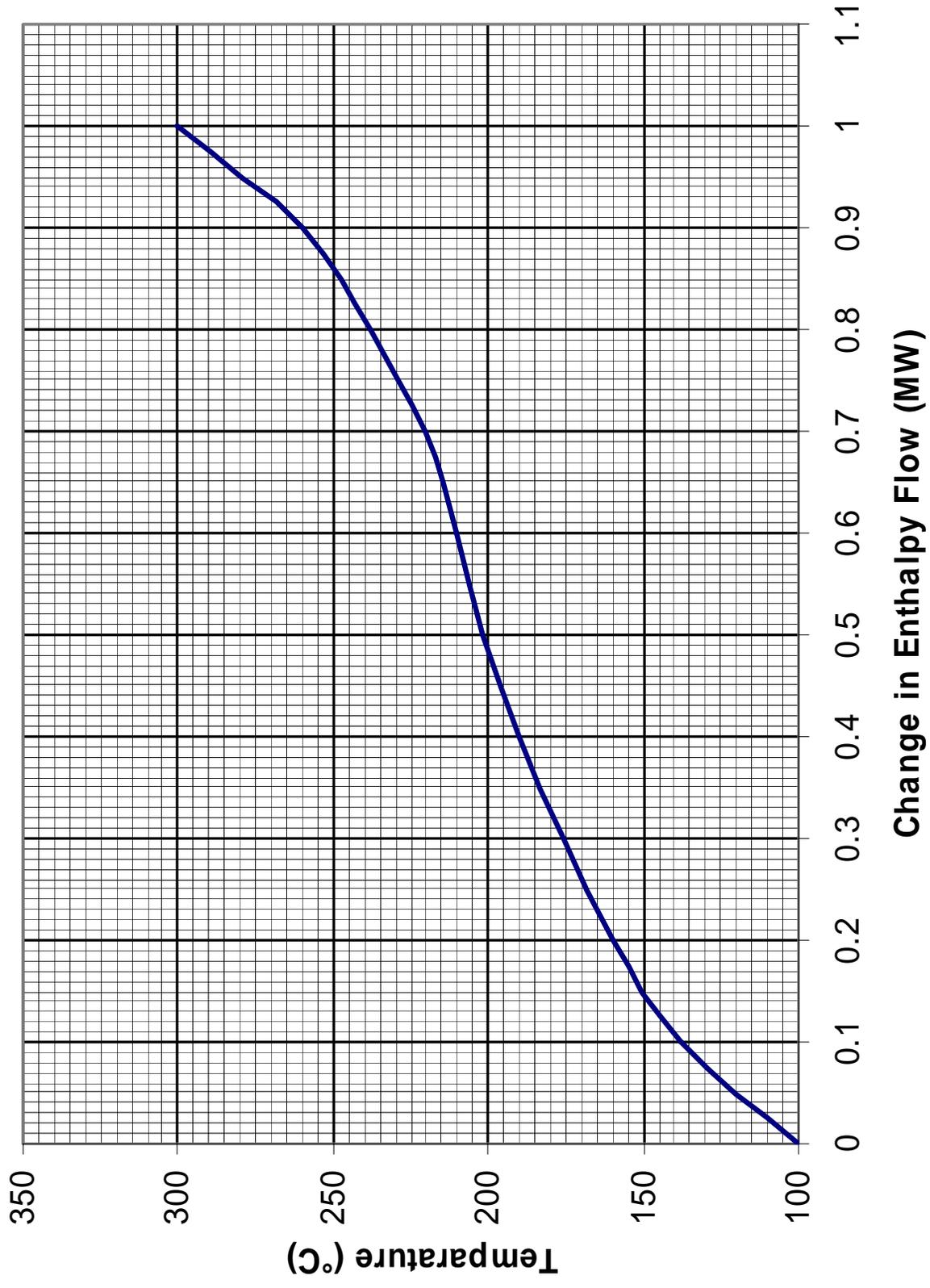


10.302
Fall 2004
Homework Problem Set 8
Due Wednesday, November 17, at start of class

Part A

1. Problem 11.38(a) of I&D What tube area would be required if the exchanger were of the true countercurrent type?

2. A mixed organic liquid is to be vaporized in a true countercurrent exchanger. The mixture will enter at 100°C and it is desired that it leave at 300°C. A temperature-enthalpy diagram is attached. As indicated, the design heat duty for the exchanger is 1 MW. A high temperature liquid heating medium will be used to achieve the vaporization. This fluid has a constant heat capacity equal to 2000 J/kg·K.
 - (a) If the heating fluid enters the exchanger at 320°C, and if the exchanger is infinitely large, what is the required flow rate of the heating medium?
 - (b) If the heating fluid enters the exchanger at 320°C, and if the exchanger is infinitely large, and if the flow rate of the heating medium is 2 kg/s, what will be the exit temperature of the mixed organic stream? Note that the actual heat duty may be less than the desired value of 1 MW.
 - (c) If the flow rate of the heating fluid (which enters at 320°C) is 3 kg/s and if the overall heat transfer coefficient is constant at 350 W/m²·K, what area will be required?



Part B

1. Problem 11.24 (a) and (b) of I&D
2. Problem 11.36 (a) of I&D. Repeat for a water flow rate of 20 kg/s

Part C

A diesel truck engine is turbocharged with 500 kg/h of air. The air is heated to 420K by the compressor in the turbocharger. It is desired to cool the air (which is at 2.5 atm) to 392K or less before it enters the engine. For this purpose, pressurized liquid water at 380K will be taken from the truck radiator at a rate of 250 kg/h. The intercooler will be configured as a true counter-current exchanger, ($F = 1$). The overall situation is depicted in the sketch.

A vendor has offered an exchanger which consists of 300 tubes, each of which is 0.5 m long and 0.5 cm in diameter. The water will flow in the tubes and the heat transfer coefficient is expected to be $9000 \text{ W/m}^2 \cdot \text{K}$. The shell side will carry the air. It will be filled with a web of longitudinal fins ($\eta_f = 1$) so that the air-side heat transfer area is 5 times greater than the heat transfer area on the water side. The air-side heat transfer coefficient is expected to be $30 \text{ W/m}^2 \cdot \text{K}$. Fluid mechanically, the ducts on the air-side may be regarded as tubes which are 0.5 m long with an equivalent diameter of 0.004 m. The cross-sectional area available for flow on the shell-side is twice that available on the tube-side.

- A. Will the vendor's exchanger do the job? For this purpose, you can assume that the vendor's claims with regard to the two heat transfer coefficients and with regard to the fin efficiency ($\eta_f = 1$) are correct.
- B. If the truck is allowed to idle so that both the air and the water flow rates are reduced ten fold, will the exchanger performance be much better, slightly better, slightly worse, or much worse? Justify your response. "Better" or "worse" should be assessed with regard to how closely the outlet air temperature approaches the inlet water temperature. Note that the heat transfer coefficients cannot necessarily be expected to remain unchanged.

Miscellaneous Data

Air $c_p = 1015 \text{ J/kg}\cdot\text{K}$
 $\rho = 2.18 \text{ kg/m}^3$
 $\nu = 26.4 \times 10^{-6} \text{ m}^2/\text{s}$
 $\mu = 57.6 \text{ N}\cdot\text{s/m}^2$
 $k = 33.8 \times 10^{-3} \text{ W/m}\cdot\text{s}$
 $\alpha = 38.3 \times 10^{-6} \text{ m}^2/\text{s}$
 $Pr = 0.69$

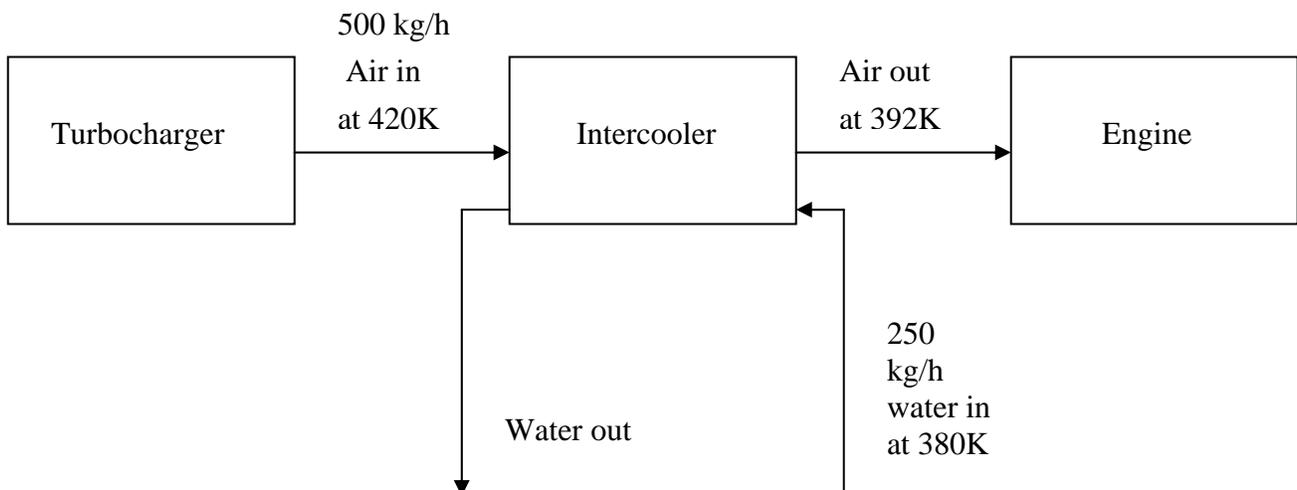
Water $\rho = 993 \text{ kg/m}^3$
 $c_p = 4250 \text{ J/kg}\cdot\text{K}$
 $\nu = 2.2 \times 10^{-7} \text{ m}^2/\text{s}$
 $\mu = 2.18 \times 10^{-4} \text{ N}\cdot\text{s/m}^2$
 $k = 0.69 \text{ W/m}\cdot\text{K}$
 $\alpha = 1.6 \times 10^{-7} \text{ m}^2/\text{s}$
 $Pr = 1.35$

Exchanger

Total cross sectional (flow) area on tube
side = $5.9 \times 10^{-3} \text{ m}^2$

Total cross sectional (flow) area on shell
side = $11.8 \times 10^{-3} \text{ m}^2$

Heat transfer area (tube-side)
= 2.36 m^2



Part D

- (i) A hot oil stream of 50,000 pounds/hr. is to be exchanged against a cold oil stream of 80,000 pounds/hr. The hot oil is available at 380°F and has a specific heat of 0.5, the cold oil will enter at 100°F and also has a specific heat of 0.5. An existing 1-2 parallel-counterflow exchanger is to be used for this purpose. The exchanger has an area of 8000 ft² and the overall heat transfer coefficient is expected to be 20 Btu/hr ft²°F. Determine the outlet temperature.

For the situation described above, it is desired that the outlet temperature of the cold stream be at least 200°F. If a new 1-2 parallel-counterflow exchanger is to be purchased for this task, what must the area be? It may be assumed that the overall heat transfer coefficient in the new exchanger will be 20 Btu/hr ft²°F.

Suggestion: For the first part of this problem, the effectiveness method may prove to be easier than the mean temperature difference method.

- (ii) It has finally been decided that the heat transfer situation described in Problem (i) will be resolved by using two existing exchangers arranged in series. Both exchangers are of the 1-2 parallel-counterflow type but are otherwise different. The areas and expected overall heat transfer coefficients are given below:

Exchanger 1:

$$\text{Area} = 1500 \text{ ft}^2$$

$$U = 30 \text{ Btu/hr. ft}^2 \text{ } ^\circ\text{F}$$

Exchanger 2:

$$\text{Area} = 1000 \text{ ft}^2$$

$$U = 25 \text{ Bru/hr. ft}^2 \text{ } ^\circ\text{F}$$

Two possible flow arrangements are given on the next page.

