



NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY
DEPARTMENT OF APPLIED CHEMISTRY
END OF FIRST SEMESTER EXAMINATIONS – DECEMBER 2004
CHEMICAL ENGINEERING PLANT DESIGN – SCH 4108
TIME: (3) THREE HOURS

INSTRUCTIONS TO CANDIDATES

Answer FIVE questions only. Total marks are 100.

1. An organic chemical is being produced by batch operation in which no product is obtained until the batch is finished. Each cycle consists of the operating time necessary to complete the reaction plus a total time of 1.4hr for discharging and charging. The operating time per cycle is equal to $1.5P_b^{0.25}$ hr, where P_b is the kg of product produced per batch. The operating costs during the operating period are USD20per hr, and the costs during the discharge-charge period are USD15per hr. The annual fixed costs for the equipment vary with the size of the batch as follows: $C_F = 340P_b^{0.8}$ USD per batch. Inventory and storage charges may be neglected. If necessary the plant can be operated 24hr per day for 300 days per year. The annual production is 1 million kg of product. At this capacity, raw material and miscellaneous costs, other than those already mentioned, amount to USD260 000 per year.

Determine:

- (i). Operating time per cycle for conditions of minimum total cost per year.
- (ii). Total operating time used per year for condition of minimum cost per year.
- (iii). Total time available per year. (20 marks)
2. (a) Cite four(4) factors characterizing loss prevention. (8marks)
- (b) The OD of an uninsulated steam pipe is 8.5cm. The outside-surface temperature of the pipe is constant at 300°C, and the pipe is located in a large room where the surrounding temperature is constant at 70°C. The heat content of the steam is valued at USD 0.50 per 35W. The emissivity of the pipe surface is 0.7 and the heat-transfer coefficient for heat loss from the surface by convection is $1.4W/m^2°C$. Under these conditions determine the cost per year for heat losses from the uninsulated pipe if the length of the pipe is 50m.
- $$Q_c = hA\Delta t$$
- $$Q_r = 0.171\epsilon[(T_1/100)^4 - (T_2/100)^4]/(T_1 - T_2) \quad (12 \text{ marks})$$
3. (a) Mention and explain fully the major factors used in the selection of most plant sites. (12 marks)

(b) After leaving the refinery, number 2 fuel oil is piped to a tank farm, where it is pumped into a large cylindrical storage tank. The tank is 15m in diameter and has a height of 12.20m. If the tank is initially empty, determine the time required to fill it to a height of 11.6m using a pumping rate of $90\text{m}^3/\text{h}$. The density of the fuel oil at the pumping conditions is $881\text{kg}/\text{m}^3$. (8marks)

4. (a) Minimize the following nonquadratic function using the Newton method $f(x) = 4x^4 - x + 1$ starting point of $x=3$ until the change in x is less than 10^{-7} . (10 marks)

(b) Examine the following problem.

$$\text{Min}f(\mathbf{x}) = 3x_1 + x_2 + x_3$$

$$\text{subject to: } x_1 - 2x_2 + x_3 \leq 1$$

$$-4x_1 + x_2 + 2x_3 \geq 3$$

$$2x_1 - x_3 = -1$$

$x_j \geq 0; j = 1, 2, 3$, Is there a basic feasible solution to the problem? Answer yes or no and explain. (10 marks)

5. (a) Determine enthalpy change when 1mol of gaseous methane is heated from 300K to 1000K at atmospheric pressure.
 $C_p = 4.75 + 1.2 \times 10^{-2}T + 0.303 \times 10^{-5}T^2 - 2.63 \times 10^{-9}T^3$ (8 marks)

(b) A saturated solution of NaCl at 100°C and a mass of 100g is cooled to 0°C whilst part of the salt crystallizes. Determine the amounts of the saturated solution and crystals obtained as product of the operation. The solubility of NaCl at 0°C and 100°C are $35.7\text{g}/100\text{gH}_2\text{O}$ and $39.8\text{g}/100\text{gH}_2\text{O}$, respectively. (12 marks)

6. (a) The total annual cost of operating a pump and motor (C_T) in a particular piece of equipment is a function of x , the size (horsepower) of the motor, namely:

$$C_T = \$500 + \$0.9x + \$0.03/x(150\ 000)$$

Determine the motor size that minimizes the total annual cost. (6 marks)

(b) List the major fields, which should be considered for plant safety and the responsibilities of the design engineer in each case. (14 marks)

END OF QUESTION PAPER!!!