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, 10 DECEMBER 2012

1315 - 1615 hrs

Examination paper inserts:

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. Ideal gas in a cylinder is heated at constant volume from a temperature of 900 K to a temperature of 1100 K, and then further heated at constant pressure from 1100 K to 1300 K. The change in specific entropy in the constant volume process is 0.0626 kJ/kg K. The change in specific entropy in the constant pressure process is 0.0869 kJ/kg K. After being heated, the gas expands isentropically to ten times its initial volume.

   (a) Sketch the processes on p-V and T-s diagrams. (6)

   (b) Calculate EACH of the following:

   (i) the values of c_V, c_P and γ for the gas; (5)

   (ii) the final temperature of the gas; (3)

   (iii) the magnitude and direction of the work transfer per kg of gas during isentropic expansion. (2)

2. An air standard Diesel cycle has minimum pressure and temperature of 1 bar and 300 K respectively. The maximum pressure and temperature are respectively 80 bar and 2000 K.

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

   (b) Calculate for the cycle EACH of the following:

   (i) the thermal efficiency; (8)

   (ii) the specific work output. (2)

   Note: *For air, γ = 1.4 and c_P = 1.005 kJ/kg K.*

3. Benzene (C_6H_6) is burned in 10% excess air and the combustion products contain 0.03 kg of CO for each kg of fuel burned.

(a) Formulate the full combustion equation per kmol of fuel for the conditions stated. (12)

(b) Calculate the percentage dry gas analysis by volume. (4)

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

4. Steam enters a turbine at a pressure of 50 bar and a temperature of 440°C, and leaves at a pressure of 0.12 bar with a dryness fraction of 0.92. It is then fully condensed without undercooling, and the condensate passes through two direct mixing feed heaters before being fed to the boiler. The high pressure bled steam is at a pressure of 15 bar and a temperature of 280°C, and the low pressure bled steam is at a pressure of 1.5 bar and a temperature of 120°C. The feed water leaves each feed heater at the saturation temperature of the bled steam.

Calculate EACH of the following:

(a) the mass of bled steam supplied to each feed heater, per kg of steam entering the turbine; (12)

(b) the work output of the turbine, per kg of steam entering the turbine. (4)

5. In a 50% reaction turbine stage, the blade/steam speed ratio is 0.8 and the fixed blade outlet angle is 27°. The blade work is 35 kJ/kg and the mean blade diameter is 0.82 m.

(a) Sketch the combined velocity diagram, clearly labelling all velocities and angles. (4)

(b) Calculate EACH of the following:

(i) the speed of rotation of the turbine rotor; (5)

(ii) the blade inlet angles; (3)

(iii) the diagram efficiency. (4)

6. A reversed Carnot refrigeration cycle uses R134a. The refrigerant is dry and saturated at the end of compression, and leaves the condenser as saturated liquid. The cycle operates between temperatures of -5°C and 40°C.

(a) Sketch the cycle on p-h and T-s diagrams. (4)

(b) Determine EACH of the following:

(i) the dryness fraction at compressor inlet; (2)

(ii) the coefficient of performance; (2)

(iii) the refrigerating effect per kg. (4)

(c) Give TWO reasons why such a cycle is unlikely to be used in practice. (4)

7. An LNG carrier has two spherical tanks each of diameter 45 m. They contain liquefied gas at a temperature of -163°C. The tanks are insulated with a 300 mm thickness of material of thermal conductivity 0.04 W/m K. The outside surface heat transfer coefficient is 8 W/m^2 K, and the temperature of the surrounding air is 35°C. The thermal resistances of the inside surface film and of the tank wall may be disregarded. The latent heat of evaporation of the gas is 515 kJ/kg. The density of the liquid is 460 kg/m^3.

(a) Calculate the total heat transfer rate to the tanks. (10)

(b) Estimate the percentage of the cargo which boils off each day. (6)

8. (a) Sketch the p-V diagram for a two-stage reciprocating air compressor, indicating the area(s) which represent the work saved by intercooling. (5)

(b) In a two stage reciprocating air compressor, the LP suction pressure is 1 bar, the LP delivery and HP suction pressure is 4 bar, and the HP delivery pressure is 15 bar. The LP suction temperature is 289 K and the HP suction temperature is 305 K. The index of compression and expansion is 1.28.

Calculate EACH of the following:

(i) the indicated work per kg; (6)

(ii) the heat removed in the intercooler per kg; (2)

(iii) the isothermal efficiency. (3)

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

9. The volume of the shell of a steam condenser is 15 m^3. The shell contains saturated water, dry saturated steam and air, all at a temperature of 41.5°C. The mass of water present is 180 g. Atmospheric pressure is 0.996 bar, and the condenser vacuum gauge reads 672 mm of mercury.

(a) Determine EACH of the following:

(i) the mass of air; (5)

(ii) the mass of dry saturated vapour. (2)

(b) The temperature in the shell now rises to 50°C.

(i) Show that the steam is now superheated. (3)

(ii) Verify that the partial pressure of the steam is now 0.1 bar. (3)

(iii) Determine the new total pressure. (3)

Note: For air, R = 0.287 kJ/kg K; 1 bar = 750 mm of mercury