GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Fall Semester 2002

Thermodynamics

EXAM AREA

Assigned Number (DO NOT SIGN YOUR NAME)

- **Please sign your name on the back of this page—**

1. Nitrogen gas is contained in a rigid 1 meter tank initially at 10 bar and 300 K. Heat transfer to the contents of the tank occurs until the temperature has increased to 400 K During the process, a pressure-relief valve allows some of the nitrogen to escape, maintaining constant pressure in the tank. Neglecting kinetic and potential energy effects, and using the ideal gas model with constant specific heats evaluated at 350 K determine the mass of nitrogen that escapes (in kg) and the amount of heat transfer to the tank in kJ.

2. A simplified power system for railroad locomotives has been suggested. The locomotive will be powered by burning fuel oil in a 90 % efficient furnace. Liquid water at 25 C and 1 bar will be provided to the feedwater pump. The efficiency of the pump is 60 %. Saturated steam at 50 bars will be generated. The steam will be expanded through a 70%-efficient turbine and exhausted to the atmosphere at 1 bar. The net output power must be 5 MW.
Sketch the process on a *T-s* diagram and determine the following performance data.

a. Power supplied to the feedwater pump _____ kW
b. Power output from the turbine _____ kW
c. Heat rated supplied to the steam generator _____ kW
d. Fuel rate required in terms of Higher Heating Value _____ kW
e. Required flow rate of feedwater _____ kg/sec

Make a rough economic comparison of this system with a conventional diesel engine that burns the same fuel oil.

3. The mixing chamber shown in the figure receives *1.0 kg/s* of saturated liquid ammonia at *-20°C* temperature from line 1, and *0.5 kg/s* of ammonia at *40°C* temperature and *250 kPa* pressure from line 2 through the depicted valve. The ammonia leaving the mixer through line 3 is to be saturated vapor at *-20°C*. The ammonia from line 3 then flows through a compressor to P_4=*7 bar* pressure. The isentropic efficiency of the compressor is *70%*.
    a) Calculate the rate of heat transfer between the mixer + valve system and the ambient.
    b) Calculate the compressor power.
    c) Assuming that heat transfer between the system and the ambient takes place at an average temperature of *-10°C*, prove whether the valve + mixer system violated the second law of thermodynamics.