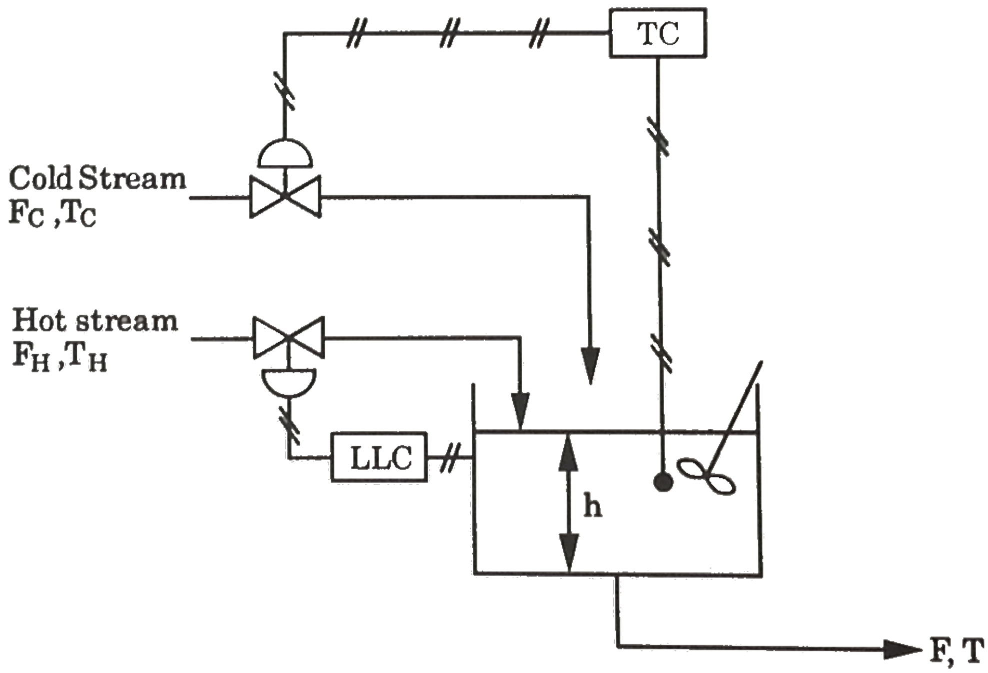
Process Control, 3P4 Your name: ____________

Tutorial 12 - Friday Student number: ____________

This tutorial provides some practice and insight into multiloop systems.

Question 1

Consider the system shown below, where the outlet flow, F is held constant.



The diagram shows the level control (CV1) is paired with the hot stream flow (MV1), and the temperature control (CV2) is paired with the cold stream flow (MV2). Let's investigate if this pairing is adequate. Maybe if the pairing is switched around we will achieve better control?

1. Draw the transfer function diagram representation of the current P&ID below.

2. Consider that all feedback loops are in manual (i.e. no feedback control).

   (a) What is the effect on CV1 ________________ and CV2 ______________ if we increase MV1?

   (b) What is the effect on CV1 ________________ and CV2 ______________ if we increase MV2?

3. If the ODEs for the tank system are written out, you will see you achieve a non-linear set of equations, which must be linearized around the steady-state. Let h_S be the steady state height, and let T_S be the steady state outlet temperature.

   The gain matrix for this system is then:

$$\mathbf{K} = \mathbf{G}(\mathbf{0}) = \begin{pmatrix} 2\sqrt{h_S} & 2\sqrt{h_S} \\ \dfrac{T_H - T_S}{\sqrt{h_S}} & \dfrac{T_C - T_S}{\sqrt{h_S}} \end{pmatrix} \qquad \text{which relates} \qquad \begin{pmatrix} \text{CV1} \\ \text{CV2} \end{pmatrix} = \mathbf{K} \begin{pmatrix} \text{MV1} \\ \text{MV2} \end{pmatrix}$$

   Explain why this matches your results from part 2.

4. Next, calculate the RGA, i.e. the $\mathbf{\Lambda}$ matrix, in symbolic form. At the very least, calculate the λ_{11} element.

5. Now consider $T_H = 65$°C and $T_C = 15$°C, and assume the steady state flow rates are such that $h_S = 3.2$ meters and $T_S = 55$°C. Calculate the RGA matrix numerically. Write down the suggested loop pairing.

   Now explain why this makes sense. To help you do so, consider the case when you wish to make a change to the tank temperature, e.g. from $T = 55$°C to $T = 50$°C; what would you like to have happen, and what will actually happen?

6. Now consider $T_H = 65$°C and $T_C = 15$°C, and assume the steady state flow rates are such that $h_S = 2.9$ meters and $T_S = 30$°C. Calculate the RGA matrix numerically. Write down the suggested loop pairing.

   Again, explain why this makes sense.

7. Finally, consider $T_H = 65$°C and $T_C = 15$°C, and assume the steady state flow rates are such that $h_S = 2.5$ meters and $T_S = 40$°C. Calculate the RGA matrix numerically. Write down the suggested loop pairing.

   Explain why this makes sense.

Question 2

1. Calculate the RGA and pairing for a system having a steady state gain matrix of $\mathbf{K} = \begin{pmatrix} 0 & 5 \\ 2 & 0 \end{pmatrix}$. Does whether the result make sense.

2. Calculate the RGA for a system having a steady state gain matrix of $\mathbf{K} = \begin{pmatrix} 1 & 1 \\ 0.8 & 0.2 \end{pmatrix}$.

3. Calculate the RGA for these two systems: $\mathbf{K_1} = \begin{pmatrix} 0.1 & 0.4 \\ -0.2 & 0.05 \end{pmatrix}$ and $\mathbf{K_2} = \begin{pmatrix} 1 & 4 \\ -2 & 0.5 \end{pmatrix}$