Exercise 11.1

Water at a rate of $45000kg/h$ is heated from $80°C$ to $150°C$ in a heat exchanger having two shell passes and eight tube passes with a total surface area of $925m^2$. Hot exhaust gases having approximately the same thermophysical properties as air enter at $350°C$ and exit at $175°C$. Determine the overall heat transfer coefficient.

Solutions $NTU = 1.27$, $U = 29.5W/m^2 \cdot K$

Exercise 11.2

Consider a concentric tube heat exchanger characterized by a uniform overall heat transfer coefficient and operating under the following conditions:

	$\dot{m}$ (kg/s)	c_p (J/kg · K)	T_i (°C)	T_o (°C)
Cold fluid	0.125	4200	40	95
Hot fluid	0.125	2100	210	—

Determine:

a) the maximum possible heat transfer rate

b) the heat exchanger effectiveness

c) what is the ratio of the required areas to operate the heat exchanger in counter-flow (A_{CF}) or in parallel-flow (A_{PF}) conditions? If we want to minimize the area which of the two configurations is more advantageous?

Solutions

a) $Q_{max} = 44625W$

b) $\epsilon = 0.65$

c) $\frac{A_{CF}}{A_{PF}} = 0.55$, counter-flow

Exercise 11.3

A recuperator is a heat exchanger that heats the air used in a combustion process by extracting energy from the products of combustion (the flue gas). Consider using a single-pass cross-flow heat exchanger as a recuperator.

Eighty silicon carbide ceramic tubes ($k = 20W/mK$) of inner and outer diameters equal to $55mm$ and $80mm$ respectively, and of length $L = 1.4m$ are arranged as an aligned tube bank of longitudinal and transverse pitches $S_L = 100mm$ and $S_T = 120mm$, respectively. Cold air is in cross flow over the tube bank with upstream conditions of $V = 1m/s$ and $T_{c,i} = 300K$, while hot-flue gases of inlet temperature $T_{h,i} = 1400K$ pass through the tubes. The tube outer surface is clean while the inner surface is characterized by a fouling factor of $R_f^i = 0.0002m^2K/W$. The air and flue gas flow rates are $\dot{m}_c = 1kg/s$ and $\dot{m}_h = 1.05kg/s$, respectively.

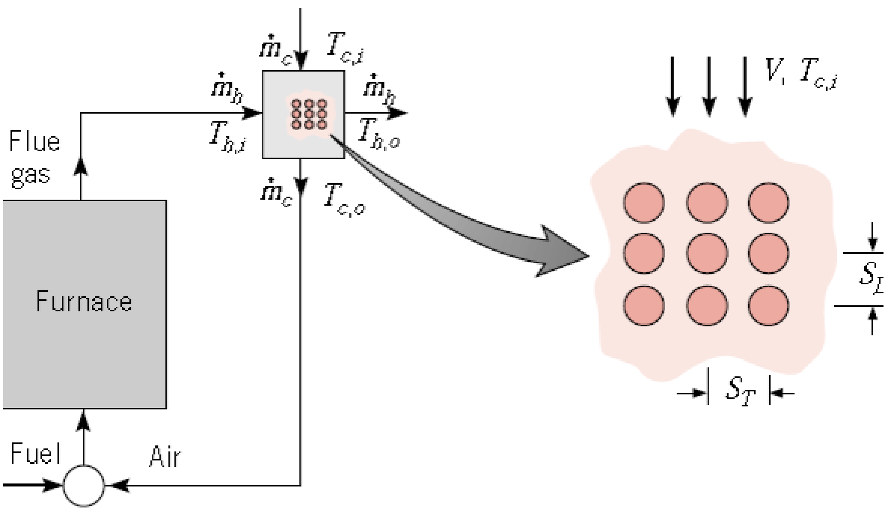
Use the following assumptions:

a) evaluate all required air properties at $1atm$ and $300K$

b) assume the flue gas to have the properties of air at $1atm$ and $1400K$

c) assume the tube wall temperature to be at $800K$ for the purpose of treating the effect of variable properties on convection heat transfer.

If there is a 1% fuel savings associated with each $10°C$ increase in temperature of the combustion air $T_{c,o}$ above $300K$, what is the percentage fuel savings for the prescribed conditions? (See the exercise in series 10 for your reference).



Solutions $T_{c,o} = 594K$, $\Delta T_c = 294K$, fuel savings = 29.4%

Exercise 11.4 FOR REVISION

A shell-tube heat exchanger consisting of one shell pass and two tube passes is used to transfer heat from an ethylene glycol-water solution (shell side) supplied from a rooftop solar collector to pure water (tube side) used for household purposes. The tubes are of inner and outer diameters $D_i = 3.6mm$ and $D_o = 3.8mm$, respectively. Each of the 100 tubes is $0.8m$ long ($0.4m$ per pass), and the heat transfer coefficient associated with the ethylene glycol-water mixture is $h_o = 11000W/m^2K$.

a) For pure copper tubes, calculate the heat transfer rate from the ethylene glycol-water solution ($\dot{m} = 2.5kg/s$, $T_{h,i} = 80°C$) to the pure water ($\dot{m} = 2.5kg/s$, $T_{c,i} = 20°C$). Determine the outlet temperatures of both streams of fluid. The density and specific heat of the ethylene glycol-water mixture are $1040kg/m^3$ and $3660J/kgK$, respectively.

b) It is proposed to replace the copper tube bundle with a bundle composed of high-temperature nylon tubes of the same diameter and tube wall thickness. The nylon is characterized by a thermal conductivity of $k_n = 0.31W/mK$. Determine the tube length required to transfer the same amount of energy as in part (a).

Solutions

a) $UA = 5522W/K$, $Q = 204120W$, $T_{h,o} \approx 57°C$, $T_{c,o} \approx 43°C$

b) $L = 2.33m$