THE UNIVERSITY OF ADELAIDE
DEPARTMENT OF MECHANICAL ENGINEERING

EXAMINATION FOR THE DEGREE OF B.E.

#9900: HEAT TRANSFER
JUNE 1999

TIME: THREE HOURS

Candidates are also allowed 10 minutes to read the paper before the examination begins.

Candidates are required to answer **FIVE** of the six questions in this paper.

Each question is worth 20 marks.

The use of notes, prescribed textbook and calculators is permitted. The textbook will be necessary to solve some of the problems.

Marks are assigned within each question for problem layout and especially for comments both through the solution and concerning the significance of the answer.

Question 1:

Two circular plates, each with a diameter of 2 m, are parallel and directly opposite each other at a distance of 1 m. The hot plate is at T_1=800 K and has an emissivity ε_1=0.8. The colder plate is at T_2=600K and also has an emissivity ε_2=0.8. The radiation heat exchange takes place between the plates as well as with a large ambient air at T_3=300K through the opening between the plates.
Calculate the net heat transfer rate by radiation at each plate and to the ambient air.

Question 2:

Stainless steel (AISI 304) ball bearings, which have uniformly been heated to 850°C, are hardened by quenching them in an oil bath that is maintained at 40°C. The ball diameter is 20 mm, and the convection coefficient associated with the oil bath is 900 W/m^2 K.

(i) If quenching is to occur until the surface temperature of the balls reaches 100°C, how long must the balls be kept in the oil?

(ii) What is the ball surface temperature at the conclusion of the cooling period?

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(iii) What is the fractional energy loss from the ball at the conclusion of the cooling period?

(iv) If 100 balls are to be quenched per minute, what is the rate at which energy must be removed by the oil bath cooling system in order to maintain its temperature at 40°C?

Question 3:

A horizontal pipe of 70 mm outside diameter passes through a room in which the air and the walls are at 25°C. The outer surface has an emissivity of 0.8 and is maintained at 150°C by steam passing through the pipe. What is the heat loss per unit length of the pipe?

Question 4:

Hot air for a large-scale drying operation is to be produced by routing the air over a tube bank (unmixed) while products of combustion are routed through the tubes. The surface area of the cross-flow heat exchanger is 25 m^2, and for the proposed operating conditions, the manufacturer specified an overall heat transfer coefficient U=35 W/ m^2 K. The air and the combustion gases may each be assumed to have a specific heat of c_p=1040 J/kg K. Consider conditions for which combustion gases flowing at 1 kg/s enter the heat exchanger at 800 K, while air at 5 kg/s has an inlet temperature of 300 K.

(i) What is the temperature of the air at the outlet?

(ii) What is the temperature of the combustion gases at the outlet?

(iii) After extended operation, deposits on the inner tube surfaces are expected to provide a fouling resistance of R_f = 0.004 m^2 K/W. What is the percentage drop in the system performance due to the fouling effect?

Question 5:

Experiments have been conducted on a metal cylinder 12.7-mm in diameter and 100-mm long. The cylinder is heated internally by an electric heater and is subjected to a cross-flow of air in a low speed wind tunnel. For a specific set of operation conditions (free stream velocity V=10 m/s at 26.2°C) the heater power dissipation was measured to be W= 46 Watts, and the ***average*** surface temperature was found to be T_s=128.4°C. An error analysis suggested that 15% of the heater power dissipation was lost through the cumulative effects of surface radiation and conduction through the end supports of the cylinder.

(i) Determine the convection heat transfer coefficient from the experimental observation.

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(ii) Compare the experimental result with the convection coefficient computed from an appropriate correlation in Table 4.10 of Mills, A.F., *Heat Transfer*.

(iii) Comment on the result.

Question 6:

A long bar of stainless steel (AISI 316) has an 80x80 mm square cross section. It is hot-rolled at 620°C and then cooled by cold air jets at 30°C, giving a heat transfer coefficient of 400 W/m^2 K.

Determine the time required for the center temperature to decrease to 130°C using:

(i) Temperature response charts

(ii) Long time approximation

(iii) Comment on the temperature used to evaluate the bar properties