APPROVED SOLUTION

Design Problem 3 – Introduction to Process Control

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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 lab 2, we examined hydraulic calculations in CHEMCAD using nodes and pumps with characteristic curves. In this lab, we will introduce three more elements, namely control valves, control sensors, and ramps for programming changes in streams. We also began our discussions of heat exchangers in lesson 7, so a natural place to go is to learn how to perform a dynamic simulation of a heat exchanger under temperature control.

Your instructor will provide you with a PowerPoint presentation that contains the detailed instructions for building and running the simulation. 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. Explain what is happening in the dynamic plots of streams 11, 13, and 16 and unit ops 6 and 7. Give a qualitative explanations of the observed changes in each plot.

2. Go to this web site (https://www.swagelok.com/en/toolbox/cv-calculator) and use the tool to calculate Cv. Use the new value of Cv in the second heat exchanger, run in steady-state mode, and explain the change in the water flow rate.

Submission Requirements

1. Print of completed slide 12 in pdf format.
2. Print of completed slides 30-34 (plots) in pdf format.
3. Print of completed slides 36-37 (questions 1 and 2) in pdf format
2. Single pdf bundle of or requirements 1-3 with cover page to Canvas.
5. Final CHEMCAD file to Canvas.
6. All work is due NLT 1445 hours (End of lab hour).

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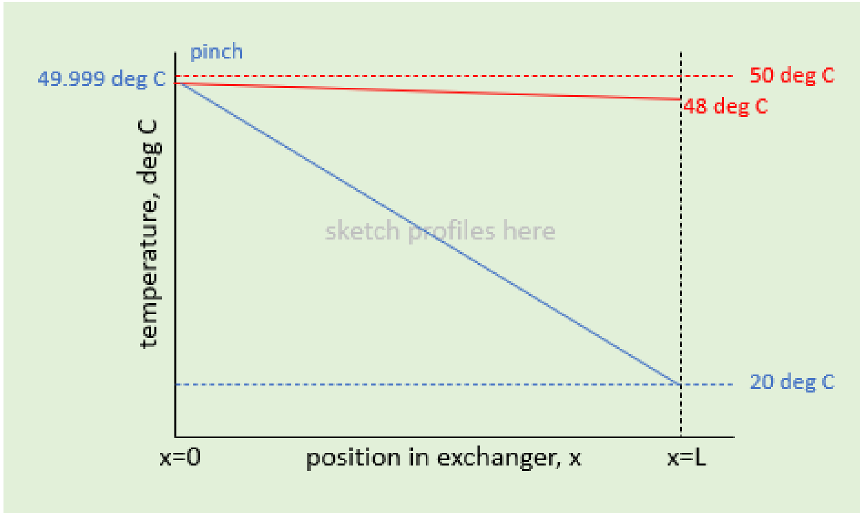
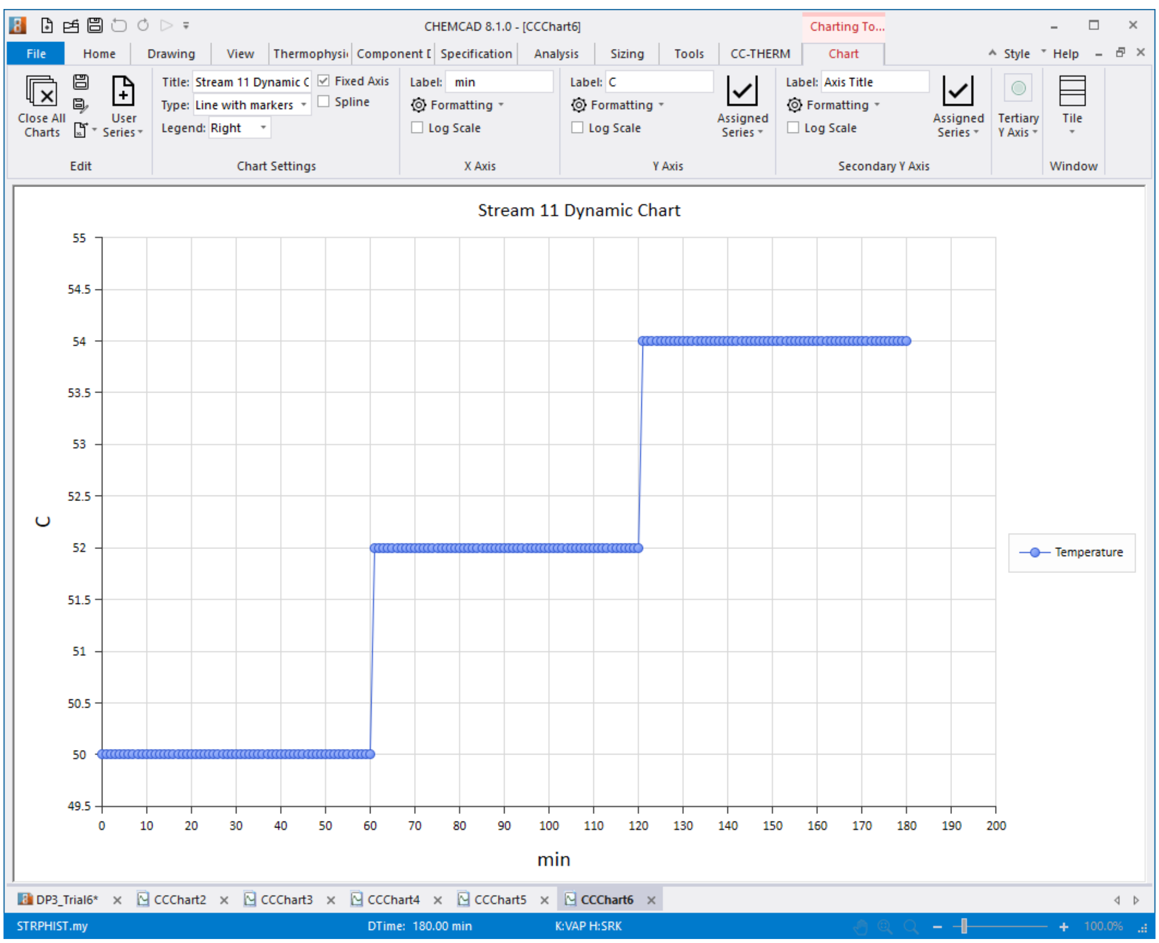
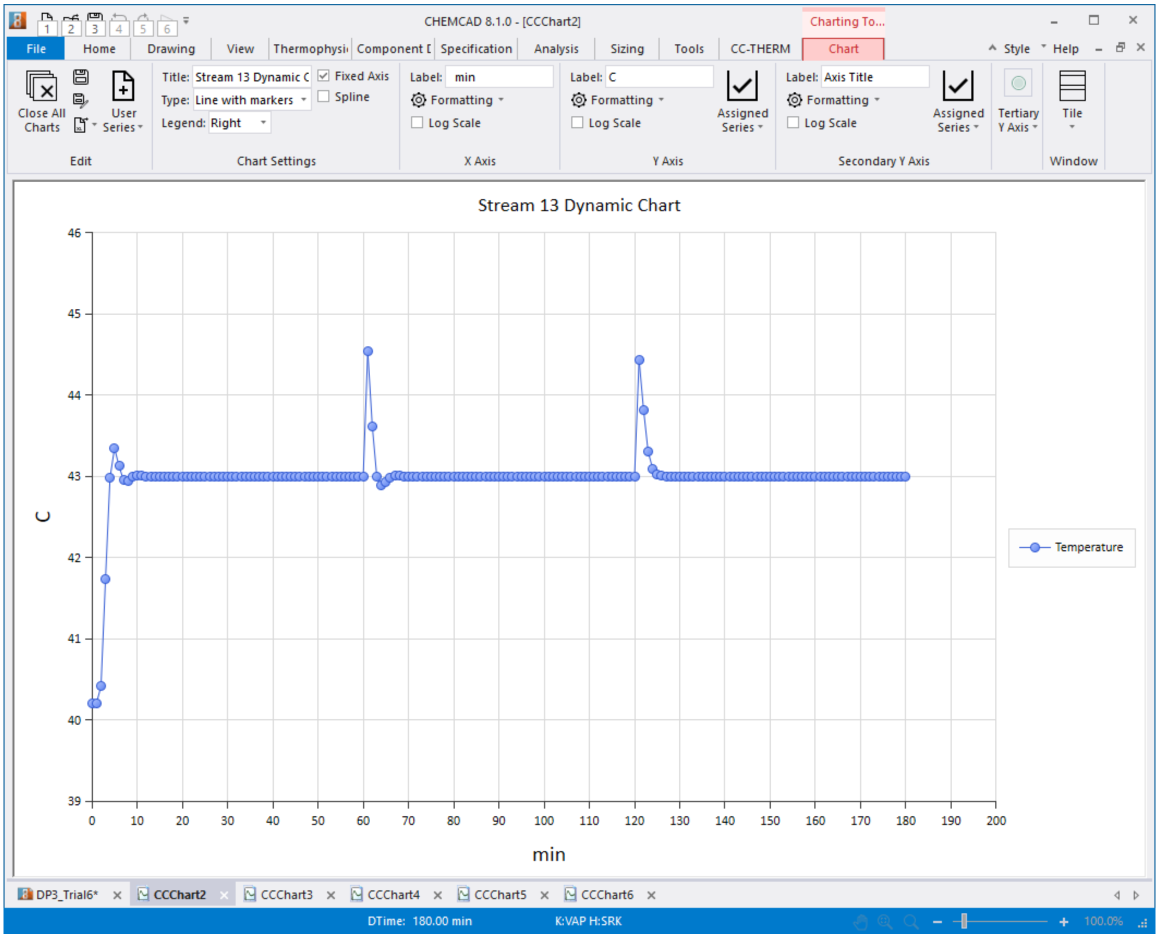
Sketch of the heat exchanger temperature profile:



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.

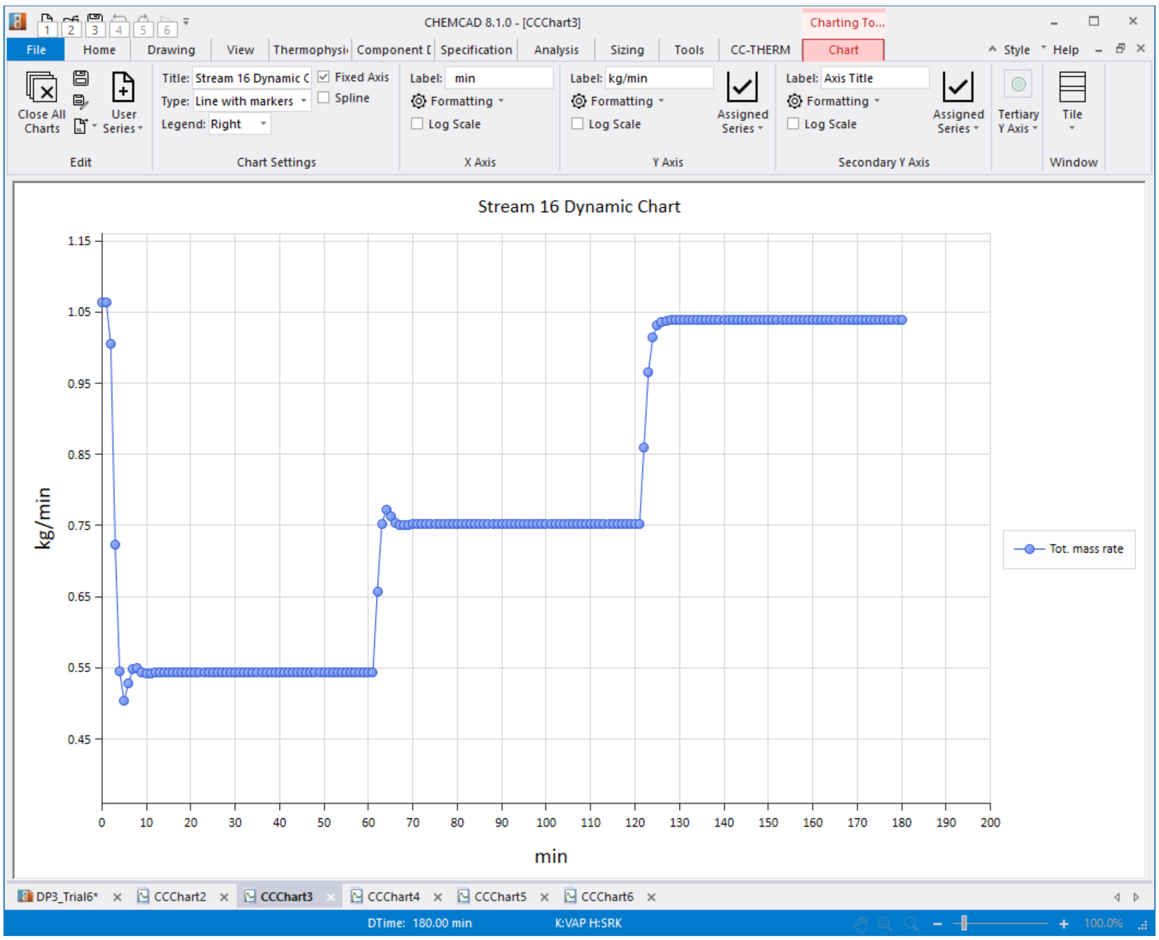


The second plot shows the output steam 13, which is under PID control. After each disturbance in the inlet stream 11, the temperature of stream 13 briefly goes off setpoint but quickly returns to the setpoint temperature of 43 deg C.

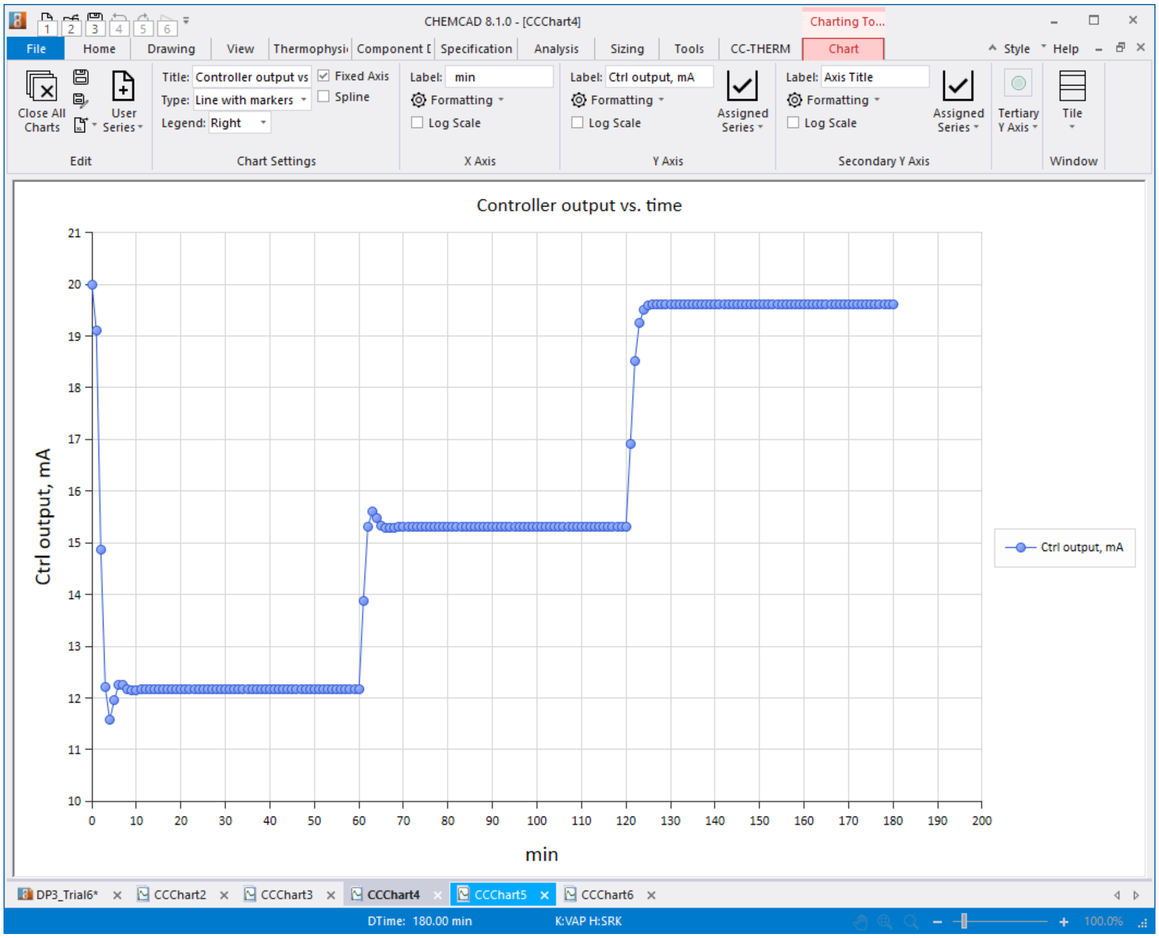


This plot flows the flow rate of the cooling water stream, which is the control effort for the process. When the temperature of stream 11 goes up, more cooling water is needed to keep stream 13 at the setpoint of 43 deg C.

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 deg C and is below setpoint of 43 deg 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.



This plot shows the controller output to the valve, and the description follows from the flow rate description in the previous plot. The controller output increases each time the temperature of stream 11 is increased. As the output signal increases, the valve opens more.



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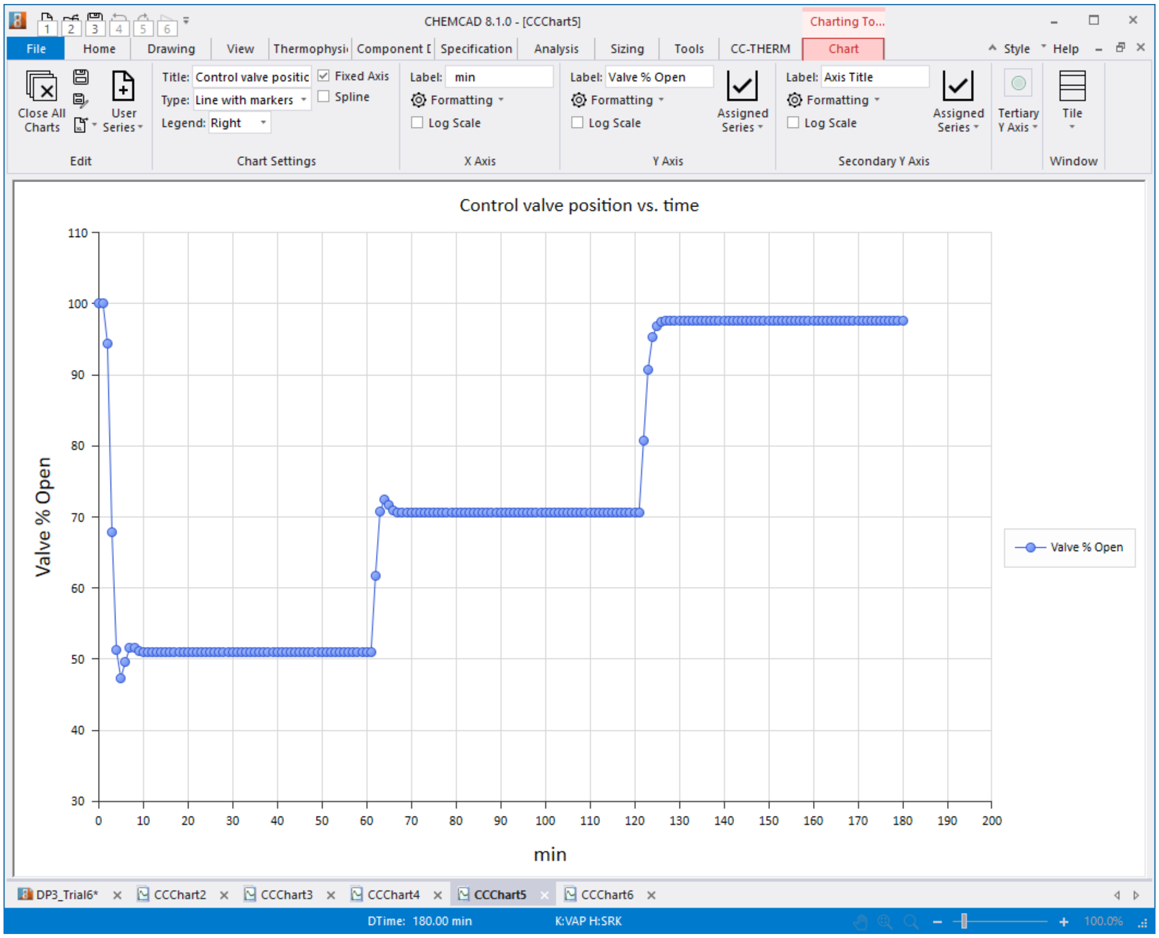
This plot shows the valve position versus time. As the output signal increases, the valve opens more, because the temperature of stream 11 is increasing, and the controller is trying to add more cooling water to keep stream 13 on setpoint.



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Question 2: 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.