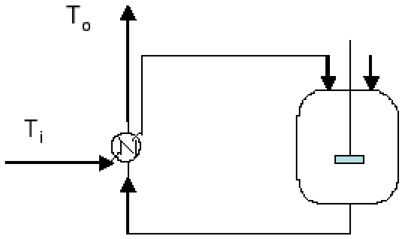
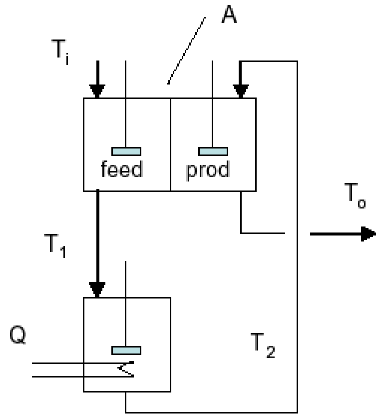
1. You are responsible for a reactor in which an exothermic liquid-phase reaction occurs. The feed must be preheated to the threshold activation temperature of the catalyst, but the product stream must be cooled. To reduce utility costs, you are considering installing a heat recovery system in which the product preheats the feed.



Of course you will design and select the heat exchanger to handle the desired steady-state heat duty, but you would also like to consider the control system as part of the design. That means you want to understand the system dynamics - how variations in the inlet temperature and reactor heat load affect the outlet temperature. You therefore represent the system as a collection of first-order lags. Here the heat exchanger is represented as two stirred tanks connected by heat transfer area A. Each tank will have its own volume. The heat of reaction is represented by a heating coil that delivers power Q.



a. Model the system: begin with M&E balances and obtain standard-form differential equations. Classify your variables as input, intermediate, and output. (You have 3 tanks - how many equations do you expect?)

b. Combine the equations into a single equation that relates output to input variables through transfer functions. Do this by taking Laplace transforms and algebraically combining to eliminate the intermediate variables. (What order do you predict for the final transfer function?)

c. Return to the Laplace transforms of the component equations. Draw a block diagram to represent the signal flow through the component transfer functions, showing how inputs are processed to become outputs. Then use this diagram to derive a single equation relating output to inputs. (Should the result be the same as in part (b)? Was it easier than (b)?)

d. To really drive it into the ground, return to your original component ODEs. Combine them in the time domain so that the dependent variable is related to input forcing functions. You will have to differentiate some of the equations to produce further independent equations so that you can eliminate intermediate variables. (What order do you predict for the resulting ODE? Can you see the relationship between this equation and the transfer function expression derived earlier?)