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, 23 MARCH 2015

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:

Candidate's 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. An ideal gas is heated in a cylinder at constant volume from a temperature of 300 K to a temperature of 1208 K. The initial pressure and volume are 1.02 bar, 0.084 m^3respectively.

   It is further heated at constant pressure to 1474 K. The gas then expands isentropically to ten times the initial volume.

   The change in specific entropy for the first process is 1.0 kJ/kgK and in the second process it is 0.2 kJ/kgK.

   (a) Sketch the p-V and T-s diagrams. (5)

   (b) Calculate EACH of the following:

   (i) the values of c_v, c_p, and γ for the gas; (3)

   (ii) the final temperature of the gas; (2)

   (iii) the specific work transfer. (6)

2. In an air standard diesel cycle the volume compression ratio is 18:1 and the volume cut off ratio is 1.8:1. The minimum pressure and temperature are 0.95 bar and 303 K respectively.

   (a) Sketch the cycle on a T-s diagram. (3)

   (b) Calculate EACH of the following:

   (i) the temperatures and pressures at the cardinal points in the cycle; (5)

   (ii) the thermal efficiency; (4)

   (iii) the mean effective pressure. (4)

   Note: For air $\gamma = 1.4$ *and* $c_p = 1.005$ *kJ/kgK*

3. A fuel with a mass analysis of 85% carbon 15% hydrogen is completely burned in air. The dry flue gas shows they contain 3.5% oxygen by volume.

(a) Use molar volumes to formulate the complete combustion equation in kmol per kg of fuel. (10)

(b) Calculate EACH of the following:

(i) the percentage excess air by volume; (3)

(ii) the fuel air ratio by mass. (3)

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

4. (a) A Carnot vapour power cycle uses saturated steam and water as the working fluid and operates between pressures of 0.05 bar and 80 bar.

(i) sketch the cycle on p-v and T-s diagrams; (2)

(ii) determine the thermal efficiency of the cycle; (2)

(iii) determine the specific steam consumption. (2)

(b) An Ideal Rankine vapour power cycle operates between the same pressure as the Carnot cycle in Q4(a). The steam is dry saturated at the beginning of expansion and there is no undercooling in the condenser.

(i) sketch the cycle on p-v and T-s diagrams; (2)

(ii) determine the thermal efficiency of the cycle; (6)

(iii) determine the specific steam consumption. (2)

5. In a 50% reaction turbine stage, the blade-to-steam speed ratio is 0.75 and the fixed blade outlet angle is 28°. The blade work is 35 kJ/kg and the mean blade ring diameter is 800 mm.

(a) Sketch the velocity vector diagram labelling all the velocities and angles. (5)

(b) Calculate EACH of the following:

(i) the blade inlet angle; (2)

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

(iii) the diagram efficiency. (4)

6. A reversed Carnot cycle uses Ammonia as the working fluid. The Ammonia is dry saturated at the end of compression and leaves the condenser as a saturated liquid. The cycle operates between temperatures of -12°C and 34°C respectively.

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

(b) Determine EACH of the following:

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

(ii) the coefficient of performance; (2)

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

(c) Give TWO reasons why such a cycle would not be used in practice. (4)

7. An LNG carrier has three spherical tanks each of 55 m diameter. The tanks contain liquefied natural gas at a temperature of -163°C in a surrounding air temperature of 30°C.
The tanks are insulated with 300 mm of polyurethane foam.

The thermal resistance of the tank wall and internal fluid film may be disregarded.

Determine EACH of the following:

(a) the rate of heat flow into one tank in kW; (10)

(b) the total mass of gas which boils off each day. (6)

Note: The thermal conductivity of the polyurethane foam is 0.06 W/mK.
The outside surface heat transfer coefficient is 12 W/m^{2}K.
The latent heat of the gas is 515 kJ/kg
For a sphere; the surface area = $4\pi r^2$, the surface area at the mean radius = $4\pi r_1 r_2$

8. In a two-stage, single acting reciprocating air compressor, the LP suction pressure is 1.05 bar, the inter-stage pressure is 3.15 bar and the HP delivery pressure is 10.2 bar. The LP suction temperature is 298 K and the HP suction temperature is 311 K. The index of compression and expansion for both stages is 1.29.

(a) Sketch the process on a p-V diagram indicating the areas which represent work saved by intercooling and the isothermal curve. (4)

(b) Calculate EACH of the following per kg of induced air:

(i) the indicated work; (4)

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

(iii) the work saved by intercooling. (3)

(c) Calculate the isothermal efficiencies with and without intercooling. (3)

Note: For air R = 0.287kJ/kgK and c_p *=1.005 kJ/kgK*

9. The volume of the shell of a steam condenser is 12 m^3. The shell contains saturated water, dry saturated steam and air, all at a temperature of 33°C.

The mass of water present is 200 grams.
The atmospheric pressure is 1.03 bar and the condenser vacuum gauge reads 720 mm of mercury.

After a period of time the temperature rises to 39°C.

(a) Determine EACH of the following:

(i) the initial mass of air present; (6)

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

(b) Show that there is still water present at the final temperature. (4)

(c) Determine the final vacuum gauge reading. (4)

Note: For air R = 0.287 kJ/kgK   1bar = 750 mm of mercury.