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, 26 MARCH 2012

1315 - 1615 hrs

Examination paper inserts:

Worksheet Q4 (Enthalpy-Entropy Chart for Steam)

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. Nitrogen at a pressure of 80 bar and a temperature of 2000 K expands isentropically in a cylinder from a volume of 0.03 m^3 to a volume of 0.36 m^3. The pressure after expansion is 2.47 bar. The nitrogen is then cooled at constant volume until the temperature is 300 K.

   (a) Sketch the processes on p-V and T-S diagrams. (5)

   (b) Calculate EACH of the following:

      (i) the isentropic index; (2)

      (ii) the work done during expansion; (5)

      (iii) the heat transfer; (2)

      (iv) the change in entropy. (2)

   Note: For nitrogen, R = 0.297 kJ/kg K.

2. In an air standard Diesel cycle the volume compression ratio is 22/1. The maximum and minimum temperatures are respectively 2010 K and 305 K, and the minimum pressure is 1.05 bar.

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

   (b) Calculate EACH of the following:

      (i) the heat supplied per kg; (3)

      (ii) the net work output per kg; (5)

      (iii) the thermal efficiency; (1)

      (iv) the mean effective pressure. (3)

   Note: For air, $\gamma = 1.4$ and $c_P = 1.005$ kJ/kg K.

3. Pure benzene (C_6H_6) is burned in air, and the dry products are found to contain 4.2% oxygen and 1.2% carbon monoxide by volume.

Determine the percentage excess air supplied. (16)

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

4. In a regenerative steam power plant, steam enters the turbine at a pressure of 60 bar and a temperature of 490°C. It expands to 0.10 bar with an isentropic efficiency of 84%. Some steam is bled from the turbine at a pressure of 10 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. (5)

(c) Estimate the thermal efficiency of the cycle. The work required to drive the feed pump may be disregarded. (8)

5. The total throat area of the nozzles of a simple impulse turbine is 2000 mm^2. The nozzles are convergent/divergent in form, and flow is choked. Steam enters the nozzles at a pressure of 9 bar and a temperature of 450°C, and expands isentropically according to the law $pv^{1.3}$ = constant. The mean blade ring diameter is 0.95 m and the speed of rotation is 9500 rev/min. The blades are symmetrical with a blade angle of 33°. The blade velocity coefficient is 1. The steam leaves the blades in an axial direction.

Determine EACH of the following:

(a) the mass flow rate of steam; (5)

(b) the blade power; (4)

(c) the nozzle angle; (3)

(d) the nozzle exit pressure. (4)

Note: $p_c = p_0 \times \left(\frac{2}{n+1}\right)^{n/(n-1)}$; $v_c = v_0 \times \left(\frac{n+1}{2}\right)^{1/(n-1)}$; $a = \sqrt{npv}$

Approximate relations for the isentropic expansion of steam, quoted in the Steam Tables, may be used as appropriate.

6. A vapour compression refrigeration cycle uses ammonia (R717) and operates between pressures of 2.680 bar and 14.70 bar. The refrigerant enters the compressor at a temperature of -8°C and is compressed with an isentropic efficiency of 85%. The refrigerant leaves the condenser as saturated liquid.

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

(b) Determine EACH of the following:

(i) the temperature leaving the compressor; (7)

(ii) the coefficient of performance of the cycle. (3)

7. A wire of diameter 3 mm carries an electric current, and each metre length generates 2.5 watts of heat. The surrounding air is at 20°C and the surface heat transfer coefficient is 12 W/m^2 K.

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

(b) The wire is to be covered with insulation 1.5 mm thick and of thermal conductivity 0.1 W/m K. The heat transfer coefficient at the outer surface may be assumed to remain the same.

Show that this *reduces* the temperature of the wire. (6)

(c) Explain why in this case the added insulation *increases* the heat flow rate. (5)

8. The free air capacity of a reciprocating air compressor is 15 m^3/min. Free air and suction pressure and temperature are 1.00 bar and 30°C respectively. The delivery pressure is 13.0 bar. Compression is carried out in two stages with perfect intercooling under minimum work conditions. The index of compression and expansion is 1.28.

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

(b) Determine EACH of the following:

(i) the total indicated power; (7)

(ii) the rate of intercooling; (2)

(iii) the isothermal efficiency. (4)

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

9. A compartment of volume 10 m^3 contains nitrogen at a pressure of 1.5 bar and is separated by a bulkhead from a second compartment of volume 5 m^3 containing methane at a pressure of 1.0 bar. The temperature in each compartment is 20°C. A door in the bulkhead is opened, and the gases mix adiabatically and completely.

Determine EACH of the following:

(a) the final temperature; (2)

(b) the final pressure; (5)

(c) the total change in entropy. (9)

Note: *For nitrogen, $R = 0.297$ kJ/kg K; for methane, $R = 0.520$ kJ/kg K.*