CM416
Second Take Home Exam
Due February 8, 1993
Name:____

1. (15 pts) **Systems requiring negative control gains.** Not all systems use positive proportional gains. For instance, the system shown in Figure 1 is a pressure control system of an evaporator. Increasing the flow of vapor out, V, decreases the pressure in the vessel. Suppose the system is described by the following differential equation (after appropriate linearization and use of perturbed variables)

$$\frac{d\bar{P}}{dt} = 0.2S + 0.1\bar{L} - 0.12\bar{P} - 0.5\bar{V}$$

where $\bar{S}$, ,$\bar{L}$, $\bar{P}$ and $\bar{V}$ is the perturbed steam rate, liquid feed rate, pressure and vapor rate, i.e. at equilibrium all these variables are zero. What range of K_c values are allowed for a stable PI controlled system using an integral (reset) time τ_i equal to 10, where the manipulated variable is V and the controlled variable is P ?

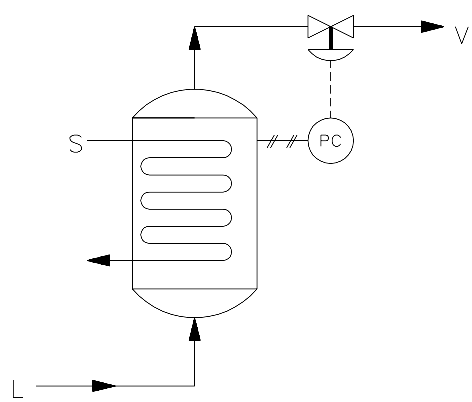

Figure 1: Pressure control in an evaporator.

2. **Temperature control of a stirred tank heater.** After linearization and transformation to perturbed variables, the equation describing tank temperature of the system shown in Figure 2 is given by

$$\frac{d\bar{T}}{dt} = 0.4\bar{T}_{in} - 0.32\bar{T} + 0.8\bar{F}$$

while the dynamics flow rate $\bar{F}$ depends on the valve position, $\bar{x}_v$

$$\frac{d\bar{F}}{dt} = 8\hat{x}_v - \bar{F}$$

(a) (10 pts) What is the transfer function from $\hat{x}_v$ to $\hat{T}$?

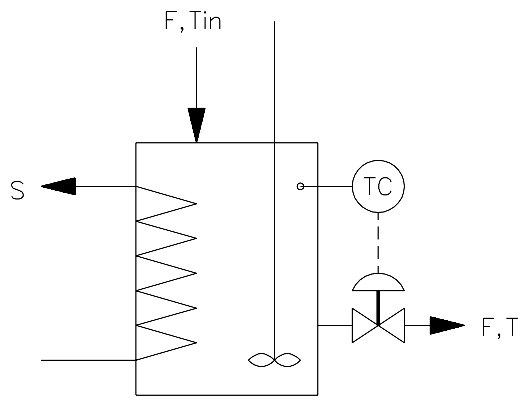

Figure 2: Stirred tank heater.

(b) (10 pts) What is the transfer function from $\hat{T}_{in}$ to $\hat{T}$?

(c) (15 pts) Using a proportional controller to control T by manipulating x_v, what is the <u>maximum</u> value of K_c such that the roots are inside the 45^o region in the LHP.

(d) (15 pts) Letting $\hat{T}_{in} = 0.5/s$ and $\hat{T}_{set} = 0.3\ e^{-2s}/s$, what is the offset as time goes to infinity ?

3. **Cascade Control.** A reboiler has been found to have the transfer function from feed $\hat{F}_o$ to measured height $\hat{h}$ given by

$$G_p(s) = 0.2\frac{-5s+1}{(10s+1)(3s+1}$$

and the valve has the transfer function from valve position $\hat{x}_v$ to feed $\hat{F}_o$ given by

$$G_v(s) = 8\frac{1}{1.5s+1}$$

(a) (15 pts) Using a simple proportional control as shown in Figure 3, show that the ultimate gain is 1.437 and using the gain prescribed by Ziegler-Nichols, calculate the percent offset for a step change in setpoint, i.e. $\hat{h}_{set} = \alpha/s$.

(b) (20 pts) Another common control configuration is to actually split the control to two levels. An inner control loop could be designed to manipulate the valve position x_v to control the flow rate F_o. Then an outer loop could be designed to decide what set point of F_o is given to the inner loop in order to control the height h. This type of configuration is called a cascade control as shown in Figure 4. Suppose the inner loop controller was designed to be a proportional controller having a gain equal to 3. The outer loop is also a proportional controller having a gain equal to K_c which treats the inner loop together with the height dynamics as the process itself. Find the ultimate gain K_u using Routh-Hurwitz method and then use the Ziegler-Nichols prescribed gain, $K_c = K_u/2$, and calculate the resulting per cent offset for a step change in set point.

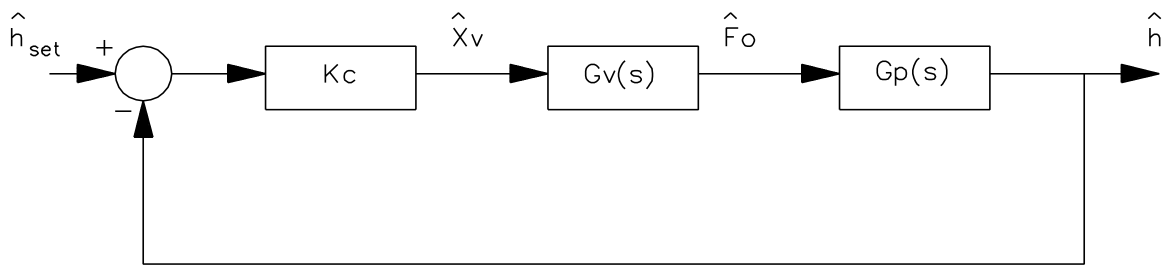

Figure 3: Direct Proportional Control for Reboiler.

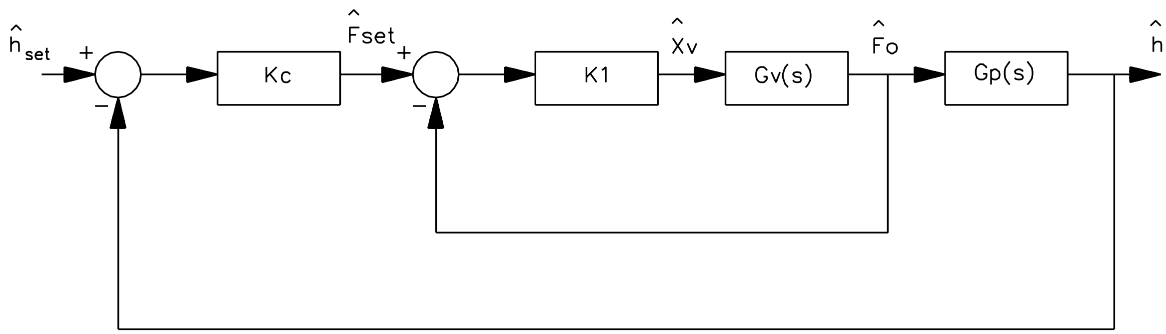

Figure 4: Cascade Control for Reboiler.

4. **Special Instruction:** Sign below to validate the exam

   I have done this exam by myself, without consulting or discussing with anyone except for the instructor and/or teaching assistants assigned to this class.

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