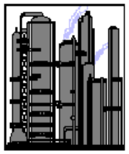
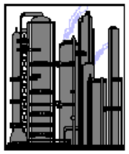
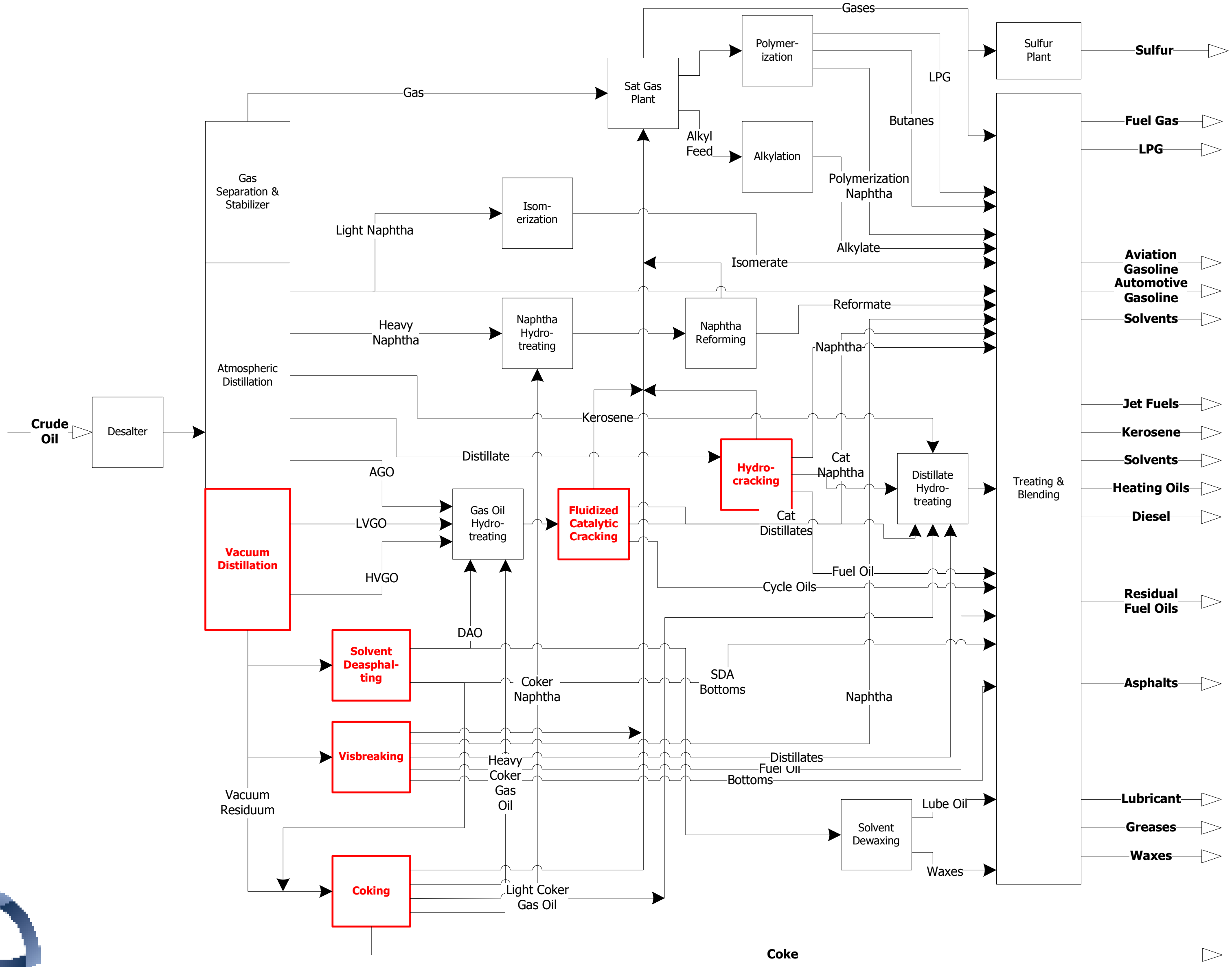


Bottom of Barrel Processing

Chapters 5 & 8





Crude Oil

Desalter

Gas Separation & Stabilizer

Atmospheric Distillation

Vacuum Distillation

Solvent Deasphalting

Visbreaking

Coking

Gas

Light Naphtha

Heavy Naphtha

AGO

LVGO

HVGO

Vacuum Residuum

DAO

Coker Naphtha

Heavy Coker Gas Oil

Light Coker Gas Oil

Isomerization

Naphtha Hydrotreating

Gas Oil Hydrotreating

Fluidized Catalytic Cracking

Hydrocracking

Kerosene

Distillate

Sat Gas Plant

Alkyl Feed

Polymerization

Alkylation

Naphtha Reforming

Distillate Hydrotreating

Gases

LPG

Butanes

Polymerization Naphtha

Alkylate

Isomerate

Reformate

Naphtha

Cat Naphtha

Cat Distillates

Fuel Oil

Cycle Oils

SDA Bottoms

Naphtha

Distillates

Fuel Oil

Bottoms

Solvent Dewaxing

Lube Oil

Waxes

Sulfur Plant

Treating & Blending

Sulfur

Fuel Gas

LPG

Aviation Gasoline

Automotive Gasoline

Solvents

Jet Fuels

Kerosene

Solvents

Heating Oils

Diesel

Residual Fuel Oils

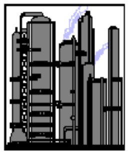
Asphalts

Lubricant

Greases

Waxes

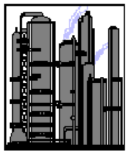
Coke

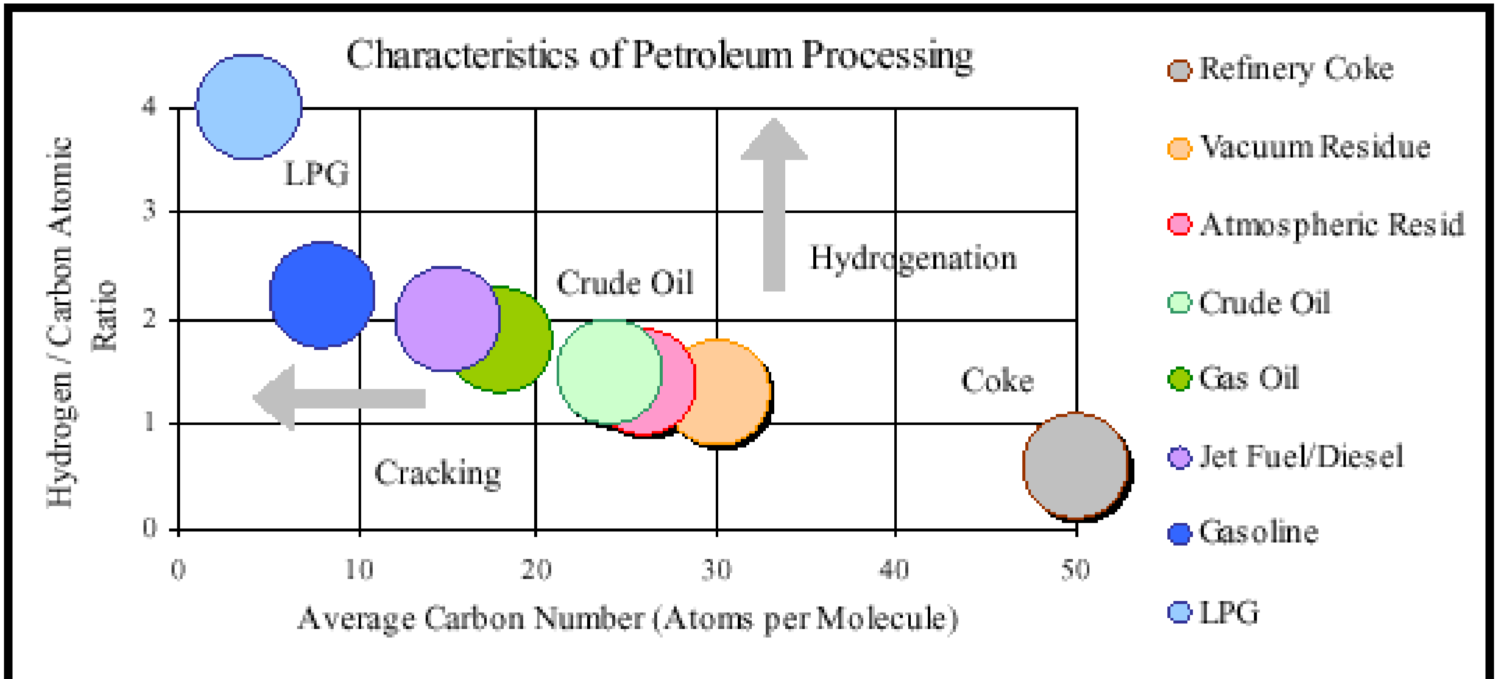


Need For Heavy Ends Processing

- World crude slate has become heavier — this will continue
- Concentration of sulfur & other contaminants has been increasing — this will continue
- Sulfur specifications becoming more stringent
  - For environmental protection
- Demand for No. 6 Fuel Oil declining
  - For environmental protection
- Cost of light crude relative to heavy crude is increasing
  - Producers are increasing the sale of heavy crudes to prolong the life of light crude fields

Characteristics of Petroleum Products

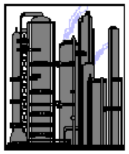




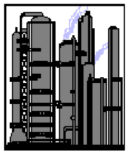
Adopted from Speight, 1999. Data variability is great and does not represent specific crudes or products.

Refining Overview – Petroleum Processes & Products,
by Freeman Self, Ed Ekholm, & Keith Bowers, AIChE CD-ROM, 2000

Processing Options



- Physical separations
  - Vacuum distillation
    - Volatility
  - Solvent Deasphalting
    - Solubility
- Chemical reactions (in order of increasing severity)
  - Visbreaking
  - Catalytic cracking
  - Hydrocracking
  - Coking
    - Delayed coking
    - Fluidized bed coking
- Lube Oil Processing
  - Requires specialized feedstocks



U.S. Refinery Implementation

Company	State	Site	Atmospheric Crude Distillation Capacity (barrels per stream day)	Vacuum Distillation Downstream Charge Capacity, Current Year (barrels per stream day)	Therm Cracking, Delayed Coking Downstream Charge Capacity, Current Year (barrels per stream day)	Therm Cracking, Fluid Coking Downstream Charge Capacity, Current Year (barrels per stream day)	Therm Cracking, Visbreaking Downstream Charge Capacity, Current Year (barrels per stream day)	Therm Cracking, Other (Incldng Gas Oil) Downstream Charge Capacity, Current Year (barrels per stream day)	Fuels Solvent Deasphalting Downstream Charge Capacity, Current Year (barrels per stream day)
ExxonMobil Refining	Texas	BAYTOWN	596,400	288,600	51,400	42,500	0	0	49,000
Hovensa LLC	Virgin Islands	KINGSHILL	525,000	225,000	62,000	0	40,000	0	0
BP	Texas	TEXAS CITY	475,000	237,000	33,000	0	0	0	17,000
Marathon Petroleum	Louisiana	GARYVILLE	275,000	142,000	40,500	0	0	0	34,000
Chevron USA Inc	California	RICHMOND	257,200	123,456	0	0	0	0	66,000
ConocoPhillips	Louisiana	WESTLAKE	252,000	132,000	64,000	0	0	10,600	0
ConocoPhillips	New Jersey	LINDEN	250,000	75,000	0	0	0	0	20,000
Total	Texas	PORT ARTHUR	240,000	54,000	0	0	0	0	19,500
Marathon Petroleum	Kentucky	CATLETTSBURG	250,000	110,500	0	0	0	0	12,500
Valero Energy Corp	Texas	TEXAS CITY	215,000	117,000	51,200	0	0	0	32,600
Valero Energy Corp	Texas	SUNRAY	181,000	50,000	0	0	0	0	15,500
Murphy Oil	Louisiana	MERAUX	125,000	50,000	0	0	0	0	18,000
Tesoro	Washington	ANACORTES	125,000	47,000	0	0	0	0	30,000
Tesoro	Hawaii	EWA BEACH	95,000	40,000	0	0	11,000	0	0
Valero Energy Corp	Texas	THREE RIVERS	97,000	35,000	0	0	0	0	10,000
Valero Energy Corp	Texas	HOUSTON	85,000	38,000	0	0	0	0	18,000
Ergon Inc	Arkansas	EL DORADO	72,000	28,500	0	0	0	0	7,400
Gary Williams Co	Oklahoma	WYNNEWOOD	75,000	30,000	0	0	0	0	4,850
Alon Israel Oil Company Ltd	Texas	BIG SPRING	70,000	24,000	0	0	0	0	10,000
Placid Oil Co	Louisiana	PORT ALLEN	58,000	27,000	0	0	0	0	11,000
Holly Corp	Utah	WOODS CROSS	26,400	0	0	0	0	0	5,600
San Joaquin Refining Co Inc	California	BAKERSFIELD	25,000	14,300	0	0	5,000	0	0

Solvent Deasphalting

- Remove asphalts from lube plant feeds
- Increase gas oil yield from crude
- Make commercial asphalts from asphaltic crude unit bottoms
- Physical recovery using light hydrocarbon solvent (C3, C4, C5)
  - Dissolve saturated components
  - Leave behind/precipitate asphaltenes
  - Resins split between phases

Solvent Deasphalting

- Three principal products
  - Deasphalted Oil (DAO)
  - Resins
  - Bottoms/pitch – asphaltenes
- Sulfur splits fairly equally amongst all products.

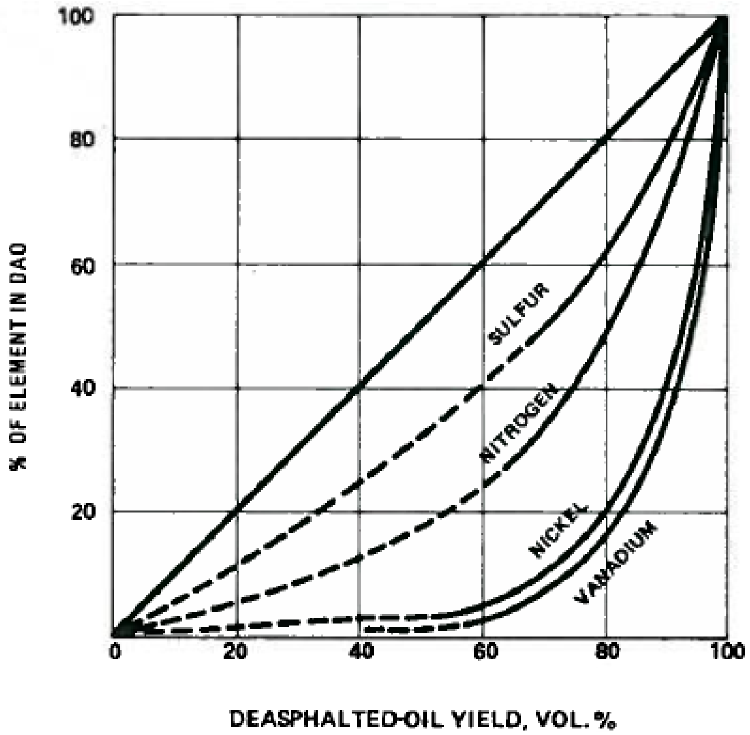
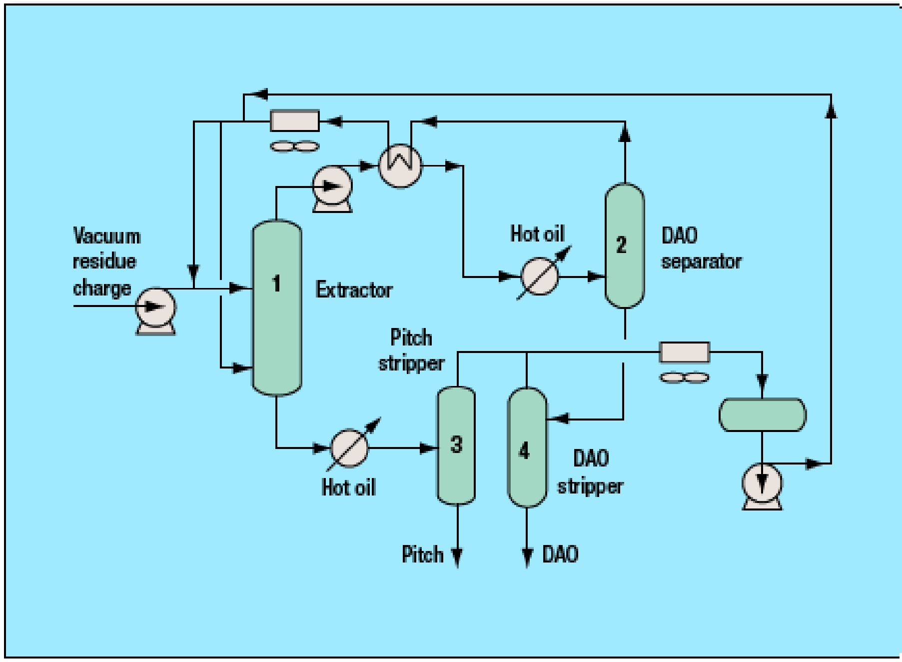


FIG. 8.3-11 Selectivity in solvent deasphalting. [*Courtesy of the Gulf Publishing Company, publishers of* Hydrocarbon Processing, *52(5), 110–113 (1973).*]

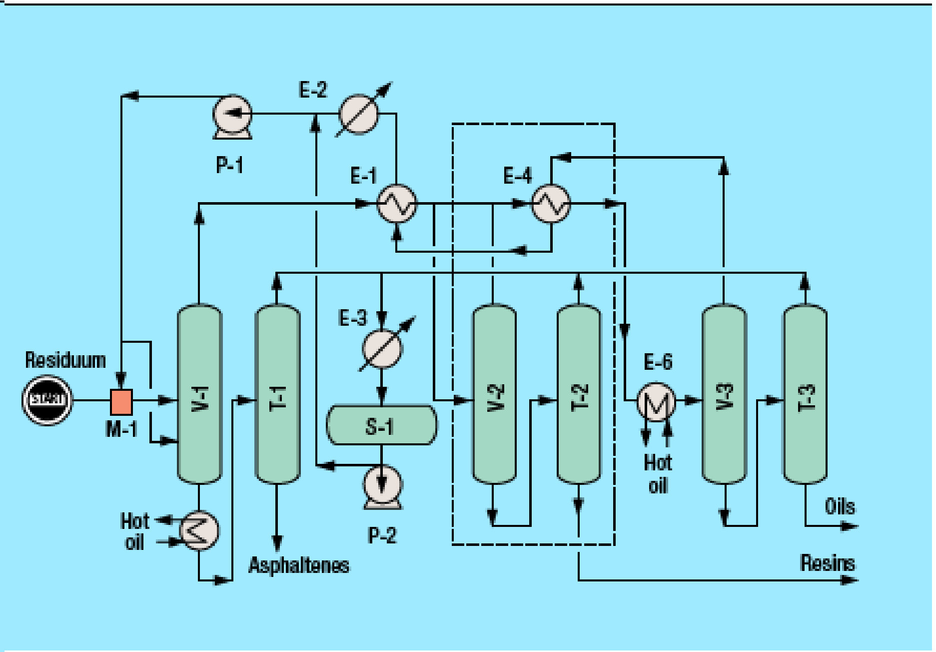
Handbook of Petroleum Refining Processes
Robert Meyers
McGraw-Hill, Inc, 1986

SDA Technology Providers

Provider	Features
Foster Wheeler	Light hydrocarbon solvent with DAO/solvent separation at supercritical conditions
KBR	



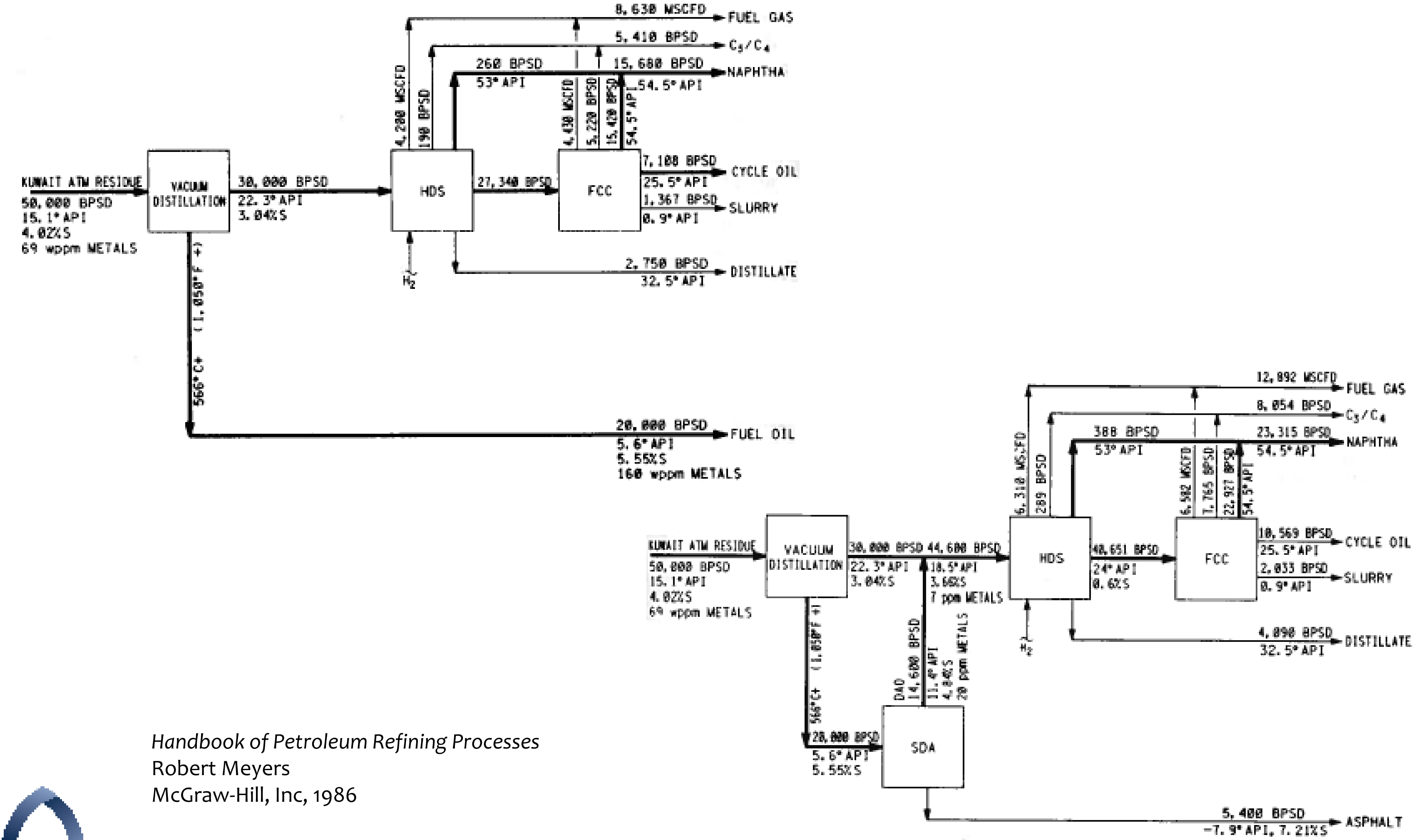
Foster Wheeler



KBR ROSE

Hydrocarbon Processing's 2008 *Refining Processes Handbook*

Integration of SDA into Refinery



Handbook of Petroleum Refining Processes
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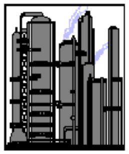
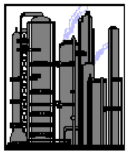


Visbreaking

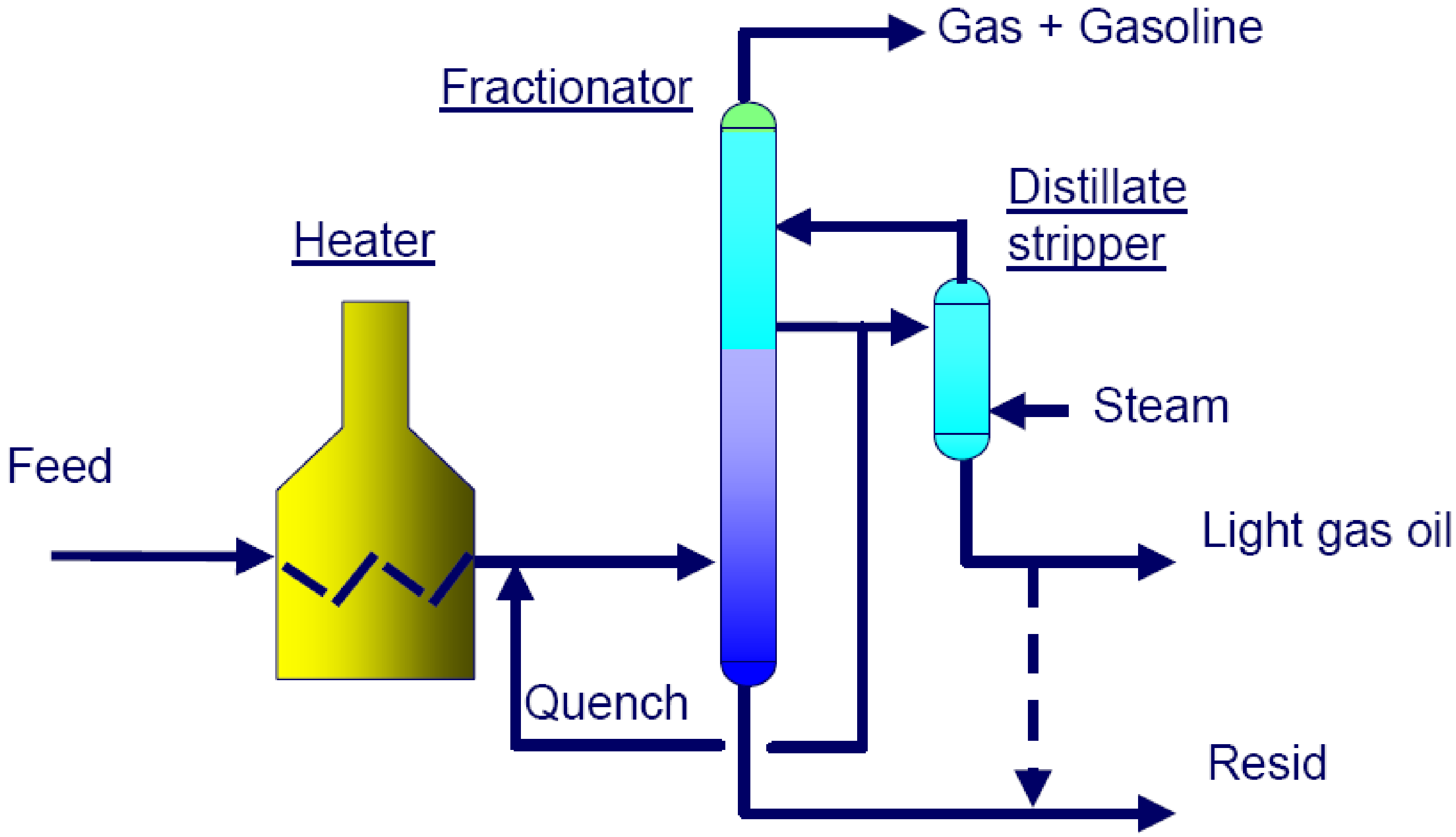
- Purpose
  - Cut viscosity in ½ of feed (specs for heavy fuel oil)
  - Reduces "cutter stock“
  - Reduces heavy fuel oil amount
- Characteristics
  - Relatively mild thermal cracking operation
  - Flexible on feedstock quality
  - Typically high resin crude oils
  - Low capital cost for process
- Products
  - About 20% feed cracked to light ends, naphtha, gas oil & sometimes distillate.
    - Low yield of valuable naphtha
  - Products contain a lot of olefins
    - Olefinic C3s & C4s often recovered
    - Naphtha & distillate often hydrotreated because of olefins & sulfur
  - Gas oil high in aromatics — more appropriate for hydrocracking than cat cracking
  - Large volumes of heavy fuel oil with high sulfur content
  - Bottoms (visbreaker tar) sent directly to heavy fuel oil



Visbreaking

- Low capital cost for process
- Low yield of valuable naphtha
- Large volumes of heavy fuel oil with high sulfur content

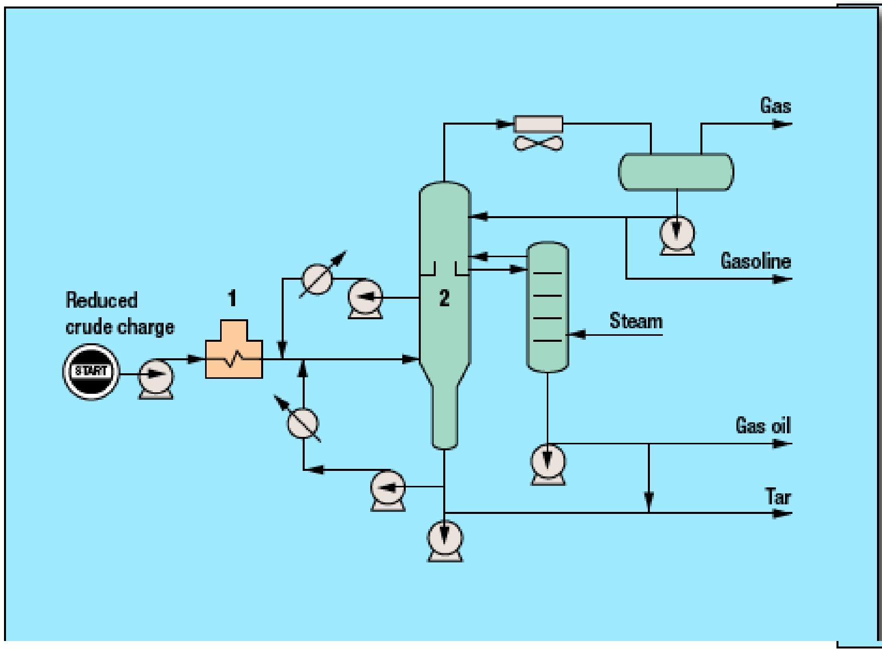
Typical Coil Visbreaker



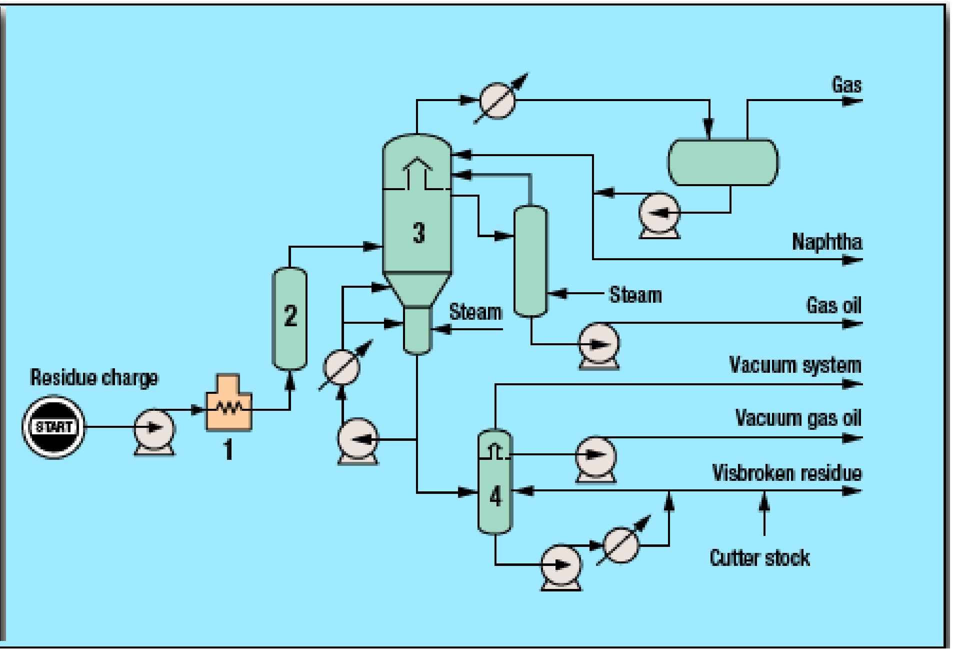
http://www.fwc.com/industries/pdf/Residue_upgrading_English_10th_Sept.pdf?DIRNAME=%23dirName%23

Visbreaking Technology Providers

Provider	Features
Foster Wheeler	Visbreaker heater & downstream coil
Shell Global Solutions	

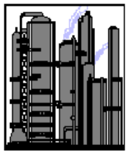


Foster Wheeler



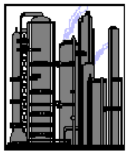
Shell Global Solutions

Hydrocarbon Processing’s *2008 Refining Processes Handbook*



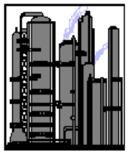
Catalytic Cracking

- Purpose
  - Make gasoline & distillates (diesel/heating oil)
  - Try to minimize heavy fuel oil
- Medium severity cracking process
- Gas oils are typical feedstocks
- Not normally used on whole atmospheric or vacuum resids
  - PNAs tend to condense, leading to coking
  - Catalysts sensitive to poisoning by sulfur & metals present in PNAs



Hydrocracking

- Purpose
  - Minimize heavy fuel oil
- Severe cracking process
  - Combines cracking & hydrogenation
  - In US, hydrocracking has been a special operation
  - More hydrocracking capability being added as shift to distillate continues
- Processes PNAs better because of hydrogen addition
  - Helps prevent condensation leading to coking
- Coking better for resids
  - Sulfur, nitrogen, oxygen, & metals in resins & asphaltenes ⇒ poison catalysts
  - High resins & asphaltenes ⇒ coke
- High pressures & large amounts of hydrogen required
- Hydrogenation reactions suppress coke formation
- Produces high yields of liquids
- Liquids low in sulfur & olefins



Coking

- Purpose
  - Create light gases & distillates
  - “Carbon rejection”
- Severe thermal cracking process
- Produces light gases, distillates (naphthas & gas oils) for catalytic upgrading & coke
- Can process a wide variety of feedstocks
  - High metals (nickel and vanadium), sulfur, resins & asphaltenes with PNAs
- Separates thermally stable PNA cores from their side chains
  - PNAs contain majority of the heteroatoms (sulfur, nitrogen, metals)
  - Concentrate in the coke as PNAs condense
- Coke with large amounts of metals & sulfur may pose a disposal problem
- Delayed coking produces low yields of liquids relative to hydrocracking
- Liquids contain large amounts of sulfur & olefins but little aromatics
- Coke use depends upon quality