A Course in

CHEMICAL ENGINEERING PRACTICE: GRADUATE PLANT DESIGN

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THE OBJECTIVE OF this year long graduate plant design course [1, 2] is to provide the students with

- **A fundamental appreciation of the profit motive that drives business activity, and the role of the chemical engineer in achieving this fundamental goal**
- **Historical and contemporary perspectives on chemical engineering practice**
- **Confidence to tackle the wide variety of problems that confront the chemical engineer**

The emphasis throughout the course is on why things are done the way they are. The "how to" aspects of design are implemented only after their needs have been established by a critical evaluation of the various problems in process invention, process development, and ultimately, detailed process design. The spectrum of design tools, i.e., ball park estimates, preliminary design techniques, and detailed design procedures, is integrated with the various phases in a process plant project.

The rapidly changing technological and social climates demand that we produce generalists who have been schooled in the basic aspects of the design methodologies and who can learn fast and quickly bring themselves up to speed for a particular application. Obviously, it is not possible to teach all of the design and economic methods that practicing chemical engineers use, so a collection of procedures that will suffice for many situations is emphasized. The students are also trained to critically study the literature, including patents, so that they may uncover or develop new procedures and analogies which they can use with confidence in situations that are new to them.

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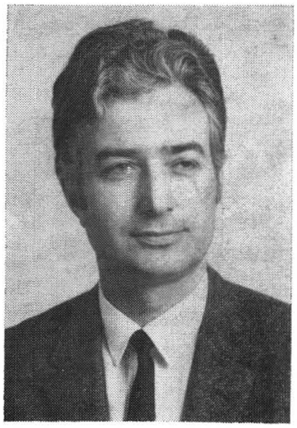

Paul Marnell is an associate professor in the Manhattan College chemical engineering department. He initiated and helped direct the coal-water fuel technology research at Brookhaven National Laboratory from 1980-83. Prior to joining Manhattan in 1976, he was Director of Environmental Projects for the U.S. operations of the Lurgi Company and also held engineering positions with the Stone and Webster and Foster Wheeler Corporations. He obtained his BChE from City College, his MS (nuclear engineering) from Union College, and an EngScD (mechanical engineering) from Columbia University in 1972.

The rationale for and some of the methods used to attain the course goals are discussed in the following.

> *"The Chemical plant is a dollar factory."*
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> —**William C. Reid** [3]

The recent recession and its disasterous effect on employment clearly illustrated the fact, which is often missed by students, that engineers provide services to companies to help them achieve the primary goal of an adequate profit. Thus, technical expertise combined with engineering economic analysis is the bedrock upon which engineering judgments are made.

Engineers create devices by applying the laws of nature and mathematics and using empiricism and intuition where needed. Analysis to provide basic knowledge is the province of the scientist or mathematician. Analysis to provide insight on the performance of a device is a valuable part of the design process and one which can reduce the cost of empiricism. However, often empiricism must be used to create things within a reasonable period of time. Thus, piping systems are designed on the basis of the empirical friction factor correlations for turbulent flow, and it will probably be many years before a truly fundamental relationship for turbulent pressure drop in pipelines will be achieved. Similar considerations hold for mass and heat transfer correlations and reaction rate expressions. Nevertheless, chemical plants have been built and will continue to be built by the judicious blending of analysis, intuition, and empiricism.

This brief essay is not the place to expand on the various aspects of engineering economic analysis that are considered in the course. However, two elements of critical importance are:

1. **Multiple alternatives are generally available to achieve a goal, and the engineer is constantly screening alternatives of increasing detail with tools of increasing accuracy. The observation is valid at all levels of decision making, from the selection of a project to fund to the choice of a vendor for, say, concrete reinforcing bars. Thus, several years ago the Mobil Oil Corporation felt that buying Montgomery Ward was an attractive venture to help maximize profits, and currently the United States Steel Corporation is shutting down more of its steel plants while increasing its real estate holdings.* Similarly, examples within the chemical process industry form a hierarchy which ranges from the general to the very specific. Which product should be made to achieve a desired result, and which reaction path should be used to produce it? Given the reaction path, which separation technologies would be best, and given that distillation might be desireable, should it be done in a plate or packed tower? What type of plate tower should be used, and who should the vendor be? Alternatives abound, from broad strategic questions to very specific hardware items, and usually one is more attractive than its competitors.**
2. **As with engineering analysis, the tools for economic analysis range from crude to sophisticated, and the choice represents a compromise between expediency and accuracy that yields a result which is acceptable for the circumstances.**

> *"Nevertheless, it would be a mistake to suppose that the present generation can afford to ignore the labours of its predecessors."*
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> —**Lord Rayleigh** [4]

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The first car built did not look like today's Ferrari. Similarly, many current chemical plants are much more complicated than their predecessors. Modern ethylene, ammonia, and sulfuric acid plants represent the evolution and refinement of their underlying processes. All too often, study of these highly integrated technologies can intimidate a student. It is essential to stress the fact that they represent thousands of man-years of engineering effort and decades of operating experience, and in no way, shape, or form were conceived, developed, and built this way on the first try. Engineers should recognize that technological progress usually represents an evolution of painstaking improvements built upon a singular revolutionary concept.

Engineers, like other creative people, design, analyze, redesign, build, and refine their artifacts. Hence, it is important to inculcate the philosophy of not reinventing the wheel. Learn from what has gone before. Minimize mistakes by learning from those of others. Understand the logic of the past to help guide the developments of the present and the future.

> *". . . the authors . . . . not include in their books anything they themselves do not understand."*
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> —**Linus Pauling** [5]

The vast majority of what a chemical engineer does is included in the categories of process development, process design, and process improvement. In these activities, analysis is the handmaiden of synthesis. How does the item that has been created perform? Can it be improved?

During the sixties and seventies the "handbook" engineer was criticized [6]. He is a person who presumably does not understand the basis of his system, and who can use solutions in books but cannot generate new ones for new situations.

In the eighties, the handbook engineer is being replaced by the "black box" engineer, i.e., one who is adept at filling out computer input forms, but who has little understanding of the underlying

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*While they are only noted here, the social and economic implications of these transactions, especially the latter, are explored in the course.

Despite the rigorous and initially abstract perspective, student reaction has been overwhelmingly favorable. Probably the primary reason for this is that we try very hard to stress the "why" of applied mathematics, so that the "how" of solving problems is seen to follow logically and naturally from an understandable conceptual framework. The major criticism of our approach might be that fewer specific techniques can be included because of the time devoted to the underlying theory. However, we strongly believe that this is no real shortcoming because the students are now equipped to learn a wider assortment of new techniques on their own because they have the background necessary to comprehend the basis of unfamiliar methods. And this, after all, is the objective of graduate education. □

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theory and its limitations and those of the numerical procedure utilized to reach a solution. The proliferation of engineering software houses is alarming. Are they becoming the de facto engineering companies of the future?

It appears that in the headlong rush to utilize the computer, the art of creating a reasonable and useful model of physical reality may be declining. The measure of the sophistication of a mathematical model is not what you include but, rather, what you leave out. However, the capability of computers to crunch complicated differential equations and systems of equations encourages overly complex models that can conceal the significant variables and their relationship.

Often, simple models and simple procedures are all that are required for the problem at hand. With the bewildering array of software being marketed and the significant use of computer design in industry, it is extremely important that the student appreciate the roles of the various levels of analysis in his work. Using a sledge hammer when a tack hammer would suffice is a cardinal sin which demonstrates a serious lack of judgment and/or knowledge. Students are encouraged to keep it as simple as possible, consistent with the results desired.

Concerning analysis itself, all too often the student is faced with papers and texts that present skimpy discussions of the physical aspects of the model, and pages and pages devoted to solving the resulting equations. They are both important, especially when the model is not correct.

A good example of a meager discussion about the physical basis of a model is the no slip boundary condition of fluid mechanics. Consult a modern text on fluid mechanics and it is probable that this boundary condition is stated with no discussion, as if it were a self-evident truth. Consider the student who has seen mercury flow in a glass thermometer; would he not question the validity of this statement? If Coulomb, Poisson, Navier, and Stokes and others of similar scientific stature debated this point during the 19th century [7], does it not deserve some textbook discussion so that the student can appreciate the turmoil that is often encountered in creating a good physical model?

In addition to the current information explosion problem, misinformation is also troublesome. For example, in one year, in just one journal, at least three authors [8, 9, 10] discussed the misapplication of Le Chatelier's Principle, while Pauling [5] describes some recent textbook errors he has detected.

To help the students develop confidence in their understanding of the literature and their creative and analytical abilities, they are required to rigorously justify the rationales for their designs, the bases for their design calculations, and the expected accuracies of their results.

If our students achieve these three primary goals, then I have no doubt that they will be able to design the bioengineering and materials processes of the future as well as the innovative petrochemical processes required to retain the vitality of the chemical process industries. □

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