

## National Exams December 2003

98-Chem-A5, Chemical Plant Design and Economics

3 hours duration

### **NOTES:**

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.
2. Any non-communicating calculator is allowed. This is an OPEN BOOK exam.
3. The questions are of equal value. The candidate will answer any five of the seven questions. Only the first five questions attempted will be marked.
4. Most questions require an answer in essay format. Clarity and organization of the answer are important.

1) Process Economics (20 marks)

As a result of recent legislation with respect to a required reduction in Sulphur content of gasoline, one Ontario refinery will be shut down. This is an example of where in a competitive business environment it is necessary to carry out regular evaluations of the plant and equipment used in production. As a result of age or changes in the market place these units may not be suitable to meet current quality specs, or the costs may have become excessive. One is faced with four mutually exclusive choices as follows.

1. An existing asset may be kept in its current use without major change.
2. An existing asset may be revamped so as to improve its performance.
3. An existing asset may be removed from service without replacement.
4. An existing asset may be replaced with another asset.

Discuss in general the various issues that one would have to consider in each of these four cases, should you be an oil refiner who finds that they can no longer meet the prescribed Sulphur spec. Environmental issues come into play in several aspects of these cases

2) Profitability Analysis (20 marks)

The following is a scenario that many process engineers have had to deal with. Your company produces polyester resin used in many applications but primarily in soft-drink bottles. One of the major costs of your business is the purchase of ethylene glycol. You have been requested to do a preliminary assessment of the potential profitability of producing your own glycol. This assessment will give guidance to your management as to whether they should proceed to the preliminary design phase. There in the literature a 1988 cost for a 16,000 Metric/tonne per year unit that produces 8,000 Mt/yr Ethylene oxide for sale and feeds 8,000 Mt/yr to a glycol unit where the yield is 75% mass of Ethylene glycol, 15% mass of Diethylene Glycol, 9% mass of Triethylene glycol and the balance Heavy ends. Your ethylene glycol demand is 18,000 Mt/yr but you want to look at 20,000Mt/yr to allow for expansion. The reference unit is a green site plant, however your facility has adequate Utilities and General facilities (considered to be approx 35% of the battery limit cost). Describe how you would go about calculating a scope Internal Rate of Return for this project.

3) Distillation Design (20 marks)

Although there are many separation unit operations multicomponent fractionation is probably the most likely to be selected on the basis of reliability and cost. Most column designs are carried out using flowchart simulators such as HYSYS, PRO/II or ASPEN. It has been said with some justification that the results of the initial column calculations will be wrong.

MESH equations are the equations used to describe the steady state operation of a distillation column.

Material or flow rate balance equations, both total and component

Equilibrium equations including the bubble-point and dew-point equations

Summation or stoichiometric equations or composition constraints

Heat or enthalpy or energy balance equations

The main problem is related to the accuracy of the K value routine selected. There are three general methods used to represent K values. Discuss these and give an indication as to why they are so important in fractionation design, with respect to the MESH equations.

4) Project Management (20 marks)

Any successful design project depends on effective project management. There is no single correct way to manage a project but there are four basic steps.

- 1 Define the project
- 2 Create a project plan
- 3 Track and maintain the project plan
- 4 Close the project

You are a process engineer in charge of preparing the process design report for a methanol from syngas unit. Give a description of how you would manage this project giving some detail of the various aspects of a modern environmentally acceptable design.

5) Materials of Construction (20 marks)

Most process units require consideration of proper materials of construction. The following table gives a relative cost of Metals using carbon steel as a base

Material	Relative Cost
Carbon Steel	Base Cost (lowest)
Low Alloy Steel	Low-Moderate
Stainless Steel	Moderate
Aluminium and Aluminium Alloys	Moderate
Copper and Copper Alloys	Moderate
Titanium and Titanium based alloys	High
Nickel and Nickel based alloys	High

Why is the selection of the correct material important, and what are some of the constraints one must deal with when making a choice. Consider different situations such as for example a crude tower in an oil refinery or a vessel in a vaccine manufacturing unit.

6) Green Engineering (20 marks)

From the perspective of potential environmental damage the design of chemical reactors is the most important unit operation in a chemical process. Although there are obviously many factors to consider the three most important are:

- 1) Process Material use (Feedstocks, by-products, intermediates etc) and selection
- 2) Reaction type and choice of reactor
- 3) Operating conditions

Discuss why these three items are so important.

7) Process Design (20 marks)

Chemical Process design encompasses a wide range of processes from major refinery units to units for the manufacture of pharmaceuticals. The same basic unit operations and design principles apply regardless of the process being designed. There are some profound differences however in many aspects of the design. Discuss the different nature of for example a crude oil distillation and a unit for the manufacture of a vaccine.