Mechanical Engineering Department
MEL 806: Thermal System Simulation & Design

Max Point:60 **<u>MAJOR TEST</u> (May 2007)** **70 minutes**

Solve Q1. <u>and</u> any two problems more Symbols have their usual meanings

Q1. A refrigeration plant in a hostel is being used to produce both warm water for use in kitchen and cold water for drinking. Water is available at 30° C and is to be cooled to 15° C in the evaporator for use as drinking water, while it is to be heated to 50° C after picking up heat from the condenser. The peak drinking water requirement is estimated at 100 liters per hour.

The first cost of heat exchangers (i.e. the condenser or the chiller) in rupees can be calculated as

$$\text{Cost} = 50\, Q^{0.8} \in^{1.5}$$

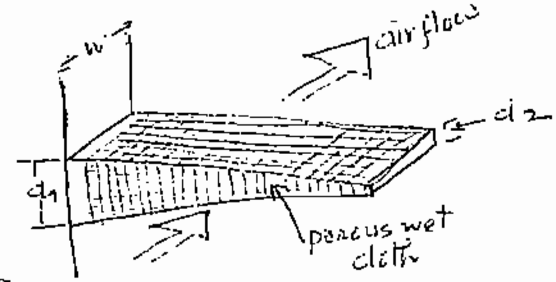
Where Q is the heat transfer rate in <u>Watts,</u> and $\in$ the effectiveness of heat exchanger.

The eompressor power consumption is related to the evaporator temperature Te(° C) and the condenser temperature Tc (° C) and the refrigerating effect in the evaporator (Qe) by the equation: $P = 1.5\, Qe\, [(Tc-Te)/(Te+273)]$

Formulate the problem of design of this refrigeration system for minimum life cycle cost, ie. Initial cost + total power cost for running it over 10years @ 3000hrs/year. Take average cost of electric energy on Rs.4/kWhr. Identify the variables and the constraints and initiate the problem solution using Box's complex method. Choose 4 suitable starting points, calculate the objective function value at these points and rejecting the worst point, identify a "better point" for search taking $\alpha = 2$. How will you find the quantity of hot water produced?

[20]

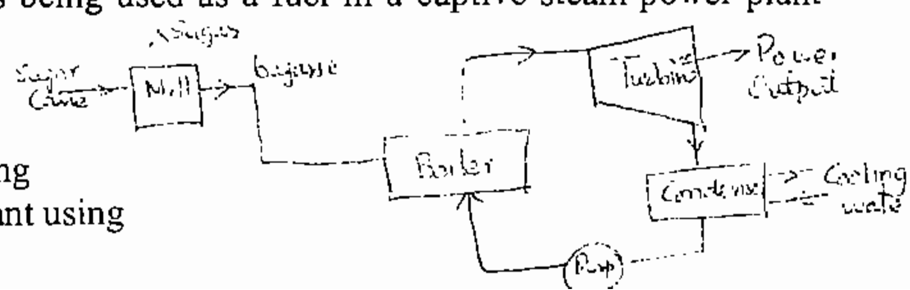
Q2. An electronic device is to be kept cool by rapid dissipation of heat generated at the rate of Q watts. For this purpose a trapezoidal fin of constant width W and thickness varying from d_1 (at the base) to d_2 (at the tip) is proposed to be used. To accelerate cooling



it is covered with a porous cloth which is constantly kept wet by a suitable arrangement. Derive, from the first principles, the differential equation governing the temperature profile in the fin as a function of distance x measured from its base. What are the boundary conditions for solution of this differential equation?

[20]

Q3. The bagasse from a sugar mill is being used as a fuel in a captive steam power plant (see fig.) Explain with the help of an information flow diagram how could we determine the power out put and the operating conditions of the steam power plant using

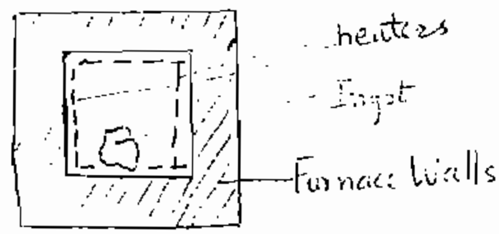


the following input information:

- Capacity of sugar mill (in tones/day of sugar)
- Bagasse production per kg of sugar
- Water flow rate and temperature at entry to the condenser
- Calorific value of bagasse

You are given the performance characteristics of the turbine and the pump and detailed boiler and condenser design. [20]

Q4. An alloy steel ingot weighing 500kg (Cp = 0.46kJ/kgK) is to be heat treated in an inert atmosphere for 1hour by raising its temperature from ambient temperature of 30^{o} C in accordance with the equation $T_{ing} = 30 + \tau/3$ where τ is the time seconds.



The heat treatment furnace has electric heaters all over its surface and transmits heat to the ingot purely by radiation. The total mass of the electric heaters is 50kg (sp. Heat = 0.44 kJ/kg K). Since these heaters also become very hot, there is also heat conduction through the furnace walls, which therefore become progressively heated up. However the furnace walls are well insulated and therefore during 1 hour the outer surface temperature doesn't rise appreciably. The mass of the furnace walls is 2500kg (average specific heat = 0.9kJ/kg K) and its average temperature (Tw) at any time can be taken as

$$Tw = (T_h + 3\,T_o) / 4$$

Where T_h is the instantaneous temperature of the electric heaters, and T_o is the ambient temperature.

Determine the variation in Tw and the electric power needed for the heaters as a function of time, and find their values for $\tau = 0$ and $\tau = 3600$secs.

Take emissivity of both the ingot and the heaters as 1.

Given effective surface area of ingot = $0.8m^2$.

[20]