CLL121 Coding Exercise: Design of an accumulator for steady boiler operation

Based on problem 6.55 of the textbook

6.55. The *total* steam demand of a plant over the period of an hour is 6,000 kg, but instantaneous demand fluctuates from 4,000 to 10,000 kg hr^{-1}. Steady boiler operation at 6,000 kg hr^{-1} is accommodated by inclusion of an *accumulator*, essentially a tank containing mostly saturated liquid water that "floats on the line" between the boiler and the plant. The boiler produces saturated steam at 1,000 kPa, and the plant operates with steam at 700 kPa. A control valve regulates the steam pressure upstream from the accumulator and a second control valve regulates the pressure downstream from the accumulator. When steam demand is less than boiler output, steam flows into and is largely condensed by liquid residing in the accumulator, in the process increasing the pressure to values greater than 700 kPa. When steam demand is greater than boiler output, water in the accumulator vaporizes and steam flows out, thus reducing the pressure to values less than 1,000 kPa. What accumulator volume is required for this service if no more that 95% of its volume should be occupied by liquid?

The design needs to be done for a specified period (Δt) of low steam demand. During this period, the increase in liquid volume fraction in the accumulator will be inversely related to the accumulator volume (V_{acc}). Another constraint determining V_{acc} is the requirement on accumulator pressure: $P_2 < P_{acc} < P_1$. Develop a code in language/library of your choice (C, Matlab, Python, etc.) to determine accumulator volume as per the problem statement given above for two separate scenarios.

1. (9 marks) The liquid volume fraction in the accumulator is a pre-specified parameter both in the initial (α_i) and in the final state (α_f). The solution approach for this part is given later in this file.
2. (3 marks) A more appropriate design will involve estimating minimum V_{acc} without fixing the liquid volume fraction in the final state. The upper limit on accumulator volume fraction ($\alpha_f = 0.95$) and the limits on accumulator pressure still need to be satisfied.

Code requirements and viva instructions

- All the parameter values listed in problem statement 6.55 (e.g., 95% liquid volume in final state, boiler operation at 6000 kg hr^{-1}, boiler pressure of 1000 kPa, etc.) should be defined as input parameters in your code to be specified by the user at time of execution. Their value should be supplied in an input file. 1 mark penalty if parameter values directly specified (hard coded) in code.

- Following constraints are applicable on various pressure values:
  - Boiler supply pressure (P_1) : 800 kPa $< P_1 <$ 1000 kPa
  - Plant supply pressure (P_2): 700 kPa $< P_2 <$ 750 kPa
  - Accumulator pressure (P_{acc}): $P_2 + 100 < P_{acc} < P_1 - 50$

The saturated steam data for above pressure range can be added directly to the code or be put in a file that is read in the code. Following data is available / determinable from the saturated steam table (see solution approach for more details):

- Specific enthalpy at P_1 and P_2
- Specific volume and specific internal energy at initial and final accumulator pressure (P_i, P_f).

Notes

- Viva schedule will be announced later. It will be in last week of march.
- Appendix 1: Solution approach for part 1.
- Appendix 2: Test cases.
- Appendix 3: Steam table to be used for given assignment.
- Appendix 4: Additional information on steam accumulators.