The University of Texas Publication

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The benefits of education and of useful knowledge, generally diffused through a community, are essential to the preservation of a free government.

Sam Houston

Cultivated mind is the guardian genius of Democracy, and while guided and controlled by virtue, the noblest attribute of man. It is the only dictator that freemen acknowledge, and the only security which freemen desire.

Mirabeau B. Lamar

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TABLE OF SYMBOLS

(Listed in order in which they occur in text)

h_t = tube side film coefficient of heat transfer, B.t.u. per hr.-sq.ft.-deg.F.
h_s = shell side film coefficient of heat transfer, B.t.u. per hr.-sq.ft.-deg.F.
D = diameter of tube (inside in Eq. 1, outside in Eq. 11), ft.
k = thermal conductivity, B.t.u.-ft. per hr.-sq.ft.-deg.F.
N = heated length of tube, ft.
G = weight rate of flow, lb. per hr.-sq.ft. of cross-sectional area
μ = absolute viscosity of fluid, lb. per hr.-ft.
c = specific heat of the fluid, B.t.u. per lb.-deg.F.
U = overall transfer coefficient, B.t.u. per hr.-sq.ft.-deg.F. m.t.d.
r_2 = outside radius of tube, ft.
r_1 = inside radius of tube, ft.
G_x = effective weight rate of flow, lb. per hr.-sq.ft. of effective area
G_R = radial flow in disk-and-doughnut type baffles, lb. per hr.-sq.ft.
G_A = flow in annular area in disk-and-doughnut type baffles, lb. per hr.-sq.ft.
G_H = flow through hole in disk-and-doughnut type baffles, lb. per hr.-sq.ft.
G_o = flow through orifices in orifice type baffles, lb. per hr.-sq.ft.
G_a = flow along tubes between baffles in orifice type baffles, lb. per hr.-sq.ft.
G_b = flow beneath baffles in half-moon type baffles, lb. per hr.-sq.ft.
G_p = flow across tubes in half-moon type baffles, lb. per hr.-sq.ft.
S = baffle spacing, ft.
A_R = free area of radial flow in disk-and-doughnut baffles, sq. ft. (See Fig. 6)
A_A = free area between shell and disk in disk-and-doughnut baffles, sq. ft.
A_H = free area in hole of doughnut in disk-and-doughnut baffles, sq. ft.
A_o = total free area of orifices at each baffle in orifice baffles, sq. ft.
A_a = free area between baffles in orifice type baffles, sq. ft.
A_b = free area beneath baffle in half-moon type baffles, sq. ft.
A_p = free area for cross-flow between baffles in half-moon baffles, sq. ft.
P = tube pitch, ft., p = tube pitch, inches
L = total baffled length of exchanger, ft.
Δp = pressure drop in baffled length of exchanger, inches of mercury
w = specific weight of fluid, lb. per cu. ft.
D_D = diameter of disk of disk-and-doughnut baffles, ft.
D_H = diameter of hole in disk-and-doughnut baffles, ft.
d_t = outside diameter of tube, inches
d_o = diameter of orifice of orifice baffles, inches
N_b = number of baffles on the tube bundle.

INTRODUCTION AND ACKNOWLEDGMENTS

This Bulletin is the result of a series of experimental investigations on the subject of heat transmission in heat exchangers which began with a series of experiments on a shell-and-tube type exchanger with a single horizontal baffle (Bulletin No. 3128, The University of Texas), then followed by a series of experiments to determine the effect of tube spacing and baffle arrangements on the pressure loss in tube bundles (Oil and Gas Journal, May 10, 1934), and was then followed by the present work, part of which was written up by Mr. S.A. Perrone and published in 1935 (Oil and Gas Journal, March 28, 1935). This experimental work was done in the Mechanical Laboratory at The University of Texas and the results were computed and correlated while the writer was a gradute student at Cornell University in 1935-36. With some minor changes, this Bulletin is a summary of the thesis presented at Cornell University in June 1936 in partial fulfillment of the requirements for a Master of Mechanical Engineering degree.

The writer wishes, therefore, to acknowledge the criticism and suggestions of Professors W.N. Barnard, F.O. Ellenwood, C.O. Mackey, and J.O. Jeffrey of Cornell University on the original phases of this work; the help of the Department of Mechanical Engineering and the Bureau of Engineering Research at The University of Texas in acquiring the materials used in the experimental work; and the able assistance of Mr. Fred Morris, Laboratory Mechanician at The University of Texas, and Mr. S.A. Perrone, former graduate student at The University of Texas, in setting up the apparatus and in the conduct of the tests. And, the writer wishes to thank the Dean of the College of Engineering of the University of Texas in obtaining funds for the publication of these results.

SUMMARY

The material in this Bulletin presents in both a graphical and an analytical manner the results of a series of experiments with water and several grades of oil being cooled in a shell-and-tube heat exchanger. The heat exchanger was first used without baffles or turbulence promoters, and then with half-moon type, then orifice type, and finally disk-and-doughnut type baffles. Both the heat transfer coefficients for the outside of the tubes in the bundles and the pressure drop on this same side are treated. Steps in the graphical correlation of the results in obtaining the final transfer coefficient plots are presented. An effective velocity that consists of a combination of the weight rates of flow in the restricted regions is used in the correlation, and methods of obtaining this velocity for the different types of construction are given. A graphical comparison of the heat transfer coefficients is made with results from tests of similar heat exchangers by Ross Heater Company and Foster Wheeler Corporation showing that the methods are applicable to units of other length and shell diameter than the one used in this experimental work. A graphical comparison is also made with the results of others on flow along and across single pipes as well as across banks of pipes. Colburn's equation for heat transfer coefficients for flow across banks of staggered pipes using the velocity in the minimum cross-section is also presented for comparison. Pressure drop relations are given using the Darcy or Fanning equation with the friction factor combined with a "roughness" coefficient. Equations for determining the roughness coefficient for the different baffle forms are given along with the friction and roughness factor graphs. The effect of cooling on the pressure drop is considered as a function of Prandtl's number.

HEAT TRANSFER AND PRESSURE DROP IN HEAT EXCHANGERS

Object

This experimental study was made to determine the possibility of establishing a relation that would permit both the film coefficient of heat transfer and the pressure drop to be calculated for a particular heat exchanger irrespective of the type, size and spacing of the baffles used, or of the size and spacing of the tubes in the bundle, or of the fluid used.

Scope

This paper covers the results of experimental work that was done on a shell-and-tube type heat exchanger in which three different forms of baffles (turbulence promoters) were used and, also, in which the spacing of these baffles and the size and spacing of the tubes were varied. The fluid used on the inside of the tubes as the coolant was water, while water and three different grades of oil were used on the shell side.

In case of the half-moon baffles, Table I shows the different arrangements (tube sizes, tube spacing, and baffle spacing) that were used:

Table I

Tube Diameter	Tube Pitch	Number of Baffles
3/8" o.d.	1/2"	19, 15, 11, 7, 3
"	11/16"	19, 15, 11, 7, 3
1/2" o.d.	19/32"	19, 15, 11, 7, 3
"	11/16"	19, 11, 3
"	25/32"	19, 11, 3
"	1"	19, 11, 3
"	1-3/32"	19, 15, 11, 7, 3
5/8" o.d.	3/4"	19, 11, 3
"	7/8"	19, 15, 11, 7, 3
"	1-1/16"	19, 11, 3

while in the case of the orifice baffles, Table II shows the different arrangements that were used:

Table II

Tube Diameter	Tube Pitch	Orifice Diameter	Number of Baffles
3/8" o.d.	11/16"	7/16"	19, 11, 3
1/2" o.d.	25/32"	17/32"	19, 15, 11, 7, 3
"	"	9/16"	19, 11, 3
"	"	5/8"	19, 11, 3
"	1-3/32"	9/16"	19, 11, 3
5/8" o.d.	1-1/16"	11/16"	19, 11, 3

while for the disk-and-doughnut baffles Table III shown the variation in construction of the unit; and for the bundles without baffles Table IV shows the arrangements:

Table III

Tube Diameter	Tube Pitch	Diameter of Disk	Diameter of Hole	Number of Baffles
3/8" o.d.	11/16"	4.5"	4.0"	19, 11, 3
1/2" o.d.	25/32"	4.5"	4.0"	19, 11, 7, 3
"	"	4.95"	3.5"	19, 11, 3
"	"	5.5"	2.5"	19, 11, 3
"	1-3/32"	4.5"	4.0"	19, 11, 3
5/8" o.d.	1-1/16"	4.5"	4.0"	19, 11, 3

Table IV

Tube Diameter	Tube Pitch
3/8" o.d.	1/2"
"	11/16"
1/2" o.d.	19/32"
"	25/32"
"	1-3/32"
5/8" o.d.	7/8"

For practically all of these investigations the rate of tube fluid was maintained at 2 ft. per sec. while the shell fluid was varied from a minimum of 2000 lb. per hour to 45000 lb. per hour. The total range in Reynolds' number was approximately 10,000 fold and, in Prandtl's number, approximately 3 to 2000.

Apparatus and Experimental Procedure

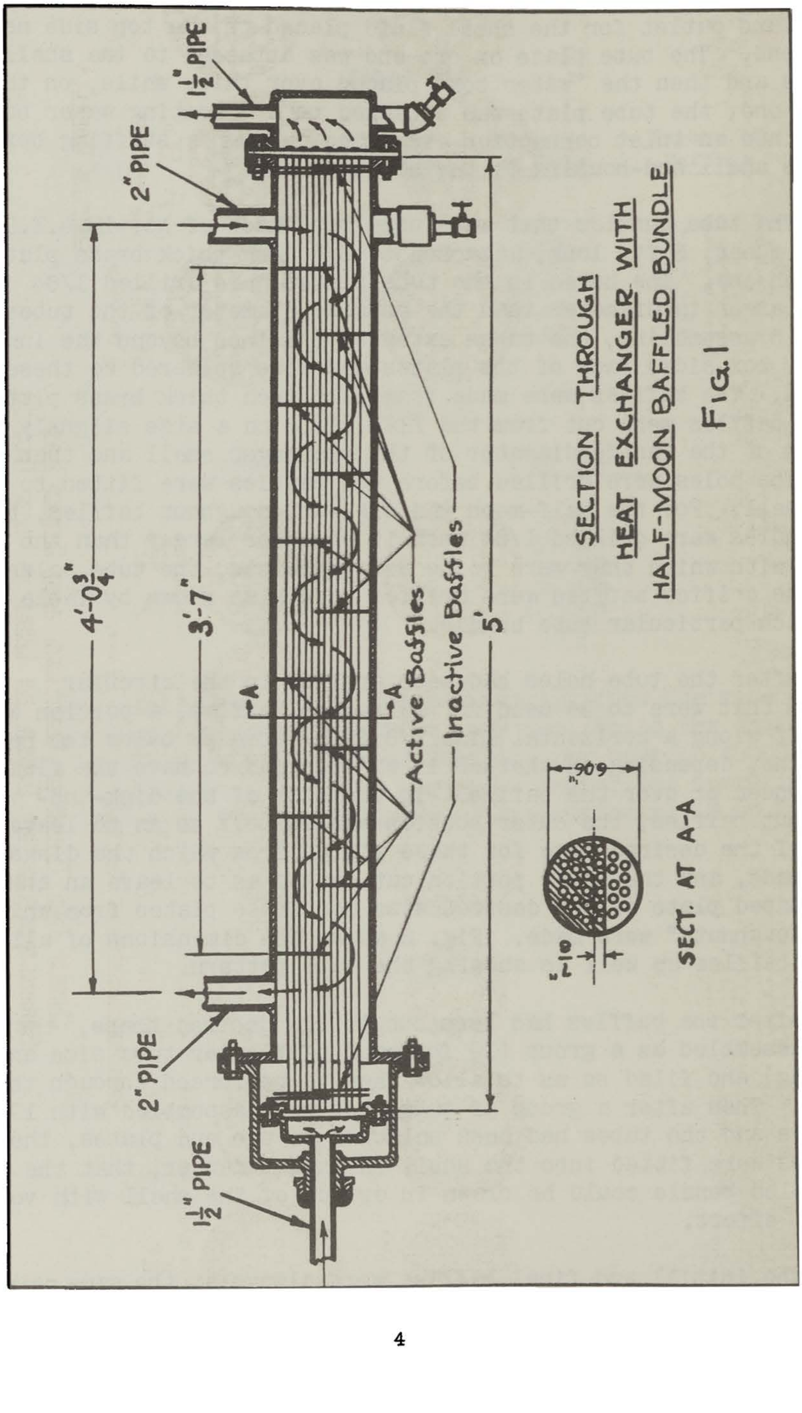
The heat exchanger used in this series of investigations consisted, as shown by Fig. 1, of a 6-inch steel pipe shell with inlet and outlet for the shell fluid placed on the top side near each end. The tube plate on one end was attached to the shell flange and then the "water box" placed over this, while, on the other end, the tube plate was attached to a "floating water box" which had an inlet connection extending through a stuffing box in the shell end-housing to the outside.

The tube bundles that were used were made of No. 18 B.W.G. brass tubes, 5 ft. long, attached to 3/8 inch thick brass plates at each end. The holes in the tube plates were drilled 1/64 inch larger in diameter than the outside diameter of the tubes and, in assembling, the tubes extended 1/8 inch beyond the inner (water box side) face of the plates and were soldered to these plates. The baffles were made from 1/16 inch thick brass plate. These baffles were cut from the flat plate to a size slightly in excess of the inside diameter of the exchanger shell and then the tube holes were drilled before the baffles were fitted to the shell. For the half-moon and disk-and-doughnut baffles, the tube holes were drilled 1/64 inch in diameter larger than the tubes with which they were to be used, whereas, the tube holes for the orifice baffles were drilled to a size shown by Table II for each particular tube bundle.

After the tube holes had been drilled in the circular plates that were to be used for half-moon baffles, a portion was cut off along a horizontal line 7/8 inch above or below the center line, depending on whether it was desired to have the fluid flow under or over the baffle. In the case of the disk-and-doughnut baffles, the outer portion was cut off so as to leave a disk of the desired size for those plates from which the disks were made, and the inner portion cut out so as to leave an annular shaped plate of the desired size for those plates from which the "doughnuts" were made. Fig. 2 shows the dimensions of all of these baffles as well as showing the tube pattern.

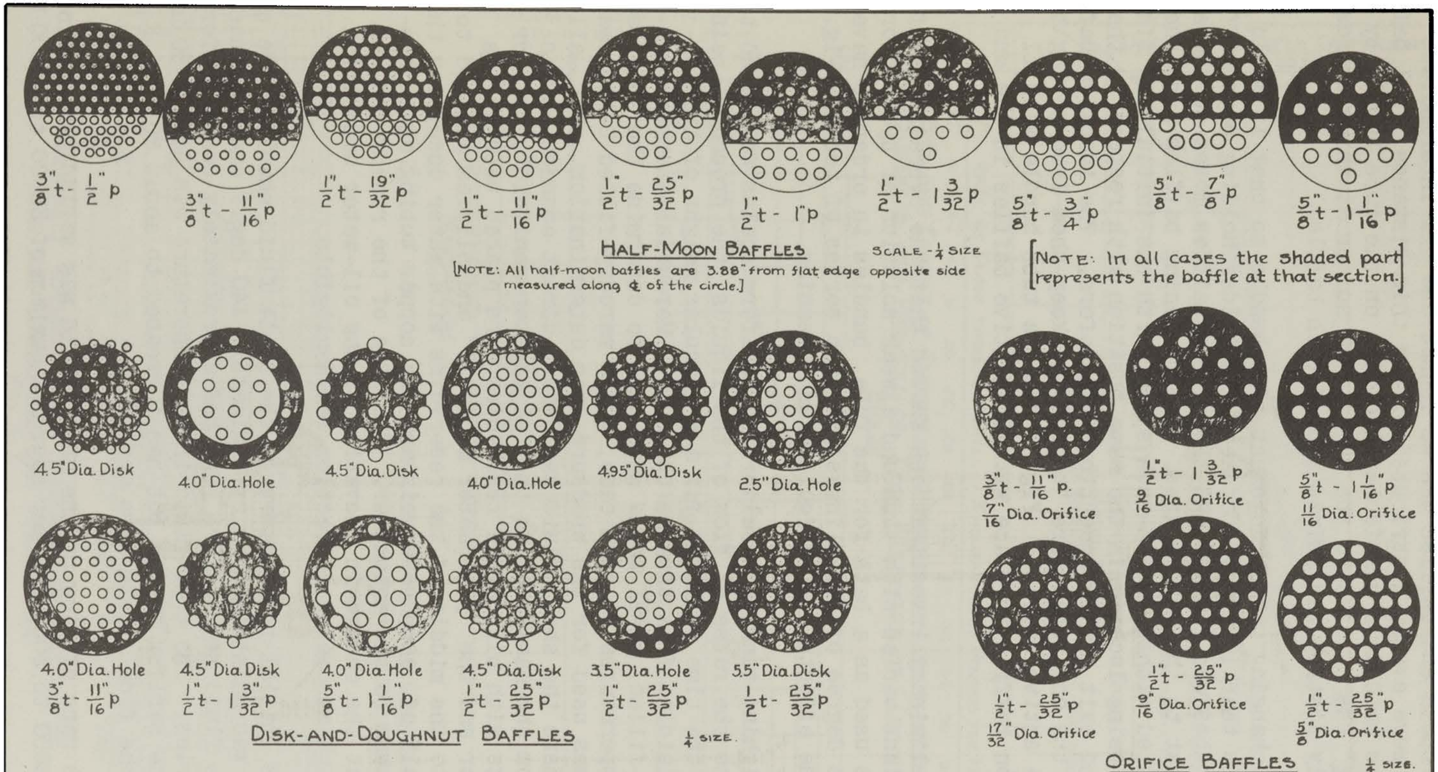
After the baffles had been cut to the desired shape, they were assembled as a group (19 for each particular tube size and spacing) and filed so as to allow them to be forced through the shell. Then after a group of tubes had been assembled with 19 baffles and the tubes had been soldered to the end plates, the baffles were fitted into the shell in such a manner, that the assembled bundle could be drawn in or out of the shell with very slight effort.

The initial and final baffles were always at the same points relative to the shell inlet and exit connections and the distance



SECTION THROUGH HEAT EXCHANGER WITH HALF-MOON BAFFLED BUNDLE

FIG. 1



SIZES AND TYPES OF BAFFLES AND SIZES AND ARRANGEMENTS OF TUBES AS USED IN THE TESTS

FIG. 2

between these end baffles was 43 inches and all intermediate baffles were evenly distributed within this distance. All baffles were held at a particular location on the tube bundle by "tacking" the baffles to the tubes with solder at three or four uniformly distributed points around each baffle.

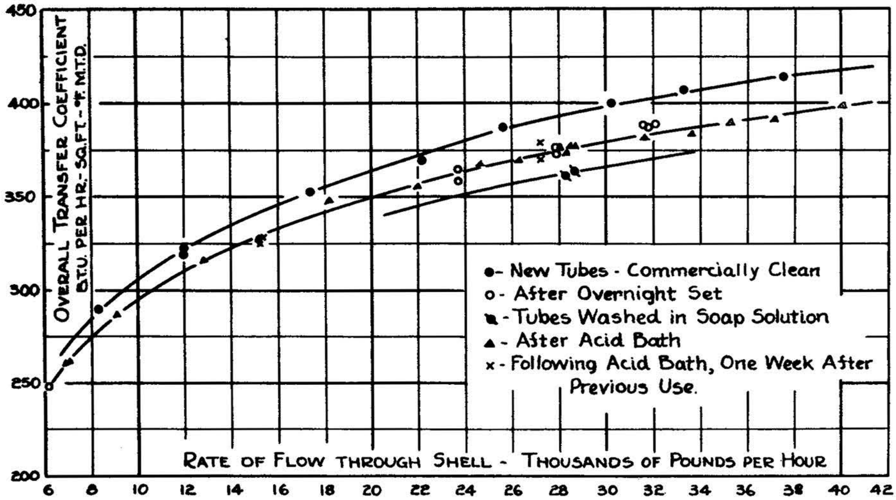
In changing the arrangement of a bundle so that it would have less than 19 active baffles, the solder holding each baffle to the tubes was removed and the excess baffles moved to the end zones next to the tube plates. The remaining baffles were then distributed within the 43-inch space, with the initial and final baffles being located in the same position with respect to the inlet and exit shell connections as before. The inactive baffles in the end zones were "tacked" to keep them from moving toward the active baffles. Fig. 1 shows a tube bundle with 11 half-moon baffles in place with 8 inactive baffles in the end zones.

Preliminary investigations showed that the overall transfer coefficient varied with time and a weak solution of hydrochloric acid was used as a bath for the tube bundles in order to have the same degree of cleanliness for each series of tests. Fig. 3 shows the effects of the fouling and cleaning.

Weighing tanks and calibrated platform scales were used to determine the rates of flow of the liquids, the procedure being to note the time required for a particular weight of tube or shell fluid to flow through the unit. Mercurial thermometers in mercury-filled, steel wells were used to determine the inlet and exit temperatures in each case, and a mercury-filled U-tube manometer was used for the pressure drop determination. For all tests where the shell fluid was water, direct connection was made from the manometer to the "piezometer manifold"; but for the tests with oil, glass reservoirs were placed between the manometer and the "piezometer manifold" and oil was allowed to extend to the middle of the reservoirs with water occupying the lower half of each reservoir and the copper tubing which connected them to the manometer. The size of the reservoirs was such that the change in elevation of the oil-water separation level with manometer deflection was negligible.

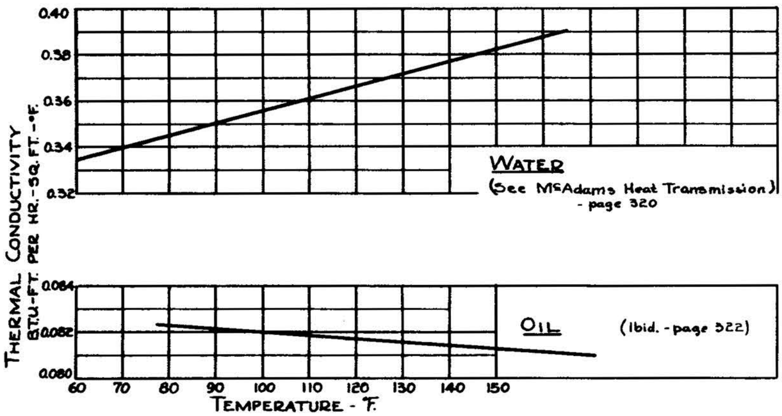
The initial temperature of the shell fluid entering the exchanger was maintained at approximately 140 deg.F and the entering tube fluid temperature remained approximately constant for each series. The tube fluid inlet temperature was around 60 deg. F for the earlier series but had increased to about 80 deg. F before the final tests were made.

The rate of flow of the shell fluid was varied from a minimum of 2000 to 3000 lb. per hour to a maximum of 35000 to 45000 lb.



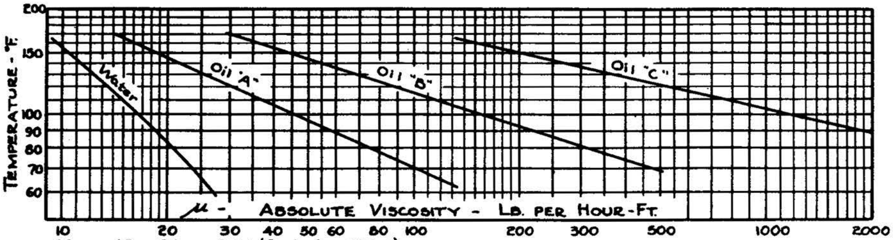
Curves Showing Effect of Different Degrees of Cleanliness of Tube Surfaces and Results of Two Methods of Cleaning

Fig. 3



Variation of Thermal Conductivity of Water and Oil with Temperature

Fig. 4



Viscosity Variation with Temperature for Water and the Three Oils That Were Used

Fig. 5

per hour. The minimum rate was governed by the stability of pumping and heating conditions while the maximum was governed by the range of the pressure drop manometer in some cases (the manometer had a range of 40 inches) and by accurate weighing ranges in other cases. Sufficient intermediate tests were made between these extreme limits to permit definite trends of results to be ascertained. Plots of the overall transfer coefficients against rate of flow and pressure drop were used as a means of control on the experimental procedure. The heat absorbed by the tube fluid was balanced against the heat given up by the shell fluid for each set of data recorded and this was used as a verification of the fluid temperature determinations. As the shell was not insulated, the heat absorbed was usually 1/2 to 3 per cent less than that given up.

The viscosity of each oil that was used was determined at several temperatures by means of a Saybolt Universal Viscosimeter and the viscosity of the water was based on the values given in the International Critical Tables. The thermal conductivities of the water and of the oils were based on the values given by McAdams.[1*] The curves of these data are shown by Fig. 4 and 5.

(* Numbers refer to bibliography at end of text of Bulletin.)

DISCUSSION AND CORRELATION OF RESULTS

TRANSFER COEFFICIENTS

Since there are numerous data available relating to film coefficients of heat transfer for liquids flowing inside of circular tubes, it was assumed that these data could be used for the computation, in this case, of the film coefficients for the tube fluid from the test data and thus allow the shell side coefficient to be determined. The equation[2] used for this purpose is as follows:

$$\frac{h\,D}{k} = 0.0225 \left[1 + \frac{50D}{N}\right] \left[\frac{DG}{\mu}\right]^{0.8} \left[\frac{c\mu}{k}\right]^{0.4} \quad \ldots\ldots(1)$$

(Note: See first page of Bulletin for symbols)

After the tube side coefficients were computed from Eq. 1, with the fluid properties evaluated at the main stream temperature, the shell side coefficients were computed from Eq. 2.

$$\frac{1}{h_s} = \frac{1}{U} - \frac{r_2}{r_1}\frac{1}{h_t} - \frac{r_2}{k}\log_e\left(\frac{r_2}{r_1}\right) \quad \ldots\ldots\ldots(2)$$

In correlating the shell side transfer coefficients and the pressure drop, it was assumed that the effective velocity of the shell fluid was governed by a combination of the velocity through the restricted passages at the baffles with the velocity across or along the tubes between successive baffles. It was assumed that the combination of these velocity components would be governed by the relative proportion of the areas involved in each case as well as by the baffle spacing since the effectiveness of the baffles as turbulence promotors would thus be indicated. Eq. 3, 4, 5, and 6 show how the effective velocity was computed for the disk-and-doughnut baffles, orifice baffles, half-moon baffles, and zero baffles, respectively.

$$G_x = \frac{(A_R)^{0.88}}{(S)^{0.33}} G_R + \frac{(A_A)^{0.48}}{(S)^{0.5}} G_A + \frac{(A_H)^{0.56}}{(S)^{0.5}} G_H \quad ..(3)$$

$$G_x = \frac{A_o}{(S)^{0.59}} G_o + \frac{G_a}{(A_a)^{0.2}(S)^n} \quad \ldots\ldots\ldots(4)$$

where

$$n = \frac{0.332}{(A_o)^{0.15}} \quad \ldots\ldots\ldots\ldots\ldots(4a)$$

$$G_x = \frac{A_b}{(S)^{0.5}} G_b + (S)^{0.44} G_p \quad \ldots\ldots\ldots\ldots(5)$$

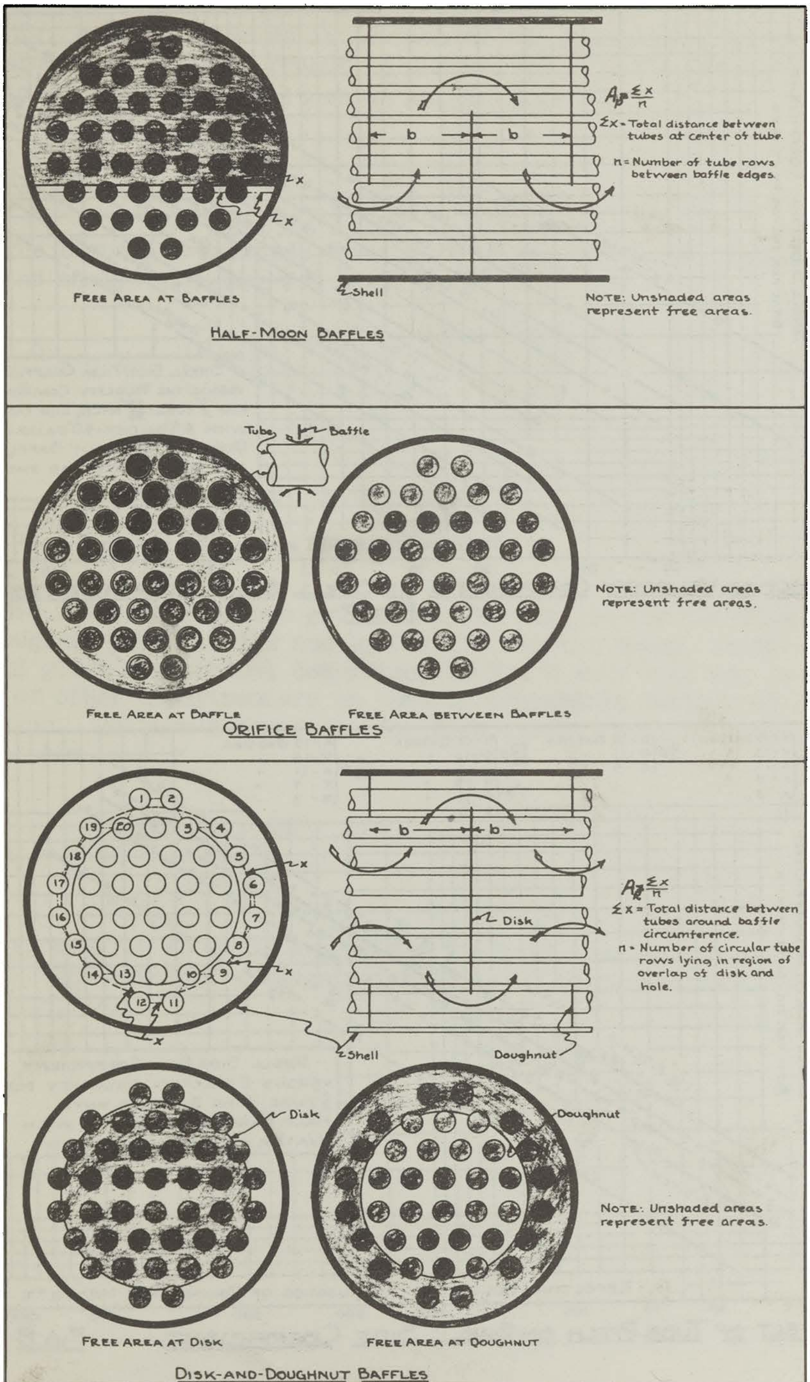
$$G_x = 0.53\ G \quad \ldots\ldots\ldots\ldots\ldots(6)$$

In these equations G_R, G_A, G_H, G_o, G_a, G_b, G_p, and G represent the weight rate of flow at the several restricted sections in the path of flow. For the case of the disk-and-doughnut baffles, G_R represents the rate of flow, W/A_R , lb. per hr.-sq.ft. of cross-sectional area, in a radial direction where A_R is determined by obtaining the average free circumferential distance through which the fluid would pass after flowing through the hole of the doughnut and before reaching the edge of the next disk in the path of flow and multiplying this distance by the distance between baffles. Then G_A represents the rate of flow, W/A_A, lb. per hr.-sq.ft. of cross-sectional area, through the free annular space between the edge of the disk and the exchanger shell. The "free" area meaning the total annular area minus the cross-sectional area of the tubes in this annular space. And then G_H is the rate of flow, W/A_H, lb. per hr.-sq.ft. of free cross-sectional area, through the hole in the doughnut. And, in this case, A_H is the area of the hole in the doughnut minus the cross-sectional area of the tubes in this region. Similarly G_o is the rate of flow, W/A_o, through the orifices at each baffle for the orifice type of baffles. In this, A_o is obtained by computing the total area of the holes in the baffle and subtracting the area of all of the tubes from it. Or, in other words, A_o is the sum of all of the small annular spaces around the tubes in each baffle. A_a is the free area between the baffles and is the shell cross-sectional area minus the cross-sectional area of all of the tubes. Hence G_a is the rate of flow, W/A_a, along the tubes in the region between the orifice type baffles and is the same as G for the unbaffled bundles. Likewise, in the case of the half-moon type of baffles, G_b is the rate of flow W/A_b, in the region beneath or above each half-moon baffle, and G_p is the average rate of flow, W/A_p, across the tubes in the region between each baffle.

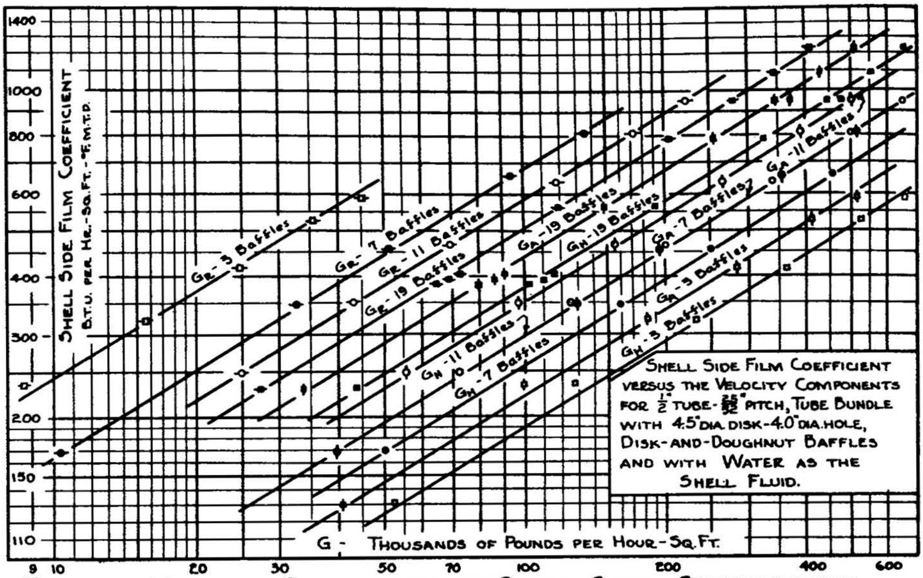
Fig. 6 shows the paths of flow for each type of baffle and the area (A_p) of cross-flow for the half-moon baffles and the area (A_R) for radial flow for the disk-and-doughnut baffles. The effect of these different components of flow is shown graphically by Fig. 7 for the disk-and-doughnut type of baffles. Eq. 3, 4, 5, and 6 were obtained for each baffle type, respectively, from such graphs as Fig. 7 for each type and size of baffle.

The effect of the tube spacing (tube pitch) is shown by Fig. 8 for the half-moon baffles and was found to affect the film coefficient of the other baffle types similarly. The result of this is given analytically by

$$h_s = B\left(\frac{P - D}{P}\right)^{0.5} \qquad \ldots\ldots\ldots\ldots\ldots (7)$$

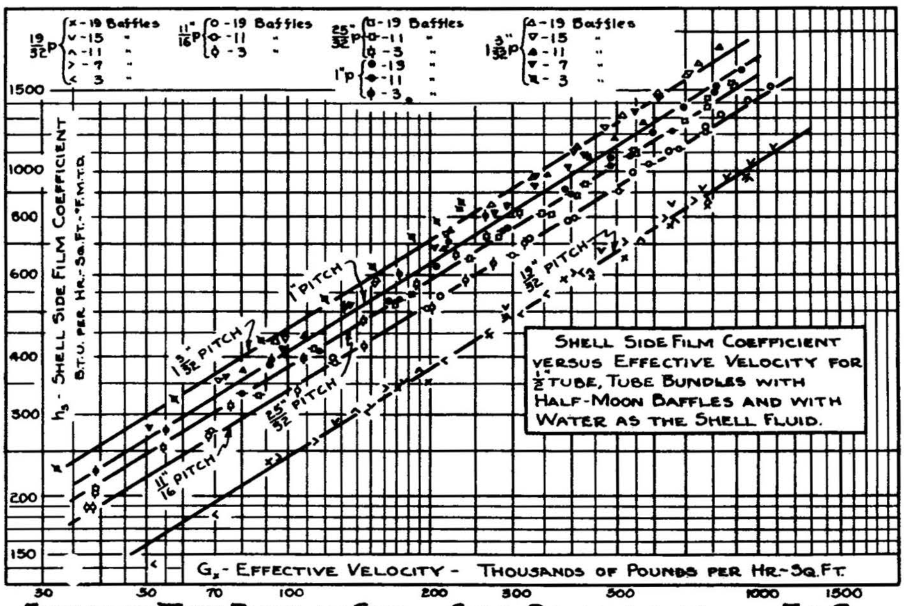


PATHS OF THE LIQUIDS AT THE BAFFLES AND FREE AREAS OF FLOW AT THE SAME POINTS - FIG. 6



EFFECT OF VELOCITY COMPONENTS ON SHELL SIDE COEFFICIENTS

FIG. 7



EFFECT OF TUBE PITCH ON SHELL SIDE COEFFICIENT - FIG. 8

Fig. 9 and 10 give an indication of the procedure used to determine the effect of Prandtl's number, $\frac{c\mu}{k}$, on the shell side coefficient and this result shown analytically is

$$h_s = B' \left(\frac{c\mu}{k}\right)^{0.32} \quad \ldots\ldots\ldots\ldots\ldots\ldots (8)$$

The composite relation obtained from the foregoing graphical and analytical analysis is

$$\frac{h_s D}{k} = 0.37 \left(\frac{P - D}{P}\right)^{0.5} \left(\frac{c\mu}{k}\right)^{0.32} \left(\frac{DG_x}{\mu}\right)^{0.6} \quad \ldots (9)$$

or

$$h_s = 0.37 \left(\frac{P - D}{P}\right)^{0.5} \frac{c^{0.32} k^{0.68} G_x^{\ 0.6}}{\mu^{0.28} D^{0.4}} \quad \ldots\ldots (9a)$$

and this relation is shown graphically by Fig. 11 for the disk-and-doughnut type baffles and by Fig. 12 for all types, while Fig. 13 gives a graphical comparison of Eq. 9 with data and results of other experimenters on nearly comparable designs of apparatus. Colburn's equation[3] for flow across banks of staggered tubes

$$h_s = 0.33 \frac{c^{0.333} k^{0.667} G_m^{\ 0.6}}{\mu^{0.267} D^{0.4}} \quad \ldots\ldots\ldots\ldots (10)$$

is quite similar to Eq. 9 except for the term showing the effect of the tube spacing. Its relation to Eq. 9 is shown graphically on Fig. 13.

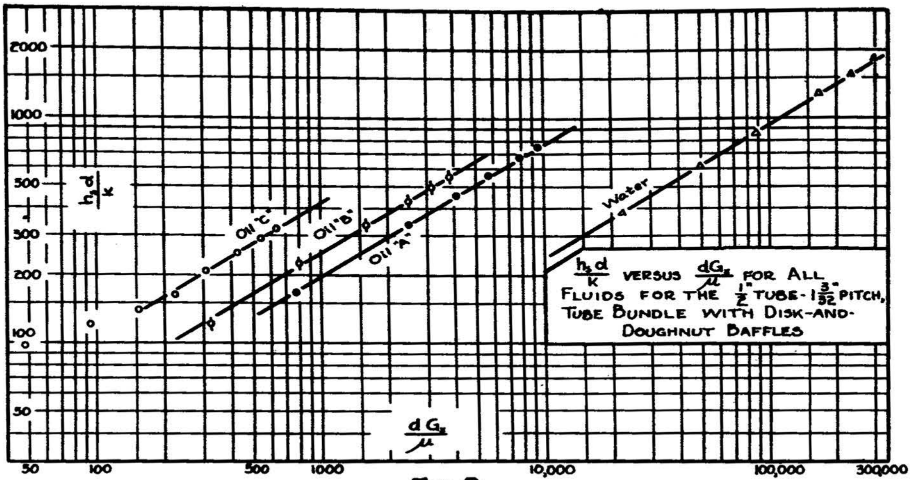
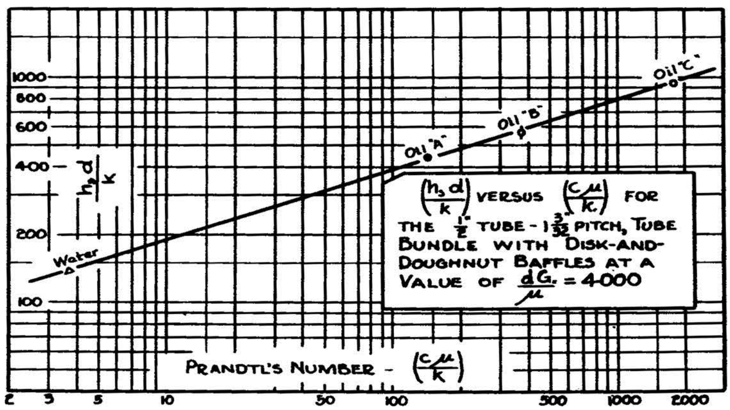
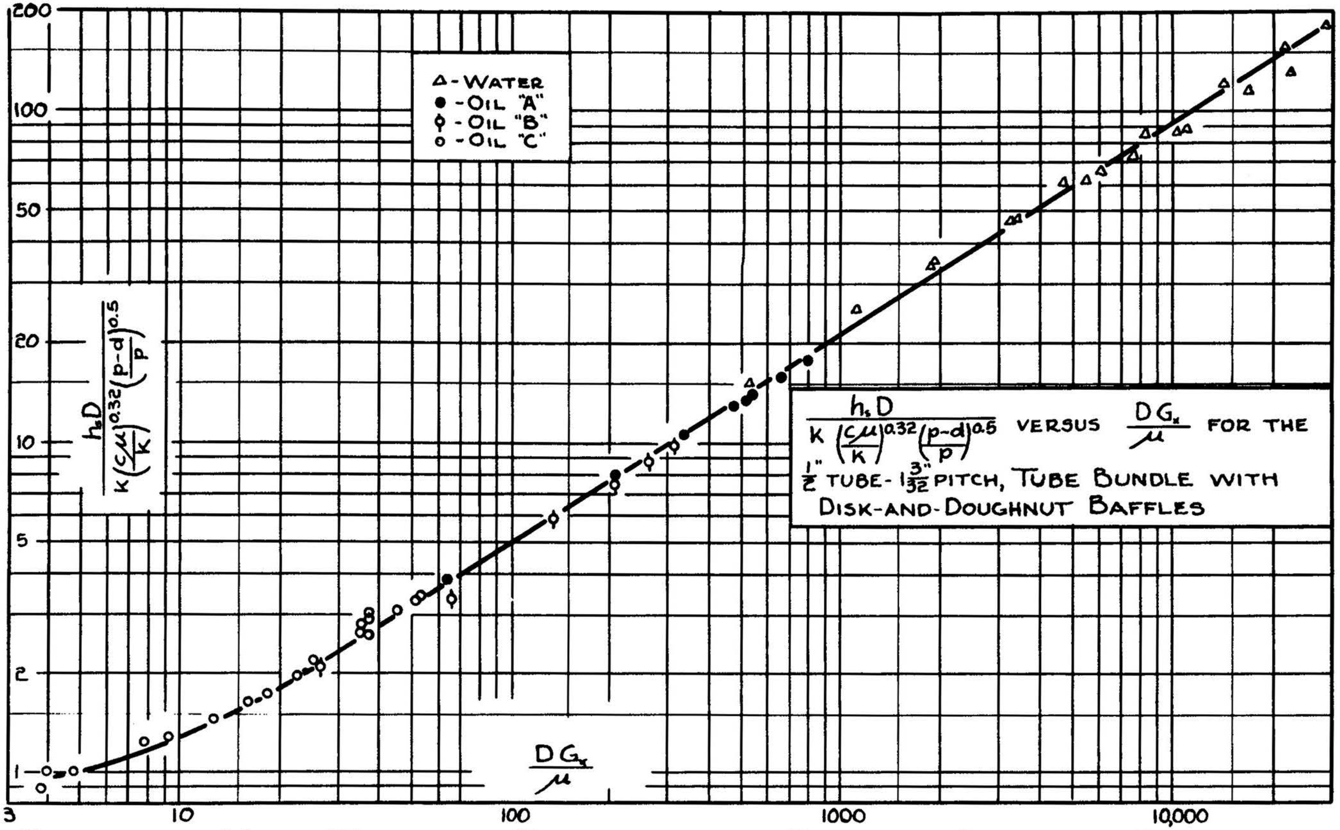


FIG. 9



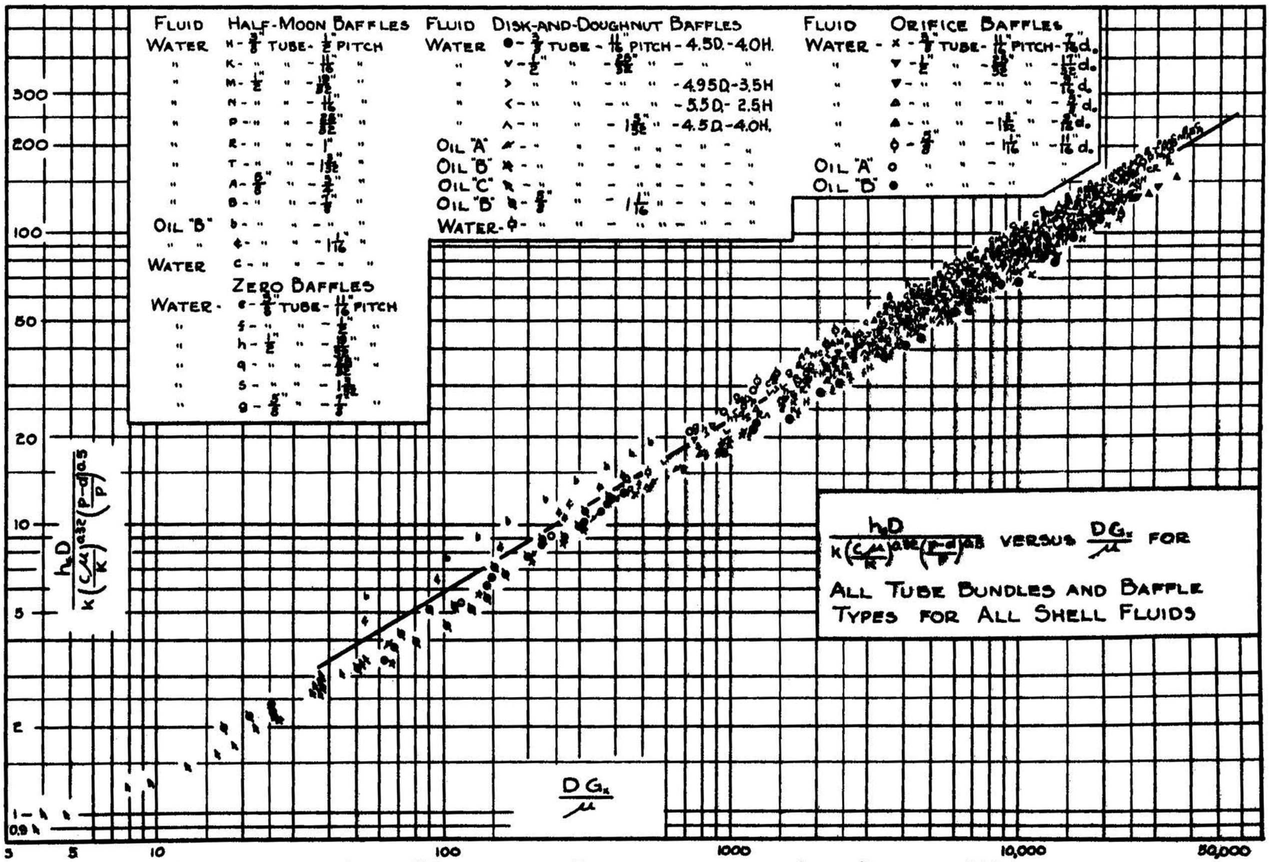
EFFECT OF PRANDTL'S NUMBER ON SHELL SIDE COEFFICIENTS

FIG. 10



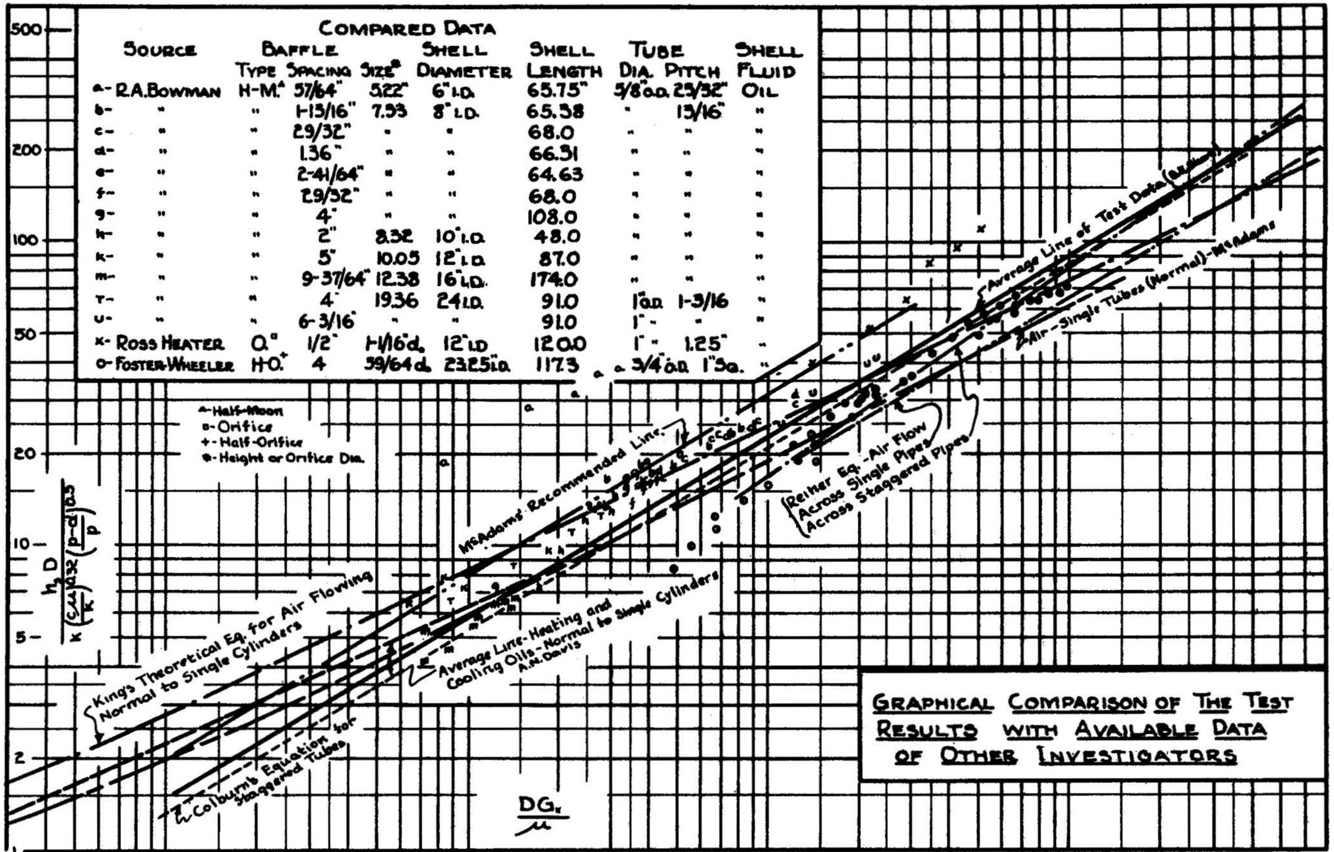
COMPOSITE HEAT TRANSFER RELATION FOR DISK-AND-DOUGHNUT BAFFLES

FIG. 11



COMPOSITE HEAT TRANSFER RELATION FOR ALL BAFFLE TYPES

FIG. 12



COMPARED DATA

	Source	Baffle Type	Baffle Spacing	Baffle Size[B]	Shell Diameter	Shell Length	Tube Dia.	Tube Pitch	Shell Fluid
a-	R.A. Bowman	H-M.[A]	57/64"	5.22"	6" I.D.	65.75"	5/8" O.D.	25/32"	Oil
b-	"	"	1-13/16"	7.53	8" I.D.	65.38	"	13/16"	"
c-	"	"	29/32"	"	"	68.0	"	"	"
d-	"	"	1.36"	"	"	66.31	"	"	"
e-	"	"	2-41/64"	"	"	64.63	"	"	"
f-	"	"	29/32"	"	"	68.0	"	"	"
g-	"	"	4"			108.0	"	"	"
h-	"	"	2"	8.32	10" I.D.	48.0	"	"	"
k-	"	"	5"	10.05	12" I.D.	87.0	"	"	"
m-	"	"	9-37/64"	12.38	16" I.D.	174.0	"	"	"
T-	"	"	4"	19.36	24 I.D.	91.0	1" O.D.	1-3/16	"
U-	"	"	6-3/16"	"	"	91.0	1" "	"	"
x-	Ross Heater	O.[o]	1/2"	1-1/16" d.	12" I.D.	120.0	1" "	1.25"	"
o-	Foster-Wheeler	H-O.[+]	4	59/64 d.	23.25 I.D.	117.3	3/4" O.D.	1" Sq.	"

FIG. 13

Pressure Drop

In correlating the pressure drop for these different cases, methods similar to those used in correlating the transfer coefficients were used with the following results.

$$\Delta p = 5.46 \times 10^{-10} \frac{(\phi f)\ L\ G_x^2}{\phi\ g\ D\ w} \qquad \text{. . . . .(11)}$$

where the friction and roughness factor, ϕf, is obtained from Fig. 14 for the three baffle types. It will be observed that the friction and roughness factor, for each of these cases, is shown as a function of the product of Reynolds' number and Prandtl's number to some exponential power. In order to account for the cooling effect on the pressure loss this method gave the best correlation. That is, plotting the friction factor as a function of the product of Reynolds' number and Prandtl's number to some power as is done in heat transfer (example Eq. 9) appeared to give the most consistent relations. The roughness effect produced by the baffles and the flow perpendicular to the tubes and the effect of variable areas in the path of flow are accounted for in the function, ϕ, in each case. This function is given for each case as follows:

Disk-and-Doughnut Baffles

$$\phi = \frac{1}{\left(\frac{D_D}{D_H}\right)^{1.25} \left(d_t\right)^{1.61}} \qquad \text{. . . . .(12)}$$

Orifice Baffles

$$\phi = \frac{(N_b - 2.3)^{0.33} (d_o - d_t + 0.031)^{2.0}}{\left(\frac{p - d_t}{p}\right)^{3.3} \left(d_t\right)^{2.38}} \qquad \text{. . . .(13)}$$

Half-Moon Baffles

$$\phi = \frac{1}{\left[0.53 \left(\frac{0.51 - S}{S}\right)^{2.0} + 2.7\right] \left[\frac{p - d_t}{p}\right]^{0.21} \left[d_t\right]^{2.06}} \qquad \text{. .(14)}$$

To determine the pressure drop for a particular heat exchanger for a particular weight and kind of fluid flowing through the shell, the effective velocity, G_X, is computed, and then the Reynolds' number is obtained. Following this the Prandtl number is calculated and then raised to the proper exponential power. Using the product of the Reynolds number and the Prandtl function

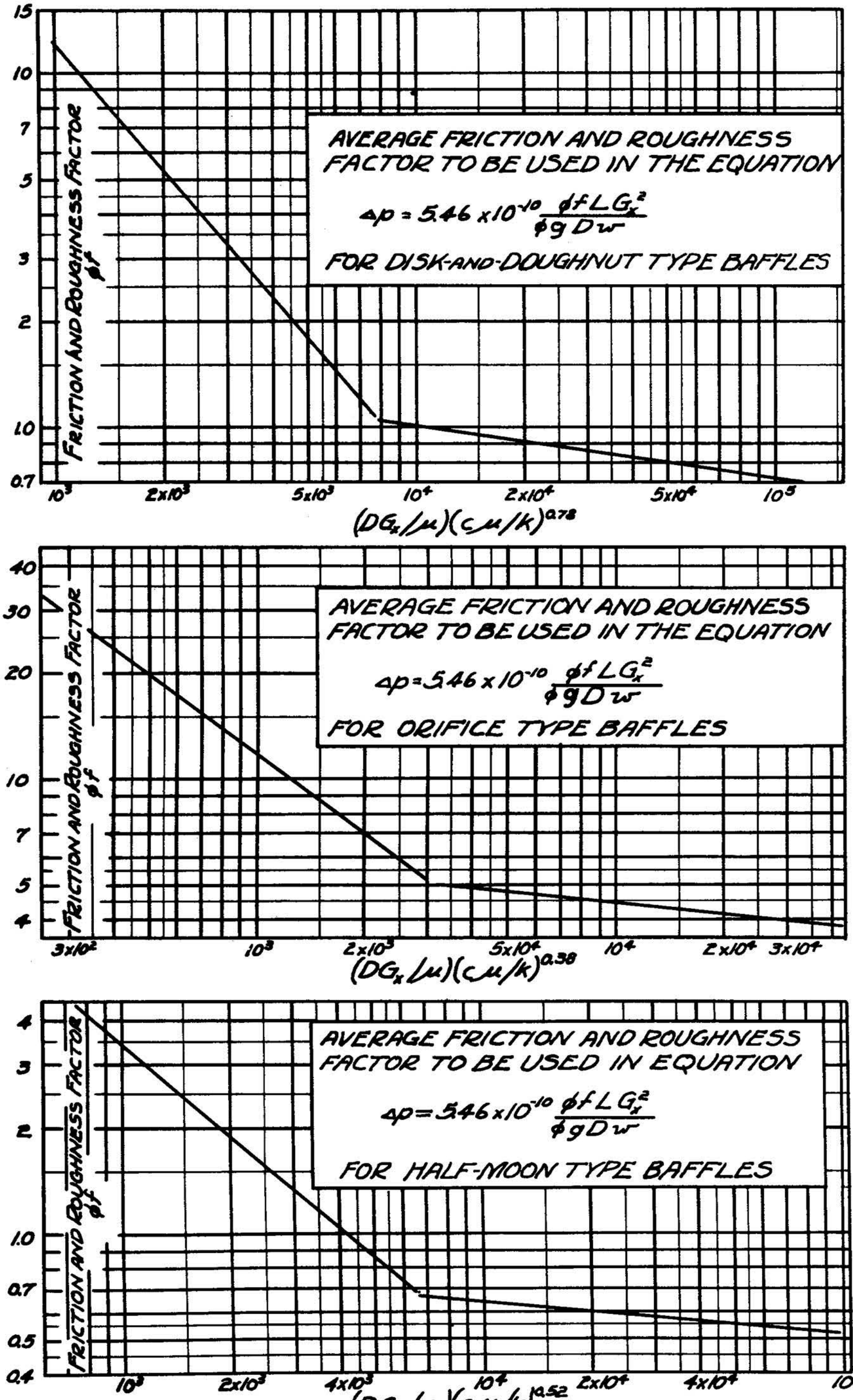

AVERAGE FRICTION AND ROUGHNESS FACTOR TO BE USED IN THE EQUATION
$\Delta p = 5.46 \times 10^{-10} \frac{\phi f L G_x^2}{\phi g D w}$
FOR DISK-AND-DOUGHNUT TYPE BAFFLES
FRICTION AND ROUGHNESS FACTOR ϕf
15
10
7
5
3
2
1.0
0.7
10^3
2×10^3
5×10^3
10^4
2×10^4
5×10^4
10^5
$(DG_x/\mu)(c\mu/k)^{0.78}$
AVERAGE FRICTION AND ROUGHNESS FACTOR TO BE USED IN THE EQUATION
$\Delta p = 5.46 \times 10^{-10} \frac{\phi f L G_x^2}{\phi g D w}$
FOR ORIFICE TYPE BAFFLES
FRICTION AND ROUGHNESS FACTOR ϕf
40
30
20
10
7
5
4
3×10^2
10^3
2×10^3
5×10^4
10^4
2×10^4
3×10^4
$(DG_x/\mu)(c\mu/k)^{0.38}$
AVERAGE FRICTION AND ROUGHNESS FACTOR TO BE USED IN EQUATION
$\Delta p = 5.46 \times 10^{-10} \frac{\phi f L G_x^2}{\phi g D w}$
FOR HALF-MOON TYPE BAFFLES
FRICTION AND ROUGHNESS FACTOR ϕf
4
3
2
1.0
0.7
0.5
0.4
10^3
2×10^3
4×10^3
10^4
2×10^4
4×10^4
10^5
$(DG_x/\mu)(c\mu/k)^{0.52}$

FIG. 14

(for the disk-and-doughnut baffles the Prandtl number is raised to the 0.78 power, for the half-moon baffles it is raised to the 0.52 power, and for the orifice baffles it is raised to the 0.38 power), reference is made to the friction-roughness factor plot corresponding to the type of baffle in question and the proper factor is obtained. Then using Eq. 12, 13 or 14, depending on the baffle type, and the dimensions of the heat exchanger bundle, the ϕ function is computed. Having determined the ϕ function in this manner, it is used along with the friction-roughness factor, effective velocity, tube diameter, length of exchanger, and spe-ific weight of the fluid in Eq. 11 to obtain the pressure drop for the exchanger.

In other words, the pressure drop is determined by means of the Darcy equation with the friction factor combined with a roughness coefficient, ϕ. With the kind of fluid and its effective rate known, the Reynolds and Prandtl functions are computed and, by reference to Fig. 14, the product, ϕf, is obtained. Then ϕ is computed from Eq. 12, 13, or 14 for the particular type of baffle and used along with ϕf in Eq. 11.

Due primarily to the effect of the tube pattern, i.e., tube arrangement over the cross-section of the bundle, on the turbulence set up at entrance and exit and its effect as the fluid passes by or through a baffle, the tube pattern enters into the pressure drop to a greater extent than in the heat transfer coefficients. This results in a wider divergence of the friction factor for the different arrangements than was found for the heat transfer coefficients. And too, in the case of the heat transfer coefficients, it was found that a single relation for all baffle types gave results not greatly different from those given by a relation for each particular type of baffle. This was not true in the case of the pressure drop data and hence, no single relation is presented.

Conclusions

In conclusions, then, it may be said that the shell side coefficient of heat transfer may be computed for shell and tube type exchangers irrespective of the size and spacing of the tubes, or the type, size, and spacing of baffles, or the kind of fluid. This may be done, as shown by Fig. 13, with a reasonable degree of accuracy by the equation,

$$h_s = 0.37 \left(\frac{P - D}{P}\right)^{0.5} \frac{c^{0.32} k^{0.68} G_x^{0.6}}{\mu^{0.28} D^{0.4}}$$

after having obtained the effective rate of flow, G_x, from Eq. 3, 4, 5, or 6, for the particular case.

It may also be concluded that the pressure loss produced by flow along and across the tubes in baffled tube. bundles of heat exchangers may be closely approximated by

$$\Delta p = 5.46 \times 10^{-10} \frac{(\phi f) L G_x^2}{\phi\, g\, D\, w}$$

after having obtained the product, ϕf, from the experimentally determined curves of Fig. 14.

It should be pointed out that a single relation for all types of baffles does not give as close a value of the coefficient as can be obtained by using a separate equation for each particular type of baffle, but the divergence is not more than 15 per cent for the usual case and this is as close as the effective areas, leakage effects, and tube patterns may be determined.

BIBLIOGRAPHY

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2. " " " " 169, 181
3. Transactions of A.S. Ch.E. (1933)(Chicago Meeting) page 197.

APPENDIX

Additional Symbols

t_{t_1} = initial temp. of tube fluid, deg. F.

t_{t_2} = final temp. of tube fluid, deg. F.

t_{s_1} = initial temp. of shell fluid, deg. F.

t_{s_2} = final temp. of shell fluid, deg. F.

Δp = pressure drop across shell, in. of hg.

W_t = weight of tube fluid, lb. per hr.

W_s = weight of shell fluid, lb. per hr.

Q_t = heat absorbed by tube fluid, B.t.u. per hr.

Q_s = heat given up by shell fluid, B.t.u. per hr.

θ_m = log mean temp. diff., deg. F.

U = overall transfer coefficient, B.t.u. per hr.-sq. ft.-deg. F.

DATA

BAFFLES- HALF-MOON
SIZE- 3.92" HIGH

* See first page of Appendix for Symbols.

TUBE DIA.-3/8"
TUBE PITCH-1/2"
NO.OF TUBES- 98

TRANSFER AREA- 48.1□'
SHELL FLUID- WATER
TUBE FLUID- WATER

RUN NUMBER	t_{t_1} *	t_{t_2}	t_{s_1}	t_{s_2}	ΔP	W_t	W_s	Q_t	Q_s	θ_m	U
19 BAFFLES											
51	58.3	77.3	140.6	74.8	0.37	18,540	5,365	352.8	353.0	34.76	211.0
52	58.2	85.3	140.7	86.0	0.88	18,380	9,220	498.2	503.8	40.10	258.3
53	58.1	88.8	140.4	92.1	1.39	18,520	11,900	569.0	574.8	42.14	280.8
54	58.1	91.6	139.6	97.6	2.22	18,730	15,040	628.0	631.0	43.60	299.5
55	58.0	95.0	139.5	102.7	3.24	18,220	18,360	673.5	676.5	44.59	314.1
56	58.1	99.2	140.1	108.2	5.19	18,330	23,630	752.5	755.0	45.34	345.2
57	58.1	99.6	141.2	109.1	5.19	18,300	23,730	759.0	760.5	46.08	342.6
58	57.9	100.3	139.2	110.8	6.86	18,370	27,430	778.0	781.0	45.50	355.4
59	58.0	101.5	140.1	112.6	7.78	18,370	29,150	800.0	802.5	46.18	360.2
60	58.0	103.1	140.2	114.3	9.63	18,420	32,430	830.5	838.0	46.00	375.4
61	58.0	104.5	140.6	117.0	11.67	18,540	36,730	862.0	867.0	46.63	384.4
62	57.8	104.9	140.0	117.3	13.52	18,460	38,530	870.0	873.0	46.25	391.1
63	57.5	94.6	139.0	101.7	3.33	18,550	18,420	688.0	687.5	44.31	322.8
219	60.1	96.4	139.6	102.4	3.06	18,530	18,280	673.5	680.0	42.73	327.8
220	60.1	101.9	139.4	110.5	5.98	17,950	26,090	750.5	753.5	43.75	356.7
15 BAFFLES											
228	58.9	80.9	138.8	80.3	0.28	15,720	5,900	345.2	345.0	36.70	195.6
229	58.8	78.5	139.0	77.9	0.28	18,540	5,970	365.0	364.6	35.90	211.4
230	58.9	81.0	138.7	81.7	0.37	19,130	7,410	423.5	423.0	37.60	234.2
231	59.0	86.7	139.7	89.9	0.70	18,850	10,420	522.8	519.0	41.00	265.1
232	59.0	86.8	139.8	90.0	0.70	18,620	10,480	518.5	522.0	41.06	262.7
233	59.2	91.2	139.4	96.9	1.20	18,150	13,610	581.0	579.0	42.80	282.3
234	59.4	95.3	140.8	102.9	1.90	18,240	17,320	655.0	656.0	44.48	306.2
235	59.5	98.6	139.9	108.4	3.15	18,540	23,120	725.0	727.5	45.00	335.0
236	59.5	101.5	139.5	112.8	4.91	18,370	28,950	771.5	774.0	45.22	354.8
237	59.5	103.4	139.6	115.5	6.51	18,330	33,520	804.0	809.0	45.46	367.8
238	59.5	104.9	140.2	117.8	7.92	18,370	37,350	834.5	838.5	45.80	378.8
239	59.5	106.2	140.4	119.7	9.63	18,330	41,460	856.5	860.0	46.00	387.1
11 BAFFLES											
247	59.2	77.2	141.5	76.5	0.14	18,380	5,080	330.3	330.2	35.84	191.6
248	59.2	86.5	140.1	91.4	0.42	18,420	10,390	501.5	506.0	42.00	248.2
249	59.5	93.1	139.5	101.6	0.88	18,400	16,250	619.0	616.0	44.20	291.2
250	59.5	97.2	139.7	108.1	1.67	18,210	21,780	686.0	687.0	45.46	313.8
251	59.5	99.4	140.5	111.3	2.18	18,470	25,360	737.0	739.0	46.15	332.0
252	59.5	102.4	141.3	115.9	3.33	18,330	31,030	787.0	788.0	47.20	346.8
253	59.3	105.2	141.8	119.8	4.91	18,390	38,370	844.0	845.0	47.58	368.8
254	59.0	105.4	140.4	120.9	6.39	18,520	44,090	859.0	858.0	47.17	378.8
7 BAFFLES											
285	61.3	81.0	139.3	86.7	0.14	18,120	6,850	357.5	360.5	39.54	188.0
286	61.5	89.1	140.4	99.1	0.32	18,100	12,120	499.5	501.0	44.06	235.8
287	61.6	92.1	140.2	104.0	0.51	18,170	15,320	554.0	555.5	45.18	255.0
288	61.6	95.9	140.4	109.4	0.74	18,230	20,030	625.0	620.0	46.10	282.0
289	61.5	98.0	140.8	112.3	1.11	18,340	23,610	670.0	674.0	46.70	298.3
290	61.5	99.7	140.5	115.0	1.48	18,160	27,330	694.0	697.0	46.90	307.7
291	61.5	102.1	141.0	118.4	2.04	18,100	32,550	734.0	737.0	47.32	322.4
292	61.5	104.2	141.5	121.4	2.59	17,390	37,000	742.0	745.0	47.65	323.8
293	61.5	105.0	140.5	122.3	3.33	17,670	42,280	769.0	770.5	47.06	339.8
3 BAFFLES											
301	60.8	77.0	138.5	93.2	0.07	17,870	6,450	289.0	292.0	45.40	132.3
302	61.0	81.8	139.7	100.4	0.12	17,910	9,550	373.0	375.0	48.12	161.1
303	61.1	87.7	139.6	109.5	0.20	17,290	15,320	459.0	461.0	50.15	190.4
304	61.2	92.1	140.0	114.2	0.39	18,250	21,800	563.0	563.5	50.40	232.2
305	61.4	96.0	140.8	119.2	0.54	16,620	26,800	576.0	578.0	50.95	235.0
306	61.2	95.3	141.0	118.7	0.54	17,360	26,580	591.0	593.0	51.42	239.0
307	61.1	95.3	138.9	118.9	0.76	18,720	32,230	641.0	643.5	50.35	264.8
308	61.2	96.2	139.2	119.6	0.76	17,940	32,150	627.0	628.0	50.30	259.2
309	61.2	97.2	138.4	120.7	1.07	18,410	37,620	663.0	665.0	49.80	276.8
310	61.2	98.4	138.2	122.2	1.34	18,430	42,800	685.0	689.0	49.70	286.6
311	61.2	97.4	139.1	121.4	1.06	18,380	37,620	664.5	666.0	50.35	274.5

DATA

BAFFLES- HALF-MOON
SIZE- 3.92" HIGH

* See first page of Appendix for Symbols.

TUBE DIA.-3/8"
TUBE PITCH-11/16"
NO.OF TUBES- 52

TRANSFER AREA- 25.51□'
SHELL FLUID- WATER
TUBE FLUID- WATER

RUN NUMBER	t_{t_1} *	t_{t_2}	t_{s_1}	t_{s_2}	Δ P	W_t	W_s	Q_t	Q_s	θ_m	U
19 BAFFLES											
10	61.6	88.6	139.3	95.2	0.37	9,960	6,135	268.9	270.8	41.55	253.6
11	61.2	109.8	141.8	126.4	8.85	9,910	31,580	481.5	485.1	46.63	404.8
12	60.3	108.0	139.4	124.4	8.89	9,900	31,800	472.2	475.0	45.80	404.1
13	58.9	108.9	140.7	125.4	7.97	9,760	32,150	488.0	492.6	47.02	406.8
14	58.5	107.8	139.9	124.7	7.97	9,830	32,150	485.0	489.8	47.13	403.3
15	58.5	107.8	140.4	124.8	7.83	9,900	31,580	488.5	492.0	47.50	403.2
16	58.2	103.2	138.9	119.8	4.26	9,870	23,680	444.5	451.0	47.42	367.6
17	58.1	102.3	138.1	119.0	4.31	10,180	23,680	450.0	453.1	47.15	374.0
18	60.4	107.2	139.5	123.3	6.11	9,690	28,000	453.0	453.5	45.93	386.7
19	60.4	107.7	140.3	123.6	6.16	9,740	28,000	460.8	467.0	46.20	391.0
24	61.0	107.9	140.7	124.3	6.30	9,870	28,500	463.3	467.3	46.40	391.5
25	60.1	89.8	139.8	97.8	0.42	9,870	7,040	293.0	295.2	43.50	264.0
26	60.1	89.1	138.5	97.3	0.42	9,870	6,920	287.0	285.0	43.03	261.5
27	60.2	92.7	138.9	102.8	0.65	10,000	9,030	325.3	325.5	44.36	287.5
28	60.2	97.0	138.3	109.6	1.30	9,950	12,800	365.8	368.0	45.20	317.2
29	60.4	99.0	138.6	112.8	1.81	9,970	15,320	385.0	394.5	45.57	331.0
30	60.3	99.8	138.4	115.7	2.55	10,050	18,000	397.0	409.3	46.52	334.6
31	60.3	102.9	138.6	118.9	3.75	10,060	22,000	428.4	434.0	46.17	363.9
32	60.3	105.4	140.5	122.0	4.82	10,060	24,780	454.0	458.3	47.15	377.4
33	60.2	105.8	140.4	122.9	5.37	10,000	26,350	458.0	461.1	47.22	380.1
34	60.2	106.0	140.0	123.1	5.97	10,120	27,980	464.0	471.0	47.00	387.0
35	60.1	106.5	139.1	124.0	7.69	10,150	31,630	470.5	478.6	46.58	396.0
36	60.1	107.3	139.4	125.1	8.80	10,170	33,650	479.6	481.2	46.65	403.0
37	60.0	107.7	139.7	125.8	9.72	10,240	35,300	488.0	492.0	46.90	408.0
38	60.1	108.2	139.8	126.5	10.74	10,160	37,260	489.5	494.5	46.84	409.6
39	60.0	108.9	139.7	127.1	13.12	10,200	40,370	498.0	506.0	46.62	418.8
40	60.0	109.4	139.5	127.8	15.56	10,160	43,380	502.0	507.5	46.46	423.7
41	59.8	100.4	138.6	115.5	2.69	10,260	18,180	416.5	420.0	46.46	351.6
142	57.8	98.5	139.2	113.0	1.81	9,760	15,220	397.0	399.2	47.62	326.9
143	57.8	99.1	141.0	113.8	1.81	9,930	15,300	410.0	415.7	48.60	330.7
144	58.1	105.8	140.4	123.1	5.70	9,750	27,280	465.2	472.0	48.20	378.3
145	58.0	106.7	141.6	124.1	5.70	9,700	27,400	472.6	478.6	48.80	379.8
146	57.8	106.5	141.7	124.0	5.70	9,850	27,280	479.8	482.8	49.10	383.0
147	57.8	105.9	141.6	123.5	5.74	10,220	27,280	492.0	492.6	49.16	392.4
15 BAFFLES											
221	60.0	92.3	139.6	104.5	0.46	10,020	9,350	324.0	328.2	45.90	276.7
222	60.0	98.9	140.3	114.4	1.07	9,960	14,820	387.5	384.6	47.67	318.8
223	60.0	102.7	139.6	119.6	2.22	10,000	21,520	426.7	430.0	47.35	353.2
224	60.2	107.2	141.1	125.5	4.86	9,870	29,760	464.0	464.3	47.92	379.6
225	59.6	106.5	139.2	125.2	5.98	10,020	34,020	470.2	476.5	47.22	390.3
226	59.8	107.5	139.2	126.4	7.32	10,090	38,300	481.0	490.4	47.06	400.8
227	59.8	108.5	139.5	127.7	8.89	10,070	42,260	490.5	499.8	47.08	408.5
11 BAFFLES											
294	61.4	83.5	138.3	93.5	0.11	9,790	4,890	216.1	219.0	42.45	199.6
295	61.4	88.4	139.7	101.3	0.18	9,830	6,900	265.0	264.8	45.18	230.0
296	61.7	93.4	139.6	109.1	0.32	9,870	10,230	312.8	312.5	46.80	262.0
297	61.8	99.6	139.8	117.5	0.83	9,860	16,630	372.2	371.4	47.53	307.0
298	62.1	103.1	138.8	122.0	1.78	9,900	24,230	406.0	407.0	46.80	340.1
299	62.2	106.6	140.6	126.5	3.03	9,910	31,350	440.5	440.0	47.56	363.2
300	62.1	108.1	140.6	128.3	4.17	9,940	36,730	457.2	454.0	47.42	378.0
7 BAFFLES											
255	60.0	78.9	139.0	91.6	0.09	9,770	3,840	185.0	182.2	44.33	163.6
256	60.2	89.0	139.2	108.2	0.19	9,800	9,230	282.5	286.7	49.12	225.3
257	60.3	94.4	139.6	115.4	0.65	10,270	14,630	350.5	353.2	50.00	275.0
258	60.5	98.4	140.1	120.4	0.86	9,830	19,120	372.8	377.2	50.20	291.1
259	60.5	100.9	140.6	123.6	1.20	10,110	24,160	408.8	411.4	50.45	317.7
260	60.5	102.6	139.2	125.1	1.81	9,950	30,100	419.2	422.5	49.30	333.3
261	60.5	104.0	139.7	126.9	2.47	9,930	34,100	432.2	435.5	49.43	342.8
262	60.5	105.5	139.7	128.3	3.31	10,060	40,260	452.2	456.4	49.10	361.0
263	60.5	106.8	140.2	129.8	3.89	9,970	44,700	461.5	465.0	49.12	368.2
3 BAFFLES											
264	59.5	80.2	138.6	105.5	0.06	10,160	6,440	210.0	213.2	51.95	158.5
265	59.5	85.9	139.1	113.8	0.21	9,815	10,370	259.0	262.6	53.73	189.0
266	59.6	90.5	139.5	119.1	0.46	10,060	15,410	310.8	314.0	54.10	225.2
267	59.7	93.8	139.7	122.5	0.56	10,070	20,150	343.7	347.2	53.93	249.8
268	59.7	96.3	139.2	124.6	0.70	9,980	25,280	365.0	368.3	53.15	269.3
269	59.7	98.7	139.8	126.9	0.93	10,015	30,570	390.5	395.0	53.13	288.2
270	59.7	100.2	140.2	128.3	1.28	10,140	34,760	410.5	413.6	53.03	303.3
271	59.7	102.1	140.1	129.5	1.44	9,740	39,300	413.0	415.3	52.35	309.2
272	59.6	102.3	140.9	129.9	1.44	9,950	39,200	425.0	428.6	52.85	315.1
273	59.6	102.5	140.2	130.1	1.34	10,270	44,300	441.0	444.8	52.45	329.6

DATA

BAFFLES- HALF-MOON
SIZE- 3.92" HIGH

* See first page of Appendix for Symbols.

TUBE DIA.-1/2"
TUBE PITCH-19/32"
NO. OF TUBES- 66

TRANSFER AREA- 43.18□'
SHELL FLUID- WATER
TUBE FLUID- WATER

RUN NUMBER	t_{t_1} *	t_{t_2}	t_{s_1}	t_{s_2}	Δ P	W_t	W_s	Q_t	Q_s	θ_m	U
19 BAFFLES											
75	57.8	65.9	139.7	66.0	0.19	26,320	2,905	212.5	214.0	29.92	164.4
76	58.0	70.9	138.2	75.9	0.56	26,480	5,450	340.5	339.5	37.35	211.2
77	58.0	72.3	138.9	80.0	0.70	25,930	6,340	371.7	373.5	40.28	213.8
78	58.0	75.3	138.2	85.0	1.25	26,060	8,570	450.0	456.0	42.46	245.6
79	57.3	78.6	138.2	91.8	2.36	26,610	12,270	568.0	569.5	45.88	286.9
80	57.3	82.0	138.8	99.9	4.03	25,870	16,520	639.6	643.0	49.43	299.7
81	57.0	84.5	139.8	104.8	6.21	26,210	20,690	722.0	724.0	51.45	325.0
82	56.7	85.9	139.2	108.1	8.80	26,430	24,860	770.0	772.0	52.36	340.9
83	56.6	88.5	140.4	112.5	12.87	26,320	30,100	838.0	840.0	53.85	360.4
84	56.4	79.0	137.6	94.9	2.96	26,240	14,010	592.0	597.5	47.88	286.4
15 BAFFLES											
321	60.8	72.4	140.6	77.0	0.28	25,400	4,625	294.8	294.4	36.13	189.0
322	61.0	74.0	140.2	80.1	0.37	24,800	5,455	321.7	328.0	37.94	196.3
323	61.0	75.4	141.4	83.0	0.46	25,840	6,420	372.2	375.5	40.05	215.3
324	61.1	80.6	141.0	92.2	1.02	26,480	10,620	516.0	518.0	44.16	270.6
325	61.2	85.9	140.9	102.8	2.50	26,200	17,020	646.0	649.0	48.10	311.2
326	61.3	89.2	140.8	109.2	4.82	26,870	23,830	749.5	752.0	49.80	348.7
327	61.3	91.1	141.0	112.8	6.58	26,090	27,700	778.0	780.0	50.75	355.2
328	61.3	92.1	140.8	114.8	8.11	26,000	31,030	801.0	805.0	51.10	363.2
329	61.3	93.1	140.7	116.8	10.28	26,090	35,030	831.5	835.0	51.45	374.3
330	61.3	94.1	140.2	118.5	12.97	25,980	39,330	852.5	854.5	51.30	385.0
11 BAFFLES											
341	60.8	73.9	139.0	82.7	0.20	25,820	6,095	339.0	343.2	39.60	198.2
342	60.8	76.9	139.0	88.9	0.37	25,740	8,320	414.5	417.0	42.85	224.0
343	60.9	81.5	139.5	98.3	0.83	25,720	12,840	530.0	529.5	46.95	261.5
344	60.9	85.5	139.5	106.5	1.81	25,820	19,200	634.5	633.5	49.75	295.5
345	60.9	88.2	139.8	111.2	2.92	25,620	24,590	699.0	702.0	51.00	317.5
346	60.9	89.7	139.9	114.2	4.08	26,000	29,230	748.0	752.0	51.80	334.5
347	60.8	90.8	139.1	116.5	5.65	25,930	34,480	777.0	781.0	51.95	346.5
348	60.8	92.4	138.9	119.5	8.15	26,010	41,800	822.0	810.0	52.40	363.3
7 BAFFLES											
349	60.4	72.4	141.1	84.8	0.09	25,900	5,570	310.8	313.6	42.80	168.3
350	60.5	73.6	140.0	88.4	0.19	25,960	6,670	340.8	344.2	44.40	177.8
351	60.5	77.2	140.9	94.7	0.28	25,860	9,410	432.0	434.7	47.40	211.1
352	60.7	83.1	140.4	106.3	0.74	25,820	16,900	577.5	575.5	51.22	261.1
353	60.7	86.5	141.3	112.3	1.39	26,280	23,420	678.0	680.3	53.17	295.6
354	60.7	88.7	140.3	116.2	2.36	26,170	30,500	733.5	735.0	53.55	317.3
355	60.7	91.3	142.0	120.2	3.38	26,100	36,720	798.5	801.0	55.00	336.4
356	60.7	92.3	141.5	122.0	4.54	26,100	42,550	825.5	830.0	54.90	348.3
3 BAFFLES											
365	60.3	69.6	139.2	94.3	0.09	25,800	5,415	240.8	243.2	49.68	112.3
366	60.5	72.3	140.1	98.4	0.09	25,610	7,300	302.3	304.4	51.45	136.1
367	60.8	78.8	140.7	110.0	0.28	26,050	15,320	468.0	470.2	55.30	196.2
368	61.0	82.4	139.9	114.9	0.51	25,900	22,310	555.0	557.0	55.65	231.0
369	61.0	84.6	140.3	118.1	0.74	25,820	27,700	610.0	613.3	56.40	250.5
370	61.0	86.0	140.0	120.0	1.02	25,720	32,360	644.0	647.0	56.50	264.0
371	61.0	87.4	141.1	122.0	1.39	26,230	36,550	692.5	696.0	57.30	280.0
372	61.0	88.7	140.0	123.5	1.95	25,960	43,680	719.0	722.0	56.65	294.0

DATA

BAFFLES- HALF-MOON
SIZE- 3.92" HIGH
* See first page of Appendix for Symbols.

TUBE DIA.-1/2"
TUBE PITCH-11/16"
NO.OF TUBES- 48

TRANSFER AREA- 31.4□'
SHELL FLUID- WATER
TUBE FLUID- WATER

RUN NUMBER	t_{t_1} *	t_{t_2}	t_{s_1}	t_{s_2}	ΔP	W_t	W_s	Q_t	Q_s	θ_m	U
19 BAFFLES											
155	58.9	73.6	138.4	79.3	0.28	18,990	4,755	279.0	280.8	38.45	231.1
156	59.0	78.9	138.3	90.5	0.70	19,070	8,000	380.0	382.2	44.05	274.8
157	59.1	84.4	140.1	100.8	1.48	19,100	12,440	482.0	488.0	48.35	317.5
158	59.2	86.1	139.4	105.1	3.15	19,130	15,060	514.5	517.0	49.46	331.3
159	59.3	89.9	139.8	111.2	4.17	19,180	20,660	587.0	589.5	50.90	367.3
160	59.3	92.5	140.5	115.5	5.74	18,460	24,450	612.0	612.0	52.00	374.8
161	59.2	92.6	142.4	116.0	5.74	19,160	24,400	640.0	642.8	53.20	383.2
162	59.1	93.2	139.9	117.6	8.36	19,370	29,750	660.0	661.5	52.45	400.8
163	59.1	94.8	140.7	119.7	9.81	18,760	31,860	670.0	670.0	53.00	402.6
164	59.1	95.5	139.9	121.3	12.50	18,680	36,370	681.0	677.0	52.80	410.8
165	59.0	95.4	138.7	121.6	15.65	19,120	40,850	696.5	698.5	52.35	423.8
11 BAFFLES											
470	61.5	73.0	140.3	80.2	0.05	18,980	3,620	218.3	217.5	37.85	183.7
471	61.5	73.4	140.3	78.0	0.05	18,850	3,610	224.8	225.0	36.05	198.6
472	61.6	78.2	138.9	91.5	0.19	18,760	6,610	312.0	313.2	43.58	228.0
473	61.8	83.1	140.3	101.0	0.37	18,850	10,320	401.0	405.3	47.60	268.2
474	62.0	87.5	140.3	109.3	0.83	18,950	15,670	483.0	486.0	50.00	307.7
475	62.0	90.5	139.0	114.4	1.53	18,390	21,300	524.0	525.0	50.45	330.8
476	62.1	92.6	139.8	118.1	2.27	18,680	26,320	570.5	572.2	51.50	353.0
477	62.0	93.7	140.2	120.1	3.10	19,390	30,690	614.5	615.5	52.15	375.5
478	62.1	95.9	141.2	123.1	4.17	19,020	35,530	642.0	644.0	52.92	386.5
479	62.0	96.8	140.7	124.4	5.33	18,850	40,450	656.0	659.0	52.55	397.8
3 BAFFLES											
518	62.0	73.4	140.8	94.9		18,720	4,640	212.8	212.8	48.13	140.8
519	62.0	73.1	140.6	94.6		19,020	4,700	212.2	216.2	48.04	140.7
520	62.2	78.0	140.6	105.3	0.04	19,130	8,570	301.7	303.0	52.25	183.9
521	62.5	81.5	139.2	112.0	0.17	18,620	13,020	353.7	353.6	53.50	210.6
522	62.5	84.4	139.4	116.3	0.32	18,940	17,940	415.0	415.2	54.40	243.0
523	62.6	87.3	139.7	120.5	0.46	18,910	24,270	468.0	465.0	55.10	270.6
524	62.6	89.4	140.0	122.8	0.70	18,950	29,620	507.0	510.5	55.50	291.1
525	62.6	90.6	140.3	124.5	0.89	18,910	33,630	529.0	530.5	55.50	303.7
526	62.6	91.5	139.1	125.2	1.11	18,980	39,560	549.0	552.0	54.82	318.8

DATA

BARRELS- HALF-MOON
SIZE- 3.92" HIGH

TUBE DIA.-1/2"
TUBE PITCH-25/32"
NO.OF TUBES- 40

TRANSFER AREA- 26.16□'
SHELL FLUID- WATER
TUBE FLUID- WATER

RUN NUMBER	t_{t_1}	t_{t_2}	t_{s_1}	t_{s_2}	ΔP	W_t	W_s	Q_t	Q_s	θ_m	U
19 BAFFLES											
95	58.1	78.8	139.6	92.8	0.51	15,800	7,075	326.0	331.0	46.58	267.7
96	58.0	84.4	139.3	104.0	1.30	15,800	11,960	417.0	422.2	50.35	316.9
97	58.1	88.6	139.8	112.2	2.59	15,660	17,370	477.0	480.0	52.67	346.3
98	58.2	92.4	140.7	117.8	4.63	15,430	23,180	527.0	530.0	53.95	373.5
99	58.1	94.3	140.1	121.0	7.41	15,430	29,340	558.0	559.5	53.95	395.6
100	58.2	95.8	140.8	123.3	9.45	15,280	32,930	574.0	577.0	54.45	403.0
101	58.2	96.0	141.6	123.3	9.45	15,780	32,930	596.5	602.0	54.85	416.0
102	58.1	96.2	140.1	124.2	12.22	15,760	37,800	601.0	603.0	54.25	423.6
103	58.0	96.7	141.1	124.7	12.22	15,770	37,500	610.0	614.0	54.90	425.0
104	57.6	86.2	138.2	108.7	2.04	15,660	15,280	447.5	450.0	51.55	332.0
11 BAFFLES											
437	61.3	83.9	138.6	104.8	0.37	15,780	10,610	356.5	358.5	48.90	278.8
438	61.4	87.0	139.2	110.4	0.74	15,775	14,120	404.0	407.4	50.63	305.2
439	61.5	90.5	139.2	116.3	1.35	15,780	20,060	458.0	459.0	51.70	338.9
440	61.7	92.8	139.4	119.7	2.08	15,770	24,880	491.5	490.0	52.10	360.8
441	61.7	95.0	139.4	122.8	3.33	15,830	31,720	528.0	528.5	52.35	385.8
442	61.8	96.8	139.5	125.1	5.10	15,820	38,300	554.0	554.0	52.45	404.0
443	61.0	75.9	137.0	90.2		15,660	5,030	233.8	235.8	43.20	206.9
444	61.2	79.6	138.5	97.1		15,825	7,110	290.8	294.2	46.45	239.3
3 BAFFLES											
508	62.2	75.0	139.5	102.1		15,680	5,365	199.7	200.6	51.25	149.0
509	62.2	75.0	139.3	101.5		15,740	5,370	201.5	203.0	50.72	152.0
510	62.4	77.8	139.8	107.0	0.02	15,730	7,470	241.8	244.6	52.85	174.9
511	62.5	80.7	139.7	111.9	0.09	15,720	10,375	286.5	288.5	54.25	201.9
512	62.6	83.9	138.9	116.5	0.19	15,580	14,880	332.3	334.0	54.45	233.4
513	62.8	87.2	140.4	121.2	0.37	15,600	19,890	379.8	381.2	55.80	260.2
514	62.9	89.8	140.6	124.2	0.53	15,560	25,640	418.8	420.5	55.70	287.5
515	62.9	91.5	139.9	125.6	0.74	15,550	31,270	444.8	446.0	55.15	308.4
516	63.0	92.4	139.0	126.2	0.93	15,660	36,370	461.4	463.0	54.50	323.8
517	62.8	93.6	138.5	127.1	1.30	15,560	42,480	479.5	482.0	54.10	339.0

DATA

BAFFLES- HALF-MOON
SIZE- 3.92" HIGH
* See first page of Appendix for Symbols.

TUBE DIA.-1/2"
TUBE PITCH-1"
NO.OF TUBES-30

TRANSFER AREA- 19.62□'
SHELL FLUID- WATER
TUBE FLUID- WATER

RUN NUMBER	t_{t_1} *	t_{t_2}	t_{s_1}	t_{s_2}	ΔP	W_t	W_s	Q_t	Q_s	θ_m	U
19 BAFFLES											
116	57.9	75.4	139.8	90.4	0.19	11,860	4,250	208.0	210.0	46.68	227.2
117	58.0	81.2	139.4	103.2	0.46	11,810	7,615	273.5	275.5	51.52	270.5
118	58.0	84.3	141.1	109.2	0.74	11,940	9,890	314.0	315.7	53.92	296.8
119	58.0	87.3	140.3	114.3	1.39	11,940	13,560	349.5	353.6	54.65	326.0
120	58.0	90.7	140.7	119.1	2.45	11,670	17,850	381.0	384.6	55.42	350.3
121	58.0	92.8	141.1	122.5	3.80	11,865	22,410	412.4	416.0	56.00	375.4
122	58.0	94.7	141.4	125.4	5.75	11,905	27,620	436.6	440.4	56.45	394.1
123	58.0	96.2	141.6	127.4	7.97	11,930	32,220	455.2	456.5	56.53	410.7
124	58.0	97.7	141.4	129.0	10.93	11,670	37,500	462.8	467.0	56.25	419.3
125	57.5	98.2	141.4	130.0	14.17	11,850	42,860	481.6	485.0	56.63	433.3
126	57.3	96.5	140.8	128.3	10.93	12,000	37,400	470.0	468.6	56.62	423.0
11 BAFFLES											
419	61.0	77.9	139.9	99.5	0.09	12,000	5,115	202.8	206.6	49.35	209.4
420	61.1	81.7	139.9	107.0	0.19	11,775	7,360	242.2	242.2	51.95	237.8
421	61.2	85.5	139.6	113.3	0.42	11,840	11,020	287.2	289.8	53.10	275.8
422	61.6	91.0	139.7	120.9	1.02	11,670	18,380	343.4	346.0	53.85	325.0
423	61.7	94.1	141.3	126.1	1.85	11,875	25,350	385.0	384.5	55.25	355.1
424	61.6	95.2	140.1	127.3	2.69	11,865	30,780	399.0	395.6	54.65	372.0
425	61.6	96.4	140.6	128.6	3.43	11,850	34,730	413.0	417.0	54.78	384.2
426	61.7	97.6	140.4	130.0	5.10	11,905	41,780	428.0	431.2	54.55	400.0
3 BAFFLES											
501	62.2	77.0	140.5	110.1	0.09	11,850	5,875	175.3	178.6	55.30	161.6
502	62.5	79.7	139.6	114.2	0.09	11,830	8,220	203.8	209.0	55.70	186.4
503	62.7	84.6	139.9	120.8	0.19	11,875	13,740	260.5	262.3	56.75	234.1
504	62.8	88.3	139.7	124.7	0.28	11,810	20,460	300.8	306.2	56.55	271.2
505	63.0	91.2	141.4	128.3	0.37	11,810	25,530	333.0	334.5	57.30	296.3
506	63.0	93.6	141.9	130.8	0.56	11,810	32,580	362.0	363.4	57.58	320.6
507	63.0	95.4	142.0	132.2	0.83	11,840	39,400	383.6	386.0	57.20	341.8

DATA

BAFFLES- HALF-MOON
SIZE- 3.92" HIGH
* See first page of Appendix for Symbols.

TUBE DIA.-1/2"
TUBE PITCH-1 3/32"
NO.OF TUBES-20

TRANSFER AREA- 13.08□'
SHELL FLUID- WATER
TUBE FLUID- WATER

RUN NUMBER	t_{t_1} *	t_{t_2}	t_{s_1}	t_{s_2}	ΔP	W_t	W_s	Q_t	Q_s	θ_m	U
19 BAFFLES											
208	61.2	81.8	140.0	105.6	0.23	7,955	4,855	164.1	167.0	51.02	245.7
209	61.0	86.1	138.8	113.1	0.46	7,895	7,890	198.2	203.0	52.35	289.3
210	61.1	90.4	140.2	119.5	0.88	7,930	11,430	232.3	236.6	54.00	328.8
211	61.1	92.2	140.3	122.1	1.25	7,935	13,900	246.7	252.2	54.22	347.6
212	61.0	94.4	140.9	125.2	1.90	7,865	16,900	262.3	264.8	54.97	365.0
213	61.1	95.7	139.5	126.4	2.87	7,875	21,130	272.6	277.5	53.90	386.6
214	61.1	97.6	140.1	128.9	4.54	8,000	26,550	292.0	297.4	54.13	412.5
215	61.1	98.8	139.7	130.1	6.44	7,980	31,650	300.5	303.9	53.78	427.3
216	61.2	99.9	140.0	131.3	8.43	7,925	36,210	306.8	314.0	53.70	436.8
217	61.2	101.0	140.7	132.5	9.66	7,820	38,460	311.5	315.3	53.96	441.3
218	61.1	101.5	141.1	133.3	11.81	8,070	42,850	325.5	334.3	54.25	458.7
15 BAFFLES											
331	61.5	79.7	139.1	104.1	0.09	7,890	4,195	143.3	146.7	50.58	216.8
332	61.8	83.3	140.3	110.6	0.13	7,965	5,825	171.2	173.0	52.78	248.0
333	62.0	87.8	140.5	117.4	0.31	7,940	9,000	204.8	207.4	54.05	289.7
334	62.1	91.4	140.7	122.3	0.60	7,940	12,720	232.8	234.4	54.60	325.8
335	62.4	95.3	140.2	126.9	1.58	7,950	19,540	261.2	259.9	54.03	369.4
336	62.5	97.2	140.8	129.1	2.27	7,965	23,700	276.4	278.0	54.30	389.3
337	62.3	98.7	141.3	130.8	3.06	7,965	27,520	289.7	290.6	54.62	405.2
338	62.1	99.0	140.3	131.0	4.08	7,955	31,800	293.3	294.7	53.95	415.7
339	62.3	100.3	141.1	132.6	5.23	8,010	36,000	304.4	306.0	54.24	429.0
340	62.2	101.4	141.4	133.8	6.95	8,020	41,300	314.3	316.4	54.35	442.0
11 BAFFLES											
357	61.1	81.5	140.6	111.4	0.09	7,880	5,650	160.7	165.0	54.62	224.8
358	61.3	84.5	141.0	116.7	0.19	7,870	7,595	183.0	184.8	55.92	250.2
359	61.6	90.7	139.7	124.6	0.56	7,890	15,090	229.3	228.8	55.83	313.9
360	61.7	93.7	140.3	127.9	1.02	7,880	20,560	252.2	255.0	55.80	345.4
361	61.9	96.4	141.9	130.9	1.67	7,940	25,060	273.5	275.0	56.45	370.3
362	61.7	97.3	141.3	132.1	2.32	7,920	30,690	280.0	281.3	56.20	381.0
363	61.6	98.0	140.9	132.6	3.06	7,940	34,700	289.0	290.0	55.85	395.3
364	61.7	98.9	140.9	133.5	4.08	7,975	40,000	297.0	298.3	55.65	407.8

DATA

BAFFLES- HALF-MOON
SIZE- 3.92" HIGH
* See first page of Appendix for Symbols.

TUBE DIA.-1/2"
TUBE PITCH-1 3/32"
NO.OF TUBES-20

TRANSFER AREA- 13.08□'
SHELL FLUID- WATER
TUBE FLUID- WATER

RUN NUMBER	t_{t_1} *	t_{t_2}	t_{s_1}	t_{s_2}	Δ P	W_t	W_s	Q_t	Q_s	θ_m	U
7 BAFFLES											
382	61.0	78.1	138.4	109.4		7,745	4,665	132.4	135.0	54.25	186.5
383	61.1	81.5	138.3	115.1	0.05	7,815	6,830	159.2	158.7	55.40	219.6
384	61.5	84.0	139.0	119.1	0.14	7,795	9,025	175.6	179.7	56.22	238.8
385	61.4	87.0	139.1	122.8	0.23	7,890	12,560	201.0	204.7	56.43	272.2
386	61.7	91.1	138.9	127.0	0.56	7,875	19,480	231.2	233.0	56.10	315.0
387	61.9	93.8	140.0	130.0	0.93	7,890	25,360	252.1	252.0	56.48	341.2
388	61.9	95.9	140.7	132.0	1.30	7,850	30,900	266.4	267.9	56.60	360.0
389	62.0	96.9	140.3	132.8	1.90	7,830	36,320	273.3	273.6	56.05	372.8
390	61.9	97.3	140.1	133.0	2.22	7,905	39,620	279.8	280.1	55.80	383.3
3 BAFFLES											
391	61.4	77.0	139.1	115.0		7,885	5,305	122.8	128.0	57.80	162.4
392	61.8	81.7	138.3	121.5	0.05	7,895	9,450	157.5	159.0	58.20	206.9
393	62.0	85.8	138.9	125.7	0.10	7,890	14,470	188.0	191.9	58.25	246.8
394	62.0	88.7	139.0	128.1	0.22	7,960	19,750	212.5	214.0	57.95	280.3
395	62.0	91.3	140.2	130.6	0.34	7,855	24,800	229.8	236.6	58.30	301.2
396	62.1	93.1	140.2	132.2	0.46	7,905	30,300	244.6	244.2	57.78	323.6
397	62.0	93.9	140.0	132.7	0.57	7,905	34,430	252.0	252.3	57.58	334.7
398	62.2	95.0	139.8	133.2	0.74	7,990	39,240	261.7	257.4	56.93	351.6
399	62.3	96.3	140.6	134.2	0.74	7,380	39,400	250.4	254.5	57.00	336.0

DATA

BAFFLES- HALF-MOON
SIZE- 3.92" HIGH
* See first page of Appendix for Symbols.

TUBE DIA.-5/8"
TUBE PITCH-3/4"
NO.OF TUBES-40

TRANSFER AREA- 32,72□'
SHELL FLUID_ WATER
TUBE FLUID- WATER

RUN NUMBER	t_{t_1} *	t_{t_2}	t_{s_1}	t_{s_2}	Δ P	W_t	W_s	Q_t	Q_s	θ_m	U
19 BAFFLES											
171	59.0	67.4	139.9	74.2	0.32	26,770	3,465	224.3	227.8	36.70	186.8
172	59.0	70.1	140.8	81.9	0.51	27,070	5,145	301.3	303.0	42.43	217.0
173	59.0	74.0	141.4	92.1	1.02	27,170	8,370	408.4	413.0	48.20	259.0
174	59.0	75.4	140.6	96.6	1.53	27,070	10,140	444.8	446.0	50.20	270.8
175	59.0	77.9	139.5	102.1	2.78	27,280	13,900	515.0	520.0	51.82	303.7
176	59.1	80.6	140.5	108.5	4.73	27,580	18,560	591.0	594.0	54.57	331.2
177	59.2	82.2	140.5	111.7	6.81	27,400	21,950	629.0	632.8	55.36	347.5
178	59.2	83.8	140.2	115.5	9.67	26,670	26,670	657.0	660.0	56.33	356.5
179	59.0	84.6	140.0	117.8	12.08	27,030	31,250	691.0	693.6	57.10	370.0
180	59.0	85.1	140.5	118.9	14.26	27,070	32,730	705.5	708.0	57.65	374.0
11 BAFFLES											
455	61.2	71.3	140.0	85.2	0.09	27,400	5,130	276.0	281.4	42.50	198.5
456	61.3	73.9	140.3	93.4	0.28	27,030	7,270	340.0	341.0	47.20	220.2
457	61.4	75.9	139.4	98.2	0.46	27,200	9,650	393.6	397.6	49.00	245.4
458	61.5	78.8	139.9	106.2	0.83	27,280	14,120	472.0	475.0	52.40	275.3
459	61.5	81.8	139.4	111.7	1.95	27,070	19,880	548.5	550.5	53.80	311.7
460	61.6	84.5	140.5	117.9	3.47	27,160	27,600	622.0	622.5	56.16	338.6
461	61.5	86.2	141.3	121.4	5.28	27,310	33,980	674.0	676.0	57.55	358.0
462	61.5	87.3	141.0	123.7	7.69	27,280	40,730	703.5	706.0	57.86	371.6
3 BAFFLES											
491	61.8	69.9	139.9	97.3	0.09	27,280	5,220	221.9	222.0	50.85	133.4
492	61.8	71.4	139.7	102.2	0.09	27,070	6,990	260.0	262.0	53.18	149.5
493	61.9	74.3	140.1	109.4	0.11	27,160	11,025	336.0	337.8	56.25	182.6
494	62.4	76.4	139.4	114.5	0.28	27,780	15,620	389.0	390.0	57.25	207.7
495	62.5	79.8	139.7	120.1	0.65	27,560	24,430	477.5	479.0	58.78	248.3
496	62.5	82.7	140.9	124.8	1.11	27,310	34,450	552.8	554.5	60.20	280.7
497	62.5	84.2	141.4	126.8	1.67	27,520	41,000	596.5	598.5	60.75	300.2
498	62.3	80.7	139.1	121.5	0.83	27,560	29,000	507.5	510.5	58.79	263.8
499	61.8	69.6	139.5	96.1		27,200	4,930	212.2	213.8	50.05	129.6
500	62.2	77.2	139.3	115.4	0.37	27,690	17,480	415.3	417.0	57.58	220.5

DATA

BAFFLES- HALF-MOON
SIZE- 3.92" HIGH
* See first page of Appendix for Symbols.

TUBE DIA.-5/8"
TUBE PITCH-7/8"
NO.OF TUBES- 30

TRANSFER AREA- 24.54□'
SHELL FLUID- WATER
TUBE FLUID- WATER

RUN NUMBER	t_{t_1} *	t_{t_2}	t_{s_1}	t_{s_2}	ΔP	W_t	W_s	Q_t	Q_s	θ_m	U
19 BAFFLES											
188	60.6	70.8	139.1	82.2	0.19	20,480	3,790	210.0	215.3	40.56	211.0
189	60.5	73.7	140.8	90.4	0.37	20,460	5,380	269.4	271.1	46.04	238.4
190	60.6	77.6	140.8	99.5	0.83	20,340	8,430	346.5	348.0	50.08	282.0
191	60.7	80.6	141.2	107.3	1.67	20,360	12,000	405.0	407.0	53.32	309.5
192	60.7	83.2	140.0	112.2	3.24	20,580	16,680	463.0	463.0	54.15	348.2
193	60.7	85.1	141.0	116.5	4.77	20,320	20,380	497.0	500.0	55.85	362.6
194	60.7	87.7	142.4	120.8	7.60	20,360	25,480	549.5	550.0	57.37	390.3
195	60.3	87.3	139.6	121.6	11.21	20,760	31,300	561.0	564.0	56.72	403.1
196	60.3	88.4	139.4	123.4	15.14	20,700	36,450	582.5	584.0	56.70	418.5
15 BAFFLES											
411	60.8	72.0	140.3	87.0	0.14	20,420	4,270	229.4	227.8	43.92	212.9
412	60.9	74.9	139.4	94.4	0.28	20,460	6,370	285.7	286.8	47.33	245.9
413	61.0	77.7	139.1	101.5	0.65	20,430	9,210	340.6	346.7	50.23	276.0
414	61.2	82.5	139.3	111.9	1.76	20,460	16,030	435.0	439.0	53.70	330.0
415	61.2	85.5	140.2	117.6	3.38	20,460	22,040	496.3	498.0	55.58	363.9
416	61.2	87.6	140.1	121.2	5.74	20,490	28,730	540.5	544.0	56.18	392.0
417	61.1	88.4	140.2	123.1	7.60	20,540	33,030	561.5	564.0	56.80	402.6
418	61.1	89.4	139.3	124.5	10.56	20,370	38,800	576.5	573.0	56.38	416.7
11 BAFFLES											
427	60.8	72.2	138.4	91.3	0.10	20,180	4,970	230.5	234.0	46.07	203.8
428	61.0	75.9	139.1	102.0	0.28	19,730	7,980	294.0	296.1	51.32	233.3
429	61.0	75.5	138.9	100.8	0.28	20,800	7,965	301.6	303.6	50.70	242.2
430	61.0	77.5	139.2	104.5	0.43	20,220	9,730	333.8	338.0	52.15	260.8
431	61.1	80.2	138.8	110.4	0.76	20,160	13,680	384.0	388.0	53.90	290.2
432	61.4	83.7	140.1	117.7	1.69	20,080	20,140	449.0	452.5	56.35	324.8
433	61.4	85.3	139.1	120.3	2.64	20,240	25,860	485.0	486.0	56.32	350.8
434	61.5	87.0	140.5	123.4	3.61	20,190	29,920	514.5	515.5	57.56	364.3
435	61.4	87.6	139.7	124.6	5.00	20,100	35,100	527.0	529.0	57.56	373.0
436	61.4	88.5	139.2	125.8	7.04	20,350	41,500	551.5	553.5	57.30	392.0
SHELL OUTLET THERMOMETER LOCATION CHANGED											
552	60.4	70.3	138.5	86.6	0.09	20,580	3,980	204.4	206.7	43.92	189.6
553	60.3	73.3	141.7	94.2	0.19	20,000	5,540	259.4	263.2	49.15	215.0
554	60.3	75.7	139.5	100.8	0.28	20,370	8,240	313.0	319.0	51.22	248.8
555	60.4	79.7	140.0	110.0	0.74	20,480	13,210	395.0	397.0	54.80	293.6
556	60.5	83.9	140.1	118.3	1.95	20,410	21,960	477.0	479.0	57.00	341.0
557	60.3	86.2	141.6	122.9	3.24	20,410	28,400	529.5	531.0	58.90	366.3
558	60.2	87.6	140.6	125.2	5.47	20,460	36,510	560.0	562.5	58.78	388.2
559	60.0	86.5	140.5	123.4	4.08	20,380	31,480	540.0	540.0	58.86	373.8
560	60.0	87.6	140.3	125.1	5.47	19,870	36,400	547.5	552.0	58.76	379.5
561	59.9	87.3	140.1	125.0	5.47	19,870	36,400	544.0	548.5	58.75	377.3
562	59.8	87.0	140.0	124.7	5.47	20,520	36,400	558.5	558.0	58.75	387.5
563	59.1	71.7	139.2	92.8		20,000	5,450	252.0	252.7	48.70	210.8
564	59.3	76.3	139.2	103.8		20,120	9,760	341.0	345.5	53.20	261.0
565	59.5	81.3	139.6	114.8		20,280	18,000	442.0	446.0	56.80	317.0
566	59.5	84.7	141.4	121.2		20,120	25,290	506.0	510.5	59.20	348.2
567	59.5	86.3	141.4	124.1		20,320	31,620	545.0	547.0	59.85	371.0
568	59.5	87.1	140.5	125.2		20,410	37,050	562.5	566.0	59.45	385.5
CHECKING SERIES											
573	59.6	73.6	139.1	96.9	0.19	20,300	6,905	284.8	291.5	50.05	231.8
574	59.7	77.8	140.2	106.5	0.46	20,390	11,130	368.4	375.0	54.30	276.3
575	59.7	81.8	139.9	114.9		20,230	18,090	445.0	451.2	56.65	320.0
576	59.7	84.3	140.9	119.9		19,970	23,450	490.8	492.5	58.40	342.3
577	59.6	84.4	141.6	120.2		20,110	23,500	498.6	503.0	59.00	344.3
578	59.5	86.0	140.3	123.4		20,580	32,230	545.0	545.5	58.90	377.0
579	59.4	86.0	140.5	123.5		20,300	32,040	539.5	543.6	59.05	372.2
580	59.4	86.8	139.7	124.8		20,430	37,260	559.0	555.0	59.10	385.4
581	59.4	87.1	140.4	125.4		20,250	37,320	560.0	562.5	59.40	384.0
7 BAFFLES											
445	61.5	76.6	139.9	107.2	0.19	20,520	9,540	310.5	312.0	53.95	234.4
446	61.5	78.6	138.7	110.3	0.37	20,300	12,140	345.6	345.0	54.43	258.6
447	61.6	81.5	139.4	115.7	0.67	20,260	16,960	402.5	401.5	56.03	292.5
448	61.9	84.2	139.6	120.4	1.25	20,120	23,380	448.8	449.5	56.90	321.2
449	61.9	86.2	140.4	123.8	1.95	20,070	29,220	487.5	487.0	57.96	342.7
450	61.9	87.5	140.2	125.6	2.69	19,770	34,840	505.5	506.5	58.17	354.2
451	61.9	88.3	140.1	126.9	3.71	20,260	40,650	535.0	537.0	58.05	375.4
452	61.9	88.6	140.8	127.6	3.71	20,280	40,980	541.5	542.0	58.70	376.0
453	61.2	71.2	137.5	92.8	0.04	20,060	4,600	201.0	205.5	46.88	174.6
454	61.4	75.6	139.7	104.6	0.14	19,880	8,140	283.5	285.4	52.90	218.3

DATA

BAFFLES- HALF-MOON
SIZE- 3.92" HIGH
* See first page of Appendix for Symbols.

TUBE DIA.-5/8"
TUBE PITCH-7/8"
NO.OF TUBES-30

TRANSFER AREA- 24.54 □'
SHELL FLUID- WATER
TUBE FLUID- WATER

RUN NUMBER	t_{t_1} *	t_{t_2}	t_{s_1}	t_{s_2}	ΔP	W_t	W_s	Q_t	Q_s	θ_m	U
3 BAFFLES											
463	61.2	71.0	139.1	103.4	0.09	20,360	5,620	198.9	201.0	54.15	149.6
464	61.3	73.0	139.5	107.8	0.09	20,220	7,515	236.6	238.0	56.08	171.8
465	61.7	77.2	139.8	115.7	0.19	20,220	13,050	313.5	315.0	58.20	219.4
466	61.8	80.6	139.6	120.8	0.37	20,220	20,380	381.0	383.0	59.01	263.0
467	61.8	83.7	141.0	125.2	0.60	20,110	28,120	441.2	443.7	60.22	298.3
468	61.8	85.5	141.1	127.3	1.02	20,180	34,870	478.0	481.0	60.56	321.7
469	61.8	86.8	141.2	129.1	1.57	20,290	42,280	506.5	509.0	60.70	340.0

DATA

BAFFLES- HALF-MOON
SIZE- 3.92" HIGH
* See first page of Appendix for Symbols.

TUBE DIA.- 5/8"
TUBE PITCH-1 1/16"
NO.OF TUBES-20

TRANSFER AREA- 16.36 □'
SHELL FLUID- WATER
TUBE FLUID- WATER

RUN NUMBER	t_{t_1} *	t_{t_2}	t_{s_1}	t_{s_2}	ΔP	W_t	W_s	Q_t	Q_s	θ_m	U
19 BAFFLES											
127	55.6	77.1	140.7	110.4	0.74	14,030	10,040	301.6	304.0	59.12	311.9
128	55.6	77.3	141.4	110.5	0.74	14,170	10,020	308.0	309.5	59.20	318.0
129	56.0	82.9	140.2	120.8	2.82	14,060	19,620	379.0	382.0	61.00	379.8
130	56.1	86.0	140.6	125.5	5.51	14,160	27,640	423.0	419.0	61.98	417.4
131	56.1	87.8	141.0	127.8	8.80	14,260	34,530	452.0	455.2	62.02	445.2
132	56.1	89.0	143.8	130.1	8.80	14,250	34,600	469.0	471.5	63.83	449.0
133	57.3	70.7	139.1	93.3	0.14	13,720	4,095	184.3	187.5	50.45	223.2
134	57.1	75.3	140.1	104.6	0.37	13,690	7,050	248.3	250.0	55.85	271.7
135	57.0	79.1	139.1	113.0	1.02	13,780	11,760	305.0	307.0	58.00	321.4
136	56.9	82.6	139.5	119.4	2.27	13,620	17,540	349.6	352.5	59.65	358.2
137	57.0	84.8	139.4	122.9	4.03	13,950	23,500	387.0	389.7	60.25	392.6
138	57.3	86.8	139.8	126.1	6.53	13,850	30,000	409.0	412.5	60.65	412.2
139	57.2	87.7	139.1	127.4	10.09	13,950	36,720	426.0	429.7	60.25	432.0
140	57.2	89.3	140.3	129.8	13.52	13,810	42,250	443.4	445.8	61.16	443.5
141	56.9	83.9	137.7	121.5	4.12	14,025	23,560	378.0	381.6	58.95	392.0
AFTER POLISHING ALL TUBES INSIDE AND OUTSIDE											
595	62.5	77.3	138.5	100.6	0.23	13,575	5,480	200.5	208.0	48.70	251.6
596	62.5	77.6	139.8	101.1	0.23	13,660	5,385	206.3	208.4	49.44	255.1
597	62.9	83.8	139.8	114.0	0.88	13,640	11,070	284.7	285.0	53.50	325.2
598	63.1	88.9	139.8	123.1	2.87	13,050	20,360	337.2	340.0	55.47	
599	62.8	88.6	141.2	123.5	2.87	13,925	20,130	358.5	357.6	56.55	387.5
600	62.5	75.5	139.0	96.5	0.14	13,500	4,260	175.0	181.2	47.20	226.7
601	62.7	81.3	138.9	109.4	0.51	13,190	8,470	246.0	250.0	52.00	289.2
602	62.6	81.7	140.5	110.4	0.56	13,480	8,520	257.5	256.3	53.17	296.0
603	62.9	85.0	139.0	116.4	1.25	13,530	13,280	299.0	299.8	53.79	340.0
604	63.0	88.6	139.9	122.8	2.92	13,540	20,140	345.8	343.3	55.45	381.0
605	63.1	90.6	140.4	126.0	4.63	13,430	25,460	370.0	366.5	56.10	403.2
606	63.0	90.1	139.9	125.5	4.63	13,600	25,470	369.0	368.2	56.00	402.8
607	63.0	90.6	138.0	126.0	6.81	13,605	30,880	376.4	370.5	54.83	419.7
608	62.9	91.1	139.3	127.0	6.81	13,550	30,920	381.5	382.3	55.76	418.2
609	62.5	84.3	139.5	115.6	1.07	13,320	12,290	290.4	293.0	54.18	327.9
610	62.4	83.7	138.5	114.8	1.07	13,770	12,390	292.7	293.3	53.65	333.4
11 BAFFLES											
527	62.6	74.7	138.3	101.1	0.05	13,490	4,455	163.2	165.6	50.00	199.5
528	62.6	74.7	138.3	101.4	0.05	13,650	4,500	165.2	165.8	50.22	201.0
529	62.8	78.0	139.5	109.0	0.19	13,700	6,970	208.6	212.8	53.40	238.7
530	63.0	81.6	140.4	116.3	0.32	13,750	10,620	255.2	256.5	56.03	278.4
531	63.2	85.3	141.0	122.3	0.74	13,275	15,840	293.8	296.7	57.35	313.2
532	63.2	87.7	140.2	125.9	1.39	13,390	23,190	328.4	331.0	57.55	348.8
533	63.2	88.8	139.9	127.8	2.13	13,440	28,720	344.6	346.8	57.50	366.3
534	63.1	89.7	140.0	129.1	2.87	13,600	33,330	361.4	363.3	57.70	383.0
535	63.2	90.4	138.7	129.5	4.26	13,420	39,900	364.5	368.0	56.85	392.0
536	63.2	90.7	139.9	130.5	4.26	13,800	40,000	379.5	378.5	57.75	401.7
3 BAFFLES											
537	62.4	73.0	139.5	110.9		13,500	5,005	143.1	143.2	57.00	153.4
538	62.6	75.4	138.8	115.0	0.02	13,410	7,370	172.5	175.0	57.85	182.3
539	62.8	78.1	139.8	119.6	0.05	13,500	10,280	206.2	207.1	59.20	213.0
540	63.0	80.4	139.0	122.4	0.14	13,450	14,170	234.5	234.8	59.00	243.0
541	63.0	83.0	139.4	125.6	0.23	13,580	19,840	271.6	273.8	59.45	279.2
542	63.2	85.7	140.0	128.7	0.45	13,625	27,430	306.2	308.4	59.75	313.2
543	63.2	87.2	140.9	130.7	0.58	13,650	32,400	327.0	330.4	60.20	332.0
544	63.1	87.5	139.0	130.2	0.79	13,730	38,500	335.5	340.0	58.97	347.8
545	62.8	81.1	139.5	123.7	0.16	13,540	15,770	248.6	248.3	59.65	254.7

DATA

BAFFLES- ORIFICE
SIZE-17/32" DIA.HOLE
* See first page of Appendix for Symbols.

TUBE DIA.-3/8"
TUBE PITCH-11/16"
NO.OF TUBES-52

TRANSFER AREA- 25.51□'
SHELL FLUID- WATER
TUBE FLUID- WATER

RUN NUMBER	t_{t_1} *	t_{t_2}	t_{s_1}	t_{s_2}	ΔP	W_t	W_s	Q_t	Q_s	θ_m	U
19 BAFFLES											
750	73.3	84.8	138.1	82.4	0.20	9,590	1,985	109.7	110.7	24.97	172.2
751	73.7	96.5	137.6	100.8	1.37	9,780	6,080	223.2	223.8	33.58	260.6
752	74.0	104.2	139.0	112.7	4.12	9,760	11,250	295.0	296.3	36.68	315.3
753	74.3	107.6	138.6	118.1	8.06	9,800	15,960	326.2	327.2	37.04	345.0
754	74.3	110.1	139.3	121.4	12.13	9,845	19,730	352.4	353.7	37.50	368.3
755	74.4	112.1	139.6	124.3	18.06	9,780	24,130	368.7	370.0	37.60	384.4
756	74.4	113.2	139.1	125.9	25.75	9,740	28,760	378.2	379.7	37.27	397.8
757	74.5	114.4	139.9	127.5	31.22	9,735	31,480	388.3	390.3	37.60	404.8
11 BAFFLES											
758	73.6	86.0	139.0	87.1	0.14	9,760	2,310	120.4	119.9	28.87	163.5
759	74.0	93.2	139.0	98.7	0.51	9,620	4,710	185.2	189.7	34.18	212.3
760	74.4	101.9	139.6	111.9	1.83	9,665	9,590	266.0	265.6	37.61	277.1
761	74.8	106.5	139.8	118.8	4.03	9,800	14,760	310.0	310.0	38.43	316.2
762	74.9	109.7	139.3	122.8	7.97	9,715	20,700	338.3	340.3	38.04	348.5
763	75.0	112.1	139.7	126.4	13.89	9,700	27,060	360.2	360.0	38.28	368.8
3 BAFFLES											
764	73.9	84.7	138.0	96.3	0.11	9,840	2,565	106.3	106.8	35.70	116.7
765	73.9	92.3	137.6	110.3	0.32	9,980	6,735	183.0	184.0	40.67	176.4
766	74.2	99.3	138.7	120.6	1.02	9,810	13,720	246.6	248.8	42.80	225.8
767	74.2	103.8	140.4	125.6	2.08	9,875	19,740	292.2	293.2	43.65	262.4
768	74.3	105.6	138.8	127.0	3.66	9,830	26,280	308.0	310.0	42.20	286.0
769	74.3	107.6	138.1	128.5	6.30	9,805	34,480	327.0	329.0	41.22	311.0

DATA

BAFFLES- ORIFICE
SIZE-17/32" DIA.HOLE

TUBE DIA.-1/2"
TUBE PITCH-25/32"
NO.OF TUBES-40

TRANSFER AREA- 26.16□'
SHELL FLUID- WATER
TUBE FLUID- WATER

RUN NUMBER	t_{t_1}	t_{t_2}	t_{s_1}	t_{s_2}	ΔP	W_t	W_s	Q_t	Q_s	θ_m	U
19 BAFFLES											
587	62.0	73.6	138.9	77.1	0.83	15,720	2,960	182.8	183.0	34.33	203.6
588	62.2	80.9	139.6	91.5	3.15	15,730	6,130	294.2	294.5	42.36	265.8
589	62.2	83.6	139.6	97.0	5.00	15,800	7,950	337.6	338.6	44.55	289.7
590	62.5	87.1	139.9	103.8	8.62	15,600	10,775	384.0	389.6	46.70	314.3
591	62.6	89.2	139.4	108.1	13.33	15,770	13,480	420.0	422.0	47.80	336.0
592	62.7	91.5	139.5	112.3	20.47	15,720	16,690	452.6	454.5	48.75	354.8
593	62.8	93.2	140.3	115.2	26.58	15,750	19,120	479.4	480.0	49.70	368.9
594	62.8	94.0	139.5	116.9	34.45	15,750	21,750	492.0	491.5	49.70	378.4
15 BAFFLES											
611	62.3	71.7	139.6	74.5	0.46	15,650	2,290	146.3	149.0	32.50	172.2
612	62.5	77.8	139.1	87.1	1.53	15,820	4,720	242.5	245.6	40.18	230.9
613	62.7	83.5	140.4	98.2	3.80	15,840	7,850	329.5	331.2	45.36	277.8
614	63.0	86.6	139.7	104.3	6.67	15,920	10,600	375.8	374.6	47.00	305.7
616	63.0	88.7	140.5	108.4	9.26	15,750	12,730	405.0	408.0	48.53	319.0
617	63.0	90.4	139.2	111.7	14.26	15,910	15,770	435.3	433.6	48.76	341.3
618	63.1	91.7	139.1	114.0	18.12	15,770	17,910	450.4	449.0	49.12	350.5
619	63.2	92.9	139.0	116.2	24.08	15,880	20,720	471.2	471.5	49.46	364.3
620	63.3	94.2	139.0	118.4	31.68	15,780	23,600	487.5	486.0	49.76	374.7
11 BAFFLES											
621	63.5	76.9	139.2	87.1	0.83	15,640	4,070	209.6	212.0	39.95	200.5
622	63.6	81.9	140.1	97.1	2.13	15,850	6,790	289.7	292.3	44.72	247.6
623	63.9	85.5	139.3	104.4	4.17	15,825	9,960	342.0	347.3	46.80	279.3
624	64.0	88.3	139.0	109.6	7.23	15,760	13,140	383.5	386.0	48.07	305.2
625	64.2	91.3	139.9	115.0	12.32	15,840	17,220	429.3	428.6	49.72	330.4
626	64.3	93.1	139.9	117.7	17.41	15,890	20,520	457.5	456.4	50.04	349.5
627	64.3	94.7	140.5	120.4	23.80	15,930	24,000	483.6	481.6	50.96	362.8
628	63.7	81.8	138.2	97.4	2.22	15,780	7,100	285.6	289.6	44.10	247.7
7 BAFFLES											
636	63.6	75.3	138.9	88.8	0.46	15,820	3,735	185.1	187.3	41.53	170.4
637	64.0	83.0	139.2	103.6	2.04	15,880	8,530	301.3	303.2	47.43	242.9
638	64.4	88.6	138.5	113.5	6.21	15,780	15,430	382.7	385.2	49.48	295.7
639	64.5	91.1	139.7	117.7	9.54	15,860	19,120	422.8	421.2	50.88	317.7
640	64.5	92.7	139.3	120.2	14.07	15,840	23,320	447.0	445.4	50.88	335.7
641	64.6	94.7	139.6	123.1	20.66	15,590	28,200	469.4	465.4	51.48	348.6
642	64.5	95.2	141.1	123.8	20.38	15,680	27,940	481.5	483.4	52.40	351.2

DATA

BAFFLES- ORIFICE
SIZE-17/32" DIA.HOLE

TUBE DIA.-1/2"
TUBE PITCH-25/32"
NO.OF TUBES-40

TRANSFER AREA- 26.16□'
SHELL FLUID- WATER
TUBE FLUID- WATER

RUN NUMBER	t_{t_1}	t_{t_2}	t_{s_1}	t_{s_2}	ΔP	W_t	W_s	Q_t	Q_s	θ_m	U
3 BAFFLES											
629	63.8	74.1	138.9	96.0	0.28	15,960	3,895	164.3	167.0	46.68	134.6
630	64.0	81.4	139.2	111.6	1.20	15,890	9,930	276.5	274.3	52.57	201.2
631	64.3	85.4	138.7	117.1	2.87	15,640	15,520	330.9	334.3	53.05	238.3
632	64.3	87.3	139.3	120.3	4.26	15,770	19,050	362.2	361.4	53.98	256.4
633	64.4	89.5	139.2	122.5	6.48	15,430	23,380	387.4	389.7	53.83	275.1
634	64.4	90.8	139.2	124.6	9.17	15,630	28,120	412.0	410.5	54.12	291.1
635	64.5	92.0	139.6	125.9	12.13	15,750	31,900	434.0	436.0	54.23	306.0

DATA

BAFFLES- ORIFICE
SIZE-9/16" DIA.HOLE
* See first page of Appendix for Symbols.

TUBE DIA.-1/2"
TUBE PITCH-25/32"
NO.OF TUBES-40

TRANSFER AREA- 26.16□'
SHELL FLUID- WATER
TUBE FLUID- WATER

RUN NUMBER	t_{t_1} *	t_{t_2}	t_{s_1}	t_{s_2}	ΔP	W_t	W_s	Q_t	Q_s	θ_m	U
19 BAFFLES											
648	65.4	77.4	139.6	83.4	0.42	16,670	3,560	201.0	200.0	35.70	215.2
649	65.4	78.0	139.2	84.2	0.42	15,590	3,640	196.5	200.4	35.97	208.9
650	65.7	85.4	139.6	99.5	1.76	15,800	7,750	311.0	310.8	43.26	275.0
651	65.9	88.0	138.6	104.8	3.06	16,220	10,600	358.0	358.6	44.44	308.0
652	66.0	88.8	139.2	106.2	3.06	15,530	10,825	353.6	357.0	45.23	299.0
653	66.0	92.4	139.9	113.2	6.30	15,580	15,360	411.8	410.0	47.30	332.8
654	66.1	93.6	139.4	115.1	8.71	15,950	18,070	438.5	438.0	47.40	353.7
655	66.2	94.8	138.7	117.5	11.76	15,810	21,240	452.0	451.5	47.48	364.0
656	66.3	96.3	139.3	119.9	16.48	16,160	24,900	484.0	482.0	48.07	385.0
657	66.4	97.2	141.0	121.3	16.40	16,000	24,930	493.0	492.0	49.10	384.0
658	66.4	98.2	140.0	122.9	23.15	15,750	29,500	501.0	502.5	48.82	392.3
11 BAFFLES											
659	66.0	75.6	139.6	83.4	0.23	15,650	2,675	149.9	150.5	35.74	160.4
660	66.3	85.5	138.3	103.4	1.25	15,650	8,680	301.0	303.0	44.50	258.7
661	66.5	89.8	138.6	111.1	2.87	15,630	13,450	364.3	369.5	46.66	298.6
662	66.5	91.8	138.5	114.8	4.40	15,620	16,650	395.2	395.0	47.48	318.4
663	66.7	94.2	139.1	118.7	7.13	15,700	21,280	431.7	432.6	48.35	341.3
664	66.7	95.8	139.5	121.2	10.00	15,700	25,030	456.0	457.5	48.82	357.0
665	66.7	97.0	139.6	123.0	13.33	15,710	28,750	475.5	478.0	49.15	370.0
666	66.7	97.9	139.8	124.3	16.48	15,690	31,820	490.0	492.5	49.26	380.3
3 BAFFLES											
667	66.2	75.2	137.5	95.4	0.09	15,690	3,370	141.2	141.7	43.72	123.4
668	66.5	82.1	137.7	110.4	0.46	15,695	9,000	244.8	246.2	49.62	188.6
669	66.7	86.9	138.6	118.3	1.20	15,700	15,600	316.5	316.0	51.63	234.3
670	66.8	89.7	139.7	122.5	2.13	15,710	21,000	360.3	360.0	52.78	261.0
671	66.8	91.1	138.9	124.0	3.15	15,650	25,390	380.6	379.0	52.40	277.7
672	66.8	93.2	139.7	126.1	4.54	15,675	30,420	413.8	413.6	52.70	300.2
673	66.8	94.5	139.6	127.6	6.67	15,690	36,360	434.6	436.4	52.58	316.0
674	66.8	95.5	139.7	128.6	8.52	15,710	41,100	451.0	453.7	52.50	328.4

DATA

BAFFLES- ORIFICE
SIZE-5/8" DIA.HOLE

TUBE DIA.-1/2"
TUBE PITCH-25/32"
NO.OF TUBES-40

TRANSFER AREA- 26.16□'
SHELL FLUID- WATER
TUBE FLUID- WATER

RUN NUMBER	t_{t_1}	t_{t_2}	t_{s_1}	t_{s_2}	ΔP	W_t	W_s	Q_t	Q_s	θ_m	U
19 BAFFLES											
686	69.0	81.3	138.2	90.8	0.17	15,605	4,165	192.0	197.4	36.53	201.0
687	69.5	87.4	140.8	102.3	0.46	16,180	7,500	290.0	289.0	42.30	
688	69.5	87.7	140.1	102.7	0.46	15,520	7,845	283.0	293.3	42.08	257.1
689	69.7	90.8	138.0	108.5	1.02	15,640	11,170	330.0	329.5	42.88	294.2
690	69.9	93.9	138.0	114.0	1.85	15,740	15,770	377.6	378.5	44.07	327.8
691	70.2	97.4	141.3	119.5	2.87	15,910	19,890	433.5	434.3	46.53	356.2
692	70.2	98.0	138.4	120.9	4.54	15,800	25,070	440.0	438.6	45.34	371.1
693	70.2	99.1	137.9	122.7	6.76	16,280	30,700	470.5	466.6	45.33	
694	70.3	99.6	138.5	123.4	6.76	15,800	30,730	463.4	464.0	45.60	388.7
695	70.4	101.1	138.2	125.4	10.32	15,780	37,950	484.5	485.6	45.52	407.0

DATA

BAFFLES- ORIFICE
SIZE-5/8" DIA.HOLE

TUBE DIA.-1/2"
TUBE PITCH-25/32"
NO.OF TUBES-40

TRANSFER AREA- 26.16□'
SHELL FLUID- WATER
TUBE FLUID- WATER

RUN NUMBER	t_{t_1}	t_{t_2}	t_{s_1}	t_{s_2}	ΔP	W_t	W_s	Q_t	Q_s	θ_m	U
11 BAFFLES											
696	70.1	80.9	138.0	92.0	0.14	15,495	3,775	167.8	173.7	36.80	174.4
697	70.4	88.1	138.0	106.3	0.42	15,720	8,950	278.3	283.4	42.60	250.0
698	70.6	92.5	140.6	113.8	0.79	15,750	13,020	345.4	348.0	45.62	289.6
699	70.7	95.3	139.2	118.0	1.58	15,690	18,300	386.0	388.0	45.62	323.4
700	70.8	97.8	139.6	122.1	2.59	15,650	24,130	423.0	421.6	46.56	347.4
701	70.8	99.2	138.7	124.2	4.17	15,650	30,410	444.0	442.7	46.15	368.0
702	71.0	100.8	139.3	126.7	6.11	15,560	36,840	464.6	463.0	46.60	381.0
3 BAFFLES											
703	70.1	80.9	137.7	102.8	0.05	15,840	4,985	171.1	173.8	43.65	149.8
704	70.5	84.8	137.8	111.0	0.10	15,940	8,615	228.0	230.8	46.57	187.3
705	70.8	88.4	139.3	117.4	0.28	15,910	12,760	279.6	280.0	48.75	219.2
706	71.0	91.6	138.5	121.6	0.48	15,650	19,200	322.0	324.0	48.73	252.7
707	71.1	93.8	137.9	123.7	0.79	15,590	24,980	353.8	355.2	48.25	280.3
708	71.2	95.9	138.1	126.0	1.34	15,710	32,430	388.0	390.5	48.26	307.4
709	71.3	97.5	138.9	128.3	1.95	15,810	38,830	413.8	414.0	48.82	324.0
710	71.3	99.0	139.7	130.0	2.64	15,710	45,150	435.3	438.0	49.10	339.0

DATA

BAFFLES- ORIFICE
SIZE-9/16" DIA.HOLE

* See first page of Appendix for Symbols.

TUBE DIA.-1/2"
TUBE PITCH-1 3/32"
NO.OF TUBES-20

TRANSFER AREA- 13.08□'
SHELL FLUID- WATER
TUBE FLUID- WATER

RUN NUMBER	t_{t_1} *	t_{t_2}	t_{s_1}	t_{s_2}	ΔP	W_t	W_s	Q_t	Q_s	θ_m	U
19 BAFFLES											
711	73.3	88.6	138.2	98.2	1.02	7,870	3,055	120.4	122.3	35.80	257.2
712	73.4	92.4	137.9	105.9	2.22	7,905	4,755	150.2	152.4	38.66	297.0
713	73.7	97.9	138.8	116.1	6.58	7,810	8,410	188.6	190.8	41.62	346.2
714	73.8	100.5	138.3	120.9	13.38	7,890	12,075	210.6	210.8	42.32	380.3
715	73.9	102.3	139.6	123.9	18.06	7,940	14,390	225.4	225.8	43.30	398.0
716	73.9	103.6	140.1	126.0	23.98	7,890	16,510	234.3	233.3	43.75	409.4
717	73.9	104.3	139.4	126.9	33.07	7,925	19,350	241.0	241.3	43.46	424.0
11 BAFFLES											
725	72.5	86.1	137.4	97.1	0.42	7,920	2,535	99.8	102.1	36.75	207.8
726	72.8	92.4	138.5	111.2	1.95	7,890	5,850	154.6	159.8	42.15	280.4
727	72.9	96.2	138.5	118.0	4.54	7,905	9,040	184.7	185.3	43.70	323.2
728	73.0	99.1	138.1	122.7	9.82	7,970	13,530	208.0	207.5	44.15	360.0
729	73.1	101.9	138.7	126.7	19.36	7,910	19,080	227.5	227.4	44.70	389.0
730	73.0	103.4	138.8	128.7	31.90	7,950	24,250	241.4	243.3	44.83	411.8
3 BAFFLES											
737	72.5	89.0	139.6	120.3	0.70	7,785	6,870	128.5	132.3	49.21	199.5
738	72.6	92.5	139.8	124.9	1.71	8,000	10,730	158.9	159.9	49.80	243.9
739	72.7	94.6	138.6	127.1	3.15	7,860	14,975	171.7	172.7	49.04	267.6
740	72.9	97.2	139.0	129.4	5.93	7,850	20,000	190.5	191.4	48.75	298.8
741	72.9	98.7	139.2	131.2	9.17	7,815	25,180	201.5	202.2	48.94	314.8
742	72.8	100.0	138.9	131.9	14.54	8,100	31,650	220.2	221.5	48.32	348.6
743	73.0	102.4	141.1	134.0	13.15	7,640	31,860	224.8	227.2	48.97	350.8

DATA

BAFFLES- ORIFICE
SIZE-11/16" DIA.HOLE

TUBE DIA.-5/8"
TUBE PITCH-1 1/16"
NO.OF TUBES-20

TRANSFER AREA- 16.36□'
SHELL FLUID- WATER
TUBE FLUID- WATER

RUN NUMBER	t_{t_1}	t_{t_2}	t_{s_1}	t_{s_2}	ΔP	W_t	W_s	Q_t	Q_s	θ_m	U
19 BAFFLES											
718	72.8	80.6	138.1	86.7	0.42	13,350	2,130	104.2	109.4	30.77	207.0
719	72.8	86.7	138.3	102.3	2.18	13,630	5,380	189.2	193.7	39.56	292.3
720	72.8	89.7	138.1	109.8	4.82	13,760	8,380	232.5	236.7	42.52	334.3
721	72.8	92.0	138.1	114.9	8.85	13,540	11,260	260.3	261.0	44.06	361.1
722	72.8	94.2	138.5	119.5	15.28	13,360	15,040	285.8	285.8	45.47	384.0
723	72.8	95.3	138.2	121.4	21.83	13,470	18,020	302.3	304.0	45.70	404.5
724	72.9	96.0	137.6	122.6	30.57	13,620	21,150	315.2	316.0	45.53	423.2
11 BAFFLES											
731	72.0	78.9	137.8	88.9	0.19	13,350	1,950	91.7	95.4	33.62	166.8
732	72.0	86.6	137.2	109.1	2.04	13,300	7,110	194.2	199.8	43.60	272.2
733	72.0	90.6	138.4	117.7	5.70	13,440	12,040	249.8	249.2	46.72	326.8
734	72.1	92.7	139.2	122.0	10.28	13,525	16,210	279.5	278.9	48.20	354.4
735	72.1	94.5	138.4	124.9	18.46	13,195	21,900	295.2	295.7	48.23	374.0
736	72.1	95.7	139.2	127.0	27.04	13,575	26,240	319.5	318.6	49.00	398.6
3 BAFFLES											
744	72.0	80.9	139.6	110.8	0.27	13,980	4,475	125.3	129.0	48.07	159.3
745	72.0	81.0	137.9	110.2	0.27	13,685	4,490	123.0	124.2	47.00	160.0
746	72.2	83.8	137.9	116.9	0.65	13,680	7,680	157.8	161.3	49.30	195.6
747	72.3	86.7	138.5	122.3	1.76	13,860	12,460	200.0	201.8	50.88	240.3
748	72.5	90.4	138.7	127.3	4.91	13,685	21,550	245.0	245.8	51.53	290.8
749	72.6	92.5	139.4	130.1	9.54	13,760	29,380	273.3	274.0	52.00	321.7

DATA

BAFFLES- DISK-AND-DOUGHNUT
SIZE-4.5" DISK,4.0" HOLE
* See first page of Appendix for Symbols.

TUBE DIA.- 3/8"
TUBE PITCH-11/16"
NO.OF TUBES-52

TRANSFER AREA- 25.51□'
SHELL FLUID- WATER
TUBE FLUID- WATER

RUN NUMBER	t_{t_1} *	t_{t_2}	t_{s_1}	t_{s_2}	ΔP	W_t	W_s	Q_t	Q_s	θ_m	U
19 BAFFLES											
781	75.4	89.6	138.8	93.2	0.06	10,105	3,200	143.5	145.9	30.92	181.8
782	75.2	91.2	139.5	97.3	0.06	10,000	3,865	159.5	163.0	33.56	186.3
783	75.8	100.3	140.1	109.7	0.16	9,615	7,820	235.6	237.6	36.80	251.0
784	76.0	105.2	139.3	116.7	0.35	9,750	12,600	284.3	284.4	37.28	299.1
785	76.3	108.9	138.8	121.7	0.79	9,780	18,630	318.8	318.5	37.18	336.0
786	76.4	112.6	140.0	126.4	1.53	9,640	25,620	349.2	349.2	37.58	364.3
787	76.6	114.5	140.1	128.5	2.41	9,780	32,150	371.0	372.0	37.22	390.7
788	76.6	114.9	138.4	129.0	3.72	9,750	39,900	373.8	375.0	36.07	406.3
11 BAFFLES											
807	75.9	89.3	140.7	96.3	0.05	9,860	3,065	132.1	136.0	33.60	154.1
808	76.1	97.8	139.5	110.2	0.10	9,920	7,300	214.6	213.9	37.80	222.5
809	76.4	102.8	139.1	117.6	0.23	9,870	12,060	260.4	260.0	38.70	263.8
810	76.7	107.0	138.1	123.0	0.43	9,785	19,670	296.7	297.0	38.22	304.3
811	76.8	110.6	139.1	127.2	0.80	9,800	27,940	331.5	331.8	38.44	338.0
812	76.9	112.4	138.5	129.2	1.50	9,780	37,360	347.6	347.3	37.73	361.0
3 BAFFLES											
842	76.3	86.8	137.9	104.1	0.03	9,780	3,110	103.3	105.2	38.31	105.7
843	76.4	95.4	138.8	115.7	0.04	9,785	8,100	186.0	187.5	41.33	176.4
844	76.7	99.8	138.8	121.7	0.07	9,850	13,350	227.5	229.2	41.97	212.5
845	76.9	104.1	138.2	126.1	0.15	9,740	21,930	265.0	265.3	41.27	251.7
846	77.2	106.9	138.8	128.7	0.25	9,810	29,000	291.3	293.0	41.07	278.0
847	77.0	108.5	137.9	129.6	0.41	9,725	37,350	306.3	307.7	39.90	301.0

DATA

BAFFLES- DISK-AND-DOUGHNUT
SIZE-4.5" DISK, 4.0" HOLE

TUBE DIA.-1/2"
TUBE PITCH-25/32"
NO. OF TUBES-40

TRANSFER AREA- 26.16 □'
SHELL FLUID- WATER
TUBE FLUID- WATER

RUN NUMBER	t_{t_1}	t_{t_2}	t_{s_1}	t_{s_2}	ΔP	W_t	W_s	Q_t	Q_s	θ_m	U
19 BAFFLES											
770	74.6	82.7	139.2	87.2	0.04	15,660	2,470	126.8	128.3	29.30	165.6
771	74.7	88.7	137.3	99.6	0.11	15,470	5,825	216.2	219.6	35.48	233.0
772	75.0	94.8	139.9	111.1	0.34	15,610	10,860	309.6	312.8	40.50	292.3
773	75.0	99.7	139.4	119.3	1.06	15,075	18,700	372.2	375.0	41.94	339.4
774	75.0	102.3	140.7	123.9	1.90	15,650	25,430	426.0	426.0	43.47	374.8
775	75.0	103.2	139.2	125.1	3.02	15,630	31,450	441.3	441.6	42.73	395.0
776	75.0	104.0	138.3	126.1	4.26	15,675	37,430	454.5	456.0	42.04	413.5
777	74.5	89.7	139.8	102.1	0.14	15,300	6,295	232.0	236.8	37.73	235.0
778	74.9	90.1	138.2	102.7	0.13	15,300	6,590	231.6	234.0	37.05	239.0
779	75.1	89.9	138.2	102.4	0.13	15,700	6,560	232.0	234.7	36.83	240.8
780	75.9	102.4	139.3	124.0	2.26	15,760	27,360	416.5	416.2	42.33	376.2
11 BAFFLES											
801	75.5	86.0	139.0	98.2	0.05	15,600	4,140	163.7	169.0	35.77	175.1
802	75.8	90.7	140.5	107.7	0.10	15,610	7,120	232.2	233.6	40.23	220.8
803	76.1	94.2	138.9	113.9	0.19	15,650	11,480	283.7	287.0	41.18	263.5
804	76.3	98.4	138.9	120.9	0.51	15,800	19,530	349.3	352.2	42.48	314.5
805	76.4	101.4	139.0	125.1	1.11	15,780	28,520	395.0	395.6	42.92	352.0
806	76.3	102.9	138.3	127.0	1.89	15,815	37,050	420.8	421.0	42.63	377.4
7 BAFFLES											
831	76.2	84.0	140.4	96.5	0.03	15,680	2,880	121.8	126.4	35.33	131.8
832	76.4	91.9	140.4	113.2	0.13	15,800	9,070	245.3	246.5	42.42	221.1
833	76.5	95.1	139.6	118.6	0.21	15,980	14,220	296.8	298.2	43.27	262.2
834	76.8	100.1	139.5	125.5	0.56	15,675	26,130	365.8	365.2	43.83	319.0
835	76.8	102.4	138.9	128.3	1.20	15,640	37,500	401.0	399.7	43.58	351.9
3 BAFFLES											
848	76.2	83.1	138.9	101.7	0.03	15,710	2,980	108.0	111.0	38.68	106.8
849	76.3	88.5	139.9	113.0	0.05	15,875	7,230	193.2	194.5	43.63	169.3
850	76.6	92.5	139.9	120.7	0.09	15,815	13,160	252.5	252.7	45.78	210.9
851	76.8	95.6	139.0	124.6	0.20	15,740	20,720	296.4	298.0	45.62	248.4
852	76.9	98.7	140.0	128.5	0.37	15,915	29,900	346.4	343.8	46.36	285.8
853	76.0	99.7	138.2	129.0	0.58	15,680	37,800	356.0	350.0	45.02	302.2

DATA

BAFFLES- DISK-AND-DOUGHNUT
SIZE-4.95" DISK-3.5" HOLE
* See first page of Appendix for Symbols.

TUBE DIA.-1/2"
TUBE PITCH-25/32"
NO. OF TUBES-40

TRANSFER AREA- 26.16 □'
SHELL FLUID- WATER
TUBE FLUID- WATER

RUN NUMBER	t_{t_1} *	t_{t_2}	t_{s_1}	t_{s_2}	ΔP	W_t	W_s	Q_t	Q_s	θ_m	U
19 BAFFLES											
854	77.0	83.7	139.8	85.3	0.04	15,560	1,930	104.3	105.3	24.97	159.8
855	77.7	93.3	141.7	103.4	0.20	15,450	6,390	242.0	244.3	35.87	258.0
856	77.8	98.3	141.5	112.6	0.57	15,525	11,060	318.8	319.0	38.88	313.4
857	78.0	102.3	139.3	119.9	1.85	15,620	19,650	379.0	380.5	39.42	367.6
858	78.2	106.2	141.3	125.8	3.82	15,525	28,010	435.5	435.4	41.12	405.0
859	78.2	107.4	139.9	127.6	6.34	15,400	36,000	449.4	450.0	40.24	427.0
860	77.6	89.8	139.4	97.1	0.13	15,560	4,540	190.8	192.3	32.26	226.2
11 BAFFLES											
861	77.5	87.2	140.3	97.1	0.05	15,520	3,580	150.2	154.7	33.50	171.4
862	77.8	91.4	139.9	106.1	0.13	15,600	6,425	212.2	217.2	37.50	216.3
863	78.0	95.9	139.4	114.5	0.33	15,805	11,500	284.0	285.6	39.90	272.1
864	78.1	99.5	138.8	120.8	1.02	16,040	19,330	344.0	348.0	40.97	321.1
865	78.3	103.1	139.2	125.9	2.07	15,605	29,120	387.0	388.3	41.68	355.0
866	78.3	104.6	139.5	128.1	3.24	15,625	36,370	411.5	412.4	41.92	375.2
3 BAFFLES											
867	77.6	85.7	137.9	104.0	0.03	15,510	3,805	125.9	129.2	37.84	127.2
868	77.8	89.6	141.5	111.8	0.06	15,600	6,280	184.1	186.2	42.35	166.2
869	78.0	93.8	140.4	119.7	0.12	15,660	11,960	247.5	248.0	44.08	214.8
870	78.2	97.1	139.8	124.5	0.24	15,830	19,520	298.7	299.2	44.45	257.0
871	78.3	99.7	138.4	127.2	0.56	15,440	29,350	330.0	330.5	43.62	289.2
872	78.3	101.8	139.1	129.6	1.07	15,400	38,100	361.0	362.0	43.98	313.8

DATA

BAFFLES- DISK-AND-DOUGHNUT
SIZE-5.5" DISK, 2.5" HOLE

TUBE DIA.-1/2"
TUBE PITCH-25/32"
NO. OF TUBES-40

TRANSFER AREA- 26.16□'
SHELL FLUID- WATER
TUBE FLUID- WATER

RUN NUMBER	t_{t_1}	t_{t_2}	t_{s_1}	t_{s_2}	Δ P	W_t	W_s	Q_t	Q_s	θ_m	U
19 BAFFLES											
873	77.5	85.3	140.0	85.7	0.11	15,830	2,290	123.5	124.6	24.50	192.8
874	77.9	90.9	137.9	96.6	0.39	15,820	5,085	206.1	210.0	30.80	255.8
875	78.1	97.3	139.1	107.9	1.32	15,690	9,730	300.2	303.8	35.50	323.4
876	78.4	102.4	139.8	116.5	3.69	15,820	16,360	380.5	380.8	37.76	385.2
877	78.4	104.4	138.3	120.8	7.60	15,780	23,450	411.0	412.0	37.95	414.0
878	78.5	106.1	138.9	123.6	11.14	15,840	28,530	437.0	436.0	38.62	432.8
11 BAFFLES											
879	77.6	87.8	139.3	93.5	0.15	15,775	3,520	161.3	161.2	30.32	203.4
880	78.0	92.6	138.5	104.5	0.40	15,850	6,910	231.4	234.9	35.32	250.5
881	78.4	97.8	139.6	113.5	1.08	15,720	11,820	304.5	308.5	38.35	303.7
882	78.5	100.7	138.2	119.0	2.54	15,660	18,280	347.6	351.4	38.98	341.0
883	78.6	104.1	139.3	124.4	5.51	15,800	27,100	403.0	403.0	40.32	382.0
884	78.7	105.8	139.4	127.1	8.99	15,550	34,500	421.2	424.5	40.60	396.8
3 BAFFLES											
885	77.8	86.4	138.0	100.5	0.07	15,820	3,740	135.7	140.4	35.20	147.4
886	78.1	90.9	138.6	109.9	0.15	15,810	7,140	201.5	205.0	39.23	196.4
887	78.4	95.0	139.0	117.4	0.32	15,470	12,080	257.2	260.6	41.43	237.3
888	78.5	98.1	138.8	122.0	0.72	15,710	18,480	307.4	310.0	42.13	279.0
889	78.6	100.7	138.0	125.3	1.47	15,530	27,070	343.3	342.0	41.95	313.0
890	78.8	103.5	140.0	129.2	2.54	15,580	35,520	384.5	384.8	43.20	340.3

DATA

BAFFLES- DISK-AND-DOUGHNUT
SIZE-4.5" DISK, 4.0" HOLE
* See first page of Appendix for Symbols.

TUBE DIA.-1/2"
TUBE PITCH-1 3/32"
NO. OF TUBES-20

TRANSFER AREA- 13.08□'
SHELL FLUID- WATER
TUBE FLUID- WATER

RUN NUMBER	t_{t_1} *	t_{t_2}	t_{s_1}	t_{s_2}	Δ P	W_t	W_s	Q_t	Q_s	θ_m	U
19 BAFFLES											
789	75.8	88.8	138.6	106.7	0.06	7,950	3,325	102.7	105.8	39.55	198.4
790	76.1	94.5	137.1	116.5	0.15	8,000	7,160	147.2	147.2	41.50	271.2
791	76.4	99.5	139.2	123.8	0.35	7,920	12,000	183.3	184.8	43.40	323.0
792	76.6	103.9	138.8	128.8	1.25	8,140	22,600	221.7	224.6	49.97	394.5
793	76.8	106.4	139.2	131.6	2.41	7,940	31,040	235.4	236.0	42.88	419.7
794	76.8	107.7	139.0	132.9	4.03	7,915	39,820	245.0	245.3	42.53	440.3
11 BAFFELES											
819	76.4	87.9	138.7	109.3	0.03	7,895	3,195	90.8	94.0	41.15	168.8
820	76.7	94.1	138.6	119.8	0.07	7,825	7,350	136.0	137.7	43.78	237.3
821	77.0	97.6	138.7	124.7	0.15	7,855	11,725	162.2	164.2	44.32	279.7
822	77.1	101.6	138.5	129.2	0.43	7,845	20,810	192.2	193.6	44.00	333.8
823	77.3	104.0	138.7	131.6	0.90	7,850	29,300	209.6	208.8	43.83	365.5
824	77.3	105.6	138.7	132.9	1.60	7,890	38,700	223.7	223.2	43.40	394.1
3 BAFFLES											
836	76.5	84.6	138.7	113.8	0.02	7,845	2,720	63.3	67.6	45.26	107.1
837	76.7	91.3	139.8	123.7	0.04	7,940	7,440	115.8	119.6	47.80	185.3
838	76.9	95.1	138.3	128.1	0.12	7,940	14,370	144.9	146.1	47.12	235.0
839	77.0	98.0	138.8	130.9	0.17	7,900	21,000	165.8	165.9	46.95	270.0
840	77.1	100.9	140.0	133.6	0.28	7,880	29,600	187.5	187.6	47.33	302.8
841	77.1	102.0	139.4	134.2	0.41	7,975	38,020	198.1	198.9	46.55	325.2

DATA

BAFFLES- DISK-AND-DOUGHNUT
SIZE-4.5" DISK,4.0" HOLE

TUBE DIA.-5/8"
TUBE PITCH-1 1/16"
NO.OF TUBES-20

TRANSFER AREA- 16.36□'
SHELL FLUID- WATER
TUBE FLUID- WATER

RUN NUMBER	t_{t_1}	t_{t_2}	t_{s_1}	t_{s_2}	Δ P	W_t	W_s	Q_t	Q_s	θ_m	U
19 BAFFLES											
795	75.5	83.2	138.4	98.3	0.05	13,550	2,760	105.2	110.5	36.68	175.3
796	75.7	88.5	137.9	110.9	0.13	13,495	6,440	172.7	173.8	41.93	251.7
797	75.9	92.1	138.0	117.9	0.35	13,405	10,925	217.6	219.2	43.94	302.7
798	76.0	95.8	138.6	124.0	0.93	13,615	18,400	269.3	268.6	45.36	363.0
799	76.1	98.2	138.5	127.4	2.13	13,710	27,340	303.0	304.4	45.62	406.0
800	76.0	99.7	138.4	129.6	3.75	13,580	36,650	321.4	322.5	45.77	429.4
11 BAFFLES											
813	75.2	81.3	137.0	98.1	0.03	13,460	2,195	82.1	85.5	36.88	136.2
814	76.0	87.5	140.6	114.2	0.05	13,650	6,030	157.0	158.8	45.28	212.0
815	76.4	91.1	139.7	120.9	0.16	13,740	10,820	201.0	203.0	46.56	263.9
816	76.7	94.3	138.4	125.6	0.44	13,440	18,700	236.6	239.3	46.52	311.0
817	76.9	96.9	138.3	129.0	1.09	13,460	28,900	269.9	269.6	46.47	355.0
818	76.9	98.5	139.2	131.5	1.71	13,440	37,350	290.4	288.7	47.28	375.6
3 BAFFLES											
825	76.2	80.8	137.7	107.6	0.02	13,605	2,195	62.3	66.1	42.97	88.7
826	76.2	86.1	139.8	120.5	0.04	13,790	7,250	136.5	140.4	48.90	170.6
827	76.5	89.0	138.6	124.9	0.07	13,495	12,475	168.2	170.9	49.03	209.6
828	76.6	91.9	139.2	129.1	0.17	13,595	20,500	207.1	207.1	49.80	254.3
829	76.8	93.6	138.9	130.9	0.28	13,570	28,450	227.6	228.4	49.58	280.6
830	76.9	95.0	138.4	131.9	0.49	13,595	37,720	246.9	246.4	49.00	307.9

DATA

BAFFLES- HALF-MOON, AND ORIFICE
NO. OF BAFFLES- 19
* See first page of Appendix for Symbols.

TUBE DIA.-5/8"
TUBE PITCH- (SEE BELOW)
NO. OF TUBES- (SEE BELOW)

TRANSFER AREA-(SEE BELOW)
SHELL FLUID-(SEE BELOW)
TUBE FLUID- WATER

RUN NUMBER	t_{t_1} *	t_{t_2}	t_{s_1}	t_{s_2}	Δ P	W_t	W_s	Q_t	Q_s	θ_m	U
5/8" TUBE-7/8" PITCH-HALF-MOON BAFFLES,3.92" HIGH-30 TUBES-24.54 SQ. FT.-OIL "B",SHELL FLUID											
902	78.9	81.3	139.5	118.8	0.93	20,580	5,310	49.4	51.9	48.50	41.6
903	78.9	81.8	140.6	121.5	1.28	20,320	6,580	59.0	59.8	50.35	47.7
904	79.0	82.2	139.0	122.4	1.99	20,520	8,590	65.7	67.5	49.90	53.6
905	79.0	82.9	139.8	124.7	2.97	20,200	11,180	78.8	80.0	51.10	62.8
906	79.0	83.3	138.5	125.4	4.31	20,270	14,280	87.2	88.6	50.65	70.1
907	79.0	84.0	139.5	127.5	6.07	19,730	17,730	98.9	101.1	51.90	77.6
908	79.0	84.4	139.0	128.2	8.48	20,270	21,650	108.9	111.6	51.82	85.6
909	79.0	84.6	139.1	128.8	10.16	20,670	24,050	116.2	117.6	52.05	91.0
910	78.8	80.6	139.6	113.9	0.46	20,300	3,070	35.5	37.2	46.00	31.5
5/8" TUBE-1-1/16" PITCH-HALF-MOON BAFFLES,3.92" HIGH-20 TUBES-16.36 SQ.FT.-OIL "B",SHELL FLUID											
938	79.5	81.3	139.5	121.4	0.23	13,570	3,155	24.4	26.9	49.63	30.1
939	79.6	82.2	139.4	125.2	0.47	13,540	5,610	34.9	37.8	51.15	41.8
940	79.7	83.0	140.0	128.6	0.97	13,670	8,900	44.7	48.3	52.85	51.7
941	79.7	83.9	138.4	129.5	2.06	13,485	14,170	56.0	60.0	52.10	65.7
942	79.8	84.8	138.4	131.0	3.65	13,385	19,250	66.3	68.3	52.40	77.4
943	79.8	85.2	138.2	131.4	5.14	13,380	23,380	72.3	74.8	52.20	84.6
944	79.9	86.7	139.5	131.3	2.22	8,300	14,700	55.8	57.5	52.10	65.4
945	79.7	82.2	138.9	130.3	2.22	22,880	14,550	56.5	59.6	53.65	64.4
5/8" TUBE-1-1/16" PITCH-ORIFICE BAFFLES,11/16" DIA.HOLE-20 TUBES-16.36 SQ.FT.-OIL "B",SHELL FLUID											
946	78.8	79.7	139.3	110.8	1.20	13,470	1,290	12.1	17.3	44.38	16.7
947	79.5	80.9	139.9	124.0	2.46	13,455	2,690	18.6	20.2	51.40	22.1
948	79.6	82.1	141.1	127.3	6.28	13,520	5,790	33.8	37.9	53.05	38.9
949	79.6	82.9	139.8	129.0	11.83	13,625	8,940	45.4	46.0	53.00	52.3
950	79.7	83.6	140.0	130.4	18.81	13,640	12,310	53.3	56.2	53.45	61.0
951	79.7	84.2	140.3	131.3	24.25	13,640	14,560	61.0	62.9	53.80	69.3
952	79.9	84.6	138.9	130.6	32.28	13,560	17,160	64.5	67.6	52.55	75.0
953	79.7	82.3	140.5	127.3	6.85	13,555	6,060	35.7	38.1	52.70	41.4
5/8" TUBE-1-1/16" PITCH-ORIFICE BAFFLES,11/16" DIA.HOLE-20 TUBES-16.36 SQ.FT.-OIL "A",SHELL FLUID											
954	78.9	80.3	137.8	113.2	0.97	13,670	2,060	19.4	24.2	44.86	26.5
955	79.4	81.9	140.5	120.3	2.37	13,740	3,890	34.4	37.8	49.30	42.6
956	79.5	83.5	141.5	124.5	5.65	13,660	6,770	54.4	55.2	51.30	64.8
957	79.6	84.9	138.4	125.2	13.62	13,540	11,465	71.8	73.2	49.40	88.8
958	79.8	85.9	138.9	126.8	21.68	13,480	14,910	82.9	86.8	50.00	101.4
959	79.9	86.9	138.3	127.5	32.93	13,600	18,820	95.2	97.2	49.50	117.6

DATA

BAFFLES- DISK-AND-DOUGHNUT
SIZE-4.5" DISK,4.0" HOLE
* See first page of Appendix for Symbols.

TUBE DIA. (SEE BELOW)
TUBE PITCH- (SEE BELOW)
NO.OF TUBES-20

TRANSFER AREA- (SEE BELOW)
SHELL FLUID- (SEE BELOW)
TUBE FLUID- WATER

RUN NUMBER	t_{t_1} *	t_{t_2}	t_{s_1}	t_{s_2}	Δ P	W_t	W_s	Q_t	Q_s	θ_m	U
5/8" TUBE-1-1/16" PITCH-16.36 SQ.FT.-OIL "B",SHELL FLUID-19 BAFFLES											
925	78.8	79.6	139.4	114.2	0.06	13,690	1,680	11.6	19.9	46.50	15.3
926	78.9	81.0	141.5	129.5	0.17	13,600	5,825	28.6	33.3	55.20	31.6
927	79.0	82.0	140.6	131.5	0.38	13,580	9,660	39.7	41.8	55.45	43.7
928	79.1	82.6	138.6	131.3	0.74	13,540	14,340	47.4	50.2	54.05	53.6
929	79.1	83.5	139.4	133.0	1.28	13,450	19,500	58.1	59.3	54.85	64.8
930	79.2	83.8	139.3	133.5	1.88	13,840	23,950	64.4	66.3	54.90	71.7
931	79.2	81.0	139.8	127.6	0.16	13,620	4,850	23.4	28.1	53.45	26.8
11 BAFFLES											
918	78.5	79.5	139.4	122.6	0.07	13,480	2,420	12.5	19.3	51.60	14.9
919	78.7	80.4	140.0	131.0	0.10	13,280	5,920	21.9	25.4	55.80	24.0
920	78.9	81.1	140.5	133.2	0.20	13,490	9,590	30.3	33.0	56.85	32.6
921	78.9	81.7	140.7	134.4	0.34	13,560	13,810	38.7	41.4	57.25	41.3
922	78.9	82.1	138.8	133.4	0.51	13,500	17,560	43.2	45.9	55.60	47.5
923	78.9	82.5	140.1	135.0	0.73	13,590	21,520	49.3	52.7	56.77	53.2
924	78.9	82.8	139.2	134.5	0.95	13,710	25,170	53.1	55.4	55.95	58.0
3 BAFFLES											
911	78.1	79.0	139.2	128.5	0.05	13,650	3,395	11.6	17.3	54.95	12.9
912	78.5	79.7	142.8	136.2	0.07	13,610	6,315	16.3	19.9	60.45	16.5
913	78.5	79.9	141.4	136.4	0.10	13,600	9,045	19.0	21.5	59.62	19.5
914	78.5	80.3	139.5	135.8	0.16	13,570	14,570	23.3	25.9	58.25	24.5
915	78.6	80.5	138.3	135.1	0.23	13,300	19,170	25.9	28.8	57.10	27.8
916	78.6	80.8	138.8	135.9	0.33	13,615	23,060	29.6	31.4	57.61	31.4
917	78.6	81.0	138.7	136.0	0.42	13,620	26,090	32.3	34.2	57.51	34.3
1/2" TUBE-1-3/32" PITCH-13.08 SQ.FT.-19 BAFFLES-OIL "B",SHELL FLUID											
932	78.9	80.5	138.3	125.5	0.06	8,070	2,415	13.2	14.7	52.00	19.3
933	79.1	82.3	139.1	129.7	0.15	7,750	5,730	24.2	25.8	53.62	34.5
934	79.3	83.9	140.7	133.4	0.38	7,840	10,580	35.8	37.1	55.40	49.5
935	79.5	85.1	140.2	134.3	0.75	7,885	16,380	44.4	45.8	54.96	61.8
936	79.5	85.7	138.9	133.8	1.20	7,970	21,170	49.8	51.2	53.75	70.8
937	79.6	86.5	138.8	134.2	1.73	7,920	25,220	54.7	55.6	53.40	78.2
OIL "A", SHELL FLUID											
960	79.3	81.5	138.8	121.4	0.09	8,015	2,210	17.0	18.5	49.40	26.3
961	79.6	84.0	139.0	128.0	0.13	7,915	6,790	34.2	35.8	51.60	50.7
962	79.8	85.5	139.2	130.2	0.28	7,920	10,840	44.8	46.7	52.05	65.7
963	79.9	86.5	138.0	130.7	0.63	7,895	15,320	52.5	54.4	51.18	78.4
964	79.9	87.8	138.4	132.1	1.19	7,890	20,680	62.0	63.3	51.38	92.3-
965	80.0	88.7	139.1	133.2	1.59	7,915	24,770	68.6	70.5	51.80	101.3
966	79.8	83.9	137.9	130.4	0.82	14,110	16,950	57.9	61.3	52.20	84.7
967	80.0	89.4	138.8	132.1	0.82	5,715	16,930	53.3	54.5	50.78	80.2
OIL "C", SHELL FLUID											
968	79.0	80.4	141.5	125.9	0.15	7,900	1,780	10.9	13.1	53.75	15.5
969	79.2	80.9	139.4	129.4	0.17	7,950	3,410	13.5	16.1	54.20	19.1
970	79.5	81.5	140.6	133.6	0.20	7,785	5,240	16.2	17.4	56.60	21.9
971	79.6	82.0	140.2	135.0	0.28	7,870	7,660	19.1	18.7	56.78	25.7
972	79.5	82.5	138.8	133.6	0.43	7,870	10,650	23.4	26.5	55.18	32.4
973	79.6	83.2	139.9	135.8	0.73	7,875	14,130	28.4	28.0	56.44	38.4
974	79.7	83.7	140.4	136.4	1.02	8,135	17,770	32.5	34.2	56.39	44.1
975	79.8	84.3	140.1	136.5	1.50	7,905	21,100	35.8	36.0	56.23	48.6
976	79.9	81.0	137.0	126.2	0.12	7,990	1,805	9.27	9.19	51.10	13.9
OIL "C", SHELL FLUID-TWO-PASS TUBE FLUID											
977	79.5	82.2	141.7	129.8	0.09	4,140	2,035	11.1	11.4	54.75	15.5
978	79.5	83.2	139.8	132.3	0.17	3,885	3,965	14.1	13.9	54.70	19.7
979	79.6	84.2	138.4	132.8	0.27	3,870	6,900	17.6	18.1	53.74	25.1
980	79.5	84.9	137.9	133.4	0.40	3,890	9,665	20.9	20.8	53.45	29.9
981	79.5	86.5	139.3	135.2	0.82	3,868	15,380	27.1	29.6	54.18	38.2
982	79.5	88.0	140.0	136.4	1.45	3,940	20,680	33.3	34.8	54.40	46.8
983	79.8	89.9	139.6	135.7	0.83	2,855	15,090	28.9	28.4	52.75	41.8
984	80.0	92.5	139.3	135.5	0.83	2,207	15,180	27.6	27.4	51.06	41.4
985	79.2	82.3	138.6	134.2	0.83	10,025	14,875	30.6	31.3	55.65	42.0

DATA

ZERO BAFFLES
* See first page of Appendix for Symbols.

TUBE DIA.- (SEE BELOW)
TUBE PITCH-(SEE BELOW)
NO.OF TUBES-(SEE BELOW)

TRANSFER AREA-(SEE BELOW)
SHELL FLUID-WATER
TUBE FLUID-WATER

RUN NUMBER	t_{t_1} *	t_{t_2}	t_{s_1}	t_{s_2}	ΔP	W_t	W_s	Q_t	Q_s	θ_m	U
3/8" TUBE-1/2" PITCH-98 TUBES - 48.1 SQ.FT. TRANSFER AREA											
312	60.7	75.6	139.8	100.7		18,020	6,905	268.0	270.5	51.15	108.9
313	60.7	78.3	139.5	105.4		18,050	9,380	317.5	319.5	52.55	125.6
314	60.8	83.0	139.0	111.7		18,050	14,780	400.5	403.5	53.40	156.0
315	61.1	88.5	140.5	117.8		18,320	22,150	501.0	503.0	54.35	191.7
316	61.2	90.9	140.1	119.8		18,430	27,200	547.5	550.5	53.68	212.0
317	61.2	92.5	139.5	121.5	0.07	18,220	31,750	571.0	572.5	53.37	222.6
318	61.1	93.5	139.2	122.1	0.09	18,330	34,860	594.0	597.0	53.00	233.1
319	61.1	94.6	138.8	123.0	0.11	18,230	38,700	609.5	613.0	52.55	241.2
320	61.2	96.2	139.5	124.8	0.12	18,160	43,370	635.5	637.0	52.85	250.0
569	60.4	84.2	140.8	113.8		18,350	16,080	435.8	433.5	55.00	164.7
570	60.5	87.9	140.1	117.6		18,360	22,300	503.8	501.0	54.55	192.0
571	60.4	91.0	140.4	120.5		18,340	28,170	560.5	559.5	54.50	214.0
572	60.3	93.0	139.8	122.3		18,240	33,970	595.0	594.5	54.20	228.2
3/8" TUBE-11/16" PITCH-52 TUBES-25,51 SQ.FT. TRANSFER AREA											
274	59.0	77.2	139.9	110.4		9,790	6,170	178.2	181.8	57.15	122.3
275	58.9	77.0	139.5	111.0		9,800	6,350	177.7	181.0	57.15	121.9
276	58.9	80.8	139.3	117.4	0.04	9,845	10,000	216.0	219.0	58.45	144.8
277	59.0	83.7	139.3	121.9	0.07	9,950	14,320	245.5	249.2	59.15	162.8
278	59.1	86.9	138.9	124.7	0.09	9,980	20,300	278.0	287.0	58.55	186.2
279	59.1	90.0	139.3	127.6	0.11	10,040	26,750	310.0	313.8	58.52	207.7
280	59.1	91.7	139.7	128.9	0.14	10,020	30,520	326.5	330.6	58.40	219.2
281	59.0	93.8	139.5	129.9	0.16	9,505	34,670	330.8	335.0	57.40	225.8
282	59.0	93.7	140.8	130.7	0.16	10,010	34,620	347.0	349.6	58.65	231.9
283	59.0	94.9	139.9	130.8	0.16	9,920	39,650	356.3	360.7	57.30	243.8
284	58.7	81.2	138.1	117.9	0.04	9,935	11,250	223.5	227.0	58.00	151.1
1/2" TUBE-19/32" PITCH-66 TUBES-43.18 SQ.FT. TRANSFER AREA											
373	60.4	68.7	140.1	100.1	0.09	26,100	5,470	216.6	218.8	54.05	92.8
374	60.5	69.8	139.6	103.5		26,010	6,820	242.0	246.2	55.35	101.3
375	60.8	74.7	140.8	115.1		25,980	14,120	361.0	363.2	60.10	139.1
376	60.8	76.7	140.0	118.3		25,980	19,100	413.0	415.4	60.40	158.3
377	60.8	79.8	140.9	121.4	0.10	26,100	25,600	495.0	498.5	60.88	188.3
378	60.8	81.8	140.7	123.4		26,010	31,800	547.0	549.0	60.70	208.8
379	60.8	82.9	139.1	124.3	0.11	26,010	38,890	576.0	575.5	59.80	223.2
380	60.6	77.1	139.1	118.3	0.09	25,860	20,560	426.0	427.5	59.85	164.8
381	60.5	72.1	139.9	110.1		25,860	10,170	301.7	303.0	58.20	120.1
1/2" TUBE-25/32" PITCH-40 TUBES-26.16 SQ.FT. TRANSFER AREA											
675	66.1	73.4	136.0	105.6	0.07	15,900	3,990	116.1	121.2	50.25	88.3
676	66.3	79.4	139.3	116.4	0.09	15,840	9,230	207.4	211.0	54.85	144.6
677	66.3	82.0	138.3	120.9		15,750	14,250	246.8	248.0	55.45	170.1
678	66.4	84.6	139.1	124.2		15,750	19,120	286.2	285.4	56.10	195.1
679	66.5	86.9	138.5	125.9		15,770	25,600	321.1	321.0	55.40	221.6
680	66.5	89.0	138.6	127.7	0.11	15,820	32,880	356.0	358.3	55.35	246.0
681	66.6	91.3	138.7	129.4	0.14	15,690	41,700	387.5	387.7	54.75	270.7
1/2" TUBE-1-3/32" PITCH-20 TUBES-13.08 SQ.FT. TRANSFER AREA											
400	61.4	72.5	139.5	120.8		7,945	4,705	88.0	88.0	63.06	106.6
401	61.7	76.0	139.6	124.3		7,925	7,415	112.8	113.6	63.08	136.7
402	62.2	79.3	140.0	127.7		7,755	10,890	132.3	134.0	63.10	160.3
403	62.3	81.6	138.9	129.4	0.02	7,760	15,790	149.5	150.9	62.08	184.0
404	62.2	81.8	140.4	130.5		7,855	15,650	153.9	155.8	63.30	185.8
405	62.2	83.5	140.5	131.8	0.03	7,890	19,560	167.8	169.0	63.02	203.6
406	62.3	85.2	139.6	132.4	0.05	7,825	25,130	179.4	181.0	62.00	221.2
407	62.3	87.0	139.9	133.5	0.07	7,810	30,560	192.9	193.7	61.65	239.2
408	62.3	87.1	140.8	134.4		7,880	30,600	195.2	196.7	62.45	238.8
409	62.2	87.9	139.8	134.0	0.07	7,870	35,500	202.4	204.8	61.30	252.5
410	62.0	88.9	139.3	134.1		7,915	41,320	212.6	215.0	60.60	268.2
5/8" TUBE-7/8" PITCH-30 TUBES-24.54 SQ.FT. TRANSFER AREA											
480	61.4	68.5	139.5	108.2		20,720	4,735	146.6	148.2	58.10	102.8
481	61.5	70.0	139.1	112.3		21,450	6,820	182.3	183.2	59.43	124.9
482	61.5	70.0	138.9	112.2		21,540	6,835	183.2	182.9	59.40	125.7
483	61.5	70.3	139.2	112.0		20,320	6,615	178.8	180.2	59.25	122.8
484	61.7	72.5	141.9	119.4		20,340	9,825	219.7	221.0	63.30	141.4
485	61.9	73.9	138.4	121.4		20,340	14,600	244.8	247.3	62.00	160.8
486	62.0	76.5	138.9	125.6		20,430	22,250	295.7	296.6	63.03	191.0
487	62.0	78.3	139.7	127.8		20,490	28,120	333.3	334.8	63.60	213.4
488	62.0	79.8	140.5	129.7	0.09	20,430	33,890	363.0	363.8	64.15	230.6
489	62.0	80.7	140.3	130.9		20,430	40,460	382.2	382.7	64.13	242.8
490	61.7	74.2	139.0	122.5		20,810	15,830	259.6	260.7	62.84	168.2