

# REFINING PROCESSES HANDBOOK

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To My Wife

**RITA**

# Preface

Petroleum refineries have grown rapidly in complexity and so, too, the refinery operations. However, the published information on the refinery processes and operation is scant and mostly confined to licensor's data, which reveal little beyond what is absolutely necessary for process sale, even when these processes have been in operation for a number of years and in many refineries. This book is an overview of the processes and operations concerned with refining of crude oil into products. The streams coming from processing units are not finished products; they must be blended to yield finished products. The refining operations presented here are those concerned with blending products in an optimum manner with the twin objectives of meeting product demand and maximizing refinery profit. The objective here is to provide basic instructions in refinery practices employing the methods and language of the industry.

Presented in the book are refinery processes, such as crude desalting and atmospheric and vacuum distillation; gasoline manufacturing processes, such as catalytic reforming, catalytic cracking, alkylation, and isomerization; hydrodesulfurization processes for naphtha, kerosene, diesel, and reduced crude; conversion processes such as distillate and resid hydrocracking; resid conversion processes such as delayed coking, visbreaking, solvent deasphalting, and bitumen manufacture; pollution control processes such as sulfur manufacture, sulfur plant tail gas treatment, and stack gas desulfurization. Also presented here are operations performed in refinery off-site facilities, such as product storage and blending, refinery steam and fuel systems, refinery boiler feedwater treatment, and wastewater treatment.

The process details include process flowsheets, process description, chemistry involved, detailed operating conditions, process yields and utilities. Among the refinery operations and practices presented are product blending, refinery inventory forecasts, spreadsheet and LP modeling of refineries, and methods for pricing crude oil, petroleum products, and intermediate stocks.

It must be recognized, however, that many variants of the same process are found in the industry, and the operating conditions can be quite

diverse, depending on the type of catalyst used and feedstock processed. We have insufficient space for bibliographic comparison and evaluations of identical basic processes from different licensors. The data presented here represent typical industrial operations practiced in refineries today. Where no mention is made of recent contributions to the literature, no slight is intended. The few references quoted are those where an industrial practice is known to have originated.

Another important subject presented in this volume is concerned with the operation of joint ownership refineries. Building a grassroots refinery requires large capital investment. It is feasible for two companies to own and operate a refinery as if it were build of two independent refineries. Each company may operate its share of the refinery virtually independent of other; that is, each company may bring in its own feedstock and produce product slate independent of the other with no need to build separate product storage facilities for the two companies.

The basic rules of operations of joint ownership refineries is discussed in this book. A typical pro-forma processing agreement between the participants is presented in the Appendix of this book. This covers detailed procedures for refinery production planning, product allocation, inventory management, and allocation of refinery operating cost to participants. Product allocation is the split of total refinery production among the participants on the basis of the feedstock processed by each. Keeping in view that the participants do not process identical feedstocks or produce identical product grades, product allocation for establishing the ownership of stock, must be done at the end of every month. This is a complex exercise and a detailed procedure for this is presented in a separate chapter.

The methods for preparing inventory forecasts and tracking refinery operating expenses in a joint ownership refinery scenario are presented as well. Even though such practices—product allocation, inventory and ullage allocation, operating costs allocation—exist in refining industry, there is no known literature examining them.

## **CHAPTER BREAKDOWN**

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Chapter 1 covers atmospheric and vacuum distillation and crude desalting. Chapter 2 covers the refinery hydrotreating processes: naphtha hydrotreating, kerosene hydrotreating, gas oil hydrodesulfurization and atmospheric resid desulfurization. Chapter 3 presents the distillate hydrocracking, mild hydrocracking, and resid hydrocracking processes.

Chapter 4 covers gasoline manufacturing processes: catalytic reforming, alkylation, isomerization, catalytic cracking, and MTBE manufacture. Chapter 5 looks at the manufacture of hydrogen for hydrotreating and hydrocracking process and its recovery from some of the hydrogen-bearing streams coming from these units. Chapter 6 presents refinery residuum processing units, on delayed coking, visbreaking, solvent deasphalting, and bitumen blowing.

Chapter 7 examines treating processes for catalytic cracker light and heavy naphthas and kerosene-type jet fuels. Chapter 8 presents sulfur manufacture and pollution control processes, such as sulfur plant, sulfur tail gas treatment, and stack gas desulfurization.

Chapter 9 examines the refinery water system. This includes treatment of cooling and boiler feedwater, the refinery's oily wastewater, and stripping the refinery's sour water.

Chapter 10 looks at the off-site and utility systems of a refinery. The topics include the tankage requirements for product export and product blending; batch and in-line product blending systems; refinery flare system, including principals of flare system design; the refinery steam system; and liquid and gaseous fuel systems.

Chapter 11 describes the procedures for product blending. Chapter 12 presents the procedure for preparing a refinery material balance using a spreadsheet program. Chapter 13 describes the general principles of building a refinery LP model. Chapter 14 discusses the mechanism of pricing petroleum products, including intermediate streams and products. Chapter 15 describes the concept of a definitive operating plan for the refinery during an operating period.

Chapter 16 shows the methodology behind product allocation in joint-ownership refineries. Chapter 17 explains methods of estimating available tankage capacity as a part of an inventory forecast system in both single- and joint-ownership refineries. Chapter 18 explains how these inventory forecasts are prepared for planning shipment of product in both single-ownership and joint-ownership refineries. Chapter 19 presents procedures for estimating the operating costs of the refinery and, in case of joint-ownership refineries, the allocation of refinery operating costs to the participants.

An appendix explains the organizational structure of joint-ownership refineries and presents an example of a processing agreement among the participants required for operating such a refinery.

We hope this book will serve as a useful tool for both practicing engineers concerned with refinery operational planning as well as for academics.