ChE160: Chemical Process Design
Spring 2016
Course Syllabus

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Purpose

The purpose of Chemical Process Design is to teach students the strategies used in the design of chemical processes. A process design typically starts from a vague statement of an opportunity to produce a new product or a new way of making an existing product. Often this initial notion is driven by economics, i.e. someone sees an economic opportunity involving the new product or the new process concept. For a new product, *process synthesis* is the most creative part of process design. It is also the part that requires the most experience from the designer. He/she must know the performance of many unit operations so that they can be integrated into a process. There are guidelines for the steps in process synthesis but there are no general methods that explicitly “output” the best process. Instead, process synthesis is a trial-and-error activity: A reasonable process alternative is put together, analyzed to some depth, and then possibly abandoned in favor of a second or third alternative. This can, of course, become very time-consuming if several alternatives are designed in detail (which experienced designers try to avoid). However, modern tools like the ASPEN Plus software package allow relatively quick generation of a *process flowsheet* that capture the essence of a candidate process. With tools like ASPEN, it is therefore advisable for the designer to put together a process flowsheet relatively quickly even though it will be modified substantially later. Development of this first flowsheet forces the designer to address feed and product rates, namely the process mass balance, at an early stage in the design. The process flowsheet for a fixed capacity (feed and product rate) is a *base-case process design*. Other process alternatives can also be developed into alternative base case designs.

The performance measure for comparing alternative base-case designs is the profitability of the process. *Process economics* is an essential part of process design. When base-case designs can be eliminated based on rough cost estimates the designer lessens his/her workload substantially. This is because development of detailed process economics requires that all units be sized and their installed costs determined. In addition, energy requirements have to be worked out by performing a detailed energy balance. Seemingly insignificant byproducts can have substantial cost implications when, for example, a byproduct finds no market and becomes a waste product requiring disposal. Today, process alternatives can often be eliminated early because of difficult byproducts. All this work means that the designer strives to carry only one base-case design to completion eliminating alternatives at the earliest possible time. However, eliminating a “winner” due to incomplete information is a worse mistake than doing extra work.

Structure

There are lectures, homework, quizzes, a design project with oral and written reports, and a final examination in this course. The purpose of the lectures is to provide students with the tools for performing their design projects. The project will require the use of ASPEN Plus calculations in the 175 Tan Hall Computer Lab (Other programs such as MATLAB and MathCad may be used for special calculations of individual units). In the final exam, students will typically be asked to do a couple of simple designs and/or analyses of unit operations and/or processes (but without design software) and some questions on the design projects done by the entire class. Some cost/economic analysis will also be included in the final.

In industry, process design projects are carried out by supervised teams. We will conduct the design projects closely mimicking industrial practice. There will be periodic Progress Review Meetings between each team, the instructor (supervisor in industry) and the GSI (technical expert in industry). There will be two written Progress Reports in addition to the written Final Report. Following industrial practice, there will be a tight schedule with fixed due dates for the “deliverables”.

Teams of three students will be formed to carry out the design projects. The first few lectures will be used to assign design projects to the teams. Students are encouraged to form teams on their own, and to divide the workload for the above deliverables. Teams, once formed, cannot be modified. All team members share the responsibility for all oral and written reports. The GSIs will assist in the team formation process and develop a schedule for the review meetings. All Progress Review Meetings are scheduled in the afternoons (Tu, W and Th 1-5 pm).

All the students are expected to attend the computer lab (175 Tan Hall) at least once a week at their assigned time of 1-4 pm.

Attendance in the computer lab is mandatory.

We expect all the students to attend the lab on the day corresponding to their section. The GSIs have been asked to take attendance every day, and report back to the instructors the names of those not present.

You will lose points for the days you are not in the lab.

Safety and Ethics

Both Safety and Ethics are an integral part of Process Design.

Throughout the semester, a number of cases of chemical plant accidents are analyzed to gain valuable understanding of how to foresee and avoid such events. Also covered are best design practices and development of inherently safe designs.

Ethics training is conducted using the video “Incident at Morales”, developed by the National Institute of Engineering Ethics. After watching the video of an imaginary chemical plant accident, the students participate in a lengthy discussion of what lapses of ethical judgment contributed, at least in part, to the serious accident.

Design Projects

The design projects offered in this course are listed below. The projects will be described in detail in the first few classes.

1: Steam reforming of natural gas, followed by methanol production
2. Steam reforming of natural gas, followed by ammonia production
3: Production of methylamines from methanol and ammonia

Report Guidelines

The Progress Review Meetings are relatively informal meetings but the team members should be prepared to answer questions about progress during the preceding weeks. If the team has made no progress, the situation can become quite awkward just as it would in industry. The team members are encouraged to prepare paper handouts and bring an updated process flow diagram to each meeting to facilitate the information exchange.

The project kick-off meetings are scheduled for the Tuesday teams on February 2, the Wednesday teams on February 3 and the Thursday teams on February 4, 1:00 -3:00 pm, in 221 Gilman. The purpose of these meetings is to make sure that all the teams understand what is required of them.

Oral progress reviews are scheduled for
OR1: February 16, 17, 18
OR2: March 8, 9, 10, and
OR3: April 19, 20, 21.

The teams will come prepared to present the progress they have made since the last oral report.

The first written Progress Report should include not more than five pages of text plus figures. A most important element of this report is a block flow diagram containing all major units (sketch of the proposed process operations and their interconnections). Mass-balance data should be included such as feed and product rates, but internal flows need not be complete at this time. If several process alternatives are presented less detailed information is expected to be available at the time of the first Progress Report.

The second written report should include not more than five pages of written text plus figures. The most important element of this report is the process flowsheet with mass and energy balances (ASPEN can conveniently provide this). It is expected that only one base-case design remains at this point but there is no penalty for having an alternative or two at the time of the second progress report.

The Final Report is a comprehensive report on the project. It should be of the order of ten written pages plus figures and tables. Detailed information should be given in appendices. The Final Report will include technical material from the first two reports with the addition of detailed unit information such as equipment sizes and costs. The economic analysis for the proposed process design should be prominent in this report. While Aspen is an indispensable tool, sample hand calculations are expected for sizing of major unit operations and economics.

The schedule of the written reports is as follows:

WR1:	February 23, 24 and 25
WR2:	March 29, 30 and 31
Final:	May 3, 4 and 5

The final examination is scheduled for May 12.

Grading

The grade for the course is determined by weighting the individual elements as follows:

Oral Review 1	3%
Oral Review 2	5%
Oral Review 3	10%
Written Report 1	3%
Written Report 2	10%
Written Final Report	24%
Homework	10%
Quiz	10%
Peer review	5%
Final	20%

Written Reports
The written reports are to be prepared to professional standards, as you have done in ChE185 and ChE154. The title page must show the names of all team members, along with their e-mail addresses. The report title includes the name of the design project and the specific contents of the report. The final report should be bound in an inexpensive folder.

Written reports that are unacceptable must be rewritten until they are acceptable. Occasionally students ask to rewrite reports to improve their grade. This may be permitted at the discretion of the instructor. If a report is rewritten for any reason, the final grade for the report will be the average of the grade originally assigned and the grade assigned after rewriting.

Textbook
Towler, Gavin and Sinnott, Ray, "Chemical Engineering Design; Principles, practice, and economics of plant and process design", 2nd Ed., Elsevier, 2013

OtherResources (on reserve in the Chemistry Library)
Biegler, L.T., Grossmann, I.E., Westerberg, A.W. *Systematic Methods of Chemical Process Design*, Prentice Hall, N.J. 1997.

Couper, J., et al., Chemical Process Equipment: Selection and Design, 2nd Ed., Butterworth-Heinemann, Burlington, MA, 2010

Douglas, J., Conceptual Design of Chemical Processes, McGraw-Hill, New York, NY, 1988

Haynes, W., (Ed.), CRC Handbook of Chemistry and Physics, 93rd Ed., CRC Press, Boca Raton, FL, 2012

McCabe, W., Smith, J., and Harriott, P., Unit Operations of Chemical Engineering, 6th Ed., McGraw-Hill, New York, NY, 2001

Perry, R. & Green, D., Perry's Chemical Engineering Handbook, 8th Ed., McGraw-Hill, New York, NY, 2007.

Peters, M., K. Timmerhaus, and West, R.E., Plant Design and Economics for Chemical Engineers, 5th Ed., McGraw-Hill, New York, NY, 2002

Poling, B., Prausnitz, J., and O'Connell, J., Properties of Gases & Liquids, 5th Ed., McGraw-Hill, New York, NY, 2001

Seidel, A. (Ed.), Kirk-Othmer Encyclopedia of Chemical Technology, 5th ed., John Wiley & Sons, Hoboken, NJ, 2006

Seider, W. D., Seader, J.D., and Lewin, D.R., *Product and Process Design Principles,* 3rd Ed., John Wiley& Sons, N.Y., 2009.

Turton, R., et al., Analysis, Synthesis and Design of Chemical Processes, 4th Ed., Prentice Hall, Englewood Cliffs, NJ, 2012

Ullmann, F., et al., Ullmann's Encyclopedia of Industrial Chemistry, 7th ed., Wiley-VCH Verlag, Germany, 2012

Ulrich, G., A Guide to Chemical Engineering Process Design and Economics, John Wiley & Sons, New York, NY, 1984

One day loan

Froment, G. F., and Bischoff, K. B., *Chemical Reactor Analysis and Design*, 2nd ed., Wiley, New York, 1990. TP157 .F76 1990Reserve

Fogler, H. Scott, *Elements of Chemical Reaction Engineering*, 3rd Ed., Prentice Hall, Upper Saddle River, N.J., 1999. TP157.F65 1999

Levenspiel, Octave, *Chemical Reaction Engineering*, 3rd edition, John Wiley & Sons, New York, 1999