Thermodynamics

Caution: Students please read before starting

(1) You should be provided with a set of thermodynamics properties tables for use during this exam.

(2) The exam consists of three (3) problems, each starting on a new page. Check NOW to verify that your exam is complete.

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If you are missing the properties tables or any of the three (3) exam problems, stop work NOW and advise your proctor immediately.

Problem 1

An open cooking pot containing 0.5 liter of water at 20^{o}C and 1 bar sits on a stove. Once the burner is turned on, the water is heated at a constant rate of 0.85 kW while the pressure remains constant. After a period of time, the water starts to boil and continues to do so until all the water has evaporated.

(a) Determine the work done by the system (the water) prior to the onset of boiling. (Assume that there is negligible evaporation during this part of the process.)

(b) Determine the time required for the onset of boiling in seconds. List all assumptions.

(c) Determine the time required for all of the water to evaporate in seconds, once boiling starts.

(d) Draw the process on a T-v diagram.

Problem 2

Problem 2. Consider the charging of a compressed air energy storage (CAES) system. A motor driven adiabatic compressor is used to charge a rigid and adiabatic vessel (10.0 cubic meters in volume) with compressed air in a transient process. Assume the walls of the vessel have negligible heat capacity. At an instant, the air in the vessel is well-mixed and at 4 bar and 300°C. The compressor inlet is at 1.0 bar and 25°C, and the compressor outlet flow is 0.1 m^3/s at 200°C. Assume the compressor outlet pressure is the same as the pressure in the vessel. Assume the air is an ideal gas with constant specific heat ratio of 1.40 and 28.97 kg/kmole average molar mass. For the air, assume a reference temperature of 0 K for the zero value (0.0 kJ/kg) of the specific internal energy if needed.

Determine first the compressor efficiency = ___________%

Then determine the instantaneous values of the following properties or rates:

The specific internal energy (u_{cv}) of the air in the vessel = ________________ kJ/kg

The extensive internal energy (U_{cv}) of the air in the vessel = ________________ kJ

The rate of entropy production (or generation) in the compressor = ________________ W/K

The rate of entropy production (or generation) in the vessel (if any) = ________________ W/K

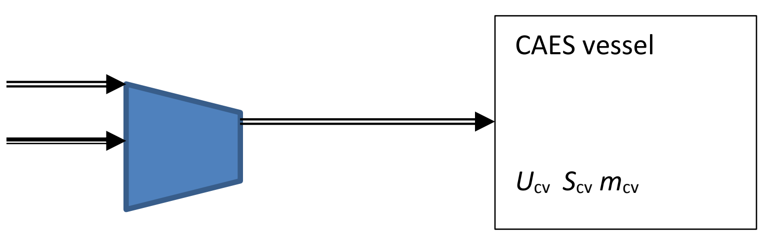
The time rate of change of the extensive internal energy (U_{cv}) of the air in the vessel = ________________ kW

The time rate of change of the mass of air (m_{cv}) in the vessel = ________________ kg/s

The time rate of change of the specific internal energy (u_{cv}) of the air in the vessel = ________________ W/kg

The time rate of change of the specific entropy (s_{cv}) of the air in the vessel = ________________ W/kg-K

The time rate of change of the specific volume ($v_{cv} = V_{cv} / m_{cv}$) of the air in the vessel = ________________ m^3/kg-s



Problem 3

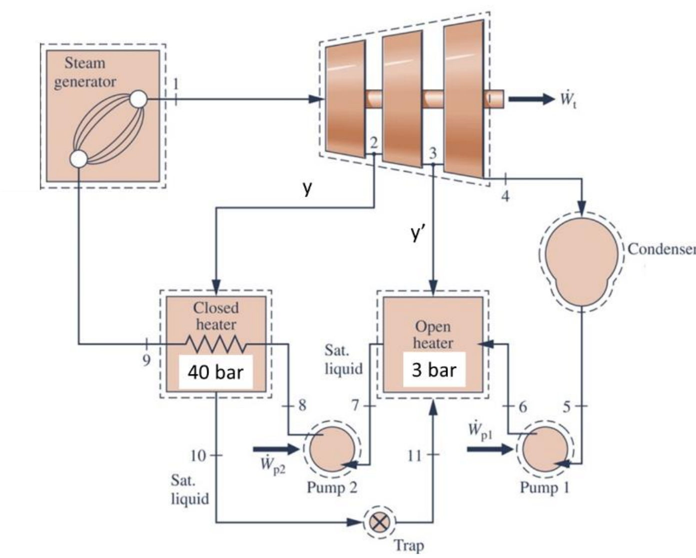
A Rankine cycle is modified to include one closed feedwater heater and one open feedwater heater, generating electricity using water as the working fluid. Superheated vapor enters the turbine at 160 bar, 560 °C, and the condenser pressure is 0.08 bar. The closed feedwater heater uses extracted steam at 40 bar, and the open feedwater heater uses extracted steam at 3 bar. Saturated liquid condensate drains from the closed feedwater heater at 40 bar and is trapped into the open feedwater heater. The feedwater leaves the closed heater at 160 bar and a temperature equal to the saturation temperature at 40 bar. Saturated liquid leaves the open heater at 3 bar. The below table provides steady-state operating data when turbine stages and pumps operate isentropically. Please reconsider the analysis assuming the isentropic efficiencies of the turbine stages and pumps are 85%. Answer the below questions for the modified cycle with $\eta_t = \eta_p = 85\%$.

(a) Sketch the process on the T-s diagram and fill in the table with properties.

(b) Determine the fraction (y) extracted to the close heater.

(c) Determine the fraction (y’) extracted to the open feedwater heater.

(d) Determine the thermal efficiency.



State	P (bar)	T (°C)	h (kJ/kg) with isentropic turbines and pumps	h (kJ/kg) with $\eta_t = \eta_p = 85\%$
1	160	560	3465.4	3465.4
2	40	[redacted]	3050.9	
3	3	T_{sat}	[redacted]	
4	0.08	T_{sat}	[redacted]	
5	0.08	T_{sat}	173.88	173.88
6	3	[redacted]	174.17	
7	3	T_{sat}	561.47	561.47
8	160	[redacted]	578.32	
9	160	[redacted]	1087.3	1087.3
10	40	T_{sat}	1087.3	1087.3
11	3	T_{sat}	1087.3	1087.3