Appendix C

Heat Exchanger Design

Table C.1 Representative values of the overall heat transfer coefficients (US)

Type of Heat Exchanger	U (Btu/(h ft^2 $^\circ$F))
Water-to-water	150–300
Water-to-oil	18–60
Water-to-gasoline or kerosene	55–180
Feedwater heaters	180–1500
Steam-to-light fuel oil	35–70
Steam-to-heavy fuel oil	10–35
Steam condenser	180–1060
Freon condenser (water cooled)	55–180
Ammonia condenser (water cooled)	140–250
Alcohol condenser (water cooled)	45–125
Gas-to-gas	2–7
Water-to-air in finned tubes (water in tubes)	5–10 (air); 70–150 (water)
Steam-to-air in finned tubes (steam in tubes)	5–50 (air); 70–705 (water)

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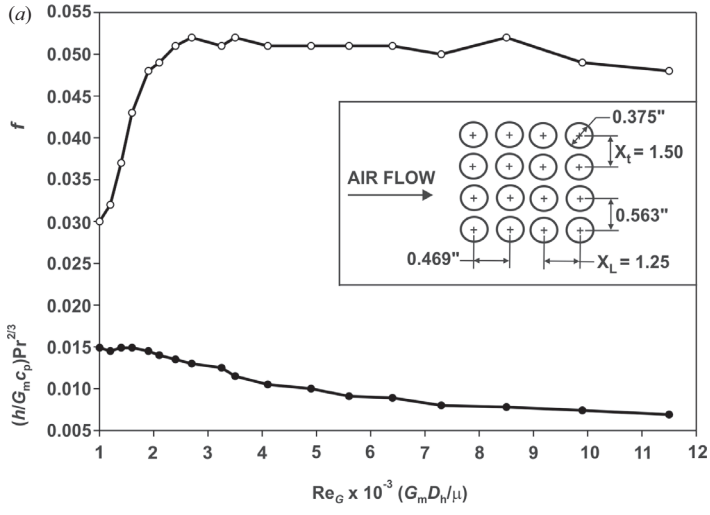
Table C.2 Representative values of the overall heat transfer coefficients (SI)

Type of Heat Exchanger	U (W/(m^2 °C))
Water-to-water	850–1700
Water-to-oil	100–350
Water-to-gasoline or kerosene	300–1000
Feedwater heater	1000–8500
Steam-to-light fuel oil	200–400
Steam-to-heavy fuel oil	50–200
Steam condenser	1000–6000
Freon condenser (water cooled)	300–1000
Ammonia condenser (water cooled)	800–1400
Alcohol condenser (water cooled)	250–700
Gas-to-gas	10–40
Water-to-air in finned tubes (water in tubes)	30–60 (air); 400–850 (water)
Steam-to-air in finned tubes (steam in tubes)	30–300 (air); 400–4000 (water)

Source: Çengel, Y.A. (2007) *Heat and Mass Transfer: A Practical Approach*, 3rd edn, McGraw-Hill, Inc., New York.

Table C.3 Representative fouling factors in heat exchangers

Fluid	R_f ((ft^2 h °F)/Btu)
Gas oil	0.00051
Transformer oil	0.00102
Lubrication oil	0.00102
Heat transfer oil	0.00102
Hydraulic oil	0.00102
Fuel oil	0.0051
Hydrogen	0.00999
Engine exhaust	0.00999
Steam (oil-free)	0.00051
Steam with oil traces	0.0010
Cooling fluid vapors with oil traces	0.00199
Organic solvent vapors	0.0010
Alcohol vapors	0.00057
Refrigerants (vapor)	0.0023
Compressed air	0.00199
Natural gas	0.0010
Distilled water, seawater, river water, boiler feedwater: below 122°F	0.00057
Distilled water, seawater, river water, boiler feedwater: above 122°F	0.0011
Refrigerants (liquid)	0.0011
Cooling fluid	0.0010
Organic heat transfer fluids	0.0010
Salts	0.00051
Liquefied petroleum gas (LPG), liquefied natural gas (LNG)	0.0010
MEA and DEA (amines) solutions	0.00199
DEG and TEG (glycols) solutions	0.00199
Vegetable oils	0.0030

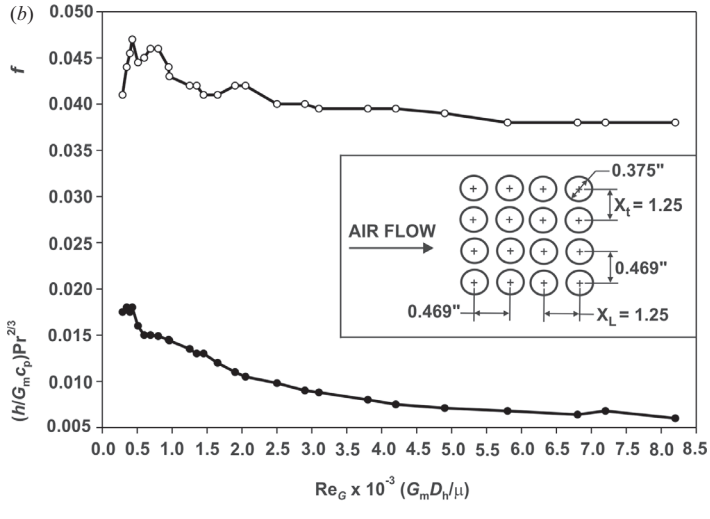


DATA
Tube outside diameter: 0.375 in.

Hydraulic diameter, D_h: 0.0248 ft

Free-flow area/Frontal area, σ: 0.333

Heat transfer area/Total volume, α: 53.6 ft^2/ft^3



DATA
Tube outside diameter: 0.375 in.

Hydraulic diameter, D_h: 0.01237 ft

Free-flow area/Frontal area, σ: 0.200

Heat transfer area/Total volume, α: 64.4 ft^2/ft^3

Figure C.1 *j*-factor versus Re_G charts for in-line tube banks. Transient tests (2 charts): (a) For $X_t = 1.50$ and $X_L = 1.25$; (b) For $X_t = 1.25$ and $X_L = 1.25$.
(Kays, W. and London, A. (1964) *Compact Heat Exchangers*, 2nd edn, McGraw-Hill, Inc., New York)

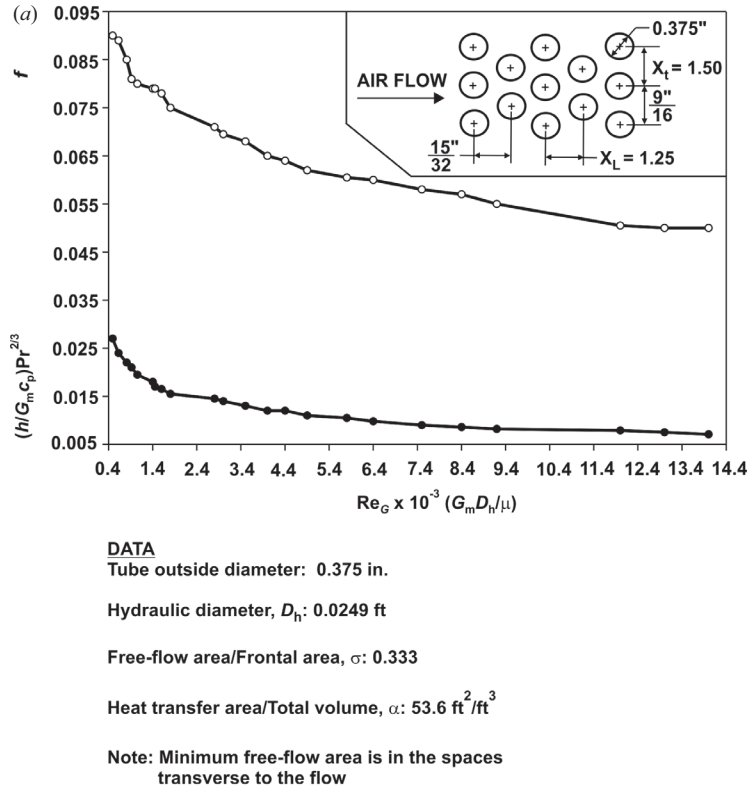
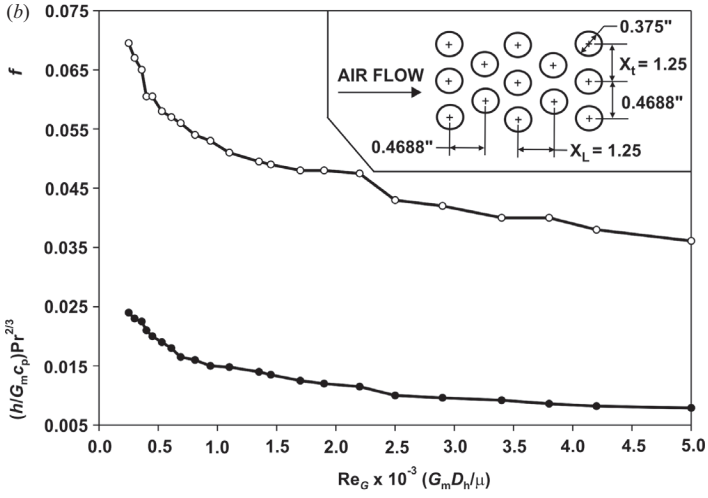


Figure C.2 *j*-factor versus Re_G charts for staggered tube banks. Transient tests (6 charts): (a) For $X_t = 1.50$ and $X_L = 1.25$; (b) For $X_t = 1.25$ and $X_L = 1.25$; (c) For $X_t = 1.50$ and $X_L = 1.0$; (d) For $X_t = 1.5$ and $X_L = 1.5$; (e) For $X_t = 2$ and $X_L = 1$; (f) For $X_t = 2.5$ and $X_L = 0.75$.
(Kays, W. and London, A. (1964) *Compact Heat Exchangers*, 2nd edn, McGraw-Hill, Inc., New York)

(*b*)



DATA
Tube outside diameter: 0.375 in.

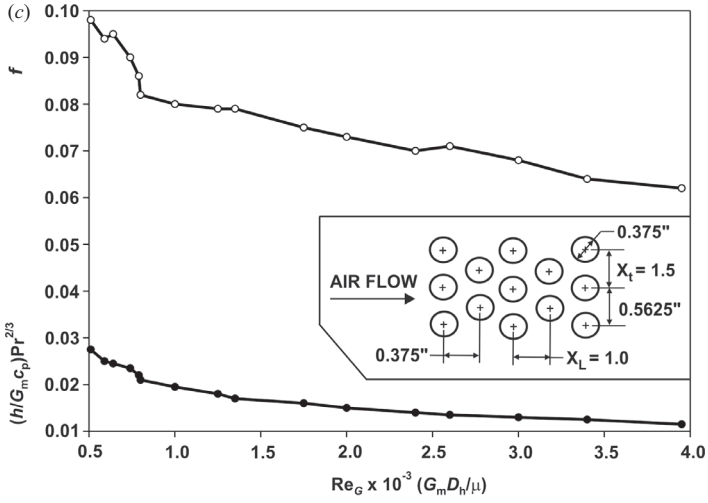
Hydraulic diameter, D_h: 0.0125 ft

Free-flow area/Frontal area, σ: 0.200

Heat transfer area/Total volume, α: 64.4 ft^2/ft^3

Note: Minimum free-flow area is in the spaces transverse to the flow

(*c*)



DATA
Tube outside diameter: 0.375 in.

Hydraulic diameter, D_h: 0.0196 ft

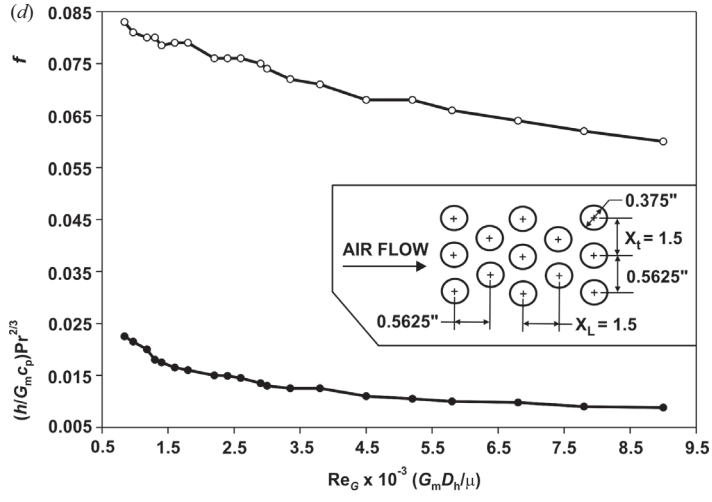
Free-flow area/Frontal area, σ: 0.333

Heat transfer area/Total volume, α: 67.1 ft^2/ft^3

Note: Minimum free-flow area is in the spaces transverse to the flow

Figure C.2 (*Continued*)

(*d*)



DATA
Tube outside diameter: 0.375 in.

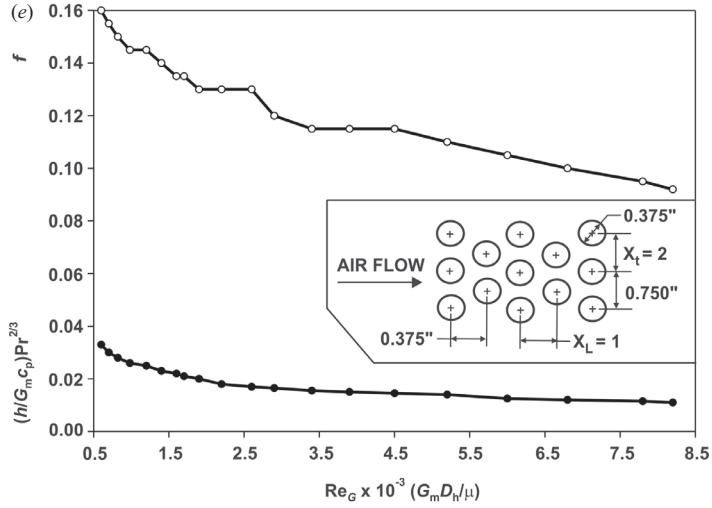
Hydraulic diameter, D_h: 0.0298 ft

Free-flow area/Frontal area, σ: 0.333

Heat transfer area/Total volume, α: 44.8 ft^2/ft^3

Note: Minimum free-flow area is in the spaces transverse to the flow

(*e*)



DATA
Tube outside diameter: 0.375 in.

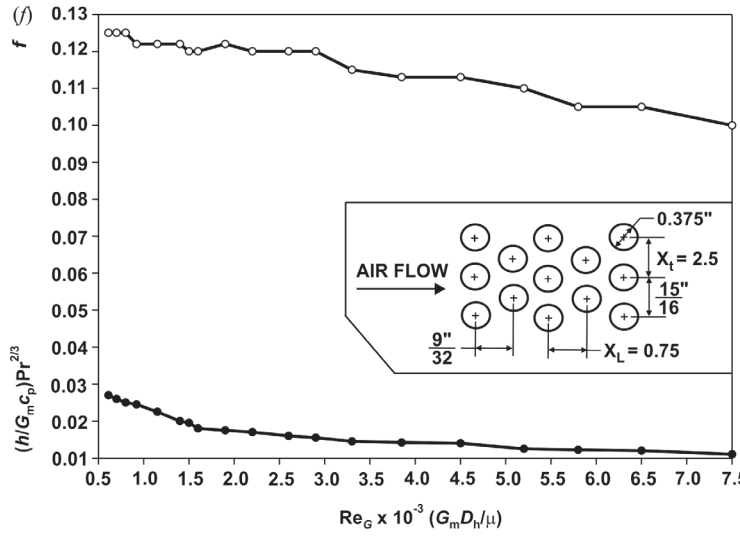
Hydraulic diameter, D_h: 0.0327 ft

Free-flow area/Frontal area, σ: 0.414

Heat transfer area/Total volume, α: 50.3 ft^2/ft^3

Note: Minimum free-flow area is in the spaces transverse to the flow

Figure C.2 (*Continued*)



DATA
Tube outside diameter: 0.375 in.

Hydraulic diameter, D_h: 0.0271 ft

Free-flow area/Frontal area, σ: 0.366

Heat transfer area/Total volume, α: 53.6 ft^2/ft^3

Note: Minimum free-flow area is in the spaces transverse to the flow

Figure C.2 (*Continued*)

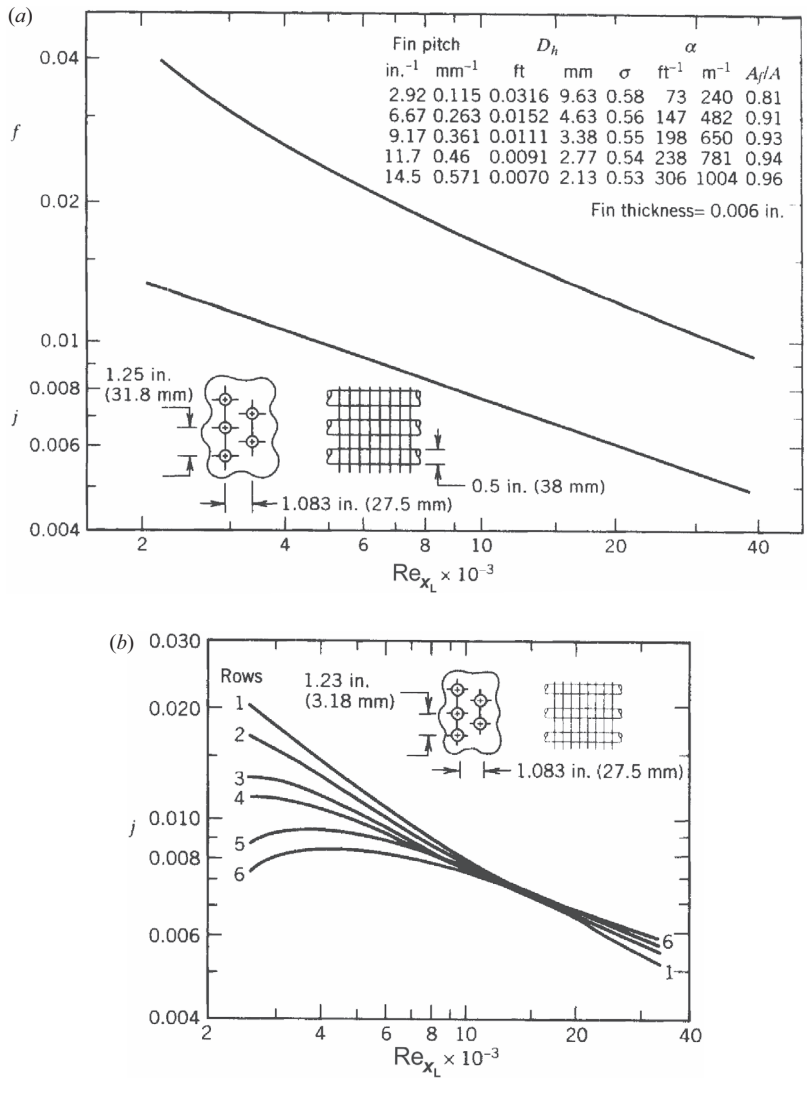


Figure C.3 *j*-factor versus Re_{x_L} charts for staggered tube banks (finned tubes): (a) five rows of tubes (*ASHRAE Transactions*, vol. 79, Part II, 1973; reprinted with permission); (b) multiple rows of tubes (*ASHRAE Transactions*, vol. 81, Part I, 1975; reprinted with permission)

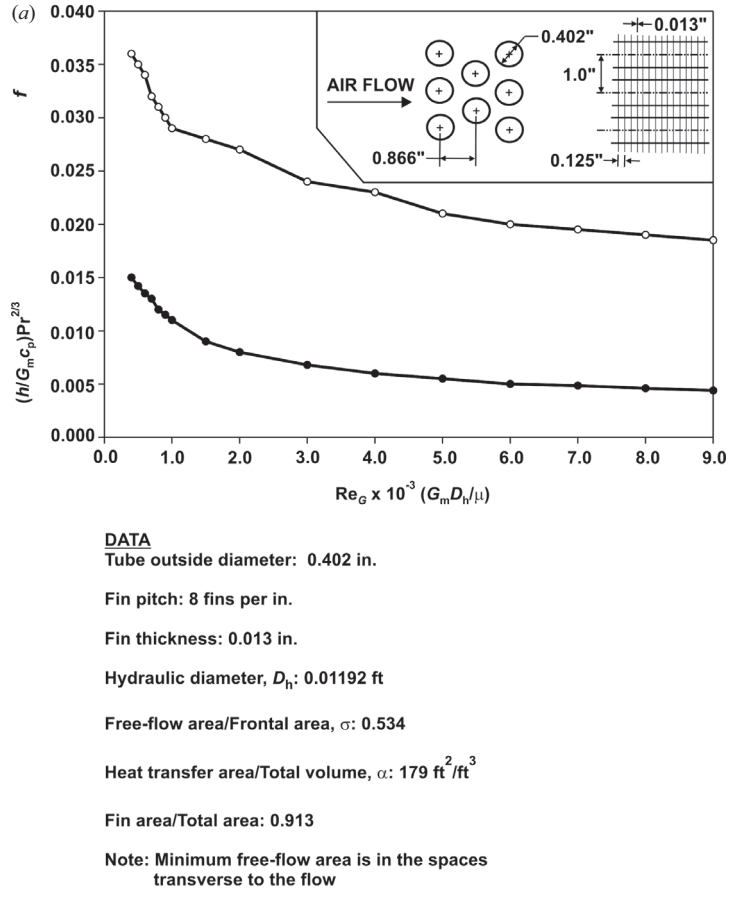
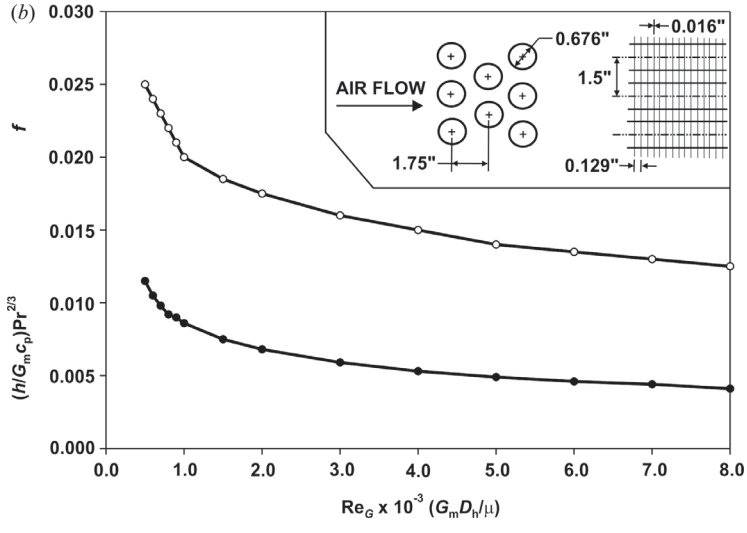


Figure C.4 *j*-factor versus Re_G charts for staggered tube banks (finned tubes). (a) Tube outer diameter = 0.402 in.; (b) tube outer diameter = 0.676 in.
(Kays, W. and London, A. (1964) *Compact Heat Exchangers*, 2nd edn, McGraw-Hill, Inc., New York)



DATA
Tube outside diameter: 0.676 in.

Fin pitch: 7.75 fins per in.

Fin thickness: 0.016 in.

Hydraulic diameter, D_h: 0.0114 ft

Free-flow area/Frontal area, σ: 0.481

Heat transfer area/Total volume, α: 169 ft^2/ft^3

Fin area/Total area: 0.950

Note: Minimum free-flow area is in the spaces transverse to the flow

Figure C.4 (*Continued*)