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Petroleum Refining

Recommended References

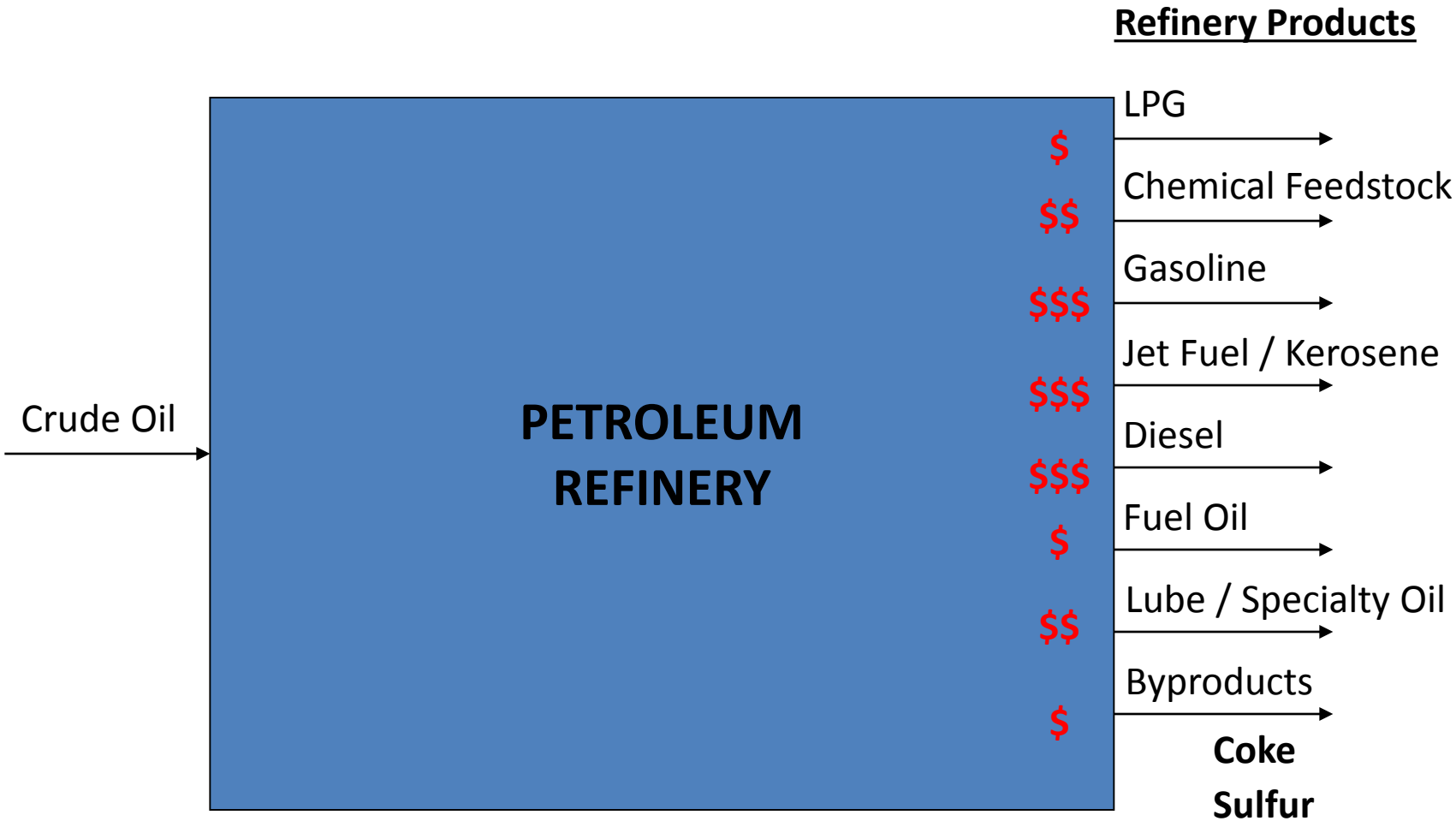
- **Handbook Of Petroleum Refining Processes**, Robert A. Meyers, ed.

- **Petroleum Refining Technology and Economics**, James H. Gary, et al.

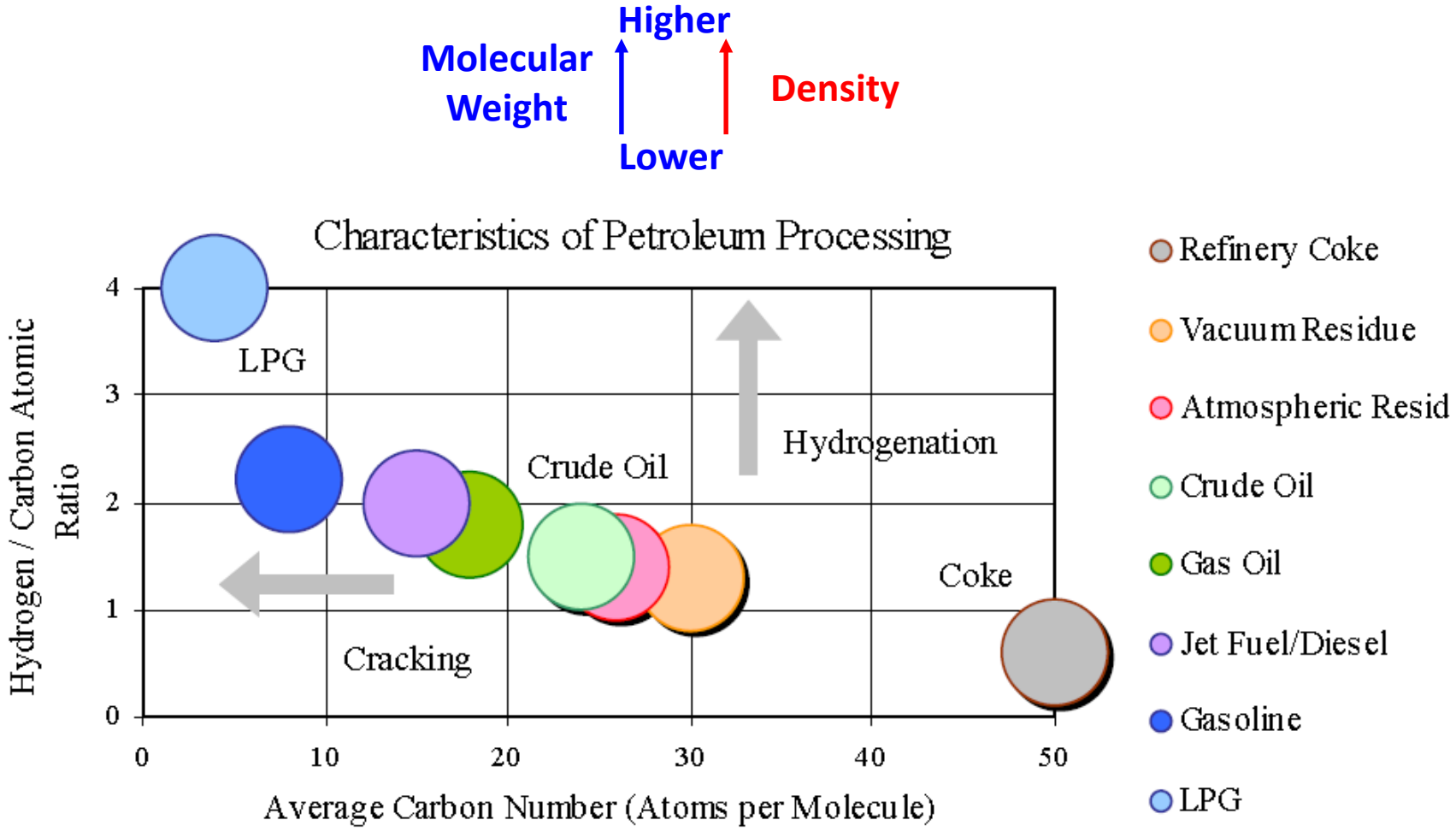
Modern Petroleum Refinery Key Objectives

- **INPUT:** Process Multiple Crude Compositions At Minimum Cost
- **OUTPUT:** Produce Slate Of Products That Provide The Most Profit For Current Market Conditions
- **CONVERSION:** Utilize Processes That Upgrade Value Of Petroleum Components
- **FULL CONVERSION REFINERY**
  - Change Less Valuable Fractions Into Higher Value Transportation Fuels
  - Process Heavier, Cheaper Crude Oil
  - Convert ~90% Of Crude Oil Into Fuels And Products

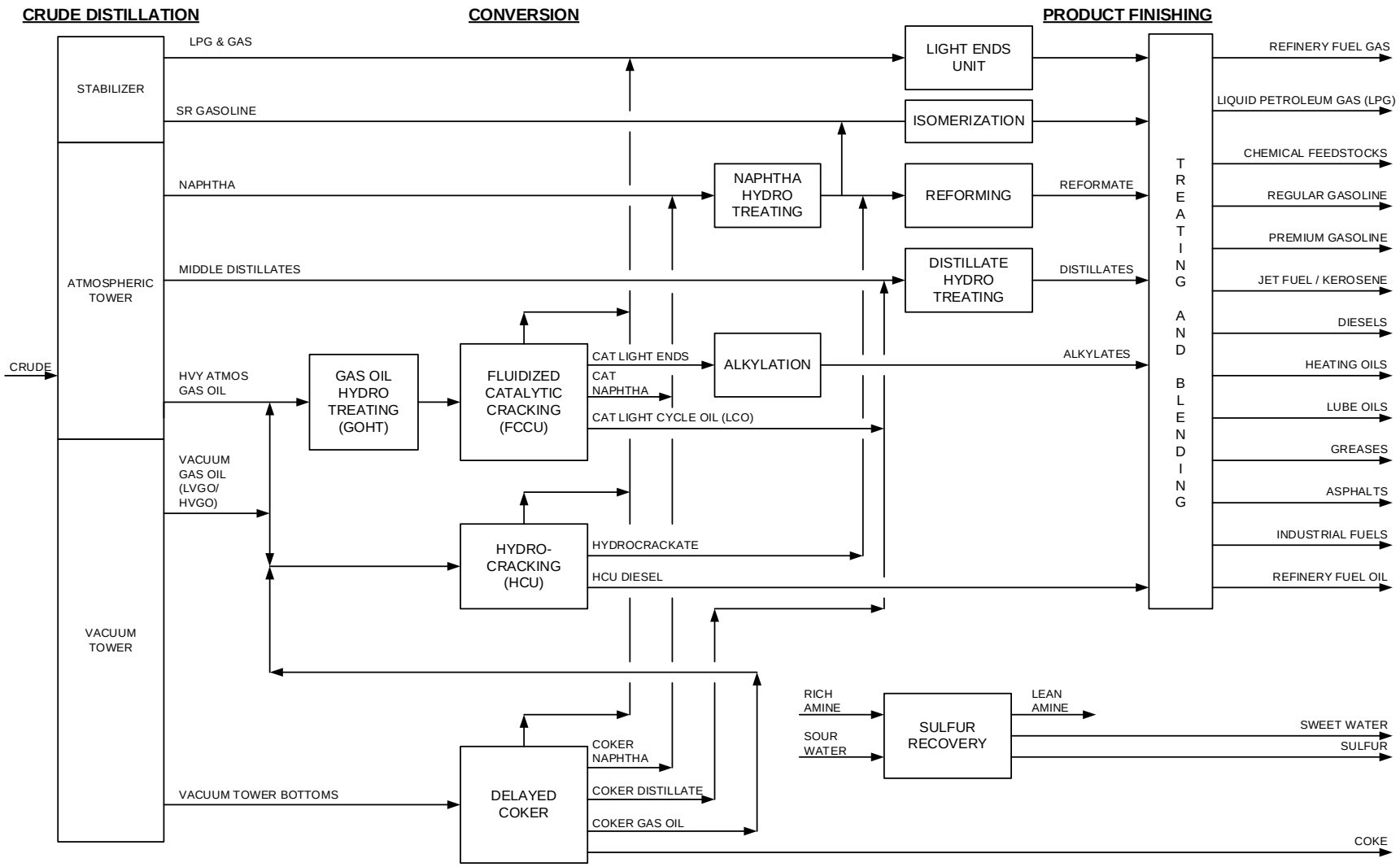
Petroleum Refinery Products



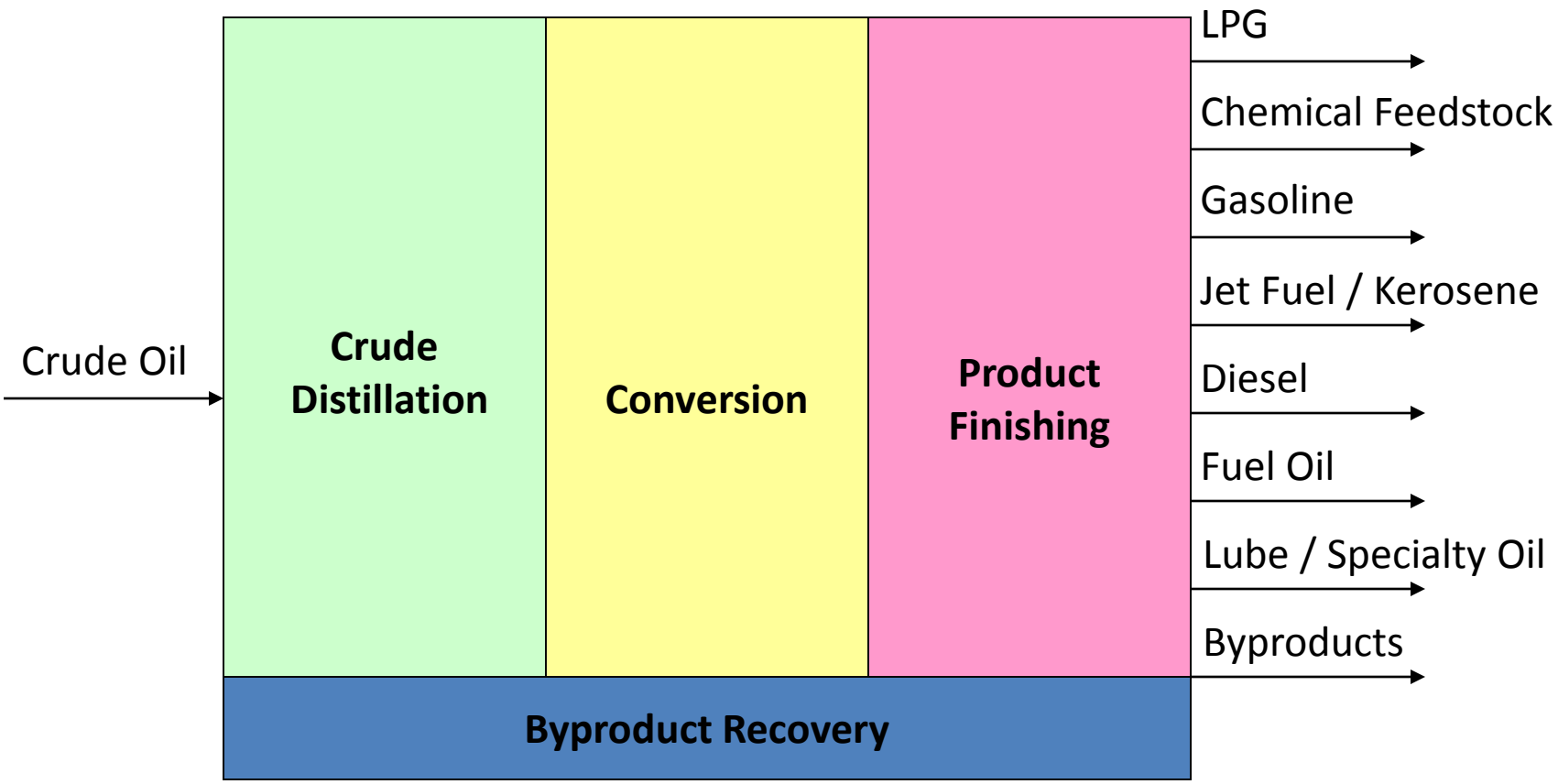
Refinery Products



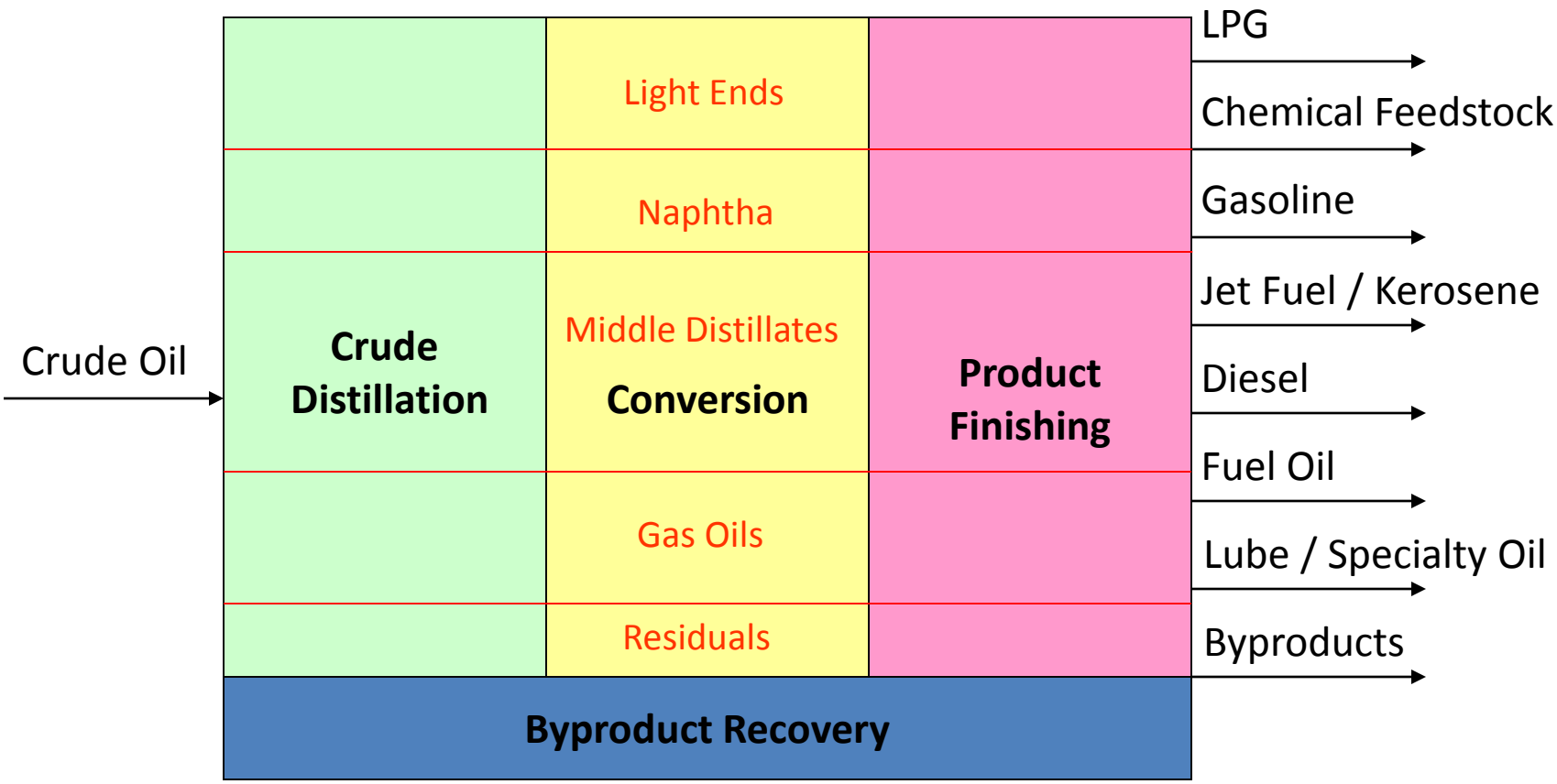
Petroleum Refinery Block Diagram



Petroleum Refinery Operation



Petroleum Refinery Operation



Refinery Value Yield

1 BARREL

CRUDE

$60 / BBL (BRENT)

1 BARREL

GASOLINE

$87 / BBL

JET FUEL

$90 / BBL

DIESEL

$92 / BBL

Refinery Volume Yield

1 BARREL CRUDE = **1.1 BARREL PRODUCT**

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Crude Oil

Crude Oil – Light & Sweet

- Crude Oil Is A Complex Mixture Of Hydrocarbons Generated By Nature
- Light Crudes Have Lower Boiling Point Components With More Value As Products
- Sweet Crudes Have Lower Sulfur Concentrations
  - Less Expensive Materials Of Construction
  - Less Sulfur Handling Requirements
- Light, Sweet Crudes Are Becoming More Scarce And More Expensive

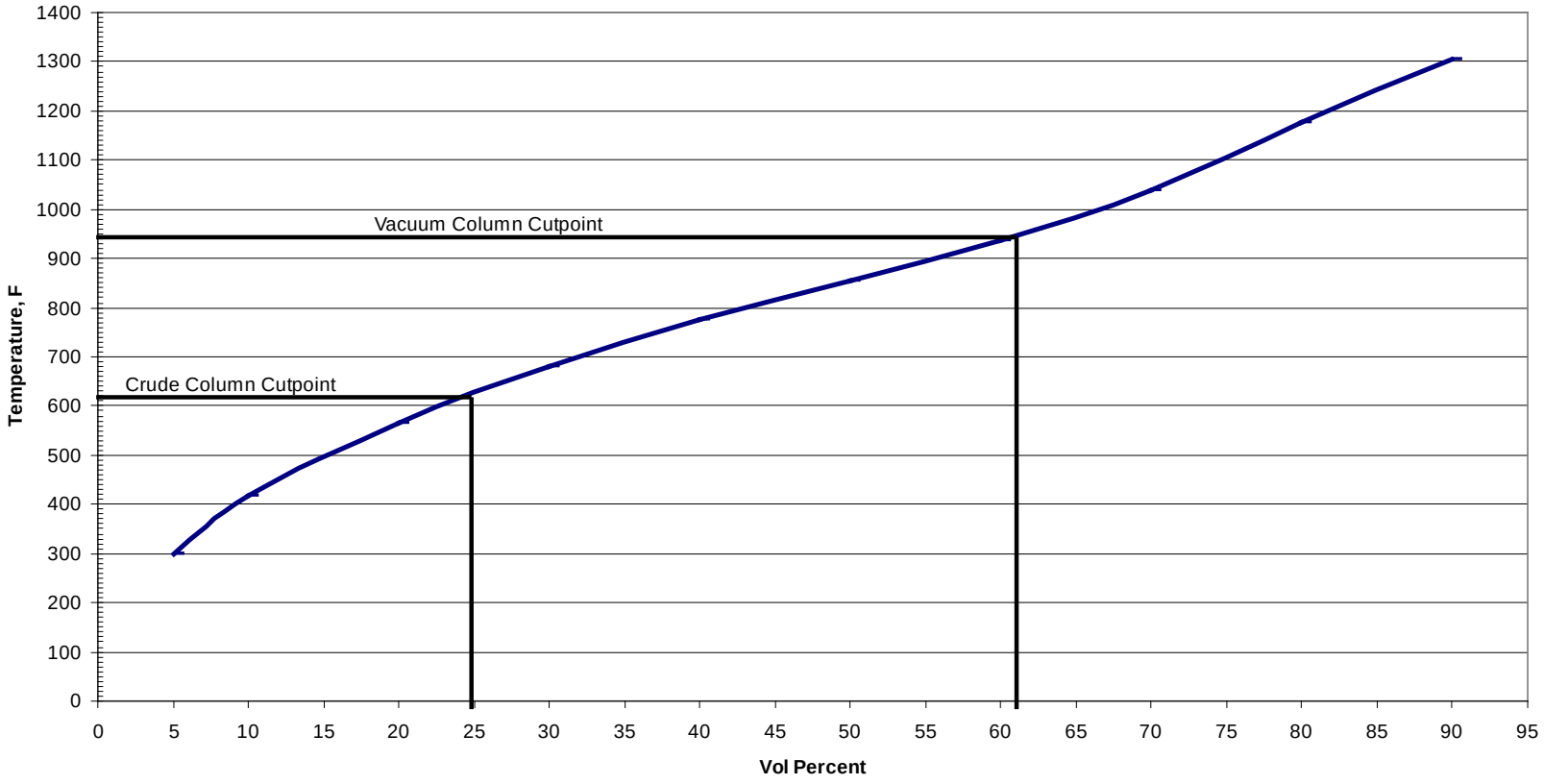
Crude Oil – Heavy & Sour

- Heavier Crudes Have Higher Boiling Point Components With Less Value As Products
- Heavier Crudes Require More Refinery Process Steps To Convert To Lower Boiling Point Components Of Higher Value
- Sour Crudes Have Higher Sulfur Concentrations
  - More Expensive Materials Of Construction
  - More Sulfur Handling Requirements
- Heavy, Sour Crudes Are More Available And Less Expensive Than Light, Sweet Crudes

Crude Oil

- **Crude Assay** Is Used To Define Specific Properties That Impact Refining
- Crude Oil Properties Include:
  - Boiling Point Curve
  - API Gravity
  - Sulfur Content
  - Nitrogen Content
  - Metals (Nickel/Vanadium)
  - Conradson Carbon Residue (CCR)
  - PONA Analysis (Paraffins/Olefins/Naphthenes/Aromatics)
  - Viscosity Curve

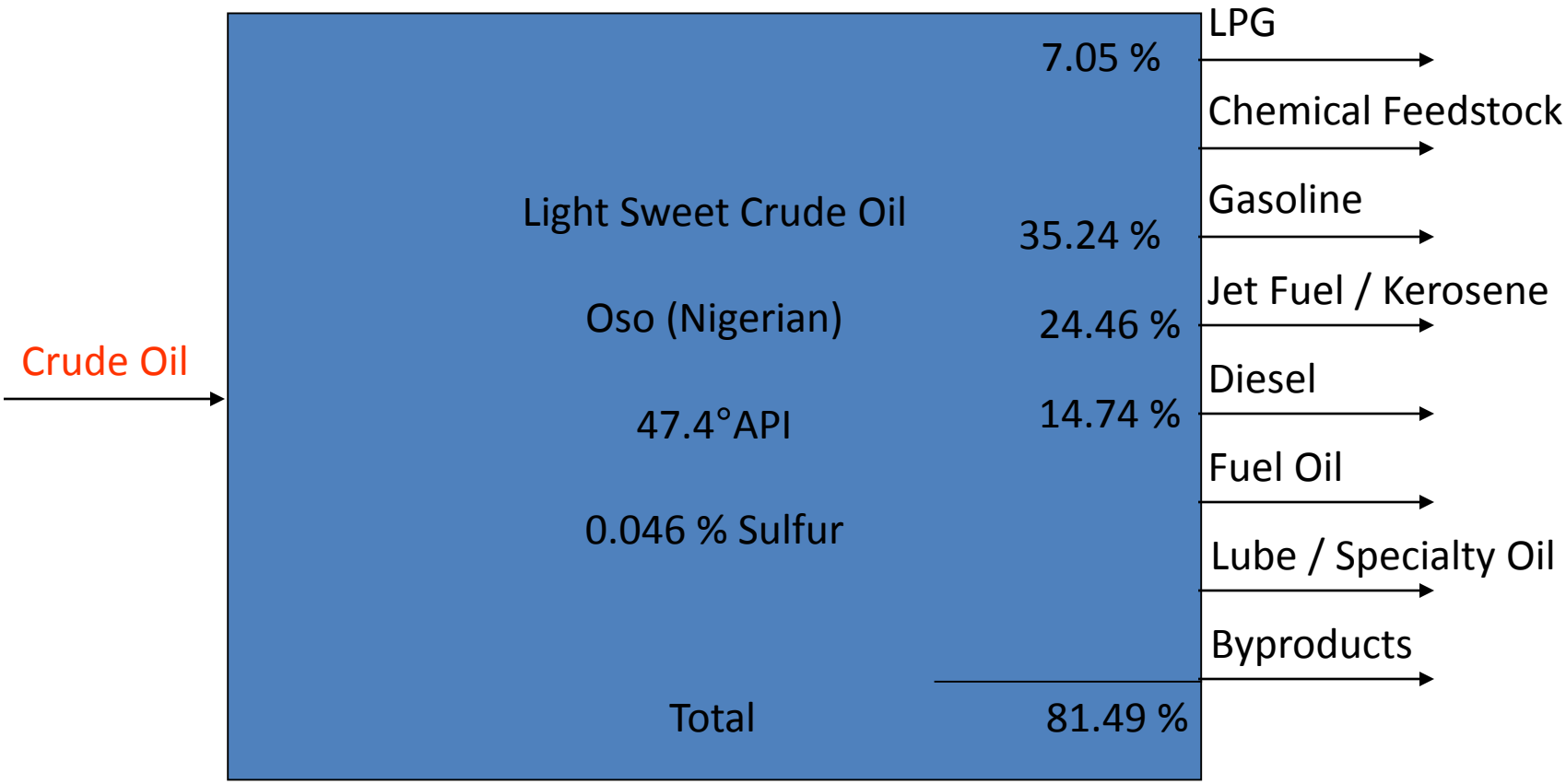
Crude Oil Boiling Point Curve



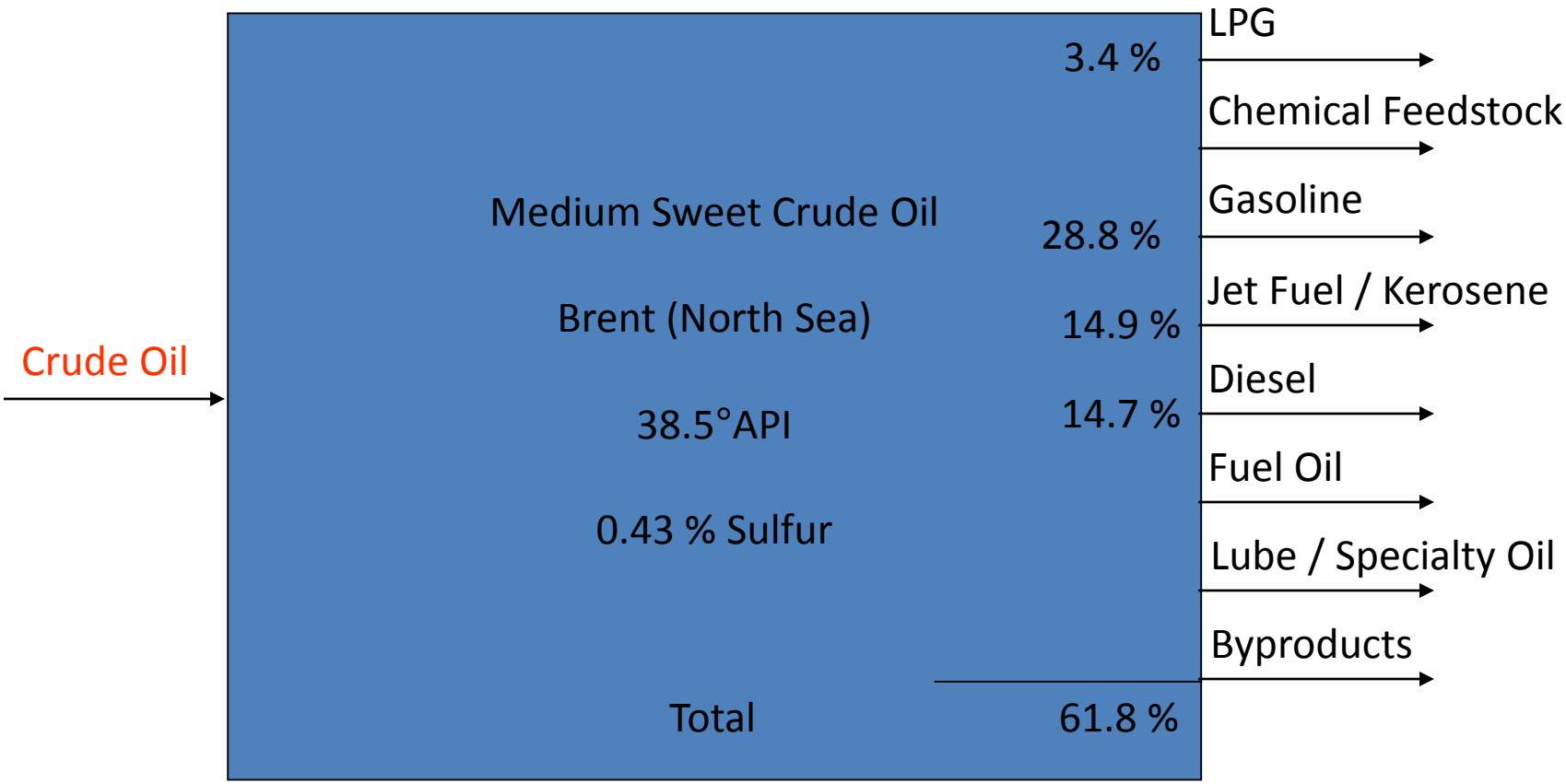
API Gravity

- API Gravity Is A Measure Of Crude Oil Density
- Higher API Gravity = Lower Density
- Lower API Gravity = Higher Density
- **Light Crudes** Are Greater Than 40° API
- **Medium Crudes** Are 20° To 40° API
- **Heavy Crudes** Are Less Than 20° API

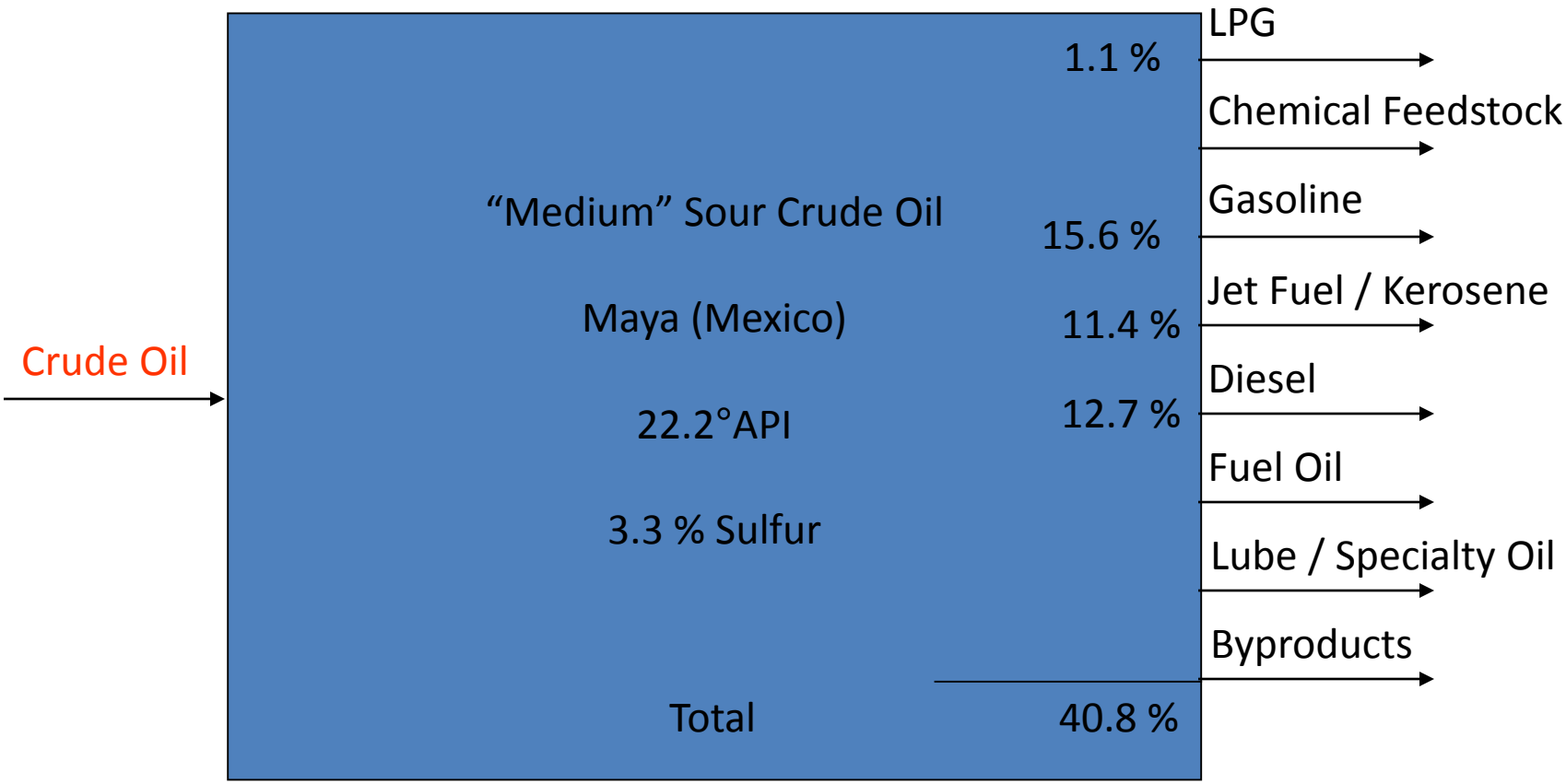
Light Sweet Crude



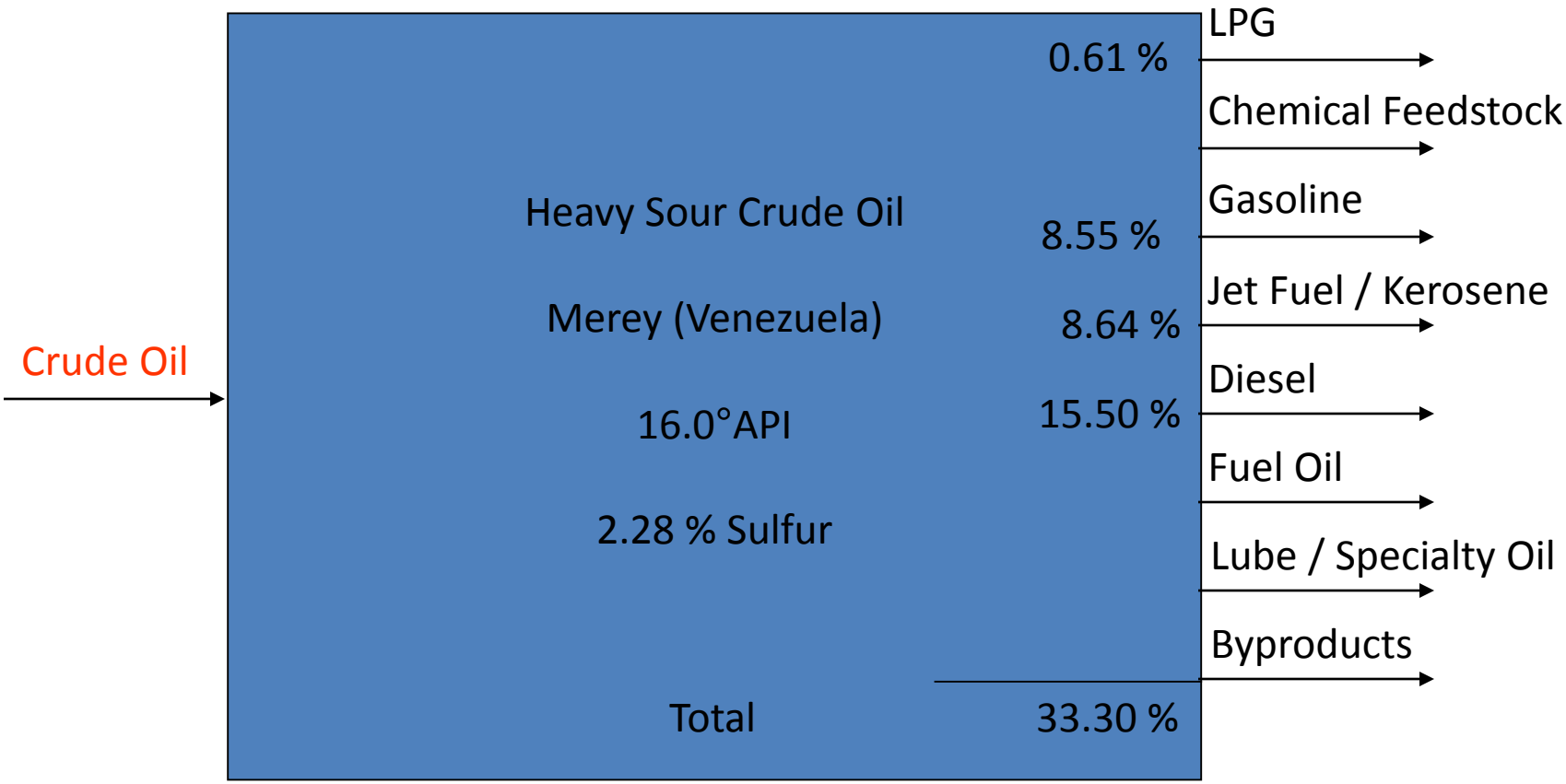
Medium Sweet Crude



Medium Sour Crude



Heavy Sour Crude



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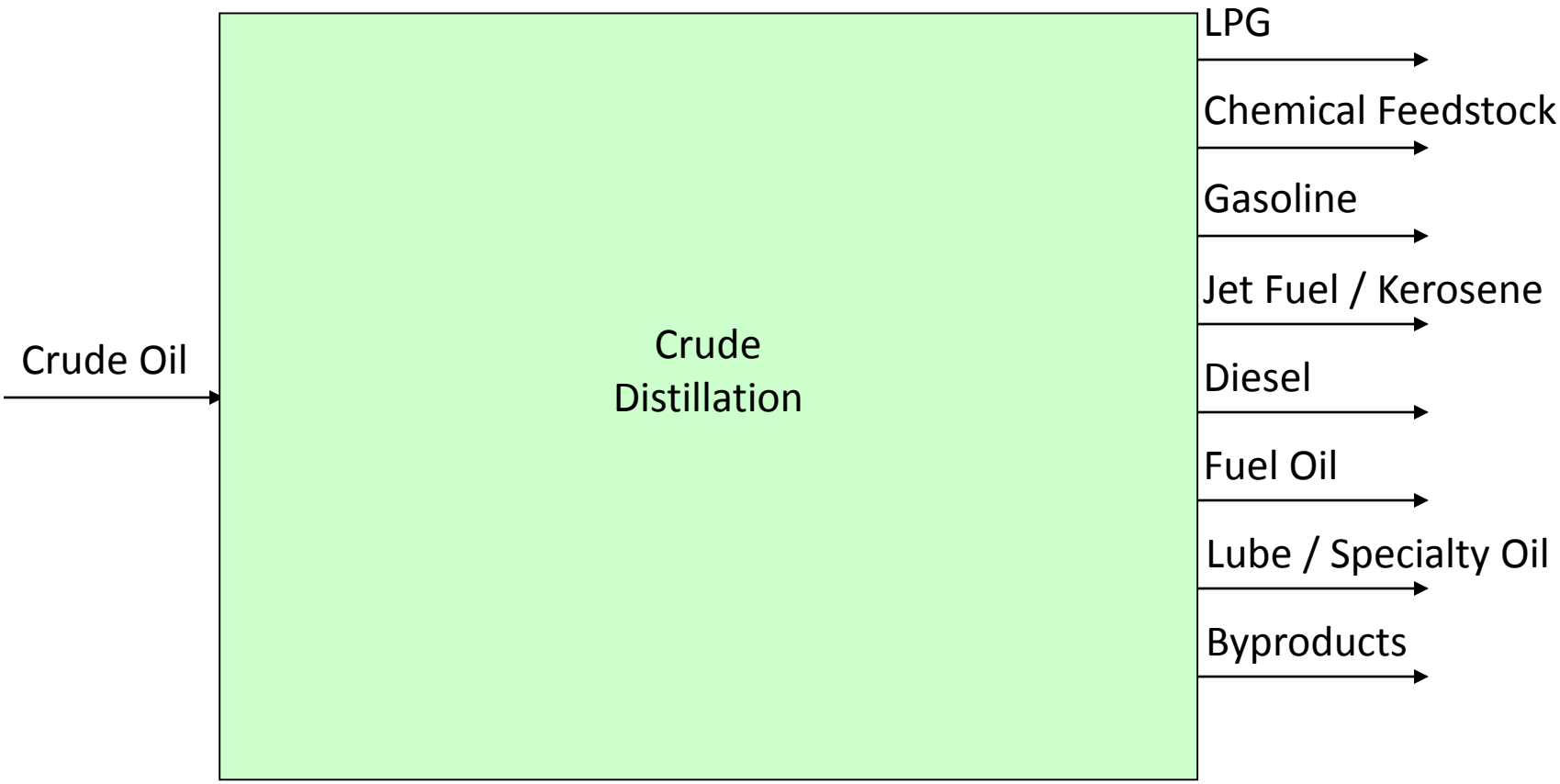
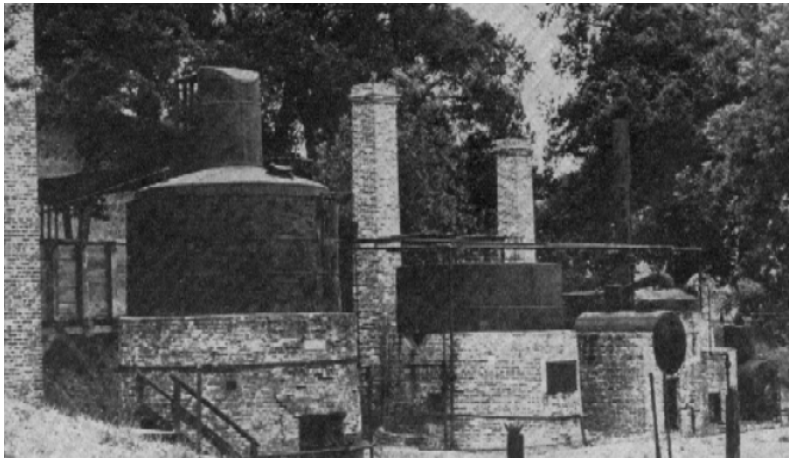
Crude Distillation

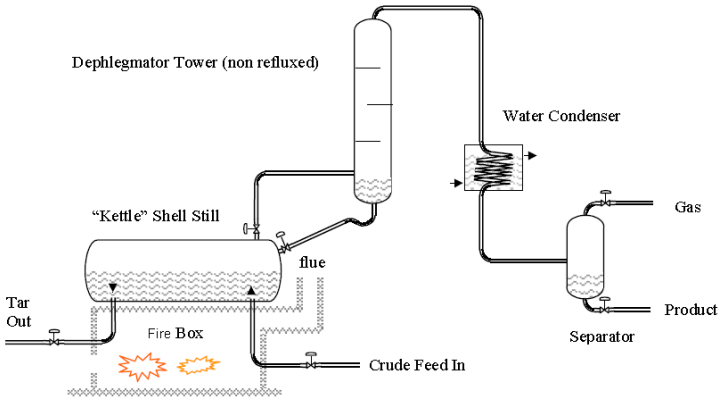
Crude Distillation



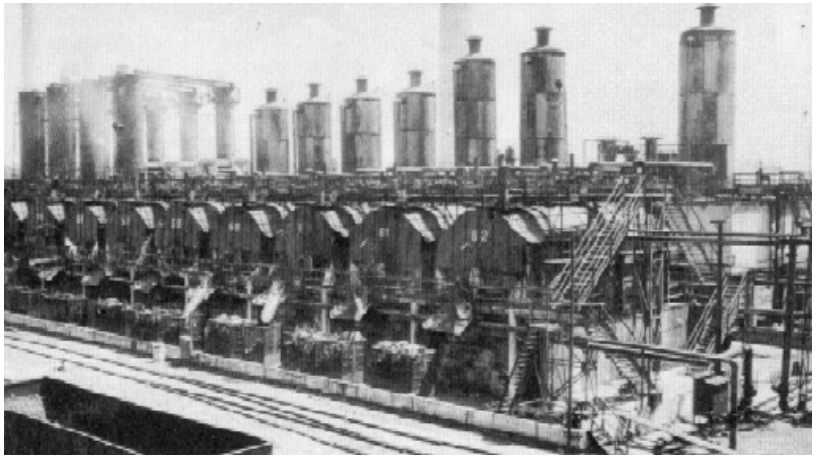
History Of Crude Distillation

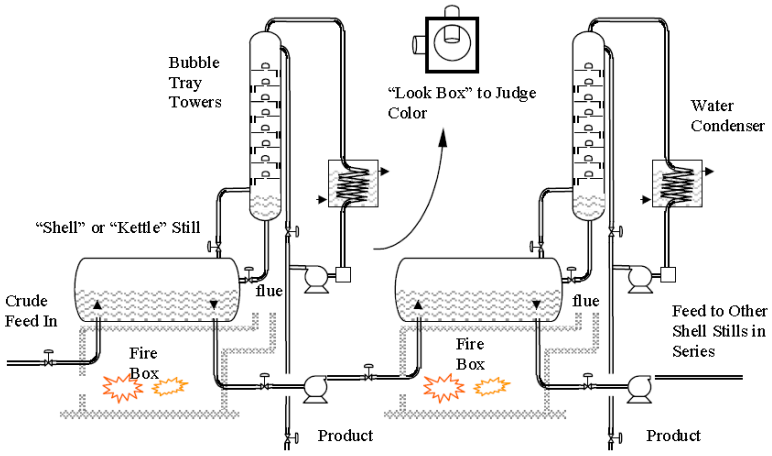
Batch Still
Late 1800's





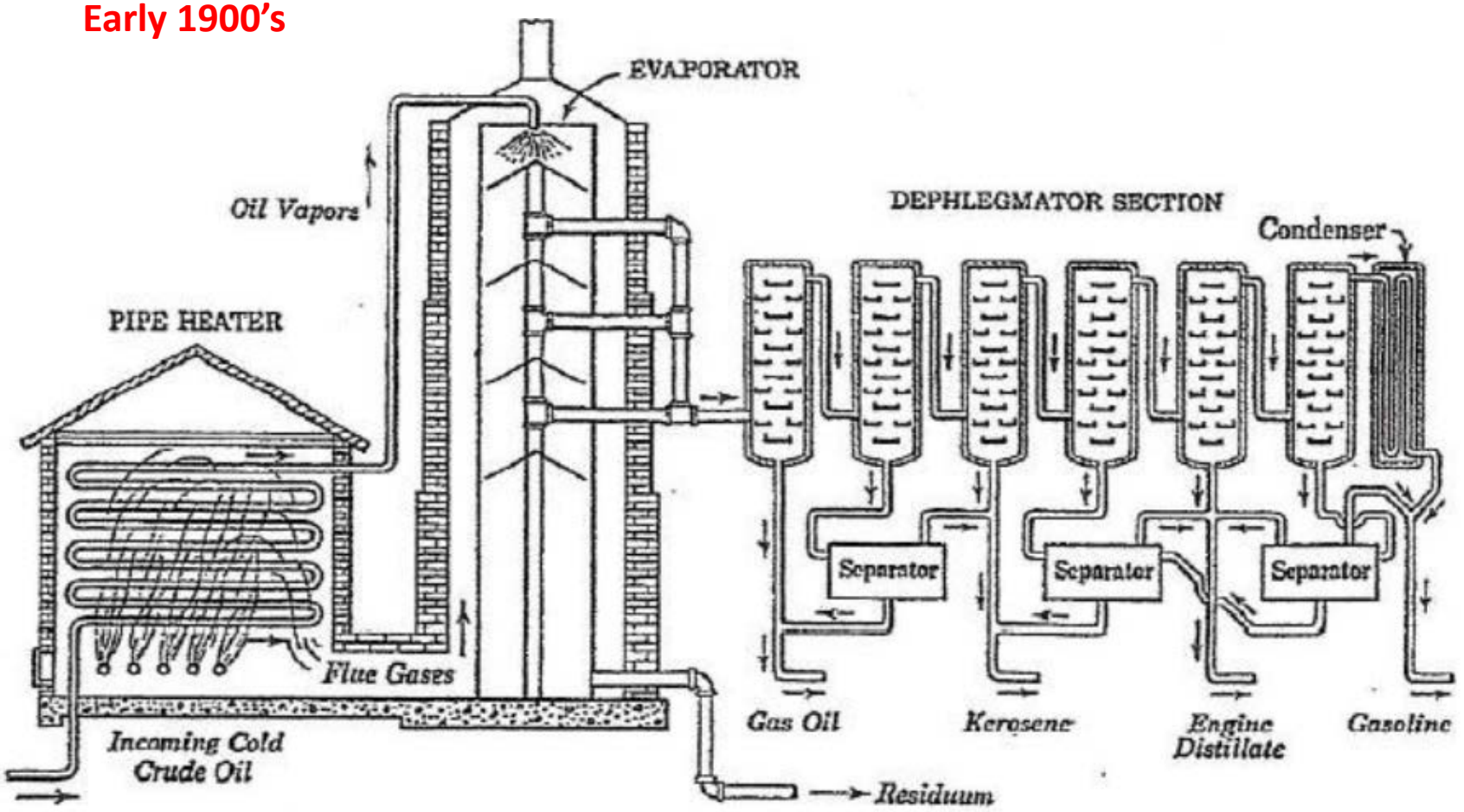
Continuous Bench Still
Early 1900's





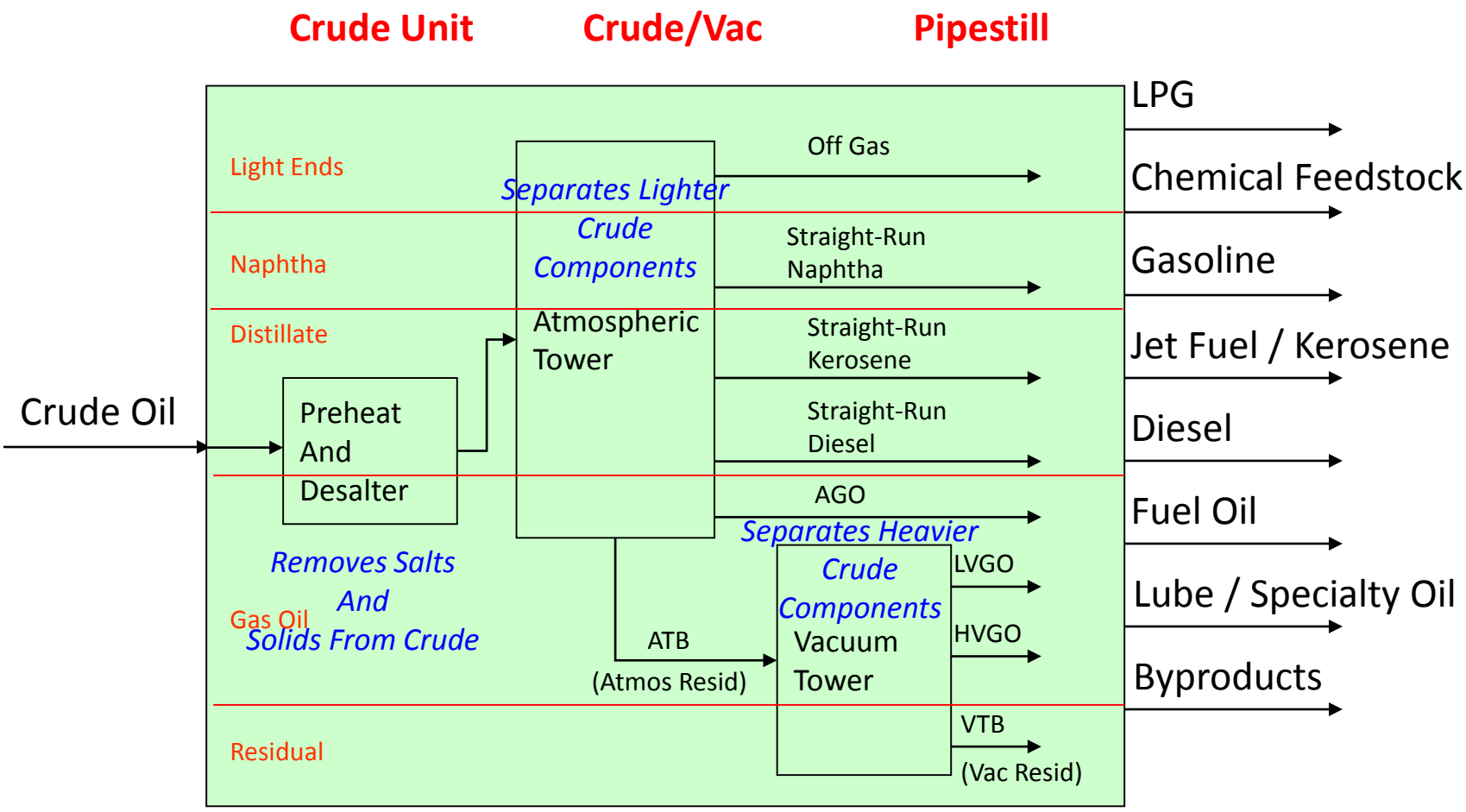
History Of Crude Distillation

Pipe Continuous Still
Early 1900's

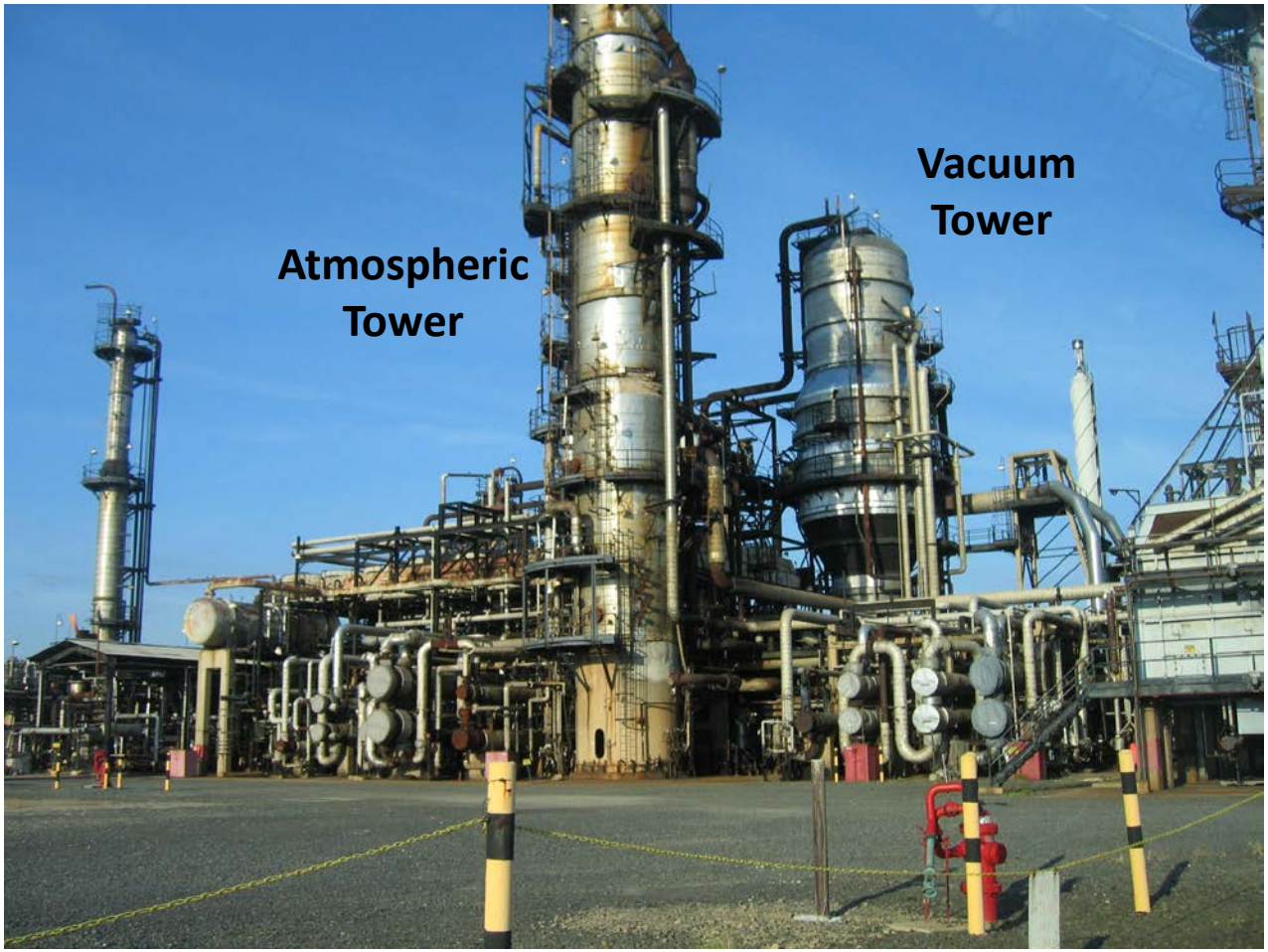


Trumble Process

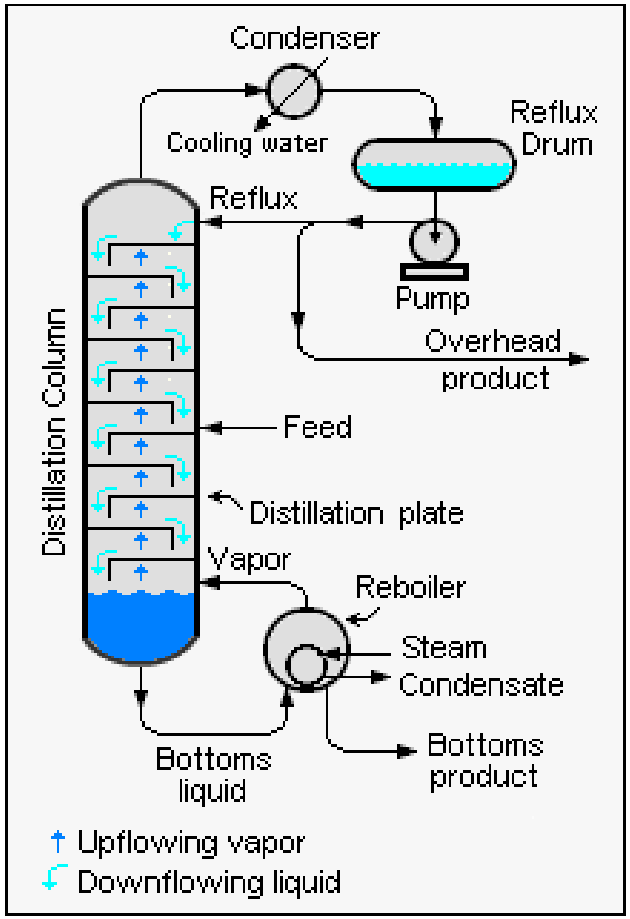
Crude Distillation



Crude Distillation

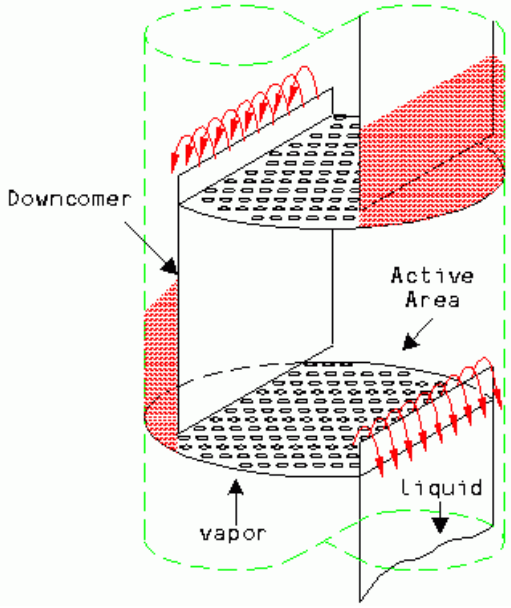


Distillation 101



Lower Boiling Temperature

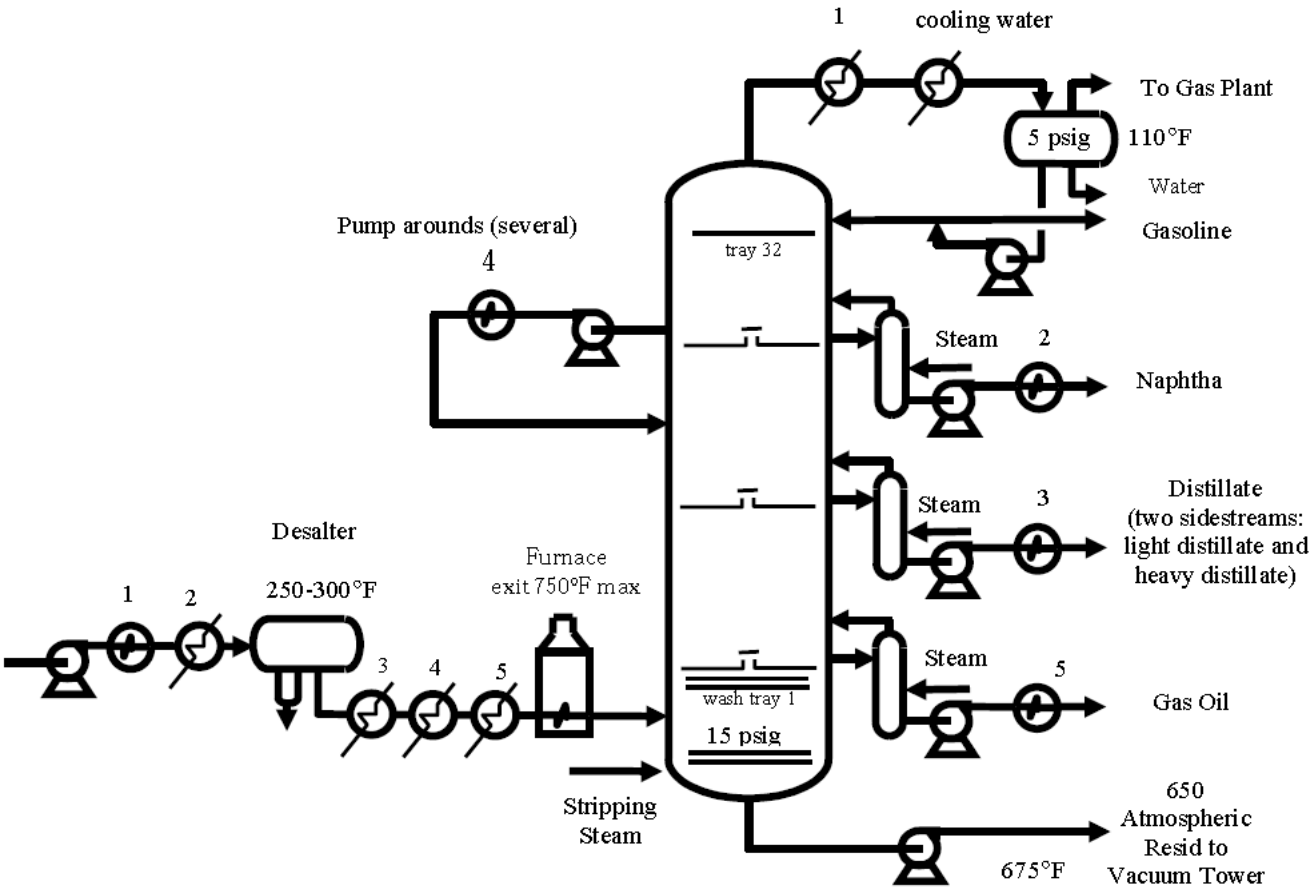
Lower Molecular Weight



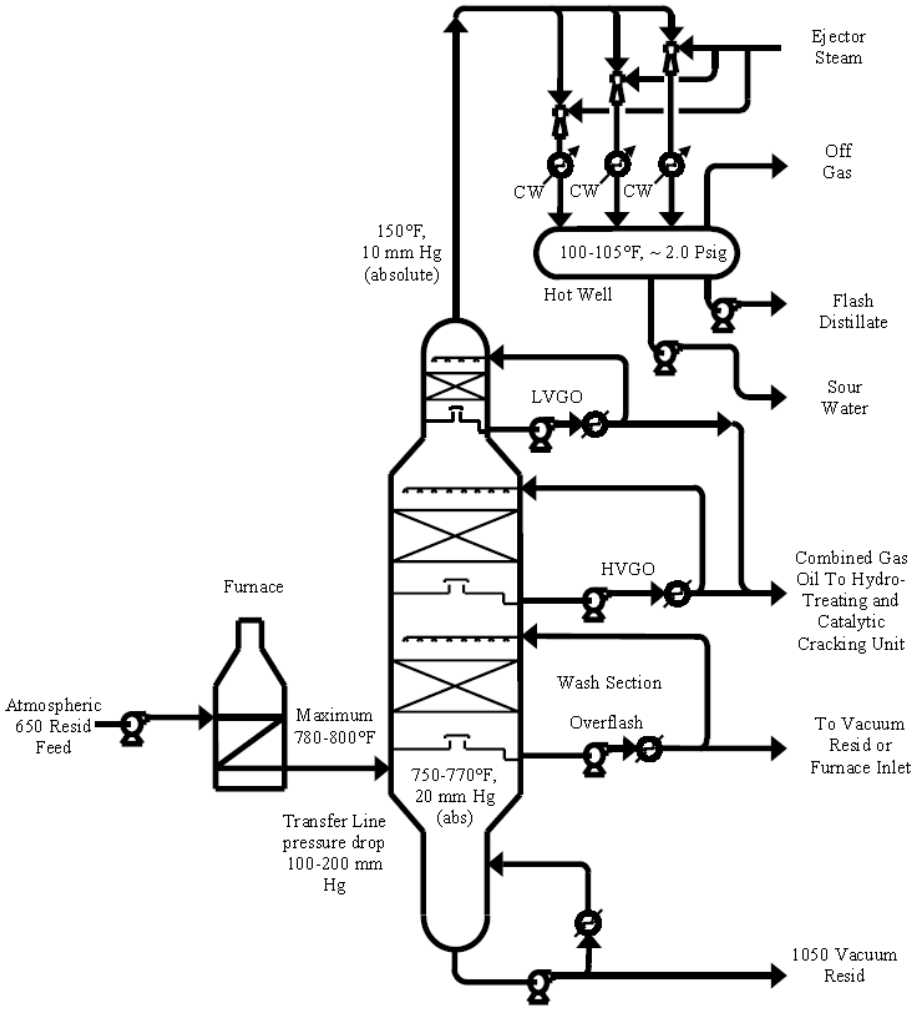
Higher Boiling Temperature

Higher Molecular Weight

Atmospheric Tower



Vacuum Tower



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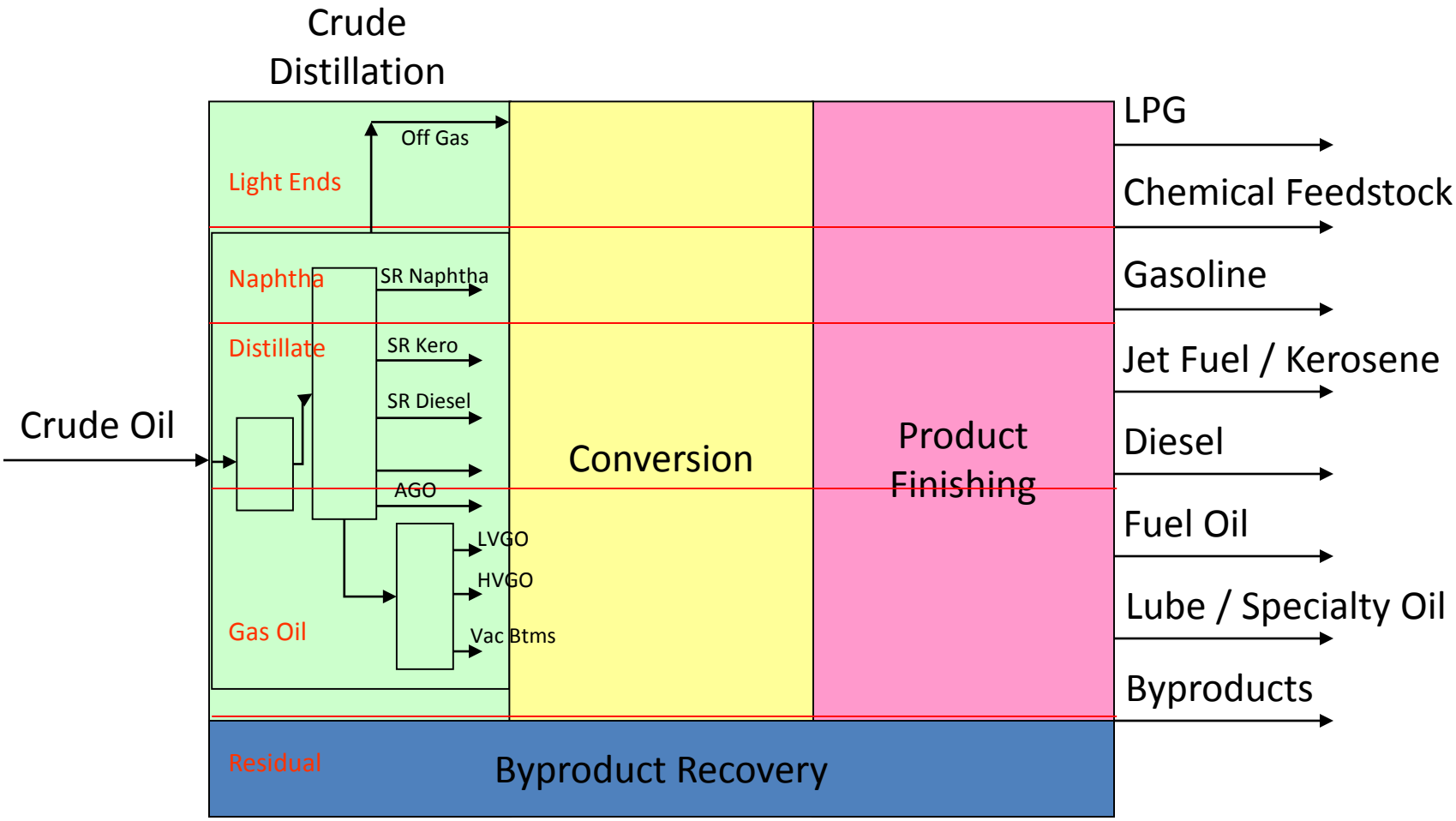
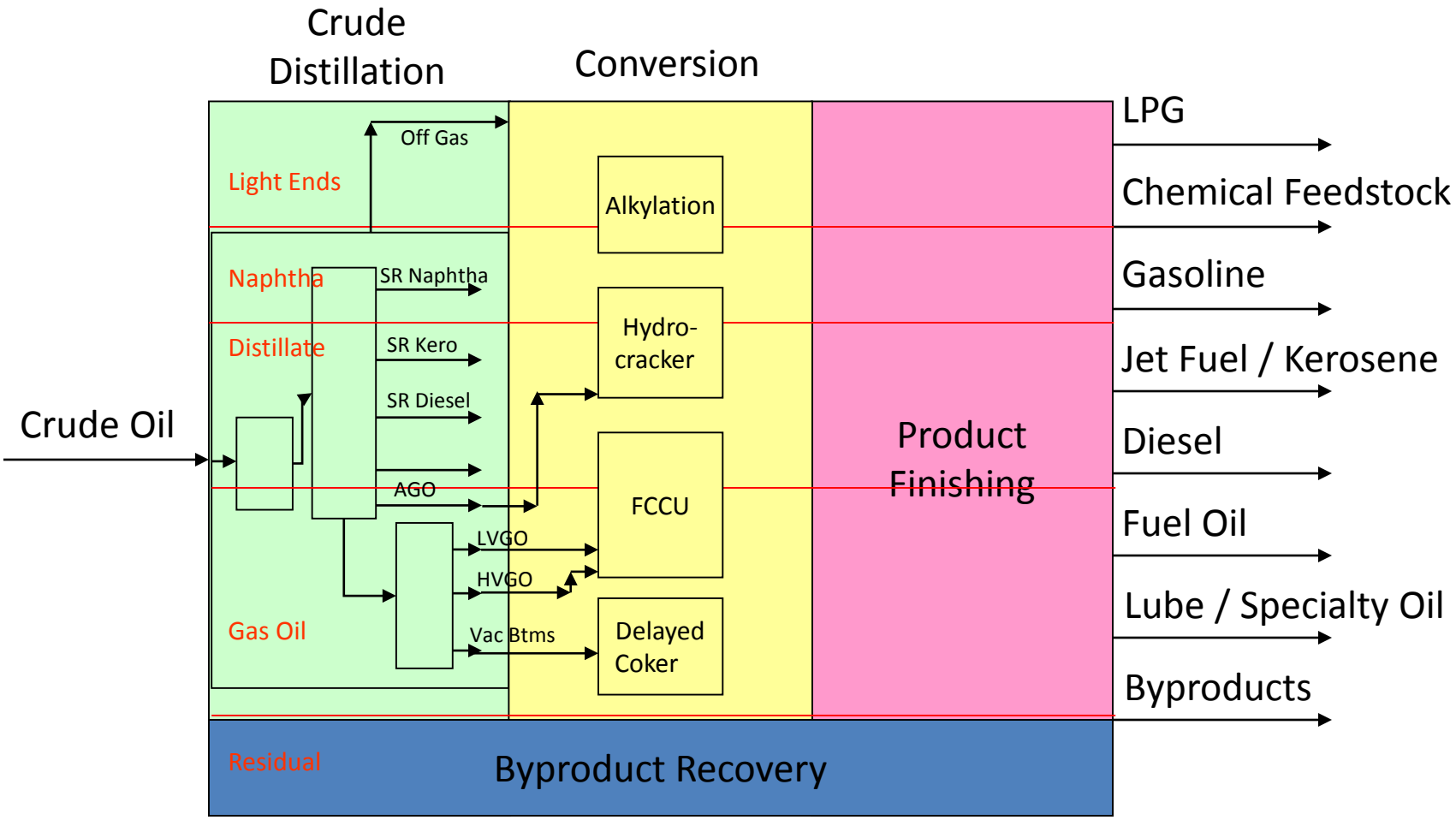
Conversion

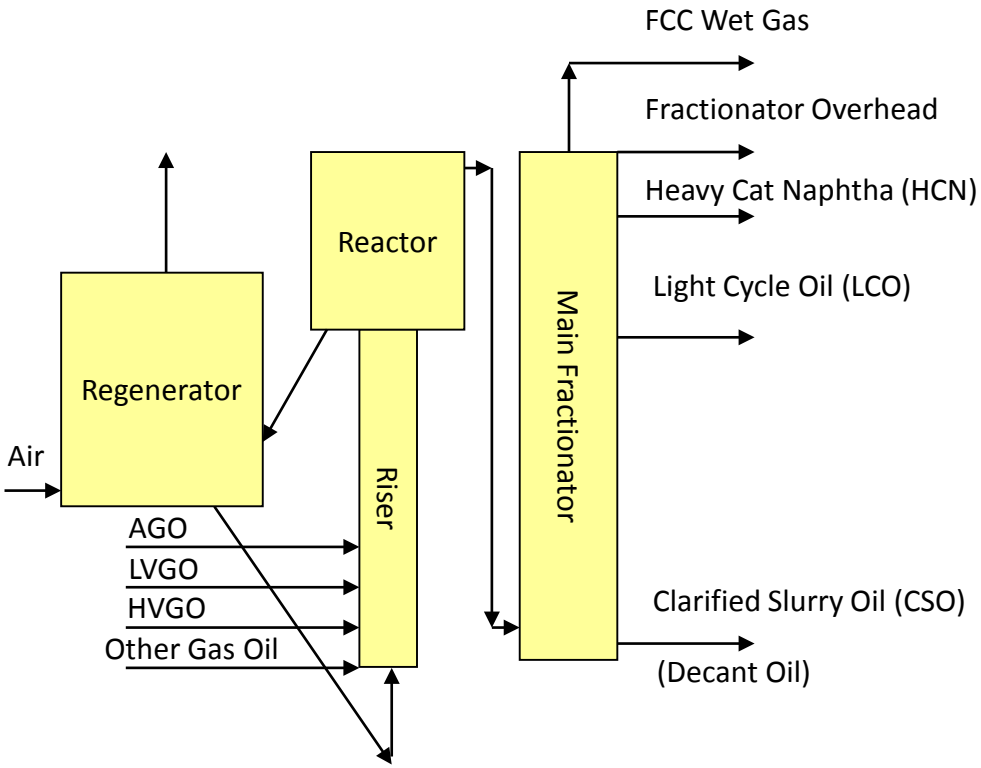
Crude Distillation



Conversion

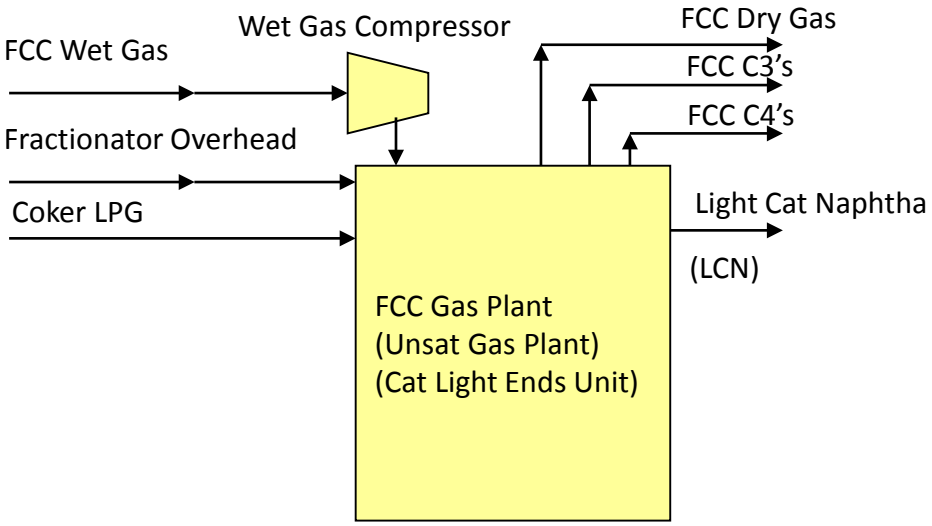

Crude Distillation
Conversion
Off Gas
Light Ends
Naphtha
SR Naphtha
Distillate
SR Kero
SR Diesel
AGO
Crude Oil
LVGO
HVGO
Gas Oil
Vac Btms
Residual
Alkylation
Hydro-cracker
FCCU
Delayed Coker
Product Finishing
Byproduct Recovery
LPG
Chemical Feedstock
Gasoline
Jet Fuel / Kerosene
Diesel
Fuel Oil
Lube / Specialty Oil
Byproducts

Fluidized Catalytic Cracking (FCC) Reaction - Regeneration



FCC Unit

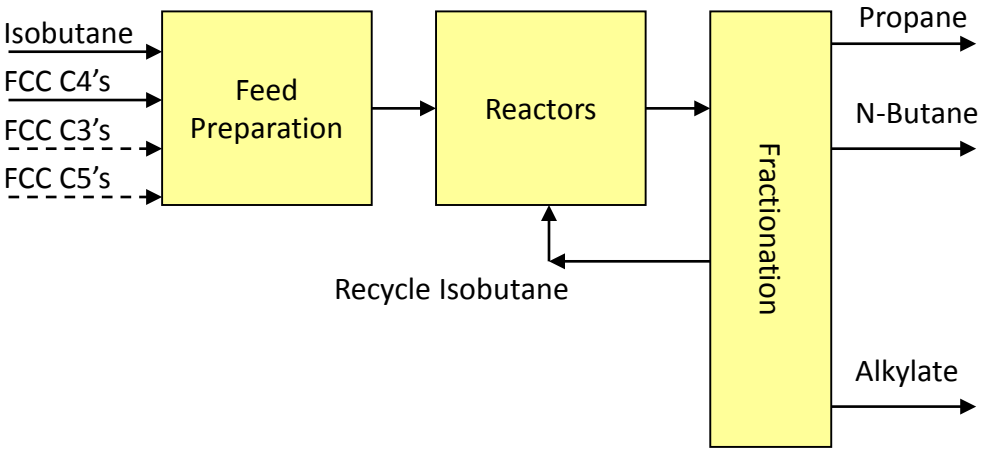
FCC Wet Gas



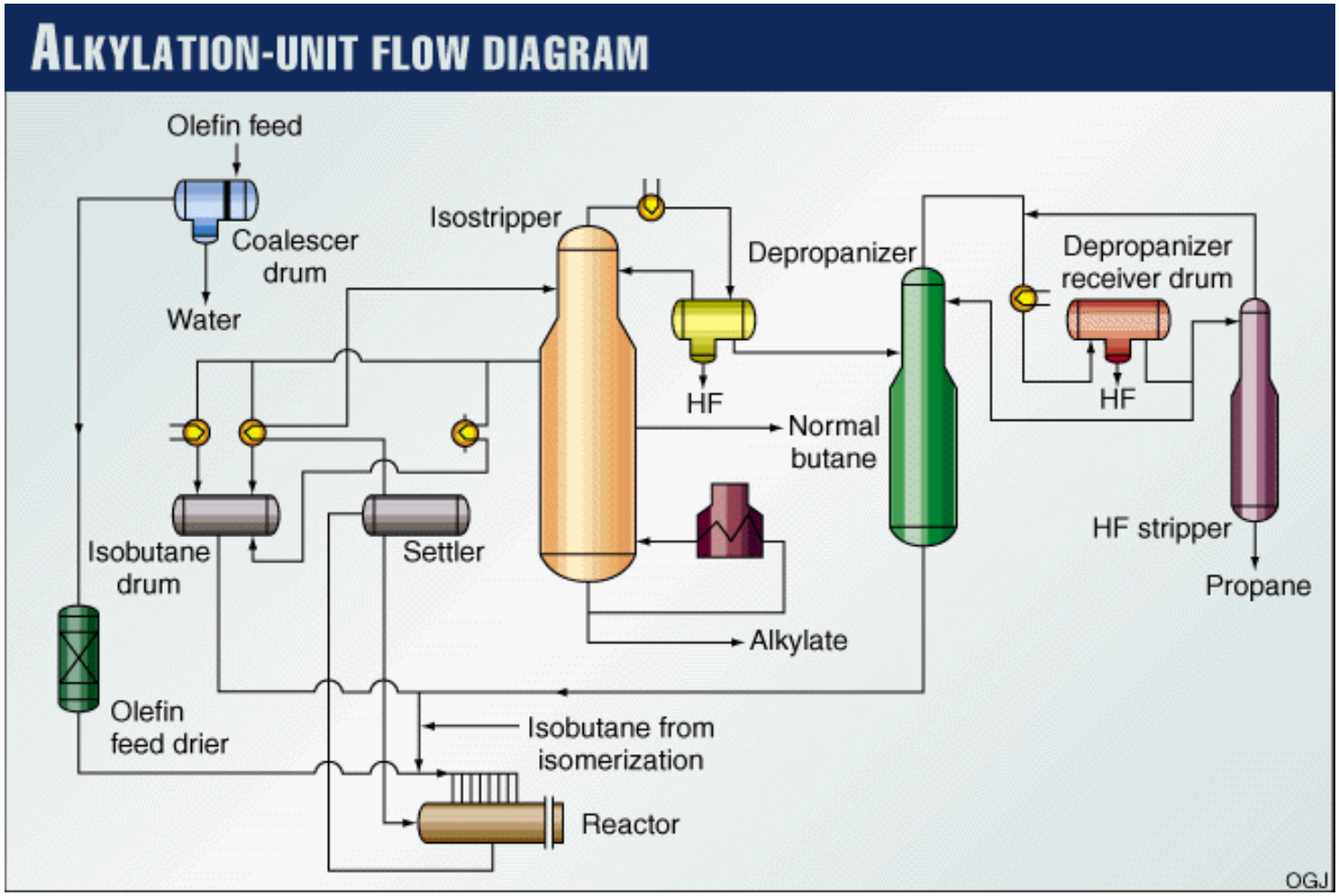
FCC C3's
P/P Olefins
C3 Olefins
Refinery Grade Propylene

FCC C4's
B/B Olefins
C4 Olefins
Refinery Butylenes

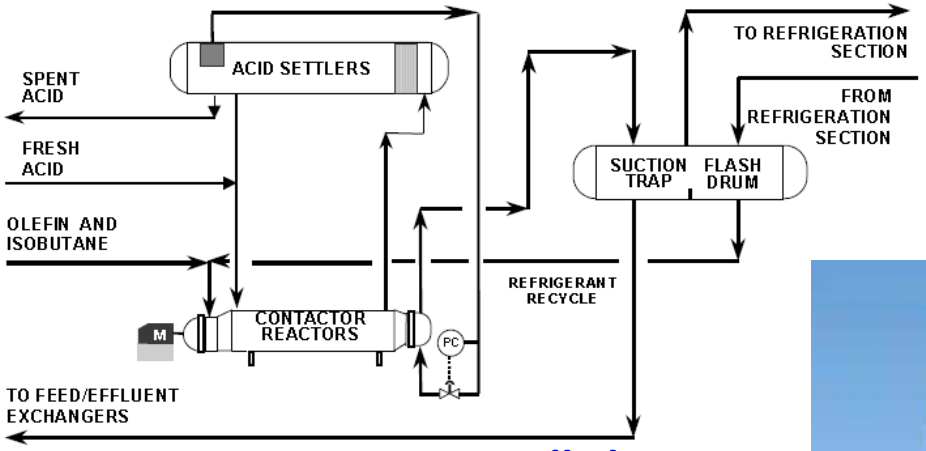
Alkylation


Isobutane
FCC C4's
FCC C3's
FCC C5's
Feed Preparation
Reactors
Fractionation
Propane
N-Butane
Alkylate
Recycle Isobutane

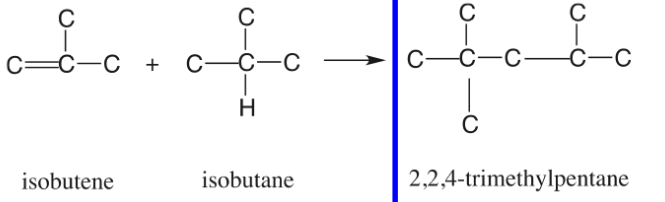
Alkylation

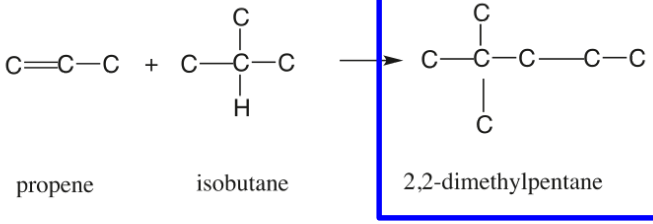

ALKYLATION-UNIT FLOW DIAGRAM
Olefin feed
Coalescer drum
Water
Isostripper
Depropanizer
Depropanizer receiver drum
HF
HF
Normal butane
Isobutane drum
Settler
HF stripper
Propane
Alkylate
Olefin feed drier
Isobutane from isomerization
Reactor
OGJ

Alkylation



Alkylates

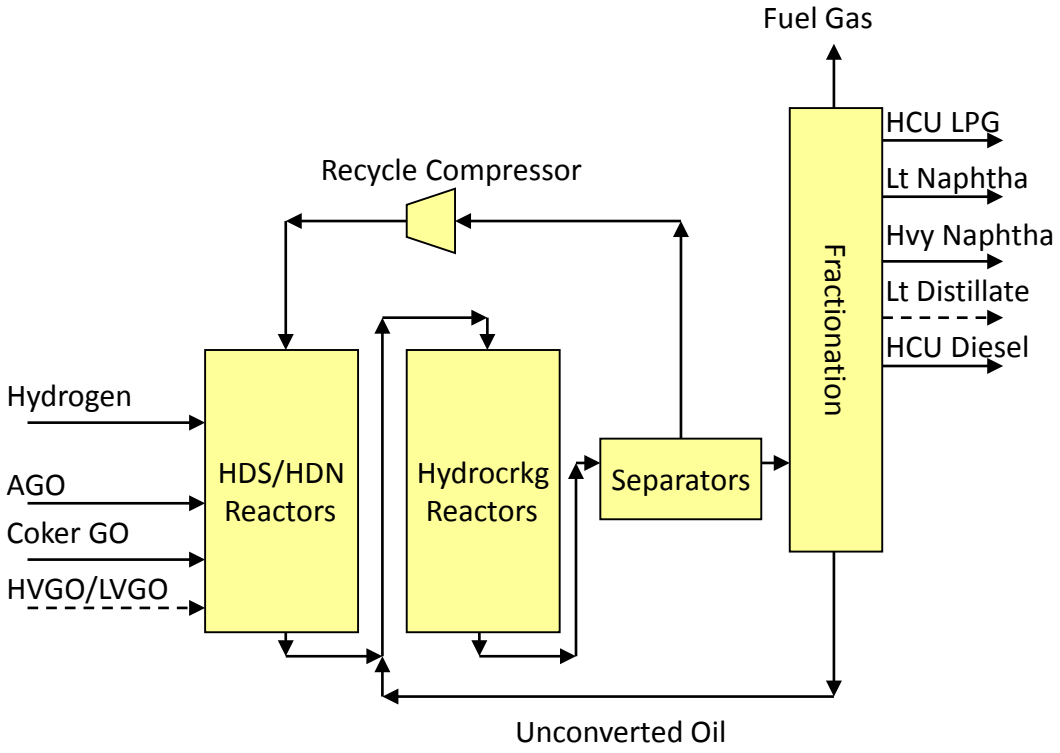




DuPont STRATCO

Full Conversion Hydrocracking

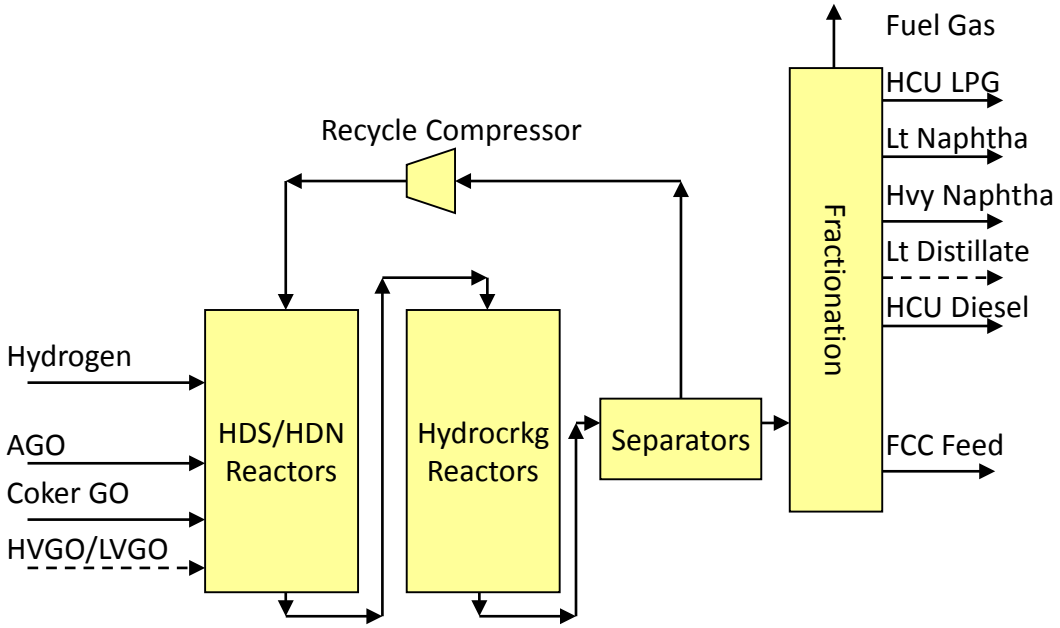
Full Conversion



Hydrocracker Naphtha = Hydrocrackate

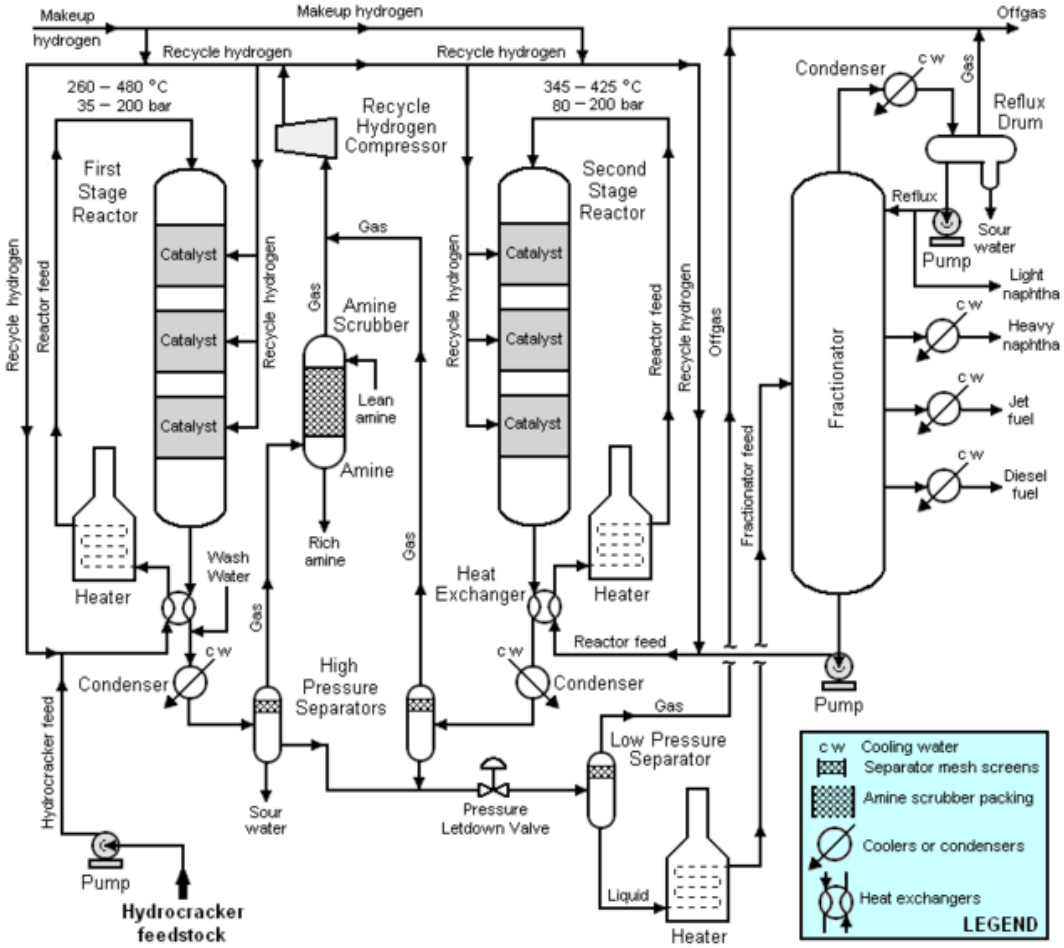
Partial Conversion Hydrocracking

Partial Conversion

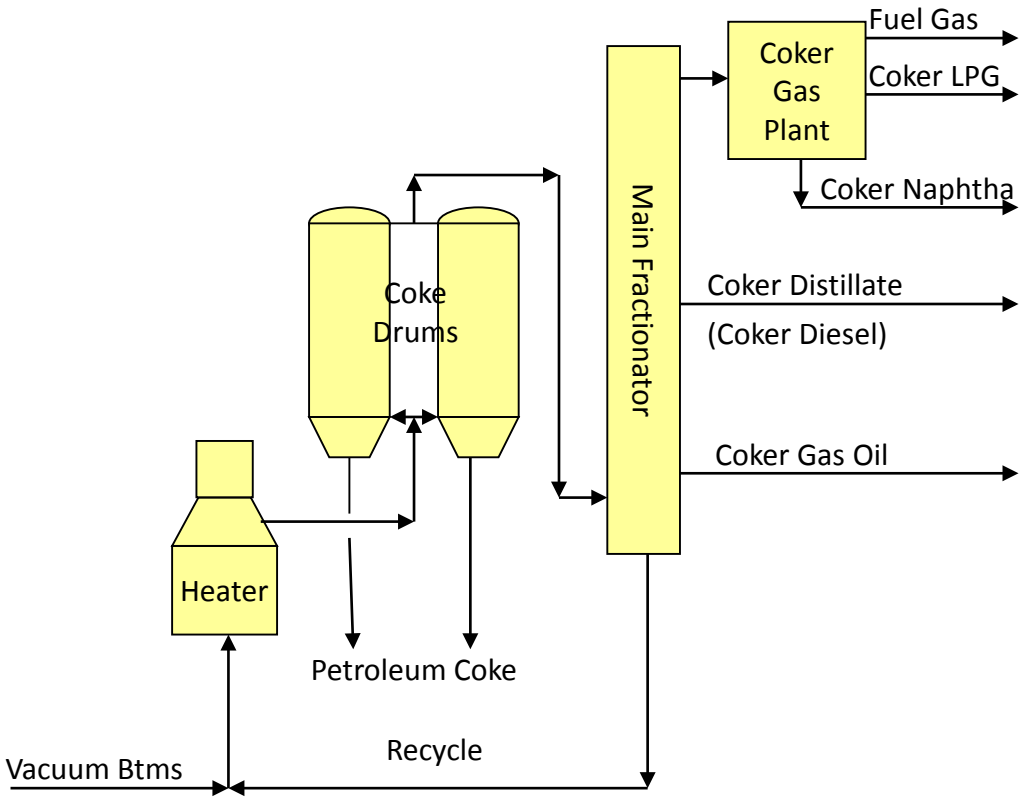


Hydrocracker Naphtha = Hydrocrackate

Hydrocracking



Delayed Coking



Delayed Coking

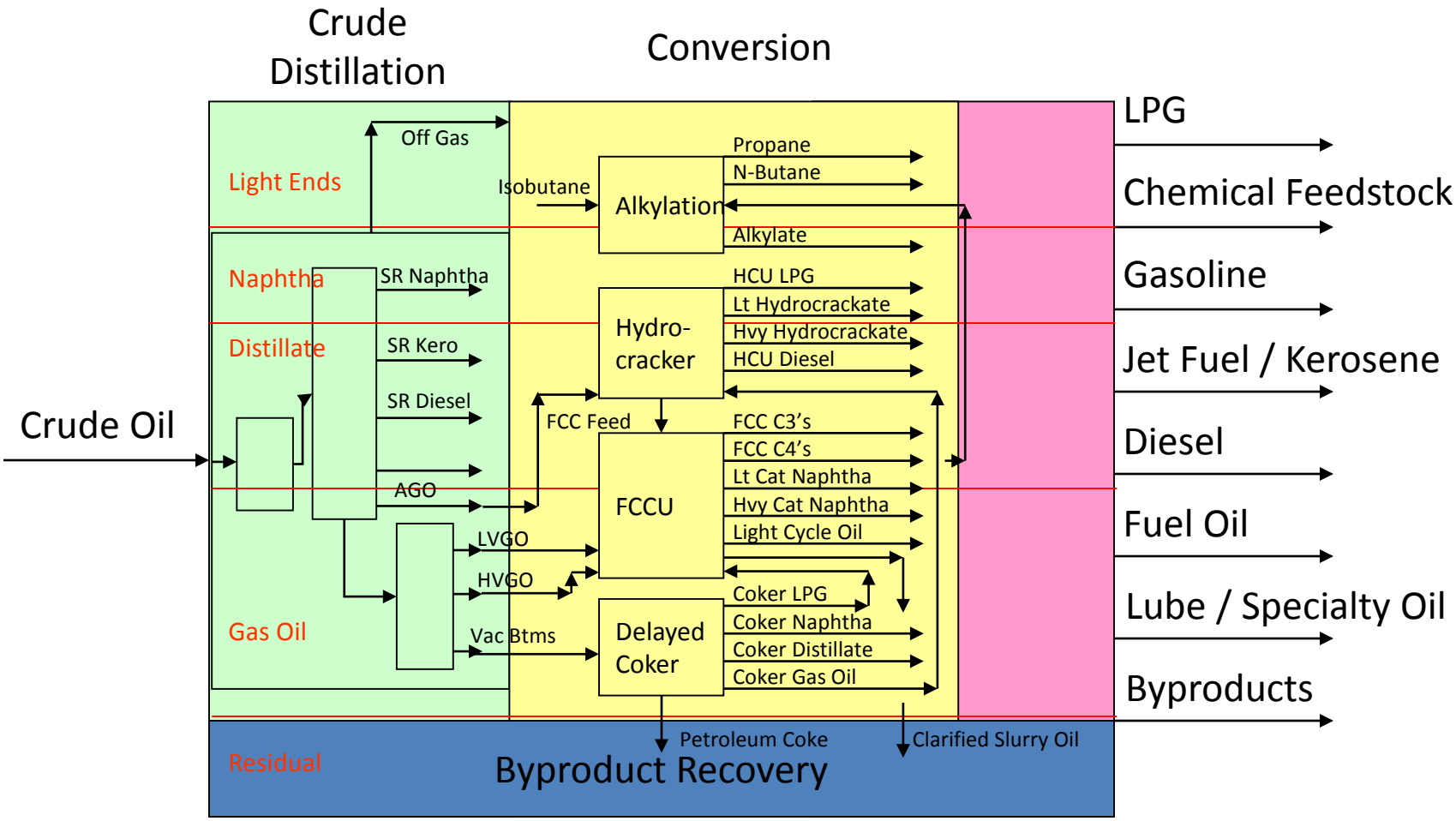
Derricks For Cutting Water

Coke Drums

Coke Pit

Feed Heaters

Conversion Overview



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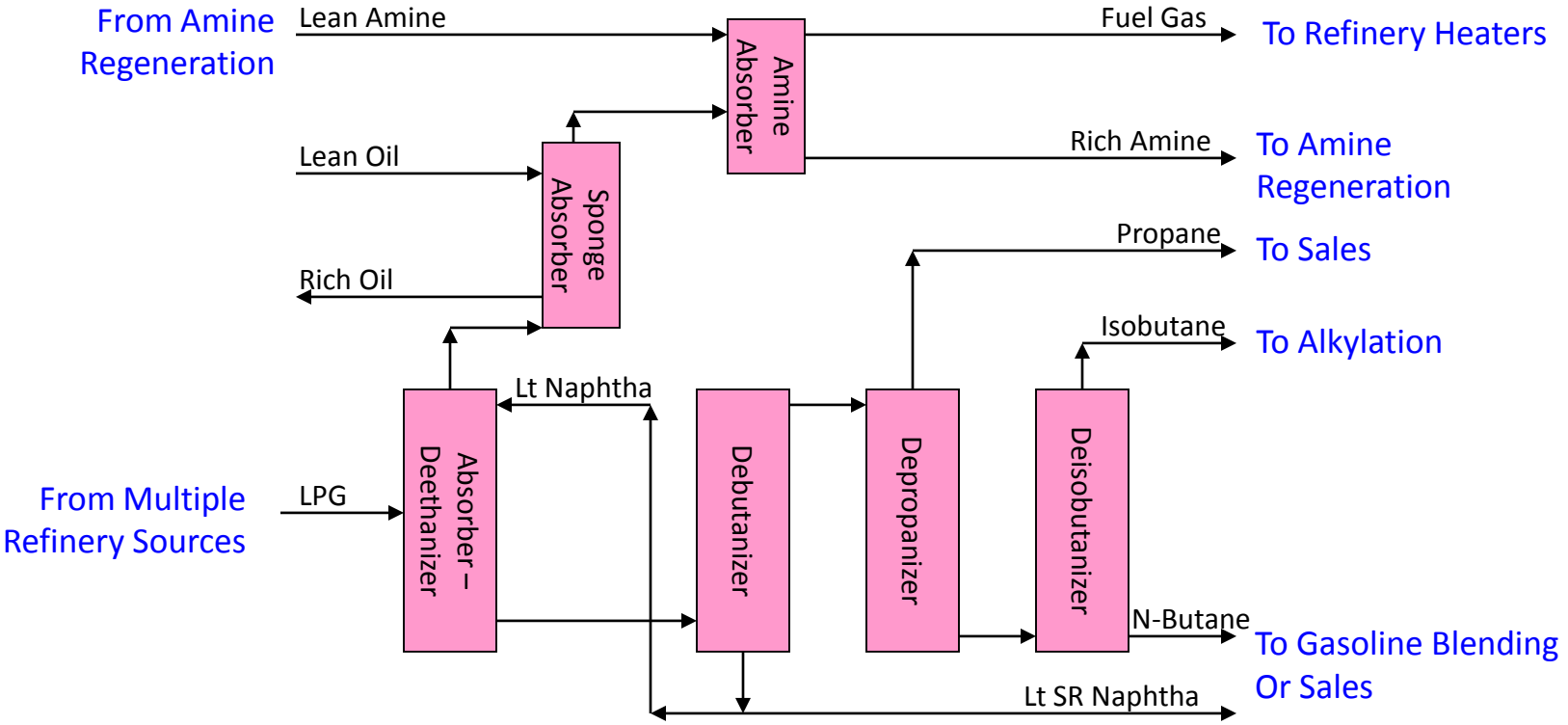
Product Finishing

Product Finishing

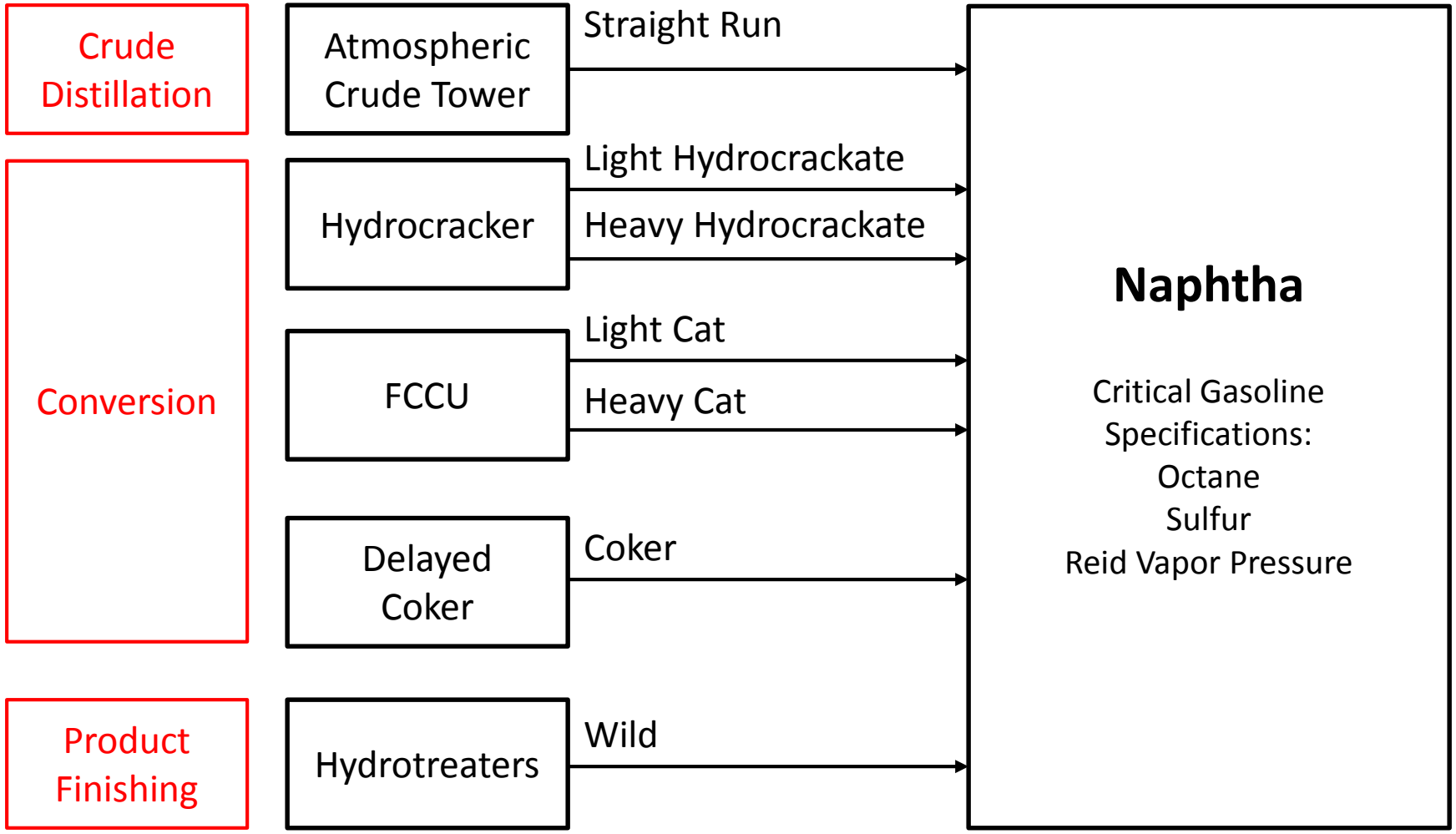
- **Light Ends** – Fuel Gas
- **Naphtha** – Gasoline
- **Distillates** – Kerosene, Jet Fuel, Diesel
- **Gas Oils** – Pre-/Post- Hydrotreating Before Converting to Gasoline (FCCU) Or Diesel (Hydrocracking)

Light Ends Processing

Saturate Gas Plant



Naphtha Processing

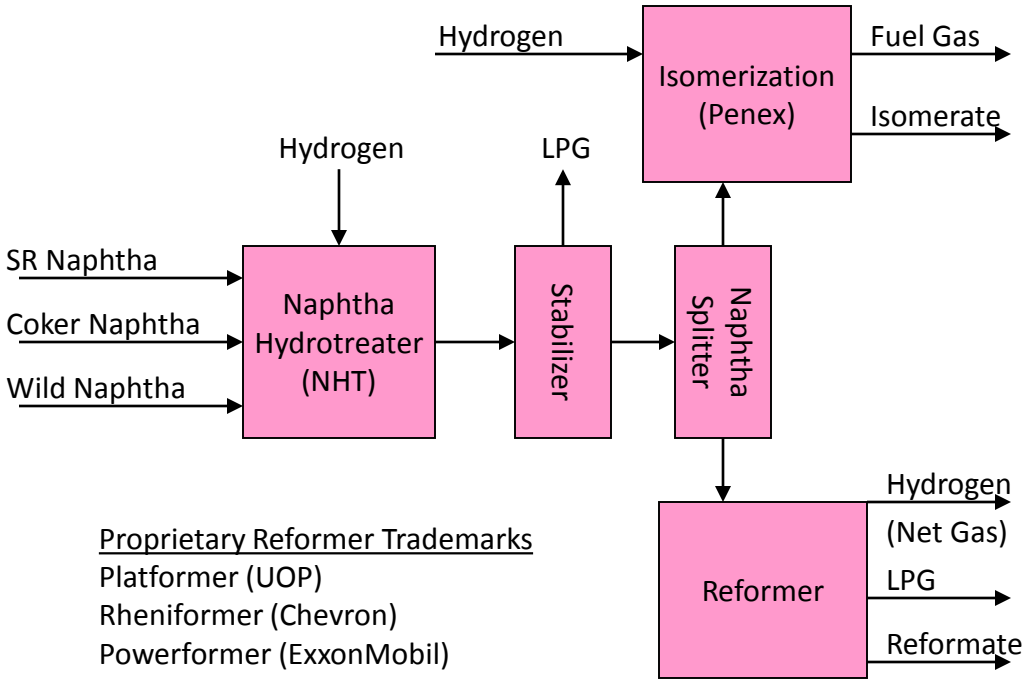


Naphtha Processing

	Octane	Sulfur	RVP
SR Naphtha →	Low	High	High
Coker Naphtha →	Medium	Very High	High
Wild Naphtha →	Very Low	Very High	Very High
Lt Hydrocrackate →	Medium	Very Low	High
Hvy Hydrocrackate →	Medium	Very Low	Low
Lt Cat Naphtha →	High	Medium	Medium
Hvy Cat Naphtha →	High	High	Low
Alkylate →	Very High	None	Low

Naphtha Processing

SR/Coker/Wild



Stabilize – Reduce RVP

Hydrotreat – Remove Sulfur and Olefins

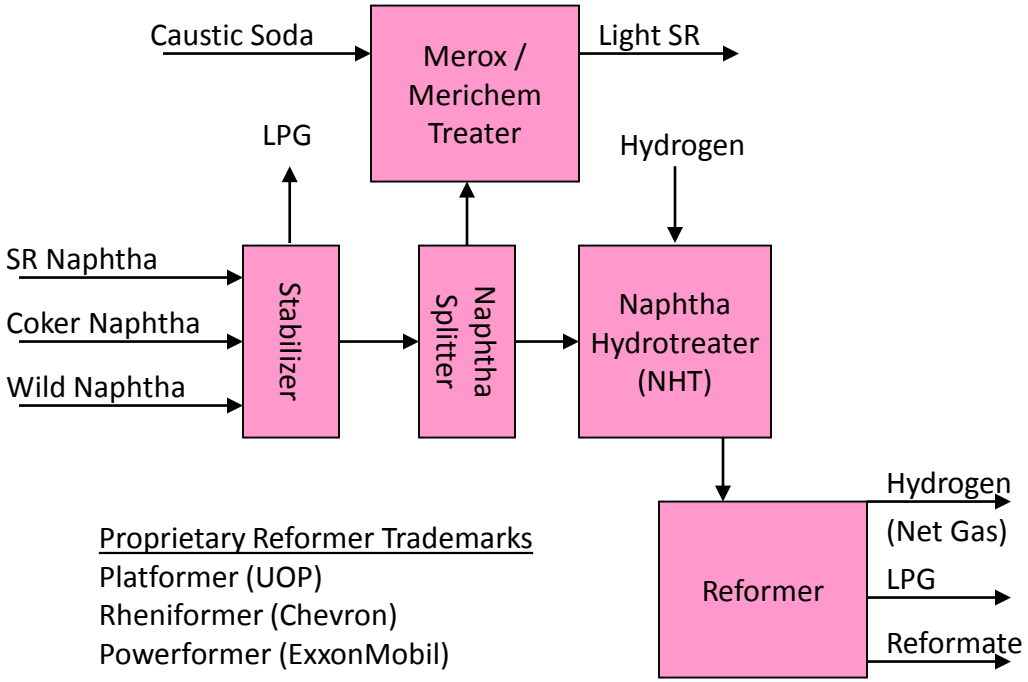
Split – Separate Light And Heavy SR

Reform – Boost Heavy SR Octane

Isomerize – Boost Light SR Octane

Naphtha Processing

SR/Coker/Wild



Stabilize – Reduce RVP

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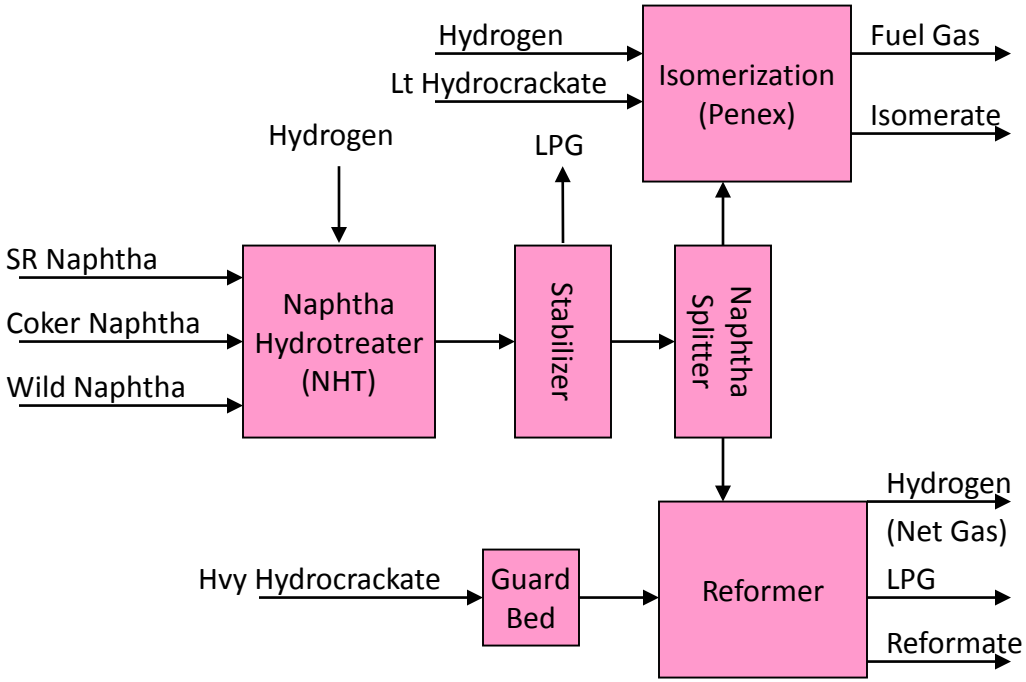
Reform – Boost Heavy SR Octane

Isomerize – Boost Light SR Octane

Naphtha Processing

SR/Coker/Wild



Stabilize – Reduce RVP

Hydrotreat – Remove Sulfur and Olefins

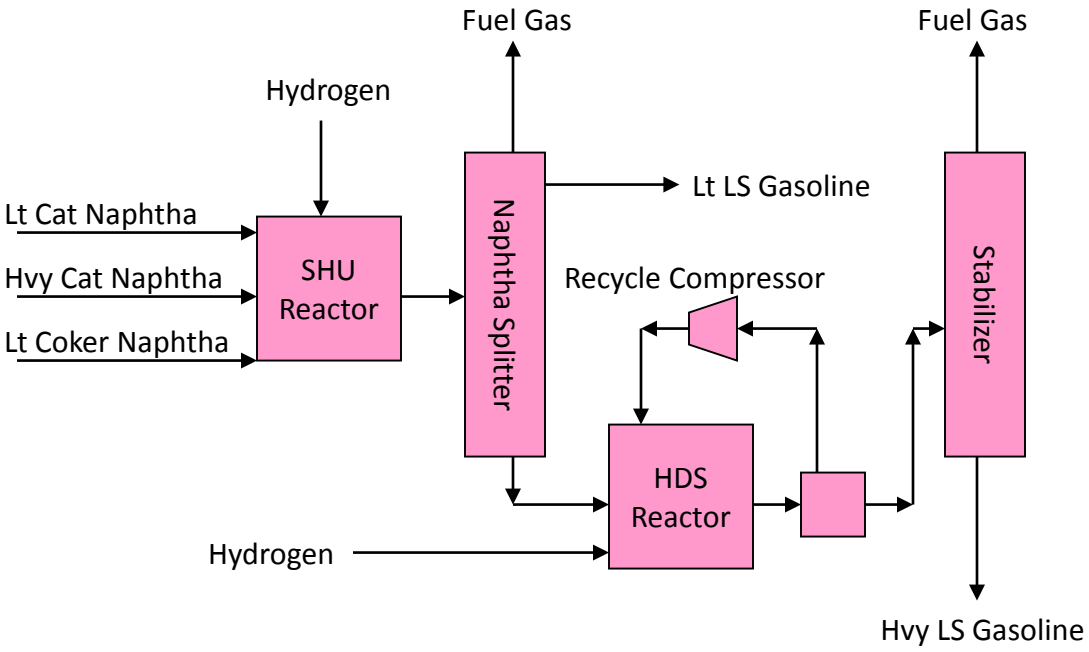
Split – Separate Light And Heavy SR

Reform – Boost Heavy SR Octane

Isomerize – Boost Light SR Octane

Naphtha Processing

Lt Cat/Hvy Cat/Lt Coker



Remove Diolefins (Gum-Formers)

Remove Mercaptans (Sulfur)

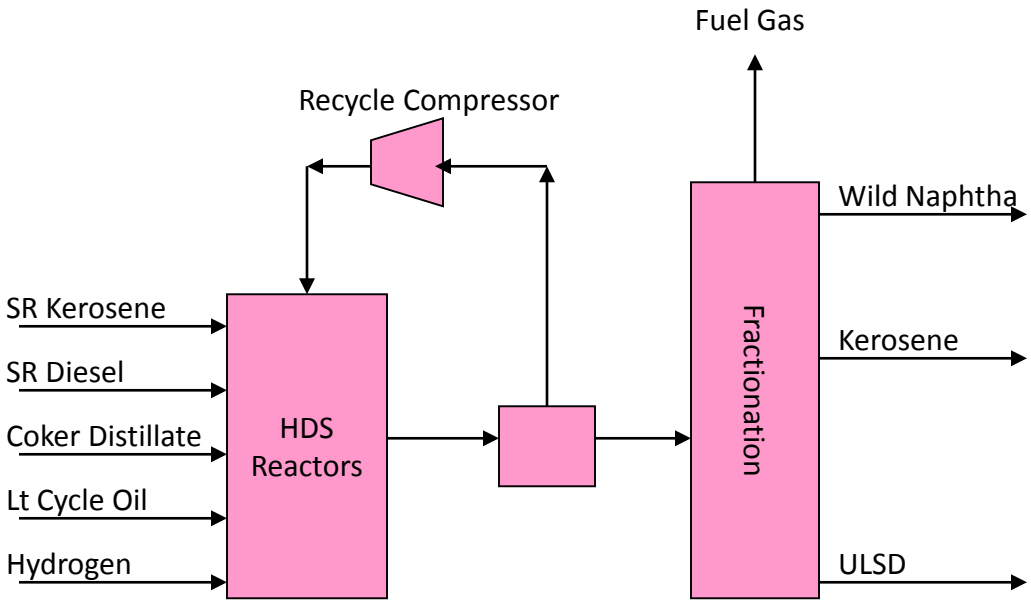
Split to Maximize Light Cat Naphtha Octane

Hydrotreat But Minimize Olefin Saturation

Stabilize To Decrease Gasoline RVP

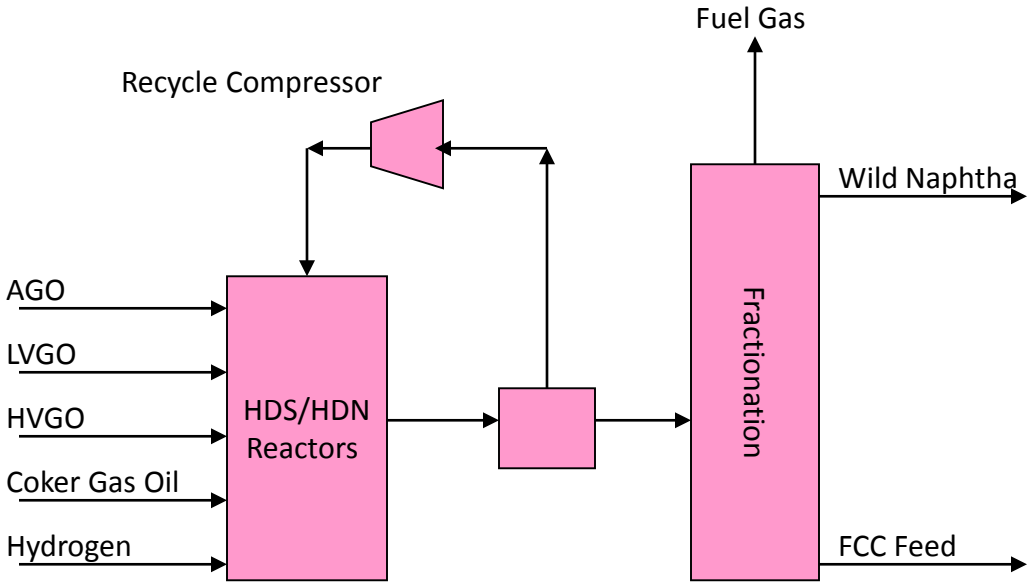
Distillate Processing

Distillate Hydrotreater (DHT)



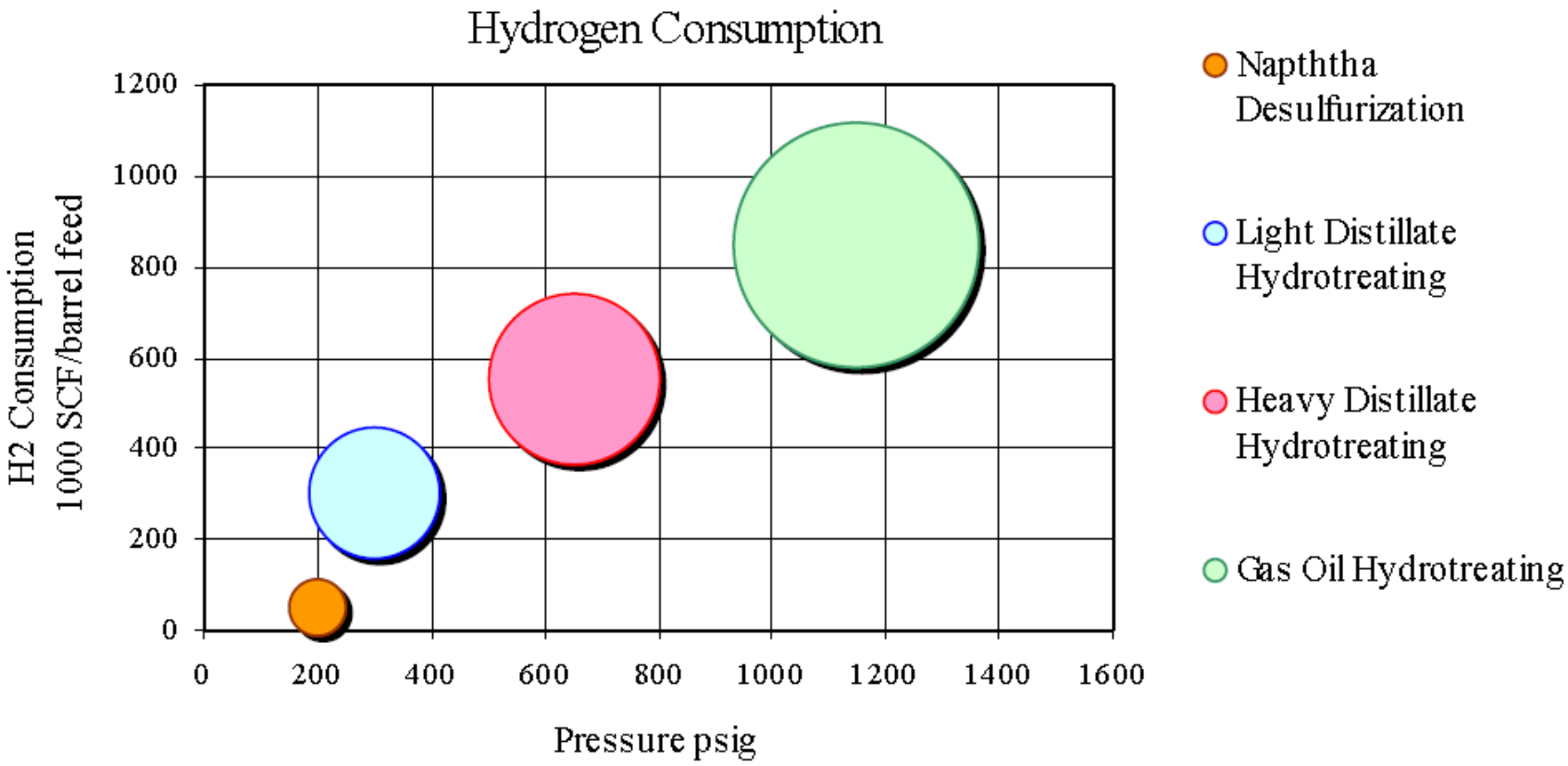
Gas Oil Processing

Gas Oil Hydrotreater (GOHT)



Hydrotreating Gas Oil Before FCCU Avoids Hydrotreating Separate FCCU Products

Hydrotreating H_2 Consumption



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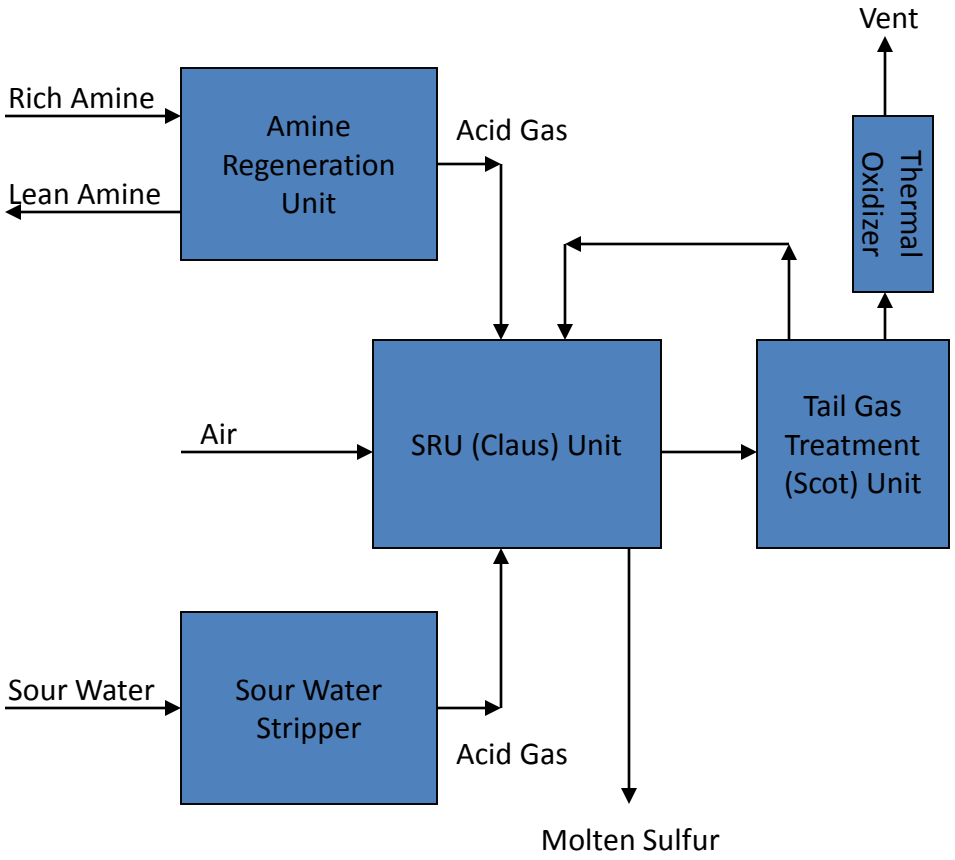
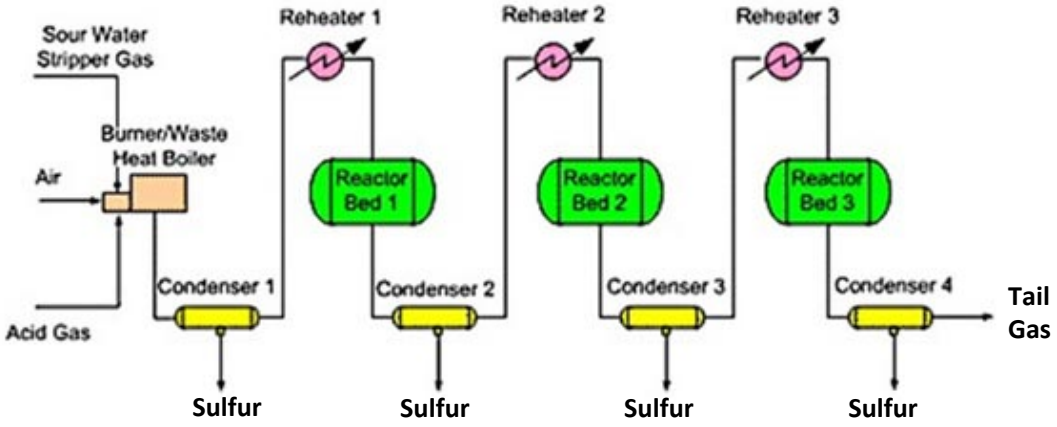
Byproduct Recovery

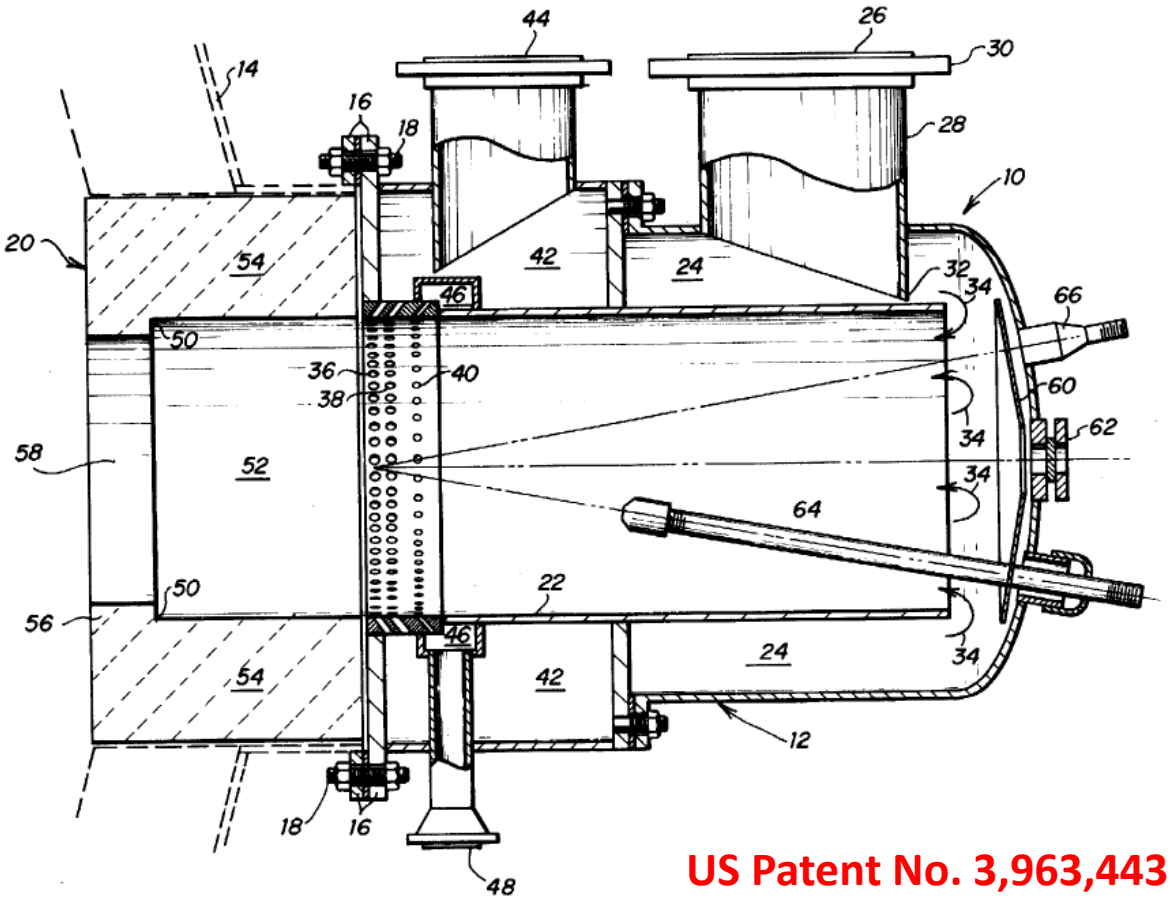
Sulfur Recovery Complex



Claus Sulfur Unit



FBD Acid Gas Burner



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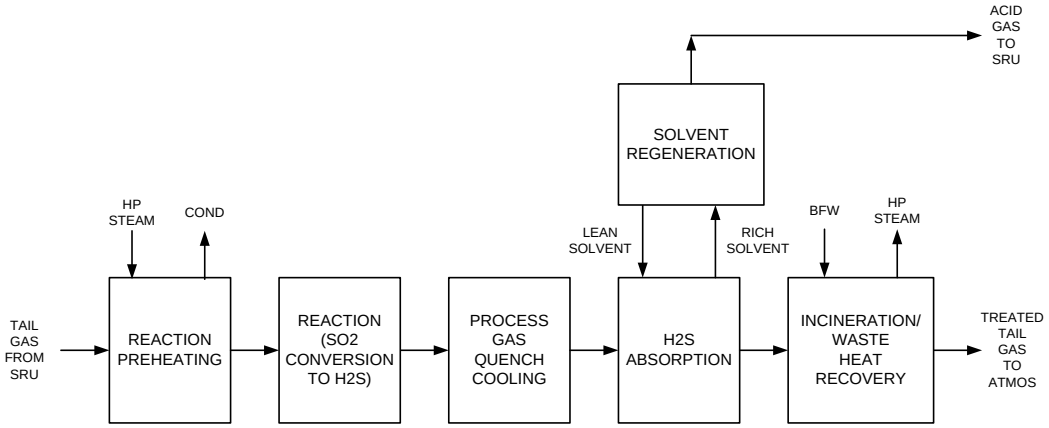
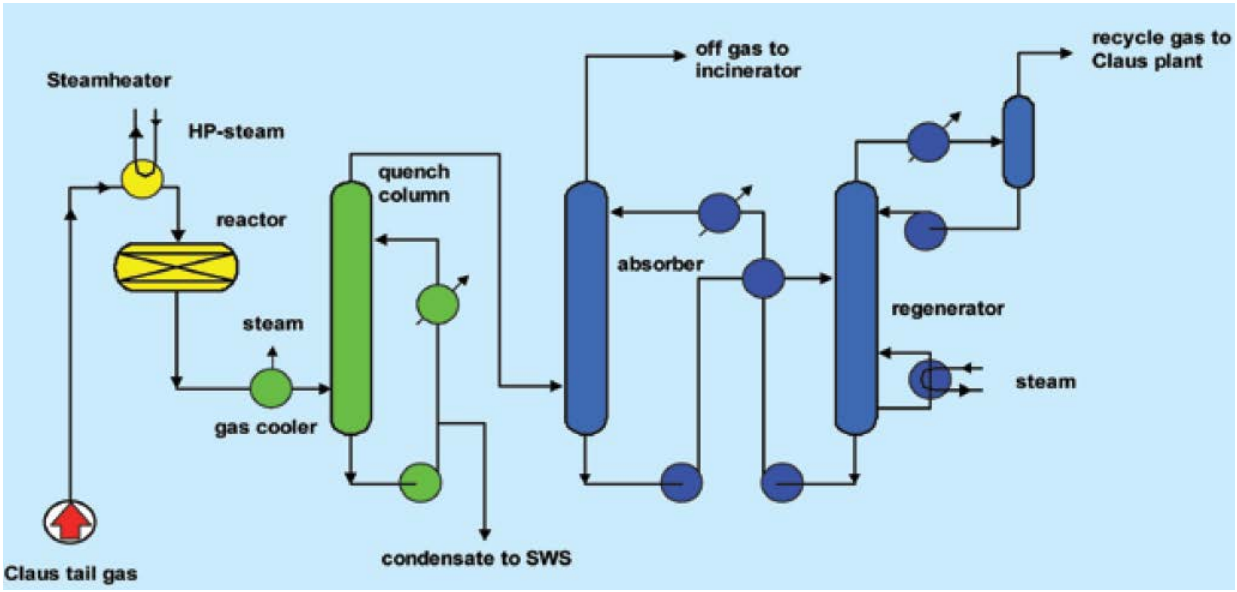
Tail Gas Treatment





Summary

- Petroleum Refinery Converts Crude Oil To Fuels and Chemical Feedstocks
- Molecules In Crude Oil Are Converted To High Value Products Through Refinery Conversion And Product Finishing Steps
- Removing Sulfur From Refinery Products Is Critical in Meeting Environmental Requirements (Tier 3 = 10 ppmw)