GWW School of Mechanical Engineering
Ph.D. Qualifier Exam, Spring 2006
Thermodynamics

Problem 1

A 5 liter tank is heated at the rate of 500 W. Initially the tank contains 0.5 kg of water. From the initial stage and throughout the heating process, a pressure regulating valve in the tank maintains the pressure at 200 kPa (2 bar), releasing steam as necessary to maintain the pressure. At the end of the process, it is found that a total of 0.2 kg of steam was released from the tank.

How long (time in minutes) did the heating process take?

Problem 2

Consider steady flow of an ideal gas through an *adiabatic* turbine with a mass flow rate of $\dot{m}$. The pressure and temperature at the inlet are specified as p_i and T_i, respectively, and the exit pressure is specified as p_e. Changes in kinetic and potential energy are negligible.

a) Writing the enthalpy per unit mass explicitly as a function of arguments T and p, e.g., $h_i = h(T_i, p_i)$, express the rate of work done by the gas on the turbine in terms of knowns $\dot{m}$, T_i, p_i, and p_e and unknown T_e. (2 pts)

b) Assuming specific heats that are independent of temperature, simplify the results of Part (a). (2 pts.)

Prove, based on the 2nd Law, that the work rate is maximal when the flow from inlet to exit has no irreversibilities for the specified conditions. Hint: Appeal to a *Tds* eqn. (6 pts.)

Problem 3

A closed gas-turbine cycle is the proposed power conversion unit for an advanced nuclear power system. Helium will be the working fluid. Helium has molar mass of 4.00 and specific heat ratio of 1.667. For simplicity, please consider an ideal cycle with 100% compressor and turbine efficiencies.

Assume that the Helium can be heated to 1300 K at the turbine inlet by heat from the nuclear reactor, and that it can be cooled to 350 K at the compressor inlet by heat exchange to the atmosphere. Assume the compressor inlet pressure is 200 bar and that the compressor and turbine pressure ratios are 6:1. Ignore any pressure drop in the heat input or heat rejection processes.

What is the efficiency of this ideal gas turbine system? __________ %

It is thought to be feasible to fabricate a regenerator or recuperator for this system that has a heat exchange effectiveness of 90 %. This device is a heat exchanger that preheats the gas leaving the compressor with heat removed from the turbine exhaust stream. How much would this regenerator improve the performance of this system? Please comment on the feasibility of this proposed modification.