BK 19

CARLETON UNIVERSITY

FINAL
EXAMINATION
April 2010

DURATION: 3.0 **HOURS** **No. of Students:** 220

Department Name & Course Number: Mechanical & Aerospace Engineering MAAE 2400 B, C

Course Instructor(s): Prof. J. Gaydos & Prof. T. Kaya

AUTHORIZED MEMORANDA

Calculator, Any hand-written notes, Downloads from course website, Course laboratory and problem set manual and "Thermodynamics" textbook by Moran & Shapiro

Students **MUST** count the number of pages in this examination question paper **before** beginning to write, and report any discrepancy immediately to a proctor. This question paper has 2 pages.

This examination question paper **MAY** be taken from the examination room.

ATTEMPT ALL QUESTIONS (Assigned Marks per Question indicated below)

Question 1 (25 Marks)

A rigid and uninsulated tank contains 2 kg of water at 130°C and 270.1 kPa. The water is stirred by a paddle wheel and the paddle wheel does 20 kJ of work on the water and the final temperature in the tank is 100°C. The surrounding environment is at 10°C. If the entropy change of the water is zero, then

(a) Show schematically the process on a temperature-entropy (T-s) diagram by showing the two-phase region, clearly indicating each state and the temperature/pressure values on your diagram.
(b) Determine the final pressure in the tank in kPa.
(c) Determine the amount of heat transfer between the tank and surrounds in kJ.
(d) Determine the entropy generation during the process in kJ/K.
(e) Briefly explain the reason for the entropy generation.

Question 2 (15 Marks)

(a) An adiabatic turbine expands steam from 500°C, 3.0 MPa to 200°C and 0.3 MPa. If the turbine generates 750 kW, then what is the mass flow rate of steam through the turbine?
(b) If a breakdown of the thermal insulation around the turbine allows a heat loss of 60 kJ per kg of steam and the existing steam is at 160°C and 0.3 MPa, then what will be the power developed by the turbine if the inlet steam conditions and mass flow rate are unchanged?

Question 3 (10 Marks)

A turbine blade can be modeled as a flat plate with a certain thickness. The temperature on the hot side of the plate is measured as 500°C and on the cold side as 480°C. The thermal conductivity of the turbine blade material is 55 W/mK.

(a) Draw a simple sketch showing the turbine blade arrangement and write down the governing equation for the rate of heat transfer for this problem,
(b) Calculate the rate of heat transfer per unit surface area across the turbine plate if the thickness is 3 mm.

Question 4 (20 Marks)

(a) A steam turbine in a small electric power plant is designed to accept 4500 kg/hr of steam at 60 bar and 500°C and to then exhaust the steam at 10 bar. Assuming the turbine operates adiabatically and has been well designed so that it is reversible, compute the exit temperature of the steam and the power generated by the turbine.
(b) The efficiency of a turbine is defined to be the ratio of the work actually obtained from the turbine to the work that would be obtained if the turbine operated isentropically between the same inlet and exit pressures. If the turbine considered above is adiabatic but only 80% efficient, then what would be the exit temperature of the steam?
(c) At what rate would entropy be generated within the turbine?

Question 5 (30 marks)

A closed-loop steam cycle has been proposed to generate work from burning fuel. The heat and work energy flows are shown below along with the state numbers around the loop. The temperature of the burning fuel is 1100°C and cooling water is available at 15°C. The steam leaving the boiler is at 20 bar and 700°C. The condenser has no pressure drop and produces a saturated liquid at 0.2 bar. The steam lines are well insulated, the turbine and pump operate reversibly and adiabatically and some of the mechanical work generated by the turbine is used to drive the pump.

(a) Create a table listing the state number (e.g., 1 through 4), the type of fluid state at each location (e.g., saturated vapour or saturated liquid, etc.), the temperature, pressure, specific enthalpy and specific entropy at each location around the loop (e.g. at locations 1 through 4).
(b) What is the net work obtained in the cycle per kilogram of steam generated in the boiler?
(c) How much heat is discarded in the condenser per kilogram of steam generated in the boiler?
(d) What fraction of the work generated by the turbine is used to operate the pump?
(e) How much heat is absorbed in the boiler per kilogram of steam generated?