COMPUTERIZED COST ENGINEERING IN THE PROCESS DESIGN COURSE

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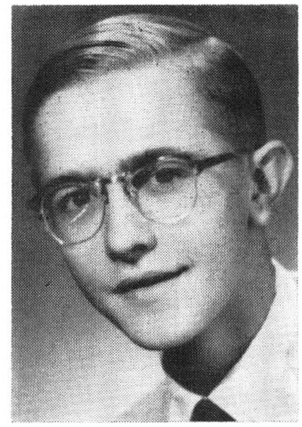

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PRIOR TO TAKING process design, the chemical engineering student has been exposed to a variety of concepts and techniques in topic-specific courses such as calculus, thermodynamics, process control, transfer and transport phenomena. In many of these courses the subject matter and examples have been directed towards process equipment and process operations. But seldom has the student critically examined a processing system as a whole or quantitatively defined and investigated the objectives of a process design.

The design course serves as the stage for a concerted examination of processing systems and their objectives by the detailed analysis and appropriate aggregation of their component parts. This is customarily achieved through a series of selected design problems supplemented with classroom presentation of required background information and suitable generalizations as illustrated by the examples.

This is by no means a simple task and makes the design course one of the most challenging courses not only for the student but the instructor as well. As a result, comprehensive tools which can serve to reduce the time required for tedious manual calculations are more than welcomed.

It is in this vein that the computer has become a welcome ally during the past decade. Experience in the use of the computer for detailed calculations, simulation of the operation of individual equipment items, and the sizing of individual equipment items is now a common denominator of students entering design. In addition, a wealth of auxiliary programs for individual equipment items is available with many being of a sufficiently general nature for use in a design course. Moreover, significant advances have been made towards easing the completion of the tedious mass and energy balances for processes as a whole as PACER, CHESS, FLOWTRAN, and similar programs amply illustrated.

One area has, however, been noticeably absent in the spectrum of computer-aided design techniques available for education-cost estimating. All too frequently, unexcelled sophistication is used in determining mass and energy balances and in sizing equipment; while cost estimating is left as a last minute effort relying on a list or graph of approximate values. Time and students' interests simply do not jive with the intricacies of manual cost estimating. As a result, short cuts are made in what is certainly one of the most significant aspects of design.

It is the objective of this paper to illustrate that this need not be the case. In particular, the potential role of a user-oriented cost estimating program, COST®* (*C*ost *O*riented *S*ystems *T*echnique), in the design course is examined. Experience has indicated that computerized estimating can minimize the drudgery of cost estimating while providing a more definitive approach to estimating than can be obtained from all but the

*COST is a service mark of Icarus Corp. registered with the U.S. Patent Office.

most detailed manual estimate. Computerized estimating is thus an ideal candidate for raising the overall integrity of the process design course through rapid, convenient, and consistent cost estimating; particularly if the system is user-oriented and is designed to assign reasonable default values to unspecified data.

BRIEF DESCRIPTION OF COST®

The COST® system was developed for use by industry for the rapid estimation of chemical processing plant investment requirements. Currently over 50 firms use the system for this purpose.

In structure, the system consists of equipment cost models[1] for over 250 separate items ranging from agitated open tanks to water cooling tower systems. Each cost model simulates the steps involved in fabrication and installing of the equipment as closely as is feasible to yield as applicable:

- **Fabrication material requirements,**
- **Fabrication labor requirements,**
- **Overhead and general and administrative expenses,**
- **Vendor or sub-contractors profit,**
- **Labor and material requirements for installation.**

Using a data base covering the rates of some 300 materials of construction, 38 trades crafts, the purchased and installed cost of each equipment model is obtained.

The system allows for three levels of input data: minimum design input; maximum design input; and maximum cost input. The user selects the appropriate category on the basis of data available to him and required by the system as outlined in the User's Manual.[2]

To provide but one example, consider the use of the system for estimating the cost of a heat exchanger.

A card is prepared that details the minimum design input and range of acceptable design information for several of the types of heat exchangers handled by the system. In each case, as well as for all other models, only one card is required to specify the minimum design input of one equipment item.

Arbitrarily choosing a U-tube exchanger and a fixed tube sheet exchanger for examples and specifying material of construction, heat transfer area, and tube pressure, the results are automatically obtained upon accessing the system. A number of additional design parameters can be reasonably chosen by the system and the purchased and installed cost as well as material and labor breakdown for installation can be provided for examination. Analogous user-oriented instructions and results can be incorporated for the cases of maximum design input and maximum cost input. Rapid review of the results is easily accomplished and the user can readily determine whether he should modify or further specify his design by comparing his data with the reasonable default values chosen by the system.

The system provides for the aggregation of equipment models into operational units and operational units into a total plant. Provisions are made for the specification of additional design data for each aggregation either by the user or by reasonable default values chosen by the system. The values chosen or computed by the system are clearly indicated for review and potential modification by the user.

TABLE 1
Table of Contents Illustrating Scope of COST® Report

TABLE OF CONTENTS

Estimated Capital Cost
Master Summary
Operational Unit Summary
Material Component Cost
Labor Component Cost
Labor Component Manhours
Field Labor Summary
Engineering Cost Breakdown
Construction Overhead
Maintenance and Operation Data
Equipment List By Unit Operation/Process Separation

The output of the COST® system is designed in the form of a concise report containing the items illustrated by the Table of Contents in Table 1 obtained for a small plant. Particularly

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convenient are the number of summary tables given in the report. Among the most useful for a process design course is the Master Summary detailing the items contributing to the total fixed capital cost of plant.

PROCESS DESIGN COURSE OUTLINE

THE TYPICAL DESIGN problem requires consideration of a number of basic elements including:

- **Process configuration**
- **Material and energy balances**
- **Equipment design and sizing**
- **Equipment costs**
- **Installed process cost**
- **Projected market and selling price**
- **Operating costs**
- **Estimation of profit.**

Most students enter design with an extensive background in completing mass and energy balances, preliminary equipment design, and sizing of key equipment parameters. Background in the other areas is generally minimal, although a co-current process economic course is frequently taken with design.

Faced with the scope of design and the students' backgrounds, the instructor seeks to satisfy four principal aims in his outline of the course:

- **Integrate and unify the student's process step-oriented background so as to be most applicable to the analysis of full scale systems**
- **Provide supplemental information on the elements of process cost, market, and profit estimation**
- **Provide a technically sound and usable summary of procedures for evaluating all the elements in a design, and**
- **Encourage the student to exercise his ingenuity in investigating alternate process configurations so as to maximize the profit of the overall operating system.**

These aims can be most satisfactorily attained by continual emphasis on the totality of the design and by a judicious combination of lecture, outside reading, design assignments, and in-class discussion. Table 2 presents a brief outline of such an approach for a 16 week-3 hour/week course.

The outline suggests a total of five design problems to be completed by each student or group.

The first problem is designed to mesh in a definite manner with the students' background. Lectures, in-class discussion, and outside readings and references are used to indicate the scope of design and supplement the background of the student in the areas of mass and energy balances and preliminary equipment sizing. Emphasis is also given to sources of physical property data and alternate design methods.

TABLE 2
Process Design Course Outline
(16 weeks, 3 hr/week)

Week	Item
1	Lecture: Elements of a design, role of students' background; Sources of additional physical property data; Sources of additional equipment design models.
	In-Class Discussion: Review of a completed design report; Review of material for design problem #1.
	Assignment: Design Problem #1 (Formulation) Mass and energy balances; Preliminary equipment sizing.
	Typical Outside Reading and References:
	TEXT
	Peters and Timmerhaus, Plant Design and Economics for Chemical Engineers Ch. 1, 2, 3, and 12
	PHYSICAL PROPERTIES
	Perry's Handbook, Hydrocarbon Processing; Reid and Sherwood, Properties of Gases and Liquids; Smith and Van Ness, Introduction to Chemical Engineering Thermodynamics; International Critical Tables
	EQUIPMENT DESIGN
	Peters and Timmerhaus, Ch. 13, 14, and 15; McAdams, Heat Transmission; Treybal, Mass Transfer Operations; B. D. Smith, Design of Equilibrium Stage Processes; J. M. Smith, Chemical Engineering Kinetics; Bennett and Myers, Momentum, Heat, and Mass Transfer
2	In-Class Discussion: Review of Problem Areas Encountered in Design Problem #1
	Lecture: Supplemental as required Discussion of Process Alternatives
	Assignment: Design Problem #1 Solution and Preparation of Report
	Outside Reading and References: Supplemental as required
3-4	Lecture: Elements of Process Economics Equipment Costs (Manual Estimation); Plant Costs (Manual Estimation); Profit Projection
	Assignment: Design Problem #2 Manual estimation of plant costs and profit
	In-Class Discussion: Review of Design Problem #1; Review of Progress and Difficulties in Design Problem #2
	Outside Reading and References:

The design course serves as the stage for a concerted examination of processing systems and their objectives by the detailed analysis and appropriate aggregation of their component parts.

TEXT

Peters and Timmerhaus, Ch. 4 to 11

REFERENCES

Happel, Chemical Process Economics; Shreve, Chemical Process Industries

5-6 Lecture: Computerized Cost Estimation Structure of Program Use of COST®
Assignment: Design Problem #3 Estimation of Profit using COST® as a tool
In-Class Discussion: Review of a completed COST® estimate; Practice session of use of Program; Review of Design Problem #2; Analysis of Design Problem #3
Outside Reading and References: COST® System Users Manual

7-12 Assignment: Design Problem #4 Comprehensive Design
Lecture, In-Class Discussion, Outside Reading and References: Chosen to suit selected problem

13-16 Assignment: Design Problem #5 AIChE Student Content Problem
Lectures, In-Class Discussion, Outside Reading, and References: Supplemental information not conflicting with rules established by AIChE for the Student Contest.

The second design problem emphasizes the manual estimation of plant costs and profit. Primary emphasis is given to the elements which collectively define these items.

The third design problem emphasizes the estimation of equipment costs and total fixed capital costs. The structure of the system is discussed and the use of the system is taught in class during a three hour practice session. The role that the program can play in the development of a total design is emphasized.

The fourth design problem is a comprehensive design problem covering all important aspects. A high degree of interaction is maintained, group solutions are encouraged, and in-class review and constructive criticism are continual.

The fifth design problem is a comprehensive design completed on an individual basis. The AIChE Student Contest Problem, completed by the individual under the rules established for the contest, is an excellent example of the class of problem recommended. Other course material may be devoted to reviews of selected design advances which do not conflict with the individuality desired in this final design problem.

COMPUTERIZED COST ENGINEERING

As IMPLIED BY the course outline given previously, a computerized cost estimating system such as COST® can be used to reduce the drudgery of cost estimating in the design course and permit additional emphasis to be placed on the design aspect itself. The estimating system can be designed so as to provide numerous advantages:

- **The estimates are quite definite, are concise, and are consistent.**
- **The input data is easy to prepare, requiring only certain critical size parameters to access the system.**
- **A comprehensive set of reasonable default values are chosen for data not supplied and concise output details the assumptions made.**
- **The output is concisely prepared and highly user-oriented.**
- **The detail of the output encourages the student to investigate labor/material relationships, purchased versus installed cost, and the effect of design parameters on cost and subsequently profit.**

In every respect, this approach has been found to offer to the student a more comprehensive cost estimate than he could ever be expected to prepare and to offer it at only a fraction of the time he would ordinarily have devoted to less definitive techniques.□

REFERENCES

1. H. G. Blecker, Simulation of Chemical Processing Plant Investment by Computer, Presented at 1972 SSC.
2. H. G. Blecker and T. M. Nichols, *COST® System Users Manual*, ICARUS Corp., Second Edition, Jan. 1973.

ACKNOWLEDGEMENT

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