NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF INDUSTRIAL TECHNOLOGY

DEPARTMENT OF INDUSTRIAL AND MANUFACTURING ENGINEERING

Bachelor of Engineering Honours Degree Industrial and Manufacturing Engineering

INTRODUCTION TO THERMAL SYSTEMS

TIE 3108

First Semester Main Examination Paper

December 2014

This examination paper consists of 4 pages

Time Allowed: 3 hours

Total Marks: 100

Special Requirements: Steam tables

Examiner's Name: Eng. D. Zimwara

INSTRUCTIONS AND INFORMATION TO CANDIDATE:

1. Answer any five (5) questions
2. Each question carries 20 marks
3. Use of calculators is permissible

QUESTION 1

a) What are the Five(5) differences between the direct and indirect method of measuring boiler efficiency? [5]

b) Discuss ways that can be used to improve the efficiency of a steam power plant [10]

c) A coal-fired boiler generates steam at 8 tonnes per hour and its coal consumption is 1.8 tonnes per hour. Steam is produced at a pressure of 9.8 Bars and temperature of 180 °C from water that is being fed into the boiler at 85 °C. Given that the Gross Calorific Value of coal is 13.4 MJ/kg, calculate the efficiency of the boiler using the direct method. [5]

QUESTION 2

A gas turbine unit and a steam turbine unit are joined together to produce 60 MW power. The isentropic efficiencies of the air compressor, gas turbine and the steam turbine are 70%, 60% and 75% respectively.The exhaust gases from the open-loop gas turbine are the supply gas to the boiler for the steam turbine unit. In the boilermore fuel is burnt. The pressure ratio for the gas-turbine unit is 9 given that the air inlet temperature is 17 °C, and the maximum cycle temperature is 700 °C. Combustion in the steam generator raises the gas temperature to 750 °C and the gas leaves at the chimney of the boiler at 100 °C. Steam is supplied to the steam turbine at 45 Bar, 600°C, and the condenser pressure is 1 Bar.

Taking C_P =1.11 kJ/kgK and γ =1.33 for the combustion gases and neglecting the effect of the mass flow rate of fuel, feed pump work, and all pressure losses, calculate:

a) The required flow rates of air and steam for the total power output, [4]

b) The power output of each unit, [4]

c) The cycle efficiency of each unit, [4]

d) The overall efficiency of the plant, [4]

e) Represent the energy flow in a Sankey diagram. [4]

QUESTION 3

a) With the aid of diagrams distinguish between the vapour-compression and the absorption refrigeration cycles. [6]

b) What are the differences between a refrigeration system and a heat pump? [4]

c) List some common refrigerants and their uses in practical applications. Indicate their standard international codes, common names and chemical formula. [5]

d) What are the important parameters characteristics in the choice of a substance as a refrigerant that should be properly considered? [5]

QUESTION 4

Suncrest factory uses blast freezers to freeze 9000 kg of dressed chickens per hour from 27 °C to - 10°C. The heat leakage into the plant is estimated at 3000 kJ/min. The refrigerant is to be ammonia and the temperature required in the evaporator is - 20 °C. The compressor delivery pressure is 10.34 Bars and the condenser liquid is undercooled to 24 °C before throttling. The plant has a brine circulating system and the temperature rise of the brine is to be limited to 3 K. Assuming that the vapour is dry saturated on leaving the evaporator and that the compression process is isentropic, determine:

a) The power input required in kW taking the mechanical efficiency of the compressor as 90% [6]

b) The swept volume of each cylinder of the twin-cylinder, single acting compressor, for which the volumetric efficiency can be taken as 85%, given that the rotational speed is 200 rpm [6]

c) The rate at which the brine must be circulated in litres per second. [8]

Take the specific heat capacity of dressed chickens to be 1.59 kJ/kgK and its density as 680 kg/m^3

For brine, the specific heat capacity is 2.93 kJ/kgK and the density is 1190 kg/m^3

QUESTION 5

a) Explain with the aid of diagrams the differences between forced convection and natural convection cooling towers and give practical applications of each. [6]

b) Propylene glycol flowing from a flat solar collector enters a tubular heat exchanger geyser at the rate of 3m/s and is cooled from 120 °C to 40 °C by water initially at 17 °C. The specific heat of propylene glycol and water are given as 3.6 and 4.19 kJ/kgK respectively.The overall heat transfer coefficient from propylene glycol to water is140W/m^{2}K. Calculate the surface area required for the geyser when the water flows at 0.4 kg/s,

   i) For parallel flow, [7]

   ii) For counter flow. [7]

QUESTION 6

a) Distinguish between impulse turbines and the reactive turbines. [2]

b) The velocity of steam leaving the nozzles of an impulse turbine is 700 m/s and the nozzle angle is 18°. The blade velocity is 200 m/s and the blade velocity coefficient is 0.8. Calculate for a mass flow rate of 1 kg/s and symmetric blading:

   i) The blade inlet angle. [4]
   ii) The driving force on the wheel. [4]
   iii) The axial thrust. [4]
   iv) The diagram factor. [3]
   v) The diagram efficiency. [3]

QUESTION 7

Calculate the total cooling load for the shoe factory building. State the latent and sensible parts of the heat load. Determine sensible heat factor (SHF). [20]

Data:

- Dimensions of the building 65 x 25 x 4 m, ground floor
- 20 wind rows $2x2$ m each and 10 windows $3x2$ m each. all with blinds, $K_w = 0.85$
- Intensity of solar radiation $q_w = 483$ W/m^2
- 220 fluorescent lights 60 W each, $K_c = 0.4$
- 150 ordinary electrical lights 100 W each, $K_c = 1$
- 25 office workers (metabolic rate $N = 140$ W, sensible heat 80 W, latent heat 60 W)
- 90 factory workers ($N = 235$W, $SH = 100$ W, $LH = 135$ W)
- Equipment: 5 electrical motors 5500 W each, 3 electrical devices 3800 W each, 20 electrical machines 1200 W each, for all $K_{ef} = 1$, $K_{fr} = 0.8$ (dry heat only)
- 8 units of presses 2 kW each and 6 steamers 1 kW each, for all $K_{ef} = 1$, $K_{fr} = 1$ (heat and moisture)
- Outside design conditions DBT = 34°C, RH=30%
- Inside design conditions DBT = 22°C, RH=60%