

NATIONAL EXAMINATIONS**December 2002****98-MEC-B3 ENERGY CONVERSION AND POWER GENERATION****3 hours duration**

Notes to Candidates

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit, with the answer paper, a clear statement of any assumptions made.
2. This is a **Closed Book** examination.
3. Candidates may use one of the approved Casio or Sharp calculators.
4. The examination paper has a total of 8 questions on pages 2 to 8.
5. Reference formulae are given on pages 9 to 11.
6. Appropriate pages from steam tables are included on pages 12 to 14.
7. Attachments for certain questions are on pages 15 to 17.
8. A Heat Balance Diagram with pressures in bar is attached. Note that 1 bar = 0.1 MPa
9. **Do two questions from Section A (Calculative) and two questions from Section B (Descriptive)**
10. **Four questions constitute a complete paper. (Total 60 marks).**
11. **All questions are of equal value. (Each 15 marks).**
12. **The Examination Paper Attachments (pages 15 to 17) must be returned with the answer booklet.**

SECTION A CALCULATIVE SECTION**QUESTION 1 STEAM CYCLE EFFICIENCY**

Refer to the Examination Paper Attachments Page 15 Steam Cycle Efficiency

A steam turbine receives saturated steam at a pressure of 5 MPa from the steam generator of a nuclear reactor and discharges exhaust steam at a pressure of 0.005 MPa to a condenser. Steam is extracted (bled) from the turbine at a pressure of 2 MPa to supply a surface (tubed) feedwater heater and the drains are cascaded back to the condenser via a throttling orifice. One feedwater pump draws condensate from the condenser and delivers it under pressure via the feedwater heater to the steam generator. Assume zero pressure drops in the lines and zero terminal temperature differences (feedwater outlet temperature is the same as the steam inlet temperature and drain outlet temperature is the same as the feedwater inlet temperature) at the heater. Assume also isentropic expansion in the steam turbine and isentropic compression in the feedwater pump. Use Steam Tables.

- (a) Calculate the steam cycle efficiency of the system. (10)
- (b) Illustrate the process on the Temperature-Entropy diagram and relate this to the system diagram by using corresponding numbers. (5)

[15 marks]

QUESTION 2 BELLEDUNE HEAT BALANCE DIAGRAM

Refer to the attached **Heat Balance Diagram for Belledune Generating Station** on Page 18.

At the rated electrical output of 430 MW determine the following:

- (a) Steam cycle efficiency based on boiler heat input and electrical output. (3)
- (b) Shaft power output of high pressure turbine. (4)
- (c) Steam power input to boiler feed water pump turbine based on steam conditions. (2)
- (d) Shaft power input to boiler feedwater pump based on enthalpy rise (Δh) in the pump. (2)
- (e) Hydraulic power output of the boiler feedwater pump based on pressure rise (P_D - Deaerator Pressure) in the pump. Density of water at the pump is 912 kg/m^3 . (3)
- (f) Feedwater pump efficiency. (1)

[15 marks]

QUESTION 3 GAS TURBINE CYCLES

An industrial gas turbine producing electrical power has the following technical specifications:

Rotational speed	3600	rev/min.
Combustion chamber pressure	600	kPa
Inlet air pressure	100	kPa
Inlet air temperature	20	°C
Exhaust gas pressure	100	kPa
Air mass flow rate	290	kg/s
Fuel mass flow rate	6	kg/s
Calorific value of fuel	40 000	kJ/kg

Assume an ideal air standard Brayton cycle with no losses in the compressor or turbine (both 100% efficient) and constant specific heats.

- (a) Calculate the temperatures and pressures at various points in the cycle based on air mass flow only. (6)
- (b) Sketch the process on a T-s diagram showing the temperatures and pressures. (1)
- (c) Calculate the electrical power output of the gas turbine (net output) assuming an electrical generator efficiency of 100% (2)
- (d) Calculate the thermodynamic efficiency of this ideal cycle. (1)

Assume that the cycle above is fitted with a regenerative heater to utilise heat in the exhaust gas to preheat the compressed air before combustion. The exhaust gas thus leaves at the same temperature as the compressor outlet and the heated air enters the combustion chamber at the same temperature as the turbine exhaust (zero terminal temperature differences).

- (e) Sketch the new process on a T-s diagram showing temperatures and pressures. (1)
- (f) Calculate the new fuel mass flow rate to give the same turbine inlet conditions as calculated in (a) above. (3)
- (g) Calculate the new thermodynamic efficiency of this ideal cycle. (1)

[15 marks]

QUESTION 4 WIND AND WATER POWER**PART I WIND TURBINE**

Refer to the Examination Paper Attachments Page 16 Wind Turbine.

The tables and graphs give information for the Vestas V80 1.8 MW Wind Turbine as well as power coefficients for ideal and actual wind turbines. Determine the following for a wind speed of 10 m/s and compare with the specified output.

- (a) Flowrate of kinetic energy and potential air power available in the wind passing through a flow area equivalent to the area swept out by the rotor. (1)
- (b) Maximum ideal shaft power and efficiency obtainable from the wind turbine. (1)
- (c) Specified power and efficiency of wind turbine based on manufacturer's output specifications for a wind of 10 m/s. (1)
- (d) For comparative purposes, the anticipated power and efficiency of wind turbine based on published power coefficient for two-bladed propeller type (closest approximation to three-bladed Vestas turbine) (2)

Question 4 continued on next page.

PART II HYDRO TURBINE

Refer to the Examination Paper Attachments Page 17 **Hydro Power Plant**.

The attached figure shows a cross-sectional drawing of an underground hydro power station close to the wall of a dam. It has the following design parameters:

Reservoir water level	1170.5 m	(point 1)
Turbine inlet elevation	1091.5 m	(point 2)
Turbine outlet elevation	1086.5 m	(point 3)
Tailrace water level	1094.5 m	(point 4)
Penstock (inlet) diameter	7.0 m	(point 2)
Draft Tube (outlet) diameter	5.0 m	(point 3)
Turbine inlet pressure	700 kPa gauge	(point 2)
Turbine outlet pressure	65 kPa gauge	(point 3)
Water volume flow rate	200 m ³ /s	

Calculate the following:

- (a) The water velocity at the turbine inlet (point 2) and at the turbine outlet (point 3).
The head loss in the intake pipe (penstock) (between point 1 and point 2) and in the outlet pipe (draft tube) and tailrace (between point 3 and point 4).
(5)
- (b) The potential power output of the turbine based on elevation difference (between point 1 and point 4) and flow.
The power developed in the turbine based on inlet and outlet conditions (between point 2 and point 3).
(5)

[15 marks]

SECTION B DESCRIPTIVE SECTION**QUESTION 5 PRINCIPLES OF NUCLEAR ENERGY**

- (a) Explain the nuclear fission process and need for neutron moderation in thermal fission reactors. (5)
- (b) Explain what determines the stability of an established fission chain reaction and how this stability is maintained in an operating reactor. (5)
- (c) Sketch the main components of a typical heterogeneous reactor showing clearly those components affecting neutron generation and absorption and heat production and removal. (5)

[15 marks]

QUESTION 6 FOSSIL BOILER SUPERHEATERS AND REHEATERS

- (a) Sketch a cross-section of a typical fossil fuel fired boiler showing the furnace zone and convection passes. Show the usual location of the primary and secondary superheaters and reheaters. State which heat exchange components receive heat primarily by radiation and which receive heat primarily by convection. (5)
- (b) Sketch the exit temperature response of convective and radiant superheaters as load and hence flowrate on the boiler is changed. Explain how the effect of these responses can be offset or minimised. Explain also what other methods may be used to control steam exit temperature. (6)
- (c) Explain the relative locations (sequence in gas path) of the two superheaters and the reheater with respect to prevailing temperatures and heat transfer coefficients. (4)

[15 marks]

QUESTION 7 STEAM TURBINE BLADING

- (a) With the aid of sketches explain the technical difference between impulse and reaction blading. Give the advantages or disadvantages of one with respect to the other. (7)
- (b) Explain why large steam turbines have separate high and low pressure cylinders, multiple low pressure cylinders and multiple stages in each cylinder. (4)
- (c) Describe losses that occur in flow through steam turbine blading and which lead to an output less than the ideal output. (4)

[15 marks]

QUESTION 8 FOSSIL FUEL EMISSION CONTROL

- (a) Consider one method for the removal of particulate matter from the exhaust gas of a coal fired boiler plant. Explain the principles of this method clarifying what determines its effectiveness or efficiency. Sketch the configuration and explain the functions of the main components of the system. (7)
- (b) Consider one method for the removal of sulphur dioxide from the exhaust gas of a coal fired boiler plant burning high sulphur coal. Explain the principles of this method giving the appropriate chemical reactions and products. Sketch the configuration and explain the functions of the main components of the system. (7)
- (c) Sketch or state where the components described in (a) and (b) above would be located in a typical power plant. (1)

[15 marks]