APPROVED SOLUTION

Design Problem 5 – Introduction to Process Control

1. Objectives.
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Objectives

1. Use CHEMCAD to design a temperature controller on a heat exchanger.
2. Use CHEMCAD control valve, temperature sensor, and ramp programmer.
3. Run a dynamic simulation in CHEMCAD.

Problem Background and Statement

You were previously introduced to piping elements in CHEMCAD. In lab 1, we examined the piping unit and pumps with a fixed pressure increment. In labs 2 and 3, we examined hydraulic calculations in CHEMCAD using nodes and pumps with characteristic curves. In lab 4, we examined pumps, reflux vessels, condensers and reboilers in a distillation process. In this lab, we will introduce four more elements, namely control valves, control sensors, ramps, and steady state controllers for programming changes in streams. Because of the heat exchangers we covered in previous lessons, a natural place to go next is to learn how to learn how to control heat exchangers under temperature and flow control.

Your instructor will provide you with a PowerPoint presentation that contains the detailed instructions for building and running the simulations. The file is located in Canvas. Carefully follow the procedure in the PowerPoint and run the simulations. When finished, proceed to the questions and submission requirements below.

Questions:

1. Answer the five exercise questions in PowerPoint Slide 12.
2. Complete the five plots in PowerPoint slides 30-34. Plots are graded based on accuracy and professional appearance. All axes are labelled and each plot has title.
3. Answer questions 1 to 5 in PowerPoint slides 36-40 and question 6 in PowerPoint slide 45. Answer the questions concisely and in less than 100 words. Answers will be based on technical accuracy, grammar, clarity, and brevity.

Submission Requirements

1. Print completed slide 12 in pdf format.
2. Print completed slides 30-34 (plots) in pdf format.
3. Print of completed slides 36-40 (questions 1 to 5) in pdf format.
4. Print of completed slides 45 (question 6) in pdf format.
5. Bundle 1-4 into a single pdf with cover page and upload to Canvas.
6. Upload final CHEMCAD file to Canvas.
7. All work is due NLT 1445 hours (End of lab hour).

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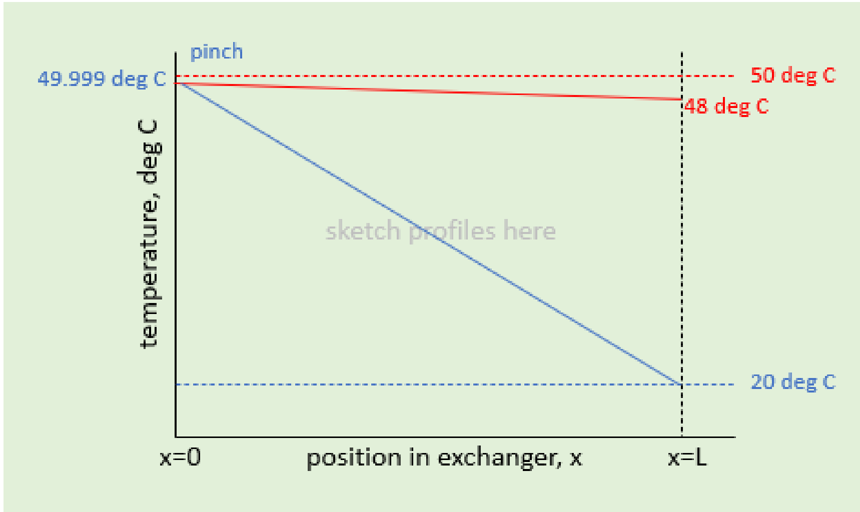
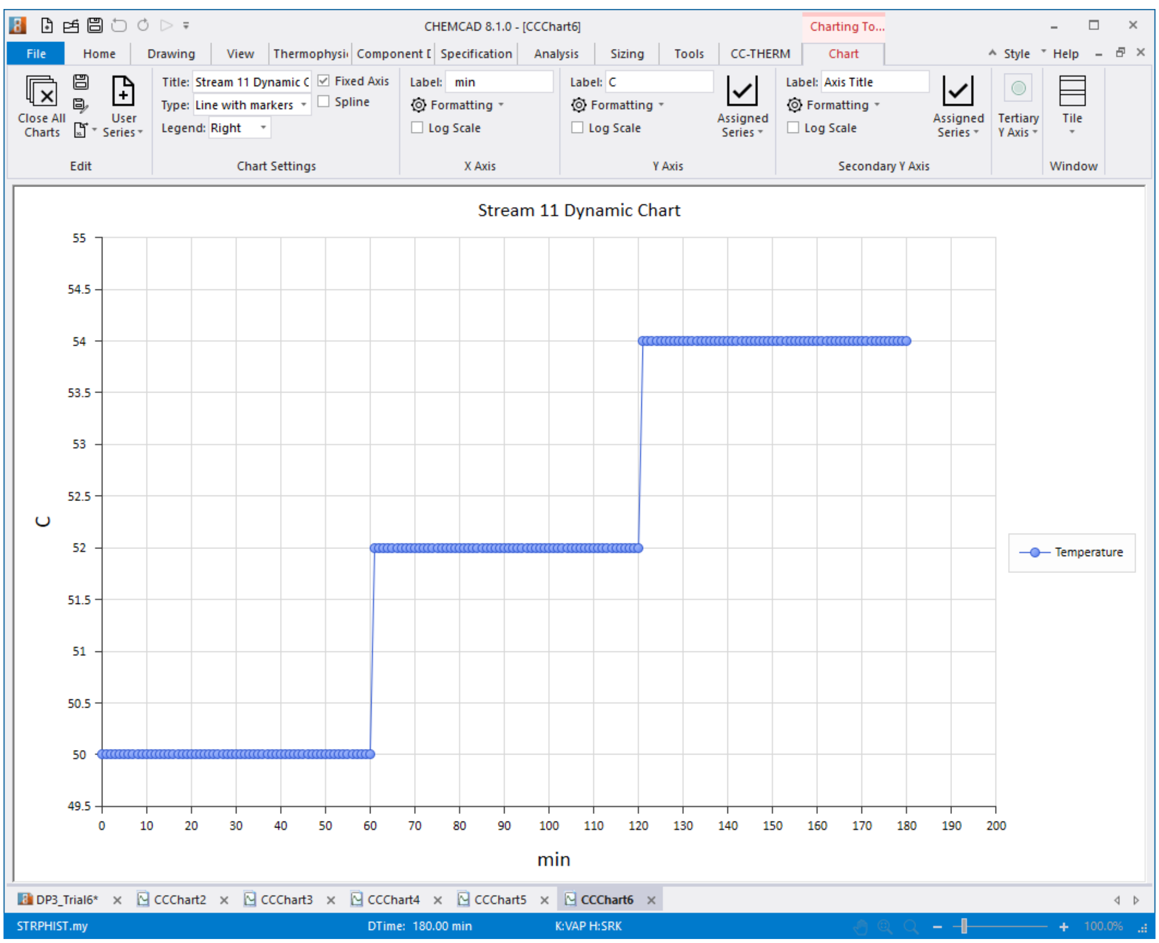
Sketch of the heat exchanger temperature profile:



The first plot shows the temperature of the warm stream, showing a 2-degree increase in temperature at 60 min and another 2-degree temperature increase at 120 min.



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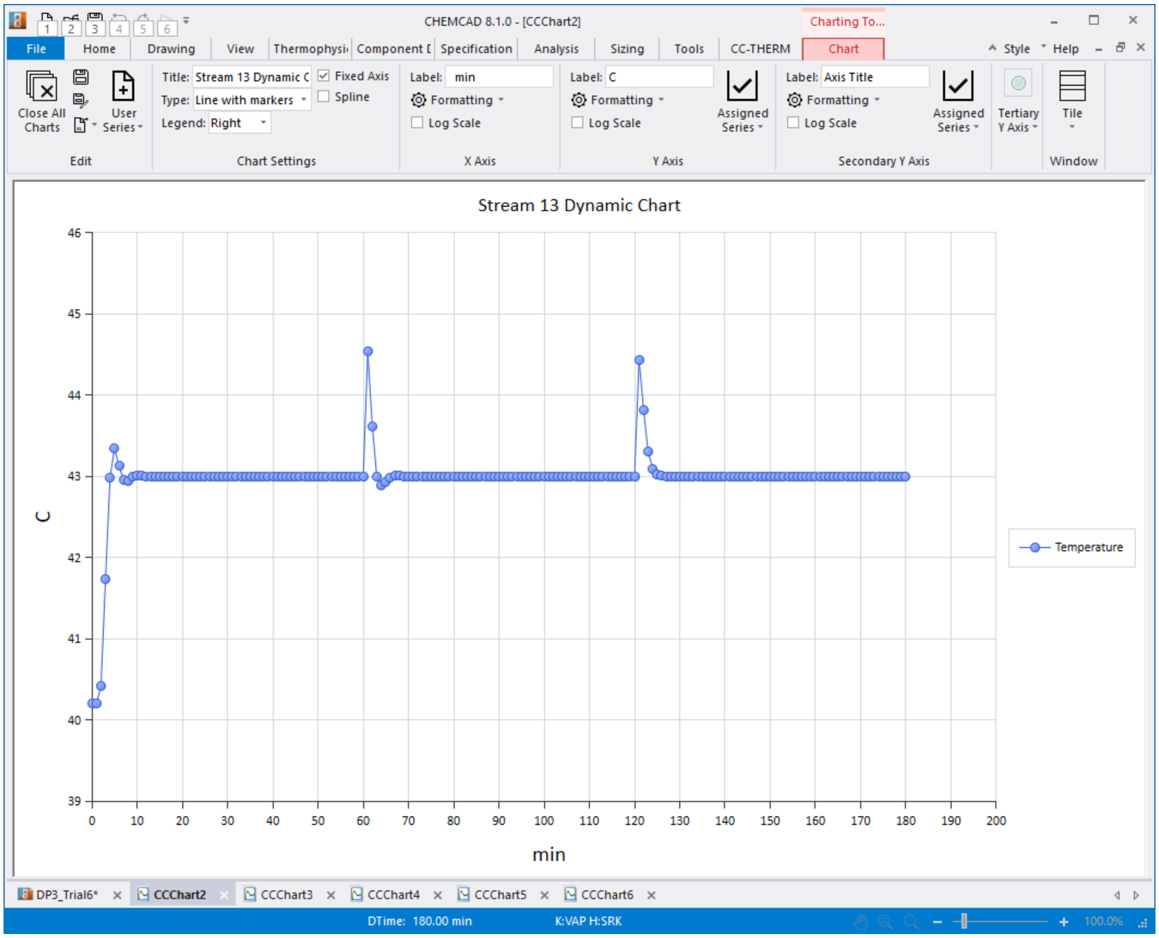
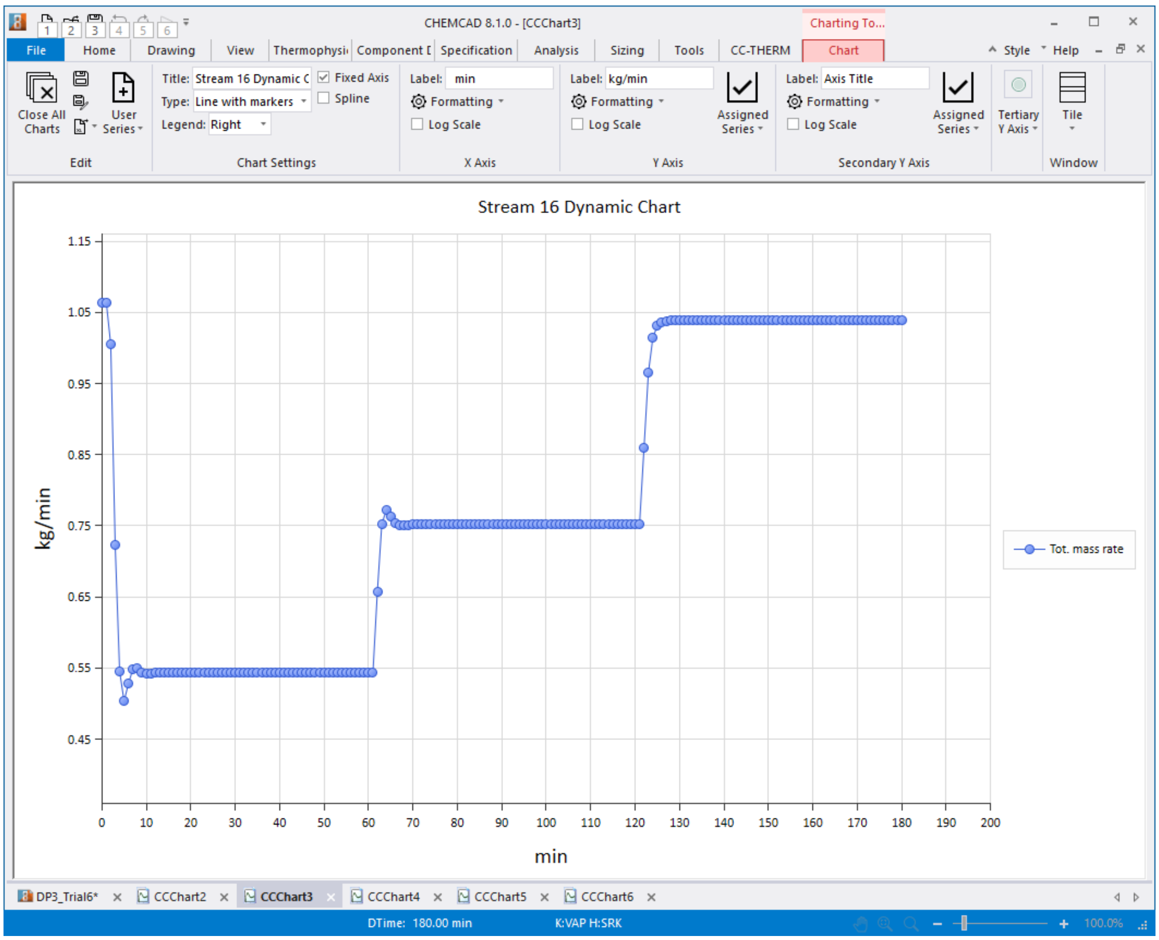
Question 1. The second plot shows the output steam 13, which is under PID control. After each disturbance in the inlet stream 11, the temperature of stream 13 briefly goes off setpoint but quickly returns to the setpoint temperature of 43 °C. //ANS



Question 2. This plot flows the flow rate of the cooling water stream, which is the control effort for the process. When the temperature of stream 11 goes up, more cooling water is needed to keep stream 13 at the setpoint of 43 °C. //ANS

Initially, the flow rate is 1.06 kg/min because the valve is 100% open. Since the measured variable (temperature of stream 13) is 40 °C and is below setpoint of 43 °C, the control valve closes to reduce the cooling water flow rate to about 0.55 kg/min. Each time the temperature of the warm inlet stream is increased, the flow rate of the cooling water increases to compensate, keeping the measured variable at set point. Small amounts of overshoot are seen at the beginning of each change, except for the third change, since the controller-vale system is nearly fully opened an underdamped at this point.



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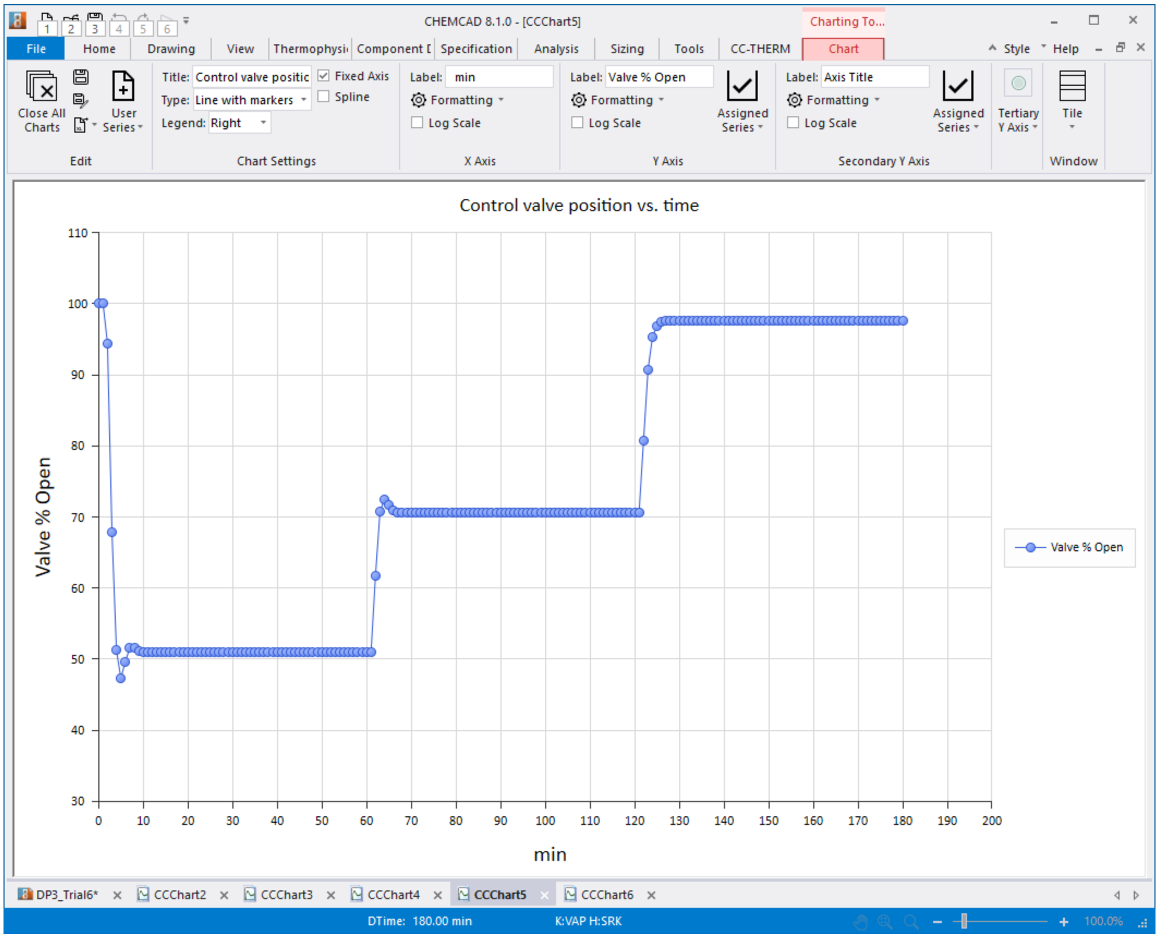
Question 3. This plot shows the valve position versus time, and the description follows from the flow rate description in the previous plot. The control valve opens each time the temperature of stream 11 increases because more flow is required to keep the temperature on setpoint because the controller is trying to add more cooling water to keep stream 13 on setpoint



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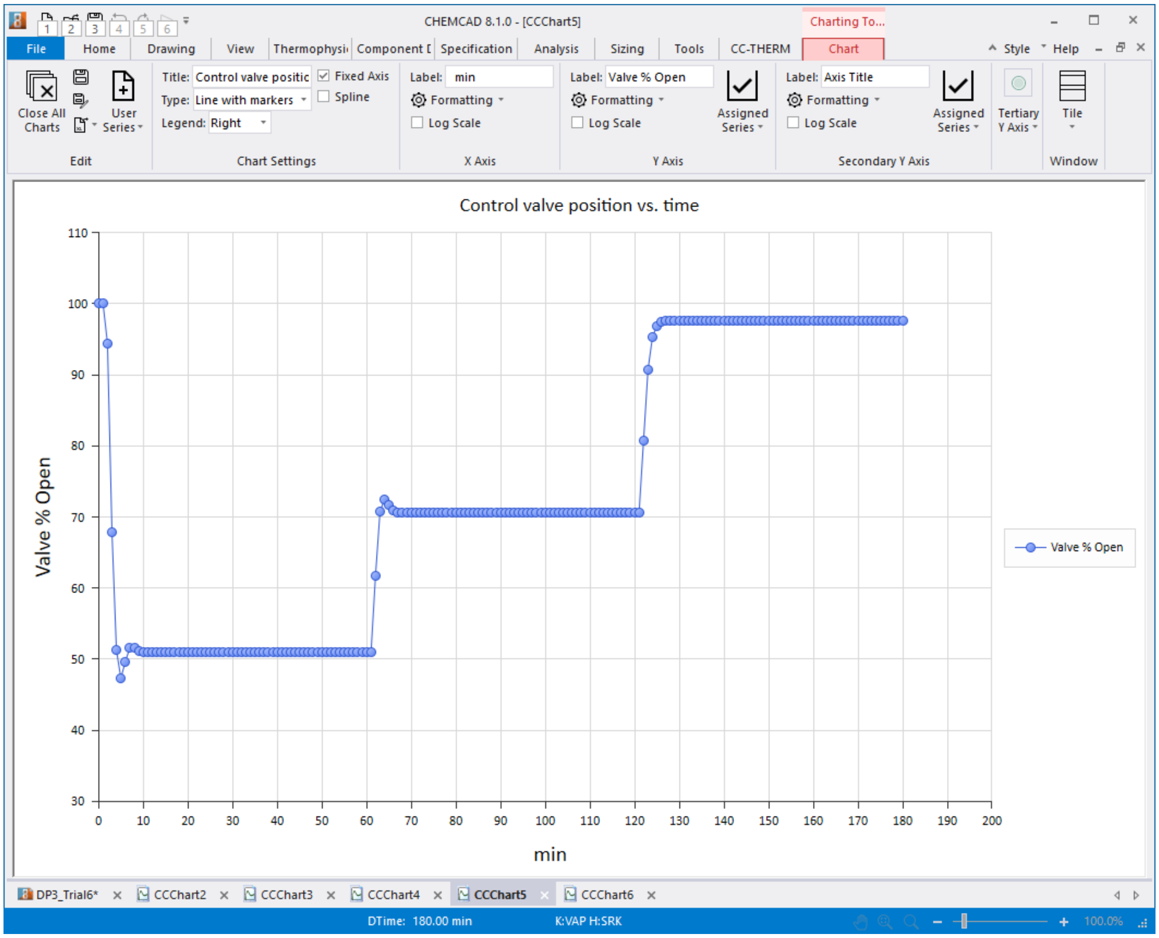
Question 4. This plot shows the controller output signal sent to the valve, and the description follows from the flow rate description in questions 2 and 3. The controller output increases each time the temperature of stream 11 is increased because more flow is required to keep the temperature on setpoint. As the output signal increases, the valve opens more to add more water flow.



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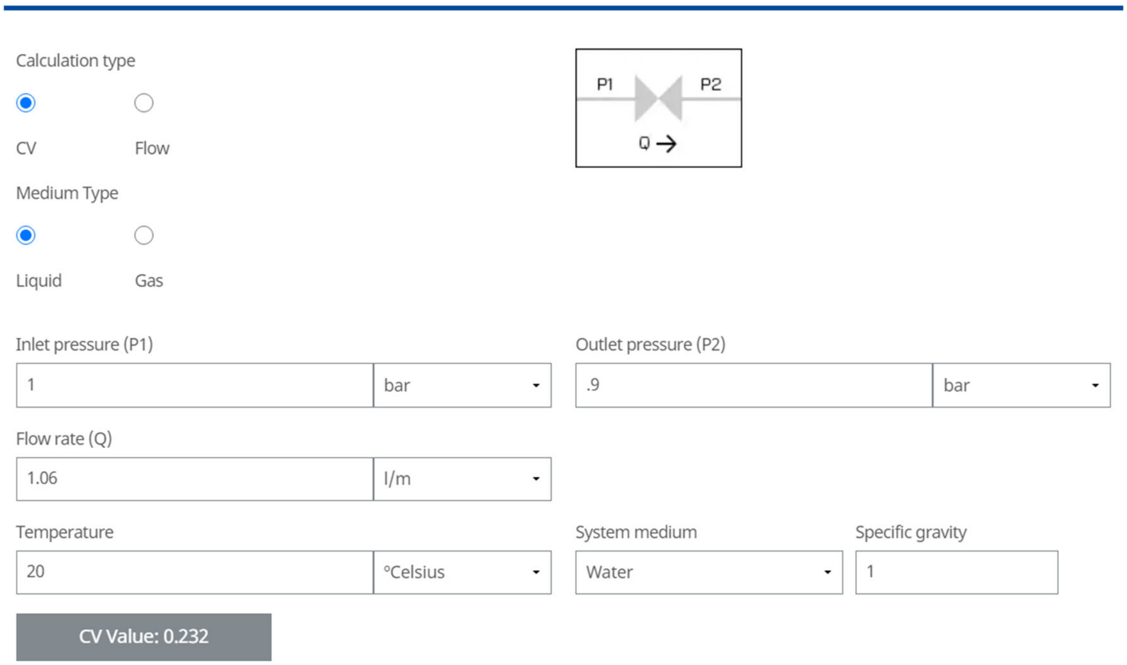
Question 5. The Cv value goes from 0.26 to 0.232, which corresponds to a smaller valve and a lower flow rate at 100% open, down from 1.06 to about 0.95 kg/min.



Question 6. The flow rates are very close.

Post-lab Quiz – DP5

Circle the correct answer

Name: Solution

1. At is the purpose of the valve on stream 8?

    (1) It adjusts the flow through stream 8, 9, and 10 in steady state mode.
    (2) It adjusts the flow of streams 5, 6, and 7 in steady state mode.
    (3) It adjusts the flow through stream 8, 9, and 10 in dynamic mode.
    (4) It adjusts the flow of streams 5, 6, and 7 in steady dynamic mode.

    (a) 1 and 3 only.
    (b) 2 and 4 only.
    (c) All of the above.
    (d) None of the above.

2. What is the purpose of the "Ramp" unit on stream 11?

    (a) It produces ramped temperature changes on stream 11.
    (b) It introduces step changes in temperature in stream 11.
    (c) It produces sinusoidal temperature changes on stream 11.
    (d) It stops the flow in stream 11.

3. The valve coefficient Cv is related to

    (a) The volume of water that will flow through the valve.
    (b) How pressure will recover after it drops to its lowest point inside the control valve.
    (c) the ratio of maximum to minimum flow in a control valve.
    (d) The position of the control valve after the flow suddenly increases or decreased by more than 50%.

4. After a 2-degree step change increase in temperature on stream 11 from steady state, the signal from the controller to the control valve

    (a) Increases, then decreases, then lines out at steady state.
    (b) Decreases, then increases, then lines out at steady state.
    (c) Increases then lines out at steady state.
    (d) Decreases then lines out at steady state.

5. After a 2-degree step change increase in temperature on stream 11 from steady state, the percentage opening of the control valve

    (a) Increases, then decreases, then lines out at steady state.
    (b) Decreases, then increases, then lines out at steady state.
    (c) Increases then lines out at steady state.
    (d) Decreases then lines out at steady state.

6. After a 2-degree step change increase in temperature on stream 11 from steady state, the mass flow rate in stream 16

    (a) Increases, then decreases, then lines out at steady state.
    (b) Decreases, then increases, then lines out at steady state.
    (c) Increases then lines out at steady state.
    (d) Decreases then lines out at steady state.

7. At the first step change in temperature on stream 11, the controller is

    (a) Overdamped.
    (b) Critically damped.
    (c) Underdamped.
    (d) Unstable.

8. At the second step change in temperature on stream 11, the controller is

    (a) Overdamped.
    (b) Critically damped.
    (c) Underdamped.
    (d) Unstable.