4.5. Final Design

The steps for the preliminary design of an air-cooled heat exchanger were given. This procedure can be followed regardless of the nature of the heat transfer inside of the tubes by making a reasonable initial estimate of the coefficients.

The next step is to calculate all the coefficients and pressure drops, using appropriate correlations, to verify the design meets the exchanger requirements. It is likely that some adjustments will have to be made in the physical arrangement but with several iterations, a suitable design is usually obtained. Whether the tube-side heat transfer is single-phase or two-phase, the coefficients are generally much larger than the air-side and do not become controlling. Thus, while some of the tube-side correlations, in particular the two-phase equations, are not exact, in accuracy is generally not a serious problem for air-cooled heat exchangers.

Attention must be given to the pressure drops so that they are within design limits. This is more important in two-phase flow because of the large volumes of vapor and generally results in larger diameters of Trufin being selected. For single-phase flow, efforts should be made to keep the fluid in the turbulent flow regime.

Correlations for the tube-side heat transfer and pressure drop are found in Section 2 for sensible heat transfer, Section 3 for condensing and Section 5 for boiling heat transfer.

Table 4.1

Typical Mass Velocities for Air-Cooler Design

n, No. of Rows of Tubes	$\vartheta_{air}V_{max}$ $lb_m/hr\ ft^2$
3	5000-6000
4	5000
5	4500
6	4000
8	3500

Table 4.2

Typical Face Velocities for Air-Cooler Design

n, No. of Rows of Tubes	V_{face} ft/min
3	900
4	800
5	700
6	600
8	500

NOMENCLATURE

A	Surface area for heat transfer. A_o and A_i are the corresponding values for the outside and inside surface, respectively, and Am denotes the logarithmic mean of A_o and A_i. A_{fin} is the total heat transfer area/ft for the fins on a tube, and A_{root} is the area/ft of the bare tube remaining between the fins. A_b is the bond contact area (per foot of length) in a bimetallic tube. A^*_{HT} is the total outsideheat transfer area of a bank of finned tubes per square foot of face area per row.	ft^2
A_{face}	Face area, or plain area of a finned tube heat exchanger. This is the total flow area of the air approaching the tube bank, $(A_{face})_{HT}$ is the face area re-quired in a given exchanger by purely heat transfer considerations; $(A_{face})_T$ is the face area required by purely thermodynamic considerations.	ft^2
AMTD	Arithmetic mean temperature difference defined by Eq. (4.24).	°F
c_p	Specific heat of the flowing fluid.	Btu/Ib$_m$°F
d	Diameter of a tube. d_o and d_i are the outside and inside diameters respectively, and d_m denotes the logarithmic mean. D_r, is the root diameter of a finned tube. d_{fin} is the outside diameter of the fin.	in. or ft.
F	Correction factor for the logarithmic mean temperature difference (LMTD) to make it applicable to heat exchangers in which the flow is not entirely countercurrent or cocurrent.	dimensionless
f_r	The friction factor for tube banks, defined by Eq. (4.14).	dimensionless
g	Gravitational acceleration at Earth's surface.	4.l7xl0^8 ft/hr^2
g_c	Gravitational conversion constant.	4.17xl0^{8}lb$_m$ft/lb$_f$hr^2
H	Fin height from root to tip.	in.
h	Film heat transfer coefficient. h_o and h_i are the values for the outside and the inside of the heat transfer surface, respectively. h_f is an equivalent heat transfer coefficient for any fouling that may be present, equal to the reciprocal of the fouling resistance.	Btu/hrft^2°F
k	Thermal conductivity of a material. k,, refers to the wall material, while k_{air}, k_ℓ, k_v, and k_g refer to air, the liquid phase, the vapor, and gas, respectively.	Btu/hrft^2(°F/ft)
L	Length, usually of a tube.	ft.
LMTD	Logarithmic mean temperature difference, defined by Eq. (4.8)	°F
MTD	True mean temperature difference, F (LMTD)	°F

m	Quantity characterizing fin geometry and properties, defined by Eq. (4.2).	dimensionless
N_f	Number of fins per inch.	$(in.)^{-1}$
n	Number of rows of tubes in a tube bank, measured in the direction of flow.	dimensionless
P	Parameter in MTD calculations, defined by Eq. (4.11).	dimensionless
P	Longitudinal tube pitch: distance between adjacent tubes in different rows, measured along the diagonal.	in.
P_t	Transverse tube pitch, distance between adjacent tubes in the same row in a tube bank.	in.
Pr	Prandtl number of a fluid defined as ($c_p\mu/k$). Subscripts "air"," ℓ ","v", and "g" refer to air, liquid, vapor,and gas phases, respectively.	dimensionless
p	Pressure of a liquid.	lb_f/in^2absolute
Δp	Pressure drop for flow of a fluid through a given path. The subscript "air" refers to the pressure drop across the tube bank on the air-side.	$lb_f/in.^2$
Q	heat flow rate.	Btu/hr
R	Parameter in MTD calculations, defined by Eq. (4.12)	dimensionless
R_b	Bond resistance based on bond contact area.	$hrft^{2\circ}F/Btu$
R_f	Resistance to heat transfer due to fouling. R_{fo} and R_{fi} are fouling resistances on the outside and inside of a heat transfer surface, respectively.	$hrft^{2\circ}F/Btu$
R_{fin}	Resistance to heat transfer in a fin, given by Eq. (4.3).	$hrft^{2\circ}F/Btu$
R_w	Resistance to heat transfer due to wall conduction.	$hrft^{2\circ}F/Btu$
r	Radius of a tube. r_o and r_i are the outside and inside radii respectively; r_m is the logarithmic mean of r_o and r_i. r' is the outside radius of the inner tube and the inside radius of the outer tube in a bimetallic tube.	in. or ft.
s	Distance between fins, surface to surface.	in. or ft.
T,t	Temperatures. Both symbols (usually subscripted) are used more or less interchangeably and for this reason every temperature must be carefully defined for each particular discussion. Usually, capital letters refer to the hot fluid and lower case to the cold fluid, but sometimes capitals refer to the outside fluid and lower case to the inside. T_i and t_i usually refer to the inlet temperatures of the two streams and T_o and to t_o the outlet temperatures.	°F
U_o	Overall heat transfer coefficient for heat transfer between two fluids separated by a finned surface, referenced to the outside (finned) surface area A_o. U^+ is the combined heat transfer coefficient for the wall and fin	$Btu/hrft^{2\circ}F$

	resistance, the coolant and any dirt films. U' is the combined heat transfer coefficient for the condensate film, tube side fouling, wall and fin resistance and air film coefficient.	
V	Mean velocity of a flowing fluid. For tube banks, V_{max} is calculated as the mean velocity at the point where the tubes are closest together. V_{face} is the air velocity approaching the face of the tube bank.	ft/sec
W,w	Mass flow rates of the fluids in a heat exchanger.	lb_m/hr
x	Usually, a length variable, especially when it appears as Δx_w, the wall thickness of a tube.	ft.
Y	Thickness of a fin.	in. or ft.

Greek

Φ	Fin efficiency: the ratio of the total heat transferred from a real fin to that transferred if the fin were isothermal at-its base temperature.	dimensionless
μ	Viscosity of a fluid. μ_{air} refers to air.	lb_m/ft^3
ϑ	Density of a fluid. ϑ_{air} refers to air.	lb_m/ft^3

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