This is [illegible] for example

TANKSPILL - A Process Control Game

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This game, run under Microsoft Windows, simulates a tank with a gas and liquid feed, and the objective is to keep the pressure and liquid level in the tank at given values by manipulating the valves of the streams leaving the tank. The parameter values chosen in this game are intended to represent a gas-oil separator where a high-pressure well stream is separated into liquid and gas. Condensation or vaporization is neglected. The objective of the game is to introduce the student to the dynamics of an interacting process.

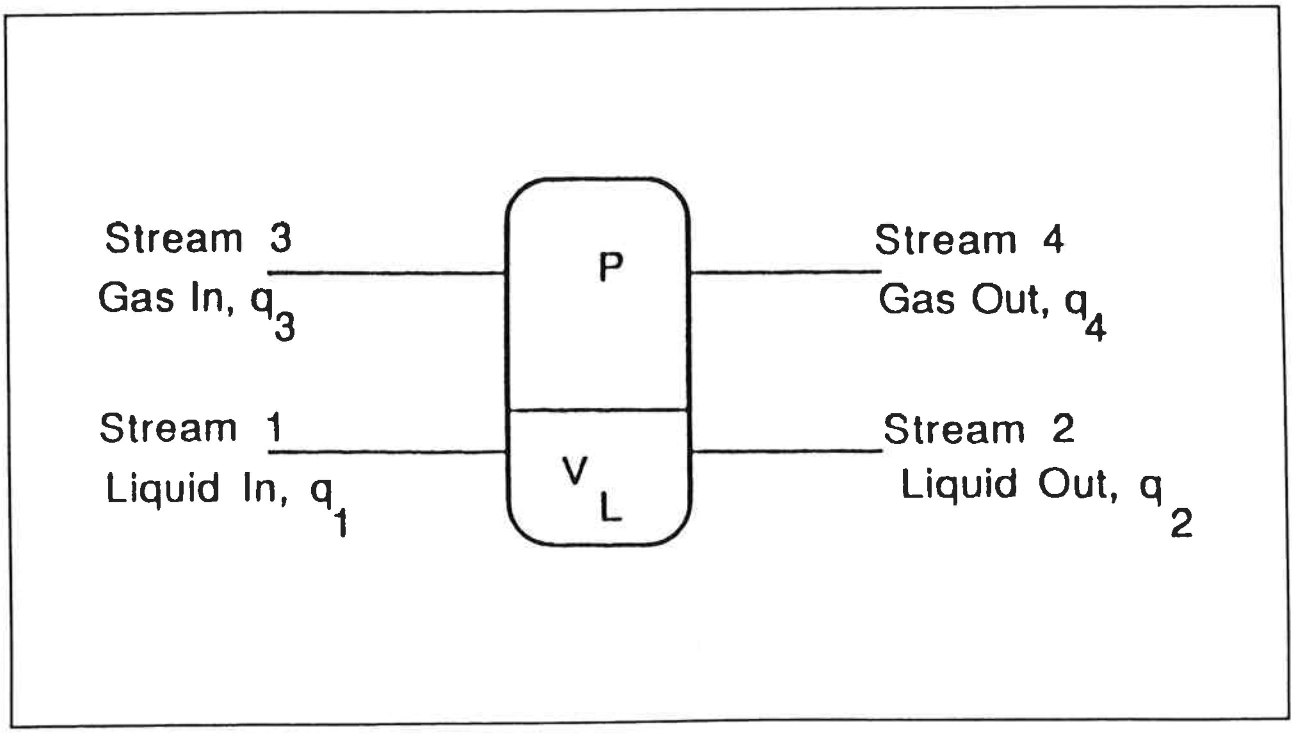
The program may be run with or without a predefined set of disturbances, and the valves may be operated manually (with a mouse) or with a P-, PI- or PID- controller. The program may be used to illustrate various aspects of process control ranging from an introduction to dynamics to controller tuning.

In Training mode the disturbances may be changed by the user. In this way a student can use step responses etc. to tune his/her own controller.

In game mode the objective is to maximize the game time. The student starts with 1000 points and points are subtracted if the level and pressure deviates from their setpoints.

'TANKSPILL' operates under WINDOWS, and a AT, PS/2 or compatible with a 286 or 386 processor is needed for acceptable speed. A color monitor is neede to identify streams etc. It is possible to operate the program with a keyboard only, but the use of a mouse is recommended.

Model of the System



The system has four independent variables (flows). The manipulated variables (inputs) are Z_2 and Z_4, the valve opening on the streams leaving the tank. Disturbances are q_1 and q_3 the flowsof the streams entering the tank. The system is described by the following differential equations:

Material Balances

$dV_L / dt = q_1 - q_2$ [m^3 /s]

$(V - V_L) * dP/dT = RT*(q_3 - q_4) + P*(q_1 - q_2)$ [Pa*m^3 /s]

Valve Equations

$q_2 = Cv_2 * f(z_2) * (P_L - P_{LO})^{1/2}$ [m^3 /s]

$q_4 = Cv_4 * f(z_4) * (P^2 - P_{GO}{}^2)^{1/2}$ [kmol/s]

Linear valves $f(z_1) = z_1$, where $z_1 = [0,1]$

$P_L = P + gV_L/A$

Nominal Steady-state Operating Conditions

V_L = 20 m^3

P = 70 bar; P_L = 70.07 bar; $P_{Lo} = P_{Go}$ = 60 bar

z_1 = z_2 = 0.5

q_1 = q_1 = 4.0 m^3/s

q_2 = q_2 = 2.56 kmol/ s

T = 400 K

Constraints

$0 < V_L < 100$ m^3; $P < 100$ bar

There is a 5 second dead-time in the valve- dynamics which is modelled using a 5th order lag. In terms of Leplace transforms:

$$dz_2 = 1/(1+s)^5 * dB/100$$

$$dz_4 = 1/(1+s)^5 * dD/100$$

where z_2 and z_4 are the actual valve openings, and D and B are the desired valve openings (in %) set manually or by the controller.

Linearizing the model at this steady state yields:

$$\begin{pmatrix} dV_L \\ dP \end{pmatrix} = G(s) \begin{pmatrix} dB \\ dD \end{pmatrix}$$

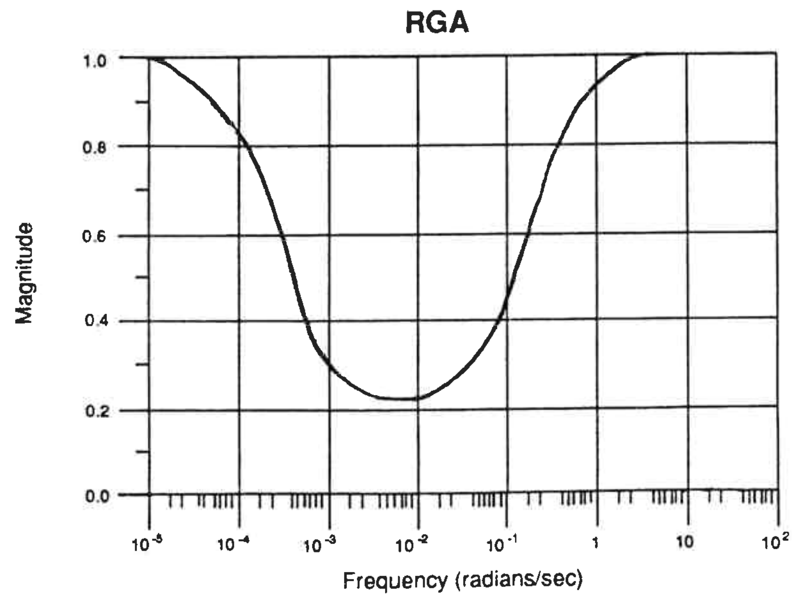
where B and D are the valve openings in percent.

Here:

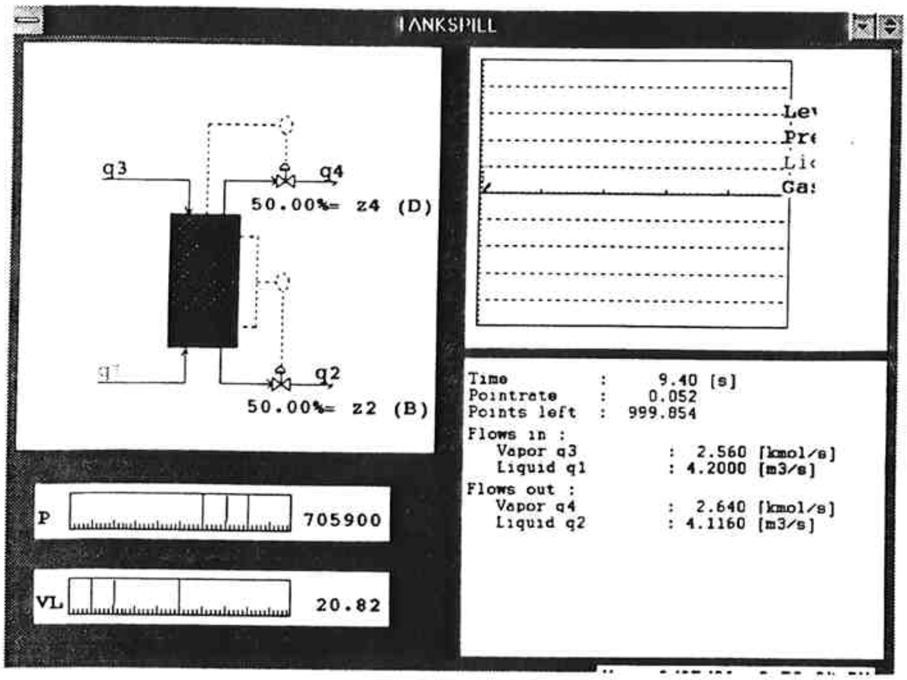
$$G(s) = Gc(s) * 1/(1+s)^5$$

$$Gc(s) = \frac{0.01}{(s + 1.72e^{-4})(4.32 * s+1)} * \begin{bmatrix} -34.54*(s+0.0572) & 1.913 \\ -30.22e+5 * s & -9.188e+5*(s+6.95e-4) \end{bmatrix}$$

The small eigenvalue of $-1.7e^{-4}$ comes from the self-regulation of liquid level which is almost negligible. As noted above the process is very interactive. The RGA has a steady-state value of 1 (see figure on succeeding page), then goes down to 0.25 at a frequency of 0.01 Hz, and returns back to 1 at about 1 Hz. This implies that interactions increase the effective gains of the loops and that interactions are most severe at intermediate frequencies. The system is triangular (and therefore has a RGA-value of 1) at steady-state because liquid flow has no effect on pressure at steady state, and the system is triangular at high frequency because the gas stream has a direct effect on pressure, but only an indirect effect on level. Note that the interactions will be more severe if the controllers are detuned than when they are tightly tuned. The interactions make this a challenge problem for single-loop control and introduces the students to some important aspects of multivariable control.



Screen Display



Use of TANKSPILL for Teaching

In our process control course, which is currently based on the book by Stephanopolous we have about five exercises where the game is used. It is a good idea to use one lecture to introduce the students to the problem.

1. After 1-2 weeks of teaching the students have an exercise divided into three parts:

   A) Find the mathematical model for the tank.

   B) Use "training mode" to perform steps in flows q1, q2, q3 and q4.

   C) Use "game mode" to achieve maximum game time with manual control and with P-control. The students will discover that it is much easier to get good response with P-control.

2. Two weeks later the students are asked to simulate the same process using MATLAB, but without the lags on the inputs. They are asked to compare the simulations they did with TANKSPILL. It is important to note that in TANKSPILL you change the valve position, and only indirectly the flow. For example, you will see in increase TANKSPILL that increasing z4 (ie., D) will first yield an increase in q4, but q4 will eventually return to its original value. On the other hand, it should be noted that changing z1 and z3 directly changes the inlet flows.

3. The next week they are asked to linearize the model equations analytically and obtain numerical values for the coefficients at the nominal steady state.

4. Finally, about 3 weeks later they are asked to:

   A) Based on the linearized model, obtain the transfer matrix GC(s).

   B) Use training mode with P-control to obtain Ziegler-Nichols PID tunings. Use these in game mode with PID control.

5. At the end of the course the TANKSPILL example is used to illustrate that the steady-state RGA may be misleading in some cases. At steady-state the RGA-value is 1. However, we know that there are dynamic interactions in TANKSPILL, and these are illustrated by plotting the frequency-dependent RGA.

If interested in a free copy of TANKSPILL, please complete the Standard Order Form in the back of the Newsletter and return to CACHE Corporation.