BITS-Pilani Dubai, International Academic City, Dubai

Second Semester, Academic Year 2007-2008

Evaluation Component : **Comprehensive Examination (Closed Book)**

CHE UC441 / INSTR UC 451 PROCESS CONTROL

Date : 21st May 2008
Duration: 3 Hours

Max. Marks: 90
Weightage : 35% (CHE)
40% (INSTR)

Note:- 1. ANSWER ALL QUESTIONS and ANSWER only to specific point being questioned.
2. Make assumptions, if any, but explicitly indicate the assumptions made
3. Students will be provided Graph sheets, if required.

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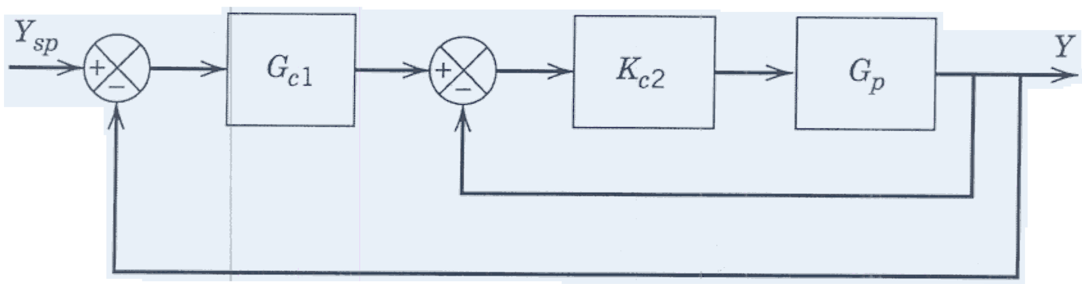
1

a) Explain the major steps in the development of Process Control, using a suitable flow chart that distinctly depicts the engineering activities involved from those activities, if any, that employ an information base. (7 M)

b) Analyze the degrees of freedom for the blending model as in the unsteady state component balance equation below (under the assumptions of perfect mixing and constant volume V of the tank) where w's are mass flow rates and x's are the mass fractions and ρ is the density; suffixes 1 and 2 represent two different inlet streams.

$$\frac{d(V\rho x)}{dt} = w_1x_1 + w_2x_2 + w_3x_3 \qquad (3\text{ M})$$

2) A Cascade control configuration is employed to first stabilize process using the inner loop and then to employ the outer loop to control the output to track set-point changes and reject disturbances as shown in the figure below:



a) Determine the maximum range of K_{inner} values for which the inner loop will be stable.

b) Assuming that K_{c2} = 6 and G_{c1} is a PI controller with gain K_{c1} and τ_I, find values of K_{c1} and τ_I such that the closed-loop poles of the transfer function from Y_{sp} to Y(s) are at s= $-0.5\pm0.2j$.

(3 + 4 = 7 M)

3) The dynamic model between an output variable y and an input variable u can be expressed by

$$\frac{d^2y(t)}{dt^2} + 3\frac{dy(t)}{dt} + y(t) = 4\frac{du(t-2)}{dt} - u(t-2)$$

a) Will this system exhibit an oscillatory response after an arbitrary change in u? (2 M)

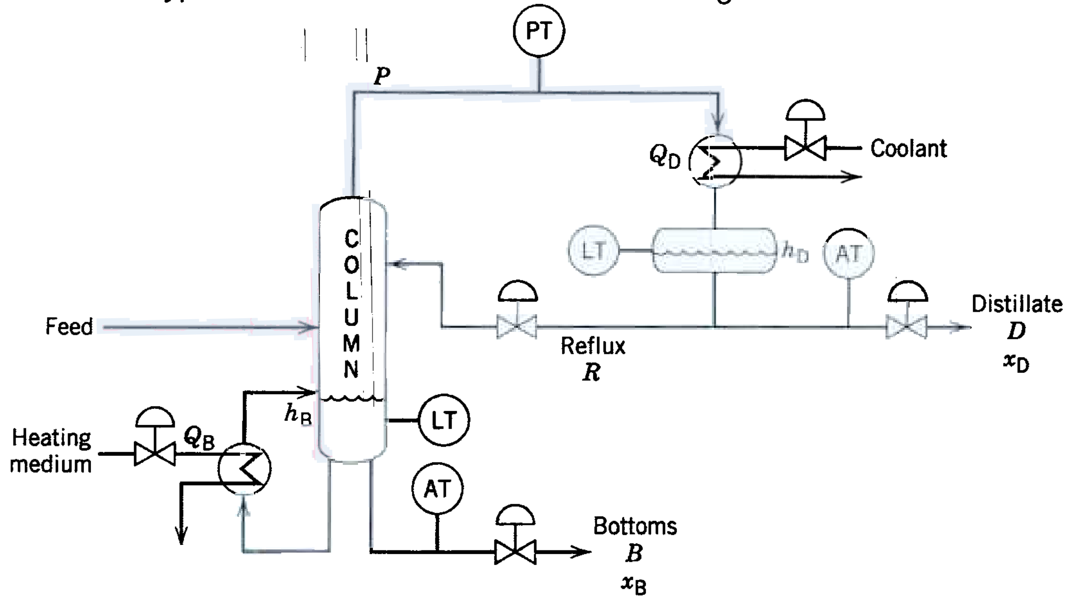
b) What is the steady-state gain? (2 M)

c) For a step change in u of magnitude 1.5 units, what is y(t) (2 M)

[Please Turn Over]

4)

a) Consider a typical distillation column shown in the figure below:



List

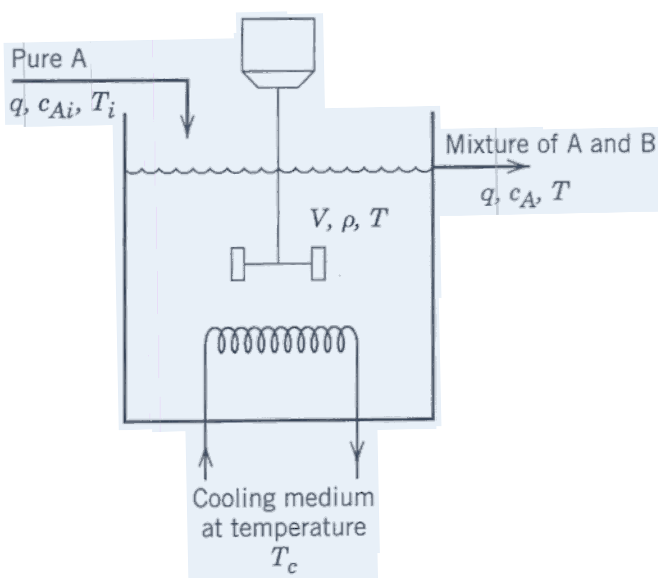
i) all the controlled variables and the symbols by which they are designated. (1.5 M)

ii) all the manipulated variables and the symbols by which they are designated (1.5 M)

iii) any three advanced process control strategies that can be employed (1.5 M)

b) Summarize a systematic and self-explanatory procedural steps that can be employed in "developing dynamic models of a typical process from its first principles" (5.0 M)

5) Consider a liquid phase, irreversible and first order chemical reaction where chemical species A (molar concentration C_A) reacts to form species B. The reaction can be written as A→B. Let, r be the rate of reaction, r. The process plant employs a Continuous Stirred-Tank Reactor (CSTR), shown in the schematic below, whose cooling coil is used to maintain the reaction mixture at the desired temperature by removing heat released in the exothermic reaction. Stating all the assumptions involved explicitly, develop a dynamic model of the process. (6.0 M)



6) A stirred tank blending system initially is full of water and is being fed pure water at a constant flow rate, q = 0.4 m^3/min. At a particular time (say, $t=t_1$), an operator adds caustic solution of concentration $\underline{c_i}$ at the same volumetric flow rate q. If the liquid volume

V is constant, the dynamic model for the process is found to be $V\frac{dc}{dt} + qc = qc_i$ with $c(0) = 0$. Assume the data: $V = 2\ m^3$; and $c_i = 50\ kg/m^3$.

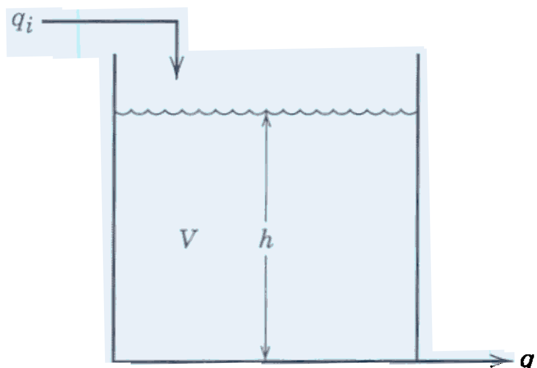
a) Find c(t), the concentration response of the reactor effluent stream as a function of t. (4.0 M)

b) Sketch c as a function of time. (3.0 M

7)

a) Draw a flow chart that depicts the step-by-step procedure for developing the transfer function model from a dynamic process model. (4.0 M)

b) In a single storage tank liquid-level system, shown in figure below, the outflow passes through a control valve (not shown in figure) whose discharge rate, q, say, is related to the square root of the liquid level, h. Develop an approximate linear dynamic model for this process through linearization of this nonlinearity. (3.0M)



Cross-sectional area = A

8) An electrically heated process is known to exhibit second order dynamics with the following parameter values: K = 3°C/kW; τ = 3min; ξ=0.7. If the process is initially is at steady state at 70°C with heater input of 20 kW and heater input is suddenly changed to 26 kW and held there:

a) What will be the expression for the process temperature as a function of time?.. (4.0 M)

b) What will be the maximum temperature that one observes? (1.0 M)

c) When will it occur? (1.0 M)

9) An operator introduces a step change in the flow rate q_i to a particular process at 3:05 A.M., changing the flow from 500 to 540 gal/min. The first change in the process temperature T (initially at 120°F) comes at 3:09 A.M. After that, the response in T is quite rapid., slowing down gradually until it appears to reach a steady-state value of 124.7°F. The operator notes in the logbook that there is no change after 3:34 AM. (a)What approximate transfer function might be used to relate temperature to flow rate for this process in the absence of more accurate information? (b)What should the operator do next time to obtain a better estimate? (4+1 M)

10) Write short notes on: (5x3=15M)

a) Features, advantages and disadvantages of Ratio control

b) Stability analysis of Process Control Systems using Root Locus Technique

c) Selection Criteria of Sensors employed as Control system instrumentation elements

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BITS-Pilani Dubai, International Academic City, Dubai

Second Semester, Academic Year 2007-2008

Evaluation Component : **TEST-II (Open Book)**

CHE UC441 / |INSTR UC 451 PROCESS CONTROL

Date : 10th April 2008
Duration: 50 mts

Max. Marks: 20
Weightage: 20%

Note:
1. ANSWER ALL QUESTIONS and ANSWER only to specific point being questioned.
2. Make assumptions, if any, but explicitly indicate the assumptions made
3. Students will be provided Graph sheets, if required.
4. Only the prescribed text book: Dale E Seborg et. al, Process Dynamics and Control, is allowed

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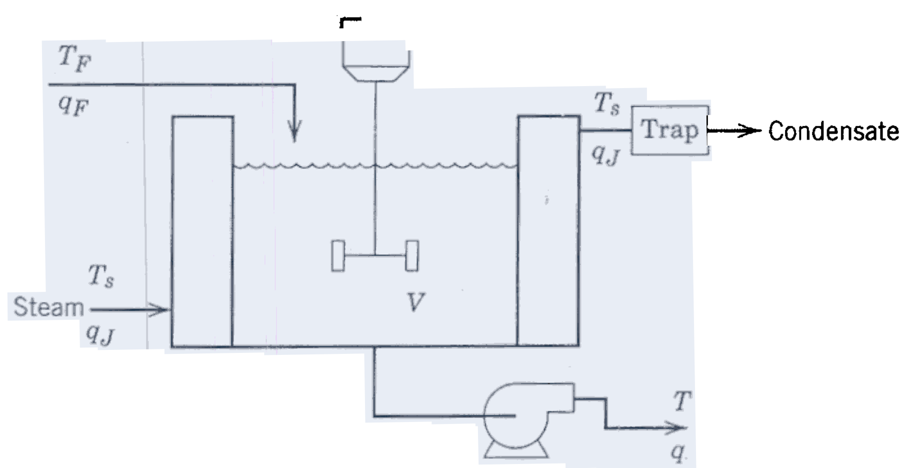
1) An electrically heated process is known to exhibit second order dynamics with the following parameter values: K = 3°C/kW; τ = 3min; ζ=0.7. If the process is initially is at steady state at 70°C with heater input of 20 kW and heater input is suddenly changed to 26 kW and held there:

   a) What will be the expression for the process temperature as a function of time? (2.0 M)

   b) What will be the maximum temperature that one observes? 1.0 M)

   c) When will it occur? 1.0 M)

2) The jacketed vessel in the figure following is used to heat a liquid by means of condensing steam. Assume (i)The volume of the liquid within the tank may vary, thus changing the area available for heat transfer; (ii) Heat losses are negligible; (iii) The tank contents are well mixed. Steam condensate is removed from the jacket by a steam trap as soon as it has formed; (iv) Thermal capacitances of the tank and jacket walls are negligible; (v) The steam condensation pressure P_s is set by a control valve and is not necessarily constant; (vi) The overall heat transfer coefficient U for this system is constant. (vii) Flow rates q_F and q are independently set by external values and may vary.



Derive a dynamic model for this process by determining different transfer functions relating the two primary output variables h (level) and T(liquid temperature) to inputs q_F, q and T_s. Note:-The model should be simplified as much as possible. State any additional assumptions that you make. (6.0 M)

[Please Turn Over]

3) Your boss has discussed implementing a level controller on a troublesome process tank that contains a boiling liquid. Someone told him that a level transmitter used with such a system has a very noisy output and that a P or PI controller will require a noise filter on the measurement. Show how a measurement noise filter can be implemented with a PI controller by drawing a block diagram of the controller, modified with a first order transfer function (time constant = τ_f where $\tau_f << \tau_I$) in the appropriate location. (4.0 M)

OR

An operator introduces a step change in the flow rate qi to a particular process at 3:05 A.M., changing the flow from 500 to 540 gal/min. The first change in the process temperature T (initially at 120°F) comes at 3:09 A.M. After that, the response in T is quite rapid., slowing down gradually until it appears to reach a steady-state value of 124.7°F. The operator notes in the logbook that there is no change after 3:34 AM. (a)What approximate transfer function might be used to relate temperature to flow rate for this process in the absence of more accurate information? (b)What should the operator do next time to obtain a better estimate? (3+1 M)

4) Several linear transmitters have been installed and calibrated as follows

A	Flow rate	400 gal/min -> 15 psig 0 gal / min -> 3 psig	Pneumatic transmitter
B	Pressure	30 in Hg -> 20 mA 10 in Hg -> 4 mA	Current transmitter
C	Level	20 m -> 5 V DC 0.5 m -> 1 V DC	Voltage transmitter
D	Concentration	20 g/L -> 10 V DC 2 g/L -> 1 V DC	Voltage transmitter

a) Develop an expression for the output of each transmitter as a function of its input. Be sure to include appropriate units. (4.0 M)

b) What is the gain of each transmitter? (2.0M)

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BITS-Pilani Dubai, International Academic City, Dubai

Second Semester, Academic Year 2007-2008

Evaluation Component : **TEST-I (Closed Book)**

CHE UC441 / |INSTR UC 451 PROCESS CONTROL

Date : 24th Nov. 2008 **Max. Marks: 30**

Duration: 50 mts **Weightage: 20% (CHE)**

25% (INSTR)

Note:- 1. ANSWER ALL QUESTIONS and ANSWER only to specific point being questioned.
2. Make assumptions, if any, but explicitly indicate the assumptions made
3. Students will be provided Graph sheets, if required.

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1)

a) Sketch a flow chart depicting the major steps in the development of Process Control System, indicating distinctly the engineering and other activities involved and the information base, if any, to be used for each activity.. (3.0 M)

b)

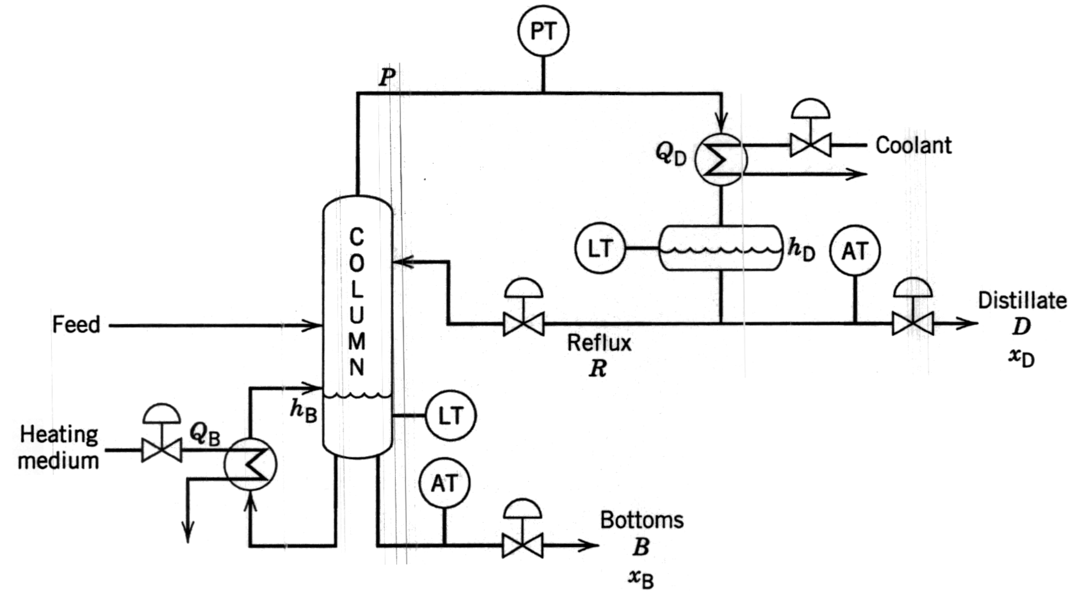
i) Does a "typical" (not most modern) microwave oven utilize feedback control to set cooking temperature or to determine if the food is "cooked"? – state "yes" or "No" (0.5 M)

ii) Indicate the control mechanism employed in the oven of (i) above (1.5 M

iii) List the disadvantages, if any, of the mechanism indicated [as answered for (ii) above] (1.0 M)

2)

a) Consider a typical distillation column shown in the figure below:



List

i) all the controlled variables and the symbols by which they are designated. (1.5 M)

ii) all the manipulated variables and the symbols by which they are designated (1.5 M)

iii) any three advanced process control strategies that can be employed (1.5 M)

b) Summarize a systematic and self-explanatory procedural steps that can be employed in "developing dynamic models of a typical process from its first principles" (4.5 M)

3) Consider a liquid phase, irreversible and first order chemical reaction where chemical species A (molar concentration C_A) reacts to form species B. The reaction can be written as A→B. Let, r be the rate of reaction, r. The process plant employs a Continuous Stirred-Tank Reactor (CSTR),