Bottom of Barrel Processing
Chapters 5, 6, & 8
Crude Oil → Desalting → Vacuum Distillation → Gas Separation & Stabilizer → Light Naphtha

Light Naphtha → Isomerization → Atmospheric Distillation → Naphtha-Reforming → Vacuum Distillation → Gas Oil Hydro-treating → Fluidized Catalytic Cracking → Coker Gas Oil

Coker Naphtha → Hydro-treating → Cat Naphtha → Distillate → Treating & Blending → Sulfur Plant → Sulfur

Heavy Naphtha → Naphtha-Hydro-treating → Distillate → Treating & Blending → Diesel Fuel Oil

Kerosene → Naphtha - Reformation → Vacuum Residue → Solvent Dewaxing → Lube Oil

Fuel Oil → Bottoms → Distillates → Hydro-treating → Cat Naphtha → Cycle Oils

DAO → Solvent Desalting → Gas Oil

DAO → Distillate Hydro-treating → Gas Oil

SAO → Heavy Coker Gas Oil

LPG → Aviation Gasoline

Jet Fuels

Kerosene

Solvants

Residual Fuel Oils

Asphalts

Lubricants

Greases

Waxes

Surplus Gas

Butanes

Fuel Gas

LPG
Need For Heavy Ends Processing

- **Worldwide** crude slate has become heavier
  - Concentration of sulfur & other contaminants has been increasing
  - Sulfur specifications becoming more stringent
    - Environmental protection
  - Demand for No. 6 Fuel Oil declining
    - Environmental protection
  - Cost of light crude relative to heavy crude is increasing
- Trends in the United States have become more complicated due to the flood of light, sweet, tight oil from shale in the United States

Gunaseelan & Buehler  
“Changing US crude imports are driving refinery upgrades”  
*Oil & Gas Journal*, Aug. 10, 2009
Processing Options

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

EIA, Jan. 1, 2016 database, published June 2016
http://www.eia.gov/petroleum/refinerycapacity/

Updated: August 12, 2016
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Solvent Deasphalting

- **Purpose**
  - Remove asphalts from lube plant feeds
  - Increase gas oil yield from crude
  - Make commercial asphalts from asphaltic crude unit bottoms

- **Characteristics**
  - Physical recovery using light hydrocarbon solvent (C3, C4, C5)
    - Dissolve saturated components
    - Leave behind/precipitate asphaltenes
    - Resins split between phases

- **Products**
  - Deasphalted Oil (DAO)
  - Resins
  - Bottoms/pitch – asphaltenes

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Updated: August 12, 2016
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Typical SDA Process

Foster Wheeler SDA process
Characteristics of Products

- DAO resembles gas oil but is of drastically different boiling point range
Characteristics of Products

First 50% DAO molecules are suitable to hydrocrack
50-70+% DAO molecules are challenging to hydrocrack

Residue Upgrading Technology Options for Cost Effective Solutions,
Steve Beeston, ARTC 2014, Singapore, March 5, 2014
Integration of SDA into Refinery

<table>
<thead>
<tr>
<th>Component</th>
<th>Base (bpsd)</th>
<th>With SDA (bpsd)</th>
<th>Base (°API)</th>
<th>With SDA (°API)</th>
<th>Base wt% S</th>
<th>With SDA wt% S</th>
<th>Base ppmw metals</th>
<th>With SDA ppmw metals</th>
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</table>

Handbook of Petroleum Refining Processes
Robert Meyers
Visbreaking

- **Purpose**
  - Reduce viscosity by 1/2 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
Typical Coil Visbreaker

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

- **Purpose**
  - β Make gasoline & distillates (diesel/heating oil)
  - β Try to minimize heavy fuel oil

- **Characteristics**
  - β Medium severity cracking process
  - β Gas oils are typical feedstocks
  - β Not normally used on whole atmospheric or vacuum residus
    - PNAs tend to condense, leading to coking
    - Catalysts sensitive to poisoning by sulfur & metals present in PNAs

- **Products**
  - β Light gases
  - Olefins
  - β Light & Heavy Naphtha
  - β Light & Heavy Cycle Oils
  - β Slurry
Hydrocracking

- Purpose
  - Minimize heavy fuel oil

- Characteristics
  - Severe cracking process
    - Combines cracking & hydrogenation
  - Coking better for resids
  - High pressures & large amounts of hydrogen required

- Products
  - Produces high yields of liquids
    - Hydrogen suppresses coke formation
    - Liquids low in sulfur & olefins
Coking

• **Purpose**
  - Produce light gases & distillates
  - “Carbon rejection”

• **Characteristics**
  - Severe thermal cracking process
  - 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

• **Products**
  - Produces light gases, distillates (naphthas & gas oils) for catalytic upgrading
    - Low yields of liquids relative to hydrocracking
    - Liquids contain large amounts of sulfur & olefins but little aromatics
  - Coke
    - Contains large amounts of metals & sulfur.
    - Coke use depends upon quality
      - May pose a disposal problem
Supplemental Slides

- SDA technology providers
- Visbreaking technology providers
## SDA Technology Providers

<table>
<thead>
<tr>
<th>Provider</th>
<th>Features</th>
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<tbody>
<tr>
<td>Foster Wheeler</td>
<td>Light hydrocarbon solvent with DAO/solvent separation at supercritical conditions</td>
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<td>KBR</td>
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Foster Wheeler

KBR ROSE©

*Hydrocarbon Processing's 2008 Refining Processes Handbook*
## Visbreaking Technology Providers

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<td>Shell Global Solutions</td>
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**Foster Wheeler**

**Shell Global Solutions**

*Hydrocarbon Processing’s 2008 Refining Processes Handbook*