Principles of Energy Conversion

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Part 10. Chemical Energy & Fuels

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Petroleum

### Table 2.3 Products of Petroleum Distillation

<table>
<thead>
<tr>
<th>Fraction</th>
<th>Molecular Size Range</th>
<th>Boiling Point Range (Degrees Celsius)</th>
<th>Typical Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas</td>
<td>C₁₋₅</td>
<td>−164 to 30</td>
<td>Gaseous fuel</td>
</tr>
<tr>
<td>Petroleum ether</td>
<td>C₆₋₇</td>
<td>30 to 90</td>
<td>Solvent, dry cleaning</td>
</tr>
<tr>
<td>Straight-run gasoline</td>
<td>C₁₀₋₁₂</td>
<td>30 to 200</td>
<td>Motor fuel</td>
</tr>
<tr>
<td>Kerosene</td>
<td>C₁₂₋₁₅</td>
<td>175 to 275</td>
<td>Fuel for stoves, diesel, and jet engines</td>
</tr>
<tr>
<td>Gas oil or fuel oil</td>
<td>C₁₅₋₁₈</td>
<td>Up to 375</td>
<td>Furnace oil</td>
</tr>
<tr>
<td>Lubricating oil</td>
<td>C₁₅₋₂₀</td>
<td>350 and up</td>
<td>Lubrication</td>
</tr>
<tr>
<td>Greases</td>
<td>C₁₈ up</td>
<td>Semisolid</td>
<td>Lubrication</td>
</tr>
<tr>
<td>Paraffin (wax)</td>
<td>C₂₀ up</td>
<td>Melts at 52–57</td>
<td>Candles</td>
</tr>
<tr>
<td>Pitch and tar</td>
<td>High</td>
<td>Residue in boiler</td>
<td>Roofing, paving</td>
</tr>
</tbody>
</table>


### Table 2.4 The Alkane Series of Hydrocarbons

<table>
<thead>
<tr>
<th>n</th>
<th>Molecule</th>
<th>Name</th>
<th>Primary Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CH₄</td>
<td>Methane</td>
<td>Natural gas</td>
</tr>
<tr>
<td>2</td>
<td>C₂H₆</td>
<td>Ethane</td>
<td>Natural gas</td>
</tr>
<tr>
<td>3</td>
<td>C₃H₈</td>
<td>Propane</td>
<td>Bottled gas</td>
</tr>
<tr>
<td>4</td>
<td>C₄H₁₀</td>
<td>Butane</td>
<td>Bottled gas</td>
</tr>
<tr>
<td>5</td>
<td>C₅H₁₂</td>
<td>Pentane</td>
<td>Gasoline</td>
</tr>
<tr>
<td>6</td>
<td>C₆H₁₄</td>
<td>Hexane</td>
<td>Gasoline</td>
</tr>
<tr>
<td>7</td>
<td>C₇H₁₆</td>
<td>Heptane</td>
<td>Gasoline</td>
</tr>
<tr>
<td>8</td>
<td>C₈H₁₈</td>
<td>Octane</td>
<td>Gasoline</td>
</tr>
</tbody>
</table>

*The heat of combustion for these hydrocarbons ranges from about 53,000 Btu/kg for methane to 45,000 Btu/kg for octane.*
Petroleum Products

![Diagram of petroleum products process](image)

Fig. 8-6. Fuel technology. (Adapted from original drawing of The Texas Co.) [Obert, 1973]
Distillation

Catalytic Cracker
Alkylation

Blending

The Swoop
April 1971
References


Petroleum Distillation

4 Steps: 1. Distillation, or Separation
2. Conversion
3. Treating, or Scrubbing
4. Blending

1. Distillation

Hot Crude → [fractionating tower (and distillation tower)]
- naphtha, gases
- gasolene, diesel fuels
- gas oils → Catalytic Cracker

vacuum distillation tower → reduced crude
- vacuum gas oil
- asphalt
- heavy fuel oil, coking feed → Delayed Coker

2. Conversion

gas oils → Catalytic Cracker → "cracks long hydrocarbons"
- refinery (cracked) fuel gas
- liquefied petroleum gas
- chemical feed stock
- gasoline
- home heating oil (lighter grades)
- heavy fuel oil

gas oils → Iso Cracker → "cracks long hydrocarbons"
- can be adjusted to produce products according to market needs, from 100% gasoline to jet aviation fuel, etc.
naphtha → Catalytic Reformer → combines short hydrocarbons
- converts naphtha into high-octane gasoline
- drycleaning fluid is 50 octane naphtha
Conversion (cont.)

Liquefied gases → Alkylation Plant → combined small molecules into large molecules
  * alkylate (> 100 octane)

Cracking Feed → Delayed Coker → thermal cracker
  * converts heaviest 10% of crude into
    * fuel gas
    * gasoline
    * distillate fuel
    * gas oils
  → Catalytic Cracker
  → ultimately used to make electrodes for the steel & aluminum industry

Trilumen Unit
  * specialty product for manufacture of clay pigeons for trap shooting

Isomerization Unit → adds small hydrocarbon chains to gasoline
  * low octane gasoline streams are "isomerized" to form high octane streams

Aromatics Unit

Naphtha Hydrogenation & Saturate Gas Plant

Lube Plant
A Treating — primarily to remove sulfur

- Sulfur Recovery Unit → elemental sulfur
- Clay Treating Unit → clear, bright, dry finished lube oil
- MEK Deoiling Unit

A Blending — 15 streams of dyes & additives → gasoline, diesel fuels, jet fuels, home heating oils, lube oils
1985 Data

- 545 employees
  - $22,000,000 annual payroll
  - $16,000,000 annual operating expenses

- Operates 24/7/365, scheduled shutdown every 3 years
- 325 acres

- Crude oil sources:
  - 1982: 70% (Nigeria), 30% domestic
  - 1985: 90% (Nigeria), 10% domestic

- Average of 142,000 bbls/day crude processed
  - 72,900 bbls/day gasoline produced ~ 20% of Ohio's gasoline consumption
  - 1,530,000 - 20 gal. gas tanks

Diesel fuel
Jet fuel
Kerosene
Lube oils
Residually (coke, heavy fuels)
Military jet fuel
Benzene

- Energy usage = 26.3 trillion BTU's (equivalent to 8% of all crude processed)

- Crude vac. I = 28,000 BPD
- II = 150,000 BPD
Lima (Ohio) Refinery → Sun Oil Company (SunOCO), 1880-1985

- Medium size refinery

1985 Data

- Delayed coker (thermal cracker)
  - Converts heaviest 10% of crude into:
    - Refining fuel gas
    - Gasoline
    - Distillate fuel
    - Gas oils → Catalytic cracker
    - Solid coke → Ultimately used to make electrodes for the steel & aluminum industries
      - 625 tons of coke per day

Fluid Catalytic Cracker
- Converts heavy gas oils to refinery fuel gas
  - Refinery fuel gas
  - Synthetic fuel stocks
  - Alkylation feed stocks
  - Gasoline
  - Distillate fuels

Vacuum Unit #1
- Produced base stocks for lube oils

Sulfur Recovery Unit
- Removes sulfur compounds from → Converts sulfur compounds to elemental sulfur
  - Sold for manufacture of sulfuric acid
  - 32 tons/day

Crude Unit #1 (1927)
- Produced
  - Naphtha
  - Kerosene
  - Distillate fuels
  - Gas oils → Catalytic cracker feed

Toluene Unit
- Specialty product used in manufacture of clay pigeons for trap shooting
Flare
- 200' tall flare -> feeds from pressure relief valves

Hydrocracker
- convert gas oils to motor gasoline or other distillate fuels

Isomerization Unit
- aromatics removed from light reformate have high octane value
- low octane gasoline streams are isomerized to form high octane streams

Aromatics
- light reformate (rich in aromatics) is fed
- aromatics benzene & toluene are removed
  - benzene separated in benzene column -> shipped to Gulf Coast
  - toluene is reacted at high temperature to make more benzene
  - H2 is cryogenically separated & used in reactor

Naphtha Hydrogenation & Saturation Gas Plant
- treats naphtha (gasoline fraction) in the presence of H2 & catalyst
  to remove sulfur, N2, & other impurities
- treatment necessary to prevent/avoid poisoning of the catalyst in the reformer
- recovering & separating light hydrocarbons (C6G) & butane (gasoline blending)

Cooling Tower
- 90,000 gal./min
- 120°F enters at top falls & cools via evaporation to 85°F
- 2,000-2,400 gallons per minute evaporated into air

Catalytic Reformer
- hydrogenated naphtha (low octane) is converted to high octane (gasoline blending)

Lube Plant
- produce base stocks for Vacuum Unit #2
- undesirable lube oils & hydrocarbons -> MEK dewaxing unit -> low pour point oil
- wax -> Fluid Catalytic Cracker

Clay treatment unit:
- cleans, brightens, dryness
- finished lube oils, blended to make various motor & industrial oils