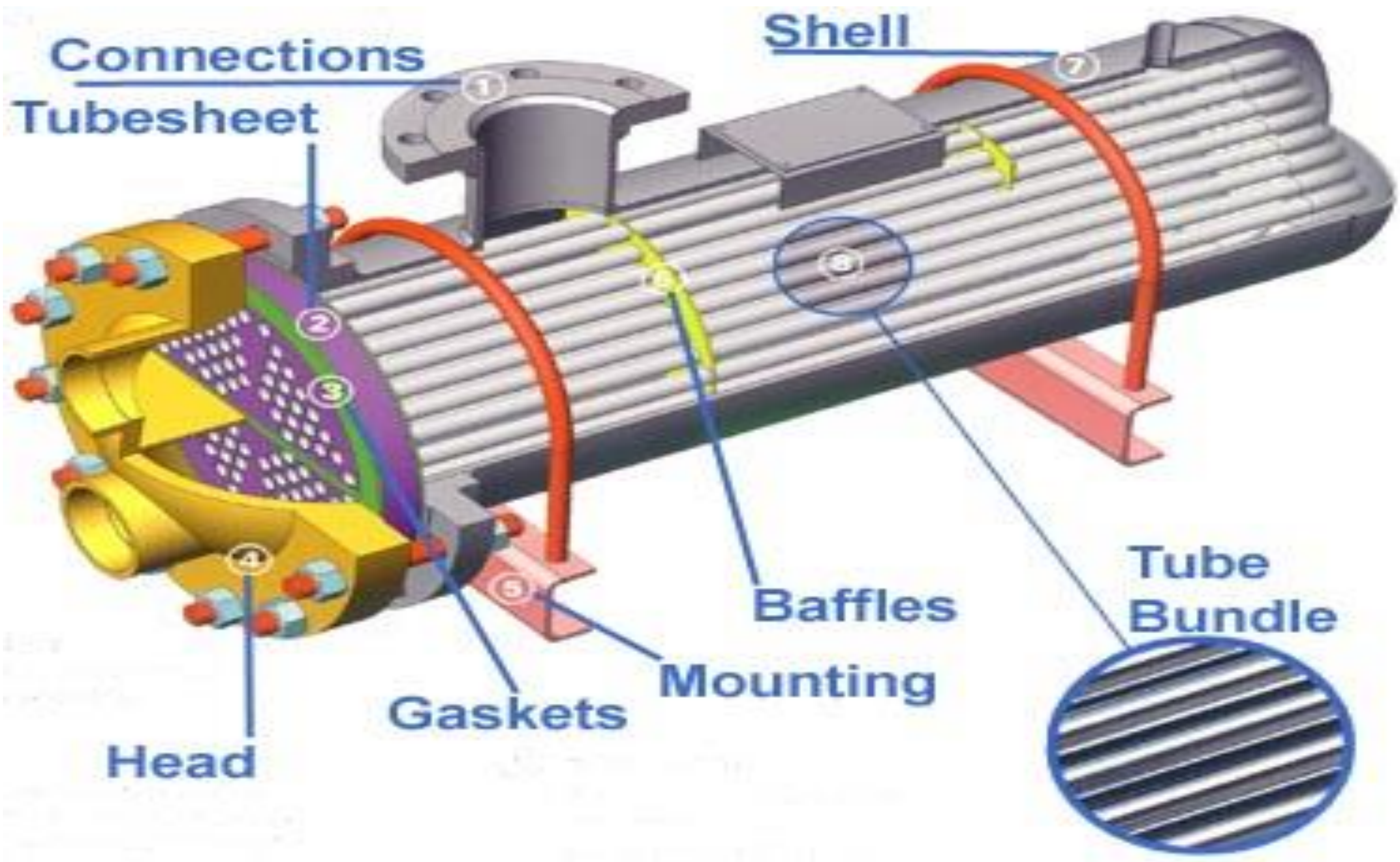
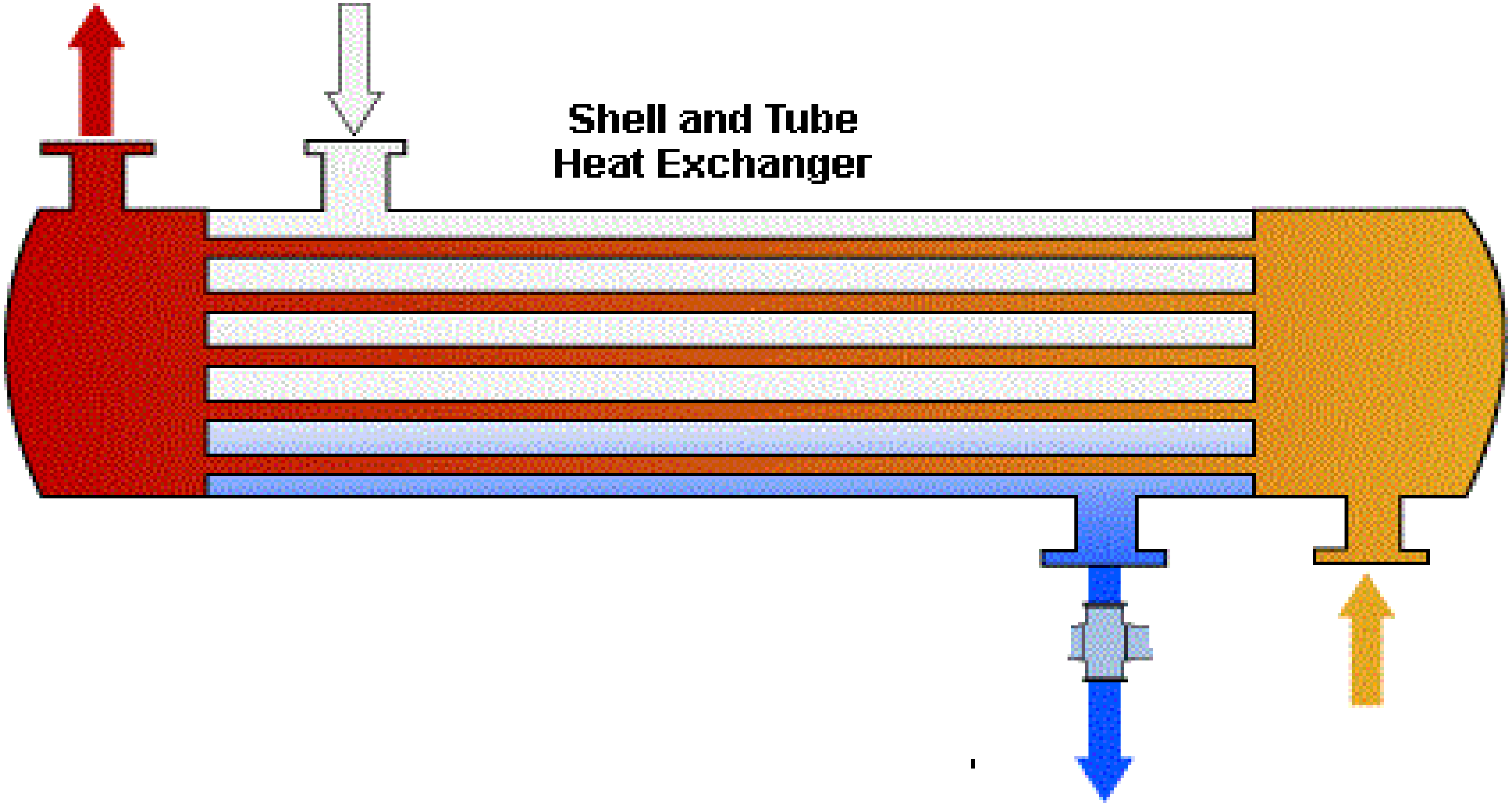
Heat Exchanger

CHE133

Engr. Conrado Monterola

Heat Exchanger




Shell and Tube
Heat Exchanger

Types of flow arrangement

- 1. Parallel flow heat exchanger
- 2. Counter-flow heat exchanger
- 3. Cross-flow heat exchanger

Parallel flow heat exchanger

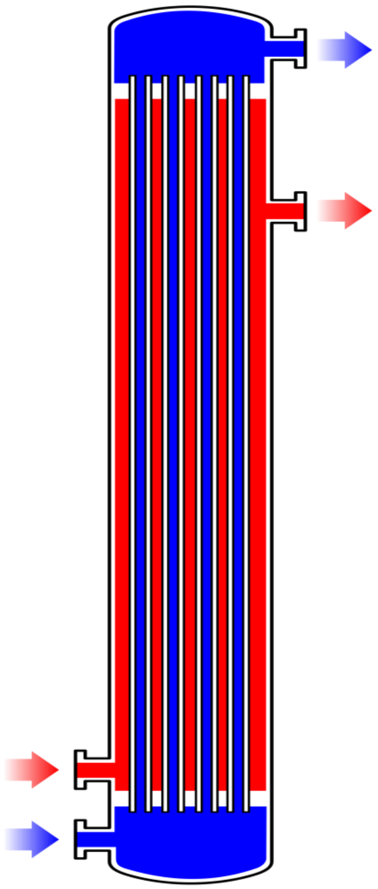
- The two fluids enter the heat exchanger at the same end,
- and travel in parallel to one another to the other side.

Parallel flow heat exchanger

Parallel Flow

Single Pass tube side

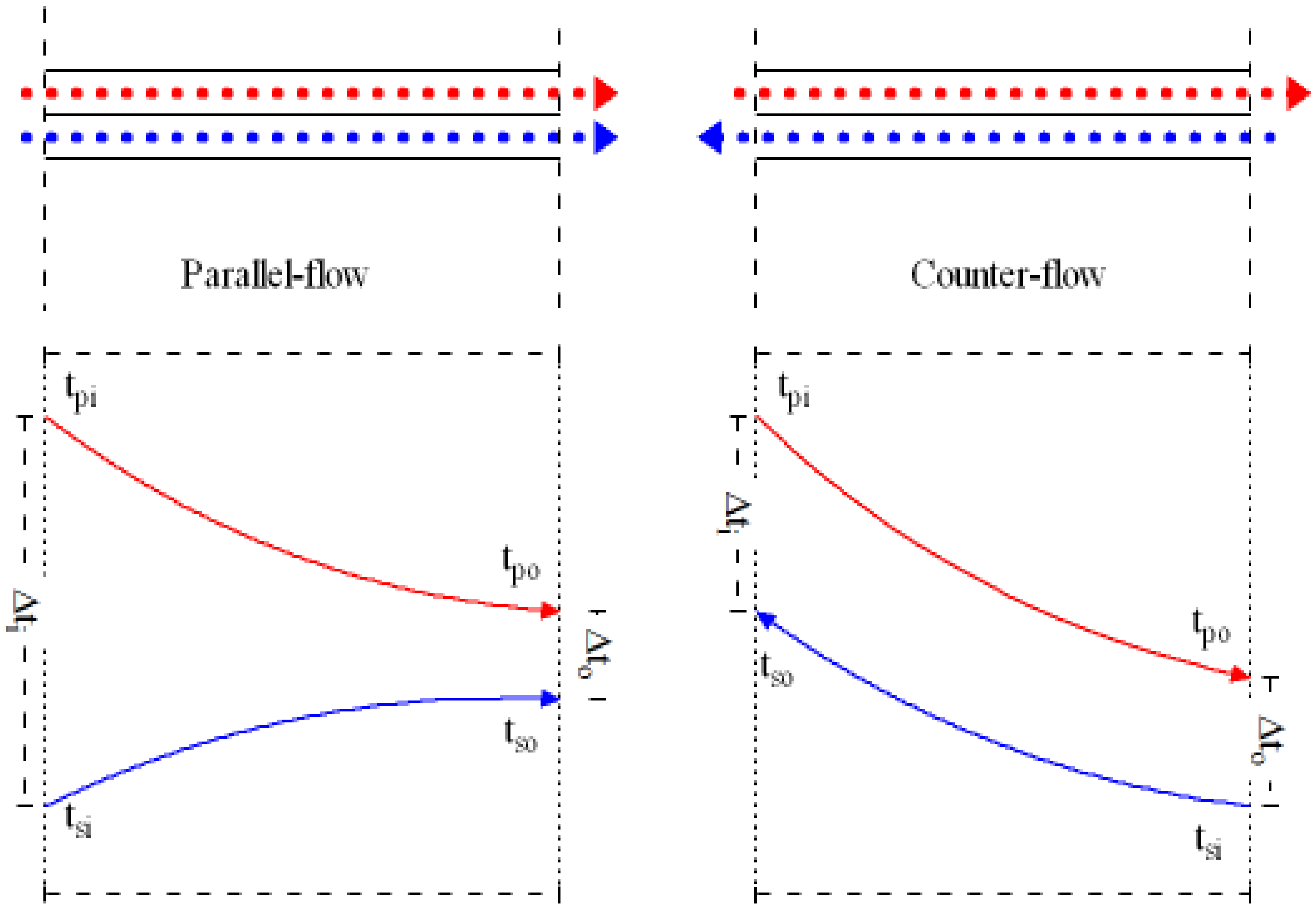
Single Pass shell side



1-1 shell and tube heat exchanger

Counter-flow heat exchanger

- 1. The fluids enter the exchanger from opposite ends.
- 2. The counter current design is the most efficient,
- Because it can transfer the most heat due to the fact that the average temperature difference along any unit length is greater.



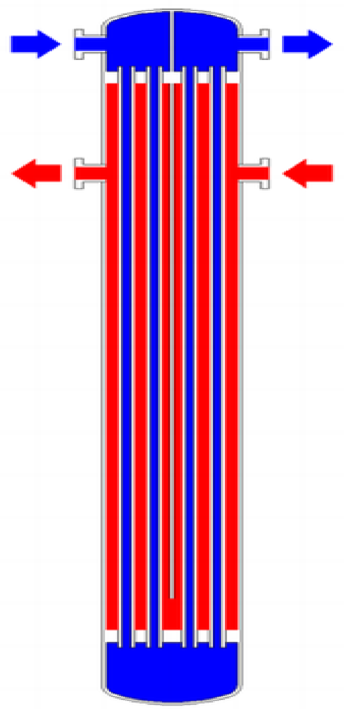
Parallel-flow
Counter-flow
t_{pi}
t_{po}
t_{si}
t_{so}
Δt_i
Δt_o
t_{pi}
t_{po}
t_{so}
t_{si}
Δt_i
Δt_o

Counter-flow heat exchanger

Countercurrent flow

Double Pass tube side

Double Pass shell side

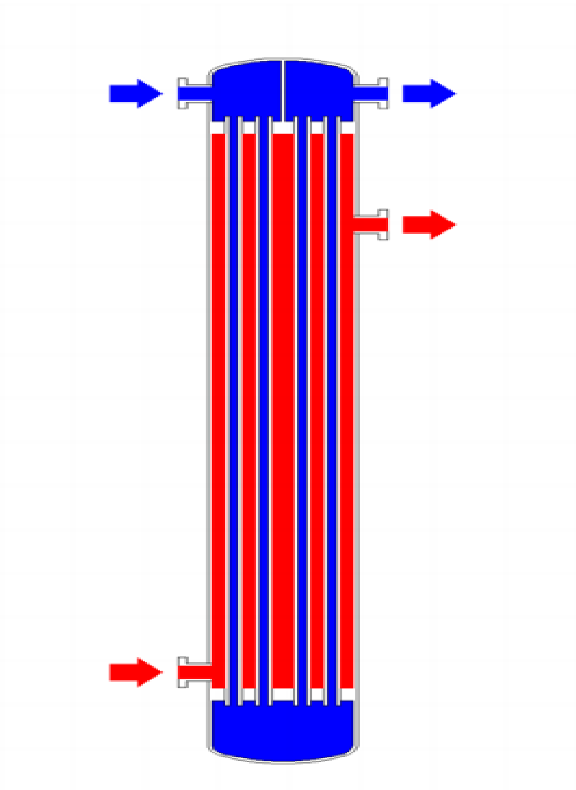


2-2 shell and tube heat exchanger

Cross-flow heat exchanger

- the fluids travel roughly perpendicular to one another through the exchanger.

Cross-flow heat exchanger



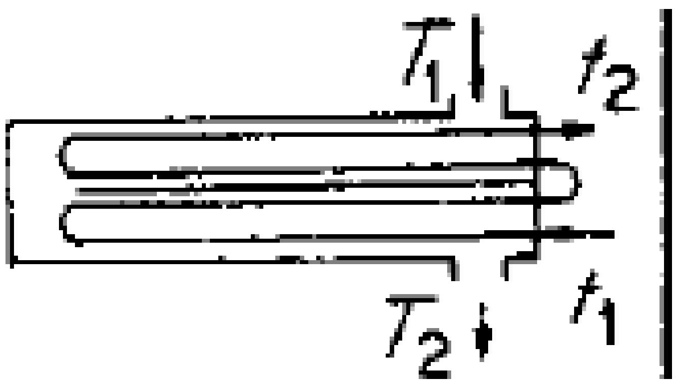
Cross flow

Double Pass tube side

Single pass shell side

1-2 shell and tube heat exchanger

Seat work 1



1. **How many tube pass?**
2. **How many shell pass?**
3. **This is a __-__shell and tube heat exchanger.**
4. **What is the flow arrangement?**

Plate Heat exchanger

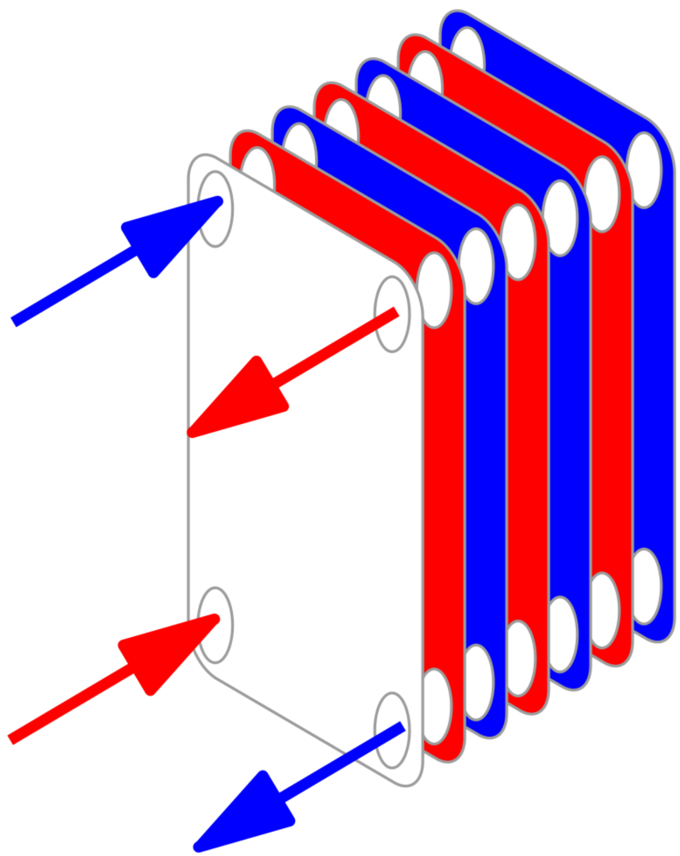
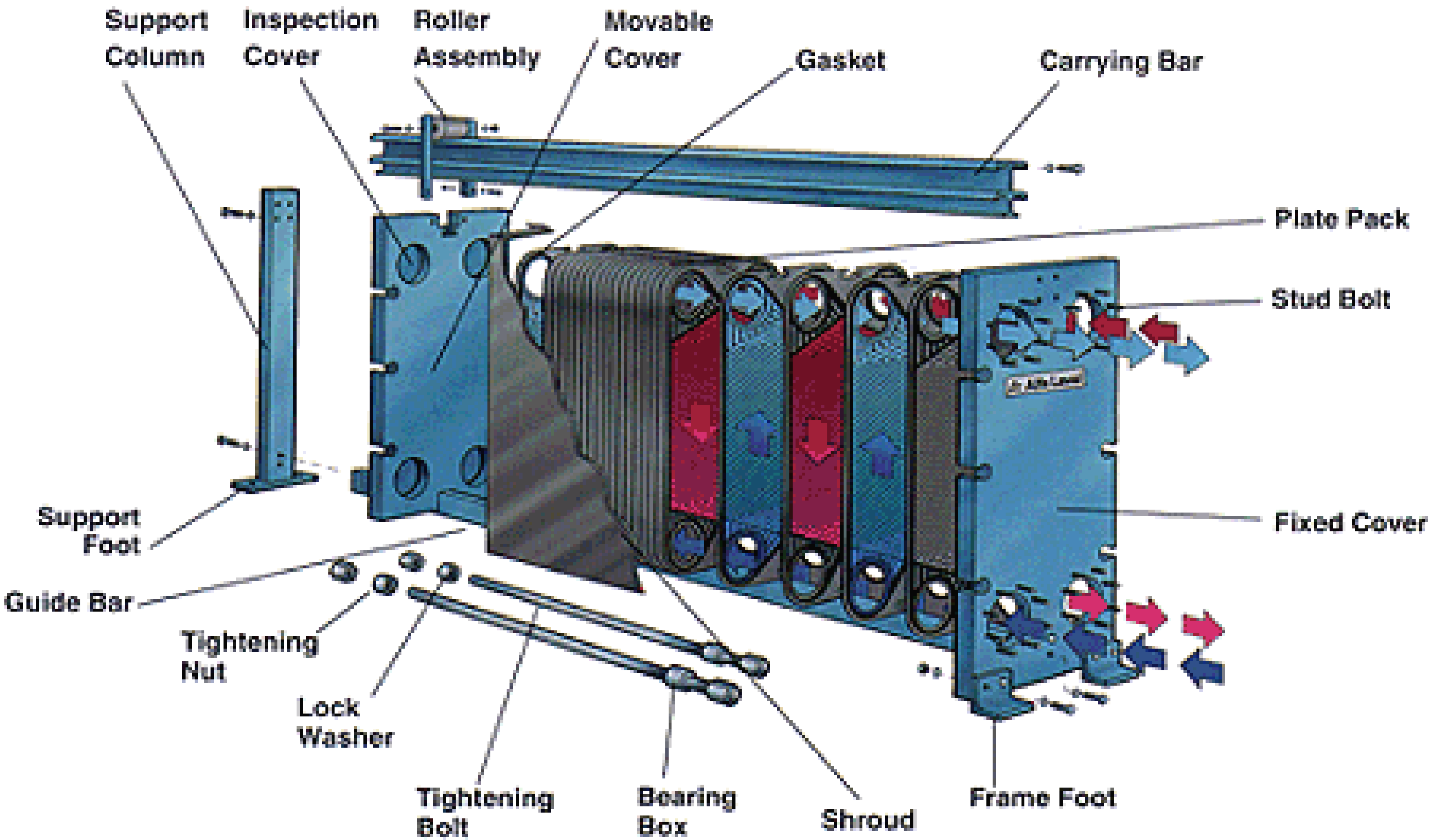


Plate Heat exchanger

Plate Heat exchanger



Fourier’s Law (Heat Conduction)

$$\frac{dq}{dA} = -k\frac{\partial T}{\partial n}$$

Where q is rate of heat transfer

A is area

T is temperature

k is thermal conductivity

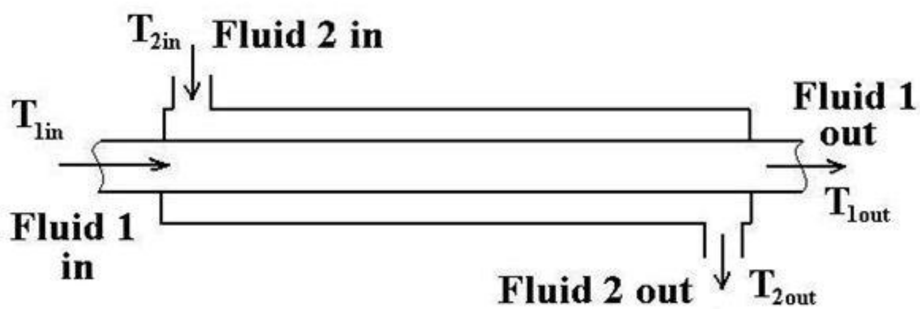
n is distance measured normal to the surface or thickness.

Newton's Law (Heat Convection)

$$q = hA(T_h - T_c)$$

Where h is the heat transfer coefficient

Double-pipe heat exchanger



Double Pipe Heat Exchanger
Parallel Flow

Double-pipe heat exchanger

Double-pipe heat exchanger

Design equation for double pipe heat exchanger

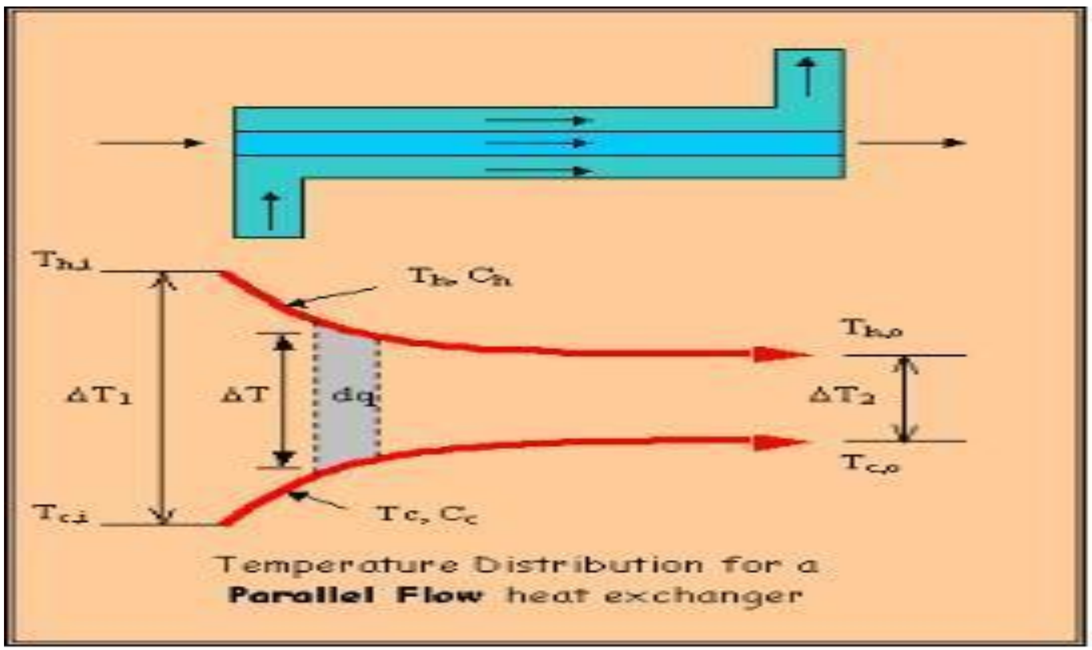
$$q = U\,A\,\Delta T_{LMTD}$$

Where:

LMTD stands for log mean temperature difference.

ΔT_{LMTD}

$$\Delta T_{LMTD} = \frac{\Delta T_2 - \Delta T_1}{\ln\left(\Delta T_2 \big/ \Delta T_1\right)}$$



Sample Problem 1

Approximate the double pipe heat exchanger tube ***area*** needed to heat coconut oil from **30°C to 70°C** flowing at **100 kg/s**. Assume that the **overall heat transfer coefficient** is **405 W/m2.°C**. The heating water enters the heat exchanger in the other side of the heat exchanger **(counter-current**) at **100°C and exits at 80°C**. Assume that coconut oil has a specific heat of **3.8 J/g°C. What are the "approach"? Calculate the heating and cooling range?**

Sample problem 2

A heat exchanger is required to heat continuously **20 kg/s of coconut oil** from **30°C to 80°C** by means of **25 kg/s of hot water**, inlet temperature of **90°C**. Assuming a constant overall heat transfer coefficient of **2 kW/m^2-K**, calculate the total surface area required in a counterflow double pipe heat exchanger . **Cpwater = 4.18kJ/kg-K Cpcoconutoil = 3.8 kJ/kg-K.**

SEAT WORK 1

Approximate the heat exchanger tube ***area*** needed to heat coconut oil from **30°C to 70°C** flowing at **100 kg/s**. Assume that the **overall heat transfer coefficient** is **405 W/m^2.°C.** The heating water enters the heat exchanger at the same side of the heat exchanger (**parallel flow**) at **100°C and exits at 80°C**. Assume that coconut oil has a specific heat of **3.8 J/g°C.**

Converting **heat exchanger area** to **pipe/tube dimensions**

- Calculate **the area** of **20 pcs of 1/2 in outer diameter with BWG gage 20 and 20 ft long.**
- **P11-42 Perry 8th ed**
- **Table 11-12**

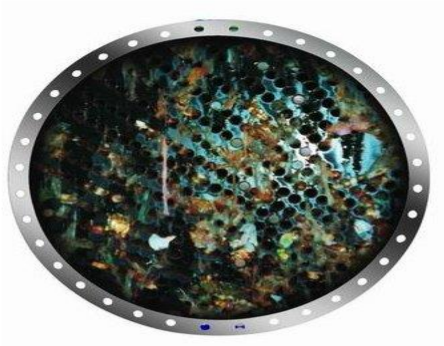
TABLE 11-12 Characterstics of Tubing (From *Standards of the Tubular Exchanger Manufacturers Association*, 8th Ed., 1999; 25 North Broadway, Tarrytown, N.Y.)

Tube O.D., in.	B.W.G. gage	Thickness, in.	Internal area, in.^{2}	Sq. ft. external surface per foot length	Sq. ft. internal surface per foot length	Weight per ft. length steel, lb*	Tube I.D., in.	Moment of inertia, in.^{4}	Section modulus, in.^{3}	Radius of gyration, in.	Constant C†	O.D. / I.D.	Transverse metal area, in.^{3}
1/4	22	0.028	0.0296	0.0654	0.0508	0.066	0.194	0.00012	0.00098	0.0791	46	1.289	0.0195
	24	0.022	0.0333	0.0654	0.0539	0.054	0.206	0.00010	0.00083	0.0810	52	1.214	0.0158
	26	0.018	0.0360	0.0654	0.0560	0.045	0.214	0.00009	0.00071	0.0823	56	1.168	0.0131
	27	0.016	0.0373	0.0654	0.0571	0.040	0.218	0.00008	0.00065	0.0829	58	1.147	0.0118
3/8	18	0.049	0.0603	0.0982	0.0725	0.171	0.277	0.00068	0.0036	0.1166	94	1.354	0.0502
	20	0.035	0.0731	0.0982	0.0798	0.127	0.305	0.00055	0.0029	0.1208	114	1.230	0.0374
	22	0.028	0.0799	0.0982	0.0835	0.104	0.319	0.00046	0.0025	0.1231	125	1.176	0.0305
	24	0.022	0.0860	0.0982	0.0867	0.083	0.331	0.00038	0.0020	0.1250	134	1.133	0.0244
1/2	16	0.065	0.1075	0.1309	0.0969	0.302	0.370	0.0021	0.0086	0.1555	168	1.351	0.0888
	18	0.049.	0.1269	0.1309	0.1052	0.236	0.402	0.0018	0.0071	0.1604	198	1.244	0.0694
	20	0.035	0.1452	0.1309	0.1126	0.174	0.430	0.0014	0.0056	0.1649	227	1.163	0.0511
	22	0.028	0.1548	0.1309	0.1162	0.141	0.444	0.0012	0.0046	0.1672	241	1.126	0.0415
5/8	12	0.109	0.1301	0.1636	0.1066	0.601	0.407	0.0061	0.0197	0.1865	203	1.536	0.177
	13	0.095	0.1486	0.1636	0.1139	0.538	0.435	0.0057	0.0183	0.1904	232	1.437	0.158
	14	0.083	0.1655	0.1636	0.1202	0.481	0.459	0.0053	0.0170	0.1939	258	1.362	0.141
	15	0.072	0.1817	0.1636	0.1259	0.426	0.481	0.0049	0.0156	0.1972	283	1.299	0.125
	16	0.065	0.1924	0.1636	0.1296	0.389	0.495	0.0045	0.0145	0.1993	300	1.263	0.114
	17	0.058	0.2035	0.1636	0.1333	0.352	0.509	0.0042	0.0134	0.2015	317	1.228	0.103
	18	0.049	0.2181	0.1636	0.1380	0.302	0.527	0.0037	0.0119	0.2044	340	1.186	0.089
	19	0.042	0.2299	0.1636	0.1416	0.262	0.541	0.0033	0.0105	0.2067	359	1.155	0.077
	20	0.035	0.2419	0.1636	0.1453	0.221	0.555	0.0028	0.0091	0.2090	377	1.126	0.065
3/4	10	0.134	0.1825	0.1963	0.1262	0.833	0.482	0.0129	0.0344	0.2229	285	1.556	0.259

Overall heat transfer coefficient(U_o)

$$\frac{1}{U_o} = \frac{D_o}{D_i h_i} + \frac{x_w D_0}{k_m D_L} + \frac{1}{h_o}$$

D_o is the outside diameter of the pipe
D_i is the inside diameter of the pipe
D_L is the log mean of diameter
h_o is the heat transfer coefficient on the outside of the pipe
h_i is the heat transfer coefficient on the inside of the pipe
k_m is the thermal conductivity of the tube
x_w is the thickness of the tube



U and Fouling factors

$$\frac{1}{U_o} = \frac{D_o}{D_i h_i} + \frac{D_o}{D_i h_{di}} + \frac{x_w D_0}{k_m D_L} + \frac{1}{h_o} + \frac{1}{h_{do}}$$

h_{di} and h_{do} are heat transfer coefficients for dirt and scales(fouling factors) inside and outside of tubes. Perry p.11-4

P.11-4 Perry 8th

$$U_o = \frac{1}{1/h_o + R_{do} + xA_o/k_w A_{wm} + (1/h_i + R_{di})A_o/A_i} \qquad (11\text{-}2)$$

Example 11.1 (Mc Cabe 5th ed.)

Methanol is flowing in the inner pipe of a double-pipe exchanger is cooled with water flowing in the jacket. The inner pipe is made from **1/2-in BWG 20**. The thermal conductivity of steel is **26 Btu/ft.h.°F**. The heat transfer coefficient for methanol is **180 Btu/ft^2.h.°F** and for water, **300 Btu/ft^2.h.°F.**

What is the overall heat transfer coefficient based on the outside diameter of the pipe?

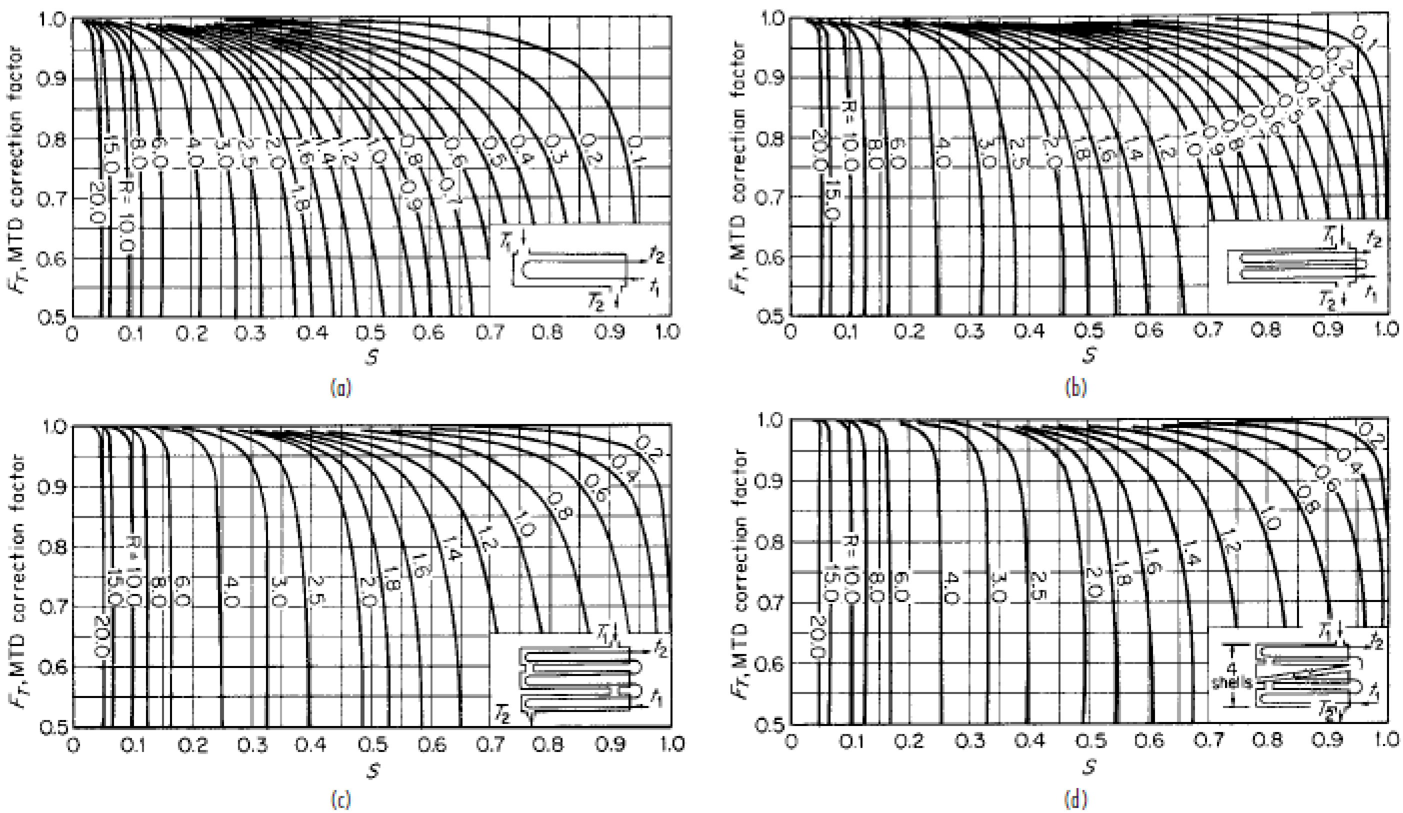
Seat Work 3

Methanol is flowing in the inner pipe of a double-pipe exchanger is cooled with water flowing in the jacket. The inner pipe is made from **1/2-in BWG gage 20 pipe**. The thermal conductivity of steel is **26 Btu/ft.h.°F**. The heat transfer coefficient for methanol is **180 Btu/ft^2.h.°F** and for water, **300 Btu/ft^2.h.°F.** The fouling factor inside and outside of the tube is **1000 Btu/ft^2.h.°F** and **500 Btu/ft^2.h.°F** respectively.

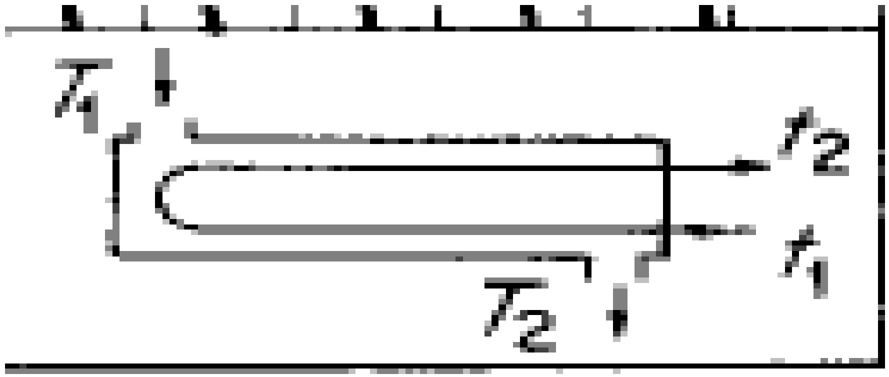
What is the overall heat transfer coefficient based on the outside diameter of the pipe?

Shell and Tube Heat Exchanger Calculations

11-6 HEAT-TRANSFER EQUIPMENT



Shell and Tube Heat Exchanger Calculations



$R = (T1 - T2)/(t2 - t1)$ and $S = (t2 - t1)/(T1 - t1)$.

Shell and Tube Heat Exchanger Calculations

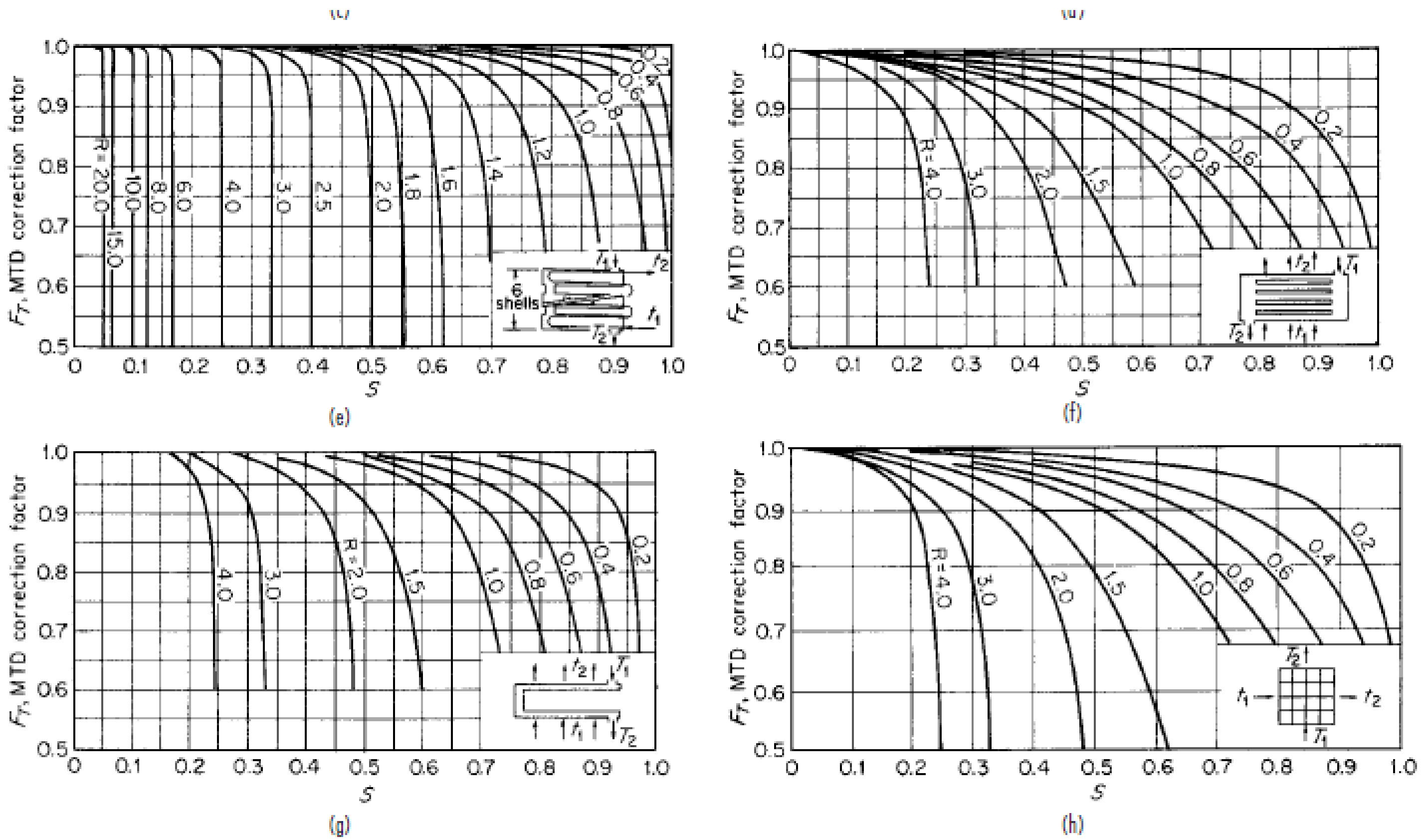


FIG. 11-4 LMTD correction factors for heat exchangers. In all charts, $R = (T_1 - T_2)/(t_2 - t_1)$ and $S = (t_2 - t_1)/(T_1 - t_1)$. (*a*) One shell pass, two or more tube passes. (*b*) Two shell passes, four or more tube passes. (*c*) Three shell passes, six or more tube passes. (*d*) Four shell passes, eight or more tube passes. (*e*) Six shell passes, twelve or more tube passes. (*f*) Cross-flow, one shell pass, one or more parallel rows of tubes. (*g*) Cross-flow, two passes, two rows of tubes; for more than two passes, use $F_T = 1.0$. (*h*) Cross-flow, one shell pass, one tube pass, both fluids unmixed. (*i*) Cross-flow (drip type), two horizontal passes with U-bend connections

Geankoplis 4.9.1

EXAMPLE 4.9-1. Temperature Correction Factor for a Heat Exchanger

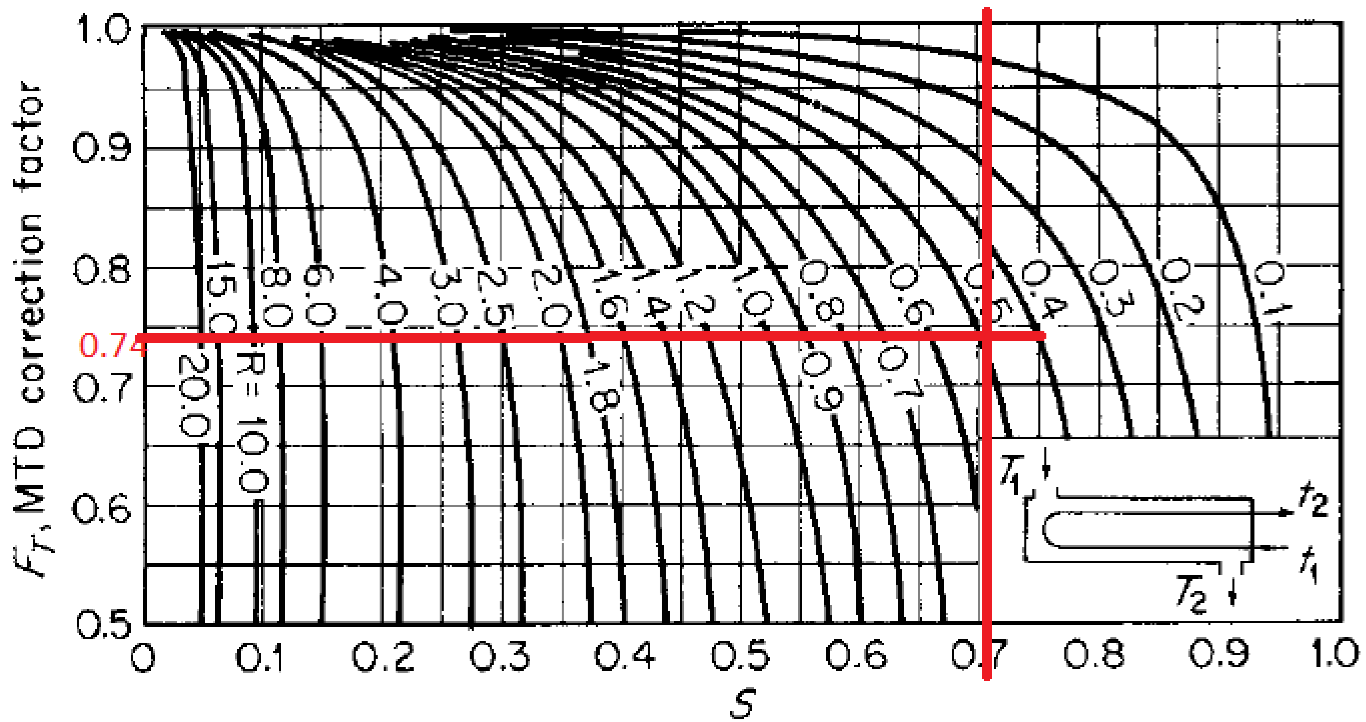
A 1–2 heat exchanger containing one shell pass and two tube passes heats 2.52 kg/s of water from 21.1 to 54.4°C by using hot water under pressure entering at 115.6 and leaving at 48.9°C. The outside surface area of the tubes in the exchanger is $A_o = 9.30\ \mathrm{m}^2$.

(a) Calculate the mean temperature difference ΔT_m in the exchanger and the overall heat-transfer coefficient U_o.

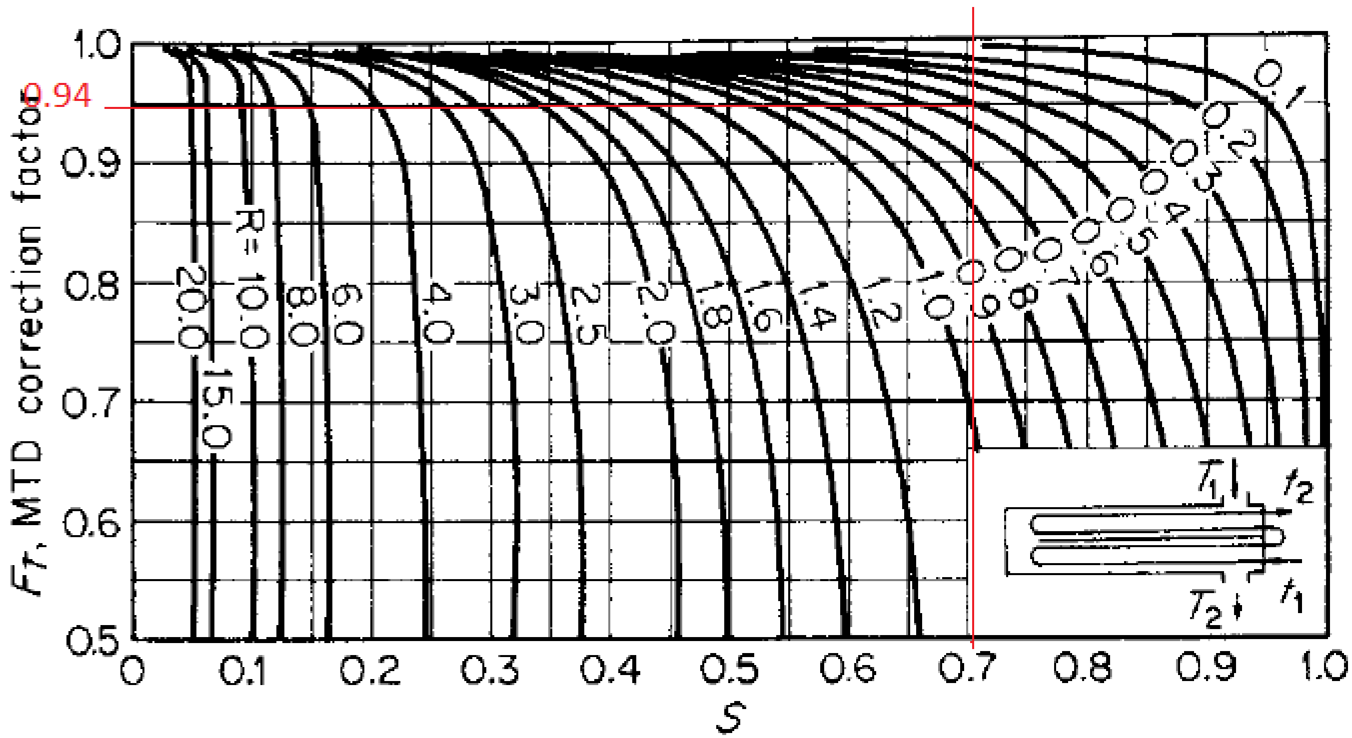
(b) For the same temperatures but using a 2–4 exchanger, what would be the ΔT_m?

Geankoplis 4.9.1

R = (T1 – T2)/(t2 – t1) and S = (t2 – t1)/(T1 – t1).



Geankoplis 4.9.1



(b)

The log mean temperature difference using Eq. (4.9-4) is

$$\Delta T_{\text{lm}} = \frac{(115.6 - 54.4) - (48.9 - 21.1)}{\ln [(115.6 - 54.4)/(48.9 - 21.1)]} = 42.3°\text{C} = 42.3 \text{ K}$$

Next substituting into Eqs. (4.9-2) and (4.9-3)

$$Z = \frac{T_{hi} - T_{ho}}{T_{co} - T_{ci}} = \frac{115.6 - 48.9}{54.4 - 21.1} = 2.00 \tag{4.9-2}$$

$$Y = \frac{T_{co} - T_{ci}}{T_{hi} - T_{ci}} = \frac{54.4 - 21.1}{115.6 - 21.1} = 0.352 \tag{4.9-3}$$

From Fig. 4.9-4a, $F_T = 0.74$. Then, by Eq. (4.9-6),

$$\Delta T_m = F_T \, \Delta T_{\text{lm}} = 0.74(42.3) = 31.3°\text{C} = 31.3 \text{ K} \tag{4.9-6}$$

Rearranging Eq. (4.9-5) to solve for U_o and substituting the known values, we have

$$U_o = \frac{q}{A_o \Delta T_m} = \frac{348\,200}{(9.30)(31.3)} = 1196 \text{ W/m}^2 \cdot \text{K} \ (211 \text{ btu/h} \cdot \text{ft}^2 \cdot °\text{F})$$

For part (b), using a 2–4 exchanger and Fig. 4.9-4b, $F_T = 0.94$. Then,

$$\Delta T_m = F_T \, \Delta T_{\text{lm}} = 0.94(42.3) = 39.8°\text{C} = 39.8 \text{ K}$$

Hence, in this case the 2–4 exchanger utilizes more of the available temperature driving force.

HEAT TRANSFER BY CONDUCTION

$$Fourier's\ Law\ Q = -KA\frac{dT}{dx}$$

$$Q = \frac{\Delta T}{\frac{\Delta x}{KA}} = \frac{\Delta T}{\bar{R}}$$

HEAT TRANSFER BY CONDUCTION

- Evaluation of average area, $\bar{A}$

a. For flat walls: $\bar{A}$ = A1 = A2

b. For cylindrical walls: $\bar{A} = 2\pi x_{ln} L$

where $x_{ln} = \dfrac{X1 - X2}{ln\frac{X1}{X2}}$

MRII Problem #13: Flat Walls

A furnace wall is constructed of firebrick 6 in thick. The temperature of the inside of the wall is 1300F and the temperature of the outside wall is 175F. If the mean thermal conductivity under these conditions is 0.17 BTU/h.ft.F. What is the rate of heat loss through 10 sq. ft. of wall surface?

a. 5700 BTU/h

b. 1070 kcal/h

c. 3825 BTU/h

d. 2354 kcal/h

MRII Problem #9: Cylindrical Walls

A thick walled copper cylinder has an inside radius of 1 cm and an outside radius of 1.8 cm. The inner and outer surface temperatures are held at 305°C and 295°C respectively. Assume

k = 371.9 W/m.K. Determine the heat loss per unit length.

a. 1 W   b. 1 kW   c. 10 W   d. 40 kW

Heat Conduction through Resistance in Series

- $R_T = R_1 + R_2 \ldots = \frac{\Delta X_1}{K_1 A_1} + \frac{\Delta X_2}{K_2 A_2} \ldots$

- $Q = \frac{\sum \Delta T}{R_T}$

MRII Problem #17: Resistance in Series

An industrial furnace wall is constructed of 0.7 ft thick fireclay having k = 0.6 BTU/ h.ft.°F. This is covered on the outer surface with 0.1 ft thick layer of insulating material having k = 0.04 BTU/h.ft.°F. The innermost surface is at 1800°F and the outermost is 100°F. Calculate the steady heat transfer per square foot.

a. 464 BTU/h.ft^2
b. 258 BTU/h-ft^2
c. 364 BTU/h.ft^2
d. 554 BTU/h.ft^2

Seat Work

For a furnace constructed with 0.7 ft thick of fireclay having k = 0.6 BTU/h.ft.°F. The innermost surface is maintained at 1800°F while the outer surface of insulating material is maintained at 100°F. How thick must the insulator be to maintain a maximum allowable heat transfer rate of 300 BTU/h.ft^2?

a. 0.30 ft   b. 0.20 ft   c. 0.10 ft   d. 0.40 ft

Heat Exchanger Effectiveness, E

E is the ratio of actual rate of heat transfer to maximum heat transfer rate if the heat exchanger has an infinite area.

Application: Most of the time only initial temperatures, heat exchanger area and overall heat transfer coefficient are given and the final temperatures are unknown, thus a technique must be develop to predict the final temperatures.

Heat Exchanger Effectiveness, E

Oil flowing at a rate of 5.0 kg/s (Cp, mean = 2.09 kJ/kg.K) is cooled in a counterflow heat exchanger from 366.5 K to 344.3 K by 2.0 kg/s of water (Cp,mean = 4.18 kJ/kg.K) entering at 283 K. The overall heat-transfer coefficient Uo is 340 W/m^2.K. Calculate the number of transfer unit (NTU) and effectiveness of the exchanger. Assume F = 1. NTU is define as:

$$NTU = UoA/Cmin$$

Heat Exchanger Effectiveness, E

$$\varepsilon = \frac{1 - \exp\left[-\frac{UA}{C_{\min}}\left(1 - \frac{C_{\min}}{C_{\max}}\right)\right]}{1 - \frac{C_{\min}}{C_{\max}} \exp\left[-\frac{UA}{C_{\min}}\left(1 - \frac{C_{\min}}{C_{\max}}\right)\right]} \qquad (4.9\text{-}18)$$

Cmin and Cmax are heat capacities.

Heat Exchanger Effectiveness, E

$$Q = E\, C_{min}\, (T_{Hi} - T_{Ci})$$

Heat Exchanger Effectiveness, E

EXAMPLE 4.9-2. Effectiveness of Heat Exchanger

Water flowing at a rate of 0.667 kg/s enters a countercurrent heat exchanger at 308 K and is heated by an oil stream entering at 383 K at a rate of 2.85 kg/s ($c_p = 1.89$ kJ/kg · K). The overall $U = 300$ W/m^2 · K and the area $A = 15.0$ m^2. Calculate the heat-transfer rate and the exit water temperature.

Solution: Assuming that the exit water temperature is about 370 K, the c_p for water at an average temperature of $(308 + 370)/2 = 339$ K is 4.192 kJ/kg·K (Appendix A.2). Then, $(mc_p)_H = C_H = 2.85(1.89 \times 10^3) = 5387$ W/K and $(mc_p)_C = C_C = 0.667(4.192 \times 10^3) = 2796$ W/K $= C_{min}$. Since C_C is the minimum, $C_{min}/C_{max} = 2796/5387 = 0.519$.

Using Eq. (4.9-19), $\text{NTU} = UA/C_{min} = 300(15.0)/2796 = 1.607$. Using Fig. (4.9-7a) for a counterflow exchanger, $\varepsilon = 0.71$. Substituting into Eq. (4.9-10),

$$q = \varepsilon C_{min}(T_{Hi} - T_{Ci}) = 0.71(2796)(383 - 308) = 148\,900 \text{ W}$$

Using Eq. (4.9-7),

$$q = 148\,900 = 2796(T_{Co} - 308)$$

Solving, $T_{Co} = 361.3$ K.

Seat work

4.9-4. *Outlet Temperature and Effectiveness of an Exchanger.* Hot oil at a flow rate of 3.00 kg/s ($c_p = 1.92$ kJ/kg · K) enters an existing counterflow exchanger at 400 K and is cooled by water entering at 325 K (under pressure) and flowing at a rate of 0.70 kg/s. The overall $U = 350 \text{ W/m}^2 \cdot \text{K}$ and $A = 12.9 \text{ m}^2$. Calculate the heat-transfer rate and the exit oil temperature.

Evaluation of Heat transfer coefficient Dittus-Boelter equation

$N_{Pr} = \frac{Cp\mu}{k}$ where Cp is specific heat

μ is viscosity

k is thermal conductivity

$N_{Re} = \frac{\rho D v}{\mu}$ $N_{Nu} = \frac{hiD}{k}$

$N_{Nu} = 0.023(N_{Re})^{0.8}(N_{Pr})^{0.3 \text{ for cooling or } 0.4 \text{ for heating}}$

Foust Example 15.3

A double-pipe heat exchanger is to be designed to cool benzene from 180°F to 100°F, under sufficient pressure to maintain the benzene in liquid phase. Water enters the annular space at 70°F and flows countercurrent to the benzene at a velocity of 5 ft/s. The inside pipe is sch. 40, 1 ¼ in steel pipe; The outside pipe is sch. 40, 2 in steel pipe. How long will the heat exchanger should be? The mass flow rate of benzene is 7500 lb/h. Assume delta T LMTD to be 51°F.

Friction factor in flow through channels of noncircular cross section

Hydraulic radius, r_H

$$r_H \equiv \frac{S}{L_p}$$

where S = cross-sectional area of channel
L_p = perimeter of channel in contact with fluid

Circular tube

Thus, for the special case of a circular tube, the hydraulic radius is

$$r_H = \frac{\pi D^2/4}{\pi D} = \frac{D}{4}$$

The equivalent diameter is $4r_H$, or simply, D.

Annulus between two concentric pipes

An important special case is the annulus between two concentric pipes. Here the hydraulic radius is

$$r_H = \frac{\pi D_o^2/4 - \pi D_i^2/4}{\pi D_i + \pi D_o} = \frac{D_o - D_i}{4} \qquad (5.55)$$

Reynolds number for noncircular cross section

$$h_{fs} = \frac{\tau_w}{\rho r_H} \Delta L = \frac{\Delta p_s}{\rho} = f \frac{\Delta L}{r_H} \frac{\bar{V}^2}{2g_c}$$

$$N_{\mathrm{Re}} = \frac{4 r_H \bar{V} \rho}{\mu}$$

Sieder-Tate equation

$N_{Nu} = 0.023(N_{Re})^{0.8}(N_{Pr})^{1/3}\ \phi$

Where $\phi = \left(\frac{\mu}{\mu_w}\right)^{0.14}$ viscosity correction factor

Where μ_w is the viscosity at T_w

T_w is the wall temperature

Colburn equation

$$St\ Pr^{2/3} = \frac{0.023\ \phi}{Re\ 0.2}$$

St is Stanton Number

St = h/CpG

G is mass velocity kg/m^2.s

The Reynolds Analogy

$f = 0.046\ Re^{-0.2}$ eqn. 1

From Colburn equation assuming Pr = 1.0 and

$\phi = 1.0$

$St = 0.023\ Re^{-0.2}$ eqn. 2

Combining eqn 1 and eqn 2

$$St = h/cpG = f/2$$

MRII Reynolds Analogy Problem

Assuming Reynolds analogy applies, estimate the heat transfer coefficient in Btu/hr-ft2-F, for water flowing inside a 2.0 in ID smooth horizontal straight pipe at a velocity of 4 fps and an average temperature of 78F.

a.1790 b. 2000 c. 2910 d. 2240

roperties of Steel Pipe

side eter, n	Schedule no.	Wall thickness, in	Inside diameter, in	Cross-sectional area: Metal, in^2	Cross-sectional area: Flow, ft^2	Circumference, ft, or surface, ft^2/ft of length: Outside	Circumference, ft, or surface, ft^2/ft of length: Inside	Capacity at 1-ft/s velocity: U.S. gal/min	Capacity at 1-ft/s velocity: lb/h water	Weight of plain-end pipe, lb/ft
05	10S	0.049	0.307	0.055	0.00051	0.106	0.0804	0.231	115.5	0.19
	40ST, 40S	.068	.269	.072	.00040	.106	.0705	.179	89.5	.24
	80XS, 80S	.095	.215	.093	.00025	.106	.0563	.113	56.5	.31
40	10S	.065	.410	.097	.00092	.141	.107	.412	206.5	.33
	40ST, 40S	.088	.364	.125	.00072	.141	.095	.323	161.5	.42
	80XS, 80S	.119	.302	.157	.00050	.141	.079	.224	112.0	.54
75	10S	.065	.545	.125	.00162	.177	.143	.727	363.5	.42
	40ST, 40S	.091	.493	.167	.00133	.177	.129	.596	298.0	.57
	80XS, 80S	.126	.423	.217	.00098	.177	.111	.440	220.0	.74
40	5S	.065	.710	.158	.00275	.220	.186	1.234	617.0	.54
	10S	.083	.674	.197	.00248	.220	.176	1.112	556.0	.67
	40ST, 40S	.109	.622	.250	.00211	.220	.163	0.945	472.0	.85
	80XS, 80S	.147	.546	.320	.00163	.220	.143	0.730	365.0	1.09
	160	.188	.464	.385	.00117	.220	.122	0.527	263.5	1.31
	XX	.294	.252	.504	.00035	.220	.066	0.155	77.5	1.71
50	5S	.065	.920	.201	.00461	.275	.241	2.072	1036.0	0.69
	10S	.083	.884	.252	.00426	.275	.231	1.903	951.5	0.86
	40ST, 40S	.113	.824	.333	.00371	.275	.216	1.665	832.5	1.13
	80XS, 80S	.154	.742	.433	.00300	.275	.194	1.345	672.5	1.47
	160	.219	.612	.572	.00204	.275	.160	0.917	458.5	1.94
	XX	.308	.434	.718	.00103	.275	.114	0.461	230.5	2.44
15	5S	.065	1.185	.255	.00768	.344	.310	3.449	1725	0.87
	10S	.109	1.097	.413	.00656	.344	.287	2.946	1473	1.40
	40ST, 40S	.133	1.049	.494	.00600	.344	.275	2.690	1345	1.68
	80XS, 80S	.179	0.957	.639	.00499	.344	.250	2.240	1120	2.17
	160	.250	0.815	.836	.00362	.344	.213	1.625	812.5	2.84
	XX	.358	0.599	1.076	.00196	.344	.157	0.878	439.0	3.66