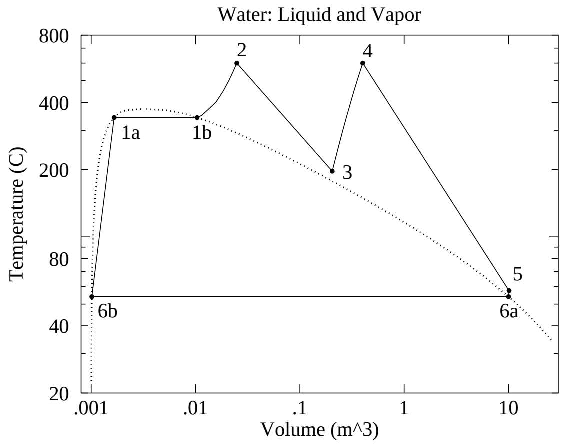

point	Volume (m^3)	Pressure (MPa)	Temperature (°C)	E_{int} (kJ)	Entropy (kJ/K)
1a	0.00166	15.	342	1586	3.6848
1b	0.01034	15.	342	2456	5.3098
2	0.02491	15.	600	3209	6.6764
3	0.2042	1.	197	2782	6.6764
4	0.4011	1.	600	3297	8.0290
5	10.1300	0.015	57	2578	8.0290
6a	10.0228	0.015	54	2449	8.0085
6b	0.00101	0.015	54	226	0.7549

The following problem is based on "steam tables"—tables of V, T, E_{int}, S etc. which substitute for the simple equations like $pV = nRT$, $\Delta S = nC_p \ln(T_f/T_i)$ etc. that apply only to the mythical ideal gas. Again steam is a non-ideal gas; you must use the tabulated V, T, E_{int}, S etc. not formulas based on $pV = nRT$. The data of this problem are very loosely based on a real coal-fired power plant in Lansing, IA.

- 1 kg of liquid water (1a) at a temperature of 342°C and pressure of 15 MPa has been pumped into a boiler. In an isobaric process the water is totally evaporated (point 1b) and then the resulting vapor is heated to 600°C (point 2).
- The high pressure steam is piped to a turbine where it expands adiabatically to pressure of 1 MPa in the process of doing work (point 3)
- This intermediate pressure steam is returned to a section of the boiler where it is again heated to 600°C (point 4, 'reheat') in an isobaric process.
- The reheated, intermediate-pressure steam is piped to a turbine where it expands adiabatically to pressure of 0.015 MPa in the process of doing more work (point 5)
- In an isobaric process, the steam is cooled until it starts to condense (point 6a) and finally all the vapor has been converted to liquid (point 6b).
- A pump is then used to re-inject this low pressure, low temperature liquid water back into the boiler. Approximate this process as a straight-line pV process.

This cycle is displayed above on a log-log T-V diagram. The region below the dotted curve consists of a mixed phase: part liquid and part vapor. In an isobaric boiling process the system moves horizontally from the left boundary to the right as 100% liquid is converted to a much larger volume of 100% vapor at a constant temperature.

1. Find the heat required to evaporate the water at a pressure of 15 MPa (i.e., the process 1a $\rightarrow$ 1b) from ΔS.
2. Find the heat required for the isobaric processes 1b $\rightarrow$ 2 and 3 $\rightarrow$ 4 from he first law of thermodynamics.
3. How much heat was added in the straightline expansion 6b $\rightarrow$ 1a?
4. Find the work done in the turbine during 2 $\rightarrow$ 3 and 4 $\rightarrow$ 5.
5. Find the efficiency of the plant and compare to the Carnot cycle operating between 600°C and 54°C.

6. Find the heat released when the vapor is condensed to liquid at a pressure of 0.015 MPa (i.e., the process 6a $\rightarrow$ 6b) from the first law of thermodynamics.
7. The condensation heat calculated above is removed by dumping it into a nearby river. If the aim is to limit the ΔT of the cooling river water to 20°C, how much river water must be diverted?