Manual of Economic Analysis of Chemical Processes

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Feasibility Studies in Refinery and Petrochemical Processes

Institut Français du Pétrole

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McGraw-Hill Book Company

New York St. Louis San Francisco Auckland Bogotá Hamburg Johannesburg London Madrid Montreal New Delhi Panama Paris São Paulo Singapore Sydney Tokyo Toronto Mexico

Library of Congress Cataloging in Publication Data

Main entry under title:

Manual of economic analysis of chemical processes.

Translation of Manuel d'évaluation économique des procédés.

Bibliography: p.

Includes index.

1. Petroleum—Refining. 2. Petroleum chemicals.

I. Chauvel, Alain. II. Rueil-Malmaison, France.

Institut français du pétrole.

TP690.M2913 338.4'566'550944 79-25247

ISBN 0-07-031745-3

Manuel D'évaluation Économique Des Procédés

Avant-projets en raffinage et pétrochimie

(Collection Pratique du Pétrole N° 6)

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1234567890 KPKP 8987654321

The editors for this book were Jeremy Robinson, Robert L. Davidson, and Susan Thomas, the designer was Mark E. Safran, and the production supervisor was Paul A. Malchow. It was set in Baskerville by Haddon Craftsmen, Inc.

Printed and bound by The Kingsport Press.

Preface

There are times when bringing together known information can result in a synergistic association that affords unprecedented effectiveness for that information. The authors have achieved such a synergism with this book.

Profitability calculations, market research, chemical engineering cost estimating, and shortcut process design methods, which are all discussed here, are well-known skills. However, anyone who has ever faced a feasibility study for a refining, a petrochemical, or a chemical plant will have discovered that finding reliable answers is something like following a will-o'-the-wisp. Profitability depends on revenues, operating costs, and investment, which in turn depend on market conditions, manufacturing efficiencies, and cost estimates, which in turn depend on the process design, so that the best efforts are frequently frustrated by one uncertain link in a long chain of calculations.

This single book spans that entire gamut of information, from discounting rate to heat-transfer coefficient, while maintaining perspective on the relative error potential so that an inordinate amount of time need not be invested in one aspect of a project only to have that time wasted by uncertainty introduced somewhere else. Perhaps this perspective is best illustrated by a paraphrase of the discussion with which the authors introduce methods for process design estimating in Section 43.3.3.:

> Even when a detailed estimate is accompanied by information on sizes for a unit, it is best to recalculate the sizes according to a consistent estimating method,

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since use of a consistent method puts everything into the same framework for making comparisons.

An extrapolated estimate based on a plant known in detail will differ from an estimate based on the consistent sizing method, and the extrapolated estimate should be more reliable. If the difference is large, an error or false information is indicated. If the difference is not too great and the basic data are reliable, the difference between the two should be converted into coefficients that can be applied to the consistent method for future estimates.

One primary source of uncertainty in feasibility studies has been the accuracy of the process design on which the estimates were based. In the past, we have carried a personal pocket notebook from which we would extract critical numbers and quick-design rules for estimating equipment variations at a proposal meeting. Many design engineers have carried such a book. However, there are very few, if any, companies that have lifted the numbers and rules of those personal notebooks to the level of formalized methods that could be tested against known accurate values and thus tuned and updated. Detailed design procedures have been thus formalized, but not estimating procedures. In this book, the authors have given us a collection of such formalized methods in their Appendixes.

Some readers may wonder, perhaps cynically, how a company happens to publish such information rather than to keep it proprietary. If so, those readers should look further into Institut Français du Pétrole (IFP). IFP was formed near the end of World War II to help close the technological gap by which France lagged behind such countries as the United States. A subsidy was established in the form of a small fraction of the French national tax on gasoline. As the sales of gasoline have grown, so has the subsidy. Also, much of IFP's research and many of its enterprises have literally paid off, so that some 30% of its present income is accounted for by its achievements, specifically licensing, royalties, and research contracts. This holds true even though, being a not-for-profit institution, IFP cannot have conventional commercial activities. Value analysis and industrialization of some of its results have thus resulted in the creation and spin-off of newly formed companies—Technip, Procatalyse, Franlab, Coflexip, etc. Result: the IFP group is one of the world's more important research-based groups.

In addition to its obligation to perform research and industrial development, IFP also has a statutory mandate to disseminate information through adequate means, such as by maintaining an information and documentation center and by promoting the transfer of knowledge and know-how through publications. An IFP subsidiary, Société des Editions Technip, publishes books, periodicals, and technical papers.

Perhaps the first of its books to attract widespread attention outside of France was *L'industrie pétrochimique et ses possibilités d'implantation dans les pays en voie de développement,* which was presented as a paper at the first United Nations conference on agricultural chemicals in Teheran in 1964 and published afterwards simultaneously in French and English (1966). Preprints of the English version were snatched up by attendees of the conference. One senior engineer with a major U.S. research company was overheard to remark, "A consultant could make a living out of that book." Continuing this publishing policy, another book, *Procédés de pétrochimie,* was published in 1971. However this edition, which is in French, has failed to find its way to many American users.

We have tried to avert a similar fate for the present book by translating it. However, we are inclined to think that, largely because of IFP, American process engineers would do well to make French a second language—or at least to gain a reading acquaintance with French, as they used to do with German. Otherwise they are apt to miss not only synergistic combinations of already available material but also information about new technology that is only now being developed.

We publicly want to thank René E. G. Smith of Mobil Research and Development Corporation for taking precious leisure time from a North Sea drilling platform to read and criticize parts of our translation. Also, we want to caution the reader that this is a liberal translation, in which we have tried to capture the authors' intent rather than their precise expression. In doing this and in converting francs to dollars for the user's convenience, we may inadvertently have let some minor errors slip by us. We would be grateful to the reader for bringing them to our attention.

Ryle Miller
Ethel B. Miller

Introduction

A new manufacturing plant can be put into perspective quantitatively by a technical and economic study. If the plant involves new technology, this study should involve not only the engineering and operating companies responsible for designing the commercial plant, constructing it, and putting it into operation but also the organization that invents and develops the technology.

Any technical and economic study more accurately reveals the potentials for a new project—whether new plant, new process, or new product—when the data, the basic assumptions, and the calculated results are thoroughly understood. The evaluation should cover technical correlations, operating feasibility for purchased equipment, properties of the manufactured product, and the financial requirements for purchasing and maintaining the equipment. Also, the needs of the industrial environment are constantly changing, and the changes should be continually incorporated into new studies that thus reexamine earlier studies and improve the accuracy of the forecasts.

The evaluation of a manufacturing project must begin by examining the economic context in which the plant will exist throughout its lifetime; e.g., it must forecast the availability of feedstocks and utilities as well as the market for the product. Next, the study must define the technology—the types and sizes of required equipment, its prices, its efficiencies, its energy consumptions, and the work force needed for its operation. The effort placed in this technical study, which is normally made by specialized departments, varies according to the state of the development of the project. A limit is reached in "control estimates" made by engineering and construction contractors from engineering drawings developed as part of a contract between the contractor and the client.

In the last stage of evaluation, the economic forecasts are combined with the technical estimates according to selected operating criteria in order to establish an optimum profitability, which guides the final decision.

In this book, when conventional methods for making economic evaluations are assembled, the authors have tried to point out the relative importance of the different aspects of the calculations, whether they relate more or less directly to the technical nature of the process, to the properties of the product in question, or to the financial means and management methods of the company under consideration.

Accordingly, the first part of the book offers a description of the principles of economic calculations, including market analysis, procedures of accounting and economic evaluation, and cost estimation, while in the second part these principles are applied to both industrial and research projects. In addition, the appendixes present a group of methods for selecting, sizing, and pricing equipment for purposes of establishing cost estimates.

All the calculations presented here were made in French francs pegged to a common base, but have been converted to dollars where necessary for the reader's convenience (conversions are given in Fig. 4.6). All of the monetary transactions are in terms of the year when the study was made, taken as the year of reference. One cannot estimate the effects of monetary depreciation over a long period. The type of calculation using fluctuating francs, in which the cash flow is corrected for the value of currency at the year in question, would be too uncertain to be of any use in the evaluation of a project.

Metric units of measurement are used in this manuscript, along with the appropriate calculation constants in the equations and calculation forms (see Appendix 13, p. 421),* so that American analysts and engineers might use these for a general reference for calculations in metric units rather than U.S. customary units. Accordingly, the metric ton of 1,000 kg (2,200 lb) is intended wherever the word ton or the abbreviation t is used.

*We have not translated the term *cheval-vapeur* (cv) into its English equivalent, *horsepower*, because a cheval is actually 0.986 horsepower; however, the terms are frequently interchanged when an approximation is acceptable.

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Part 1

Principles of Economic Evaluation

Chapter 1

Market Research

Before undertaking the economic evaluation of a manufacturing project, it is necessary to have a certain amount of information about the marketing prospects of the product to be manufactured. In order to make a product, it is necessary first to buy the raw materials and chemicals and then to realize a profit in selling the product. It is therefore indispensable, on the one hand, to know that the raw materials are available and can be bought for a price and, on the other hand, to estimate the ability of a user to pay for the product. Consequently, availability-to-price relationships of both raw materials and products should be constantly kept in mind.

1.1 AVAILABILITY OF RAW MATERIALS

For raw materials, quantity-price relationships are illustrated by an example in which several parameters govern. Suppose that a company wants to build in France a plant that would use butene-2 as feedstock. There are four ways of procuring butene-2:

1. Purchase from an existing plant.
2. Separation from the C_4 distillate fraction resulting from catalytic cracking.

3. Separation from the C_4 distillate fraction resulting from steam pyrolysis for the production of ethylene and propylene.
4. Catalytic dehydrogenation of normal butane.

The first method assumes obtaining surplus quantities from a manufacturer whose price is fixed by his principal use for butene-2. The following two methods involve the by-products of existing plants, and the last implies construction of a new plant. Each of these different methods thus imposes its own restrictions.

If it is decided to buy the product, the cost of shipping is added to its price at the manufacturing plant. If the C_4 fractions are used, the unit to separate the butene-2 will have to be connected in some manner to the catalytic cracking or steam pyrolysis plants. If catalytic dehydrogenation is used, the supply of normal butane (refinery or natural gas field) will be of concern.

In the event that any one of these sources alone is not enough, some combination of two or more sources will be necessary. Consequently, it will be necessary to take into account the particular limitations of each source, as reflected in a specific cost.

Added to this problem of supply is the fact that C_4 distillate fractions from catalytic cracking and steam pyrolysis contain concentrations of butene-2 that vary from one installation to another. As shown in Table 1.1, the percentage can range from 10 to 22%. It follows that the cost of separation will be different.

To help relate such disparate conditions, the amounts of available material can be classed as a function of price at the plant, starting with those available at the lowest price. Thus, in the case of butene-2, the following case might typify a given location:

Quantity available, Q_1 = 20,000 tons/yr, at price P_1 = 560 fr/ton
Quantity available, Q_2 = 20,000 tons/yr, at price P_2 = 680 fr/ton
Quantity available, Q_3 = 10,000 tons/yr, at price P_3 = 720 fr/ton
Quantity available, Q_4 = 40,000 tons/yr, at price P_4 = 1,000 fr/ton

The price for each of these quantities includes

Cost of the initial raw material (C_4 fraction or n-butane)
Cost of separation and purification
Cost of transporting the product from place of production to point of use

Using these prices, a curve of price versus quantity can be plotted (Fig. 1.1) to determine the average price P_m:

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