DEPARTMENT OF CHEMICAL AND METALLURGICAL ENGINEERING
Heat Transfer Laboratory

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THE BOND RESISTANCE OF TYPE L/C BIMETAL TUBES WITH STEEL LINERS

Report No. 56

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ABSTRACT

Bond resistance measurements are presented for three 2-inch diameter Type L/C bimetallic finned tubes with steel liners for temperatures of the hot oil inside the tube from 250 °F to 500 °F and temperatures for the cooling oil outside the tube from 150 °F to 400 °F in a concentric pipe heat exchanger. Initial contact pressures were calculated using the bond resistance model of Gardner and Carnavos. Based on the results, a procedure is recommended for the design of air coolers containing bimetallic tubes.

OBJECTIVE

The purpose of this investigation was to accurately determine experimentally the bond resistance of 2-inch diameter Type L/C duplex finned tubing containing steel liners with tube-side inlet fluid temperatures up to 600 °F. The bond resistance data were to be used to determine if the Gardner and Carnavos proposed model for bond resistance could be used to predict the bond resistance of Type L/C finned tubing. The investigation was also to include a recommended procedure for the design of heat exchangers containing Type L/C finned tubing.

INTRODUCTION

The enormous growth of air cooling in the chemical and petroleum processing industries during the past decade has stimulated an interest in the bond resistance of bimetallic and duplex finned tubing. Bimetallic and duplex tubing consist of a liner or base tube made from a corrosion-resistant material such as admiralty brass, cupro-nickel, steel or stainless steel and an outer finned tube usually made of aluminum. A section of a 2-inch fin diameter bimetallic integrally finned tube with a 1-inch diameter admiralty brass liner is shown in Figure 1. The fins are made of aluminum.

At low temperatures the residual compressive stresses between the liner and the outer aluminum finned tube caused by the finning process maintains a good contact between the two tubes. There may be a bond or contact resistance of the order of 0.00002 to 0.0002 Btu/hr.-sq.ft.(liner area)- °F up to temperatures of approximately 250 °F which results from slight imperfections in the contact between the surfaces due to roughness or from oxides or oils present at the interface. Differences in the thermal expansion coefficients between the liner and fin material at elevated temperatures may reduce the residual compressive stresses at the interface. At temperatures above 250 °F, the residual stresses become relieved and with increasing temperatures an air gap may form between the liner and the finned tube. The resistance to heat transfer caused by the air gap is called the bond resistance. The bond resistance is a function of the temperature and thermal expansion coefficients of the liner and finned tubes and the residual compressive stress at the tube fabrication temperature. At high temperatures the bond resistance can become a significant fraction of the overall resistance to heat transfer.

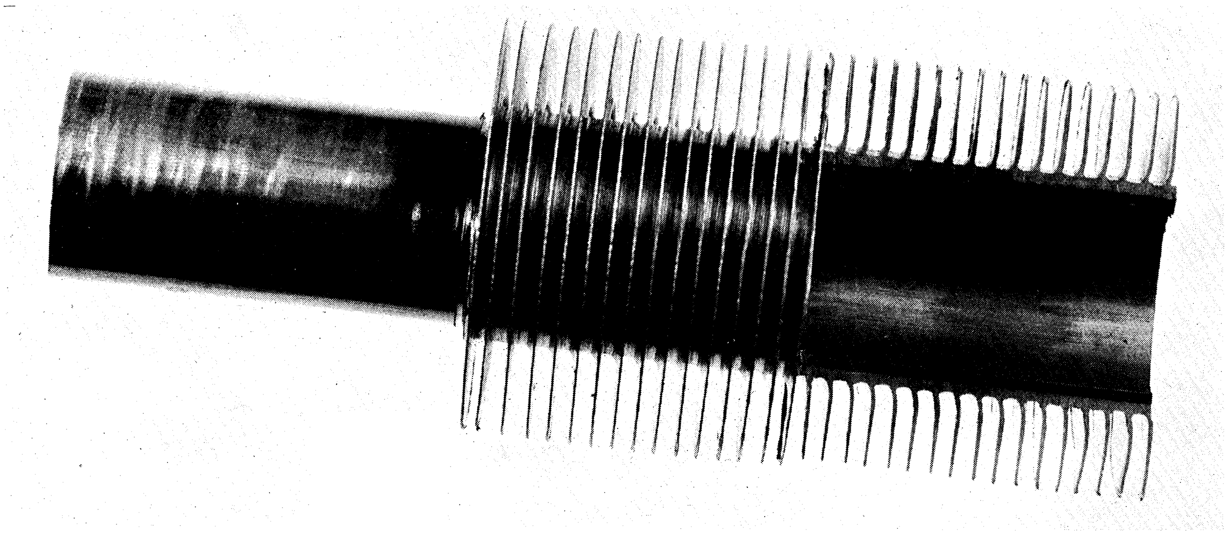

Figure 1. Section of a Stripped-end 2-Inch O.D. Bimetallic Finned Tube with a 1-Inch Admiralty Liner

REVIEW OF THE LITERATURE

The resistance to heat transfer resulting from imperfect contact of adjacent metal surfaces has been under active investigation since about 1948[1-12]. The areas of concern have varied from the influence of temperature on the rating of electrical equipment with laminated metal components[2] to the thermal contact resistance of fuel elements for a nuclear reactor[9]. In 1957, an apparatus was developed for the measurements of contact resistances (low temperature bond resistances) of bare and finned duplex tubing at liner temperatures of approximately 160 °F[10]. In 1958, an investigation was completed in which the effects of thermal cycling to 350 ° and 600 °F on the heat transfer performance of duplex integral-finned tubes was determined[11]. Bond resistance measurements were made in the apparatus described in reference (10). A theoretical and experimental investigation of the bond resistance of tension-wound, muff and embedded types of finned tubes was completed by Gardner and Carnavos[12] in 1960. The tension-wound finned tube investigated was a typical applied fin tube without a fin foot. The muff type of finned tube was an integrally finned tube over a plain tube liner.

Gardner and Carnavos derived expressions for the gap thicknesses between the fin and liner of tension-wound and muff type finned tubes based on the thermal expansion of an elastically deformed annular disk. The gap thickness was given as*

$$g = \frac{d}{2}\left\{\left[(\alpha_f - \alpha_t)(T_h - T_o) + \mu (p_c - p_{co})\right] - \left[\alpha_f\left[1 - \frac{r_o}{R^* + r_g}\right] - \alpha_t\left[\frac{r_i}{R^* + r_g}\right]\right](T_h - T_a)\right\} \quad (1)$$

where

$$\mu = \left\{\frac{1}{E_f}\left[\frac{(D^2 + d^2)}{(D^2 - d^2)} + \nu_f\right] + \frac{1}{E_t}\,\frac{t_f}{P}\left[\frac{d^2 + (d - 2t)^2}{d^2 - (d - 2t)^2} - \nu_t\right]\right\} \quad (2)$$

* See pages 50-53 for Nomenclature

For tension-wound finned tubes where

$$r_g = \frac{g\,(D^2 - d^2)}{24\,k_e\,d\,b} \tag{3}$$

they expressed the bond resistance based on the outside area as

$$r_g = \frac{D^2 - d^2}{48\,b\,k_e} \left\{ (\alpha_f - \alpha_t)(T_h - T_o) - \mu\,p_{co} - \left[\alpha_f \left[1 - \frac{r_o}{R^* + r_g} \right] - \alpha_t \left[\frac{r_i}{R^* + r_g} \right] \right] (T_h - T_a) \right\} \tag{4}$$

As can be seen in Equation (4), the bond resistance is dependent upon the residual contact pressure caused by the finning process. The maximum possible contact pressure is of the order of 2/3 of the yield stress of the fin material. When aluminum fins are subjected to temperatures above 400 °F for any length of time, the fins become fully annealed resulting in a yield stress of approximately 5000 lb./sq.in. Based on this criterion, the contact pressure is of the order of 3500 lbs./sq.in. for annealed finned tubes. Gardner and Carnavos experimentally determined initial contact pressures from their bond resistance measurements. The initial contact pressure varied from 3500 to 7100 lbs./sq.in. There experimental apparatus consisted of a centrifugal blower which forced atmospheric air across the outside of the test section within which high pressure steam was condensed. Steam temperatures up to 380 °F were used.

HEAT TRANSFER EQUIPMENT

The experimental equipment used in this investigation is shown in Figure 2. The system consisted of a test shell, a 48 KW resistance heater, shell-side and tube-side circulating pumps, expansion tanks, concentric pipe oil coolers and automatic controllers. Figure 3 presents a line diagram showing the flow of the shell-side and tube-side fluids. Mobiltherm Light was used on the shell-side and Mobiltherm 600 was used on the tube-side. Both fluids are aromatic heat transfer oils which are resistant to thermal cracking up to temperatures of 500 °F and 600 °F, respectively. The physical properties[(13)] of the oils are given in Figures 23-25, Appendix A. All the piping used in the system was standard schedule 2-inch diameter steel pipe insulated to prevent heat loss.

The test section shell was constructed of a 5-foot length of 3-inch diameter standard schedule steel pipe. The entrance and exit sections of the test shell were formed from 3-inch lengths of 6-inch diameter standard schedule steel pipe with 1/4-inch thick annular rings welded to one end. The inner diameter of the annular ring was 1/16-inch larger than the test shell. The annular rings were slipped over the ends of the shell and welded to the shell such that the outer edge of the 6-inch pipe extended out beyond the end of the shell 1-inch as shown in Figure 4. Standard 400 pound 5-inch blind flanges with 2 3/4-inch diameter holes drilled through the center were welded to the outer edges of the 6-inch diameter pipe sections.

A concentric pipe heat exchanger was formed by placing one of the tubes under investigation into the test shell and holding the tube in place by specially constructed split flanges which were bolted to the shell flanges. The flange assemblies were designed to keep the tube centered in the shell and to provide a leak-proof seal. Detailed drawings of the flanges are given in Figure 5. To provide a good surface on which to seat the gasket material in the flange, the fins were removed from the tubes investigated over a length of approximately 6 inches where the flanges were located over the tube. After the fins were removed, the section was filed until smooth. This provided a plain aluminum tube approximately 0.040 inch thick upon which the gasket could be seated.

A 48 KW resistance heater fabricated by the Hynes Electric Heating Division, Turbine Equipment Company was used as the heat source for heating the oil used in the investigation. The unit shown in Figure 6 was operated with 440 volt, 3 phase, 60 cycle, electrical power. There were four resistance heating elements which could be operated independently. The heating elements were located in 3-inch diameter steel pipes which were heated by radiation from the hot heating elements. Oil in forced convection was heated by passing over the outside of the radiantly heated

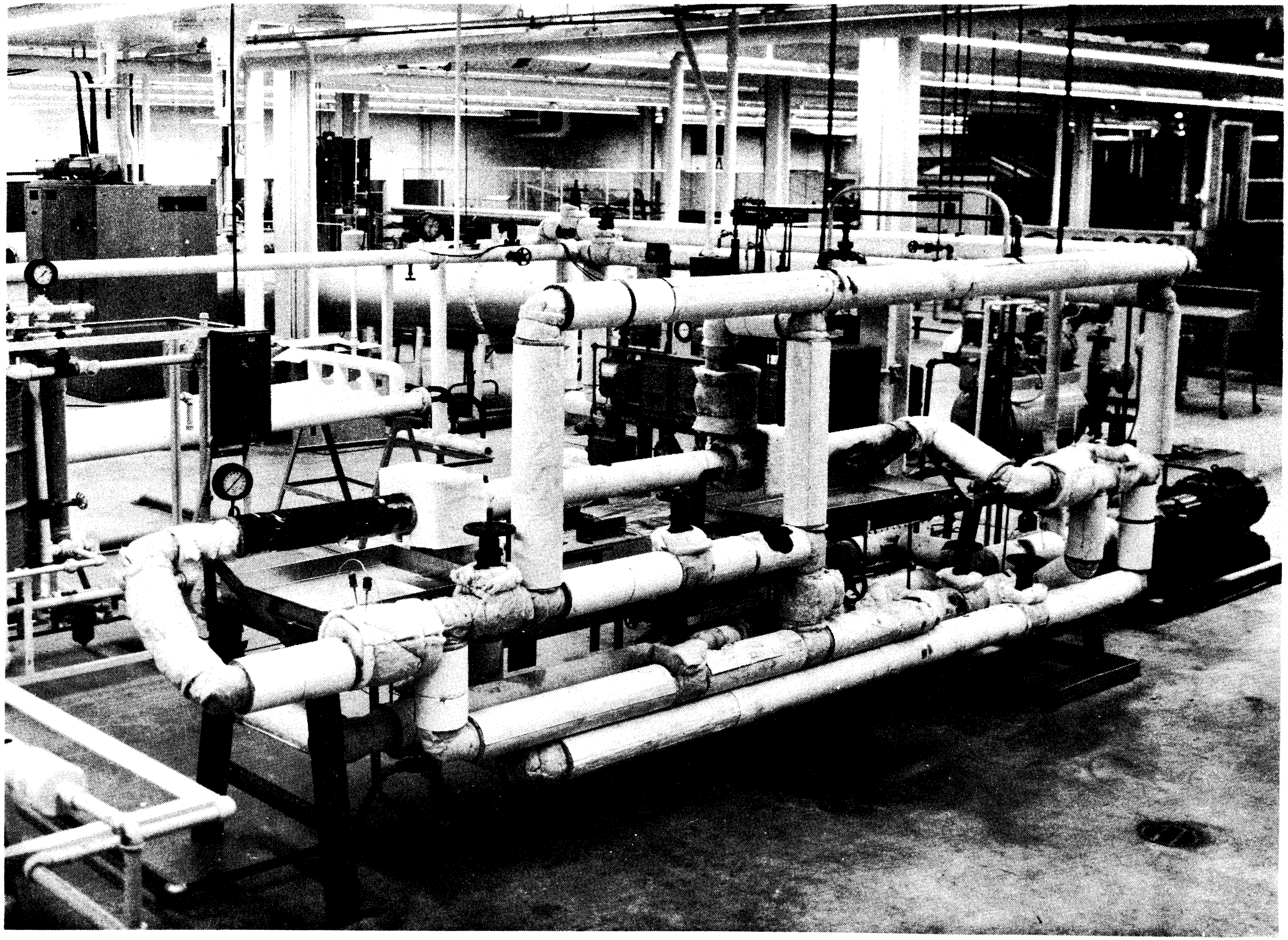

Figure 2. Overall View of Bond Resistance Measurement Equipment

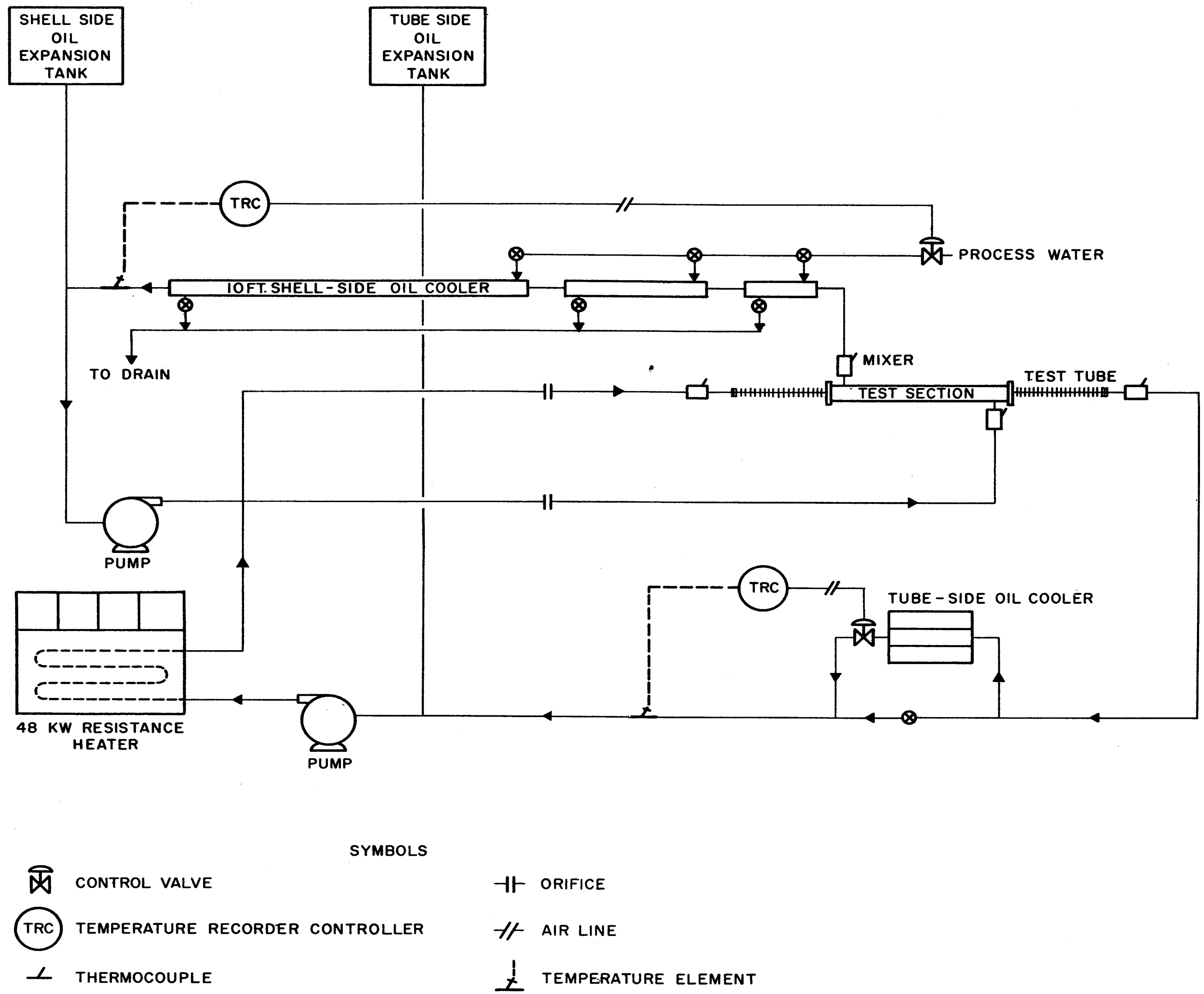

Figure 3. Line Diagram of Equipment Showing Flows of Shell-side and Tube-side Oils

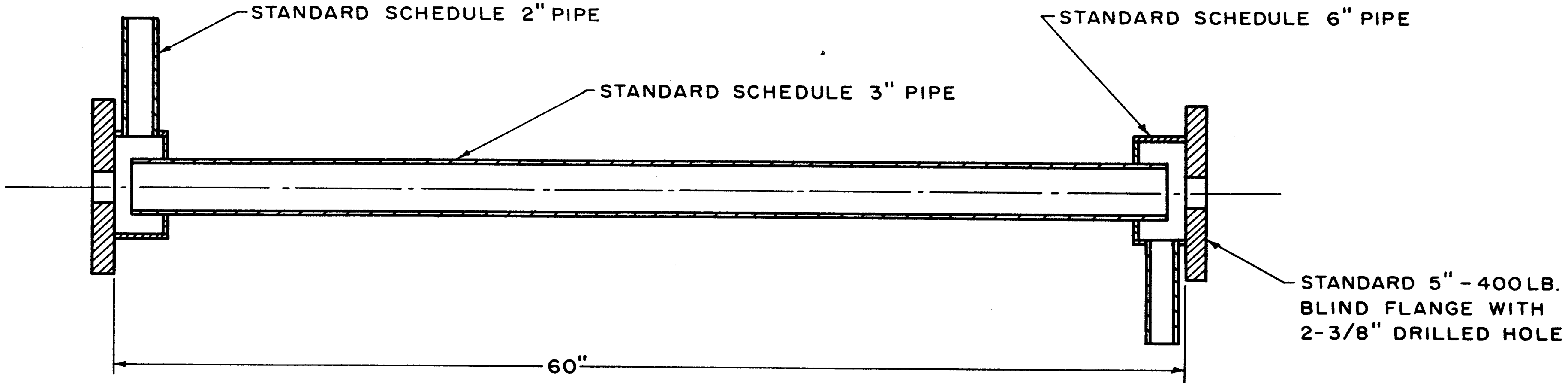

Figure 4. Cross-sectional Drawing of Test Shell

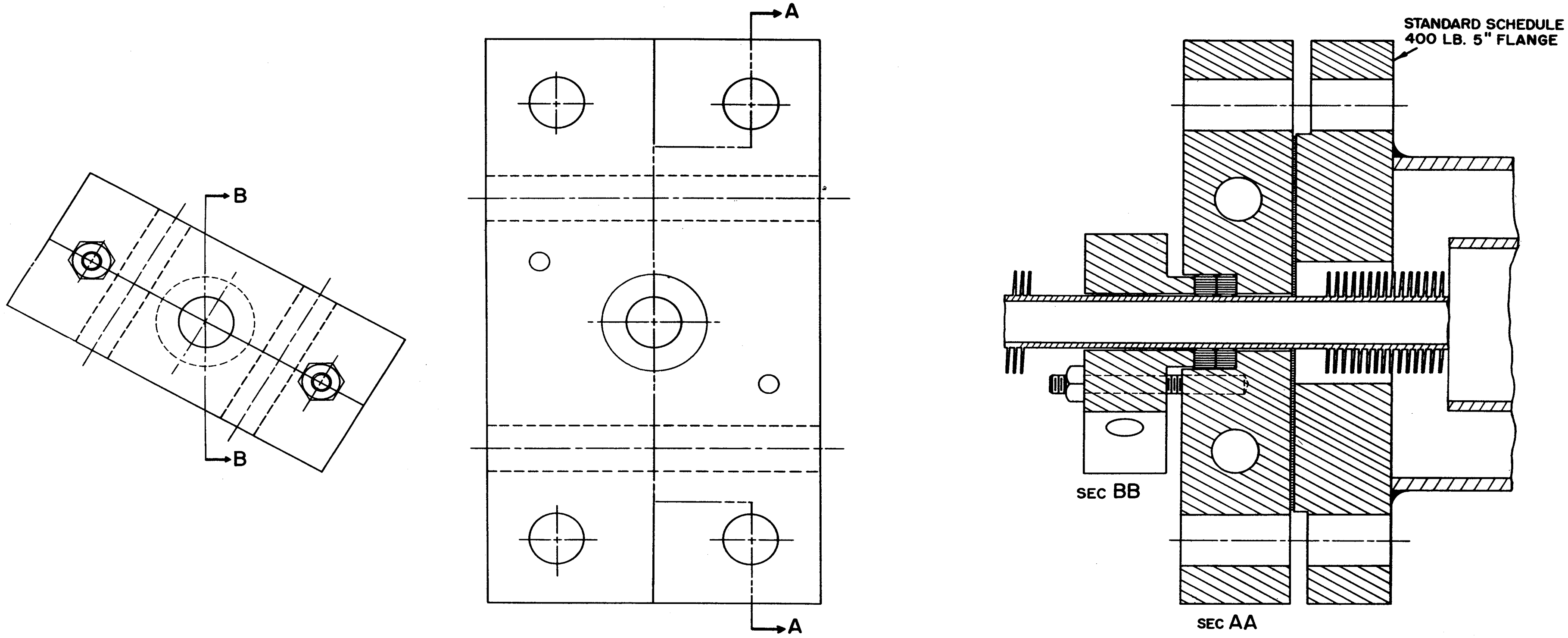

Figure 5. Detailed Drawings of Shell Flanges

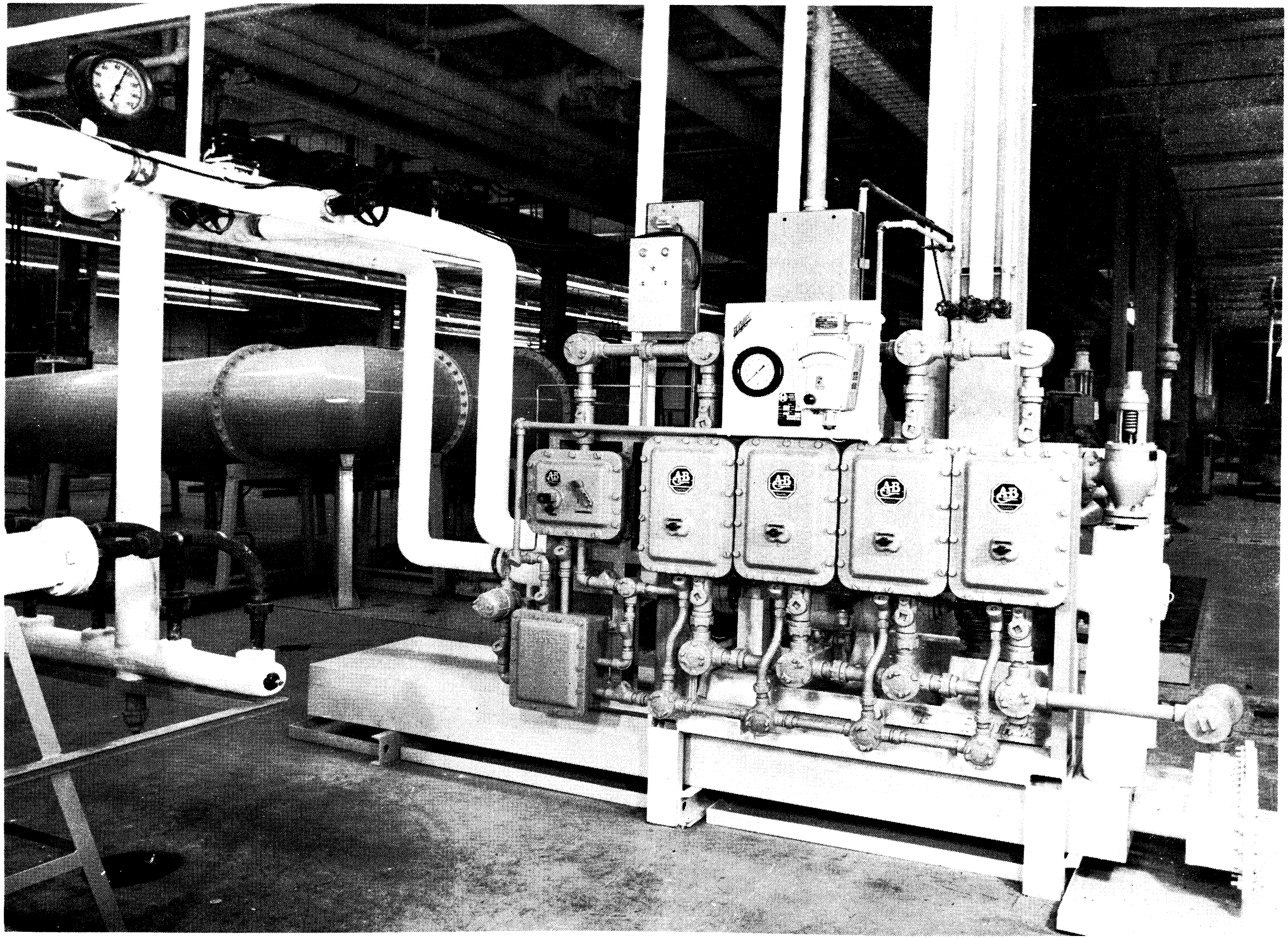

Figure 6. View of the 48 KW Resistance Heater

steel pipes. A by-pass relief line containing a pressure relief valve set to open at 40 lb./sq.in. was furnished with the equipment in order to maintain a positive flow of oil through the unit when the heating elements were on. A thermostatic controller was also provided with the equipment but was found to be unsatisfactory in maintaining the oil at a sufficiently constant temperature. To correct this deficiency, a small air cooled by-pass heat exchanger was installed in the hot oil line. The heat exchanger is shown in Figure 7. A centrifugal air blower operating in forced convection blew air across five 2-inch diameter, 30-inch long bimetallic finned tubes in parallel. The tubes had steel liners. A 2-inch pneumatically operated control valve regulated the amount of by-pass oil through the heat exchanger. By controlling the flow rate of the by-pass oil, the hot oil temperature could be maintained at the desired temperature.

Two high temperature Dean Brothers centrifugal pumps were used to circulate the shell-side and tube-side oils. The shell-side pump had a capacity of 100 gpm at 190 lb./sq.in. and the tube-side pump had a capacity of 60 gpm at 30 lb./sq.in.

Expansion tanks for the shell-side and tube-side oils were located on the floor above the equipment. The tanks were connected to the equipment on the suction-side of the pumps with 3/4-inch diameter pipes and accommodated changes in the volume of the oil with temperature.

Three concentric pipe heat exchangers were located in series in the shell-side fluid line immediately after the test shell to remove the sensible heat picked up in the test shell by the shell-side fluid. Water was used as the coolant. The heat exchangers which were 2, 4, and 10 feet long were constructed by placing standard schedule 3-inch diameter steel pipe over the standard schedule 2-inch diameter shell-side fluid line and welding an annular ring into one end and a flange into the other end. The flange end of the exchanger was designed to permit free expansion of the concentric pipes. Companion flanges with extended annular rings were used to seat the packing material to the inner pipe and prevent leakage of water from the annulus. Water was piped to the heat exchangers in such a way that the exchangers could be used in any combination as required.

Two automatic temperature controller-recorders were installed to assist in the operation of the equipment when taking data. One controller kept the inlet hot oil on the tube-side of the test section at a constant temperature by controlling the oil flow rate through the pneumatically actuated valve in the by-pass heat exchanger line. The other controller was used to maintain a constant inlet oil temperature to the shell-side of the test section by controlling the water flow rate through the concentric pipe with a pneumatically operated globe valve.

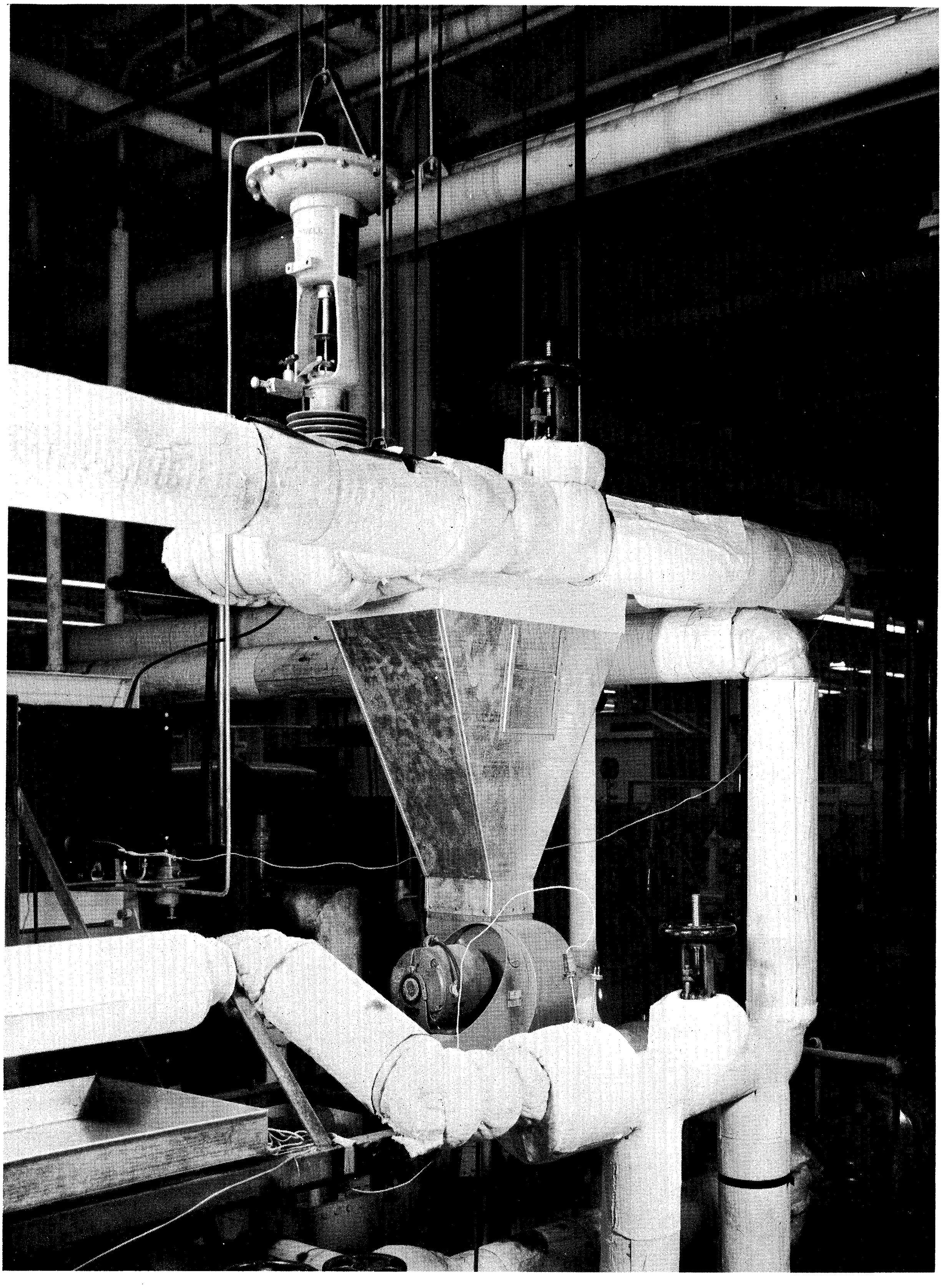

Figure 7. Overall View of the By-pass Oil Cooler Located in the Tube-side Oil Piping System

The oil flow rates were measured with calibrated orifices placed in orifice flanges located in long straight runs of pipe immediately ahead of the shell and tube entrances. Water was used to calibrate the orifices. The pressure drops across the shell-side and tube-side flow rate orifices were measured with 60-inch and 40-inch oil over mercury manometers, respectively.

Inlet and outlet oil temperatures on the shell- and tube-sides were measured with 24 gauge iron-constantan, calibrated thermocouples using a Leeds and Northrup precision portable potentiometer. The thermocouples were located in the outlet ends of mixers located at the entrances and exits of the shell and tube. Figure 8 shows a detailed drawing of the mixers. The shell-side thermocouples were calibrated against each other under isothermal conditions in order to obtain accurate temperature changes when taking data. The tube-side thermocouples were also calibrated against each other.

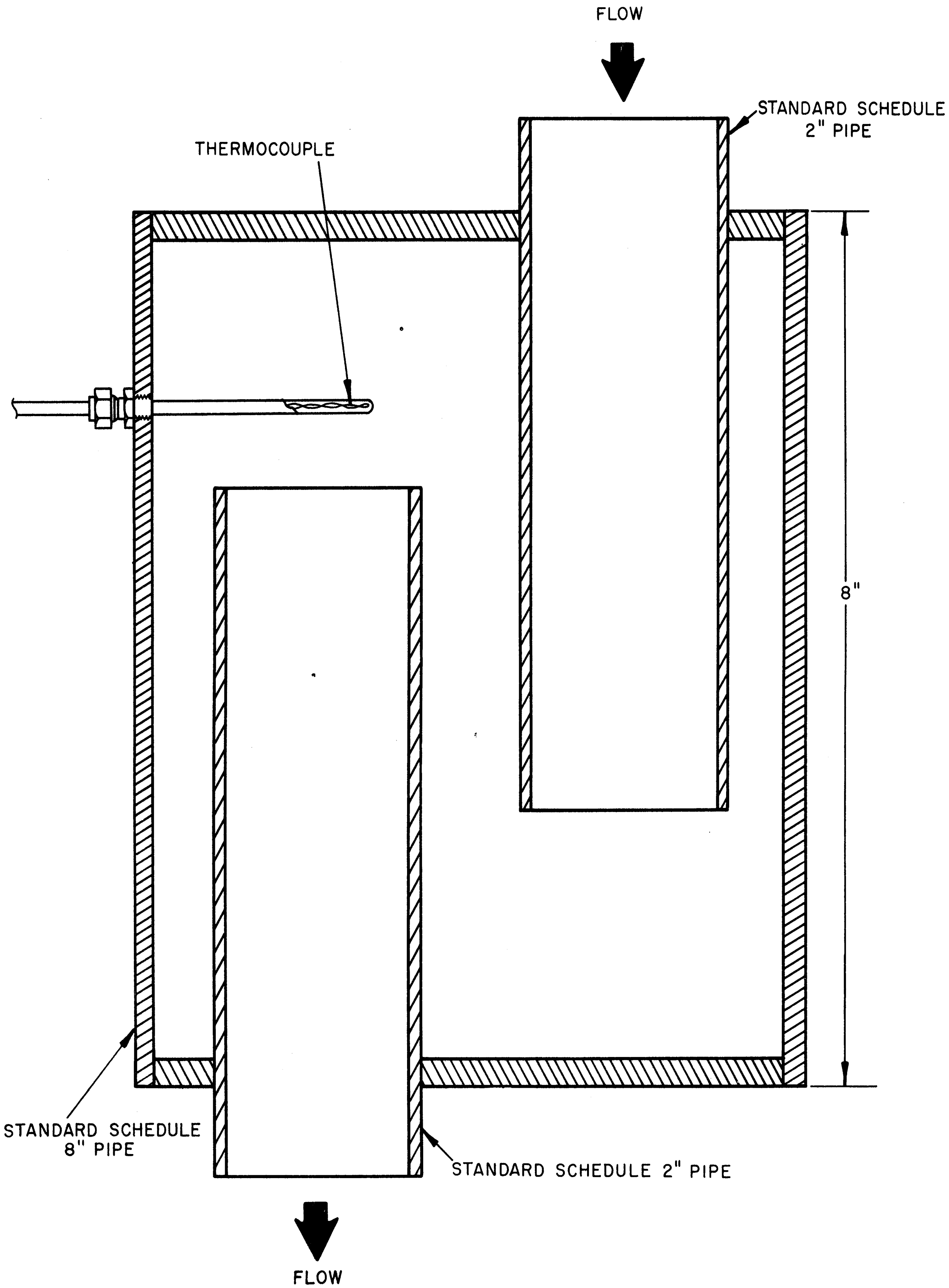

Figure 8. Detailed Drawing of an Oil Mixer and Thermocouple

TEST PROCEDURE

One barrel each of Mobiltherm Light and Mobiltherm 600 were circulated through the shell-side and tube-side piping systems, respectively, after completion of the construction phase. Both oils were completely drained from the equipment and discarded after they had been circulated for several hours to clean the system. After the piping had been completely drained, the shell-side and tube-side were filled with clean Mobiltherm Light and Mobiltherm 600 oils, respectively, through the expansion tanks located on the floor above. The oils were allowed to circulate through the piping at the ambient temperature until the air was removed from the system through valves located at high points in each network.

During normal operation, the shell-side and tube-side pumps were started and the automatic temperature controllers were set at the desired set-points. The oil flow rates were adjusted to the desired valves with manual valves. Three or four of the four resistance heating circuits in the 48 KW electric oil heater were turned on and the heater thermostat set at 600 °F. The number of circuits required depended upon the desired heat duty. The shell-side oil was heated in the test shell by the tube-side oil. When the shell-side oil reached the desired temperature, the automatic control system regulated the amount of cooling water flow through the shell-side oil concentric pipe heat exchangers. The choice between the 2-, 4-, or 10-foot heat exchanger or a combination of the three, depended upon the shell-side heat duty and temperature level. When the tube-side oil temperature reached the set-point temperature, the tube-side automatic control system regulated the amount of oil by-passed through the air cooler shown in Figure 7. By keeping the electric heater thermostats set at a temperature higher than the desired tube-side oil temperature, the electric heaters remained on constantly and allowed the control system to control the oil by-pass flow and maintain the temperature at the set-point temperature.

Heat transfer data were taken when the automatic controllers had stabilized the temperatures at the desired values. For each operating condition, the following readings were taken in order: emf of the inlet tube-side oil thermocouple, emf of the outlet tube-side oil thermocouple, pressure drop across the tube-side flow orifice with an oil over mercury manometer, emf of the inlet shell-side oil thermocouple, emf of the outlet shell-side oil thermocouple, and pressure drop across the shell-side flow orifice with an oil over mercury manometer. A total of three sets of readings were taken for each operating condition and the data averaged. Calibration charts were used to convert the thermocouple emf's to temperature readings and orifice calibration charts corrected for temperature were used to convert the pressure drop readings to oil flow rates.

Samples of oil were frequently removed from the system and the viscosity checked. This served as a monitoring technique to insure that the oil properties did not vary. The tube-side and shell-side oil were normally changed when a new tube was placed in the equipment.

TUBE-SIDE AND SHELL-SIDE HEAT TRANSFER CORRELATIONS

The quantitative evaluation of the bond resistance of bimetallic tubes is determined indirectly by comparing the experimentally measured overall heat transfer coefficient for the bimetallic tube with the predicted overall heat transfer coefficient for the same tube without bond resistance. The experimental overall heat transfer coefficient is calculated from

$$U_{o_{exp}} = \frac{Q}{A_o \Delta T_m} \tag{5}$$

In terms of the individual resistances the experimentally determined overall coefficient is

$$\frac{1}{U_{o_{exp}}} = \frac{1}{h'_o} + r_{fin} + \frac{A_o}{A_i h_i} + \frac{A_o}{A_\ell} r_\ell + \frac{A_o}{A_{fb}} r_{fb} + \frac{A_o}{A_b} r_b \tag{6}$$

The predicted overall heat transfer coefficient for a tube without bond resistance is

$$\frac{1}{U_{o_{pred}}} = \frac{1}{h'_o} + r_{fin} + \frac{A_o}{A_i h_i} + \frac{A_o}{A_\ell} r_\ell + \frac{A_o}{A_{fb}} r_{fb} \tag{7}$$

Subtracting Equation (7) from Equation (6) gives

$$\frac{1}{U_{o_{exp}}} - \frac{1}{U_{o_{pred}}} = \frac{A_o}{A_b} r_b \tag{8}$$

which can be rearranged to give the bond resistance in terms of the bond area.

$$r_b = \frac{A_b}{A_o}\left[\frac{1}{U_{o_{exp}}} - \frac{1}{U_{o_{pred}}}\right] \tag{9}$$

If accurate measurements of bond resistances are to be made, it is imperative that accurate values of the experimental and predicted overall heat transfer coefficients be known. The accuracy can be improved by making the difference between the experimental and predicted overall heat transfer coefficients as large as possible. By the proper choice of tube-side and shell-side fluids and flowrates, the bond resistance can be made a significant fraction of the overall resistance. The choice of experimental equipment and aromatic heat transfer oils previously described was made with regards to obtaining as large a predicted overall heat transfer coefficient as possible.

The accurate evaluation of the predicted overall heat transfer coefficient depends upon being able to determine the tube-side and shell-side heat transfer coefficients since the remaining variables in Equation (7) can be calculated without difficulty. Tube-side and shell-side heat transfer correlations were experimentally obtained using two monometallic aluminum high fin tubes with essentially the same dimensions as the bimetallic tubes under investigation. The dimensions of the tubes are given in Table I.

A well known method for determining individual coefficients from the overall coefficient is known as the Wilson Plot technique[14]. The general scheme is to hold either the inside or outside coefficient constant while varying the other coefficient. The variation of the overall coefficient is, thereby, due to the varying heat transfer coefficient alone. Equations (10) and (11) were used as the models for the tube-side and shell-side heat transfer coefficients.

$$\frac{h_i D_i}{k_i} = C_i \left[\frac{D_i G}{\mu}\right]_i^{0.8} \left[\frac{c_p \mu}{k}\right]_i^{1/3} \left[\frac{\mu}{\mu_w}\right]_i^{0.14} \tag{10}$$

TABLE I

Description and Dimensions of the Tubes Used in the Investigation

Tube No.	455	456	461	462	463
Tube Type	monometallic	monometallic	bimetallic	bimetallic	bimetallic
Diameter over Fins, in.	2.026	2.020	2.020	1.963	1.954
Root Diameter, in.	1.086	1.085	1.090	1.095	1.090
Liner Outside Diameter, in.	none	none	0.997	0.997	0.997
Inside Diameter, in.	0.835	0.835	0.832	0.832	0.832
Fins Per Inch	9.39	9.40	8.72	8.80	8.77
Fin Thickness, in.	0.0184	0.0190	0.0159	0.0163	0.0163
Fin Material	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
Liner Material	none	none	Steel	Steel	Steel
Outside Heat Transfer Area, sq.ft.	19.850	19.959	18.446	17.383	16.994
Inside Heat Transfer Area, sq.ft.	1.140	1.140	1.135	1.135	1.135
Bond Area, sq.ft.	none	none	1.360	1.360	1.360
Volumetric Equivalent Diameter, ft.	0.0366	0.0363	0.0393	0.0417	0.0421

$$\frac{h_o' D_{eq}}{k_o} = C_o \left[\frac{D_{eq} G}{\mu}\right]_o^P \left[\frac{c_p \mu}{k}\right]_o^{1/3} \left[\frac{\mu}{\mu_w}\right]_o^{0.14} \qquad (11)$$

If the expression for the overall heat transfer coefficient of a mono-metallic finned tube is written as

$$\left[\frac{1}{U_{o_{exp}}} - r_{fin} - \frac{A_o}{A_m} r_m\right] = \frac{1}{h_o'} + \frac{A_o}{A_i h_i} \qquad (12)$$

and rearrangements of Equations (10) and (11) are substituted for h_i and h_o', respectively, then

$$\left[\frac{1}{U_{o_{exp}}} - r_{fin} - \frac{A_o}{A_m} r_m\right]$$

$$= \frac{D_{eq}}{k_o C_o \left[\frac{D_{eq} G}{\mu}\right]_o^P \left[\frac{c_p \mu}{k}\right]_o^{1/3} \left[\frac{\mu}{\mu_w}\right]_o^{0.14}}$$

$$+ \frac{A_o D_i}{A_i k_i C_i \left[\frac{D_i G}{\mu}\right]_i^{0.8} \left[\frac{c_p \mu}{k}\right]_i^{1/3} \left[\frac{\mu}{\mu_w}\right]_i^{0.14}} \qquad (13)$$

The group of terms representing the shell-side coefficient can be held constant, except for the group

$$\left[\frac{\mu}{\mu_w}\right]_o^{0.14}$$

by keeping the flow rate and the average temperature of the shell-side fluid constant. By multiplying Equation (13) by

$$\left[\frac{\mu}{\mu_w}\right]_o^{0.14}$$

Equation (14) is obtained.

$$\left[\frac{1}{U_{o_{exp}}} - r_{fin} - \frac{A_o}{A_m} r_m\right]\left[\frac{\mu}{\mu_w}\right]_o^{0.14}$$

$$= \frac{D_{eq}}{k_o C_o \left[\frac{D_{eq} G}{\mu}\right]_o^P \left[\frac{c_p \mu}{k}\right]_o^{1/3}} + \frac{A_o D_i \left[\frac{\mu}{\mu_w}\right]_o^{0.14}}{A_i k_i C_i \left[\frac{D_i G}{\mu}\right]_i^{0.8} \left[\frac{c_p \mu}{k}\right]_i^{1/3} \left[\frac{\mu}{\mu_w}\right]_i^{0.14}} \qquad (14)$$

which has the form

$$B = I + \frac{A}{C_i} \tag{15}$$

where

$$B = \left[\frac{1}{U_{o_{exp}}} - r_{fin} - \frac{A_o}{A_m} r_m \right] \left[\frac{\mu}{\mu_w} \right]_o^{0.14} \tag{16}$$

$$I = \frac{D_{eq}}{k_o\, C_o \left[\frac{D_{eq}\, G}{\mu} \right]_o^{P} \left[\frac{c_p\, \mu}{k} \right]_o^{1/3}} \tag{17}$$

and

$$A = \frac{A_o\, D_i \left[\frac{\mu}{\mu_w} \right]_o^{0.14}}{A_i\, k_i \left[\frac{D_i\, G}{\mu} \right]_i^{0.8} \left[\frac{c_p\, \mu}{k} \right]^{1/3} \left[\frac{\mu}{\mu_w} \right]_i^{0.14}} \tag{18}$$

If the flowrate and average temperature of the shell-side fluid is kept constant and data are taken for several different tube-side fluid flow rates, the constant, C_i, for the inside heat transfer coefficient can be obtained. The analysis of the data for C_i requires successive trial-and-error calculations. The constant C_i is assumed and the calculations made to determine the wall temperatures necessary to evaluate the viscosities at the inside and outside walls of the tube. The functions A and B are evaluated and a line drawn through the plotted data in a least square sense. The reciprocal of the slope of the line is C_i and the intercept of the line with the ordinate is the function B. When the calculated value of C_i differs more than a desired amount from the assumed value of C_i, the procedure is repeated with the new value of C_i.

A program was prepared for The University of Michigan IBM 7090 digital computer and all the Wilson plot data were processed using that program. The input data to the program were the inlet and outlet temperatures and the flow rates for the shell-side and tube-side oils, the tube dimensions, the metal resistance, and an initial estimate of the inside heat transfer coefficient correlation constant, C_i. The necessary physical properties of Mobiltherm Light and Mobiltherm 600 were fitted to polynomials and the constants included as input data. The program took the value of C_i, went through the process outlined and obtained the values of the two functions necessary for the modified Wilson plot. A least square subroutine was then used to compute the slope of the best straight line through the processed data. The reciprocal of the slope, C_i, was compared to the assumed value and when it differed by more than 0.05 per cent, the calculated value was used and the process repeated until the assumed and calculated values agreed within 0.05 per cent.

A total of six sets of Wilson plot data were obtained on two monometallic aluminum high fin tubes with essentially the same overall dimensions as the bimetallic finned tubes for which bond resistances were to be determined. The tube dimensions are given in Table I. The computer program, heat transfer data and calculated results are given in Tables V - XI, Appendix B, and the final Wilson plot results are presented in Figures 9 - 14. Table II gives the calculated values of the inside heat transfer coefficient correlation constant. The average value of C_i for the six sets of data is 0.02957. Using the average value of C_i, the tube side correlation becomes

$$\frac{h_i D_i}{k_i} = 0.02957 \left[\frac{D_i G}{\mu}\right]_i^{0.8} \left[\frac{c_p \mu}{k}\right]_i^{1/3} \left[\frac{\mu}{\mu_w}\right]^{0.14} \tag{19}$$

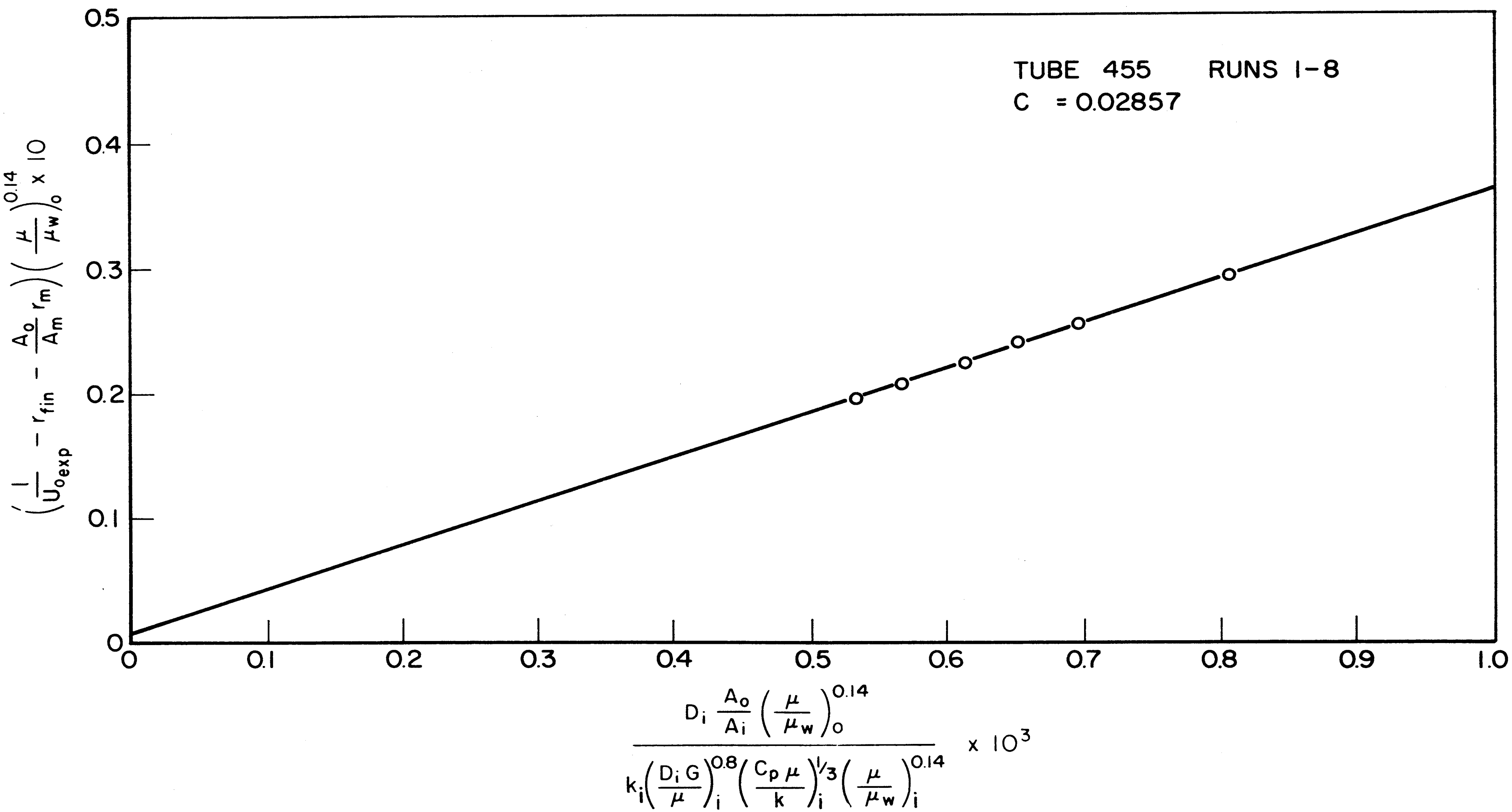

Figure 9. Modified Wilson Plot for Tube Number 455, Runs 1-8

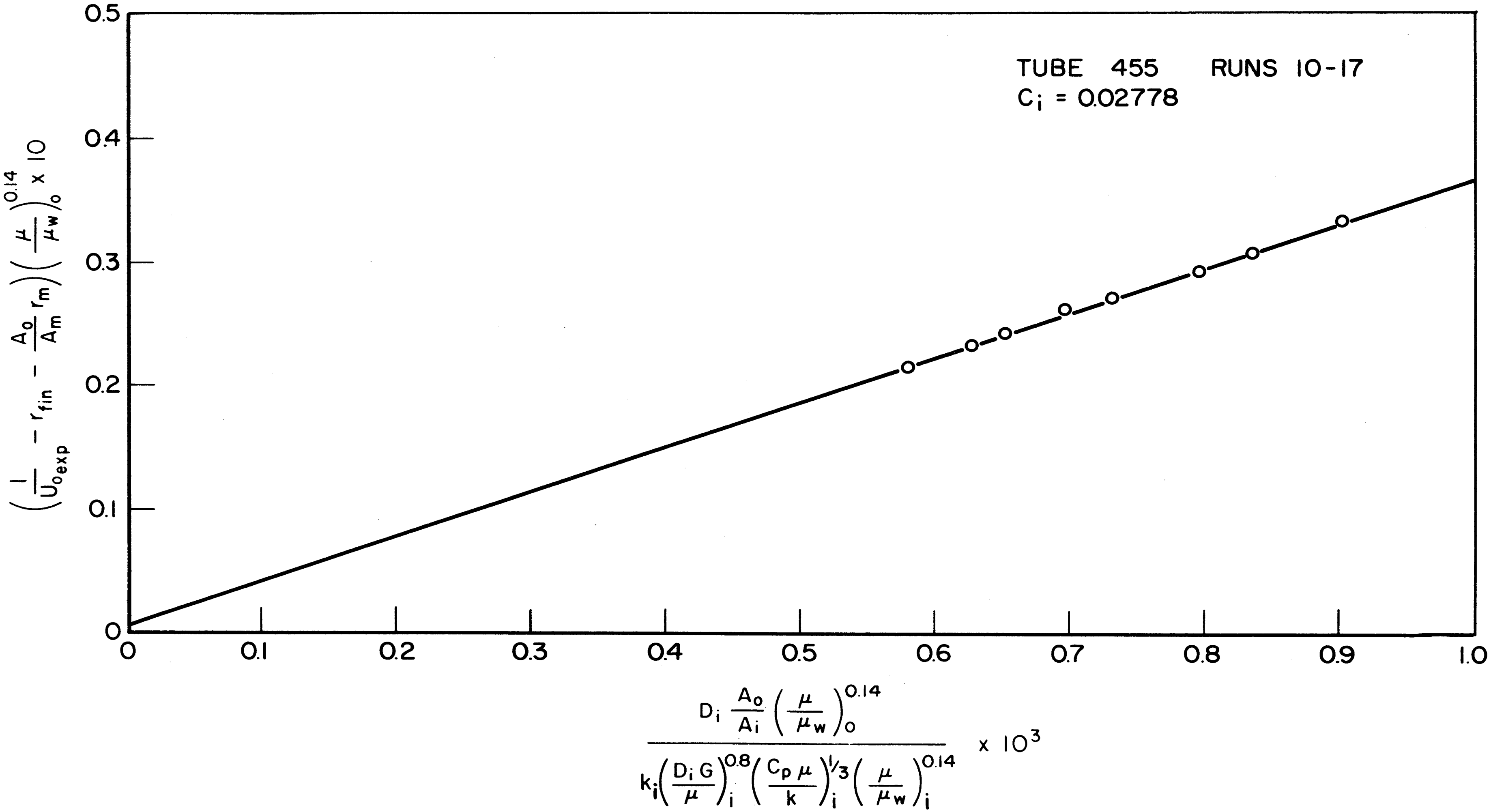

Figure 10. Modified Wilson Plot for Tube Number 455, Runs 10-17

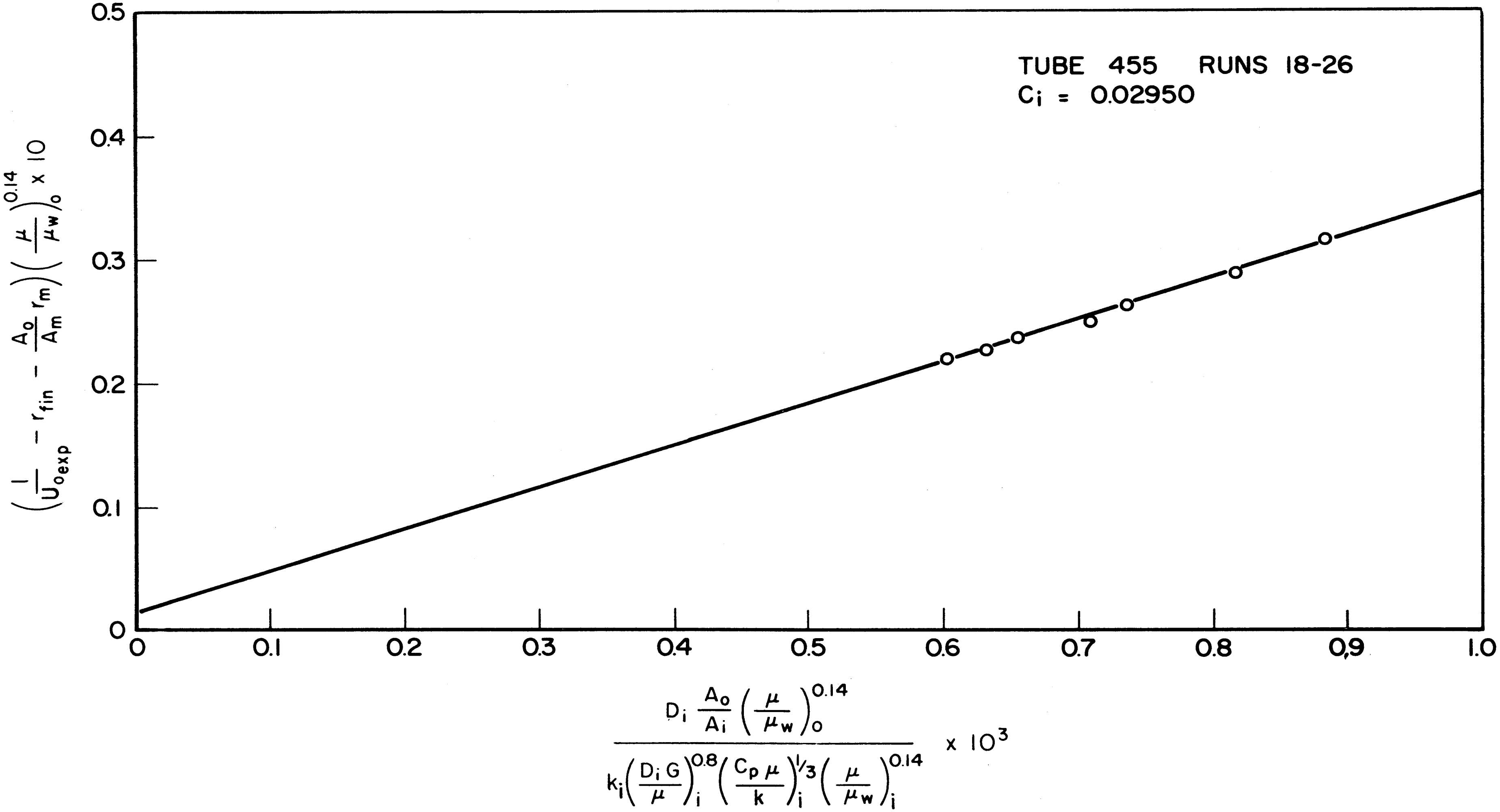

Figure 11. Modified Wilson Plot for Tube Number 455, Runs 18-25

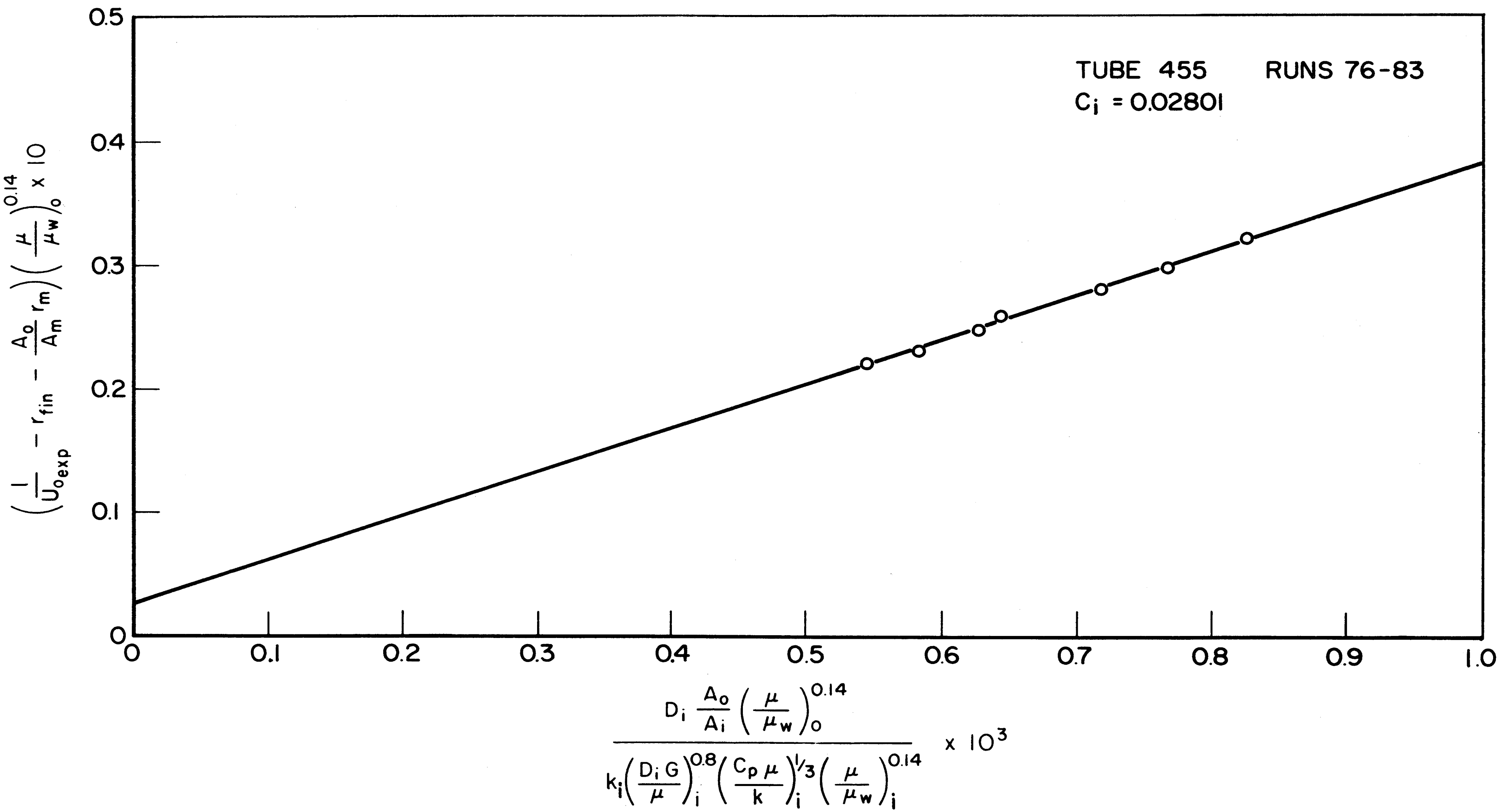

Figure 12. Modified Wilson Plot for Tube Number 455, Runs 76-83

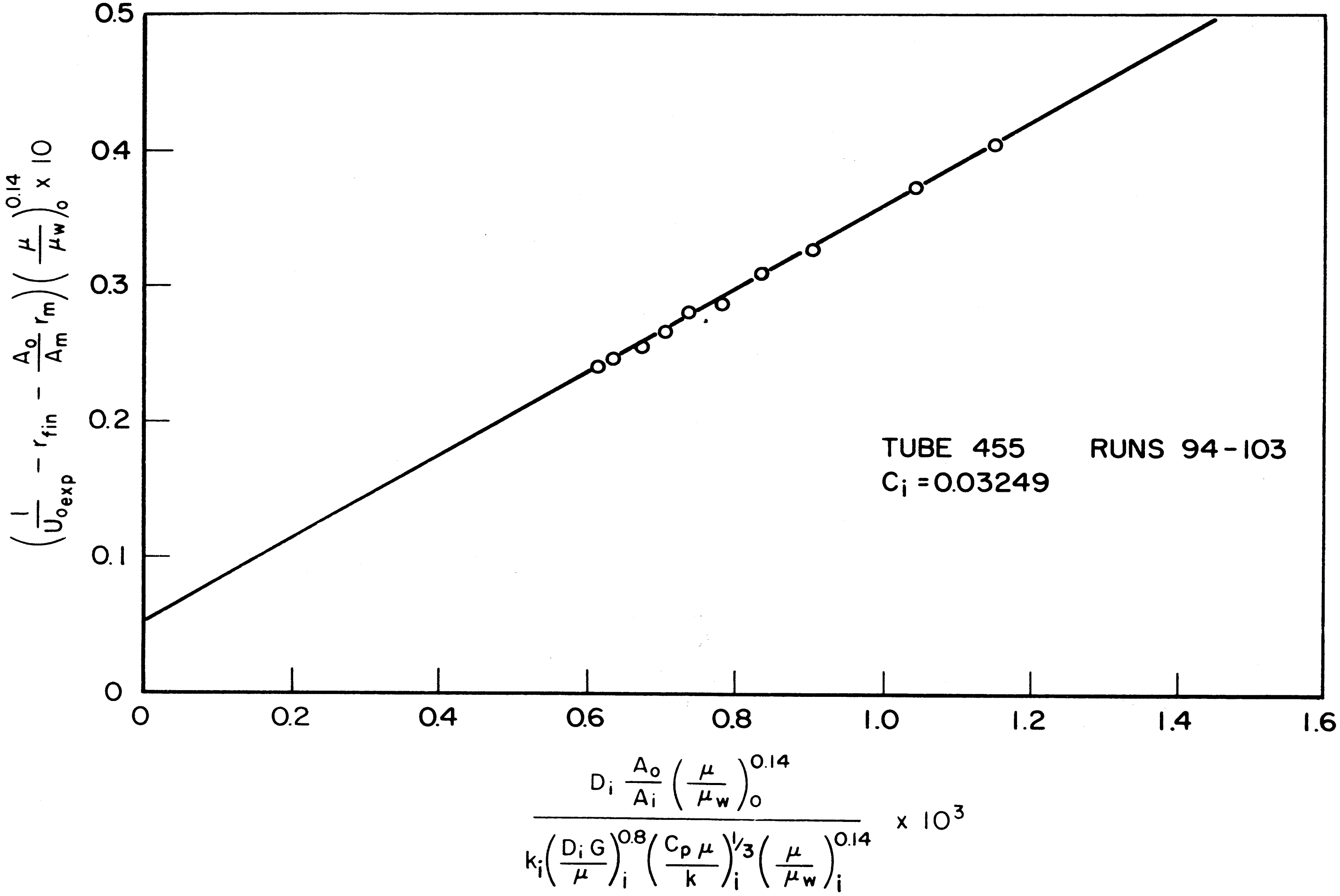

Figure 13. Modified Wilson Plot for Tube Number 455, Runs 94-103

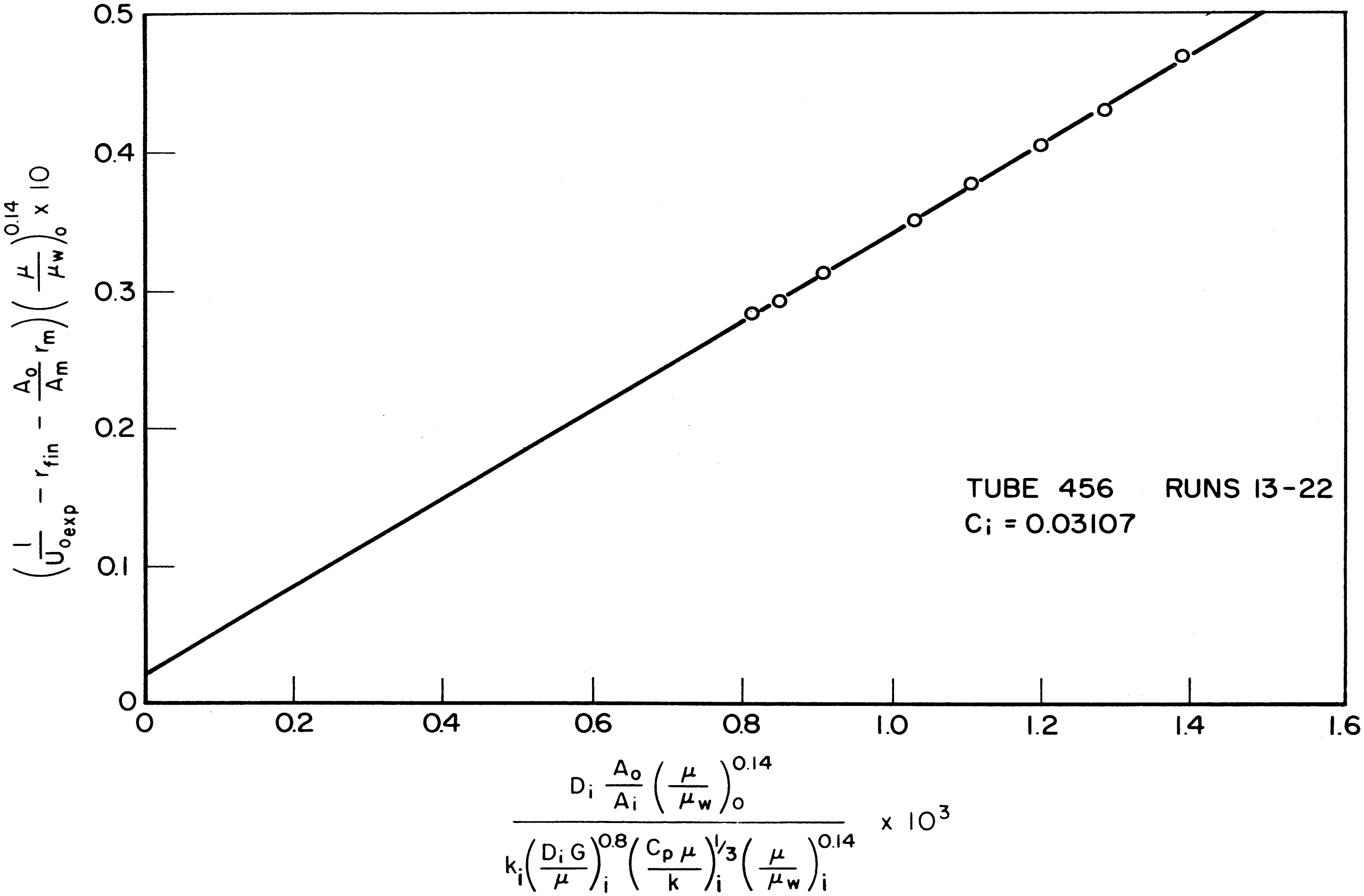

Figure 14. Modified Wilson Plot for Tube Number 456, Runs 13-22

TABLE II

Calculated Values for the Inside Heat Transfer Coefficient Correlation Constant

Tube No.	Run Nos.	Avg. Shell-Side Temp. °F	Avg. Tube-Side Temp. °F	C_i
455	1- 8	355	503	0.02857
455	10- 17	357	470	0.02778
455	18- 26	352	416	0.02950
455	76- 83	399	508	0.02801
455	94-103	303	425	0.03249
456	13- 22	230	335	0.03107
			average	0.02957

The equation for the shell-side heat transfer correlation, Equation (11) contains the constants C_o and P which must be evaluated experimentally. This can be done by rearranging Equation (11) and taking the logarithms of both sides giving

$$\ln\left[\frac{\left[\frac{h'_o D_{eq}}{k_o}\right]}{\left[\frac{c_p \mu}{k}\right]^{1/3}\left[\frac{\mu}{\mu_w}\right]^{0.14}}\right]_o = C_o + P \ln\left[\frac{D_{eq} G}{\mu}\right]_o \qquad (20)$$

Equation (20) has the form

$$D = C_o + P \times E \qquad (21)$$

where

$$D = \ln\left[\frac{\left[\frac{h'_o D_{eq}}{k_o}\right]}{\left[\frac{c_p \mu}{k}\right]^{1/3}\left[\frac{\mu}{\mu_w}\right]^{0.14}}\right]_o \qquad (22)$$

and

$$E = \ln\left[\frac{D_{eq} G}{\mu}\right]_o \qquad (23)$$

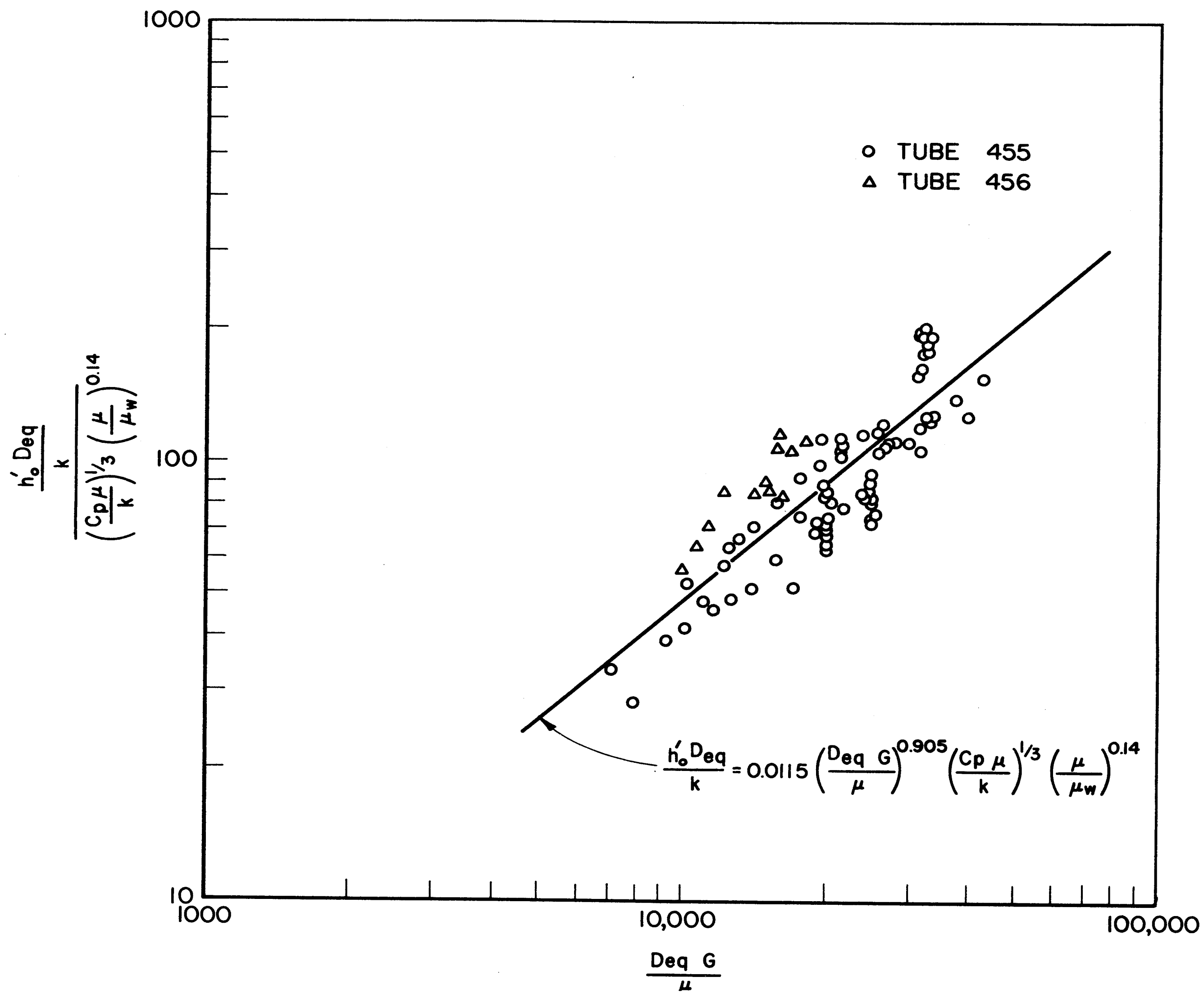

Figure 15. Shell-side Heat Transfer Correlation for a 2-Inch Fin Diameter, Type L/C Finned Tube in a 3-Inch Diameter Shell

Knowing the values of the functions D and E for a set of data, the constants C_o and P can be evaluated by placing a straight line through the data in a least square sense. The intercept of the line with the ordinate is C_o and the slope of the line is P.

A computer program was prepared for The University of Michigan IBM 7090 digital computer. The input data to the program were the inlet and outlet temperatures and the flow rates for the shell-side and tube-side oils, the tube dimensions, the metal resistance, the polynomial constants for the physical properties and the average value of the inside heat transfer coefficient correlation constant. The shell-side heat transfer coefficient was calculated from

$$\frac{1}{h_o'} = \frac{1}{U_{o_{exp}}} - \frac{A_o}{A_i h_i} - r_{fin} - \frac{A_o}{A_m} r_m \qquad (24)$$

Knowing the flow rate and average temperature of the shell-side oil as well as the shell-side coefficient, the values of the Nusselt, Reynolds, and Prandtl numbers and the viscosity ratio for Equation (11) were calculated. The program next calculated the values of the function D and E and a least square subroutine computed the least square values for C_o and P.

A total of 88 runs for the two monometallic aluminum tubes were evaluated. A portion of the data analyzed were tube-side Wilson plot data. The computer program, heat transfer data and calculated results are given in Tables XII - XV, Appendix C and the final shell coefficient results are presented in Figure 15. Using the least square line through the data, the shell-side coefficient becomes

$$\frac{h_o' D_{eq}}{k_o} = 0.0115 \left[\frac{D_{eq} G}{\mu}\right]_o^{0.905} \left[\frac{c_p \mu}{k}\right]_o^{1/3} \left[\frac{\mu}{\mu_w}\right]_o^{0.14} \qquad (25)$$

with a standard deviation of $\pm$ 24 per cent. Since the ratio of the external to internal heat transfer surface is approximately 17.4, an error of $\pm$ 24 per cent in the shell-side coefficient represents approximately a $\pm$ 3 per cent error in the predicted overall heat transfer coefficient which is of the order of the per cent deviations in the heat balances.

The probable error in the measurement of bond resistance was determined by evaluating Equation (9) for all the shell-side coefficient correlation data. The bond area was based on the logarithmic mean between the inside and root diameters of the monometallic tube. Equations (19) and (25) were used in conjunction with Equation (7) to calculate the predicted overall heat transfer coefficient. The results of the analysis are given in Figure 16 and in Tables XVI and XVII, Appendix D. The average predicted bond resistance for the monometallic tube was 0.000000 hr.-sq.ft.(bond area) °F/Btu with a standard deviation of 0.000065 hr.-sq.ft. (bond area) °F/Btu. For the number of data, the 95 per cent confidence limits are $\pm$ 0.000130 hr.-sq.ft.(bond area) °F/Btu. Bond resistances can, therefore, be measured for bimetallic finned tubes with the heat transfer apparatus to $\pm$ 0.000130 hr.-sq.ft.(bond area) °F/Btu with a 95 per cent certainty.

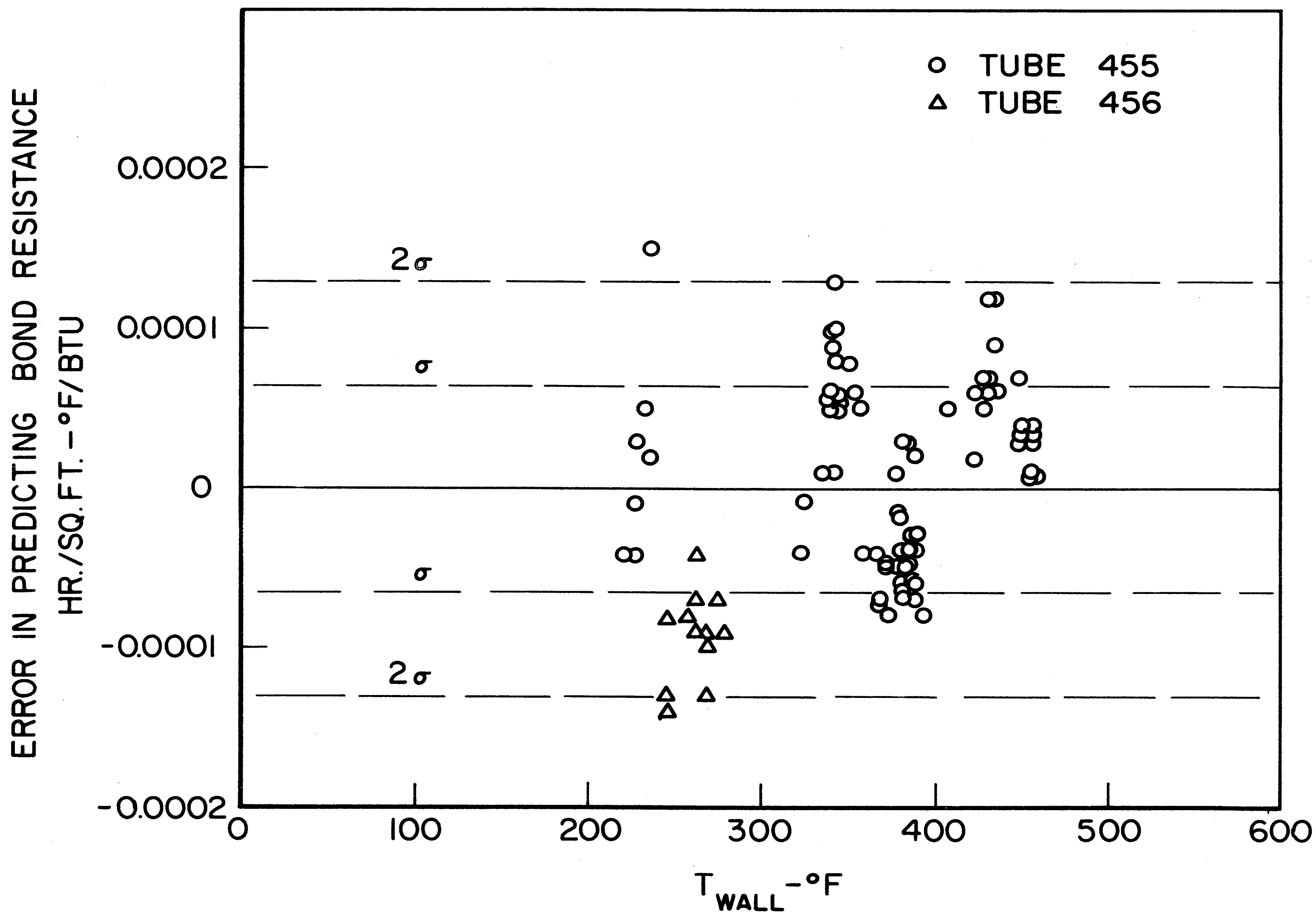

Figure 16. Bond Resistance Error Analysis Using Data for Monometallic Tube Numbers 455 and 456

BOND RESISTANCE MEASUREMENTS

Bond resistance data were taken on three type L/C bimetallic finned tubes with 14 BWG steel liners over a wide range of shell-side and tube-side temperatures and flow rates using the same equipment as was used in determining the shell-side and tube-side heat transfer correlations. The tube dimensions appear in Table I. Equations (19) and (25) were used to determine the tube-side and shell-side heat transfer coefficients, respectively, and Equation (7) was used to calculate the predicted overall heat transfer coefficient exclusive of bond resistance. Equation (5) was used to calculate the experimental overall heat transfer coefficient, and the experimental and predicted overall coefficients were substituted into Equation (9) to give the bond resistance in terms of the bond area. The bond resistance data are given in Tables XIX - XXI, Appendix E.

An objective of this investigation was to use the model for bond resistance derived by Gardner and Carnavos[12] to examine the bond resistance data. Gardner and Carnavos gave Equations (26) and (27) for the change in the deformation of the fin base and liner from the fabrication condition with increasing temperature, assuming a uniform distribution of the initial contact pressure.

$$\Delta u_f = \frac{d}{2}\left\{\alpha_f\left[(T_a - T_o) + \phi\,(T_b - T_a)\right] + \frac{(p_c - p_{co})}{E_f}\left[\frac{(D^2 + d^2)}{(D^2 - d^2)} + {}_f\right]\right\} \qquad (26)$$

$$\Delta u_t = \frac{d}{2}\left\{\alpha_t\,(T_{liner} - T_o) - \frac{(p_c - p_{co})}{E_t}\;\frac{t_f}{P}\left[\frac{d^2 + (d - 2t)^2}{d^2 - (d - 2t)^2} - {}_t\right]\right\} \qquad (27)$$

The difference between Equations (26) and (27) is equal to the radial gap between the liner and fin base.

$$g = u_f - u_t \qquad (28)$$

Since $$\phi\,(T_b - T_a) = (T_{fin} - T_a) \qquad (29)$$

$$g = \frac{d}{2}\left[\alpha_f\,(T_{fin} - T_o) - \alpha_t\,(T_{liner} - T_o) + \mu\,(p_c - p_{co})\right] \qquad (30)$$

where

$$\mu = \left\{\frac{1}{E_f}\left[\frac{(D^2 + d^2)}{(D^2 - d^2)} + \nu_f\right] + \frac{1}{E_f}\,\frac{t_f}{P}\left[\frac{d^2 + (d - 2t)^2}{d^2 - (d - 2t)^2} - \nu_t\right]\right\} \qquad (31)$$

Positive values of g indicate that there is no net contact between the fin base and liner and the contact pressure, p_c is zero. For positive values of g the bond resistance in terms of the bond area can be expressed as

$$r_b = \frac{g}{12\,k_e} \qquad (32)$$

Substituting Equation (30) into Equation (32) with $p_c = 0$ gives

$$r_b = \frac{d}{24\,k_e}\left[\alpha_f\,(T_{fin} - T_o) - \alpha_t\,(T_{liner} - T_o) - \mu\,p_{co}\right] \qquad (33)$$

If the fabrication temperature T_o is taken as 70 °F, the bond resistance for a given tube is a function of k_e, T_{liner}, T_{fin} and p_{co} for the model postulated by Gardner and Carnavos. The bond resistance, the liner temperature, and the average fin temperature can be calculated using the experimentally determined heat transfer correlations. The effective thermal conductivity and initial contact pressure cannot, however, be determined independently. If the effective thermal conductivity is taken as the conductivity of air at the bond temperature and the model of Gardner and Carnavos is assumed to be valid, the initial contact pressure can be calculated by rearranging Equation (33) to give

$$p_{co} = \frac{\alpha_f (T_{fin} - 70) - \alpha_t (T_{liner} - 70) - \dfrac{24 k_e r_b}{d}}{\mu} \qquad (34)$$

A computer program was prepared for The University of Michigan IBM 7090 digital computer to process the bond resistance data. The input data to the program were the inlet and outlet temperatures and the flow rates for the shell-side and tube-side oils, the tube dimension, the metal resistances, and the polynomial constants for the physical properties. Bond resistances were calculated using Equations (9), (19), and (25). The initial contact pressure was calculated for each run using Equation (34). Upper and lower limits of the contact pressure were also calculated based on an error in the bond resistance of 0.00013 hr.-sq.ft.(bond area)/Btu. The computer program and tabulated bond resistance results are given in Tables XVIII - XXI, Appendix E. Figures 17, 18, and 19 present the calculated values of the bond resistance as a function of the liner temperature. The results given in Figures 17, 18, and 19 indicate the general trend only since as shown in Equation (33) the bond resistance for a definite initial contact pressure is a function of the average liner and fin temperatures as well as the effective thermal conductivity of the fluid (air) in the gap between the liner and the fin base. Average values of the initial contact pressures for the three tubes investigated are given in Table III.

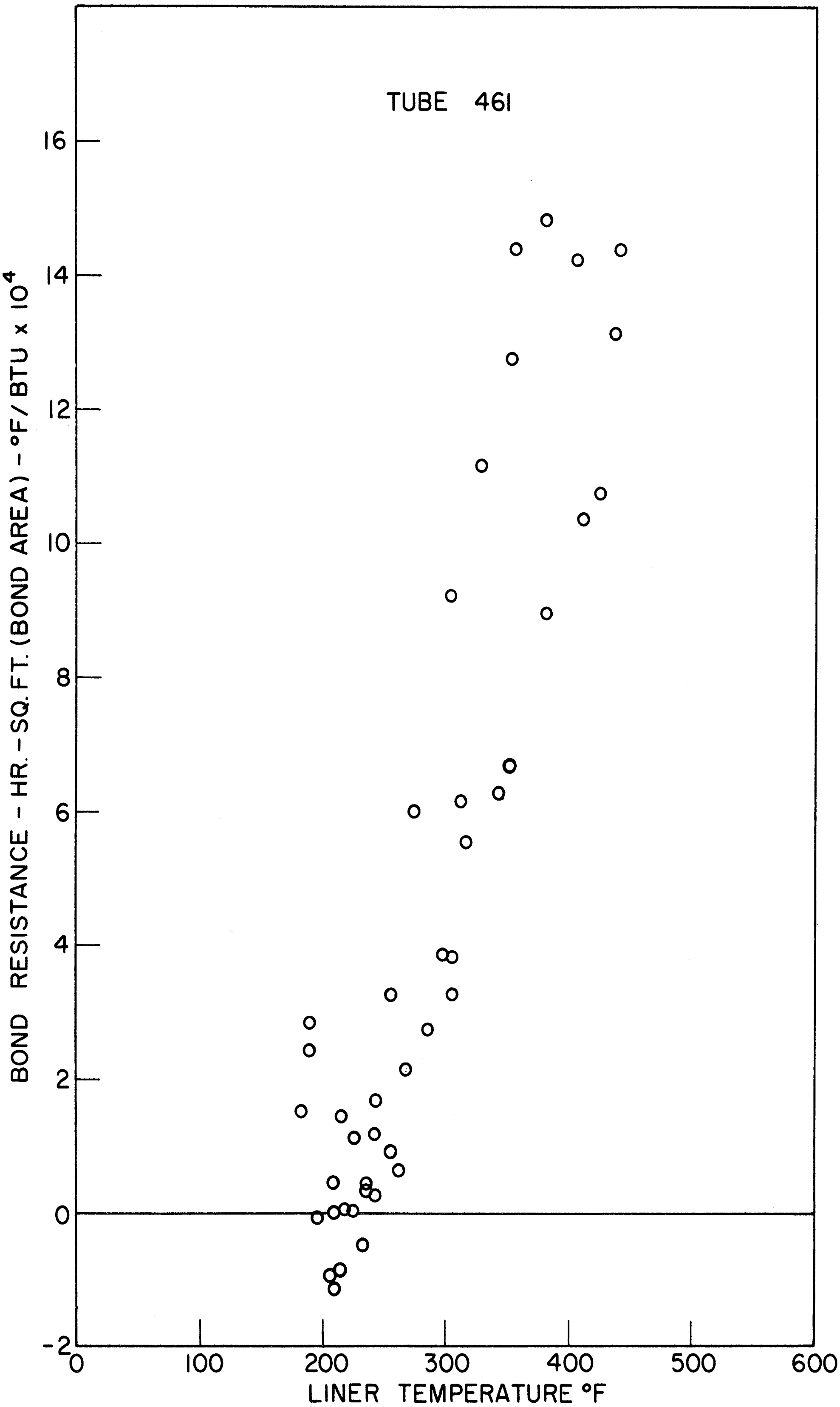

Figure 17. Bond Resistance Results for Bimetallic Tube Number 461

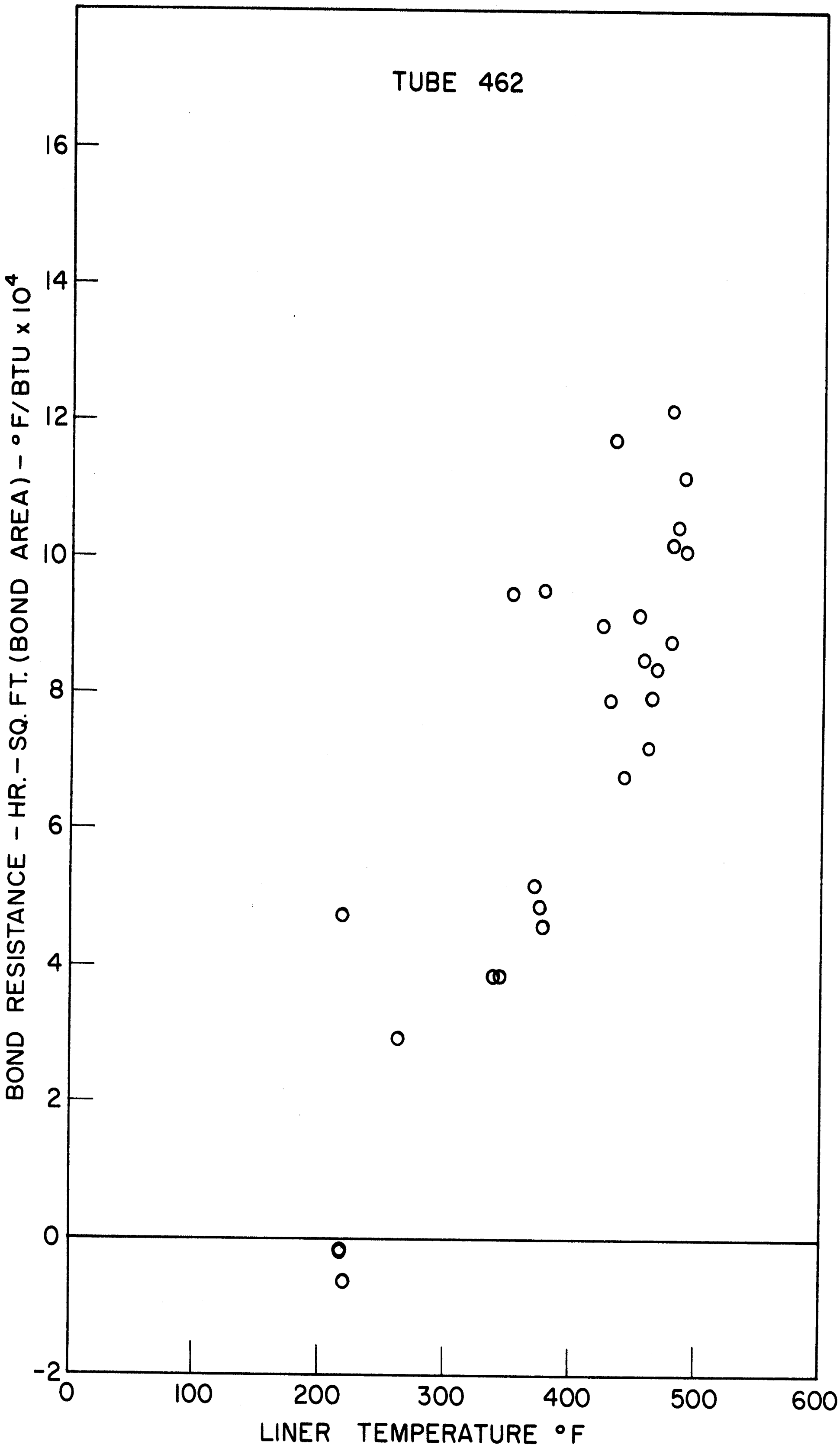

Figure 18. Bond Resistance Results for Bimetallic Tube Number 462

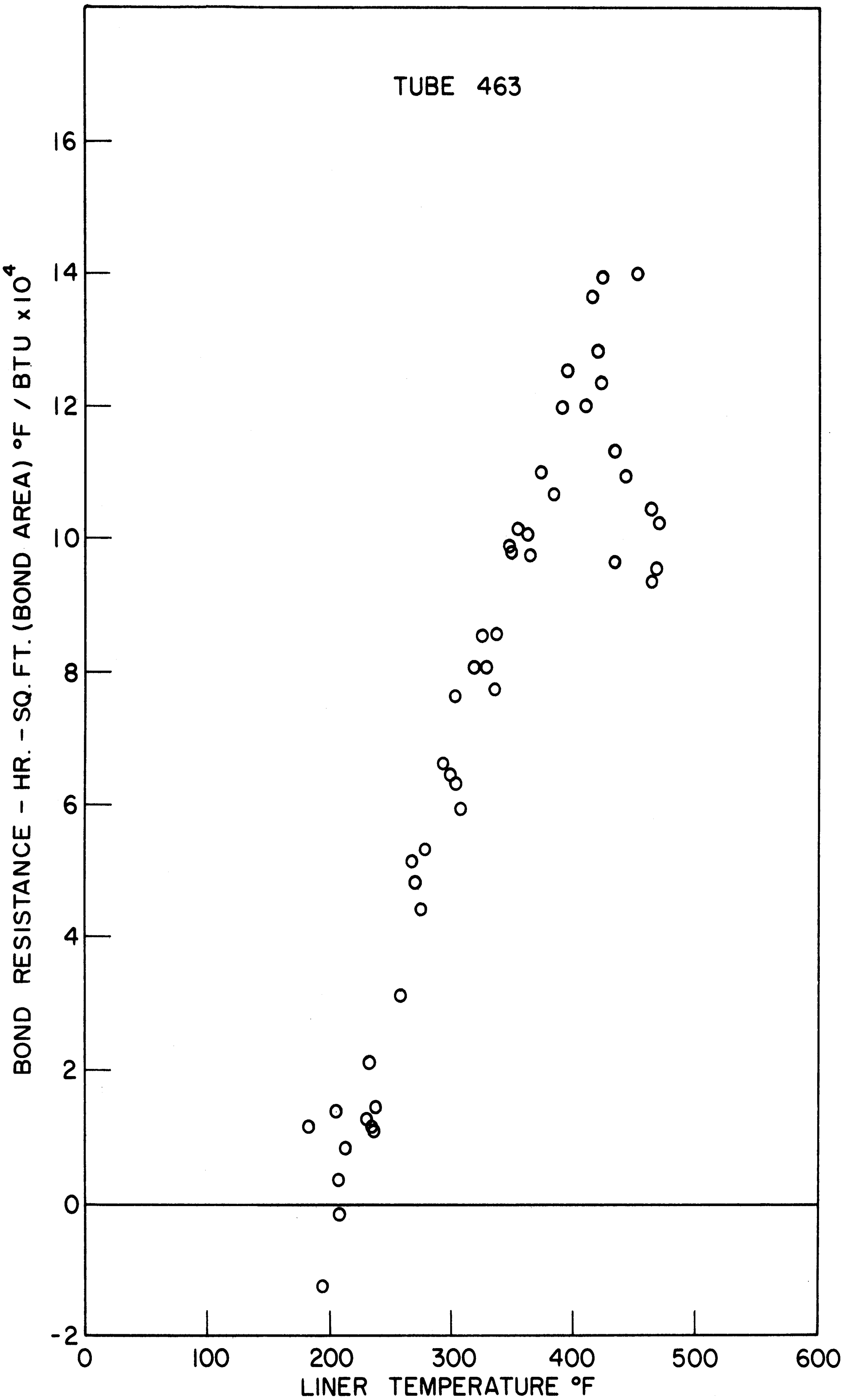

Figure 19. Bond Resistance Results for Bimetallic Tube Number 463

TABLE III

Calculated Values for the Initial Contact Pressure for the Bimetallic Tubes Investigated

Tube No.		Average Initial Contact Pressure lb./sq.in.	Standard Deviation lb./sq.in.
461		3477	523
462		4480	822
463		3138	696
	average	3698	

CONCLUSIONS AND DESIGN RECOMMENDATIONS

Based on the analysis of the bond resistance data, the Gardner and Carnavos procedure for determining the bond resistance of integral high finned bimetallic finned tubes appears to be satisfactory. The results obtained for three such tubes indicated that the average initial contact pressure was 3700 lbs./sq.in. This compares favorably with the value of 3500 lbs./sq.in. recommended by Gardner and Carnavos for finned tubes in the annealed condition. Taking the initial contact pressure to be 3500 lb./sq.in., and the fabrication temperature to be 70 °F, the bond resistance of an integral high finned tube can be calculated using Equation (35).

$$r_b = \frac{d}{24 k_e} \quad \alpha_f (T_{fin} - 70) - \alpha_t (T_{liner} - 70) - 3500 \mu) \tag{35}$$

To use Equation (35) to determine the bond resistance in a design calculation requires a trial-and-error calculation. If a value for the bond resistance is assumed, the overall heat transfer equation can be calculated from

$$\frac{1}{U_o} = \frac{1}{h'_o} + r_{fin} + \frac{A_o}{A_i h_i} + \frac{A_o}{A_\ell} r_\ell + \frac{A_o}{A_{fb}} r_{fb} + \frac{A_o}{A_i} r_{fi} + r_{fo} + \frac{A_o}{A_b} r_b \tag{36}$$

The mean temperature difference between the tube-side fluid and the air at the point in question is

$$\Delta T_m = T_h - T_a \tag{37}$$

The liner temperature at that point is

$$T_{liner} = T_h - U_o \times A_o \times \Delta T_m \left[\frac{1}{A_i h_i} - \frac{r_\ell}{2 A_\ell} \right] \tag{38}$$

and the average fin temperature at the same location in the exchanger is

$$T_{fin} = T_a + \frac{U_o \times A_o \times \Delta T_m}{h_o' \left[A_f + \frac{A_r}{\phi} \right]} \tag{39}$$

Once the values of T_{liner} and T_{fin} are known, the bond resistance can be calculated using Equation (35) and the calculated value compared with the assumed value. If there is insufficient agreement between the two values, the calculations should be repeated.

To simplify the procedure for determining bond resistance, graphs were prepared giving the bond resistance of 2 inch O.D., 9 fins per inch integral high finned tubes for nine different combinations of the outside and the inside heat transfer coefficients as a function of the tube-side fluid and the air temperatures. The graphs given in Figures 20, 21, and 22, are based on the tube dimensions given in Table IV. The values of the outside and inside heat transfer coefficients used in preparing the graphs span the range of normal air cooled heat exchanger conditions so that interpolation between graphs can be done to accurately predict the bond resistance of 2 inch diameter type L/C bimetallic finned tubes containing steel liners.

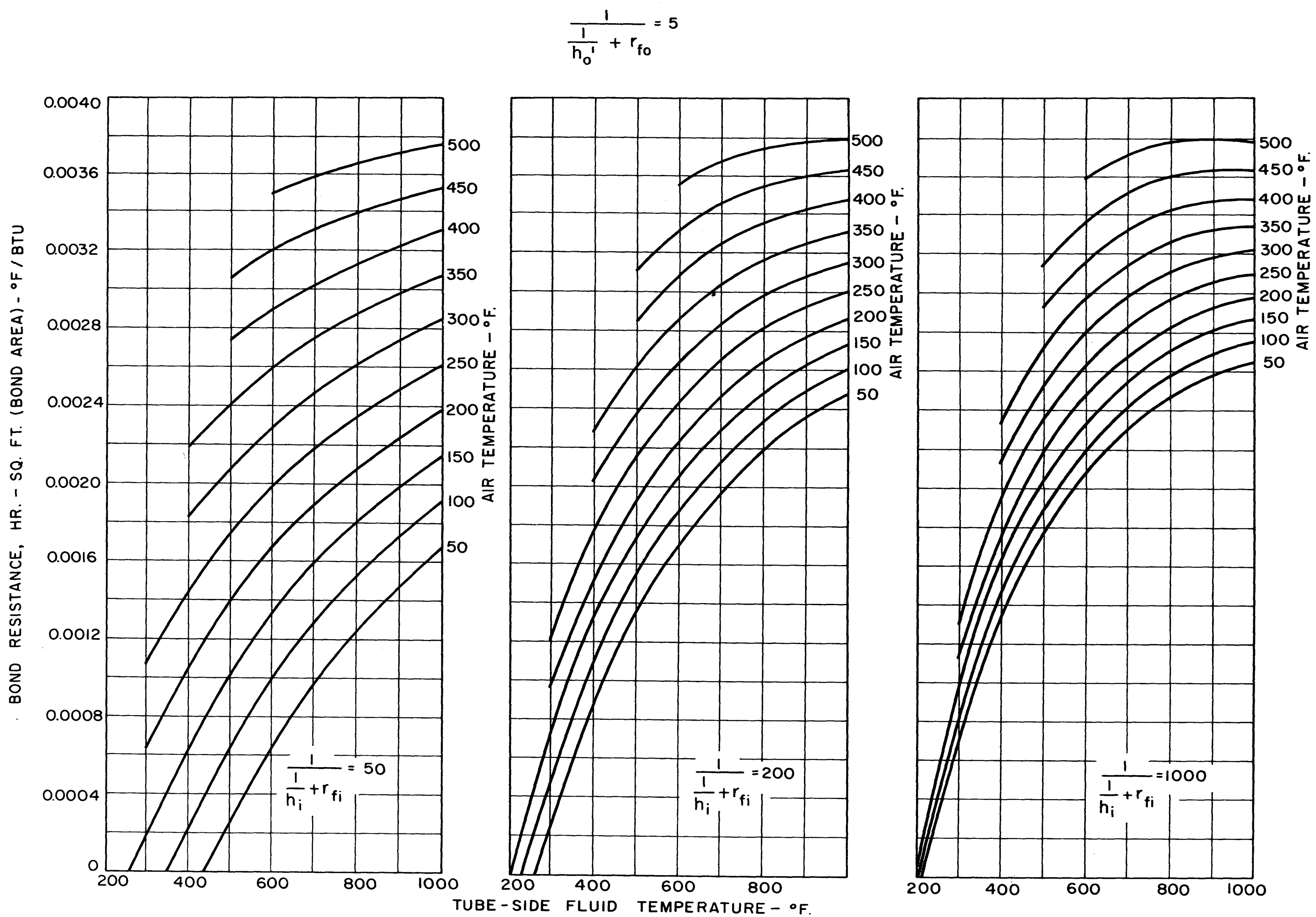

Figure 20. Bond Resistances for a 2-Inch Fin Diameter, 9 Fins per Inch, Type L/C Finned Tube for an Effective Air-film Heat Transfer Coefficient of 5 Btu/hr.-sq.ft.- °F

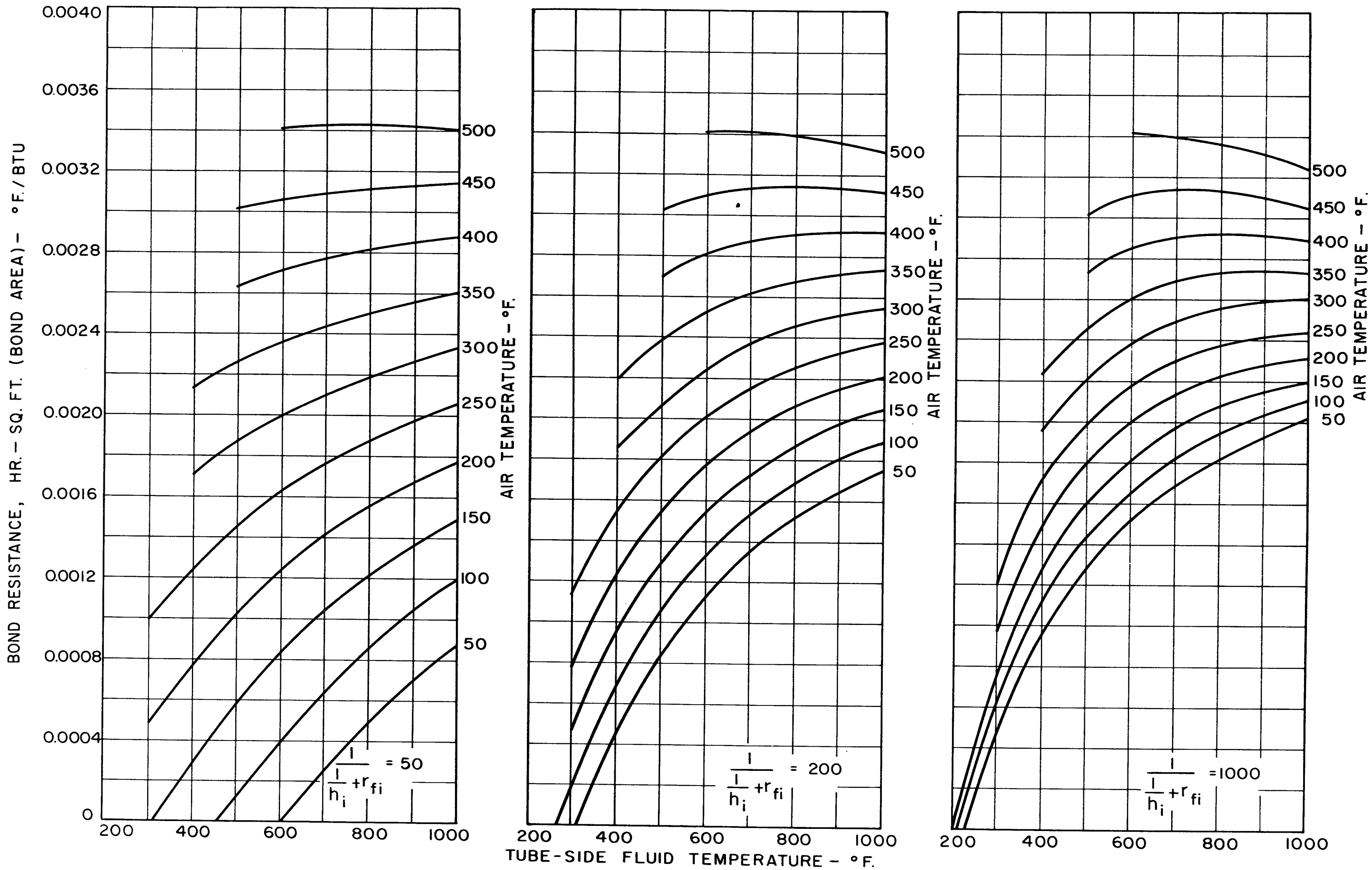

Figure 21. Bond Resistances for a 2-Inch Fin Diameter, 9 Fins per Inch, Type L/C Finned Tube for an Effective Air-film Heat Transfer Coefficient of 8 Btu/hr.-sq.ft.-°F

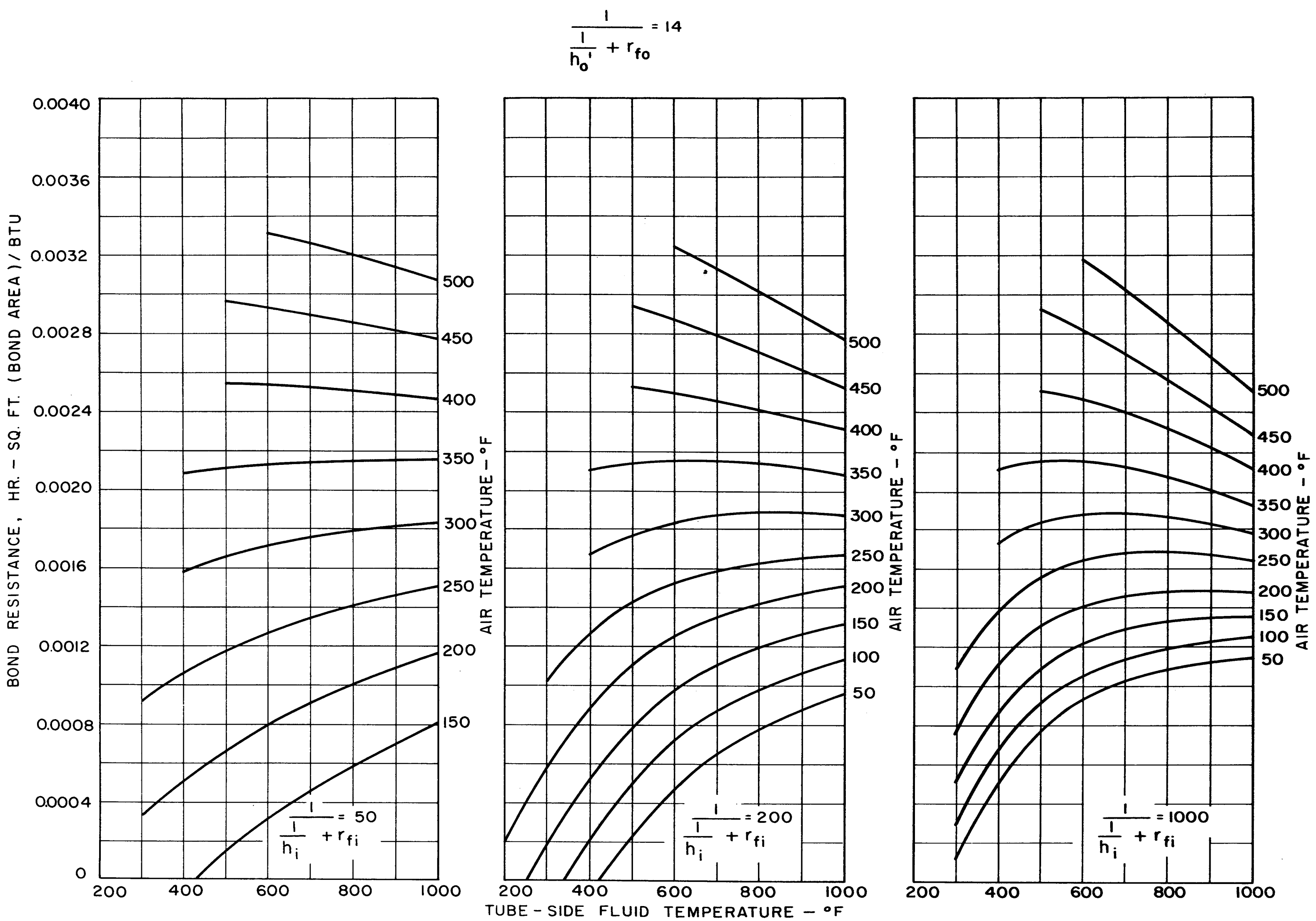

Figure 22. Bond Resistances for a 2-Inch Fin Diameter, 9 Fins per Inch, Type L/C Finned Tube for an Effective Air-film Heat Transfer Coefficient of 14 Btu/hr.-sq.ft.- °F

TABLE IV

Description and Dimensions of the Tube Used in Preparing Figures 20-22

Outside diameter	2.00 in.
Root diameter	1.08 in.
Liner diameter	1.00 in.
Inside diameter	0.87 in.
Fins per inch	9.0
Fin thickness	0.019 in.
Liner wall thickness	0.065 in.
Liner material	steel
Fin material	aluminum
Outside heat transfer area	3.622 sq.ft./ft.
Inside heat transfer area	0.228 sq.ft./ft.
Bond area	0.262 sq.ft./ft.
Fin area	3.398 sq.ft./ft.
Root area	0.224 sq.ft./ft.

NOMENCLATURE

A_b	heat transfer area at the bond between the liner outside diameter and the fin tube inside diameter, sq.ft./ft.
A_f	heat transfer area of the fins, sq.ft./ft.
A_{fb}	mean fin base metal heat transfer area, sq.ft./ft.
A_i	inside heat transfer area, sq.ft./ft.
A_ℓ	mean liner metal heat transfer area, sq.ft./ft.
A_m	mean metal wall heat transfer area, sq.ft./ft.
A_o	outside heat transfer area, sq.ft./ft.
A_r	heat transfer area of root portion of fin tube, sq.ft./ft.
b	base contact length per fin, in.
C_i	tube-side heat transfer coefficient correlation constant
C_o	shell-side heat transfer coefficient correlation constant
c_p	specific heat of oil, Btu/lb.-°F
D	outside diameter of fin, in.
d	outside diameter of liner, in.
D_{eq}	volumetric equivalent diameter for shell-side of test equipment defined as $\frac{4 \times \text{free volume}}{\text{heat transfer area}}$, ft.
D_i	inside diameter of liner or monometallic tube, ft.
E_f	modulus of elasticity of fin material
E_t	modulus of elasticity of liner material
g	radial gap between fin tube and liner, in.
G	mass flow rate at minimum flow area normal to flow, lbs./sq.ft.

h_i	inside heat transfer coefficient, Btu/hr.-sq.ft.(inside area)- °F
h_o'	outside heat transfer coefficient, Btu/hr.-sq.ft.(outside area)- °F
k	thermal conductivity of oil, Btu/hr.-sq.ft.- °F/ft.
k_e	thermal conductivity of fluid in the gap between liner and finned tube, Btu/hr.-sq.ft.- °F/ft.
P	fin spacing in./fin or power to which Reynolds number is raised in outside heat transfer correlation
p_c	contact pressure between fin base and liner, lbs./sq.in.
p_{co}	contact pressure as fabricated between fin base and tube, lbs./sq.in.
Q	mean of the shell-side and tube-side heat duties, Btu/hr.
r_b	bond resistance, hr.-sq.ft.(bond area)- °F/Btu
r_{fb}	metal resistance of the root metal of the fin tube, hr.-sq.ft.(mean metal area)- °F/Btu
r_{fin}	fin resistance, hr.-sq.ft.- °F/Btu
r_g	gap resistance, hr.-sq.ft.(outside area)- °F/Btu
r_{fi}	inside fouling resistance, hr.-sq.ft.(inside area)- °F/Btu
r_{fo}	outside fouling resistance, hr.-sq.ft.- °F/Btu
r_i	inside heat transfer film resistance based on outside area hr.-sq.ft.(outside area)- °F/Btu
r_ℓ	metal resistance of the liner, hr.-sq.ft.(mean metal area)-F/Btu
r_m	metal resistance of a monometallic tube, hr.-sq.ft.(mean metal area)- °F/Btu
r_o	outside heat transfer film resistance, hr.-sq.ft.- °F/Btu
R^*	overall heat transfer resistance exclusive of gap or bond resistance, hr.-sq.ft.(outside area)- °F/Btu

t	tube wall thickness, in.
T_a	ambient fluid bulk temperature or air temperature, °F
t_f	mean fin thickness, in.
T_{fin}	average fin temperature, °F
T_h	heating medium temperature or tube-side fluid temperature, °F
T_{liner}	mean liner temperature, °F
T_o	fin and liner temperature as fabricated, °F
u_f	radial displacement of fin, in.
U_o	overall heat transfer coefficient, Btu/hr.-sq.ft.- °F
$U_{o_{exp}}$	experimentally obtained overall heat transfer coefficient, Btu/hr.-sq.ft.- °F
$U_{o_{pred}}$	predicted overall heat transfer coefficient exclusive of bond resistance, Btu/hr.-sq.ft.- °F
u_t	radial displacement of liner, in.
α_f	thermal expansion coefficient of fin metal, in./in.
α_t	thermal expansion coefficient of liner metal, in./in.
ΔT_m	mean temperature difference between hot and cold fluids, °F
μ	viscosity, lb./ft.-hr. or constant defined by Equation (31)
ν_f	Poisson ratio of fin material
ν_t	Poisson ratio of liner material
ϕ	fin efficiency, fraction

Subscripts

i	inside
o	outside
w	wall

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APPENDIX A. PHYSICAL PROPERTIES OF MOBILTHERM LIGHT AND MOBILTHERM 600

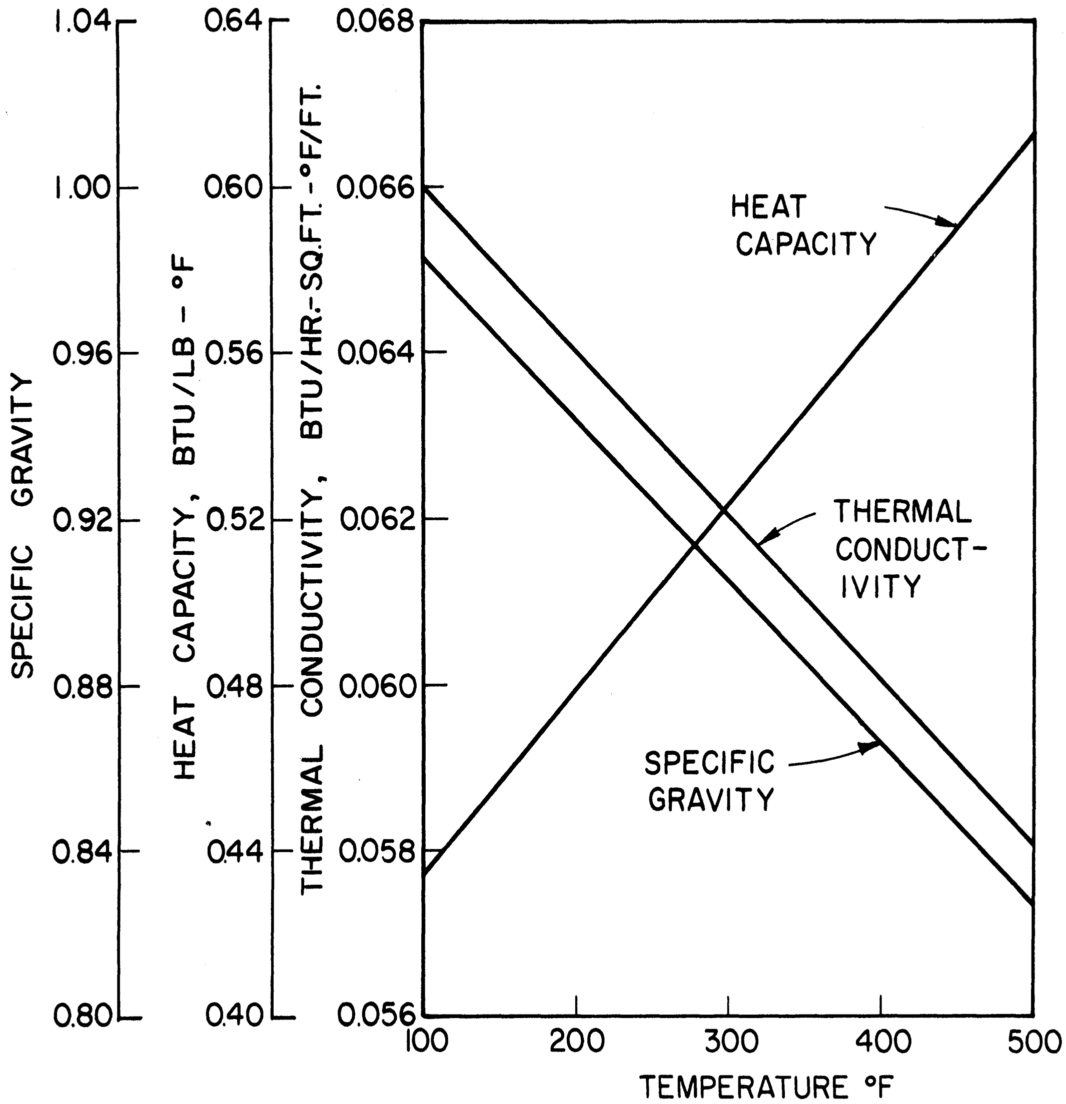

Figure 23. Physical Properties of Mobiltherm Light Aromatic Heat Transfer Oil

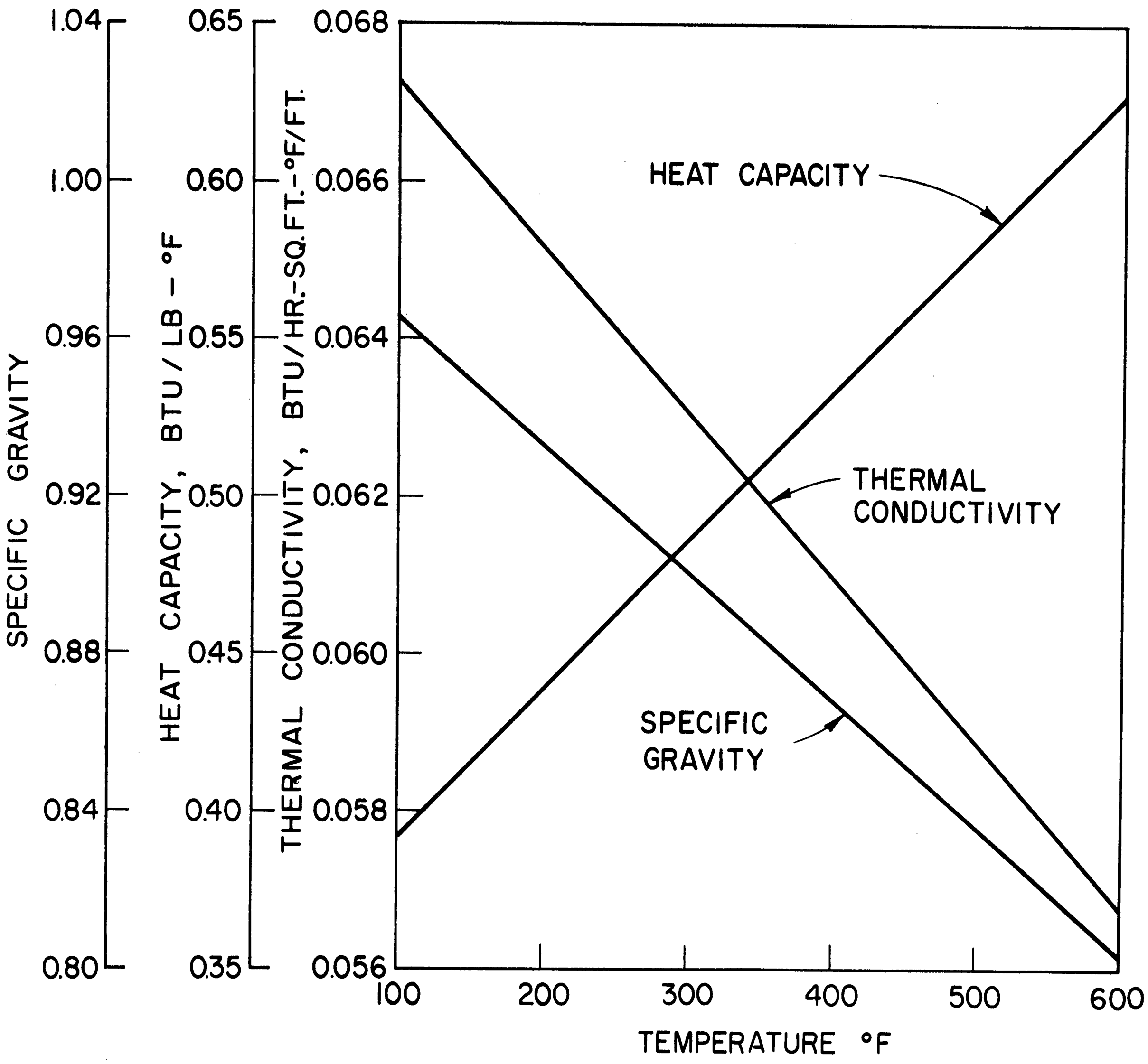

Figure 24. Physical Properties of Mobiltherm 600 Aromatic Heat Transfer Oil

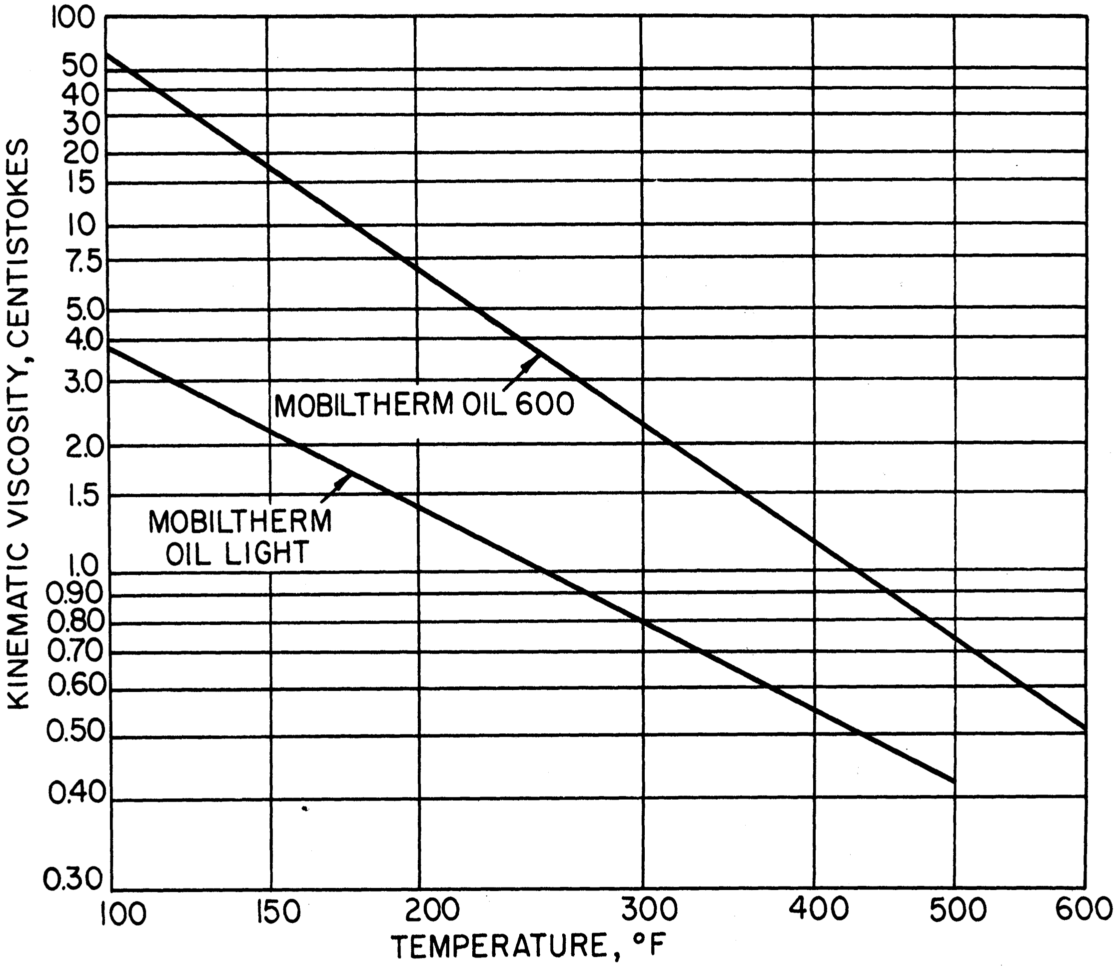

Figure 25. Viscosities of Mobiltherm Light and Mobiltherm 600 Aromatic Oils

APPENDIX B. MODIFIED WILSON PLOT COMPUTER PROGRAM AND WILSON PLOT DATA AND CALCULATED RESULTS FOR TUBES NUMBERS 455 AND 456

TABLE V

Modified Wilson Plot Computer Program Written in The University of Michigan Algorithm Decoder Language

```
         WILSON PLOT DETERMINATION OF INSIDE COEFFICIENT CONSTANT
          DIMENSION TSIC(100), TSOC(100), TTIC(100), TTOC(100),
        1  TSIF(100), TSOF(100), TTIF(100), TTOF(100), WSHEL(100),
        2  WTUBE(100), QTUBE(100), CPT(100), VISS(100), VIST(100),
        3  KTUBE(100), KSHEL(100), PRSH(100), RVISS(100), RVIST(100),
        4  NUSHEL(100), NUTUBE(100), HOPR(100), HIP(100), RFININ(100),
        5  SCALE(5), PRTU(100), TWIA(100), TWIB(100), VISWI(100),
        6  HI(100), RET(100), RES(100), VISWO(100), FUNA(100),
        7  FUNB(100), FUNC(100), UO(100), RHO(100), RFIN(100),
        8  TWO(100), K(8), L(8), M(8), NN(8), O(8), P(8), TTAV(100),
        9  TSAV(100), Q(8), B(2), HO(100), UM(2), MU(2), GRAPH(9000)
          DIMENSION QSHEL(100), QAVG(100), PERDE(100), LMTA(100),
        1  XAMT(100), CPS(100), R(100)
          INTEGER RUNS, TEMP, N, J, R,
        1 POWA, POWB, MAXVA, MAXVC, SH, LIH, SV, LIV, SCALE,
        1 O, ITER, FIRST, LAST
BEGIN     READ FORMAT INFO, RUNS, TUBE, TEMP, ITER, XAO, XAI, XAM, RM,
        1  CI, REP
          PRINT FORMAT TITLE, TUBE, RUNS
          THROUGH INPUT, FOR J=1, 1, J.G. RUNS
INPUT     READ FORMAT DATAT, TSIC(J), TSOC(J), TTIC(J), TTOC(J),
        1 WSHEL(J), WTUBE(J), R(J)
          THROUGH NOR, FOR J = 1, 1, J .G. 8
          READ FORMAT CONSTA, K(J), L(J), M(J), NN(J)
NOR       READ FORMAT CONSTB, O(J), P(J), Q(J)
          READ FORMAT DATAC, DIAS, AFS, AFT, DIAT,TTEMP, NAMEA,
        1  NAMEB, NAMEC, NAMED
          PRINT FORMAT FLUIDS, NAMEA, NAMEB
          PRINT FORMAT FLUIDT, NAMEC, NAMED
          PRINT COMMENT $-$
          PRINT FORMAT HEDA
          PRINT FORMAT INPUTA, RUNS, TUBE, TEMP, ITER, XAO, XAI, XAM,
        1  RM, CI, REP
          PRINT COMMENT $-$
          PRINT FORMAT HEDB
          THROUGH NORTH, FOR J = 1, 1, J .G. 8
NORTH     PRINT FORMAT INPUTB, J, K(J), L(J), M(J), NN(J), O(J), P(J),
        1 Q(J)
          PRINT COMMENT $-$
          PRINT FORMAT HEDC
          PRINT FORMAT INPUTC, DIAS, AFS, AFT, DIAT
          PRINT COMMENT $-$
          PRINT FORMAT HED
          THROUGH FOUR , FOR J=1,1,J.G.RUNS
FOUR      PRINT FORMAT  DATAA, R(J), TSIC(J), TSOC(J), TTIC(J),TTOC(J),
        1 WSHEL(J), WTUBE(J)
          PRINT FORMAT NOTE, TTEMP
          N= 1
ALPHA     WHENEVER TEMP .E. 1, TRANSFER TO GAMMA
          TSIF(N) = TSIC(N)
          TSOF(N) = TSOC(N)
          TTIF(N) = TTIC(N)
          TTOF(N) = TTOC(N)
          TRANSFER TO SIGMA
GAMMA     TSIF(N) = 1.8 * TSIC(N) + 32
          TSOF(N) = 1.8 * TSOC(N) + 32
          TTIF(N) = 1.8 * TTIC(N) + 32
          TTOF(N) = 1.8 * TTOC(N) + 32
SIGMA     TSAV(N) = 0.5 * ( TSIF(N) + TSOF(N))
          TTAV(N) = 0.5 * ( TTIF(N) + TTOF(N))
          CPS(N) = K(1) + L(1)*TSAV(N) + M(1)*TSAV(N).P.2
        1 + NN(1)*TSAV(N).P.3 + O(1)*TSAV(N).P.4
          CPT(N) = K(2) + L(2)*TTAV(N) + M(2)*TTAV(N).P.2
        1 +NN(2)*TTAV(N).P.3 + O(2)*TTAV(N).P.4
          QSHEL(N) = WSHEL(N)*CPS(N)*.ABS.(TSOF(N)-TSIF(N))
          QTUBE(N) = WTUBE(N)*CPT(N)*.ABS. (TTOF(N)-TTIF(N))
          QAVG(N) = 0.5 * ( QSHEL(N) + QTUBE(N))
          PERDE(N) = (100*(QTUBE(N)-QSHEL(N)))/(QTUBE(N) + QSHEL(N))
          XAMT(N) = .ABS. (TTAV(N) - TSAV(N))
          DELA = .ABS.(TTIF(N)-TSOF(N))
          DELB = .ABS.(TTOF(N)-TSIF(N))
          WHENEVER .ABS. (DELA - DELB) .L. 0.3
          LMTA(N) = XAMT(N)
          OTHERWISE
          LMTA(N) = (DELA -DELB)/(ELOG.(DELA/DELB))
          END OF CONDITIONAL
          WHENEVER LMTA(N) .G. XAMT(N), LMTA(N) = XAMT(N)
          UO(N) = ( QAVG(N))/( XAO*LMTA(N))
          VISS(N) = EXP.(K(6) + L(6)/TSAV(N) + M(6)/TSAV(N).P.2 +
        1 NN(6)/TSAV(N).P.3 + O(6)/TSAV(N).P.4 + P(6)/TSAV(N).P.5 +
        1 Q(6)/TSAV(N).P.6)
          VIST(N) = EXP.(K(7) + L(7)/TTAV(N) + M(7)/TTAV(N).P.2 +
        1 NN(7)/TTAV(N).P.3 + O(7)/TTAV(N).P.4 + P(7)/TTAV(N).P.5 +
        1 Q(7)/TTAV(N).P.6)
          KSHEL(N) = K(3) + L(3)*TSAV(N) + M(3)*TSAV(N).P.2 +
        1 NN(3)*TSAV(N).P.3 + O(3)*TSAV(N).P.4
          KTUBE(N) = K(4) + L(4)*TTAV(N) + M(4)*TTAV(N).P.2 +
        1 NN(4)*TTAV(N).P.3 + O(4)*TTAV(N).P.4
          RES(N) = (DIAS*WSHEL(N))/(AFS*VISS(N))
          RET(N) = (DIAT*WTUBE(N))/(AFT*VIST(N))
          PRSH(N) = (CPS(N)*VISS(N))/KSHEL(N)
          PRTU(N) = (CPT(N)*VIST(N))/KTUBE(N)
          WHENEVER N .E. RUNS, TRANSFER TO XRAY
          N = N + 1
          TRANSFER TO ALPHA
XRAY      PRINT FORMAT HEADA
          THROUGH CHI, FOR J=1,1, J.G. RUNS
CHI       PRINT FORMAT RESLT1, R(J), TSIF(J), TSOF(J), TTIF(J),TTOF(J),
        1 WSHEL(J), WTUBE(J), QSHEL(J), QTUBE(J)
```

```
          PRINT FORMAT HEADB
          THROUGH OUT, FOR J=1,1, J.G. RUNS
OUT       PRINT FORMAT RESLT2, R(J), QAVG(J), PERDE(J), LMTA(J), UO(J),
        1 RES(J), RET(J), PRSH(J), PRTU(J)
          D = 1
DELTA     N = 1
          MAG = 0
OMEGA     TWIA(N) = TTAV(N)
BETA      VISWI(N) = EXP.(K(7) + L(7)/TWIA(N) + M(7)/TWIA(N).P.2 +
        1 NN(7)/TWIA(N).P.3 + O(7)/TWIA(N).P.4 + P(7)/TWIA(N).P.5 +
        1 Q(7)/TWIA(N).P.6)
          HIP(N) = (CI*RET(N).P.0.8*PRTU(N).P.0.33333*KTUBE(N)*VIST(N)
        1 .P.0.14)/(VISWI(N).P.0.14*DIAT)
          RFININ(N) = K(8) + L(8)/HIP(N) + M(8)/HIP(N).P.2 +
        1 NN(8)/HIP(N).P.3 + O(8)/HIP(N).P.4 + P(8)/HIP(N).P.5 +
        1 Q(8)/HIP(N).P.6
          HI(N) = 1/(1/HIP(N) + RFININ(N))
          WHENEVER TTAV(N) .G. TSAV(N), TRANSFER TO KAPPA
          TWIB(N) = TTAV(N) + (QAVG(N)/(XAI*HI(N)))
          TRANSFER TO PHI
KAPPA     TWIB(N) = TTAV(N) -(QAVG(N)/(XAI*HI(N)))
PHI       WHENEVER .ABS. (TWIA(N) - TWIB(N)) .LE. 0.2, TRANSFER TOEIGHT
          TWIA(N) = TWIB(N)
          TRANSFER TO BETA
EIGHT     WHENEVER TTAV(N) .G. TSAV(N), TRANSFER TO NINE
          TWO(N) = TWIB(N) + (QAVG(N)*RM/XAM)
          TRANSFER TO TEN
NINE      TWO(N) = TWIB(N) - (QAVG(N)*RM/XAM)
TEN       VISWO(N) = EXP.(K(6) + L(6)/TWO(N) + M(6)/TWO(N).P.2 +
        1 NN(6)/TWO(N).P.3 + O(6)/TWO(N).P.4 + P(6)/TWO(N).P.5 +
        1 Q(6)/TWO(N).P.6)
          RHO(N) = (1/UO(N)) - (XAO/(XAI*HI(N))) - (XAO*RM/XAM)
          RFIN(N) = K(5) + L(5)*RHO(N) + M(5)*RHO(N).P.2 +
        1 NN(5)*RHO(N).P.3 + O(5)*RHO(N).P.4
        1 + P(5)*RHO(N).P.5 + Q(5)*RHO(N).P.6
          HOPR(N) = 1/(RHO(N) - RFIN(N))
          RVISS(N) = VISS(N)/VISWO(N)
          RVIST(N) = VIST(N)/VISWI(N)
          HO(N) = 1/RHO(N)
          NUSHEL(N) = HOPR(N)*DIAS/KSHEL(N)
          NUTUBE(N) = HIP(N)*DIAT/KTUBE(N)
          FUNA(N) = (CI*VISS(N).P.0.14*XAO)/(HIP(N)*VISWO(N).P.0.14*XAI
        1 )
          FUNB(N) = (1/UO(N) - RM*(XAO/XAM) - RFIN(N) - RFININ(N)*(XAO/
        1 XAI))*(VISS(N).P.0.14/VISWO(N).P.0.14)
          WHENEVER FUNA(N) .G. MAG
          MAG = FUNA(N)
          MAGN = FUNB(N)
          OTHERWISE
          CONTINUE
          END OF CONDITIONAL
          WHENEVER N.E. RUNS, TRANSFER TO ELEVEN
          N = N + 1
          TRANSFER TO OMEGA
ELEVEN    EXECUTE LSTSQ.(FUNA, FUNB, RUNS, B, 1)
          CIC = 1.0/B(1)
          PRINT FORMAT SUE, D, B(0), CIC
          PRINT FORMAT MARIE
          THROUGH CAT, FOR J = 1, 1, J.G. RUNS
CAT       PRINT FORMAT DOG, R(J), FUNA(J), FUNB(J)
          WHENEVER (.ABS.(CI - CIC))/CIC .LE. 0.0005, TRANSFER TO BLUR
          WHENEVER  D .E. ITER, TRANSFER TO BLUR
          D = D + 1
          CI = CIC
          TRANSFER TO DELTA
BLUR      PRINT FORMAT HEADT
          THROUGH BED, FOR J = 1, 1, J .G. RUNS
BED       PRINT FORMAT TEMPA, R(J), TSAV(J), TWO(J), TWIB(J),TTAV(J)
          PRINT FORMAT HEADD
          THROUGH DEB, FOR J = 1, 1, J .G. RUNS
DEB       PRINT FORMAT RESLT4, R(J),HIP(J),RFININ(J),HI(J),HOPR(J),
        1 RFIN(J), HO(J), NUSHEL(J), NUTUBE(J)
          PRINT FORMAT VISCO
          THROUGH SCHOOL, FOR J = 1, 1,  J.G. RUNS
SCHOOL    PRINT FORMAT RESLT8, R(J), VISS(J), VISWO(J), RVISS(J),
        1 VIST(J), VISWI(J), RVIST(J)
          PRINT FORMAT RESLT3, CIC, B(0)
          POWA = .ABS.(ELOG.(MAG)/2.303)
          POWB = .ABS.(ELOG.(MAGN)/2.303)
          MAXVA = MAG*10.P.(POWA + 1)
          MAXVB = (MAXVA + 1)/10.0.P.(POWA + 1)
TROD      MAXVC = MAGN*10.P.(POWB + 1)
          MAXVD = (MAXVC + 1)/10.0.P.(POWB + 1)
          SCALE(0) = 1
          SCALE(1) = POWB
          SCALE(2) = 3
          SCALE(3) = POWA
          SCALE(4) = 3
          UM(0) = 0.0
          MU(0) = B(0)
          UM(1) = MAXVB
          MU(1) = B(0) + B(1)*MAXVB
          WHENEVER MU(1) .G. MAXVD
          MAGN = MU(1)
          TRANSFER TO TROD
          OTHERWISE
          CONTINUE
          END OF CONDITIONAL
          LIH = MAXVC + 1
```

TABLE V (Continued)

```
      SH = 5.0/(MAXVD*10.0.P.POWB)
      LIV = MAXVA + 1
      SV = 10.0/(MAXVB*10.0.P.POWA)
      EXECUTE PLOI1.(SCALE, LIH, SH, LIV, SV)
      EXECUTE PLOT2.(GRAPH, MAXVB, 0, MAXVD, 0)
      EXECUTE PLOT3. ($*$, FUNA(1), FUNB(1), RUNS)
      EXECUTE PLOT3. ($X$, UM(0), MU(0), 2)
      PRINT FORMAT NAME
      EXECUTE PLOT4.(36, ORD)
      PRINT FORMAT ABSS, POWA
      PRINT FORMAT TRANS, POWB
      LIH = 1
      SH = 50
      LIV = 1
      SV = 100
      EXECUTE PLOT1.(SCALE, LIH, SH, LIV, SV)
      EXECUTE PLOT2.(GRAPH, MAXVB, 0, MAXVD, 0)
      EXECUTE PLOT3. ($*$, FUNA(1), FUNB(1), RUNS)
      EXECUTE PLOT3. ($X$, UM(0), MU(0), 2)
      PRINT FORMAT NAME
      EXECUTE PLOT4.(36, ORD)
      PRINT FORMAI ABSS, POWA
      PRINT FORMAT TRANS, POWB
      PRINT COMMENT $1$
      VECTOR VALUES INFO = $ I5, C5, 2I5, 3F10.4, 2E10.4, F10.2 *$
      VECTOR VALUES TITLE = $ 75H1WILSON PLOT DETERMINATION OF THE
    1 INSIDE HEAT-TRANSFER COEFFICIENT FOR TUBE C5, 20H , NUMBER OF
    1  RUNS IS   I3  *$
      VECTOR VALUES DATAT = $ 4F10.3, 2F10.0,   S7, I3  .*$
      VECTOR VALUES CONSTA = $ 4E15.8*$
      VECTOR VALUES CONSTB = $ 3E15.8*$
      VECTOR VALUES DATAC = $ 4E10.5, C5, 4C6   *$
      VECTOR VALUES HEADA = $ 101H1         RUN       TSIF      TSOF
    1      TTIF       TTOF   W SHELL    W TUBE         Q SHELL
    1  Q TUBE /  *$
      VECTOR VALUES SUE = $ 6H2AFTER I3, 25H ITERATIONS, INTERCEPT
    1 IS E15.8, 8H , CI IS F11.8 *$
      VECTOR VALUES RESLT1 = $ I11, 4F10.3, 2F10.0, 2F15.0 *$
      VECTOR VALUES HEADB = $  86H1  RUN     Q AVG   PER DEV       L
    1 MTD        UO  RE SHELL   RE TUBE  PR SHELL   PR TUBE  /*$
      VECTOR VALUES RESLT2 = $ I6, F10.0, 3F10.3, 2F10.0, 2F10.3 *$
      VECTOR VALUES RESLT3 = $ 29H2WILSON PLOT CONSTANT EQUALS
    1 F10.8, 19H , INTERCEPT EQUALS E15.8 *$
      VECTOR VALUES MARIE = $ 66H0  RUN              FUNCTION A
    1   FUNCTION B                          *$
      VECTOR VALUES DOG = $ I6, 2E20.8 *$
      VECTOR VALUES HEDA = $ 86H0RUNS TUBE TEMP ITER       XAO
    1   XAI        XAM            RM            CI          REP / *$
      VECTOR VALUES INPUTA = $ I5, C5, 2I5, 3F10.4, 2E12.4, F12.4*$
      VECTOR VALUES HEDB = $ 110H0  NO                   K
    1 L                M              NN                O               P
    1                Q / *$
      VECTOR VALUES INPUTB = $ I5, 7E15.8 *$
      VECTOR VALUES HEDC = $ 48H0        DIAS           AFS           AF
    1 T        DIAT / *$
      VECTOR VALUES INPUTC = $ 4E12.5 *$
      VECTOR VALUES HEADT = $ 45H1 RUN      TSAV   TWALL O   TWALL
    1 I       TTAV   / *$
      VECTOR VALUES TEMPA = $ I5, 4F10.3   *$
      VECTOR VALUES HEADD = $ 89H1 RUN  HI PRIME     RFIN IN
    1  HI    PRIME    RFIN OUT        HO  NU SHELL   NU TUBE  /*$
      VECT      ES RESLT4 = $ I5, F10.3, E12.4, 2F10.3, E12.4,
    1 3F1(
      VEC      ALUES VISCO = $ 1H1 S35, 22H VISCOSITIES  LB/FT-HR //
    1  95   UN    VISC. SHELL   VISC SH WALL      VISS/VISSW     VI
    1 SC. TUBE   VISC TU WALL      VIST/VISTW  / *$
      VECTOR VALUES RESLT8 = $ I5, 6F15.4  *$
      VECTOR VALUES FLUIDS = $ 21H0SHELL SIDE FLUID IS  2C6 *$
      VECTOR VALUES FLUIDT = $ 20H0TUBE SIDE FLUID IS 2C6   *$
      VECTOR VALUES NOTE = $ 42H0  NOTE - INPUT DATA TEMPERATURES A
    1 RE IN  C5  *$
      VECTOR VALUES HED = $ 66H1  RUN       TSI       TSO       TTI
    1        TTO  W SHELL    W TUBE  /*$
      VECTOR VALUES DATAA = $ I6, 4F10.3, 2F10.0  *$
      VECTOR VALUES ORD  = $                    FUNCTION B  X TEN.P.E *$
      VECTOR VALUES NAME = $ 1H1 S46, 31H FUNCTION B VERSUS FUNCTIO
    1 N A   *$
      VECTOR VALUES ABSS = $ 1H0 S47, 20H FUNCTION A  X 10.P.  I1*$
      VECTOR VALUES TRANS = $ 1H0 S56, 4H E =    I2  *$
      TRANSFER TO BEGIN
      END OF PROGRAM
```

NOMENCLATURE

```
AFS        SHELL-SIDE FLOW AREA - SQFT
AFT        TUBE-SIDE FLOW AREA - SQFT
B          CONSTANTS FROM LEAST SQUARE SUBROUTINE
CI         INSIDE HEAT TRANSFER COEFFICIENT CORRELATION CONSTANT
CIC        CALCULATED VALUE OF INSIDE HEAT TRANSFER COEFFICIENT CONSTANT
CPS        SHELL-SIDE SPECIFIC HEAT - BTU/LB-F
CPT        TUBE-SIDE SPECIFIC HEAT - BTU/LB-F
DIAS       SHELL-SIDE EQUIVALENT DIAMETER - FT
DIAT       INSIDE DIAMETER OF TUBE - FT
FUNA       FUNCTION A
FUNB       FUNCTION B
HIP        INSIDE HEAT TRANSFER COEFFICIENT - BTU/HR-SQFT-F
HI         INSIDE HEAT TRANSFER COEFFICIENT(INCLUDES INSIDE FIN RESISTANCE
           IF ANY) BTU/HR-SQFT-F
HOPR       SHELL-SIDE HEAT TRANSFER COEFFICIENT - BTU/HR-SQFT-F
HO         SHELL-SIDE HEAT TRANSFER COEFFICIENT (INCLUDES RFIN) - BTU/HR-SQFT-F
K          POLYNOMIAL CONSTANT FOR PHYSICAL PROPERTIES
KSHEL      THERMAL CONDUCTIVITY OF SHELL-SIDE FLUID - BTU/HR-SQFT-F/FT
KTUBE      THERMAL CONDUCTIVITY OF TUBE-SIDE FLUID - BTU/HR-SQFT-F/FT
L          POLYNOMIAL CONSTANT FOR PHYSICAL PROPERTIES
LMTA       LOGARITHMIC TEMPERATURE DIFFERENCR - F
M          POLYNOMIAL CONSTANT FOR PHYSICAL PROPERTIES
NN         POLYNOMIAL CONSTANT FOR PHYSICAL PROPERTIES
NUSHEL     SHELL-SIDE NUSSELT NUMBER
NUTUBE     TUBE-SIDE NUSSELT NUMBER
O          POLYNOMIAL CONSTANT FOR PHYSICAL PROPERTIES
P          POLYNOMIAL CONSTANT FOR PHYSICAL PROPERTIES
PERDE      PER CENT DEVIATION IN HEAT BALANCE
PRSH       PRANDTL NUMBER OF SHELL-SIDE FLUID
PRTU       PRANDTL NUMBER OF TUBE-SIDE FLUID
Q          POLYNOMIAL CONSTANT FOR PHYSICAL PROPERTIES
QAVG       AVERAGE OF SHELL-SIDE AND TUBE-SIDE HEAT FLUXES - BTU/HR
QSHEL      SHELL-SIDE HEAT FLUX - BTU/HR
QTUBE      TUBE-SIDE HEAT FLUX - BTU
RES        SHELL-SIDE REYNOLDS NUMBER
RET        TUBE-SIDE REYNOLDS NUMBER
RFININ     FIN RESISTANCE OF FINS INSIDE OF TUBE IF ANY - HR-SQFT-F/BTU
RFIN       FIN RESISTANCE OF EXTERNAL FINS - HR-SQFT-F/BTU
RM         METAL RESISTANCE - HR-SQFT-F/BTU
TSAV       AVERAGE SHELL-SIDE FLUID TEMPERATURE - F
TSIC       INLET SHELL-SIDE FLUID TEMPERATURE - F OR C
TSIF       INLET SHELL-SIDE FLUID TEMPERATURE - F
TSOC       OUTLET SHELL-SIDE FLUID TEMPERATURE - F OR C
TSOF       OUTLET SHELL-SIDE FLUID TEMPERATURE - F
TTAV       AVERAGE TUBE-SIDE FLUID TEMPERATURE - F
TTIC       INLET TUBE-SIDE FLUID TEMPERATURE - F OR C
TTIF       INLET TUBE-SIDE FLUID TEMPERATURE - F
TTOC       OUTLET TUBE-SIDE FLUID TEMPERATURE - F OR C
TTOF       OUTLET TUBE-SIDE FLUID TEMPERATURE - F
TWIA,TWIB  INSIDE TUBE-WALL TEMPERATURE - F
TWO        OUTSIDE TUBE-WALL TEMPERATURE - F
UO         OVERALL HEAT TRANSFER COEFFICIENT - BTU/HR-SQFT-F
VISS       SHELL-SIDE FLUID VISCOSITY - LB/FT-HR
VIST       TUBE-SIDE FLUID VISCOSITY - LB/FT-HR
VISWI      VISCOSITY AT INSIDE TUBE-WALL TEMPERATURE - LB/FT-HR
VISWO      VISCOSITY AT OUTSIDE TUBE-WALL TEMPERATURE - LB/FT-HR
WSHEL      SHELL-SIDE FLUID FLOW RATE - LB/HR
WTUBE      TUBE-SIDE FLUID FLOWRATE - LB/HR
XAI        INSIDE HEAT TRANSFER AREA - SQFT
XAM        MEAN METAL HEAT TRANSFER AREA - SQFT
XAO        OUTSIDE HEAT TRANSFER AREA - SQFT
```

TABLE VI

Wilson Plot Data and Calculated Results for Tube Number 455, Runs 1-8

SHELL SIDE FLUID IS MOBIL LIGHT

TUBE SIDE FLUID IS MOBIL 600

RUNS	TUBE	TEMP	ITER	XAO	XAI	XAM	RM	CI	REP
6	455	0	10	19.8500	1.1400	1.3100	.9340E-04	.2800E-01	1.0000

NO	K	L	M	NN	O	P	Q
1	.38925000E 00	.44750000E-03	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
2	.34400000E 00	.46333332E-03	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
3	.67977499E-01	-.19775000E-04	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
4	.71699999E-01	-.21000000E-04	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
5	-.20489551E-03	.10464268E 01	-.52113342E 02	.54997295E 03	.32380452E 05	-.75056534E 06	.00000000E 00
6	-.21480229E 01	.14160692E 04	-.27029259E 06	.32850279E 08	-.20186315E 10	.45553047E 11	.00000000E 00
7	-.29052144E 01	.22908387E 04	-.40461752E 06	.38134658E 08	-.70443591E 09	.00000000E 00	.00000000E 00
8	.00000000E 00	.00000000E 00	.00000000E 00	.00000000E 00	.00000000E 00	.00000000E 00	.00000000E 00

DIAS	AFS	AFT	DIAT
.36600E-01	.28800E-01	.37950E-02	.69500E-01

RUN	TSI	TSO	TTI	TTO	W SHELL	W TUBE
1	352.810	359.200	507.330	494.230	34700	15250
2	352.400	358.670	507.630	493.800	34460	14080
3	352.520	358.300	507.860	493.630	34800	12800
4	352.290	357.710	510.330	495.350	34600	11820
5	353.140	358.630	519.750	503.150	34350	10720
8	353.070	357.780	514.060	497.160	34500	9025

NOTE - INPUT DATA TEMPERATURES ARE IN FAHR.

RUN	TSIF	TSOF	TTIF	TTOF	W SHELL	W TUBE	Q SHELL	Q TUBE
1	352.810	359.200	507.330	494.230	34700	15250	121634	115076
2	352.400	358.670	507.630	493.800	34460	14080	118479	112162
3	352.520	358.300	507.860	493.630	34800	12800	110286	104917
4	352.290	357.710	510.330	495.350	34600	11820	102789	102163
5	353.140	358.630	519.750	503.150	34350	10720	103439	103385
8	353.070	357.780	514.060	497.160	34500	9025	89096	88199

RUN	Q AVG	PER DEV	LMTD	UO	RE SHELL	RE TUBE	PR SHELL	PR TUBE
1	118355	-2.771	144.749	41.192	32430	197132	12.241	13.338
2	115321	-2.739	145.147	40.026	32144	181956	12.258	13.341
3	107602	-2.495	145.294	37.309	32445	165436	12.262	13.340
4	102476	-.305	147.789	34.932	32205	154188	12.277	13.249
5	103412	-.026	155.499	33.503	32087	145173	12.245	12.888
8	88647	-.506	150.103	29.752	32167	119165	12.262	13.131

AFTER 7 ITERATIONS, INTERCEPT IS .93935383E-03 , CI IS .02857228

RUN	FUNCTION A	FUNCTION B
1	.53210098E-03	.19634040E-01
2	.56833798E-03	.20690982E-01
3	.61373201E-03	.22365588E-01
4	.65218849E-03	.23906303E-01
5	.69611913E-03	.25321983E-01
8	.80781739E-03	.29173537E-01

RUN	HI PRIME	RFIN IN	HI	HO PRIME	RFIN OUT	HO	NU SHELL	NU TUBE
1	948.285	.0000E 00	948.285	1011.027	.3510E-02	222.244	607.238	1077.180
2	885.951	.0000E 00	885.951	1278.823	.3133E-02	255.428	767.964	1006.351
3	820.353	.0000E 00	820.353	1154.449	.3297E-02	240.227	693.246	931.848
4	772.636	.0000E 00	772.636	945.919	.3619E-02	213.864	567.948	878.278
5	723.315	.0000E 00	723.315	1067.194	.3423E-02	229.356	640.948	824.652
8	622.017	.0000E 00	622.017	1136.054	.3322E-02	237.951	682.203	707.738

TABLE VII

Wilson Plot Data and Calculated Results for Tube Number 455, Runs 10-17

WILSON PLOT DETERMINATION OF THE INSIDE HEAT-TRANSFER COEFFICIFNT FOR TUBE 455 , NUMBER OF RUNS IS 8

SHELL SIDE FLUID IS MOBIL LIGHT

TUBE SIDE FLUID IS MOBIL 600

RUNS	TUBE	TEMP	ITER	XAO	XAI	XAM	RM	CI	REP
8	455	0	10	19.8500	1.1400	1.3100	.9340E-04	.2800E-01	1.0000

NO	K	L	M	NN	O	P	Q
1	.38925000E 00	.44750000E-03	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
2	.34400000E 00	.46333332E-03	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
3	.67977499E-01	-.19775000E-04	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
4	.71699999E-01	-.21000000E-04	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
5	-.20489551E-03	.10464268E 01	-.52113342E 02	.54997295E 03	.32380452E 05	-.75056534E 06	.00000000E 00
6	-.21480229E 01	.14160692E 04	-.27029259E 06	.32850279E 08	-.20186315E 10	.45553047E 11	.00000000E 00
7	-.29052144E 01	.22908387E 04	-.40461752E 06	.38134658E 08	-.70443591E 09	.00000000E 00	.00000000E 00
8	.00000000E 00	.00000000E 00	.00000000E 00	.00000000E 00	.00000000E 00	.00000000E 00	.00000000E 00

DIAS	AFS	AFT	DIAT
.36600E-01	.28800E-01	.37950E-02	.69500E-01

RUN	TSI	TSO	TTI	TTO	W SHELL	W TUBE
10	352.820	357.400	473.500	462.910	34300	14660
11	353.590	357.980	474.210	463.700	34300	13350
12	351.610	355.930	473.780	462.980	34300	12700
13	359.670	363.290	477.270	466.270	34150	11520
14	358.570	362.440	475.760	464.760	33860	10890
15	355.490	359.040	476.800	464.680	34500	9850
16	358.060	361.540	482.000	469.310	35000	9160
17	358.640	362.030	492.740	478.560	34450	8150

NOTE - INPUT DATA TEMPERATURES ARE IN FAHR.

RUN	TSIF	TSOF	TTIF	TTOF	W SHELL	W TUBE	Q SHELL	Q TUBE
10	352.820	357.400	473.500	462.910	34300	14660	86113	87085
11	353.590	357.980	474.210	463.700	34300	13350	82586	78753
12	351.610	355.930	473.780	462.980	34300	12700	81136	76949
13	359.670	363.290	477.270	466.270	34150	11520	68118	71291
14	358.570	362.440	475.760	464.760	33860	10890	72146	67308
15	355.490	359.040	476.800	464.680	34500	9850	67254	67106
16	358.060	361.540	482.000	469.310	35000	9160	67022	65605
17	358.640	362.030	492.740	478.560	34450	8150	64290	65760

RUN	Q AVG	PER DEV	LMTD	UO	RE SHELL	RE TUBE	PR SHELL	PR TUBE
10	86599	.561	113.068	38.584	31940	163046	12.273	14.930
11	80669	-2.376	113.142	35.919	32027	149013	12.249	14.889
12	79042	-2.648	114.580	34.753	31767	141366	12.321	14.920
13	69704	2.276	110.249	31.851	32621	130334	12.051	14.737
14	69727	-3.469	109.716	32.016	32219	122319	12.085	14.818
15	67180	-.110	113.421	29.839	32406	110892	12.197	14.792
16	66313	-1.069	115.794	28.850	33211	105563	12.109	14.533
17	65025	1.130	125.238	26.157	32758	98404	12.090	14.033

AFTER 5 ITERATIONS, INTERCEPT IS .83635468E-03 , CI IS .02778355

RUN	FUNCTION A	FUNCTION B
10	.58126117E-03	.21656724E-01
11	.62548427E-03	.23365291E-01
12	.65295748E-03	.24335810E-01
13	.69718346E-03	.26343816E-01
14	.73300364E-03	.27067725E-01
15	.79624251E-03	.29347547E-01
16	.83569170E-03	.30683516E-01
17	.90167879E-03	.33492961E-01

RUN	HI PRIME	RFIN IN	HI	HO PRIME	RFIN OUT	HO	NU SHELL	NU TUBE
10	840.265	.0000E 00	840.265	1354.693	.3041E-02	264.574	813.413	943.924
11	780.964	.0000E 00	780.964	1170.190	.3275E-02	242.168	702.784	877.531
12	747.932	.0000E 00	747.932	1194.677	.3242E-02	245.177	717.021	840.250
13	701.009	.0000E 00	701.009	800.460	.3893E-02	194.482	481.624	788.442
14	664.901	.0000E 00	664.901	1445.285	.2939E-02	275.407	869.330	747.447
15	612.005	.0000E 00	612.005	1435.390	.2950E-02	274.227	862.470	688.097
16	582.743	.0000E 00	582.743	1627.724	.2752E-02	297.058	978.842	656.293
17	541.241	.0000E 00	541.241	957.022	.3600E-02	215.305	575.611	611.632

TABLE VIII

Wilson Plot Data and Calculated Results for Tube Number 455, Runs 18-26

WILSON PLOT DETERMINATION OF THE INSIDE HEAT-TRANSFER COEFFICIENT FOR TUBE 455 , NUMBER OF RUNS IS 7

SHELL SIDE FLUID IS MOBIL LIGHT

TUBE SIDE FLUID IS MOBIL 600

RUNS	TUBE	TEMP	ITER	XAO	XAI	XAM	RM	CI	REP
7	455	0	10	19.8500	1.1400	1.3100	.9340E-04	.2800E-01	1.0000

NO	K	L	M	NN	O	P	Q
1	.38925000E 00	.44750000E-03	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
2	.34400000E 00	.46333332E-03	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
3	.67977499E-01	-.19775000E-04	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
4	.71699999E-01	-.21000000E-04	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
5	-.20489551E-03	.10464268E 01	-.52113342E 02	.54997295E 03	.32380452E 05	-.75056534E 06	.00000000E 00
6	-.21480229E 01	.14160692E 04	-.27029259E 06	.32850279E 08	-.20186315E 10	.45553047E 11	.00000000E 00
7	-.29052144E 01	.22908387E 04	-.40461752E 06	.38134658E 08	-.70443591E 09	.00000000E 00	.00000000E 00
8	.00000000E 00	.00000000E 00	.00000000E 00	.00000000E 00	.00000000E 00	.00000000E 00	.00000000E 00

DIAS	AFS	AFT	DIAT
.36600E-01	.28800E-01	.37950E-02	.69500E-01

RUN	TSI	TSO	TTI	TTO	W SHELL	W TUBE
18	342.100	344.230	423.060	415.280	34800	9840
19	351.520	353.550	421.440	414.890	35100	10750
21	351.340	353.560	419.020	413.180	34400	12320
22	351.430	353.820	418.410	412.700	34400	12920
24	351.440	353.790	417.760	412.310	34400	14300
25	352.710	355.090	417.790	412.530	34400	14930
26	352.030	354.550	418.510	413.440	34400	15780

NOTE - INPUT DATA TEMPERATURES ARE IN FAHR.

RUN	TSIF	TSOF	TTIF	TTOF	W SHELL	W TUBE	Q SHELL	Q TUBE
18	342.100	344.230	423.060	415.280	34800	9840	40236	41203
19	351.520	353.550	421.440	414.890	35100	10750	38976	37864
21	351.340	353.560	419.020	413.180	34400	12320	41771	38622
22	351.430	353.820	418.410	412.700	34400	12920	44976	39582
24	351.440	353.790	417.760	412.310	34400	14300	44223	41797
25	352.710	355.090	417.790	412.530	34400	14930	44835	42121
26	352.030	354.550	418.510	413.440	34400	15780	47448	42941

RUN	Q AVG	PER DEV	LMTD	UO	RE SHELL	RE TUBE	PR SHELL	PR TUBE
18	40719	1.188	75.970	27.002	30851	84946	12.716	18.153
19	38420	-1.447	65.604	29.503	32346	92285	12.365	18.233
21	40196	-3.918	63.633	31.823	31690	104553	12.368	18.398
22	42279	-6.379	62.915	33.854	31712	109312	12.362	18.442
24	43010	-2.821	62.407	34.719	31711	120635	12.362	18.485
25	43478	-3.121	61.249	35.761	31877	126038	12.316	18.474
26	45195	-4.986	62.676	36.327	31798	133823	12.338	18.408

AFTER 8 ITERATIONS, INTERCEPT IS .12962611E-02 , CI IS .02950350

RUN	FUNCTION A	FUNCTION B
18	.88477304E-03	.31572182E-01
19	.81952750E-03	.28915072E-01
21	.73742182E-03	.26263699E-01
22	.71083096E-03	.24964339E-01
24	.65539375E-03	.23552234E-01
25	.63225392E-03	.22740908E-01
26	.60383583E-03	.22029391E-01

RUN	HI PRIME	RFIN IN	HI	HO PRIME	RFIN OUT	HO	NU SHELL	NU TUBE
18	584.453	.0000E 00	584.453	640.047	.4264E-02	171.635	382.827	645.805
19	629.954	.0000E 00	629.954	890.968	.3716E-02	206.661	534.527	695.849
21	700.504	.0000E 00	700.504	797.809	.3898E-02	194.119	478.624	773.246
22	726.058	.0000E 00	726.058	1164.483	.3283E-02	241.465	698.640	801.308
24	788.638	.0000E 00	788.638	756.419	.3986E-02	188.390	453.818	870.222
25	817.476	.0000E 00	817.476	771.916	.3953E-02	190.547	463.308	902.082
26	856.747	.0000E 00	856.747	647.481	.4245E-02	172.738	388.545	945.674

TABLE IX

Wilson Plot Data and Calculated Results for Tube Tube Number 455, Runs 76-83

WILSON PLOT DETERMINATION OF THE INSIDE HEAT-TRANSFER COEFFICIENT FOR TUBE 455 , NUMBER OF RUNS IS 7

SHELL SIDE FLUID IS MOBIL LIGHT

TUBE SIDE FLUID IS MOBIL 600

RUNS	TUBE	TEMP	ITER	XAO	XAI	XAM	RM	CI	REP
7	455	0	10	19.8500	1.1400	1.3100	.9340E-04	.2800E-01	1.0000

NO	K	L	M	NN	O	P	Q
1	.38925000E 00	.44750000E-03	-.00000000E ,00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
2	.34400000E 00	.46333332E-03	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
3	.67977499E-01	-.19775000E-04	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
4	.71699999E-01	-.21000000E-04	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
5	-.20489551E-03	.10464268E 01	-.52113342E 02	.54997295E 03	.32380452E 05	-.75056534E 06	.00000000E 00
6	-.21480229E 01	.14160692E 04	-.27029259E 06	.32850279E 08	-.20186315E 10	.45553047E 11	.00000000E 00
7	-.29052144E 01	.22908387E 04	-.40461752E 06	.38134658E 08	-.70443591E 09	.00000000E 00	.00000000E 00
8	.00000000E 00	.00000000E 00	.00000000E 00	.00000000E 00	.00000000E 00	.00000000E 00	.00000000E 00

DIAS	AFS	AFT	DIAT
.36600E-01	.28800E-01	.37950E-02	.69500E-01

RUN	TSI	TSO	TTI	TTO	W SHELL	W TUBE
76	398.330	402.710	518.340	505.850	22200	8280
77	395.770	400.580	515.570	503.670	22200	9100
78	396.880	401.850	514.550	503.340	22350	9910
80	396.080	401.150	515.170	504.170	22400	11350
81	394.620	400.360	511.790	501.920	22530	11820
82	395.600	401.700	512.920	503.280	22580	12850
83	397.200	402.810	508.470	499.490	22580	14080

NOTE - INPUT DATA TEMPERATURES ARE IN FAHR.

RUN	TSIF	TSOF	TTIF	TTOF	W SHELL	W TUBE	Q SHELL	Q TUBE
76	398.330	402.710	518.340	505.850	22200	8280	55277	60113
77	395.770	400.580	515.570	503.670	22200	9100	60592	62822
78	396.880	401.850	514.550	503.340	22350	9910	63089	64412
80	396.080	401.150	515.170	504.170	22400	11350	64465	72431
81	394.620	400.360	511.790	501.920	22530	11820	73342	67530
82	395.600	401.700	512.920	503.280	22580	12850	78186	71775
83	397.200	402.810	508.470	499.490	22580	14080	71983	73020

RUN	Q AVG	PER DEV	LMTD	UO	RE SHELL	RE TUBE	PR SHELL	PR TUBE
76	57695	4.191	111.526	26.062	24530	112441	10.887	12.862
77	61707	1.807	111.407	27.903	24328	122267	10.948	12.963
78	63751	1.037	109.550	29.316	24595	132762	10.917	12.991
80	68448	5.820	111.029	31.057	24585	152530	10.937	12.961
81	70436	-4.126	109.352	32.449	24630	156920	10.967	13.078
82	74981	-4.275	109.441	34.515	24786	171519	10.936	13.026
83	72501	.715	103.966	35.131	24905	184590	10.900	13.200

AFTER 1 ITERATIONS, INTERCEPT IS .25144634E-02 , CI IS .02800828

RUN	FUNCTION A	FUNCTION B
76	.82586990E-03	.32163493E-01
77	.76981308E-03	.29826924E-01
78	.71878251E-03	.28056646E-01
80	.64355127E-03	.25866242E-01
81	.62641169E-03	.24757463E-01
82	.58411239E-03	.23043045E-01
83	.54526136E-03	.22187726E-01

RUN	HI PRIME	RFIN IN	HI	HO PRIME	RFIN OUT	HO	NU SHELL	NU TUBE
76	596.742	.0000E 00	596.742	378.858	.5137E-02	128.596	230.883	680.497
77	640.197	.0000E 00	640.197	433.171	.4916E-02	138.421	263.779	729.429
78	685.944	.0000E 00	685.944	423.868	.4952E-02	136.780	258.215	781.371
80	767.720	.0000E 00	767.720	351.591	.5258E-02	123.416	214.132	874.742
81	788.026	.0000E 00	788.026	424.410	.4950E-02	136.876	258.386	897.008
82	845.191	.0000E 00	845.191	464.093	.4801E-02	143.763	282.653	962.492
83	906.338	.0000E 00	906.338	373.469	.5160E-02	127.587	227.560	1030.664

TABLE X

Wilson Plot Data and Calculated Results for Tube Number 455, Runs 94-103

WILSON PLOT DETERMINATION OF THE INSIDE HEAT-TRANSFER COEFFICIENT FOR TUBE 455 , NUMBER OF RUNS IS 10

SHELL SIDE FLUID IS MOBIL LIGHT

TUBE SIDE FLUID IS MOBIL 600

RUNS	TUBE	TEMP	ITER	XAU	XAI	XAM	RM	CI	REP
10	455	0	10	19.8500	1.1400	1.3100	.9340E-04	.2800E-01	1.0000

NO	K	L	M	NN	O	P	Q
1	.38925000E 00	.44750000E-03	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
2	.34400000E 00	.46333332E-03	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
3	.67977499E-01	-.19775000E-04	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
4	.71699999E-01	-.21000000E-04	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
5	-.20489551E-03	.10464268E 01	-.52113342E 02	.54997295E 03	.32380452E 05	-.75056534E 06	.00000000E 00
6	-.21480229E 01	.14160692E 04	-.27029259E 06	.32850279E 08	-.20186315E 10	.45553047E 11	.00000000E 00
7	-.29052144E 01	.22908367E 04	-.40461752E 06	.38134658E 08	-.70443591E 09	.00000000E 00	.00000000E 00
8	.00000000E 00	.00000000E 00	.00000000E 00	.00000000E 00	.00000000E 00	.00000000E 00	.00000000E 00

DIAS	AFS	AFT	DIAT
.36300E-01	.29100E-01	.38000E-02	.69500E-01

RUN	TSI	TSO	TTI	TTO	W SHELL	W TUBE
94	302.180	305.700	428.180	415.500	26200	7330
95	300.790	304.440	423.580	412.040	26850	8350
96	307.890	312.950	456.650	443.150	26780	9200
97	301.360	306.590	449.650	436.870	26800	10310
98	298.500	303.890	440.550	428.810	26780	11500
99	299.630	304.820	438.780	427.800	27180	12340
100	301.010	306.300	434.440	424.140	26950	13270
101	299.610	305.030	431.150	421.380	26900	14180
102	301.470	306.920	430.150	420.890	26820	15100
103	301.470	306.790	427.390	418.490	26850	15990

NOTE - INPUT DATA TEMPERATURES ARE IN FAHR.

RUN	TSIF	TSOF	TTIF	TTOF	W SHELL	W TUBE	Q SHELL	Q TUBE
94	302.180	305.700	428.180	415.500	26200	7330	48442	50139
95	300.790	304.440	423.580	412.040	26850	8350	51419	51801
96	307.890	312.950	456.650	443.150	26780	9200	71570	68615
97	301.360	306.590	449.650	436.870	26800	10310	73625	72387
98	298.500	303.890	440.550	428.810	26780	11500	75641	73635
99	299.630	304.820	438.780	427.800	27180	12340	73988	73811
100	301.010	306.300	434.440	424.140	26950	13270	74866	74205
101	299.610	305.030	431.150	421.380	26900	14180	76477	75019
102	301.470	306.920	430.150	420.890	26820	15100	76794	75668
103	301.470	306.790	427.390	418.490	26850	15990	75042	76843

RUN	Q AVG	PER DEV	LMTD	UO	RE SHELL	RE TUBE	PR SHELL	PR TUBE
94	49290	1.722	117.841	21.072	19120	64132	14.489	17.945
95	51610	.370	115.150	22.579	19470	71447	14.559	18.261
96	70092	-2.108	139.437	25.324	20153	93344	14.158	15.997
97	73006	-.848	139.251	26.412	19561	101110	14.488	16.421
98	74638	-1.344	133.460	28.174	19286	107832	14.635	17.002
99	73899	-.120	131.044	28.409	19672	114858	14.580	17.099
100	74535	-.444	125.618	29.892	19640	120901	14.504	17.386
101	75748	-.962	123.932	30.791	19478	127098	14.575	17.609
102	76231	-.739	121.315	31.656	19596	134798	14.476	17.665
103	75942	1.186	118.801	32.203	19612	140747	14.479	17.860

AFTER 5 ITERATIONS, INTERCEPT IS .51550185E-02 , CI IS .03253048

RUN	FUNCTION A	FUNCTION B
94	.11531950E-02	.40629388E-01
95	.10476325E-02	.37429564E-01
96	.90313588E-03	.32768061E-01
97	.83850878E-03	.31092225E-01
98	.78283582E-03	.28799747E-01
99	.74000400E-03	.28328018E-01
100	.70275673E-03	.26636983E-01
101	.67086352E-03	.25649157E-01
102	.63737563E-03	.24717805E-01
103	.61161703E-03	.24125262E-01

RUN	HI PRIME	RFIN IN	HI	HO PRIME	RFIN OUT	HO	NU SHELL	NU TUBE
94	499.964	.0000E 00	499.964	196.732	.6131E-02	89.175	115.244	552.940
95	550.868	.0000E 00	550.868	195.197	.6141E-02	88.776	114.297	608.418
96	642.212	.0000E 00	642.212	204.767	.6077E-02	91.239	120.200	716.984
97	693.276	.0000E 00	693.276	193.212	.6155E-02	88.257	113.184	772.263
98	741.985	.0000E 00	741.985	216.756	.5998E-02	94.239	126.863	824.142
99	786.448	.0000E 00	786.448	184.263	.6217E-02	85.882	107.881	873.121
100	827.006	.0000E 00	827.006	203.979	.6082E-02	91.038	119.479	916.918
101	866.740	.0000E 00	866.740	204.373	.6079E-02	91.139	119.659	959.999
102	912.511	.0000E 00	912.511	200.504	.6105E-02	90.150	117.464	1010.443
103	951.369	.0000E 00	951.369	193.078	.6156E-02	88.222	113.111	1052.563

TABLE XI

Wilson Plot Data and Calculated Results for Tube Number 456, Runs 13-22

WILSON PLOT DETERMINATION OF THE INSIDE HEAT-TRANSFER COEFFICIENT FOR TUBE 456 , NUMBER OF RUNS IS 8

SHELL SIDE FLUID IS MOBIL LIGHT

TUBE SIDE FLUID IS MOBIL 600

RUNS	TUBE	TEMP	ITER	XAU	XAI	XAM	RM	CI	REP
8	456	0	8	19.9590	1.1400	1.3080	.9300E-04	.2800E-01	1.0000

NO	K	L	M	NN	O	P	Q
1	.38925000E 00	.44750000E-03	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
2	.34400000E 00	.46333332E-03	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
3	.67977499E-01	-.19775000E-04	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
4	.71699999E-01	-.21000000E-04	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
5	-.20489551E-03	.10464268E 01	-.52113342E 02	.54997295E 03	.32380452E 05	-.75056534E 06	.00000000E 00
6	-.21480229E 01	.14160692E 04	-.27029259E 06	.32850279E 08	-.20186315E 10	.45553047E 11	.00000000E 00
7	-.29052144E 01	.22908387E 04	-.40461752E 06	.38134658E 08	-.70443591E 09	.00000000E 00	.00000000E 00
8	.00000000E 00	.00000000E 00	.00000000E 00	.00000000E 00	.00000000E 00	.00000000E 00	.00000000E 00

DIAS	AFS	AFT	DIAT
.36300E-01	.29100E-01	.38000E-02	.69500E-01

RUN	TSI	TSO	TTI	TTO	W SHELL	W TUBE
13	228.160	230.670	338.960	329.940	30900	8470
15	227.750	230.590	338.730	329.770	30900	9303
16	228.970	232.000	337.900	329.450	30900	10150
17	230.580	233.480	335.240	327.340	30800	11250
18	230.450	233.420	331.120	323.770	30800	12480
19	226.630	230.810	346.590	337.790	30900	13930
20	227.410	231.790	342.610	334.490	30300	15230
22	227.090	231.760	348.050	340.250	30800	15830

NOTE - INPUT DATA TEMPERATURES ARE IN FAHR.

RUN	TSIF	TSOF	TTIF	TTOF	W SHELL	W TUBE	Q SHELL	Q TUBE
13	228.160	230.670	338.960	329.940	30900	8470	38152	38120
15	227.750	230.590	338.730	329.770	30900	9303	43159	41583
16	228.970	232.000	337.900	329.450	30900	10150	46101	42764
17	230.580	233.480	335.240	327.340	30800	11250	44042	44215
18	230.450	233.420	331.120	323.770	30800	12480	45101	45471
19	226.630	230.810	346.590	337.790	30900	13930	63496	61604
20	227.410	231.790	342.610	334.490	30300	15230	65295	61940
22	227.090	231.760	348.050	340.250	30800	15830	70755	62164

RUN	Q AVG	PER DEV	LMTD	UO	RE SHELL	RE TUBE	PR SHELL	PR TUBE
13	38136	-.042	105.001	18.197	14870	42637	20.100	28.030
15	42371	-1.859	105.050	20.208	14846	46762	20.126	28.064
16	44433	-3.755	103.166	21.579	14974	50805	19.985	28.162
17	44129	.196	99.239	22.279	15077	55329	19.823	28.576
18	45286	.408	95.493	23.760	15067	59642	19.833	29.266
19	62550	-1.512	113.454	27.623	14802	74149	20.175	26.765
20	63618	-2.636	108.939	29.259	14599	78984	20.080	27.347
22	66460	-6.464	114.718	29.026	14823	85441	20.099	26.461

AFTER 8 ITERATIONS, INTERCEPT IS .21737521E-02 , CI IS .03106755

RUN	FUNCTION A	FUNCTION B
13	.13820273E-02	.48556836E-01
15	.12857516E-02	.43764472E-01
16	.11980738E-02	.40731467E-01
17	.11045638E-02	.38717383E-01
18	.10267793E-02	.35986915E-01
19	.90929025E-03	.30966429E-01
20	.85318458E-03	.29030193E-01
22	.81245877E-03	.28655219F-01

RUN	HI PRIME	RFIN IN	HI	HO PRIME	RFIN OUT	HO	NU SHELL	NU TUBE
13	399.288	.0000E 00	399.288	254.843	.5763E-02	103.236	145.818	429.066
15	427.988	.0000E 00	427.988	440.530	.4888E-02	139.707	252.046	459.876
16	459.245	.0000E 00	459.245	483.673	.4732E-02	147.065	276.844	493.370
17	499.523	.0000E 00	499.523	328.177	.5370E-02	118.812	187.932	536.227
18	537.243	.0000E 00	537.243	353.443	.5250E-02	123.774	202.395	576.000
19	606.950	.0000E 00	606.950	618.667	.4321E-02	168.434	353.916	653.858
20	646.542	.0000E 00	646.542	670.116	.4187E-02	176.067	383.454	695.686
22	682.626	.0000E 00	682.626	416.178	.4982E-02	135.411	238.132	735.853

APPENDIX C. SHELL-SIDE CORRELATION COMPUTER PROGRAM AND SHELL-SIDE HEAT TRANSFER DATA AND CALCULATED RESULTS FOR TUBE NUMBERS 455 AND 456

TABLE XII

Shell-side Heat Transfer Correlation Computer Program Written in The University of Michigan Algorithm Decoder Language

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           OUTSIDE HEAT-TRANSFER COEFFICIENT CORRELATION PROGRAM
           DIMENSION LRES(100), LPRSH(100), LNUSH(100), LRVISS(100),
         1  TSIC(100), TSOC(100), TTIC(100), TTOC(100), TSIF(100),
         2  TSOF(100), TTIF(100), TTOF(100), WSHEL(100), WTUBE(100),
         3  QTUBE(100), QSHEL(100), QAVG(100), PERDE(100), LMTA(100),
         4  XAMT(100), CPS(100), CPT(100), VISS(100), VIST(100),
         5  KTUBE(100), KSHEL(100), PRSH(100), PRTU(100), TWIA(100),
         6  TWIB(100), VISWI(100), HI(100), RET(100), RES(100),
         7  RES(100), VISWO(100), FUNC(100), FUND(100), UO(100),
         8  RHO(100), RFIN(100), TWO(100), K(8), L(8), M(8), NN(8),
         9  O(8), P(8), RVISS(100), RVIST(100), NUSHEL(100), NUTUBE(100)
           DIMENSION HOPR(100), GRAPH(10000), HIP(100), RFININ(100),
         1  SCALE(5), FUNE(100), HO(100), LNNUVI(100), TTAV(100),
         2  TSAV(100), Q(8), B(2), UM(2), MU(2), R(100)
           DIMENSION DEV(100), FUNCC(100)
           INTEGER RUNS,   R,  TEMP, N, J, MM1, MM2, MM3, MM4, DECR.,
         1 MAXVA, MAXVC, SH, LIH, SV, LIV, SCALE, FIRST, LAST, MINVA,
         1 MINVC
BEGIN      READ FORMAT INFO, RUNS, TUBE, TEMP, XAO, XAI, XAM, RM, CI
           PRINT FORMAT TITLEA
           PRINT FORMAT TITLEB, TUBE, RUNS
           THROUGH INPUT, FOR J=1, 1, J.G. RUNS
INPUT      READ FORMAT DATAT, TSIC(J), TSOC(J), TTIC(J), TTOC(J),
         1 WSHEL(J), WTUBE(J), R(J)
           THROUGH NOR, FOR J = 1, 1, J .G. 8
           READ  FORMAT CONSTA, K(J), L(J), M(J), NN(J)
NOR        READ FORMAT CONSTB, O(J), P(J), Q(J)
           READ FORMAT DATAC, DIAS, AFS, AFT, DIAT, TTEMP, NAMEA,
         1  NAMEB, NAMEC, NAMED
           PRINT FORMAT FLUIDS, NAMEA, NAMEB
           PRINT FORMAT FLUIDT, NAMEC, NAMED
           PRINT COMMENT $-$
           PRINT FORMAT HEDA
           PRINT  FORMAT OUTA, RUNS, TUBE, TEMP, XAO, XAI, XAM, RM, CI
           PRINT COMMENT $-$
           PRINT FORMAT HEDB
           THROUGH NORTH, FOR J = 1, 1, J .G. 8
NORTH      PRINT FORMAT OUTB, J, K(J), L(J), M(J), NN(J), O(J), P(J),
         1 Q(J)
           PRINT COMMENT $-$
           PRINT FORMAT HEDC
           PRINT FORMAT OUTC, DIAS, AFS, AFT, DIAT
           PRINT COMMENT $-$
           PRINT FORMAT HED
           THROUGH FOUR , FOR J=1,1,J.G.RUNS
FOUR       PRINT FORMAT DATAA, R(J), TSIC(J), TSOC(J), TTIC(J), TTOC(J),
         1 WSHEL(J), WTUBE(J)
           PRINT FORMAT NOTE, TTEMP
           N = 1
ALPHA      WHENEVER TEMP .E. 1, TRANSFER TO GAMMA
           TSIF(N) = TSIC(N)
           TSOF(N) = TSOC(N)
           TTIF(N) = TTIC(N)
           TTOF(N) = TTOC(N)
           TRANSFER TO SIGMA
GAMMA      TSIF(N) = 1.8 * TSIC(N) + 32
           TSOF(N) = 1.8 * TSOC(N) + 32
           TTIF(N) = 1.8 * TTIC(N) + 32
           TTOF(N) = 1.8 * TTOC(N) + 32
SIGMA      TSAV(N) = 0.5 * ( TSIF(N) + TSOF(N))
           TTAV(N) = 0.5 * ( TTIF(N) + TTOF(N))
           CPS(N) = K(1) + L(1)*TSAV(N) + M(1)*TSAV(N).P.2
         1 + NN(1)*TSAV(N).P.3 + O(1)*TSAV(N).P.4
           CPT(N) = K(2) + L(2)*TTAV(N) + M(2)*TTAV(N).P.2
         1 +NN(2)*TTAV(N).P.3 + O(2)*TTAV(N).P.4
           QSHEL(N) = WSHEL(N)*CPS(N)*.ABS.(TSOF(N)-TSIF(N))
           QTUBE(N) = WTUBE(N)*CPT(N)*.ABS. (TTOF(N)-TTIF(N))
           QAVG(N) = 0.5 * ( QSHEL(N) + QTUBE(N))
           PERDE(N) = (100*(QTUBE(N)-QSHEL(N)))/(QTUBE(N) + QSHEL(N))
           XAMT(N) = .ABS. (TTAV(N) - TSAV(N))
           DELA = .ABS.(TTIF(N)-TSOF(N))
           DELB = .ABS.(TTOF(N)-TSIF(N))
           WHENEVER .ABS. (DELA - DELB) .L. 0.3
           LMTA(N) = XAMT(N)
           OTHERWISE
           LMTA(N) = (DELA -DELB)/(ELOG.(DELA/DELB))
           END OF CONDITIONAL
           WHENEVER LMTA(N) .G. XAMT(N), LMTA(N) = XAMT(N)
           UO(N) = ( QAVG(N))/( XAO*LMTA(N))
           VISS(N) = EXP.(K(6) + L(6)/TSAV(N) + M(6)/TSAV(N).P.2 +
         1 NN(6)/TSAV(N).P.3 + O(6)/TSAV(N).P.4 + P(6)/TSAV(N).P.5 +
         1 Q(6)/TSAV(N).P.6)
           VIST(N) = EXP.(K(7) + L(7)/TTAV(N) + M(7)/TTAV(N).P.2 +
         1 NN(7)/TTAV(N).P.3 + O(7)/TTAV(N).P.4 + P(7)/TTAV(N).P.5 +
         1 Q(7)/TTAV(N).P.6)
           KSHEL(N) = K(3) + L(3)*TSAV(N) + M(3)*TSAV(N).P.2 +
         1 NN(3)*TSAV(N).P.3 + O(3)*TSAV(N).P.4
           KTUBE(N) = K(4) + L(4)*TTAV(N) + M(4)*TTAV(N).P.2 +
         1 NN(4)*TTAV(N).P.3 + O(4)*TTAV(N).P.4
           RES(N) = (DIAS*WSHEL(N))/(AFS*VISS(N))
           LRES(N) = ELOG.(RES(N))
           RET(N) = (DIAT*WTUBE(N))/(AFT*VIST(N))
           PRSH(N) = (CPS(N)*VISS(N))/KSHEL(N)
           LPRSH(N) = ELOG.(PRSH(N))
           PRTU(N) = (CPT(N)*VIST(N))/KTUBE(N)
           WHENEVER N .E. RUNS, TRANSFER TO DELTA
           N = N + 1
           TRANSFER TO ALPHA
DELTA      PRINT FORMAT HEADA
           THROUGH CHI, FOR J=1,1, J.G. RUNS
CHI        PRINT FORMAT RESLT1,R(J),TSIF(J),TSOF(J),TTIF(J),TTOF(J),
         1 WSHEL(J), WTUBE(J), QSHEL(J), QTUBE(J)
           PRINT FORMAT HEADC
           THROUGH OUT, FOR J = 1, 1, J.G. RUNS
OUT        PRINT FORMAT RESLT9, R(J), QAVG(J), PERDE(J), LMTA(J), UO(J),
         1 RES(J), RET(J)
           N = 1
           MAG = 0
           MMAG = 1000.0
OMEGA      TWIA(N) = TTAV(N)
BETA       VISWI(N) = EXP.(K(7) + L(7)/TWIA(N) + M(7)/TWIA(N).P.2 +
         1 NN(7)/TWIA(N).P.3 + O(7)/TWIA(N).P.4 + P(7)/TWIA(N).P.5 +
         1 Q(7)/TWIA(N).P.6)
           HIP(N) = (CI*RET(N).P.0.8*PRTU(N).P.0.33333*KTUBE(N)*VIST(N)
         1 .P.0.14)/(VISWI(N).P.0.14*DIAT)
           RFININ(N) = K(8) + L(8)/HIP(N) + M(8)/HIP(N).P.2 +
         1 NN(8)/HIP(N).P.3 + O(8)/HIP(N).P.4 + P(8)/HIP(N).P.5 +
         1 Q(8)/HIP(N).P.6
           HI(N) = 1/(1/HIP(N) + RFININ(N))
           WHENEVER TTAV(N) .G. TSAV(N), TRANSFER TO KAPPA
           TWIB(N) = TTAV(N) + (QAVG(N)/(XAI*HI(N)))
           TRANSFER TO PHI
KAPPA      TWIB(N) = TTAV(N) -(QAVG(N)/(XAI*HI(N)))
PHI        WHENEVER .ABS. (TWIA(N) - TWIB(N)) .LE. 0.2, TRANSFER TOEIGHT
           TWIA(N) = TWIB(N)
           TRANSFER TO BETA
EIGHT      WHENEVER TTAV(N) .G. TSAV(N), TRANSFER TO NINE
           TWO(N) = TWIB(N) + (QAVG(N)*RM/XAM)
           TRANSFER TO TEN
NINE       TWO(N) = TWIB(N) - (QAVG(N)*RM/XAM)
TEN        VISWO(N) = EXP.(K(6) + L(6)/TWO(N) + M(6)/TWO(N).P.2 +
         1 NN(6)/TWO(N).P.3 + O(6)/TWO(N).P.4 + P(6)/TWO(N).P.5 +
         1 Q(6)/TWO(N).P.6)
           RHO(N) = (1/UO(N)) - (XAO/(XAI*HI(N))) - (XAO*RM/XAM)
           RFIN(N) = K(5) + L(5)*RHO(N) + M(5)*RHO(N).P.2 +
         1 NN(5)*RHO(N).P.3 + O(5)*RHO(N).P.4
         1  + P(5)*RHO(N).P.5 + Q(5)*RHO(N).P.6
           HOPR(N) = 1/(RHO(N) - RFIN(N))
           HO(N) = 1/RHO(N)
           NUSHEL(N) = HOPR(N)*DIAS/KSHEL(N)
           LNUSH(N) = ELOG.(NUSHEL(N))
           NUTUBE(N) = HIP(N)*DIAT/KTUBE(N)
           RVISS(N) = VISS(N)/VISWO(N)
           LRVISS(N) = ELOG.(RVISS(N))
           RVIST(N) = VIST(N)/VISWI(N)
           LNNUVI(N) = ELOG.(NUSHEL(N)/(RVISS(N).P.0.14))
           FUNC(N) = (HOPR(N)*DIAS*VISWO(N).P.0.14)/(KSHEL(N)*VISS(N)
         1 .P.0.14*PRSH(N).P.0.33333)
           FUND(N) = ELOG.(FUNC(N))
           FUNE(N) = ELOG.(RES(N))
           WHENEVER FUNE(N) .G. MAG
           MAG = FUNE(N)
           MAGN = FUNC(N)
           OTHERWISE
           CONTINUE
           END OF CONDITIONAL
           WHENEVER FUNE(N) .L. MMAG
           MMAG = FUNE(N)
           MMAGN = FUNC(N)
           OTHERWISE
           CONTINUE
           END OF CONDITIONAL
           WHENEVER N.E. RUNS, TRANSFER TO ELEVEN
           N = N + 1
           TRANSFER TO OMEGA
ELEVEN     PRINT FORMAT HEADD
           THROUGH DEB, FOR J = 1, 1, J.G. RUNS
DEB        PRINT FORMAT RESLT4, R(J),HIP(J),RFININ(J),HI(J),HOPR(J),
         1 RFIN(J), HO(J), TSAV(J), TWO(J), TWIB(J), TTAV(J)
           PRINT FORMAT HEADE
           THROUGH WEST, FOR J =  1, 1, J.G. RUNS
WEST       PRINT FORMAT RESLT7, R(J), FUNC(J), FUND(J), FUNE(J),
         1 NUSHEL(J), NUTUBE(J), PRSH(J), PRTU(J)
           PRINT FORMAT VISCO
           THROUGH SCHOOL, FOR J = 1, 1,  J.G. RUNS
SCHOOL     PRINT FORMAT RESLT8, R(J), VISS(J), VISWO(J), RVISS(J),
         1 VIST(J), VISWI(J), RVIST(J)
           PRINT FORMAT HEDG
           THROUGH DOOR, FOR J = 1, 1, J .G. RUNS
DOOR       PRINT FORMAT RELOG, R(J), LRES(J), LPRSH(J), LRVISS(J),
         1  LNUSH(J), LNNUVI(J), FUND(J)
           THROUGH RODD, FOR J = 1, 1, J .G. RUNS
RODD       PUNCH FORMAT HEDH, R(J), LRES(J), LPRSH(J), LRVISS(J),
         1  LNUSH(J), LNNUVI(J), FUND(J)
```

```
              EXECUTE LSTSQ.(FUNE, FUND, RUNS, B, 1)
              INTCPT = EXP.(B(0))
              SUMSDE = 0.0
              THROUGH OUT1, FOR N = 1, 1, N .G. RUNS
              FUNCC(N) = INTCPT*RES(N).P.B(1)
              DEV(N) = (FUNC(N) - FUNCC(N))/FUNCC(N)
OUT1          SUMSDE = SUMSDE + DEV(N)*DEV(N)
              STDEV = SQRT.(SUMSDE/RUNS)
              PRINT FORMAT HEADM
              THROUGH JET, FOR J = 1, 1, J .G. RUNS
JET           PRINT FORMAT JET1, R(J), RES(J), FUNC(J), FUNCC(J), DEV(J)
              PRINT  FORMAT RESLT5, INTCPT, B(1)
              PRINT FORMAT JET2, STDEV
              SCALE(0) = 1
              SCALE(1) = 0
              SCALE(2) = 3
              SCALE(3) = 0
              SCALE(4) = 3
              MAXVA = MAG*10.0
              MAXVB = (MAXVA + 2)/10.0
              MAXVC = MAGN*10.0
              MAXVD = (MAXVC + 2)/10.0
              MINVA = MMAG*10.0
              MINVB = (MINVA - 1)/10.0
              MINVC = MMAGN*10.0
              MINVD = (MINVC - 1)/10.0
              UM(0) = MINVB
              MU(0) = B(0) + B(1)*MINVB
              UM(1) = MAXVB
              MU(1) = B(0) + B(1)*MAXVB
              LIH = 1
              SH = 50
              LIV = 1
              SV = 100
              EXECUTE PLOT1.(SCALE, LIH, SH, LIV, SV)
              EXECUTE PLOT2.(GRAPH,MAXVB,MINVB,MAXVD,MINVD)
              EXECUTE PLOT3. ($*$, FUNE(1), FUND(1), RUNS)
              EXECUTE PLOT3. ($X$, UM(0), MU(0), 2)
              PRINT COMMENT $1$
              PRINT FORMAT NAME
              EXECUTE PLOT4.(40, ORD)
              PRINT FORMAT ABSS
              PRINT COMMENT $1$
              VECTOR VALUES TITLEA = $ 103H1DETERMINATION OF THE POWER OF T
            1 HE REYNOLDS NO. AND THE CONSTANT FOR THE SEIDER-TATE EQN. - S
            1 HELL SIDE *$
              VECTOR VALUES TITLEB = $ 21H0CORRELATION FOR TUBE C5, 20H , N
            2 UMBER OF RUNS IS I3 *$
              VECTOR VALUES INFO = $ I5, C5, 1I5, 3F10.4, 2E10.4 *$
              VECTOR VALUES DATAT = $ 4F10.3, 2F10.0, S7, I3  *$
              VECTOR VALUES CONSTA = $ 4E15.8*$
              VECTOR VALUES CONSTB = $ 3E15.8*$
              VECTOR VALUES DATAC = $ 4E10.5, C5, 4C6  *$
              VECTOR VALUES HEADA = $ 101H1        RUN       TSIF       TSOF
            1      TTIF        TTOF   W SHELL    W TUBE         Q SHELL
            1  Q TUBE / *$
              VECTOR VALUES RESLT1 = $ I11, 4F10.2, 2F10.0, 2F15.0*$
              VECTOR VALUES HEADC = $ 66H1  RUN      Q AVG   PER DEV        LM
            1 TD         UO  RE SHELL   RE TUBE  /*$
              VECTOR VALUES RESLT5  = $ 17H2CONSTANT EQUALS F12.8, 15H , PO
            1 WER EQUALS F12.8 *$
              VECTOR VALUES LOUISE = $ 2I5, C5, 4C6  *$
              VECTOR VALUES HECA = $ 69H0RUNS TUBE TEMP       XAO        XAI
            1         XAM            RM              CI / *$
              VECTOR VALUES OUTA = $ I5, C5, I5, 3F10.4, 2E12.4 *$
              VECTOR VALUES HEDB = $ 110H0  NO                   K
            1 L                M                NN                0              P
            1                  Q / *$
              VECTOR VALUES OUTB = $ I5, 7E15.8 *$
              VECTOR VALUES HEDC = $ 48H0        DIAS           AFS         AF
            1 T          DIAT / *$
              VECTOR VALUES OUTC = $ 4E12.5 *$
              VECTOR VALUES HEADD = $109H1 RUN  HI PRIME      RFIN IN
            1  HI  HO PRIME    RFIN OUT         HO       TSAV   TWALL O   TWA
            1 LL I       TTAV      /*  $
              VECTOR VALUES RESLT4 = $ I5,  F10.2, F12.6, 2F10.2, F12.6,
            1  F10.2, 4F10.2  *$
              VECTOR VALUES HEADE = $ 105H1 RUN          FUNCTION C
            1   FUNCTION D          FUNCTION E  NU SHELL   NU TUBE  PR SHEL
            1 L   PR TUBE  /*$
              VECTOR VALUES RESLT7 = $ I5, 3F20.3, 4F10.2   *$
              VECTOR VALUES FLUIDT = $ 20H0TUBE SIDE FLUID IS 2C6   *$
              VECTOR VALUES FLUIDS = $ 21H0SHELL SIDE FLUID IS  2C6 *$
              VECTOR VALUES HED = $ 66H0  RUN        TSI         TSO        TTI
            1        TTO   W SHELL    W TUBE  /*$
              VECTOR VALUES DATAA = $ I6, 4F10.2, 2F10.0  *$
              VECTOR VALUES NOTE = $ 40H0NOTE - INPUT DATA TEMPERATURES ARE
            1  IN  C5  *$
              VECTOR VALUES VISCO = $ 1H1 S35, 22H VISCOSITIES  LB/FT-HR //
            1  95H  RUN    VISC. SHELL   VISC SH WALL     VISS/VISSW     VI
            1 SC. TUBE   VISC TU WALL      VIST/VISTW /*$
              VECTOR VALUES RESLT8 = $ I5, 6F15.3  *$
              VECTOR VALUES RESLT9 = $ I6, F10.0, 3F10.3, 2F10.0  *$
              VECTOR VALUES ORD = $            FUNCTION D  -  LN NU/PR.P.1/3
            1  *$
              VECTOR VALUES NAME = $ 1H1 S46, 31H FUNCTION D VERSUS FUNCTIO
            1 N E   *$
              VECTOR VALUES ABSS = $ 1H0 S40, 36H FUNCTION E  -  LN REYNOLD
            1 S NUMBER   *$
              VECTOR VALUES HEDG = $            95H1 RUN    LN RE SHELL    L
            1 N PR SHELL LN VIST. RATIO    LN NU SHELL   LN NU/VISC-R
            1    FUNC D       / *$
              VECTOR VALUES RELOG = $ I5, 6F15.6 *$
              VECTOR VALUES HEDH = $ I5, 6F12.6  *$
              VECTOR VALUES HEADM = $ 78H1 RUN       REYNOLDS NO.       FUNCT
            1 ION C       FUNCTION C CALC.       DEVIATION            /*$
              VECTOR VALUES JET1 = $ I5, F14.0, F18.2, F19.2, F18.3    *$
              VECTOR VALUES  JET2 = $  22H4STANDARD DEVIATION =   F5.3  *$
              TRANSFER TO BEGIN
              END OF PROGRAM
```

NOMENCLATURE

AFS	SHELL-SIDE FLOW AREA - SQFT
AFT	TUBE-SIDE FLOW AREA - SQFT
B	CONSTANTS FROM LEAST SQUARE SUBROUTINE
CI	INSIDE HEAT TRANSFER COEFFICIENT CORRELATION CONSTANT
CPS	SHELL-SIDE SPECIFIC HEAT - BTU/LB-F
CPT	TUBE-SIDE SPECIFIC HEAT - BTU/LB-F
DIAS	SHELL-SIDE EQUIVALENT DIAMETER - FT
DIAT	INSIDE DIAMETER OF TUBE - FT
FUNCC	PREDICTED VALUE OF FUNCTION C
FUNC	ACTUAL VALUE OF FUNCTION C
FUND	FUNCTION D
FUNE	FUNCTION E
HIP	INSIDE HEAT TRANSFER COEFFICIENT - BTU/HR-SQFT-F
HI	INSIDE HEAT TRANSFER COEFFICIENT(INCLUDES INSIDE FIN RESISTANCE IF ANY) BTU/HR-SQFT-F
HOPR	SHELL-SIDE HEAT TRANSFER COEFFICIENT - BTU/HR-SQFT-F
HC	SHELL-SIDE HEAT TRANSFER COEFFICIENT (INCLUDES RFIN) - BTU/HR-SQFT-F
K	POLYNOMIAL CONSTANT FOR PHYSICAL PROPERTIES
KSHEL	THERMAL CONDUCTIVITY OF SHELL-SIDE FLUID - BTU/HR-SQFT-F/FT
KTUBE	THERMAL CONDUCTIVITY OF TUBE-SIDE FLUID - BTU/HR-SQFT-F/FT
L	POLYNOMIAL CONSTANT FOR PHYSICAL PROPERTIES
LMTA	LOGARITHMIC TEMPERATURE DIFFERENCR - F
M	POLYNOMIAL CONSTANT FOR PHYSICAL PROPERTIES
NN	POLYNOMIAL CONSTANT FOR PHYSICAL PROPERTIES
NUSHEL	SHELL-SIDE NUSSELT NUMBER
NUTUBE	TUBE-SIDE NUSSELT NUMBER
O	POLYNOMIAL CONSTANT FOR PHYSICAL PROPERTIES
P	POLYNOMIAL CONSTANT FOR PHYSICAL PROPERTIES
PERDE	PER CENT DEVIATION IN HEAT BALANCE
PRSH	PRANDTL NUMBER OF SHELL-SIDE FLUID
PRTU	PRANDTL NUMBER OF TUBE-SIDE FLUID
Q	POLYNOMIAL CONSTANT FOR PHYSICAL PROPERTIES
QAVG	AVERAGE OF SHELL-SIDE AND TUBE-SIDE HEAT FLUXES - BTU/HR
QSHEL	SHELL-SIDE HEAT FLUX - BTU/HR
QTUBE	TUBE-SIDE HEAT FLUX - BTU
RES	SHELL-SIDE REYNOLDS NUMBER
RET	TUBE-SIDE REYNOLDS NUMBER
RFININ	FIN RESISTANCE OF FINS INSIDE OF TUBE IF ANY - HR-SQFT-F/BTU
RFIN	FIN RESISTANCE OF EXTERNAL FINS - HR-SQFT-F/BTU
RM	METAL RESISTANCE - HR-SQFT-F/BTU
TSAV	AVERAGE SHELL-SIDE FLUID TEMPERATURE - F
TSIC	INLET SHELL-SIDE FLUID TEMPERATURE - F OR C
TSIF	INLET SHELL-SIDE FLUID TEMPERATURE - F
TSOF	OUTLET SHELL-SIDE FLUID TEMPERATURE - F
TSOC	OUTLET SHELL-SIDE FLUID TEMPERATURE - F OR C
TTAV	AVERAGE TUBE-SIDE FLUID TEMPERATURE - F
TTIF	INLET TUBE-SIDE FLUID TEMPERATURE - F
TTIC	INLET TUBE-SIDE FLUID TEMPERATURE - F OR C
TTOF	OUTLET TUBE-SIDE FLUID TEMPERATURE - F
TTOC	OUTLET TUBE-SIDE FLUID TEMPERATURE - F OR C
TWIA,TWIB	INSIDE TUBE-WALL TEMPERATURE - F
TWO	OUTSIDE TUBE-WALL TEMPERATURE - F
UO	OVERALL HEAT TRANSFER COEFFICIENT - BTU/HR-SQFT-F
VISS	SHELL-SIDE FLUID VISCOSITY - LB/FT-HR
VIST	TUBE-SIDE FLUID VISCOSITY - LB/FT-HR
VISWI	VISCOSITY AT INSIDE TUBE-WALL TEMPERATURE - LB/FT-HR
VISWO	VISCOSITY AT OUTSIDE TUBE-WALL TEMPERATURE - LB/FT-HR
WSHEL	SHELL-SIDE FLUID FLOW RATE - LB/HR
WTUBE	TUBE-SIDE FLUID FLOWRATE - LB/HR
XAI	INSIDE HEAT TRANSFER AREA - SQFT
XAM	MEAN METAL HEAT TRANSFER AREA - SQFT
XAO	OUTSIDE HEAT TRANSFER AREA - SQFT

TABLE XIII

Shell-side Heat Transfer Data and Calculated Results for Tube Number 455

DETERMINATION OF THE POWER OF THE REYNOLDS NO. AND THE CONSTANT FOR THE SEIDER-TATE EQN. - SHELL SIDE

CORRELATION FOR TUBE 455 , NUMBER OF RUNS IS 76

SHELL SIDE FLUID IS MOBIL LIGHT

TUBE SIDE FLUID IS MOBIL 600

RUNS	TUBE	TEMP	XAC	XAI	XAM	RM	CI
76	455	0	19.8500	1.1400	1.3100	.9340E-04	.2957E-01

NC	K	L	M	NN	O	P	Q
1	.38925000E 00	.44750000E-03	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
2	.34400000E 00	.46333332E-03	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
3	.67977459E-01	-.19775000E-04	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
4	.71659999E-01	-.21000000E-04	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
5	-.20489551E-03	.10464268E 01	-.52113342E 02	.54997295E 03	.32380452E 05	-.75056534E 06	.00000000E 00
6	-.21480229E 01	.14160492E 04	-.27029259E 06	.32850279E 08	-.20186315E 10	.45553047E 11	.00000000E 00
7	-.29052144E 01	.22908387E 04	-.40461752E 06	.38134658E 08	-.70443591E 09	.00000000E 00	.00000000E 00
8	.00000000E 00	.00000000E 00	.00000000E 00	.00000000E 00	.00000000E 00	.00000000E 00	.00000000E 00

DIAS	AFS	AFT	DIAT
.36600E-01	.28800E-01	.37950E-02	.69500E-01

RUN	TSI	TSC	TTI	TTO	W SHELL	W TUBE	Q SHELL	Q TUBE	Q AVG	PER DEV	LMTD	UO	RE SHELL	RE TUBE
1	352.81	359.20	507.33	494.23	34700	15250	121634	115076	118355	-2.771	144.749	41.192	32430	197132
4	352.29	357.71	510.33	495.35	34600	11820	102789	102163	102476	-.305	147.789	34.932	32205	154188
5	353.14	358.63	519.75	503.15	34350	10720	103439	103385	103412	-.026	155.499	33.503	32087	145173
8	353.07	357.78	514.06	497.16	34500	9025	89096	88199	88647	-.506	150.103	29.752	32167	119165
11	353.59	357.98	474.21	463.70	34300	13350	82586	78753	80669	-2.376	113.142	35.919	32027	149013
12	351.61	355.93	473.78	462.98	34300	12700	81136	76949	79042	-2.648	114.580	34.753	31767	141366
13	359.67	363.29	477.27	466.27	34150	11520	68118	71291	69704	2.276	110.249	31.851	32621	130334
14	358.57	362.44	475.76	464.76	33860	10890	72146	67308	69727	-3.469	109.716	32.016	32219	122319
15	355.49	359.04	476.80	464.68	34500	9850	67254	67106	67180	-.110	113.421	29.839	32406	110892
16	358.06	361.54	482.00	469.31	35000	9160	67022	65605	66313	-1.069	115.794	28.850	33211	105563
17	358.64	362.03	492.74	478.56	34450	8150	64290	65760	65025	1.130	125.238	26.157	32758	98404
18	342.10	344.23	423.06	415.28	34800	9840	40236	41203	40719	1.168	75.970	27.002	30851	84946
24	351.44	353.79	417.76	412.31	34400	14300	44223	41797	43010	-2.821	62.407	34.719	31711	120635
25	352.71	355.09	417.79	412.53	34400	14930	44835	42121	43478	-3.121	61.249	35.761	31877	126038
26	352.03	354.55	418.51	413.44	34400	15780	47448	42941	45195	-4.986	62.676	36.327	31798	133823
28	413.46	403.14	540.91	530.08	15430	14530	91078	93175	92127	1.138	126.901	36.573	17517	217529
30	402.90	412.51	541.50	530.70	16900	14440	92849	92385	92617	-.250	128.394	36.340	19146	216711
32	397.88	407.01	538.74	527.72	18660	14530	96997	94641	95819	-1.229	130.783	36.910	20758	215539
33	414.54	421.35	539.53	528.98	22700	14530	89085	90678	89882	.886	116.300	38.934	26626	216439
34	414.91	422.07	538.39	528.39	21950	14520	90608	85833	88220	-2.706	114.894	38.682	25793	215531
36	412.08	418.44	537.64	527.41	25550	14520	93449	87748	90598	-3.147	117.254	38.925	29700	214773
40	410.82	416.60	539.14	528.41	29300	14350	97274	91048	94161	-3.306	120.048	39.515	33881	213341
42	407.54	412.45	540.08	528.62	34900	14520	98141	98439	98290	.151	124.326	39.828	39850	216373
43	410.90	415.68	542.54	531.03	37200	14520	102101	99057	100579	-1.514	123.465	41.040	42956	218515
45	411.29	416.52	541.18	529.83	32400	14530	97346	97649	97497	.156	121.574	40.401	37491	217538
52	336.58	342.14	510.05	493.63	33060	10100	99464	95611	97538	-1.975	162.420	30.253	28841	131172
54	339.74	345.94	509.39	493.45	28900	10100	97236	92785	95010	-2.342	158.530	30.192	25585	130929
55	341.86	348.61	508.94	493.32	26520	10100	97335	90901	94118	-3.418	155.853	30.423	23715	130762
57	326.11	333.89	507.77	491.39	25600	10520	106938	99164	103051	-3.772	169.544	30.620	21449	135268
58	327.29	335.88	509.45	492.93	23000	10340	106220	98428	102324	-3.808	169.574	30.399	19404	133904
59	325.93	335.03	508.38	492.08	21000	10200	102647	95728	99188	-3.488	169.725	29.441	17632	131532
60	326.45	336.26	506.16	490.36	18680	10230	98503	92917	95710	-2.918	166.887	28.892	15744	130770
61	326.41	338.69	509.93	494.28	14770	10250	97592	92501	95046	-2.678	169.550	28.241	12513	133276
62	326.66	337.86	511.75	495.67	16650	10250	100314	95165	97740	-2.634	171.439	28.721	14088	134219
64	394.62	399.01	489.70	481.66	25050	12850	62333	58789	60561	-2.926	88.853	34.337	27319	155174
65	394.96	398.70	491.29	482.91	28950	12850	61373	61346	61359	-.022	90.250	34.251	31574	156189
67	395.15	400.28	490.24	482.92	22600	15300	65763	63776	64770	-1.534	88.861	36.720	24726	185525
68	352.10	358.10	463.26	454.74	23000	15380	75646	72945	74295	-1.816	103.895	36.025	21417	163536
69	350.29	355.45	463.03	454.26	28250	15380	79759	75063	77411	-3.033	105.765	36.872	26069	163249
70	349.99	354.28	463.42	454.58	34180	15380	80183	75684	77934	-2.886	106.849	36.745	31447	163536
71	349.32	354.74	462.16	452.88	23580	12970	69881	66919	68400	-2.165	105.478	32.669	21685	136903
72	350.66	356.30	458.06	449.68	23550	15750	72711	73158	72935	.307	100.384	36.602	21786	163246
75	375.29	380.13	484.72	475.17	23100	11400	62417	61661	62039	-.609	102.217	30.576	23492	134053
76	398.33	402.71	518.34	505.85	22200	8280	55277	60113	57695	4.191	111.526	26.062	24530	112441
77	395.77	400.58	515.57	503.67	22200	9100	60592	62822	61707	1.807	111.407	27.903	24328	122267
78	396.88	401.85	514.55	503.34	22350	9910	63089	64412	63751	1.037	109.550	29.316	24595	132762
80	396.08	401.15	515.17	504.17	22400	11350	64465	72431	68448	5.820	111.029	31.057	24585	152530
81	394.62	400.36	511.79	501.92	22530	11820	73342	67530	70436	-4.126	109.352	32.449	24630	156920
82	395.60	401.70	512.92	503.28	22580	12850	78186	71775	74981	-4.275	109.441	34.515	24786	171519
83	397.20	402.81	508.47	499.49	22580	14080	71983	73020	72501	.715	103.966	35.131	24905	184590
85	305.32	315.58	432.34	424.34	13310	15920	72128	69088	70608	-2.153	117.886	30.174	10206	144495
86	303.28	312.66	432.60	424.31	15210	15920	75196	71600	73398	-2.450	120.484	30.690	11527	144584
87	302.61	310.94	430.42	421.97	16750	15920	73466	72841	73153	-.427	119.420	30.860	12623	142828
88	302.61	310.09	429.63	421.08	18660	15920	73465	73650	73557	.126	119.004	31.139	14034	142178
89	301.56	308.50	429.46	420.75	21150	15920	77170	75012	76091	-1.418	120.073	31.925	15806	141984
90	301.34	307.34	428.87	419.97	22850	15920	72038	76603	74321	3.071	120.074	31.182	17021	141455
91	301.22	306.99	429.57	420.38	25500	15920	77295	79137	78216	1.177	120.862	32.602	18973	141884
92	301.90	307.25	430.70	421.57	29150	15920	81960	78698	80329	-2.030	121.550	33.293	21736	142781
93	301.15	305.82	433.28	423.83	34050	15920	83492	81625	82559	-1.130	125.055	33.258	25259	144662
94	302.18	305.70	428.18	415.50	26200	7330	48442	50139	49290	1.722	117.841	21.072	19479	64217
95	300.79	304.44	423.58	412.04	26850	8350	51419	51801	51610	.370	115.150	22.579	19835	71541
96	307.89	312.95	456.65	443.15	26780	9200	71570	68615	70092	-2.108	139.437	25.324	20531	93467
97	301.36	306.59	449.65	436.87	26800	10310	73625	72387	73006	-.848	139.251	26.412	19928	101243
98	298.50	303.89	440.55	428.81	26780	11500	75641	73635	74638	-1.344	133.460	28.174	19648	107974
99	299.63	304.82	438.78	427.60	27180	12340	73988	73811	73899	-.120	131.044	28.409	20041	115009
100	301.01	306.30	434.44	424.14	26950	13270	74866	74205	74535	-.444	125.618	29.892	20009	121060
101	299.61	305.03	431.15	421.38	26900	14180	76477	75019	75748	-.962	123.932	30.791	19844	127266
102	301.47	306.92	430.15	420.89	26820	15100	76794	75668	76231	-.739	121.315	31.656	19964	134975
103	301.47	306.79	427.39	418.49	26850	15990	75042	76843	75942	1.186	118.801	32.203	19980	140933
104	217.11	220.37	280.97	277.42	15500	15980	24615	26853	25734	4.349	60.455	21.445	7070	51083
105	213.34	216.28	280.04	276.49	17850	15980	25472	26829	26150	2.594	63.455	20.761	7921	50639
106	214.73	217.28	279.33	275.72	20850	15980	25835	27262	26549	2.689	61.519	21.741	9330	50287
107	214.28	216.83	280.63	276.92	23300	15980	28859	28052	28455	-1.417	63.218	22.676	10394	50883
108	212.60	214.89	279.38	275.67	25600	15980	28427	28018	28222	-.725	63.777	22.293	11274	50287
109	210.47	212.57	278.07	274.20	28350	15900	28809	29040	28925	.399	64.611	22.553	12287	49379
110	207.55	209.61	275.49	271.81	31100	15820	30916	27408	29163	-6.017	65.067	22.579	13193	47972

NOTE - INPUT DATA TEMPERATURES ARE IN FAHR.

TABLE XIII (Continued)

RUN	HI PRIME	RFIN IN	HI	HO PRIME	RFIN OUT	HO	TSAV	TWALL O	TWALL I	TTAV
1	985.16	.000000	985.16	788.16	.003918	192.79	356.00	386.96	395.40	500.78
4	802.92	.000000	802.92	703.97	.004105	180.97	355.00	383.58	390.88	502.84
5	751.91	.000000	751.91	764.78	.003968	189.56	355.88	383.43	390.81	511.45
8	646.65	.000000	646.65	766.51	.003964	189.80	355.42	379.04	385.36	505.61
11	835.06	.000000	835.06	693.15	.004131	179.41	355.78	378.46	384.22	468.95
12	799.88	.000000	799.88	689.39	.004140	178.87	353.77	376.06	381.70	468.38
13	749.34	.000000	749.34	490.98	.004707	148.28	361.48	385.20	390.17	471.77
14	711.02	.000000	711.02	750.99	.003998	187.63	360.50	379.27	384.24	470.26
15	654.67	.000000	654.67	709.71	.004092	181.79	357.26	375.94	380.73	470.74
16	623.49	.000000	623.49	753.67	.003992	188.00	359.80	377.63	382.36	475.65
17	579.23	.000000	579.23	489.59	.004712	148.05	360.33	382.54	387.17	485.65
18	586.06	.000000	586.06	624.15	.004306	169.26	343.16	355.32	358.22	419.17
24	790.78	.000000	790.78	741.47	.004019	186.29	352.61	364.26	367.33	415.03
25	819.69	.000000	819.69	757.07	.003985	188.48	353.90	365.53	368.63	415.16
26	859.07	.000000	859.07	636.56	.004273	171.12	353.29	366.60	369.83	415.97
28	1044.21	.000000	1044.21	276.66	.005638	108.08	408.30	451.54	458.10	535.49
30	1039.79	.000000	1039.79	271.15	.005669	106.88	407.70	451.36	457.97	536.10
32	1036.55	.000000	1036.55	297.91	.005523	112.62	402.44	445.31	452.14	533.23
33	1042.85	.000000	1042.85	397.63	.005057	132.06	417.94	452.24	458.65	534.25
34	1041.35	.000000	1041.35	384.29	.005113	129.61	418.49	452.79	459.08	533.39
36	1037.88	.000000	1037.88	404.79	.005028	133.36	415.26	449.49	455.95	532.52
40	1027.95	.000000	1027.95	464.43	.004800	143.82	413.71	446.71	453.42	533.77
42	1036.87	.000000	1036.87	471.00	.004777	144.93	409.99	444.19	451.20	534.35
43	1040.89	.000000	1040.89	568.16	.004463	160.69	413.29	444.85	452.02	536.78
45	1040.62	.000000	1040.62	510.06	.004643	151.42	413.90	446.37	453.32	535.50
52	700.18	.000000	700.18	487.46	.004719	147.70	339.36	372.69	379.64	501.84
54	701.56	.000000	701.56	472.69	.004771	145.22	342.84	375.85	382.62	501.42
55	701.78	.000000	701.78	504.61	.004661	150.53	345.23	376.78	383.49	501.13
57	717.07	.000000	717.07	463.56	.004803	143.67	330.00	366.17	373.52	499.58
58	709.69	.000000	709.69	465.33	.004797	143.97	331.58	367.42	374.72	501.19
59	701.96	.000000	701.96	381.57	.005125	129.10	330.48	369.21	376.28	500.23
60	703.14	.000000	703.14	327.03	.005375	118.58	331.35	372.03	378.86	498.26
61	712.06	.000000	712.06	261.82	.005722	104.81	332.55	378.24	385.02	502.10
62	712.78	.000000	712.78	292.31	.005553	111.44	332.26	376.46	383.43	503.71
64	858.93	.000000	858.93	411.01	.005003	134.49	396.81	419.51	423.83	485.68
65	861.33	.000000	861.33	398.27	.005055	132.18	396.83	420.24	424.61	487.10
67	993.14	.000000	993.14	337.66	.005324	120.69	397.71	424.75	429.37	486.58
68	923.32	.000000	923.32	406.12	.005023	133.60	355.10	383.12	388.42	459.00
69	919.95	.000000	919.95	486.53	.004722	147.54	352.87	379.31	384.83	458.64
70	920.41	.000000	920.41	473.26	.004769	145.32	352.13	379.17	384.73	459.00
71	799.56	.000000	799.56	412.84	.004995	134.81	352.03	377.60	382.48	457.52
72	930.49	.000000	930.49	436.69	.004902	139.04	353.48	379.91	385.11	453.87
75	764.52	.000000	764.52	321.39	.005403	117.45	377.71	404.34	408.76	479.94
76	632.48	.000000	632.48	267.64	.005689	106.10	400.52	427.96	432.08	512.09
77	678.54	.000000	678.54	305.21	.005485	114.14	398.17	425.45	429.85	509.62
78	726.91	.000000	726.91	306.45	.005478	114.40	399.36	427.47	432.01	508.94
80	813.53	.000000	813.53	269.95	.005675	106.61	398.61	430.99	435.87	509.67
81	835.08	.000000	835.08	318.91	.005415	116.95	397.49	427.85	432.87	506.85
82	895.62	.000000	895.62	350.56	.005263	123.22	398.65	429.32	434.66	508.10
83	959.91	.000000	959.91	296.08	.005533	112.23	400.00	432.56	437.73	503.98
85	875.26	.000000	875.26	179.22	.006252	84.52	310.45	352.54	357.58	428.34
86	873.07	.000000	873.07	196.39	.006133	89.09	307.97	349.48	354.71	428.45
87	867.40	.000000	867.40	206.26	.006067	91.62	306.77	347.00	352.22	426.19
88	864.84	.000000	864.84	218.42	.005987	94.65	306.35	345.50	350.75	425.35
89	861.86	.000000	861.86	253.97	.005768	103.04	305.03	342.24	347.66	425.10
90	861.70	.000000	861.70	222.78	.005959	95.71	304.34	343.46	348.76	424.42
91	859.54	.000000	859.54	290.77	.005561	111.11	304.10	339.58	345.15	424.97
92	860.62	.000000	860.62	330.18	.005360	119.21	304.57	338.53	344.26	426.13
93	864.92	.000000	864.92	320.96	.005405	117.36	303.48	338.94	344.83	428.55
94	450.56	.000000	450.56	415.17	.004986	135.23	303.94	322.36	325.88	421.84
95	496.71	.000000	496.71	375.23	.005153	127.92	302.61	322.99	326.67	417.81
96	578.53	.000000	578.53	361.82	.005212	125.38	310.42	338.63	343.62	449.90
97	624.70	.000000	624.70	317.39	.005423	116.64	303.97	335.54	340.75	443.26
98	668.81	.000000	668.81	356.28	.005237	124.32	301.19	331.47	336.79	434.68
99	709.50	.000000	709.50	277.18	.005635	108.19	302.22	336.66	341.92	433.29
100	746.37	.000000	746.37	308.48	.005468	114.82	303.65	336.38	341.69	429.29
101	782.43	.000000	782.43	302.32	.005500	113.54	302.32	335.94	341.34	426.26
102	824.14	.000000	824.14	288.08	.005575	110.54	304.19	338.95	344.38	425.52
103	859.57	.000000	859.57	269.92	.005676	106.61	304.13	340.03	345.44	422.94
104	530.30	.000000	530.30	165.75	.006349	80.76	218.74	234.79	236.63	279.19
105	526.99	.000000	526.99	139.54	.006544	72.94	214.81	232.87	234.74	278.26
106	524.02	.000000	524.02	192.55	.006159	88.08	216.00	231.19	233.08	277.52
107	524.28	.000000	524.28	265.20	.005702	105.56	215.55	229.14	231.17	278.77
108	521.08	.000000	521.08	239.63	.005854	99.73	213.74	228.00	230.02	277.52
109	513.48	.000000	513.48	289.92	.005565	110.93	211.52	224.66	226.72	276.13
110	503.46	.000000	503.46	337.49	.005325	120.66	208.58	220.76	222.84	273.65

TABLE XIII (Continued)

RUN	FUNCTION C	FUNCTION D	FUNCTION E	NU SHELL	NU TUBE	PR SHELL	PR TUBE
1	202.014	5.308	10.387	473.38	1119.07	12.24	13.34
4	180.414	5.195	10.380	422.68	912.70	12.28	13.25
5	196.335	5.280	10.376	459.32	857.25	12.25	12.89
8	197.063	5.284	10.379	460.29	735.76	12.26	13.13
11	178.374	5.184	10.374	416.29	938.32	12.25	14.89
12	176.969	5.176	10.366	413.76	898.61	12.32	14.92
13	127.228	4.846	10.393	295.41	842.80	12.05	14.74
14	194.861	5.272	10.380	451.71	799.29	12.08	14.82
15	183.381	5.212	10.386	426.44	736.07	12.20	14.79
16	195.472	5.275	10.411	453.22	702.18	12.11	14.53
17	126.778	4.842	10.397	294.47	654.56	12.09	14.03
18	158.826	5.068	10.337	373.32	647.58	12.72	18.15
24	191.140	5.253	10.364	444.85	872.58	12.36	18.48
25	195.493	5.276	10.370	454.39	904.53	12.32	18.47
26	164.092	5.100	10.367	381.99	948.24	12.34	18.41
28	75.250	4.321	9.771	169.03	1200.45	10.69	11.98
30	73.688	4.300	9.860	165.64	1195.61	10.70	11.96
32	80.490	4.388	9.941	181.67	1190.71	10.84	12.06
33	109.764	4.698	10.190	243.72	1198.36	10.46	12.02
34	106.148	4.665	10.158	235.59	1196.28	10.44	12.06
36	111.409	4.713	10.299	247.89	1191.94	10.52	12.09
40	127.666	4.849	10.431	284.27	1181.05	10.56	12.04
42	128.859	4.859	10.593	287.93	1191.53	10.65	12.02
43	156.205	5.051	10.668	347.71	1197.17	10.57	11.94
45	140.274	4.944	10.532	312.22	1196.32	10.55	11.98
52	121.961	4.804	10.270	291.20	795.64	12.87	13.29
54	118.866	4.778	10.150	282.70	797.09	12.73	13.31
55	127.415	4.847	10.074	302.02	797.26	12.64	13.32
57	114.250	4.738	9.973	276.09	814.21	13.25	13.39
58	114.976	4.745	9.873	277.29	806.27	13.19	13.32
59	93.979	4.543	9.777	227.29	797.23	13.23	13.36
60	80.565	4.389	9.664	194.86	798.02	13.20	13.45
61	64.442	4.166	9.435	156.07	809.22	13.14	13.28
62	71.972	4.276	9.553	174.22	810.48	13.16	13.21
64	111.319	4.712	10.215	250.17	970.65	10.98	14.03
65	107.834	4.681	10.360	242.42	973.84	10.98	13.96
67	91.365	4.515	10.116	205.59	1122.66	10.96	13.99
68	104.125	4.646	9.972	243.85	1033.99	12.27	15.45
69	124.470	4.824	10.168	291.92	1030.09	12.35	15.47
70	120.918	4.795	10.356	283.89	1030.73	12.38	15.45
71	105.547	4.659	9.984	247.64	894.95	12.38	15.54
72	111.813	4.717	9.989	262.07	1040.22	12.33	15.75
75	84.901	4.441	10.064	194.40	862.27	11.53	14.31
76	72.645	4.286	10.108	163.11	721.25	10.89	12.86
77	82.620	4.414	10.099	185.86	773.12	10.95	12.96
78	83.041	4.419	10.110	186.69	828.04	10.92	12.99
80	72.946	4.290	10.110	164.41	926.93	10.94	12.96
81	86.138	4.456	10.112	194.16	950.57	10.97	13.08
82	94.805	4.552	10.118	213.51	1019.91	10.94	13.03
83	80.129	4.384	10.123	180.41	1091.59	10.90	13.20
85	42.735	3.755	9.231	106.07	970.11	14.16	17.46
86	46.661	3.843	9.352	116.14	967.72	14.28	17.45
87	48.948	3.891	9.443	121.93	960.71	14.34	17.61
88	51.832	3.948	9.549	129.10	957.60	14.36	17.68
89	60.209	4.098	9.668	150.05	954.22	14.43	17.70
90	52.696	3.965	9.742	131.60	953.82	14.47	17.75
91	68.903	4.233	9.851	171.75	951.62	14.48	17.71
92	78.370	4.361	9.987	195.05	953.18	14.46	17.62
93	75.981	4.330	10.137	189.54	958.72	14.51	17.44
94	99.387	4.599	9.877	245.21	498.30	14.49	17.94
95	89.528	4.495	9.895	221.53	548.60	14.56	18.26
96	86.973	4.466	9.930	214.14	645.89	14.16	16.00
97	75.372	4.322	9.900	187.47	695.88	14.49	16.42
98	84.295	4.434	9.886	210.25	742.87	14.64	17.00
99	65.525	4.182	9.906	163.62	787.69	14.58	17.10
100	73.168	4.293	9.904	182.19	827.51	14.50	17.39
101	71.512	4.270	9.896	178.47	866.62	14.58	17.61
102	68.304	4.224	9.902	170.16	912.59	14.48	17.66
103	63.949	4.158	9.902	159.44	951.00	14.48	17.86
104	33.860	3.522	8.864	95.31	559.81	21.32	41.19
105	28.196	3.339	8.977	80.14	556.15	21.81	41.50
106	39.118	3.667	9.141	110.62	552.88	21.66	41.75
107	53.899	3.987	9.249	152.34	553.38	21.72	41.33
108	48.467	3.881	9.330	137.58	549.78	21.95	41.75
109	58.391	4.067	9.416	166.33	541.52	22.24	42.23
110	67.556	4.213	9.487	193.45	530.53	22.64	43.11

TABLE XIV

Shell-side Heat Transfer Data and Calculated Results for Tube Number 456

DETERMINATION OF THE POWER OF THE REYNOLDS NO. AND THE CONSTANT FOR THE SEIDER-TATE EQN. - SHELL SIDE

CORRELATION FOR TUBE 456 , NUMBER OF RUNS IS 12

SHELL SIDE FLUID IS MOBIL LIGHT

TUBE SIDE FLUID IS MOBIL 600

RUNS	TUBE	TEMP	XAO	XAI	XAM	RM	CI
12	456	0	19.9590	1.1400	1.3080	.9300E-04	.2957E-01

NO	K	L	M	NN	O	P	Q
1	.38925000E 00	.44750000E-03	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
2	.34400000E 00	.46333332E-03	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
3	.67977499E-01	-.19775000E-04	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
4	.71699999E-01	-.21000000E-04	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
5	-.20489551E-03	.10464268E 01	-.52113342E 02	.54997295E 03	.32380452E 05	-.75056534E 06	.00000000E 00
6	-.21480229E 01	.14160692E 04	-.27029259E 06	.32850279E 08	-.20186315E 10	.45553047E 11	.00000000E 00
7	-.29052144E 01	.22908367E 04	-.40461752E 06	.38134658E 08	-.70443591E 09	.00000000E 00	.00000000E 00
8	.00000000E 00	.00000000E 00	.00000000E 00	.00000000E 00	.00000000E 00	.00000000E 00	.00000000E 00

DIAS	AFS	AFT	DIAT
.36300E-01	.29100E-01	.38000E-02	.69500E-01

RUN	TSI	TSO	TTI	TTO	W SHELL	W TUBE	Q SHELL	Q TUBE	Q AVG	PER DEV	LMTD	UO	RE SHELL	RE TUBE
1	251.31	256.06	339.63	333.88	17910	15720	42772	45198	43985	2.757	83.069	26.529	10017	80473
2	250.38	255.05	339.64	333.90	19240	15720	45136	45120	45128	-.018	84.054	26.900	10700	80482
3	249.50	253.73	338.54	332.56	20800	15720	44155	46953	45554	3.072	83.932	27.193	11493	79771
4	247.18	251.32	337.17	331.17	22370	15520	46379	46451	46415	.078	84.917	27.386	12188	77966
7	240.67	244.23	336.10	329.58	27000	15730	47843	51097	49470	3.288	90.382	27.423	14116	78253
8	239.98	243.30	336.61	329.92	29050	15730	47971	52450	50210	4.460	91.615	27.459	15112	78498
9	239.47	242.60	337.14	330.43	31350	15730	48779	52632	50706	3.799	92.739	27.394	16248	78798
10	238.94	241.97	337.69	330.72	33570	15730	50539	54693	52616	3.948	93.736	28.123	17336	79041
11	238.12	240.99	336.70	329.76	35600	15730	50723	54408	52566	3.505	93.660	28.120	18281	78478
13	228.16	230.67	338.96	329.94	30900	8470	38152	38120	38136	-.042	105.001	18.197	14870	42637
17	230.58	233.48	335.24	327.34	30800	11250	44042	44215	44129	.196	99.239	22.279	15077	55329
18	230.45	233.42	331.12	323.77	30800	12480	45101	45471	45286	.408	95.493	23.760	15067	59642

NOTE - INPUT DATA TEMPERATURES ARE IN FAHR.

RUN	HI PRIME	RFIN IN	HI	HO PRIME	RFIN OUT	HO	TSAV	TWALL O	TWALL I	TTAV
1	652.75	.000000	652.75	266.20	.005697	105.78	253.68	274.52	277.65	336.75
2	651.35	.000000	651.35	298.09	.005522	112.66	252.71	272.79	275.99	336.77
3	647.51	.000000	647.51	335.39	.005335	120.25	251.61	270.60	273.84	335.55
4	635.47	.000000	635.47	400.25	.005047	132.54	249.25	266.80	270.10	334.17
7	635.23	.000000	635.23	406.13	.005022	133.60	242.45	261.01	264.53	332.84
8	635.38	.000000	635.38	410.21	.005006	134.34	241.64	260.38	263.95	333.26
9	636.13	.000000	636.13	398.54	.005054	132.23	241.03	260.26	263.86	333.78
10	634.62	.000000	634.62	517.70	.004619	152.67	240.45	257.74	261.48	334.20
11	631.96	.000000	631.96	534.05	.004567	155.30	239.55	256.53	260.27	333.23
13	377.91	.000000	377.91	435.14	.004908	138.77	229.41	243.22	245.93	334.45
17	473.17	.000000	473.17	530.25	.004579	154.69	232.03	246.34	249.48	331.29
18	509.07	.000000	509.07	559.57	.004489	159.35	231.93	246.19	249.41	327.44

RUN	FUNCTION C	FUNCTION D	FUNCTION E	NU SHELL	NU TUBE	PR SHELL	PR TUBE
1	57.818	4.057	9.212	153.48	701.96	17.81	27.64
2	64.661	4.169	9.278	171.81	700.45	17.89	27.64
3	72.657	4.286	9.350	193.24	696.05	17.98	27.84
4	86.401	4.459	9.408	230.44	682.80	18.19	28.08
7	86.420	4.459	9.555	233.33	682.25	18.80	28.31
8	87.133	4.467	9.623	235.62	682.51	18.87	28.23
9	84.517	4.437	9.696	228.87	683.43	18.93	28.14
10	109.827	4.699	9.761	297.25	681.89	18.98	28.07
11	113.113	4.728	9.814	306.54	678.82	19.07	28.24
13	90.459	4.505	9.607	248.98	406.10	20.10	28.03
17	110.800	4.708	9.621	303.65	507.94	19.82	28.58
18	116.909	4.761	9.620	320.43	545.79	19.83	29.27

TABLE XV

Regression Analysis Results for Tube Numbers 455 and 456 for the Shell-side Heat Transfer Coefficient Correlation Constant and Power to which Reynolds Number is Raised

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STEPWISE  REGRESSION

PROBLEM NO          1

NO OF DATA =   88

NO OF VARIABLES =          2

WEIGHTED DEGREES OF FREEDOM =        88.00

F LEVEL TO ENTER VARIABLE =       .004

F LEVEL TO REMOVE VARIABLE =      .004


                              SUM  OF  VARIABLES


        X( 1) =   .8738E 03      X(
          Y   =   .3987E 03

                           RAW  SUM  OF  SQUARES  AND  CROSS PRODUCTS


     X( 1) VS X( 1) =    .869126E 04    X(
     X( 1) VS   Y   =    .397182E 04    X(
     Y      VS   Y   =    .182268E 04

                            RESIDUAL  SUMS  OF  SQUARES  AND  CROSS PRODUCTS


     X( 1) VS X( 1) =    .138629E 02    X(
     X( 1) VS   Y   =    .125461E 02    X(
     Y      VS   Y   =    .161572E 02

                                  AVERAGE  VALUE  OF  VARIABLES


        X( 1) =   .9930E 01      X(
          Y   =   .4531E 01

                                                 STANDARD DEVIATIONS

        X( 1) =   .3992E 00      X(
          Y   =   .4309E 00

                                          CORRELATION  COEFFICIENTS


     X( 1) VS X( 2) =    .838297E 00    X(
     X( 1) VS   Y   =    .838297E 00    X(

  STANDARD ERROR OF Y =  .430947E 00     VARIANCE = .185715E 00

STEP NO.    1
  VARIABLE ENTERING        1
  F LEVEL =    203.3106
  STANDARD ERROR OF Y =   .2363E 00
  COEFF OF DETERMINATION =   .70274159E 00
  MULTIPLE CORLTN COEFF =   .83829683E 00




  CONSTANT TERM =  -.44559877E 01
  VARIABLE NO.          COEFFICIENT            STD ERR CF COEFF
     X- 1               .90501034E 00           .63470740E-01
COMPLETED    1 STEPS OF REGRESSION

     DIAGONAL  ELEMENTS

  VAR.NO.     VALUE

     1         1.000000

SUM OF SQUARED DEVIATIONS =  .48026E 01

NUMBER OF DATA CASES =   88
```

PREDICTED VS ACTUAL RESULTS

RUN	ACTUAL	PREDICTED	DEVIATION	PERCENT
1	.53083E 01	.49442E 01	.36414E 00	6.86
4	.51953E 01	.49379E 01	.25734E 00	4.95
5	.52798E 01	.49346E 01	.34524E 00	6.54
8	.52835E 01	.49368E 01	.34668E 00	6.56
11	.51839E 01	.49329E 01	.25099E 00	4.84
12	.51760E 01	.49255E 01	.25044E 00	4.84
13	.48460E 01	.49495E 01	-.10354E 00	-2.14
14	.52723E 01	.49383E 01	.33399E 00	6.33
15	.52116F 01	.49435E 01	.26802E 00	5.14
16	.52754E 01	.49657E 01	.30968E 00	5.87
17	.48424E 01	.49533E 01	-.11089E 00	-2.29
18	.50678E 01	.48990E 01	.16878E 00	3.33
24	.52530E 01	.49239E 01	.32909E 00	6.26
25	.52755E 01	.49286E 01	.34689E 00	6.58
26	.51004E 01	.49264E 01	.17403E 00	3.41
28	.43208E 01	.43868E 01	-.65973E-01	-1.53
30	.42998E 01	.44673E 01	-.16745E 00	-3.89
32	.43881E 01	.45404E 01	-.15231E 00	-3.47
33	.46983E 01	.47657E 01	-.67404E-01	-1.43
34	.46648E 01	.47370E 01	-.72148E-01	-1.55
36	.47132E 01	.48646E 01	-.15141E 00	-3.21
40	.48494E 01	.49838E 01	-.13441E 00	-2.77
42	.48587E 01	.51307E 01	-.27196E 00	-5.60
43	.50512E 01	.51986E 01	-.14742E 00	-2.92
45	.49436E 01	.50754E 01	-.13185E 00	-2.67
52	.48037E 01	.48381E 01	-.34362E-01	-.72
54	.47780E 01	.47297E 01	.48338E-01	1.01
55	.48474E 01	.46610E 01	.18649E 00	3.85
57	.47384E 01	.45701E 01	.16833E 00	3.55
58	.47447E 01	.44794E 01	.26532E 00	5.59
59	.45431E 01	.43927E 01	.15036E 00	3.31
60	.43891E 01	.42902E 01	.98843E-01	2.25
61	.41658E 01	.40824E 01	.83390E-01	2.00
62	.42763E 01	.41897E 01	.86602E-01	2.03
64	.47124E 01	.47890E 01	-.76591E-01	-1.63
65	.46806E 01	.49200E 01	-.23940E 00	-5.11
67	.45149E 01	.46987E 01	-.18387E 00	-4.07
68	.46456E 01	.45687E 01	.76885E-01	1.66
69	.48241E 01	.47466E 01	.77463E-01	1.61
70	.47951E 01	.49163E 01	-.12123E 00	-2.53
71	.46592E 01	.45800E 01	.79187E-01	1.70
72	.47168E 01	.45842E 01	.13267E 00	2.81
75	.44415E 01	.46524E 01	-.21094E 00	-4.75
76	.42856E 01	.46915E 01	-.40595E 00	-9.47
77	.44143E 01	.46841E 01	-.26980E 00	-6.11
78	.44193E 01	.46940E 01	-.27462E 00	-6.21
80	.42897E 01	.46936E 01	-.40386E 00	-9.41
81	.44560E 01	.46952E 01	-.23925E 00	-5.37
82	.45518E 01	.47009E 01	-.14911E 00	-3.28
83	.43836E 01	.47053E 01	-.32161E 00	-7.34
85	.37550E 01	.38979E 01	-.14288E 00	-3.81
86	.38429E 01	.40081E 01	-.16519E 00	-4.30
87	.38908E 01	.40902E 01	-.19948E 00	-5.13
88	.39480E 01	.41861E 01	-.23814E 00	-6.03
89	.40978E 01	.42938E 01	-.19598E 00	-4.78
90	.39645E 01	.43608E 01	-.39624E 00	-9.99
91	.42327E 01	.44591E 01	-.22637E 00	-5.35
92	.43614E 01	.45822E 01	-.22074E 00	-5.06
93	.43305E 01	.47181E 01	-.38758E 00	-8.95
94	.45990E 01	.44829E 01	.11616E 00	2.53
95	.44945E 01	.44993E 01	-.47196E-02	-.11
96	.44656E 01	.45305E 01	-.64906E-01	-1.45
97	.43224E 01	.45035F 01	-.18107E 00	-4.19
98	.44343E 01	.44907E 01	-.56372E-01	-1.27
99	.41824E 01	.45086E 01	-.32619E 00	-7.80
100	.42923E 01	.45072E 01	-.21441E 00	-4.99
101	.42699E 01	.44997E 01	-.22980E 00	-5.38
102	.42240E 01	.45051E 01	-.28116E 00	-6.66
103	.41581E 01	.45059E 01	-.34778E 00	-8.36
104	.35222E 01	.35657E 01	-.43488E-01	-1.23
105	.33392E 01	.36685E 01	-.32932E 00	-9.86
106	.36666E 01	.38167E 01	-.15017E 00	-4.10
107	.39871E 01	.39144E 01	.72703E-01	1.82
108	.38809E 01	.39880E 01	-.10708E 00	-2.76
109	.40672E 01	.40658E 01	.13266E-02	.03
110	.42130E 01	.41302E 01	.82748E-01	1.96
1	.45049E 01	.42385E 01	.26637E 00	5.91
2	.47077E 01	.42510E 01	.45670E 00	9.70
3	.47614F 01	.42505E 01	.51093E 00	10.73
4	.40573E 01	.38810E 01	.17626E 00	4.34
7	.41692E 01	.39407E 01	.22844E 00	5.48
8	.42857E 01	.40054E 01	.28034E 00	6.54
9	.44590E 01	.40585E 01	.40046E 00	8.98
10	.44592E 01	.41915E 01	.26777E 00	6.00
11	.44674E 01	.42532E 01	.21428E 00	4.80
13	.44369E 01	.43187E 01	.11823E 00	2.66
17	.46939E 01	.43774E 01	.32152E 00	6.84
18	.47284E 01	.44254E 01	.30295E 00	6.41

APPENDIX D. BOND RESISTANCE ERROR ANALYSIS

TABLE XVI

Bond Resistance Error Analysis Using the Heat Transfer Correlation Data for Tube Number 455 in Conjunction with the Experimentally Obtained Heat Transfer Correlations

BOND RESISTANCES FOR TUBE 455 NUMBER OF RUNS IS 76

RUN	TUBE	TEMP	XAO	XAI	XAB	RMT	RMI	RMO
76	455	0	19.8500	1.1400	1.3100	.14130E-02	.46700E-04	.46700E-04

CO	POWER	PRPOW	CI	AMI	AMO	ODL	OD
.01150	.90500	.33333	.02957	1.22500	1.39500	.96100	2.02600

NO	K	L	M	NN	O	P	Q
1	.38925000E 00	.44750000E-03	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
2	.34400000E 00	.46333332E-03	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
3	.67977499E-01	-.19775000E-04	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
4	.71699999E-01	-.21000000E-04	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
5	.13965872E-02	.24329326E 01	-.49320430E 03	.50414862E 05	-.24712216E 07	.48344347E 08	-.12876992E 09
6	-.21480229E 01	.14160692E 04	-.27029259E 06	.32850279E 08	-.20186315E 10	.45553047E 11	.00000000E 00
7	-.29052144E 01	.22908387E 04	-.40461752E 06	.38134658E 08	-.70443591E 09	.00000000E 00	.00000000E 00
8	.66227230E-01	.12066216E 03	-.15979375E 05	.16121989E 07	-.10121598E 09	.34104823E 10	-.46683010E 11

DIAS	AFS	AFT	DIAT	AFIN	AROOT	FPI	FINT	RCONT
.03660	.02888	.00379	.06950	18.70000	1.13000	9.39000	.01840	.0000000

RUN	TS IN F	TS OUT F	TT IN F	TT OUT F	W SHELL LB/HR	W TUBE LB/HR	Q SHELL BTU/HR	Q TUBE BTU/HR	PER DEV + OR -
1	352.81	359.20	507.33	494.23	34700	15250	121634	115076	2.77
4	352.29	357.71	510.33	495.35	34600	11820	102789	102163	.31
5	353.14	358.63	519.75	503.15	34350	10720	103439	103385	.03
8	353.07	357.78	514.06	497.16	34500	9025	89096	88199	.51
11	353.59	357.98	474.21	463.70	34300	13350	82586	78753	2.38
12	351.61	355.93	473.78	462.98	34300	12700	81136	76949	2.65
13	359.67	363.29	477.27	466.27	34150	11520	68118	71291	2.28
14	358.57	362.44	475.76	464.76	33860	10890	72146	67308	3.47
15	355.49	359.04	476.80	464.68	34500	9850	67254	67106	.11
16	358.06	361.54	482.00	469.31	35000	9160	67022	65605	1.07
17	358.64	362.03	492.74	478.56	34450	8150	64290	65760	1.13
18	342.10	344.23	423.06	415.28	34800	9840	40236	41203	1.19
24	351.44	353.79	417.76	412.31	34400	14300	44223	41797	2.82
25	352.71	355.09	417.79	412.53	34400	14930	44835	42121	3.12
26	352.03	354.55	418.51	413.44	34400	15780	47448	42941	4.99
28	413.46	403.14	540.91	530.08	15430	14530	91078	93175	1.14
30	402.90	412.51	541.50	530.70	16900	14440	92849	92385	.25
32	397.88	407.01	538.74	527.72	18660	14530	96997	94641	1.23
33	414.54	421.35	539.53	528.98	22700	14530	89085	90678	.89
34	414.91	422.07	538.39	528.39	21950	14520	90608	85833	2.71
36	412.08	418.44	537.64	527.41	25550	14520	93449	87748	3.15
40	410.82	416.60	539.14	528.41	29300	14350	97274	91048	3.31
42	407.54	412.45	540.08	528.62	34900	14520	98141	98439	.15
43	410.90	415.68	542.54	531.03	37200	14520	102101	99057	1.51
45	411.29	416.52	541.18	529.83	32400	14530	97346	97649	.16
52	336.58	342.14	510.05	493.63	33060	10100	99464	95611	1.98
54	339.74	345.94	509.39	493.45	28900	10100	97236	92785	2.34
55	341.86	348.61	508.94	493.32	26520	10100	97335	90901	3.42
57	326.11	333.89	507.77	491.39	25600	1[illegible]520	106938	99164	3.77
58	327.29	335.88	509.45	492.93	23000	10340	106220	98428	3.81
59	325.93	335.03	508.38	492.08	21000	10200	102647	95728	3.49
60	326.45	336.26	506.16	490.36	18680	10230	98503	92917	2.92
61	326.41	338.69	509.93	494.28	14770	10250	97592	92501	2.68
62	326.66	337.86	511.75	495.67	16650	10250	100314	95165	2.63
64	394.62	399.01	489.70	481.66	25050	12850	62333	58789	2.93
65	394.96	398.70	491.29	482.91	28950	12850	61373	61346	.02
67	395.15	400.28	490.24	482.92	22600	15300	65763	63776	1.53
68	352.10	358.10	463.26	454.74	23000	15380	75646	72945	1.82
69	350.29	355.45	463.03	454.26	28250	15380	79759	75063	3.03
70	349.99	354.28	463.42	454.58	34180	15380	80183	75684	2.89
71	349.32	354.74	462.16	452.88	23580	12970	69881	66919	2.16
72	350.66	356.30	458.06	449.68	23550	15750	72711	73158	.31
75	375.29	380.13	484.72	475.17	23100	11400	62417	61661	.61
76	398.33	402.71	518.34	505.85	22200	8280	55277	60113	4.19
77	395.77	400.58	515.57	503.67	22200	9100	60592	62822	1.81
78	396.88	401.85	514.55	503.34	22350	9910	63089	64412	1.04
80	396.08	401.15	515.17	504.17	22400	11350	64465	72431	5.82
81	394.62	400.36	511.79	501.92	22530	11820	73342	67530	4.13
82	395.60	401.70	512.92	503.28	22580	12850	78186	71775	4.28
83	397.20	402.81	508.47	499.49	22580	14080	71983	73020	.72
85	305.32	315.58	432.34	424.34	13310	15920	72128	69088	2.15
86	303.28	312.66	432.60	424.31	15210	15920	75196	71600	2.45
87	302.61	310.94	430.42	421.97	16750	15920	73466	72841	.43
88	302.61	310.09	429.63	421.08	18660	15920	73465	73650	.13
89	301.56	308.50	429.46	420.75	21150	15920	77170	75012	1.42
90	301.34	307.34	428.87	419.97	22850	15920	72038	76603	3.07
91	301.22	306.99	429.57	420.38	25500	15920	77295	79137	1.18
92	301.90	307.25	430.70	421.57	29150		1960	78698	2.03
93	301.15	305.82	433.28	423.83	34050	15920	13492	81625	1.13
94	302.18	305.70	428.18	415.50	26200	7330	48442	50139	1.72
95	300.79	304.44	423.58	412.04	26850	8350	51419	51801	.37
96	307.89	312.95	456.65	443.15	26780	9200	71570	68615	2.11
97	301.36	306.59	449.65	436.87	26800	10310	73625	72387	.85
98	298.50	303.89	440.55	428.81	26780	11500	75641	73635	1.34
99	299.63	304.82	438.78	427.80	27180	12340	73988	73811	.12
100	301.01	306.30	434.44	424.14	26950	13270	74866	74205	.44
101	299.61	305.03	431.15	421.38	26900	14180	76477	75019	.96
102	301.47	306.92	430.15	420.89	26820	15100	76794	75668	.74
103	301.47	306.79	427.39	418.49	26850	15990	75042	76843	1.19
104	217.11	220.37	280.97	277.42	15500	15980	24615	26853	4.35
105	213.34	216.28	280.04	276.49	17850	15980	25472	26829	2.59
106	214.73	217.28	279.33	275.72	20850	15980	25835	27262	2.69
107	214.28	216.83	280.63	276.92	23300	15980	28859	28052	1.42
108	212.60	214.89	279.38	275.67	25600	15980	28427	28018	.72
109	210.47	212.57	278.07	274.20	28350	15900	28809	29040	.40
110	207.55	209.61	275.49	271.81	31100	15820	30918	27408	6.02

TABLE XVI (Continued)

RUN	RE SHELL	RE TUBE	PR SHELL	PR TUBE	VISC SHELL LB/FT-HR	VISC S-WALL LB/FT-HR	VISC RATIO SHELL	VISC TUBE LB/FT-HR	VISC T-WALL LB/FT-HR	VISC RATIO TUBE
1	32340	197132	12.241	13.338	1.360	1.178	1.154	1.417	2.431	.583
4	32116	154188	12.277	13.249	1.365	1.204	1.134	1.404	2.497	.562
5	31998	145173	12.245	12.888	1.360	1.198	1.136	1.352	2.498	.541
8	32078	119165	12.262	13.131	1.363	1.221	1.116	1.387	2.582	.537
11	31939	149013	12.249	14.889	1.361	1.231	1.106	1.641	2.602	.631
12	31679	141366	12.321	14.920	1.372	1.242	1.105	1.645	2.642	.623
13	32530	130334	12.051	14.737	1.330	1.221	1.090	1.619	2.509	.645
14	32130	122319	12.085	14.818	1.336	1.224	1.091	1.630	2.601	.627
15	32317	110892	12.197	14.792	1.353	1.244	1.088	1.627	2.658	.612
16	33119	105563	12.109	14.533	1.339	1.234	1.085	1.589	2.631	.604
17	32668	98404	12.090	14.033	1.336	1.233	1.084	1.517	2.554	.594
18	30765	84946	12.716	18.153	1.434	1.357	1.056	2.121	3.072	.691
24	31623	120635	12.362	18.485	1.379	1.304	1.057	2.171	2.894	.750
25	31789	126038	12.316	18.474	1.371	1.297	1.058	2.169	2.870	.756
26	31710	133823	12.338	18.408	1.375	1.297	1.060	2.159	2.848	.758
28	17468	217529	10.689	11.981	1.119	.977	1.146	1.223	1.728	.708
30	19093	216711	10.703	11.960	1.122	.983	1.141	1.220	1.730	.706
32	20700	215539	10.837	12.061	1.142	1.001	1.141	1.235	1.782	.693
33	26552	216439	10.456	12.025	1.083	.974	1.112	1.229	1.724	.713
34	25722	215531	10.444	12.055	1.081	.973	1.112	1.234	1.720	.717
36	29618	214773	10.520	12.086	1.093	.987	1.108	1.238	1.747	.709
40	33788	213341	10.557	12.041	1.099	.995	1.104	1.232	1.771	.696
42	39740	216373	10.647	12.021	1.113	1.011	1.101	1.229	1.791	.686
43	42837	218515	10.567	11.936	1.101	1.002	1.098	1.217	1.783	.682
45	37387	217538	10.552	11.981	1.098	.996	1.102	1.223	1.772	.690
52	28761	131172	12.866	13.292	1.457	1.276	1.141	1.410	2.675	.527
54	25514	130929	12.729	13.310	1.435	1.253	1.145	1.413	2.626	.538
55	23649	130762	12.637	13.323	1.421	1.237	1.149	1.415	2.612	.541
57	21389	135268	13.253	13.391	1.517	1.286	1.179	1.424	2.780	.512
58	19351	133904	13.185	13.320	1.506	1.269	1.187	1.414	2.759	.513
59	17583	131532	13.232	13.362	1.514	1.271	1.191	1.420	2.732	.520
60	15700	130770	13.195	13.449	1.508	1.262	1.194	1.433	2.688	.533
61	12479	133276	13.145	13.281	1.500	1.234	1.216	1.408	2.588	.544
62	14049	134219	13.157	13.211	1.502	1.242	1.209	1.399	2.613	.535
64	27243	155174	10.985	14.032	1.165	1.080	1.079	1.517	2.066	.734
65	31486	156189	10.984	13.964	1.165	1.085	1.074	1.507	2.058	.732
67	24657	185525	10.961	13.988	1.162	1.067	1.089	1.510	2.006	.753
68	21357	163536	12.273	15.449	1.365	1.217	1.121	1.722	2.536	.679
69	25996	163249	12.353	15.470	1.377	1.236	1.114	1.725	2.592	.666
70	31359	163536	12.380	15.449	1.381	1.251	1.104	1.722	2.594	.664
71	21625	136903	12.384	15.536	1.382	1.243	1.112	1.735	2.630	.660
72	21725	163246	12.331	15.754	1.374	1.228	1.118	1.767	2.585	.684
75	23427	134053	11.530	14.315	1.250	1.145	1.092	1.557	2.247	.693
76	24462	112441	10.887	12.862	1.150	1.066	1.079	1.349	1.978	.682
77	24260	122267	10.948	12.963	1.160	1.068	1.085	1.363	2.001	.681
78	24527	132762	10.917	12.991	1.155	1.062	1.087	1.367	1.978	.691
80	24517	152530	10.937	12.961	1.158	1.058	1.094	1.363	1.936	.704
81	24561	156920	10.967	13.078	1.162	1.060	1.096	1.379	1.967	.701
82	24717	171519	10.936	13.026	1.158	1.051	1.102	1.372	1.949	.704
83	24836	184590	10.900	13.200	1.152	1.049	1.098	1.397	1.918	.728
85	10177	144495	14.156	17.456	1.657	1.395	1.188	2.018	3.089	.653
86	11495	144584	14.281	17.447	1.677	1.415	1.185	2.016	3.149	.640
87	12588	142828	14.342	17.614	1.686	1.433	1.177	2.041	3.203	.637
88	13995	142178	14.364	17.677	1.690	1.445	1.169	2.051	3.236	.634
89	15763	141984	14.432	17.696	1.700	1.459	1.166	2.053	3.306	.621
90	16973	141455	14.468	17.748	1.706	1.476	1.156	2.061	3.280	.628
91	18921	141884	14.481	17.706	1.708	1.478	1.155	2.055	3.364	.611
92	21678	142781	14.456	17.619	1.704	1.484	1.148	2.042	3.385	.603
93	25189	144662	14.513	17.440	1.713	1.501	1.141	2.015	3.372	.598
94	19425	64217	14.489	17.945	1.709	1.558	1.097	2.090	3.871	.540
95	19780	71541	14.559	18.261	1.720	1.562	1.101	2.137	3.848	.556
96	20474	93467	14.158	15.997	1.658	1.465	1.131	1.803	3.399	.530
97	19873	101243	14.488	16.421	1.709	1.497	1.141	1.865	3.470	.538
98	19593	107974	14.635	17.002	1.732	1.511	1.147	1.951	3.570	.546
99	19985	115009	14.580	17.099	1.724	1.507	1.143	1.965	3.441	.571
100	19953	121060	14.504	17.386	1.712	1.496	1.144	2.007	3.447	.582
101	19789	127266	14.575	17.609	1.723	1.501	1.148	2.041	3.456	.590
102	19909	134975	14.476	17.665	1.707	1.488	1.147	2.049	3.382	.606
103	19925	140933	14.479	17.860	1.708	1.489	1.147	2.078	3.357	.619
104	7051	51083	21.322	41.190	2.786	2.507	1.111	5.729	9.034	.634
105	7899	50639	21.812	41.501	2.864	2.583	1.109	5.779	9.250	.625
106	9305	50287	21.661	41.752	2.840	2.578	1.101	5.820	9.470	.615
107	10365	50883	21.718	41.330	2.849	2.582	1.103	5.752	9.709	.592
108	11243	50287	21.950	41.752	2.886	2.625	1.099	5.820	9.858	.590
109	12253	49379	22.242	42.230	2.932	2.670	1.098	5.897	10.305	.572
110	13156	47972	22.642	43.110	2.996	2.731	1.097	6.039	10.879	.555

TABLE XVI (Continued)

RUN	Q AVG BTU/HR	LMTD F	HO PRIME BTU/HR-SQFT-F	R FIN HR-SQFT-F/BTU	HO BTU/HR-SQFT-F	HI BTU/HR-SQFT-F	UO CALC BTU/HR-SQFT-F	UO EXP BTU/HR-SQFT-F	R BOND HR-SQFT-F/BTU
1	118355	144.75	542.92	.00449	157.88	985.16	39.34	41.19	-.00008
4	102476	147.79	538.91	.00451	157.17	802.92	33.94	34.93	-.00006
5	103412	155.50	536.59	.00452	156.77	751.91	32.31	33.50	-.00007
8	88647	150.10	536.82	.00451	156.81	646.65	28.80	29.75	-.00007
11	80669	113.14	533.77	.00453	156.27	835.06	34.89	35.92	-.00005
12	79042	114.58	531.15	.00454	155.81	799.88	33.78	34.75	-.00005
13	69704	110.25	537.69	.00451	156.96	749.34	32.24	31.85	.00002
14	69727	109.72	532.41	.00453	156.03	711.02	30.95	32.02	-.00007
15	67180	113.42	537.22	.00451	156.88	654.67	29.08	29.84	-.00006
16	66313	115.79	547.30	.00448	158.64	623.49	28.06	28.85	-.00006
17	65025	125.24	540.10	.00450	157.38	579.23	26.44	26.16	.00003
18	40719	75.97	521.27	.00457	154.06	586.06	26.59	27.00	-.00004
24	43010	62.41	527.85	.00455	155.23	790.78	33.47	34.72	-.00007
25	43478	61.25	529.48	.00454	155.51	819.69	34.38	35.76	-.00007
26	45195	62.68	528.89	.00454	155.41	859.07	35.57	36.33	-.00004
28	92127	126.90	291.85	.00565	110.15	1044.21	36.81	36.57	.00001
30	92617	128.39	316.32	.00552	115.19	1039.79	37.26	36.34	.00004
32	95819	130.78	342.35	.00538	120.44	1036.55	37.72	36.91	.00004
33	89882	116.30	420.11	.00500	135.54	1042.85	39.23	38.93	.00001
34	88220	114.89	407.94	.00505	133.23	1041.35	39.00	38.68	.00001
36	90598	117.25	464.83	.00480	143.87	1037.88	39.78	38.93	.00004
40	94161	120.05	524.36	.00456	154.61	1027.95	40.29	39.51	.00003
42	98290	124.33	609.48	.00427	169.30	1036.87	41.47	39.83	.00007
43	100579	123.46	649.75	.00414	175.99	1040.89	41.98	41.04	.00004
45	97497	121.57	574.39	.00438	163.33	1040.62	41.21	40.40	.00003
52	97538	162.42	498.32	.00466	149.96	700.18	30.35	30.25	.00001
54	95010	158.53	445.26	.00488	140.26	701.56	29.97	30.19	-.00002
55	94118	155.85	414.55	.00502	134.49	701.78	29.71	30.42	-.00005
57	103051	169.54	387.88	.00515	129.38	717.07	29.92	30.62	-.00005
58	102324	169.57	353.80	.00532	122.72	709.69	29.33	30.40	-.00008
59	99188	169.72	325.07	.00547	116.97	701.96	28.76	29.44	-.00005
60	95710	166.89	293.17	.00565	110.42	703.14	28.38	28.89	-.00004
61	95046	169.55	238.35	.00594	98.64	712.06	27.77	28.24	-.00004
62	97740	171.44	265.26	.00580	104.52	712.78	28.24	28.72	-.00004
64	60561	88.85	438.30	.00491	138.96	858.93	34.62	34.34	.00002
65	61359	90.25	499.31	.00466	150.14	861.33	35.35	34.25	.00006
67	64770	88.86	400.57	.00509	131.82	993.14	37.69	36.72	.00005
68	74295	103.90	371.88	.00523	126.27	923.32	35.47	36.03	-.00003
69	77411	105.76	445.19	.00488	140.24	919.95	36.40	36.87	-.00002
70	77934	106.85	527.38	.00455	155.14	920.41	37.35	36.74	.00003
71	68400	105.48	377.14	.00520	127.30	799.56	32.21	32.67	-.00003
72	72935	100.38	378.33	.00520	127.53	930.49	35.76	36.60	-.00004
75	62039	102.22	391.65	.00513	130.11	764.52	31.37	30.58	.00005
76	57695	111.53	395.93	.00511	130.93	632.48	27.34	26.06	.00012
77	61707	111.41	394.35	.00512	130.63	678.54	28.79	27.90	.00007
78	63751	109.55	397.84	.00510	131.30	726.91	30.32	29.32	.00007
80	68448	111.03	398.37	.00510	131.40	813.53	32.87	31.06	.00012
81	70436	109.35	399.64	.00509	131.64	835.08	33.49	32.45	.00006
82	74981	109.44	401.69	.00508	132.04	895.62	35.18	34.52	.00004
83	72501	103.97	402.61	.00508	132.21	959.91	36.88	35.13	.00009
85	70608	117.89	203.94	.00612	90.73	875.26	30.93	30.17	.00005
86	73398	120.48	228.47	.00599	96.42	873.07	31.52	30.69	.00006
87	73153	119.42	248.25	.00589	100.83	867.40	31.84	30.86	.00007
88	73557	119.00	273.15	.00575	106.21	864.84	32.30	31.14	.00008
89	76091	120.07	304.67	.00558	112.80	861.86	32.81	31.92	.00006
90	74321	120.07	325.75	.00547	117.10	861.70	33.16	31.18	.00013
91	78216	120.86	359.49	.00529	123.84	859.54	33.62	32.60	.00006
92	80329	121.55	405.95	.00506	132.85	860.62	34.28	33.29	.00006
93	82559	125.05	465.40	.00480	143.98	864.92	35.10	33.26	.00010
94	49290	117.84	365.58	.00526	125.04	450.56	20.81	21.07	-.00004
95	51610	115.15	372.58	.00523	126.41	496.71	22.53	22.58	-.00001
96	70092	139.44	381.31	.00518	128.11	578.53	25.43	25.32	.00001
97	73006	139.25	375.26	.00521	126.93	624.70	26.91	26.41	.00005
98	74638	133.46	372.31	.00523	126.36	668.81	28.28	28.17	.00001
99	73899	131.04	378.29	.00520	127.52	709.50	29.59	28.41	.00009
100	74535	125.62	376.95	.00520	127.26	746.37	30.67	29.89	.00006
101	75748	123.93	375.06	.00521	126.89	782.43	31.70	30.79	.00006
102	76231	121.32	376.02	.00521	127.08	824.14	32.88	31.66	.00008
103	75942	118.80	376.31	.00521	127.14	859.57	33.86	32.20	.00010
104	25734	60.45	171.02	.00628	82.49	530.30	21.57	21.44	.00002
105	26150	63.45	191.14	.00618	87.63	526.99	21.80	20.76	.00015
106	26549	61.52	220.88	.00603	94.69	524.02	22.12	21.74	.00005
107	28455	63.22	243.85	.00591	99.86	524.28	22.40	22.68	-.00004
108	28222	63.78	263.41	.00581	104.12	521.08	22.51	22.29	.00003
109	28925	64.61	286.16	.00568	108.96	513.48	22.47	22.55	-.00001
110	29163	65.07	307.23	.00557	113.33	503.46	22.31	22.58	-.00004

TABLE XVI (Continued)

RUN	TS AVG F	T FIN AVG F	T ROOT F	T BOND O F	T BOND F	T BOND I F	T LINER F	T WALL I F	TT AVG F	FIN EFF
1	356.00	365.34	393.77	397.73	394.31	390.88	393.14	395.40	500.78	.243
4	355.00	363.15	387.85	391.28	389.13	386.98	388.93	390.88	502.84	.244
5	355.88	364.15	389.12	392.58	389.72	386.87	388.84	390.81	511.45	.245
8	355.42	362.51	383.90	386.87	384.43	381.98	383.67	385.36	505.61	.245
11	355.78	362.27	381.79	384.49	382.82	381.14	382.68	384.22	468.95	.246
12	353.77	360.16	379.33	381.97	380.33	378.68	380.19	381.70	468.38	.246
13	361.48	367.04	383.85	386.19	386.85	387.52	388.84	390.17	471.77	.245
14	360.50	366.13	383.02	385.35	383.47	381.58	382.91	384.24	470.26	.246
15	357.26	362.63	378.84	381.09	379.63	378.16	379.45	380.73	470.74	.245
16	359.80	364.99	380.86	383.08	381.45	379.83	381.09	382.36	475.65	.242
17	360.33	365.50	381.15	383.33	384.01	384.70	385.94	387.17	485.65	.244
18	343.16	346.53	356.48	357.84	357.26	356.67	357.45	358.22	419.17	.249
24	352.61	356.12	366.57	368.01	366.85	365.69	366.51	367.33	415.03	.247
25	353.90	357.43	367.98	369.44	368.21	366.97	367.80	368.63	415.16	.247
26	353.29	356.96	367.94	369.45	368.78	368.10	368.97	369.83	415.97	.247
28	408.30	422.66	450.44	453.52	454.06	454.59	456.35	458.10	535.49	.344
30	407.70	420.94	448.21	451.31	452.87	454.43	456.20	457.97	536.10	.330
32	402.44	415.01	442.52	445.73	447.11	448.49	450.32	452.14	533.23	.316
33	417.94	427.37	451.35	454.36	454.79	455.22	456.94	458.65	534.25	.282
34	418.49	428.04	451.85	454.80	455.26	455.71	457.39	459.08	533.39	.286
36	415.26	423.75	446.98	450.02	451.26	452.50	454.23	455.95	532.52	.266
40	413.71	421.43	444.39	447.54	448.69	449.83	451.63	453.42	533.77	.248
42	409.99	416.81	439.24	442.53	444.99	447.45	449.32	451.20	534.35	.228
43	413.29	419.78	442.08	445.45	446.82	448.19	450.11	452.02	536.78	.219
45	413.90	421.13	443.98	447.24	448.42	449.60	451.46	453.32	535.50	.235
52	339.36	347.83	372.13	375.39	375.66	375.93	377.78	379.64	501.84	.256
54	342.84	352.18	376.97	380.15	379.57	379.00	380.81	382.62	501.42	.272
55	345.23	355.24	380.49	383.64	381.77	379.90	381.69	383.49	501.13	.284
57	330.00	341.79	370.13	373.58	371.58	369.59	371.55	373.52	499.58	.295
58	331.58	344.53	373.59	377.02	373.92	370.81	372.76	374.72	501.19	.310
59	330.48	344.24	373.20	376.52	374.51	372.50	374.39	376.28	500.23	.325
60	331.35	346.20	375.02	378.23	376.72	375.21	377.03	378.86	498.26	.344
61	332.55	350.97	381.09	384.27	382.83	381.39	383.21	385.02	502.10	.383
62	332.26	349.15	379.37	382.64	381.17	379.70	381.56	383.43	503.71	.362
64	396.81	402.87	418.77	420.80	421.16	421.52	422.68	423.83	485.68	.275
65	396.83	402.14	417.42	419.47	420.87	422.27	423.44	424.61	487.10	.255
67	397.71	404.87	422.47	424.64	425.77	426.90	428.14	429.37	486.58	.289
68	355.10	364.00	384.74	387.23	386.41	385.58	387.00	388.42	459.00	.302
69	352.87	360.48	380.68	383.27	382.57	381.88	383.36	384.83	458.64	.273
70	352.13	358.49	377.44	380.05	380.90	381.75	383.24	384.73	459.00	.247
71	352.03	360.10	379.10	381.39	380.63	379.87	381.17	382.48	457.52	.299
72	353.48	362.05	382.29	384.73	383.53	382.33	383.72	385.11	453.87	.299
75	377.71	384.73	401.73	403.81	405.10	406.40	407.58	408.76	479.94	.293
76	400.52	406.97	422.72	424.65	427.26	429.88	430.98	432.08	512.09	.291
77	398.17	405.11	421.97	424.04	425.77	427.50	428.67	429.85	509.62	.292
78	399.36	406.46	423.83	425.96	427.77	429.58	430.80	432.01	508.94	.290
80	398.61	406.22	424.86	427.15	430.20	433.26	434.56	435.87	509.67	.290
81	397.49	405.29	424.44	426.80	428.49	430.18	431.52	432.87	506.85	.290
82	398.65	406.91	427.26	429.77	430.79	431.80	433.23	434.66	508.10	.289
83	400.00	407.97	427.63	430.06	432.51	434.96	436.34	437.73	503.98	.289
85	310.45	326.61	349.66	352.02	353.45	354.88	356.23	357.58	428.34	.414
86	307.97	322.85	346.32	348.77	350.34	351.91	353.31	354.71	428.45	.391
87	306.77	320.35	343.32	345.77	347.60	349.43	350.82	352.22	426.19	.375
88	306.35	318.67	341.24	343.70	345.82	347.94	349.34	350.75	425.35	.357
89	305.03	316.35	339.01	341.56	343.16	344.76	346.21	347.66	425.10	.337
90	304.34	314.63	336.31	338.80	342.36	345.93	347.35	348.76	424.42	.325
91	304.10	313.83	335.92	338.54	340.36	342.17	343.66	345.15	424.97	.307
92	304.57	313.32	335.04	337.73	339.46	341.20	342.73	344.26	426.13	.287
93	303.48	311.21	332.37	335.14	338.41	341.68	343.25	344.83	428.55	.266
94	303.94	309.96	323.80	325.45	324.72	324.00	324.94	325.88	421.84	.305
95	302.61	308.79	323.18	324.91	324.80	324.70	325.68	326.67	417.81	.301
96	310.42	318.59	337.98	340.33	340.64	340.95	342.29	343.62	449.90	.297
97	303.97	312.64	332.95	335.39	336.68	337.96	339.35	340.75	443.26	.300
98	301.19	310.13	330.95	333.45	333.70	333.94	335.36	336.79	434.68	.301
99	302.22	310.91	331.42	333.89	336.50	339.11	340.52	341.92	433.29	.299
100	303.65	312.45	333.16	335.66	337.25	338.85	340.27	341.69	429.29	.299
101	302.32	311.31	332.39	334.93	336.69	338.46	339.90	341.34	426.26	.300
102	304.19	313.22	334.41	336.97	339.22	341.48	342.93	344.38	425.52	.300
103	304.13	313.11	334.22	336.76	339.66	342.55	343.99	345.44	422.94	.300
104	218.74	225.84	234.46	235.32	235.48	235.65	236.14	236.63	279.19	.451
105	214.81	221.22	229.84	230.72	232.23	233.74	234.24	234.74	278.26	.428
106	216.00	221.59	230.13	231.02	231.54	232.07	232.58	233.08	277.52	.398
107	215.55	220.94	229.91	230.86	230.47	230.08	230.62	231.17	278.77	.379
108	213.74	218.66	227.40	228.34	228.64	228.94	229.48	230.02	277.52	.364
109	211.52	216.13	224.89	225.86	225.74	225.62	226.17	226.72	276.13	.348
110	208.58	212.88	221.54	222.52	222.12	221.73	222.28	222.84	273.65	.335

TABLE XVI (Continued)

RUN	T LINER F	T FIN F	TLINER-TFIN F	MU	K AIR BTU/HR-SQFT-F/FT	ALPHA LINER IN/IN	ALPHA FIN IN/IN	R BOND HR-SQFT-F/BTU
1	393.14	365.34	27.80	.2338E-06	.0223	.6761E-05	.1350E-04	-.00008
4	388.93	363.15	25.78	.2334E-06	.0222	.6751E-05	.1349E-04	-.00006
5	388.84	364.15	24.69	.2336E-06	.0222	.6751E-05	.1349E-04	-.00007
8	383.67	362.51	21.16	.2333E-06	.0221	.6739E-05	.1349E-04	-.00007
11	382.68	362.27	20.41	.2332E-06	.0221	.6737E-05	.1349E-04	-.00005
12	380.19	360.16	20.03	.2328E-06	.0220	.6732E-05	.1348E-04	-.00005
13	388.84	367.04	21.80	.2342E-06	.0222	.6751E-05	.1350E-04	.00002
14	382.91	366.13	16.78	.2339E-06	.0221	.6738E-05	.1350E-04	-.00007
15	379.45	362.63	16.82	.2333E-06	.0220	.6730E-05	.1349E-04	-.00006
16	381.09	364.99	16.11	.2337E-06	.0220	.6734E-05	.1349E-04	-.00006
17	385.94	365.50	20.44	.2338E-06	.0221	.6744E-05	.1350E-04	.00003
18	357.45	346.53	10.92	.2301E-06	.0215	.6681E-05	.1344E-04	-.00004
24	366.51	356.12	10.39	.2320E-06	.0217	.6701E-05	.1347E-04	-.00007
25	367.80	357.43	10.38	.2322E-06	.0218	.6704E-05	.1347E-04	-.00007
26	368.97	356.96	12.00	.2321E-06	.0218	.6706E-05	.1347E-04	-.00004
28	456.35	422.66	33.69	.2458E-06	.0236	.6902E-05	.1367E-04	.00001
30	456.20	420.94	35.26	.2454E-06	.0236	.6902E-05	.1366E-04	.00004
32	450.32	415.01	35.31	.2441E-06	.0235	.6889E-05	.1365E-04	.00004
33	456.94	427.37	29.57	.2468E-06	.0236	.6904E-05	.1368E-04	.00001
34	457.39	428.04	29.36	.2470E-06	.0236	.6905E-05	.1368E-04	.00001
36	454.23	423.75	30.47	.2460E-06	.0235	.6897E-05	.1367E-04	.00004
40	451.63	421.43	30.20	.2455E-06	.0235	.6892E-05	.1366E-04	.00003
42	449.32	416.81	32.51	.2445E-06	.0234	.6886E-05	.1365E-04	.00007
43	450.11	419.78	30.33	.2452E-06	.0235	.6888E-05	.1366E-04	.00004
45	451.46	421.13	30.33	.2455E-06	.0235	.6891E-05	.1366E-04	.00003
52	377.78	347.83	29.96	.2305E-06	.0219	.6726E-05	.1344E-04	.00001
54	380.81	352.18	28.63	.2313E-06	.0220	.6733E-05	.1346E-04	-.00002
55	381.69	355.24	26.45	.2319E-06	.0220	.6735E-05	.1347E-04	-.00005
57	371.55	341.79	29.76	.2293E-06	.0218	.6712E-05	.1343E-04	-.00005
58	372.76	344.53	28.24	.2298E-06	.0219	.6715E-05	.1343E-04	-.00008
59	374.39	344.24	30.15	.2298E-06	.0219	.6719E-05	.1343E-04	-.00005
60	377.03	346.20	30.83	.2302E-06	.0219	.6725E-05	.1344E-04	-.00004
61	383.21	350.97	32.24	.2311E-06	.0221	.6738E-05	.1345E-04	-.00004
62	381.56	349.15	32.41	.2307E-06	.0220	.6735E-05	.1345E-04	-.00004
64	422.68	402.87	19.80	.2415E-06	.0229	.6827E-05	.1361E-04	.00002
65	423.44	402.14	21.30	.2413E-06	.0229	.6829E-05	.1361E-04	.00006
67	428.14	404.87	23.27	.2419E-06	.0230	.6839E-05	.1361E-04	.00005
68	387.00	364.00	23.00	.2336E-06	.0221	.6747E-05	.1349E-04	-.00003
69	383.36	360.48	22.87	.2329E-06	.0221	.6739E-05	.1348E-04	-.00002
70	383.24	358.49	24.75	.2325E-06	.0220	.6738E-05	.1348E-04	.00003
71	381.17	360.10	21.08	.2328E-06	.0220	.6734E-05	.1348E-04	-.00003
72	383.72	362.05	21.67	.2332E-06	.0221	.6740E-05	.1349E-04	-.00004
75	407.58	384.73	22.85	.2377E-06	.0226	.6793E-05	.1355E-04	.00005
76	430.98	406.97	24.00	.2424E-06	.0230	.6845E-05	.1362E-04	.00012
77	428.67	405.11	23.56	.2420E-06	.0230	.6840E-05	.1362E-04	.00007
78	430.80	406.46	24.34	.2423E-06	.0230	.6845E-05	.1362E-04	.00007
80	434.56	406.22	28.34	.2422E-06	.0231	.6853E-05	.1362E-04	.00012
81	431.52	405.29	26.24	.2420E-06	.0231	.6847E-05	.1362E-04	.00006
82	433.23	406.91	26.33	.2424E-06	.0231	.6850E-05	.1362E-04	.00004
83	436.34	407.97	28.38	.2426E-06	.0231	.6857E-05	.1362E-04	.00009
85	356.23	326.61	29.62	.2277E-06	.0214	.6678E-05	.1338E-04	.00005
86	353.31	322.85	30.46	.2276E-06	.0214	.6671E-05	.1337E-04	.00006
87	350.82	320.35	30.47	.2275E-06	.0213	.6666E-05	.1336E-04	.00007
88	349.34	318.67	30.68	.2274E-06	.0213	.6663E-05	.1336E-04	.00008
89	346.21	316.35	29.86	.2273E-06	.0212	.6656E-05	.1335E-04	.00006
90	347.35	314.63	32.72	.2273E-06	.0212	.6658E-05	.1334E-04	.00013
91	343.66	313.83	29.83	.2272E-06	.0212	.6650E-05	.1334E-04	.00006
92	342.73	313.32	29.41	.2272E-06	.0211	.6648E-05	.1334E-04	.00006
93	343.25	311.21	32.04	.2272E-06	.0211	.6649E-05	.1333E-04	.00010
94	324.94	309.96	14.98	.2270E-06	.0208	.6608E-05	.1333E-04	-.00004
95	325.68	308.79	16.90	.2270E-06	.0208	.6610E-05	.1333E-04	-.00001
96	342.29	318.59	23.70	.2274E-06	.0212	.6647E-05	.1336E-04	.00001
97	339.35	312.64	26.72	.2272E-06	.0211	.6640E-05	.1334E-04	.00005
98	335.36	310.13	25.24	.2271E-06	.0210	.6631E-05	.1333E-04	.00001
99	340.52	310.91	29.60	.2271E-06	.0211	.6643E-05	.1333E-04	.00009
100	340.27	312.45	27.82	.2272E-06	.0211	.6642E-05	.1334E-04	.00006
101	339.90	311.31	28.59	.2271E-06	.0211	.6641E-05	.1333E-04	.00006
102	342.93	313.22	29.71	.2272E-06	.0211	.6648E-05	.1334E-04	.00008
103	343.99	313.11	30.88	.2272E-06	.0211	.6651E-05	.1334E-04	.00010
104	236.14	225.84	10.30	.2239E-06	.0189	.6409E-05	.1308E-04	.00002
105	234.24	221.22	13.02	.2237E-06	.0188	.6405E-05	.1306E-04	.00015
106	232.58	221.59	10.99	.2237E-06	.0188	.6401E-05	.1306E-04	.00005
107	230.62	220.94	9.69	.2237E-06	.0188	.6397E-05	.1306E-04	-.00004
108	229.48	218.66	10.82	.2236E-06	.0187	.6394E-05	.1306E-04	.00003
109	226.17	216.13	10.04	.2235E-06	.0187	.6387E-05	.1305E-04	-.00001
110	222.28	212.88	9.40	.2234E-06	.0186	.6378E-05	.1304E-04	-.00004

TABLE XVII

Bond Resistance Error Analysis Using the Heat Transfer Correlation Data for Tube Number 456 in Conjunction with the Experimentally Obtained Heat Transfer Correlations

BOND RESISTANCES FOR TUBE 456 NUMBER OF RUNS IS 12

RUN	TUBE	TEMP	XAC	XAI	XAB	RMT	RMI	RMO
12	456	0	19.9590	1.1400	1.3080	.14200E-02	.46500E-04	.46500E-04

CO	POWER	PRPOW	CI	AMI	AMO	ODL	OD
.01150	.90500	.33333	.02957	1.22500	1.39500	.96100	2.02000

NO	K	L	M	NN	O	P	Q
1	.38925000E 00	.44750000E-03	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
2	.34400000E 00	.46333332E-03	-.00000000E 00	-.C0000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
3	.67977499E-01	-.19775000E-04	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
4	.71699999E-01	-.21000000E-04	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
5	.13965872E-02	.24329326E 01	-.49320430E 03	.50414862E 05	-.24712216E 07	.48344347E 08	-.12876992E 09
6	-.21480229E 01	.14160692E 04	-.27029259E 06	.32850279E 08	-.20186315E 10	.45553047E 11	.00000000E 00
7	-.29052144E 01	.22908387E 04	-.40461752E 06	.38134658E 08	-.70443591E 09	.00000000E 00	.00000000E 00
8	.66227230E-01	.12066216E 03	-.15979375E 05	.16121989E 07	-.10121598E 09	.34104823E 10	-.46683010E 11

DIAS	AFS	AFT	CIAT	AFIN	AROOT	FPI	FINT	RCONT
.03630	.02910	.00380	.06950	18.83000	1.13000	9.40000	.01840	.0000000

RUN	TS IN F	TS OUT F	TT IN F	TT OUT F	W SHELL LB/HR	W TUBE LB/HR	Q SHELL BTU/HR	Q TUBE BTU/HR	PER DEV + OR -
1	251.31	256.06	339.63	333.88	17910	15720	42772	45198	2.76
2	250.38	255.05	339.64	333.90	19240	15720	45136	45120	.02
3	249.50	253.73	338.54	332.56	20800	15720	44155	46953	3.07
4	247.18	251.32	337.17	331.17	22370	15520	46379	46451	.08
7	240.67	244.23	336.10	329.58	27000	15730	47843	51097	3.29
8	239.98	243.30	336.61	329.92	29050	15730	47971	52450	4.46
9	239.47	242.60	337.14	330.43	31350	15730	48779	52632	3.80
10	238.94	241.97	337.69	330.72	33570	15730	50539	54693	3.95
11	238.12	240.99	336.70	329.76	35600	15730	50723	54408	3.50
13	228.16	230.67	338.96	329.94	30900	8470	38152	38120	.04
17	230.58	233.48	335.24	327.34	30800	11250	44042	44215	.20
18	230.45	233.42	331.12	323.77	30800	12480	45101	45471	.41

RUN	Q AVG BTU/HR	LMTD F	HO PRIME BTU/HR-SQFT-F	R FIN HR-SQFT-F/BTU	HO BTU/HR-SQFT-F	HI BTU/HR-SQFT-F	UO CALC BTU/HR-SQFT-F	UO EXP BTU/HR-SQFT-F	R BOND HR-SQFT-F/BTU
1	43985	83.07	221.47	.00603	94.83	652.75	25.78	26.53	-.00007
2	45128	84.05	235.50	.00596	98.01	651.35	25.97	26.90	-.00009
3	45554	83.93	251.66	.00587	101.58	647.51	26.11	27.19	-.00010
4	46415	84.92	266.58	.00579	104.80	635.47	25.97	27.39	-.00013
7	49470	90.38	308.57	.00556	113.60	635.23	26.47	27.42	-.00009
8	50210	91.61	328.64	.00545	117.69	635.38	26.69	27.46	-.00007
9	50706	92.74	351.18	.00534	122.20	636.13	26.94	27.39	-.00004
10	52616	93.74	372.86	.00523	126.46	634.62	27.09	28.12	-.00009
11	52566	93.66	391.75	.00513	130.13	631.96	27.17	28.12	-.00008
13	38136	105.00	330.93	.00544	118.15	377.91	17.79	18.20	-.00008
17	44129	99.24	333.92	.00543	118.75	473.17	21.35	22.28	-.00013
18	45286	95.49	333.93	.00543	118.76	509.07	22.61	23.76	-.00014

RUN	RE SHELL	RE TUBE	PR SHELL	PR TUBE	VISC SHELL LB/FT-HR	VISC S-WALL LB/FT-HR	VISC RATIO SHELL	VISC TUBE LB/FT-HR	VISC T-WALL LB/FT-HR	VISC RATIO TUBE
1	10017	80473	17.810	27.642	2.230	1.959	1.138	3.573	5.812	.615
2	10700	80482	17.890	27.640	2.243	1.971	1.138	3.572	5.903	.605
3	11493	79771	17.983	27.844	2.258	1.989	1.135	3.604	6.027	.598
4	12188	77966	18.185	28.077	2.290	2.018	1.135	3.641	6.250	.582
7	14116	78253	18.796	28.306	2.386	2.099	1.137	3.676	6.609	.556
8	15112	78498	18.872	28.232	2.398	2.114	1.134	3.665	6.648	.551
9	16248	78798	18.929	28.143	2.407	2.128	1.131	3.651	6.654	.549
10	17336	79041	18.984	28.071	2.416	2.135	1.132	3.640	6.819	.534
11	18281	78478	19.070	28.238	2.429	2.153	1.128	3.666	6.906	.531
13	14870	42637	20.100	28.030	2.592	2.339	1.108	3.633	8.079	.450
17	15077	55329	19.823	28.576	2.548	2.268	1.124	3.719	7.761	.479
18	15067	59642	19.833	29.266	2.550	2.263	1.127	3.827	7.769	.493

RUN	TS AVG F	T FIN AVG F	T ROOT F	T BOND O F	T BOND F	T BOND I F	T LINER F	T WALL I F	TT AVG F	FIN EFF
1	253.68	262.85	276.92	278.39	277.18	275.98	276.81	277.65	336.75	.398
2	252.71	261.52	275.79	277.29	275.79	274.28	275.14	275.99	336.77	.385
3	251.61	259.89	274.08	275.60	273.86	272.11	272.97	273.84	335.55	.372
4	249.25	257.18	271.44	272.99	270.66	268.34	269.22	270.10	334.17	.361
7	242.45	249.67	264.27	265.92	264.28	262.65	263.59	264.53	332.84	.334
8	241.64	248.48	263.02	264.69	263.36	262.04	262.99	263.95	333.26	.323
9	241.03	247.46	261.82	263.51	262.73	261.94	262.90	263.86	333.78	.311
10	240.45	246.70	261.30	263.05	261.27	259.48	260.48	261.48	334.20	.301
11	239.55	245.47	259.79	261.55	259.91	258.27	259.27	260.27	333.23	.293
13	229.41	234.57	245.59	246.86	245.67	244.48	245.21	245.93	334.45	.322
17	232.03	237.94	250.65	252.12	249.96	247.81	248.64	249.48	331.29	.320
18	231.93	238.00	251.04	252.55	250.12	247.69	248.55	249.41	327.44	.320

RUN	T LINER F	T FIN F	TLINER-TFIN F	MU	K AIR BTU/HR-SQFT-F/FT	ALPHA LINER IN/IN	ALPHA FIN IN/IN	R BOND HR-SQFT-F/BTU
1	276.81	262.85	13.96	.2257E-06	.0198	.6500E-05	.1319E-04	-.00007
2	275.14	261.52	13.62	.2257E-06	.0198	.6496E-05	.1318E-04	-.00009
3	272.97	259.89	13.08	.2256E-06	.0197	.6491E-05	.1318E-04	-.00010
4	269.22	257.18	12.04	.2255E-06	.0196	.6483E-05	.1317E-04	-.00013
7	263.59	249.67	13.92	.2253E-06	.0195	.6470E-05	.1315E-04	-.00009
8	262.99	248.48	14.51	.2252E-06	.0195	.6469E-05	.1315E-04	-.00007
9	262.90	247.46	15.44	.2252E-06	.0195	.6469E-05	.1314E-04	-.00004
10	260.48	246.70	13.77	.2251E-06	.0194	.6463E-05	.1314E-04	-.00009
11	259.27	245.47	13.80	.2251E-06	.0194	.6461E-05	.1314E-04	-.00008
13	245.21	234.57	10.63	.2247E-06	.0191	.6429E-05	.1310E-04	-.00008
17	248.64	237.94	10.70	.2248E-06	.0192	.6437E-05	.1311E-04	-.00013
18	248.55	238.00	10.55	.2248E-06	.0192	.6437E-05	.1311E-04	-.00014

APPENDIX E. BOND RESISTANCE COMPUTER PROGRAM AND BOND RESISTANCE DATA AND CALCULATED RESULTS FOR BIMETALLIC TUBE NUMBERS 461-463

TABLE XVIII

Bond Resistance Program Written in The University of Michigan Algorithm Decoder Language

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         BOND RESISTANCE MEASUREMENTS
          DIMENSION TSIC(90), TSOC(90), TTIF(90), TTOC(90), TSIF(90),
        1  TSOF(90), TTIF(90), WSHEL(90), WTUBE(90), QTUBE(90),
        2  QSHEL(90), QAVG(90), PERDE(90), LMTA(90), XAMT(90), CPS(90),
        3  CPT(90), VISS(90), VIST(90), KTUBE(90), KSHEL(90), PRSH(90),
        4  PRTU(90), TWIA(90), TWIB(90), VISWI(90), HI(90), RET(90),
        5  RES(90), VISWO(90),  UO(90), RHO(90), HOPR(90), TWOA(90),
        6  RFIN(90), TWO(90), K(8), L(8), M(8), NN(8), O(8), P(8),
        7  RUOT(90), RBOND(90), RHOPR(90), UOT(90), TTOF(90), MU(90),
        8  FEFF(90), ILINE(90), TFIN(90), DELT(90), VISRS(90), PCO(90),
        9  VISRT(90), ALINER(90), ALFIN(90), TTAV(90), TSAV(90), Q(8)
          DIMENSION TBOND(90), TBONDI(90), TBONDO(90), R(90), PCOLL(90)
          DIMENSION TIIC(90), HO(90), KAIR(90), ELINER(90), EFIN(90),
        1  PCOUL(90), DEV(90)
          INTEGER RUNS, TUBE, TEMP, N, J, R
BEGIN     READ FORMAT INFO, RUNS, TUBE, TEMP, XAO, XAI, XAB, RMT,
        1  RMI, RMO
          READ FORMAT INFOA, CO, POWER, PRPOW, CI, AMI, AMO, ODL, OD
          READ FORMAT DATAC, DIAS, AFS, AFT, DIAT, AFIN, AROOT,
        1  FPI, FINT, RCONT, BRERR
          PRINT FORMAT TITLE, TUBE, RUNS
          THROUGH INPUT, FOR J = 1, 1, J.G. RUNS
INPUT     READ FORMAT DATAT, TSIC(J), TSOC(J), TTIC(J), TTOC(J),
        1 WSHEL(J), WTUBE(J), R(J)
          THROUGH NOR, FOR J = 1, 1, J.G. 8
          READ FORMAT CONSTA, K(J), L(J), M(J), NN(J)
NOR       READ FORMAT CONSTB, O(J), P(J), Q(J)
          ID = DIAT*12.0
          PRINT FORMAT HEDA
          PRINT FORMAT INPUTA, RUNS, TUBE, TEMP, XAO, XAI, XAB, RMT,
        1  RMI, RMO
          PRINT FORMAT HEDB
          PRINT FORMAT INPUTB, CO, POWER, PRPOW, CI, AMI, AMO, ODL, OD
          PRINT FORMAT HEDC
          THROUGH NORTH, FOR J = 1, 1, J.G. 8
NORTH     PRINT FORMAT INPUTC, J, K(J), L(J), M(J), NN(J), O(J), P(J),
        1 Q(J)
          PRINT FORMAT HEDD
          PRINT FORMAT INPUTD, DIAS, AFS, AFT, DIAT, AFIN, AROOT,
        1  FPI, FINT, RCONT, BRERR
          PCOTOT = 0.0
          SUMSDE = 0.0
          N = 1
ALPHA     WHENEVER TEMP .E. 1, TRANSFER TO GAMMA
          TSIF(N) = TSIC(N)
          TSOF(N) = TSOC(N)
          TTIF(N) = TTIC(N)
          TTOF(N) = TTOC(N)
          TRANSFER TO SIGMA
GAMMA     TSIF(N) = 1.8 * TSIC(N) + 32
          TSOF(N) = 1.8 * TSOC(N) + 32
          TTIF(N) = 1.8 * TTIC(N) + 32
          TTOF(N) = 1.8 * TTOC(N) + 32
SIGMA     TSAV(N) = 0.5 * ( TSIF(N) + TSOF(N))
          TTAV(N) = 0.5 * ( TTIF(N) + TTOF(N))
          CPS(N) = K(1) + L(1)*TSAV(N) + M(1)*TSAV(N).P.2
        1 + NN(1)*TSAV(N).P.3 + O(1)*TSAV(N).P.4
          CPT(N) = K(2) + L(2)*TTAV(N) + M(2)*TTAV(N).P.2
        1 +NN(2)*TTAV(N).P.3 + O(2)*TTAV(N).P.4
          QSHEL(N) = WSHEL(N)*CPS(N)*.ABS.(TSOF(N)-TSIF(N))
          QTUBE(N) = WTUBE(N)*CPT(N)*.ABS.(TTOF(N)-TTIF(N))
          QAVG(N) = 0.5 * ( QSHEL(N) + QTUBE(N))
          PERDE(N) = ( 100 * .ABS.(QTUBE(N)-QSHEL(N)))/(QTUBE(N) +
        1 QSHEL(N))
          LMTA(N) = (.ABS.(TTIF(N)-TSOF(N))-.ABS.(TTOF(N)-TSIF(N)))/
        1 ELOG.((TTIF(N)-TSOF(N)) /(TTOF(N)-TSIF(N)))
          XAMT(N) = .ABS. (TTAV(N)-TSAV(N))
          WHENEVER LMTA(N) .G. XAMT(N), LMTA(N) = XAMT(N)
          UO(N) = ( QAVG(N))/( XAO*LMTA(N))
          VISS(N) = EXP.(K(6) + L(6)/TSAV(N) + M(6)/TSAV(N).P.2 +
        1 NN(6)/TSAV(N).P.3 + O(6)/TSAV(N).P.4 + P(6)/TSAV(N).P.5 +
        1 Q(6)/TSAV(N).P.6)
          VIST(N) = EXP.(K(7) + L(7)/TTAV(N) + M(7)/TTAV(N).P.2 +
        1 NN(7)/TTAV(N).P.3 + O(7)/TTAV(N).P.4 + P(7)/TTAV(N).P.5 +
        1 Q(7)/TTAV(N).P.6)
          KSHEL(N) = K(3) + L(3)*TSAV(N) + M(3)*TSAV(N).P.2 +
        1 NN(3)*TSAV(N).P.3 + O(3)*TSAV(N).P.4
          KTUBE(N) = K(4) + L(4)*TTAV(N) + M(4)*TTAV(N).P.2 +
        1 NN(4)*TTAV(N).P.3 + O(4)*TTAV(N).P.4
          RES(N) = (DIAS*WSHEL(N))/(AFS*VISS(N))
          RET(N) = (DIAT*WTUBE(N))/(AFT*VIST(N))
          PRSH(N) = (CPS(N)*VISS(N))/KSHEL(N)
          PRTU(N) = (CPT(N)*VIST(N))/KTUBE(N)
          TWIA(N) = TTAV(N)
BETA      VISWI(N) = EXP.(K(7) + L(7)/TWIA(N) + M(7)/TWIA(N).P.2 +
        1 NN(7)/TWIA(N).P.3 + O(7)/TWIA(N).P.4 + P(7)/TWIA(N).P.5 +
        1 Q(7)/TWIA(N).P.6)
          HI(N) = (CI*RET(N).P.0.8*PRTU(N).P.0.33333*KTUBE(N)
        1 VIST(N).P.0.14)/(VISWI(N).P.0.14*DIAT)
          WHENEVER TTAV(N) .G. TSAV(N), TRANSFER TO KAPPA
          TWIB(N) = TTAV(N) + (QAVG(N)/(XAI*HI(N)))
          TRANSFER TO PHI
KAPPA     TWIB(N) = TTAV(N) -(QAVG(N)/(XAI*HI(N)))
PHI       WHENEVER .ABS. (TWIA(N) - TWIB(N)) .LE. 0.2, TRANSFER TOEIGHT
          TWIA(N) = TWIB(N)
          TRANSFER TO BETA
EIGHT     TWO(N) = TSAV(N)
LOOP      VISWO(N) = EXP.(K(6) + L(6)/TWO(N) + M(6)/TWO(N).P.2 +
        1 NN(6)/TWO(N).P.3 + O(6)/TWO(N).P.4 + P(6)/TWO(N).P.5 +
        1 Q(6)/TWO(N).P.6)
          HOPR(N)=(CO*RES(N).P.POWER*PRSH(N).P.PRPOW  *VISS(N).P.0.14*
        1 KSHEL(N))/(VISWO(N).P.0.14*DIAS)
          RHOPR(N) = 1/HOPR(N)
          RFIN(N) = K(5) + L(5)*RHOPR(N) + M(5)*RHOPR(N).P.2 +
        1 NN(5)*RHOPR(N).P.3 + O(5)*RHOPR(N).P.4
        1 + P(5)*RHOPR(N).P.5 + Q(5)*RHOPR(N).P.6
          RHO(N) = RHOPR(N) + RFIN(N)
          HO(N) = 1.0/RHO(N)
          WHENEVER TTAV(N).G.TSAV(N), TRANSFER TO NINE
          TWOA(N) = TSAV(N) - QAVG(N)*RHO(N)/XAO
          TRANSFER TO TEN
NINE      TWOA(N) = TSAV(N) + QAVG(N)*RHO(N)/XAO
TEN       WHENEVER .ABS. (TWOA(N) - TWO(N)).LE.0.2, TRANSFER TO BOUT
          TWO(N) = TWOA(N)
          TRANSFER TO LOOP
BOUT      RUOT(N) = RHO(N) + XAO/(XAI*HI(N))    + RMT + XAO*RCONT/XAB
          VISRS(N) = VISS(N)/VISWO(N)
          VISRT(N) = VIST(N)/VISWI(N)
          UOT(N) = 1/RUOT(N)
          RBOND(N) = ((1/UO(N)) - RUOT(N))*XAB/XAO
          FEFF(N) = K(8) + L(8)/HOPR(N) + M(8)/HOPR(N).P.2 +
        1 NN(8)/HOPR(N).P.3 + O(8)/HOPR(N).P.4 + P(8)/HOPR(N).P.5 +
        1 Q(8)/HOPR(N).P.6
          WHENEVER TTAV(N) .G. TSAV(N), TRANSFER TO TRA
          TBONDI(N) = TWIB(N) + QAVG(N)*RMI/AMI
          TBONDO(N) = TWOA(N) - QAVG(N)*RMO/AMO
          TFIN(N) = TSAV(N) - QAVG(N)/(HOPR(N)*(AFIN + AROOT/FEFF(N)))
          TRANSFER TO EXCH
TRA       TBONDI(N) = TWIB(N) - QAVG(N)*RMI/AMI
          TBONDO(N) = TWOA(N) + QAVG(N)*RMO/AMO
          TFIN(N) = TSAV(N) + QAVG(N)/(HOPR(N)*(AFIN + AROOT/FEFF(N)))
EXCH      TBOND(N) = ( TBONDI(N) + TBONDO(N))/2
          TLINE(N) = (TBONDI(N) + TWIB(N))/2
          DELT(N) = TLINE(N) - TFIN(N)
          MFIN = 0.32
          MLINER = 0.30
          KAIR(N) = 0.0138 + 0.0000216*TBOND(N)
          ALINER(N) = (5.88 + 0.00224*TLINE(N))/10.0.P.6
          ALFIN(N) = (12.4 + 0.003*TFIN(N))/10.0.P.6
          WHENEVER TLINE .LE. 265.0
          ELINER(N) = (30.1 - 0.00308*TLINE(N))*10.0.P.6
          OTHERWISE
          ELINER(N) = (31.3 - 0.00767*TLINE(N))*10.0.P.6
          END OF CONDITIONAL
          WHENEVER TFIN(N) .LE. 335.0
          EFIN(N) = (10.75 - 0.00183*TFIN(N))*10.0.P.6
          OTHERWISE
          EFIN(N) = (13.42 - 0.0098*TFIN(N))*10.0.P.6
          END OF CONDITIONAL
          MU(N) = ((1.0/EFIN(N))*((OD*OD + ODL*ODL)/(OD*OD -ODL*ODL) +
        1  MFIN) + (FPI*FINT/ELINER(N))*((ODL*ODL + ID*ID)/(ODL*ODL -
        2  ID*ID) - MLINER))
          PCO(N) = (ALFIN(N)*(TFIN(N) - 70.0) - ALINER(N)*(TLINE(N) -
        1  70.0) - 24.0*RBOND(N)*KAIR(N)/ODL)/MU(N)
          PCOUL(N) = (ALFIN(N)*(TFIN(N) - 70.0) - ALINER(N)*(TLINE(N) -
        1  70.0) - 24.0*(RBOND(N) - BRERR)*KAIR(N)/ODL)/MU(N)
          PCOLL(N) = (ALFIN(N)*(TFIN(N) - 70.0) - ALINER(N)*(TLINE(N) -
        1  70.0) - 24.0*(RBOND(N) + BRERR)*KAIR(N)/ODL)/MU(N)
          PCOTOT = PCOTOT + PCO(N)
          WHENEVER  N.E. RUNS, TRANSFER TO PRIOUT
          N = N + 1
          TRANSFER TO ALPHA
PRIOUT    PRINT FORMAT HEADA
          THROUGH OUT1, FOR J = 1, 1, J .G. RUNS
OUT1      PRINT FORMAT RESLT1, R(J), TSIF(J), TSOF(J), TTIF(J),
        1  TTOF(J), WSHEL(J), WTUBE(J), QSHEL(J), QTUBE(J), PERDE(J)
          PCOAVG = PCOTOT/RUNS
          THROUGH TWA, FOR N = 1, 1, N .G. RUNS
          DEV(N) = PCO(N) - PCOAVG
TWA       SUMSDE = SUMSDE + DEV(N)*DEV(N)
          STDEV = SQRT.(SUMSDE/RUNS)
          PRINT FORMAT HEADB
```

```
              THROUGH OUT2, FOR J = 1, 1, J .G. RUNS
OUT2          PRINT FORMAT RESLT2, R(J), QAVG(J), LMTA(J), HOPR(J),
            1  RFIN(J), HO(J), HI(J), UOT(J), UO(J), RBOND(J)
              PRINT FORMAT HEADC
              THROUGH OUT3, FOR J = 1, 1, J .G. RUNS
OUT3          PRINT FORMAT RESLT3, R(J), RES(J), RET(J), PRSH(J), PRTU(J),
            1  VISS(J), VISWO(J), VISRS(J), VIST(J), VISWI(J), VISRT(J)
              PRINT FORMAT HEADD
              THROUGH OUT4, FOR J = 1, 1, J .G. RUNS
OUT4          PRINT FORMAT  RESLT4, R(J), TSAV(J), TFIN(J), TWOA(J),
            1  TBONDO(J), TBOND(J), TBONDI(J), TLINE(J), TWIB(J), TTAV(J),
            2  FEFF(J)
              PRINT FORMAT HEADC
              THROUGH OUT5, FOR J = 1, 1, J .G. RUNS
OUT5          PRINT FORMAT RESLT5, R(J), TLINE(J), TFIN(J), DELT(J),
            1  MU(J), KAIR(J), ALINER(J),ALFIN(J), RBOND(J), PCO(J)
              PRINT FORMAT JET
              THROUGH THREE, FOR J = 1, 1, J .G. RUNS
THREE         PRINT FORMAT JET1, R(J), PCO(J), PCOAVG, DEV(J), PCOLL(J),
            1  PCOUL(J)
              PRINT FORMAT JET2, STDEV
              VECTOR VALUES JET2 = $ 22H4STANDARD DEVIATION =   F5.0   *$
              VECTOR VALUES TITLE = $ 26H1BOND RESISTANCES FOR TUBE I5,
            1 18H NUMBER OF RUNS IS I5 *$
              VECTOR VALUES INFO = $ 3I5, 3F10.4, 3E10.5  *$
              VECTOR VALUES INFOA = $ 8F10.5  *$
              VECTOR VALUES DATAT = $ 4F10.3, 2F10.0, S7, I3  *$
              VECTOR VALUES CONSTA = $ 4E15.8*$
              VECTOR VALUES CONSTB = $ 3E15.8*$
              VECTOR VALUES DATAC = $ 4E10.5, 4F10.5  /2F10.7  *$
              VECTOR VALUES HEDA = $ 81HO RUN TUBE TEMP        XAO        XAI
            1         XAB          RMT           RMI          RMO   *$
              VECTOR VALUES INPUTA = $ 3I5, 3F10.4, 3E12.5  *$
              VECTOR VALUES HEDB = $ 80HO         CO       POWER       PRPOW
            1    CI        AMI        AMO        ODL          OD     *$
              VECTOR VALUES INPUTB = $ 8F10.5  *$
              VECTOR VALUES   HEDC = $ 110HC  NO                 K
            1   L               M                NN                 O
            1  P               Q *$
              VECTOR VALUES INPUTC = $ I5, 7E15.8 *$
              VECTOR VALUES HEDD = $100HO       DIAS          AFS          AFT
            1  DIAT      AFIN      AROOT        FPI       FINT       RCONT      B
            1 RERR      *$
              VECTOR VALUES INPUTD = $ 8F10.5, F10.7, F10.6   *$
              VECTOR VALUES HEADA = $  95H1 RUN       TS IN     TS OUT      TT
            1 IN     TT OUT    W SHELL     W TUBE   Q SHELL     Q TUBE   PER DE
            2 V    /  95H               F            F           F
            3 LB/HR      LB/HR     BTU/HR     BTU/HR     + OR -      / *$
              VECTOR VALUES RESLT1 = $I5, 4F10.2, 4F10.0,  F9.2  *$
              VECTOR VALUES HEADB = $ 130H1 RUN      Q AVG     LMTD      HO
            1 PRIME          R FIN             HO              HI            UO C
            2 ALC          UO EXP          R BOND      /  130H           BTU/HR
            3      F    BTU/HR-SQFT-F  HR-SQFT-F/BTU  BTU/HR-SQFT-F  BTU/HR
            4 -SQFT-F  BTU/HR-SQFT-F  BTU/HR-SQFT-F  HR-SQFT-F/BTU    /*$
              VECTOR VALUES RESLT2 = $ I5, F10.0, F10.2, F11.2, F16.5,
            1  F14.2, F15.2, F15.2, F15.2, F16.6   *$
              VECTOR VALUES HEADC = $ 130H1 RUN   RE SHELL   RE TUBE   PR S
            1 HELL   PR TUBE   VISC SHELL   VISC S-WALL   VISC RATIO   VISC
            2  TUBE   VISC T-WALL   VISC RATIO      /  130H
            3                                    LB/FT-HR       LB/FT-HR
            4    SHELL       LB/FT-HR      LB/FT-HR          TUBE          /*$
              VECTOR VALUES RESLT3 = $ I5, 2F10.0, F11.3, F11.3, F11.3,
            1  F13.3, F14.3, F12.3, F13.3, F14.3  *$
              VECTOR VALUESHEADD = $ 126H1 RUN     TS AVG      T FIN AVG
            1  T ROOT       T BOND O      T BOND       T BOND I      T LINER
            2 T WALL I      TT AVG      FIN EFF      /
            3                              114H              F            F
            2        F            F            F            F            F
            3        F            F           /  *$
              VECTOR VALUES RESLT4 = $ I5, F11.2, F12.2,  F13.2, 4F12.2,
            1   F13.2, F12.2, F10.3   *$
              VECTOR VALUES HEADE = $ 120H1 RUN   T LINER    T FIN   TLINER
            1 -TFIN         MU              K AIR       ALPHA LINER   ALPHA FI
            2 N        R BOND        P CO      /  120H              F          F
            3          F                        BTU/HR-SQFT-F/FT      IN/IN
            4      IN/IN     HR-SQFT-F/BTU     PSI            / *$
              VECTOR VLAUES RESLT5 = $ I5, F9.2, F10.2, F11.2, E15.4,
            1  F14.4, E18.4, E13.4, F14.6, F10.0   *$
              VECTOR VALUES JET = $ 60H1 RUN      P CO      P CO AVG      DEV
            1     P CO LL      P CO UL     /   60H             PSI         PSI
            1      PSI         PSI            PSI              /  *$
              VECTOR VALUES JET1 = $ I5, F9.0, F11.0, 2F10.0, F12.0   *$
              TRANSFER TO BEGIN
              END OF PROGRAM
```

NOMENCLATURE

AFIN	FIN HEAT TRANSFER AREA - SQFT
AFS	SHELL-SIDE FLOW AREA - SQFT
AFT	TUBE-SIDE FLOW AREA - SQFT
ALFIN	THERMAL EXPANSION COEFFICIENT OF FIN MATERIAL - IN/IN
ALINER	THERMAL EXPANSION COEFFICIENT OF LINER MATERIAL IN/IN
AMI	MEAN HEAT TRANSFER AREA OF LINER METAL - SQFT
AMO	MEAN HEAT TRANSFER AREA OF ROOT METAL - SQFT
AROOT	HEAT TRANSFER AREA AT ROOT OF TUBE - SQFT
BRERR	MAXIMUM LIKELY ERROR IN BOND RESISTANCE - HR-SQFT-F/BTU
CI	INSIDE HEAT TRANSFER COEFFICIENT CORRELATION CONSTANT
CO	SHELL-SIDE HEAT TRANSFER COEFFICIENT CORRELATION CONSTANT
CPS	SHELL-SIDE SPECIFIC HEAT - BTU/LB-F
CPT	TUBE-SIDE SPECIFIC HEAT - BTU/LB-F
DIAS	SHELL-SIDE EQUIVALENT DIAMETER - FT
DIAT	INSIDE DIAMETER OF TUBE - FT
EFIN	MODULUS OF ELASTICITY OF FIN METAL
ELINER	MODULUS OF ELASTICITY OF LINER METAL
FEFF	FIN EFFICIENCY
FINT	FIN THICKNESS - IN
FPI	FINS PER INCH
HI	INSIDE HEAT TRANSFER COEFFICIENT - BTU/HR-SQFT-F
HOPR	SHELL-SIDE HEAT TRANSFER COEFFICIENT - BTU/HR-SQFT-F
HO	SHELL-SIDE HEAT TRANSFER COEFFICIENT (INCLUDES RFIN) - BTU/HR-SQFT-F
K	POLYNOMIAL CONSTANT FOR PHYSICAL PROPERTIES
KSHEL	THERMAL CONDUCTIVITY OF SHELL-SIDE FLUID - BTU/HR-SQFT-F/FT
KTUBE	THERMAL CONDUCTIVITY OF TUBE-SIDE FLUID - BTU/HR-SQFT-F/FT
L	POLYNOMIAL CONSTANT FOR PHYSICAL PROPERTIES
LMTA	LOGARITHMIC TEMPERATURE DIFFERENCR - F
M	POLYNOMIAL CONSTANT FOR PHYSICAL PROPERTIES
MFIN	POISSONS RATIO FOR FIN METAL
MLINER	POISSONS RATIO FOR LINER METAL
NN	POLYNOMIAL CONSTANT FOR PHYSICAL PROPERTIES
NUSHEL	SHELL-SIDE NUSSELT NUMBER
NUTUBE	TUBE-SIDE NUSSELT NUMBER
O	POLYNOMIAL CONSTANT FOR PHYSICAL PROPERTIES
ODL	LINER OUTSIDE DIAMETER - IN
OD	FIN DIAMETER - IN
P	POLYNOMIAL CONSTANT FOR PHYSICAL PROPERTIES
PCOAVG	AVERAGE INITIAL CONTACT PRESSURE - PSI
PCOLL	LOWER LIMIT OF INITIAL CONTACT PRESSURE - PSI
PCO	CALCULATED VALUE OF INITIAL CONTACT PRESSURE - PSI
PCOUL	UPPER LIMIT OF INITIAL CONTACT PRESSURE - PSI
PERDE	PER CENT DEVIATION IN HEAT BALANCE
PRPOW	POWER TO WHICH PRANDTL NUMBER IS RAISED
PRSH	PRANDTL NUMBER OF SHELL-SIDE FLUID
PRTU	PRANDTL NUMBER OF TUBE-SIDE FLUID
Q	POLYNOMIAL CONSTANT FOR PHYSICAL PROPERTIES
QAVG	AVERAGE OF SHELL-SIDE AND TUBE-SIDE HEAT FLUXES - BTU/HR
QSHEL	SHELL-SIDE HEAT FLUX - BTU/HR
QTUBE	TUBE-SIDE HEAT FLUX - BTU
RBOND	BOND RESISTANCE - HR-SQFT(BOND AREA)-F/BTU
RCONT	INITIAL CONTACT RESISTANCE IF ANY - HR-SQFT(BOND AREA)-F/BTU
REP	POWER TO WHICH REYNOLDS NUMBER IS RAISED
RES	SHELL-SIDE REYNOLDS NUMBER
RET	TUBE-SIDE REYNOLDS NUMBER
RFIN	FIN RESISTANCE OF EXTERNAL FINS - HR-SQFT-F/BTU
RMI	METAL RESISTANCE OF LINER - HR-SQFT-F/BTU
RMO	METAL RESISTANCE OF FIN ROOT - HR-SQFT-F/BTU
RMT	TOTAL METAL RESISTANCE - HR-SQFT(OUTSIDE AREA)-F/BTU
TBONDI	TEMPERATURE AT LINER OD - F
TBONDO	TEMPERATURE AT FIN TUBE ID - F
TBOND	BOND TEMPERATURE - F
TFIN	AVERAGE FIN TEMPERATURE - F
TLINE	LINER TEMPERATURE - F
TSAV	AVERAGE SHELL-SIDE FLUID TEMPERATURE - F
TSIC	INLET SHELL-SIDE FLUID TEMPERATURE - F OR C
TSIF	INLET SHELL-SIDE FLUID TEMPERATURE - F
TSOC	OUTLET SHELL-SIDE FLUID TEMPERATURE - F OR C
TSOF	OUTLET SHELL-SIDE FLUID TEMPERATURE - F
TTAV	AVERAGE TUBE-SIDE FLUID TEMPERATURE - F
TTIC	INLET TUBE-SIDE FLUID TEMPERATURE - F OR C
TTIF	INLET TUBE-SIDE FLUID TEMPERATURE - F
TTOC	OUTLET TUBE-SIDE FLUID TEMPERATURE - F OR C
TTOF	OUTLET TUBE-SIDE FLUID TEMPERATURE - F
TWIA,TWIB	INSIDE TUBE-WALL TEMPERATURE - F
TWOA, TWO	TEMPERATURE AT ROOT OF FIN - F
UO	OVERALL HEAT TRANSFER COEFFICIENT - BTU/HR-SQFT-F
VISS	SHELL-SIDE FLUID VISCOSITY - LB/FT-HR
VIST	TUBE-SIDE FLUID VISCOSITY - LB/FT-HR
VISWI	VISCOSITY AT INSIDE TUBE-WALL TEMPERATURE - LB/FT-HR
VISWO	VISCOSITY AT OUTSIDE TUBE-WALL TEMPERATURE - LB/FT-HR
WSHEL	SHELL-SIDE FLUID FLOW RATE - LB/HR
WTUBE	TUBE-SIDE FLUID FLOWRATE - LB/HR
XAI	INSIDE HEAT TRANSFER AREA - SQFT
XAO	OUTSIDE HEAT TRANSFER AREA - SQFT

TABLE XIX

Bond Resistance Data and Calculated Results for Bimetallic Tube Number 461

BOND RESISTANCES FOR TUBE 461 NUMBER OF RUNS IS 43

RUN	TUBE	TEMP	XAC	XAI	XAB	RMT	RMI	RMO
43	461	0	18.4460	1.1350	1.3600	.43690E-02	.26400E-03	.34600E-04

CC	POWER	PRPOW	CI	AMI	AMO	ODL	OD
.01150	.90500	.33333	.02957	1.24200	1.42100	.99700	2.02000

NO	K	L	M	NN	O	P	Q
1	.38925000E 00	.44750000E-03	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
2	.34400000E 00	.46333332E-03	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
3	.67977499E-01	-.19775000E-04	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
4	.71699999E-01	-.21000000E-04	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
5	.10162712E-02	.33618253E 01	-.95869080E 03	.15870848E 06	-.14467381E 08	.65730443E 09	-.11027932E 11
6	-.21480229E 01	.14160692E 04	-.27029259E 06	.32850279E 08	-.20186315E 10	.45553047E 11	.00000000E 00
7	-.29052144E 01	.22908387E 04	-.40461752E 06	.38134658E 08	-.70443591E 09	.00000000E 00	.00000000E 00
8	.46279078E-01	.15340877E 03	-.46291989E 05	.11906814E 08	-.17615316E 10	.13164353E 12	-.38659818E 13

DIAS	AFS	AFT	DIAT	AFIN	AROOT	FPI	FINT	RCONT	BRERR
.03930	.02900	.00378	.06930	17.24100	1.20600	8.72000	.01595	.0000000	.000130

RUN	TS IN F	TS OUT F	TT IN F	TT OUT F	W SHELL LB/HR	W TUBE LB/HR	Q SHELL BTU/HR	Q TUBE BTU/HR	PER DEV + OR -
5	169.11	173.59	305.16	298.13	25700	14400	53645	48972	4.55
6	168.74	172.80	307.64	299.78	25800	11820	48778	45033	3.99
7	178.68	181.90	320.08	310.82	26850	8730	40629	39624	1.25
8	177.42	180.58	314.86	306.68	32300	11480	47906	45825	2.22
9	177.41	183.11	315.61	308.13	17700	11950	47410	43665	4.11
10	200.32	204.38	340.91	332.05	25250	9800	49187	43406	6.24
11	199.75	203.36	338.69	330.54	32800	12050	56770	49009	7.34
12	200.00	204.38	339.03	331.10	24850	12050	52215	47706	4.51
13	168.16	169.90	249.63	245.47	24900	9550	20142	18223	5.00
14	168.08	170.05	242.99	239.86	24850	14200	22759	20261	5.81
15	185.71	188.61	284.43	279.63	26400	15000	36213	34177	2.89
16	183.23	184.84	259.93	255.61	26700	9010	20273	18038	5.83
17	157.98	162.55	332.76	321.48	26500	9320	55826	52099	3.45
19	182.06	189.02	377.11	365.99	26450	14100	86943	80928	3.58
20	192.00	197.22	342.89	335.12	26600	14960	66140	58244	6.35
21	191.45	194.93	332.32	322.71	26600	9710	44035	46260	2.46
22	201.87	204.45	286.25	282.13	26500	14550	32829	28515	7.03
23	202.41	203.86	269.31	265.19	26200	8400	18241	16191	5.96
24	225.74	228.38	310.18	306.06	25950	14620	33628	29320	6.84
25	248.76	251.05	324.87	321.26	25500	14620	29261	26056	5.79
26	272.00	274.06	342.99	339.86	25300	14630	26655	22996	7.37
27	295.17	297.01	359.84	357.07	24850	14670	23857	20728	7.02
28	218.07	222.78	358.87	351.20	26550	14500	61011	56553	3.79
29	217.41	221.50	368.13	357.68	26450	9060	52733	48488	4.19
30	241.79	245.75	388.18	378.03	26350	9030	51999	47798	4.21
31	242.25	246.89	382.04	374.47	26050	14300	60278	56210	3.49
32	324.46	325.98	384.45	381.94	25750	14070	20932	18419	6.39
33	323.49	324.97	394.49	390.04	25650	7910	20285	18506	4.59
35	339.11	341.01	414.22	410.94	25500	13200	26232	23170	6.20
36	261.27	265.49	392.66	385.85	26400	13530	56496	48314	7.81
37	259.27	263.11	396.86	387.41	25150	8970	48880	44561	4.62
38	185.96	191.44	391.72	376.52	27100	8480	70347	67281	2.23
39	212.63	218.01	407.15	392.79	26950	8550	70408	64989	4.00
40	247.06	252.05	403.58	394.26	27100	12600	67740	62102	4.34
41	245.01	249.45	404.89	395.57	27050	12600	60037	62173	1.75
42	291.20	294.87	433.98	424.08	26500	8830	50610	47449	3.22
43	289.03	293.35	430.43	422.60	26450	12750	59367	54071	4.67
44	312.26	316.51	448.78	442.17	25650	14900	57770	54209	3.18
46	335.51	339.69	473.71	467.07	25200	14520	56916	54179	2.46
47	359.89	363.66	490.23	484.53	24900	14480	51738	47031	4.77
48	360.71	364.13	498.67	489.39	25050	8320	47242	44233	3.29
49	367.04	368.75	433.19	430.35	25600	14700	24247	22713	3.27
50	389.83	392.18	476.75	473.05	25100	14640	33281	30553	4.27

RUN	Q AVG BTU/HR	LMTC F	HO PRIME BTU/HR-SQFT-F	R FIN HR-SQFT-F/BTU	HO BTU/HR-SQFT-F	HI BTU/HR-SQFT-F	UO CALC BTU/HR-SQFT-F	UO EXP BTU/HR-SQFT-F	R BOND HR-SQFT-F/BTU
5	51309	130.29	218.52	.00641	91.05	497.52	20.83	21.35	-.000087
6	46905	132.93	218.01	.00641	90.93	422.48	18.58	19.13	-.000115
7	40127	135.14	236.07	.00629	94.98	348.95	16.27	16.10	.000048
8	46866	131.75	277.72	.00604	103.70	429.37	19.28	19.28	-.000000
9	45537	131.61	163.41	.00683	77.22	452.75	18.79	18.76	.000007
10	46296	134.12	248.08	.00622	97.57	424.93	18.92	18.71	.000042
11	52890	133.05	313.32	.00584	110.66	499.77	21.77	21.55	.000035
12	49961	132.87	244.86	.00624	96.88	505.94	21.36	20.38	.000165
13	19183	78.51	205.29	.00650	87.96	281.62	13.62	13.25	.000151
14	21510	72.36	205.32	.00650	87.96	382.68	17.18	16.12	.000283
15	35195	94.87	239.68	.00627	95.77	493.86	20.96	20.11	.000148
16	19156	73.73	236.21	.00629	95.01	289.12	14.06	14.09	-.000008
17	53962	166.83	211.95	.00645	89.53	362.40	16.56	17.53	-.000247
19	83936	186.00	244.58	.00624	96.82	630.40	24.71	24.46	.000029
20	62192	144.39	253.30	.00619	98.66	608.23	24.26	23.35	.000118
21	45147	134.30	249.50	.00621	97.87	404.15	18.25	18.22	.000005
22	30672	81.03	257.91	.00616	99.64	495.18	21.18	20.52	.000111
23	17216	64.11	253.40	.00619	98.70	293.67	14.32	14.56	-.000085
24	31474	81.06	278.87	.00604	103.93	559.23	23.23	21.05	.000328
25	27658	73.16	297.58	.00593	107.63	601.76	24.59	20.50	.000599
26	24826	68.39	318.32	.00582	111.61	649.94	26.09	19.68	.000920
27	22292	62.36	335.25	.00573	114.79	694.67	27.42	19.38	.001115
28	58782	134.60	280.80	.00603	104.31	639.13	25.39	23.67	.000211
29	50611	143.43	277.82	.00604	103.72	438.84	19.59	19.13	.000091
30	49899	139.31	302.63	.00590	108.61	475.53	20.94	19.42	.000276
31	58244	133.68	301.32	.00591	108.35	690.78	26.94	23.62	.000384
32	19675	57.97	374.43	.00553	121.95	729.94	28.71	18.40	.001439
33	19395	68.02	372.13	.00554	121.54	467.53	21.12	15.46	.001278
35	24701	72.52	385.79	.00547	123.98	751.80	29.37	18.47	.001482
36	52405	125.87	323.86	.00579	112.66	690.27	27.18	22.57	.000554
37	46721	130.93	307.30	.00588	109.51	492.19	21.50	19.35	.000381
38	68814	195.38	251.63	.00620	98.32	421.54	18.83	19.09	-.000053
39	67699	184.61	280.04	.00603	104.16	458.53	20.24	19.88	.000066
40	64921	149.35	318.25	.00582	111.60	657.37	26.28	23.56	.000323
41	61105	152.99	314.82	.00584	110.95	664.40	26.42	21.65	.000615
42	49029	135.97	355.02	.00563	118.44	544.85	23.45	19.55	.000628
43	56719	135.32	353.31	.00564	118.12	733.68	28.58	22.72	.000665
44	55989	131.09	366.24	.00557	120.48	884.05	32.20	23.15	.000895
46	55547	132.79	382.33	.00549	123.37	923.36	33.25	22.68	.001034
47	49384	125.60	399.78	.00541	126.46	964.16	34.33	21.32	.001311
48	45738	131.59	402.21	.00539	126.89	619.15	25.97	18.84	.001074
49	23480	63.87	413.20	.00534	128.81	866.45	32.37	19.93	.001422
50	31917	83.89	427.49	.00528	131.30	956.06	34.50	20.62	.001438

TABLE XIX (Continued)

RUN	RE SHELL	RE TUBE	PR SHELL	PR TUBE	VISC SHELL LB/FT-HR	VISC S-WALL LB/FT-HR	VISC RATIO SHELL	VISC TUBE LB/FT-HR	VISC T-WALL LB/FT-HR	VISC RATIO TUBE
5	8532	56216	29.448	34.756	4.082	3.150	1.296	4.696	13.066	.359
6	8518	46946	29.588	34.257	4.105	3.228	1.271	4.616	14.174	.326
7	9672	38130	27.447	31.616	3.762	3.119	1.206	4.197	12.377	.339
8	11502	48305	27.719	32.623	3.806	3.112	1.223	4.357	12.292	.354
9	6374	50729	27.454	32.382	3.763	2.918	1.290	4.319	10.814	.399
10	10901	50188	23.542	27.688	3.139	2.615	1.200	3.580	8.630	.415
11	14074	60877	23.662	28.002	3.158	2.626	1.203	3.629	8.538	.425
12	10715	61078	23.566	27.925	3.143	2.580	1.218	3.617	7.884	.459
13	8086	22040	30.017	54.793	4.173	3.740	1.116	7.944	20.430	.389
14	8072	30497	30.008	58.404	4.172	3.692	1.130	8.536	18.541	.460
15	10090	49285	26.092	40.266	3.546	3.029	1.170	5.580	11.455	.487
16	9937	23282	26.691	49.604	3.641	3.324	1.096	7.095	15.946	.445
17	7888	44538	32.382	29.326	4.553	3.381	1.347	3.836	17.071	.225
19	9972	91737	26.399	22.762	3.595	2.541	1.415	2.818	7.365	.383
20	10809	78025	24.772	27.273	3.335	2.603	1.281	3.515	7.807	.450
21	10686	46540	25.013	29.253	3.373	2.797	1.206	3.825	9.975	.383
22	11511	48764	23.421	39.586	3.120	2.762	1.130	5.470	9.908	.552
23	11379	23942	23.424	45.533	3.120	2.909	1.073	6.432	12.110	.531
24	13357	60211	20.356	33.219	2.633	2.369	1.111	4.452	7.037	.633
25	15153	67748	18.129	30.088	2.281	2.103	1.084	3.956	5.547	.713
26	17139	77638	16.349	26.886	2.000	1.877	1.066	3.455	4.463	.774
27	18962	87583	14.916	24.409	1.776	1.687	1.053	3.071	3.749	.819
28	13066	84592	21.118	24.873	2.754	2.266	1.215	3.143	6.015	.522
29	12930	55718	21.235	23.826	2.772	2.336	1.187	2.981	6.822	.437
30	15088	63189	18.674	21.464	2.367	2.048	1.155	2.620	5.158	.508
31	14990	97087	18.601	21.992	2.355	1.993	1.182	2.700	4.605	.586
32	22525	98513	13.461	21.454	1.549	1.491	1.039	2.618	3.050	.858
33	22339	58531	13.505	20.525	1.556	1.498	1.039	2.478	3.127	.792
35	23793	109946	12.838	18.687	1.452	1.388	1.046	2.201	2.611	.843
36	16959	98314	17.044	20.826	2.110	1.844	1.144	2.523	3.977	.634
37	15957	66323	17.210	20.538	2.136	1.885	1.133	2.480	4.436	.559
38	10492	59714	25.807	21.356	3.500	2.640	1.326	2.604	8.648	.301
39	12798	66229	21.747	19.791	2.854	2.272	1.256	2.367	6.261	.378
40	16070	97000	18.159	19.888	2.285	1.917	1.192	2.381	4.315	.552
41	15818	97749	18.362	19.767	2.317	1.958	1.184	2.363	4.075	.580
42	19917	80529	15.090	17.405	1.803	1.618	1.115	2.010	3.258	.617
43	19696	114710	15.197	17.590	1.620	1.606	1.133	2.038	3.072	.663
44	21361	148155	13.963	16.278	1.627	1.455	1.118	1.844	2.515	.733
47	25393	176417	12.041	13.950	1.329	1.225	1.085	1.505	1.874	.803
48	25611	104473	12.019	13.640	1.325	1.229	1.078	1.460	2.010	.726
49	26740	136046	11.838	17.207	1.297	1.249	1.039	1.981	2.260	.876
50	28588	168297	11.143	14.573	1.190	1.135	1.048	1.595	1.844	.865

RUN	TS AVG F	T FIN AVG F	T RCOT F	T BOND O F	T BOND F	T BOND I F	T LINER F	T WALL I F	TT AVG F	FIN EFF
5	171.35	182.83	201.90	203.15	201.51	199.88	205.33	210.78	301.64	.376
6	170.77	181.29	198.73	199.88	197.90	195.92	200.91	205.89	303.71	.377
7	180.29	188.55	203.19	204.17	204.89	205.61	209.87	214.14	315.45	.361
8	179.00	187.07	203.50	204.64	204.64	204.64	209.62	214.60	310.77	.329
9	180.26	194.19	212.23	213.34	213.46	213.57	218.41	223.25	311.87	.437
11	201.55	209.53	227.47	228.75	229.44	230.13	235.75	241.37	334.61	.308
12	202.19	212.07	230.15	231.36	234.40	237.44	242.75	248.06	335.06	.353
13	169.03	173.62	180.85	181.32	182.39	183.46	185.50	187.54	247.55	.389
14	169.06	174.22	182.32	182.85	185.09	187.33	189.62	191.90	241.42	.389
15	187.16	194.28	207.08	207.94	209.85	211.76	215.50	219.24	282.03	.358
16	184.03	187.97	194.97	195.43	195.38	195.32	197.36	199.40	257.77	.360
17	160.26	172.75	192.94	194.26	189.36	184.46	190.20	195.93	327.12	.382
19	185.54	202.16	232.54	234.58	235.49	236.40	245.32	254.24	371.55	.354
20	194.61	206.46	228.78	230.29	232.99	235.70	242.31	248.92	339.00	.347
21	193.19	201.94	218.20	219.30	219.40	219.50	224.29	229.09	327.51	.350
22	203.16	208.89	219.85	220.59	221.85	223.10	226.36	229.62	284.19	.343
23	203.13	206.41	212.59	213.01	212.48	211.94	213.77	215.60	267.25	.347
24	227.06	232.46	243.48	244.24	248.04	251.84	255.19	258.53	308.12	.329
25	249.90	254.32	263.84	264.51	270.60	276.69	279.63	282.57	323.06	.317
26	273.03	276.71	285.09	285.69	294.09	302.49	305.13	307.77	341.42	.306
27	296.09	299.21	306.62	307.16	316.30	325.44	327.81	330.18	358.45	.297
28	220.42	230.43	250.97	252.41	256.96	261.51	267.75	274.00	355.03	.327
29	219.45	228.17	245.91	247.14	248.84	250.54	255.91	261.29	362.90	.329
30	243.77	251.59	268.68	269.89	274.97	280.05	285.35	290.65	383.10	.314
31	244.57	253.74	273.71	275.13	283.36	291.59	297.78	303.97	378.25	.315
32	325.22	327.66	333.97	334.45	344.85	355.26	357.36	359.45	383.19	.279
33	324.23	326.65	332.88	333.35	342.47	351.59	353.65	355.71	392.26	.280
35	340.06	343.02	350.86	351.46	364.92	378.38	381.01	383.63	412.58	.275
36	263.38	271.00	288.60	289.67	300.55	311.23	316.80	322.37	389.25	.303
37	261.19	268.39	284.32	285.46	292.01	298.57	303.54	308.50	392.13	.312
38	188.70	201.91	226.64	228.32	226.99	225.67	232.98	240.29	384.12	.348
39	215.32	226.88	250.55	252.20	253.85	255.50	262.69	269.89	399.97	.328
40	249.55	259.18	281.09	282.67	290.39	298.11	305.01	311.91	398.92	.306
41	247.23	256.40	277.09	278.58	292.39	306.21	312.71	319.20	400.23	.307
42	293.03	299.48	315.48	316.67	328.00	339.33	344.54	349.75	429.03	.288
43	291.19	298.68	317.22	318.60	332.47	346.35	352.37	358.40	426.51	.288
44	314.38	321.49	339.58	340.94	359.36	377.77	383.72	389.68	445.47	.283
46	337.60	344.32	362.01	363.36	384.47	405.58	411.48	417.39	470.39	.276
47	361.77	367.46	382.95	384.15	407.95	431.76	437.00	442.25	487.38	.270
48	362.42	367.65	381.96	383.07	401.15	419.22	424.08	428.94	494.03	.269
49	367.89	370.50	377.78	378.35	390.63	402.90	405.40	407.89	431.77	.265
50	391.00	394.42	404.18	404.96	421.83	438.70	442.09	445.49	474.90	.260

TABLE XIX (Continued)

RUN	T LINER F	T FIN F	TLINER-TFIN F	MU	K AIR BTU/HR-SQFT-F/FT	ALPHA LINER IN/IN	ALPHA FIN IN/IN	R BOND HR-SQFT-F/BTU	P CO PSI
5	205.33	182.83	22.50	.2135E-06	.0182	.6340E-05	.1295E-04	-.000087	3003
6	200.91	181.29	19.61	.2134E-06	.0181	.6330E-05	.1294E-04	-.000115	3102
7	209.87	188.55	21.32	.2137E-06	.0182	.6350E-05	.1297E-04	.000048	2938
8	209.62	187.07	22.55	.2136E-06	.0182	.6350E-05	.1296E-04	-.000000	2954
9	218.41	194.19	24.22	.2139E-06	.0184	.6369E-05	.1298E-04	.000007	3104
10	235.57	211.37	24.19	.2145E-06	.0188	.6408E-05	.1303E-04	.000042	3556
11	235.75	209.53	26.22	.2144E-06	.0188	.6406E-05	.1303E-04	.000035	3450
12	242.75	212.07	30.68	.2145E-06	.0189	.6424E-05	.1304E-04	.000165	3110
13	185.50	173.62	11.87	.2131E-06	.0177	.6296E-05	.1292E-04	.000151	2568
14	189.62	174.22	15.40	.2131E-06	.0178	.6305E-05	.1292E-04	.000283	2210
15	215.50	194.28	21.22	.2139E-06	.0183	.6363E-05	.1298E-04	.000148	2911
16	197.36	187.97	9.39	.2136E-06	.0180	.6322E-05	.1296E-04	-.000008	3407
17	190.20	172.75	17.45	.2131E-06	.0179	.6306E-05	.1292E-04	-.000247	3172
19	245.32	202.16	43.16	.2142E-06	.0189	.6430E-05	.1301E-04	.000029	2700
20	242.31	206.46	35.85	.2143E-06	.0188	.6423E-05	.1302E-04	.000118	2876
21	224.29	201.94	22.36	.2142E-06	.0185	.6382E-05	.1301E-04	.000005	3403
22	226.36	208.89	17.47	.2144E-06	.0186	.6387E-05	.1303E-04	.000111	3549
23	213.77	206.41	7.36	.2143E-06	.0184	.6359E-05	.1302E-04	-.000085	4198
24	255.19	232.46	22.73	.2153E-06	.0192	.6452E-05	.1310E-04	.000328	3631
25	279.63	254.32	25.31	.2161E-06	.0196	.6506E-05	.1316E-04	.000599	3606
26	305.13	276.71	28.42	.2169E-06	.0202	.6563E-05	.1323E-04	.000920	3435
27	327.81	299.21	28.60	.2177E-06	.0206	.6614E-05	.1330E-04	.001115	3623
28	267.75	230.43	37.32	.2152E-06	.0194	.6480E-05	.1309E-04	.000211	3349
29	255.91	228.17	27.74	.2151E-06	.0192	.6453E-05	.1308E-04	.000091	3849
30	285.35	251.59	33.76	.2160E-06	.0197	.6519E-05	.1315E-04	.000276	3952
31	297.78	253.74	44.03	.2161E-06	.0199	.6547E-05	.1316E-04	.000384	3437
32	357.36	327.66	29.70	.2186E-06	.0212	.6680E-05	.1338E-04	.001439	3622
33	353.65	326.65	27.00	.2187E-06	.0212	.6672E-05	.1338E-04	.001278	4065
35	381.01	343.02	37.99	.2206E-06	.0217	.6733E-05	.1343E-04	.001482	3620
36	316.80	271.00	45.79	.2167E-06	.0203	.6590E-05	.1321E-04	.000554	3502
37	303.54	268.39	35.15	.2166E-06	.0201	.6560E-05	.1321E-04	.000381	4170
38	232.98	201.91	31.07	.2142E-06	.0187	.6402E-05	.1301E-04	-.000053	3250
39	262.69	226.88	35.82	.2151E-06	.0193	.6466E-05	.1308E-04	.000066	3604
40	305.01	259.18	45.83	.2163E-06	.0201	.6563E-05	.1318E-04	.000323	3673
41	312.71	256.40	56.30	.2162E-06	.0201	.6580E-05	.1317E-04	.000615	2590
42	344.54	299.48	45.06	.2178E-06	.0209	.6652E-05	.1330E-04	.000628	4178
43	352.37	298.68	53.69	.2178E-06	.0210	.6669E-05	.1330E-04	.000665	3772
44	383.72	321.49	62.23	.2186E-06	.0216	.6740E-05	.1336E-04	.000895	3578
46	411.48	344.32	67.16	.2210E-06	.0221	.6802E-05	.1343E-04	.001034	3676
47	437.00	367.46	69.54	.2255E-06	.0226	.6859E-05	.1350E-04	.001311	3483
48	424.08	367.65	56.43	.2255E-06	.0225	.6830E-05	.1350E-04	.001074	4522
49	405.40	370.50	34.90	.2261E-06	.0222	.6788E-05	.1351E-04	.001422	4522
50	442.09	394.42	47.68	.2311E-06	.0229	.6870E-05	.1358E-04	.001438	4575

RUN	P CC PSI	P CC AVG PSI	DEV PSI	P CO LL PSI	P CO UL PSI
5	3003	3477	-474	2737	3269
6	3102	3477	-375	2837	3367
7	2938	3477	-538	2671	3205
8	2954	3477	-522	2687	3221
9	3104	3477	-372	2835	3374
10	3556	3477	79	3282	3830
11	3450	3477	-26	3177	3724
12	3110	3477	-367	2835	3385
13	2568	3477	-909	2307	2828
14	2210	3477	-1266	1949	2472
15	2911	3477	-565	2643	3179
16	3407	3477	-70	3143	3671
17	3172	3477	-305	2909	3435
19	2700	3477	-777	2424	2976
20	2876	3477	-601	2601	3151
21	3403	3477	-74	3132	3674
22	3549	3477	73	3278	3821
23	4198	3477	721	3929	4466
24	3631	3477	154	3352	3909
25	3606	3477	129	3321	3890
26	3435	3477	-42	3144	3726
27	3623	3477	146	3326	3919
28	3349	3477	-128	3068	3630
29	3849	3477	372	3570	4128
30	3952	3477	476	3666	4238
31	3437	3477	-39	3149	3726
32	3622	3477	145	3318	3926
33	4065	3477	588	3761	4368
35	3620	3477	144	3313	3928
36	3502	3477	25	3209	3795
37	4170	3477	694	3880	4461
38	3250	3477	-227	2977	3523
39	3604	3477	127	3324	3885
40	3673	3477	196	3382	3963
41	2590	3477	-887	2298	2881
42	4178	3477	702	3878	4478
43	3772	3477	295	3470	4073
44	3578	3477	102	3270	3887
46	3676	3477	200	3363	3989
47	3483	3477	7	3169	3797
48	4522	3477	1045	4210	4834
49	4522	3477	1045	4214	4829
50	4575	3477	1099	4265	4885

STANDARD DEVIATION = 523

TABLE XX

Bond Resistance Data and Calculated Results for Bimetallic Tube Number 462

BOND RESISTANCES FOR TUBE 462 NUMBER OF RUNS IS 27

RUN	TUBE	TEMP	XAC	XAI	XAB	RMT	RMI	RMO
27	462	0	17.3830	1.1350	1.3600	.41550E-02	.26400E-03	.36100E-04

CO	POWER	PRPOW	CI	AMI	AMO	CCL	CD
.01150	.90500	.33333	.02957	1.24800	1.42800	.99700	1.96300

NO	K	L	M	NN	O	P	Q
1	.38925000E 00	.44750000E-03	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
2	.34400000E 00	.46333332E-03	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
3	.67977499E-01	-.19775000E-04	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
4	.71699999E-01	-.21000000E-04	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
5	.13487617E-02	.24102085E 01	-.58313584E 03	.78192497E 05	-.53278815E 07	.13695548E 09	.64530490E 09
6	-.21480229E 01	.14160692E 04	-.27029259E 06	.32850279E 08	-.20186315E 10	.45553047E 11	.00000000E 00
7	-.29052144E 01	.22908387E 04	-.40461752E 06	.38134658E 08	-.70443591E 09	.00000000E 00	.00000000E 00
8	.66165308E-01	.13773820E 03	-.26808245E 05	.45075696E 07	-.45949754E 09	.23585991E 11	-.45373062E 12

DIAS	AFS	AFT	DIAT	AFIN	AROOT	FPI	FINT	RCONT	BRERR
.04170	.03040	.00378	.06930	16.14300	1.24000	8.80000	.01630	.0000000	.000130

RUN	TS IN F	TS OUT F	TT IN F	TT OUT F	W SHELL LB/HR	W TUBE LB/HR	Q SHELL BTU/HR	Q TUBE BTU/HR	PER DEV + OR -
1	301.18	304.83	416.75	407.78	19800	8350	37931	40072	2.75
2	301.72	305.82	412.52	405.16	19700	10750	42419	42205	.25
3	302.92	309.99	465.03	455.61	19150	13810	71268	72497	.85
4	302.92	309.73	466.71	456.65	19040	12260	68245	68810	.41
5	303.18	309.41	472.27	460.37	19040	9720	62431	64781	1.85
7	205.21	206.79	275.15	270.73	25450	9410	19359	19566	.54
8	203.92	205.82	272.54	268.77	24900	11980	22753	21200	3.53
9	204.01	205.88	267.50	264.24	26380	14600	23726	22236	3.24
11	385.82	390.18	519.91	511.78	21400	11160	52519	52897	.36
12	385.33	390.10	515.17	508.46	21400	14420	57445	56230	1.07
13	375.33	380.30	548.74	533.96	21700	6630	60215	58288	1.63
14	393.16	398.00	539.36	530.26	21590	11400	59173	61393	1.84
15	380.77	386.51	534.02	525.98	21630	14620	69643	69301	.25
16	381.95	386.82	570.13	555.23	26400	8120	72160	73162	.69
17	400.73	405.47	566.81	557.13	25200	11820	68042	69152	.81
18	379.25	384.57	561.36	551.68	28130	14470	83828	84301	.28
19	342.58	350.26	520.19	509.15	16120	10350	67382	66555	.62
20	341.37	345.47	514.22	502.68	28800	10380	64109	69425	3.98
21	407.80	412.93	545.17	538.46	18550	14420	54517	57575	2.73
22	400.99	405.02	542.43	535.20	26650	14400	61174	61806	.51
23	402.77	406.13	544.99	537.60	32420	14420	62117	63384	1.01
24	226.19	229.29	332.13	326.65	29030	14900	44261	40550	4.31
25	202.74	203.90	258.27	255.34	25400	9440	14150	12806	4.99
26	302.17	305.84	415.41	408.86	19400	10650	37400	37317	.11
27	300.95	306.85	474.34	463.67	19050	9540	59035	57136	1.63
28	351.20	355.71	530.61	517.58	22600	7280	55796	55666	.12
29	373.03	378.83	547.77	539.71	21700	14550	70164	69887	.20

RUN	Q AVG BTU/HR	LMTD F	HO PRIME BTU/HR-SQFT-F	R FIN HR-SQFT-F/BTU	HO BTU/HR-SQFT-F	HI BTU/HR-SQFT-F	UO CALC BTU/HR-SQFT-F	UO EXP BTU/HR-SQFT-F	R BOND HR-SQFT-F/BTU
1	39001	109.24	266.93	.00536	109.83	502.05	22.85	20.54	.000385
2	42312	105.06	266.57	.00536	109.75	613.10	26.15	23.17	.000385
3	71862	153.86	264.20	.00537	109.21	850.29	31.92	26.88	.000460
4	68528	155.35	262.48	.00538	108.81	773.30	30.17	25.38	.000489
5	63606	160.01	262.06	.00538	108.71	644.79	26.95	22.87	.000518
7	19463	66.93	238.47	.00550	103.15	331.65	16.66	16.73	-.000020
8	21977	65.78	233.03	.00553	101.83	400.12	19.14	19.22	-.000017
9	22981	60.92	245.65	.00546	104.87	460.89	21.31	21.70	-.000066
11	52708	127.84	352.17	.00496	128.21	826.67	32.81	23.72	.000914
12	56837	124.10	352.27	.00496	128.23	1010.74	36.89	26.35	.000849
13	59251	163.49	349.47	.00497	127.65	559.91	25.42	20.85	.000675
14	60283	139.22	361.13	.00492	130.04	871.65	34.00	24.91	.000839
15	69472	146.36	353.56	.00495	128.49	1055.33	37.81	27.31	.000796
16	72661	178.25	423.76	.00466	142.42	687.02	29.88	23.45	.000718
17	68597	158.86	421.91	.00467	142.07	944.18	36.48	24.84	.001005
18	84065	174.60	447.22	.00457	146.90	1096.14	40.11	27.70	.000874
19	66968	168.24	249.95	.00544	105.89	764.81	29.74	22.90	.000786
20	66767	165.00	417.55	.00469	141.22	755.86	31.75	23.28	.000897
21	56046	131.45	324.19	.00509	122.39	1077.08	37.67	24.53	.001113
22	61490	135.80	443.06	.00459	146.11	1066.21	39.43	26.05	.001019
23	62751	136.84	530.10	.00428	162.14	1072.11	40.64	26.38	.001040
24	42376	101.65	295.98	.00522	116.32	608.95	26.38	23.98	.000297
25	13478	53.48	234.51	.00552	102.19	313.06	15.91	14.50	.000478
26	37358	108.12	262.66	.00538	108.85	618.78	26.25	19.88	.000956
27	58086	165.09	260.04	.00539	108.25	643.56	26.89	20.24	.000956
28	55731	170.60	343.07	.00500	126.33	586.10	26.18	18.79	.001174
29	70026	167.81	348.88	.00497	127.53	1081.25	38.23	24.01	.001212

RUN	RE SHELL	RE TUBE	PR SHELL	PR TUBE	VISC SHELL LB/FT-HR	VISC S-WALL LB/FT-HR	VISC RATIO SHELL	VISC TUBE LB/FT-HR	VISC T-WALL LB/FT-HR	VISC RATIO TUBE
1	15818	69426	14.539	18.713	1.717	1.561	1.100	2.205	3.396	.649
2	15796	87658	14.498	19.002	1.711	1.543	1.109	2.248	3.293	.683
3	15553	147961	14.359	15.372	1.689	1.427	1.184	1.711	2.576	.664
4	15454	132236	14.365	15.294	1.690	1.437	1.176	1.700	2.612	.651
5	15452	107239	14.367	15.033	1.690	1.453	1.163	1.662	2.680	.620
7	11432	28370	23.006	43.368	3.054	2.822	1.082	6.081	11.133	.546
8	11091	35320	23.169	44.215	3.080	2.813	1.095	6.218	10.970	.567
9	11756	41038	23.158	46.088	3.078	2.807	1.096	6.522	11.023	.592
11	24404	154165	11.227	12.712	1.203	1.106	1.087	1.327	1.716	.773
12	24378	195798	11.236	12.873	1.204	1.100	1.094	1.350	1.694	.797
13	23829	101730	11.526	11.780	1.249	1.134	1.101	1.195	1.819	.657
15	24274	214262	11.353	12.176	1.222	1.095	1.116	1.251	1.616	.774
16	29709	135356	11.331	11.106	1.219	1.099	1.109	1.100	1.636	.672
17	30328	196504	10.820	11.127	1.140	1.038	1.098	1.103	1.434	.769
18	31367	235607	11.404	11.292	1.230	1.095	1.124	1.126	1.493	.754
19	15636	142262	12.592	12.759	1.414	1.226	1.153	1.334	1.921	.694
20	27588	138910	12.707	13.012	1.432	1.284	1.115	1.370	1.993	.687
21	22892	221669	10.638	11.765	1.112	1.019	1.091	1.193	1.447	.824
22	32062	218722	10.822	11.866	1.140	1.050	1.086	1.207	1.500	.805
23	39201	221210	10.785	11.782	1.134	1.052	1.078	1.195	1.488	.803
24	15193	72425	20.281	28.913	2.621	2.297	1.141	3.772	6.377	.591
25	11182	24142	23.397	50.055	3.116	2.945	1.058	7.169	11.502	.623
26	15573	88484	14.486	18.724	1.709	1.558	1.097	2.207	3.058	.721
27	15284	106627	14.491	14.886	1.710	1.486	1.151	1.640	2.519	.651
28	22564	104119	12.332	12.394	1.374	1.243	1.105	1.282	1.893	.677
29	23661	225385	11.584	11.700	1.258	1.122	1.121	1.184	1.509	.784

TABLE XX (Continued)

RUN	TS AVG F	T FIN AVG F	T ROOT F	T BOND O F	T BOND F	T BOND I F	T LINER F	T WALL I F	TT AVG F	FIN EFF
1	303.00	310.50	323.43	324.42	330.00	335.57	339.70	343.82	412.26	.369
2	303.77	311.91	325.95	327.02	333.05	339.08	343.56	348.04	408.84	.369
3	306.45	320.42	344.32	346.14	358.38	370.63	378.23	385.84	460.32	.371
4	306.32	319.73	342.56	344.29	356.70	369.11	376.35	383.60	461.68	.372
5	306.29	318.76	339.95	341.56	353.76	365.95	372.68	379.41	466.32	.372
7	206.00	210.23	216.85	217.35	217.23	217.12	219.18	221.23	272.94	.391
8	204.87	209.76	217.29	217.84	217.73	217.61	219.94	222.26	270.65	.395
9	204.94	209.78	217.55	218.13	217.60	217.08	219.51	221.94	265.87	.385
11	388.00	395.47	411.65	412.98	430.75	448.52	454.09	459.67	515.84	.319
12	387.71	395.77	413.21	414.65	432.45	450.25	456.26	462.27	511.81	.319
13	377.81	386.28	404.52	406.01	420.80	435.58	441.85	448.11	541.35	.320
14	395.58	403.89	422.25	423.77	442.45	461.12	467.50	473.88	534.81	.314
15	383.64	393.44	414.74	416.50	436.90	457.30	464.65	472.00	530.00	.318
16	384.38	392.77	413.73	415.57	434.85	454.13	461.81	469.50	562.68	.289
17	403.10	411.06	430.88	432.61	458.03	483.45	490.70	497.96	561.97	.289
18	381.91	391.05	414.83	416.96	444.06	471.17	480.06	488.95	556.52	.280
19	346.42	360.23	382.80	384.50	403.93	423.36	430.44	437.52	514.67	.381
20	343.42	351.26	370.62	372.31	394.40	416.50	423.56	430.62	508.45	.291
21	410.36	419.07	436.71	438.13	461.12	484.11	490.04	495.97	541.81	.333
22	403.00	409.76	427.21	428.77	451.88	475.00	481.50	488.00	538.81	.282
23	404.45	410.09	426.71	428.30	452.38	476.45	483.09	489.73	541.29	.256
24	227.74	235.01	248.70	249.77	254.44	259.12	263.60	268.08	329.39	.349
25	203.32	206.30	210.91	211.25	213.64	216.02	217.45	218.87	256.80	.394
26	304.00	311.31	323.75	324.69	337.87	351.04	354.99	358.94	412.13	.372
27	303.90	315.38	334.77	336.24	356.72	377.20	383.34	389.48	469.00	.374
28	353.45	361.58	378.83	380.24	404.38	428.53	434.42	440.32	524.09	.323
29	375.93	385.96	407.52	409.29	440.58	471.87	479.27	486.68	543.74	.320

RUN	T LINER F	T FIN F	TLINER-TFIN F	MU	K AIR BTU/HR-SQFT-F/FT	ALPHA LINER IN/IN	ALPHA FIN IN/IN	R BOND HR-SQFT-F/BTU	P CO PSI
1	339.70	310.50	29.20	.2240E-06	.0209	.6641E-05	.1333E-04	.000385	5452
2	343.56	311.91	31.65	.2240E-06	.0210	.6650E-05	.1334E-04	.000385	5413
3	378.23	320.42	57.82	.2244E-06	.0215	.6727E-05	.1336E-04	.000460	4606
4	376.35	319.73	56.63	.2244E-06	.0215	.6723E-05	.1336E-04	.000489	4560
5	372.68	318.76	53.92	.2243E-06	.0214	.6715E-05	.1336E-04	.000518	4558
7	219.18	210.23	8.95	.2201E-06	.0185	.6371E-05	.1303E-04	-.000020	4023
8	219.94	209.76	10.18	.2201E-06	.0185	.6373E-05	.1303E-04	-.000017	3967
9	219.51	209.78	9.73	.2201E-06	.0185	.6372E-05	.1303E-04	-.000066	4079
11	454.09	395.47	58.62	.2375E-06	.0231	.6897E-05	.1359E-04	.000914	5325
12	456.26	395.77	60.49	.2376E-06	.0231	.6902E-05	.1359E-04	.000849	5420
13	441.85	386.28	55.56	.2355E-06	.0229	.6870E-05	.1356E-04	.000675	5785
14	467.50	403.89	63.61	.2394E-06	.0234	.6927E-05	.1361E-04	.000839	5511
15	464.65	393.44	71.21	.2371E-06	.0232	.6921E-05	.1358E-04	.000796	5129
16	461.81	392.77	69.04	.2369E-06	.0232	.6914E-05	.1358E-04	.000718	5372
17	490.70	411.06	79.65	.2410E-06	.0237	.6979E-05	.1363E-04	.001005	4732
18	480.06	391.05	89.01	.2366E-06	.0234	.6955E-05	.1357E-04	.000874	4283
19	430.44	360.23	70.20	.2301E-06	.0225	.6844E-05	.1348E-04	.000786	4431
20	423.56	351.26	72.31	.2282E-06	.0223	.6829E-05	.1345E-04	.000897	3890
21	490.04	419.07	70.98	.2428E-06	.0238	.6978E-05	.1366E-04	.001113	4941
22	481.50	409.76	71.74	.2407E-06	.0236	.6959E-05	.1363E-04	.001019	4940
23	483.09	410.09	73.00	.2408E-06	.0236	.6962E-05	.1363E-04	.001040	4855
24	263.60	235.01	28.59	.2211E-06	.0193	.6470E-05	.1311E-04	.000297	3491
25	217.45	206.30	11.15	.2200E-06	.0184	.6367E-05	.1302E-04	.000478	2835
26	354.99	311.31	43.68	.2240E-06	.0211	.6675E-05	.1333E-04	.000956	3704
27	383.34	315.38	67.96	.2243E-06	.0215	.6739E-05	.1335E-04	.000956	2981
28	434.42	361.58	72.84	.2303E-06	.0225	.6853E-05	.1348E-04	.001174	3462
29	479.27	385.96	93.32	.2355E-06	.0233	.6954E-05	.1356E-04	.001212	3216

RUN	P CC PSI	P CO AVG PSI	DEV PSI	P CO LL PSI	P CO UL PSI
1	5452	4480	972	5160	5745
2	5413	4480	933	5120	5706
3	4606	4480	126	4305	4906
4	4560	4480	80	4260	4860
5	4558	4480	78	4259	4857
7	4023	4480	-457	3760	4286
8	3967	4480	-513	3704	4230
9	4079	4480	-401	3816	4342
11	5325	4480	845	5020	5629
12	5420	4480	940	5115	5725
13	5785	4480	1305	5481	6089
14	5511	4480	1031	5206	5817
15	5129	4480	649	4822	5436
16	5372	4480	892	5066	5678
17	4732	4480	252	4424	5039
18	4283	4480	-197	3974	4592
19	4431	4480	-49	4125	4738
20	3890	4480	-590	3584	4196
21	4941	4480	461	4635	5247
22	4940	4480	460	4634	5246
23	4855	4480	375	4549	5162
24	3491	4480	-989	3218	3764
25	2835	4480	-1645	2573	3097
26	3704	4480	-776	3409	3998
27	2981	4480	-1499	2681	3281
28	3462	4480	-1018	3156	3768
29	3216	4480	-1264	2906	3525

STANDARD DEVIATION = 822

TABLE XXI

Bond Resistance Data and Calculated Results for Bimetallic Tube Number 463

BOND RESISTANCES FOR TUBE 463 NUMBER OF RUNS IS 49

RUN	TUBE	TEMP	XAC	XAI	XAB	RMT	RMI	RMO
49	463	0	16.9940	1.1350	1.3600	.40240E-02	.26400E-03	.34600E-04

CC	PCALR	PRPCW	CI	AMI	AMO	OCL	OD
.01150	.90500	.33333	.02957	1.24200	1.42100	.99700	1.95400

NC	K	L	M	NN	O	P	Q
1	.38925000E 00	.44750000E-03	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
2	.34400000E 00	.46333332E-03	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
3	.67977499E-01	-.19775000E-04	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
4	.71699999E-01	-.21000000E-04	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00	-.00000000E 00
5	.13487617E-02	.24107085E 01	-.58313584E 03	.78192497E 05	-.53278815E 07	.13695548E 09	.64530490E 09
6	-.21480229E 01	.14160692E 04	-.27029259E 06	.32850279E 08	-.20186315E 10	.45553047E 11	.00000000E 00
7	-.29052144E 01	.22908387E 04	-.40461752E 06	.38134658E 08	-.70443591E 09	.00000000E 00	.00000000E 00
8	.66165306E-01	.13773820E 03	-.26808245E 05	.45075696E 07	-.45949754E 09	.23585991E 11	-.45373062E 12

CIAS	AFS	AFT	CIAT	AFIN	AROCT	FPI	FINT	RCONT	BRERR
.04210	.03045	.00378	.06930	15.79700	1.19700	8.77000	.01633	.0000000	.000130

RUN	TS IN F	TS OUT F	TT IN F	TT OUT F	W SHELL LB/HR	W TUBE LB/HR	Q SHELL BTU/HR	Q TUBE BTU/HR	PER DEV + OR -
4	172.34	176.36	309.70	302.30	26400	11900	49838	42778	7.62
7	154.13	159.62	282.26	275.52	17750	12030	39868	38370	1.91
9	150.94	154.81	279.11	272.76	26800	14600	47467	43745	4.08
10	170.03	174.41	307.75	300.82	25800	14750	52696	49574	3.05
11	170.94	174.03	308.69	300.08	28100	8970	40500	37460	3.90
12	198.01	201.28	336.07	326.95	25950	8380	40612	38029	3.28
13	194.56	198.18	332.64	324.84	26300	12000	51687	46455	5.33
14	194.29	198.67	327.91	321.24	26300	15100	54968	49793	4.94
14	220.08	225.66	356.75	349.81	16900	12150	46112	42809	3.72
15	216.90	220.00	355.84	347.65	31000	11600	46801	46165	1.44
16	216.72	220.90	353.80	346.15	25200	11800	51316	45691	5.80
17	192.99	199.13	332.00	324.24	17030	12100	49876	46575	3.42
18	191.90	195.32	331.51	323.19	32200	12000	52407	49488	2.86
19	216.55	220.99	352.51	345.87	25500	15400	55155	51720	3.21
20	216.88	220.42	362.04	352.14	25500	8520	43970	42971	1.15
21	242.58	245.92	381.58	372.16	24900	8530	41463	41672	.25
22	241.62	245.78	379.58	371.84	24950	12100	49238	48520	.73
23	241.70	246.05	376.42	369.85	24950	15400	54091	52297	1.69
24	265.13	269.57	404.13	397.62	24650	15250	55696	52591	2.87
25	262.87	266.09	403.85	394.46	25250	8280	41271	41125	.18
26	262.63	266.33	398.74	391.26	25200	12040	47329	47463	.14
27	286.91	292.19	431.56	424.02	18400	11870	50405	48528	1.90
28	242.86	246.08	385.14	376.37	31800	12100	51060	55225	3.92
29	242.44	248.50	387.61	380.06	17900	12430	54139	48973	5.01
30	264.87	270.41	411.08	403.28	18780	11840	52959	49192	3.69
31	262.90	266.13	409.81	401.21	32600	11580	53451	52969	.45
32	288.73	291.73	433.05	424.76	32000	11250	49836	50616	.78
33	288.62	292.43	432.73	424.70	25000	11420	49459	49761	.30
34	288.42	291.65	439.65	429.33	26450	8360	44343	47047	2.96
35	287.79	291.75	430.01	423.27	26050	14900	53531	54398	.80
36	312.97	317.16	452.06	445.75	25900	15250	57542	53117	4.00
37	310.95	314.01	449.37	439.92	25850	8530	41851	44336	2.88
38	313.34	318.08	455.13	447.65	18050	11650	45391	48202	3.00
39	312.50	316.01	454.01	446.11	25450	11650	47334	50852	3.58
40	311.64	314.74	442.77	434.81	31200	11950	51204	52061	.83
41	338.00	340.84	477.14	469.63	30800	11870	47335	50218	2.96
42	338.81	343.90	477.66	470.73	17470	11880	48196	46409	1.89
43	342.17	345.75	483.06	475.65	25100	11860	48808	49750	.96
44	340.90	344.00	486.37	476.41	24900	8460	41875	47780	6.59
45	339.93	343.76	479.65	473.36	25050	15100	52022	53642	1.53
46	362.87	366.68	504.47	498.25	25900	15100	54519	54127	.36
47	361.81	365.55	505.94	498.18	25350	11720	52334	52442	.10
48	361.11	364.69	510.64	500.70	25400	8970	50162	51562	1.38
49	364.24	369.49	505.00	497.52	17400	11730	50555	50560	.01
50	361.47	364.85	503.23	495.07	31000	11820	57814	55486	2.05
51	387.08	390.53	530.57	522.52	30850	11680	59947	55283	4.05
52	390.25	395.76	532.46	524.82	17750	11660	55270	52464	2.60
53	388.78	392.90	529.76	521.70	25400	11680	59037	55316	3.25
54	389.58	393.70	520.98	514.57	25250	15020	58726	56217	2.18

RUN	Q AVG BTU/HR	LMTD F	HO PRIME BTU/HR-SQFT-F	R FIN HR-SQFT-F/BTU	HO BTU/HR-SQFT-F	HI BTU/HR-SQFT-F	UO CALC BTU/HR-SQFT-F	UO EXP BTU/HR-SQFT-F	R BOND HR-SQFT-F/BTU
4	46308	131.63	215.60	.00562	97.49	433.49	20.48	20.70	-.000041
7	39119	122.31	136.94	.00609	74.65	378.31	17.54	18.82	-.000309
9	45606	123.06	194.12	.00574	91.85	429.92	20.11	21.81	-.000311
10	51135	132.06	209.58	.00565	95.94	518.40	23.08	22.78	.000045
11	38980	131.88	224.68	.00557	99.77	336.48	17.08	17.39	-.000084
12	39320	131.84	238.15	.00550	103.08	368.39	18.39	17.55	.000209
13	49071	132.61	238.56	.00550	103.17	490.25	22.60	21.77	.000133
14	57380	128.09	239.36	.00550	103.37	588.29	25.54	24.06	.000193
14	44460	130.41	178.94	.00582	87.63	559.31	23.69	20.06	.000611
15	47483	133.28	302.96	.00519	117.84	529.68	24.52	20.96	.000554
16	48503	131.16	252.20	.00543	106.42	532.54	24.08	21.76	.000353
17	48225	132.06	161.90	.00593	82.62	494.02	21.54	21.49	.000008
18	50947	133.73	282.86	.00528	113.43	483.26	22.82	22.42	.000063
19	53438	130.42	255.42	.00542	107.17	663.51	27.89	24.11	.000450
20	43471	138.42	254.13	.00542	106.87	414.27	20.19	18.48	.000367
21	41567	132.60	273.15	.00533	111.25	451.13	21.64	18.45	.000641
22	48879	131.90	274.02	.00532	111.44	601.16	26.38	21.81	.000637
23	53194	129.26	274.56	.00532	111.57	729.02	29.83	24.22	.000622
24	54144	133.52	293.48	.00523	115.78	792.69	31.70	23.86	.000829
25	41198	134.65	295.85	.00522	116.30	475.71	22.68	18.00	.000916
26	47396	130.51	295.94	.00522	116.32	641.23	27.80	21.37	.000866
27	49466	138.24	240.99	.00549	103.76	699.16	28.51	21.06	.000993
28	53142	136.27	341.64	.00501	126.08	607.37	27.32	22.95	.000558
29	51556	138.36	205.03	.00568	94.76	630.43	26.09	21.93	.000583
30	51076	139.54	230.01	.00554	101.09	653.81	27.16	21.54	.000769
31	53210	140.98	373.54	.00487	132.55	635.94	28.48	22.21	.000793
32	50226	138.66	396.81	.00477	137.17	669.41	29.69	21.32	.001059
33	49610	138.18	316.13	.00511	121.10	678.29	29.11	21.13	.001039
34	45695	144.43	333.80	.00504	124.41	531.20	24.85	18.62	.001077
35	53965	136.87	329.81	.00506	123.57	840.34	33.41	23.20	.001054
36	55330	133.64	351.88	.00496	128.15	910.29	35.37	24.33	.001027
37	43094	132.14	347.74	.00498	127.30	558.65	25.85	19.19	.001075
38	46796	135.68	254.28	.00542	106.91	737.07	29.68	20.30	.001247
39	49093	135.79	345.10	.00499	126.75	732.69	30.91	21.27	.001173
40	51632	125.58	413.49	.00470	140.44	723.75	31.41	24.19	.000760
41	48776	133.95	436.63	.00461	144.89	790.69	33.49	21.43	.001345
42	47303	132.84	263.41	.00538	109.02	793.88	31.19	20.95	.001254
43	49279	135.39	367.30	.00489	131.29	801.46	32.98	21.42	.001310
44	44828	138.91	362.95	.00491	130.41	609.59	27.58	18.99	.001313
45	52832	134.66	365.11	.00490	130.84	970.36	36.90	23.09	.001298
46	54323	136.58	396.93	.00477	137.20	1027.45	38.63	23.40	.001348
47	52388	138.37	388.23	.00481	135.48	835.07	34.09	22.28	.001244
48	50862	142.75	388.10	.00481	135.45	674.15	29.75	20.97	.001127
49	50558	134.39	276.66	.00530	112.49	835.33	32.43	22.14	.001147
50	56650	135.98	465.08	.00450	150.26	832.57	34.89	24.52	.000971
51	57615	137.73	489.59	.00442	154.80	875.63	36.25	24.62	.001044
52	53867	135.63	300.22	.00520	117.25	880.57	33.83	23.37	.001059
53	57177	134.88	412.77	.00471	140.30	874.37	35.37	24.94	.000945
54	57471	126.13	411.28	.00471	140.01	1058.67	39.51	26.81	.000959

TABLE XXI (Continued)

RUN	RE SHELL	RE TUBE	PR SHELL	PR TUBE	VISC SHELL LB/FT-HR	VISC S-WALL LB/FT-HR	VISC RATIO SHELL	VISC TUBE LB/FT-HR	VISC T-WALL LB/FT-HR	VISC RATIO TUBE
4	9196	48166	28.741	33.709	3.969	3.140	1.264	4.529	12.833	.353
7	5187	38386	33.492	41.292	4.731	3.539	1.337	5.745	20.304	.283
9	7528	45304	34.681	42.300	4.922	3.703	1.329	5.908	23.010	.257
10	8810	58863	29.240	34.115	4.049	3.110	1.302	4.594	11.785	.390
11	9619	35826	29.177	34.091	4.039	3.312	1.219	4.590	15.089	.304
12	11194	41380	23.957	28.537	3.205	2.722	1.177	3.713	8.955	.415
13	11035	58047	24.521	29.030	3.295	2.686	1.227	3.790	8.609	.440
14	11067	70783	24.463	29.800	3.286	2.646	1.242	3.911	8.066	.485
14	8628	70040	20.830	25.118	2.708	2.243	1.207	3.180	5.516	.577
15	15353	66169	21.357	25.335	2.792	2.390	1.168	3.214	6.087	.528
16	12512	66494	21.313	25.590	2.785	2.340	1.190	3.253	6.271	.519
17	7142	58259	24.531	29.143	3.297	2.576	1.280	3.808	8.451	.451
18	13242	57444	24.941	29.283	3.362	2.761	1.218	3.830	9.301	.412
19	12657	86310	21.318	25.704	2.785	2.305	1.208	3.271	5.767	.567
20	12647	50401	21.333	24.592	2.788	2.384	1.169	3.099	6.595	.470
21	14589	57410	18.630	22.148	2.360	2.076	1.137	2.724	4.938	.552
22	14578	80842	18.671	22.279	2.366	2.038	1.161	2.744	4.601	.596
23	14585	101218	18.665	22.576	2.365	2.012	1.175	2.789	4.425	.630
24	16516	118756	16.750	19.708	2.063	1.787	1.155	2.354	3.468	.679
25	16651	63831	16.961	19.867	2.097	1.873	1.119	2.378	3.962	.600
26	16618	90562	16.961	20.259	2.097	1.845	1.136	2.437	3.758	.649
27	13864	107532	15.293	17.496	1.835	1.603	1.144	2.024	2.928	.691
28	18657	83446	18.610	21.717	2.357	2.042	1.154	2.658	4.616	.576
29	10566	87375	18.520	21.386	2.342	1.953	1.199	2.608	4.321	.604
30	12603	95633	16.729	19.146	2.060	1.765	1.167	2.270	3.531	.643
31	21502	92638	16.959	19.292	2.096	1.848	1.134	2.292	3.704	.619
32	24194	102530	15.253	17.414	1.829	1.646	1.111	2.012	2.983	.674
33	18930	103973	15.236	17.428	1.826	1.625	1.123	2.014	2.951	.682
34	19978	78498	15.265	17.015	1.830	1.647	1.112	1.952	3.065	.637
35	19650	134144	15.280	17.581	1.833	1.619	1.132	2.036	2.843	.716
36	22075	154316	13.930	16.060	1.622	1.450	1.119	1.812	2.431	.745
37	21770	84455	14.056	16.331	1.642	1.500	1.094	1.852	2.727	.679
38	15430	119382	13.899	15.905	1.617	1.444	1.120	1.789	2.429	.736
39	21610	118581	13.969	15.987	1.628	1.470	1.108	1.801	2.494	.722
40	26362	114776	14.021	16.719	1.636	1.484	1.102	1.909	2.737	.697
41	29240	135477	12.864	14.652	1.456	1.342	1.086	1.606	2.122	.757
42	16722	136113	12.787	14.609	1.444	1.302	1.109	1.600	2.091	.765
43	24289	139228	12.686	14.344	1.429	1.306	1.094	1.562	2.052	.761
44	23943	100262	12.744	14.242	1.438	1.323	1.086	1.547	2.150	.719
45	24026	174906	12.768	14.490	1.441	1.308	1.102	1.583	2.015	.785
46	27267	195905	11.941	13.313	1.313	1.202	1.093	1.413	1.758	.804
47	26574	152524	11.977	13.282	1.319	1.209	1.091	1.409	1.831	.770
48	26545	118598	12.003	13.128	1.323	1.216	1.088	1.387	1.903	.728
49	18469	152116	11.872	13.317	1.303	1.180	1.104	1.414	1.820	.777
50	32430	151858	11.995	13.410	1.322	1.214	1.089	1.427	1.904	.750
51	35564	168756	11.205	12.303	1.199	1.110	1.081	1.269	1.643	.772
52	20775	169930	11.088	12.226	1.181	1.075	1.099	1.258	1.596	.788
53	29498	168187	11.148	12.333	1.191	1.094	1.088	1.273	1.647	.773
54	29409	209193	11.126	12.636	1.187	1.091	1.088	1.316	1.633	.806

RUN	TS AVG F	T FIN AVG F	T ROOT F	T BOND O F	T BOND F	T BOND I F	T LINER F	T WALL I F	TT AVG F	FIN EFF
4	174.36	185.84	202.31	203.44	202.74	202.04	206.96	211.88	306.00	.412
7	156.57	172.33	187.41	188.36	183.92	179.47	183.63	187.78	278.89	.512
9	152.87	165.54	182.09	183.20	177.99	172.78	177.63	182.47	275.93	.434
10	172.22	185.29	203.58	204.83	205.67	206.51	211.94	217.38	304.28	.418
11	172.48	181.73	195.47	196.42	195.23	194.03	198.18	202.32	304.38	.403
12	199.64	208.40	222.09	223.05	226.08	229.11	233.29	237.47	331.51	.391
13	196.12	207.03	224.11	225.30	227.71	230.12	235.34	240.55	328.74	.391
14	196.48	208.08	226.30	227.57	231.28	234.99	240.56	246.13	324.57	.390
14	222.87	236.34	252.73	253.81	263.80	273.79	278.52	283.24	353.28	.452
15	218.45	226.58	242.16	243.32	252.99	262.67	267.72	272.76	351.74	.345
16	218.81	228.96	245.63	246.81	253.11	259.42	264.57	269.73	349.97	.380
17	196.06	212.32	230.41	231.58	231.72	231.86	236.99	242.11	328.12	.474
18	193.61	203.02	220.04	221.28	222.46	223.64	229.05	234.47	327.35	.358
19	218.77	229.80	248.11	249.41	258.25	267.09	272.77	278.44	349.19	.377
20	218.65	227.67	242.59	243.64	249.52	255.40	260.02	264.64	357.09	.378
21	244.25	252.22	266.24	267.25	277.05	286.85	291.27	295.69	376.87	.364
22	243.80	253.14	269.61	270.80	282.24	293.68	298.88	304.07	375.71	.364
23	243.87	254.02	271.93	273.23	285.38	297.54	303.19	308.85	373.13	.363
24	267.35	276.95	294.87	296.19	312.69	329.19	334.94	340.70	400.87	.351
25	264.48	271.72	285.33	286.33	300.21	314.10	318.47	322.85	399.15	.349
26	264.48	272.81	288.46	289.61	304.71	319.80	324.84	329.88	395.00	.349
27	289.55	300.42	317.60	318.81	336.87	354.94	360.20	365.45	427.79	.389
28	244.47	252.44	269.27	270.57	281.47	292.37	298.02	303.67	380.75	.324
29	245.47	258.97	277.49	278.74	289.78	300.82	306.30	311.78	383.83	.422
30	267.64	279.45	297.37	298.61	313.05	327.50	332.92	338.35	407.18	.398
31	264.51	271.76	288.14	289.43	304.96	320.48	326.13	331.79	405.51	.309
32	290.23	296.62	311.78	313.00	332.56	352.12	357.46	362.80	428.90	.299
33	290.52	298.58	314.63	315.84	334.78	353.73	359.00	364.27	428.71	.336
34	290.03	297.07	311.65	312.76	330.87	348.99	353.84	358.70	434.49	.328
35	289.77	298.19	315.47	316.78	337.69	358.59	364.32	370.06	426.64	.330
36	315.06	323.11	340.47	341.82	362.71	383.59	389.47	395.35	448.90	.319
37	312.48	318.83	332.40	333.45	350.49	367.52	372.10	376.68	444.64	.321
38	315.71	325.41	341.47	342.61	364.06	385.51	390.48	395.45	451.39	.378
39	314.25	321.54	337.05	338.24	359.42	380.59	385.81	391.03	450.06	.322
40	313.19	319.47	334.82	336.08	350.52	364.96	370.45	375.94	438.79	.292
41	339.42	345.00	359.23	360.42	384.54	408.67	413.85	419.03	473.38	.284
42	341.35	350.80	366.89	368.04	389.84	411.64	416.67	421.70	474.19	.371
43	343.96	350.79	366.05	367.25	390.98	414.71	419.94	425.18	479.35	.312
44	342.45	348.75	362.68	363.77	385.42	407.07	411.84	416.60	481.39	.314
45	341.84	349.22	365.61	366.89	392.10	417.31	422.92	428.54	476.50	.313
46	364.77	371.69	388.07	389.40	416.31	443.23	449.00	454.78	501.36	.299
47	361.68	370.51	386.43	387.71	411.68	435.65	441.22	446.79	502.06	.302
48	362.90	369.53	385.00	386.23	407.31	428.39	433.79	439.20	505.67	.302
49	366.86	376.35	393.31	394.54	415.87	437.19	442.56	447.93	501.26	.360
50	363.16	369.20	385.34	386.72	406.94	427.16	433.18	439.20	499.15	.274
51	388.80	394.61	410.71	412.11	434.22	456.33	462.45	468.57	526.54	.267
52	393.00	402.33	420.04	421.35	442.32	463.29	469.02	474.74	528.64	.347
53	390.84	397.61	414.82	416.21	436.09	455.96	462.04	468.12	525.73	.293
54	391.64	398.67	415.80	417.19	437.46	457.73	463.84	469.95	517.77	.293

TABLE XXI (Continued)

RUN	T LINER F	T FIN F	TLINER-TFIN F	MU	K AIR BTU/HR-SQFT-F/FT	ALPHA LINER IN/IN	ALPHA FIN IN/IN	R BOND HR-SQFT-F/BTU	P CO PSI
4	206.96	185.84	21.12	.2201E-06	.0182	.6344E-05	.1296E-04	-.000041	2955
7	183.63	172.33	11.30	.2195E-06	.0178	.6291E-05	.1292E-04	-.000309	3367
9	177.63	165.54	12.09	.2193E-06	.0176	.6278E-05	.1290E-04	-.000311	3140
10	211.94	185.29	26.65	.2201E-06	.0182	.6355E-05	.1296E-04	.000045	2600
11	198.18	181.73	16.45	.2197E-06	.0180	.6324E-05	.1295E-04	-.000084	3057
12	233.29	208.40	24.89	.2209E-06	.0187	.6403E-05	.1303E-04	.000209	3002
13	235.34	207.03	28.31	.2209E-06	.0187	.6407E-05	.1302E-04	.000133	3010
14	240.56	208.08	32.48	.2209E-06	.0188	.6419E-05	.1302E-04	.000193	2790
14	278.52	236.34	42.18	.2220E-06	.0195	.6504E-05	.1311E-04	.000611	2421
15	267.72	226.59	41.13	.2216E-06	.0193	.6480E-05	.1308E-04	.000554	2301
16	264.57	228.96	35.62	.2217E-06	.0193	.6473E-05	.1309E-04	.000353	2963
17	236.99	212.32	24.67	.2210E-06	.0188	.6411E-05	.1304E-04	.000008	3534
18	229.05	203.02	26.03	.2207E-06	.0186	.6393E-05	.1301E-04	.000063	3106
19	272.77	229.80	42.97	.2217E-06	.0194	.6491E-05	.1309E-04	.000450	2551
20	260.02	227.67	32.35	.2216E-06	.0192	.6462E-05	.1308E-04	.000367	3001
21	291.27	252.22	39.05	.2226E-06	.0198	.6532E-05	.1316E-04	.000641	2906
22	298.88	253.14	45.73	.2226E-06	.0199	.6549E-05	.1316E-04	.000637	2723
23	303.19	254.02	49.17	.2227E-06	.0200	.6559E-05	.1316E-04	.000622	2667
24	334.94	276.95	57.99	.2236E-06	.0206	.6630E-05	.1323E-04	.000829	2556
25	318.47	271.72	46.75	.2233E-06	.0203	.6593E-05	.1322E-04	.000916	2598
26	324.84	272.81	52.03	.2234E-06	.0204	.6608E-05	.1322E-04	.000866	2560
27	360.20	300.42	59.77	.2245E-06	.0211	.6687E-05	.1330E-04	.000993	2764
28	298.02	252.44	45.57	.2226E-06	.0199	.6548E-05	.1316E-04	.000558	2878
29	306.30	258.97	47.34	.2229E-06	.0201	.6566E-05	.1318E-04	.000583	2948
30	332.92	279.45	53.47	.2237E-06	.0206	.6626E-05	.1324E-04	.000769	2906
31	326.13	271.76	54.38	.2234E-06	.0204	.6611E-05	.1322E-04	.000793	2614
32	357.46	296.62	60.84	.2243E-06	.0210	.6681E-05	.1329E-04	.001059	2480
33	359.00	298.58	60.42	.2244E-06	.0210	.6684E-05	.1330E-04	.001039	2592
34	353.84	297.07	56.77	.2243E-06	.0209	.6673E-05	.1329E-04	.001077	2589
35	364.32	298.19	66.13	.2244E-06	.0211	.6696E-05	.1329E-04	.001054	2352
36	389.47	323.11	66.37	.2254E-06	.0216	.6752E-05	.1337E-04	.001027	3070
37	372.10	318.83	53.28	.2252E-06	.0214	.6714E-05	.1336E-04	.001075	3297
38	390.48	325.41	65.06	.2254E-06	.0217	.6755E-05	.1338E-04	.001247	2668
39	385.81	321.54	64.26	.2253E-06	.0216	.6744E-05	.1336E-04	.001173	2765
40	370.45	319.47	50.98	.2252E-06	.0214	.6710E-05	.1336E-04	.000760	4109
41	413.85	345.00	68.85	.2278E-06	.0221	.6807E-05	.1344E-04	.001345	2802
42	416.67	350.80	65.87	.2290E-06	.0222	.6813E-05	.1345E-04	.001254	3253
43	419.94	350.79	69.15	.2290E-06	.0222	.6821E-05	.1345E-04	.001310	3010
44	411.84	348.75	63.09	.2285E-06	.0221	.6803E-05	.1345E-04	.001313	3165
45	422.92	349.22	73.70	.2287E-06	.0223	.6827E-05	.1345E-04	.001298	2841
46	449.00	371.69	77.32	.2333E-06	.0228	.6886E-05	.1352E-04	.001348	3121
47	441.22	370.51	70.71	.2330E-06	.0227	.6868E-05	.1351E-04	.001244	3566
48	433.79	369.53	64.26	.2328E-06	.0226	.6852E-05	.1351E-04	.001127	4041
49	442.56	376.35	66.21	.2343E-06	.0228	.6871E-05	.1353E-04	.001147	4079
50	433.18	369.20	63.98	.2327E-06	.0226	.6850E-05	.1351E-04	.000971	4408
51	462.45	394.61	67.84	.2382E-06	.0232	.6916E-05	.1358E-04	.001044	4672
52	469.02	402.33	66.69	.2399E-06	.0234	.6931E-05	.1361E-04	.001059	4840
53	462.04	397.81	64.23	.2389E-06	.0232	.6915E-05	.1359E-04	.000945	5093
54	463.84	398.67	65.17	.2391E-06	.0232	.6919E-05	.1360E-04	.000959	5047

RUN	P CC PSI	P CC AVG PSI	DEV PSI	P CO LL PSI	P CO UL PSI
4	2955	3138	-183	2697	3214
7	3367	3138	229	3114	3620
9	3140	3138	1	2888	3391
10	2600	3138	-539	2340	2859
11	3057	3138	-81	2800	3313
12	3002	3138	-136	2737	3267
13	3010	3138	-129	2745	3275
14	2790	3138	-348	2524	3057
14	2421	3138	-718	2146	2696
15	2301	3138	-837	2029	2573
16	2963	3138	-175	2691	3235
17	3534	3138	396	3268	3800
18	3106	3138	-32	2842	3370
19	2551	3138	-587	2277	2824
20	3001	3138	-137	2730	3272
21	2906	3138	-232	2628	3184
22	2723	3138	-416	2443	3002
23	2667	3138	-472	2386	2947
24	2556	3138	-583	2268	2843
25	2598	3138	-540	2314	2882
26	2560	3138	-578	2275	2846
27	2764	3138	-375	2470	3058
28	2878	3138	-260	2598	3157
29	2948	3138	-190	2667	3230
30	2906	3138	-232	2619	3194
31	2614	3138	-525	2328	2899
32	2480	3138	-658	2187	2773
33	2592	3138	-546	2299	2885
34	2589	3138	-549	2297	2881
35	2352	3138	-786	2058	2647
36	3070	3138	-68	2770	3370
37	3297	3138	159	3000	3594
38	2668	3138	-470	2368	2969
39	2765	3138	-373	2466	3065
40	4109	3138	971	3812	4406
41	2802	3138	-337	2498	3105
42	3253	3138	114	2949	3556
43	3010	3138	-129	2706	3314
44	3165	3138	27	2863	3468
45	2841	3138	-298	2536	3146
46	3121	3138	-18	2815	3427
47	3566	3138	427	3261	3870
48	4041	3138	903	3737	4345
49	4079	3138	941	3775	4383
50	4408	3138	1269	4104	4711
51	4672	3138	1534	4368	4977
52	4840	3138	1702	4535	5144
53	5093	3138	1954	4788	5397
54	5047	3138	1909	4743	5352

STANDARD DEVIATION = 696