CHBE 470 – Process Dynamics and Control – Fall 2007

Homework Set 5

Assigned: Wednesday, October 17 **Due:** Wednesday, October 24

Note: Please staple your papers and include your name in the first page

Problem 1: Consider the general closed-loop block diagram with $G_c(s) = 1.6$, $G_p(s) = \frac{5}{(s+1)(2s+1)}$, $G_f(s) = G_m(s) = 1$. Suppose that the system is subject to a set point change in the input of magnitude 0.1. Determine:

a) The maximum value of the response
b) The offset
c) The period of the oscillation

Problem 2: *Consult chapter 11 of the book for details on interacting 2^{nd} order systems.* Consider the liquid-level system of two noninteracting tanks with a proportional control and linear resistances. It was found that when the steady-state inlet flow rate q (ft^3/min) is plotted against the steady-state liquid level in both tanks (h in ft), the slope of the line is 2 ft^2/min. Both tanks have the same cross sectional areas of 2 ft^2. The control valve was tested separately and it was found that a change of 1 psi in pressure to the valve produced a change in flow of 0.1 ft^3/min. There is no dynamic lag in the valve or the measuring device.

a) Draw a block diagram of this control system and in each block give the transfer function with numerical values of the parameters
b) Determine the controller gain Kc for a critically damped response
c) If the tanks were connected so that they were interacting, what is the value of Kc needed for critical damping?
d) Using 1.5 times the value of Kc determined in part (c), determine the response of the level in tank 2 to a step change of 1 inch in the set point.

Problem 3: A mixing process consists of a single stirred tank instrumented as shown in figure 3. The concentration of the specie A in the feed stream varies as a result of upstream processes. The controller attempts to compensate for this change by varying the flow rate of pure A through the control valve. The transmission line dynamics are negligible (i.e. τ_L=0).

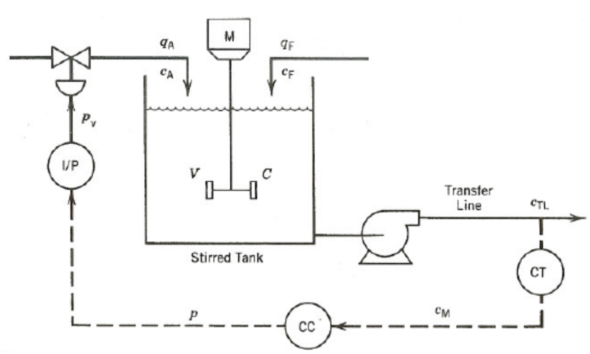

Figure 3

(a) Draw a block diagram for the controlled process.
(b) Derive a transfer function for each block in your block diagram.

Process

1. The volume is constant ($5m^3$)
2. The feed flow rate is constant ($q_F = 7m^3/min$)
3. The flow rate of the A stream varies but is small compared to q_F ($q_A = 0.5m^3/min$)
4. $c_F = 50\ kg/m^3$ and $c_A = 800\ kg/m^3$
5. All densities are constant and equal

Transfer Line

1. The transfer line is 20 m long and has 0.5 m inside diameter
2. Pump volume can be neglected

Composition Transmitter Data

$c(kg/m^3)$	$c_m(mA)$
0	4
200	20

Controller

1. Ideal PID controller
2. Current (mA) input and output signals

I/P Transducer

$p(mA)$	$p_v(psig)$
4	3
20	15

Control Valve

An equal percentage valve is used which has the following relation:

$$q_A = 0.17 + 0.03(20)^{\frac{p_v - 3}{12}}$$

For a step change in input pressure, the valve requires approximately 1 min to move in its new position.