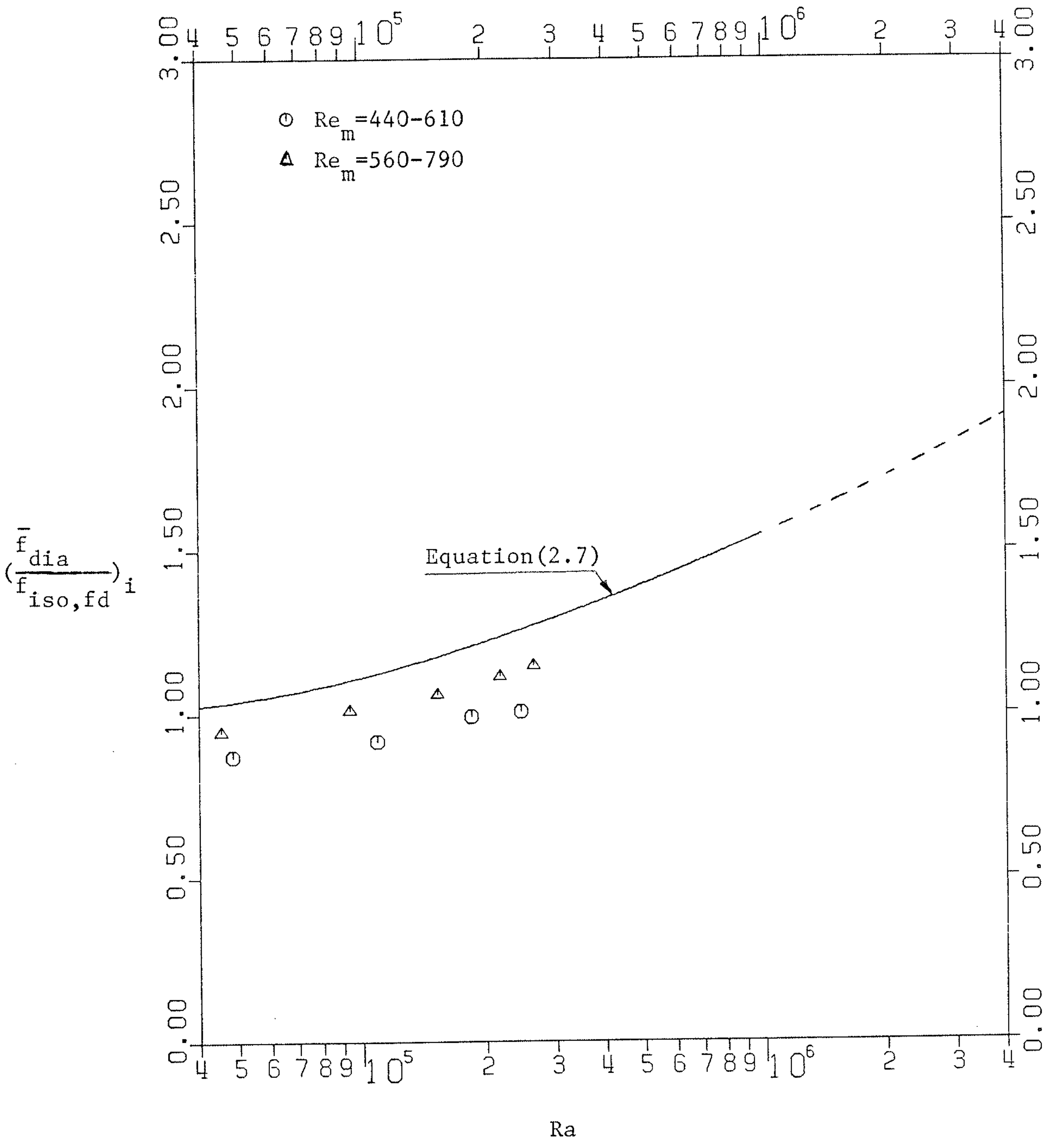


Figure 4.12 Comparison between the present diabatic friction factor data for tube No.13 and equation(2.7) reported in[6]

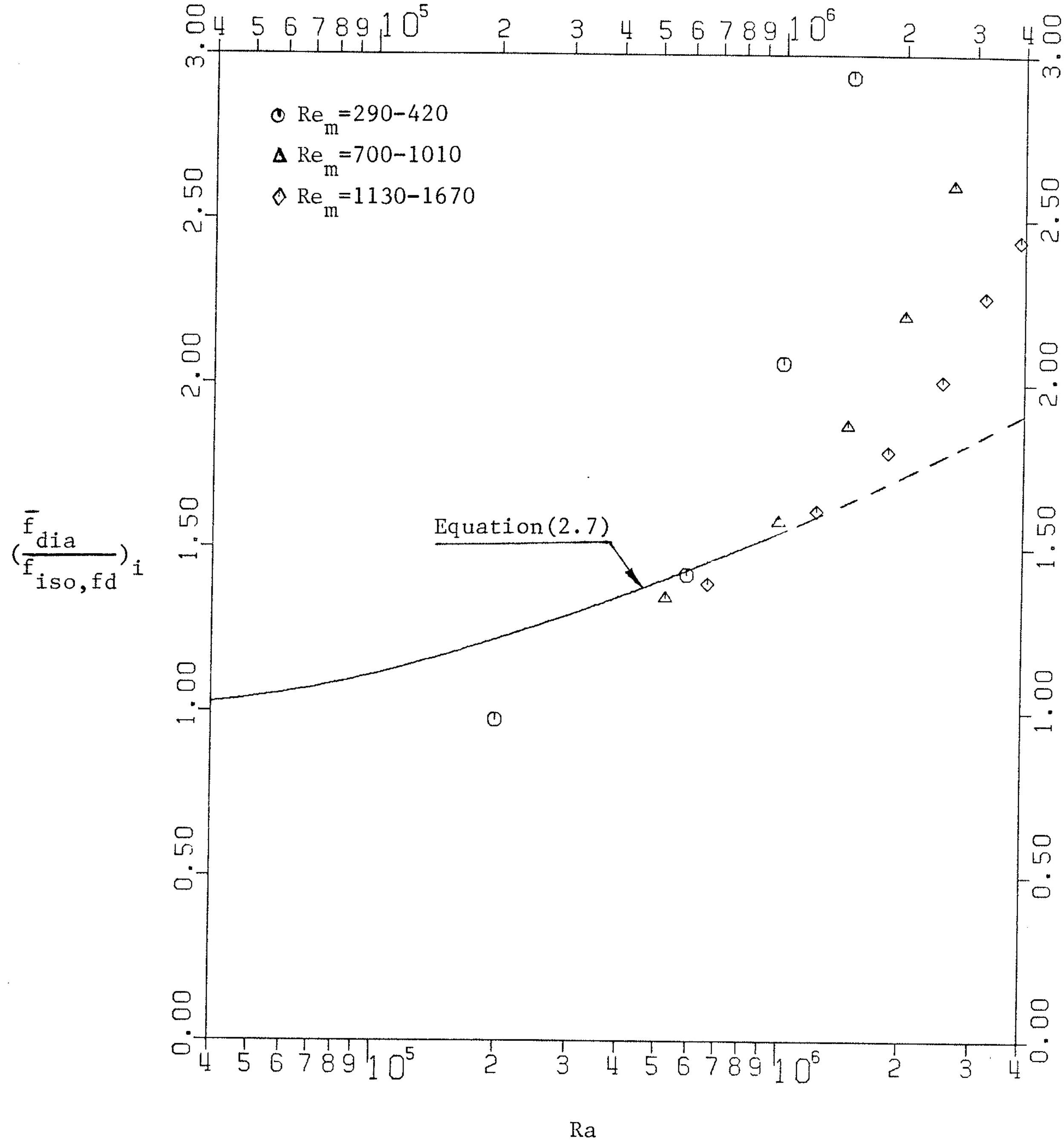


Figure 4.13 Comparison between the present diabatic friction factor data for tube No.14 and equation(2.7) reported in[6]

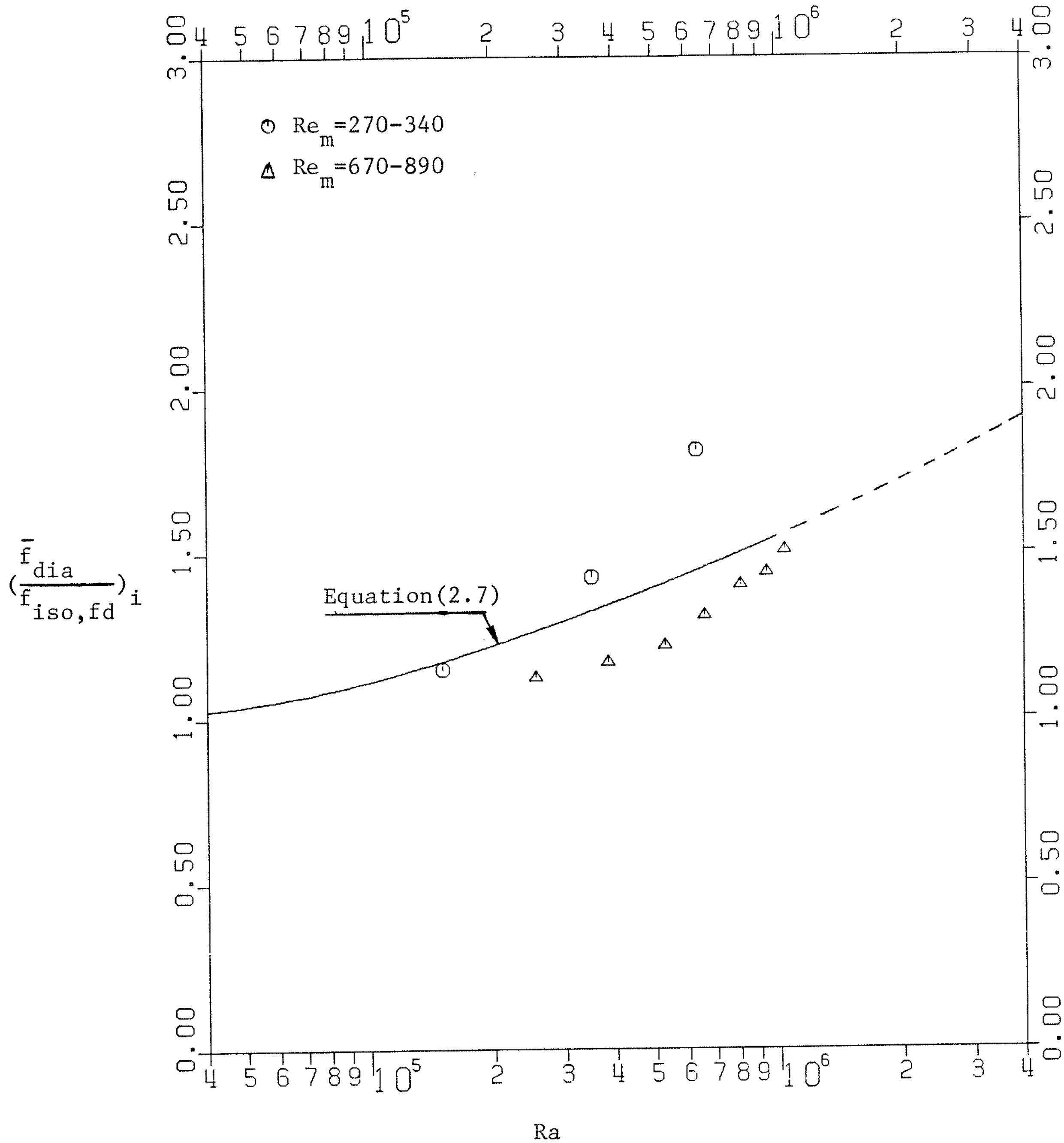


Figure 4.14 Comparison between the present diabatic friction factor data for tube No.20 and equation(2.7) reported in[6]

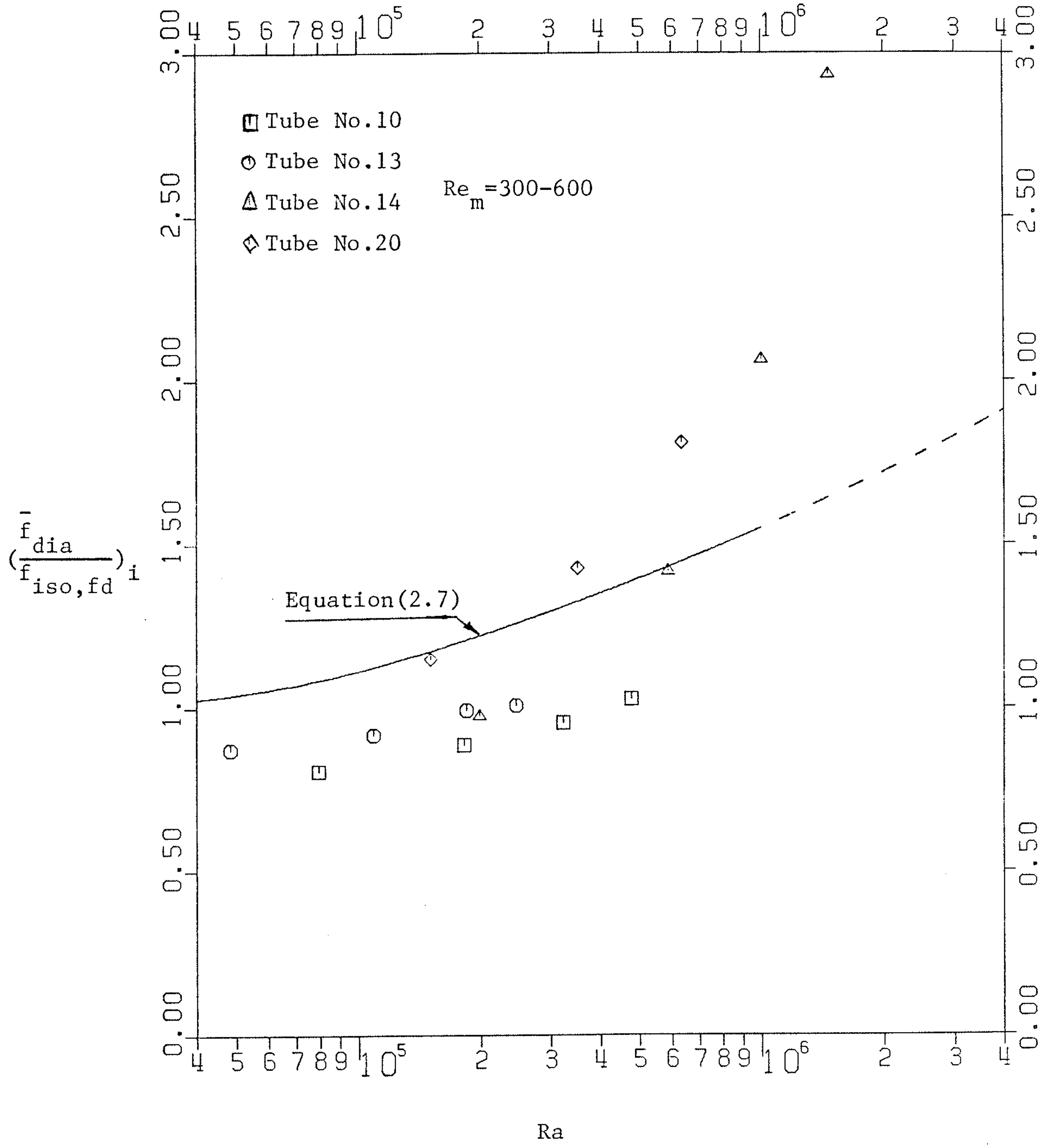


Figure 4.15 Effect of tube geometry on the diabatic friction factor for $300<Re_m<600$

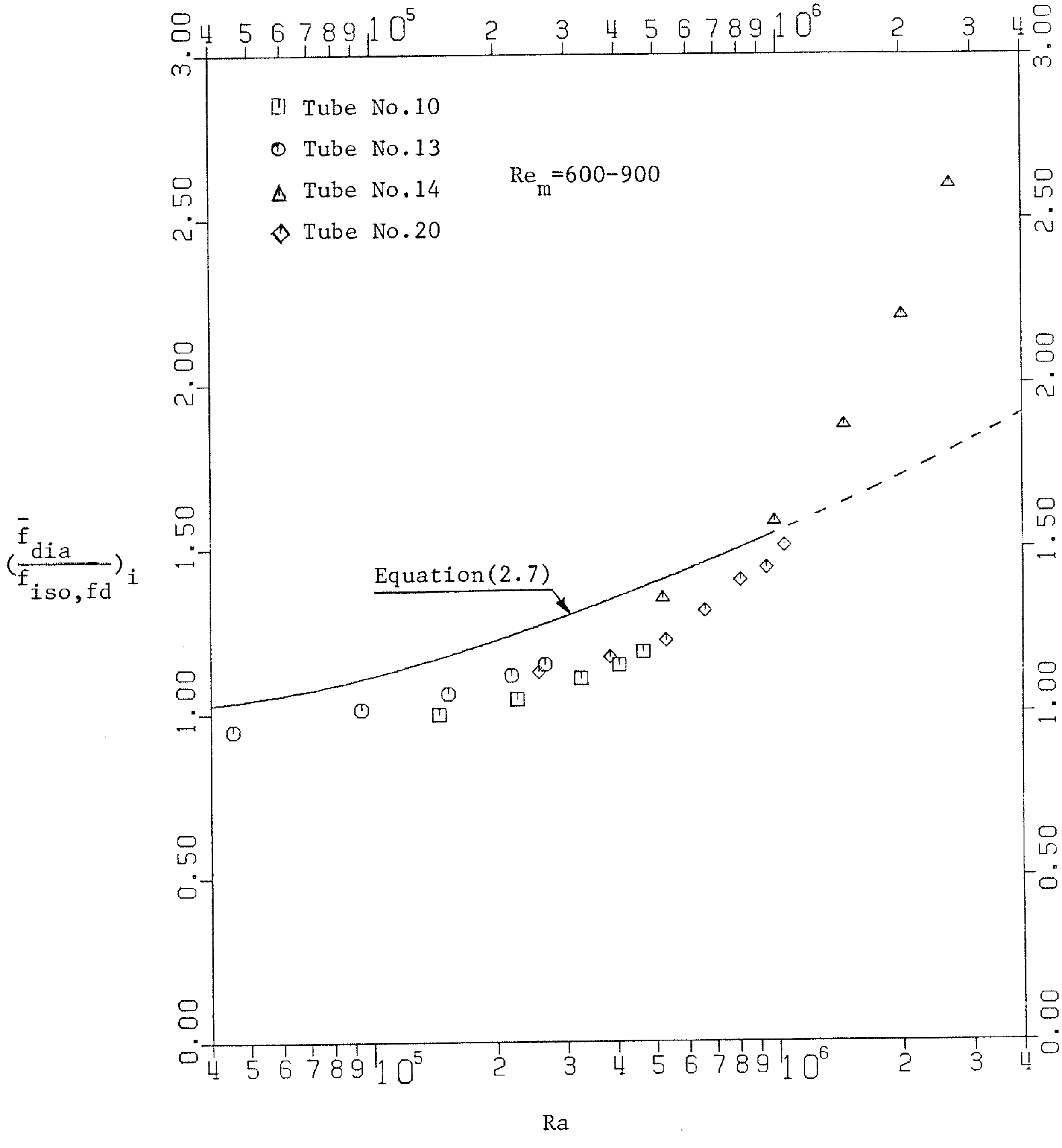


Figure 4.16 Effect of tube geometry on the diabatic friction factor for $600<Re_m<900$

4.2 Heat Transfer Results

The testing procedure was described in detail in the last chapter. After the raw data were recorded, the local Nusselt number Nu_x was calculated as follows:

$$Nu_x = Q_f / \pi L (\bar{T}_w - T_b) k_f] \qquad (4.4)$$

The dimensionless distance along the heated section was calculated as:

$$X^+ = [x/R_i]/(Re_x Pr_x) \qquad (4.5)$$

and the dimensionless wall temperature was calculated as

$$\Theta_w = [\pi L (\bar{T}_w - T_b) k_f] / Q_f \qquad (4.6)$$

The local Reynolds number Re_x, local Prandtl number Pr_x and local modified Rayleigh number Ra_x^* were calculated at the local bulk temperature.

4.2.1 Wall Temperature

The local wall temperatures were recorded at the top and bottom of the tube for all wall-temperature-measurement stations. For each tested tube, two or three runs at different values of Ra_m^* were selected to cover the range of Ra_m^* used for that tube. The selected runs were plotted on a log-log scale for each tube separately, with the theoretical predictions for pure forced convection in smooth tubes [21]. As was mentioned earlier, no solution is available yet for the thermal entry region of internally finned tubes. Figures 4.17 to 4.22 show Θ_w against X^+ for each tube separately.

In Figure 4.17 for the smooth tube, the experimental data in the early part of the thermal entry region converge to the analytical prediction for all values of Ra_m^*. This convergence indicates that the free convection effect is very weak in this part due to the small differ-

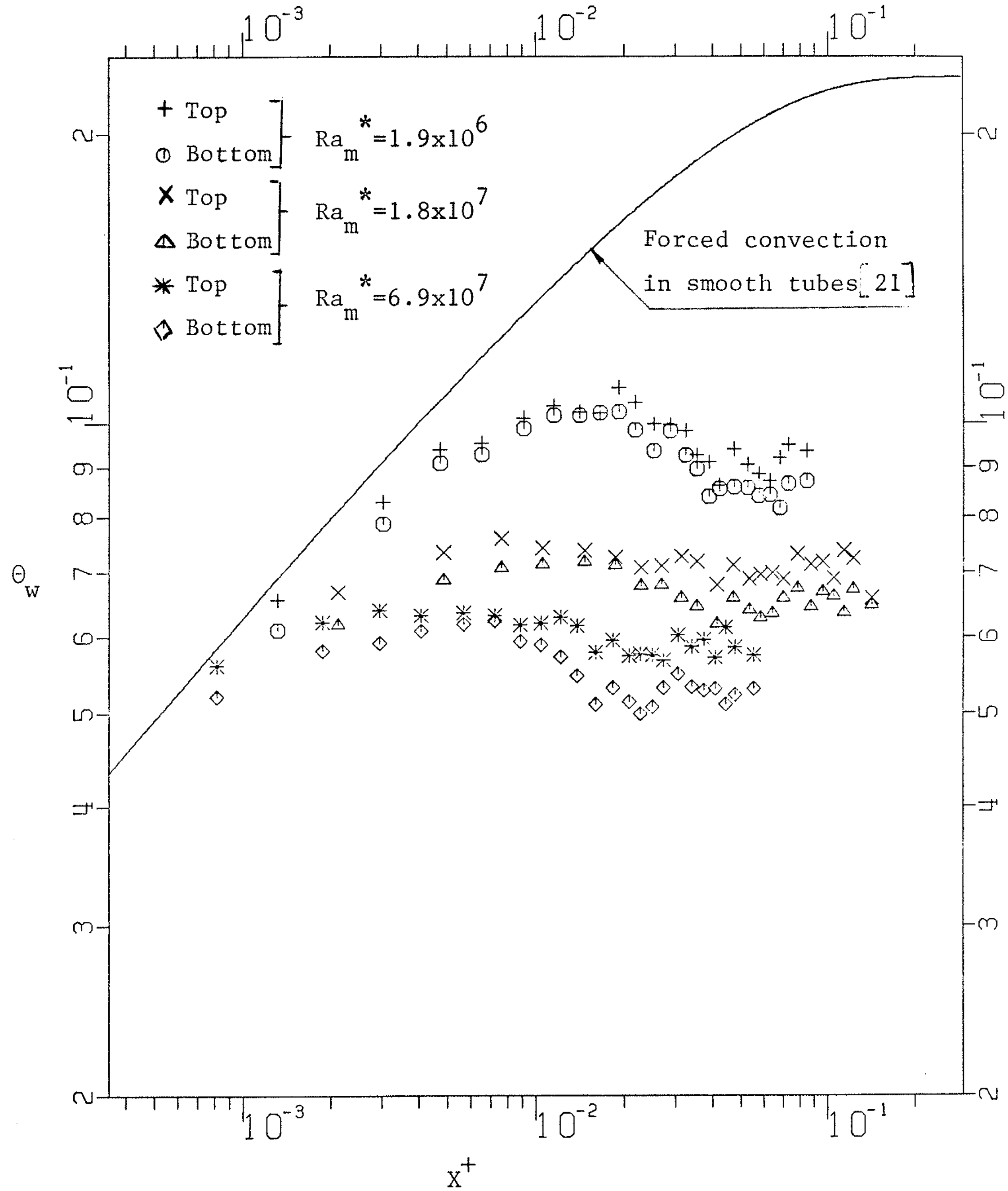


Figure 4.17 Axial distribution of top and bottom wall temperature for tube No.1 at different values of Ra_m^*

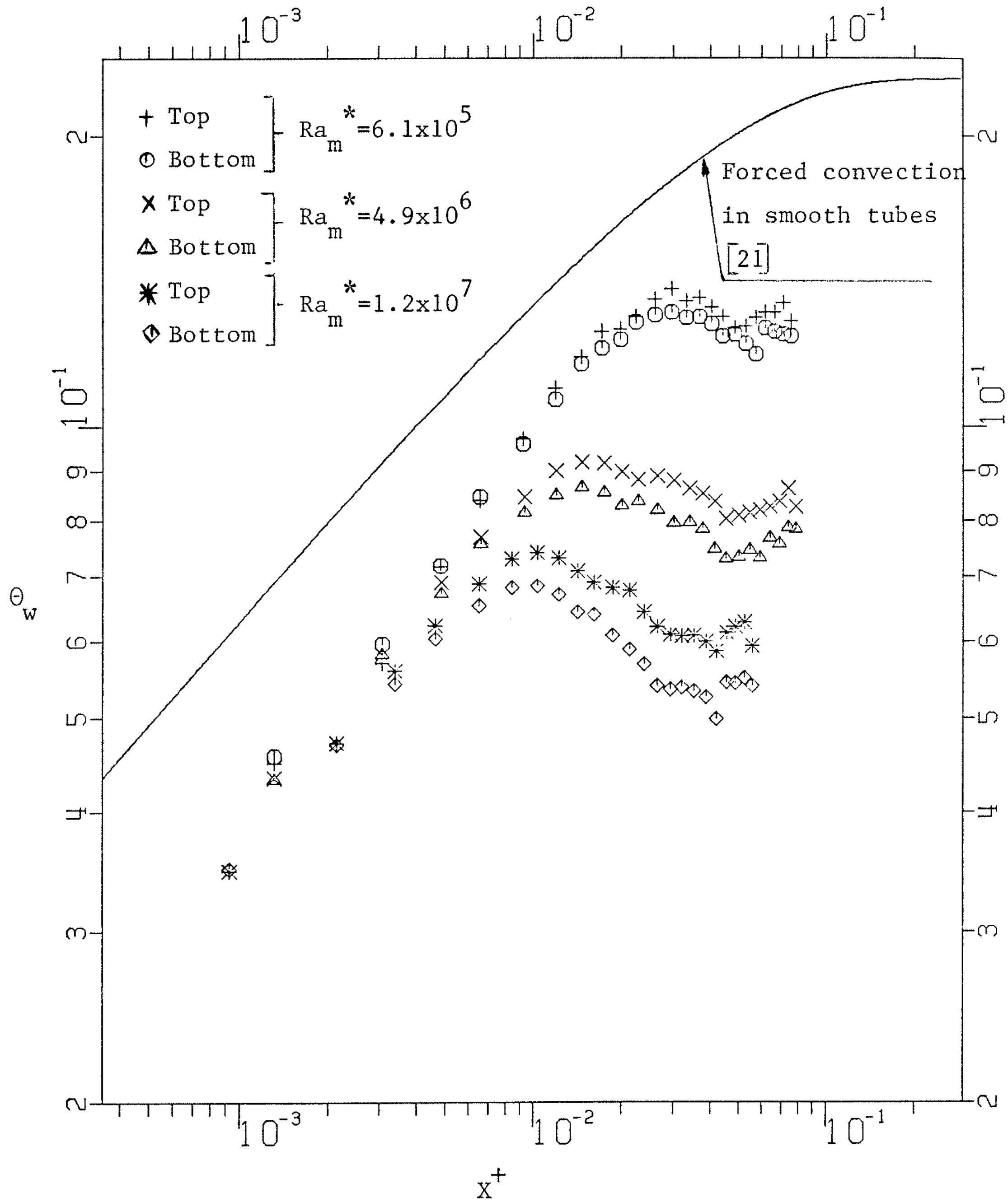


Figure 4.18 Axial distribution of top and bottom wall temperature for tube No.9 at different values of Ra_m^*

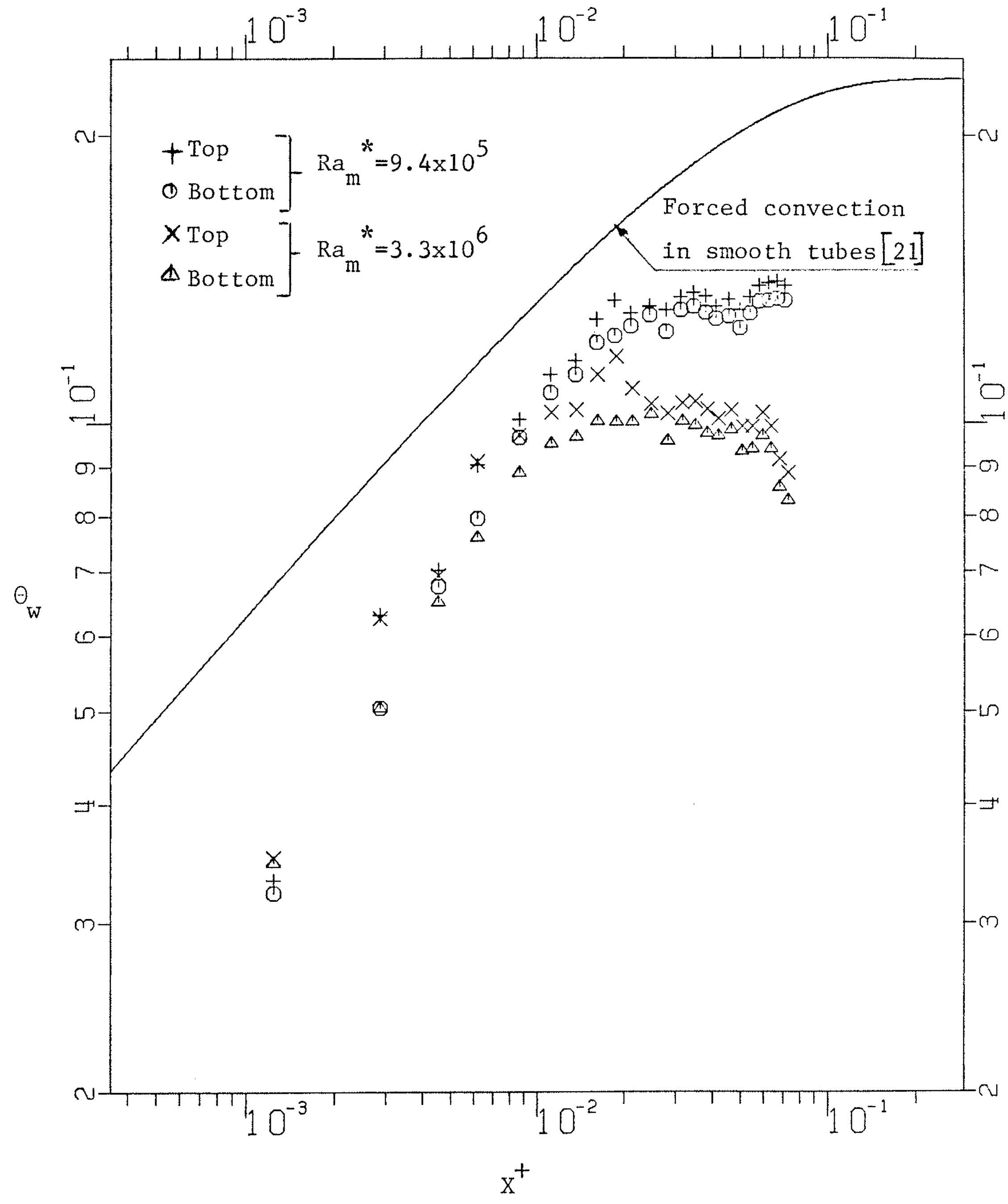


Figure 4.19 Axial distribution of top and bottom wall temperature for tube No.10 at different values of Ra_m^*

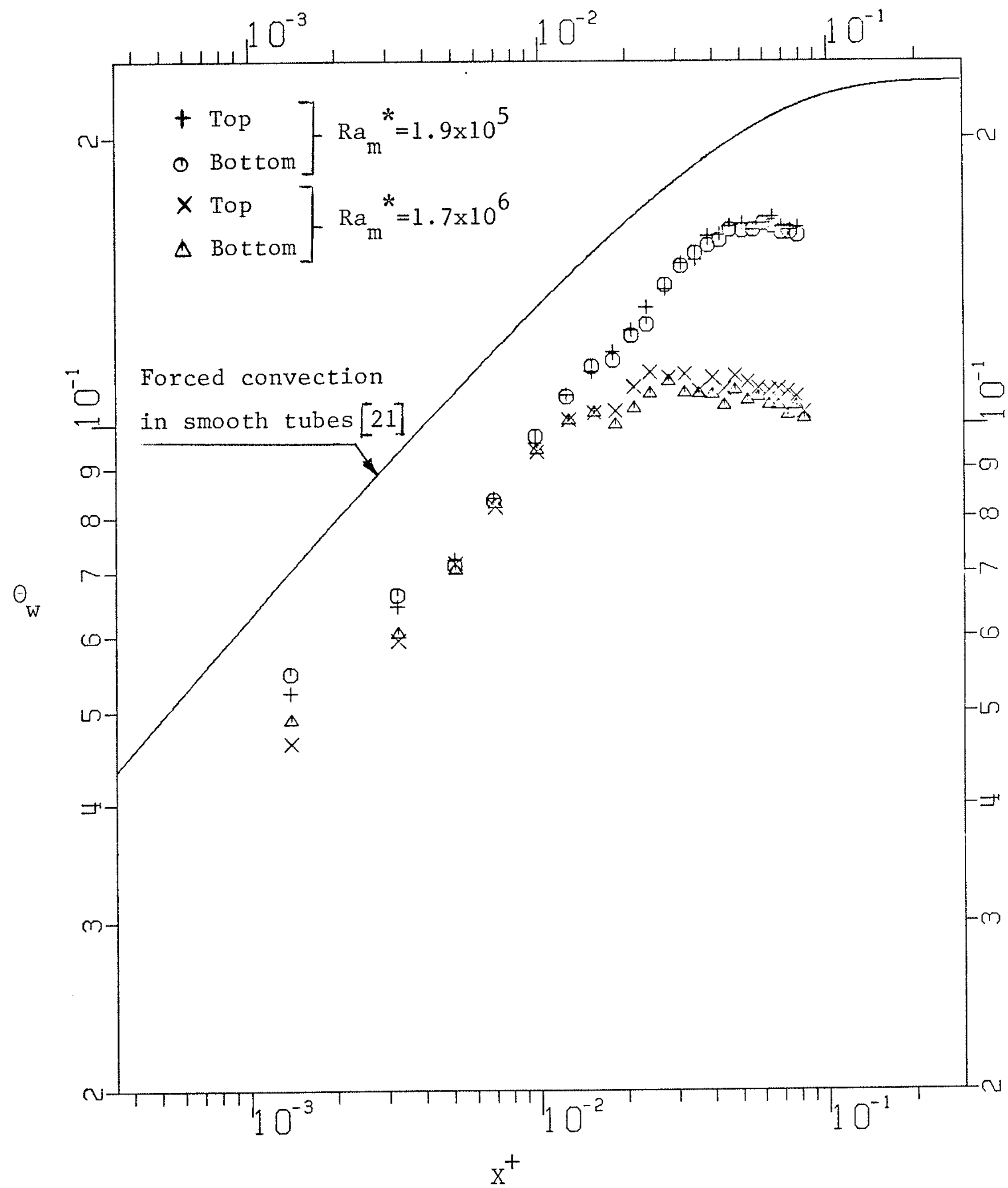


Figure 4.20 Axial distribution of top and bottom wall temperature for tube No.13 at different values of Ra_m^*

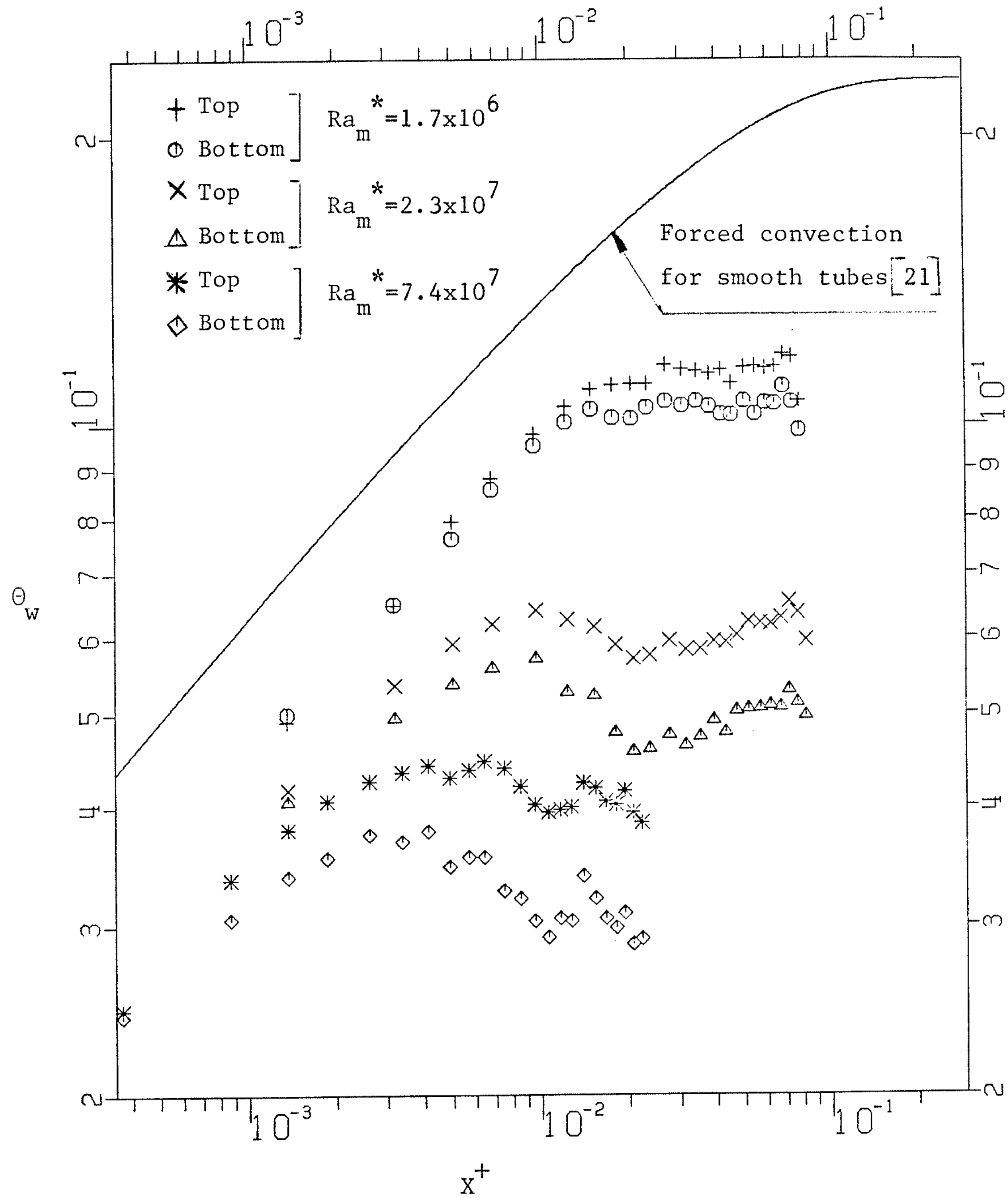


Figure 4.21 Axial distribution of top and bottom wall temperature for tube No.14 at different values of Ra_m^*

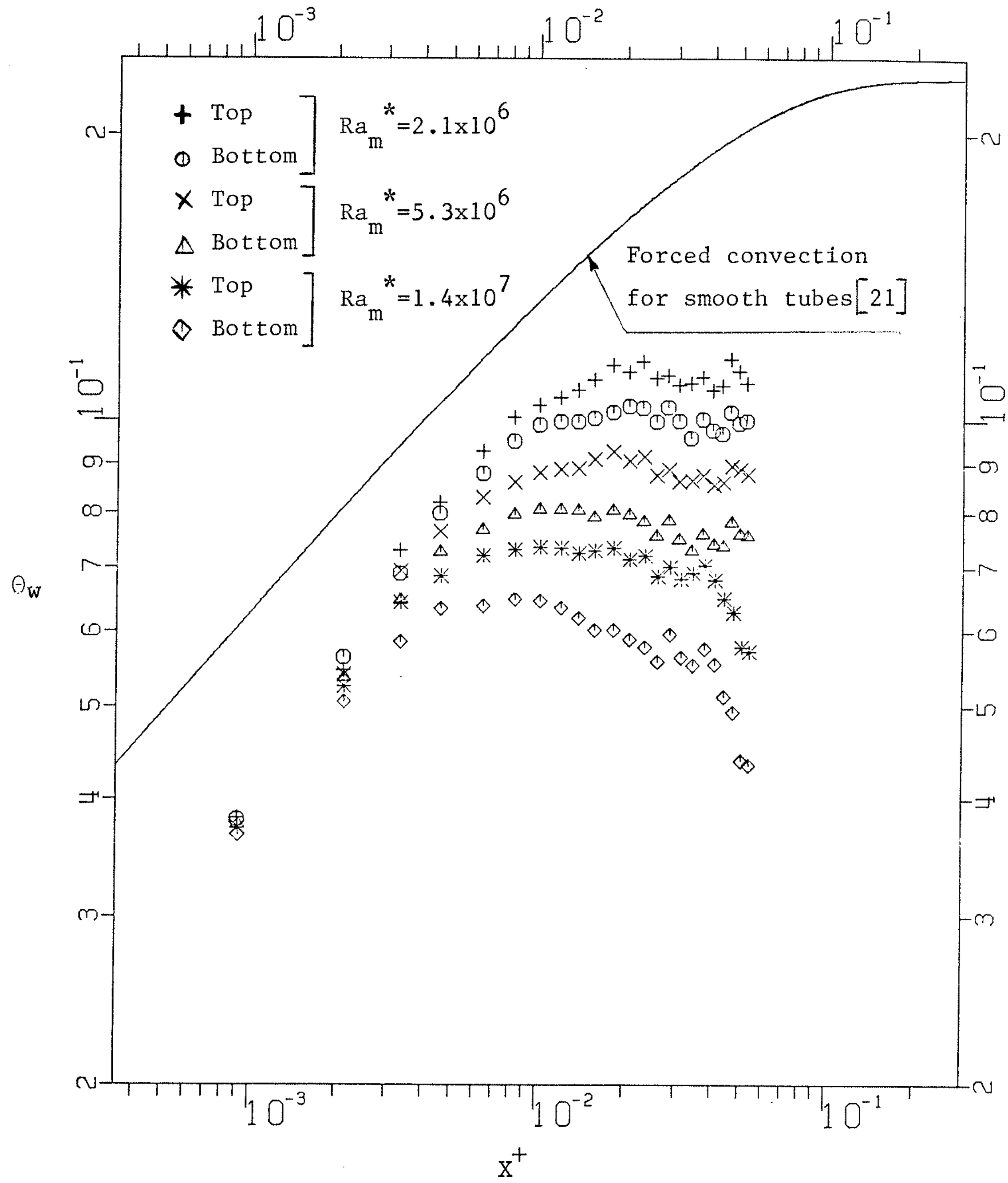


Figure 4.22 Axial distribution of top and bottom wall temperature for tube No.20 at different values of Ra_m^*

ence between wall and bulk temperatures. As we move to higher values of X^+, the experimental data start to deviate from the analytical prediction indicating that the effect of free convection is starting to take place. As the effect of free convection grows, a separation between the wall top and bottom temperatures starts to take place. The temperature at the top is always higher than the temperature at the bottom which agrees with the trend reported in all previous experiments and analyses. The difference in wall temperature between the top and bottom reached its maximum value in the fully developed flow region. Runs with higher values of Ra_m^* showed higher differences in local wall temperature between the top and bottom. Similar results are shown for the finned tubes in Figures 4.18 to 4.22, except that at the entry region the experimental data did not approach the analytical predictions due to the geometrical effects. However, all runs corresponding to different values of Ra_m^* approach each other indicating a weak effect of free convection at the early part of the thermal entry region. At similar values of Ra^*, the smooth tube which has the thickest wall, exhibited smaller wall temperature difference between the top and bottom as compared with the finned tubes which had smaller wall thicknesses.

4.2.2 Local Nusselt Number

For each run the average-local Nusselt number was calculated as defined by equation (4.4). In order to show the effect of Reynolds number on the local Nusselt number, two runs for each tube were selected with nearly the same Ra_m^* but different Re_m. The average-local Nusselt number for the two selected runs was plotted on a log-log scale versus

X^+ along with the theoretical prediction for the thermal entry region of smooth tubes with pure forced convection, as shown in Figures 4.23 to 4.28. In Figures 4.23 to 4.28 the experimental data for each tube are practically identical showing no effect of Reynolds number either in the thermal entrance region or the fully developed region. Based on the previous analytical and experimental investigations, Reynolds number is not expected to have any effect on Nusselt number in the fully developed region. However, Reynolds number does have an effect on Nusselt number in the entrance region which was eliminated in Figures 4.23 to 4.28 by using X^+ as a measure of distance. To demonstrate this effect, the two runs of tube No. 9 were replotted using x/R_i instead of the reduced length X^+. Figure 4.29 as compared with Figure 4.24 shows the effect of Reynolds number on the local Nusselt number in the thermal entry region. At the same x/R_i, Nusselt number increases as Reynolds number increases. This trend is consistent with other investigations.

A second set of figures was prepared for all the tubes to illustrate the effect of Ra_m^* on the local Nusselt number. For each tested tube, two selected runs with nearly equal values of Re_m but different values of Ra_m^* are presented in a separate plot in Figures 4.30 to 4.35. With each plot the analytical prediction of the local Nusselt number in the thermal entry region of smooth tubes is shown for comparison. Figures 4.30 to 4.35 show that in the early part of the thermal entry regions the data of different runs approach each other despite the difference in Ra_m^*, indicating a weak effect of free convection in that region. As we move towards the end of the heated section, values of the local Nusselt number for the two runs start to

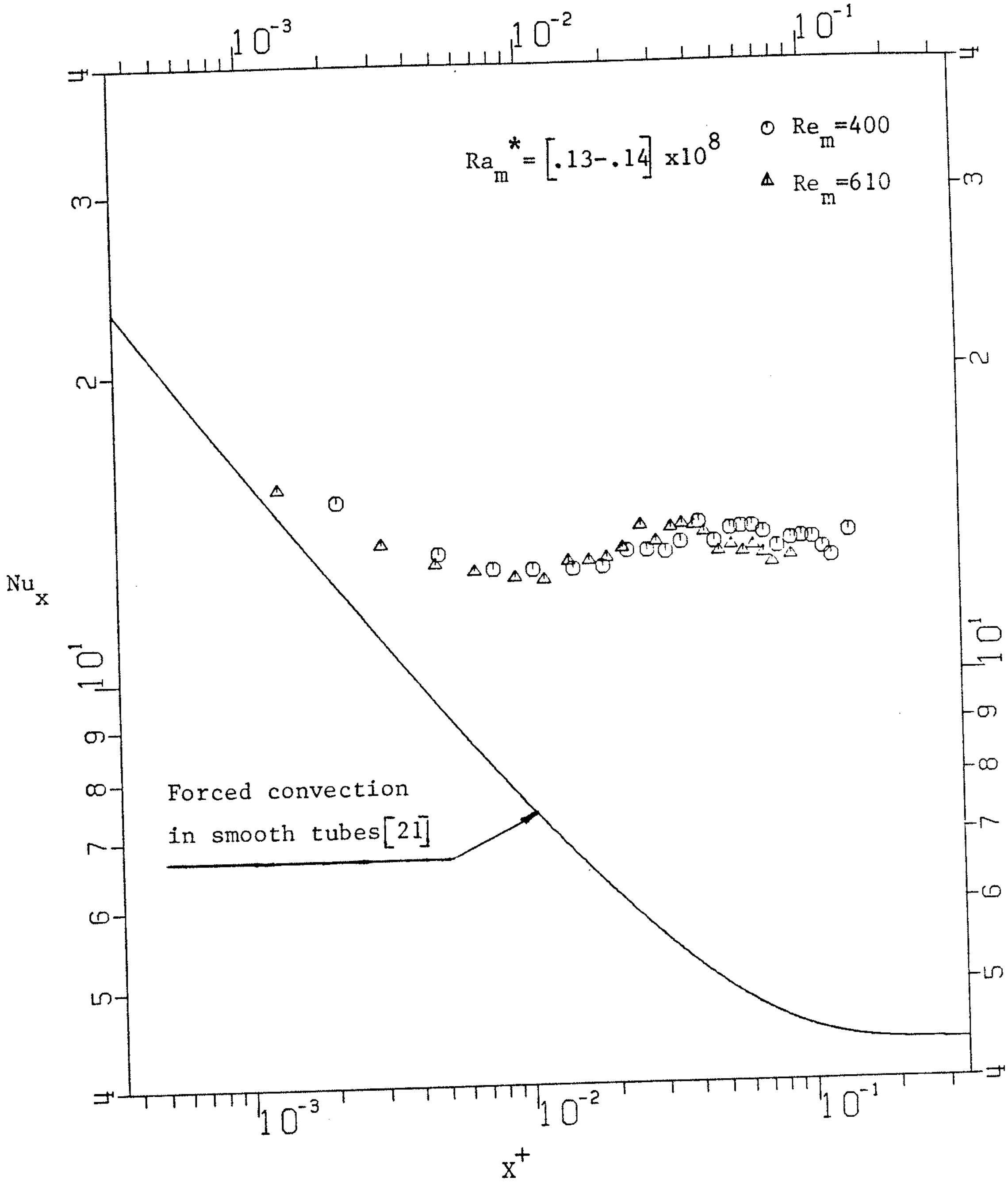


Figure 4.23 Effect of Reynolds number on the local Nusselt number for tube No.1

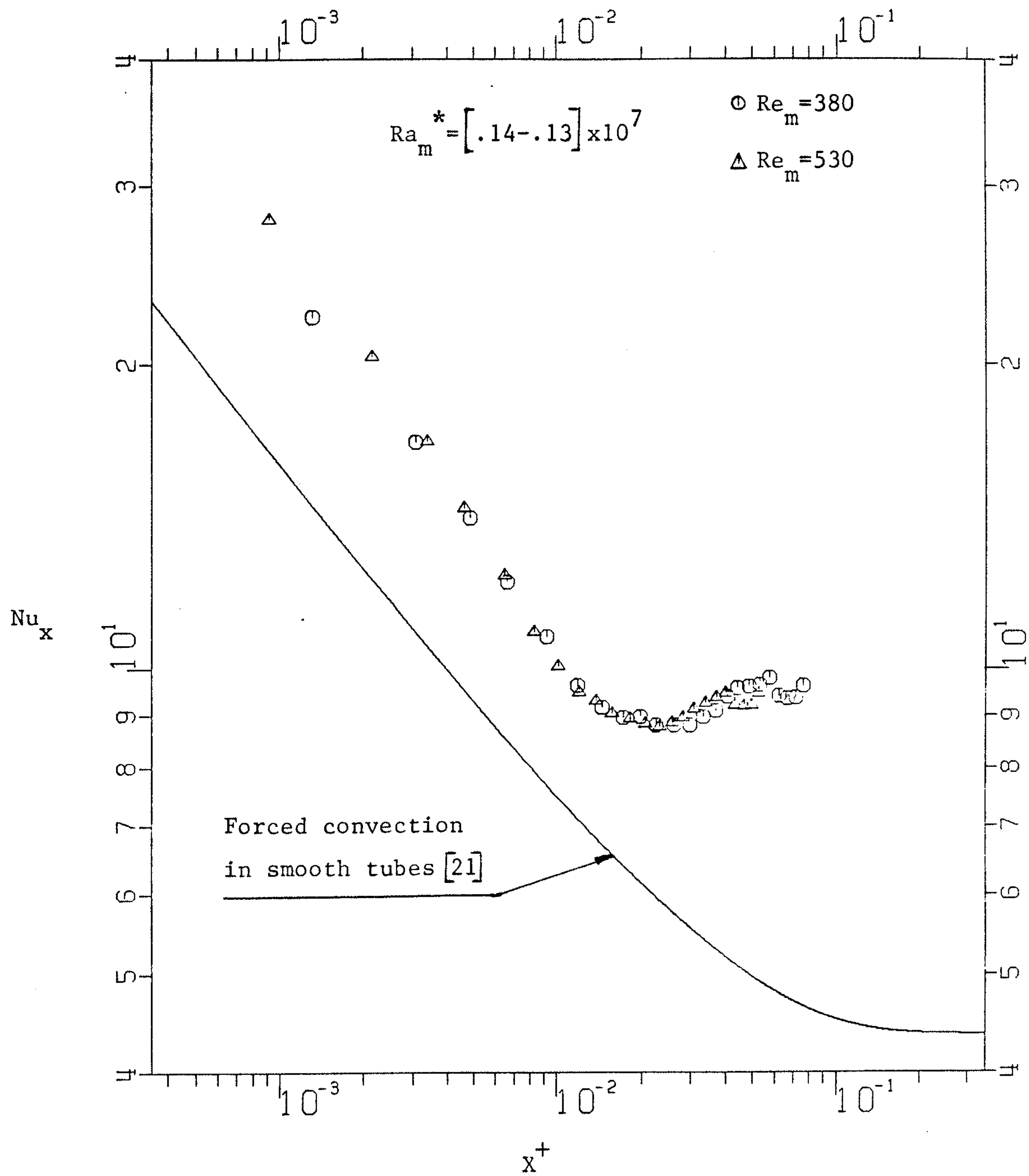


Figure 4.24 Effect of Reynolds number on the local Nusselt number for tube No.9

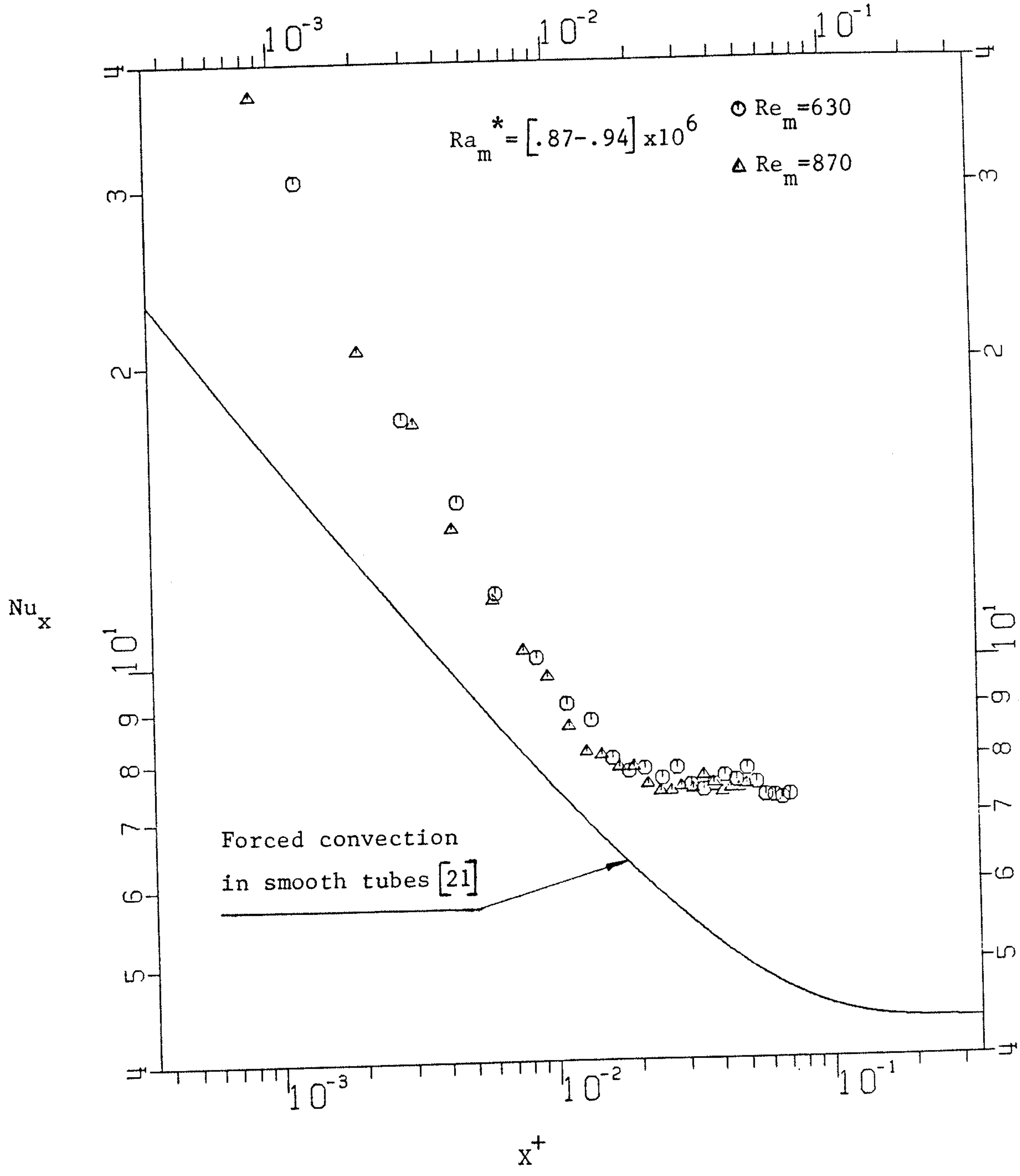


Figure 4.25 Effect of Reynolds number on the local Nusselt number for tube No.10

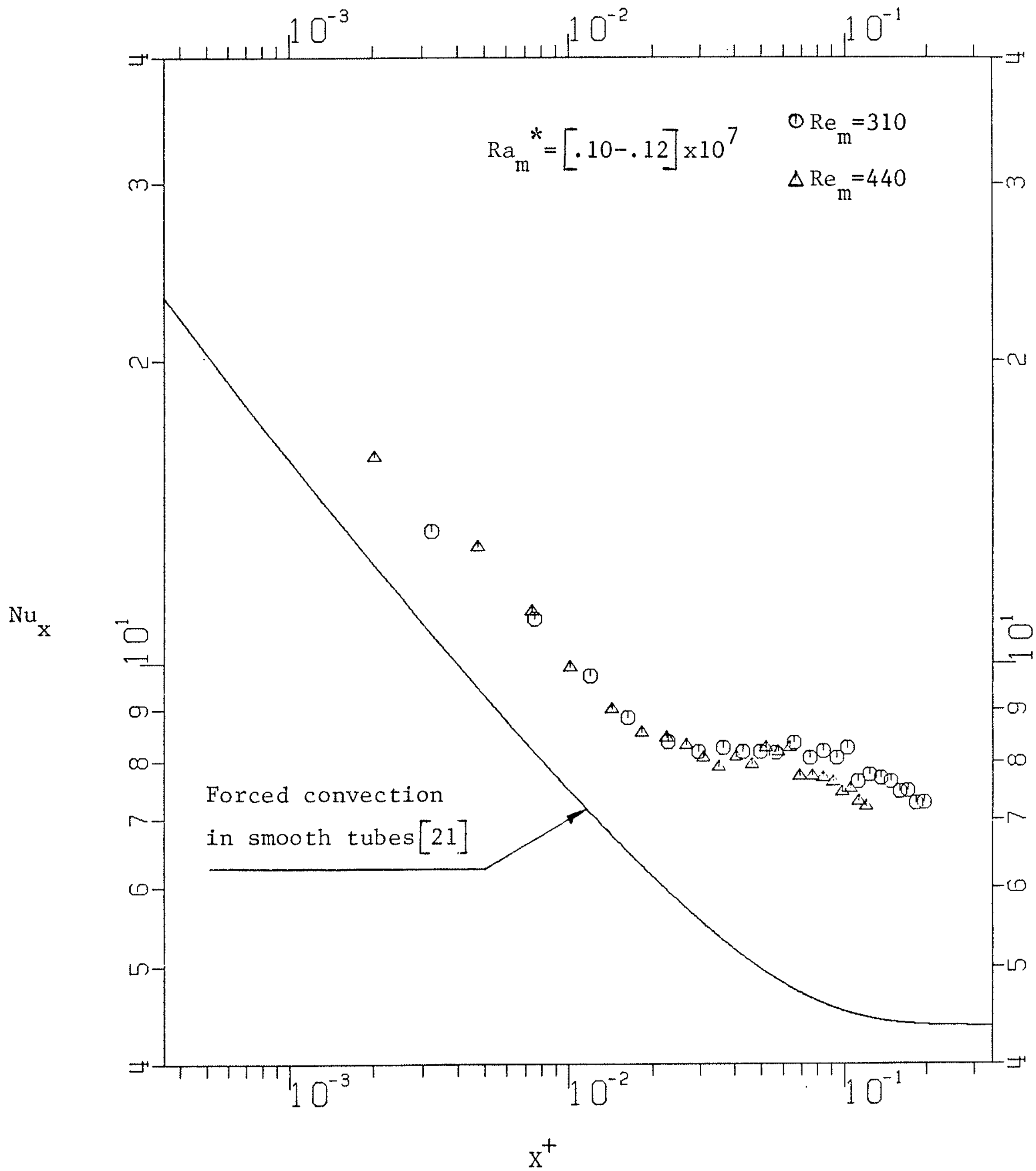


Figure 4.26 Effect of Reynolds number on the local Nusselt number for tube No.13

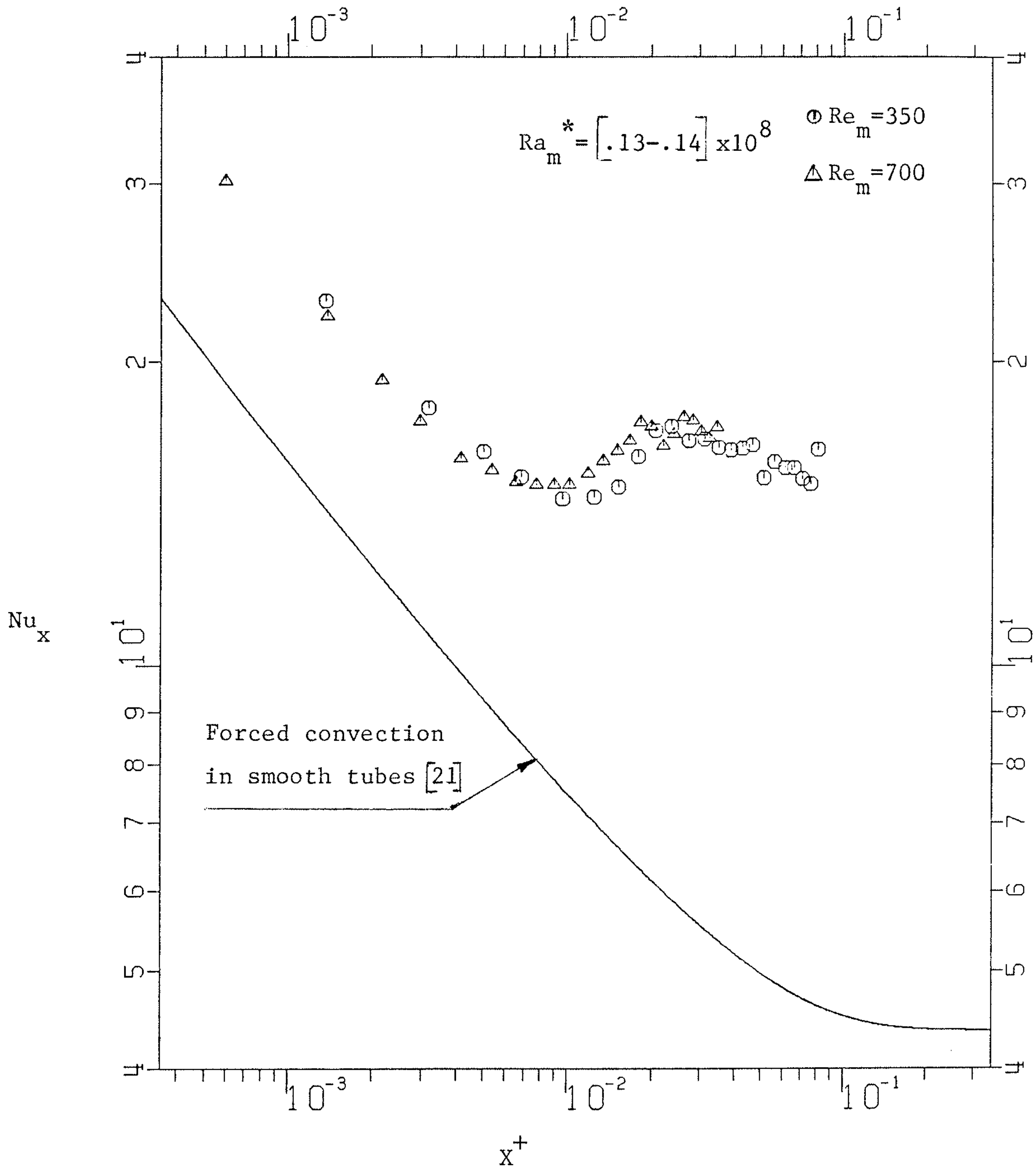


Figure 4.27 Effect of Reynolds number on the local Nusselt number for tube No.14

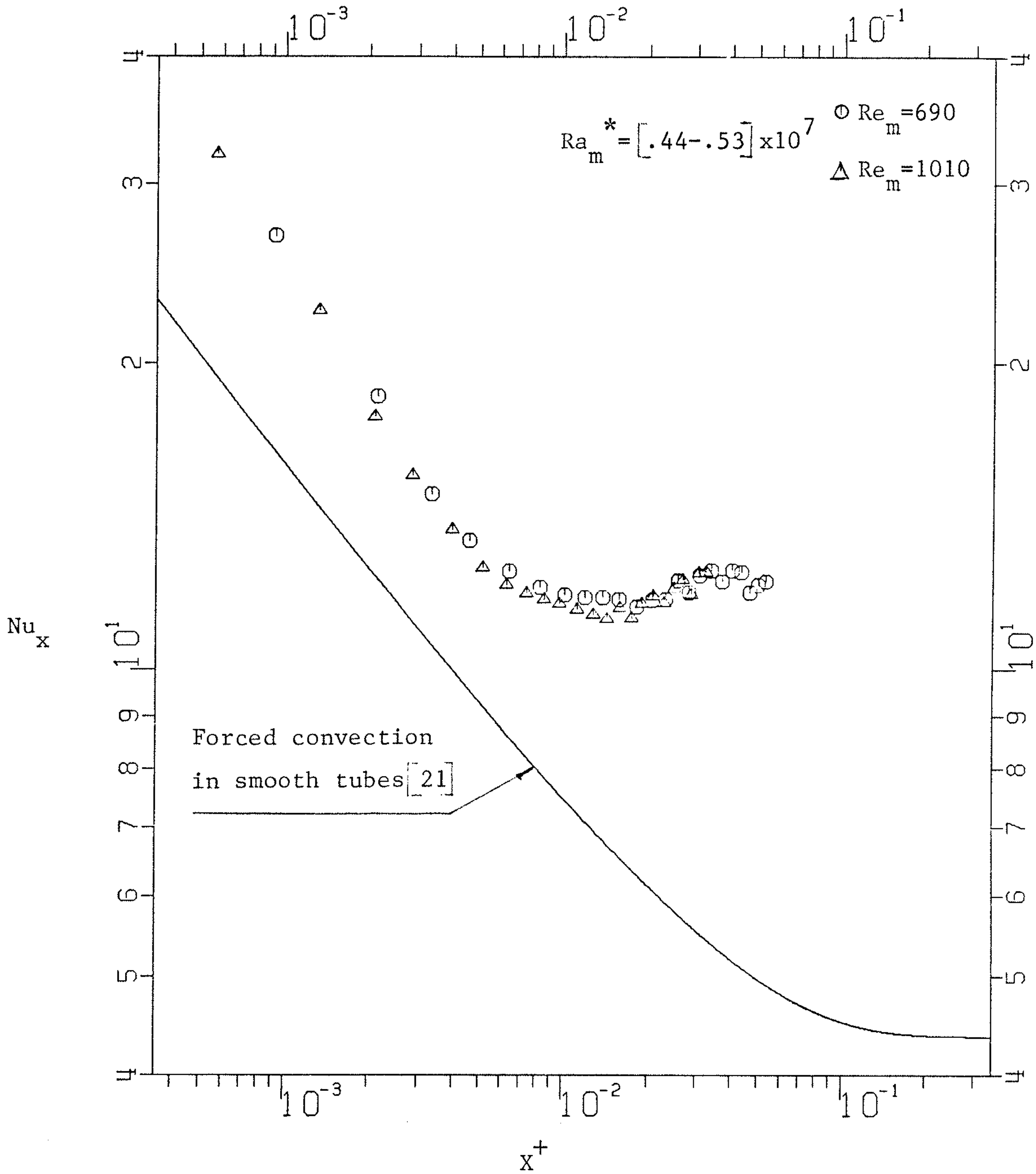


Figure 4.28 Effect of Reynolds number on the local Nusselt number for tube No.20

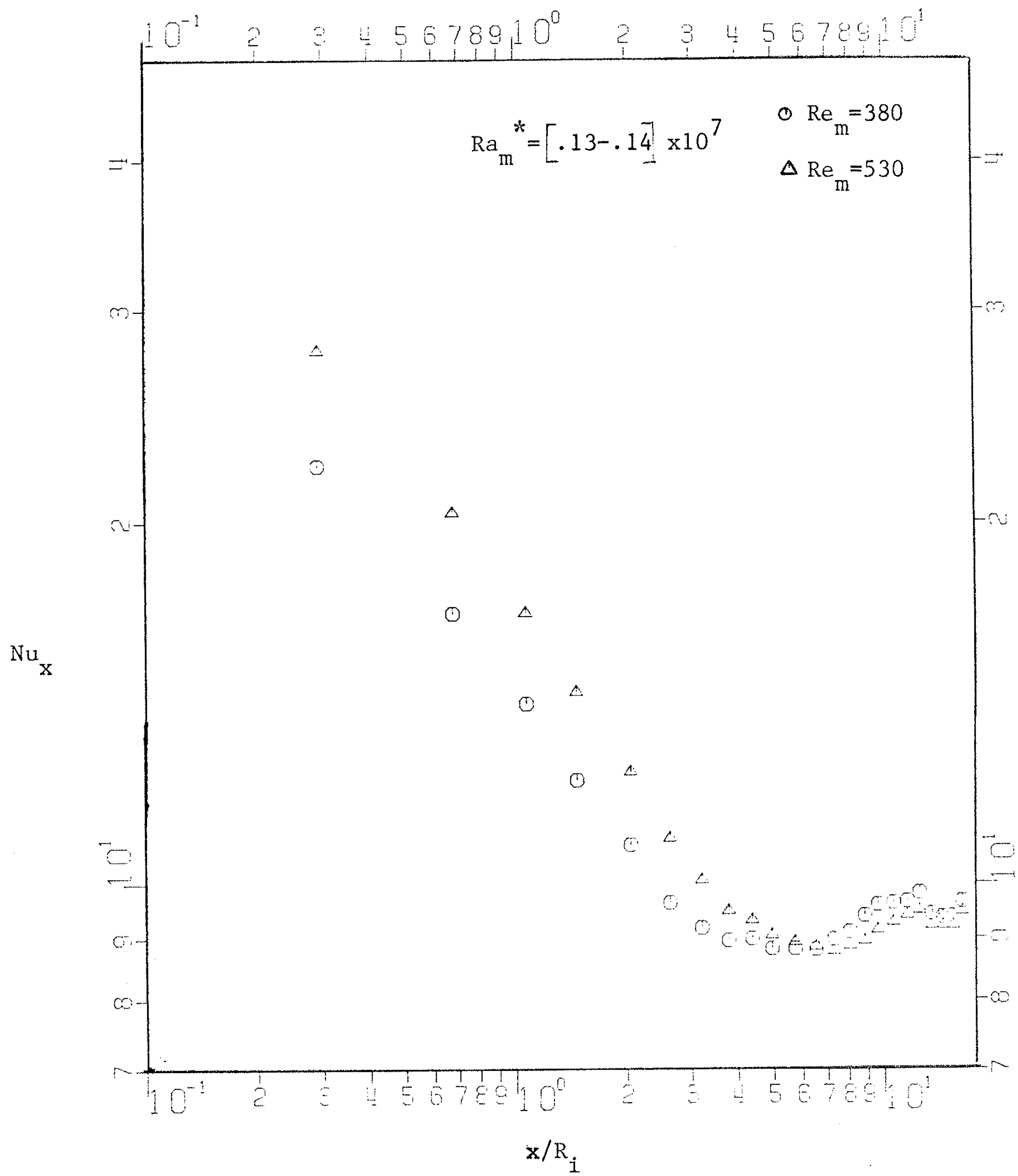


Figure 4.29 Demonstration of the Reynolds number effect for tube No.9

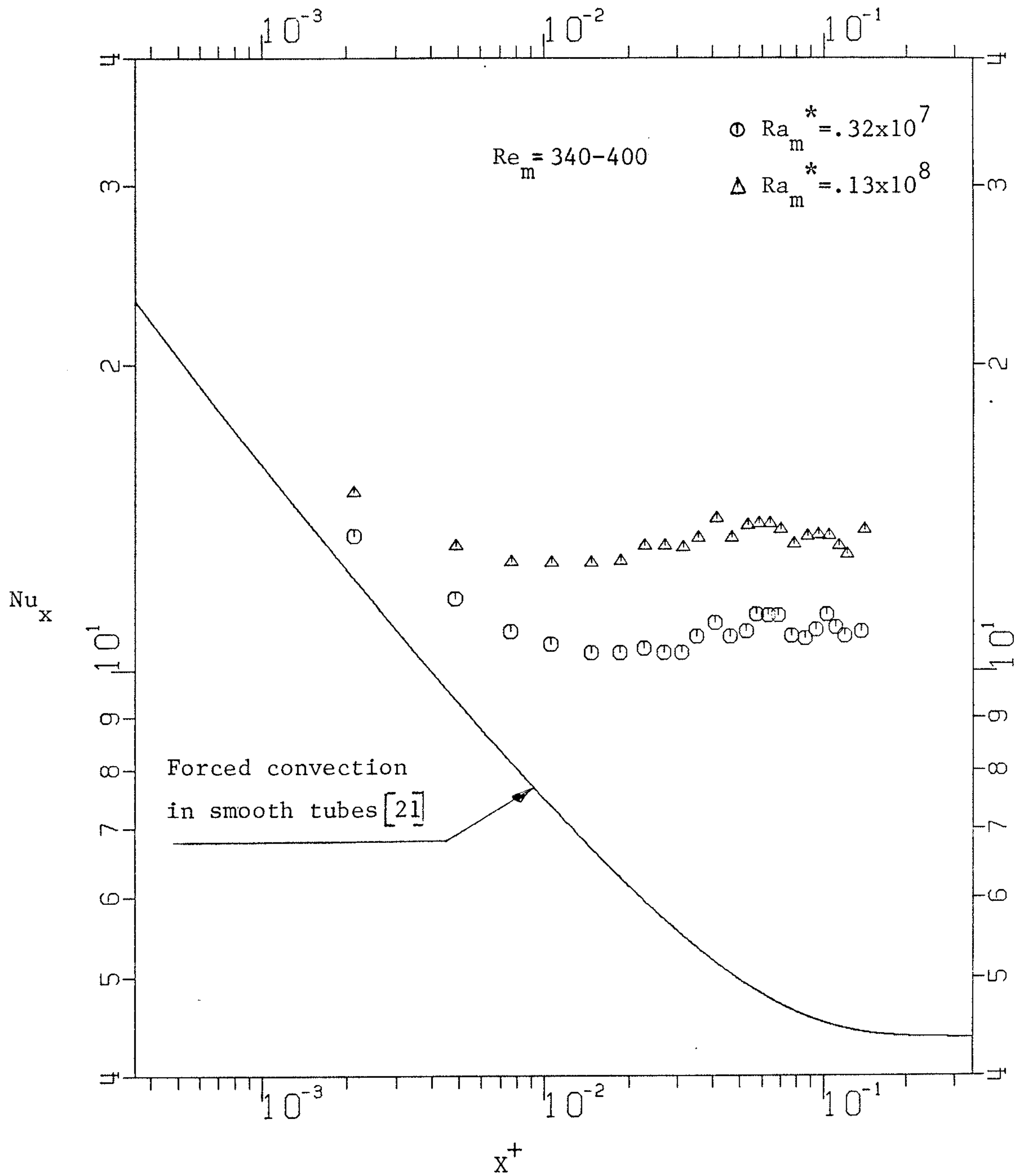


Figure 4.30 Effect of modified Rayleigh number on the local Nusselt number for tube No.1

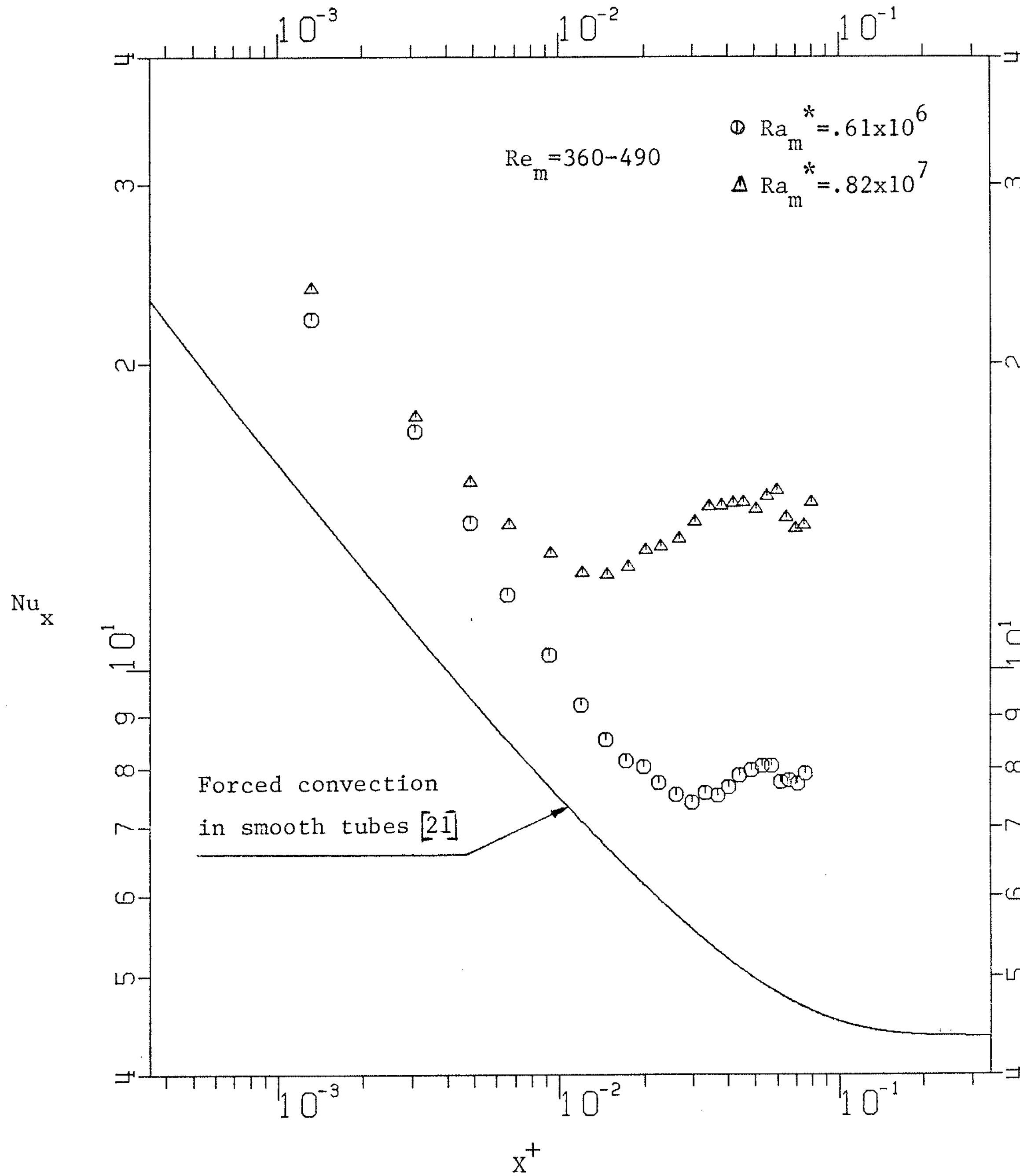


Figure 4.31 Effect of modified Rayleigh number on the local Nusselt number for tube No.9

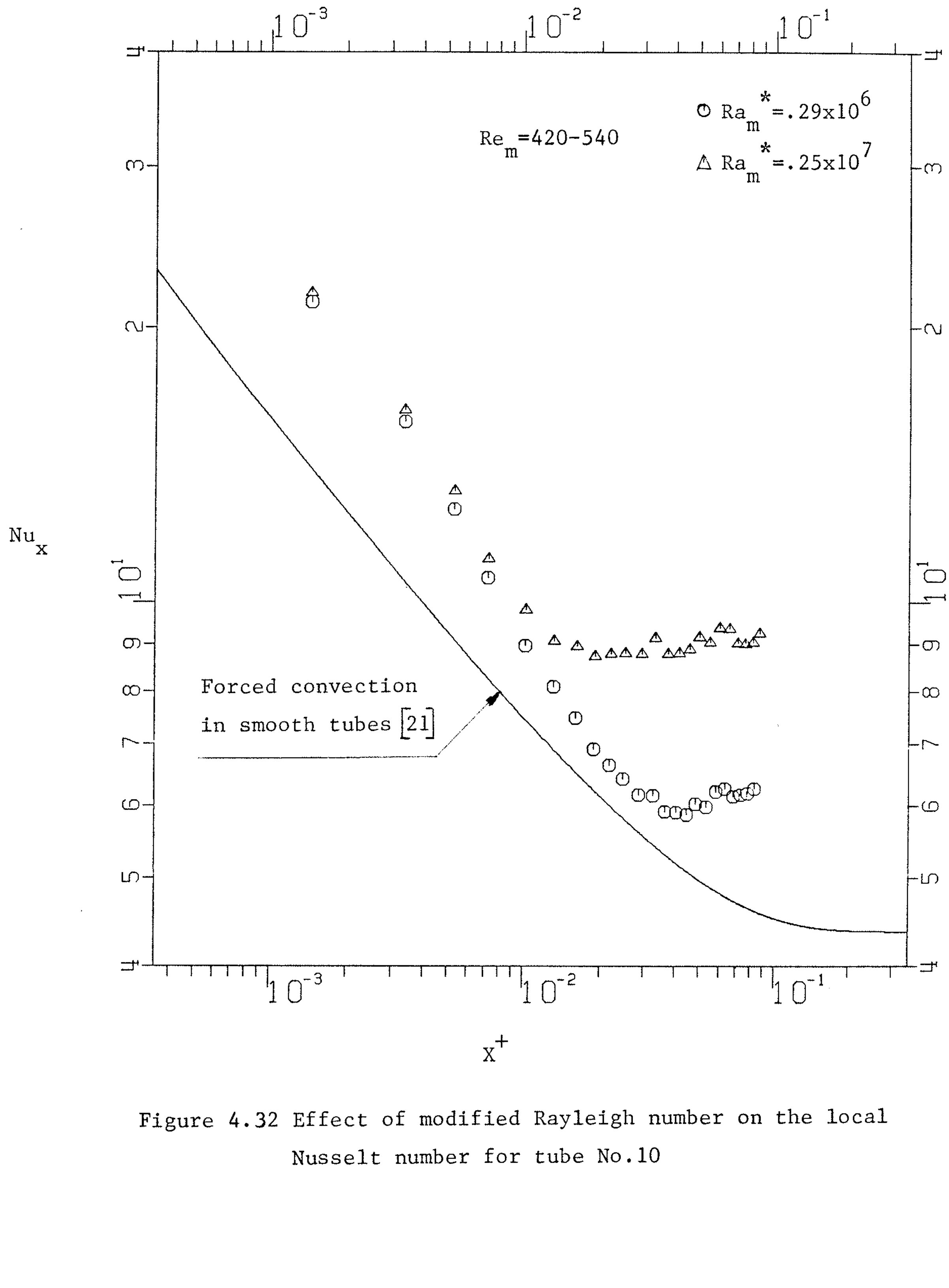


Figure 4.32 Effect of modified Rayleigh number on the local Nusselt number for tube No.10

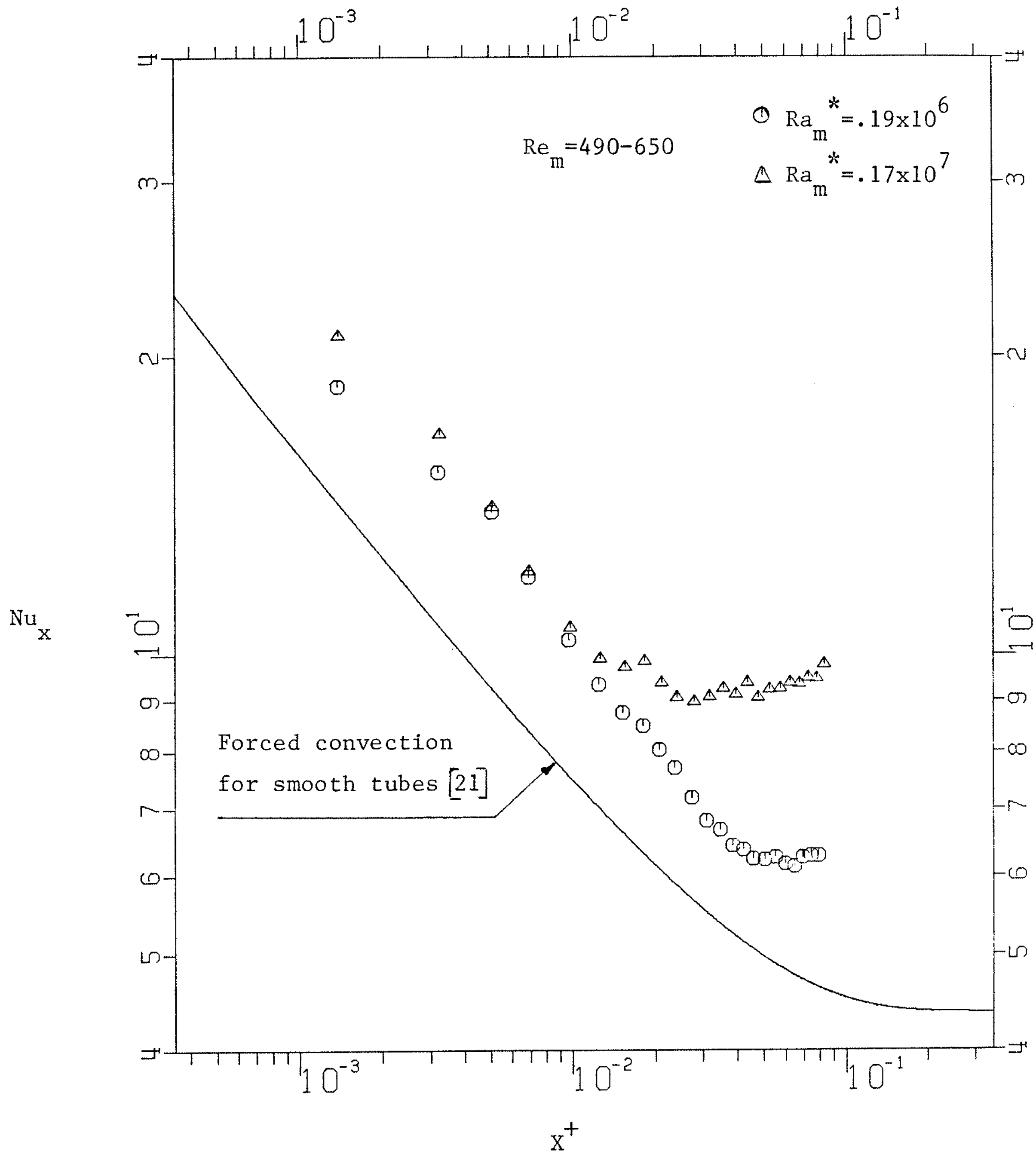


Figure 4.33 Effect of modified Rayleigh number on the local Nusselt number for tube No.13

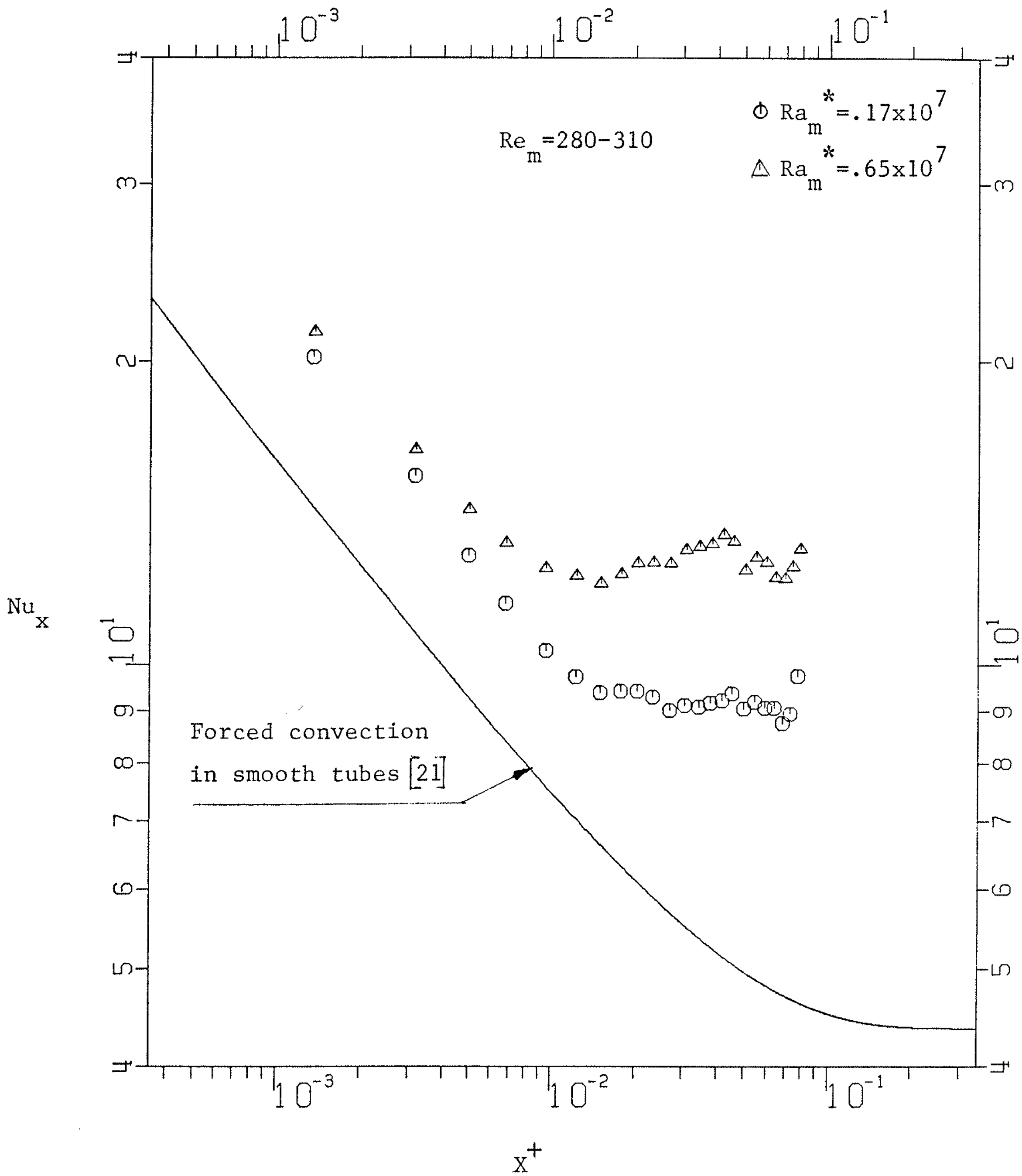


Figure 4.34 Effect of modified Rayleigh number on the local Nusselt number for tube No.14

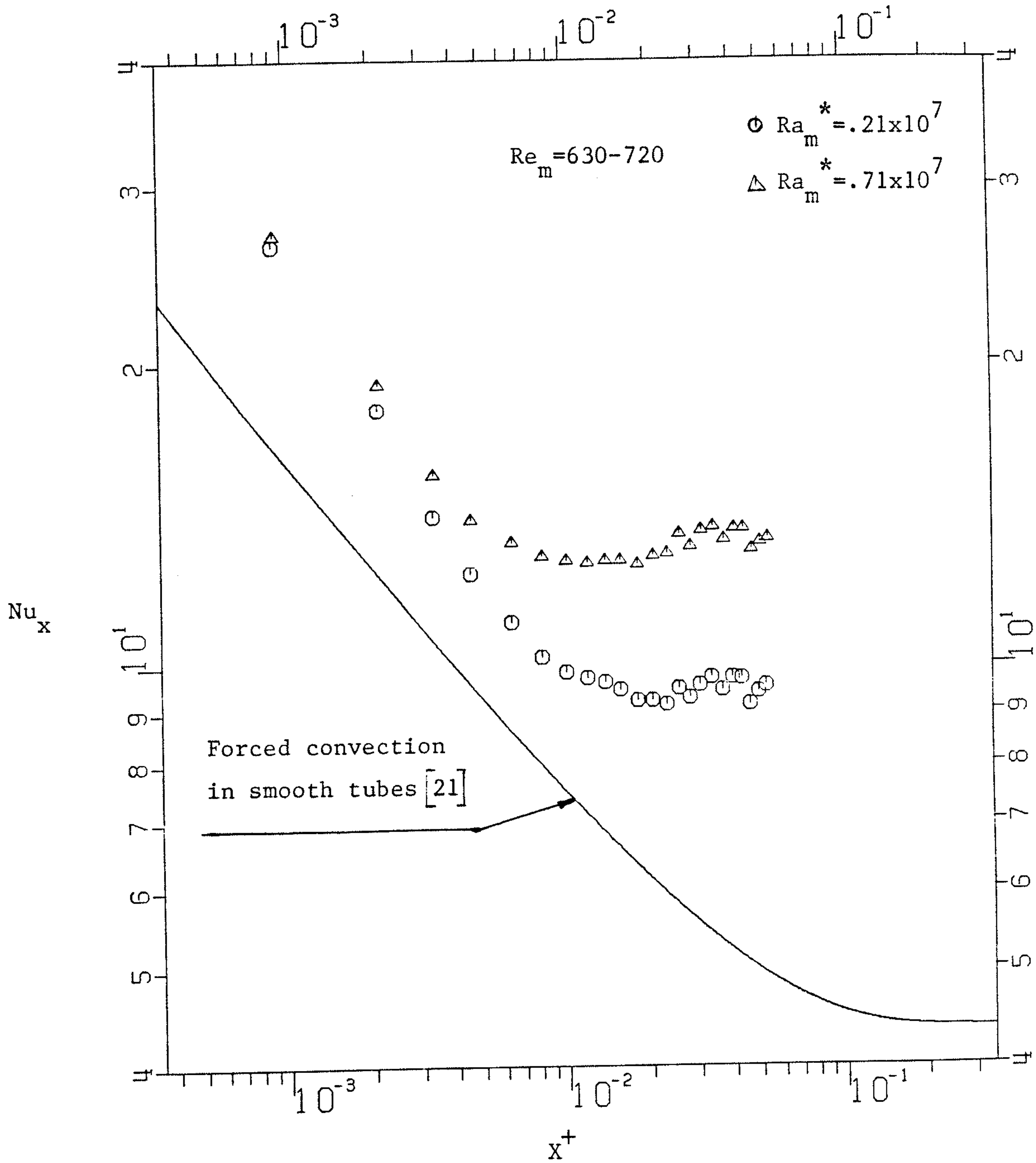


Figure 4.35 Effect of modified Rayleigh number on the local Nusselt number for tube No.20

separate from each other indicating the effect of Ra_m*. As the fully developed flow region was reached, which was indicated by constancy of the local Nusselt number with X^+; the difference in the local Nusselt number between the runs with different Ra* remained constant except for some experimental scattering. The effect of Ra* on the fully developed Nusselt number is shown to be quite substantial. For tube No. 1 (smooth), the fully developed Nusselt number rises for the well-known value of 4.36 at Ra_m* = 0 to 13.6 at Ra_m* = 0.13×10^8; and for tube No. 9, the rise is from 5.00 [14] at Ra_m* = 0 to about 14 at $4a_m$* = 0.82 $\times 10^7$. No other data (analytical or experimental) is available for comparison, especially in the thermal entrance region of internally finned tubes.

4.2.3 Fully Developed Nusselt Number

Comparison with previous works under similar experimental and boundary conditions is possible only for the case of tube No. 1. The predictions of equations (2.1) and (2.4) are shown with the present experimental data in Figure 4.36. Equation (2.1) was developed for a stainless steel tube with water as the working fluid, and equation (2.4) was developed for copper and aluminum tubes with water as the working fluid. All properties needed in plotting the data in Figure 4.36 were evaluated at the mean bulk temperature as recommended in [1,3]. Figure 4.36 shows generally a very good agreement between the two empirical equations and the present experimental data. Most of the experimental data fell between the two empirical equations, with equation (2.1) overpredicting the experimental results while equation (2.4) is underpre-

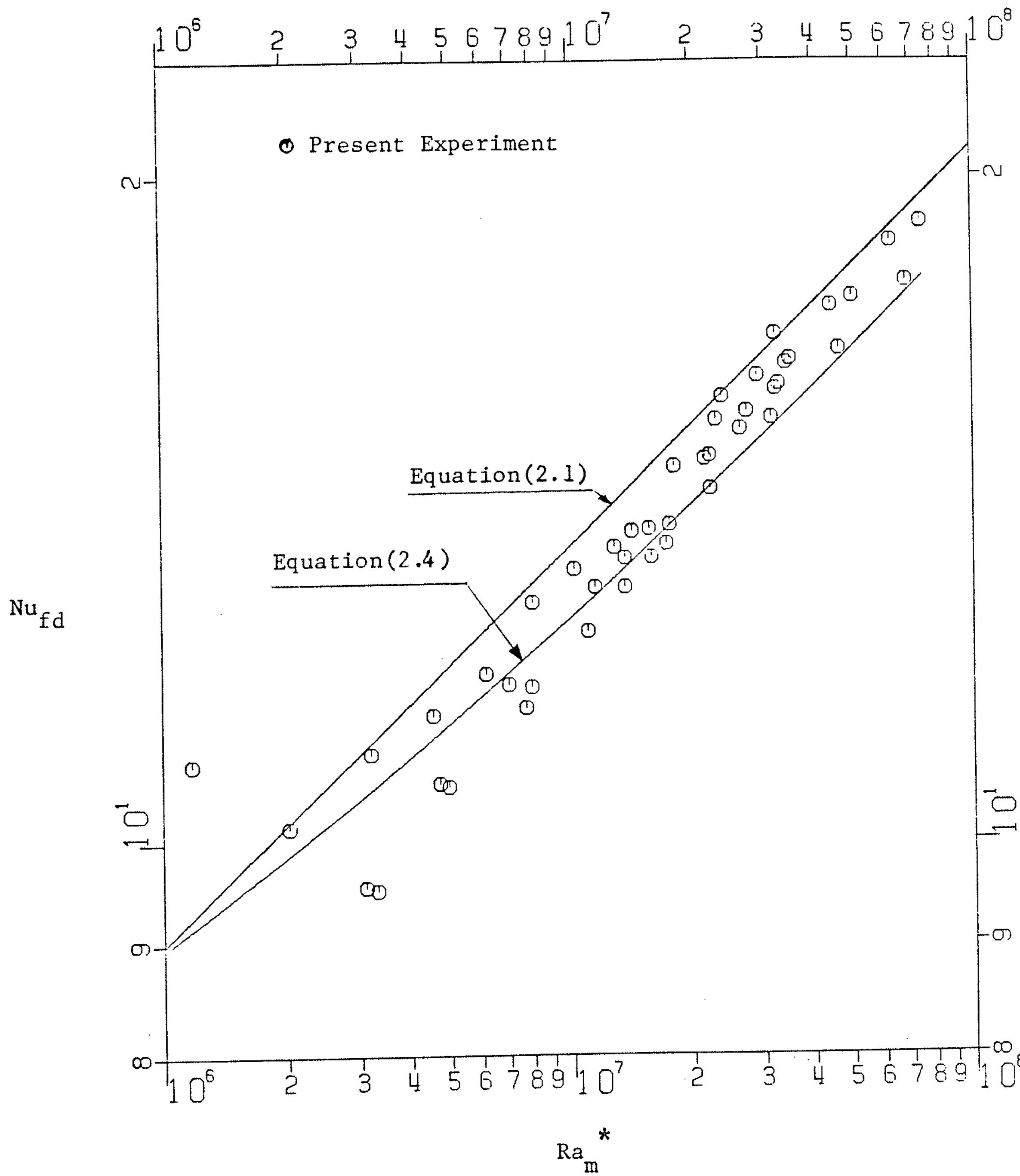


Figure 4.36 Comparison between the experimental data and two empirical correlations of the fully developed Nusselt number for tube No.1

dicting. However, the deviation between the two predictions is very small. The good agreement displayed in Figure 4.36 also serves to validate the experimental technique followed in this investigation.

The effect of free convection on the degree of heat transfer enhancement is presented for each finned tube individually in Figures 4.37 to 4.41. In each of these figures the ratio (N_{fd}/Nu_o) is plotted against Ra_m^*, where Nu_o is the Nusselt number for pure forced convection (i.e. $Ra_m^* = 0$). Values of Nu_o used here are based on the analysis in [14] and are listed in Table 5. An attempt to correlate the data of each tube was done assuming the following relationship:

$$Nu_{fd}/Nu_o = 1 + C_1(Ra_m^*)^{C_2} \qquad (4.7)$$

Equation (4.7) has the same form of equation (2.4) developed by Ede [3] for smooth tubes. Geometrical effects are expected to influence the values of C_1 and C_2. A standard program based on the least square method was used to obtain the values of C_1 and C_2 that allowed for the best fit between equation (4.7) and the experimental data of each tube. The resulting values of C_1 and C_2 are listed in Table 5.

From Figures 4.37 to 4.41, it is noticed that equation (4.7) is successful in correlating the effect of Ra_m^* on Nu_{fd}. This success is reflected by the minimum data scattering shown in these figures. It must be pointed out that values of C_1 and C_2 for each tube are applicable within the tested range of Ra_m^* listed in Table 5, and caution must be exercised when used outside this test range.

The value of C_2 is a measure of the rate of increase of Nu_{fd} with Ra_m^*. It is seen from Table 5 that the smooth tube has the lowest value of C_2. Also, for the same M, C_2 increases as H increases and this trend

Table 5 Values of Nu_o, C_1 and C_2 Used in Equation (4.7)

Tube Number	H	M	Nu_o [14] With $\gamma = 3°$	$Ra_m^* \times 10^{-6}$	$C_1 \times 10^4$	C_2	Source
1	0	0	4.36	1.88 - 74.8	≃ 150	0.300	Equation (2.4)
9	0.248	10	5.00	0.61 - 16.6	6.27	0.503	Present Experiment
10	0.318	16	4.90	0.47 - 4.26	12.7	0.443	Present Experiment
13	0.325	10	5.53	0.27 - 2.52	0.929	0.628	Present Experiment
14	0.216	10	4.84	1.70 - 73.5	17.2	0.439	Present Experiment
20	0.288	16	4.79	1.20 - 13.8	18.7	0.430	Present Experiment

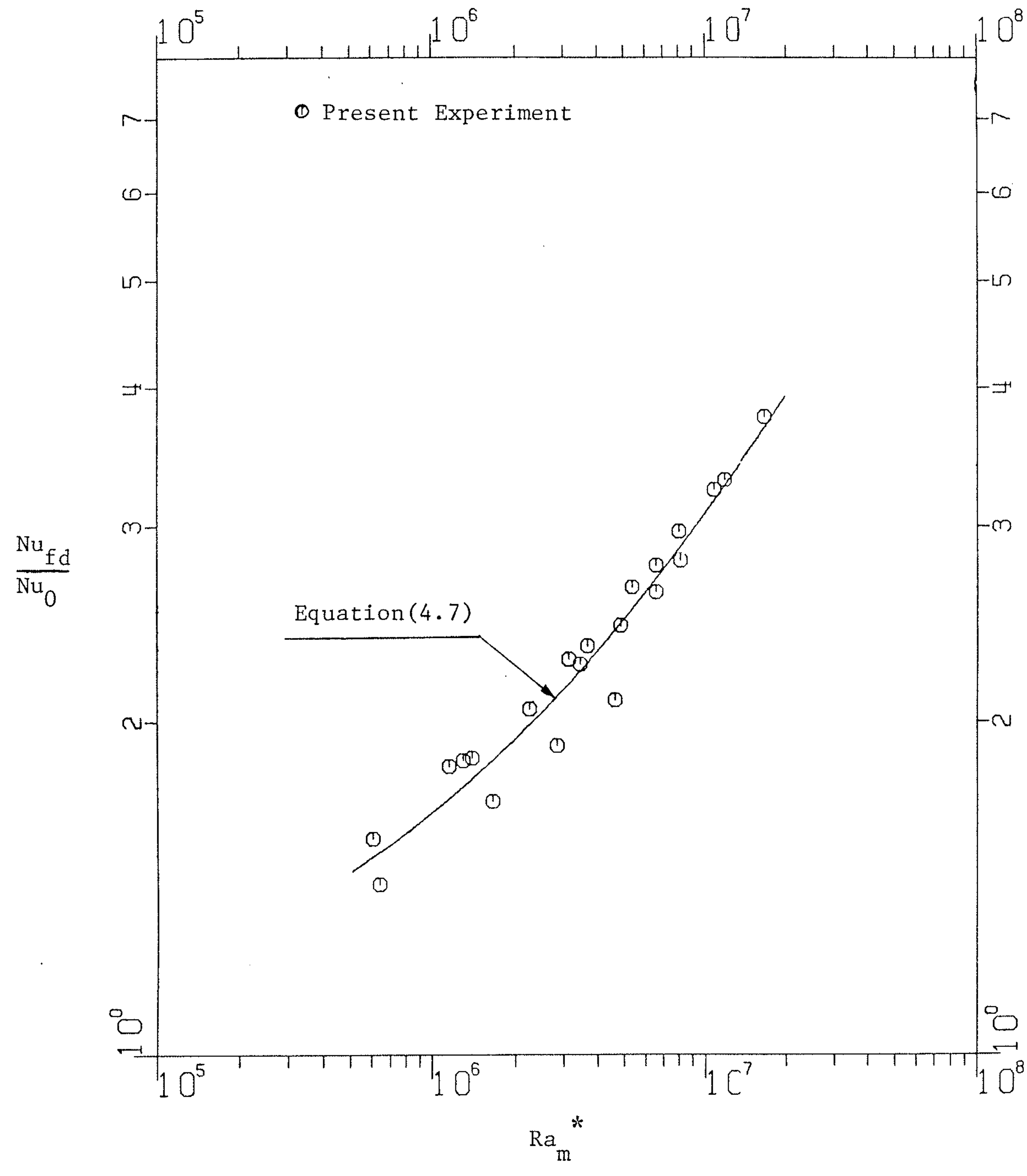


Figure 4.37 The effect of free convection on the fully developed Nusselt number for tube No.9

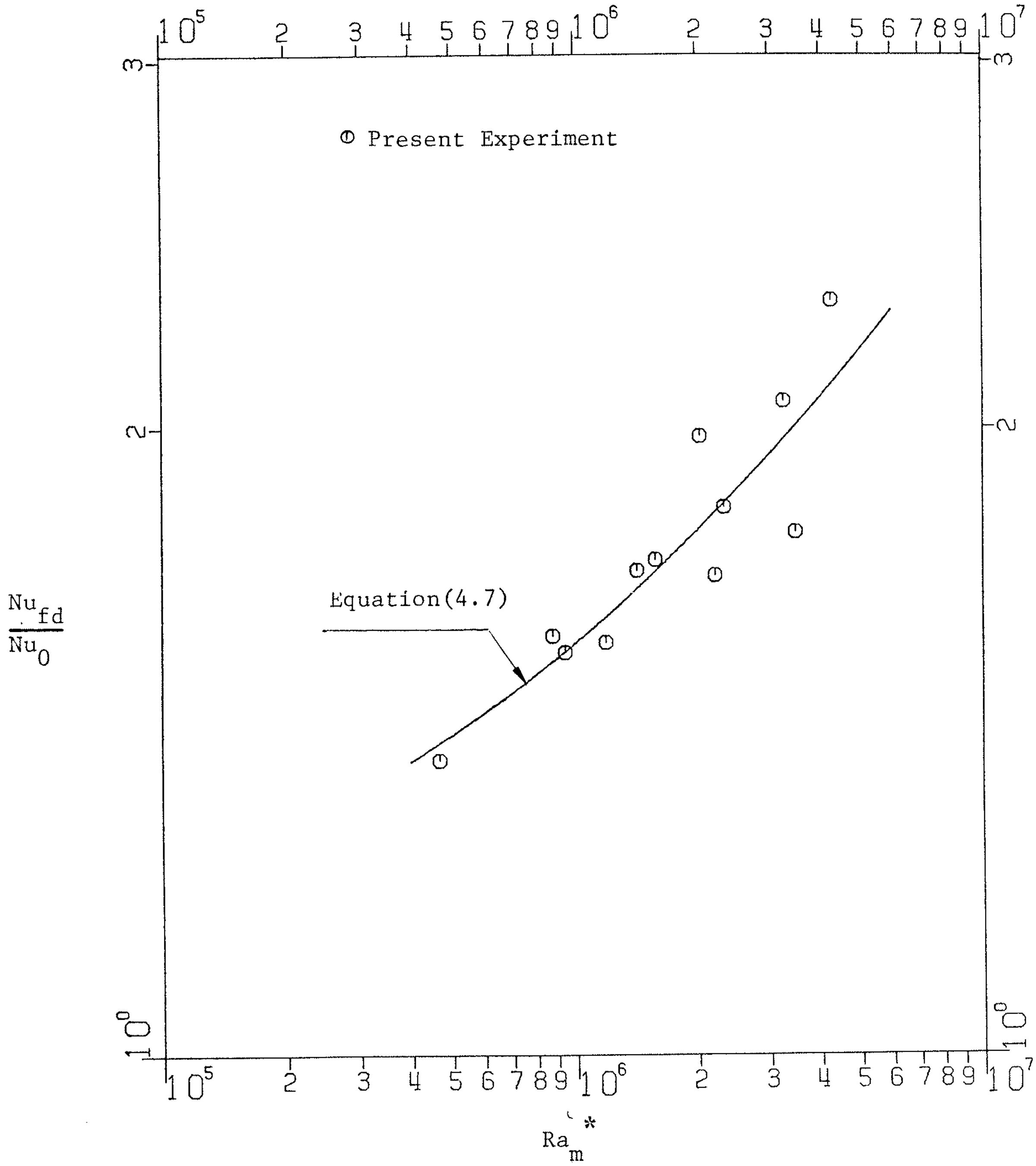


Figure 4.38 The effect of free convection on the fully developed Nusselt number for tube No.10

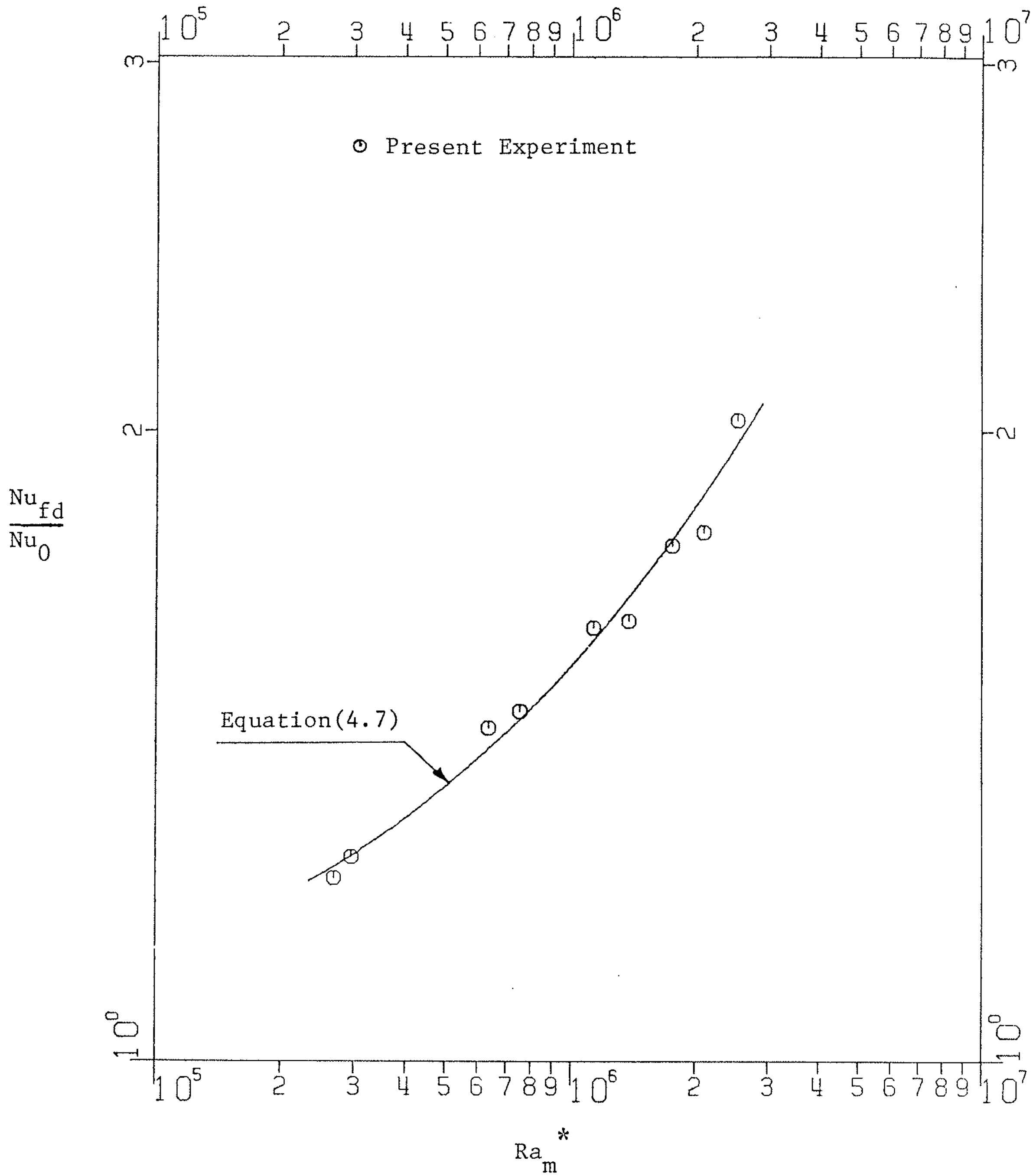


Figure 4.39 The effect of free convection on the fully developed Nusselt number for tube No.13

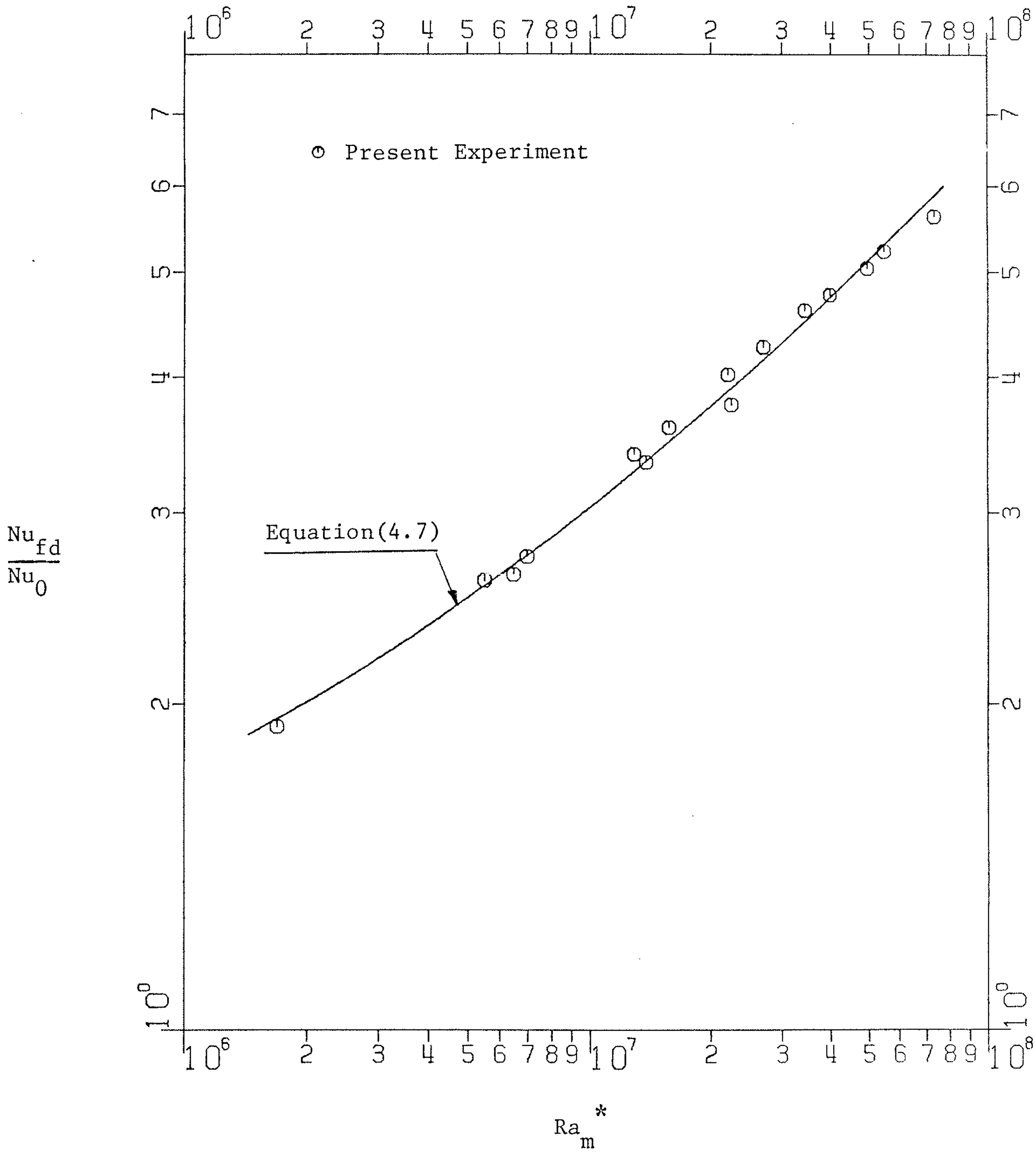


Figure 4.40 The effect of free convection on the fully developed Nusselt number for tube No.14

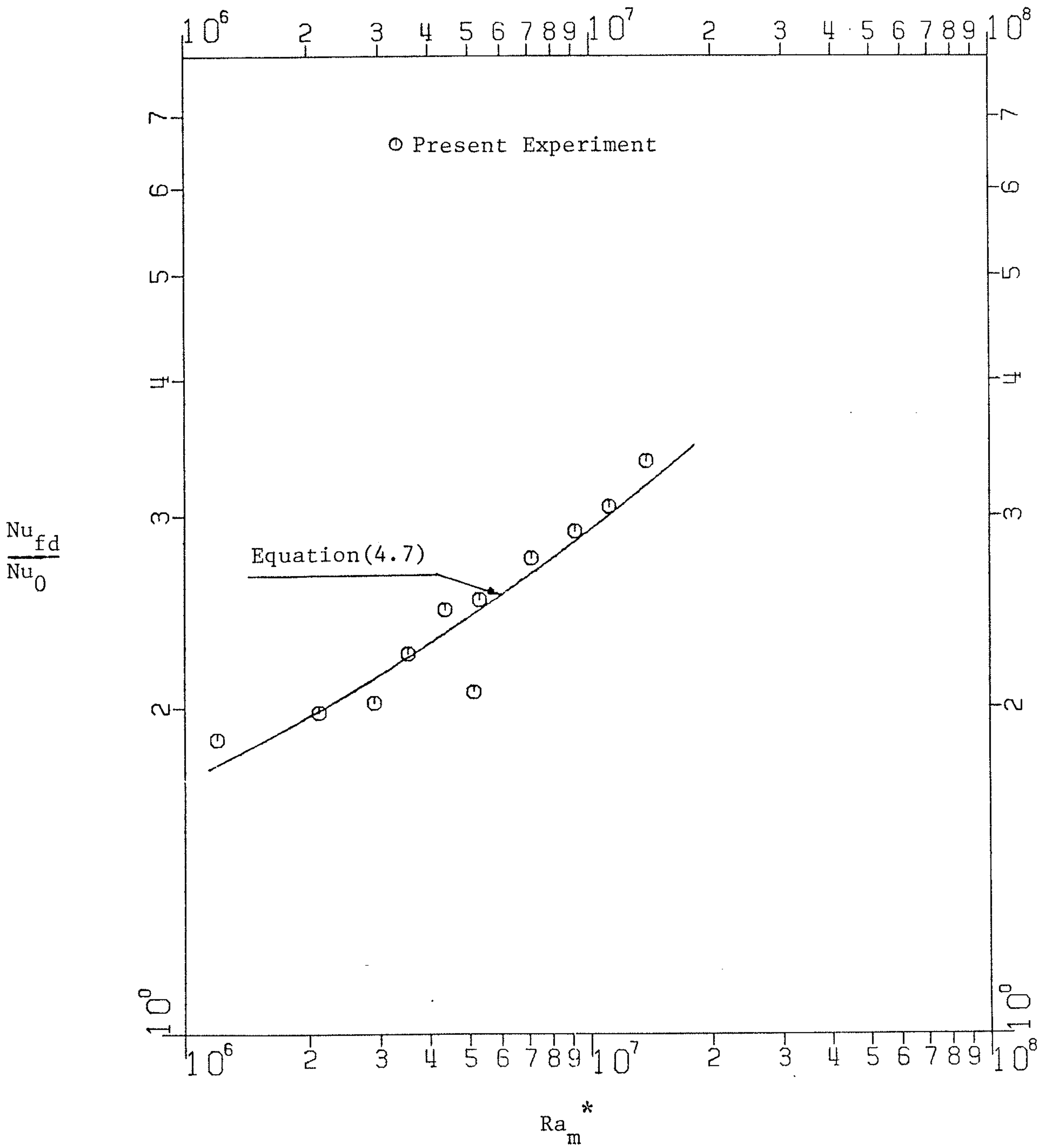


Figure 4.41 The effect of free convection on the fully developed Nusselt number for tube No.20

is consistent with the results of Mirza [19]. For the same H, C_2 seems to decrease as M increases. Tube No. 13 with the largest value of H and smallest value of M has the largest value of C_2.

On the other hand, the value of C_1 can be seen from equation (4.7) to be related to the critical Rayleigh number at which free convective effects become significant. The higher the value of C_1 the lower the critical Rayleigh number. From Table 5 it is clear that the smooth tube has the highest C_1, i.e. the lowest critical Rayleigh number. The presence of fins delayed the effect of free convection. This delay increases as H increases and/or M decreases.

The effects of geometry on C_1 and C_2 (discussed above) are illustrated further in Figure 4.42 in which the smooth tube performance is represented by equation (2.4) and the finned tubes performances are represented by equation (4.7) with the appropriate values of C_1 and C_2. Since the free convective effects starts early in smooth tubes, the value of (Nu_{fd}/Nu_o) for smooth tubes exceeds that of all tested tubes up to Ra_m^* of about 5×10^6. Beyond this value a reverse of trend is apparent in Figure 4.42. Keeping in mind that Nu_o for any finned tube is higher than Nu_o for smooth tubes, the results of Figure 4.42 indicate that finned tubes are capable of a significantly enhanced heat transfer performance, compared with smooth tubes particularly at high Rayleigh numbers.

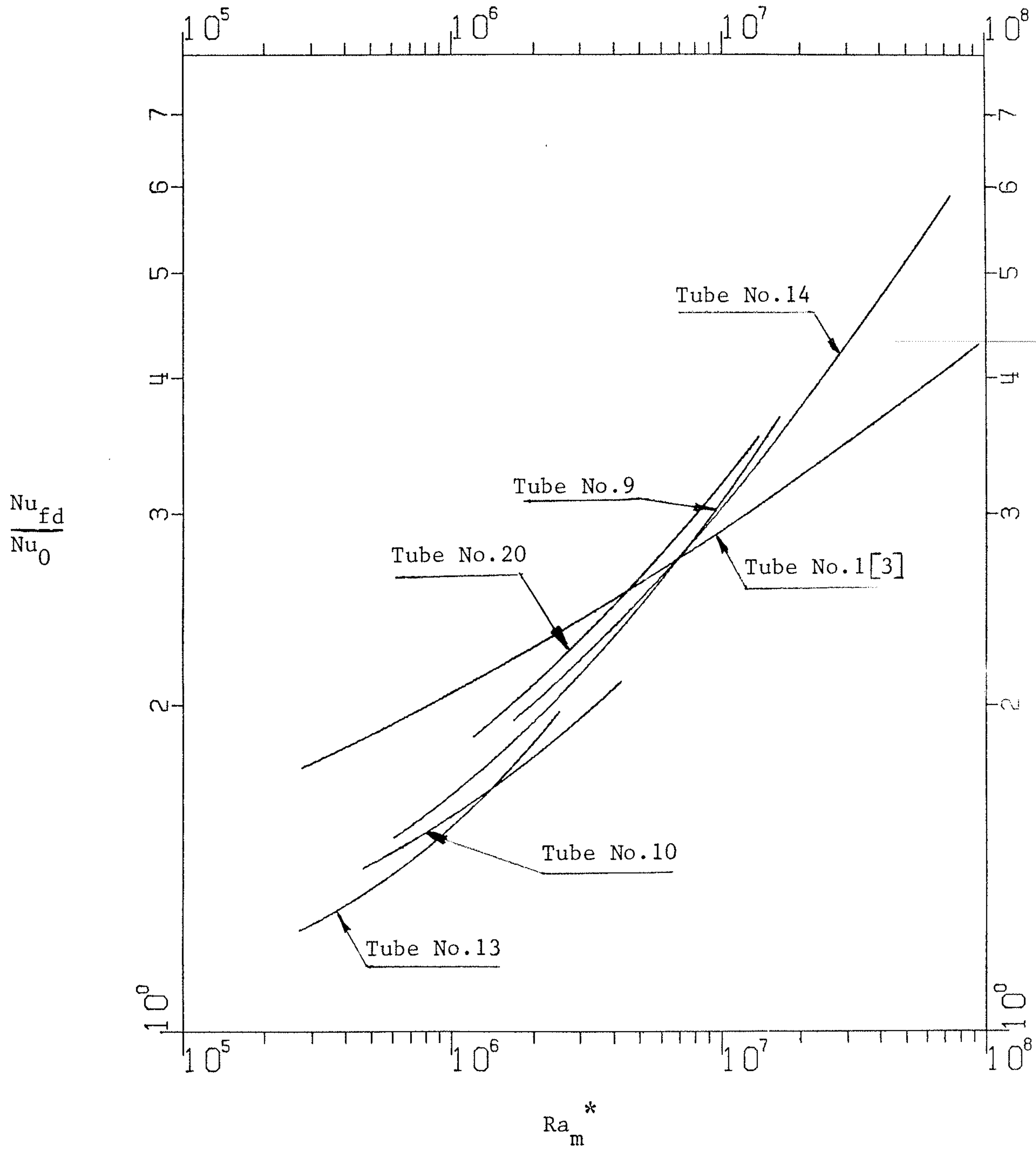


Figure 4.42 The effect of tube geometry on the degree of heat transfer enhancement due to free convection

Chapter V

CONCLUSION AND RECOMMENDATIONS

An experimental investigation was carried out to study the pressure drop and heat transfer characteristics in the thermal entrance region of six tubes (five internally finned and one smooth) under laminar flow conditions. The flow was hydrodynamically developed but thermally developing. Uniform heat input axially and circumferentially was supplied in the heated section. Measurements of wall temperature, friction factor, and local Nusselt number were performed over a wide range of operating conditions. From the present experimental results, the following conclusions can be drawn:

1. The isothermal friction factor for all the internally finned tubes in the laminar flow region was found to agree well with two analytical predictions [11,13] for internally finned tubes of similar geometries under laminar and fully developed flow conditions.

2. The critical Reynolds number at which the transition to turbulent flow started was found to increase with M and decrease with H. These findings were also reported in [9]. Both the present results and those reported in [9] showed reasonable agreement in trend.

3. The ratio of diabatic to isothermal friction factor for the internally finned tubes was compared with an empirical equation for smooth tubes. The comparison showed that the presence of fins suppressed the effect of secondary flow, hence at $Ra < 10^6$ the finned tubes showed lower values of diabatic to isothermal friction factor. At higher Ra,

the internally finned tubes showed higher increases in the friction factor over the extrapolated empirical equation for smooth tubes.

4. The experimental top and bottom wall temperatures for the smooth tube at any value of mean Rayleigh number was found to approach the pure forced convection analytical prediction at the early part of the thermal entry region indicating that the effect of free convection is not strong in that part. However, the top and bottom temperatures started to separate from the analytical prediction and from each other at higher values of X^+ indicating stronger free convection effects. The maximum effect of Rayleigh number was found in the fully developed flow region. For any tube the difference in wall temperature between the top and the bottom was found to increase with Rayleigh number.

5. The local Nusselt number was found to be influenced by the Reynolds and Rayleigh numbers. The effect of Reynolds number was in the thermal entry region only, where the local Nusselt number increased with Reynolds number. The Rayleigh number effect started at the thermal entry region and increased to its maximum effect in the fully developed flow region. Its effect was found to be very strong in enhancing the Nusselt number up to 500% over the forced convection value.

6. The fully developed Nusselt number for the smooth tube was compared with two other empirical equations of two different sources. Most of the experimental data fell between the two empirical equations, thus supporting the method of testing used in this study.

7. The values of Nu_{fd}/Nu_o for the internally finned tubes were found to be lower than the smooth tube for value of $Ra_m^* < \sim 5 \times 10^6$ indicating that the presence of fins suppressed the effect of free con-

vection. However, the rate of increase of Nu_{fd}/Nu_o with Ra_m^* for the internally finned tubes was higher than for the smooth tube, hence at $Ra_m^* > \sim 5 \times 10^6$ the finned tube ratios exceeded those for the smooth tube. Tubes with longer and fewer fins exhibited the largest critical Rayleigh number at which the effect of free convection starts and the highest rate of increase of Nu_{fd}/Nu_o with Ra_m^*.

Based on the literature survey and the present study, the author wishes to recommend the following to assist in guiding further studies:

1. The effect of Prandtl number on the heat transfer performance of the internally finned tubes should be investigated.

2. Wider ranges of M and H should be used for similar investigations to assist in developing the most efficient geometry.

3. Analytical investigations are needed for the thermal entry region of the internally finned tubes. Due to the complexity of the problem, pure forced convection flow can be assumed in the initial stages.

4. Analytical investigations of fully developed flow in internally finned tubes for mixed convection should be considered.

5. Analytical and experimental investigations for finned tubes should be extended to higher values of Rayleigh number to explore the effect of Rayleigh number on the fully developed Nusselt number. These investigations are needed to confirm the present results where the enhancement in Nusselt number due to free convection was shown to be higher for finned tubes than for the smooth tube at large values of Rayleigh number.

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Appendix A

LISTING OF COMPUTER PROGRAM FOR DATA REDUCTION

```
      DIMENSION T(80),TF(80),X(80),FLMA(100),FLMB(100),FLMC(100),TC(80)
      DIMENSION NU(60),XP(30),Y(5),X1(60,4),RE(40),RA(40),NUA(40)
      REAL L,NU,KC,K,NUA
C
C KC IS THE THERMAL CONDUCTIVITY OF COPPER IN (WATT/METER. DEG C)
C
      KC=.......
C
C L IS THE HEATED SECTION LENGTH IN CENTIMETERS
C
      L=......
C
C PI  IS A MATHMATCAL CONSTANT
C
      PI=3.1415927
C
C D IS IHE INSIDE DIAMETER IN METERS
C
      D=.......
C
C AW IS THE CROSS-SEC. AREA OF THE WALL IN SQUARED CENTIMETERS
C
      AW=.......
C
C AS IS THE NOMINAL SURFACE AREA OF THE TUBE IN(SQUARED METERS)
C
      AS=.......
C
C AF IS THE ACTUAL FLOW AREA IN(SQUARED MILLIMETERS)
C
      AF=......
      I=10
      DO 5 J=1,10
      READ,FLMA(I),FLMB(I),FLMC(I)
      I=I+10
    5 CONTINUE
      READ,(X(I),I=1,14)
      READ,(X(I),I=15,23)
      READ,(Y(I),I=1,4)
      DO 2 J=1,54
      READ,(X1(J,I),I=1,4)
    2 CONTINUE
C
C THE NEXT LOOP IS FOR THE NUMBER OF RUNS
C
      DO 3 N=1,....
C
C R1,R2,R3  ARE THE READINGS OF THE FLOWMETERS IN PERCENT
C R1,R2 ARE FOR THE WORKING FLUID FLOWRATE
C R3 IS FOR THE COOLING WATER FLOWRATE
```

```
C Q IS THE INPUT POWER IN WATTS ,P IS THE PRESSURE DROP READING IN (MA)
C
      READ,R1,R2,R3,Q,P
      READ, (T(I),I=1,10)
      READ, (T(I),I=11,20)
      READ, (T(I),I=21,30)
      READ, (T(I),I=31,40)
      READ, (T(I),I=41,50)
      READ, (T(I),I=51,62)
      CALL CALIBR (T,TC,Y,X1)
      DO 10 I=1,54
      T(I)=TC(I)
   10 CONTINUE
      DO 15 I=1,62
      T(I)=(5./9.)*(T(I)-32.)
   15 CONTINUE
      TA=(T(55)+T(56))/2.
      CALL FLMETR(R1,R2,R3,FLMA,FLMB,FLMC,FLRT,FLRTC)
      PRINT 7,N,N,N,N,N,N,N,N,N,N,N,N,N,N,N,N,N
    7 FORMAT('1',35X,17(I4))
      CALL HETBAL (Q,FLRT,TA,T)
C
C THE FOLLOWING 10 STATEMENTS ARE FOR CORRECTING THE INLET AND OUTLET
C TEMPERATURE BY CONSIDERING THE AXIAL HEAT CODUCTED OUT OF THE HEATED
C SECTION OF THE TUBE.
C
      T1=(T(1)+T(28))/2.0
      T2=(T(2)+T(29))/2.0
      T3=(T(3)+T(30))/2.0
      B=(T1-T3-0.66667*(T1-T2))/2.66667
      T(55)=T(55)-(1000.0*B*AW*KC)/(100.0*FLRT*CP(T(55)))
      T11=(T(25)+T(52))/2.0
      T12=(T(26)+T(53))/2.0
      T13=(T(27)+T(54))/2.0
      B1=(T13-T11-3.2*(T11-T12))/24.0
      T(56)=T(56)+(1000.0*B1*AW*KC)/(100.0*FLRT*CP(T(56)))
      DO 20 J=1,23
      TF(J)=T(55)*(1.-X(J)/L)+(X(J)/L)*T(56)
   20 CONTINUE
      QC=FLRT/1000.*CP(TA)*(T(56)-T(55))
      DO 4 J=1,23
      RA(J)=(9.81*10000.0*BETA(TF(J))*(D**4)*QC*((RO(TF(J)))**2)*
     *CP(TF(J)))/(VISC(TF(J))*(K(TF(J))**2)*AS*10000.0)
    4 CONTINUE
      CALL PRESS(P,DP,DP1,DP2,CF,D,TA,FLRT,AF)
      REM=FLRT*D*1000.0/VISC(TA)/AF
      RAM=(9.81*10000.0*BETA(TA)*(D**4)*QC*((RO(TA))**2)*CP(TA))/
     *(VISC(TA)*K(TA)**2*AS*10000.0)
      PRM=PR(TA)
      PRINT 6,REM,RAM,PRM
    6 FORMAT('0',10X,'REM = ',F6.1,25X,'RAM = ',E9.3,25X,
     *'PRM = ',F5.2,/)
      TIN=T(55)*9./5.+32.0
      TOU=T(56)*9./5.+32.0
      PRINT 8,TIN,TOU
    8 FORMAT('0',10X,'INLET TEMP =',F6.2,25X,'OUTLET TEMP =',F6.2,/)
      CALL RENOLD (FLRT,D,TF,PI,RE,AF)
      CALL EXHBAL (FLRT,FLRTC,T)
      CALL NUSELT (FLRT,L,T,TF,X,PI,TA,Q,NU,D,NUA,AS,FNU)
      DO 1 J=1,23
      XP(J)=(2.*X(J)/D/RE(J)/PR(TF(J))/100.)
    1 CONTINUE
      CALL PRINTS (NU,RE,XP,RA,TF,X,TC,NUA)
      PRINT 9,FNU
```

```
    9 FORMAT('0',30X,'AVERAGE FULLY DEVELOPED NUSSELT =',F6.2,/)
    3 CONTINUE
      PRINT 30
   30 FORMAT('1',40X,'END OF DATA')
      STOP
      END
C
C THE FOLLOWING SUBROUTINE CORRECTS THE READINGS OF ALL WALL
C THERMOCOUPLES ACCORDING TO THE CALIBRATION.
C
      SUBROUTINE CALIBR (TR,TC,Y,X)
      DIMENSION Z(5,5),X(60,4),Y(5),TR(80),TC(80)
      DO 10 J=1,54
      DO 20 I=2,4
      Z(I,1)=(Y(1)*(X(J,I)-TR(J))-Y(I)*(X(J,1)-TR(J)))/(X(J,I)-X(J,1))
   20 CONTINUE
      DO 30 I=3,4
      Z(I,2)=(Z(2,1)*(X(J,I)-TR(J))-Z(I,1)*(X(J,2)-TR(J)))/
     *(X(J,I)-X(J,2))
   30 CONTINUE
      TC(J)=(Z(4,2)*(X(J,4)-TR(J))-Z(4,2)*(X(J,3)-TR(J)))/
     *(X(J,4)-X(J,3))
   10 CONTINUE
      RETURN
      END
C
C THE FOLLOWING SUBROUTINE CALCULATES THE PRESSURE DROP
C AND THE FRICTION FACTOR.
C
      SUBROUTINE PRESS(P,DP,DP1,DP2,CF,D,TA,FLRT,AF)
      DP=(P-4.)*3./8.0
      DP1=DP*RO(TA)*9.81*.0254
      DP2=DP1/6894.76
      CF=DP1*D*RO(TA)*((AF/1000000.0)**2)/(2.*1.0*(FLRT/1000.)**2)
      PRINT 10 ,DP,DP1,DP2,CF
   10 FORMAT('0',5X,'PRESSURE DROP = ',F4.2,' IN H2O',' OR ',
     *F8.2,' PASCAL',' OR ',F6.3,' PSI',10X,'CF = ',F10.7,/)
      RETURN
      END
C
C THE FOLLOWING SUBROUTINE CALCULATES NUSSELT NUMBER AT THE TOP AND
C THE BOTTOM OF EACH STATION IN THE HEATED SECTION
C
      SUBROUTINE NUSELT (FLRT,L,T,TF,X,PI,TA,Q,NU,D,NUA,AS,FNU)
      DIMENSION T(80),TF(80),X(60),NU(60),NUA(40)
      REAL NU,L,PI,K,NUA
      QC=FLRT/1000.0*CP(TA)*(T(56)-T(55))
      DO 20 J=1,23
      NU(J)=QC*D/(T(J+2)-TF(J))/AS/K(TF(J))
   20 CONTINUE
      DO 25 J=24,46
      NU(J)=QC*D/(T(J+6)-TF(J-23))/AS/K(TF(J-23))
   25 CONTINUE
      DO 30 J=1,23
      NUA(J)=QC*D/(((T(J+2)+T(J+29))/2.0)-TF(J))/AS/K(TF(J))
   30 CONTINUE
      SUM=0.0
      DO 40 J=7,23
      SUM=SUM+NUA(J)
   40 CONTINUE
      FNU=SUM/17.0
      RETURN
      END
C
```

```
C THE FOLLOWING SUBROUTINE PRINTS ALL THE RESULTS IN A CERTAIN FORMAT
C
      SUBROUTINE PRINTS (NU,RE,XP,RA,TF,X,TC,NUA)
      DIMENSION NU(60),RE(40),XP(30),RA(40),TF(80),X(80),TC(80),NUA(40)
      DIMENSION TEMP(40),TL(30)
      REAL NU,NUA
      PRINT 10
   10 FORMAT('0',' ST.NO  BOT NUS  TOP NUS  AVE NUS    X+.      RAYL NUM
     *',' RE NUM  PR NUM   X   BOT TEMP  TOP TEMP  AVE TEMP  BUL TEMP')
      DO 20 J=1,23
      TEMP(J)=((TC(J+2)+TC(J+29))/2.0)
      TL(J)=TF(J)*9.0/5.0+32.0
      PRINT 30,J,NU(J),NU(J+23),NUA(J),XP(J),RA(J),RE(J),PR(TF(J)),X(J)
     *,TC(J+2),TC(J+29),TEMP(J),TL(J)
   30  FORMAT('0',3X,I2,4X,F5.2,4X,F5.2,4X,F5.2,3X,F7.5,3X,E9.3
     *,2X,F6.1,3X,F4.2,2X,F4.1,3X,F5.1,5X,F5.1,5X,F5.1,5X,F5.1)
   20 CONTINUE
      RETURN
      END
C
C THE FOLLOWING SUBROUTINE TAKES THE FLOWRATE READINGS OF ALL THE
C FLOWMETERS IN PERCENTAGE AND GIVE THEM BACK IN (GR/SEC) ACCORDING
C TO THE CALIBRATION OF THE FLOWMETERS.
C
      SUBROUTINE FLMETR (R1,R2,R3,FLMA,FLMB,FLMC,FLRT,FLRTC)
      DIMENSION FLMA(100),FLMB(100),FLMC(100)
      IF (R1.LE.10.) THEN DO
      FLM1=(R1/10.)*FLMA(10)
      ELSE DO
      I=20
      DO 10 J=1,9
      IF (R1.LE.I) THEN DO
      FLM1=((R1-I+10.)/10.)*(FLMA(I)-FLMA(I-10))+FLMA(I-10)
      GO TO 40
      END IF
      I=I+10
   10 CONTINUE
      END IF
   40 IF (R2.LE.10) THEN DO
      FLM2=(R2/10.)*FLMB(10)
      ELSE DO
      I=20
      DO 20 J=1,9
      IF(R2.LE.I) THEN DO
      FLM2=((R2-I+10.)/10.)*(FLMB(I)-FLMB(I-10))+FLMB(I-10)
      GO TO 50
      END IF
      I=I+10
   20 CONTINUE
      END IF
   50 FLRT=FLM1+FLM2
      IF(R3.LE.10) THEN DO
      FLRTC=(R3/10.)*FLMC(10)
      ELSE DO
      I=20
      DO 30 J=1,9
      IF(R3.LE.I) THEN DO
      FLRTC=((R3-I+10)/10.)*(FLMC(I)-FLMC(I-10))+FLMC(I-10)
      GO TO 60
      END IF
      I=I+10
   30 CONTINUE
      END IF
   60 RETURN
```

```
      END
C
C THE FOLLOWING SUBROUTINE CALCULATES THE LOCAL REYNOLDS NUMBER AT
C EACH STATION BASED ON THE INSIDE DIAMETER AND THE LOCAL BULK TEMP.
C
      SUBROUTINE RENOLD (FLRT,D,TF,PI,RE,AF)
      DIMENSION RE(40),TF(80)
      DO 10 J=1,23
      RE(J)=FLRT*D*1000.0/VISC(TF(J))/AF
   10 CONTINUE
      RETURN
      END
C THIS SUBROUTINE CALCULATES THE HEAT BALANCE IN THE HEATED SECTION
C AND FINDS THE PERCENTAGE OF LOSSES.
C
      SUBROUTINE HETBAL (Q,FLRT,TA,T)
      DIMENSION T(70)
      QC=FLRT/1000.*CP(TA)*(T(56)-T(55))
      ERR=(Q-QC)/Q*100.
      PRINT 10,Q,QC,ERR
   10 FORMAT('0',10X,'MEASURED Q =',F7.2,' WATT',5X,'CALCULATED Q =',
     *F7.2,' WATT',5X,'HEAT LOSSES =',F6.2,'%',/)
      RETURN
      END
C
C THIS SUBROUTINE CALCULATES THE HEAT EXCHANGED BY EACH HEATEXCHANGER
C AND FINDS THE PERCENTAGE OF HEAT LOSSES.
C
      SUBROUTINE EXHBAL (FLRT,FLRTC,T)
      DIMENSION T(70)
      Q1=FLRT/1000.*CP((T(57)+T(58))/2.)*(T(57)-T(58))
      Q2=FLRT/1000.*CP((T(58)+T(59))/2.)*(T(58)-T(59))
      QC1=FLRTC/1000.*CP((T(62)+T(61))/2.)*(T(62)-T(61))
      QC2=FLRTC/1000.*CP((T(61)+T(60))/2.)*(T(61)-T(60))
      HL1=(Q1-QC1)/Q1*100.
      HL2=(Q2-QC2)/Q2*100.
      RETURN
      END
C
C THE FOLLOWING FUNCTION CALCULATES THE FLUID THERMAL CONDUCTIVITY
C AT A GIVEN TEMPERATURE.
C
      FUNCTION K(T)
      REAL K
      K=(T-10.)/80.*0.091+0.585
      RETURN
      END
C
C THE FOLLOWING FUNCTION CALCULATES THE SPECIFIC HEAT CP AT A GIVEN
C TEMPERATURE
C
      FUNCTION CP(T)
      IF(T.LT.30.) THEN DO
      CP=4190.-1.15*(T-20.)+.005*(T-20.)**2
      ELSE DO
      IF(T.LT.50.) THEN DO
      CP=4177.-.05*(T-40.)+.015*(T-40.)**2
      ELSE DO
      IF(T.LT.70.) THEN DO
      CP=4183.+.45*(T-60.)-.005*(T-60.)**2
      ELSE DO
      CP=4197.+.95*(T-80.)-.005*(T-80.)**2
      END IF
      END IF
```

```
      END IF
      RETURN
      END
C
C THE FOLLOWING FUNCTION CALCULATES PRANDTL NUMBER AT A GIVEN TEMP.
C
      FUNCTION PR(T)
      IF(T.LT.30.) THEN DO
      PR=7.03-.1995*(T-20.)+.00385*(T-20.)**2
      ELSE DO
      IF(T.LT.50.) THEN DO
      PR=4.33-.097*(T-40.)+.0012*(T-40.)**2
      ELSE DO
      IF(T.LT.70.) THEN DO
      PR=3.04-.04535*(T-60.)-.000135*(T-60.)**2
      ELSE DO
      PR=2.245-.0297*(T-80.)+.00031*(T-80.)**2
      END IF
      END IF
      END IF
      RETURN
      END
C
C THE FOLLOWING FUNCTION CALCULATES THE WATER THERMAL EXPANSION
C COEFFICINT AT A GIVEN TEMPERATURE.
C
      FUNCTION BETA(T)
      IF(T.LT.30.) THEN DO
      BETA=.0002+9.5E-6*(T-20.)-5.E-8*(T-20.)**2
      ELSE DO
      IF(T.LT.50.) THEN DO
      BETA=.00038+8.5E-6*(T-40.)-5.E-8*(T-40.)**2
      ELSE DO
      IF(T.LT.70.) THEN DO
      BETA=.00053+6.5E-6*(T-60.)-5.E-8*(T-60.)**2
      ELSE DO
      BETA=.00064+5.E-6*(T-80.)
      END IF
      END IF
      END IF
      RETURN
      END
C
C THE FOLLOWING FUNCTION CALCULATES THE WATER DENSITY AT A GIVEN
C TEMPERATURE.
C
      FUNCTION RO(T)
      IF(T.LT.30.) THEN DO
      RO=998.-.2*(T-20.)
      ELSE DO
      IF(T.LT.50.) THEN DO
      RO=992.6-.395*(T-40.)-.0055*(T-40.)**2
      ELSE DO
      IF(T.LT.70.) THEN DO
      RO=983.3-.515*(T-60.)-.0035*(T-60.)**2
      ELSE DO
      RO=971.8-.62*(T-80.)-.002*(T-80.)**2
      END IF
      END IF
      END IF
      RETURN
      END
C
C THIS FUNCTION CALCULATES THE WATER DYNAMIC VISCOSITY AT A GIVEN TEMP.
```

```
C
      FUNCTION VISC(T)
      IF(T.LT.30.) THEN DO
      VISC=1.01E-3-.2535E-4*(T-20.)+.465E-6*(T-20.)**2
      ELSE DO
      IF(T.LT.50.) THEN DO
      VISC=.656E-3-.133333E-4*(T-40.)+.135E-6*(T-40.)**2
      ELSE DO
      IF(T.LT.70.) THEN DO
      VISC=.475E-3-.64E-5*(T-60.)-.3E-7*(T-60.)**2
      ELSE DO
      VISC=.359E-3-.45E-5*(T-80.)+.4E-7*(T-80.)**2
      END IF
      END IF
      END IF
      RETURN
      END
$ENTRY
```

Appendix B

SAMPLE CALCULATIONS FOR RUN NO. 1 of TUBE NO. 10

Run No. 1 of tube No. 10 was selected as a sample to show how different parameters are calculated. Local parameters will only be calculated at station No. 15, since they are calculated the same way at all other stations. The following table is for the raw data as they were recorded for the above mentioned run with wall temperatures corrected according to the calibration formulae.

Flowrate $\dot{m}$, g/s	Input Power Q_e, W	Pressure Drop Reading mA	Wall Bottom Temperature °C	Wall Top Temperature °C	Upstream Bulk Temperature °C	Downstream Bulk Temperature °C
1.307	50	4.27	40.7	40.9	31.9	40.8

The following table is for the dimensional data of tube No. 10

Inside Diameter D_i-mm	Flow Area A_{fl}-mm^2	Location of station 15, x - cm	Total Heated Length l-cm	Wall Cross-Sectional Area A_w-mm^2
8.00	40.6	45.5	87.5	30.73

Mean bulk temperature $T_m = (31.9 + 40.8) / 2 = 36.35°C$

Specific heat at mean bulk temperature, $c_p = 4177$ J/kg.K

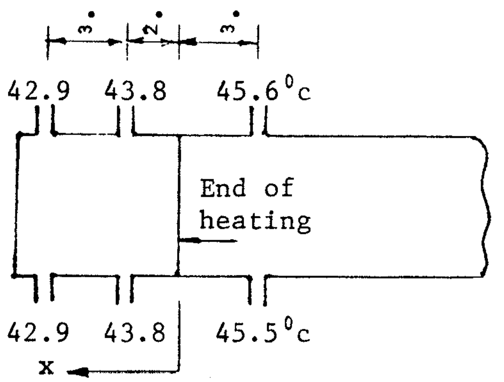
Rate of heat gained by the fluid, $Q_f = \dot{m}\, c_p \Delta T_b$

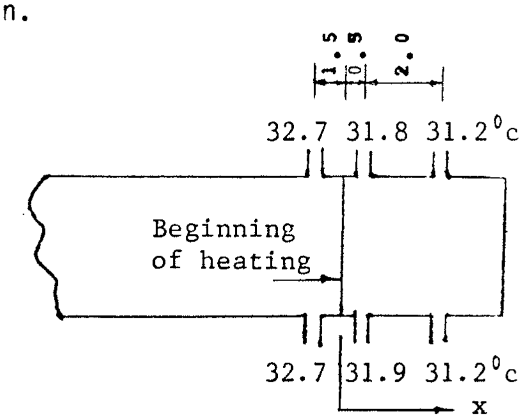
$$Q_f = [1.307 \times 10^{-3} \times 4177\, (40.78 - 31.94)] = 48.2 \text{ W}$$

Percentage heat balance error $E = [(Q_f - Q_e)/Q_f) \times 100]$

$$E = [(50 - 48.2)/50) \times 100] = 3.54\%$$

The thermocouple upstream and downstream of the heated section were used to find the wall temperature gradient at the beginning and end of heating by fitting a parabolic equation.





At $x = 2$, $\bar{T}_w = (43.77 + 43.81)/2$
At $x = 5$, $\bar{T}_w = (42.90 + 42.92)/2$
At $x = -3$, $\bar{T}_w = (45.54 + 45.57)/2$

$$\bar{T}_w = A + Bx + cx^2$$

At $x = 0.5$, $\bar{T}_w = (31.92 + 31.81)/2$
At $x = 2.5$, $\bar{T}_w = (31.21 + 31.18)/2$
At $x = -1.5$, $\bar{T}_w = (32.72 + 32.67)/2$

$$\bar{T}_w = D + Ex + Fx^2$$

After substitution of the above three conditions, all the constants can be evaluated.

$$d\bar{T}_w/dx \Big|_{\text{end of heating}} = B = 0.345 \text{ °C/cm}$$

$$d\bar{T}_w/dx \Big|_{\text{beginning of heating}} = E = 0.396 \text{ °C/cm}$$

With the wall temperature gradient being known at both the beginning and end of the heated section, we got

$$T_{bi} = T_{in} + [k_w(d\bar{T}_w/dx)A_w]/(\dot{m}c_p)$$

$$T_{bi} = 31.9 + (386 \times 39.6 \times 30.73 \times 10^{-6})/(1.307 \times 10^{-3} \times 4178) = 32.03°C$$

$$T_{bo} = T_{out} - [k_w(d\bar{T}_w/dx)A_w]/(\dot{m}c_p)$$

$$T_{bo} = 40.78 - (386 \times 34.5 \times 30.73 \times 10^{-6})/(1.307 \times 10^{-3} \times 4178) = 40.71°C$$

where T_{bi} and T_{bo} are the bulk inlet and outlet temperatures.

Within the heated section, the local bulk temperature can be found from

$$T_b = T_{bi} + (T_{bo} - T_{bi})\, x/L$$

The span used for the pressure transducer was 0-6 inches of water. The pressure transducer reads linearly, i.e; at zero pressure drop it reads 4 mA, and at a pressure drop of 6 inches of water it reads 20 mA. For the present reading of 4.27 mA, the pressure drop and average friction factor were calculated as follows:

$$\Delta P = (6/16)\ (4.27 - 4.0) = 0.10 \text{ inches of water}$$

The density of water was evaluated at the mean bulk temperture.

$$\text{Density, } \rho = 994 \text{ kg/m}^3$$

$$\Delta P = 0.10 \times 0.0254 \times 994 \times 9.81 = 25 \text{ Pa}$$

The average diabatic friction factor f_{dia} was calculated as follows:

$$\bar{f}_{dia} = (\Delta P\ D_i\ \ \rho\ A_{f1}^{2})\ /\ (2L_p\ \dot{m}^2)$$

$$\bar{f}_{dia} = \{[25 \times 0.008 \times 994 \times (0.0000406)^2]\ /\ [2 \times (0.001307)^2]\}$$

$$\bar{f}_{dia} = 0.0962$$

The bulk temperature at station 15 was evaluated as shown earlier:

$$T_b = 45.5/87.5\ (40.70 - 32.03) + 32.03 = 36.54°\text{C}$$

at this temperature, the local viscosity is

$$\mu_x = 7.0229 \times 10^{-4} \ \ \text{N.s/m}^2$$

$Re = \frac{\dot{m} D}{A_{fl} \mu}$ D – inside diameter not D_h ?

and the local Reynolds number is

$$Re_x = (0.001307 \times 0.008)/(7.0029 \times 10^{-4} \times 0.0000406) = 366.7$$

At the mean bulk temperature, the viscosity is

$$\mu_m = 7.0632 \times 10^{-4} \ \ \text{N.s/m}^2$$

and the corresponding mean Reynolds number is

$$Re_m = (0.001307 \times 0.008)\ /\ (7.0632 \times 10^{-4} \times 0.0000406)$$

$$Re_m = 364.62$$

The modified Rayleigh number was also evaluated locally and at the mean bulk temperature.

$$Ra^* = (g \quad D_i^3 Q_f \quad {}^2 c_p)/(\quad k_f^2 \quad L)$$

β (36.35) = 3.484 x 10^{-4} 1/K, β (36.54) = 3.500 x 10^{-4} 1/K

c_p (36.35) = 4177.38 j/kg.K, c_p (36.54) = 4177.35 j/kg.K

k_f (36.35) = 0.6150 W/mK, k_f (36.54) = 0.6152 W/mK

ρ (36.35) = 994 kg/m^3, ρ (36.54) = 994 kg/m^3

$$Ra_m^* = [9.81 \times 3.484 \times 10^{-4} \times (0.008)^3 \times 48.23 \times (994)^2 \times 4177] / [7.0632 \times 10^{-4} \times (0.6150)^2 \times \quad \times 0.875] = 4.66 \times 10^5$$

$$Ra_x^* = [9.81 \times 3.500 \times 10^{-4} \times (0.008)^3 \times 48.23 \times (994)^2 \times 4177] / [7.0229 \times 10^{-4} \times (0.6152)^2 \times \quad \times 0.875] = 4.70 \times 10^5$$

With the proprties listed above, the local and mean Prandtl numbers are:

$$Pr_x = Pr\ (36.54) = 4.68, \quad Pr_m = Pr\ (36.35) = 4.70$$

The local-average Nusselt number was calculated from

$$Nu_x = Q_f/[\pi\ L(\overline{T}_w - T_b)\ k_f]$$

where T_w = (40.7 + 40.9) / 2 = 40.8°C

$$Nu_x = 48.2 / [\pi \times 0.875\ (40.8 - 36.54)\ 0.6152] = 6.7$$

and the corresponding reduced length $X^+ = x/(R_i Re_x Pr_x)$

$$X^+ = 0.455 / (0.004 \times 366.71 \times 4.68) = 0.0663$$

Appendix C

TABULATION OF ALL EXPERIMENTAL RESULTS

F $\equiv \bar{f}_{dia}$

REM $\equiv (Re_m)_i$

RAM $\equiv Ra_m^*$

RAMF $\equiv Ra_m$ (evaluated at mean film temperature)

PRM $\equiv Pr_m$

TW $\equiv T_w$

TB $\equiv T_b$

RE $\equiv Re_x$

PR $\equiv Pr_x$

X+ $\equiv X^+$

RA $\equiv Ra_x^*$

NU $\equiv Nu_x$

RUN NUMBER (1) TUBE NUMBER 1

INPUT POWER = 95.0 W HEAT RATE GAINED BY WATER = 92.5 W HEAT BALANCE ERROR = 2.6%

REM = 325.1 RAM = 0.203E 07 PRM = 5.43

UPSTREAM BULK TEMPERATURE =26.5 DEG C DOWNSTREAM BULK TEMPERATURE =33.3 DEG C

INLET BULK TEMPERATURE =26.6 DEG C OUTLET BULK TEMPERATURE =33.2 DEG C

MASS FLOW RATE = 11.8 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	2.8	28.3	28.2	26.7	303.6	5.87	0.00212	0.174E 07	13.5
2	6.8	28.7	28.6	26.8	304.4	5.85	0.00487	0.175E 07	11.2
3	10.6	29.0	28.9	26.9	305.2	5.84	0.00763	0.176E 07	10.2
4	14.6	29.1	29.1	27.0	306.0	5.82	0.01053	0.177E 07	10.1
5	20.4	29.3	29.3	27.2	307.1	5.80	0.01463	0.178E 07	10.0
6	26.0	29.5	29.5	27.3	308.3	5.77	0.01860	0.180E 07	9.6
7	31.8	29.7	29.6	27.5	309.4	5.75	0.02264	0.181E 07	9.7
8	37.6	29.9	29.8	27.7	310.5	5.72	0.02668	0.183E 07	9.7
9	43.5	30.1	29.9	27.9	311.7	5.70	0.03095	0.184E 07	9.8
10	49.3	30.3	30.1	28.0	312.8	5.68	0.03507	0.186E 07	9.9
11	57.2	30.4	30.3	28.3	314.4	5.65	0.04077	0.188E 07	10.2
12	65.6	30.7	30.6	28.5	315.9	5.61	0.04626	0.190E 07	9.7
13	73.1	30.9	30.7	28.7	317.6	5.58	0.05246	0.193E 07	10.0
14	80.4	31.1	30.9	28.9	318.9	5.55	0.05725	0.194E 07	10.4
15	88.1	31.2	31.1	29.2	320.4	5.53	0.06283	0.196E 07	10.7
16	95.9	31.4	31.4	29.4	321.9	5.50	0.06835	0.199E 07	10.6
17	107.3	31.9	31.7	29.7	324.1	5.45	0.07652	0.202E 07	10.3
18	118.9	32.2	32.0	30.1	326.4	5.41	0.08498	0.205E 07	10.3
19	130.6	32.4	32.3	30.4	328.6	5.37	0.09325	0.208E 07	10.8
20	142.3	32.8	32.7	30.8	330.9	5.33	0.10167	0.212E 07	10.7
21	153.8	33.3	33.0	31.1	333.2	5.29	0.11003	0.215E 07	10.1
22	165.2	33.7	33.5	31.4	335.4	5.25	0.11812	0.218E 07	9.7
23	190.4	34.4	34.3	32.2	340.4	5.16	0.13637	0.226E 07	9.6

FULLY DEVELOPED NUSSELT NUMBER =10.2

RUN NUMBER (2)   TUBE NUMBER 1

INPUT POWER = 149.0 W   HEAT RATE GAINED BY WATER = 133.5 W   HEAT BALANCE ERROR =10.4%

REM = 335.8   RAM = 0.321E 07   PRM = 5.24

UPSTREAM BULK TEMPERATURE =26.6 DEG C   DOWNSTREAM BULK TEMPERATURE =36.4 DEG C

INLET BULK TEMPERATURE =26.7 DEG C   OUTLET BULK TEMPERATURE =36.4 DEG C

MASS FLOW RATE = 11.8 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	2.9	29.2	29.1	26.9	304.9	5.84	0.00212	0.257E 07	13.6
2	6.8	29.7	29.6	27.0	306.0	5.82	0.00487	0.259E 07	11.8
3	10.7	30.1	29.9	27.2	307.2	5.80	0.00763	0.261E 07	10.9
4	14.7	30.3	30.2	27.4	308.3	5.77	0.01054	0.264E 07	10.6
5	20.6	30.6	30.6	27.6	310.0	5.74	0.01465	0.267E 07	10.4
6	26.1	30.8	30.8	27.8	311.6	5.70	0.01862	0.270E 07	10.5
7	31.9	31.1	31.0	28.1	313.3	5.67	0.02268	0.273E 07	10.5
8	37.6	31.3	31.2	28.3	314.9	5.63	0.02673	0.277E 07	10.5
9	43.6	31.7	31.4	28.6	316.6	5.60	0.03101	0.280E 07	10.4
10	49.4	31.8	31.6	28.8	318.3	5.57	0.03515	0.283E 07	10.8
11	57.3	32.1	31.8	29.2	320.6	5.52	0.04087	0.288E 07	11.2
12	65.4	32.4	32.4	29.5	322.7	5.48	0.04639	0.292E 07	10.8
13	73.5	32.8	32.6	29.9	325.2	5.44	0.05263	0.297E 07	11.0
14	80.5	33.0	32.8	30.2	327.1	5.40	0.05743	0.302E 07	11.4
15	88.3	33.3	33.1	30.5	329.3	5.36	0.06304	0.307E 07	11.4
16	96.0	33.6	33.5	30.9	331.5	5.32	0.06858	0.311E 07	11.4
17	107.4	34.3	34.0	31.3	334.8	5.26	0.07680	0.319E 07	10.8
18	119.1	34.8	34.6	31.8	338.2	5.20	0.08534	0.326E 07	10.8
19	130.7	35.2	35.1	32.3	341.6	5.14	0.09367	0.334E 07	11.0
20	142.4	35.6	35.5	32.8	345.1	5.09	0.10217	0.341E 07	11.4
21	153.9	36.3	35.9	33.3	348.6	5.03	0.11061	0.349E 07	11.1
22	165.2	36.8	36.5	33.8	352.0	4.97	0.11878	0.356E 07	10.8
23	190.4	37.8	37.7	34.9	359.8	4.85	0.13723	0.373E 07	10.9

FULLY DEVELOPED NUSSELT NUMBER =11.0

RUN NUMBER (3) TUBE NUMBER 1

INPUT POWER = 188.0 W HEAT RATE GAINED BY WATER = 177.4 W HEAT BALANCE ERROR = 5.6%

REM = 348.0 RAM = 0.457E 07 PRM = 5.04

UPSTREAM BULK TEMPERATURE =26.8 DEG C DOWNSTREAM BULK TEMPERATURE =39.8 DEG C

INLET BULK TEMPERATURE =26.9 DEG C OUTLET BULK TEMPERATURE =39.7 DEG C

MASS FLOW RATE = 11.8 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	3.0	30.1	29.9	27.1	306.5	5.81	0.00212	0.342E 07	14.0
2	6.9	30.8	30.5	27.3	308.0	5.78	0.00488	0.346E 07	12.1
3	10.8	31.2	31.0	27.5	309.5	5.75	0.00764	0.350E 07	11.4
4	14.8	31.5	31.3	27.8	311.0	5.71	0.01055	0.354E 07	11.2
5	20.6	31.8	31.7	28.1	313.2	5.67	0.01467	0.359E 07	11.0
6	26.2	32.1	32.1	28.4	315.3	5.63	0.01865	0.365E 07	11.0
7	32.0	32.4	32.3	28.7	317.5	5.58	0.02272	0.371E 07	11.2
8	37.7	32.7	32.6	29.1	319.6	5.54	0.02679	0.376E 07	11.2
9	43.6	33.2	32.8	29.4	321.8	5.50	0.03108	0.382E 07	11.2
10	49.4	33.5	33.1	29.7	324.0	5.45	0.03524	0.388E 07	11.4
11	57.4	33.8	33.5	30.2	327.0	5.40	0.04097	0.396E 07	11.6
12	65.3	34.3	34.1	30.6	329.9	5.35	0.04650	0.405E 07	11.2
13	73.7	34.7	34.4	31.1	333.1	5.29	0.05277	0.414E 07	11.7
14	80.5	35.0	34.7	31.5	335.7	5.24	0.05760	0.422E 07	11.9
15	88.3	35.5	35.2	31.9	338.7	5.19	0.06324	0.430E 07	11.8
16	96.1	35.9	35.7	32.4	341.6	5.14	0.06882	0.439E 07	11.7
17	107.5	36.7	36.4	33.0	346.1	5.07	0.07710	0.452E 07	11.3
18	119.2	37.4	37.0	33.7	350.8	4.99	0.08570	0.465E 07	11.5
19	130.8	37.9	37.8	34.3	355.4	4.92	0.09410	0.479E 07	11.4
20	142.4	38.5	38.3	35.0	360.2	4.85	0.10267	0.492E 07	11.6
21	154.0	39.4	38.9	35.6	365.0	4.78	0.11119	0.506E 07	11.4
22	165.3	40.1	39.8	36.3	369.7	4.71	0.11944	0.520E 07	11.0
23	190.5	41.3	41.3	37.7	380.6	4.56	0.13809	0.551E 07	11.2

FULLY DEVELOPED NUSSELT NUMBER =11.4

RUN NUMBER (4)   TUBE NUMBER 1

INPUT POWER = 246.0 W   HEAT RATE GAINED BY WATER = 222.9 W   HEAT BALANCE ERROR = 9.4%

REM = 360.3   RAM = 0.619E 07   PRM = 4.85

UPSTREAM BULK TEMPERATURE =26.8 DEG C   DOWNSTREAM BULK TEMPERATURE =43.2 DEG C

INLET BULK TEMPERATURE =27.0 DEG C   OUTLET BULK TEMPERATURE =43.0 DEG C

MASS FLOW RATE = 11.8 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA.	NU (AVERAGE)
1	3.0	30.9	30.6	27.2	307.4	5.79	0.00212	0.432E 07	14.4
2	6.9	31.8	31.5	27.5	309.2	5.75	0.00488	0.438E 07	12.4
3	10.8	32.3	32.0	27.8	311.1	5.71	0.00765	0.444E 07	11.7
4	14.9	32.6	32.4	28.1	313.0	5.67	0.01056	0.451E 07	11.5
5	20.7	33.0	32.9	28.5	315.8	5.62	0.01468	0.460E 07	11.4
6	26.3	33.4	33.3	28.9	318.4	5.56	0.01868	0.469E 07	11.4
7	32.0	33.7	33.6	29.3	321.1	5.51	0.02275	0.478E 07	11.6
8	37.7	34.1	34.0	29.7	323.8	5.46	0.02683	0.487E 07	11.6
9	43.7	34.7	34.2	30.1	326.6	5.41	0.03113	0.496E 07	11.7
10	49.5	35.0	34.6	30.5	329.3	5.36	0.03530	0.506E 07	11.9
11	57.5	35.4	35.0	31.1	333.1	5.29	0.04106	0.520E 07	12.3
12	65.2	36.0	35.9	31.7	336.8	5.22	0.04661	0.533E 07	11.7
13	73.8	36.6	36.2	32.2	341.0	5.15	0.05291	0.549E 07	12.2
14	80.6	37.0	36.7	32.7	344.3	5.10	0.05777	0.561E 07	12.3
15	88.4	37.6	37.1	33.3	348.1	5.04	0.06344	0.575E 07	12.4
16	96.1	38.0	37.9	33.8	352.0	4.97	0.06906	0.589E 07	12.3
17	107.5	39.1	38.8	34.6	357.8	4.88	0.07739	0.610E 07	11.8
18	119.3	39.9	39.4	35.5	363.9	4.79	0.08605	0.632E 07	12.2
19	130.8	40.7	40.4	36.3	370.0	4.70	0.09452	0.654E 07	11.9
20	142.5	41.4	41.2	37.1	376.3	4.62	0.10317	0.677E 07	12.0
21	154.1	42.5	41.9	38.0	382.6	4.53	0.11177	0.699E 07	11.8
22	165.3	43.3	43.0	38.8	388.9	4.45	0.12009	0.722E 07	11.4
23	190.5	44.8	44.7	40.5	403.3	4.28	0.13892	0.773E 07	11.8

FULLY DEVELOPED NUSSELT NUMBER =11.9

RUN NUMBER (5)   TUBE NUMBER 1

INPUT POWER = 297.0 W   HEAT RATE GAINED BY WATER = 267.6 W   HEAT BALANCE ERROR = 9.9%

REM = 373.3   RAM = 0.807E 07   PRM = 4.66

UPSTREAM BULK TEMPERATURE =26.9 DEG C   DOWNSTREAM BULK TEMPERATURE =46.6 DEG C

INLET BULK TEMPERATURE =27.2 DEG C   OUTLET BULK TEMPERATURE =46.5 DEG C

MASS FLOW RATE = 11.8 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	3.0	31.9	31.5	27.4	308.6	5.76	0.00212	0.529E 07	14.5
2	6.9	32.8	32.4	27.7	310.9	5.72	0.00488	0.538E 07	12.7
3	10.8	33.4	33.0	28.1	313.1	5.67	0.00765	0.547E 07	12.2
4	14.9	33.7	33.5	28.4	315.5	5.62	0.01057	0.556E 07	12.0
5	20.7	34.1	34.0	28.9	318.8	5.56	0.01470	0.569E 07	12.0
6	26.3	34.6	34.5	29.4	322.0	5.49	0.01871	0.582E 07	12.0
7	32.0	35.0	34.8	29.9	325.2	5.43	0.02279	0.596E 07	12.5
8	37.7	35.4	35.2	30.4	328.5	5.37	0.02687	0.610E 07	12.5
9	43.7	36.1	35.7	30.9	331.9	5.31	0.03119	0.625E 07	12.4
10	49.5	36.6	36.0	31.4	335.2	5.25	0.03537	0.640E 07	12.6
11	57.5	37.0	36.5	32.1	339.9	5.17	0.04115	0.660E 07	13.2
12	65.2	37.8	37.5	32.8	344.5	5.09	0.04674	0.680E 07	12.5
13	73.9	38.4	37.9	33.5	349.7	5.01	0.05306	0.703E 07	13.1
14	80.6	39.0	38.5	34.1	353.8	4.95	0.05795	0.721E 07	13.3
15	88.4	39.6	39.1	34.8	358.6	4.87	0.06366	0.743E 07	13.3
16	96.1	40.1	39.9	35.4	363.5	4.80	0.06931	0.764E 07	13.2
17	107.5	41.4	41.0	36.4	370.8	4.69	0.07770	0.796E 07	12.7
18	119.3	42.4	41.9	37.4	378.5	4.59	0.08642	0.829E 07	13.0
19	130.8	43.3	42.9	38.4	386.2	4.49	0.09496	0.863E 07	12.9
20	142.5	44.2	43.9	39.4	394.2	4.39	0.10368	0.897E 07	13.1
21	154.1	45.5	44.8	40.4	402.3	4.29	0.11235	0.932E 07	12.8
22	165.3	46.4	46.1	41.4	410.2	4.20	0.12075	0.967E 07	12.4
23	190.5	48.2	48.2	43.6	428.7	4.00	0.13974	0.105E 08	13.0

FULLY DEVELOPED NUSSELT NUMBER =12.9

RUN NUMBER (6)   TUBE NUMBER 1

INPUT POWER = 328.0 W   HEAT RATE GAINED BY WATER = 313.1 W   HEAT BALANCE ERROR = 4.5%

REM = 387.0   RAM = 0.102E 08   PRM = 4.48

UPSTREAM BULK TEMPERATURE =27.1 DEG C   DOWNSTREAM BULK TEMPERATURE =50.0 DEG C

INLET BULK TEMPERATURE =27.3 DEG C   OUTLET BULK TEMPERATURE =50.0 DEG C

MASS FLOW RATE = 11.8 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	3.0	32.7	32.3	27.6	309.9	5.74	0.00212	0.626E 07	14.8
2	6.9	33.8	33.4	28.0	312.5	5.68	0.00489	0.639E 07	13.0
3	10.8	34.4	34.0	28.4	315.2	5.63	0.00766	0.651E 07	12.5
4	14.9	34.8	34.5	28.8	317.9	5.57	0.01058	0.664E 07	12.4
5	20.7	35.2	35.1	29.4	321.8	5.50	0.01472	0.682E 07	12.6
6	26.3	35.8	35.6	30.0	325.5	5.43	0.01873	0.700E 07	12.5
7	32.0	36.2	36.0	30.5	329.3	5.36	0.02282	0.720E 07	12.9
8	37.7	36.8	36.5	31.1	333.2	5.29	0.02692	0.740E 07	13.0
9	43.7	37.5	37.0	31.7	337.2	5.22	0.03125	0.761E 07	13.0
10	49.5	38.1	37.4	32.3	341.2	5.15	0.03544	0.782E 07	13.3
11	57.5	38.6	38.1	33.1	346.8	5.06	0.04125	0.811E 07	13.8
12	65.2	39.5	39.2	33.9	352.3	4.97	0.04686	0.839E 07	13.1
13	73.9	40.2	39.7	34.8	358.6	4.87	0.05322	0.871E 07	13.8
14	80.6	40.9	40.4	35.4	363.6	4.80	0.05813	0.897E 07	13.8
15	88.4	41.7	41.1	36.2	369.4	4.71	0.06387	0.927E 07	13.8
16	96.1	42.3	42.1	37.0	375.3	4.63	0.06955	0.957E 07	13.6
17	107.5	43.9	43.4	38.2	384.2	4.51	0.07800	0.100E 08	13.0
18	119.3	45.0	44.4	39.3	393.6	4.39	0.08678	0.105E 08	13.4
19	130.8	46.1	45.7	40.5	403.0	4.28	0.09538	0.110E 08	13.2
20	142.5	47.1	46.8	41.7	412.8	4.17	0.10416	0.115E 08	13.4
21	154.1	48.6	47.9	42.9	422.7	4.06	0.11289	0.120E 08	13.2
22	165.3	49.8	49.3	44.0	432.6	3.96	0.12135	0.125E 08	12.7
23	190.5	51.9	51.7	46.5	455.4	3.75	0.14046	0.136E 08	13.3

FULLY DEVELOPED NUSSELT NUMBER =13.3

RUN NUMBER (7) TUBE NUMBER 1

INPUT POWER = 395.0 W HEAT RATE GAINED BY WATER = 364.7 W HEAT BALANCE ERROR = 7.7%

REM = 402.6 RAM = 0.128E 08 PRM = 4.28

UPSTREAM BULK TEMPERATURE =27.1 DEG C DOWNSTREAM BULK TEMPERATURE =53.8 DEG C

INLET BULK TEMPERATURE =27.4 DEG C OUTLET BULK TEMPERATURE =53.9 DEG C

MASS FLOW RATE = 11.8 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	3.0	33.6	33.2	27.7	310.8	5.72	0.00212	0.734E 07	15.0
2	6.9	34.8	34.3	28.2	313.9	5.65	0.00489	0.751E 07	13.3
3	10.8	35.5	35.0	28.7	316.9	5.59	0.00767	0.767E 07	12.8
4	14.9	35.9	35.5	29.1	320.1	5.53	0.01059	0.785E 07	12.8
5	20.7	36.5	36.3	29.8	324.6	5.44	0.01474	0.810E 07	12.8
6	26.3	37.1	36.9	30.5	329.0	5.36	0.01875	0.836E 07	12.9
7	32.0	37.6	37.3	31.1	333.4	5.28	0.02285	0.863E 07	13.3
8	37.7	38.3	37.9	31.8	337.9	5.20	0.02696	0.890E 07	13.3
9	43.7	39.2	38.5	32.5	342.8	5.12	0.03131	0.919E 07	13.3
10	49.5	39.7	39.1	33.2	347.5	5.04	0.03552	0.947E 07	13.5
11	57.5	40.4	39.7	34.1	354.2	4.94	0.04135	0.987E 07	14.2
12	65.2	41.4	41.1	35.1	360.7	4.84	0.04698	0.103E 08	13.4
13	73.9	42.3	41.7	36.1	368.3	4.73	0.05337	0.107E 08	14.1
14	80.6	43.1	42.5	36.9	374.2	4.65	0.05832	0.111E 08	14.0
15	88.4	44.0	43.4	37.8	381.2	4.55	0.06409	0.115E 08	14.0
16	96.1	44.8	44.5	38.7	388.3	4.46	0.06981	0.119E 08	13.8
17	107.5	46.5	45.9	40.0	399.0	4.33	0.07831	0.125E 08	13.4
18	119.3	47.8	47.1	41.4	410.4	4.20	0.08715	0.132E 08	13.7
19	130.8	49.0	48.5	42.8	421.9	4.07	0.09581	0.139E 08	13.6
20	142.5	50.3	50.0	44.1	433.8	3.95	0.10464	0.146E 08	13.6
21	154.1	52.1	51.2	45.5	445.9	3.83	0.11343	0.153E 08	13.4
22	165.3	53.3	52.8	46.8	457.9	3.72	0.12193	0.160E 08	13.1
23	190.5	55.7	55.6	49.8	485.9	3.50	0.14108	0.176E 08	13.8

FULLY DEVELOPED NUSSELT NUMBER =13.6

RUN NUMBER (8)   TUBE NUMBER 1

INPUT POWER = 488.0 W   HEAT RATE GAINED BY WATER = 464.0 W   HEAT BALANCE ERROR = 4.9%

REM = 428.2   RAM = 0.182E 08   PRM = 4.01

UPSTREAM BULK TEMPERATURE =26.5 DEG C   DOWNSTREAM BULK TEMPERATURE =60.5 DEG C

INLET BULK TEMPERATURE =26.8 DEG C   OUTLET BULK TEMPERATURE =60.7 DEG C

MASS FLOW RATE = 11.8 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE --	PR --	X+ --	RA --	NU (AVERAGE)
1	3.0	34.5	33.9	27.3	307.7	5.78	0.00212	0.918E 07	15.6
2	6.9	35.8	35.2	27.9	311.7	5.70	0.00489	0.945E 07	14.1
3	10.8	36.7	36.0	28.5	315.6	5.62	0.00766	0.972E 07	13.7
4	14.9	37.1	36.7	29.1	319.7	5.54	0.01059	0.100E 08	13.8
5	20.7	37.9	37.6	29.9	325.4	5.43	0.01474	0.104E 08	13.8
6	26.3	38.6	38.3	30.8	331.0	5.33	0.01877	0.108E 08	14.0
7	32.0	39.2	38.9	31.6	336.7	5.22	0.02288	0.113E 08	14.5
8	37.7	40.1	39.7	32.5	342.6	5.13	0.02701	0.117E 08	14.4
9	43.7	41.2	40.4	33.4	348.9	5.02	0.03137	0.122E 08	14.5
10	49.5	41.9	41.1	34.3	355.1	4.92	0.03561	0.127E 08	14.8
11	57.5	42.7	42.0	35.5	363.8	4.79	0.04147	0.134E 08	15.5
12	65.2	44.2	43.7	36.6	372.5	4.67	0.04715	0.140E 08	14.5
13	73.9	45.3	44.5	37.9	382.5	4.53	0.05360	0.148E 08	15.3
14	80.6	46.3	45.5	39.0	390.4	4.43	0.05858	0.154E 08	15.2
15	88.4	47.5	46.8	40.1	399.8	4.32	0.06441	0.161E 08	15.1
16	96.1	48.5	48.2	41.3	409.4	4.21	0.07019	0.168E 08	14.9
17	107.5	50.7	50.0	43.0	423.9	4.05	0.07877	0.179E 08	14.3
18	119.3	52.2	51.4	44.8	439.4	3.89	0.08770	0.191E 08	14.9
19	130.8	54.0	53.4	46.5	455.0	3.75	0.09643	0.202E 08	14.5
20	142.5	55.4	55.1	48.3	471.4	3.61	0.10533	0.215E 08	14.9
21	154.1	57.7	56.5	50.0	488.2	3.48	0.11412	0.227E 08	14.7
22	165.3	59.2	58.6	51.7	497.3	3.41	0.12271	0.236E 08	14.4
23	190.5	62.3	62.1	55.5	519.9	3.24	0.14219	0.256E 08	15.3

FULLY DEVELOPED NUSSELT NUMBER =14.8

RUN NUMBER (9)   TUBE NUMBER 1

INPUT POWER = 590.0 W   HEAT RATE GAINED BY WATER = 546.6 W   HEAT BALANCE ERROR = 7.3%

REM = 453.7   RAM = 0.240E 08   PRM = 3.76

UPSTREAM BULK TEMPERATURE =26.3 DEG C   DOWNSTREAM BULK TEMPERATURE =66.4 DEG C

INLET BULK TEMPERATURE =26.7 DEG C   OUTLET BULK TEMPERATURE =67.0 DEG C

MASS FLOW RATE = 11.8 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE --	PR --	X+ --	RA --	NU (AVERAGE)
1	3.0	35.5	34.8	27.2	307.5	5.79	0.00212	0.109E 08	16.3
2	6.9	37.0	36.4	27.9	312.2	5.69	0.00489	0.113E 08	14.7
3	10.8	37.9	37.2	28.6	316.8	5.59	0.00766	0.117E 08	14.4
4	14.9	38.5	38.0	29.4	321.7	5.50	0.01060	0.121E 08	14.5
5	20.7	39.3	39.0	30.4	328.6	5.37	0.01476	0.127E 08	14.6
6	26.3	40.3	39.9	31.4	335.2	5.25	0.01879	0.133E 08	14.7
7	32.0	41.0	40.6	32.4	342.2	5.13	0.02292	0.139E 08	15.3
8	37.7	42.0	41.5	33.5	349.3	5.02	0.02707	0.146E 08	15.3
9	43.7	43.4	42.4	34.5	356.9	4.90	0.03145	0.153E 08	15.3
10	49.5	44.2	43.2	35.6	364.5	4.78	0.03571	0.160E 08	15.7
11	57.5	45.2	44.3	37.0	375.2	4.63	0.04162	0.169E 08	16.4
12	65.2	46.8	46.3	38.4	385.9	4.49	0.04733	0.179E 08	15.4
13	73.9	48.1	47.2	39.9	398.3	4.34	0.05382	0.190E 08	16.4
14	80.6	49.3	48.4	41.1	408.1	4.22	0.05885	0.199E 08	16.3
15	88.4	50.8	49.8	42.5	419.8	4.09	0.06472	0.210E 08	16.1
16	96.1	51.9	51.5	43.9	431.7	3.97	0.07054	0.220E 08	16.0
17	107.5	54.4	53.6	45.9	449.9	3.80	0.07918	0.236E 08	15.4
18	119.3	56.3	55.3	48.1	469.4	3.63	0.08816	0.254E 08	16.1
19	130.8	58.3	57.6	50.1	488.7	3.48	0.09688	0.271E 08	15.9
20	142.5	60.0	59.5	52.2	500.2	3.39	0.10586	0.284E 08	16.3
21	154.1	62.6	61.3	54.3	512.4	3.29	0.11482	0.297E 08	16.0
22	165.3	64.4	63.7	56.3	525.0	3.21	0.12352	0.310E 08	15.8
23	190.5	68.0	67.8	60.8	556.8	3.00	0.14328	0.342E 08	17.0

FULLY DEVELOPED NUSSELT NUMBER =16.0

RUN NUMBER (10)   TUBE NUMBER 1

INPUT POWER = 650.0 W HEAT RATE GAINED BY WATER = 614.9 W HEAT BALANCE ERROR = 5.4%

REM = 475.9   RAM = 0.292E 08   PRM = 3.57

UPSTREAM BULK TEMPERATURE =26.2 DEG C   DOWNSTREAM BULK TEMPERATURE =71.3 DEG C

INLET BULK TEMPERATURE =26.6 DEG C   OUTLET BULK TEMPERATURE =72.0 DEG C

MASS FLOW RATE = 11.8 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	3.0	36.3	35.5	27.2	307.4	5.79	0.00212	0.123E 08	16.7
2	6.9	38.0	37.3	28.0	312.7	5.68	0.00489	0.128E 08	15.1
3	10.8	39.0	38.1	28.8	318.0	5.57	0.00767	0.133E 08	14.9
4	14.9	39.5	39.0	29.6	323.4	5.47	0.01060	0.138E 08	15.0
5	20.7	40.5	40.1	30.8	331.2	5.32	0.01477	0.146E 08	15.2
6	26.3	41.5	41.2	31.9	338.7	5.19	0.01882	0.153E 08	15.3
7	32.0	42.4	41.9	33.1	346.7	5.06	0.02296	0.162E 08	15.8
8	37.7	43.5	43.0	34.2	354.8	4.93	0.02712	0.170E 08	15.8
9	43.7	45.1	44.0	35.4	363.6	4.80	0.03152	0.179E 08	15.8
10	49.5	46.1	45.0	36.6	372.3	4.67	0.03579	0.188E 08	16.0
11	57.5	47.3	46.2	38.2	384.7	4.51	0.04173	0.201E 08	16.8
12	65.2	49.1	48.5	39.8	397.0	4.35	0.04747	0.213E 08	15.7
13	73.9	50.6	49.5	41.5	411.5	4.18	0.05400	0.228E 08	16.6
14	80.6	52.0	50.8	42.9	422.9	4.06	0.05905	0.239E 08	16.6
15	88.4	53.5	52.4	44.5	436.6	3.92	0.06495	0.253E 08	16.6
16	96.1	54.8	54.3	46.0	450.5	3.79	0.07079	0.267E 08	16.4
17	107.5	57.6	56.7	48.3	471.8	3.61	0.07947	0.288E 08	15.8
18	119.3	59.7	58.6	50.7	491.8	3.45	0.08844	0.309E 08	16.4
19	130.8	62.0	61.2	53.0	504.8	3.35	0.09728	0.326E 08	16.1
20	142.5	63.9	63.4	55.4	519.1	3.25	0.10634	0.343E 08	16.6
21	154.1	67.0	65.4	57.7	534.5	3.14	0.11539	0.360E 08	16.3
22	165.3	68.9	68.1	60.0	550.6	3.04	0.12418	0.378E 08	16.0
23	190.5	73.0	72.7	65.1	592.1	2.81	0.14417	0.421E 08	17.4

FULLY DEVELOPED NUSSELT NUMBER =16.3

RUN NUMBER (11)   TUBE NUMBER 1

INPUT POWER = 703.0 W   HEAT RATE GAINED BY WATER = 651.4 W   HEAT BALANCE ERROR = 7.3%

REM = 487.7   RAM = 0.324E 08   PRM = 3.48

UPSTREAM BULK TEMPERATURE =26.1 DEG C   DOWNSTREAM BULK TEMPERATURE =73.8 DEG C

INLET BULK TEMPERATURE =26.5 DEG C   OUTLET BULK TEMPERATURE =74.9 DEG C

MASS FLOW RATE = 11.8 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
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1	3.0	36.7	36.0	27.2	307.1	5.80	0.00212	0.130E 08	16.9
2	6.9	38.5	37.8	28.0	312.7	5.68	0.00489	0.136E 08	15.2
3	10.8	39.6	38.7	28.9	318.3	5.57	0.00767	0.141E 08	15.0
4	14.9	40.2	39.6	29.7	324.1	5.45	0.01061	0.147E 08	15.2
5	20.7	41.2	40.8	31.0	332.3	5.30	0.01478	0.156E 08	15.3
6	26.3	42.2	41.9	32.2	340.4	5.16	0.01883	0.165E 08	15.5
7	32.0	43.2	42.6	33.4	348.9	5.02	0.02297	0.175E 08	16.1
8	37.7	44.4	43.9	34.6	357.6	4.89	0.02714	0.184E 08	16.0
9	43.7	46.0	44.9	35.9	367.1	4.75	0.03155	0.194E 08	16.0
10	49.5	47.0	45.8	37.2	376.5	4.61	0.03584	0.205E 08	16.4
11	57.5	48.3	47.1	38.9	389.8	4.44	0.04179	0.219E 08	17.2
12	65.2	50.2	49.5	40.5	403.1	4.28	0.04755	0.233E 08	16.1
13	73.9	51.7	50.6	42.4	418.7	4.10	0.05409	0.250E 08	17.2
14	80.6	53.2	51.9	43.8	431.1	3.98	0.05915	0.263E 08	17.3
15	88.4	54.8	53.6	45.5	446.0	3.83	0.06507	0.279E 08	17.3
16	96.1	56.1	55.6	47.2	461.1	3.70	0.07092	0.295E 08	17.1
17	107.5	59.1	58.2	49.6	484.2	3.51	0.07960	0.320E 08	16.5
18	119.3	61.3	60.2	52.1	499.8	3.39	0.08862	0.340E 08	17.3
19	130.8	63.7	62.8	54.6	514.4	3.28	0.09751	0.359E 08	17.0
20	142.5	65.7	65.2	57.1	530.5	3.17	0.10661	0.379E 08	17.6
21	154.1	68.9	67.3	59.6	548.0	3.06	0.11571	0.400E 08	17.4
22	165.3	70.9	70.0	62.0	566.4	2.95	0.12455	0.421E 08	17.3
23	190.5	75.2	74.9	67.4	614.5	2.70	0.14468	0.472E 08	18.9

FULLY DEVELOPED NUSSELT NUMBER =17.0

RUN NUMBER (12) TUBE NUMBER 1

INPUT POWER = 95.0 W HEAT RATE GAINED BY WATER = 91.3 W HEAT BALANCE ERROR = 3.9%

REM = 507.9 RAM = 0.188E 07 PRM = 5.60

UPSTREAM BULK TEMPERATURE =26.5 DEG C DOWNSTREAM BULK TEMPERATURE =30.7 DEG C

INLET BULK TEMPERATURE =26.5 DEG C OUTLET BULK TEMPERATURE =30.6 DEG C

MASS FLOW RATE = 18.9 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	3.0	28.0	27.9	26.6	486.5	5.88	0.00132	0.170E 07	15.9
2	6.9	28.4	28.3	26.7	487.3	5.87	0.00303	0.171E 07	12.4
3	10.8	28.7	28.6	26.7	488.1	5.86	0.00475	0.172E 07	10.8
4	14.9	28.8	28.7	26.8	488.9	5.85	0.00655	0.172E 07	10.7
5	20.7	29.0	29.0	26.9	490.0	5.83	0.00911	0.173E 07	10.0
6	26.3	29.2	29.1	27.0	491.1	5.82	0.01158	0.174E 07	9.7
7	32.0	29.3	29.2	27.1	492.2	5.80	0.01409	0.175E 07	9.8
8	37.7	29.4	29.4	27.2	493.3	5.79	0.01660	0.176E 07	9.8
9	43.7	29.6	29.5	27.3	494.5	5.77	0.01925	0.177E 07	9.5
10	49.5	29.6	29.5	27.4	495.6	5.76	0.02182	0.178E 07	9.8
11	57.5	29.7	29.5	27.6	497.1	5.74	0.02535	0.179E 07	10.4
12	65.2	29.8	29.8	27.7	498.6	5.72	0.02876	0.180E 07	10.1
13	73.9	29.9	29.8	27.9	500.3	5.70	0.03261	0.182E 07	10.6
14	80.6	29.9	29.8	28.0	501.6	5.68	0.03558	0.183E 07	11.0
15	88.4	30.0	29.9	28.1	503.1	5.66	0.03904	0.184E 07	11.5
16	96.1	30.1	30.0	28.3	504.6	5.64	0.04246	0.185E 07	11.7
17	107.5	30.4	30.3	28.5	506.8	5.61	0.04752	0.187E 07	11.2
18	119.3	30.6	30.5	28.7	509.1	5.59	0.05277	0.189E 07	11.4
19	130.8	30.7	30.6	28.9	511.3	5.56	0.05789	0.191E 07	11.6
20	142.5	30.9	30.8	29.1	513.5	5.53	0.06310	0.193E 07	11.7
21	154.1	31.2	31.0	29.3	515.7	5.50	0.06828	0.195E 07	11.6
22	165.3	31.5	31.3	29.5	517.8	5.48	0.07328	0.196E 07	11.0
23	190.5	31.9	31.8	30.0	522.6	5.42	0.08455	0.201E 07	11.1

FULLY DEVELOPED NUSSELT NUMBER =10.9

RUN NUMBER (13) TUBE NUMBER 1

INPUT POWER = 297.0 W HEAT RATE GAINED BY WATER = 292.1 W HEAT BALANCE ERROR = 1.7%

REM = 557.3 RAM = 0.704E 07 PRM = 5.05

UPSTREAM BULK TEMPERATURE =26.5 DEG C DOWNSTREAM BULK TEMPERATURE =39.8 DEG C

INLET BULK TEMPERATURE =26.6 DEG C OUTLET BULK TEMPERATURE =38.9 DEG C

MASS FLOW RATE = 18.9 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	3.0	31.3	30.9	26.8	488.6	5.85	0.00132	0.521E 07	14.6
2	6.9	32.2	31.9	27.0	490.9	5.82	0.00304	0.527E 07	12.5
3	10.8	32.7	32.4	27.2	493.2	5.79	0.00476	0.533E 07	11.8
4	14.9	33.0	32.8	27.4	495.7	5.76	0.00657	0.539E 07	11.5
5	20.7	33.4	33.3	27.8	499.1	5.71	0.00913	0.547E 07	11.2
6	26.3	33.8	33.7	28.1	502.3	5.67	0.01161	0.556E 07	11.0
7	32.0	34.0	33.9	28.4	505.7	5.63	0.01414	0.564E 07	11.3
8	37.7	34.3	34.2	28.7	509.0	5.59	0.01667	0.572E 07	11.3
9	43.7	34.8	34.3	29.0	512.5	5.54	0.01935	0.581E 07	11.3
10	49.5	35.0	34.5	29.3	515.8	5.50	0.02193	0.590E 07	11.6
11	57.5	35.2	34.7	29.8	520.4	5.45	0.02551	0.602E 07	12.1
12	65.2	35.7	35.4	30.2	524.9	5.40	0.02895	0.614E 07	11.7
13	73.9	36.1	35.5	30.7	529.9	5.34	0.03285	0.628E 07	12.2
14	80.6	36.3	35.9	31.0	533.8	5.30	0.03586	0.639E 07	12.3
15	88.4	36.8	36.3	31.5	538.4	5.25	0.03936	0.652E 07	12.3
16	96.1	37.1	36.9	31.9	543.0	5.20	0.04284	0.665E 07	12.2
17	107.5	38.0	37.6	32.5	549.8	5.13	0.04799	0.684E 07	11.7
18	119.3	38.6	38.2	33.1	557.0	5.05	0.05333	0.704E 07	11.8
19	130.8	39.2	38.9	33.8	564.1	4.98	0.05856	0.723E 07	11.8
20	142.5	39.7	39.5	34.4	571.4	4.91	0.06389	0.744E 07	11.9
21	154.1	40.7	40.0	35.0	578.8	4.84	0.06919	0.764E 07	11.7
22	165.3	41.3	40.9	35.7	586.0	4.77	0.07432	0.784E 07	11.3
23	190.5	42.5	42.3	37.0	602.5	4.63	0.08592	0.830E 07	11.6

FULLY DEVELOPED NUSSELT NUMBER =11.8

RUN NUMBER (14) TUBE NUMBER 1

INPUT POWER = 488.0 W HEAT RATE GAINED BY WATER = 467.2 W HEAT BALANCE ERROR = 4.3%

REM = 606.3 RAM = 0.136E 08 PRM = 4.60

UPSTREAM BULK TEMPERATURE =26.7 DEG C DOWNSTREAM BULK TEMPERATURE =48.0 DEG C

INLET BULK TEMPERATURE =26.9 DEG C OUTLET BULK TEMPERATURE =46.8 DEG C

MASS FLOW RATE = 18.9 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	3.0	34.0	33.5	27.1	492.3	5.80	0.00132	0.860E 07	15.5
2	6.9	35.2	34.7	27.5	496.0	5.75	0.00304	0.875E 07	13.6
3	10.8	36.0	35.4	27.8	499.7	5.71	0.00476	0.890E 07	13.0
4	14.9	36.3	36.0	28.2	503.6	5.66	0.00658	0.906E 07	12.8
5	20.7	36.8	36.7	28.7	509.1	5.59	0.00916	0.929E 07	12.6
6	26.3	37.4	37.3	29.2	514.3	5.52	0.01165	0.951E 07	12.5
7	32.0	37.6	37.4	29.7	519.7	5.46	0.01419	0.973E 07	13.0
8	37.7	38.2	37.8	30.2	525.1	5.40	0.01674	0.996E 07	13.0
9	43.7	38.9	38.1	30.7	530.7	5.33	0.01943	0.102E 08	13.1
10	49.5	39.3	38.4	31.2	536.2	5.27	0.02203	0.105E 08	13.4
11	57.5	39.5	38.8	32.0	543.8	5.19	0.02563	0.108E 08	14.1
12	65.2	40.4	39.9	32.6	551.3	5.11	0.02911	0.112E 08	13.5
13	73.9	40.9	40.2	33.4	559.9	5.02	0.03306	0.115E 08	14.1
14	80.6	41.5	40.8	34.0	566.7	4.96	0.03610	0.119E 08	14.1
15	88.4	42.2	41.5	34.7	574.6	4.88	0.03966	0.122E 08	14.0
16	96.1	42.8	42.5	35.4	582.6	4.80	0.04318	0.126E 08	13.8
17	107.5	44.3	43.7	36.4	594.6	4.70	0.04841	0.131E 08	13.2
18	119.3	45.2	44.5	37.4	607.4	4.59	0.05385	0.137E 08	13.4
19	130.8	46.3	45.8	38.4	620.1	4.48	0.05917	0.142E 08	13.2
20	142.5	47.1	46.7	39.5	633.3	4.38	0.06461	0.148E 08	13.4
21	154.1	48.6	47.6	40.5	646.6	4.28	0.07002	0.154E 08	13.2
22	165.3	49.5	48.9	41.5	659.8	4.19	0.07526	0.160E 08	12.9
23	190.5	51.5	51.2	43.7	690.3	3.99	0.08710	0.174E 08	13.1

FULLY DEVELOPED NUSSELT NUMBER =13.5

RUN NUMBER (15) TUBE NUMBER 1

INPUT POWER = 657.0 W HEAT RATE GAINED BY WATER = 632.7 W HEAT BALANCE ERROR = 3.7%

REM = 656.1 RAM = 0.217E 08 PRM = 4.21

UPSTREAM BULK TEMPERATURE =26.8 DEG C DOWNSTREAM BULK TEMPERATURE =55.7 DEG C

INLET BULK TEMPERATURE =27.0 DEG C OUTLET BULK TEMPERATURE =54.4 DEG C

MASS FLOW RATE = 18.9 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	3.0	36.3	35.6	27.4	495.1	5.77	0.00132	0.120E 08	16.4
2	6.9	37.7	37.1	27.9	500.2	5.70	0.00304	0.122E 08	14.7
3	10.8	38.6	37.9	28.3	505.2	5.63	0.00477	0.125E 08	14.1
4	14.9	39.0	38.6	28.8	510.6	5.57	0.00659	0.128E 08	14.0
5	20.7	39.7	39.5	29.5	518.0	5.48	0.00918	0.133E 08	13.9
6	26.3	40.4	40.1	30.2	525.3	5.39	0.01168	0.137E 08	13.9
7	32.0	40.8	40.4	30.9	532.6	5.31	0.01423	0.141E 08	14.4
8	37.7	41.4	41.1	31.6	540.0	5.23	0.01679	0.146E 08	14.4
9	43.7	42.4	41.4	32.3	548.0	5.14	0.01950	0.151E 08	14.5
10	49.5	42.9	41.8	33.0	555.8	5.06	0.02212	0.156E 08	14.9
11	57.5	43.3	42.4	34.0	566.8	4.95	0.02576	0.163E 08	15.7
12	65.2	44.6	43.9	34.9	577.6	4.85	0.02927	0.169E 08	14.9
13	73.9	45.4	44.4	36.0	590.1	4.74	0.03325	0.177E 08	15.6
14	80.6	46.2	45.2	36.8	599.9	4.65	0.03633	0.183E 08	15.6
15	88.4	47.2	46.2	37.8	611.6	4.55	0.03993	0.190E 08	15.4
16	96.1	48.0	47.5	38.7	623.3	4.46	0.04350	0.197E 08	15.2
17	107.5	50.0	49.1	40.1	641.1	4.32	0.04880	0.208E 08	14.5
18	119.3	51.3	50.3	41.5	660.1	4.19	0.05432	0.220E 08	14.8
19	130.8	52.6	51.9	42.9	679.1	4.06	0.05971	0.231E 08	14.6
20	142.5	53.7	53.2	44.3	698.9	3.93	0.06523	0.243E 08	14.9
21	154.1	55.8	54.3	45.7	719.1	3.81	0.07071	0.256E 08	14.7
22	165.3	56.9	56.1	47.1	739.1	3.70	0.07601	0.268E 08	14.4
23	190.5	59.4	59.0	50.2	784.7	3.47	0.08793	0.295E 08	14.9

FULLY DEVELOPED NUSSELT NUMBER =14.9

RUN NUMBER (16) TUBE NUMBER 1

INPUT POWER = 750.0 W HEAT RATE GAINED BY WATER = 725.1 W HEAT BALANCE ERROR = 3.3%

REM = 678.7 RAM = 0.266E 08 PRM = 4.06

UPSTREAM BULK TEMPERATURE =26.3 DEG C DOWNSTREAM BULK TEMPERATURE =59.4 DEG C

INLET BULK TEMPERATURE =26.6 DEG C OUTLET BULK TEMPERATURE =58.0 DEG C

MASS FLOW RATE = 18.9 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	3.0	37.0	36.2	27.0	491.2	5.82	0.00132	0.135E 08	16.8
2	6.9	38.7	38.0	27.6	497.0	5.74	0.00304	0.139E 08	14.9
3	10.8	39.6	38.8	28.1	502.9	5.66	0.00477	0.142E 08	14.5
4	14.9	40.1	39.7	28.7	509.0	5.59	0.00659	0.146E 08	14.3
5	20.7	40.9	40.6	29.5	517.6	5.48	0.00918	0.152E 08	14.2
6	26.3	41.6	41.4	30.3	525.9	5.39	0.01168	0.158E 08	14.3
7	32.0	42.1	41.6	31.1	534.3	5.29	0.01424	0.164E 08	14.8
8	37.7	42.8	42.3	31.9	542.9	5.20	0.01680	0.170E 08	14.9
9	43.7	44.0	42.8	32.7	552.1	5.10	0.01952	0.176E 08	14.9
10	49.5	44.5	43.2	33.5	561.2	5.01	0.02215	0.183E 08	15.5
11	57.5	45.0	43.9	34.6	574.0	4.89	0.02579	0.192E 08	16.2
12	65.2	46.4	45.6	35.7	586.6	4.77	0.02932	0.201E 08	15.4
13	73.9	47.4	46.3	36.9	601.2	4.64	0.03332	0.211E 08	16.0
14	80.6	48.3	47.2	37.9	612.7	4.54	0.03642	0.219E 08	16.0
15	88.4	49.4	48.4	38.9	626.4	4.43	0.04004	0.229E 08	15.9
16	96.1	50.5	49.9	40.0	640.3	4.33	0.04362	0.239E 08	15.5
17	107.5	52.7	51.7	41.6	661.3	4.18	0.04895	0.253E 08	14.9
18	119.3	54.0	53.0	43.3	683.8	4.03	0.05450	0.269E 08	15.3
19	130.8	55.1	54.7	44.9	706.4	3.89	0.05993	0.285E 08	15.5
20	142.5	56.9	56.3	46.5	730.0	3.75	0.06546	0.301E 08	15.4
21	154.1	59.2	57.6	48.1	754.1	3.62	0.07096	0.318E 08	15.1
22	165.3	60.5	59.6	49.7	778.0	3.50	0.07627	0.334E 08	14.9
23	190.5	63.4	63.0	53.2	811.8	3.34	0.08831	0.363E 08	15.4

FULLY DEVELOPED NUSSELT NUMBER =15.4

RUN NUMBER (17) TUBE NUMBER 1

INPUT POWER = 877.0 W HEAT RATE GAINED BY WATER = 814.0 W HEAT BALANCE ERROR = 7.2%

REM = 709.6 RAM = 0.323E 08 PRM = 3.87

UPSTREAM BULK TEMPERATURE =26.5 DEG C DOWNSTREAM BULK TEMPERATURE =63.7 DEG C

INLET BULK TEMPERATURE =26.8 DEG C OUTLET BULK TEMPERATURE =62.2 DEG C

MASS FLOW RATE = 18.9 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	3.0	38.3	37.5	27.3	493.8	5.78	0.00132	0.154E 08	17.1
2	6.9	40.1	39.3	27.9	500.4	5.70	0.00304	0.159E 08	15.3
3	10.8	41.2	40.2	28.5	507.0	5.61	0.00477	0.163E 08	14.9
4	14.9	41.6	41.1	29.1	513.9	5.53	0.00660	0.168E 08	14.8
5	20.7	42.4	42.1	30.1	523.6	5.41	0.00919	0.176E 08	14.8
6	26.3	43.3	43.0	30.9	532.9	5.31	0.01170	0.183E 08	14.8
7	32.0	43.7	43.2	31.8	542.5	5.20	0.01426	0.191E 08	15.4
8	37.7	44.7	44.0	32.7	552.4	5.10	0.01684	0.199E 08	15.5
9	43.7	45.9	44.6	33.7	563.0	4.99	0.01956	0.207E 08	15.5
10	49.5	46.5	45.1	34.6	573.4	4.89	0.02220	0.216E 08	16.0
11	57.5	47.1	45.8	35.8	588.2	4.75	0.02586	0.228E 08	16.8
12	65.2	48.7	47.8	37.1	602.8	4.63	0.02941	0.239E 08	15.9
13	73.9	49.8	48.4	38.4	619.8	4.49	0.03343	0.253E 08	16.6
14	80.6	50.8	49.5	39.5	633.2	4.38	0.03654	0.263E 08	16.6
15	88.4	52.1	50.8	40.7	649.1	4.26	0.04018	0.276E 08	16.5
16	96.1	53.1	52.5	41.9	665.3	4.15	0.04379	0.289E 08	16.2
17	107.5	55.6	54.5	43.7	689.9	3.99	0.04915	0.308E 08	15.5
18	119.3	57.1	55.9	45.6	716.3	3.83	0.05472	0.328E 08	16.1
19	130.8	59.0	57.9	47.4	742.8	3.68	0.06017	0.349E 08	15.8
20	142.5	60.4	59.7	49.2	770.7	3.54	0.06571	0.371E 08	16.1
21	154.1	62.9	61.1	51.0	792.1	3.44	0.07121	0.389E 08	15.9
22	165.3	64.4	63.3	52.8	808.0	3.36	0.07658	0.405E 08	15.7
23	190.5	67.6	67.1	56.7	847.3	3.19	0.08876	0.441E 08	16.1

FULLY DEVELOPED NUSSELT NUMBER =16.1

RUN NUMBER (18) TUBE NUMBER 1

INPUT POWER = 200.0 W HEAT RATE GAINED BY WATER = 191.3 W HEAT BALANCE ERROR = 4.4%

REM = 642.8 RAM = 0.331E 07 PRM = 5.76

UPSTREAM BULK TEMPERATURE =24.1 DEG C DOWNSTREAM BULK TEMPERATURE =30.8 DEG C

INLET BULK TEMPERATURE =24.1 DEG C OUTLET BULK TEMPERATURE =29.9 DEG C

MASS FLOW RATE = 24.5 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	3.0	27.2	27.1	24.2	597.6	6.26	0.00101	0.279E 07	13.3
2	6.9	28.0	27.8	24.3	599.0	6.24	0.00232	0.280E 07	10.9
3	10.8	28.5	28.3	24.4	600.4	6.23	0.00363	0.282E 07	9.8
4	14.9	28.6	28.6	24.5	601.9	6.21	0.00501	0.284E 07	9.5
5	20.7	28.9	28.9	24.7	604.0	6.18	0.00697	0.286E 07	9.2
6	26.3	29.1	29.1	24.8	606.1	6.16	0.00886	0.288E 07	9.0
7	32.0	29.3	29.2	25.0	608.2	6.14	0.01079	0.291E 07	9.0
8	37.7	29.4	29.4	25.1	610.2	6.11	0.01271	0.293E 07	9.0
9	43.7	29.7	29.5	25.3	612.4	6.09	0.01474	0.296E 07	9.0
10	49.5	29.8	29.5	25.4	614.5	6.06	0.01671	0.298E 07	9.2
11	57.5	29.8	29.6	25.6	617.4	6.03	0.01942	0.301E 07	9.5
12	65.2	30.1	29.9	25.8	620.2	6.00	0.02203	0.305E 07	9.3
13	73.9	30.2	29.9	26.0	623.4	5.97	0.02499	0.308E 07	9.6
14	80.6	30.3	30.0	26.2	625.9	5.94	0.02727	0.311E 07	9.9
15	88.4	30.4	30.2	26.4	628.7	5.91	0.02993	0.314E 07	10.0
16	96.1	30.6	30.4	26.6	631.5	5.88	0.03256	0.318E 07	9.9
17	107.5	31.1	30.8	26.9	635.6	5.84	0.03645	0.323E 07	9.6
18	119.3	31.4	31.1	27.2	639.9	5.79	0.04049	0.328E 07	9.6
19	130.8	31.6	31.4	27.5	644.1	5.75	0.04443	0.333E 07	9.7
20	142.5	31.8	31.7	27.8	648.3	5.71	0.04845	0.338E 07	9.9
21	154.1	32.4	32.0	28.1	652.5	5.67	0.05243	0.343E 07	9.6
22	165.3	32.7	32.4	28.4	656.5	5.63	0.05629	0.347E 07	9.4
23	190.5	33.2	33.2	29.0	665.5	5.54	0.06499	0.358E 07	9.3

FULLY DEVELOPED NUSSELT NUMBER = 9.5

RUN NUMBER (19)   TUBE NUMBER 1

INPUT POWER = 378.0 W   HEAT RATE GAINED BY WATER = 374.4 W   HEAT BALANCE ERROR = 1.0%

REM = 686.6   RAM = 0.776E 07   PRM = 5.35

UPSTREAM BULK TEMPERATURE =24.0 DEG C   DOWNSTREAM BULK TEMPERATURE =37.2 DEG C

INLET BULK TEMPERATURE =24.1 DEG C   OUTLET BULK TEMPERATURE =35.9 DEG C

MASS FLOW RATE = 24.5 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	3.0	29.9	29.6	24.3	598.7	6.25	0.00101	0.564E 07	14.3
2	6.9	31.1	30.8	24.5	601.6	6.21	0.00232	0.571E 07	12.2
3	10.8	31.7	31.4	24.7	604.5	6.18	0.00364	0.577E 07	11.4
4	14.9	32.0	31.8	24.9	607.5	6.14	0.00502	0.584E 07	11.1
5	20.7	32.5	32.4	25.2	611.7	6.10	0.00698	0.594E 07	10.9
6	26.3	32.9	32.9	25.5	615.8	6.05	0.00888	0.604E 07	10.6
7	32.0	33.1	32.9	25.8	620.0	6.00	0.01081	0.613E 07	10.9
8	37.7	33.4	33.2	26.1	624.2	5.96	0.01275	0.623E 07	10.8
9	43.7	33.9	33.4	26.4	628.6	5.91	0.01479	0.633E 07	10.8
10	49.5	34.1	33.4	26.7	632.9	5.87	0.01677	0.643E 07	11.1
11	57.5	34.1	33.6	27.1	638.7	5.80	0.01951	0.657E 07	11.7
12	65.2	34.6	34.2	27.5	644.3	5.75	0.02215	0.671E 07	11.3
13	73.9	34.9	34.3	28.0	650.7	5.68	0.02514	0.686E 07	11.8
14	80.6	35.1	34.6	28.3	655.5	5.64	0.02744	0.698E 07	12.0
15	88.4	35.5	34.9	28.7	661.2	5.58	0.03013	0.711E 07	12.1
16	96.1	35.8	35.6	29.1	666.7	5.53	0.03279	0.725E 07	11.9
17	107.5	36.8	36.3	29.7	674.8	5.45	0.03674	0.745E 07	11.4
18	119.3	37.2	36.8	30.3	683.3	5.38	0.04083	0.767E 07	11.7
19	130.8	37.8	37.4	30.9	691.6	5.31	0.04483	0.789E 07	11.6
20	142.5	38.3	38.0	31.6	700.1	5.23	0.04891	0.812E 07	11.7
21	154.1	39.3	38.5	32.2	708.7	5.16	0.05296	0.835E 07	11.6
22	165.3	39.8	39.3	32.7	717.0	5.10	0.05689	0.857E 07	11.3
23	190.5	41.0	40.7	34.1	736.3	4.95	0.06576	0.908E 07	11.4

FULLY DEVELOPED NUSSELT NUMBER =11.5

RUN NUMBER (20)   TUBE NUMBER 1

INPUT POWER = 590.0 W   HEAT RATE GAINED BY WATER = 557.5 W   HEAT BALANCE ERROR = 5.5%

REM = 731.7   RAM = 0.136E 08   PRM = 4.98

UPSTREAM BULK TEMPERATURE =23.9 DEG C   DOWNSTREAM BULK TEMPERATURE =43.6 DEG C

INLET BULK TEMPERATURE =24.1 DEG C   OUTLET BULK TEMPERATURE =42.0 DEG C

MASS FLOW RATE = 24.5 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE --	PR --	X+ --	RA --	NU (AVERAGE)
1	3.0	32.5	32.0	24.4	599.8	6.23	0.00101	0.861E 07	15.1
2	6.9	34.1	33.5	24.7	604.2	6.18	0.00232	0.876E 07	13.1
3	10.8	34.8	34.2	25.0	608.5	6.13	0.00364	0.892E 07	12.5
4	14.9	35.2	34.9	25.3	613.1	6.08	0.00503	0.908E 07	12.2
5	20.7	35.8	35.6	25.8	619.6	6.01	0.00699	0.930E 07	12.0
6	26.3	36.3	36.2	26.2	625.8	5.94	0.00890	0.953E 07	11.9
7	32.0	36.5	36.3	26.7	632.2	5.87	0.01084	0.975E 07	12.2
8	37.7	36.9	36.7	27.1	638.5	5.81	0.01279	0.998E 07	12.2
9	43.7	37.7	36.9	27.6	645.2	5.74	0.01485	0.102E 08	12.2
10	49.5	37.9	36.9	28.0	651.6	5.67	0.01684	0.105E 08	12.7
11	57.5	37.9	37.1	28.7	660.4	5.59	0.01960	0.108E 08	13.4
12	65.2	38.8	38.2	29.3	668.8	5.51	0.02226	0.111E 08	12.9
13	73.9	39.2	38.4	30.0	678.2	5.42	0.02527	0.114E 08	13.4
14	80.6	39.6	38.7	30.5	685.6	5.36	0.02760	0.117E 08	13.6
15	88.4	40.2	39.4	31.1	694.1	5.29	0.03031	0.121E 08	13.6
16	96.1	40.7	40.3	31.7	702.7	5.21	0.03300	0.124E 08	13.4
17	107.5	42.1	41.4	32.6	715.5	5.11	0.03699	0.130E 08	12.9
18	119.3	42.8	42.1	33.6	729.1	5.00	0.04114	0.135E 08	13.2
19	130.8	43.7	43.1	34.5	742.7	4.90	0.04520	0.141E 08	13.1
20	142.5	44.4	44.0	35.4	756.7	4.80	0.04935	0.146E 08	13.3
21	154.1	46.0	44.6	36.3	770.9	4.70	0.05347	0.152E 08	13.1
22	165.3	46.7	45.9	37.2	784.9	4.61	0.05747	0.158E 08	12.9
23	190.5	48.3	47.9	39.2	817.4	4.41	0.06652	0.171E 08	13.1

FULLY DEVELOPED NUSSELT NUMBER =13.1

RUN NUMBER (21)   TUBE NUMBER 1

INPUT POWER = 703.0 W   HEAT RATE GAINED BY WATER = 660.1 W   HEAT BALANCE ERROR = 6.1%

REM = 759.8   RAM = 0.177E 08   PRM = 4.78

UPSTREAM BULK TEMPERATURE =24.0 DEG C   DOWNSTREAM BULK TEMPERATURE =47.2 DEG C

INLET BULK TEMPERATURE =24.2 DEG C   OUTLET BULK TEMPERATURE =45.6 DEG C

MASS FLOW RATE = 24.5 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	3.0	34.0	33.3	24.5	601.7	6.21	0.00101	0.104E 08	15.7
2	6.9	35.6	35.0	24.9	606.9	6.15	0.00232	0.106E 08	13.8
3	10.8	36.4	35.7	25.2	612.1	6.09	0.00364	0.109E 08	13.2
4	14.9	36.8	36.4	25.6	617.6	6.03	0.00503	0.111E 08	13.0
5	20.7	37.5	37.3	26.2	625.4	5.95	0.00700	0.114E 08	12.7
6	26.3	38.1	37.9	26.7	632.9	5.87	0.00891	0.117E 08	12.6
7	32.0	38.4	38.1	27.2	640.5	5.79	0.01086	0.121E 08	13.0
8	37.7	38.9	38.5	27.8	648.1	5.71	0.01282	0.124E 08	13.0
9	43.7	39.7	38.8	28.4	656.0	5.63	0.01488	0.127E 08	13.1
10	49.5	40.0	38.9	28.9	663.6	5.56	0.01688	0.131E 08	13.5
11	57.5	40.1	39.1	29.7	674.1	5.46	0.01965	0.136E 08	14.3
12	65.2	41.1	40.3	30.4	684.2	5.37	0.02232	0.140E 08	13.8
13	73.9	41.6	40.6	31.2	695.6	5.27	0.02534	0.146E 08	14.3
14	80.6	42.1	41.1	31.9	704.6	5.20	0.02768	0.150E 08	14.5
15	88.4	42.8	41.8	32.6	715.1	5.11	0.03042	0.155E 08	14.5
16	96.1	43.4	42.9	33.3	725.8	5.03	0.03312	0.161E 08	14.3
17	107.5	45.1	44.2	34.4	741.8	4.91	0.03714	0.168E 08	13.7
18	119.3	46.0	45.1	35.6	758.8	4.79	0.04132	0.177E 08	14.0
19	130.8	47.0	46.2	36.6	775.8	4.67	0.04542	0.185E 08	14.0
20	142.5	47.9	47.4	37.8	793.6	4.55	0.04960	0.193E 08	14.1
21	154.1	49.6	48.2	38.9	811.5	4.44	0.05377	0.202E 08	13.9
22	165.3	50.5	49.6	39.9	829.3	4.34	0.05781	0.210E 08	13.7
23	190.5	52.5	52.0	42.3	870.7	4.11	0.06694	0.230E 08	13.9

FULLY DEVELOPED NUSSELT NUMBER =13.9

RUN NUMBER (23) TUBE NUMBER 1

INPUT POWER = 930.0 W HEAT RATE GAINED BY WATER = 863.7 W HEAT BALANCE ERROR = 7.1%

REM = 818.9 RAM = 0.276E 08 PRM = 4.40

UPSTREAM BULK TEMPERATURE =24.1 DEG C DOWNSTREAM BULK TEMPERATURE =54.5 DEG C

INLET BULK TEMPERATURE =24.4 DEG C OUTLET BULK TEMPERATURE =53.1 DEG C

MASS FLOW RATE = 24.5 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	3.0	36.6	35.8	24.7	605.3	6.17	0.00101	0.142E 08	16.8
2	6.9	38.5	37.7	25.2	612.3	6.09	0.00233	0.146E 08	15.0
3	10.8	39.5	38.5	25.7	619.3	6.01	0.00365	0.150E 08	14.5
4	14.9	39.9	39.4	26.3	626.7	5.93	0.00504	0.154E 08	14.3
5	20.7	40.8	40.5	27.0	637.1	5.82	0.00702	0.160E 08	14.0
6	26.3	41.4	41.3	27.7	647.1	5.72	0.00894	0.166E 08	14.0
7	32.0	41.8	41.4	28.4	657.2	5.62	0.01090	0.172E 08	14.5
8	37.7	42.6	42.0	29.2	667.2	5.52	0.01287	0.178E 08	14.5
9	43.7	43.6	42.4	29.9	677.7	5.43	0.01494	0.184E 08	14.6
10	49.5	44.0	42.6	30.7	688.0	5.34	0.01695	0.191E 08	15.1
11	57.5	44.2	42.8	31.7	702.2	5.22	0.01974	0.200E 08	16.1
12	65.2	45.5	44.5	32.7	716.2	5.10	0.02244	0.209E 08	15.4
13	73.9	46.2	44.9	33.8	732.4	4.98	0.02550	0.220E 08	16.1
14	80.6	46.9	45.6	34.6	745.1	4.88	0.02786	0.228E 08	16.3
15	88.4	47.9	46.6	35.6	760.3	4.78	0.03063	0.238E 08	16.2
16	96.1	48.7	48.1	36.6	775.6	4.67	0.03337	0.248E 08	16.0
17	107.5	50.9	49.8	38.1	798.8	4.52	0.03745	0.263E 08	15.3
18	119.3	52.0	51.0	39.6	823.6	4.37	0.04169	0.279E 08	15.7
19	130.8	53.5	52.4	41.1	848.6	4.23	0.04585	0.295E 08	15.7
20	142.5	54.4	53.8	42.5	874.7	4.09	0.05010	0.311E 08	16.1
21	154.1	56.8	54.8	44.0	901.4	3.96	0.05432	0.328E 08	15.9
22	165.3	57.7	56.6	45.5	927.8	3.84	0.05842	0.345E 08	15.8
23	190.5	60.5	59.7	48.7	989.7	3.58	0.06765	0.384E 08	16.1

FULLY DEVELOPED NUSSELT NUMBER =15.7

RUN NUMBER (24)   TUBE NUMBER 1

INPUT POWER =1041.0 W   HEAT RATE GAINED BY WATER =1001.0 W   HEAT BALANCE ERROR = 3.8%

REM = 860.1   RAM = 0.352E 08   PRM = 4.17

UPSTREAM BULK TEMPERATURE =24.1 DEG C   DOWNSTREAM BULK TEMPERATURE =59.3 DEG C

INLET BULK TEMPERATURE =24.4 DEG C   OUTLET BULK TEMPERATURE =57.9 DEG C

MASS FLOW RATE = 24.5 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	3.0	38.2	37.2	24.8	606.6	6.15	0.00101	0.166E 08	17.4
2	6.9	40.3	39.3	25.4	614.8	6.06	0.00233	0.172E 08	15.6
3	10.8	41.4	40.3	26.0	623.0	5.97	0.00365	0.177E 08	15.1
4	14.9	41.8	41.3	26.6	631.5	5.88	0.00505	0.183E 08	14.9
5	20.7	42.8	42.4	27.5	643.7	5.75	0.00703	0.191E 08	14.7
6	26.3	43.6	43.3	28.3	655.3	5.64	0.00895	0.199E 08	14.7
7	32.0	44.1	43.4	29.2	667.0	5.53	0.01092	0.207E 08	15.2
8	37.7	44.8	44.2	30.0	678.7	5.42	0.01289	0.215E 08	15.3
9	43.7	46.0	44.6	30.9	691.0	5.31	0.01498	0.225E 08	15.4
10	49.5	46.5	44.9	31.8	703.0	5.21	0.01700	0.234E 08	15.9
11	57.5	46.7	45.2	33.0	720.1	5.07	0.01980	0.247E 08	17.0
12	65.2	48.3	47.0	34.1	736.9	4.94	0.02251	0.260E 08	16.3
13	73.9	49.1	47.5	35.4	756.4	4.80	0.02559	0.274E 08	17.0
14	80.6	50.1	48.4	36.4	771.9	4.70	0.02797	0.286E 08	17.1
15	88.4	51.2	49.6	37.6	790.3	4.57	0.03076	0.300E 08	17.1
16	96.1	52.1	51.3	38.7	808.9	4.46	0.03352	0.314E 08	16.8
17	107.5	54.5	53.3	40.4	837.2	4.29	0.03763	0.335E 08	16.1
18	119.3	55.8	54.6	42.1	867.7	4.13	0.04191	0.358E 08	16.7
19	130.8	57.5	56.2	43.9	898.3	3.97	0.04610	0.381E 08	16.7
20	142.5	58.7	57.9	45.6	930.5	3.82	0.05037	0.404E 08	17.0
21	154.1	61.4	59.1	47.3	963.4	3.68	0.05462	0.429E 08	16.8
22	165.3	62.5	61.2	49.0	996.1	3.55	0.05872	0.453E 08	16.7
23	190.5	65.6	64.8	52.7	1048.1	3.36	0.06801	0.497E 08	17.1

FULLY DEVELOPED NUSSELT NUMBER =16.5

RUN NUMBER (25)   TUBE NUMBER 1

INPUT POWER = 200.0 W HEAT RATE GAINED BY WATER = 197.7 W HEAT BALANCE ERROR = 1.1%

REM = 765.8   RAM = 0.311E 07   PRM = 6.02

UPSTREAM BULK TEMPERATURE =22.9 DEG C   DOWNSTREAM BULK TEMPERATURE =28.5 DEG C

INLET BULK TEMPERATURE =22.9 DEG C   OUTLET BULK TEMPERATURE =27.8 DEG C

MASS FLOW RATE = 30.3 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	3.0	26.0	25.8	23.0	719.1	6.47	0.00081	0.267E 07	13.8
2	6.9	26.7	26.6	23.1	720.5	6.45	0.00187	0.268E 07	11.2
3	10.8	27.2	27.0	23.2	722.0	6.44	0.00292	0.269E 07	10.2
4	14.9	27.5	27.4	23.3	723.5	6.42	0.00403	0.271E 07	9.6
5	20.7	27.7	27.8	23.4	725.6	6.40	0.00561	0.273E 07	9.2
6	26.3	28.0	28.0	23.5	727.7	6.38	0.00713	0.275E 07	8.9
7	32.0	28.1	28.1	23.6	729.8	6.36	0.00868	0.277E 07	9.0
8	37.7	28.3	28.2	23.7	731.9	6.34	0.01022	0.279E 07	8.9
9	43.7	28.6	28.3	23.9	734.2	6.31	0.01186	0.281E 07	8.8
10	49.5	28.6	28.3	24.0	736.3	6.29	0.01344	0.283E 07	9.0
11	57.5	28.6	28.3	24.2	739.3	6.26	0.01562	0.285E 07	9.3
12	65.2	28.8	28.6	24.3	742.2	6.24	0.01772	0.288E 07	9.1
13	73.9	28.9	28.7	24.5	745.4	6.21	0.02009	0.291E 07	9.3
14	80.6	28.9	28.7	24.7	747.9	6.18	0.02192	0.294E 07	9.7
15	88.4	29.0	28.8	24.8	750.8	6.16	0.02406	0.296E 07	9.8
16	96.1	29.1	29.0	25.0	753.7	6.13	0.02617	0.299E 07	9.9
17	107.5	29.5	29.3	25.2	758.0	6.09	0.02929	0.303E 07	9.7
18	119.3	29.7	29.5	25.5	762.4	6.05	0.03254	0.307E 07	9.8
19	130.8	29.9	29.6	25.7	766.7	6.01	0.03570	0.311E 07	10.0
20	142.5	30.0	29.9	26.0	771.0	5.97	0.03892	0.316E 07	10.2
21	154.1	30.5	30.0	26.2	775.4	5.93	0.04212	0.320E 07	9.9
22	165.3	30.7	30.4	26.5	779.5	5.90	0.04522	0.324E 07	9.9
23	190.5	31.2	31.0	27.0	788.9	5.82	0.05219	0.333E 07	9.7

FULLY DEVELOPED NUSSELT NUMBER = 9.5

RUN NUMBER (26)   TUBE NUMBER 1

INPUT POWER = 432.0 W   HEAT RATE GAINED BY WATER = 426.5 W   HEAT BALANCE ERROR = 1.3%

REM = 815.4   RAM = 0.801E 07   PRM = 5.60

UPSTREAM BULK TEMPERATURE =22.5 DEG C   DOWNSTREAM BULK TEMPERATURE =34.6 DEG C

INLET BULK TEMPERATURE =22.6 DEG C   OUTLET BULK TEMPERATURE =33.4 DEG C

MASS FLOW RATE = 30.3 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	3.0	29.0	28.5	22.8	714.7	6.51	0.00081	0.586E 07	15.0
2	6.9	30.2	29.9	22.9	717.9	6.48	0.00187	0.593E 07	12.6
3	10.8	30.9	30.5	23.1	721.2	6.44	0.00292	0.599E 07	11.8
4	14.9	31.3	31.1	23.3	724.6	6.41	0.00404	0.606E 07	11.4
5	20.7	31.6	31.7	23.6	729.4	6.36	0.00561	0.616E 07	11.1
6	26.3	32.1	32.1	23.9	734.0	6.32	0.00714	0.626E 07	10.9
7	32.0	32.3	32.1	24.1	738.8	6.27	0.00869	0.636E 07	11.1
8	37.7	32.6	32.4	24.4	743.5	6.22	0.01025	0.646E 07	11.0
9	43.7	33.1	32.6	24.7	748.5	6.18	0.01189	0.656E 07	10.9
10	49.5	33.3	32.7	25.0	753.3	6.13	0.01348	0.666E 07	11.1
11	57.5	33.3	32.7	25.4	760.0	6.07	0.01567	0.681E 07	11.7
12	65.2	33.8	33.3	25.7	766.4	6.01	0.01779	0.694E 07	11.4
13	73.9	34.0	33.4	26.1	773.7	5.95	0.02019	0.710E 07	11.8
14	80.6	34.1	33.5	26.5	779.3	5.90	0.02205	0.722E 07	12.1
15	88.4	34.5	33.8	26.8	785.7	5.85	0.02421	0.736E 07	12.2
16	96.1	34.6	34.4	27.2	792.1	5.79	0.02634	0.750E 07	12.1
17	107.5	35.6	35.0	27.8	801.6	5.72	0.02952	0.770E 07	11.8
18	119.3	36.0	35.4	28.3	811.3	5.64	0.03281	0.792E 07	12.0
19	130.8	36.4	35.9	28.9	820.7	5.56	0.03603	0.813E 07	12.1
20	142.5	36.8	36.5	29.4	830.2	5.49	0.03931	0.835E 07	12.3
21	154.1	37.8	36.9	30.0	839.6	5.42	0.04257	0.856E 07	12.0
22	165.3	38.2	37.6	30.5	848.8	5.36	0.04572	0.878E 07	12.0
23	190.5	39.3	38.9	31.7	869.6	5.22	0.05284	0.929E 07	11.9

FULLY DEVELOPED NUSSELT NUMBER =11.8

RUN NUMBER (27) TUBE NUMBER 1

INPUT POWER = 680.0 W HEAT RATE GAINED BY WATER = 635.5 W HEAT BALANCE ERROR = 6.5%

REM = 865.3 RAM = 0.142E 08 PRM = 5.24

UPSTREAM BULK TEMPERATURE =22.4 DEG C DOWNSTREAM BULK TEMPERATURE =40.5 DEG C

INLET BULK TEMPERATURE =22.6 DEG C OUTLET BULK TEMPERATURE =39.3 DEG C

MASS FLOW RATE = 30.3 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	3.0	31.7	31.1	22.8	716.0	6.50	0.00081	0.911E 07	16.1
2	6.9	33.4	32.8	23.1	721.0	6.45	0.00187	0.927E 07	13.9
3	10.8	34.3	33.6	23.4	726.0	6.40	0.00293	0.943E 07	13.1
4	14.9	34.6	34.3	23.7	731.2	6.34	0.00404	0.960E 07	12.8
5	20.7	35.3	35.1	24.1	738.7	6.27	0.00562	0.984E 07	12.5
6	26.3	35.7	35.6	24.6	745.9	6.20	0.00715	0.101E 08	12.4
7	32.0	36.0	35.7	25.0	753.3	6.13	0.00871	0.103E 08	12.7
8	37.7	36.5	36.2	25.4	760.6	6.07	0.01028	0.106E 08	12.6
9	43.7	37.1	36.3	25.8	768.4	6.00	0.01193	0.108E 08	12.7
10	49.5	37.3	36.4	26.3	775.9	5.93	0.01353	0.111E 08	13.1
11	57.5	37.3	36.4	26.9	786.2	5.84	0.01575	0.114E 08	13.8
12	65.2	38.1	37.3	27.4	796.1	5.76	0.01789	0.117E 08	13.4
13	73.9	38.4	37.5	28.1	807.2	5.67	0.02031	0.121E 08	14.0
14	80.6	38.7	37.8	28.6	815.8	5.60	0.02218	0.124E 08	14.2
15	88.4	39.2	38.3	29.2	825.6	5.53	0.02437	0.128E 08	14.3
16	96.1	39.6	39.1	29.7	835.3	5.45	0.02653	0.131E 08	14.2
17	107.5	40.9	40.1	30.6	849.7	5.35	0.02973	0.136E 08	13.8
18	119.3	41.4	40.6	31.4	864.7	5.25	0.03307	0.142E 08	14.2
19	130.8	42.3	41.5	32.3	879.6	5.15	0.03633	0.148E 08	14.2
20	142.5	42.7	42.3	33.2	895.1	5.05	0.03966	0.154E 08	14.5
21	154.1	44.3	43.0	34.0	910.8	4.95	0.04297	0.160E 08	14.2
22	165.3	44.9	44.1	34.8	926.2	4.86	0.04618	0.165E 08	14.0
23	190.5	46.4	46.0	36.7	961.8	4.66	0.05344	0.179E 08	14.2

FULLY DEVELOPED NUSSELT NUMBER =13.8

RUN NUMBER (28) TUBE NUMBER 1

INPUT POWER = 751.0 W HEAT RATE GAINED BY WATER = 746.8 W HEAT BALANCE ERROR = 0.6%

REM = 893.3 RAM = 0.174E 08 PRM = 5.06

UPSTREAM BULK TEMPERATURE =22.4 DEG C DOWNSTREAM BULK TEMPERATURE =43.7 DEG C

INLET BULK TEMPERATURE =22.6 DEG C OUTLET BULK TEMPERATURE =41.6 DEG C

MASS FLOW RATE = 30.3 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	3.0	33.2	32.4	22.9	716.9	6.49	0.00081	0.104E 08	15.9
2	6.9	35.0	34.3	23.2	722.6	6.43	0.00187	0.106E 08	13.8
3	10.8	35.9	35.1	23.5	728.3	6.37	0.00293	0.108E 08	13.2
4	14.9	36.3	35.9	23.9	734.3	6.31	0.00404	0.111E 08	12.9
5	20.7	37.0	36.8	24.4	742.8	6.23	0.00563	0.114E 08	12.6
6	26.3	37.5	37.4	24.8	751.1	6.15	0.00716	0.117E 08	12.4
7	32.0	37.8	37.6	25.3	759.5	6.08	0.00872	0.120E 08	12.7
8	37.7	38.4	38.0	25.8	767.9	6.00	0.01029	0.123E 08	12.7
9	43.7	39.1	38.2	26.3	776.7	5.92	0.01195	0.126E 08	12.7
10	49.5	39.3	38.3	26.8	785.2	5.85	0.01355	0.130E 08	13.1
11	57.5	39.3	38.3	27.5	796.9	5.75	0.01578	0.134E 08	13.8
12	65.2	40.2	39.3	28.1	808.2	5.66	0.01792	0.139E 08	13.4
13	73.9	40.6	39.5	28.9	820.8	5.56	0.02036	0.143E 08	14.0
14	80.6	41.0	39.9	29.4	830.4	5.49	0.02224	0.147E 08	14.2
15	88.4	41.6	40.5	30.1	841.7	5.41	0.02442	0.152E 08	14.2
16	96.1	42.1	41.5	30.7	852.7	5.33	0.02659	0.157E 08	14.1
17	107.5	43.6	42.7	31.7	869.3	5.22	0.02981	0.164E 08	13.6
18	119.3	44.3	43.4	32.7	886.9	5.10	0.03316	0.171E 08	13.9
19	130.8	45.4	44.4	33.7	904.4	4.99	0.03644	0.179E 08	13.8
20	142.5	46.0	45.4	34.7	922.6	4.88	0.03979	0.187E 08	14.0
21	154.1	47.7	46.1	35.6	941.1	4.78	0.04313	0.195E 08	13.8
22	165.3	48.4	47.4	36.6	959.3	4.68	0.04636	0.203E 08	13.6
23	190.5	50.2	49.6	38.7	1001.6	4.46	0.05368	0.221E 08	13.7

FULLY DEVELOPED NUSSELT NUMBER =13.7

RUN NUMBER (29)   TUBE NUMBER 1

INPUT POWER = 878.0 W   HEAT RATE GAINED BY WATER = 877.8 W   HEAT BALANCE ERROR = 0.0%

REM = 927.4   RAM = 0.224E 08,   PRM = 4.85

UPSTREAM BULK TEMPERATURE =22.4 DEG C   DOWNSTREAM BULK TEMPERATURE =47.4 DEG C

INLET BULK TEMPERATURE =22.7 DEG C   OUTLET BULK TEMPERATURE =45.2 DEG C

MASS FLOW RATE = 30.3 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	3.0	34.9	34.0	23.0	718.2	6.47	0.00081	0.124E 08	16.3
2	6.9	36.7	36.1	23.3	724.9	6.41	0.00187	0.127E 08	14.3
3	10.8	37.8	36.9	23.7	731.7	6.34	0.00293	0.130E 08	13.7
4	14.9	38.2	37.7	24.1	738.8	6.27	0.00405	0.133E 08	13.5
5	20.7	39.0	38.7	24.7	749.0	6.17	0.00563	0.138E 08	13.2
6	26.3	39.6	39.4	25.3	758.7	6.08	0.00717	0.142E 08	13.1
7	32.0	39.9	39.5	25.9	768.7	5.99	0.00874	0.146E 08	13.4
8	37.7	40.5	40.0	26.4	778.6	5.91	0.01031	0.151E 08	13.4
9	43.7	41.4	40.3	27.0	789.1	5.82	0.01197	0.156E 08	13.5
10	49.5	41.7	40.3	27.6	799.2	5.73	0.01359	0.160E 08	13.9
11	57.5	41.6	40.4	28.4	813.0	5.62	0.01582	0.167E 08	14.7
12	65.2	42.7	41.7	29.2	826.1	5.52	0.01797	0.173E 08	14.2
13	73.9	43.1	41.8	30.1	841.0	5.41	0.02042	0.180E 08	14.9
14	80.6	43.7	42.3	30.7	852.4	5.33	0.02230	0.186E 08	15.1
15	88.4	44.4	43.1	31.5	865.9	5.24	0.02451	0.193E 08	15.1
16	96.1	45.0	44.3	32.3	879.4	5.15	0.02669	0.200E 08	14.9
17	107.5	46.8	45.8	33.4	899.8	5.02	0.02993	0.210E 08	14.2
18	119.3	47.7	46.6	34.6	921.5	4.89	0.03331	0.221E 08	14.6
19	130.8	48.9	47.8	35.8	943.3	4.76	0.03662	0.232E 08	14.5
20	142.5	49.6	48.9	36.9	965.9	4.64	0.04000	0.244E 08	14.8
21	154.1	51.7	49.8	38.1	989.0	4.52	0.04336	0.255E 08	14.5
22	165.3	52.4	51.3	39.2	1011.8	4.41	0.04663	0.267E 08	14.4
23	190.5	54.5	53.8	41.7	1065.0	4.17	0.05401	0.294E 08	14.6

FULLY DEVELOPED NUSSELT NUMBER =14.5

RUN NUMBER (30)   TUBE NUMBER 1

INPUT POWER =1099.0 W   HEAT RATE GAINED BY WATER =1036.0 W   HEAT BALANCE ERROR = 5.7%

REM = 1008.6   RAM = 0.316E 08   PRM = 4.42

UPSTREAM BULK TEMPERATURE =24.3 DEG C   DOWNSTREAM BULK TEMPERATURE =53.8 DEG C

INLET BULK TEMPERATURE =24.6 DEG C   OUTLET BULK TEMPERATURE =51.5 DEG C

MASS FLOW RATE = 30.3 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE --	PR --	X+ --	RA --	NU (AVERAGE)
1	3.0	38.4	37.5	24.9	752.4	6.14	0.00082	0.166E 08	17.1
2	6.9	40.5	39.6	25.4	760.6	6.07	0.00188	0.170E 08	15.1
3	10.8	41.6	40.5	25.9	768.7	5.99	0.00295	0.175E 08	14.6
4	14.9	42.0	41.5	26.3	777.2	5.92	0.00407	0.179E 08	14.4
5	20.7	42.9	42.5	27.0	789.3	5.82	0.00567	0.186E 08	14.1
6	26.3	43.6	43.4	27.7	800.9	5.72	0.00722	0.192E 08	14.0
7	32.0	43.9	43.4	28.4	812.6	5.63	0.00880	0.198E 08	14.5
8	37.7	44.7	44.0	29.1	824.3	5.54	0.01039	0.205E 08	14.4
9	43.7	45.7	44.3	29.8	836.4	5.45	0.01207	0.212E 08	14.5
10	49.5	46.0	44.4	30.5	848.2	5.36	0.01369	0.219E 08	15.0
11	57.5	46.0	44.5	31.4	864.6	5.25	0.01594	0.229E 08	16.0
12	65.2	47.4	46.0	32.4	880.8	5.14	0.01811	0.239E 08	15.3
13	73.9	47.8	46.3	33.4	899.4	5.02	0.02058	0.250E 08	16.0
14	80.6	48.6	46.8	34.2	914.0	4.93	0.02248	0.259E 08	16.2
15	88.4	49.5	47.9	35.1	931.4	4.83	0.02471	0.270E 08	16.1
16	96.1	50.2	49.3	36.0	948.9	4.73	0.02692	0.280E 08	15.9
17	107.5	52.3	51.1	37.4	975.5	4.59	0.03020	0.296E 08	15.2
18	119.3	53.2	52.0	38.8	1003.8	4.45	0.03362	0.313E 08	15.7
19	130.8	54.7	53.4	40.2	1032.2	4.31	0.03697	0.330E 08	15.6
20	142.5	55.6	54.7	41.6	1061.9	4.18	0.04039	0.348E 08	15.9
21	154.1	58.0	55.7	43.0	1092.2	4.05	0.04380	0.366E 08	15.6
22	165.3	58.8	57.5	44.3	1122.3	3.93	0.04709	0.384E 08	15.6
23	190.5	61.3	60.4	47.3	1192.5	3.68	0.05454	0.426E 08	15.8

FULLY DEVELOPED NUSSELT NUMBER =15.6

RUN NUMBER (31) TUBE NUMBER 1

INPUT POWER =1411.0 W HEAT RATE GAINED BY WATER =1307.6 W HEAT BALANCE ERROR = 7.3%

REM = 1091.0 RAM = 0.465E 08 PRM = 4.06

UPSTREAM BULK TEMPERATURE =24.3 DEG C DOWNSTREAM BULK TEMPERATURE =61.5 DEG C

INLET BULK TEMPERATURE =24.6 DEG C OUTLET BULK TEMPERATURE =58.8 DEG C

MASS FLOW RATE = 30.3 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	3.0	41.5	40.4	25.1	755.0	6.12	0.00082	0.213E 08	17.8
2	6.9	44.0	42.8	25.7	765.3	6.02	0.00188	0.220E 08	15.9
3	10.8	45.2	43.8	26.3	775.7	5.93	0.00295	0.227E 08	15.5
4	14.9	45.7	45.0	26.9	786.5	5.84	0.00408	0.234E 08	15.3
5	20.7	46.7	46.2	27.8	801.8	5.71	0.00568	0.245E 08	15.0
6	26.3	47.5	47.3	28.6	816.4	5.60	0.00724	0.255E 08	15.0
7	32.0	48.0	47.3	29.5	831.2	5.48	0.00883	0.266E 08	15.5
8	37.7	48.8	48.1	30.3	846.0	5.38	0.01042	0.277E 08	15.5
9	43.7	50.1	48.3	31.3	861.6	5.27	0.01211	0.289E 08	15.6
10	49.5	50.5	48.6	32.1	876.9	5.17	0.01374	0.301E 08	16.1
11	57.5	50.6	48.6	33.4	898.7	5.03	0.01601	0.318E 08	17.2
12	65.2	52.2	50.6	34.5	920.1	4.90	0.01820	0.334E 08	16.5
13	73.9	52.9	51.1	35.8	945.1	4.75	0.02069	0.354E 08	17.2
14	80.6	53.9	51.8	36.9	964.8	4.65	0.02262	0.369E 08	17.4
15	88.4	55.0	53.0	38.1	988.3	4.52	0.02487	0.387E 08	17.4
16	96.1	55.8	54.9	39.2	1012.0	4.41	0.02711	0.405E 08	17.1
17	107.5	58.5	57.0	41.0	1048.3	4.24	0.03043	0.433E 08	16.4
18	119.3	59.8	58.2	42.7	1087.2	4.07	0.03389	0.462E 08	16.9
19	130.8	61.7	60.0	44.5	1126.4	3.92	0.03728	0.492E 08	16.7
20	142.5	62.8	61.7	46.3	1167.6	3.77	0.04073	0.523E 08	17.1
21	154.1	65.8	62.8	48.0	1209.7	3.63	0.04417	0.555E 08	16.8
22	165.3	66.7	65.0	49.7	1251.5	3.50	0.04748	0.586E 08	16.8
23	190.5	70.0	68.9	53.6	1309.9	3.33	0.05500	0.640E 08	16.9

FULLY DEVELOPED NUSSELT NUMBER =16.7

RUN NUMBER (32) TUBE NUMBER 1

INPUT POWER =1763.0 W HEAT RATE GAINED BY WATER =1636.2 W HEAT BALANCE ERROR = 7.2%

REM = 1197.4 RAM = 0.687E 08 PRM = 3.67

UPSTREAM BULK TEMPERATURE =24.3 DEG C DOWNSTREAM BULK TEMPERATURE =70.8 DEG C

INLET BULK TEMPERATURE =24.6 DEG C OUTLET BULK TEMPERATURE =67.7 DEG C

MASS FLOW RATE = 30.3 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	3.0	45.1	43.6	25.2	757.1	6.10	0.00082	0.270E 08	18.6
2	6.9	48.0	46.5	25.9	770.1	5.98	0.00188	0.281E 08	16.7
3	10.8	49.4	47.6	26.7	783.1	5.87	0.00296	0.292E 08	16.3
4	14.9	49.9	48.9	27.5	796.7	5.75	0.00409	0.304E 08	16.2
5	20.7	51.0	50.3	28.6	815.8	5.60	0.00570	0.321E 08	16.0
6	26.3	51.9	51.5	29.6	834.0	5.46	0.00726	0.337E 08	16.0
7	32.0	52.5	51.6	30.7	852.6	5.33	0.00885	0.355E 08	16.6
8	37.7	53.6	52.5	31.8	871.5	5.20	0.01046	0.373E 08	16.6
9	43.7	55.0	52.9	33.0	891.8	5.07	0.01216	0.393E 08	16.7
10	49.5	55.6	53.1	34.1	912.0	4.95	0.01380	0.413E 08	17.3
11	57.5	55.8	53.3	35.6	940.7	4.78	0.01609	0.441E 08	18.5
12	65.2	57.8	55.7	37.1	969.2	4.62	0.01831	0.468E 08	17.7
13	73.9	58.6	56.3	38.8	1002.5	4.45	0.02082	0.501E 08	18.6
14	80.6	59.9	57.2	40.0	1028.9	4.33	0.02277	0.526E 08	18.8
15	88.4	61.3	58.9	41.5	1060.6	4.18	0.02505	0.556E 08	18.6
16	96.1	62.5	61.2	43.0	1092.8	4.05	0.02731	0.587E 08	18.3
17	107.5	65.8	63.9	45.2	1142.1	3.86	0.03067	0.634E 08	17.4
18	119.3	67.4	65.5	47.4	1195.3	3.67	0.03416	0.685E 08	18.0
19	130.8	69.9	67.5	49.6	1249.0	3.51	0.03757	0.735E 08	17.9
20	142.5	71.2	69.7	51.9	1284.7	3.40	0.04104	0.776E 08	18.3
21	154.1	74.8	71.2	54.1	1318.0	3.30	0.04452	0.815E 08	18.0
22	165.3	75.9	73.7	56.2	1352.6	3.21	0.04791	0.854E 08	18.2
23	190.5	80.2	78.7	61.1	1440.6	2.99	0.05559	0.946E 08	18.2

FULLY DEVELOPED NUSSELT NUMBER =17.9

RUN NUMBER (33) TUBE NUMBER 1

INPUT POWER = 313.0 W HEAT RATE GAINED BY WATER = 304.8 W HEAT BALANCE ERROR = 2.6%

REM = 951.4 RAM = 0.474E 07 PRM = 6.04

UPSTREAM BULK TEMPERATURE =22.1 DEG C DOWNSTREAM BULK TEMPERATURE =29.1 DEG C

INLET BULK TEMPERATURE =22.2 DEG C OUTLET BULK TEMPERATURE =28.1 DEG C

MASS FLOW RATE = 37.8 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	3.0	26.4	26.2	22.3	879.3	6.60	0.00065	0.391E 07	15.2
2	6.9	27.4	27.2	22.4	881.5	6.58	0.00150	0.394E 07	12.4
3	10.8	28.1	27.9	22.5	883.8	6.56	0.00234	0.396E 07	11.2
4	14.9	28.4	28.3	22.6	886.1	6.54	0.00323	0.399E 07	10.7
5	20.7	28.8	28.7	22.7	889.4	6.52	0.00449	0.403E 07	10.2
6	26.3	29.0	29.1	22.9	892.5	6.49	0.00571	0.406E 07	10.0
7	32.0	29.1	29.1	23.0	895.8	6.46	0.00695	0.410E 07	10.1
8	37.7	29.4	29.3	23.2	899.0	6.44	0.00819	0.414E 07	9.9
9	43.7	29.7	29.4	23.3	902.4	6.41	0.00950	0.418E 07	9.9
10	49.5	29.8	29.4	23.5	905.8	6.38	0.01077	0.421E 07	10.0
11	57.5	29.7	29.4	23.7	910.3	6.35	0.01252	0.427E 07	10.5
12	65.2	30.1	29.8	23.9	914.7	6.31	0.01421	0.432E 07	10.2
13	73.9	30.2	29.8	24.1	919.7	6.27	0.01611	0.437E 07	10.5
14	80.6	30.2	29.8	24.3	923.5	6.24	0.01758	0.442E 07	10.7
15	88.4	30.4	29.9	24.5	928.0	6.21	0.01930	0.447E 07	10.9
16	96.1	30.4	30.3	24.7	932.4	6.18	0.02099	0.452E 07	10.9
17	107.5	31.0	30.6	25.0	938.9	6.13	0.02350	0.460E 07	10.6
18	119.3	31.1	30.7	25.3	945.7	6.08	0.02611	0.468E 07	11.0
19	130.8	31.4	31.1	25.6	952.3	6.03	0.02865	0.475E 07	11.0
20	142.5	31.5	31.4	25.9	959.0	5.98	0.03125	0.483E 07	11.1
21	154.1	32.1	31.5	26.2	965.7	5.93	0.03382	0.491E 07	11.1
22	165.3	32.3	31.9	26.5	972.1	5.89	0.03631	0.499E 07	11.0
23	190.5	32.9	32.7	27.2	986.5	5.79	0.04193	0.516E 07	10.9

FULLY DEVELOPED NUSSELT NUMBER =10.6

RUN NUMBER (34) TUBE NUMBER 1

INPUT POWER = 613.0 W HEAT RATE GAINED BY WATER = 604.1 W HEAT BALANCE ERROR = 1.4%

REM = 1026.2 RAM = 0.115E 08 PRM = 5.54

UPSTREAM BULK TEMPERATURE =22.2 DEG C DOWNSTREAM BULK TEMPERATURE =35.9 DEG C

INLET BULK TEMPERATURE =22.3 DEG C OUTLET BULK TEMPERATURE =34.4 DEG C

MASS FLOW RATE = 37.8 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	3.0	30.4	29.9	22.4	883.4	6.57	0.00065	0.807E 07	16.4
2	6.9	32.0	31.5	22.7	887.9	6.53	0.00150	0.817E 07	13.8
3	10.8	32.9	32.3	22.9	892.4	6.49	0.00235	0.828E 07	12.9
4	14.9	33.2	32.9	23.1	897.2	6.45	0.00324	0.839E 07	12.6
5	20.7	33.9	33.7	23.4	903.9	6.40	0.00450	0.855E 07	12.1
6	26.3	34.2	34.2	23.7	910.4	6.35	0.00573	0.870E 07	11.9
7	32.0	34.4	34.2	24.0	917.1	6.29	0.00697	0.885E 07	12.1
8	37.7	34.8	34.6	24.3	923.8	6.24	0.00822	0.901E 07	12.0
9	43.7	35.4	34.7	24.6	930.8	6.19	0.00954	0.918E 07	12.0
10	49.5	35.5	34.7	24.9	937.6	6.14	0.01082	0.934E 07	12.3
11	57.5	35.4	34.6	25.4	946.9	6.07	0.01259	0.956E 07	13.0
12	65.2	36.0	35.4	25.8	955.9	6.00	0.01429	0.978E 07	12.6
13	73.9	36.2	35.4	26.3	966.1	5.93	0.01622	0.100E 08	13.1
14	80.6	36.5	35.6	26.6	973.9	5.88	0.01771	0.102E 08	13.3
15	88.4	36.7	35.9	27.0	983.0	5.82	0.01945	0.104E 08	13.4
16	96.1	37.0	36.6	27.5	992.0	5.76	0.02117	0.107E 08	13.3
17	107.5	38.0	37.3	28.1	1005.2	5.67	0.02372	0.110E 08	13.0
18	119.3	38.4	37.6	28.7	1018.8	5.58	0.02637	0.113E 08	13.4
19	130.8	38.9	38.3	29.3	1032.0	5.50	0.02897	0.117E 08	13.4
20	142.5	39.3	38.8	30.0	1045.2	5.42	0.03161	0.120E 08	13.7
21	154.1	40.3	39.1	30.6	1058.6	5.35	0.03423	0.124E 08	13.6
22	165.3	40.8	40.0	31.2	1071.5	5.28	0.03677	0.127E 08	13.4
23	190.5	42.0	41.5	32.5	1101.1	5.12	0.04251	0.135E 08	13.4

FULLY DEVELOPED NUSSELT NUMBER =13.1

RUN NUMBER (35)   TUBE NUMBER 1

INPUT POWER = 751.0 W   HEAT RATE GAINED BY WATER = 754.9 W   HEAT BALANCE ERROR =-0.5%

REM = 1063.9   RAM = 0.157E 08   PRM = 5.32

UPSTREAM BULK TEMPERATURE =22.2 DEG C   DOWNSTREAM BULK TEMPERATURE =39.4 DEG C

INLET BULK TEMPERATURE =22.4 DEG C   OUTLET BULK TEMPERATURE =37.6 DEG C

MASS FLOW RATE = 37.8 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	3.0	32.4	31.7	22.6	886.0	6.54	0.00065	0.102E 08	16.6
2	6.9	34.2	33.6	22.8	891.7	6.50	0.00150	0.104E 08	14.2
3	10.8	35.1	34.4	23.1	897.4	6.45	0.00235	0.106E 08	13.5
4	14.9	35.5	35.2	23.4	903.4	6.40	0.00324	0.107E 08	13.2
5	20.7	36.2	36.0	23.8	911.9	6.33	0.00451	0.110E 08	12.8
6	26.3	36.6	36.6	24.1	920.1	6.27	0.00573	0.112E 08	12.7
7	32.0	36.9	36.7	24.5	928.5	6.21	0.00699	0.115E 08	12.8
8	37.7	37.4	37.1	24.9	936.9	6.14	0.00824	0.117E 08	12.8
9	43.7	38.1	37.2	25.3	945.7	6.08	0.00956	0.120E 08	12.7
10	49.5	38.3	37.3	25.7	954.3	6.02	0.01085	0.123E 08	13.0
11	57.5	38.1	37.1	26.3	966.1	5.93	0.01262	0.126E 08	13.8
12	65.2	38.9	38.1	26.8	977.4	5.85	0.01433	0.130E 08	13.4
13	73.9	39.1	38.2	27.4	990.1	5.77	0.01627	0.133E 08	13.9
14	80.6	39.4	38.3	27.8	999.9	5.70	0.01777	0.137E 08	14.2
15	88.4	39.8	38.9	28.4	1011.3	5.63	0.01952	0.140E 08	14.2
16	96.1	40.1	39.6	28.9	1022.4	5.56	0.02126	0.144E 08	14.2
17	107.5	41.4	40.5	29.7	1038.8	5.46	0.02383	0.149E 08	13.8
18	119.3	41.8	41.0	30.5	1055.8	5.37	0.02649	0.155E 08	14.2
19	130.8	42.6	41.8	31.2	1072.4	5.27	0.02910	0.160E 08	14.2
20	142.5	43.0	42.4	32.0	1089.6	5.18	0.03176	0.166E 08	14.6
21	154.1	44.4	42.8	32.8	1107.0	5.09	0.03441	0.172E 08	14.4
22	165.3	45.0	44.0	33.6	1124.1	5.00	0.03697	0.178E 08	14.2
23	190.5	46.5	45.8	35.3	1163.6	4.81	0.04277	0.192E 08	14.2

FULLY DEVELOPED NUSSELT NUMBER =13.9

RUN NUMBER (36)   TUBE NUMBER 1

INPUT POWER = 957.0 W   HEAT RATE GAINED BY WATER = 947.2 W   HEAT BALANCE ERROR = 1.0%

REM = 1118.1   RAM = 0.223E 08   PRM = 5.03

UPSTREAM BULK TEMPERATURE =22.5 DEG C   DOWNSTREAM BULK TEMPERATURE =44.1 DEG C

INLET BULK TEMPERATURE =22.7 DEG C   OUTLET BULK TEMPERATURE =42.0 DEG C

MASS FLOW RATE = 37.8 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	3.0	34.9	34.0	22.9	893.8	6.48	0.00065	0.132E 08	17.4
2	6.9	36.9	36.2	23.3	901.0	6.42	0.00150	0.135E 08	15.1
3	10.8	37.9	37.1	23.6	908.3	6.36	0.00235	0.138E 08	14.4
4	14.9	38.3	37.9	23.9	915.9	6.30	0.00325	0.141E 08	14.1
5	20.7	39.2	38.8	24.4	926.7	6.22	0.00452	0.145E 08	13.7
6	26.3	39.6	39.5	24.9	937.1	6.14	0.00575	0.149E 08	13.6
7	32.0	39.9	39.5	25.4	947.8	6.06	0.00701	0.153E 08	13.9
8	37.7	40.6	40.1	25.9	958.4	5.99	0.00827	0.157E 08	13.8
9	43.7	41.4	40.2	26.4	969.6	5.91	0.00960	0.161E 08	13.8
10	49.5	41.6	40.3	26.9	980.4	5.83	0.01089	0.165E 08	14.2
11	57.5	41.5	40.2	27.6	995.2	5.74	0.01267	0.171E 08	15.0
12	65.2	42.5	41.4	28.3	1009.4	5.64	0.01440	0.177E 08	14.5
13	73.9	42.8	41.5	29.0	1025.4	5.54	0.01635	0.183E 08	15.1
14	80.6	43.2	41.7	29.6	1037.5	5.47	0.01786	0.188E 08	15.4
15	88.4	43.7	42.4	30.3	1051.8	5.39	0.01962	0.194E 08	15.4
16	96.1	44.1	43.5	30.9	1065.8	5.31	0.02136	0.200E 08	15.3
17	107.5	45.7	44.7	31.9	1087.0	5.19	0.02395	0.210E 08	14.8
18	119.3	46.3	45.2	32.9	1109.4	5.08	0.02664	0.219E 08	15.3
19	130.8	47.3	46.2	33.9	1131.7	4.97	0.02928	0.229E 08	15.3
20	142.5	47.8	47.1	34.9	1154.9	4.85	0.03197	0.239E 08	15.5
21	154.1	49.6	47.7	35.9	1178.4	4.75	0.03465	0.250E 08	15.4
22	165.3	50.2	49.0	36.9	1201.6	4.65	0.03725	0.260E 08	15.3
23	190.5	52.1	51.3	39.0	1255.6	4.42	0.04313	0.283E 08	15.3

FULLY DEVELOPED NUSSELT NUMBER =15.0

RUN NUMBER (37) TUBE NUMBER 1

INPUT POWER =1250.0 W HEAT RATE GAINED BY WATER =1236.7 W HEAT BALANCE ERROR = 1.1%

REM = 1202.1 RAM = 0.343E 08 PRM = 4.64

UPSTREAM BULK TEMPERATURE =22.8 DEG C DOWNSTREAM BULK TEMPERATURE =51.0 DEG C

INLET BULK TEMPERATURE =23.0 DEG C OUTLET BULK TEMPERATURE =48.5 DEG C

MASS FLOW RATE = 37.8 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	3.0	38.2	37.2	23.3	902.5	6.41	0.00065	0.179E 08	18.4
2	6.9	40.6	39.6	23.8	912.0	6.33	0.00150	0.184E 08	16.2
3	10.8	41.8	40.5	24.2	921.6	6.26	0.00236	0.189E 08	15.5
4	14.9	42.2	41.6	24.7	931.7	6.18	0.00325	0.194E 08	15.3
5	20.7	43.2	42.7	25.3	946.0	6.08	0.00453	0.201E 08	14.9
6	26.3	43.8	43.6	26.0	959.8	5.98	0.00577	0.208E 08	14.8
7	32.0	44.1	43.6	26.6	973.8	5.88	0.00703	0.215E 08	15.2
8	37.7	45.0	44.3	27.3	987.8	5.78	0.00830	0.222E 08	15.1
9	43.7	46.0	44.4	27.9	1002.5	5.69	0.00964	0.230E 08	15.2
10	49.5	46.2	44.5	28.6	1016.6	5.60	0.01094	0.237E 08	15.6
11	57.5	46.0	44.4	29.5	1035.9	5.48	0.01274	0.248E 08	16.6
12	65.2	47.4	46.0	30.4	1054.5	5.37	0.01447	0.258E 08	16.0
13	73.9	47.8	46.1	31.4	1075.5	5.26	0.01644	0.270E 08	16.8
14	80.6	48.4	46.5	32.1	1092.1	5.17	0.01797	0.280E 08	17.0
15	88.4	49.2	47.4	33.0	1111.7	5.07	0.01975	0.291E 08	17.0
16	96.1	49.7	48.9	33.9	1131.4	4.97	0.02151	0.303E 08	16.8
17	107.5	51.7	50.5	35.2	1161.4	4.82	0.02413	0.320E 08	16.2
18	119.3	52.5	51.2	36.5	1193.3	4.68	0.02686	0.338E 08	16.8
19	130.8	54.0	52.5	37.8	1225.4	4.55	0.02954	0.357E 08	16.7
20	142.5	54.7	53.7	39.2	1258.9	4.41	0.03227	0.376E 08	17.1
21	154.1	57.0	54.4	40.5	1293.0	4.28	0.03499	0.395E 08	16.9
22	165.3	57.7	56.2	41.7	1326.9	4.16	0.03763	0.415E 08	16.8
23	190.5	60.2	59.1	44.6	1406.1	3.91	0.04360	0.460E 08	16.9

FULLY DEVELOPED NUSSELT NUMBER =16.5

RUN NUMBER (38) TUBE NUMBER 1

INPUT POWER =1582.0 W HEAT RATE GAINED BY WATER =1545.7 W HEAT BALANCE ERROR = 2.3%

REM = 1298.7 RAM = 0.503E 08 PRM = 4.26

UPSTREAM BULK TEMPERATURE =23.1 DEG C DOWNSTREAM BULK TEMPERATURE =58.3 DEG C

INLET BULK TEMPERATURE =23.3 DEG C OUTLET BULK TEMPERATURE =55.5 DEG C

MASS FLOW RATE = 37.8 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	3.0	41.9	40.6	23.7	911.3	6.34	0.00065	0.231E 08	19.0
2	6.9	44.6	43.3	24.3	923.4	6.24	0.00151	0.239E 08	16.9
3	10.8	45.9	44.3	24.9	935.5	6.15	0.00236	0.246E 08	16.4
4	14.9	46.3	45.6	25.4	948.2	6.06	0.00326	0.255E 08	16.2
5	20.7	47.4	46.8	26.3	966.3	5.93	0.00454	0.266E 08	15.9
6	26.3	48.1	47.8	27.1	983.6	5.81	0.00579	0.277E 08	15.8
7	32.0	48.6	47.8	27.9	1001.2	5.70	0.00706	0.289E 08	16.2
8	37.7	49.4	48.6	28.7	1018.7	5.59	0.00833	0.300E 08	16.2
9	43.7	50.8	48.9	29.6	1036.9	5.47	0.00968	0.313E 08	16.3
10	49.5	51.3	49.0	30.4	1054.5	5.37	0.01099	0.325E 08	16.7
11	57.5	50.9	48.9	31.5	1079.0	5.24	0.01280	0.343E 08	17.9
12	65.2	52.6	50.8	32.6	1103.1	5.11	0.01455	0.361E 08	17.2
13	73.9	53.1	51.0	33.9	1131.2	4.97	0.01654	0.381E 08	18.0
14	80.6	54.0	51.6	34.8	1153.3	4.86	0.01808	0.397E 08	18.2
15	88.4	55.0	52.8	36.0	1179.6	4.74	0.01988	0.417E 08	18.2
16	96.1	55.6	54.6	37.1	1206.3	4.63	0.02166	0.436E 08	18.0
17	107.5	58.1	56.5	38.7	1246.9	4.46	0.02432	0.465E 08	17.4
18	119.3	59.3	57.5	40.4	1290.4	4.29	0.02709	0.497E 08	17.9
19	130.8	61.0	59.0	42.0	1334.3	4.14	0.02979	0.528E 08	17.9
20	142.5	61.9	60.7	43.7	1380.4	3.99	0.03256	0.561E 08	18.2
21	154.1	64.9	61.6	45.4	1427.6	3.84	0.03532	0.595E 08	18.0
22	165.3	65.6	63.7	47.0	1474.5	3.71	0.03798	0.628E 08	18.1
23	190.5	68.7	67.4	50.6	1576.9	3.46	0.04397	0.702E 08	18.1

FULLY DEVELOPED NUSSELT NUMBER =17.6

RUN NUMBER (39)   TUBE NUMBER 1

INPUT POWER =1763.0 W HEAT RATE GAINED BY WATER =1733.2 W HEAT BALANCE ERROR = 1.7%

REM = 1371.8   RAM = 0.627E 08   PRM = 4.02

UPSTREAM BULK TEMPERATURE =23.6 DEG C   DOWNSTREAM BULK TEMPERATURE =63.2 DEG C

INLET BULK TEMPERATURE =23.9 DEG C   OUTLET BULK TEMPERATURE =60.3 DEG C

MASS FLOW RATE = 37.8 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	3.0	44.2	42.8	24.4	925.0	6.23	0.00065	0.271E 08	19.7
2	6.9	47.0	45.6	25.0	938.7	6.13	0.00151	0.281E 08	17.6
3	10.8	48.4	46.6	25.6	952.4	6.03	0.00237	0.291E 08	17.1
4	14.9	48.7	47.9	26.3	966.8	5.93	0.00327	0.301E 08	17.0
5	20.7	50.0	49.3	27.2	987.1	5.79	0.00456	0.316E 08	16.7
6	26.3	50.8	50.5	28.1	1006.6	5.66	0.00580	0.331E 08	16.5
7	32.0	51.3	50.5	29.1	1026.3	5.54	0.00708	0.346E 08	17.0
8	37.7	52.3	51.3	30.0	1045.8	5.42	0.00836	0.360E 08	17.1
9	43.7	53.7	51.6	31.0	1066.5	5.31	0.00971	0.378E 08	17.1
10	49.5	54.2	51.7	31.9	1086.8	5.20	0.01103	0.394E 08	17.6
11	57.5	53.9	51.6	33.2	1115.4	5.05	0.01285	0.418E 08	18.9
12	65.2	55.7	53.7	34.4	1143.8	4.91	0.01461	0.442E 08	18.2
13	73.9	56.3	54.0	35.8	1176.9	4.75	0.01661	0.469E 08	19.1
14	80.6	57.3	54.6	36.9	1203.0	4.64	0.01816	0.490E 08	19.4
15	88.4	58.4	56.0	38.2	1234.2	4.51	0.01998	0.516E 08	19.3
16	96.1	59.2	58.0	39.4	1265.9	4.39	0.02178	0.542E 08	19.1
17	107.5	62.1	60.2	41.3	1314.2	4.21	0.02445	0.581E 08	18.3
18	119.3	63.4	61.4	43.2	1366.2	4.03	0.02724	0.623E 08	18.9
19	130.8	65.3	63.0	45.0	1418.6	3.87	0.02996	0.665E 08	18.9
20	142.5	66.3	64.8	46.9	1473.8	3.71	0.03274	0.709E 08	19.4
21	154.1	69.6	65.9	48.8	1530.3	3.57	0.03550	0.754E 08	19.1
22	165.3	70.3	68.1	50.6	1578.0	3.45	0.03816	0.795E 08	19.3
23	190.5	74.0	72.5	54.7	1653.5	3.28	0.04423	0.870E 08	19.2

FULLY DEVELOPED NUSSELT NUMBER =18.7

RUN NUMBER (40) TUBE NUMBER 1

INPUT POWER = 313.0 W HEAT RATE GAINED BY WATER = 305.6 W HEAT BALANCE ERROR = 2.4%

REM = 1095.1 RAM = 0.498E 07 PRM = 5.91

UPSTREAM BULK TEMPERATURE =23.3 DEG C DOWNSTREAM BULK TEMPERATURE =29.5 DEG C

INLET BULK TEMPERATURE =23.4 DEG C OUTLET BULK TEMPERATURE =28.7 DEG C

MASS FLOW RATE = 42.7 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	3.0	27.6	27.3	23.5	1022.5	6.39	0.00058	0.423E 07	15.6
2	6.9	28.6	28.4	23.5	1024.7	6.37	0.00133	0.425E 07	12.6
3	10.8	29.2	29.0	23.6	1027.0	6.36	0.00208	0.428E 07	11.3
4	14.9	29.5	29.5	23.7	1029.3	6.34	0.00287	0.430E 07	10.7
5	20.7	29.9	29.9	23.9	1032.7	6.32	0.00399	0.433E 07	10.2
6	26.3	30.2	30.2	24.0	1035.9	6.29	0.00507	0.437E 07	10.0
7	32.0	30.3	30.3	24.1	1039.2	6.27	0.00618	0.440E 07	10.0
8	37.7	30.6	30.5	24.3	1042.4	6.25	0.00728	0.443E 07	9.9
9	43.7	30.9	30.5	24.4	1045.9	6.22	0.00844	0.447E 07	9.8
10	49.5	30.9	30.5	24.5	1049.2	6.20	0.00957	0.450E 07	10.0
11	57.5	30.9	30.5	24.7	1053.9	6.17	0.01112	0.455E 07	10.3
12	65.2	31.2	30.9	24.9	1058.3	6.14	0.01262	0.460E 07	10.1
13	73.9	31.3	30.9	25.1	1063.3	6.11	0.01431	0.465E 07	10.3
14	80.6	31.2	30.9	25.3	1067.2	6.08	0.01562	0.469E 07	10.6
15	88.4	31.4	31.0	25.5	1071.7	6.05	0.01714	0.474E 07	10.7
16	96.1	31.4	31.3	25.6	1076.1	6.03	0.01864	0.478E 07	10.8
17	107.5	31.9	31.6	25.9	1082.7	5.99	0.02087	0.485E 07	10.5
18	119.3	32.1	31.7	26.2	1089.5	5.94	0.02318	0.493E 07	10.7
19	130.8	32.2	31.9	26.5	1096.1	5.90	0.02543	0.500E 07	11.0
20	142.5	32.3	32.0	26.7	1102.9	5.86	0.02773	0.507E 07	11.3
21	154.1	32.8	32.2	27.0	1109.5	5.82	0.03001	0.514E 07	11.2
22	165.3	33.0	32.5	27.3	1116.0	5.78	0.03222	0.521E 07	11.2
23	190.5	33.6	33.2	27.9	1130.4	5.70	0.03720	0.536E 07	11.1

FULLY DEVELOPED NUSSELT NUMBER =10.6

RUN NUMBER (41) TUBE NUMBER 1

INPUT POWER = 591.0 W HEAT RATE GAINED BY WATER = 577.8 W HEAT BALANCE ERROR = 2.2%

REM = 1163.1 RAM = 0.110E 08 PRM = 5.52

UPSTREAM BULK TEMPERATURE =23.4 DEG C DOWNSTREAM BULK TEMPERATURE =35.1 DEG C

INLET BULK TEMPERATURE =23.5 DEG C OUTLET BULK TEMPERATURE =33.7 DEG C

MASS FLOW RATE = 42.7 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	3.0	31.2	30.8	23.6	1026.6	6.36	0.00058	0.822E 07	16.1
2	6.9	32.9	32.4	23.8	1030.9	6.33	0.00133	0.830E 07	13.4
3	10.8	33.8	33.2	24.0	1035.2	6.30	0.00208	0.839E 07	12.5
4	14.9	34.1	33.9	24.2	1039.8	6.27	0.00288	0.848E 07	12.1
5	20.7	34.6	34.5	24.4	1046.2	6.22	0.00400	0.861E 07	11.7
6	26.3	35.0	34.9	24.7	1052.4	6.18	0.00509	0.873E 07	11.5
7	32.0	35.2	35.0	24.9	1058.7	6.14	0.00619	0.886E 07	11.7
8	37.7	35.6	35.3	25.2	1065.1	6.10	0.00730	0.898E 07	11.5
9	43.7	36.1	35.4	25.5	1071.7	6.05	0.00847	0.912E 07	11.5
10	49.5	36.3	35.5	25.7	1078.2	6.01	0.00960	0.925E 07	11.7
11	57.5	36.1	35.4	26.1	1087.1	5.96	0.01117	0.943E 07	12.3
12	65.2	36.6	36.1	26.4	1095.6	5.91	0.01268	0.960E 07	11.9
13	73.9	36.8	36.1	26.8	1105.2	5.85	0.01439	0.980E 07	12.4
14	80.6	36.9	36.1	27.1	1112.7	5.80	0.01570	0.995E 07	12.6
15	88.4	37.1	36.4	27.5	1121.3	5.75	0.01724	0.101E 08	12.8
16	96.1	37.3	37.0	27.8	1129.8	5.70	0.01876	0.103E 08	12.7
17	107.5	38.2	37.6	28.4	1142.3	5.63	0.02102	0.106E 08	12.3
18	119.3	38.5	37.8	28.9	1155.1	5.56	0.02336	0.108E 08	12.8
19	130.8	38.9	38.3	29.4	1167.6	5.49	0.02565	0.111E 08	12.8
20	142.5	39.1	38.7	29.9	1180.2	5.43	0.02798	0.114E 08	13.1
21	154.1	40.1	38.9	30.5	1192.9	5.36	0.03029	0.117E 08	13.0
22	165.3	40.3	39.6	31.0	1205.1	5.30	0.03253	0.120E 08	13.1
23	190.5	41.4	40.9	32.1	1233.0	5.17	0.03759	0.126E 08	12.9

FULLY DEVELOPED NUSSELT NUMBER =12.5

RUN NUMBER (42)   TUBE NUMBER 1

INPUT POWER = 751.0 W HEAT RATE GAINED BY WATER = 734.4 W HEAT BALANCE ERROR = 2.2%

REM = 1224.0   RAM = 0.159E 08   PRM = 5.21

UPSTREAM BULK TEMPERATURE =24.3 DEG C   DOWNSTREAM BULK TEMPERATURE =39.2 DEG C

INLET BULK TEMPERATURE =24.5 DEG C   OUTLET BULK TEMPERATURE =37.6 DEG C

MASS FLOW RATE = 42.7 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	3.0	34.1	33.5	24.6	1051.2	6.19	0.00058	0.112E 08	16.6
2	6.9	36.0	35.4	24.9	1056.7	6.15	0.00133	0.113E 08	14.1
3	10.8	36.9	36.2	25.1	1062.3	6.12	0.00209	0.115E 08	13.3
4	14.9	37.1	36.8	25.3	1068.2	6.08	0.00289	0.116E 08	13.0
5	20.7	37.8	37.7	25.7	1076.4	6.02	0.00402	0.118E 08	12.6
6	26.3	38.3	38.2	26.0	1084.4	5.97	0.00511	0.120E 08	12.4
7	32.0	38.6	38.3	26.3	1092.6	5.92	0.00622	0.123E 08	12.5
8	37.7	39.0	38.7	26.6	1100.7	5.87	0.00733	0.125E 08	12.5
9	43.7	39.6	38.9	27.0	1109.2	5.82	0.00851	0.127E 08	12.4
10	49.5	39.9	38.8	27.3	1117.5	5.77	0.00965	0.129E 08	12.7
11	57.5	39.7	38.7	27.8	1128.8	5.71	0.01122	0.132E 08	13.3
12	65.2	40.4	39.6	28.2	1139.7	5.65	0.01274	0.135E 08	12.9
13	73.9	40.5	39.5	28.8	1151.9	5.58	0.01447	0.138E 08	13.4
14	80.6	40.9	39.7	29.1	1161.2	5.53	0.01579	0.141E 08	13.6
15	88.4	41.1	40.1	29.6	1172.1	5.47	0.01734	0.144E 08	13.7
16	96.1	41.4	40.8	30.0	1182.9	5.41	0.01887	0.147E 08	13.7
17	107.5	42.4	41.7	30.7	1198.7	5.33	0.02114	0.152E 08	13.3
18	119.3	42.7	41.9	31.4	1215.3	5.25	0.02350	0.157E 08	13.8
19	130.8	43.3	42.4	32.1	1231.8	5.18	0.02581	0.162E 08	13.9
20	142.5	43.6	43.0	32.7	1248.8	5.10	0.02816	0.167E 08	14.2
21	154.1	45.0	43.4	33.4	1265.8	5.02	0.03050	0.172E 08	14.0
22	165.3	45.3	44.3	34.1	1282.6	4.95	0.03277	0.177E 08	14.0
23	190.5	46.7	46.0	35.5	1321.2	4.79	0.03789	0.188E 08	13.8

FULLY DEVELOPED NUSSELT NUMBER =13.5

RUN NUMBER (43)   TUBE NUMBER 1

INPUT POWER =1188.0 W HEAT RATE GAINED BY WATER =1149.4 W HEAT BALANCE ERROR = 3.2%

REM = 1365.5   RAM = 0.329E 08   PRM = 4.61

UPSTREAM BULK TEMPERATURE =25.6 DEG C   DOWNSTREAM BULK TEMPERATURE =48.8 DEG C

INLET BULK TEMPERATURE =25.7 DEG C   OUTLET BULK TEMPERATURE =47.2 DEG C

MASS FLOW RATE = 42.7 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE --	PR --	X+ --	RA --	NU (AVERAGE)
1	3.0	39.9	39.0	26.0	1085.2	5.97	0.00058	0.198E 08	18.6
2	6.9	42.2	41.3	26.4	1094.3	5.91	0.00134	0.201E 08	16.2
3	10.8	43.3	43.7	26.8	1103.4	5.86	0.00210	0.205E 08	14.9
4	14.9	43.6	44.1	27.1	1112.9	5.80	0.00290	0.210E 08	14.9
5	20.7	44.5	45.0	27.7	1126.4	5.72	0.00404	0.215E 08	14.6
6	26.3	45.1	44.7	28.2	1139.4	5.65	0.00514	0.221E 08	14.9
7	32.0	45.4	45.4	28.8	1152.5	5.58	0.00626	0.227E 08	14.9
8	37.7	46.0	****	29.3	1165.5	5.50	0.00739	0.233E 08	7.8
9	43.7	47.0	45.6	29.9	1179.1	5.43	0.00858	0.239E 08	15.1
10	49.5	47.2	45.6	30.4	1192.5	5.37	0.00973	0.245E 08	15.5
11	57.5	46.9	45.5	31.2	1210.8	5.28	0.01132	0.254E 08	16.5
12	65.2	48.1	46.8	31.9	1228.8	5.19	0.01286	0.263E 08	15.9
13	73.9	48.4	46.9	32.8	1249.4	5.09	0.01461	0.273E 08	16.6
14	80.6	48.9	47.1	33.4	1265.6	5.02	0.01595	0.281E 08	16.9
15	88.4	49.4	47.8	34.2	1284.8	4.94	0.01753	0.290E 08	17.0
16	96.1	49.9	49.1	34.9	1304.0	4.86	0.01909	0.300E 08	16.8
17	107.5	51.6	50.4	36.0	1332.9	4.74	0.02140	0.314E 08	16.3
18	119.3	52.2	50.8	37.1	1363.7	4.62	0.02381	0.329E 08	17.0
19	130.8	53.3	51.9	38.2	1394.4	4.51	0.02617	0.343E 08	16.9
20	142.5	53.8	52.9	39.3	1426.3	4.40	0.02858	0.359E 08	17.4
21	154.1	55.8	53.3	40.4	1458.8	4.29	0.03098	0.374E 08	17.3
22	165.3	56.3	54.7	41.5	1490.8	4.19	0.03330	0.390E 08	17.4
23	190.5	58.2	57.2	43.9	1565.3	3.97	0.03855	0.425E 08	17.5

FULLY DEVELOPED NUSSELT NUMBER =16.1

RUN NUMBER (44)   TUBE NUMBER 1

INPUT POWER =1478.0 W   HEAT RATE GAINED BY WATER =1399.6 W   HEAT BALANCE ERROR = 5.3%

REM = 1442.3   RAM = 0.445E 08   PRM = 4.34

UPSTREAM BULK TEMPERATURE =25.7 DEG C   DOWNSTREAM BULK TEMPERATURE =54.0 DEG C

INLET BULK TEMPERATURE =25.9 DEG C   OUTLET BULK TEMPERATURE =52.0 DEG C

MASS FLOW RATE = 42.7 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	3.0	42.7	41.5	26.3	1091.5	5.93	0.00058	0.243E 08	19.1
2	6.9	45.3	44.1	26.7	1102.6	5.86	0.00134	0.249E 08	16.8
3	10.8	46.5	45.1	27.2	1113.6	5.80	0.00210	0.255E 08	16.3
4	14.9	46.8	46.2	27.7	1125.2	5.73	0.00291	0.261E 08	16.0
5	20.7	47.9	47.4	28.3	1141.5	5.64	0.00405	0.270E 08	15.6
6	26.3	48.4	48.3	29.0	1157.1	5.55	0.00515	0.278E 08	15.5
7	32.0	48.8	48.1	29.6	1172.9	5.47	0.00628	0.287E 08	16.0
8	37.7	49.6	48.8	30.3	1188.8	5.38	0.00741	0.296E 08	15.9
9	43.7	50.7	49.0	31.0	1205.4	5.30	0.00860	0.306E 08	15.9
10	49.5	51.1	49.0	31.7	1221.8	5.22	0.00976	0.316E 08	16.3
11	57.5	50.8	48.9	32.6	1244.8	5.12	0.01136	0.329E 08	17.4
12	65.2	52.1	50.5	33.5	1267.3	5.01	0.01291	0.343E 08	16.8
13	73.9	52.4	50.6	34.5	1293.4	4.90	0.01466	0.358E 08	17.5
14	80.6	53.1	50.8	35.3	1313.8	4.82	0.01602	0.370E 08	17.9
15	88.4	53.8	51.7	36.2	1338.1	4.72	0.01761	0.384E 08	18.0
16	96.1	54.2	53.3	37.1	1362.5	4.63	0.01918	0.399E 08	17.8
17	107.5	56.4	54.9	38.4	1399.6	4.49	0.02152	0.420E 08	17.2
18	119.3	57.1	55.5	39.7	1439.0	4.35	0.02395	0.443E 08	17.9
19	130.8	58.5	56.6	41.1	1478.5	4.23	0.02633	0.466E 08	18.0
20	142.5	59.0	57.9	42.4	1519.8	4.10	0.02876	0.490E 08	18.3
21	154.1	61.5	58.5	43.8	1561.8	3.98	0.03118	0.515E 08	18.2
22	165.3	62.1	60.1	45.1	1603.4	3.87	0.03352	0.538E 08	18.3
23	190.5	64.5	63.2	48.0	1700.4	3.63	0.03881	0.594E 08	18.4

FULLY DEVELOPED NUSSELT NUMBER =17.5

RUN NUMBER (45) TUBE NUMBER 1

INPUT POWER =1992.0 W HEAT RATE GAINED BY WATER =1916.6 W HEAT BALANCE ERROR = 3.8%

REM = 1614.4 RAM = 0.748E 08 PRM = 3.84

UPSTREAM BULK TEMPERATURE =26.1 DEG C DOWNSTREAM BULK TEMPERATURE =64.8 DEG C

INLET BULK TEMPERATURE =26.3 DEG C OUTLET BULK TEMPERATURE =62.1 DEG C

MASS FLOW RATE = 42.7 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	3.0	48.3	46.8	26.8	1104.3	5.85	0.00058	0.343E 08	20.0
2	6.9	51.3	49.7	27.4	1119.4	5.76	0.00135	0.354E 08	17.9
3	10.8	52.7	50.8	28.0	1134.5	5.68	0.00211	0.365E 08	17.5
4	14.9	53.1	52.2	28.7	1150.3	5.59	0.00292	0.377E 08	17.2
5	20.7	54.4	53.7	29.6	1172.4	5.47	0.00406	0.393E 08	16.9
6	26.3	55.1	54.8	30.5	1193.7	5.36	0.00517	0.410E 08	16.8
7	32.0	55.6	54.5	31.4	1215.6	5.25	0.00630	0.428E 08	17.4
8	37.7	56.6	55.4	32.3	1237.9	5.15	0.00744	0.446E 08	17.3
9	43.7	58.0	55.7	33.3	1261.9	5.04	0.00865	0.466E 08	17.4
10	49.5	58.5	55.8	34.2	1285.6	4.93	0.00982	0.485E 08	17.9
11	57.5	58.1	55.5	35.5	1319.1	4.80	0.01143	0.512E 08	19.2
12	65.2	60.0	57.6	36.7	1352.2	4.66	0.01300	0.539E 08	18.5
13	73.9	60.4	57.8	38.1	1390.7	4.52	0.01478	0.570E 08	19.4
14	80.6	61.4	58.4	39.1	1421.1	4.41	0.01616	0.594E 08	19.6
15	88.4	62.5	59.7	40.4	1457.4	4.29	0.01777	0.623E 08	19.6
16	96.1	63.2	61.8	41.6	1494.1	4.18	0.01936	0.652E 08	19.4
17	107.5	65.9	64.0	43.4	1550.1	4.01	0.02174	0.697E 08	18.7
18	119.3	67.0	64.9	45.3	1610.2	3.85	0.02420	0.744E 08	19.4
19	130.8	69.1	66.3	47.1	1670.6	3.70	0.02661	0.792E 08	19.5
20	142.5	69.9	68.2	49.0	1734.0	3.56	0.02907	0.842E 08	19.8
21	154.1	73.3	69.0	50.8	1786.1	3.44	0.03150	0.886E 08	19.7
22	165.3	73.7	71.2	52.6	1822.2	3.37	0.03388	0.922E 08	20.0
23	190.5	77.4	75.7	56.6	1911.6	3.19	0.03927	0.101E 09	19.7

FULLY DEVELOPED NUSSELT NUMBER =19.1

RUN NUMBER (1)   TUBE NUMBER 9

INPUT POWER = 50.0 W HEAT RATE GAINED BY WATER = 47.4 W HEAT BALANCE ERROR = 5.3%

REM = 214.9   RAM = 0.641E 06   PRM = 5.79

UPSTREAM BULK TEMPERATURE =22.9 DEG C   DOWNSTREAM BULK TEMPERATURE =31.6 DEG C

INLET BULK TEMPERATURE =23.0 DEG C   OUTLET BULK TEMPERATURE =31.5 DEG C

MASS FLOW RATE = 4.7 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	24.8	24.8	23.2	195.7	6.44	0.00231	0.512E 06	16.8
2	3.5	25.6	25.6	23.3	196.6	6.41	0.00540	0.518E 06	12.4
3	5.5	26.2	26.1	23.5	197.5	6.37	0.00849	0.524E 06	10.7
4	7.5	26.8	26.7	23.7	198.4	6.34	0.01158	0.530E 06	9.3
5	10.5	27.4	27.4	24.0	199.8	6.29	0.01623	0.539E 06	8.4
6	13.5	28.0	27.9	24.3	201.1	6.24	0.02088	0.548E 06	7.7
7	16.5	28.4	28.3	24.6	202.5	6.19	0.02554	0.557E 06	7.5
8	19.5	28.8	28.6	24.9	203.9	6.15	0.03022	0.566E 06	7.3
9	22.5	29.0	28.8	25.2	205.3	6.10	0.03490	0.575E 06	7.5
10	25.5	29.2	29.3	25.5	206.6	6.05	0.03958	0.584E 06	7.4
11	29.5	29.7	29.6	25.9	208.5	5.99	0.04585	0.597E 06	7.3
12	33.5	30.3	29.9	26.2	210.3	5.93	0.05213	0.609E 06	7.2
13	37.5	30.6	30.4	26.6	212.1	5.88	0.05842	0.622E 06	7.2
14	41.5	31.0	30.7	27.0	213.9	5.82	0.06473	0.634E 06	7.3
15	45.5	31.3	31.1	27.4	215.8	5.76	0.07105	0.646E 06	7.3
16	49.5	31.7	31.6	27.8	217.6	5.71	0.07738	0.659E 06	7.2
17	54.5	32.2	32.1	28.3	219.8	5.64	0.08531	0.675E 06	7.2
18	59.5	32.7	32.6	28.8	222.1	5.58	0.09327	0.691E 06	7.1
19	64.5	33.4	33.1	29.2	224.3	5.51	0.10124	0.706E 06	7.0
20	69.5	34.0	33.9	29.7	226.5	5.45	0.10923	0.722E 06	6.6
21	74.5	34.6	34.4	30.2	228.8	5.39	0.11721	0.739E 06	6.5
22	79.5	35.1	34.9	30.7	231.0	5.34	0.12522	0.756E 06	6.5
23	84.5	35.3	35.1	31.2	233.3	5.28	0.13324	0.773E 06	6.9

FULLY DEVELOPED NUSSELT NUMBER = 7.1

RUN NUMBER (2)   TUBE NUMBER 9

INPUT POWER = 100.0 W   HEAT RATE GAINED BY WATER = 98.6 W   HEAT BALANCE ERROR = 1.4%

REM = 236.2   RAM = 0.166E 07   PRM = 5.21

UPSTREAM BULK TEMPERATURE =22.8 DEG C   DOWNSTREAM BULK TEMPERATURE =40.8 DEG C

INLET BULK TEMPERATURE =23.0 DEG C   OUTLET BULK TEMPERATURE =40.7 DEG C

MASS FLOW RATE = 4.7 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	26.7	26.8	23.3	196.5	6.41	0.00231	0.108E 07	17.1
2	3.5	28.3	28.2	23.7	198.4	6.34	0.00540	0.110E 07	13.0
3	5.5	29.5	29.3	24.1	200.3	6.27	0.00850	0.113E 07	11.1
4	7.5	30.4	30.3	24.5	202.2	6.20	0.01161	0.116E 07	10.0
5	10.5	31.6	31.3	25.1	205.1	6.11	0.01628	0.120E 07	9.2
6	13.5	32.6	32.3	25.7	207.9	6.01	0.02097	0.124E 07	8.7
7	16.5	33.3	33.0	26.4	210.8	5.92	0.02568	0.128E 07	8.6
8	19.5	34.0	33.5	27.0	213.7	5.83	0.03041	0.132E 07	8.6
9	22.5	34.4	34.0	27.6	216.5	5.74	0.03515	0.136E 07	8.7
10	25.5	34.9	34.7	28.2	219.3	5.66	0.03991	0.140E 07	8.7
11	29.5	35.8	35.4	29.0	223.1	5.55	0.04627	0.145E 07	8.7
12	33.5	36.7	36.2	29.8	226.8	5.45	0.05266	0.151E 07	8.6
13	37.5	37.5	37.0	30.6	230.5	5.35	0.05905	0.157E 07	8.6
14	41.5	38.3	37.8	31.4	234.3	5.25	0.06547	0.163E 07	8.6
15	45.5	39.0	38.6	32.2	238.1	5.16	0.07192	0.169E 07	8.8
16	49.5	39.8	39.4	33.0	242.0	5.07	0.07839	0.175E 07	8.7
17	54.5	40.9	40.5	34.0	247.0	4.95	0.08651	0.183E 07	8.6
18	59.5	42.0	41.6	35.0	252.1	4.84	0.09466	0.191E 07	8.5
19	64.5	43.2	42.6	36.0	257.3	4.73	0.10285	0.200E 07	8.4
20	69.5	44.4	44.0	37.0	262.6	4.63	0.11107	0.208E 07	8.0
21	74.5	45.6	45.2	38.1	268.0	4.52	0.11933	0.217E 07	7.8
22	79.5	46.7	46.2	39.1	273.6	4.42	0.12761	0.226E 07	7.7
23	84.5	47.1	46.8	40.1	279.2	4.32	0.13592	0.234E 07	8.3

FULLY DEVELOPED NUSSELT NUMBER = 8.5

RUN NUMBER (3)   TUBE NUMBER 9

INPUT POWER = 150.0 W   HEAT RATE GAINED BY WATER = 142.3 W   HEAT BALANCE ERROR = 5.2%

REM = 256.1   RAM = 0.286E 07   PRM = 4.76

UPSTREAM BULK TEMPERATURE =22.8 DEG C   DOWNSTREAM BULK TEMPERATURE =48.8 DEG C

INLET BULK TEMPERATURE =23.1 DEG C   OUTLET BULK TEMPERATURE =48.6 DEG C

MASS FLOW RATE = 4.7 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE --	PR --	X+ --	RA --	NU (AVERAGE)
1	1.5	28.4	28.4	23.6	197.6	6.37	0.00231	0.158E 07	17.5
2	3.5	30.4	30.4	24.2	200.4	6.27	0.00541	0.164E 07	13.5
3	5.5	32.1	31.8	24.7	203.1	6.17	0.00852	0.169E 07	11.7
4	7.5	33.3	33.2	25.3	205.9	6.08	0.01164	0.175E 07	10.6
5	10.5	34.7	34.4	26.2	210.0	5.94	0.01634	0.183E 07	10.0
6	13.5	36.0	35.5	27.1	214.2	5.81	0.02106	0.191E 07	9.6
7	16.5	37.0	36.4	27.9	218.3	5.69	0.02580	0.200E 07	9.6
8	19.5	37.7	37.1	28.8	222.3	5.57	0.03057	0.209E 07	9.7
9	22.5	38.4	37.8	29.7	226.4	5.46	0.03536	0.217E 07	9.9
10	25.5	39.2	38.8	30.6	230.4	5.35	0.04015	0.226E 07	9.9
11	29.5	40.5	39.9	31.7	235.9	5.21	0.04658	0.239E 07	9.8
12	33.5	41.7	41.0	32.9	241.5	5.08	0.05304	0.252E 07	9.8
13	37.5	42.9	42.3	34.1	247.2	4.95	0.05953	0.265E 07	9.7
14	41.5	44.0	43.4	35.2	253.1	4.82	0.06605	0.279E 07	9.7
15	45.5	45.1	44.5	36.4	259.2	4.69	0.07261	0.293E 07	9.8
16	49.5	46.3	45.8	37.6	265.4	4.57	0.07920	0.307E 07	9.7
17	54.5	47.8	47.3	39.0	273.3	4.43	0.08747	0.325E 07	9.6
18	59.5	49.4	48.8	40.5	281.6	4.28	0.09579	0.344E 07	9.4
19	64.5	51.2	50.3	41.9	290.0	4.15	0.10414	0.363E 07	9.2
20	69.5	52.8	52.3	43.4	298.7	4.01	0.11253	0.383E 07	8.9
21	74.5	54.5	53.9	44.9	307.7	3.89	0.12094	0.403E 07	8.7
22	79.5	56.0	55.3	46.3	316.9	3.77	0.12937	0.424E 07	8.7
23	84.5	56.6	56.1	47.8	326.3	3.65	0.13781	0.445E 07	9.4

FULLY DEVELOPED NUSSELT NUMBER = 9.5

RUN NUMBER (4) TUBE NUMBER 9

INPUT POWER = 200.0 W HEAT RATE GAINED BY WATER = 192.6 W HEAT BALANCE ERROR = 3.7%

REM = 281.2 RAM = 0.465E 07 PRM = 4.29

UPSTREAM BULK TEMPERATURE =22.8 DEG C DOWNSTREAM BULK TEMPERATURE =58.1 DEG C

INLET BULK TEMPERATURE =23.2 DEG C OUTLET BULK TEMPERATURE =57.8 DEG C

MASS FLOW RATE = 4.7 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	30.3	30.2	23.8	198.9	6.32	0.00232	0.218E 07	17.8
2	3.5	33.0	32.9	24.6	202.6	6.19	0.00542	0.228E 07	13.7
3	5.5	35.0	34.6	25.4	206.4	6.06	0.00854	0.238E 07	12.1
4	7.5	36.4	36.1	26.2	210.1	5.94	0.01167	0.248E 07	11.3
5	10.5	38.2	37.7	27.4	215.7	5.77	0.01639	0.264E 07	10.8
6	13.5	39.7	39.0	28.6	221.2	5.60	0.02115	0.279E 07	10.5
7	16.5	40.9	40.1	29.8	226.7	5.45	0.02594	0.295E 07	10.5
8	19.5	41.8	41.0	30.9	232.2	5.31	0.03073	0.312E 07	10.8
9	22.5	42.8	41.9	32.1	237.8	5.17	0.03556	0.330E 07	11.0
10	25.5	43.9	43.3	33.3	243.5	5.03	0.04041	0.348E 07	10.9
11	29.5	45.6	44.9	34.9	251.4	4.86	0.04692	0.373E 07	10.8
12	33.5	47.5	46.4	36.5	259.6	4.69	0.05347	0.398E 07	10.7
13	37.5	49.0	48.1	38.1	268.1	4.52	0.06006	0.424E 07	10.6
14	41.5	50.5	49.6	39.6	276.8	4.36	0.06670	0.452E 07	10.6
15	45.5	52.0	51.2	41.2	285.8	4.21	0.07336	0.479E 07	10.7
16	49.5	53.6	52.7	42.8	295.2	4.07	0.08006	0.508E 07	10.7
17	54.5	55.4	54.7	44.8	307.2	3.89	0.08846	0.545E 07	10.7
18	59.5	57.6	56.7	46.8	319.7	3.73	0.09689	0.583E 07	10.5
19	64.5	59.8	58.7	48.7	332.6	3.57	0.10533	0.622E 07	10.4
20	69.5	62.1	61.4	50.7	343.9	3.45	0.11375	0.659E 07	9.8
21	74.5	64.5	63.6	52.7	351.6	3.36	0.12228	0.688E 07	9.5
22	79.5	66.6	65.5	54.7	359.8	3.28	0.13086	0.719E 07	9.5
23	84.5	67.9	67.2	56.6	368.6	3.19	0.13949	0.750E 07	9.9

FULLY DEVELOPED NUSSELT NUMBER =10.4

RUN NUMBER (5)   TUBE NUMBER 9

INPUT POWER = 50.0 W   HEAT RATE GAINED BY WATER = 48.9 W   HEAT BALANCE ERROR = 2.2%

REM = 361.3   RAM = 0.605E 06   PRM = 6.06

UPSTREAM BULK TEMPERATURE =22.9 DEG C   DOWNSTREAM BULK TEMPERATURE =28.0 DEG C

INLET BULK TEMPERATURE =22.9 DEG C   OUTLET BULK TEMPERATURE =28.0 DEG C

MASS FLOW RATE = 8.2 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	24.3	24.4	23.0	341.4	6.46	0.00132	0.528E 06	22.1
2	3.5	24.8	24.9	23.1	342.4	6.44	0.00308	0.531E 06	17.2
3	5.5	25.3	25.3	23.3	343.3	6.42	0.00485	0.535E 06	13.9
4	7.5	25.8	25.8	23.4	344.2	6.40	0.00661	0.539E 06	11.9
5	10.5	26.4	26.3	23.5	345.7	6.37	0.00926	0.544E 06	10.4
6	13.5	26.9	26.8	23.7	347.1	6.34	0.01191	0.549E 06	9.2
7	16.5	27.3	27.3	23.9	348.5	6.31	0.01457	0.555E 06	8.5
8	19.5	27.7	27.6	24.1	349.9	6.28	0.01722	0.561E 06	8.1
9	22.5	27.9	27.8	24.2	351.3	6.25	0.01988	0.566E 06	8.0
10	25.5	28.2	28.1	24.4	352.7	6.23	0.02255	0.572E 06	7.7
11	29.5	28.6	28.4	24.6	354.6	6.19	0.02610	0.579E 06	7.5
12	33.5	28.9	28.7	24.9	356.5	6.15	0.02966	0.586E 06	7.4
13	37.5	29.0	28.9	25.1	358.4	6.11	0.03323	0.594E 06	7.6
14	41.5	29.3	29.1	25.3	360.3	6.08	0.03680	0.601E 06	7.5
15	45.5	29.4	29.3	25.6	362.2	6.04	0.04038	0.609E 06	7.7
16	49.5	29.5	29.4	25.8	364.1	6.01	0.04396	0.617E 06	7.9
17	54.5	29.7	29.7	26.1	366.5	5.96	0.04844	0.626E 06	8.0
18	59.5	30.0	29.9	26.4	368.9	5.92	0.05293	0.636E 06	8.0
19	64.5	30.4	30.1	26.6	371.2	5.87	0.05743	0.645E 06	8.1
20	69.5	30.7	30.6	26.9	373.6	5.83	0.06193	0.655E 06	7.8
21	74.5	31.0	30.8	27.2	376.0	5.79	0.06644	0.664E 06	7.8
22	79.5	31.4	31.1	27.5	378.3	5.75	0.07096	0.674E 06	7.7
23	84.5	31.5	31.4	27.8	380.7	5.71	0.07549	0.683E 06	7.9

FULLY DEVELOPED NUSSELT NUMBER = 7.8

RUN NUMBER (6)   TUBE NUMBER 9

INPUT POWER = 100.0 W   HEAT RATE GAINED BY WATER = 98.3 W   HEAT BALANCE ERROR = 1.7%

REM = 383.1   RAM = 0.140E 07   PRM = 5.67

UPSTREAM BULK TEMPERATURE =22.9 DEG C   DOWNSTREAM BULK TEMPERATURE =33.2 DEG C

INLET BULK TEMPERATURE =23.1 DEG C   OUTLET BULK TEMPERATURE =33.2 DEG C

MASS FLOW RATE = 8.2 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	25.8	25.9	23.2	343.0	6.43	0.00132	0.107E 07	22.3
2	3.5	26.9	27.0	23.5	344.9	6.39	0.00309	0.109E 07	16.8
3	5.5	27.9	27.8	23.7	346.8	6.35	0.00485	0.110E 07	14.1
4	7.5	28.7	28.7	23.9	348.7	6.31	0.00662	0.112E 07	12.2
5	10.5	29.7	29.7	24.3	351.6	6.25	0.00928	0.114E 07	10.8
6	13.5	30.8	30.6	24.6	354.5	6.19	0.01194	0.116E 07	9.6
7	16.5	31.4	31.2	25.0	357.3	6.14	0.01461	0.119E 07	9.2
8	19.5	32.0	31.7	25.3	360.2	6.08	0.01729	0.121E 07	9.0
9	22.5	32.3	32.0	25.7	363.1	6.03	0.01997	0.123E 07	9.0
10	25.5	32.7	32.6	26.0	365.9	5.97	0.02266	0.125E 07	8.8
11	29.5	33.2	32.9	26.5	369.7	5.90	0.02625	0.129E 07	8.8
12	33.5	33.8	33.3	26.9	373.5	5.83	0.02985	0.132E 07	8.8
13	37.5	34.0	33.7	27.4	377.3	5.77	0.03346	0.135E 07	9.0
14	41.5	34.4	34.1	27.8	381.1	5.70	0.03708	0.138E 07	9.1
15	45.5	34.7	34.3	28.3	384.9	5.64	0.04071	0.141E 07	9.4
16	49.5	35.0	34.7	28.8	388.7	5.58	0.04434	0.144E 07	9.6
17	54.5	35.5	35.2	29.3	393.3	5.50	0.04890	0.148E 07	9.6
18	59.5	36.1	35.7	29.9	398.0	5.43	0.05347	0.152E 07	9.6
19	64.5	36.6	36.1	30.5	402.7	5.36	0.05803	0.156E 07	9.8
20	69.5	37.3	37.1	31.1	407.3	5.29	0.06261	0.161E 07	9.4
21	74.5	38.0	37.6	31.7	412.1	5.22	0.06721	0.165E 07	9.4
22	79.5	38.6	38.2	32.2	416.9	5.16	0.07182	0.169E 07	9.4
23	84.5	38.9	38.7	32.8	421.7	5.09	0.07644	0.174E 07	9.6

FULLY DEVELOPED NUSSELT NUMBER = 9.3

RUN NUMBER (7) TUBE NUMBER 9

INPUT POWER = 150.0 W HEAT RATE GAINED BY WATER = 143.4 W HEAT BALANCE ERROR = 4.4%

REM = 401.8 RAM = 0.227E 07 PRM = 5.37

UPSTREAM BULK TEMPERATURE =22.9 DEG C DOWNSTREAM BULK TEMPERATURE =37.9 DEG C

INLET BULK TEMPERATURE =23.0 DEG C OUTLET BULK TEMPERATURE =37.8 DEG C

MASS FLOW RATE = 8.2 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	27.0	27.1	23.3	343.6	6.41	0.00132	0.157E 07	22.7
2	3.5	28.7	28.8	23.6	346.4	6.36	0.00309	0.161E 07	16.8
3	5.5	30.0	29.9	24.0	349.2	6.30	0.00486	0.164E 07	14.2
4	7.5	31.2	31.1	24.3	351.9	6.24	0.00663	0.167E 07	12.4
5	10.5	32.7	32.4	24.8	356.1	6.16	0.00930	0.172E 07	11.0
6	13.5	33.9	33.6	25.3	360.3	6.08	0.01197	0.177E 07	10.1
7	16.5	34.8	34.4	25.8	364.5	6.00	0.01465	0.181E 07	9.7
8	19.5	35.3	34.9	26.3	368.7	5.92	0.01735	0.186E 07	9.7
9	22.5	35.7	35.2	26.8	372.8	5.85	0.02004	0.191E 07	9.8
10	25.5	36.1	35.9	27.3	377.0	5.77	0.02275	0.196E 07	9.8
11	29.5	36.9	36.4	28.0	382.5	5.68	0.02637	0.203E 07	9.8
12	33.5	37.5	36.9	28.7	388.0	5.59	0.03000	0.210E 07	9.9
13	37.5	38.1	37.4	29.4	393.5	5.50	0.03365	0.216E 07	10.1
14	41.5	38.6	37.9	30.0	399.0	5.42	0.03730	0.223E 07	10.2
15	45.5	39.0	38.4	30.7	404.4	5.33	0.04096	0.231E 07	10.6
16	49.5	39.5	39.0	31.4	409.9	5.25	0.04463	0.238E 07	10.7
17	54.5	40.3	39.8	32.2	416.9	5.16	0.04923	0.247E 07	10.8
18	59.5	41.2	40.5	33.1	424.0	5.06	0.05386	0.257E 07	10.8
19	64.5	42.0	41.3	33.9	431.3	4.96	0.05849	0.267E 07	10.9
20	69.5	43.0	42.6	34.8	438.7	4.87	0.06315	0.276E 07	10.4
21	74.5	44.0	43.4	35.6	446.2	4.78	0.06782	0.287E 07	10.3
22	79.5	44.9	44.2	36.4	453.9	4.69	0.07251	0.297E 07	10.2
23	84.5	45.3	45.0	37.3	461.7	4.60	0.07722	0.307E 07	10.6

FULLY DEVELOPED NUSSELT NUMBER =10.3

RUN NUMBER (8)   TUBE NUMBER 9

INPUT POWER = 200.0 W   HEAT RATE GAINED BY WATER = 193.8 W   HEAT BALANCE ERROR = 3.1%

REM = 423.6   RAM = 0.347E 07   PRM = 5.06

UPSTREAM BULK TEMPERATURE =22.9 DEG C   DOWNSTREAM BULK TEMPERATURE =43.2 DEG C

INLET BULK TEMPERATURE =23.1 DEG C   OUTLET BULK TEMPERATURE =43.0 DEG C

MASS FLOW RATE = 8.2 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	28.4	28.5	23.4	344.8	6.39	0.00132	0.215E 07	23.0
2	3.5	30.7	30.7	23.9	348.5	6.31	0.00309	0.220E 07	17.0
3	5.5	32.5	32.3	24.4	352.3	6.23	0.00486	0.226E 07	14.4
4	7.5	33.9	33.8	24.8	356.1	6.16	0.00664	0.232E 07	12.8
5	10.5	35.6	35.3	25.5	361.7	6.05	0.00932	0.241E 07	11.5
6	13.5	37.1	36.6	26.2	367.4	5.94	0.01200	0.250E 07	10.8
7	16.5	38.1	37.4	26.9	373.0	5.84	0.01470	0.259E 07	10.5
8	19.5	38.7	38.1	27.5	378.7	5.74	0.01741	0.268E 07	10.5
9	22.5	39.2	38.5	28.2	384.3	5.65	0.02013	0.277E 07	10.8
10	25.5	39.7	39.3	28.9	389.8	5.56	0.02285	0.286E 07	10.8
11	29.5	40.7	40.0	29.8	397.2	5.44	0.02650	0.299E 07	10.8
12	33.5	41.6	40.7	30.7	404.6	5.33	0.03016	0.312E 07	11.0
13	37.5	42.2	41.4	31.6	412.0	5.22	0.03383	0.326E 07	11.2
14	41.5	42.9	42.1	32.6	419.6	5.12	0.03752	0.339E 07	11.4
15	45.5	43.6	42.7	33.5	427.4	5.01	0.04122	0.354E 07	11.7
16	49.5	44.3	43.6	34.4	435.3	4.91	0.04494	0.368E 07	11.9
17	54.5	45.5	44.8	35.5	445.5	4.79	0.04961	0.386E 07	11.7
18	59.5	46.6	45.8	36.7	455.9	4.67	0.05430	0.405E 07	11.8
19	64.5	47.8	46.8	37.8	466.5	4.55	0.05901	0.424E 07	11.8
20	69.5	49.1	48.5	38.9	477.5	4.43	0.06374	0.443E 07	11.4
21	74.5	50.4	49.6	40.1	488.7	4.32	0.06849	0.463E 07	11.3
22	79.5	51.7	50.8	41.2	500.1	4.21	0.07325	0.484E 07	11.1
23	84.5	52.2	51.8	42.4	511.8	4.11	0.07804	0.505E 07	11.6

FULLY DEVELOPED NUSSELT NUMBER =11.2

RUN NUMBER (9) TUBE NUMBER 9

INPUT POWER = 250.0 W HEAT RATE GAINED BY WATER = 243.6 W HEAT BALANCE ERROR = 2.5%

REM = 446.6 RAM = 0.488E 07 PRM = 4.78

UPSTREAM BULK TEMPERATURE =22.9 DEG C DOWNSTREAM BULK TEMPERATURE =48.4 DEG C

INLET BULK TEMPERATURE =23.2 DEG C OUTLET BULK TEMPERATURE =48.2 DEG C

MASS FLOW RATE = 8.2 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE --	PR --	X+ --	RA --	NU (AVERAGE)
1	1.5	29.9	29.9	23.6	346.0	6.36	0.00132	0.272E 07	23.1
2	3.5	32.6	32.6	24.2	350.7	6.27	0.00309	0.281E 07	17.2
3	5.5	34.7	34.5	24.7	355.4	6.17	0.00487	0.291E 07	14.7
4	7.5	36.4	36.3	25.3	360.2	6.08	0.00665	0.300E 07	13.1
5	10.5	38.4	37.9	26.2	367.3	5.95	0.00934	0.314E 07	12.0
6	13.5	40.0	39.3	27.0	374.4	5.82	0.01203	0.329E 07	11.4
7	16.5	41.1	40.4	27.9	381.5	5.70	0.01474	0.343E 07	11.2
8	19.5	41.9	41.0	28.7	388.5	5.58	0.01747	0.358E 07	11.3
9	22.5	42.5	41.5	29.6	395.4	5.47	0.02020	0.372E 07	11.6
10	25.5	43.1	42.5	30.5	402.4	5.36	0.02294	0.387E 07	11.6
11	29.5	44.3	43.4	31.6	411.7	5.23	0.02661	0.409E 07	11.7
12	33.5	45.3	44.1	32.8	421.3	5.10	0.03030	0.431E 07	11.9
13	37.5	46.2	45.2	33.9	431.2	4.97	0.03401	0.453E 07	12.0
14	41.5	47.2	46.2	35.1	441.3	4.84	0.03773	0.476E 07	12.2
15	45.5	48.1	46.8	36.2	451.7	4.72	0.04148	0.500E 07	12.6
16	49.5	48.7	47.7	37.3	462.3	4.60	0.04524	0.524E 07	13.0
17	54.5	50.2	49.1	38.8	475.9	4.45	0.04996	0.554E 07	13.0
18	59.5	51.7	50.7	40.2	490.0	4.31	0.05471	0.586E 07	12.8
19	64.5	53.2	51.9	41.6	504.5	4.17	0.05948	0.618E 07	12.9
20	69.5	54.6	53.8	43.1	519.4	4.04	0.06427	0.651E 07	12.5
21	74.5	56.2	55.1	44.5	534.7	3.92	0.06908	0.685E 07	12.5
22	79.5	58.0	56.9	45.9	550.4	3.80	0.07389	0.720E 07	12.1
23	84.5	58.9	58.3	47.4	566.5	3.68	0.07871	0.756E 07	12.4

FULLY DEVELOPED NUSSELT NUMBER =12.2

RUN NUMBER (10)   TUBE NUMBER 9

INPUT POWER = 300.0 W   HEAT RATE GAINED BY WATER = 295.1 W   HEAT BALANCE ERROR = 1.6%

REM = 471.6   RAM = 0.660E 07   PRM = 4.49

UPSTREAM BULK TEMPERATURE =22.9 DEG C   DOWNSTREAM BULK TEMPERATURE =53.8 DEG C

INLET BULK TEMPERATURE =23.2 DEG C   OUTLET BULK TEMPERATURE =53.6 DEG C

MASS FLOW RATE = 8.2 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	31.2	31.3	23.7	347.2	6.34	0.00132	0.333E 07	23.4
2	3.5	34.5	34.4	24.4	352.9	6.22	0.00309	0.346E 07	17.6
3	5.5	36.9	36.6	25.1	358.7	6.11	0.00487	0.360E 07	15.1
4	7.5	38.8	38.5	25.8	364.4	6.00	0.00666	0.374E 07	13.6
5	10.5	41.0	40.5	26.9	373.0	5.84	0.00935	0.395E 07	12.6
6	13.5	42.9	42.0	27.9	381.6	5.69	0.01206	0.416E 07	12.0
7	16.5	44.2	43.1	28.9	390.1	5.55	0.01479	0.437E 07	11.9
8	19.5	45.1	43.9	30.0	398.5	5.42	0.01753	0.459E 07	12.0
9	22.5	45.7	44.4	31.0	406.9	5.30	0.02027	0.482E 07	12.4
10	25.5	46.4	45.5	32.1	415.5	5.17	0.02303	0.506E 07	12.5
11	29.5	47.8	46.6	33.5	427.3	5.02	0.02673	0.539E 07	12.6
12	33.5	49.1	47.6	34.9	439.5	4.86	0.03045	0.572E 07	12.8
13	37.5	49.9	48.6	36.2	452.0	4.71	0.03419	0.607E 07	13.2
14	41.5	50.9	49.6	37.6	465.0	4.57	0.03795	0.642E 07	13.6
15	45.5	52.1	50.6	39.0	478.3	4.43	0.04173	0.678E 07	13.9
16	49.5	53.3	52.1	40.4	492.0	4.29	0.04554	0.716E 07	13.8
17	54.5	55.3	54.0	42.1	509.7	4.13	0.05031	0.763E 07	13.6
18	59.5	56.7	55.4	43.9	527.9	3.97	0.05511	0.813E 07	13.9
19	64.5	58.7	57.3	45.6	546.8	3.82	0.05992	0.863E 07	13.6
20	69.5	60.8	59.8	47.4	566.3	3.68	0.06474	0.916E 07	13.0
21	74.5	62.6	61.2	49.1	586.3	3.55	0.06956	0.969E 07	13.1
22	79.5	64.2	62.8	50.8	602.6	3.44	0.07438	0.102E 08	13.2
23	84.5	65.6	64.8	52.6	614.5	3.37	0.07925	0.106E 08	13.2

FULLY DEVELOPED NUSSELT NUMBER =13.1

RUN NUMBER (11) TUBE NUMBER 9

INPUT POWER = 350.0 W HEAT RATE GAINED BY WATER = 335.4 W HEAT BALANCE ERROR = 4.2%

REM = 492.3 RAM = 0.815E 07 PRM = 4.29

UPSTREAM BULK TEMPERATURE =22.9 DEG C DOWNSTREAM BULK TEMPERATURE =58.0 DEG C

INLET BULK TEMPERATURE =23.2 DEG C OUTLET BULK TEMPERATURE =57.8 DEG C

MASS FLOW RATE = 8.2 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	32.3	32.3	23.8	348.1	6.32	0.00132	0.381E 07	23.7
2	3.5	35.9	35.9	24.6	354.6	6.19	0.00310	0.398E 07	17.7
3	5.5	38.7	38.2	25.4	361.1	6.06	0.00488	0.416E 07	15.3
4	7.5	40.8	40.3	26.2	367.7	5.94	0.00667	0.434E 07	13.9
5	10.5	43.0	42.3	27.4	377.5	5.77	0.00937	0.461E 07	13.0
6	13.5	45.0	44.0	28.6	387.2	5.60	0.01209	0.489E 07	12.5
7	16.5	46.3	45.1	29.8	396.7	5.45	0.01482	0.517E 07	12.4
8	19.5	47.2	45.9	31.0	406.3	5.31	0.01756	0.547E 07	12.6
9	22.5	47.9	46.4	32.1	416.1	5.17	0.02032	0.577E 07	13.1
10	25.5	48.7	47.7	33.3	426.2	5.03	0.02309	0.609E 07	13.2
11	29.5	50.3	48.7	34.9	440.0	4.86	0.02681	0.652E 07	13.4
12	33.5	51.4	49.6	36.5	454.3	4.69	0.03056	0.697E 07	14.0
13	37.5	52.3	50.8	38.1	469.1	4.52	0.03433	0.743E 07	14.5
14	41.5	53.8	52.3	39.6	484.4	4.36	0.03812	0.791E 07	14.5
15	45.5	55.3	53.7	41.2	500.2	4.21	0.04193	0.839E 07	14.6
16	49.5	56.7	55.3	42.8	516.6	4.07	0.04575	0.889E 07	14.6
17	54.5	58.9	57.5	44.8	537.7	3.89	0.05056	0.954E 07	14.4
18	59.5	60.5	59.0	46.8	559.5	3.73	0.05537	0.102E 08	14.8
19	64.5	62.3	60.6	48.7	582.1	3.57	0.06020	0.109E 08	15.0
20	69.5	64.8	63.7	50.7	601.8	3.45	0.06501	0.115E 08	14.1
21	74.5	67.2	65.7	52.7	615.3	3.36	0.06989	0.121E 08	13.8
22	79.5	69.1	67.5	54.7	629.7	3.28	0.07479	0.126E 08	13.9
23	84.5	70.0	69.0	56.6	645.1	3.19	0.07972	0.131E 08	14.6

FULLY DEVELOPED NUSSELT NUMBER =14.0

RUN NUMBER (12) TUBE NUMBER 9

INPUT POWER = 100.0 W HEAT RATE GAINED BY WATER = 99.5 W HEAT BALANCE ERROR = 0.5%

REM = 528.3 RAM = 0.130E 07 PRM = 5.90

UPSTREAM BULK TEMPERATURE =22.8 DEG C DOWNSTREAM BULK TEMPERATURE =30.1 DEG C

INLET BULK TEMPERATURE =22.9 DEG C OUTLET BULK TEMPERATURE =30.1 DEG C

MASS FLOW RATE = 11.8 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	25.2	25.1	23.0	487.6	6.46	0.00092	0.108E 07	27.8
2	3.5	26.1	26.1	23.2	489.5	6.43	0.00216	0.109E 07	20.3
3	5.5	26.9	26.9	23.3	491.5	6.40	0.00339	0.110E 07	16.8
4	7.5	27.6	27.6	23.5	493.4	6.38	0.00463	0.111E 07	14.4
5	10.5	28.6	28.5	23.8	496.3	6.33	0.00649	0.112E 07	12.4
6	13.5	29.5	29.4	24.0	499.2	6.29	0.00835	0.114E 07	10.9
7	16.5	30.2	30.1	24.3	502.1	6.25	0.01021	0.116E 07	10.1
8	19.5	30.8	30.6	24.5	505.0	6.21	0.01207	0.117E 07	9.5
9	22.5	31.2	31.0	24.7	507.9	6.17	0.01394	0.119E 07	9.3
10	25.5	31.6	31.5	25.0	510.8	6.13	0.01581	0.120E 07	9.0
11	29.5	32.1	31.8	25.3	514.6	6.08	0.01831	0.123E 07	8.9
12	33.5	32.5	32.1	25.6	518.5	6.03	0.02082	0.125E 07	8.8
13	37.5	32.9	32.6	26.0	522.4	5.98	0.02332	0.127E 07	8.8
14	41.5	33.2	32.8	26.3	526.2	5.93	0.02584	0.129E 07	8.9
15	45.5	33.4	33.0	26.6	530.1	5.88	0.02836	0.131E 07	8.9
16	49.5	33.5	33.3	27.0	534.0	5.83	0.03088	0.134E 07	9.1
17	54.5	33.9	33.6	27.4	538.8	5.77	0.03404	0.136E 07	9.3
18	59.5	34.2	33.9	27.8	543.6	5.71	0.03721	0.139E 07	9.4
19	64.5	34.6	34.1	28.2	548.4	5.66	0.04038	0.142E 07	9.5
20	69.5	35.1	34.8	28.6	553.1	5.60	0.04356	0.145E 07	9.2
21	74.5	35.6	35.2	29.0	557.9	5.55	0.04675	0.148E 07	9.2
22	79.5	36.0	35.5	29.4	562.6	5.49	0.04994	0.151E 07	9.2
23	84.5	36.1	35.9	29.8	567.3	5.44	0.05314	0.153E 07	9.5

FULLY DEVELOPED NUSSELT NUMBER = 9.2

RUN NUMBER (13)   TUBE NUMBER 9

INPUT POWER = 200.0 W   HEAT RATE GAINED BY WATER = 201.0 W   HEAT BALANCE ERROR =-0.5%

REM = 569.1   RAM = 0.313E 07   PRM = 5.42

UPSTREAM BULK TEMPERATURE =22.6 DEG C   DOWNSTREAM BULK TEMPERATURE =37.3 DEG C

INLET BULK TEMPERATURE =22.7 DEG C   OUTLET BULK TEMPERATURE =37.2 DEG C

MASS FLOW RATE = 11.8 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	27.2	27.3	23.0	487.2	6.47	0.00092	0.217E 07	28.1
2	3.5	29.2	29.2	23.3	491.1	6.41	0.00216	0.222E 07	20.4
3	5.5	30.8	30.7	23.7	495.0	6.35	0.00340	0.226E 07	17.0
4	7.5	32.1	32.1	24.0	498.9	6.30	0.00464	0.230E 07	14.8
5	10.5	33.9	33.7	24.5	504.8	6.21	0.00650	0.237E 07	12.8
6	13.5	35.5	35.1	25.0	510.7	6.13	0.00837	0.244E 07	11.6
7	16.5	36.6	36.2	25.5	516.6	6.05	0.01025	0.250E 07	11.0
8	19.5	37.3	36.8	26.0	522.4	5.98	0.01213	0.257E 07	10.8
9	22.5	37.8	37.2	26.5	528.3	5.90	0.01402	0.264E 07	10.8
10	25.5	38.3	37.9	27.0	534.2	5.83	0.01591	0.271E 07	10.7
11	29.5	39.1	38.5	27.6	542.0	5.73	0.01844	0.280E 07	10.7
12	33.5	39.8	38.9	28.3	549.7	5.64	0.02098	0.289E 07	10.7
13	37.5	40.2	39.5	29.0	557.4	5.55	0.02353	0.298E 07	10.9
14	41.5	40.8	39.9	29.6	565.0	5.47	0.02609	0.308E 07	11.1
15	45.5	41.1	40.3	30.3	572.7	5.39	0.02864	0.317E 07	11.4
16	49.5	41.4	40.7	30.9	580.4	5.31	0.03121	0.328E 07	11.7
17	54.5	42.2	41.4	31.8	590.1	5.21	0.03443	0.340E 07	11.8
18	59.5	42.9	42.0	32.6	600.0	5.11	0.03766	0.354E 07	12.0
19	64.5	43.6	42.6	33.4	610.1	5.02	0.04090	0.367E 07	12.2
20	69.5	44.6	43.9	34.3	620.4	4.93	0.04416	0.380E 07	11.8
21	74.5	45.5	44.7	35.1	630.9	4.83	0.04742	0.394E 07	11.8
22	79.5	46.3	45.4	35.9	641.6	4.75	0.05070	0.408E 07	11.8
23	84.5	46.6	46.2	36.8	652.4	4.66	0.05399	0.422E 07	12.2

FULLY DEVELOPED NUSSELT NUMBER =11.4

RUN NUMBER (14) TUBE NUMBER 9

INPUT POWER = 300.0 W HEAT RATE GAINED BY WATER = 295.0 W HEAT BALANCE ERROR = 1.7%

REM = 609.2 RAM = 0.537E 07 PRM = 5.03

UPSTREAM BULK TEMPERATURE =22.6 DEG C DOWNSTREAM BULK TEMPERATURE =44.2 DEG C

INLET BULK TEMPERATURE =22.7 DEG C OUTLET BULK TEMPERATURE =44.0 DEG C

MASS FLOW RATE = 11.8 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	29.3	29.3	23.1	488.7	6.45	0.00092	0.321E 07	28.3
2	3.5	32.2	32.1	23.6	494.4	6.36	0.00216	0.331E 07	20.6
3	5.5	34.4	34.2	24.1	500.1	6.28	0.00340	0.340E 07	17.2
4	7.5	36.3	36.1	24.6	505.9	6.20	0.00464	0.350E 07	15.2
5	10.5	38.5	38.1	25.3	514.5	6.08	0.00652	0.364E 07	13.5
6	13.5	40.5	39.8	26.0	523.1	5.97	0.00840	0.379E 07	12.4
7	16.5	41.8	40.9	26.8	531.7	5.86	0.01029	0.393E 07	12.0
8	19.5	42.6	41.7	27.5	540.3	5.75	0.01218	0.408E 07	12.0
9	22.5	43.2	42.1	28.2	548.9	5.65	0.01409	0.423E 07	12.1
10	25.5	43.7	42.9	29.0	557.4	5.55	0.01600	0.438E 07	12.1
11	29.5	44.8	43.7	29.9	568.6	5.43	0.01856	0.458E 07	12.1
12	33.5	45.7	44.3	30.9	579.9	5.31	0.02112	0.480E 07	12.4
13	37.5	46.2	45.1	31.9	591.3	5.20	0.02369	0.502E 07	12.6
14	41.5	46.8	45.6	32.9	603.0	5.08	0.02628	0.525E 07	13.0
15	45.5	47.4	46.1	33.8	614.9	4.97	0.02888	0.548E 07	13.4
16	49.5	47.9	46.6	34.8	627.1	4.87	0.03149	0.572E 07	13.9
17	54.5	48.9	47.6	36.0	642.8	4.74	0.03477	0.602E 07	14.1
18	59.5	49.8	48.5	37.2	658.9	4.61	0.03806	0.633E 07	14.4
19	64.5	50.8	49.4	38.4	675.3	4.48	0.04137	0.664E 07	14.7
20	69.5	52.4	51.5	39.7	692.3	4.36	0.04469	0.696E 07	13.9
21	74.5	54.0	52.8	40.9	709.6	4.25	0.04802	0.729E 07	13.6
22	79.5	55.1	53.8	42.1	727.4	4.13	0.05137	0.763E 07	13.8
23	84.5	55.5	54.7	43.3	745.6	4.02	0.05473	0.797E 07	14.4

FULLY DEVELOPED NUSSELT NUMBER =13.2

RUN NUMBER (15)   TUBE NUMBER 9

INPUT POWER = 400.0 W   HEAT RATE GAINED BY WATER = 384.4 W   HEAT BALANCE ERROR = 3.9%

REM = 651.0   RAM = 0.805E 07   PRM = 4.67

UPSTREAM BULK TEMPERATURE =22.6 DEG C   DOWNSTREAM BULK TEMPERATURE =50.7 DEG C

INLET BULK TEMPERATURE =22.8 DEG C   OUTLET BULK TEMPERATURE =50.6 DEG C

MASS FLOW RATE = 11.8 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	31.3	31.4	23.3	490.6	6.42	0.00093	0.423E 07	28.5
2	3.5	34.9	34.9	23.9	498.1	6.31	0.00216	0.439E 07	20.9
3	5.5	37.7	37.3	24.5	505.6	6.20	0.00341	0.455E 07	17.7
4	7.5	39.9	39.6	25.2	513.1	6.10	0.00465	0.472E 07	15.7
5	10.5	42.6	42.0	26.1	524.3	5.95	0.00653	0.496E 07	14.2
6	13.5	44.9	43.8	27.1	535.6	5.81	0.00843	0.521E 07	13.2
7	16.5	46.1	45.1	28.0	546.7	5.67	0.01033	0.547E 07	13.0
8	19.5	47.1	45.8	29.0	557.8	5.55	0.01224	0.572E 07	13.0
9	22.5	47.7	46.3	29.9	568.8	5.43	0.01416	0.598E 07	13.3
10	25.5	48.2	47.2	30.9	579.8	5.31	0.01608	0.626E 07	13.5
11	29.5	49.5	48.0	32.2	594.8	5.16	0.01865	0.664E 07	13.6
12	33.5	50.6	48.7	33.4	610.2	5.02	0.02124	0.702E 07	13.9
13	37.5	51.0	49.3	34.7	626.0	4.88	0.02385	0.742E 07	14.5
14	41.5	51.9	50.2	36.0	642.3	4.74	0.02647	0.783E 07	14.9
15	45.5	52.5	50.8	37.2	659.1	4.61	0.02910	0.825E 07	15.6
16	49.5	53.1	51.5	38.5	676.3	4.48	0.03175	0.868E 07	16.2
17	54.5	54.9	53.4	40.1	698.4	4.32	0.03507	0.923E 07	15.8
18	59.5	56.7	55.1	41.7	721.3	4.17	0.03842	0.980E 07	15.7
19	64.5	58.1	56.2	43.3	744.9	4.02	0.04177	0.104E 08	16.0
20	69.5	59.6	58.2	44.9	769.3	3.89	0.04514	0.110E 08	15.8
21	74.5	61.3	59.5	46.5	794.3	3.75	0.04851	0.116E 08	15.8
22	79.5	63.0	61.2	48.0	820.1	3.63	0.05189	0.122E 08	15.6
23	84.5	63.8	62.8	49.6	846.4	3.51	0.05527	0.129E 08	16.0

FULLY DEVELOPED NUSSELT NUMBER =14.8

RUN NUMBER (16)   TUBE NUMBER 9

INPUT POWER = 500.0 W   HEAT RATE GAINED BY WATER = 486.7 W   HEAT BALANCE ERROR = 2.7%

REM = 700.9   RAM = 0.118E 08   PRM = 4.30

UPSTREAM BULK TEMPERATURE =22.4 DEG C   DOWNSTREAM BULK TEMPERATURE =58.1 DEG C

INLET BULK TEMPERATURE =22.8 DEG C   OUTLET BULK TEMPERATURE =57.9 DEG C

MASS FLOW RATE = 11.8 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	33.5	33.5	23.4	491.6	6.40	0.00093	0.538E 07	28.8
2	3.5	37.8	37.8	24.2	501.0	6.27	0.00216	0.564E 07	21.3
3	5.5	41.2	40.7	25.0	510.5	6.13	0.00341	0.590E 07	18.2
4	7.5	43.8	43.3	25.8	520.0	6.01	0.00466	0.617E 07	16.3
5	10.5	46.9	45.9	27.0	534.3	5.83	0.00655	0.657E 07	14.9
6	13.5	49.3	47.9	28.2	548.4	5.66	0.00845	0.697E 07	14.2
7	16.5	50.7	49.1	29.4	562.4	5.50	0.01037	0.738E 07	14.0
8	19.5	51.6	49.9	30.6	576.3	5.35	0.01228	0.781E 07	14.3
9	22.5	52.1	50.2	31.8	590.4	5.21	0.01421	0.827E 07	14.8
10	25.5	52.7	51.3	33.0	604.9	5.07	0.01616	0.873E 07	15.0
11	29.5	54.0	52.0	34.6	624.9	4.89	0.01876	0.937E 07	15.5
12	33.5	55.5	53.0	36.2	645.6	4.71	0.02138	0.100E 08	15.8
13	37.5	56.1	53.9	37.8	667.0	4.55	0.02402	0.107E 08	16.5
14	41.5	57.0	54.7	39.4	689.2	4.38	0.02667	0.114E 08	17.2
15	45.5	58.2	56.1	41.1	712.1	4.23	0.02934	0.121E 08	17.5
16	49.5	59.7	57.7	42.7	735.7	4.08	0.03202	0.129E 08	17.5
17	54.5	61.7	59.6	44.7	766.3	3.90	0.03538	0.138E 08	17.5
18	59.5	63.4	61.3	46.7	798.1	3.74	0.03876	0.148E 08	17.8
19	64.5	65.0	62.5	48.7	830.9	3.58	0.04214	0.158E 08	18.4
20	69.5	67.6	65.8	50.7	859.6	3.45	0.04551	0.168E 08	17.3
21	74.5	69.9	67.7	52.7	879.2	3.36	0.04892	0.175E 08	17.2
22	79.5	72.0	69.8	54.7	900.2	3.28	0.05236	0.183E 08	17.0
23	84.5	73.0	71.5	56.7	922.6	3.19	0.05581	0.191E 08	17.6

FULLY DEVELOPED NUSSELT NUMBER =16.5

RUN NUMBER (17) TUBE NUMBER 9

INPUT POWER = 100.0 W HEAT RATE GAINED BY WATER = 96.0 W HEAT BALANCE ERROR = 4.0%

REM = 661.6 RAM = 0.115E 07 PRM = 6.17

UPSTREAM BULK TEMPERATURE =22.1 DEG C DOWNSTREAM BULK TEMPERATURE =27.4 DEG C

INLET BULK TEMPERATURE =22.1 DEG C OUTLET BULK TEMPERATURE =27.4 DEG C

MASS FLOW RATE = 15.3 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	24.1	24.0	22.2	622.5	6.61	0.00071	0.987E 06	31.1
2	3.5	24.7	24.8	22.3	624.3	6.59	0.00165	0.994E 06	23.2
3	5.5	25.5	25.5	22.4	626.1	6.57	0.00260	0.100E 07	19.0
4	7.5	26.0	26.1	22.6	628.0	6.55	0.00354	0.101E 07	16.4
5	10.5	26.9	26.8	22.7	630.8	6.51	0.00496	0.102E 07	13.9
6	13.5	27.7	27.6	22.9	633.5	6.48	0.00639	0.103E 07	12.1
7	16.5	28.3	28.3	23.1	636.3	6.45	0.00781	0.104E 07	10.9
8	19.5	28.9	28.9	23.3	639.1	6.42	0.00923	0.105E 07	10.2
9	22.5	29.4	29.2	23.5	641.9	6.38	0.01066	0.107E 07	9.8
10	25.5	29.9	29.7	23.6	644.7	6.35	0.01209	0.108E 07	9.3
11	29.5	30.4	30.2	23.9	648.4	6.31	0.01400	0.109E 07	9.0
12	33.5	30.8	30.5	24.1	652.1	6.27	0.01591	0.111E 07	8.8
13	37.5	31.1	30.8	24.4	655.8	6.23	0.01782	0.112E 07	8.7
14	41.5	31.4	31.2	24.6	659.5	6.19	0.01974	0.114E 07	8.6
15	45.5	31.6	31.3	24.9	663.3	6.15	0.02165	0.115E 07	8.6
16	49.5	31.7	31.5	25.1	667.0	6.11	0.02358	0.117E 07	8.7
17	54.5	32.0	31.7	25.4	671.7	6.06	0.02598	0.119E 07	8.8
18	59.5	32.3	32.0	25.7	676.3	6.02	0.02839	0.121E 07	8.8
19	64.5	32.6	32.0	26.0	681.0	5.97	0.03081	0.123E 07	9.0
20	69.5	33.0	32.6	26.3	685.7	5.92	0.03323	0.125E 07	8.8
21	74.5	33.3	32.9	26.6	690.3	5.88	0.03565	0.127E 07	8.8
22	79.5	33.6	33.2	26.9	695.0	5.83	0.03808	0.129E 07	8.8
23	84.5	33.6	33.3	27.2	699.6	5.79	0.04051	0.131E 07	9.2

FULLY DEVELOPED NUSSELT NUMBER = 9.1

RUN NUMBER (18)   TUBE NUMBER 9

INPUT POWER = 250.0 W   HEAT RATE GAINED BY WATER = 247.0 W   HEAT BALANCE ERROR = 1.2%

REM = 726.6   RAM = 0.368E 07   PRM = 5.55

UPSTREAM BULK TEMPERATURE =22.1 DEG C   DOWNSTREAM BULK TEMPERATURE =35.9 DEG C

INLET BULK TEMPERATURE =22.2 DEG C   OUTLET BULK TEMPERATURE =35.9 DEG C

MASS FLOW RATE = 15.3 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	27.0	27.1	22.4	625.6	6.57	0.00071	0.258E 07	31.7
2	3.5	29.1	29.2	22.7	630.4	6.52	0.00165	0.263E 07	22.9
3	5.5	30.9	30.8	23.0	635.2	6.46	0.00260	0.268E 07	18.9
4	7.5	32.3	32.3	23.3	639.9	6.41	0.00355	0.273E 07	16.5
5	10.5	34.3	34.1	23.8	647.1	6.33	0.00498	0.280E 07	14.2
6	13.5	36.1	35.8	24.3	654.4	6.25	0.00641	0.288E 07	12.6
7	16.5	37.5	37.0	24.8	661.6	6.17	0.00785	0.296E 07	11.8
8	19.5	38.5	37.9	25.2	668.8	6.09	0.00929	0.304E 07	11.4
9	22.5	39.1	38.4	25.7	676.0	6.02	0.01074	0.311E 07	11.3
10	25.5	39.6	39.1	26.2	683.3	5.95	0.01218	0.319E 07	11.1
11	29.5	40.4	39.7	26.8	692.9	5.85	0.01412	0.330E 07	11.0
12	33.5	41.1	40.2	27.4	702.5	5.76	0.01607	0.341E 07	11.1
13	37.5	41.6	40.9	28.0	712.0	5.68	0.01802	0.351E 07	11.1
14	41.5	42.2	41.3	28.7	721.5	5.59	0.01998	0.362E 07	11.2
15	45.5	42.6	41.6	29.3	731.0	5.51	0.02194	0.373E 07	11.4
16	49.5	42.7	41.8	29.9	740.3	5.43	0.02391	0.384E 07	11.8
17	54.5	43.5	42.5	30.7	752.2	5.34	0.02637	0.398E 07	11.9
18	59.5	44.0	43.0	31.5	764.0	5.24	0.02884	0.413E 07	12.1
19	64.5	44.7	43.5	32.3	776.1	5.15	0.03132	0.428E 07	12.3
20	69.5	45.5	44.6	33.0	788.5	5.06	0.03381	0.444E 07	12.1
21	74.5	46.3	45.2	33.8	801.0	4.97	0.03631	0.459E 07	12.2
22	79.5	46.9	45.8	34.6	813.8	4.89	0.03881	0.475E 07	12.3
23	84.5	47.1	46.4	35.4	826.8	4.80	0.04133	0.491E 07	12.7

FULLY DEVELOPED NUSSELT NUMBER =11.7

RUN NUMBER (19)   TUBE NUMBER 9

INPUT POWER = 400.0 W   HEAT RATE GAINED BY WATER = 375.3 W   HEAT BALANCE ERROR = 6.2%

REM = 780.7   RAM = 0.660E 07   PRM = 5.12

UPSTREAM BULK TEMPERATURE =22.0 DEG C   DOWNSTREAM BULK TEMPERATURE =43.1 DEG C

INLET BULK TEMPERATURE =22.2 DEG C   OUTLET BULK TEMPERATURE =43.0 DEG C

MASS FLOW RATE = 15.3 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	29.7	29.7	22.5	627.6	6.55	0.00071	0.395E 07	31.4
2	3.5	32.8	32.9	23.0	634.8	6.47	0.00166	0.406E 07	22.7
3	5.5	35.3	35.1	23.5	642.1	6.38	0.00261	0.418E 07	19.1
4	7.5	37.4	37.2	24.0	649.4	6.30	0.00356	0.430E 07	16.8
5	10.5	40.0	39.6	24.7	660.4	6.18	0.00499	0.448E 07	14.8
6	13.5	42.4	41.7	25.4	671.3	6.07	0.00644	0.466E 07	13.4
7	16.5	44.0	43.1	26.1	682.3	5.96	0.00788	0.484E 07	12.8
8	19.5	45.1	44.0	26.8	693.3	5.85	0.00934	0.502E 07	12.6
9	22.5	45.7	44.5	27.5	704.3	5.75	0.01080	0.521E 07	12.7
10	25.5	46.3	45.4	28.2	715.1	5.65	0.01226	0.539E 07	12.7
11	29.5	47.3	46.1	29.2	729.5	5.52	0.01422	0.564E 07	12.7
12	33.5	48.3	46.5	30.1	743.9	5.40	0.01619	0.590E 07	12.8
13	37.5	48.6	47.3	31.1	758.2	5.29	0.01816	0.617E 07	13.1
14	41.5	49.2	47.7	32.0	772.8	5.18	0.02014	0.645E 07	13.5
15	45.5	49.5	47.8	33.0	787.7	5.07	0.02213	0.673E 07	14.1
16	49.5	49.8	48.2	34.0	803.0	4.96	0.02413	0.702E 07	14.6
17	54.5	51.2	49.5	35.1	822.5	4.83	0.02664	0.739E 07	14.4
18	59.5	51.9	50.3	36.3	842.6	4.70	0.02916	0.776E 07	14.8
19	64.5	52.6	50.7	37.5	863.2	4.58	0.03170	0.815E 07	15.5
20	69.5	53.8	52.4	38.7	884.3	4.46	0.03424	0.854E 07	15.2
21	74.5	55.4	53.9	39.9	906.0	4.34	0.03680	0.895E 07	14.7
22	79.5	57.2	55.6	41.1	928.1	4.23	0.03936	0.936E 07	14.2
23	84.5	57.5	56.4	42.3	950.8	4.11	0.04194	0.978E 07	14.8

FULLY DEVELOPED NUSSELT NUMBER =13.8

RUN NUMBER (20)   TUBE NUMBER 9

INPUT POWER = 550.0 W   HEAT RATE GAINED BY WATER = 517.4 W   HEAT BALANCE ERROR = 5.9%

REM = 845.5   RAM = 0.108E 08   PRM = 4.68

UPSTREAM BULK TEMPERATURE =21.9 DEG C   DOWNSTREAM BULK TEMPERATURE =51.1 DEG C

INLET BULK TEMPERATURE =22.2 DEG C   OUTLET BULK TEMPERATURE =50.9 DEG C

MASS FLOW RATE = 15.3 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	32.3	32.4	22.7	629.7	6.52	0.00071	0.550E 07	31.9
2	3.5	36.5	36.5	23.3	639.7	6.41	0.00166	0.572E 07	23.4
3	5.5	39.8	39.4	24.0	649.8	6.30	0.00261	0.594E 07	19.8
4	7.5	42.4	42.0	24.6	659.9	6.19	0.00357	0.617E 07	17.6
5	10.5	45.7	45.0	25.6	675.1	6.03	0.00501	0.651E 07	15.6
6	13.5	48.6	47.2	26.6	690.2	5.88	0.00646	0.686E 07	14.4
7	16.5	50.3	48.7	27.6	705.3	5.74	0.00792	0.721E 07	14.0
8	19.5	51.2	49.5	28.6	720.3	5.60	0.00938	0.756E 07	14.1
9	22.5	51.8	50.0	29.6	735.1	5.47	0.01086	0.792E 07	14.4
10	25.5	52.2	50.8	30.6	750.0	5.35	0.01233	0.829E 07	14.6
11	29.5	53.4	51.5	31.9	770.0	5.20	0.01431	0.882E 07	14.8
12	33.5	54.5	52.1	33.2	790.6	5.05	0.01630	0.936E 07	15.1
13	37.5	54.6	52.5	34.5	811.8	4.90	0.01830	0.991E 07	15.9
14	41.5	56.0	53.7	35.8	833.7	4.76	0.02032	0.105E 08	15.9
15	45.5	56.7	54.3	37.1	856.2	4.62	0.02234	0.111E 08	16.4
16	49.5	57.1	54.8	38.4	879.3	4.48	0.02437	0.117E 08	17.2
17	54.5	58.4	56.0	40.1	909.2	4.32	0.02693	0.124E 08	17.5
18	59.5	59.8	57.7	41.7	940.0	4.17	0.02950	0.132E 08	17.6
19	64.5	61.4	58.8	43.4	971.9	4.02	0.03208	0.140E 08	17.8
20	69.5	63.1	61.1	45.0	1004.8	3.87	0.03467	0.149E 08	17.4
21	74.5	65.3	63.0	46.6	1038.6	3.74	0.03726	0.157E 08	16.9
22	79.5	66.2	63.6	48.3	1073.4	3.61	0.03986	0.166E 08	17.8
23	84.5	67.4	65.9	49.9	1109.1	3.48	0.04245	0.175E 08	17.6

FULLY DEVELOPED NUSSELT NUMBER =16.2

RUN NUMBER (21)   TUBE NUMBER 9

INPUT POWER = 700.0 W   HEAT RATE GAINED BY WATER = 670.4 W   HEAT BALANCE ERROR = 4.2%

REM = 922.7   RAM = 0.166E 08   PRM = 4.25

UPSTREAM BULK TEMPERATURE =21.9 DEG C   DOWNSTREAM BULK TEMPERATURE =59.7 DEG C

INLET BULK TEMPERATURE =22.2 DEG C   OUTLET BULK TEMPERATURE =59.5 DEG C

MASS FLOW RATE = 15.3 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	35.1	35.2	22.9	632.8	6.49	0.00071	0.722E 07	32.7
2	3.5	40.3	40.3	23.7	645.9	6.34	0.00166	0.759E 07	24.2
3	5.5	44.3	43.7	24.6	659.0	6.20	0.00262	0.797E 07	20.6
4	7.5	47.3	46.7	25.4	672.1	6.06	0.00358	0.835E 07	18.5
5	10.5	51.0	49.9	26.7	691.7	5.86	0.00503	0.894E 07	16.8
6	13.5	54.0	52.1	28.0	711.3	5.68	0.00649	0.953E 07	15.9
7	16.5	55.6	53.5	29.3	730.6	5.51	0.00796	0.101E 08	15.7
8	19.5	56.4	54.1	30.5	749.8	5.35	0.00943	0.108E 08	16.0
9	22.5	57.0	54.4	31.8	769.3	5.20	0.01091	0.114E 08	16.6
10	25.5	57.5	55.5	33.1	789.3	5.06	0.01241	0.121E 08	16.9
11	29.5	58.6	55.8	34.8	817.0	4.87	0.01441	0.130E 08	17.5
12	33.5	60.3	57.2	36.5	845.6	4.68	0.01643	0.140E 08	17.6
13	37.5	61.2	58.3	38.2	875.4	4.51	0.01846	0.150E 08	18.2
14	41.5	62.4	59.5	39.9	906.3	4.34	0.02050	0.160E 08	18.5
15	45.5	62.9	59.5	41.6	938.2	4.18	0.02255	0.171E 08	19.8
16	49.5	63.4	60.3	43.3	971.2	4.02	0.02462	0.182E 08	20.9
17	54.5	66.0	63.1	45.5	1014.0	3.84	0.02720	0.196E 08	20.2
18	59.5	68.3	65.6	47.6	1058.5	3.66	0.02980	0.210E 08	19.8
19	64.5	69.7	66.4	49.7	1104.5	3.50	0.03239	0.225E 08	20.9
20	69.5	71.8	69.5	51.9	1133.9	3.40	0.03500	0.237E 08	20.3
21	74.5	74.3	71.3	54.0	1162.0	3.31	0.03763	0.249E 08	20.2
22	79.5	76.2	73.2	56.1	1192.3	3.21	0.04028	0.260E 08	20.4
23	84.5	77.7	75.7	58.2	1224.9	3.12	0.04294	0.273E 08	20.4

FULLY DEVELOPED NUSSELT NUMBER =18.8

RUN NUMBER (1)   TUBE NUMBER 10

INPUT POWER = 50.0 W   HEAT RATE GAINED BY WATER = 48.2 W   HEAT BALANCE ERROR = 3.5%

PRESSURE DROP = 2.6 MM H2O   F =0.09621

REM = 364.6   RAM = 0.466E 06   RAMF =0.903E 05   PRM = 4.70

UPSTREAM BULK TEMPERATURE =31.9 DEG C   DOWNSTREAM BULK TEMPERATURE =40.8 DEG C

INLET BULK TEMPERATURE =32.0 DEG C   OUTLET BULK TEMPERATURE =40.7 DEG C

MASS FLOW RATE = 4.7 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	32.7	32.7	32.2	335.1	5.16	0.00217	0.389E 06	54.4
2	3.5	33.9	33.5	32.4	336.4	5.14	0.00506	0.393E 06	21.3
3	5.5	34.2	34.3	32.6	337.8	5.12	0.00796	0.396E 06	17.0
4	7.5	35.0	34.9	32.8	339.1	5.09	0.01085	0.400E 06	12.9
5	10.5	35.7	35.8	33.1	341.2	5.06	0.01521	0.405E 06	10.6
6	13.5	36.4	36.4	33.4	343.2	5.03	0.01956	0.410E 06	9.2
7	16.5	36.8	36.7	33.7	345.3	4.99	0.02393	0.416E 06	9.1
8	19.5	37.4	37.3	34.0	347.4	4.96	0.02830	0.421E 06	8.4
9	22.5	37.8	37.7	34.3	349.5	4.93	0.03268	0.427E 06	8.1
10	25.5	38.1	38.1	34.6	351.6	4.89	0.03706	0.432E 06	8.0
11	29.5	38.7	38.7	35.0	354.4	4.85	0.04291	0.440E 06	7.6
12	33.5	39.2	39.0	35.4	357.2	4.81	0.04877	0.447E 06	7.5
13	37.5	39.8	39.7	35.7	360.1	4.76	0.05464	0.455E 06	7.1
14	41.5	40.3	40.2	36.1	363.0	4.72	0.06053	0.462E 06	6.8
15	45.5	40.9	40.7	36.5	365.9	4.68	0.06642	0.470E 06	6.6
16	49.5	41.3	41.2	36.9	368.9	4.64	0.07232	0.477E 06	6.5
17	54.5	42.0	41.8	37.4	372.6	4.59	0.07971	0.487E 06	6.2
18	59.5	42.6	42.4	37.9	376.4	4.54	0.08712	0.497E 06	6.1
19	64.5	43.3	43.2	38.4	380.2	4.49	0.09454	0.507E 06	5.8
20	69.5	44.0	44.0	38.9	384.1	4.44	0.10198	0.517E 06	5.5
21	74.5	44.7	44.5	39.4	387.9	4.39	0.10943	0.527E 06	5.4
22	79.5	45.3	45.1	39.9	391.9	4.34	0.11690	0.537E 06	5.3
23	84.5	45.6	45.5	40.4	395.8	4.29	0.12438	0.547E 06	5.4

FULLY DEVELOPED NUSSELT NUMBER = 6.8

RUN NUMBER (2) TUBE NUMBER 10

INPUT POWER = 100.0 W HEAT RATE GAINED BY WATER = 100.1 W HEAT BALANCE ERROR =-0.1%

PRESSURE DROP = 2.5 MM H20 F =0.09228

REM = 404.3 RAM = 0.118E 07 RAMF =0.201E 06 PRM = 4.19

UPSTREAM BULK TEMPERATURE =32.3 DEG C DOWNSTREAM BULK TEMPERATURE =50.6 DEG C

INLET BULK TEMPERATURE =32.4 DEG C OUTLET BULK TEMPERATURE =50.5 DEG C

MASS FLOW RATE = 4.7 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	34.8	34.8	32.8	339.0	5.10	0.00217	0.830E 06	28.1
2	3.5	37.0	36.3	33.2	341.8	5.05	0.00507	0.846E 06	16.7
3	5.5	37.8	37.8	33.6	344.7	5.00	0.00797	0.861E 06	13.9
4	7.5	39.3	38.8	34.0	347.5	4.96	0.01088	0.877E 06	11.5
5	10.5	40.3	40.3	34.6	351.9	4.89	0.01526	0.901E 06	10.3
6	13.5	41.5	41.2	35.2	356.3	4.82	0.01965	0.925E 06	9.5
7	16.5	42.1	41.9	35.8	360.8	4.75	0.02405	0.949E 06	9.5
8	19.5	43.2	42.9	36.5	365.4	4.69	0.02846	0.974E 06	8.9
9	22.5	43.9	43.5	37.1	370.0	4.62	0.03288	0.999E 06	8.8
10	25.5	44.3	44.3	37.7	374.7	4.56	0.03732	0.102E 07	8.8
11	29.5	45.5	45.3	38.5	381.0	4.48	0.04325	0.106E 07	8.4
12	33.5	46.3	46.0	39.3	387.4	4.39	0.04920	0.109E 07	8.5
13	37.5	47.6	47.3	40.2	394.0	4.31	0.05517	0.113E 07	8.0
14	41.5	48.5	48.3	41.0	400.6	4.23	0.06116	0.116E 07	7.8
15	45.5	49.5	49.2	41.8	407.4	4.16	0.06716	0.120E 07	7.6
16	49.5	50.4	50.2	42.6	414.3	4.08	0.07318	0.124E 07	7.5
17	54.5	51.8	51.5	43.7	423.0	3.99	0.08073	0.128E 07	7.2
18	59.5	52.8	52.5	44.7	432.0	3.90	0.08830	0.133E 07	7.2
19	64.5	54.2	53.9	45.7	441.1	3.81	0.09589	0.138E 07	6.9
20	69.5	55.5	55.3	46.8	450.3	3.73	0.10349	0.143E 07	6.6
21	74.5	56.7	56.4	47.8	459.7	3.65	0.11111	0.148E 07	6.5
22	79.5	57.8	57.5	48.8	469.3	3.57	0.11873	0.153E 07	6.4
23	84.5	58.6	58.3	49.9	479.0	3.49	0.12636	0.158E 07	6.6

FULLY DEVELOPED NUSSELT NUMBER = 7.7

RUN NUMBER (3)   TUBE NUMBER 10

INPUT POWER = 150.0 W   HEAT RATE GAINED BY WATER = 155.3 W   HEAT BALANCE ERROR =-3.5%

PRESSURE DROP = 2.4 MM H20   F =0.08832

REM = 449.4   RAM = 0.221E 07   RAMF =0.353E 06   PRM = 3.74

UPSTREAM BULK TEMPERATURE =32.4 DEG C   DOWNSTREAM BULK TEMPERATURE =60.9 DEG C

INLET BULK TEMPERATURE =32.7 DEG C   OUTLET BULK TEMPERATURE =60.7 DEG C

MASS FLOW RATE = 4.7 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	36.8	36.8	33.2	341.9	5.05	0.00217	0.131E 07	25.2
2	3.5	40.1	39.0	33.8	346.3	4.98	0.00508	0.135E 07	15.9
3	5.5	41.2	41.1	34.5	350.8	4.90	0.00799	0.139E 07	13.6
4	7.5	43.6	42.6	35.1	355.4	4.83	0.01091	0.143E 07	11.3
5	10.5	44.7	44.5	36.1	362.4	4.73	0.01531	0.149E 07	10.6
6	13.5	46.3	45.8	37.0	369.5	4.63	0.01973	0.155E 07	10.0
7	16.5	47.2	46.8	38.0	376.8	4.53	0.02416	0.161E 07	10.0
8	19.5	48.9	48.1	38.9	384.2	4.43	0.02861	0.167E 07	9.5
9	22.5	50.1	49.1	39.9	391.8	4.34	0.03308	0.173E 07	9.3
10	25.5	50.6	50.2	40.9	399.5	4.25	0.03757	0.180E 07	9.4
11	29.5	52.1	51.9	42.1	410.0	4.13	0.04357	0.189E 07	9.1
12	33.5	53.4	52.8	43.4	420.8	4.01	0.04960	0.198E 07	9.3
13	37.5	55.2	54.8	44.7	431.9	3.90	0.05565	0.207E 07	8.7
14	41.5	56.8	56.4	46.0	443.2	3.79	0.06172	0.216E 07	8.4
15	45.5	58.3	57.8	47.3	454.8	3.69	0.06780	0.225E 07	8.2
16	49.5	59.6	59.2	48.5	466.6	3.59	0.07390	0.235E 07	8.2
17	54.5	61.6	61.1	50.1	481.2	3.47	0.08150	0.247E 07	7.9
18	59.5	63.2	62.7	51.7	489.8	3.41	0.08918	0.256E 07	7.9
19	64.5	65.3	64.9	53.3	498.9	3.34	0.09690	0.266E 07	7.5
20	69.5	67.4	67.0	54.9	508.4	3.27	0.10465	0.275E 07	7.1
21	74.5	69.2	68.7	56.5	518.5	3.19	0.11244	0.285E 07	7.1
22	79.5	71.0	70.4	58.2	529.1	3.12	0.12026	0.295E 07	6.9
23	84.5	72.3	71.9	59.8	540.4	3.05	0.12812	0.305E 07	7.0

FULLY DEVELOPED NUSSELT NUMBER = 8.3

RUN NUMBER (4) TUBE NUMBER 10

INPUT POWER = 200.0 W HEAT RATE GAINED BY WATER = 209.7 W HEAT BALANCE ERROR =-4.8%

PRESSURE DROP = 2.4 MM H2O F =0.08790

REM = 489.2 RAM = 0.346E 07 RAMF =0.518E 06 PRM = 3.41

UPSTREAM BULK TEMPERATURE =32.4 DEG C DOWNSTREAM BULK TEMPERATURE =70.8 DEG C

INLET BULK TEMPERATURE =32.8 DEG C OUTLET BULK TEMPERATURE =70.6 DEG C

MASS FLOW RATE = 4.7 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	38.7	38.6	33.4	343.6	5.02	0.00217	0.180E 07	23.6
2	3.5	43.0	41.6	34.3	349.6	4.92	0.00508	0.187E 07	15.4
3	5.5	44.6	44.2	35.2	355.8	4.83	0.00800	0.194E 07	13.3
4	7.5	47.5	46.0	36.0	362.1	4.74	0.01094	0.201E 07	11.4
5	10.5	48.9	48.3	37.3	371.8	4.60	0.01535	0.212E 07	10.8
6	13.5	50.9	50.1	38.6	381.7	4.47	0.01980	0.223E 07	10.3
7	16.5	52.0	51.3	39.9	391.9	4.34	0.02426	0.235E 07	10.4
8	19.5	54.3	53.2	41.2	402.4	4.21	0.02875	0.246E 07	9.7
9	22.5	55.9	54.4	42.5	413.2	4.09	0.03326	0.258E 07	9.6
10	25.5	56.5	55.8	43.8	424.2	3.98	0.03778	0.271E 07	9.8
11	29.5	58.4	58.0	45.5	439.3	3.83	0.04384	0.288E 07	9.5
12	33.5	60.1	59.3	47.3	454.9	3.69	0.04992	0.305E 07	9.7
13	37.5	62.6	62.0	49.0	470.9	3.55	0.05602	0.323E 07	9.0
14	41.5	64.6	64.1	50.7	484.4	3.45	0.06211	0.339E 07	8.8
15	45.5	66.7	66.1	52.5	493.8	3.37	0.06827	0.352E 07	8.6
16	49.5	68.4	67.9	54.2	503.9	3.30	0.07446	0.366E 07	8.5
17	54.5	71.0	70.4	56.4	517.3	3.20	0.08223	0.384E 07	8.3
18	59.5	73.2	72.5	58.5	531.7	3.11	0.09006	0.402E 07	8.2
19	64.5	75.9	75.4	60.7	547.3	3.01	0.09793	0.421E 07	7.8
20	69.5	78.8	78.2	62.9	564.2	2.91	0.10585	0.440E 07	7.5
21	74.5	81.0	80.3	65.0	582.5	2.81	0.11383	0.461E 07	7.4
22	79.5	82.6	81.7	67.2	602.5	2.71	0.12186	0.483E 07	7.7
23	84.5	84.3	83.5	69.4	624.3	2.60	0.12994	0.506E 07	7.9

FULLY DEVELOPED NUSSELT NUMBER = 8.7

RUN NUMBER (5)   TUBE NUMBER 10

INPUT POWER = 100.0 W   HEAT RATE GAINED BY WATER = 98.2 W   HEAT BALANCE ERROR = 1.8%

PRESSURE DROP = 5.4 MM H2O   F =0.06635

REM = 632.3   RAM = 0.936E 06   RAMF =0.146E 06   PRM = 4.75

UPSTREAM BULK TEMPERATURE =30.8 DEG C   DOWNSTREAM BULK TEMPERATURE =41.1 DEG C

INLET BULK TEMPERATURE =30.9 DEG C   OUTLET BULK TEMPERATURE =41.0 DEG C

MASS FLOW RATE = 8.2 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	33.0	32.9	31.0	573.0	5.30	0.00124	0.754E 06	30.5
2	3.5	34.9	34.2	31.3	575.6	5.27	0.00288	0.762E 06	17.6
3	5.5	35.6	35.4	31.5	578.3	5.24	0.00454	0.770E 06	14.5
4	7.5	37.0	36.3	31.7	581.0	5.22	0.00619	0.779E 06	11.8
5	10.5	37.9	37.7	32.1	585.1	5.17	0.00867	0.791E 06	10.1
6	13.5	38.9	38.6	32.4	589.2	5.13	0.01116	0.804E 06	9.1
7	16.5	39.5	39.2	32.8	593.3	5.09	0.01365	0.817E 06	8.7
8	19.5	40.5	40.1	33.1	597.5	5.05	0.01614	0.829E 06	8.0
9	22.5	41.2	40.6	33.5	601.7	5.02	0.01864	0.842E 06	7.8
10	25.5	41.3	41.1	33.8	605.9	4.98	0.02114	0.855E 06	7.8
11	29.5	41.9	41.7	34.3	611.6	4.93	0.02448	0.873E 06	7.6
12	33.5	42.3	41.9	34.7	617.3	4.87	0.02783	0.890E 06	7.8
13	37.5	43.0	42.7	35.2	623.2	4.82	0.03119	0.908E 06	7.5
14	41.5	43.5	43.3	35.7	629.0	4.77	0.03455	0.926E 06	7.4
15	45.5	43.9	43.6	36.1	635.0	4.72	0.03792	0.944E 06	7.5
16	49.5	44.2	44.0	36.6	640.9	4.68	0.04130	0.962E 06	7.7
17	54.5	44.9	44.6	37.2	648.5	4.61	0.04553	0.985E 06	7.6
18	59.5	45.3	44.9	37.7	656.2	4.55	0.04977	0.101E 07	7.8
19	64.5	46.1	45.8	38.3	663.9	4.50	0.05402	0.103E 07	7.5
20	69.5	46.9	46.5	38.9	671.8	4.44	0.05828	0.106E 07	7.3
21	74.5	47.4	47.1	39.5	679.7	4.38	0.06255	0.108E 07	7.3
22	79.5	48.1	47.7	40.1	687.8	4.32	0.06683	0.110E 07	7.3
23	84.5	48.5	48.3	40.6	695.9	4.27	0.07111	0.113E 07	7.3

FULLY DEVELOPED NUSSELT NUMBER = 7.6

RUN NUMBER (6)   TUBE NUMBER 10

INPUT POWER = 150.0 W HEAT RATE GAINED BY WATER = 146.5 W HEAT BALANCE ERROR = 2.3%

PRESSURE DROP = 5.2 MM H2O   F =0.06389

REM = 669.3   RAM = 0.157E 07   RAMF =0.226E 06   PRM = 4.46

UPSTREAM BULK TEMPERATURE =31.1 DEG C   DOWNSTREAM BULK TEMPERATURE =46.4 DEG C

INLET BULK TEMPERATURE =31.2 DEG C   OUTLET BULK TEMPERATURE =46.3 DEG C

MASS FLOW RATE = 8.2 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	34.4	34.4	31.4	577.5	5.25	0.00124	0.115E 07	28.9
2	3.5	37.1	36.1	31.8	581.5	5.21	0.00289	0.117E 07	17.8
3	5.5	38.0	37.8	32.1	585.6	5.17	0.00454	0.118E 07	14.9
4	7.5	40.1	39.1	32.5	589.7	5.13	0.00620	0.120E 07	12.0
5	10.5	41.5	40.9	33.0	595.9	5.07	0.00869	0.123E 07	10.5
6	13.5	42.7	42.3	33.5	602.1	5.01	0.01118	0.126E 07	9.6
7	16.5	43.5	43.1	34.0	608.5	4.95	0.01369	0.129E 07	9.2
8	19.5	44.9	44.2	34.5	614.9	4.90	0.01619	0.132E 07	8.6
9	22.5	45.9	44.7	35.1	621.3	4.84	0.01871	0.135E 07	8.4
10	25.5	45.9	45.3	35.6	627.9	4.78	0.02123	0.138E 07	8.6
11	29.5	46.4	46.3	36.3	636.8	4.71	0.02459	0.142E 07	8.5
12	33.5	47.0	46.5	37.0	645.8	4.64	0.02797	0.146E 07	8.7
13	37.5	48.0	47.6	37.6	654.9	4.56	0.03136	0.150E 07	8.4
14	41.5	48.8	48.4	38.3	664.1	4.49	0.03476	0.154E 07	8.3
15	45.5	49.5	49.0	39.0	673.5	4.43	0.03816	0.158E 07	8.3
16	49.5	49.9	49.6	39.7	683.1	4.36	0.04158	0.163E 07	8.5
17	54.5	50.9	50.5	40.6	695.2	4.27	0.04586	0.168E 07	8.4
18	59.5	51.5	51.0	41.5	707.5	4.19	0.05016	0.174E 07	8.6
19	64.5	52.6	52.1	42.3	720.0	4.11	0.05446	0.179E 07	8.4
20	69.5	53.6	53.2	43.2	732.8	4.03	0.05878	0.185E 07	8.3
21	74.5	54.5	54.1	44.0	745.8	3.96	0.06311	0.191E 07	8.2
22	79.5	55.4	54.9	44.9	758.9	3.88	0.06745	0.197E 07	8.2
23	84.5	56.3	55.7	45.8	772.3	3.81	0.07180	0.203E 07	8.2

FULLY DEVELOPED NUSSELT NUMBER = 8.5

RUN NUMBER (7)   TUBE NUMBER 10

INPUT POWER = 200.0 W   HEAT RATE GAINED BY WATER = 195.8 W   HEAT BALANCE ERROR = 2.1%

PRESSURE DROP = 5.1 MM H20   F =0.06260

REM = 707.0   RAM = 0.232E 07   RAMF =0.321E 06   PRM = 4.19

UPSTREAM BULK TEMPERATURE =31.2 DEG C   DOWNSTREAM BULK TEMPERATURE =51.7 DEG C

INLET BULK TEMPERATURE =31.3 DEG C   OUTLET BULK TEMPERATURE =51.5 DEG C

MASS FLOW RATE = 8.2 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	35.7	35.7	31.7	580.2	5.22	0.00124	0.155E 07	28.5
2	3.5	39.4	38.0	32.1	585.6	5.17	0.00289	0.158E 07	17.6
3	5.5	40.6	40.2	32.6	591.1	5.12	0.00455	0.162E 07	14.7
4	7.5	43.6	42.0	33.0	596.6	5.06	0.00621	0.165E 07	11.8
5	10.5	45.2	44.3	33.7	605.0	4.99	0.00870	0.170E 07	10.4
6	13.5	46.7	46.0	34.4	613.5	4.91	0.01121	0.175E 07	9.7
7	16.5	47.5	46.9	35.1	622.2	4.83	0.01372	0.181E 07	9.5
8	19.5	49.4	48.2	35.8	631.0	4.76	0.01624	0.186E 07	8.8
9	22.5	50.7	48.8	36.5	639.9	4.68	0.01877	0.192E 07	8.6
10	25.5	50.4	49.5	37.2	649.0	4.61	0.02130	0.197E 07	8.9
11	29.5	51.1	50.7	38.1	661.3	4.52	0.02470	0.204E 07	9.0
12	33.5	51.7	51.0	39.1	673.8	4.42	0.02810	0.212E 07	9.3
13	37.5	53.1	52.5	40.0	686.6	4.33	0.03152	0.220E 07	8.9
14	41.5	54.1	53.5	40.9	699.7	4.24	0.03494	0.228E 07	8.8
15	45.5	54.9	54.3	41.8	712.9	4.16	0.03838	0.236E 07	8.9
16	49.5	55.5	55.0	42.8	726.5	4.07	0.04183	0.244E 07	9.1
17	54.5	56.8	56.1	43.9	743.7	3.97	0.04616	0.254E 07	9.0
18	59.5	57.5	56.8	45.1	761.3	3.87	0.05049	0.264E 07	9.3
19	64.5	58.8	58.3	46.2	779.3	3.77	0.05484	0.275E 07	9.1
20	69.5	60.4	59.8	47.4	797.6	3.68	0.05920	0.286E 07	8.8
21	74.5	61.5	60.9	48.5	816.3	3.59	0.06356	0.297E 07	8.8
22	79.5	62.7	62.0	49.7	835.3	3.50	0.06793	0.308E 07	8.8
23	84.5	63.8	63.1	50.8	848.6	3.44	0.07229	0.317E 07	8.9

FULLY DEVELOPED NUSSELT NUMBER = 9.0

RUN NUMBER (8) TUBE NUMBER 10

INPUT POWER = 250.0 W HEAT RATE GAINED BY WATER = 247.3 W HEAT BALANCE ERROR = 1.1%

PRESSURE DROP = 5.0 MM H20 F =0.06129

REM = 748.4 RAM = 0.325E 07 RAMF =0.389E 06 PRM = 3.94

UPSTREAM BULK TEMPERATURE =31.3 DEG C DOWNSTREAM BULK TEMPERATURE =57.2 DEG C

INLET BULK TEMPERATURE =31.5 DEG C OUTLET BULK TEMPERATURE =57.0 DEG C

MASS FLOW RATE = 8.2 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	37.0	37.0	31.9	583.0	5.20	0.00124	0.198E 07	28.6
2	3.5	41.6	39.8	32.5	589.9	5.13	0.00289	0.204E 07	17.7
3	5.5	43.2	42.5	33.1	596.8	5.06	0.00455	0.209E 07	14.9
4	7.5	46.9	44.7	33.6	603.9	4.99	0.00622	0.214E 07	12.0
5	10.5	48.6	47.4	34.5	614.7	4.90	0.00872	0.223E 07	10.8
6	13.5	50.3	49.2	35.4	625.7	4.80	0.01123	0.231E 07	10.1
7	16.5	51.2	50.3	36.3	636.9	4.71	0.01376	0.240E 07	10.0
8	19.5	53.4	51.7	37.2	648.4	4.62	0.01629	0.249E 07	9.4
9	22.5	55.0	52.5	38.0	660.0	4.53	0.01883	0.258E 07	9.2
10	25.5	54.6	53.3	38.9	671.9	4.44	0.02138	0.267E 07	9.6
11	29.5	55.1	54.8	40.1	688.1	4.32	0.02480	0.279E 07	9.7
12	33.5	55.9	55.0	41.2	704.6	4.21	0.02823	0.292E 07	10.1
13	37.5	57.5	56.8	42.4	721.6	4.10	0.03167	0.304E 07	9.7
14	41.5	58.6	57.8	43.6	738.9	4.00	0.03513	0.318E 07	9.8
15	45.5	59.5	58.7	44.8	756.6	3.90	0.03859	0.331E 07	9.9
16	49.5	60.3	59.7	45.9	774.7	3.80	0.04207	0.345E 07	10.1
17	54.5	62.1	61.4	47.4	797.8	3.68	0.04642	0.362E 07	9.9
18	59.5	62.9	62.1	48.9	821.5	3.57	0.05079	0.380E 07	10.4
19	64.5	64.3	63.6	50.3	843.6	3.47	0.05514	0.397E 07	10.4
20	69.5	66.2	65.4	51.8	857.4	3.40	0.05954	0.410E 07	10.0
21	74.5	67.2	66.4	53.2	871.8	3.34	0.06395	0.423E 07	10.3
22	79.5	67.6	66.7	54.7	887.0	3.28	0.06839	0.437E 07	11.3
23	84.5	68.6	67.8	56.2	902.9	3.21	0.07284	0.451E 07	11.6

FULLY DEVELOPED NUSSELT NUMBER =10.1

RUN NUMBER (9) TUBE NUMBER 10

INPUT POWER = 300.0 W HEAT RATE GAINED BY WATER = 296.2 W HEAT BALANCE ERROR = 1.3%

PRESSURE DROP = 5.0 MM H2O F =0.06114

REM = 788.9 RAM = 0.426E 07 RAMF =0.426E 06 PRM = 3.72

UPSTREAM BULK TEMPERATURE =31.3 DEG C DOWNSTREAM BULK TEMPERATURE =62.3 DEG C

INLET BULK TEMPERATURE =31.5 DEG C OUTLET BULK TEMPERATURE =62.2 DEG C

MASS FLOW RATE = 8.2 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	38.2	38.2	32.1	585.0	5.18	0.00124	0.240E 07	28.6
2	3.5	43.7	41.5	32.8	593.3	5.09	0.00289	0.247E 07	17.8
3	5.5	45.5	44.8	33.5	601.7	5.02	0.00456	0.255E 07	14.9
4	7.5	49.9	47.2	34.2	610.3	4.94	0.00622	0.263E 07	12.1
5	10.5	51.7	50.3	35.2	623.4	4.82	0.00873	0.275E 07	11.0
6	13.5	53.4	52.2	36.3	636.8	4.71	0.01126	0.288E 07	10.5
7	16.5	54.4	53.3	37.3	650.6	4.60	0.01379	0.300E 07	10.5
8	19.5	57.1	54.9	38.4	664.6	4.49	0.01633	0.313E 07	9.8
9	22.5	58.9	55.9	39.4	679.0	4.39	0.01889	0.326E 07	9.6
10	25.5	58.4	56.8	40.5	693.6	4.28	0.02145	0.340E 07	10.1
11	29.5	58.8	58.2	41.9	713.7	4.15	0.02489	0.358E 07	10.3
12	33.5	59.0	57.9	43.3	734.3	4.02	0.02834	0.377E 07	11.3
13	37.5	61.0	60.3	44.7	755.5	3.90	0.03180	0.396E 07	10.7
14	41.5	62.6	61.9	46.1	777.2	3.78	0.03528	0.415E 07	10.5
15	45.5	63.8	62.9	47.5	799.4	3.67	0.03876	0.435E 07	10.7
16	49.5	64.6	63.9	48.9	822.2	3.56	0.04225	0.456E 07	11.1
17	54.5	66.3	65.5	50.6	846.7	3.45	0.04661	0.479E 07	11.1
18	59.5	67.0	66.0	52.4	863.4	3.38	0.05102	0.498E 07	11.9
19	64.5	68.2	67.4	54.2	881.2	3.30	0.05544	0.518E 07	12.3
20	69.5	71.0	70.3	55.9	900.0	3.22	0.05989	0.538E 07	11.4
21	74.5	71.8	71.0	57.7	920.0	3.15	0.06436	0.559E 07	12.1
22	79.5	72.0	71.3	59.4	941.3	3.07	0.06885	0.580E 07	13.6
23	84.5	73.0	72.4	61.2	963.9	2.99	0.07337	0.602E 07	14.4

FULLY DEVELOPED NUSSELT NUMBER =11.3

RUN NUMBER (10)   TUBE NUMBER 10

INPUT POWER = 100.0 W   HEAT RATE GAINED BY WATER = 97.8 W   HEAT BALANCE ERROR = 2.2%

PRESSURE DROP = 8.5 MM H2O   F =0.05083

REM = 874.3   RAM = 0.873E 06   RAMF =0.137E 06   PRM = 4.92

UPSTREAM BULK TEMPERATURE =30.7 DEG C   DOWNSTREAM BULK TEMPERATURE =37.9 DEG C

INLET BULK TEMPERATURE =30.8 DEG C   OUTLET BULK TEMPERATURE =37.8 DEG C

MASS FLOW RATE = 11.8 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	32.4	32.4	30.9	816.2	5.31	0.00086	0.748E 06	37.2
2	3.5	34.2	33.5	31.0	818.8	5.29	0.00202	0.754E 06	20.6
3	5.5	34.6	34.4	31.2	821.5	5.28	0.00317	0.759E 06	17.4
4	7.5	36.0	35.2	31.4	824.2	5.26	0.00433	0.765E 06	13.7
5	10.5	36.9	36.3	31.6	828.2	5.23	0.00606	0.774E 06	11.6
6	13.5	37.6	37.3	31.9	832.2	5.20	0.00780	0.782E 06	10.3
7	16.5	38.1	38.0	32.1	836.3	5.17	0.00954	0.791E 06	9.7
8	19.5	39.2	38.8	32.3	840.4	5.14	0.01128	0.800E 06	8.6
9	22.5	40.1	39.3	32.6	844.5	5.12	0.01302	0.809E 06	8.1
10	25.5	40.1	39.8	32.8	848.6	5.09	0.01477	0.818E 06	8.1
11	29.5	40.5	40.5	33.2	854.2	5.05	0.01710	0.830E 06	7.9
12	33.5	41.0	40.7	33.5	859.8	5.01	0.01943	0.842E 06	7.8
13	37.5	41.5	41.3	33.8	865.4	4.98	0.02176	0.854E 06	7.5
14	41.5	42.0	41.8	34.1	871.1	4.94	0.02410	0.866E 06	7.4
15	45.5	42.4	42.1	34.4	876.8	4.91	0.02645	0.878E 06	7.4
16	49.5	42.6	42.3	34.8	882.5	4.87	0.02879	0.890E 06	7.5
17	54.5	43.0	42.7	35.2	889.8	4.83	0.03173	0.906E 06	7.4
18	59.5	43.2	42.9	35.6	897.1	4.78	0.03467	0.921E 06	7.7
19	64.5	43.7	43.5	36.0	904.5	4.74	0.03762	0.937E 06	7.5
20	69.5	44.3	44.0	36.4	911.9	4.70	0.04057	0.953E 06	7.4
21	74.5	44.6	44.3	36.8	919.4	4.65	0.04353	0.969E 06	7.4
22	79.5	45.1	44.7	37.2	927.0	4.61	0.04649	0.985E 06	7.4
23	84.5	45.3	45.1	37.6	934.7	4.57	0.04946	0.100E 07	7.5

FULLY DEVELOPED NUSSELT NUMBER = 7.8

RUN NUMBER (11) TUBE NUMBER 10

INPUT POWER = 150.0 W HEAT RATE GAINED BY WATER = 146.3 W HEAT BALANCE ERROR = 2.4%

PRESSURE DROP = 8.3 MM H2O F =0.04962

REM = 907.3 RAM = 0.141E 07 RAMF =0.208E 06 PRM = 4.72

UPSTREAM BULK TEMPERATURE =30.8 DEG C DOWNSTREAM BULK TEMPERATURE =41.5 DEG C

INLET BULK TEMPERATURE =30.8 DEG C OUTLET BULK TEMPERATURE =41.4 DEG C

MASS FLOW RATE = 11.8 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	33.6	33.6	31.0	818.4	5.30	0.00086	0.113E 07	33.8
2	3.5	36.1	35.0	31.3	822.4	5.27	0.00202	0.114E 07	20.1
3	5.5	36.9	36.4	31.5	826.4	5.24	0.00318	0.115E 07	16.8
4	7.5	38.8	37.6	31.7	830.4	5.21	0.00433	0.117E 07	13.4
5	10.5	40.1	39.2	32.1	836.5	5.17	0.00607	0.118E 07	11.4
6	13.5	41.1	40.7	32.5	842.6	5.13	0.00781	0.120E 07	10.3
7	16.5	41.9	41.5	32.8	848.8	5.09	0.00955	0.122E 07	9.7
8	19.5	43.5	42.6	33.2	855.1	5.04	0.01130	0.124E 07	8.7
9	22.5	44.7	43.3	33.6	861.3	5.00	0.01305	0.126E 07	8.3
10	25.5	44.6	43.9	33.9	867.7	4.96	0.01480	0.128E 07	8.4
11	29.5	44.8	44.8	34.4	876.2	4.91	0.01714	0.131E 07	8.3
12	33.5	45.3	44.8	34.9	884.8	4.86	0.01949	0.134E 07	8.4
13	37.5	46.2	45.8	35.4	893.5	4.80	0.02184	0.137E 07	8.1
14	41.5	46.7	46.4	35.9	902.4	4.75	0.02420	0.140E 07	8.0
15	45.5	47.2	46.8	36.4	911.2	4.70	0.02656	0.142E 07	8.0
16	49.5	47.4	47.1	36.8	920.2	4.65	0.02893	0.145E 07	8.2
17	54.5	48.0	47.5	37.4	931.6	4.59	0.03189	0.149E 07	8.3
18	59.5	48.3	47.9	38.0	943.1	4.52	0.03486	0.152E 07	8.5
19	64.5	49.1	48.8	38.7	954.8	4.46	0.03784	0.156E 07	8.3
20	69.5	49.9	49.5	39.3	966.6	4.40	0.04083	0.160E 07	8.2
21	74.5	50.3	49.9	39.9	978.6	4.34	0.04382	0.164E 07	8.3
22	79.5	50.9	50.5	40.5	990.7	4.28	0.04682	0.168E 07	8.3
23	84.5	51.7	51.2	41.1	1003.0	4.23	0.04983	0.171E 07	8.2

FULLY DEVELOPED NUSSELT NUMBER = 8.4

RUN NUMBER (12)   TUBE NUMBER 10

INPUT POWER = 200.0 W   HEAT RATE GAINED BY WATER = 194.8 W   HEAT BALANCE ERROR = 2.6%

PRESSURE DROP = 8.3 MM H20   F =0.04956

REM = 941.7   RAM = 0.203E 07   RAMF =0.261E 06   PRM = 4.53

UPSTREAM BULK TEMPERATURE =30.8 DEG C   DOWNSTREAM BULK TEMPERATURE =45.1 DEG C

INLET BULK TEMPERATURE =30.9 DEG C   OUTLET BULK TEMPERATURE =45.0 DEG C

MASS FLOW RATE = 11.8 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	34.6	34.6	31.2	820.6	5.28	0.00087	0.151E 07	33.9
2	3.5	37.8	36.4	31.5	825.9	5.24	0.00202	0.153E 07	20.4
3	5.5	38.8	38.3	31.8	831.3	5.21	0.00318	0.156E 07	17.1
4	7.5	41.5	39.8	32.1	836.7	5.17	0.00434	0.158E 07	13.5
5	10.5	42.9	41.9	32.6	844.9	5.11	0.00608	0.162E 07	11.7
6	13.5	44.2	43.6	33.1	853.2	5.06	0.00782	0.165E 07	10.6
7	16.5	45.3	44.7	33.6	861.6	5.00	0.00957	0.169E 07	10.1
8	19.5	47.3	46.0	34.1	870.0	4.95	0.01132	0.172E 07	9.1
9	22.5	48.7	46.8	34.5	878.6	4.89	0.01308	0.176E 07	8.7
10	25.5	48.3	47.4	35.0	887.2	4.84	0.01484	0.180E 07	8.9
11	29.5	48.6	48.3	35.7	898.9	4.77	0.01719	0.185E 07	8.9
12	33.5	49.1	48.5	36.3	910.8	4.70	0.01955	0.190E 07	9.1
13	37.5	50.1	49.7	37.0	922.8	4.63	0.02192	0.195E 07	8.8
14	41.5	50.4	49.7	37.6	934.9	4.57	0.02429	0.200E 07	9.2
15	45.5	50.2	49.6	38.3	947.3	4.50	0.02667	0.205E 07	9.8
16	49.5	50.6	50.4	38.9	959.8	4.44	0.02906	0.210E 07	9.8
17	54.5	52.0	51.7	39.7	975.7	4.36	0.03205	0.217E 07	9.4
18	59.5	52.9	52.5	40.5	991.8	4.28	0.03505	0.224E 07	9.3
19	64.5	53.9	53.5	41.3	1008.2	4.20	0.03805	0.231E 07	9.2
20	69.5	54.6	54.1	42.1	1024.9	4.13	0.04107	0.238E 07	9.3
21	74.5	54.4	54.0	42.9	1041.8	4.05	0.04409	0.245E 07	10.1
22	79.5	54.3	53.0	43.8	1059.0	3.98	0.04712	0.252E 07	11.4
23	84.5	53.0	52.4	44.6	1076.5	3.91	0.05016	0.259E 07	13.8

FULLY DEVELOPED NUSSELT NUMBER = 9.7

RUN NUMBER (1) TUBE NUMBER 13

INPUT POWER = 50.0 W HEAT RATE GAINED BY WATER = 47.9 W HEAT BALANCE ERROR = 4.1%

PRESSURE DROP = 5.2 MM H2O F =0.09362

REM = 423.9 RAM = 0.296E 06 RAMF =0.530E 05 PRM = 4.85

UPSTREAM BULK TEMPERATURE =30.6 DEG C DOWNSTREAM BULK TEMPERATURE =39.4 DEG C

INLET BULK TEMPERATURE =30.7 DEG C OUTLET BULK TEMPERATURE =39.3 DEG C

MASS FLOW RATE = 4.7 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	31.6	31.7	30.9	390.2	5.31	0.00206	0.246E 06	36.4
2	3.5	32.5	32.4	31.1	391.7	5.29	0.00480	0.249E 06	20.8
3	5.5	33.1	33.1	31.3	393.2	5.27	0.00754	0.251E 06	15.6
4	7.5	33.7	33.6	31.5	394.8	5.24	0.01029	0.253E 06	12.6
5	10.5	34.7	34.5	31.8	397.1	5.21	0.01442	0.257E 06	9.9
6	13.5	35.3	35.2	32.1	399.5	5.18	0.01855	0.260E 06	8.7
7	16.5	35.8	35.7	32.4	401.8	5.14	0.02269	0.264E 06	8.3
8	19.5	36.3	36.2	32.6	404.2	5.11	0.02683	0.267E 06	7.8
9	22.5	36.7	36.5	32.9	406.6	5.07	0.03098	0.271E 06	7.6
10	25.5	37.0	36.9	33.2	409.0	5.04	0.03513	0.274E 06	7.5
11	29.5	37.5	37.3	33.6	412.2	5.00	0.04068	0.279E 06	7.4
12	33.5	37.9	37.7	34.0	415.5	4.95	0.04624	0.284E 06	7.3
13	37.5	38.2	38.1	34.4	418.8	4.91	0.05181	0.289E 06	7.4
14	41.5	38.6	38.6	34.8	422.1	4.87	0.05739	0.294E 06	7.3
15	45.5	39.0	39.0	35.2	425.5	4.82	0.06297	0.299E 06	7.3
16	49.5	39.5	39.4	35.6	428.9	4.78	0.06857	0.304E 06	7.2
17	54.5	40.1	40.0	36.1	433.2	4.73	0.07558	0.310E 06	6.9
18	59.5	40.8	40.7	36.6	437.5	4.68	0.08260	0.316E 06	6.6
19	64.5	41.5	41.3	37.1	441.8	4.63	0.08964	0.323E 06	6.3
20	69.5	42.3	42.2	37.5	446.3	4.58	0.09669	0.329E 06	5.9
21	74.5	42.9	42.7	38.0	450.7	4.53	0.10376	0.336E 06	5.8
22	79.5	43.6	43.4	38.5	455.2	4.48	0.11084	0.342E 06	5.5
23	84.5	44.0	43.9	39.0	459.8	4.43	0.11794	0.349E 06	5.6

FULLY DEVELOPED NUSSELT NUMBER = 6.9

RUN NUMBER (2) TUBE NUMBER 13

INPUT POWER = 100.0 W HEAT RATE GAINED BY WATER = 99.8 W HEAT BALANCE ERROR = 0.2%

PRESSURE DROP = 4.9 MM H20 F =0.08650

REM = 468.3 RAM = 0.754E 06 RAMF =0.119E 06 PRM = 4.34

UPSTREAM BULK TEMPERATURE =30.8 DEG C DOWNSTREAM BULK TEMPERATURE =49.1 DEG C

INLET BULK TEMPERATURE =31.0 DEG C OUTLET BULK TEMPERATURE =48.9 DEG C

MASS FLOW RATE = 4.7 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	33.5	33.6	31.3	393.7	5.26	0.00206	0.525E 06	26.2
2	3.5	35.1	35.0	31.7	396.9	5.21	0.00481	0.535E 06	17.7
3	5.5	36.2	36.2	32.1	400.2	5.17	0.00756	0.545E 06	14.3
4	7.5	37.4	37.3	32.6	403.5	5.12	0.01032	0.556E 06	12.1
5	10.5	39.1	39.0	33.2	408.5	5.05	0.01446	0.571E 06	9.9
6	13.5	40.1	40.0	33.8	413.6	4.98	0.01862	0.587E 06	9.3
7	16.5	41.0	40.8	34.4	418.7	4.91	0.02279	0.603E 06	9.0
8	19.5	41.7	41.5	35.0	423.9	4.84	0.02698	0.619E 06	8.7
9	22.5	42.4	42.0	35.6	429.2	4.78	0.03117	0.635E 06	8.8
10	25.5	42.9	42.6	36.2	434.6	4.71	0.03538	0.651E 06	8.9
11	29.5	43.7	43.4	37.1	441.8	4.63	0.04100	0.674E 06	8.9
12	33.5	44.6	44.3	37.9	449.2	4.54	0.04664	0.696E 06	8.8
13	37.5	45.3	45.1	38.7	456.8	4.46	0.05230	0.719E 06	8.8
14	41.5	46.3	46.2	39.5	464.4	4.38	0.05798	0.742E 06	8.5
15	45.5	47.0	46.9	40.3	472.2	4.30	0.06368	0.766E 06	8.6
16	49.5	48.0	47.9	41.1	480.1	4.22	0.06939	0.790E 06	8.4
17	54.5	49.3	49.1	42.2	490.2	4.13	0.07656	0.820E 06	8.1
18	59.5	50.6	50.4	43.2	500.4	4.03	0.08374	0.851E 06	7.8
19	64.5	52.0	51.7	44.2	510.9	3.94	0.09095	0.883E 06	7.4
20	69.5	53.4	53.2	45.2	521.6	3.86	0.09818	0.915E 06	7.0
21	74.5	54.5	54.4	46.2	532.4	3.77	0.10542	0.947E 06	6.9
22	79.5	55.9	55.6	47.3	543.5	3.69	0.11267	0.980E 06	6.7
23	84.5	56.7	56.5	48.3	554.7	3.61	0.11993	0.101E 07	6.8

FULLY DEVELOPED NUSSELT NUMBER = 8.1

RUN NUMBER (3)   TUBE NUMBER 13

INPUT POWER = 150.0 W   HEAT RATE GAINED BY WATER = 152.3 W   HEAT BALANCE ERROR =-1.5%

PRESSURE DROP = 4.7 MM H2O   F =0.08277

REM = 516.9   RAM = 0.138E 07   RAMF =0.201E 06   PRM = 3.89

UPSTREAM BULK TEMPERATURE =30.8 DEG C   DOWNSTREAM BULK TEMPERATURE =58.7 DEG C

INLET BULK TEMPERATURE =31.2 DEG C   OUTLET BULK TEMPERATURE =58.5 DEG C

MASS FLOW RATE = 4.7 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	35.3	35.3	31.7	396.4	5.22	0.00206	0.815E 06	24.6
2	3.5	37.5	37.3	32.3	401.4	5.15	0.00481	0.839E 06	17.4
3	5.5	39.2	39.1	32.9	406.5	5.08	0.00757	0.863E 06	14.2
4	7.5	41.0	40.8	33.6	411.6	5.01	0.01034	0.887E 06	12.1
5	10.5	43.3	43.0	34.5	419.5	4.90	0.01451	0.924E 06	10.3
6	13.5	44.6	44.4	35.4	427.5	4.80	0.01869	0.962E 06	9.8
7	16.5	45.7	45.3	36.4	435.7	4.70	0.02290	0.100E 07	9.7
8	19.5	46.7	46.4	37.3	444.0	4.60	0.02712	0.104E 07	9.5
9	22.5	47.5	47.2	38.2	452.6	4.51	0.03135	0.108E 07	9.7
10	25.5	48.3	47.9	39.2	461.3	4.41	0.03560	0.112E 07	9.8
11	29.5	49.6	49.2	40.4	473.1	4.29	0.04129	0.117E 07	9.7
12	33.5	50.9	50.4	41.7	485.3	4.17	0.04701	0.123E 07	9.7
13	37.5	52.0	51.7	42.9	497.7	4.06	0.05275	0.129E 07	9.8
14	41.5	53.6	53.2	44.2	510.5	3.95	0.05851	0.135E 07	9.4
15	45.5	54.6	54.3	45.4	523.5	3.84	0.06429	0.141E 07	9.6
16	49.5	56.1	55.8	46.7	536.9	3.74	0.07009	0.147E 07	9.3
17	54.5	57.9	57.6	48.2	554.0	3.61	0.07734	0.154E 07	9.1
18	59.5	59.8	59.5	49.8	571.5	3.50	0.08461	0.162E 07	8.7
19	64.5	61.9	61.5	51.3	582.6	3.42	0.09189	0.169E 07	8.3
20	69.5	64.1	63.7	52.9	593.0	3.36	0.09923	0.175E 07	7.8
21	74.5	65.8	65.4	54.5	604.0	3.29	0.10661	0.181E 07	7.7
22	79.5	67.8	67.4	56.0	615.5	3.22	0.11402	0.187E 07	7.4
23	84.5	69.1	68.8	57.6	627.7	3.15	0.12146	0.193E 07	7.5

FULLY DEVELOPED NUSSELT NUMBER = 9.0

RUN NUMBER (4) TUBE NUMBER 13

INPUT POWER = 200.0 W HEAT RATE GAINED BY WATER = 199.6 W HEAT BALANCE ERROR = 0.2%

PRESSURE DROP = 4.5 MM H2O F =0.07906

REM = 564.5 RAM = 0.209E 07 RAMF =0.268E 06 PRM = 3.54

UPSTREAM BULK TEMPERATURE =30.9 DEG C DOWNSTREAM BULK TEMPERATURE =67.4 DEG C

INLET BULK TEMPERATURE =31.4 DEG C OUTLET BULK TEMPERATURE =67.2 DEG C

MASS FLOW RATE = 4.7 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	36.7	36.8	32.0	398.8	5.19	0.00206	0.109E 07	24.3
2	3.5	39.5	39.3	32.8	405.4	5.09	0.00482	0.113E 07	17.6
3	5.5	41.7	41.6	33.6	412.2	5.00	0.00758	0.117E 07	14.5
4	7.5	43.9	43.6	34.4	419.0	4.91	0.01036	0.121E 07	12.5
5	10.5	46.6	46.3	35.7	429.6	4.77	0.01455	0.128E 07	10.8
6	13.5	48.1	47.8	36.9	440.4	4.64	0.01876	0.134E 07	10.5
7	16.5	49.4	49.0	38.1	451.5	4.52	0.02299	0.141E 07	10.4
8	19.5	50.7	50.3	39.4	463.0	4.39	0.02724	0.148E 07	10.4
9	22.5	51.8	51.2	40.6	474.7	4.27	0.03151	0.155E 07	10.6
10	25.5	52.7	52.2	41.8	486.7	4.16	0.03580	0.162E 07	10.8
11	29.5	54.3	53.8	43.4	503.1	4.01	0.04154	0.172E 07	10.8
12	33.5	56.0	55.3	45.1	520.1	3.87	0.04731	0.182E 07	10.8
13	37.5	57.4	57.0	46.7	537.6	3.73	0.05310	0.193E 07	10.9
14	41.5	59.5	59.0	48.4	555.5	3.60	0.05891	0.204E 07	10.4
15	45.5	60.9	60.5	50.0	574.1	3.48	0.06470	0.215E 07	10.6
16	49.5	62.8	62.4	51.6	584.6	3.41	0.07055	0.223E 07	10.3
17	54.5	65.2	64.7	53.7	598.5	3.32	0.07790	0.233E 07	9.9
18	59.5	67.5	67.3	55.7	613.3	3.23	0.08530	0.244E 07	9.6
19	64.5	70.3	69.7	57.8	629.3	3.14	0.09274	0.255E 07	9.1
20	69.5	73.0	72.5	59.8	646.4	3.05	0.10023	0.266E 07	8.6
21	74.5	75.1	74.6	61.9	664.8	2.95	0.10776	0.278E 07	8.5
22	79.5	77.7	77.1	63.9	684.8	2.86	0.11533	0.290E 07	8.2
23	84.5	79.5	78.9	66.0	706.3	2.76	0.12295	0.303E 07	8.3

FULLY DEVELOPED NUSSELT NUMBER = 9.9

RUN NUMBER (5)   TUBE NUMBER 13

INPUT POWER = 50.0 W   HEAT RATE GAINED BY WATER = 45.0 W   HEAT BALANCE ERROR =10.1%

PRESSURE DROP = 7.5 MM H2O   F =0.07963

REM = 541.8   RAM = 0.269E 06   RAMF =0.491E 05   PRM = 4.94

UPSTREAM BULK TEMPERATURE =31.0 DEG C   DOWNSTREAM BULK TEMPERATURE =37.3 DEG C

INLET BULK TEMPERATURE =31.1 DEG C   OUTLET BULK TEMPERATURE =37.3 DEG C

MASS FLOW RATE = 6.1 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	31.7	31.7	31.2	510.3	5.28	0.00158	0.235E 06	53.2
2	3.5	32.3	32.3	31.3	511.7	5.26	0.00369	0.236E 06	27.6
3	5.5	32.9	32.8	31.5	513.2	5.24	0.00581	0.238E 06	19.2
4	7.5	33.5	33.4	31.6	514.6	5.23	0.00792	0.239E 06	14.4
5	10.5	34.3	34.2	31.8	516.8	5.20	0.01109	0.242E 06	10.9
6	13.5	34.8	34.8	32.0	519.0	5.18	0.01427	0.244E 06	9.5
7	16.5	35.3	35.2	32.2	521.2	5.15	0.01745	0.247E 06	8.7
8	19.5	35.7	35.8	32.5	523.5	5.13	0.02063	0.249E 06	8.0
9	22.5	36.2	36.1	32.7	525.7	5.11	0.02382	0.251E 06	7.6
10	25.5	36.5	36.4	32.9	528.0	5.08	0.02701	0.254E 06	7.3
11	29.5	36.9	36.8	33.2	531.0	5.05	0.03126	0.257E 06	7.2
12	33.5	37.3	37.2	33.5	534.0	5.02	0.03552	0.260E 06	7.0
13	37.5	37.5	37.4	33.7	537.1	4.98	0.03979	0.263E 06	7.0
14	41.5	37.9	37.8	34.0	540.1	4.95	0.04407	0.267E 06	6.8
15	45.5	38.1	38.1	34.3	543.2	4.92	0.04834	0.270E 06	6.9
16	49.5	38.4	38.3	34.6	546.3	4.89	0.05263	0.273E 06	6.9
17	54.5	38.9	38.8	34.9	550.3	4.85	0.05799	0.278E 06	6.7
18	59.5	39.4	39.3	35.3	554.2	4.81	0.06336	0.282E 06	6.4
19	64.5	39.9	39.8	35.6	558.2	4.78	0.06874	0.286E 06	6.2
20	69.5	40.5	40.4	36.0	562.2	4.74	0.07413	0.290E 06	5.8
21	74.5	41.0	40.9	36.4	566.2	4.70	0.07953	0.295E 06	5.6
22	79.5	41.6	41.4	36.7	570.3	4.66	0.08493	0.299E 06	5.4
23	84.5	41.9	41.7	37.1	574.4	4.63	0.09034	0.303E 06	5.5

FULLY DEVELOPED NUSSELT NUMBER = 6.8

RUN NUMBER (6)   TUBE NUMBER 13

INPUT POWER = 100.0 W HEAT RATE GAINED BY WATER = 92.7 W HEAT BALANCE ERROR = 7.3%

PRESSURE DROP = 7.3 MM H2O   F =0.07743

REM = 579.3   RAM = 0.637E 06   RAMF =0.101E 06   PRM = 4.58

UPSTREAM BULK TEMPERATURE =30.9 DEG C   DOWNSTREAM BULK TEMPERATURE =44.0 DEG C

INLET BULK TEMPERATURE =31.1 DEG C   OUTLET BULK TEMPERATURE =43.9 DEG C

MASS FLOW RATE = 6.1 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	32.8	32.9	31.3	511.6	5.26	0.00158	0.488E 06	34.8
2	3.5	34.1	34.0	31.6	514.6	5.23	0.00370	0.495E 06	22.2
3	5.5	35.1	35.0	31.9	517.7	5.19	0.00581	0.502E 06	17.1
4	7.5	36.2	36.1	32.2	520.7	5.16	0.00793	0.508E 06	13.7
5	10.5	37.7	37.5	32.6	525.3	5.11	0.01111	0.518E 06	10.9
6	13.5	38.6	38.6	33.1	530.0	5.06	0.01430	0.529E 06	9.8
7	16.5	39.4	39.4	33.5	534.7	5.01	0.01750	0.539E 06	9.2
8	19.5	40.2	40.1	34.0	539.4	4.96	0.02070	0.550E 06	8.7
9	22.5	40.9	40.7	34.4	544.2	4.91	0.02391	0.560E 06	8.5
10	25.5	41.3	41.0	34.8	549.1	4.86	0.02713	0.571E 06	8.5
11	29.5	41.9	41.7	35.4	555.6	4.80	0.03142	0.585E 06	8.4
12	33.5	42.6	42.3	36.0	562.2	4.74	0.03573	0.600E 06	8.3
13	37.5	43.0	42.8	36.6	568.9	4.68	0.04005	0.614E 06	8.5
14	41.5	43.7	43.6	37.2	575.7	4.61	0.04438	0.629E 06	8.3
15	45.5	44.2	44.0	37.8	582.6	4.55	0.04872	0.644E 06	8.4
16	49.5	44.9	44.7	38.3	589.5	4.49	0.05307	0.659E 06	8.3
17	54.5	45.8	45.7	39.1	598.3	4.42	0.05852	0.678E 06	8.0
18	59.5	46.7	46.6	39.8	607.3	4.35	0.06399	0.698E 06	7.8
19	64.5	47.8	47.4	40.5	616.4	4.28	0.06947	0.718E 06	7.5
20	69.5	48.9	48.7	41.3	625.6	4.21	0.07497	0.738E 06	7.0
21	74.5	49.8	49.6	42.0	634.9	4.14	0.08048	0.758E 06	6.9
22	79.5	50.8	50.5	42.7	644.4	4.08	0.08600	0.778E 06	6.7
23	84.5	51.4	51.1	43.4	654.1	4.01	0.09153	0.799E 06	6.8

FULLY DEVELOPED NUSSELT NUMBER = 8.0

RUN NUMBER (7) TUBE NUMBER 13

INPUT POWER = 150.0 W HEAT RATE GAINED BY WATER = 143.1 W HEAT BALANCE ERROR = 4.6%

PRESSURE DROP = 7.0 MM H20 F =0.07371

REM = 622.7 RAM = 0.113E 07 RAMF =0.161E 06 PRM = 4.23

UPSTREAM BULK TEMPERATURE =30.9 DEG C DOWNSTREAM BULK TEMPERATURE =51.1 DEG C

INLET BULK TEMPERATURE =31.2 DEG C OUTLET BULK TEMPERATURE =51.0 DEG C

MASS FLOW RATE = 6.1 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	34.2	34.3	31.5	513.7	5.24	0.00158	0.762E 06	30.8
2	3.5	36.1	35.9	32.0	518.4	5.19	0.00370	0.778E 06	20.8
3	5.5	37.5	37.5	32.4	523.1	5.13	0.00582	0.794E 06	16.3
4	7.5	39.1	38.9	32.9	527.9	5.08	0.00794	0.810E 06	13.7
5	10.5	41.2	41.1	33.6	535.1	5.00	0.01114	0.835E 06	11.0
6	13.5	42.6	42.5	34.2	542.5	4.93	0.01434	0.860E 06	10.1
7	16.5	43.8	43.5	34.9	550.0	4.85	0.01756	0.886E 06	9.6
8	19.5	44.6	44.5	35.6	557.6	4.78	0.02078	0.911E 06	9.3
9	22.5	45.4	45.1	36.3	565.3	4.71	0.02401	0.938E 06	9.2
10	25.5	46.1	45.6	36.9	573.1	4.64	0.02726	0.964E 06	9.3
11	29.5	46.9	46.5	37.8	583.7	4.54	0.03159	0.100E 07	9.3
12	33.5	47.8	47.4	38.8	594.5	4.45	0.03595	0.104E 07	9.4
13	37.5	48.5	48.2	39.7	605.6	4.36	0.04032	0.107E 07	9.5
14	41.5	49.6	49.3	40.6	616.8	4.28	0.04470	0.111E 07	9.3
15	45.5	50.4	50.0	41.5	628.2	4.19	0.04910	0.115E 07	9.4
16	49.5	51.2	51.0	42.4	639.9	4.11	0.05351	0.119E 07	9.4
17	54.5	52.7	52.3	43.5	654.7	4.01	0.05904	0.124E 07	9.1
18	59.5	54.0	53.8	44.6	669.9	3.91	0.06459	0.129E 07	8.8
19	64.5	55.6	55.0	45.8	685.3	3.81	0.07015	0.134E 07	8.5
20	69.5	57.2	56.8	46.9	701.1	3.72	0.07573	0.139E 07	8.0
21	74.5	58.5	58.1	48.0	717.2	3.63	0.08131	0.144E 07	7.9
22	79.5	59.9	59.5	49.1	733.6	3.54	0.08690	0.150E 07	7.7
23	84.5	60.9	60.4	50.3	748.6	3.47	0.09246	0.155E 07	7.8

FULLY DEVELOPED NUSSELT NUMBER = 8.9

RUN NUMBER (8)   TUBE NUMBER 13

INPUT POWER = 200.0 W   HEAT RATE GAINED BY WATER = 194.8 W   HEAT BALANCE ERROR = 2.6%

PRESSURE DROP = 6.8 MM H2O   F =0.07099

REM = 668.1   RAM = 0.175E 07   RAMF =0.230E 06   PRM = 3.92

UPSTREAM BULK TEMPERATURE =30.8 DEG C   DOWNSTREAM BULK TEMPERATURE =58.2 DEG C

INLET BULK TEMPERATURE =31.1 DEG C   OUTLET BULK TEMPERATURE =58.0 DEG C

MASS FLOW RATE = 6.1 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	35.4	35.5	31.6	514.0	5.23	0.00158	0.104E 07	29.2
2	3.5	37.8	37.8	32.2	520.4	5.16	0.00370	0.107E 07	20.3
3	5.5	39.9	39.8	32.8	526.9	5.09	0.00582	0.110E 07	16.1
4	7.5	41.9	41.7	33.4	533.5	5.02	0.00795	0.113E 07	13.5
5	10.5	44.6	44.4	34.3	543.5	4.92	0.01116	0.118E 07	11.1
6	13.5	46.3	46.1	35.3	553.8	4.82	0.01438	0.122E 07	10.4
7	16.5	47.7	47.2	36.2	564.2	4.72	0.01761	0.127E 07	10.0
8	19.5	48.7	48.4	37.1	574.9	4.62	0.02085	0.132E 07	9.9
9	22.5	49.6	49.2	38.0	585.8	4.53	0.02411	0.137E 07	9.9
10	25.5	50.4	49.9	38.9	596.9	4.43	0.02737	0.142E 07	10.1
11	29.5	51.5	51.0	40.2	612.0	4.31	0.03175	0.149E 07	10.2
12	33.5	52.6	52.1	41.4	627.5	4.20	0.03615	0.156E 07	10.3
13	37.5	53.5	53.1	42.6	643.4	4.08	0.04056	0.163E 07	10.4
14	41.5	55.0	54.6	43.9	659.6	3.97	0.04499	0.171E 07	10.2
15	45.5	56.0	55.5	45.1	676.3	3.87	0.04943	0.178E 07	10.5
16	49.5	57.3	56.9	46.3	693.3	3.76	0.05389	0.186E 07	10.3
17	54.5	59.2	58.7	47.9	715.1	3.64	0.05947	0.196E 07	10.0
18	59.5	60.9	60.6	49.4	737.4	3.52	0.06506	0.206E 07	9.7
19	64.5	63.0	62.3	50.9	754.1	3.44	0.07065	0.214E 07	9.4
20	69.5	65.2	64.6	52.5	767.2	3.37	0.07629	0.222E 07	8.8
21	74.5	66.8	66.2	54.0	781.1	3.31	0.08196	0.229E 07	8.8
22	79.5	68.7	68.1	55.6	795.6	3.24	0.08766	0.237E 07	8.5
23	84.5	70.0	69.4	57.1	811.0	3.17	0.09337	0.245E 07	8.7

FULLY DEVELOPED NUSSELT NUMBER = 9.7

RUN NUMBER (9) TUBE NUMBER 13

INPUT POWER = 250.0 W HEAT RATE GAINED BY WATER = 247.6 W HEAT BALANCE ERROR = 0.9%

PRESSURE DROP = 6.7 MM H2O F =0.06974

REM = 720.1 RAM = 0.252E 07 RAMF =0.275E 06 PRM = 3.61

UPSTREAM BULK TEMPERATURE =30.8 DEG C DOWNSTREAM BULK TEMPERATURE =65.7 DEG C

INLET BULK TEMPERATURE =31.2 DEG C OUTLET BULK TEMPERATURE =65.5 DEG C

MASS FLOW RATE = 6.1 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	36.7	36.9	31.8	516.2	5.21	0.00158	0.134E 07	28.9
2	3.5	39.7	39.6	32.5	524.4	5.12	0.00370	0.139E 07	20.5
3	5.5	42.2	42.1	33.3	532.7	5.03	0.00583	0.144E 07	16.4
4	7.5	44.8	44.5	34.1	541.2	4.94	0.00797	0.149E 07	13.8
5	10.5	48.0	47.7	35.3	554.2	4.81	0.01118	0.156E 07	11.5
6	13.5	49.8	49.6	36.5	567.6	4.69	0.01441	0.164E 07	10.9
7	16.5	51.3	50.8	37.6	581.3	4.56	0.01766	0.172E 07	10.7
8	19.5	52.6	52.2	38.8	595.4	4.45	0.02093	0.180E 07	10.6
9	22.5	53.6	53.0	40.0	609.8	4.33	0.02421	0.189E 07	10.8
10	25.5	54.5	53.8	41.2	624.6	4.22	0.02750	0.197E 07	11.1
11	29.5	55.8	55.2	42.7	644.8	4.07	0.03191	0.209E 07	11.2
12	33.5	57.2	56.4	44.3	665.6	3.93	0.03635	0.221E 07	11.4
13	37.5	58.4	57.9	45.9	687.1	3.80	0.04079	0.233E 07	11.6
14	41.5	60.2	59.6	47.5	709.1	3.67	0.04526	0.246E 07	11.3
15	45.5	61.4	60.8	49.0	731.7	3.55	0.04973	0.259E 07	11.7
16	49.5	63.1	62.6	50.6	751.1	3.45	0.05419	0.271E 07	11.5
17	54.5	65.5	64.8	52.6	767.8	3.37	0.05983	0.283E 07	11.1
18	59.5	67.7	67.3	54.5	785.6	3.28	0.06550	0.296E 07	10.8
19	64.5	70.2	69.4	56.5	804.6	3.20	0.07121	0.308E 07	10.4
20	69.5	72.6	72.0	58.4	824.9	3.11	0.07695	0.322E 07	10.0
21	74.5	74.0	73.4	60.4	846.7	3.02	0.08272	0.335E 07	10.4
22	79.5	74.2	73.5	62.4	870.1	2.93	0.08852	0.350E 07	12.0
23	84.5	74.4	74.0	64.3	895.3	2.84	0.09436	0.364E 07	13.9

FULLY DEVELOPED NUSSELT NUMBER =11.2

RUN NUMBER (1) TUBE NUMBER 14

INPUT POWER = 50.0 W HEAT RATE GAINED BY WATER = 47.8 W HEAT BALANCE ERROR = 4.4%

PRESSURE DROP = 1.0 MM H20 F =0.25443

REM = 281.5 RAM = 0.170E 07 RAMF =0.203E 06 PRM = 5.58

UPSTREAM BULK TEMPERATURE =26.2 DEG C DOWNSTREAM BULK TEMPERATURE =31.2 DEG C

INLET BULK TEMPERATURE =26.3 DEG C OUTLET BULK TEMPERATURE =31.2 DEG C

MASS FLOW RATE = 8.2 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	27.8	27.8	26.4	267.6	5.91	0.00136	0.152E 07	20.2
2	3.5	28.3	28.3	26.5	268.3	5.90	0.00318	0.153E 07	15.4
3	5.5	28.8	28.7	26.6	268.9	5.88	0.00500	0.153E 07	12.9
4	7.5	29.2	29.1	26.7	269.6	5.86	0.00683	0.154E 07	11.5
5	10.5	29.6	29.6	26.9	270.6	5.84	0.00956	0.156E 07	10.4
6	13.5	30.0	29.9	27.0	271.6	5.82	0.01230	0.157E 07	9.7
7	16.5	30.3	30.1	27.2	272.6	5.79	0.01504	0.158E 07	9.4
8	19.5	30.5	30.2	27.4	273.6	5.77	0.01778	0.160E 07	9.4
9	22.5	30.6	30.4	27.5	274.6	5.74	0.02053	0.161E 07	9.4
10	25.5	30.8	30.6	27.7	275.6	5.72	0.02328	0.162E 07	9.3
11	29.5	31.2	30.9	27.9	276.9	5.69	0.02695	0.164E 07	9.0
12	33.5	31.4	31.1	28.2	278.2	5.66	0.03062	0.166E 07	9.1
13	37.5	31.6	31.3	28.4	279.5	5.63	0.03430	0.168E 07	9.1
14	41.5	31.8	31.5	28.6	280.8	5.60	0.03798	0.169E 07	9.2
15	45.5	32.0	31.7	28.8	282.1	5.57	0.04167	0.171E 07	9.2
16	49.5	32.1	31.9	29.1	283.4	5.54	0.04536	0.173E 07	9.4
17	54.5	32.5	32.3	29.3	285.1	5.50	0.04998	0.175E 07	9.1
18	59.5	32.8	32.5	29.6	286.7	5.47	0.05461	0.178E 07	9.2
19	64.5	33.1	32.8	29.9	288.3	5.43	0.05924	0.180E 07	9.1
20	69.5	33.4	33.1	30.2	290.0	5.40	0.06386	0.182E 07	9.1
21	74.5	33.7	33.5	30.4	291.6	5.37	0.06850	0.185E 07	8.8
22	79.5	34.0	33.7	30.7	293.2	5.33	0.07314	0.187E 07	9.0
23	84.5	33.9	33.7	31.0	294.9	5.30	0.07780	0.190E 07	9.8

FULLY DEVELOPED NUSSELT NUMBER = 9.2

RUN NUMBER (2)   TUBE NUMBER 14

INPUT POWER = 150.0 W   HEAT RATE GAINED BY WATER = 143.9 W   HEAT BALANCE ERROR = 4.1%

PRESSURE DROP = 1.3 MM H2O   F =0.32289

REM = 312.0   RAM = 0.650E 07   RAMF =0.598E 06   PRM = 4.98

UPSTREAM BULK TEMPERATURE =26.3 DEG C   DOWNSTREAM BULK TEMPERATURE =41.3 DEG C

INLET BULK TEMPERATURE =26.5 DEG C   OUTLET BULK TEMPERATURE =41.2 DEG C

MASS FLOW RATE = 8.2 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	30.7	30.7	26.8	269.8	5.86	0.00137	0.467E 07	21.4
2	3.5	32.4	32.1	27.1	271.8	5.81	0.00319	0.475E 07	16.3
3	5.5	33.5	33.1	27.4	273.8	5.76	0.00502	0.483E 07	14.3
4	7.5	34.4	33.9	27.8	275.8	5.71	0.00685	0.491E 07	13.2
5	10.5	35.2	34.8	28.3	278.8	5.64	0.00960	0.503E 07	12.5
6	13.5	36.0	35.3	28.8	281.8	5.58	0.01236	0.516E 07	12.3
7	16.5	36.5	36.0	29.3	284.7	5.51	0.01513	0.528E 07	12.1
8	19.5	36.9	36.3	29.8	287.7	5.45	0.01790	0.540E 07	12.3
9	22.5	37.4	36.5	30.3	290.7	5.39	0.02068	0.553E 07	12.6
10	25.5	37.8	37.0	30.8	293.6	5.33	0.02347	0.567E 07	12.7
11	29.5	38.6	37.6	31.5	297.6	5.25	0.02719	0.585E 07	12.6
12	33.5	39.0	38.1	32.1	301.6	5.17	0.03092	0.603E 07	13.0
13	37.5	39.6	38.7	32.8	305.7	5.09	0.03467	0.622E 07	13.1
14	41.5	40.2	39.4	33.5	309.9	5.01	0.03843	0.641E 07	13.2
15	45.5	40.8	39.8	34.1	314.1	4.94	0.04220	0.660E 07	13.5
16	49.5	41.5	40.7	34.8	318.4	4.86	0.04598	0.679E 07	13.3
17	54.5	42.8	41.9	35.7	323.9	4.77	0.05072	0.704E 07	12.4
18	59.5	43.5	42.5	36.5	329.4	4.68	0.05548	0.729E 07	12.8
19	64.5	44.3	43.5	37.3	335.1	4.60	0.06025	0.754E 07	12.6
20	69.5	45.4	44.5	38.2	340.9	4.51	0.06504	0.780E 07	12.2
21	74.5	46.2	45.4	39.0	346.7	4.43	0.06984	0.806E 07	12.2
22	79.5	47.0	45.9	39.9	352.7	4.34	0.07466	0.833E 07	12.5
23	84.5	47.4	46.6	40.7	358.8	4.26	0.07950	0.860E 07	13.0

FULLY DEVELOPED NUSSELT NUMBER =12.7

RUN NUMBER (3) TUBE NUMBER 14

INPUT POWER = 250.0 W HEAT RATE GAINED BY WATER = 244.1 W HEAT BALANCE ERROR = 2.3%

PRESSURE DROP = 1.7 MM H2O F =0.41357

REM = 347.4 RAM = 0.138E 08 RAMF =0.104E 07 PRM = 4.42

UPSTREAM BULK TEMPERATURE =26.3 DEG C DOWNSTREAM BULK TEMPERATURE =51.9 DEG C

INLET BULK TEMPERATURE =26.7 DEG C OUTLET BULK TEMPERATURE =51.7 DEG C

MASS FLOW RATE = 8.2 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	33.4	33.3	27.1	272.0	5.80	0.00137	0.809E 07	23.0
2	3.5	35.9	35.4	27.7	275.4	5.72	0.00319	0.833E 07	18.0
3	5.5	37.4	36.7	28.3	278.8	5.64	0.00503	0.856E 07	16.3
4	7.5	38.6	37.7	28.8	282.2	5.57	0.00687	0.880E 07	15.4
5	10.5	39.9	39.0	29.7	287.2	5.46	0.00964	0.916E 07	14.6
6	13.5	40.8	39.7	30.6	292.2	5.35	0.01242	0.954E 07	14.7
7	16.5	41.5	40.3	31.4	297.3	5.25	0.01521	0.993E 07	15.0
8	19.5	41.9	40.3	32.3	302.5	5.15	0.01801	0.103E 08	16.1
9	22.5	42.3	40.6	33.1	307.7	5.05	0.02082	0.107E 08	17.1
10	25.5	43.0	41.4	34.0	313.1	4.96	0.02364	0.111E 08	17.3
11	29.5	44.5	42.8	35.1	320.4	4.83	0.02742	0.117E 08	16.7
12	33.5	45.5	43.9	36.3	327.9	4.71	0.03122	0.123E 08	16.8
13	37.5	46.7	45.2	37.4	335.6	4.59	0.03503	0.129E 08	16.5
14	41.5	47.9	46.4	38.6	343.5	4.47	0.03887	0.135E 08	16.4
15	45.5	49.1	47.4	39.7	351.6	4.36	0.04272	0.141E 08	16.4
16	49.5	50.1	48.5	40.8	359.8	4.25	0.04658	0.147E 08	16.5
17	54.5	52.1	50.7	42.3	370.4	4.12	0.05143	0.155E 08	15.4
18	59.5	53.3	51.6	43.7	381.3	3.99	0.05630	0.163E 08	15.9
19	64.5	54.7	53.3	45.1	392.5	3.86	0.06119	0.172E 08	15.7
20	69.5	56.2	54.6	46.6	404.0	3.75	0.06609	0.180E 08	15.7
21	74.5	57.8	56.2	48.0	415.8	3.63	0.07099	0.189E 08	15.3
22	79.5	59.3	57.8	49.4	427.8	3.52	0.07590	0.198E 08	15.1
23	84.5	59.9	58.6	50.9	437.0	3.44	0.08080	0.206E 08	16.4

FULLY DEVELOPED NUSSELT NUMBER =16.1

RUN NUMBER (4)   TUBE NUMBER 14

INPUT POWER = 350.0 W   HEAT RATE GAINED BY WATER = 333.8 W   HEAT BALANCE ERROR = 4.6%

PRESSURE DROP = 2.2 MM H2O   F =0.52640

REM = 382.1   RAM = 0.225E 08   RAMF =0.152E 07   PRM = 3.98

UPSTREAM BULK TEMPERATURE =26.3 DEG C   DOWNSTREAM BULK TEMPERATURE =61.3 DEG C

INLET BULK TEMPERATURE =26.8 DEG C   OUTLET BULK TEMPERATURE =61.1 DEG C

MASS FLOW RATE = 8.2 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	35.6	35.4	27.4	273.6	5.77	0.00137	0.112E 08	24.3
2	3.5	38.7	37.9	28.2	278.2	5.66	0.00320	0.117E 08	19.4
3	5.5	40.6	39.5	28.9	282.8	5.55	0.00504	0.121E 08	17.7
4	7.5	41.9	40.7	29.7	287.4	5.45	0.00689	0.126E 08	17.0
5	10.5	43.5	42.1	30.9	294.3	5.31	0.00966	0.133E 08	16.5
6	13.5	44.3	42.4	32.1	301.3	5.17	0.01246	0.140E 08	17.3
7	16.5	45.3	43.4	33.3	308.5	5.04	0.01527	0.148E 08	17.6
8	19.5	45.9	43.7	34.4	315.9	4.91	0.01810	0.156E 08	18.7
9	22.5	46.7	44.5	35.6	323.5	4.78	0.02094	0.164E 08	19.5
10	25.5	47.9	45.7	36.8	331.3	4.65	0.02379	0.172E 08	19.3
11	29.5	49.8	47.5	38.3	342.1	4.49	0.02762	0.183E 08	18.7
12	33.5	51.1	48.8	39.9	353.1	4.34	0.03147	0.195E 08	19.1
13	37.5	52.7	50.6	41.5	364.5	4.19	0.03534	0.206E 08	18.9
14	41.5	54.4	52.4	43.0	376.3	4.05	0.03922	0.219E 08	18.4
15	45.5	55.9	53.7	44.6	388.5	3.91	0.04313	0.231E 08	18.7
16	49.5	57.7	55.8	46.2	401.0	3.78	0.04704	0.244E 08	18.1
17	54.5	60.0	57.7	48.1	417.0	3.62	0.05195	0.260E 08	17.7
18	59.5	61.8	59.7	50.1	433.4	3.48	0.05684	0.277E 08	17.7
19	64.5	63.7	61.6	52.1	442.9	3.39	0.06178	0.289E 08	17.7
20	69.5	65.8	63.5	54.0	453.0	3.31	0.06676	0.302E 08	17.6
21	74.5	68.2	65.9	56.0	463.8	3.22	0.07177	0.315E 08	16.9
22	79.5	69.8	67.5	57.9	475.4	3.13	0.07680	0.329E 08	17.4
23	84.5	70.9	69.1	59.9	487.8	3.04	0.08186	0.343E 08	18.3

FULLY DEVELOPED NUSSELT NUMBER =18.3

RUN NUMBER (5)   TUBE NUMBER 14

INPUT POWER = 150.0 W   HEAT RATE GAINED BY WATER = 147.3 W   HEAT BALANCE ERROR = 1.8%

PRESSURE DROP = 3.1 MM H2O   F =0.14518

REM = 656.9   RAM = 0.551E 07   RAMF =0.499E 06   PRM = 5.47

UPSTREAM BULK TEMPERATURE =26.2 DEG C   DOWNSTREAM BULK TEMPERATURE =32.9 DEG C

INLET BULK TEMPERATURE =26.3 DEG C   OUTLET BULK TEMPERATURE =32.9 DEG C

MASS FLOW RATE = 18.9 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	29.3	29.4	26.4	613.9	5.91	0.00060	0.472E 07	29.3
2	3.5	30.7	30.6	26.6	615.9	5.89	0.00139	0.475E 07	21.4
3	5.5	31.6	31.5	26.7	618.0	5.86	0.00218	0.479E 07	18.1
4	7.5	32.3	32.2	26.9	620.1	5.84	0.00298	0.483E 07	16.1
5	10.5	33.3	33.1	27.1	623.2	5.81	0.00417	0.488E 07	14.2
6	13.5	34.1	33.7	27.3	626.3	5.78	0.00537	0.494E 07	13.2
7	16.5	34.7	34.2	27.5	629.3	5.74	0.00657	0.500E 07	12.6
8	19.5	35.0	34.5	27.8	632.4	5.71	0.00777	0.505E 07	12.5
9	22.5	35.3	34.6	28.0	635.5	5.68	0.00897	0.511E 07	12.5
10	25.5	35.6	35.0	28.2	638.6	5.65	0.01017	0.516E 07	12.2
11	29.5	36.2	35.5	28.5	642.7	5.61	0.01177	0.524E 07	11.8
12	33.5	36.5	35.8	28.8	646.7	5.57	0.01338	0.532E 07	11.8
13	37.5	36.8	36.1	29.1	650.8	5.53	0.01499	0.539E 07	11.9
14	41.5	37.0	36.4	29.4	654.8	5.49	0.01661	0.547E 07	11.9
15	45.5	37.3	36.5	29.7	658.8	5.45	0.01822	0.554E 07	12.0
16	49.5	37.4	36.7	30.0	663.0	5.42	0.01983	0.562E 07	12.3
17	54.5	38.0	37.2	30.4	668.0	5.37	0.02186	0.572E 07	12.0
18	59.5	38.2	37.3	30.8	673.0	5.33	0.02388	0.583E 07	12.3
19	64.5	38.4	37.4	31.2	678.1	5.28	0.02591	0.593E 07	12.8
20	69.5	38.5	37.6	31.5	683.3	5.24	0.02795	0.604E 07	13.2
21	74.5	38.8	37.9	31.9	688.5	5.19	0.02998	0.614E 07	13.4
22	79.5	39.0	38.0	32.3	693.7	5.15	0.03202	0.625E 07	13.9
23	84.5	39.0	38.2	32.7	699.0	5.11	0.03407	0.636E 07	14.5

FULLY DEVELOPED NUSSELT NUMBER =12.6

RUN NUMBER (6)   TUBE NUMBER 14

INPUT POWER = 300.0 W   HEAT RATE GAINED BY WATER = 295.7 W   HEAT BALANCE ERROR = 1.4%

PRESSURE DROP = 3.3 MM H2O   F =0.15368

REM = 703.3   RAM = 0.129E 08   RAMF =0.939E 06   PRM = 5.07

UPSTREAM BULK TEMPERATURE =26.2 DEG C   DOWNSTREAM BULK TEMPERATURE =39.7 DEG C

INLET BULK TEMPERATURE =26.4 DEG C   OUTLET BULK TEMPERATURE =39.6 DEG C

MASS FLOW RATE = 18.9 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	32.4	32.4	26.6	616.4	5.88	0.00060	0.957E 07	30.2
2	3.5	34.9	34.6	26.9	620.6	5.84	0.00139	0.972E 07	22.2
3	5.5	36.5	36.1	27.2	624.7	5.79	0.00219	0.987E 07	19.2
4	7.5	37.8	37.2	27.5	628.9	5.75	0.00298	0.100E 08	17.5
5	10.5	39.1	38.5	28.0	635.1	5.69	0.00418	0.102E 08	16.1
6	13.5	40.1	39.1	28.4	641.2	5.62	0.00539	0.105E 08	15.6
7	16.5	40.8	39.8	28.9	647.4	5.56	0.00659	0.107E 08	15.2
8	19.5	41.4	40.2	29.3	653.5	5.50	0.00780	0.109E 08	15.1
9	22.5	42.0	40.6	29.8	659.5	5.45	0.00901	0.112E 08	15.1
10	25.5	42.5	41.0	30.2	665.7	5.39	0.01022	0.114E 08	15.1
11	29.5	42.9	41.1	30.8	673.8	5.32	0.01184	0.117E 08	15.5
12	33.5	43.1	41.4	31.4	682.0	5.25	0.01347	0.121E 08	16.0
13	37.5	43.6	41.7	32.1	690.4	5.18	0.01510	0.124E 08	16.3
14	41.5	43.9	42.1	32.7	698.9	5.11	0.01673	0.128E 08	16.7
15	45.5	44.1	42.2	33.3	707.4	5.04	0.01837	0.131E 08	17.4
16	49.5	44.7	43.0	33.9	716.1	4.97	0.02001	0.135E 08	17.3
17	54.5	46.0	44.1	34.6	727.2	4.89	0.02207	0.139E 08	16.5
18	59.5	46.5	44.6	35.4	738.4	4.80	0.02414	0.144E 08	16.9
19	64.5	46.8	44.9	36.1	749.8	4.72	0.02621	0.148E 08	17.6
20	69.5	47.5	45.9	36.9	761.4	4.64	0.02829	0.153E 08	17.5
21	74.5	48.6	46.8	37.7	773.2	4.56	0.03038	0.158E 08	17.1
22	79.5	49.5	47.7	38.4	785.2	4.49	0.03247	0.163E 08	16.8
23	84.5	49.8	48.3	39.2	797.3	4.41	0.03457	0.168E 08	17.2

FULLY DEVELOPED NUSSELT NUMBER =16.4

RUN NUMBER (7)   TUBE NUMBER 14

INPUT POWER = 450.0 W   HEAT RATE GAINED BY WATER = 438.0 W   HEAT BALANCE ERROR = 2.7%

PRESSURE DROP = 3.6 MM H20   F =0.16648

REM = 751.0   RAM = 0.221E 08   RAMF =0.141E 07   PRM = 4.71

UPSTREAM BULK TEMPERATURE =26.2 DEG C   DOWNSTREAM BULK TEMPERATURE =46.2 DEG C

INLET BULK TEMPERATURE =26.4 DEG C   OUTLET BULK TEMPERATURE =46.1 DEG C

MASS FLOW RATE = 18.9 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	35.0	35.0	26.8	618.9	5.85	0.00060	0.143E 08	31.4
2	3.5	38.5	37.9	27.2	625.0	5.79	0.00139	0.147E 08	23.6
3	5.5	40.7	39.8	27.7	631.2	5.73	0.00219	0.150E 08	20.6
4	7.5	42.2	41.0	28.1	637.3	5.66	0.00299	0.153E 08	19.2
5	10.5	43.8	42.5	28.8	646.4	5.57	0.00419	0.158E 08	18.0
6	13.5	44.9	43.2	29.5	655.4	5.49	0.00540	0.163E 08	17.7
7	16.5	45.9	44.2	30.1	664.5	5.40	0.00661	0.168E 08	17.3
8	19.5	46.4	44.2	30.8	673.6	5.32	0.00783	0.174E 08	17.8
9	22.5	46.7	44.2	31.5	682.7	5.24	0.00905	0.180E 08	18.4
10	25.5	47.2	44.8	32.2	692.0	5.16	0.01027	0.185E 08	18.6
11	29.5	48.5	45.8	33.1	704.6	5.06	0.01190	0.193E 08	18.2
12	33.5	48.9	46.2	34.0	717.5	4.96	0.01355	0.201E 08	18.8
13	37.5	49.5	46.8	34.9	730.7	4.86	0.01520	0.209E 08	19.2
14	41.5	50.0	47.3	35.8	744.1	4.76	0.01685	0.217E 08	19.8
15	45.5	50.6	47.7	36.7	757.8	4.67	0.01851	0.225E 08	20.4
16	49.5	51.2	48.5	37.6	771.7	4.57	0.02018	0.233E 08	20.7
17	54.5	52.6	50.0	38.7	789.5	4.46	0.02227	0.244E 08	20.1
18	59.5	54.2	51.7	39.8	807.7	4.35	0.02437	0.255E 08	19.3
19	64.5	54.9	52.3	40.9	826.4	4.24	0.02648	0.266E 08	19.9
20	69.5	55.6	52.6	42.1	845.5	4.14	0.02860	0.277E 08	20.9
21	74.5	57.3	54.8	43.2	865.0	4.03	0.03072	0.289E 08	19.5
22	79.5	58.0	55.2	44.3	884.9	3.94	0.03285	0.300E 08	20.5
23	84.5	58.2	55.7	45.4	905.2	3.84	0.03498	0.312E 08	21.7

FULLY DEVELOPED NUSSELT NUMBER =19.5

RUN NUMBER (8)   TUBE NUMBER 14

INPUT POWER = 600.0 W   HEAT RATE GAINED BY WATER = 592.5 W   HEAT BALANCE ERROR = 1.2%

PRESSURE DROP = 3.9 MM H2O   F =0.17917

REM = 805.0   RAM = 0.343E 08   RAMF =0.197E 07   PRM = 4.37

UPSTREAM BULK TEMPERATURE =26.1 DEG C   DOWNSTREAM BULK TEMPERATURE =53.2 DEG C

INLET BULK TEMPERATURE =26.4 DEG C   OUTLET BULK TEMPERATURE =53.0 DEG C

MASS FLOW RATE = 18.9 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	37.6	37.4	26.8	619.8	5.85	0.00060	0.195E 08	33.0
2	3.5	41.8	40.9	27.5	628.1	5.76	0.00139	0.201E 08	25.2
3	5.5	44.4	43.0	28.1	636.4	5.67	0.00219	0.207E 08	22.4
4	7.5	46.1	44.4	28.7	644.6	5.59	0.00299	0.213E 08	21.1
5	10.5	47.9	46.1	29.6	656.9	5.47	0.00420	0.222E 08	20.1
6	13.5	49.2	46.9	30.5	669.2	5.36	0.00542	0.232E 08	19.8
7	16.5	50.3	47.5	31.4	681.5	5.25	0.00663	0.242E 08	19.9
8	19.5	50.8	47.7	32.3	694.1	5.15	0.00786	0.253E 08	20.6
9	22.5	51.1	47.9	33.2	707.0	5.04	0.00908	0.263E 08	21.4
10	25.5	52.1	49.1	34.1	720.1	4.94	0.01032	0.274E 08	21.0
11	29.5	53.2	49.4	35.4	738.1	4.81	0.01197	0.289E 08	21.7
12	33.5	53.9	50.2	36.6	756.5	4.68	0.01363	0.304E 08	22.3
13	37.5	54.6	51.0	37.8	775.4	4.55	0.01530	0.319E 08	22.9
14	41.5	55.7	52.3	39.0	794.9	4.43	0.01697	0.335E 08	22.9
15	45.5	56.9	53.4	40.2	814.8	4.31	0.01865	0.351E 08	23.0
16	49.5	58.1	54.6	41.5	835.2	4.19	0.02034	0.367E 08	23.0
17	54.5	60.2	57.2	43.0	861.4	4.05	0.02247	0.388E 08	21.6
18	59.5	61.0	57.2	44.5	888.4	3.92	0.02459	0.410E 08	23.3
19	64.5	61.8	58.1	46.0	916.1	3.79	0.02673	0.432E 08	24.3
20	69.5	63.8	60.4	47.5	944.6	3.67	0.02887	0.454E 08	23.3
21	74.5	66.5	63.2	49.1	973.8	3.55	0.03101	0.478E 08	21.4
22	79.5	67.2	63.4	50.6	998.8	3.46	0.03315	0.499E 08	22.8
23	84.5	67.7	64.6	52.1	1015.8	3.39	0.03531	0.516E 08	23.8

FULLY DEVELOPED NUSSELT NUMBER =22.3

RUN NUMBER (9) TUBE NUMBER 14

INPUT POWER = 750.0 W HEAT RATE GAINED BY WATER = 748.2 W HEAT BALANCE ERROR = 0.2%

PRESSURE DROP = 4.3 MM H20 F =0.19606

REM = 866.2 RAM = 0.496E 08 RAMF =0.262E 07 PRM = 4.03

UPSTREAM BULK TEMPERATURE =26.2 DEG C DOWNSTREAM BULK TEMPERATURE =60.3 DEG C

INLET BULK TEMPERATURE =26.5 DEG C OUTLET BULK TEMPERATURE =60.2 DEG C

MASS FLOW RATE = 18.9 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	40.0	39.7	27.1	622.9	5.81	0.00060	0.249E 08	34.7
2	3.5	45.2	43.7	27.8	633.5	5.70	0.00139	0.259E 08	26.7
3	5.5	48.1	45.9	28.6	643.9	5.60	0.00220	0.269E 08	24.0
4	7.5	50.0	47.4	29.4	654.2	5.50	0.00300	0.278E 08	22.9
5	10.5	52.0	49.7	30.5	669.7	5.36	0.00421	0.294E 08	21.7
6	13.5	53.3	50.2	31.7	685.4	5.22	0.00543	0.310E 08	21.9
7	16.5	54.6	51.3	32.8	701.5	5.09	0.00665	0.327E 08	21.8
8	19.5	55.3	51.5	34.0	718.0	4.96	0.00789	0.344E 08	22.6
9	22.5	55.9	51.6	35.2	735.0	4.83	0.00912	0.362E 08	23.5
10	25.5	56.4	52.2	36.3	752.3	4.70	0.01037	0.379E 08	24.3
11	29.5	58.1	53.4	37.8	776.2	4.54	0.01203	0.404E 08	24.3
12	33.5	59.8	55.4	39.4	800.8	4.39	0.01371	0.429E 08	23.8
13	37.5	60.7	56.2	40.9	826.3	4.24	0.01540	0.455E 08	24.7
14	41.5	61.9	57.4	42.5	852.5	4.10	0.01709	0.482E 08	25.2
15	45.5	63.6	59.5	44.0	879.6	3.96	0.01879	0.509E 08	24.5
16	49.5	64.5	59.8	45.5	907.4	3.83	0.02050	0.537E 08	25.8
17	54.5	67.0	62.6	47.5	943.2	3.67	0.02264	0.573E 08	24.7
18	59.5	68.7	64.3	49.4	980.2	3.53	0.02478	0.610E 08	24.9
19	64.5	70.3	65.9	51.3	1006.8	3.42	0.02692	0.641E 08	25.2
20	69.5	72.5	68.2	53.2	1029.1	3.34	0.02909	0.669E 08	24.7
21	74.5	75.1	70.6	55.2	1052.8	3.26	0.03127	0.698E 08	23.8
22	79.5	76.2	71.6	57.1	1078.1	3.17	0.03346	0.727E 08	25.0
23	84.5	77.2	73.2	59.0	1105.2	3.08	0.03566	0.758E 08	25.9

FULLY DEVELOPED NUSSELT NUMBER =24.4

RUN NUMBER (10)   TUBE NUMBER 14

INPUT POWER = 200.0 W   HEAT RATE GAINED BY WATER = 197.6 W   HEAT BALANCE ERROR = 1.2%

PRESSURE DROP = 5.2 MM H20   F =0.09380

REM = 1027.7   RAM = 0.697E 07   RAMF =0.664E 06   PRM = 5.64

UPSTREAM BULK TEMPERATURE =25.5 DEG C   DOWNSTREAM BULK TEMPERATURE =31.1 DEG C

INLET BULK TEMPERATURE =25.6 DEG C   OUTLET BULK TEMPERATURE =31.1 DEG C

MASS FLOW RATE = 30.3 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	28.9	29.0	25.6	969.3	6.03	0.00037	0.609E 07	35.4
2	3.5	30.4	30.3	25.8	972.1	6.01	0.00086	0.613E 07	25.5
3	5.5	31.4	31.3	25.9	974.9	5.99	0.00136	0.617E 07	21.6
4	7.5	32.2	32.2	26.0	977.6	5.97	0.00185	0.621E 07	19.0
5	10.5	33.3	33.2	26.2	981.8	5.94	0.00259	0.627E 07	16.6
6	13.5	34.2	33.8	26.4	986.0	5.91	0.00333	0.634E 07	15.4
7	16.5	34.9	34.6	26.6	990.2	5.88	0.00408	0.640E 07	14.4
8	19.5	35.4	34.9	26.8	994.3	5.85	0.00482	0.646E 07	14.0
9	22.5	35.8	35.1	27.0	998.5	5.83	0.00556	0.652E 07	13.8
10	25.5	36.3	35.6	27.2	1002.7	5.80	0.00631	0.659E 07	13.3
11	29.5	36.8	36.1	27.4	1008.2	5.76	0.00731	0.667E 07	12.9
12	33.5	37.2	36.4	27.7	1013.7	5.73	0.00830	0.676E 07	12.8
13	37.5	37.4	36.7	27.9	1019.2	5.69	0.00930	0.684E 07	12.8
14	41.5	37.7	37.0	28.2	1024.7	5.66	0.01030	0.692E 07	12.7
15	45.5	38.1	37.2	28.4	1030.2	5.62	0.01130	0.701E 07	12.7
16	49.5	38.2	37.3	28.7	1035.7	5.59	0.01230	0.709E 07	12.8
17	54.5	38.8	37.9	29.0	1042.5	5.55	0.01356	0.720E 07	12.4
18	59.5	38.9	38.0	29.3	1049.3	5.51	0.01481	0.731E 07	12.7
19	64.5	39.0	38.1	29.6	1056.1	5.47	0.01607	0.741E 07	13.0
20	69.5	39.4	38.3	29.9	1062.8	5.43	0.01733	0.752E 07	13.1
21	74.5	39.6	38.5	30.2	1069.8	5.39	0.01859	0.764E 07	13.2
22	79.5	39.7	38.4	30.6	1076.5	5.35	0.01985	0.775E 07	13.7
23	84.5	39.4	38.2	30.9	1083.3	5.31	0.02112	0.787E 07	14.6

FULLY DEVELOPED NUSSELT NUMBER =13.2

RUN NUMBER (11) TUBE NUMBER 14

INPUT POWER = 400.0 W HEAT RATE GAINED BY WATER = 393.0 W HEAT BALANCE ERROR = 1.7%

PRESSURE DROP = 5.5 MM H2O F =0.09879

REM = 1086.6 RAM = 0.158E 08 RAMF =0.115E 07 PRM = 5.30

UPSTREAM BULK TEMPERATURE =25.4 DEG C DOWNSTREAM BULK TEMPERATURE =36.6 DEG C

INLET BULK TEMPERATURE =25.6 DEG C OUTLET BULK TEMPERATURE =36.5 DEG C

MASS FLOW RATE = 30.3 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	32.2	32.3	25.7	971.4	6.01	0.00037	0.122E 08	36.0
2	3.5	35.0	34.7	26.0	976.9	5.97	0.00086	0.123E 08	26.4
3	5.5	36.7	36.3	26.2	982.4	5.93	0.00136	0.125E 08	22.7
4	7.5	38.1	37.6	26.5	988.0	5.90	0.00185	0.127E 08	20.5
5	10.5	39.9	39.2	26.9	996.3	5.84	0.00260	0.129E 08	18.3
6	13.5	41.1	40.0	27.2	1004.6	5.79	0.00334	0.132E 08	17.5
7	16.5	42.0	40.8	27.6	1012.8	5.73	0.00409	0.134E 08	16.9
8	19.5	42.5	40.9	28.0	1021.1	5.68	0.00484	0.137E 08	17.0
9	22.5	43.0	41.2	28.4	1029.3	5.63	0.00559	0.139E 08	16.9
10	25.5	43.8	42.2	28.8	1037.5	5.58	0.00634	0.142E 08	16.3
11	29.5	44.9	42.9	29.3	1048.3	5.51	0.00734	0.145E 08	15.9
12	33.5	45.0	43.0	29.8	1059.1	5.45	0.00835	0.149E 08	16.3
13	37.5	45.2	43.1	30.3	1070.0	5.39	0.00936	0.152E 08	16.7
14	41.5	45.3	43.2	30.8	1080.8	5.33	0.01037	0.156E 08	17.1
15	45.5	45.8	43.6	31.3	1091.8	5.27	0.01138	0.160E 08	17.2
16	49.5	46.0	43.8	31.8	1102.8	5.21	0.01240	0.163E 08	17.5
17	54.5	47.0	44.8	32.4	1116.8	5.14	0.01367	0.168E 08	17.1
18	59.5	46.7	44.1	33.0	1131.0	5.07	0.01494	0.173E 08	18.6
19	64.5	46.9	44.5	33.7	1145.4	4.99	0.01622	0.178E 08	19.1
20	69.5	48.1	45.9	34.3	1160.0	4.92	0.01751	0.183E 08	18.1
21	74.5	49.0	46.5	34.9	1174.8	4.86	0.01879	0.188E 08	17.9
22	79.5	49.3	46.7	35.5	1189.8	4.79	0.02008	0.193E 08	18.4
23	84.5	49.4	47.3	36.2	1205.1	4.72	0.02138	0.198E 08	18.8

FULLY DEVELOPED NUSSELT NUMBER =17.4

RUN NUMBER (12) TUBE NUMBER 14

INPUT POWER = 600.0 W HEAT RATE GAINED BY WATER = 592.4 W HEAT BALANCE ERROR = 1.3%

PRESSURE DROP = 5.6 MM H2O F =0.10031

REM = 1150.3 RAM = 0.271E 08 RAMF =0.172E 07 PRM = 4.97

UPSTREAM BULK TEMPERATURE =25.4 DEG C DOWNSTREAM BULK TEMPERATURE =42.3 DEG C

INLET BULK TEMPERATURE =25.6 DEG C OUTLET BULK TEMPERATURE =42.2 DEG C

MASS FLOW RATE = 30.3 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	35.3	35.4	25.9	974.5	5.99	0.00037	0.185E 08	37.2
2	3.5	39.1	38.6	26.3	982.9	5.93	0.00086	0.189E 08	27.8
3	5.5	41.6	40.8	26.6	991.2	5.87	0.00136	0.193E 08	24.2
4	7.5	43.6	42.4	27.0	999.6	5.82	0.00186	0.196E 08	22.0
5	10.5	45.6	44.3	27.6	1012.1	5.74	0.00260	0.202E 08	20.2
6	13.5	46.9	44.7	28.2	1024.5	5.66	0.00335	0.208E 08	19.9
7	16.5	48.0	45.7	28.7	1036.9	5.58	0.00410	0.214E 08	19.3
8	19.5	48.7	46.4	29.3	1049.1	5.51	0.00485	0.219E 08	19.2
9	22.5	49.3	46.6	29.9	1061.3	5.44	0.00561	0.225E 08	19.3
10	25.5	49.9	46.9	30.4	1073.7	5.37	0.00637	0.231E 08	19.4
11	29.5	51.1	47.7	31.2	1090.1	5.28	0.00738	0.240E 08	19.1
12	33.5	51.2	48.0	31.9	1106.8	5.19	0.00839	0.248E 08	19.7
13	37.5	51.6	48.4	32.7	1123.7	5.10	0.00941	0.257E 08	20.1
14	41.5	52.1	48.9	33.5	1141.0	5.02	0.01043	0.266E 08	20.4
15	45.5	52.7	49.6	34.2	1158.6	4.93	0.01146	0.275E 08	20.5
16	49.5	52.7	48.9	35.0	1176.5	4.85	0.01249	0.284E 08	21.9
17	54.5	53.7	50.3	35.9	1199.2	4.75	0.01378	0.295E 08	21.5
18	59.5	54.8	51.6	36.9	1222.5	4.65	0.01508	0.307E 08	21.1
19	64.5	55.2	51.6	37.8	1246.2	4.55	0.01638	0.319E 08	22.1
20	69.5	56.3	52.9	38.8	1270.4	4.45	0.01768	0.331E 08	21.7
21	74.5	57.4	53.5	39.7	1295.1	4.36	0.01899	0.344E 08	21.8
22	79.5	58.1	54.5	40.7	1320.2	4.27	0.02031	0.356E 08	21.9
23	84.5	58.8	55.8	41.6	1345.9	4.18	0.02162	0.369E 08	21.8

FULLY DEVELOPED NUSSELT NUMBER =20.6

RUN NUMBER (13)   TUBE NUMBER 14

INPUT POWER = 800.0 W   HEAT RATE GAINED BY WATER = 776.0 W   HEAT BALANCE ERROR = 3.0%

PRESSURE DROP = 5.8 MM H2O   F =0.10352

REM = 1216.8   RAM = 0.399E 08   RAMF =0.239E 07   PRM = 4.67

UPSTREAM BULK TEMPERATURE =25.6 DEG C   DOWNSTREAM BULK TEMPERATURE =47.7 DEG C

INLET BULK TEMPERATURE =25.8 DEG C   OUTLET BULK TEMPERATURE =47.5 DEG C

MASS FLOW RATE = 30.3 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	38.1	38.1	26.2	981.1	5.94	0.00037	0.247E 08	38.8
2	3.5	43.0	42.1	26.7	992.0	5.87	0.00086	0.253E 08	29.1
3	5.5	45.9	44.5	27.2	1003.0	5.80	0.00136	0.260E 08	25.5
4	7.5	48.2	46.2	27.7	1013.9	5.73	0.00186	0.266E 08	23.5
5	10.5	50.4	48.3	28.4	1030.1	5.62	0.00261	0.276E 08	22.0
6	13.5	51.7	48.6	29.2	1046.3	5.53	0.00336	0.286E 08	21.8
7	16.5	53.1	50.2	29.9	1062.3	5.43	0.00411	0.296E 08	21.1
8	19.5	53.8	50.5	30.7	1078.4	5.34	0.00487	0.307E 08	21.3
9	22.5	54.0	50.1	31.4	1094.6	5.25	0.00563	0.317E 08	22.1
10	25.5	55.2	51.4	32.1	1111.1	5.17	0.00639	0.329E 08	21.6
11	29.5	56.9	52.5	33.1	1133.6	5.05	0.00741	0.344E 08	21.1
12	33.5	56.8	52.4	34.1	1156.5	4.94	0.00844	0.359E 08	22.2
13	37.5	57.1	52.6	35.1	1180.0	4.83	0.00946	0.375E 08	23.0
14	41.5	57.3	53.0	36.1	1204.0	4.72	0.01050	0.391E 08	23.8
15	45.5	58.4	54.1	37.1	1228.5	4.62	0.01153	0.407E 08	23.6
16	49.5	58.5	53.7	38.1	1253.5	4.52	0.01258	0.423E 08	25.0
17	54.5	60.6	56.5	39.3	1285.5	4.39	0.01388	0.444E 08	23.4
18	59.5	61.8	57.3	40.6	1318.4	4.27	0.01520	0.466E 08	23.7
19	64.5	62.5	57.4	41.8	1352.1	4.16	0.01651	0.488E 08	24.7
20	69.5	63.8	59.1	43.1	1386.6	4.04	0.01784	0.511E 08	24.3
21	74.5	66.0	61.4	44.3	1421.9	3.93	0.01916	0.534E 08	23.0
22	79.5	66.5	62.0	45.6	1458.1	3.83	0.02049	0.557E 08	23.8
23	84.5	67.1	63.0	46.8	1495.1	3.73	0.02182	0.581E 08	24.3

FULLY DEVELOPED NUSSELT NUMBER =23.1

RUN NUMBER (14)   TUBE NUMBER 14

INPUT POWER =1000.0 W   HEAT RATE GAINED BY WATER = 959.7 W   HEAT BALANCE ERROR = 4.0%

PRESSURE DROP = 6.1 MM H2O   F =0.10839

REM = 1285.9   RAM = 0.550E 08   RAMF =0.312E 07   PRM = 4.39

UPSTREAM BULK TEMPERATURE =25.7 DEG C   DOWNSTREAM BULK TEMPERATURE =53.0 DEG C

INLET BULK TEMPERATURE =26.0 DEG C   OUTLET BULK TEMPERATURE =52.9 DEG C

MASS FLOW RATE = 30.3 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	40.9	40.7	26.4	986.4	5.91	0.00037	0.309E 08	39.7
2	3.5	46.8	45.3	27.0	999.9	5.82	0.00087	0.319E 08	30.0
3	5.5	50.1	48.0	27.7	1013.4	5.73	0.00136	0.329E 08	26.6
4	7.5	52.5	49.8	28.3	1026.9	5.64	0.00186	0.339E 08	24.8
5	10.5	54.8	51.9	29.2	1046.9	5.52	0.00261	0.354E 08	23.5
6	13.5	56.2	52.4	30.1	1066.8	5.41	0.00337	0.370E 08	23.4
7	16.5	57.8	54.2	31.0	1086.7	5.30	0.00412	0.386E 08	22.7
8	19.5	58.1	53.6	32.0	1107.0	5.19	0.00489	0.403E 08	23.7
9	22.5	58.9	54.1	32.9	1127.7	5.08	0.00565	0.420E 08	23.9
10	25.5	60.6	55.9	33.8	1148.9	4.98	0.00642	0.438E 08	23.0
11	29.5	61.7	55.6	35.0	1177.8	4.84	0.00744	0.462E 08	23.7
12	33.5	61.5	55.9	36.3	1207.5	4.71	0.00848	0.486E 08	25.0
13	37.5	61.8	56.3	37.5	1237.9	4.58	0.00951	0.511E 08	25.9
14	41.5	62.2	57.0	38.7	1269.3	4.46	0.01056	0.537E 08	26.7
15	45.5	63.4	57.8	39.9	1301.4	4.33	0.01160	0.563E 08	26.9
16	49.5	64.5	58.8	41.2	1334.3	4.22	0.01266	0.590E 08	27.1
17	54.5	67.4	62.2	42.7	1376.6	4.08	0.01398	0.624E 08	25.1
18	59.5	68.6	63.1	44.3	1420.2	3.94	0.01530	0.659E 08	25.5
19	64.5	69.4	64.1	45.8	1465.0	3.81	0.01663	0.695E 08	26.3
20	69.5	71.0	65.4	47.3	1511.1	3.68	0.01797	0.732E 08	26.3
21	74.5	73.4	67.8	48.9	1558.3	3.56	0.01930	0.770E 08	25.2
22	79.5	74.1	68.2	50.4	1601.4	3.46	0.02063	0.806E 08	26.3
23	84.5	74.7	69.5	51.9	1628.9	3.40	0.02197	0.834E 08	27.0

FULLY DEVELOPED NUSSELT NUMBER =25.3

RUN NUMBER (15) TUBE NUMBER 14

INPUT POWER =1200.0 W HEAT RATE GAINED BY WATER =1149.3 W HEAT BALANCE ERROR = 4.2%

PRESSURE DROP = 6.3 MM H2O F =0.11151

REM = 1362.9 RAM = 0.735E 08 RAMF =0.379E 07 PRM = 4.12

UPSTREAM BULK TEMPERATURE =25.9 DEG C DOWNSTREAM BULK TEMPERATURE =58.6 DEG C

INLET BULK TEMPERATURE =26.2 DEG C OUTLET BULK TEMPERATURE =58.4 DEG C

MASS FLOW RATE = 30.3 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	43.5	43.3	26.7	992.9	5.86	0.00037	0.376E 08	41.0
2	3.5	50.4	48.3	27.5	1009.1	5.76	0.00087	0.391E 08	31.2
3	5.5	54.0	51.3	28.2	1025.3	5.65	0.00137	0.405E 08	27.9
4	7.5	56.6	53.0	28.9	1041.3	5.56	0.00187	0.419E 08	26.3
5	10.5	58.9	55.5	30.0	1065.2	5.42	0.00262	0.441E 08	25.0
6	13.5	60.6	56.1	31.1	1089.0	5.28	0.00338	0.465E 08	24.9
7	16.5	62.1	57.8	32.2	1113.5	5.15	0.00414	0.490E 08	24.4
8	19.5	62.4	56.7	33.4	1138.5	5.03	0.00490	0.515E 08	25.8
9	22.5	63.9	58.3	34.5	1164.2	4.90	0.00567	0.540E 08	25.2
10	25.5	65.6	59.4	35.6	1190.5	4.78	0.00644	0.566E 08	25.0
11	29.5	66.5	59.0	37.0	1226.6	4.63	0.00748	0.602E 08	26.1
12	33.5	66.6	60.0	38.5	1263.9	4.48	0.00852	0.638E 08	27.0
13	37.5	66.8	60.3	40.0	1302.3	4.33	0.00957	0.676E 08	28.3
14	41.5	67.7	60.9	41.5	1341.9	4.19	0.01062	0.714E 08	29.1
15	45.5	69.3	63.2	42.9	1382.6	4.06	0.01167	0.754E 08	28.4
16	49.5	70.9	64.5	44.4	1424.6	3.93	0.01273	0.794E 08	28.4
17	54.5	74.2	68.6	46.2	1478.6	3.77	0.01406	0.846E 08	26.2
18	59.5	75.6	69.2	48.1	1534.3	3.62	0.01540	0.900E 08	27.0
19	64.5	76.5	70.0	49.9	1591.7	3.49	0.01673	0.955E 08	28.1
20	69.5	78.1	71.3	51.8	1625.9	3.40	0.01807	0.996E 08	28.5
21	74.5	80.7	73.8	53.6	1660.6	3.32	0.01942	0.104E 09	27.5
22	79.5	81.1	74.1	55.5	1697.5	3.24	0.02078	0.108E 09	29.3
23	84.5	82.2	76.1	57.3	1736.8	3.16	0.02214	0.112E 09	29.6

FULLY DEVELOPED NUSSELT NUMBER =27.3

RUN NUMBER (1) TUBE NUMBER 20

INPUT POWER = 50.0 W HEAT RATE GAINED BY WATER = 52.2 W HEAT BALANCE ERROR =-4.3%

PRESSURE DROP = 2.0 MM H20 F =0.35634

REM = 256.6 RAM = 0.120E 07 RAMF =0.167E 06 PRM = 4.74

UPSTREAM BULK TEMPERATURE =31.2 DEG C DOWNSTREAM BULK TEMPERATURE =40.8 DEG C

INLET BULK TEMPERATURE =31.4 DEG C OUTLET BULK TEMPERATURE =40.7 DEG C

MASS FLOW RATE = 4.7 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	32.7	32.8	31.6	234.8	5.23	0.00228	0.989E 06	27.0
2	3.5	33.6	33.5	31.8	235.8	5.21	0.00533	0.999E 06	17.7
3	5.5	34.4	34.2	32.0	236.8	5.18	0.00838	0.101E 07	13.5
4	7.5	34.8	34.6	32.2	237.8	5.16	0.01143	0.102E 07	12.6
5	10.5	35.3	35.1	32.5	239.3	5.12	0.01602	0.103E 07	11.6
6	13.5	35.7	35.5	32.9	240.8	5.08	0.02061	0.105E 07	11.4
7	16.5	36.2	35.9	33.2	242.4	5.05	0.02521	0.106E 07	10.8
8	19.5	36.5	36.2	33.5	243.9	5.01	0.02981	0.108E 07	10.7
9	22.5	36.8	36.5	33.8	245.5	4.98	0.03443	0.109E 07	10.8
10	25.5	37.3	37.0	34.1	247.1	4.94	0.03904	0.111E 07	10.3
11	29.5	38.0	37.5	34.5	249.2	4.89	0.04521	0.113E 07	9.6
12	33.5	38.3	38.0	35.0	251.3	4.85	0.05139	0.115E 07	9.7
13	37.5	38.9	38.5	35.4	253.4	4.80	0.05758	0.117E 07	9.2
14	41.5	39.3	39.0	35.8	255.6	4.76	0.06379	0.119E 07	9.2
15	45.5	39.8	39.6	36.2	257.8	4.71	0.07000	0.121E 07	8.8
16	49.5	40.2	40.0	36.7	260.0	4.67	0.07623	0.123E 07	8.8
17	54.5	41.0	40.6	37.2	262.8	4.61	0.08402	0.126E 07	8.5
18	59.5	41.6	41.3	37.7	265.6	4.56	0.09184	0.129E 07	8.1
19	64.5	42.2	41.9	38.2	268.5	4.51	0.09967	0.131E 07	8.0
20	69.5	42.9	42.6	38.8	271.4	4.45	0.10752	0.134E 07	7.7
21	74.5	43.6	43.4	39.3	274.3	4.40	0.11538	0.137E 07	7.2
22	79.5	44.2	43.9	39.8	277.2	4.35	0.12326	0.140E 07	7.2
23	84.5	44.5	44.2	40.3	280.2	4.30	0.13116	0.143E 07	7.6

FULLY DEVELOPED NUSSELT NUMBER = 9.0

RUN NUMBER (2)   TUBE NUMBER 20

INPUT POWER = 100.0 W HEAT RATE GAINED BY WATER = 103.7 W HEAT BALANCE ERROR =-3.7%

PRESSURE DROP = 2.2 MM H2O   F =0.38881

REM = 283.7   RAM = 0.291E 07   RAMF =0.391E 06   PRM = 4.24

UPSTREAM BULK TEMPERATURE =31.4 DEG C   DOWNSTREAM BULK TEMPERATURE =50.4 DEG C

INLET BULK TEMPERATURE =31.9 DEG C   OUTLET BULK TEMPERATURE =50.2 DEG C

MASS FLOW RATE = 4.7 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	35.1	35.1	32.2	237.5	5.16	0.00229	0.203E 07	20.9
2	3.5	36.6	36.5	32.6	239.5	5.11	0.00534	0.207E 07	15.7
3	5.5	37.9	37.4	33.0	241.6	5.07	0.00840	0.211E 07	13.2
4	7.5	38.6	38.2	33.4	243.6	5.02	0.01147	0.214E 07	12.4
5	10.5	39.5	38.9	34.1	246.7	4.95	0.01607	0.220E 07	11.9
6	13.5	40.2	39.7	34.7	249.9	4.88	0.02070	0.227E 07	11.7
7	16.5	41.0	40.4	35.3	253.1	4.81	0.02533	0.233E 07	11.4
8	19.5	41.6	41.0	36.0	256.4	4.74	0.02998	0.239E 07	11.5
9	22.5	42.2	41.6	36.6	259.7	4.68	0.03464	0.245E 07	11.5
10	25.5	43.1	42.3	37.2	263.0	4.61	0.03932	0.252E 07	11.1
11	29.5	44.3	43.4	38.1	267.5	4.52	0.04557	0.260E 07	10.5
12	33.5	45.1	44.4	38.9	272.1	4.44	0.05184	0.269E 07	10.4
13	37.5	46.2	45.4	39.7	276.8	4.36	0.05813	0.278E 07	10.0
14	41.5	47.0	46.3	40.6	281.6	4.27	0.06445	0.287E 07	10.0
15	45.5	48.0	47.5	41.4	286.4	4.19	0.07078	0.296E 07	9.5
16	49.5	48.9	48.3	42.3	291.4	4.12	0.07713	0.306E 07	9.5
17	54.5	50.2	49.4	43.3	297.7	4.02	0.08509	0.317E 07	9.3
18	59.5	51.6	50.9	44.4	304.1	3.93	0.09307	0.329E 07	8.8
19	64.5	52.7	52.1	45.4	310.6	3.84	0.10108	0.342E 07	8.6
20	69.5	54.0	53.2	46.5	317.2	3.75	0.10910	0.354E 07	8.4
21	74.5	55.4	54.8	47.5	324.0	3.67	0.11713	0.367E 07	7.9
22	79.5	56.5	55.8	48.6	330.9	3.59	0.12518	0.380E 07	7.9
23	84.5	57.2	56.6	49.6	337.9	3.51	0.13323	0.393E 07	8.2

FULLY DEVELOPED NUSSELT NUMBER = 9.7

RUN NUMBER (3)   TUBE NUMBER 20

INPUT POWER = 150.0 W   HEAT RATE GAINED BY WATER = 154.7 W   HEAT BALANCE ERROR =-3.1%

PRESSURE DROP = 2.5 MM H2O   F =0.43779

REM = 311.2   RAM = 0.513E 07   RAMF =0.705E 06   PRM = 3.83

UPSTREAM BULK TEMPERATURE =31.3 DEG C   DOWNSTREAM BULK TEMPERATURE =59.7 DEG C

INLET BULK TEMPERATURE =31.9 DEG C   OUTLET BULK TEMPERATURE =59.4 DEG C

MASS FLOW RATE = 4.7 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	37.0	36.9	32.4	238.5	5.14	0.00229	0.306E 07	20.2
2	3.5	39.1	38.8	33.0	241.6	5.07	0.00535	0.315E 07	15.5
3	5.5	40.8	40.1	33.6	244.6	5.00	0.00841	0.324E 07	13.6
4	7.5	41.8	41.1	34.3	247.8	4.93	0.01149	0.333E 07	12.8
5	10.5	43.1	42.1	35.2	252.5	4.82	0.01612	0.346E 07	12.4
6	13.5	44.1	43.2	36.2	257.4	4.72	0.02077	0.360E 07	12.2
7	16.5	45.2	44.2	37.1	262.4	4.62	0.02543	0.375E 07	12.1
8	19.5	46.1	45.1	38.0	267.4	4.53	0.03012	0.389E 07	12.0
9	22.5	47.1	46.0	39.0	272.6	4.43	0.03482	0.404E 07	12.0
10	25.5	48.5	47.2	39.9	277.9	4.34	0.03955	0.419E 07	11.4
11	29.5	50.2	48.9	41.2	285.1	4.22	0.04587	0.439E 07	10.8
12	33.5	51.5	50.4	42.4	292.4	4.10	0.05222	0.460E 07	10.6
13	37.5	53.1	51.9	43.7	300.0	3.99	0.05859	0.481E 07	10.3
14	41.5	54.2	53.2	44.9	307.7	3.88	0.06498	0.503E 07	10.3
15	45.5	55.8	54.9	46.2	315.6	3.77	0.07139	0.525E 07	9.8
16	49.5	57.1	56.2	47.5	323.7	3.67	0.07782	0.548E 07	9.7
17	54.5	59.1	57.9	49.0	334.0	3.55	0.08587	0.576E 07	9.4
18	59.5	61.2	60.1	50.6	342.9	3.45	0.09391	0.603E 07	8.9
19	64.5	62.8	61.8	52.2	348.9	3.39	0.10203	0.624E 07	8.8
20	69.5	64.8	63.6	53.7	355.3	3.32	0.11018	0.646E 07	8.5
21	74.5	66.9	65.9	55.3	362.0	3.25	0.11838	0.669E 07	7.9
22	79.5	68.6	67.6	56.9	369.1	3.18	0.12661	0.692E 07	7.9
23	84.5	69.9	68.9	58.5	376.6	3.11	0.13487	0.716E 07	8.0

FULLY DEVELOPED NUSSELT NUMBER = 9.9

RUN NUMBER (4)   TUBE NUMBER 20

INPUT POWER = 100.0 W   HEAT RATE GAINED BY WATER = 95.5 W   HEAT BALANCE ERROR = 4.5%

PRESSURE DROP = 4.9 MM H2O   F =0.13860

REM = 629.3   RAM = 0.213E 07   RAMF =0.253E 06   PRM = 4.84

UPSTREAM BULK TEMPERATURE =31.6 DEG C   DOWNSTREAM BULK TEMPERATURE =38.6 DEG C

INLET BULK TEMPERATURE =31.7 DEG C   OUTLET BULK TEMPERATURE =38.5 DEG C

MASS FLOW RATE = 11.8 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	34.0	34.0	31.8	589.1	5.21	0.00091	0.184E 07	26.3
2	3.5	35.1	35.2	31.9	591.0	5.19	0.00213	0.186E 07	18.0
3	5.5	36.3	36.0	32.1	592.8	5.17	0.00335	0.187E 07	14.1
4	7.5	36.9	36.8	32.3	594.7	5.15	0.00457	0.188E 07	12.4
5	10.5	37.8	37.5	32.5	597.5	5.13	0.00641	0.190E 07	11.1
6	13.5	38.5	38.1	32.7	600.3	5.10	0.00824	0.192E 07	10.2
7	16.5	38.9	38.6	33.0	603.1	5.07	0.01008	0.194E 07	9.9
8	19.5	39.2	38.9	33.2	605.9	5.05	0.01192	0.196E 07	9.7
9	22.5	39.5	39.1	33.4	608.8	5.02	0.01376	0.199E 07	9.6
10	25.5	39.9	39.4	33.7	611.7	4.99	0.01560	0.201E 07	9.5
11	29.5	40.5	39.8	34.0	615.5	4.96	0.01806	0.203E 07	9.2
12	33.5	40.7	40.2	34.3	619.4	4.92	0.02053	0.206E 07	9.2
13	37.5	41.1	40.4	34.6	623.3	4.89	0.02299	0.209E 07	9.1
14	41.5	41.2	40.6	34.9	627.3	4.86	0.02547	0.212E 07	9.5
15	45.5	41.5	41.1	35.2	631.2	4.82	0.02794	0.215E 07	9.3
16	49.5	41.7	41.2	35.5	635.2	4.79	0.03042	0.217E 07	9.6
17	54.5	42.1	41.3	35.9	640.2	4.75	0.03352	0.221E 07	9.7
18	59.5	42.6	42.0	36.3	645.3	4.71	0.03663	0.225E 07	9.4
19	64.5	42.8	42.2	36.7	650.4	4.66	0.03974	0.228E 07	9.7
20	69.5	43.2	42.6	37.1	655.6	4.62	0.04286	0.232E 07	9.7
21	74.5	44.0	43.2	37.5	660.8	4.58	0.04598	0.235E 07	9.2
22	79.5	44.2	43.5	37.9	666.0	4.54	0.04911	0.239E 07	9.4
23	84.5	44.4	43.9	38.2	671.3	4.50	0.05224	0.243E 07	9.5

FULLY DEVELOPED NUSSELT NUMBER = 9.5

RUN NUMBER (5)   TUBE NUMBER 20

INPUT POWER = 150.0 W HEAT RATE GAINED BY WATER = 144.8 W HEAT BALANCE ERROR = 3.5%

PRESSURE DROP = 4.8 MM H2O   F =0.13568

REM = 656.4   RAM = 0.353E 07   RAMF =0.377E 06   PRM = 4.62

UPSTREAM BULK TEMPERATURE =31.8 DEG C   DOWNSTREAM BULK TEMPERATURE =42.4 DEG C

INLET BULK TEMPERATURE =32.0 DEG C   OUTLET BULK TEMPERATURE =42.3 DEG C

MASS FLOW RATE = 11.8 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	35.5	35.5	32.2	593.8	5.16	0.00091	0.285E 07	25.7
2	3.5	37.2	37.2	32.4	596.6	5.13	0.00214	0.288E 07	18.2
3	5.5	38.8	38.5	32.7	599.5	5.11	0.00336	0.291E 07	14.4
4	7.5	39.8	39.5	32.9	602.3	5.08	0.00458	0.294E 07	12.8
5	10.5	40.9	40.3	33.2	606.6	5.04	0.00642	0.299E 07	11.7
6	13.5	41.6	41.1	33.6	611.0	5.00	0.00826	0.304E 07	11.1
7	16.5	42.2	41.6	34.0	615.4	4.96	0.01010	0.308E 07	10.8
8	19.5	42.6	42.0	34.3	619.8	4.92	0.01195	0.313E 07	10.8
9	22.5	43.1	42.4	34.7	624.2	4.88	0.01380	0.318E 07	10.7
10	25.5	43.6	42.7	35.0	628.7	4.84	0.01565	0.323E 07	10.6
11	29.5	44.3	43.3	35.5	634.8	4.79	0.01813	0.329E 07	10.4
12	33.5	44.7	43.8	36.0	640.9	4.74	0.02061	0.336E 07	10.4
13	37.5	45.3	44.2	36.4	647.0	4.69	0.02309	0.343E 07	10.4
14	41.5	45.4	44.4	36.9	653.3	4.64	0.02558	0.349E 07	10.8
15	45.5	45.9	45.1	37.4	659.6	4.59	0.02808	0.356E 07	10.6
16	49.5	46.1	45.3	37.8	665.9	4.54	0.03058	0.363E 07	10.9
17	54.5	46.7	45.6	38.4	674.0	4.48	0.03371	0.371E 07	11.1
18	59.5	47.4	46.4	39.0	682.1	4.43	0.03685	0.380E 07	10.8
19	64.5	47.9	46.8	39.6	690.3	4.37	0.03999	0.389E 07	11.1
20	69.5	48.5	47.3	40.2	698.7	4.31	0.04315	0.398E 07	11.1
21	74.5	49.3	48.4	40.8	707.1	4.25	0.04631	0.407E 07	10.6
22	79.5	49.9	48.8	41.4	715.7	4.20	0.04947	0.416E 07	10.7
23	84.5	50.3	49.3	42.0	724.3	4.14	0.05264	0.425E 07	10.9

FULLY DEVELOPED NUSSELT NUMBER =10.7

RUN NUMBER (6) TUBE NUMBER 20

INPUT POWER = 200.0 W HEAT RATE GAINED BY WATER = 198.6 W HEAT BALANCE ERROR = 0.7%

PRESSURE DROP = 4.7 MM H20 F =0.13274

REM = 687.1 RAM = 0.530E 07 RAMF =0.514E 06 PRM = 4.39

UPSTREAM BULK TEMPERATURE =32.1 DEG C DOWNSTREAM BULK TEMPERATURE =46.7 DEG C

INLET BULK TEMPERATURE =32.3 DEG C OUTLET BULK TEMPERATURE =46.5 DEG C

MASS FLOW RATE = 11.8 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	37.0	37.0	32.6	598.5	5.12	0.00092	0.399E 07	26.7
2	3.5	39.3	39.3	32.9	602.4	5.08	0.00214	0.405E 07	18.6
3	5.5	41.5	40.9	33.2	606.4	5.04	0.00336	0.410E 07	14.9
4	7.5	42.6	42.2	33.5	610.4	5.01	0.00459	0.416E 07	13.4
5	10.5	43.9	43.1	34.0	616.4	4.95	0.00643	0.425E 07	12.5
6	13.5	44.7	44.0	34.5	622.5	4.90	0.00828	0.434E 07	12.0
7	16.5	45.4	44.5	35.0	628.6	4.84	0.01013	0.444E 07	11.8
8	19.5	46.0	45.0	35.5	634.9	4.79	0.01198	0.453E 07	11.8
9	22.5	46.5	45.5	36.0	641.2	4.74	0.01384	0.462E 07	11.8
10	25.5	47.2	45.8	36.5	647.5	4.69	0.01570	0.472E 07	11.7
11	29.5	48.1	46.6	37.1	656.1	4.62	0.01819	0.484E 07	11.5
12	33.5	48.5	47.2	37.8	664.8	4.55	0.02069	0.497E 07	11.7
13	37.5	49.2	47.6	38.4	673.6	4.49	0.02319	0.510E 07	11.7
14	41.5	49.4	48.0	39.1	682.6	4.42	0.02570	0.523E 07	12.2
15	45.5	50.2	48.9	39.7	691.7	4.36	0.02822	0.537E 07	11.9
16	49.5	50.5	49.2	40.4	700.9	4.29	0.03074	0.550E 07	12.4
17	54.5	51.3	49.7	41.2	712.5	4.22	0.03390	0.567E 07	12.5
18	59.5	52.2	50.9	42.0	724.4	4.14	0.03707	0.584E 07	12.2
19	64.5	52.8	51.4	42.8	736.4	4.07	0.04025	0.602E 07	12.5
20	69.5	53.6	52.2	43.6	748.6	4.00	0.04343	0.620E 07	12.5
21	74.5	54.9	53.5	44.4	761.1	3.92	0.04663	0.638E 07	11.9
22	79.5	55.6	54.1	45.2	773.7	3.85	0.04983	0.656E 07	12.1
23	84.5	56.2	54.8	46.0	786.4	3.79	0.05303	0.675E 07	12.2

FULLY DEVELOPED NUSSELT NUMBER =12.0

RUN NUMBER (7)   TUBE NUMBER 20

INPUT POWER = 250.0 W   HEAT RATE GAINED BY WATER = 247.1 W   HEAT BALANCE ERROR = 1.1%

PRESSURE DROP = 4.8 MM H20   F =0.13523

REM = 715.6   RAM = 0.712E 07   RAMF =0.641E 06   PRM = 4.20

UPSTREAM BULK TEMPERATURE =32.3 DEG C   DOWNSTREAM BULK TEMPERATURE =50.4 DEG C

INLET BULK TEMPERATURE =32.6 DEG C   OUTLET BULK TEMPERATURE =50.3 DEG C

MASS FLOW RATE = 11.8 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	38.4	38.4	32.9	602.5	5.08	0.00092	0.504E 07	26.9
2	3.5	41.1	41.0	33.3	607.4	5.03	0.00214	0.513E 07	19.1
3	5.5	43.6	42.9	33.7	612.4	4.99	0.00337	0.522E 07	15.5
4	7.5	45.0	44.4	34.1	617.4	4.94	0.00459	0.532E 07	14.0
5	10.5	46.3	45.3	34.7	625.1	4.88	0.00644	0.546E 07	13.3
6	13.5	47.3	46.3	35.3	632.8	4.81	0.00829	0.560E 07	12.8
7	16.5	48.1	46.9	35.9	640.6	4.74	0.01015	0.574E 07	12.7
8	19.5	48.8	47.5	36.5	648.5	4.68	0.01201	0.589E 07	12.7
9	22.5	49.3	48.0	37.2	656.5	4.62	0.01388	0.604E 07	12.7
10	25.5	50.1	48.4	37.8	664.7	4.55	0.01575	0.619E 07	12.7
11	29.5	51.1	49.3	38.6	675.7	4.47	0.01825	0.639E 07	12.6
12	33.5	51.6	49.9	39.4	686.9	4.39	0.02076	0.659E 07	12.8
13	37.5	52.5	50.5	40.2	698.3	4.31	0.02328	0.680E 07	12.9
14	41.5	52.7	50.9	41.0	709.8	4.23	0.02580	0.701E 07	13.5
15	45.5	53.6	52.2	41.8	721.6	4.16	0.02834	0.723E 07	13.1
16	49.5	54.1	52.5	42.6	733.6	4.08	0.03088	0.744E 07	13.6
17	54.5	55.2	53.2	43.6	748.8	3.99	0.03406	0.772E 07	13.7
18	59.5	56.4	54.6	44.6	764.3	3.91	0.03725	0.800E 07	13.3
19	64.5	57.1	55.4	45.6	780.0	3.82	0.04045	0.828E 07	13.7
20	69.5	58.1	56.3	46.7	796.1	3.74	0.04366	0.857E 07	13.6
21	74.5	59.5	57.9	47.7	812.4	3.66	0.04687	0.887E 07	13.0
22	79.5	60.4	58.6	48.7	829.0	3.58	0.05009	0.917E 07	13.2
23	84.5	61.3	59.6	49.7	845.9	3.50	0.05330	0.947E 07	13.3

FULLY DEVELOPED NUSSELT NUMBER =13.1

RUN NUMBER (8)   TUBE NUMBER 20

INPUT POWER = 300.0 W   HEAT RATE GAINED BY WATER = 295.7 W   HEAT BALANCE ERROR = 1.4%

PRESSURE DROP = 4.9 MM H2O   F =0.13771

REM = 743.6   RAM = 0.913E 07   RAMF =0.790E 06   PRM = 4.02

UPSTREAM BULK TEMPERATURE =32.4 DEG C   DOWNSTREAM BULK TEMPERATURE =54.1 DEG C

INLET BULK TEMPERATURE =32.8 DEG C   OUTLET BULK TEMPERATURE =53.9 DEG C

MASS FLOW RATE = 11.8 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	39.8	39.8	33.1	605.2	5.05	0.00092	0.609E 07	26.6
2	3.5	43.0	42.8	33.6	611.1	5.00	0.00214	0.622E 07	19.0
3	5.5	45.9	44.9	34.1	617.1	4.95	0.00337	0.636E 07	15.6
4	7.5	47.2	46.4	34.6	623.1	4.89	0.00460	0.649E 07	14.4
5	10.5	48.8	47.4	35.3	632.4	4.81	0.00645	0.669E 07	13.7
6	13.5	49.8	48.5	36.0	641.7	4.73	0.00831	0.690E 07	13.4
7	16.5	50.7	49.3	36.8	651.3	4.66	0.01017	0.711E 07	13.3
8	19.5	51.5	49.9	37.5	660.9	4.58	0.01204	0.732E 07	13.3
9	22.5	52.1	50.4	38.2	670.7	4.51	0.01391	0.754E 07	13.4
10	25.5	53.0	50.8	38.9	680.7	4.44	0.01579	0.776E 07	13.5
11	29.5	54.0	51.8	39.9	694.2	4.34	0.01830	0.805E 07	13.4
12	33.5	54.6	52.5	40.9	708.0	4.25	0.02082	0.836E 07	13.8
13	37.5	55.6	53.2	41.8	722.1	4.16	0.02336	0.866E 07	13.8
14	41.5	55.9	53.7	42.8	736.4	4.07	0.02590	0.897E 07	14.5
15	45.5	57.1	55.3	43.8	751.0	3.98	0.02844	0.929E 07	14.0
16	49.5	57.7	55.7	44.7	765.9	3.90	0.03100	0.961E 07	14.5
17	54.5	59.0	56.7	46.0	784.9	3.80	0.03420	0.100E 08	14.5
18	59.5	60.5	58.3	47.2	804.2	3.70	0.03741	0.104E 08	14.1
19	64.5	61.3	59.2	48.4	824.0	3.60	0.04062	0.109E 08	14.5
20	69.5	62.6	60.4	49.6	844.1	3.51	0.04384	0.113E 08	14.4
21	74.5	64.3	62.3	50.8	858.8	3.45	0.04705	0.117E 08	13.7
22	79.5	65.4	63.2	52.0	870.5	3.39	0.05030	0.120E 08	13.9
23	84.5	66.4	64.3	53.2	882.6	3.34	0.05355	0.123E 08	14.0

FULLY DEVELOPED NUSSELT NUMBER =13.9

RUN NUMBER (9) TUBE NUMBER 20

INPUT POWER = 350.0 W HEAT RATE GAINED BY WATER = 338.9 W HEAT BALANCE ERROR = 3.2%

PRESSURE DROP = 4.9 MM H2O F =0.13751

REM = 769.5 RAM = 0.111E 08 RAMF =0.906E 06 PRM = 3.88

UPSTREAM BULK TEMPERATURE =32.6 DEG C DOWNSTREAM BULK TEMPERATURE =57.4 DEG C

INLET BULK TEMPERATURE =32.9 DEG C OUTLET BULK TEMPERATURE =57.2 DEG C

MASS FLOW RATE = 11.8 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	41.1	41.0	33.3	607.7	5.03	0.00092	0.705E 07	26.3
2	3.5	44.8	44.5	33.9	614.6	4.97	0.00214	0.723E 07	18.8
3	5.5	48.0	46.9	34.4	621.5	4.91	0.00337	0.740E 07	15.6
4	7.5	49.5	48.5	35.0	628.5	4.85	0.00460	0.758E 07	14.5
5	10.5	51.1	49.5	35.8	639.2	4.76	0.00646	0.785E 07	14.0
6	13.5	52.2	50.6	36.7	650.1	4.67	0.00832	0.813E 07	13.6
7	16.5	53.2	51.4	37.5	661.2	4.58	0.01018	0.841E 07	13.6
8	19.5	53.9	52.0	38.3	672.4	4.50	0.01206	0.869E 07	13.7
9	22.5	54.7	52.6	39.2	683.9	4.41	0.01394	0.898E 07	13.9
10	25.5	55.5	53.0	40.0	695.6	4.33	0.01582	0.927E 07	14.0
11	29.5	56.8	54.1	41.1	711.5	4.22	0.01835	0.967E 07	13.9
12	33.5	57.4	54.9	42.2	727.7	4.12	0.02088	0.101E 08	14.3
13	37.5	58.6	55.7	43.3	744.3	4.02	0.02342	0.105E 08	14.4
14	41.5	58.9	56.4	44.4	761.2	3.92	0.02597	0.109E 08	15.1
15	45.5	60.2	58.2	45.5	778.5	3.83	0.02853	0.113E 08	14.5
16	49.5	60.9	58.6	46.7	796.1	3.74	0.03110	0.118E 08	15.1
17	54.5	62.4	59.7	48.0	818.6	3.63	0.03431	0.123E 08	15.2
18	59.5	64.1	61.6	49.4	841.6	3.52	0.03752	0.129E 08	14.7
19	64.5	65.1	62.7	50.8	859.1	3.44	0.04074	0.134E 08	15.1
20	69.5	66.6	64.0	52.2	872.5	3.39	0.04398	0.138E 08	15.0
21	74.5	68.3	65.9	53.6	886.6	3.32	0.04724	0.142E 08	14.5
22	79.5	69.0	66.1	55.0	901.3	3.26	0.05051	0.147E 08	15.6
23	84.5	69.5	66.7	56.4	916.7	3.20	0.05380	0.151E 08	16.6

FULLY DEVELOPED NUSSELT NUMBER =14.7

RUN NUMBER (10)   TUBE NUMBER 20

INPUT POWER = 400.0 W   HEAT RATE GAINED BY WATER = 392.0 W   HEAT BALANCE ERROR = 2.0%

PRESSURE DROP = 5.0 MM H2O   F =0.13994

REM = 802.1   RAM = 0.138E 08   RAMF =0.971E 06   PRM = 3.71

UPSTREAM BULK TEMPERATURE =32.7 DEG C   DOWNSTREAM BULK TEMPERATURE =61.4 DEG C

INLET BULK TEMPERATURE =33.1 DEG C   OUTLET BULK TEMPERATURE =61.2 DEG C

MASS FLOW RATE = 11.8 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	42.3	42.2	33.6	610.5	5.00	0.00092	0.826E 07	27.1
2	3.5	46.5	46.1	34.2	618.5	4.93	0.00214	0.849E 07	19.4
3	5.5	49.9	48.6	34.8	626.6	4.86	0.00337	0.873E 07	16.3
4	7.5	51.6	50.3	35.5	634.8	4.79	0.00461	0.897E 07	15.1
5	10.5	53.3	51.4	36.5	647.4	4.69	0.00647	0.934E 07	14.7
6	13.5	54.5	52.6	37.4	660.2	4.59	0.00833	0.972E 07	14.5
7	16.5	55.5	53.4	38.4	673.2	4.49	0.01020	0.101E 08	14.5
8	19.5	56.4	54.1	39.4	686.6	4.39	0.01208	0.105E 08	14.6
9	22.5	57.2	54.7	40.3	700.2	4.30	0.01397	0.109E 08	14.9
10	25.5	58.2	55.3	41.3	714.1	4.21	0.01586	0.113E 08	15.0
11	29.5	59.6	56.5	42.6	733.0	4.09	0.01840	0.118E 08	15.0
12	33.5	60.4	57.4	43.9	752.4	3.97	0.02094	0.124E 08	15.3
13	37.5	61.8	58.5	45.1	772.2	3.86	0.02350	0.130E 08	15.4
14	41.5	62.2	59.2	46.4	792.5	3.76	0.02606	0.135E 08	16.1
15	45.5	63.8	61.4	47.7	813.3	3.65	0.02863	0.141E 08	15.4
16	49.5	64.6	61.9	49.0	834.5	3.55	0.03120	0.147E 08	16.1
17	54.5	66.4	63.2	50.6	857.1	3.45	0.03441	0.154E 08	16.1
18	59.5	68.3	65.3	52.2	872.7	3.38	0.03766	0.160E 08	15.6
19	64.5	69.3	66.4	53.8	889.0	3.31	0.04091	0.166E 08	16.2
20	69.5	70.1	67.0	55.4	906.3	3.24	0.04419	0.172E 08	17.2
21	74.5	71.2	68.2	57.1	924.5	3.17	0.04748	0.178E 08	17.8
22	79.5	71.6	68.5	58.7	943.8	3.10	0.05078	0.184E 08	19.7
23	84.5	73.1	70.0	60.3	964.3	3.03	0.05410	0.190E 08	19.9

FULLY DEVELOPED NUSSELT NUMBER =16.1

RUN NUMBER (11) TUBE NUMBER 20

INPUT POWER = 200.0 W HEAT RATE GAINED BY WATER = 194.7 W HEAT BALANCE ERROR = 2.7%

PRESSURE DROP = 7.1 MM H20 F =0.07914

REM = 1009.9 RAM = 0.437E 07 RAMF =0.444E 06 PRM = 4.84

UPSTREAM BULK TEMPERATURE =30.6 DEG C DOWNSTREAM BULK TEMPERATURE =39.5 DEG C

INLET BULK TEMPERATURE =30.7 DEG C OUTLET BULK TEMPERATURE =39.4 DEG C

MASS FLOW RATE = 18.9 KG/HR

STATION NO.	X CM	TW(TOP) DEG C	TW(BOTTOM) DEG C	TB DEG C	RE	PR	X+	RA	NU (AVERAGE)
1	1.5	34.5	34.5	30.9	928.3	5.32	0.00057	0.362E 07	32.1
2	3.5	36.3	36.3	31.1	932.0	5.29	0.00133	0.366E 07	22.5
3	5.5	38.0	37.7	31.3	935.7	5.27	0.00209	0.369E 07	17.7
4	7.5	39.1	38.9	31.5	939.5	5.24	0.00285	0.373E 07	15.5
5	10.5	40.5	40.1	31.8	945.1	5.21	0.00399	0.378E 07	13.7
6	13.5	41.5	41.1	32.1	950.8	5.18	0.00513	0.383E 07	12.6
7	16.5	42.3	41.7	32.4	956.5	5.14	0.00627	0.388E 07	12.1
8	19.5	42.8	42.1	32.7	962.3	5.11	0.00742	0.394E 07	11.9
9	22.5	43.3	42.5	33.0	968.1	5.07	0.00856	0.399E 07	11.7
10	25.5	43.8	42.8	33.3	973.9	5.04	0.00971	0.404E 07	11.6
11	29.5	44.3	43.3	33.7	981.7	4.99	0.01125	0.411E 07	11.5
12	33.5	44.8	43.8	34.1	989.6	4.95	0.01278	0.419E 07	11.3
13	37.5	45.4	44.2	34.5	997.6	4.91	0.01432	0.426E 07	11.2
14	41.5	45.5	44.4	34.9	1005.7	4.86	0.01587	0.433E 07	11.5
15	45.5	46.0	45.1	35.2	1013.8	4.82	0.01741	0.441E 07	11.3
16	49.5	46.1	45.1	35.6	1022.0	4.78	0.01896	0.448E 07	11.6
17	54.5	46.6	45.3	36.1	1032.4	4.72	0.02090	0.457E 07	11.8
18	59.5	47.2	46.0	36.6	1042.8	4.67	0.02284	0.467E 07	11.6
19	64.5	47.4	46.1	37.1	1053.4	4.62	0.02479	0.476E 07	12.0
20	69.5	47.7	46.4	37.6	1064.1	4.57	0.02674	0.486E 07	12.3
21	74.5	48.5	47.3	38.1	1074.9	4.52	0.02869	0.496E 07	11.9
22	79.5	48.6	47.2	38.6	1085.8	4.47	0.03065	0.506E 07	12.4
23	84.5	49.0	47.8	39.1	1096.8	4.42	0.03261	0.516E 07	12.5

FULLY DEVELOPED NUSSELT NUMBER =11.8