CERTIFICATES OF COMPETENCY IN THE MERCHANT NAVY – MARINE ENGINEER OFFICER

EXAMINATIONS ADMINISTERED BY THE
SCOTTISH QUALIFICATIONS AUTHORITY
ON BEHALF OF THE
MARITIME AND COASTGUARD AGENCY

STCW 95 CHIEF ENGINEER REG. III/2 (UNLIMITED)

041-32 – APPLIED HEAT

MONDAY 25 MARCH 2013

1315 - 1615 hrs

Examination paper inserts:

Enthalpy-Entropy Chart for Steam Worksheet Q4

Notes for the guidance of candidates:

1. Non-programmable calculators may be used.

2. All formulae used must be stated and the method of working and ALL intermediate steps must be made clear in the answer.

Materials to be supplied by examination centres:

Candidates examination workbook Graph paper 'Thermodynamic and Transport Properties of Fluids' by Mayhew & Rogers (5th edition)

APPLIED HEAT

Attempt SIX questions only.

All questions carry equal marks.

Marks for each part question are shown in brackets.

1. Air at a pressure of 1.2 bar and a temperature of 295 K is compressed in an engine cylinder from a volume of 0.4 m^3 to a volume of 0.05 m^3. The index of compression is 1.55. Heat is then supplied at constant pressure until the volume is 0.1 m^3.

   (a) Sketch the processes on p-V and T-S diagrams. (4)

   (b) Calculate EACH of the following:

   (i) the temperature after compression; (2)

   (ii) the magnitude and direction of the total work transfer; (5)

   (iii) the total change in entropy. (5)

   Note: For air, $\gamma = 1.4$ and $R = 0.287$ kJ/kg K.

2. (a) The maximum temperature in a simple open cycle gas turbine plant is 1500°C. In normal operation, the turbine exhaust temperature (in K) may be assumed to be 0.68 times the turbine inlet temperature (in K), and the compressor delivery temperature may be assumed to be 1.89 times the suction (ambient) temperature. Calculate the specific work output when the ambient temperature is:

   (i) 15°C; (4)

   (ii) 35°C. (4)

   (b) During hot weather, it is proposed to improve the performance of the plant by cooling the inlet air from 35°C to 15°C using a refrigerator. Calculate the minimum required coefficient of performance of the refrigerator if it is not to use more than 20% of the work saved. (4)

   (c) Suggest (with reasons) a modification which could produce a significant improvement in the thermal efficiency of this plant. (4)

   Note: It may be assumed that $c_P = 1.005$ kJ/kg K for both air and hot gas.

3. Ethane (C_2H_6) is burned in 15% excess air.

Calculate the volumetric analysis of the dry flue gases, given that they contain 1% carbon monoxide by volume. (16)

Note: Relative atomic masses: H = 1; C = 12; N = 14; O = 16
Air contains 21% oxygen by volume.

4. In a regenerative steam power plant, steam enters the turbine at a pressure of 40 bar and a temperature of 480°C. It expands to 0.12 bar and a dryness fraction of 0.92. Some steam is bled from the turbine at a pressure of 2.5 bar and supplied to a direct mixing feed heater. There is no undercooling in the condenser, and the feed water leaves the feed heater at the saturation temperature of the bled steam.

(a) Sketch a line diagram of the plant. (3)

(b) On Worksheet Q4, plot the expansion process. To estimate the bled steam condition, it may be assumed that the process line on the h-s chart is straight. (4)

(c) Determine, with the aid of the worksheet, the thermal efficiency of the cycle. The work required to drive the feed pump may be disregarded. (6)

(d) Determine the isentropic efficiency of the turbine. (3)

5. In a two row velocity compounded impulse turbine stage, steam leaves the nozzles with a velocity of 950 m/s at an angle of 20° to the plane of rotation. The mean blade velocity is 198 m/s. All the blade rows are symmetrical, and the blade velocity coefficient is 0.92 for both the moving rows and for the fixed row.

Determine EACH of the following:

(a) the total blade work per kg of steam; (13)

(b) the diagram efficiency. (3)

6. A vapour compression refrigeration cycle uses R134a and operates between pressures of 1.6393 bar and 8.8672 bar. The refrigerant enters the compressor at a temperature of -10°C and leaves at a temperature of 50°C. It leaves the condenser as saturated liquid.

(a) Sketch the cycle on p-h and T-s diagrams. (6)

(b) Calculate EACH of the following:

(i) the coefficient of performance of the cycle; (5)

(ii) the isentropic efficiency of the compressor. (5)

7. A wire of diameter 2 mm carries an electric current, and each metre length generates 2 watts of heat. The surrounding air is at 20°C and the surface heat transfer coefficient is 8 W/m^2 K.

(a) Calculate the temperature of the wire. (5)

(b) The wire is now covered with insulation 1 mm thick and of thermal conductivity 0.12 W/m K. The heat transfer coefficient at the outer surface may be assumed to remain the same.

(i) Show that this will *reduce* the temperature of the wire. (8)

(ii) Explain the cooling effect of the insulation. (3)

8. The free air capacity of a reciprocating air compressor is 20 m^3/min. Free air and suction pressure and temperature are respectively 1.1 bar and 31°C. The delivery pressure is 6.875 bar. Compression is carried out in two stages with perfect intercooling. The stage pressure ratios are equal. The index of compression and expansion is 1.30.

(a) Sketch the p-V diagram for the compressor. (3)

(b) Calculate EACH of the following:

(i) the total indicated power; (6)

(ii) the rate of intercooling; (3)

(iii) the power saved by intercooling. (4)

Note: For air, R = 0.287 kJ/kg K and c_P *= 1.005 kJ/kg K.*

9. Air flows isentropically in a convergent-divergent nozzle. The flow is choked. The stagnation pressure and temperature are respectively 10 bar and 350 K. The throat area is 50 mm^2. The exit velocity is 535.4 m/s.

Calculate EACH of the following:

(a) the mass flow rate; (6)

(b) the exit plane pressure; (5)

(c) the exit area. (5)

Note: $p_c = p_0 \times \left(\dfrac{2}{\gamma+1}\right)^{\gamma/(\gamma-1)}$; $\quad T_c = T_0 \times \left(\dfrac{2}{\gamma+1}\right)$; $\quad a = \sqrt{\gamma RT}$

For air, $\gamma = 1.4$ *and R = 0.287 kJ/kg K*