Conversion Processes

Institut Français du Pétrole Publications

PETROLEUM REFINING

3 CONVERSION PROCESSES

Edited by
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Institut Français du Pétrole

ranslated from the French
y Barbara Brown Balvet

2001

Editions TECHNIP 27 rue Ginoux, 75737 PARIS Cedex 15, FRANCE

Translation of
Le raffinage du pétrole.
Tome 3. Procédés de transformation.
P. Leprince

ISBN 2-7108-0779-3
Series ISBN 2-7108-0686-X

PETROLEUM REFINING

3 CONVERSION PROCESSES

FROM THE SAME PUBLISHER

Pretoleum Refining

1. Crude Oil. Petroleum Products. Process Flowsheets
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2. Separation Processes
   J. P. WAUQUIER, Ed.
4. Materials and Equipment
   P. TRAMBOUZE, Ed.
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Nature, to be commanded,
must be obeyed

Francis Bacon

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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
Institut Français du Pétrole

Foreword

Pierre Leprince

The third volume of the "Petroleum Refining" collection deals with conversion processes for petroleum fractions as produced by the separation operations that are covered in the second volume. Conversion processes have three objectives:

- improve product quality so as to meet the requirements of the corresponding end use (e.g. heat engines, burners);
- convert crude oil fractions that can not directly find an outlet into products better adapted to the market;
- protect the natural environment during product manufacturing and utilization.

Following an introduction which shows the growing importance of conversion processes in the refining industry, this volume presents the fundamentals of the chemical mechanisms at the basis of the processes. These disciplines are thermodynamics, chemical kinetics, reactor calculation and industrial catalysts.

Then the major refining conversion processes are discussed. The first group of processes is designed to improve the quality of light fractions: catalytic reforming and isomerization. The second group involves the conversion of distillates: catalytic cracking and hydrocracking, along with their related units: alkylation, oligomerization and etherification. The third includes processes for converting residues: visbreaking, coking and hydroconversion with its related hydrogen production unit. Lastly, processes which deal with reducing air and water pollution: sweetening of white products and hydrotreating to eliminate sulfur and nitrogen compounds, sour gas treatments to remove hydrogen sulfide, desulfurization of heavy fuel oil combustion off gases and treatment of process water.

In each of the chapters mentioned above, the authors have endeavoured to present both the basics needed to understand the chemical reactions put into

practice, as well as the technical and economic data required to gauge the impact of the processes on refinery operation.

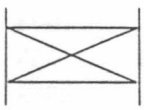
Obviously, not all process variations can be presented in this volume. The sole objective here is to give the reader a grasp of the complex world of oil product conversion techniques and their role in the industry. Then, at a later date, specialized literature can be approached to get a more thorough understanding of refining.

Nomenclature

C_P	isobaric molar or mass specific heat	J/(mol·K), J/(kg·K)
d_4^{15}	specific gravity at 15°C	
E	activation energy	J/mol
F	Helmholtz molar free energy	J/mol
	molar flow rate	mol/s
G	Gibbs molar free energy	J/mol
H	molar enthalpy	J/mol
P	pressure	bar, (mmHg)
R	ideal gas constant	0.083·m^3·bar/(K·kmol)
		8.31 J/(mol·K)
S	molar entropy	J/(mol·K)
V_t	blending viscosity index at t°C	–
ν_t	kinematic viscosity at t°C	m^2/s

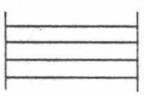
Graphic symbols

Even though French standards of graphic symbols for equipment {E 04-202 (1 to 5) and E 04-203 (1 to 5)} are complete and updated, they do not correspond to usage in the oil industry professions. We have adopted here a code that is generally accepted in the oil industry, simplifying it however in order to adapt it to the needs of this volume. We have used the ANSI/ISA S5.1 standard for control and monitoring instruments which seems to be unanimously accepted.



Packing bed

Demisters



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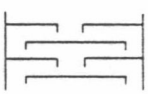
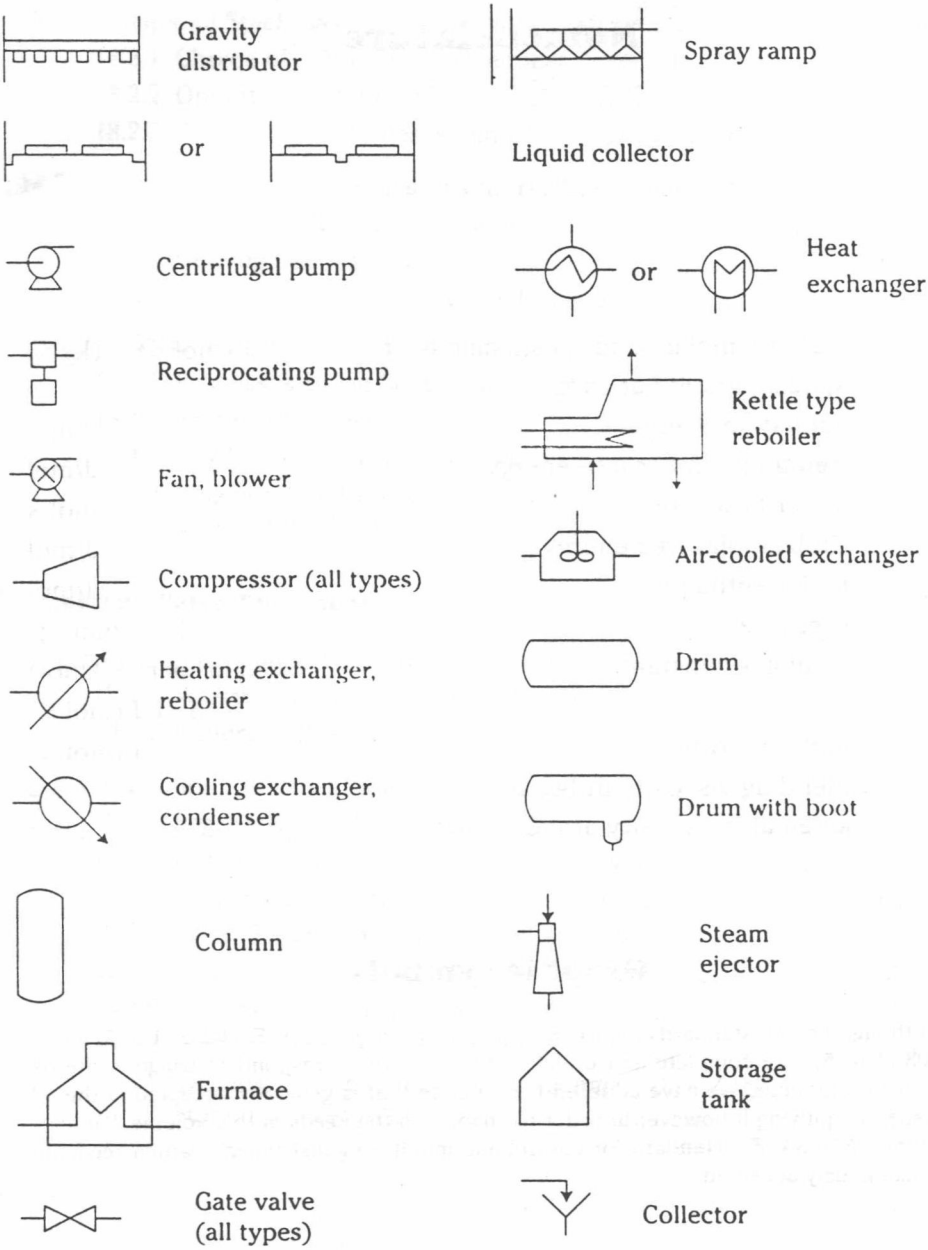


Tray zone


Gravity distributor
Spray ramp
or
Liquid collector
Centrifugal pump
or
Heat exchanger
Reciprocating pump
Kettle type reboiler
Fan, blower
Air-cooled exchanger
Compressor (all types)
Drum
Heating exchanger, reboiler
Cooling exchanger, condenser
Drum with boot
Column
Steam ejector
Furnace
Storage tank
Gate valve (all types)
Collector

Abbreviations and Acronyms

ABD	Average bulk density
ACS	Average crushing strength
ATR	Atmospheric residue
BOD	Biological oxygen demand
BOD_5	Biological oxygen demand over 5 days
CCR	Conradson carbon residue
CCR	Continuous catalytic reformer
COD	Chemical oxygen demand
CONV	Conversion
CSTR	Continuous stirred tank reactor
CTE	Coefficient of thermal expansion
DAO	Deasphalted oil
DBT	Dibenzothiophene
DENOX	Elimination of NO_x
DESOX	Elimination of SO_x
DIPA	Diisopropyl amine
DIPE	Diisopropyl ether
DME	Dimethyl ether
DMF	Dimethyl formamide
EFAL	Alumina species
EP	End point
ETBE	Ethyl tert-butyl ether
FCC	Fluid catalytic cracking
FO	Fuel oil
HCO	Heavy cycle oil
HDA C_7	C_7 hydrodeasphalting
HDC	Hydrocracking
HDCC	Conradson carbon hydroreduction
HDM	Hydrodemetallization
HDN	Hydrodenitrogenation
HDO	Hydrodeoxygenation
HDS	Hydrodesulfurization
HDT	Hydrotreating
HGI	Hardgrove grindability index
HS	High sulfur
HYD	Hydrogenation
IBP	Initial boiling point
IPA	Isopropyl alcohol
KTN	Kjeldahl total nitrogen
LBG	Low Btu gas
LCO	Light cycle oil
LHSV	Liquid hourly space velocity
LHV	Lower heating value
LP	Low pressure
LPG	Liquefied petroleum gas
LS	Low sulfur
LSFO	Low sulfur fuel oil
MAT	Microactivity test
MDEA	Methyl diethanol amine
MEA	Methyl ethanol amine
MEK	Methyl ethyl ketone
MIBK	Methyl isobutyl ketone
MON	Motor octane number

MP	Medium pressure
MTBE	Methyl tert-butyl ether
NMP	N-methyl pyrrolidone
PFR	Plug flow reactor
PNA	Polynuclear aromatic
P/O/N/A	Paraffins/olefins/ naphthenes/aromatics
POX	Partial oxidation
PSA	Pressure swing adsorption
ROI	Return on investment
RON	Research octane number
RVP	Reid vapor pressure
SCR	Selective catalytic reduction
SD	Solvent deasphalting
SR	Semi-regenerative (reforming)
SR	Straight run
T_{EOR}	End of run temperature
T_{SOR}	Start of run temperature
TAEE	Tert-amyl ethyl ether
TAME	Tert-amyl methyl ether
TBA	Tert-butyl alcohol
TBP	True boiling point
TCC	Thermofor catalytic cracking
TEA	Triethanolamine
TIPP	Domestic oil product tax
TR	Topping-reforming
TRCV	Topping-reforming-cracking-visbreaking
TRCVAI	Topping-reforming-cracking-visbreaking-alkylation-isomerization
TSS	Total suspended solids
UCS	Unit cell size
VBD	Vibrated bulk density
VCM	Volatile combustible matter
VD	Vacuum distillation
VGO	Vacuum gas oil
VI	Viscosity index
VLS	Very low sulfur
VR	Vacuum residue
VRDS	Vacuum residue desulfurization
WHSV	Weight hourly space velocity

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