Ph.D. Qualifying Examination

Thermodynamics

Spring 2013

Logistics Notes:

- Time allowed: 2 hours.
- Exam is open-book (one book) and closed-notes; one sheet (8.50 in. × 11.00 in.) of notes is allowed.
- Calculators are allowed.
- Laptops, cell phones, and similar electronic devices are not allowed.

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Clearly state your assumptions

Problem 1. (45 points) In a boiler, heat is transferred from the products of combustion to the water/steam. The temperature of the products of combustion decreases from 1100 ^{o}C to 550 ^{o}C while the pressure remains constant at 0.1 MPa. The average constant pressure specific heat of the products of combustion is 1.09 kJ/kg*K. The liquid water enters at 0.8 MPa, 150 ^{o}C and steam leaves at 0.8 MPa, 250 ^{0}C. Assuming no heat transfer from the boiler to the surrounding, determine the irreversibility of the process in the boiler per kilogram of water evaporated. Show the process for heating of water to steam in the boiler on T-s diagram.

Problem 2. (55 points) A converging-diverging nozzle is used to accelerate a fluid from subsonic to supersonic velocity. The nozzle is well insulated, and argon enters the inlet of the nozzle at low velocity with a pressure of 360 kPa and a temperature of 1300 K. At the nozzle exit the pressure and temperature of the argon are 130 kPa and 900 K, respectively. Determine the actual exit velocity of the argon, the isentropic efficiency of the nozzle, and the irreversibility per unit mass of argon associated with the process. Assume the temperature of surrounding T_0= 293 K and the flow through the nozzle is steady.

NOTE: for argon, use C_p = 0.52 kJ/kg*K.