Materials and Equipment

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PETROLEUM REFINING

4 MATERIALS AND EQUIPMENT

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FROM THE SAME PUBLISHER

Pretoleum Refining

1. Crude Oil. Petroleum Products. Process Flowsheets
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2. Separation Processes
   J. P. WAUQUIER, Ed.
3. Conversion Processes (to be published in 2000)
   P. LEPRINCE, Ed.
5. Refinery Operations and Management (to be published in 2001)
   J. P. FAVENNEC, Ed.

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Introducing the Collection

"PETROLEUM REFINING"

The collection **"Petroleum Refining"** includes five volumes covering the following aspects of the technology involved in the oil refining industry:

- Crude oil. Petroleum products. Process flowsheets.
- Separation processes.
- Conversion processes.
- Materials and equipment.
- Refinery operation and management.

The collection is designed for the engineers and technicians who will be operating the refineries of the twenty-first century. Two types of problems will have to be solved at the same time: increasingly severe product specifications and, even more importantly, protecting our air and water from pollution. It will provide operational people in the field with an understanding of the fundamentals of oil refining as well as an overview of the specific technology they will be using.

The collection was written by a group of eminent specialists whose names will be found at the beginning of each volume. We would like to thank them all for being so dynamic and enthusiastic in their work on this project.

Michel VERWAERDE
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Foreword

Volume 4 in the collection "Petroleum Refining" is devoted to the main equipment found in a refinery or a petrochemical complex. As such, it is a logical sequel to the first three volumes that have already been published.

Distillation operations, which are crucial in oil refining, obviously rely mainly on separation techniques. However, they also require the use of heat transfer equipment which provides the heat energy needed for all these separations. Moreover, reaction techniques are central to all the refining processes which convert molecular species in crude oil so as to obtain products with constantly adapted and improved properties to meet market demand.

One of the features of the oil industry is that it implements liquids and gases almost exclusively. In order to carry these phases at every stage of their proçessing, specific equipment such as pumps, compressors, turbines and ejectors is required. In addition, a highly complex piping system makes the connections among the different pieces of equipment, in order to constitute the end products by blending and dispatch them to consumption nodes.

A refinery is thus a very complex technical facility and its profitability can be ensured only by strict and constant control of all the component parts, to guarantee product quality, operational safety and environmental protection. These aims are attained by measurement, control and supervision techniques, which are now of vital importance in all petroleum and petrochemical complexes.

Since there are numerous and varied pieces of equipment involved, they have been grouped in type categories having similar functions. In this connection, the classification of chemical engineering unit operations has been used and the following will be examined successively:

1. Equipment for separating the components of a mixture, either by mass transfer between phases (gas-liquid or liquid-liquid) or by physical separation

of multiphase systems such as gas-liquid, liquid-liquid, gas-solid and liquid-solid mixtures.

2. Equipment for achieving heat transfers, such as furnaces and heat exchangers.

3. Equipment called reactors where chemical reactions take place.

4. Equipment used to accomplish the mechanical operations of fluid transport (pumps, compressors) or mixing.

5. Equipment in charge of controlling all the above-mentioned operations by measuring physical or physicochemical variables with sensors and using the measurements in control and management systems. These measurements allow operations to be optimized as illustrated by the last chapter, devoted to energy optimization in the units.

Due to the diversity of all this equipment, it was necessary to call on authors from a variety of sectors (engineering companies, construction, operations, process engineering), each having a specific approach. As a result, the chapters in this volume were not drafted according to a uniform blueprint, but present the diversified viewpoints of the engineers in the profession instead.

Nomenclature

Because of the diversity of equipment and systems described in this volume, it is difficult to observe a single nomenclature. Nevertheless, to the extent possible an attempt is made to comply with the nomenclature recommendations given in the previous volumes. Any deviation from this rule is the result of a deliberate choice, either to conform to the usage in the profession or to avoid any ambiguity in the meaning of symbols. In all cases each use of a new symbol in a chapter is associated with a definition. A definition may sometimes not be systematically repeated for classical variables in order to save space. In this instance the reader will find the definition of the relevant symbol in the list below.

The same holds true for units. The SI system is generally employed except when the specifications in use in the profession involve particular units, usually from the US/British systems.

In addition to the basic units in the SI system, i.e. m, kg, s, mol and K, the multiples and sub-multiples of these basic units and derived or compound units are also used.

Symbols

A	interfacial area per unit of volume	m^2/m^3
C_P	molar heat capacity at constant pressure	J/(mol·K)
C	with a number *n*: hydrocarbon whose number of carbon atoms is equal to *n*	
C	concentration	$kmol/m^3$
d, D	diameter	m
$\mathcal{D}$	diffusion coefficient	m^2/s

E	overall efficiency in number of stages	—
E_m	Murphree efficiency	—
G	gas superficial mass flow rate	kg/m^2·s
h, H	height	m
k	mass transfer coefficient	m/s
K	overall mass transfer coefficient	m/s
l, L	width, length	m
L	liquid superficial mass flow rate	kg/m^2·s
m	weight	kg
M	molecular weight	kg/kmol
P	pressure	Pa
Q	volume flow rate	m^3/s
r	radius	m
R	ideal gas constant	= 8,31 J/(mol·K)
Re	Reynolds number (= $ud\rho/\mu$)	—
S	surface or cross-sectional area	m^2
Sc	Schmidt number (= $\mu/\rho\cdot\mathscr{D}$)	—
Sh	Sherwood number (= $k\cdot d/\mathscr{D}$)	—
t	time	s
T	absolute temperature	K
u, U	velocity	m/s
V	volume	m^3
V	superficial velocity (= Q/S)	m/s
We	Weber number (= $\rho du^2/\sigma$)	—
x	mole fraction (in the liquid phase)	—
y	mole fraction (in the vapor phase)	—
z	mole fraction	—
Z	compressibility factor	—

Greek letters

α, ω	angle	(rad ou °)
ε	volume void fraction	—
ε_i	volume fraction occupied by phase i	—
θ	contact or residence time	s
λ	thermal conductivity	W/(m·K)
μ	dynamic (or absolute) viscosity	Pa·s
ν	kinematic viscosity	m^2/s
ρ	density	kg/m^3
σ	interfacial tension	N/m

Subscripts and superscripts

A, B, i	relative to compound A, B, i	1, 2	relative to phase 1 or 2
P	at constant pressure	G, L, V, i	relative to the gas, liquid, vapor or i phase
p	relative to the particle (grain or drop)		

Functional symbols

d	"derivative" operator	exp	exponential
∂	"partial differential" operator	log	base 10 logarithm
Σ	"sum" operator	ln	Napierian logarithm
Δ	"difference" operator	$\approx$	approximately equal to
$\int$	"integral" operator	$\neq$	different from

Abbreviations and acronyms

API	American Petroleum Institute	HTU	Height of a Transfer Unit
ASTM	American Society for Testing and Materials	IFP	Institut français du pétrole
ASVAHL	Association pour la valorisation des huiles lourdes (Association for upgrading heavy oils)	LPG	Liquefied Petroleum Gases
FCC	Fluid Catalytic Cracking	MTBE	Methyltertiobutylether
HDS	Hydrodesulfurization	RDC	Rotating Disc Contactor
HETP	Height Equivalent to a Theoretical Plate	VR	Vacuum residue
HF	Hydrofluoric acid	TEMA	Tubular Exchanger Manufacturers Association
		UOP	Union Oil Products
		VGO	Vacuum Gas Oil

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