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, 14 December 2015

1315 - 1615 hrs

Examination paper inserts:

Worksheet Q4 Specific Enthalpy – Specific 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. In an Ideal diesel cycle the pressure and temperature at the start of compression are 1.0 bar and 57°C respectively. The volume compression ratio is 16:1 and the heat energy added at constant pressure is 1250 kJ/kg.

   (a) Sketch the cycle on Pressure-Volume and Temperature-specific entropy diagrams. (4)

   (b) Calculate EACH of the following:

   (i) the cycle efficiency; (6)

   (ii) the mean effective pressure. (6)

   Note: f*or air* c_p *= 1.005 kJ/kgK and* γ *= 1.4*

2. Air enters an open cycle gas turbine plant at a pressure and temperature of 1.013 bar and 27°C respectively and is compressed to 12.5 bar.

   The hot gases leave the combustion chamber and enter the turbine at a pressure of 12.5 bar and a temperature of 827°C expanding in two stages of equal pressure ratio to the initial pressure.

   The gases are reheated to 827°C between the turbine stages.
   The isentroic efficiency of the compressor is 0.8.
   The isentropic efficiency of each turbine stage is 0.85.
   The mass flow rate of fuel may be ignored.

   (a) Sketch the cycle on a Temperature-specific entropy diagram. (4)

   (b) Calculate EACH of the following:

   (i) the compressor outlet temperature; (4)

   (ii) the second stage turbine outlet temperature; (4)

   (iii) the work ratio. (4)

   Note: for air γ *= 1.4 and* c_p *= 1.005 kJ/kgK*
   for the hot gas γ *= 1.33 and* c_p *= 1.15 kJ/kgK*

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3. A marine diesel engine produces 60 MW of brake power with a brake thermal efficiency of 47% when completely burning a residual fuel oil.

The residual fuel consists of 96% hydrocarbon with a chemical formula of $C_{30}H_{62}$ and 4% non-combustible ash.

The air fuel ratio is 30:1.

Calculate EACH of the following:

(a) the lower calorific value of the residual fuel; (4)

(b) the mass flow rate of the fuel; (2)

(c) the gravimetric analysis of the exhaust gas. (10)

Note: *Atomic mass relationships carbon = 12, hydrogen = 1, oxygen = 16.*
the calorific value of carbon = 32.8 MJ/kg
the lower calorific value of hydrogen = 120.9 MJ/kg
Air contains 23% oxygen by mass

4. A three stage steam turbine with reheat operates under the following design conditions.

First stage: isentropic expansion from 60 bar 450°C to 10 bar, followed by constant pressure reheat to 370°C.
Second stage: isentropic expansion to 2 bar, followed by constant pressure reheating to 320°C.
Third stage: isentropic expansion to a condenser pressure of 0.2 bar.

The plant is also capable of operating with the re-heaters bypassed giving a single isentropic expansion from 60 bar 450°C to 0.2 bar.

In both cases there is no under cooling in the condenser and the feed pump work may be ignored.

(a) Plot on Worksheet Q4:

(i) the design expansion and reheat processes; (3)

(ii) the bypass expansion process. (1)

(b) Determine EACH of the following:

(i) the specific power output under the design conditions; (4)

(ii) the designed thermal efficiency of the cycle; (3)

(iii) the thermal efficiency of the cycle with the re-heaters by passed. (2)

(c) State the MAIN reason why the plant has been designed with reheat. (3)

5. The fixed blades of a particular stage in a 50% reaction turbine deliver 14 kg/s of steam at pressure of 4 bar and temperature of 200°C.

The blade inlet and outlet angles are 30° and 20° respectively and the mean blade speed is 60 m/s.

The blade height is one tenth of the mean blade ring diameter and the stage efficiency is 0.85

(a) Sketch the velocity vector diagram for the stage and identify ALL velocities. (4)

(b) Calculate EACH of the following:

(i) the blade height; (4)

(ii) the power developed in the stage; (3)

(iii) the diagram efficiency for the stage; (3)

(iv) the specific enthalpy drop across the stage. (2)

6. In a vapour compression refrigeration plant using refrigerant R134a, the refrigerant enters the compressor at a pressure of 1.0637 bar and after isentropic compression leaves at a pressure and temperature of 7.7 bar 50°C respectively.

The refrigerant leaves the condenser at the rate of 20 kg/min with 5 K of sub-cooling.

(a) Sketch the cycle on EACH of the following:

(i) a P-h diagram indicating the refrigeration effect, compressor work and condenser heat rejection; (2)

(ii) a T-s diagram, indicating superheat and sub-cooling. (2)

(b) Determine EACH of the following:

(i) the condition of the refrigerant at the compressor suction; (4)

(ii) the compressor power required; (3)

(iii) the heat rejection in the condenser; (3)

(iv) the coefficient of performance. (2)

7. Dry saturated steam at 14 bar enters a steam pipe 50 m long with an outer diameter of 150 mm. The pipe is covered with an inner layer of moulded insulation 50 mm thick and an outer layer of mineral felt 30 mm thick.

The mass flow rate of steam in the pipe is 500 kg/hr.

The air temperature surrounding the pipe is 15°C.

Calculate EACH of the following:

(a) the rate of heat loss from the pipe; (8)

(b) the mass of steam condensed per hour. (8)

Note: inner heat transfer coefficient of the pipe = 1000 W/m^2K
thermal conductivity of moulded insulation = 0.075 W/mK
thermal conductivity of mineral felt = 0.15 W/mK
outer heat transfer coefficient of the pipe = 13W/m^2K

8. A single cylinder single acting air compressor has a bore of 268 mm and stroke of 535 mm with a clearance volume of 1.7 litres.

Air is induced at a pressure and temperature of 1 bar and 27°C respectively.

The law for both expansion and compression process is $pV^{1.3} = C$.

The temperature after compression is 225°C.

The compressor has a mechanical efficiency of 0.88 when delivering 650 kg/hr.

(a) Sketch the process on a p–V diagram, indicating ALL volumes. (3)

(b) Calculate EACH of the following:

(i) the delivery pressure; (2)

(ii) the volumetric efficiency; (4)

(iii) the input power at full load; (3)

(iv) the full load speed. (4)

Note: for air R = 0.287 kJ/kgK

9. An ideal gas mixture has the following mass composition: carbon monoxide 30%, hydrogen 18%, methane (CH_4) 10% and nitrogen 42%.

The mixture is isentropically compressed in a gas tight cylinder, from an initial pressure and temperature of 1.5 bar and 27°C respectively to a final pressure of 6 bar.

Calculate EACH of the following:

(a) the specific enthalpy of the mixture before compression; (4)

(b) the characteristic gas constant for the mixture; (3)

(c) the specific internal energy of the mixture after compression; (5)

(d) the volumetric composition of the mixture. (4)

Note: *the universal gas constant = 8.3145 kJ/kmolK.*
for each constituent gas the values of c_p at 300 K are:
carbon monoxide = 1.040 kJ/kgK, hydrogen = 14.31 kJ/kgK,
methane = 2.226 kJ/kgK and nitrogen = 1.040 kJ/kgK .
Atomic mass relationships: H =1, C = 12, N = 14, O = 16.