The Petroleum Industry

- Exploration
The Petroleum Industry

- Exploration
- Production & Supply
The Petroleum Industry

- Exploration
- Production & Supply
- REFINING
The Petroleum Industry

- Exploration
- Production & Supply
- REFINING
- Distribution & Marketing
Purpose of Petroleum Refining

Safely, and efficiently transform crude oil and other raw materials into on-spec finished products.
Crude Oil

To the consuming public, crude oil is the raw material that will ultimately power our vehicles, provide heating, pave our roads, and become the building blocks for many of the plastics we use.
What is Crude Oil?

- Usually naturally occurring
- Not a single compound, but a complex mixture of thousands of compounds
- Wide boiling range
- Mostly hydrocarbons (compounds with carbon and hydrogen) but traces of other compounds are present, such as sulfur, nitrogen, oxygen, and metals
What is Crude Oil?

- Usually naturally occurring - but what about synthetic crude?
What are Synthetic Crudes?

- The oil sands of Canada and Venezuela are the source of the synthetic crudes.

- Using refinery units, the heavy bitumen is upgraded to yield products from the oil sands.

- So, the term “synthetic crudes” refers to partially processed, hydrocarbon blends suitable for processing in a crude unit.
Classifying Crude Oil

- Location

- Density (light, heavy) - the scale most commonly used in API Gravity. The higher the number the lighter the crude oil.
  - Generally, the lighter crudes are more valuable since they’ll produce more of the higher valued products.

- Sulfur content (sweet, sour)
  - Low sulfur is sweet
  - High sulfur is sour
  - Sweet is usually defined as less than 0.5% sulfur
  - Sweet crudes are more valuable as the sulfur is an undesirable component that must be removed in the refining process.
Are Crude oils all pretty much the same?

Definitely not. No more than people are all the same.
Crude Oil Assay Program

- Crude oils are characterized utilizing a very comprehensive testing slate

- Typical full crude assay cost:
  - $10,000 - $20,000 per crude

- Information is used for:
  - Purchase decisions
  - Refining planning and optimization
  - Capital project decisions
Crude Oil Assay Program

Analytical Testing

- A representative sample of the crude is distilled in the laboratory under similar conditions as the refinery.
- Ten or more boiling range fractions are obtained.
- Very extensive testing is conducted on the whole crude and the various fractions.
- Tests performed are selected based on the products.
Crude Assay Laboratory
Crude Oil Assay Program

Converting Information to Intelligence

- Following the analytical testing, special software programs are used to put the raw analytical data into a form that conclusions, comparisons, and correlations can be made.

- Sophisticated computer models use the crude assay data together with operational data and price information to allow for optimal planning and operation.
<table>
<thead>
<tr>
<th></th>
<th>Whole Crude</th>
<th>Light Naphtha</th>
<th>Medium Naphtha</th>
<th>Heavy Naphtha</th>
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</table>
Other Non-Crude Refinery Feedstocks

- Gas oil, feed to the cat cracker
- Gasoline blendstocks - intermediate materials to be blended into the finished gasoline
- Butane(s)
- Raw materials for specialty units
REFINERIES are like snowflakes...

no two are the same!!
Refinery Configuration Factors

- Process Units (Type & Size)
- Location
- Transportation Options
- Tankage
A Very Simple Refinery

Crude

DISTILLATION

Light Naphtha

BTX Naphtha

REFORMER

GASOLINE BLENDING

Ethylene, Propylene, Propane

Heavy Naphtha

FCCU

ALKYLATION

LCO and Slurry

Kerosene

Distillate

Reduced Crude

DISTILLATE BLENDING

Kero/Jet

Low S Diesel

High S Diesel

RBOB

PBOB

Premium

Regular

Blend Grade
Refining Process
Refining Crude Into Useful Products

Physical Processes

- Separate hydrocarbon compounds based on physical characteristics without causing chemical reactions
  - Boiling point
  - Solubility in selected solvent
- No change to hydrocarbon structures
  - Distillation
Refining Crude Into Useful Products

Chemical Processes

- Alter chemical structure of hydrocarbon molecules
  - Example: rearrange molecules into ones with more desirable properties

- Change the size of hydrocarbon molecules
  - Example: break large molecules into several smaller ones
  - Example: combine several small molecules into larger ones

- Remove impurities such as sulfur and nitrogen
Desalting

- Prior to introducing the crude to the main units, it must be “cleaned.”
- By using chemicals, heat, and electrical fields, the sediment, salts, and water are removed.
Distillation

- Primary **physical** separation process within the refinery
- Separates hydrocarbon mixtures according to boiling point
- Used in various places in the refinery
Refining Processes Involving Chemical Reactions

- Reforming
- Cracking
- Hydrotreating
- Alkylation
- Coking
Catalytic Reforming

- Function is to chemically alter “naturally-occurring” gasoline-like material (naphtha) to boost its octane

- Converts low octane paraffins and naphthenes into high octane aromatics
Catalytic Reforming – Primary Process Chemistry

- Dehydrogenation of naphthenes to aromatics

\[
\text{C}_6\text{H}_{12} \quad \rightleftharpoons \quad \text{C}_6\text{H}_6 + 3\text{H}_2
\]

RON 80

Benzene - \text{C}_6\text{H}_6

RON 115

(an example)
Catalytic Cracking

- Function is to “crack” the gas oil (650°F - 1000 °F) fraction of the crude oil to produce more gasoline and distillate fuels
- Usually uses a fluidized catalyst - thus Fluidized Catalytic Cracking Unit (FCCU)
- FCC was developed since the amount of naphtha in crude oil is insufficient to meet the demand for gasoline per barrel of crude
Hydrotreating

- Removes sulfur (and nitrogen) compounds from intermediate feedstocks
- Hydrotreating is necessary to meet low sulfur product quality specifications
- Uses hydrogen produced by reformers
“Links” small molecules together to yield high octane, low vapor pressure gasoline blendstock
Alkylate Product
An Ideal “Green” Gasoline Blendstock

- Very high octane
- NO sulfur
- NO aromatics
- NO olefins
- NO benzene
- Can be low vapor pressure
Coking

- A method of bottoms upgrading

- Feedstock:
  - Vacuum resid – heaviest
  - Highest boiling crude fraction
  - High sulfur
  - High metals

- Products:
  - 6-10% gas
  - 15-20% naphtha
  - 35-60% gas oil
  - 20-40% coke
What Products do we make?
Petroleum Refinery Products

- Propane and Propylene
- Butane(s)
- Specialty Solvents
- Specialty Products
  - Benzene
  - Toluene
  - Cumene...
- Gasoline - various grades
- Kerosene
- Jet Fuel
- Diesel Fuel - various grades
- Heavy Fuel Oils
  - No. 4, No. 6, etc.
- Roofing Flux
- Road Asphalt - various grades
- Petroleum Coke
Gasoline Blending (at the Refinery)

- Natural Gasoline (purchased)
- N-Butane
- LSR
- Isomerate
- Reformate
- Cat Naphtha
- Coker Naphtha
- Hydrocrackate
- Alkylate
- Raffinate
- Additives

Output:
- Blendgrade
- Unleaded
- Mid-Grade
- Unleaded
- Premium
- Unleaded
- RBOB
- PBOB
## Typical Gasoline Specifications
### 87 Regular Conventional

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<tr>
<th>Specification</th>
<th>Test Method</th>
<th>Unit</th>
<th>Minimum</th>
<th>Maximum</th>
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Safely, and efficiently transform crude oil and other raw materials into on-spec finished products.
Refining Resources

- Marathon Petroleum “The Basics of Refining” multi-media program

- “Petroleum Refining in Nontechnical Language,” by William L. Leffler
Questions?