Student number: _____

Chemical Engineering: 4N4
Engineering Economics and Problem Solving
McMaster University: *Final examination*

Duration of exam: 3 hours **Instructor: Kevin Dunn**
06 December 2013 **kevin.dunn@mcmaster.ca**

This exam paper has 5 pages and 8 questions. You are responsible for ensuring that your copy of the paper is complete. Bring any discrepancy to the attention of the invigilator.

Note:
- *I want to, and I can!*
- You may bring in any printed materials to the exam; any textbooks, any papers, *etc*.
- You may use **any calculator** during the exam.
- However, no cellular phones, tablets, or other electronic devices are permitted.
- You may answer the questions in any order on any pages of the answer booklet.
- *Time saving tip*: please use bullet points to answer, where appropriate, and **never repeat the question** back in your answer.
- If any part of the question seems ambiguous, please make a clear and reasonable assumption, and continue your answer.
- Total marks: 100 marks; 105 marks available.
- Total time: 3 hours.

Question 1 [14 = 1 + 1 + 3 + 2 + 4 + 3]

Provide single word, or short sentence/bullet point answers to the following.

1. In a HAZOP study, what are suitable guide words when considering **temperature** for a node (e.g. a pipe carrying the feed to a flash drum)? **[1]**
2. When considering "flexibility" on a flowsheet we require a certain number of control valves to achieve desired operating points. What is the rule for the minimum number of control valves required? **[1]**
3. Explain why for critical safety systems we require isolation between the BPCS and SIS. **[3]**
4. When considering batch sequencing, what is the main difference between flow shop and job shop schedules? **[2]**
5. Name 4 factors that contribute to the cost of BFW. You would then use these factors to estimate the cost, per cubic metre of BFW, at your processing plant. **[4]**
6. We discussed flares in class, and you had a SDL reading on flares. It seems counterintuitive, but many flares have a "steam assist", which injects steam into the flare. Explain the reason(s) for this. **[3]**

Question 2 [6]

1. In your chosen profession of Chemical Engineering, what does the acronym PEO stand for?
2. Which license does the PEO issue, and why is a license required from the PEO?

Question 3 [13 = 2 + 2 + 3 + 4 + 2]

Provide single word, or short sentence/bullet point answers to the following. **Show brief calculations for calculated answers.**

1. Return on investment (ROI) is defined as $\text{ROI} = \dfrac{\text{Average annual profit}}{\text{Capital invested}} \times 100$

   What's one disadvantage of this profitability measure (answer in the context of the methanol synthesis plant from the course project **if** you want to use an example). **[2]**

2. What does RRSP stand for in the context of retirement planning? **[2]**

3. A new addition to a plant requires 5 operating staff to be present on the plant floor and/or the control room at all times during the day. The plant operates 24 hours per day. Your company requires an estimate of the additional operator salaries required [the annual amount]. Provide this estimate to them, with a justification. No need to estimate maintenance and managerial salaries. **[3]**

4. Using **either** a) a waste water treatment plant, *or* b) polymer extrusion process *or* c) frozen pizza manufacturing and packaging plant as an example; list 2 items which are fixed capital costs and 2 items which are working capital costs. **[4]**

5. What is meant by the term "salvage value" for a piece of equipment. **[2]**

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

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 around the cutting unit could be boosted using your \$8m budget? In your answer, sketch the proposed change. **[3]**

Question 5 [16 = 3 + 2 + 2 + 3 + 6]

Referring to the figure on the next page:

1. At the top of the diagram, why has PSV1 been marked as "set at 1.8 MPa"? In your answer describe what PSV1 is, and what the 1.8 MPa setting achieves. **[3]**

2. What is a depropanizer? Be specific in your answer. **[2]**

3. What is the "F.O." and "F.C." designation mean near a valve? **[2]**

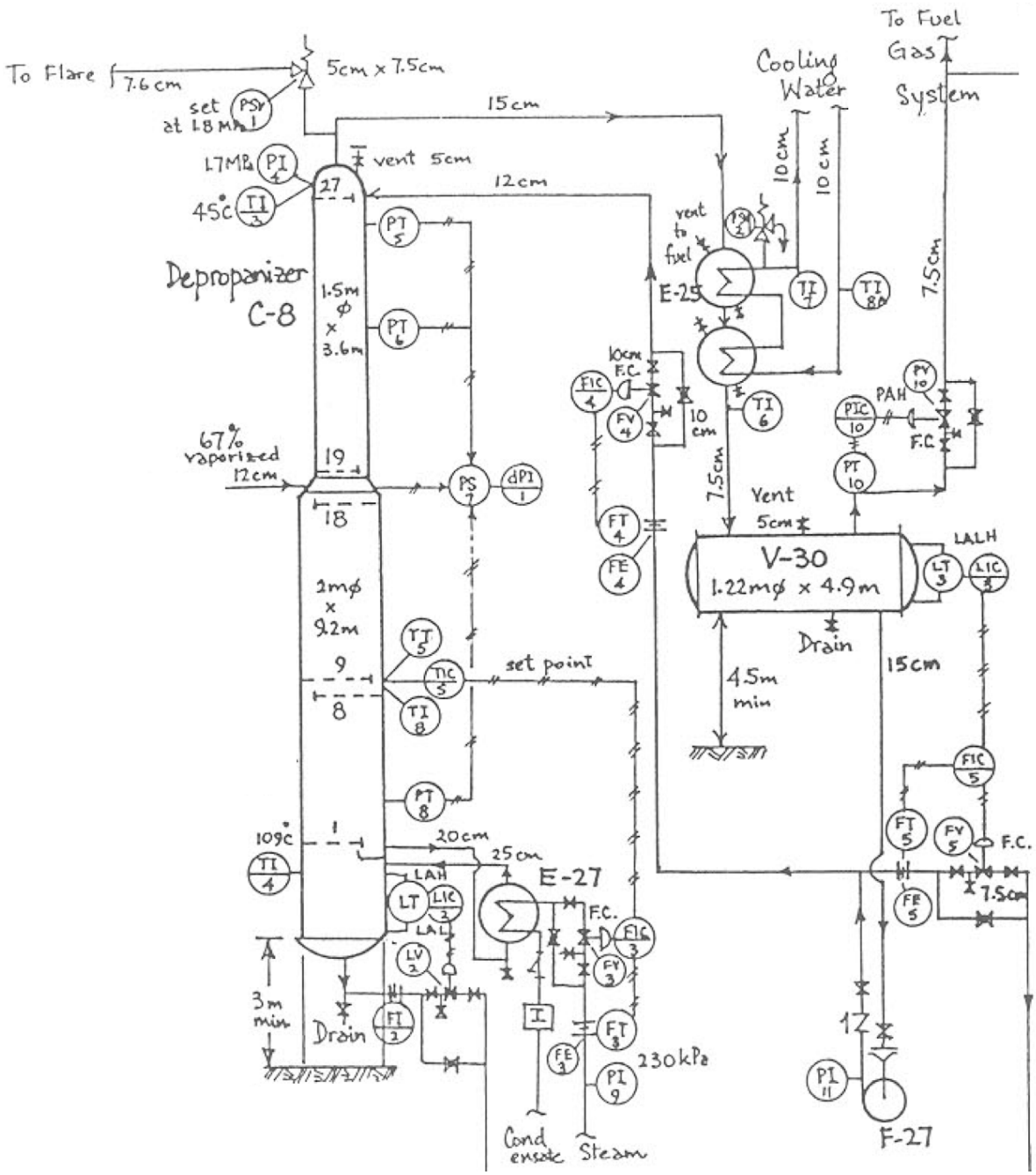
4. Clearly explain the purpose of the 5 valves on/near PIC10. Redraw that section of the diagram in your booklet, label the five valves as V1, V2, ... V5, and use that to explain your answer efficiently. **[3]**

5. In the context of a HAZOP, consider the node to be the top tray, i.e. the 27th tray, specifically the opening in the column where the liquid reflux reenters. Let the guide word be **flow**. **[6]**

   For each of the deviations below, write out a cause and the corresponding consequence:

   (a) NO

   (b) REVERSE



Question 6 [12 = 3 + 9]

Sally graduated three years ago and has been working at a polymer company PolyON since graduation. PolyON does not hold patents, but it maintains trade secrets for many processes. Not long ago, Sally responded to an advertisement for a position at another polymer company, PolyTO. The new company does not compete directly with PolyON in any product line.

After being at PolyTO for a few months, Sally recognizes a new application of the reactor design that she learned at PolyON. This could be a big money maker for her new employer, and a boost to her career.

1. Which ethical considerations must Sally bear in mind, if she decides to disclose the use of the reactor design to her new employer, PolyTO? You should refer to the code of ethics numbering, where possible.
2. Brainstorm 3 actions that Sally might take when deciding on an ethical course of conduct.

Question 7 [5 + 5 bonus grades for calculations]

A production process that was completed in 2012 showed annual sales of approximately $1 million. There are 3 steps in the flowsheet: the first is a catalytic reactor which must be stopped after every 18 hours. It takes 6 hours to separate the catalyst from the liquid product, regenerate it with steam, and bring the reactor back on line. During these 6 hours the rest of the process is shut down. After this reactor is a screen separator (it was over-designed by 200% when originally purchased), then the last and third step is a packaging line for the final product.

This is the only information you have heard from your colleagues so far. But you also have knowledge from this course on topics such as turn-over ratios, capital cost estimates, profitability calculations, cash flows, NPV, operability concepts, and troubleshooting.

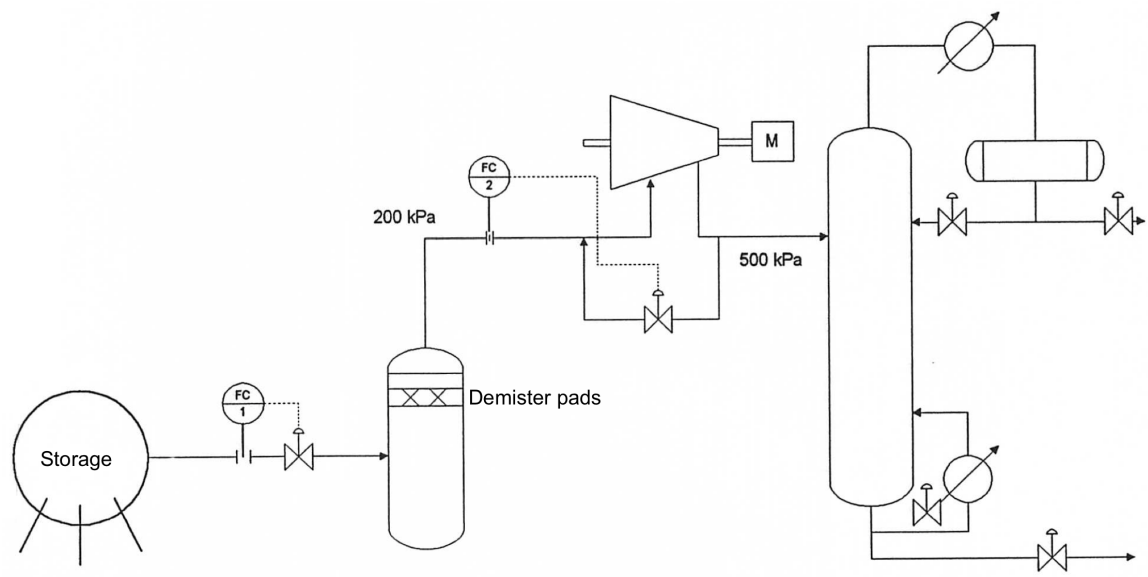
Use any/all of the topics from this course, and your other undergraduate courses to brainstorm, in bullet points, a way you could improve profitability for your company, given that the market demand is higher than you can currently produce. Be as specific as time allows for a rough calculation of a profitability metric/or metrics to back up your answer. Make realistic assumptions where required.

One more question left to go ...

Question 8 [19 = 1.5 + 1.5 + 3 + 5 + 5 + 3]

You are the engineer responsible for the operation of the process shown below. A feed gas from a storage vessel is compressed and sent to a distillation tower for separation. The compressor must have a minimum flow or it will "surge", i.e., experience an unstable, oscillatory flow that will quickly damage the blades of the compressor. To protect the rotating compressor, a flow sensor measures the flow to the compressor and a PID controller with the minimum flow rate as its set point opens the recycle valve if the flow is below the minimum (the controller setpoint). The distillation tower has composition control on both product streams.

At design rates, the process operates well. Recently, the production rate has decreased and the process is operating smoothly with excellent product quality control. However, you have received a note from the control room manager that the process is consuming much more energy (hint: *electrical* power) than expected. You've got today to correct the problem before they have to report the situation to the plant manager.



1. Define the current state of the problem. **[1.5]**
2. What is the desired final state? **[1.5]**
3. Which areas of chemical engineering knowledge might/will be used to identify the problem? **[3]**
4. For two of the areas in the prior subsection, describe a principle of operation or equation that is relevant. **[5]**

   For example, if you had said "radiation heat transfer" in the previous question, (which isn't a correct answer), then a principle of operation would be that radiation heat flux is proportional to the fourth power of temperature, and you would show that equation.
5. Write down your thoughts in **short and concise bullet points** for the *Explore* stage of the troubleshooting strategy. **[5]**
6. State 2 working hypotheses for the cause of the higher energy consumption. **[3]**

Note: you are **not** required to identify the true cause, nor solve, the problem in this exam.

The end.