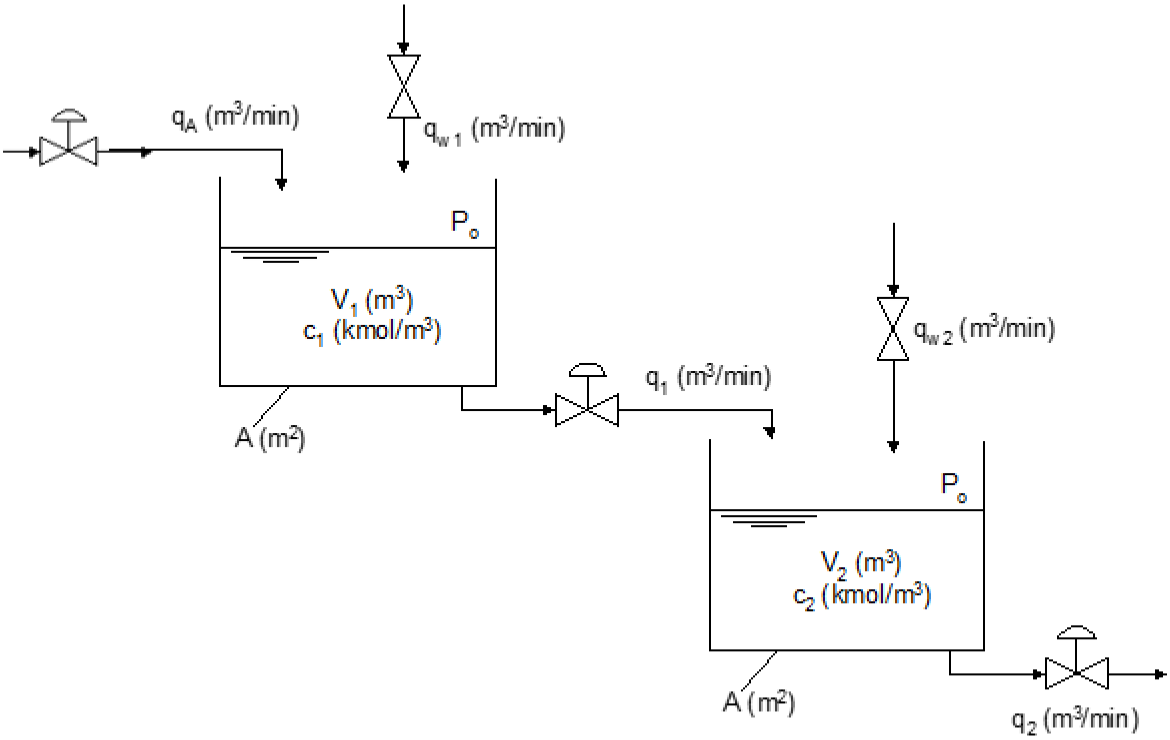
Exam process control. Dec. 2017

Problem 1 - Mixing process (30%)



Note that the three parts of this problem can be done independently.

Two mixing tanks are used to produce a diluted acid (q_2) from concentrated acid (q_A) and water (q_{w1} and q_{w2}), (see figure). The main part of the dilution is done in tank 1, while tank 2 is used to fine tune the dilution to obtain the desired concentration (q_{w1} is about 10x q_{w2}).

(a) Write a dynamic model for the process (two balances for each tank). You may need to introduce symbols (variables) in addition to the ones given on the figure. No linearization or Laplace is required.

(b) Formulate the 2x3 transfer matrix G_1 for the first tank with q_A, q_{w1} and q_1 as independent variables (inputs or disturbances) and V_1 and c_1 as dependent variables (outputs). No numbers are required, just the form (first-order, integrating, etc.) and sign of the gain.

(c) Now we consider control. The flow of dilute acid is set by the downstream process, so q_2 is a disturbance. Suggest a control structure on the flowsheet for each of the following two cases:

1) Measurements are c_1, c_2 and the two levels. Suggest a control structure with four feedback loops.

2) Measurements are c_2 and the two levels. Suggest a control structure that makes q_{w2} return to its desired value at steady state.

2017 Solution (preliminary) 06 Dec. 2017

Problem 1

(a) We assume constant density.
Overall mass balances and component mass balances (acid) for the two tanks then given

Tank 1:

(1) $\frac{dV_1}{dt} = q_A + q_{w1} - q_1$ [mol/s]

(2) $\frac{d(C_1V_1)}{dt} = q_A C_A + q_{w1} C_{w1} - q_1 C_1$ [mol acid/s] (C_{w1} = 0)

Tank 2:

(3) $\frac{dV_2}{dt} = q_1 + q_{w2} - q_2$ [mol/s]

(4) $\frac{d(C_2V_2)}{dt} = q_1 C_1 + q_{w2} C_{w2} - q_2 C_2$ [mol acid/s] (C_{w2} = 0)

(b) Transfer matrix G_1

	q_A	q_{w1}	q_1
V_1	$\frac{1}{s}$	$\frac{1}{s}$	$-\frac{1}{s}$
C_1	$\frac{k_A}{\tau_1 s+1}$	$\frac{k_{w1}}{\tau_1 s+1}$	0

$\tau_1 = \frac{V_1^*}{q_A^*+q_{w1}^*} = \frac{V_1^*}{q_1^*}$ = residence time (could be derived by linearizing (2)) but not required.

$k_A > 0$
$k_{w1} < 0$

(c) (1) Feedback

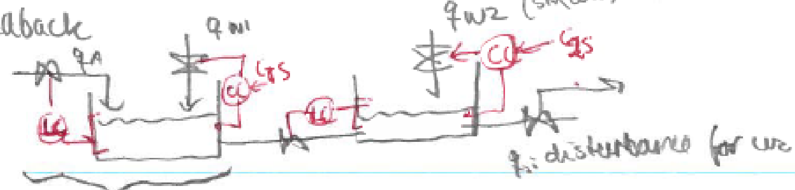


Fig. 1

Could interchange LC and CC_1, the largest flow should be used for level control to reduce interactions, so here we have assumed $q_A > q_{w1}$, but it could be opposite. Actually, this is probably more likely since it is given that q_{w1} is large!

2) No measurement of C_1

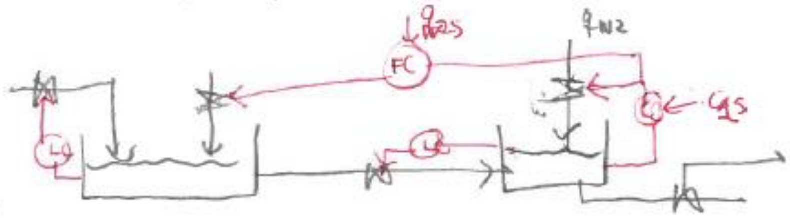


Fig. 2

- Also here the (LC) and (FC) could be interchanged (tank 1).
- The FC may alternatively be called VPC (valve position controller) as it resets the position of the valve for q_{w2} to some middle position (say 50% open)
- Comment on structure 1 (feedback): The setpoint for C_1 needs to be decided. It could be set by a FC (or VPC) similar to Fig. 2.