Department of Chemical Engineering
University of California, Santa Barbara

Ch. E. 152B **Winter, 2010**

Lab 2: SISO Controller Tuning

1. Introduction

In this lab you will design SISO PI control strategies for the 4-Tank System in Figure 1 and evaluate several controller tuning techniques. Two controller design and tuning strategies from Chapter 12 of the textbook will be evaluated:

a. Relay auto-tuning (experimental tests)

b. A model-based design method (using your transfer function model from Lab 1).

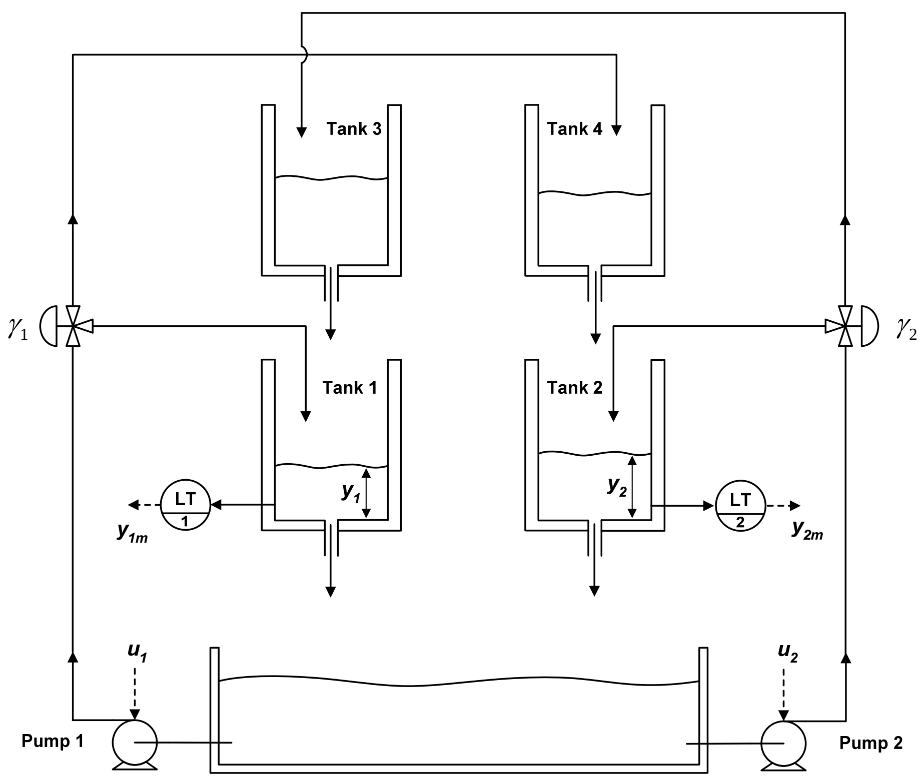

Figure 1. Schematic diagram of the 4-Tank System.

2. Pre-lab Analysis

Before Lab 2 you should select the better multiloop control configuration (1-1/2-2 vs. 1-2/2-1), based on your results for Lab 1. For each of the two controller design and tuning methods of Section 1, select an appropriate method for specifying the controller settings. Write a brief statement justifying your decisions and bring this statement with you to Lab 2.

Calculate the controller settings for method (b), based on your results from Lab 1.

Hint: For this lab, pay special attention to the units of K_c and τ_I in both the experimental and simulation studies.

3. Experimental Activities

Important: Be sure to record all transient responses and other relevant information, such as controller settings and bypass valve positions. Save the data at the end of each simulation with a unique filename.

The experimental activities will be carried out in MATLAB. Transfer control of the tanks to MATLAB and open the appropriate Simulink files by typing their filename at the MATLAB command prompt.

1. For auto-relay tuning use *autoRelay.mdl*
2. For the closed-loop experiments use *closedLoop.mdl*

Relay Auto-Tuning for the h_1 Controller (Controller 1)

Relay auto-tuning should be implemented manually using *autoRelay.mdl* as follows:

a. Set both pumps at 55%. Record the steady-state value of h_1. This value will be used as the set point, h_{1sp}, for relay auto-tuning.
b. Switch the pump setting for pump X up to 95%. ("Pump X" is the designation for the pump used to control h_1 in your multiloop control scheme.) As soon as the level sensor indicates that the h_1 is increasing, switch pump X to 15%.
c. Repeat this procedure of "bang-bang" control action: when $h_1 < h_{1sp}$, switch pump X back to 95%; then when $h_1 > h_{1sp}$, switch pump X back to 15%.

Repeat this procedure for several cycles until a sustained oscillation in h_1 occurs. Record the amplitude a and period P of the oscillation. The relay amplitude for this experiment is d = (95% - 15%) /2 = 10%.

The ultimate gain K_{cu} and ultimate period P_u can be calculated from the following approximate expressions:

$$K_{cu} = \frac{4\,d}{\pi\,a} \qquad (3\text{-}1)$$

$$P_u = P \qquad (3\text{-}2)$$

Calculate the PI controller settings for Controller 1 using the method you selected for Section 2.

Experimentally evaluate these PI settings using *closedLoop.mdl* for either a step disturbance or an h_{1sp} step change of +2 cm. The step disturbance should be implemented by partially closing the upper bypass valve for Tank 3. The valve should not be closed by more than 30°. (This bypass valve is *not* shown in Figure 1.) Record the new bypass valve setting. Repeat this test for the Controller 1 settings that you determined from method (b) in Section 1. Which Controller 1 settings result in better control?

3.2 Relay Auto-Tuning for the h_2 Controller (Controller 2)

Place Controller 1 in the manual mode and set the pump X speed to 55%. Repeat the experimental tests of Section 3.1 for h_2 by adjusting the speed of the other pump (which will be designated as Pump Y). Which controller settings give the better results?

4. Lab Report

Analyze your results and prepare a lab report using the memo/personal file format described in previous handouts. (Recall the limits on the maximum numbers of figures and tables in the memo.) Compare the controller settings for different design/tuning methods. Which controller design/tuning method provided the best results?