Engineering Economics and Problem Solving, 4N4, 2014

Tutorial/Assignment 7

Tutorial date: 23, 24 October 2014; due date: **05 November 2014, 11:30** (please note the date and time)

AIM: *To improve your confidence with the Operability topic, and start with some significant progress on your course SDL project.*

Please note: these assignments and tutorials are not assumed to be completed in the tutorial period. Significant work on the assignment is required outside of class; this is intentional, as it trains you for your group project. You must find efficient ways to collaborate outside of class, as this is what's required from you when you are employed.

Question 1 [15 = 2 + 4 + 5 + 1 + 3]

Final exam, 2013. This is quick warm-up question. Quickly move to the next questions.

Potato chips are continuously produced by washing potatoes, then peeling off the skins, cutting them into slices, frying them in oil, and finally packaging them after they have cooled on a conveyor belt. The 6 major unit operations are washing, peeling, cutting, frying, cooling conveyor, packaging. There is no recycle. From statistical analyses, the reliability of each unit is 90, 92, 84, 96, 95, and 89%, respectively.

1. What is the overall plant's reliability? **[2]**
2. Draw a BFD of the current process, then add to it and show how you could improve overall reliability. **[4]**
3. New units cost \$5m, \$7m, \$2m, \$20m, \$9, \$10m respectively for the washer, peeler, cutter, fryer, conveyor, and packaging units. Justify how you would best boost reliability if you had \$8 million left over in your budget to allocate? (Show calculations) **[5]**
4. For your answer in part 3, what would the new reliability be? **[1]**
5. Propose an alternative way the reliability could be boosted only around the cutting unit, using the \$8m budget. In your answer, sketch the proposed change. **[3]**

Something to think about: you have 3 items in series, then a recycle loop from item 3, back to item 1. In the middle of the recycle loop you have a 4th item. If each item has a reliability of 0.98, what is the overall system's reliability?

Question 2 [15]

The rest of the questions in this tutorial refer to the SDL project on the phthalic anhydride (PA) process.

Show a brief summary of your group's bare module capital cost calculations (in 2013 dollars) for the following units:

- P-701 A/B
- E-702
- V-701
- C-701
- T-702

Does your group know the maximum temperature, maximum pressure and material of construction of these units?

Have you started costing the fired heater?

Question 3 [10]

Take a look at the pump curve for `P-701 A/B` and notice its general shape. Most centrifugal pumps have a curve like this. The operating window for a single centrifugal pump is actually not a "window"; rather it is the pump curve. As you adjust the flow, the pressure rise across the pump shifts to a new location on the curve.

In your answer here you are required to think analytically and

1. draw what the overall operating window (a new pump curve) is expected to look like for two pumps (A and B) in series;
2. draw what the overall operating window is expected to look like for two pumps in parallel;
3. Next, from your group discussion, what do you expect the advantages are of the series arrangement?
4. From your group discussion, what do you expect the advantages of the parallel arrangement are?
5. How would you expect the two pumps, A and B, to be arranged in the PA P&ID? Update your group's P&ID with this information.

Question 4 [12]

Read the document with DOI `10.1002/14356007.a20_181.pub2`, section 2.4.

1. What is a DOI?
2. Is this resource reliable? Explain your answer.
3. Which alternative raw material is commonly used to create phthalic anhydride?
4. What is the expected yield, using units of kg PA/kg naphthalene?
5. This section talks about reactors used to create PA. What is a "von Heyden" catalyst?
6. Which of the 4 reactor geometries in the article does it appear that our system is closest to?

Now start to think about how cost the reactor. Which other resources are available for you to find cost information? How much catalyst will you need to purchase for the reactor?

Question 5 [3]

There was a small error on slide 44 of Dr. Marlin's notes. Make a change to the diagram to improve it.

Question 6 [15]

Steam costs for the heat exchanger are to be estimated. Consider exchanger E-701, with a process stream inlet temperature of 164°C and outlet of 240°C. It is heated using a utility stream: *high pressure steam* (HPS).

1. The first memo indicated this heat exchanger has a duty of 11,370 MJ/hour. Prove that this number is correct.
2. HPS can be assumed to be available at 42 bar, saturated, dry vapour. What is the temperature of this steam at these conditions?
3. Assuming no heat losses and 100% efficiency, the energy reported in part 1 is the amount of heat that is supplied by the steam's latent heat.
   (a) What is latent heat (in general)?
   (b) The steam is condensed, and this condensate is recirculated and reused to become boiler feed water (BFW). What is the latent heat of steam at these conditions?
   (c) Calculate the minimum required flow rate of HPS to supply this heat.

4. Simulate this heat exchanger in Aspen, and report your results; contrasting them to the values calculated earlier in this question. In your simulation, use the heat transfer coefficients and description in the first project memo.
5. Now consider the economics of operating this heat exchanger.
   (a) What is the cost of HPS (*hint*: use a reference such as Turton).
   (b) The condensed BFW is "sold" back to the utility plant for a credit. What is a fair price estimate for this "sale"? (*hint*: again, use a reference such as Turton).

Question 7 [8]

This question is related to control loops. Last week you considered temperature control in a debutanizer distillation column. This week, consider the distillation column, `T-701`.

There are 4 control loops on the column: pressure, level, flow and level on the auxiliary unit, `V-701`.

For each control loop state:

- the manipulated variable
- explain why that control loop pairing drawn makes sense

Question 8 [8]

Consider the "Process 1" and "Process 2" example from Dr. Marlin's class on Wednesday, 22 October, where he showed how a tank can decouple a process, even though it adds inventory to the overall system.

1. Suggest a location for such a tank in this flowsheet.
2. What safety precautions will the tank require?
3. Suggest an initial estimate of the tank's size, showing all calculations.

Question 9 [7]

The first memo describes the control loop for the fired heater but it is not shown in the block flow diagram.

1. What is/are the manipulated variable/s?
2. What is the controlled variable?
3. Add these loops to a sketch of the fired heater.

Think carefully about what is happening in the furnace, and how it might be controlled.

Question 10 [0]

Check points for your project:

- Has your group reproduced the flowsheet in a professional software package, like Visio, Inkscape, or AutoCAD?
- Start adding valves for reliability and flexibility: for example, control valves and heat exchangers need bypasses for repairs (as Dr. Marlin covered in his class 8A)
- Add flow meters, temperature sensors, pressure indicators where needed. Remember these cost money, so where do you think operators and control engineers will benefit and use these measurements?

Question 11 [20]

The grading from your group's peer-evaluation (electronic survey) will be added to this tutorial's grade.

END