

AQ-2842

Faculty of Engineering & Technology
M.E. Mechanical Engg. (Thermal Engg.) Semester-II (New-CGS) Examination
Elective-I HEAT EXCHANGER DESIGN

Paper—2 MTE 4

Sections—A & B

Time—Three Hours]

[Maximum Marks—80

INSTRUCTIONS TO CANDIDATES

- (1) All questions carry marks as indicated.
- (2) Answer **THREE** questions from Section A and **THREE** questions from Section B.
- (3) Due credit will be given to neatness and adequate dimensions.
- (4) Assume suitable data wherever necessary.
- (5) Illustrate your answers wherever necessary with the help of neat sketches.
- (6) Use of Slide rule, Logarithmic tables, Steam tables, Mollier's chart, Drawing instruments, Thermodynamic tables for moist air, Psychrometric charts and Refrigeration charts is permitted.
- (7) Use pen of Blue/Black ink/refill only for writing the answer book.

SECTION—A

1. (a) What are various selection criteria of heat exchangers based on operating parameters ?
7
- (b) A 4 kg/s product stream from a distillation column is to be cooled by a 3 kg/s water stream in a counterflow heat exchanger. The hot and cold stream inlet temperatures are 400 K and 300 K respectively, and the area of the exchanger is 30 m². If the overall heat transfer coefficient is estimated to be 820 W/m²K, determine the product stream outlet temperature, if its specific heat is 2500 J/kgK and the coolant outlet temperature.
7

OR

2. (a) Differentiate between recuperative and regenerating type of heat exchangers. State applications of regenerators and discuss any one of them in brief. 7
- (b) In an open heart surgery under hypothermic conditions, the patients blood is cooled before the surgery and rewarmed afterwards. It is proposed that a concentric tube counterflow heat exchanger of length 0.5 m is to be used for this purpose, with a thin-walled inner tube having a diameter of 55 mm. If water at 60°C and 0.1 kg/s is used to heat blood entering the exchanger at 18 °C and 0.05 kg/s, what is the temperature of blood leaving the exchanger and the heat flow rate. Take $U_o = 500 \text{ W/m}^2\text{K}$, C_p of blood = 3.5 kJ/kgK and C_p of water = 4.183 kJ/kgK. 7
3. (a) Explain any two thermal design theories used in designing the regenerators. 7
- (b) What is the limitation of LMTD method ? How is E-NTU method superior to correction factor-LMTD method ? 6

OR

4. In an oil-to-water heat exchanger, the oil enters the exchanger at 100 °C with a heat capacity rate of 3700 W/K. Water is available at 15 °C and 0.6 kg/s. Determine the exit temperatures in (a) counterflow and (b) parallel flow arrangements for $U = 500 \text{ W/m}^2\text{K}$ and surface area of 10 m². Consider $C_p = 1.88$ and 4.19 J/g.K for oil and water, respectively. If the ratio of convection thermal resistances of oil to water is 1.2, and the wall and fouling resistances are negligible, calculate the wall temperature at each end of the counterflow and parallel flow exchangers. 13
5. (a) Explain primary and secondary stresses in tubes of heat exchangers. 7
- (b) Classify the floating tube sheet heat exchangers. Explain construction and working of any one type of them. 6

OR

6. (a) Explain pressure loss phenomenon in heat exchangers. What are the various theories to minimize it ? 7
- (b) Explain prevention and mitigation of fouling in heat exchangers. 6

SECTION—B

7. (a) Enlist the causes of entropy generation in heat exchangers. Explain one of them in detail. 7
- (b) A brass condenser tube has a 30 mm outer diameter and 2 mm thickness. Sea water enters the tube at 290 K and saturated low pressure steam condenses on the outer side of the tube. The inside and outside heat transfer coefficients are estimated to be 4000 and 8000 W/m²K, respectively and a fouling factor resistance of 10⁻⁴ (W/m²K) on the water side is expected. Estimate the overall heat transfer coefficient based on inside area. Take conductivity of Brass as 111 W/mK. 7

OR

8. (a) Explain corrosion in heat exchangers (i) its types, (ii) corrosion locations in heat exchangers, (iii) corrosion control. 7
- (b) The condenser of a large steam power plant is a shell-and-tube heat exchanger having a single shell and 30000 tubes, with each tube making two passes. The tubes are thin walled with 25 mm diameter and steam condenses on the outside of the tubes with $h_o = 11 \text{ kW/m}^2\text{K}$. The cooling water flowing through the tubes is 30000 kg/s and the heat transfer rate is 2 GW. Water enters at 20 °C while steam condenses at 50 °C. Find the length of the tubes in one pass. Properties of water at 27 °C are $C_p = 4.18 \text{ kJ/kgK}$; $\mu = 855 \times 10^{-6} \text{ NS/m}^2$, $K = 0.613 \text{ W/mK}$ and $p_s = 5.83$. 7
9. A 1-pass 1-pass plate heat exchanger with Chevron plates is being used to cool hot water with cold water on the other fluid side. The following information is provided for the geometry and operating conditions : number of flow passages 24 on the hot water side; plate width = 0.5 m, plate height = 1.1 m; port diameter = 0.1 m; channel spacing = 0.0035 m; equivalent diameter = 0.007 m; hot-water flow rate = 18 kg/s; mean dynamic viscosity = 0.00081 Pa.s; and mean density 995.4 kg/m³ for both manifolds and core. The hot water is flowing vertically upward in the exchanger. The friction factor for the plate is given by $f = 0.8 \text{ Re}^{-0.25}$, where Re is Reynolds number. Compute the pressure drop on the hot-water side. 13

OR

10. Determine the effect of change in the cross-sectional area on the pressure drop of square pipe. The original square pipe has a cross section side length of 70.7 mm. To reduce the pressure drop, an engineer decided to double the pipe cross section with a side length of 141.4 mm over the pipe length of 1 m. Consider air flowing at 0.05 kg/s at 27 °C. The air density and dynamic viscosity are 1.1614 kg/m³ and 184.6×10^{-7} Pa.s, respectively. For fully developed turbulent flow for rectangular duct, consider $f = 0.0791 Re^{-0.25} (1.0875 - 0.1125\alpha)$ where α is aspect ratio of the rectangular flow passage. 13
11. (a) Explain construction and working of wet cooling towers. 6
 (b) Explain any two experimental techniques for determining surface characteristics of heat exchangers. 7

OR

12. A surface condenser receives 250 ton/hr of steam at 40 °C with 12% moisture. The cooling water enters at 32 °C and leaves at 38 °C. The pressure inside the condenser is found to be 0.078 bar. The velocity of circulating water is 1.8 m/s. The condenser tubes are of 25.4 mm outside diameter and 1.25 mm thickness. Taking the overall heat transfer coefficient as 2600 W/m²K, determine :
- (a) the rate of flow of cooling water.
 (b) the rate of air leakage into the condenser shell.
 (c) the length of tubes.
 (d) the number of tubes. 13