GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff School of Mechanical Engineering

Ph.D. Qualifiers Exam - Spring Quarter 1998

Thermodynamics
EXAM AREA

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Assigned Number (DO NOT SIGN YOUR NAME)

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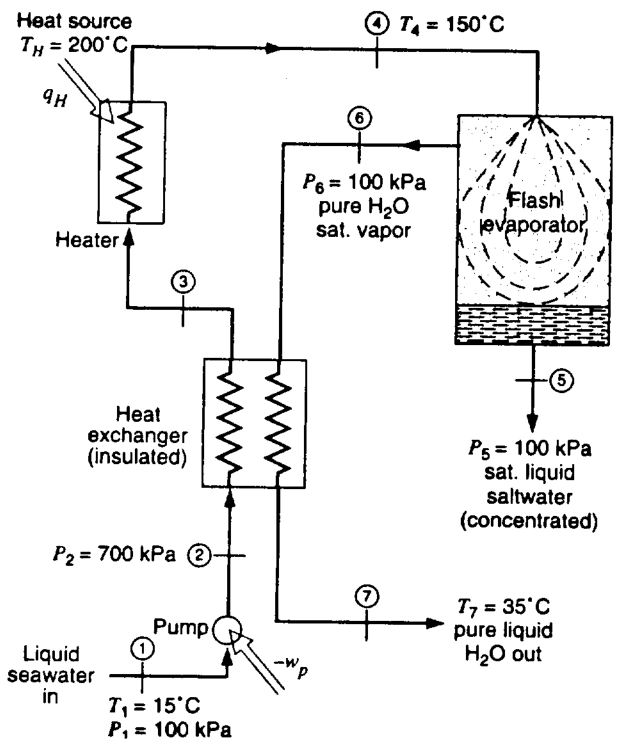
Thermodynamics

1. Consider the system shown below for producing fresh water from salt water. The conditions are as shown in the figure. ASSUME THAT THE PROPERTIES OF SALT WATER ARE THE SAME AS FOR PURE WATER: NEGLECT ALL CHEMICAL DIFFERENCES !!!! Also assume that the pump is reversible and adiabatic.

   1. Determine the ratio ($\dot{m}_7/\dot{m}_1$), the fraction of salt water purified.

   2. Determine the input quantities, w_p, and q_H.

   3. Perform a second law analysis of the overall system. Discuss indicate the source of the major irreversibilities.



2. A cycle, possibly called the "Stirlingson" cycle, has been proposed for a totally reversible heat engine. The cycle has four processes - a heat input process from state 1 to state 2, a constant pressure expansion process from state 2 to state 3, a heat rejection process from state 3 to state 4, and a constant volume process from state 4 to state 1 to complete the cycle. Assume the working fluid is an ideal gas with constant specific heats. Mechanically, the engine must comprise a closed piston-cylinder assembly and a reversible (i.e., highly conductive) heat storage component.

(a) Sketch this cycle on the T-S diagram and on a P-V diagram.

(b) Explain the important features of the heat input process and the heat rejection process if the cycle is to be totally reversible.

(c) Assume that this process is fundamentally feasible for a totally reversible heat engine. Then if the heat source is at 300 C and the heat sink is at 30 C, determine the cycle efficiency.

(d) Describe and analyze the constant pressure process and the constant volume process in general terms. For example, are these processes adiabatic? What are the directions of any heat flows? Is any work involved in either process?

(e) What are the slopes, i.e. $\frac{\partial T}{\partial s}$, for the constant pressure process and the constant volume process? Which process has the steeper slope. You may want to use the first two Gibbs equations,

$$T\,ds = du + P\,dv$$
$$T\,ds = dh - v\,dP,$$

suitably modified for and restricted to ideal gases to determine these derivatives.

(f) Is this cycle fundamentally feasible as a totally reversible heat engine cycle? Answer explicitly "yes" or "no" and give a complete and convincing explanation of your answer based on thermodynamics principles.

3 Given a new substance, describe how you could determine experimentally the needed data and how this data would be manipulated to develop the thermodynamic tables of energy, enthalpy, and entropy for that substance. Simplify your description with the following assumptions:

(a) Assume the substance is a simple compressible substance.
(b) For any experimental technique that you propose, assume that the name of the technique and a brief generic description suffices to identify it. In other words, no experimental details need be given.

Do not spend more than 30 minutes writing about this, but proceed toward the goal of showing how a comprehensive set of tables could be established.

4 One-half kilogram of superheated water vapor at 600 C and 2.0 MPa is contained in a horizontal gun barrel behind a 50 kg projectile that is initially held in place by a pin. The pin is then removed and the vapor pushes the projectile forward into the atmosphere at typical conditions (100 kPa and 25 C). The process is adabatic and occurs without friction.

(a) Determine the volume expansion ratio, V_2/V_1, necessary to obtain the maximum projectile velocity.

(b) Determine the maximum projectile velocity in m/sec units.