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CHEMICAL ENGINEERING REFRESHER PROGRAM

HEAT TRANSFER AND EVAPORATION

1. This dimensionless ratio is used to determine the thermal development on the entrance to ducts where a value of less than 1000 is considered a thermally developed fluid.
   a. Grashof number
   b. Eckert number
   c. Graetz number
   d. Stanton number

2. What is installed to prevent tube damage from incoming high-velocity shell inlet fluid?
   a. impingement baffle
   b. bar baffle
   c. spacer
   d. tie rod

3. What is the TEMA designation for a fixed-tube sheet exchanger with removable channel and cover, bonnet type rear head, and two-pass shell?
   a. DGS
   b. CKT
   c. BEN
   d. AFM

4. A 2-shell passes and 4-tube passes heat exchanger is used to heat glycerin from 20 °C to 50 °C by hot water, which enters the thin-walled 2-cm-diameter tubes at 80 °C and leaves at 40 °C. Determine the LMTD.
   a. 32.66 K
   b. 27.44 K
   c. 24.66 K
   d. 22.44 K

5-7. Your task is to select a plate exchanger from suppliers designed to cool 100,000 kg/hr of methanol from 95 °C to 40 °C with duty of 4,340 kW using brackish water. Cooling water inlet temperature is at 25 °C and outlet temperature at 40 °C. Flow rates of methanol and water are 27.8 and 68.9 kg/s, respectively. Titanium plates are specified to resist corrosion. The logarithmic mean temperature difference is 31 K with a correction factor of 0.96. The overall coefficient for light-organic water of 2,000 W/m-K.

5. What is the required total heat transfer area in m^2?
   a. 62.29
   b. 92.04
   c. 82.35
   d. 72.92

6. Selecting an effective plate area of 0.75 m^2, length of 1.5 m, width of 0.50 m, plate spacing at 3 mm, and number of passes of 48; what is the channel velocity of methanol in m/s?
   a. 0.61
   b. 0.51
   c. 0.41
   d. 0.32

7. What is the channel velocity of brackish water in m/s?
   a. 0.85
   b. 0.96
   c. 1.32
   d. 2.17

8-10. A flat slab of rubber 1-in thick at an initial temperature of 70 °F is placed between two heated steel plates maintained at 280 °F. The heating is discontinued when the temperature at the midplane of the slab reaches 270 °F. The thermal conductivity of rubber is 0.092 BTU/h-ft-F° and thermal diffusivity of 0.0029 ft^2/hr, respectively. In the Gurney and Lurie chart, the Fourier number is X = 1.35.

8. How many hours is the heating period time?
   a. 1.20
   b. 0.99
   c. 0.81
   d. 7.35

9. What is the temperature in °F of the rubber if it is 0.25 in from the metal at the end of the run?
   a. 274.0
   b. 247.0
   c. 270.4
   d. 240.7

10. How long will it take in hours for the rubber to reach a temperature of 270 °F?
   a. 0.596
   b. 0.694
   c. 0.744
   d. 0.964

11-12. A 4-shell passes and 8-tube passes heat exchanger is used to heat peanut oil by hot water, which enters 80 thin-walled 2.5-cm-inner diameter tubes. The shell has an inside diameter of 40 cm, baffle spacing of 10 cm, tube clearance of 0.625 cm, and tube pitch of 3.125 cm.

11. Determine the total tube side crossflow area in cm^2.
   a. 28.9
   b. 74.5
   c. 98.2
   d. 57.4

12. Determine the total shell side crossflow area in cm^2.
   a. 85.0
   b. 80.0
   c. 90.0
   d. 95.0

13. Which of the following statements describe Duhring's rule?
   a. The boiling point of a solution is inversely proportional to the boiling point of the pure solvent for a given pressure.
   b. There is a linear relationship between the boiling point of the pure solvent and the solution for a given pressure.
   c. The enthalpy of mixing of a concentrated solution is directly proportional to its concentration at increasing pressure.
   d. There is a non-linear relationship between the boiling point rise of a solution and its concentration for a given pressure.

14. Why is thermocompression utilized in a single-effect evaporator?
   a. To reduce energy requirement of evaporation
   b. To decrease steam economy
   c. To reduce fouling in the shell side of the heat exchanger
   d. To increase boiling point rise of the solution

15. What models a perfect diffuse surface that scatters incident illumination equally in all directions?
   a. Planck surface
   b. gray body
   c. black body
   d. Lambert surface

16. This is the type of operation used in the evaporation of brine to make salt.
   a. forward feed
   b. backward feed
   c. mixed feed
   d. parallel feed

17. A basket-type short-tube vertical evaporator has 4-ft long steel tubes with an outside diameter of 2 in and wall gauge of 12. Its liquid level is maintained at the top tube sheet. Estimate the overall heat transfer coefficient in BTU/ft^2-hr-F° if a dilute aqueous solution is concentrated at ambient conditions with a temperature difference of 30 R°.
   a. 565
   b. 495
   c. 505
   d. 405

18-20. 4 kg/s of a liquor containing 10% wt solids is fed at 294 K to the first effect of a triple-effect unit. Liquor with 50% wt solids is to be withdrawn from the third effect, which is at a pressure of 13 kN/m^2. The liquor may be assumed to have a specific heat of 4.18 kJ/kg K and to have no boiling point rise. Saturated dry steam at 205 kN/m^2 is fed to the heating element of the first effect and the condensate is removed at the steam temperature in each effect. The three units are to have equal areas with heat transfer coefficients of 3.1, 2.0 and 1.1 kW/m^2-K for the first, second, and third effects, respectively.

18. What is the heat transfer surface area in m^2 of the first effect?
    a. 68.75
    b. 85.50
    c. 74.25
    d. 64.25

19. What is the temperature difference in the second effect?
    a. 17.32 K
    b. 55.81 K
    c. 34.57 K
    d. 19.60 K

20. What is the steam economy of the multi-effect system?
    a. 2.00
    b. 3.00
    c. 2.50
    d. 1.25

21. What boiling mechanism is characterized with a slow initial heat flux rise for increasing temperature drop then followed by a rapid heat flux rise significantly due to radiation?
    a. nucleate boiling
    b. film boiling
    c. natural convection
    d. transition boiling

22. What type of fouling pertains to the accumulation of organisms that are attracted to the warm surface?
    a. Biofouling
    b. freezing fouling
    c. corrosion fouling
    d. particulate fouling

23. Which of the following is the best insulator at 300 °C?
    a. calcium silicate
    b. polyurethane
    c. cellular glass
    d. mineral wool

24. Which statement is false regarding forced-draft air-cooled heat exchanger?
    a. It requires less power when air-temperature rise is less than 30 K.
    b. The fans are located below the tube bundles and pushes air across the tube surface.
    c. It offers better accessibility to fan maintenance and adjustment.
    d. Structural costs are less and mechanical life is longer.

25. What heat exchanger has a series of stacked helical-coil tubes and can be used as cryogenic vaporizer?
    a. spiral-plate
    b. graphite
    c. plate-fin tubular
    d. spiral-tube

26-27. Two parallel gray planes which are very large have emissivities of 0.8 and 0.7 with temperatures of 1100 °F and 600 °F for the first and second surfaces, respectively.

26. What is the net radiation from the first to the second surface in BTU/hr-F°?
    a. 3380
    b. 5210
    c. 7960
    d. 4750

27. If the surfaces are both black, what is the net radiation in in BTU/hr-F°?
    a. 5210
    b. 7960
    c. 3380
    d. 4750

28-30. Air flowing at a 0.90 kg/s is warmed from 283 K to 366 K by passing through pipes of a bank consisting of 20 pipes in each row. The arrangement is in-line with center-center spacing, in both directions, equal to twice the pipe diameter. The heating medium is flue gas with a mass velocity of 10 kg/m^2-s; and enters at 700 K and leaves at 366 K, passes across outside of the pipes. For simplicity, the diameter of the outer and inner pipes can be taken as 12 mm. The specific heat capacity of air and flue gas is 1.0 kJ/kg-K. Values for k and μ are shown:

T (K)	k (W/m-k)	μ (mPa-s)
250	0.022	0.0165
500	0.044	0.0276
800	0.055	0.0367

28. What is the mass velocity of the air inside the pipe in kg/m^2-s?
    a. 23.1
    b. 29.1
    c. 19.9
    d. 21.9

29. Calculate the overall heat transfer coefficient in W/m^2-K.
    a. 66.5
    b. 67.3
    c. 65.6
    d. 63.7

30. Neglecting gas radiation, how long should the pipes be?
    a. 962 m
    b. 926 m
    c. 692 m
    d. 629 m

31-32. A 2-tube passes TEMA Class B heat exchanger has: tube bundle outer diameter of 3 ft, baffle spacing and entrance/exit baffle spacing both equal to 8 in, effective length of 14 ft, tube outer diameter of 1 in, and square tube pitch of 1.25 in.

31. Determine the number of baffles.
    a. 14
    b. 40
    c. 20
    d. 12

32. Estimate the number of tubes.
    a. 579
    b. 1266
    c. 1166
    d. 550

33. If the LMTD of a countercurrent heat exchanger cannot easily be determined, which of the following can be used to calculate its heat transfer rate?
    a. Planck's law
    b. effectiveness-NTU method
    c. pinch analysis
    d. Biot number

34. Which evaporator is commonly used for concentrating heat-sensitive fruit juices?
    a. falling-film
    b. forced circulation
    c. short-tube vertical
    d. horizontal tube

35. Which evaporator has the highest average overall heat transfer coefficient and lowest cost per capacity?
    a. horizontal-tube
    b. long-tube vertical
    c. short-tube vertical
    d. agitated thin-film

36-37. A single effect evaporator is to concentrate 20,000 lb/hr of a 20% wt NaOH solution to 50 wt%. The gauge pressure of the steam is 20 psi while the absolute pressure in the vapor space is 100 mm Hg. The overall coefficient is estimated to b 250 BTU/ft^2-hr-F° while the feed temperature is 100 °F.

36. Calculate its economy.
    a. 0.78
    b. 0.87
    c. 0.99
    d. 0.66

37. Calculate its heating surface required in ft^2.
    a. 1215
    b. 670
    c. 864
    d. 930

38-40. A double-effect evaporator system is to be used to concentrate glycerol-water solution from 10 to 40 percent glycerol by weight at a rate of 1000 kg/h of feed. Identical long-tube natural circulation evaporators are to be used, with overall heat transfer coefficients of 2270 and 1703 W/m^2-C° expected for the first and second effects, respectively, when using backward feed. The feed enters at 15 °C while saturated steam at 120°C is used to heat the first effect. An absolute pressure of 115 mm Hg is to be maintained in the second effect. Assume that the specific heat of all solutions is equal to 4.187 J/g-C° and units are to have equal areas.

38. What is the heat transfer surface area in m^2 of the second effect?
    a. 4.34
    b. 5.35
    c. 6.22
    d. 3.01

39. What is the steam consumption in kg/h?
    a. 525
    b. 874
    c. 478
    d. 255

40. What is the steam economy of the multi-effect system?
    a. 1.89
    b. 1.23
    c. 0.89
    d. 1.56