Engineering Economics and Problem Solving, 4N4, 2013

Tutorial/Assignment 7

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AIM: *To expand your knowledge of process operability*. You will need to read and consider slides/material not covered in class and about to be covered in class.

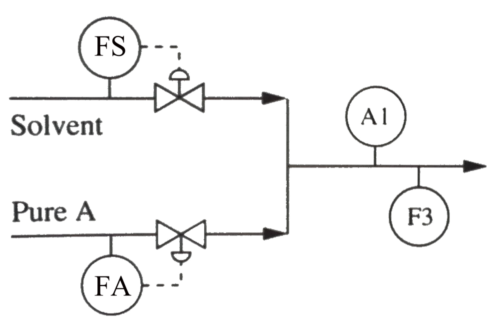
Question 1

Refer back to the P & ID from the prior tutorial (depropanizer and debutanizer column sequence).

1. The trays on these columns function properly when the vapour and liquid flows vary within 65-105% of their design values. We have been asked by management to operate the tower at 45% of the design feed rate for the next month (low demand for our product). Determine whether this lower feed rate is possible and explain your decision. If possible, explain how to operate the tower. If not possible, what design change would make the low feed operation possible?
2. The tower is running at 100% of the design feed rate. It is a very hot day and the cooling water temperature is 7 °C higher than anticipated in the design operating window. Describe the effects on the plant operation. Specifically,
   (a) can it operate safely and
   (b) what is the effect on the product compositions?
3. The tower is specified to be 3m above ground level (grade). Why?
4. The level in `V-30` is low but within its 0-100% range. The pump `F-27` has a lower than expected outlet pressure, and the reflux and propane product flows cannot be achieved. Propose reasons for these symptoms. (*Hint*: Look up the term "vortex breaker")

Question 2

The simple mixing system was considered in class. Blending occurs in many processes, especially near the end of a flow sheet where the company tries to obtain the right product properties by blending two or more streams together.

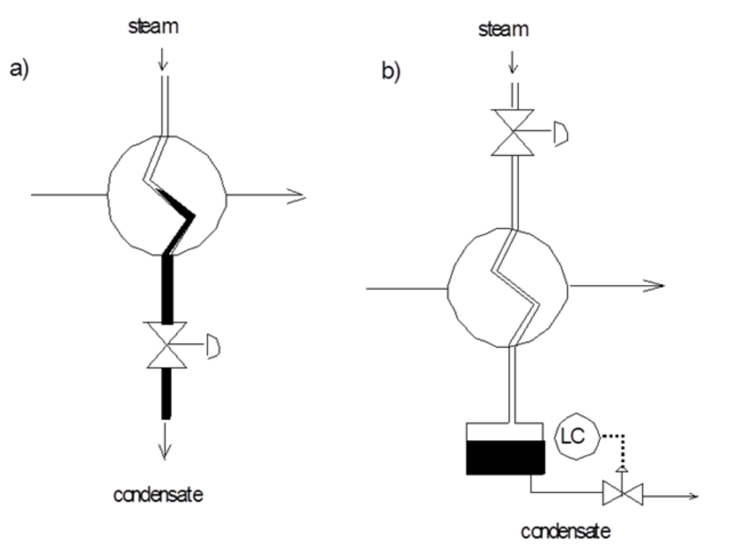


The valves and piping are such that F_A has a maximum flow of $F_A^{\max} = 30$ L/s and F_S has a maximum flow of $F_S^{\max} = 60$ L/s. Further, the composition of stream A is 100% pure species A, while stream S has 0% of the species. The two important variables from any blend are the composition and flow rate.

Draw an operating window that shows the composition A_1 on the horizontal axis and the combined flow, F_3, on the vertical axis. Label the important vertices in your drawing, indicating how the operator might move the process to that point in the window. Highlight the regions of feasible and infeasible operation (*hint*: the region is **not** linear).

Question 3

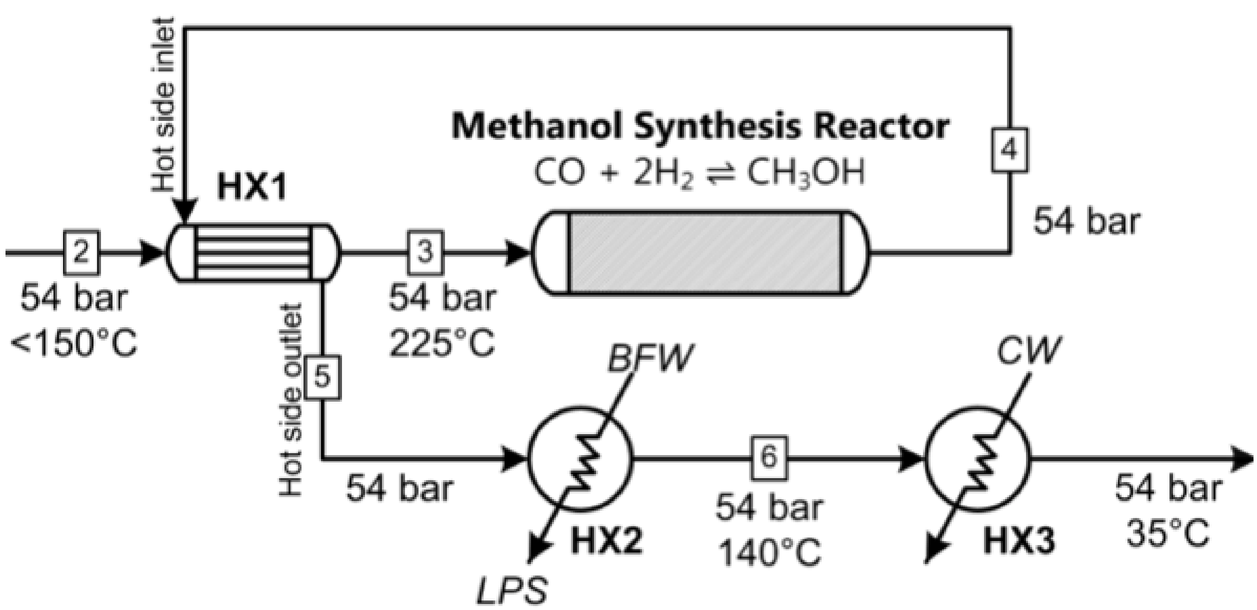
Two designs for adding flexibility to a heat exchanger are shown below. The hot stream is *steam* that condenses. Explain each of these designs (how they work) and give strengths and weaknesses of each.



Hint: when judging flexibility of a control system we consider (a) range of operation (b) large or small gain (c) dynamics, i.e. speed of response (d) symmetry in operation (does it behave symmetrically when opening vs closing valves) (e) linearity and (f) safety.

Question 4

Consider the methanol synthesis reactor system below. It is an exothermic reaction in the forward direction.



1. Redraw the main elements for the diagram. Now adding equipment, piping, valves and describe the protocol that operators might follow to allow starting up the reactor after a one week shutdown (February every year). The reaction kinetics do not proceed very much at low temperature.
2. As a secondary consideration, how does the modification you made affect the controllability of the process? In other words, do any of your modifications assist with the ability to control the system? Consider the points (a) to (e) in the prior question. Note also, an important aspect of controllability is that your control loop *should not* have side-effects on other variables (hint: which is a variable that you should not alter in this process?)
3. A primary consideration is process safety. What will happen in the current system, as drawn, if the feed in stream 2 temporarily enters at 200°C for a few minutes (i.e. an upstream disturbance occurs)? Do your modifications in part 1 of this question make this problem worse, or better? Comment on your proposed changes from part 1, redrawing the diagram if necessary to mitigate any safety concerns.

Question 5

Consider the methanol synthesis project. For each of the following units, please identify 8 sources of variation that will impact the equipment design and day-to-day operation of the process:

1. The gasifier unit, the first step in the flowsheet. (Consider only a feed of biomass).
2. The distillation column in the methanol synthesis block. It is producing the final product, it's the last unit in the flowsheet, and we have to maintain >99.9 mol% purity methanol, despite these disturbances.