**INDIAN INSTITUTE OF TECHNOLOGY–KHARAGPUR**

Mid-Spring Semester 2013-2014 (Closed Book)
Date: 22 February 2014

*Course No.*: CH 61016 | *Max. Time*: 2 hrs
*Course Title*: Process Dynamics and Control | *Total Marks*: 30

**Answer all questions**

[No need of separate answer script]

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Q1. (a) What are the merits and demerits of the discrete form of PID controller over its continuous analogous?
(b) Discuss the use of override control for a liquid tank system. Briefly discuss the use of HSS with an example of a chemical system. **[(1+1)+(1+1) = 4]**

Q2. The bottoms temperature of a distillation column, in $^0$C (represented as $y$ in deviation variables) is controlled by manipulating the steam flow rate to the reboiler, in lb/hr (represented as $u_1$ in deviation variables). This purely feedback control strategy is shown in Figure 1. An approximate transfer function model for this process is given as:

$$\bar{y}(s) = \frac{0.25}{(10s+1)}\bar{u}_1(s)$$ **[1+(2+2+1)+(1+2+2) = 11]**

However, the steam flow rate itself depends on the percent valve opening (represented as $u_2$ in deviation variables), and the steam supply pressure, in psi (represented as $d_1$ in deviation variables) which is known to fluctuate in an unpredictable, but measurable, fashion. These process variables are related according to the following approximate model:

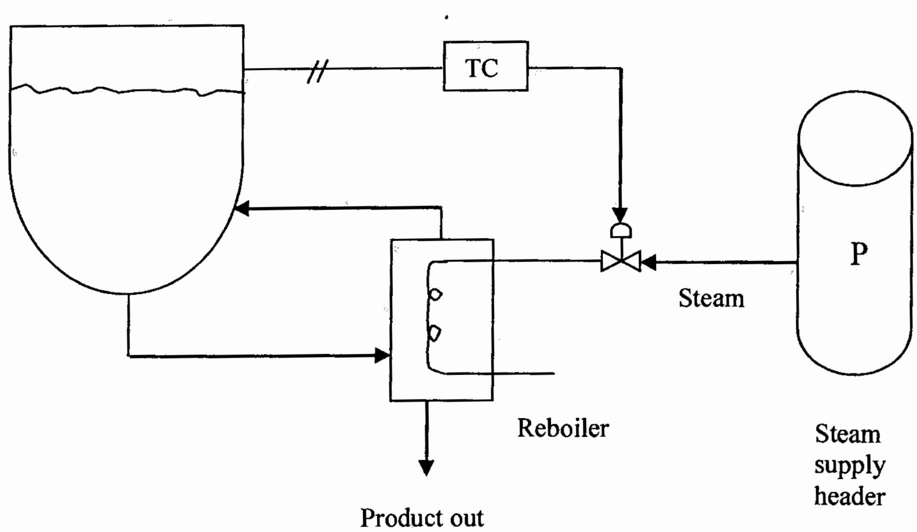



**Figure 1:** Feedback control of a distillation column's bottom temperature [Ref: B.A. Ogunnaike, W.H. Ray, *Process Dynamics, Modeling, and Control*, Oxford University Press, 1994].

$$\bar{u}_1(s) = \frac{2.2}{(2s+1)}\bar{u}_2(s) + \frac{1.5}{(0.5s+1)}\bar{d}_1(s)$$

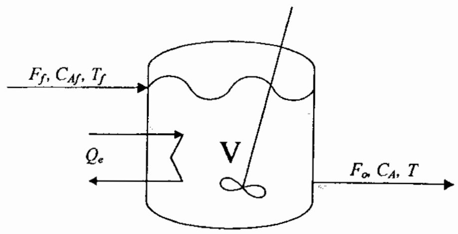
(a) Develop the block diagram for the feedback controlled process as shown in Figure 1.

(b) Cascade control is a popular strategy for dealing with the control problems related to such steam pressure fluctuations. Draw a block diagram for this process under such a cascade control strategy; include all the transfer functions (and the suitable controllers), and label all the signals.

(c) Because the steam supply pressure is measured, it is also possible to configure this process for feedforward-feedback control instead of cascade control. Reconfigure the process for this new control structure, draw a block diagram showing all transfer functions, and obtain the expression(s) for the feedforward controller to be implemented.

Q3. Consider a second order irreversible reaction 2A →B is taking place in a stirred tank non-isothermal jacketed reactor. The modelling equations for this reactor is given below:

$$V\frac{d(C_A)}{dt} = F_f(C_{Af} - C_A) - k_0 e^{-E/RT} V C_A^2$$




$$\rho\tilde{C}_p V\frac{dT}{dt} = \rho F_f \tilde{C}_p (T_f - T) + (-\Delta H_r) V C_A^2 k_0 e^{-E/RT} - Q_e$$

$Q_e = UA(T-T_c)$

Where, U,A, $\rho, \tilde{C}_p, V, (-\Delta H_r), k_0, E, R$ are constant and known. The reactor temperature T needs to be controlled by manipulating heat removal amount $Q_e$ ,i.e, $T_c$ in spite of the changes in inlet feed stream conditions. Based on the above dynamic model and control requirement,

a) Develop a nonlinear state-space model

b) Develop a linear state-space model

**[2+5]**

Q4. Consider a transfer function $\frac{y(s)}{u(s)} = G(s) = \frac{3.8e^{-2s}}{(10s+1)(5s+1)}$

a) Realize both controllable and observable canonical forms of state-space models

b) Develop a Z-transform model using zero order hold.

**[4+4]**

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