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SELF STUDY MODULE

Turbines, Pumps, Compressors, Steam Tables

Objective

Balances around turbines and compressors. Learning how to use the steam tables.

Vocabulary

Turbines are used to generate work. We will see examples of the systems where flow work is converted to shaft work. In most cases we will assume turbines operating adiabatically (why?).

Compressors are used to increase the pressure of gases and vapors.

Pumps are used to increase the pressure of liquids.

Entropy a useful, mysterious (!) state variable.

Interpolation: finding a value for a property between two available values, assuming a straight line behavior.

Extrapolate: finding a value outside the domain assuming a straight line behavior.

Conservation Laws

The general mass conservation law $\frac{dm}{dt} = \sum_{in} m_i - \sum_{out} m_j$

The general conservation of energy or the first law of thermodynamics

$$\frac{dU}{dt} = \sum_{in} m_i h_i - \sum_{out} m_j h_j + \dot{Q} + \dot{W} - P\frac{dv}{dt}$$

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Get familiar with the steam table and its graphical representation

Fill the following table from the given TS diagram or from the steam table. Electronic version of the TS diagram is uploaded in ODTUCLASS.

State	$\hat{H}(kJ/kg)$	$\hat{V}(m^3/kg)$
400 ^oC, 1 MPa		
400 ^oC, 5 MPa		
200 ^oC, 1.6 MPa, q=0.5		
At the critical point of water (T?, P?)		

Calculate

1. A turbine generates energy using steam at 1 kg/s 800 ^oC and 4 MPa. If the steam at the turbine exit is at atmospheric pressure and 190 ^oC, how much shaft work can we obtain? Before getting numbers, answer the following questions:
    a. What are your assumptions?
    b. Is this process at steady state?
    c. Is this process adiabatic?

2. A process needs air at 100 m^3/h and 10 bar. If you start from air at ambient conditions how much shaft work is needed?
    a. What are your assumptions?
    b. Is this process at steady state?
    c. Is this process adiabatic?

3. 100 l/min water at ambient conditions will be pressurized to 10 atm. How much shaft work is needed?
    a. What are your assumptions?
    b. Is this process at steady state?
    c. Is this process adiabatic?

4. Using the newly acquired knowledge of the steam table, let us solve this problem again. 1 L of water initially at room temperature is in a teapot is on the stove. At time t=0, the stove is turned on and heat is being transferred at a constant rate of 100 W. Using your skills in material and energy balances answer the following questions:

a. Derive an expression for the amount of water in the teapot as a function of time until water starts to boil. State all of your assumptions clearly.
b. Derive an expression for the temperature in the teapot as a function of time until water starts to boil. State all of your assumptions clearly.
c. How does the temperature of water change as a function of time after boiling starts?
d. How does the amount of water change as a function of time after boiling starts?

5. How much time is needed to evaporate water in a tea glass (approximately 100 ml capacity) at room temperature, if the rate of evaporation is considered as constant at 1 ml/hour? List all the assumptions you make.

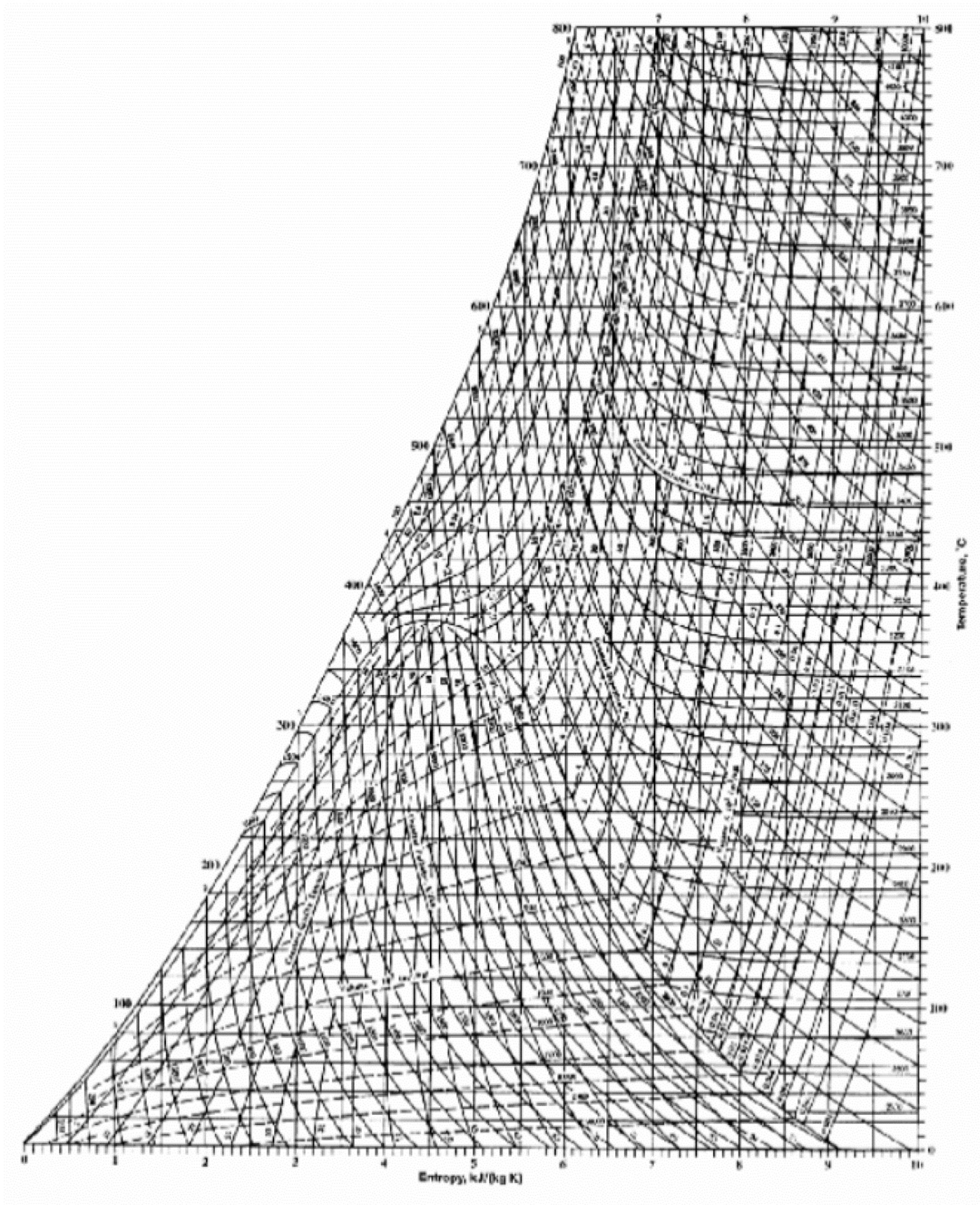
6. How much energy is required to evaporate all of the water in the tea glass at room temperature?

Bibliography

S. Sandler Chemical Biochemical and Engineering thermodynamics, 4th edition, Wiley

M. Koretsky, Engineering and Chemical Thermodynamics, 2nd edition, Wiley, 2013, NY.

M.J. Moran, H. N. Shapiro, D.D. Boettner, M.B. Bailey, Principles of Engineering Thermodynamics, 7th edition, John Wiley and Sons, 2012, NY.



TS diagram of steam, from S. I. Sandler.