16.050 Thermal Energy

Recitation #8 – Fall 2002

Problem 1:

Please refer to the figure drawn on the board.

A power plant operates on a Brayton Cycle with air as the working fluid. The Brayton cycle consists of a compressor, a combustor, and two turbines (the first drives the compressor and the second provides net power output). The exhaust gases from the second turbine flow into a heat exchanger and are used to heat steam that flows into a third turbine (assume that this turbine also provides net power output). Assume that no other heat inputs occur to the steam.

You may assume that the air behaves as a perfect gas with cp=1 kJ/kgK. Neglect kinetic energies, pressure drops, and heat transfer to the surroundings (except in combustor).

T_1=300 K, P_1= 1bar
P_2=8 bar
T_3=1300 K
T_6=450 K, P_6=1 bar
Saturated liquid at state 7
Saturated vapor into steam turbine, P_8=7 MPa
X_9=0.75, P_9=5 kPa
Adiabatic efficiency, compressor=0.8
Adiabatic efficiency of Brayton turbines=0.85

@P=5 kPa, h_f=137.82 kJ/kg and h_g=2561.5 kJ/kg **For steam**
@P=7 MPa h_f=1267 kJ/kg and h_g=2772.1 kJ/kg **For steam**

a) Find the ratio of steam mass flow to air mass flow required for steady state operation.
b) Find the net power output per unit mass flow of air.
c) Find the thermal efficiency of the cycle.

Problem 2:

A turbine and a throttle valve are operating steadily in series as shown on the board. Assume steam is the working fluid, and use the following information:

Turbine inlet pressure=30 bar
Turbine pressure ratio=1/3
Throttle exit pressure=1 bar
Turbine inlet flow and throttle exit flow are saturated vapor

@P=1 bar, h_f=417.46 kJ/kg and h_g=2675.5 kJ/kg
@P=10 bar h_f=762.81 kJ/kg and h_g=2778.1 kJ/kg
@P=30 bar h_f=1008.42 kJ/kg and h_g=2804.2 kJ/kg

Neglect heat losses and kinetic energy terms.

a) What can be said about the phase composition of the working fluid at state 2? If there is a liquid/vapor mixture, find the quality at state 2.

b) What is the specific work output of the turbine?