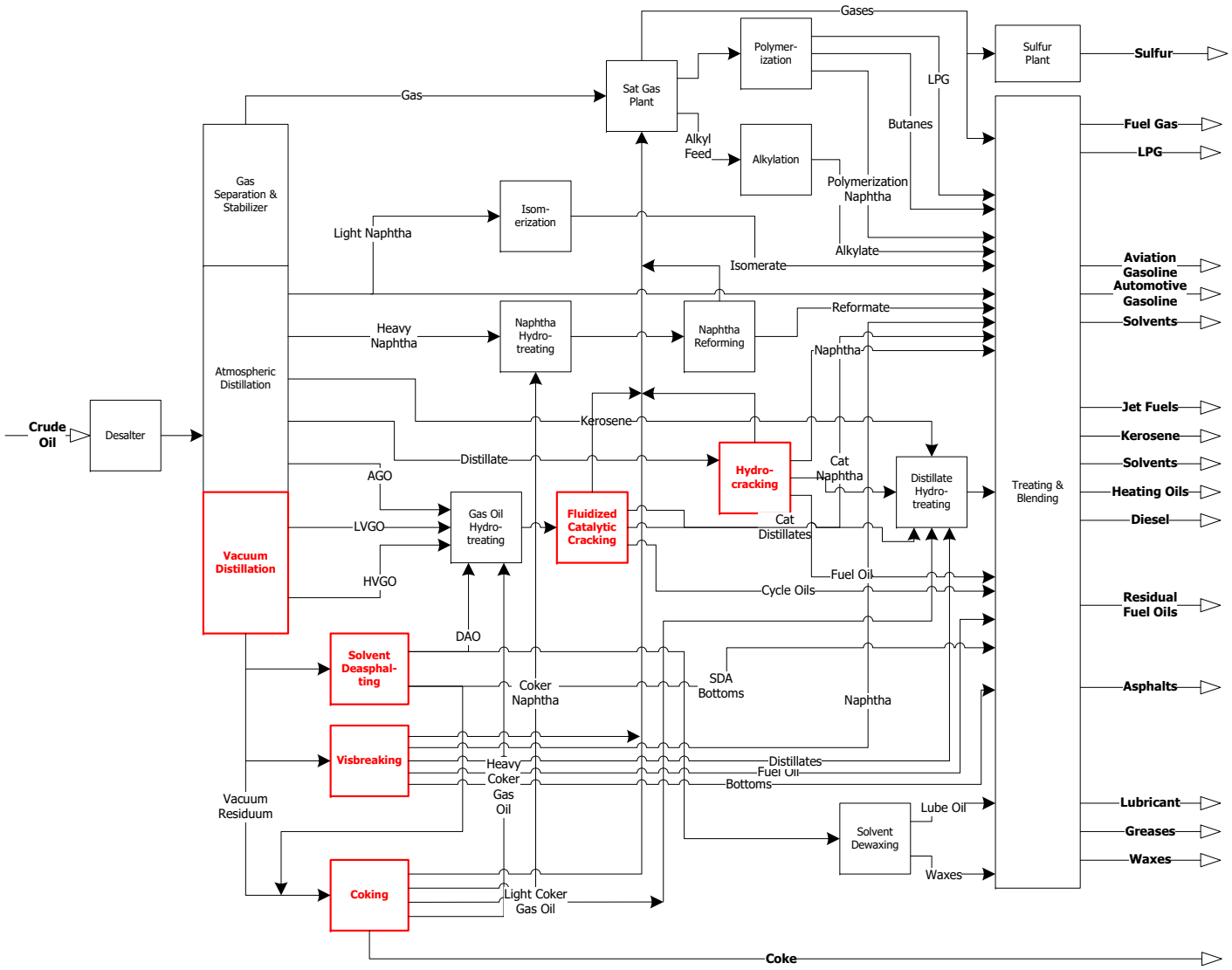
Bottom of Barrel Processing

Chapters 5, 6, & 8



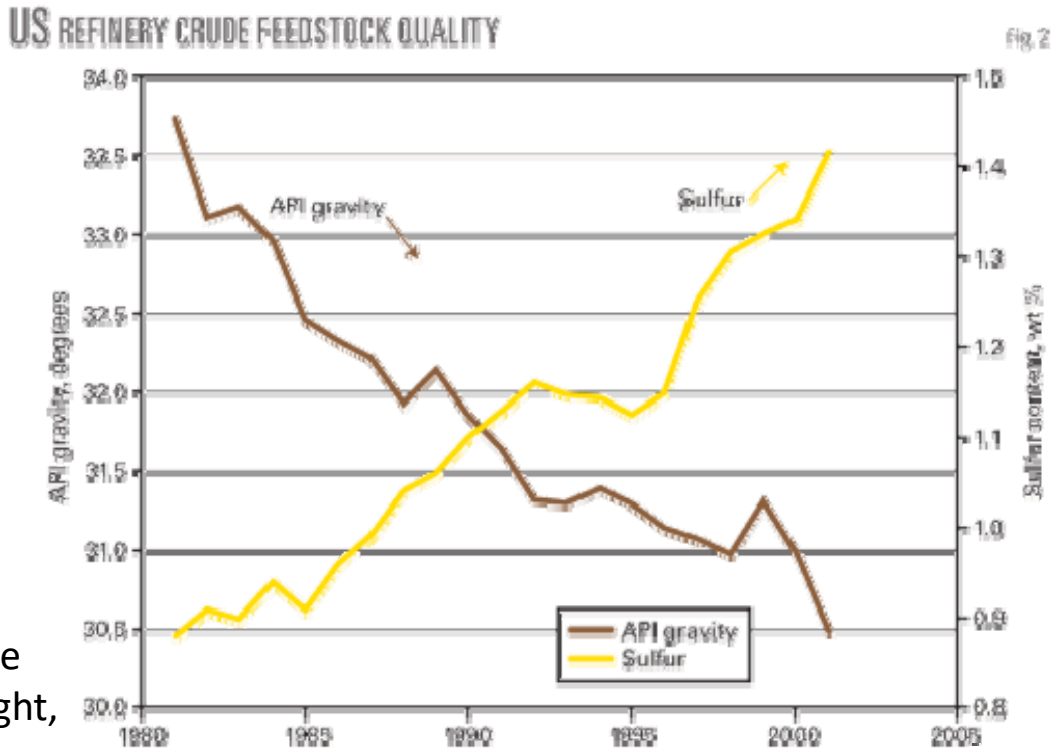
COLORADOSCHOOLOFMINES
EARTH • ENERGY • ENVIRONMENT

Need For Heavy Ends Processing

<u>Worldwide</u> 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

COLORADOSCHOOLOFMINES
EARTH • ENERGY • ENVIRONMENT

Processing Options

Physical separations

- Vacuum distillation
  - Volatility
- **Solvent Deasphalting**
  - Solubility

Lube Oil Processing

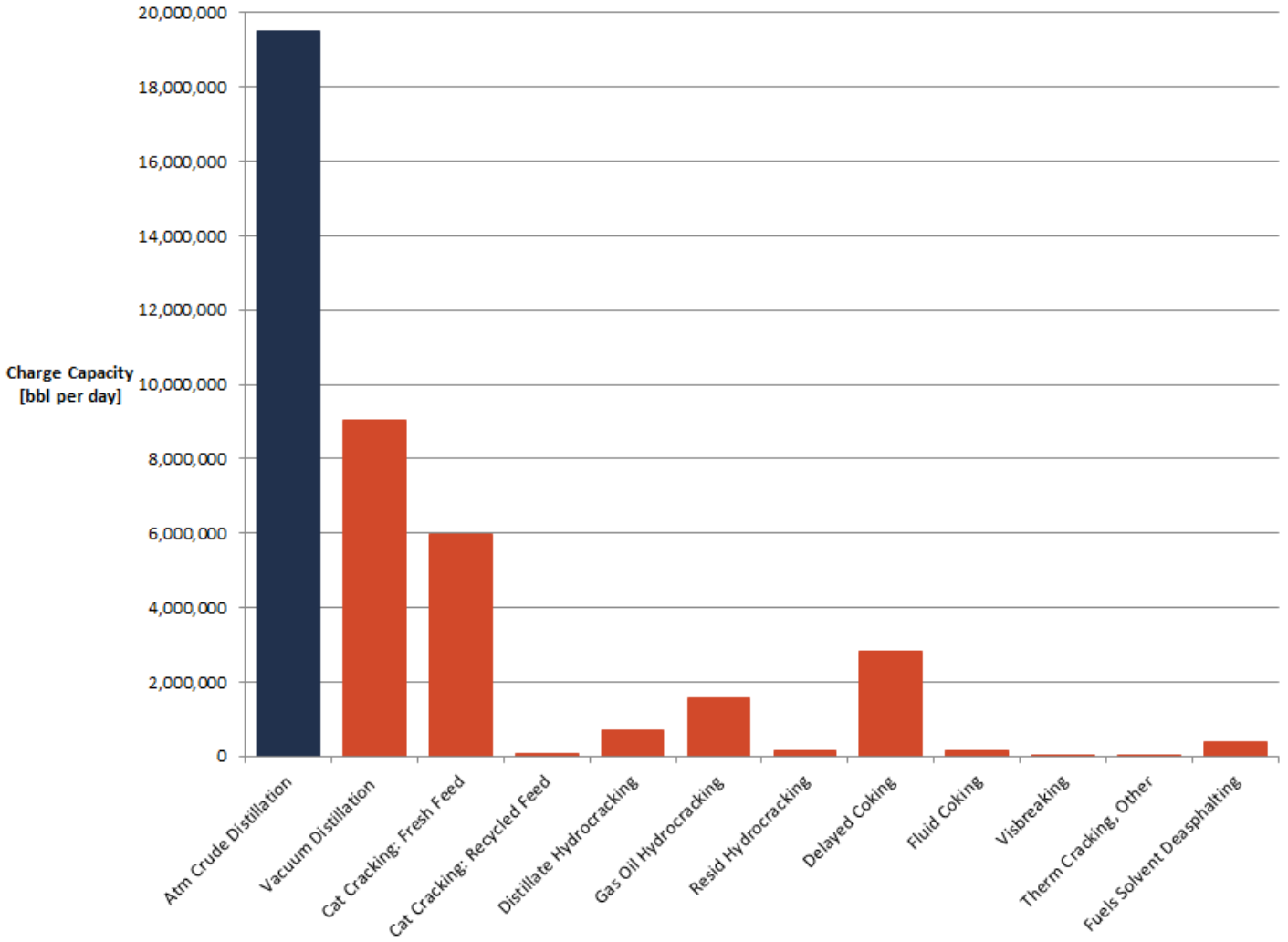
- Requires specialized feedstocks

Chemical reactions (in order of increasing severity)

- **Visbreaking**
- Catalytic cracking
- Coking
  - Delayed coking
  - Fluidized bed coking
- Hydrocracking

Updated: July 5, 2017

U.S. Refinery Implementation



EIA, Jan. 1, 2017 database, published June 2017
http://www.eia.gov/petroleum/refinerycapacity/

Updated: July 5, 2017

COLORADOSCHOOLOFMINES
EARTH • ENERGY • ENVIRONMENT

Solvent Deasphalting

Purpose

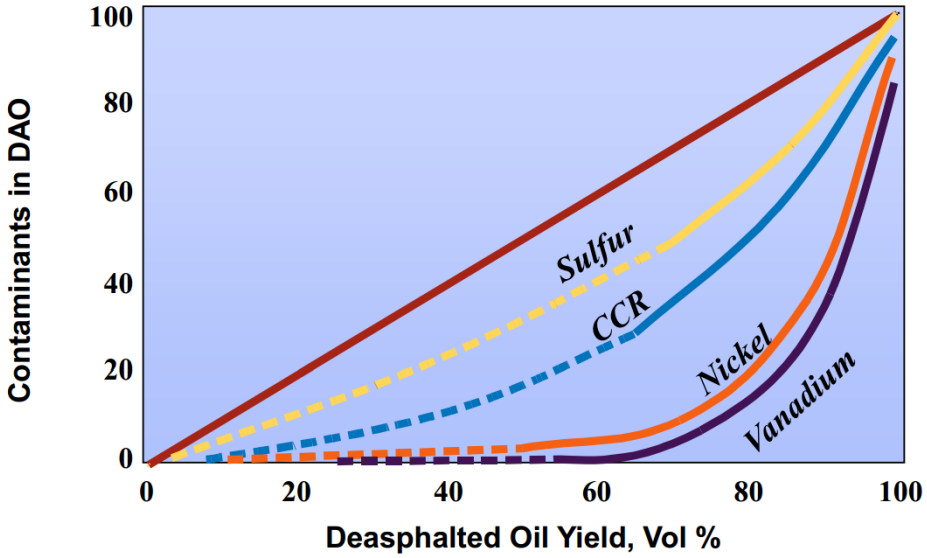
- Remove asphalts from lube plant feeds
- Increase gas oil yield from crude
- Make commercial asphalts from asphaltic crude unit bottoms

Characteristics

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

Products

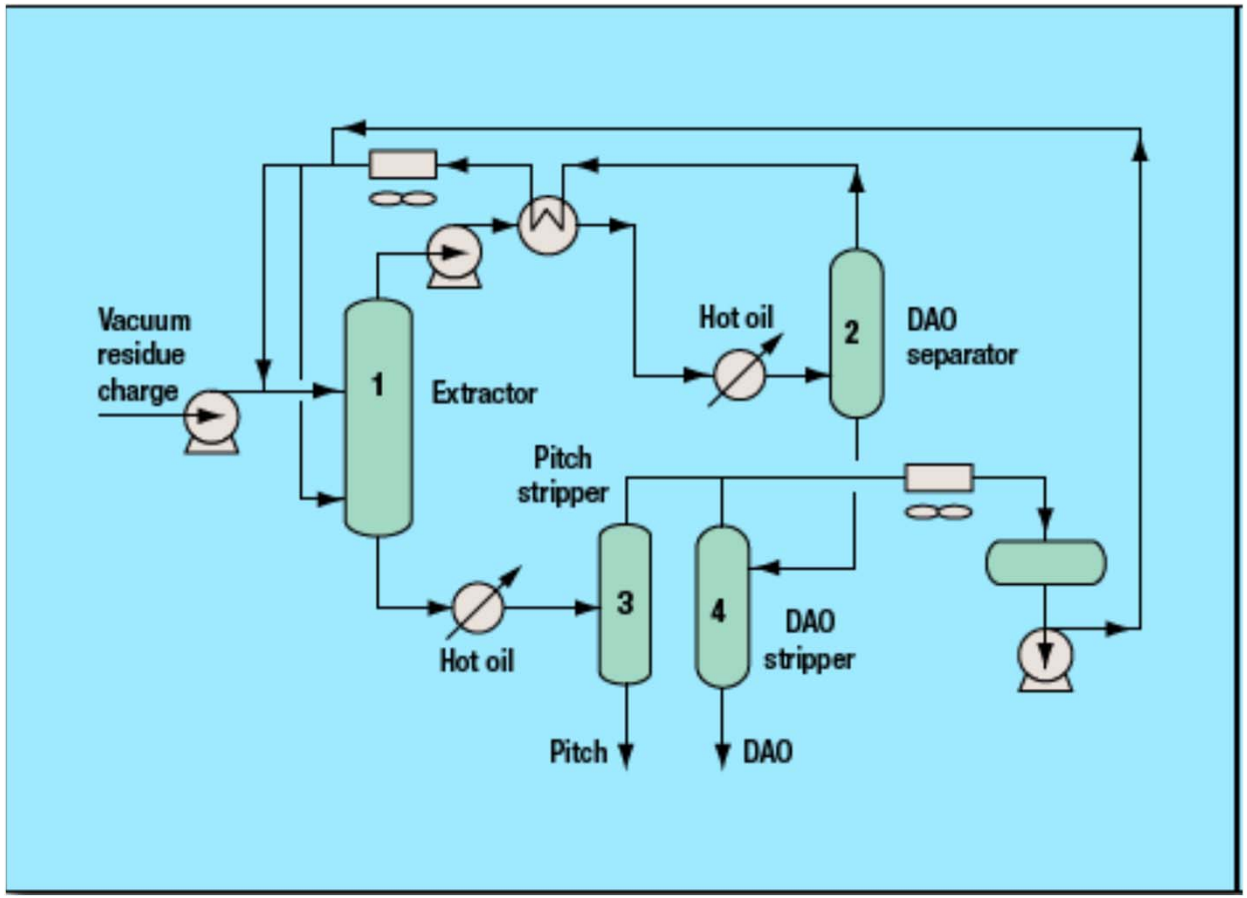
- Deasphalted Oil (DAO)
- Resins
- Bottoms/pitch – asphaltenes



Residue Upgrading Technology Options for Cost Effective Solutions,
Steve Beeston, ARTC 2014, Singapore, March 5, 2014
http://www.fwc.com/getmedia/200f27cb-c130-439e-aa08-51adaca15dd0/Residue-upgrading-technology-options-for-cost-effective-solutions.pdf.aspx?ext=.pdf

COLORADOSCHOOLOFMINES
EARTH • ENERGY • ENVIRONMENT

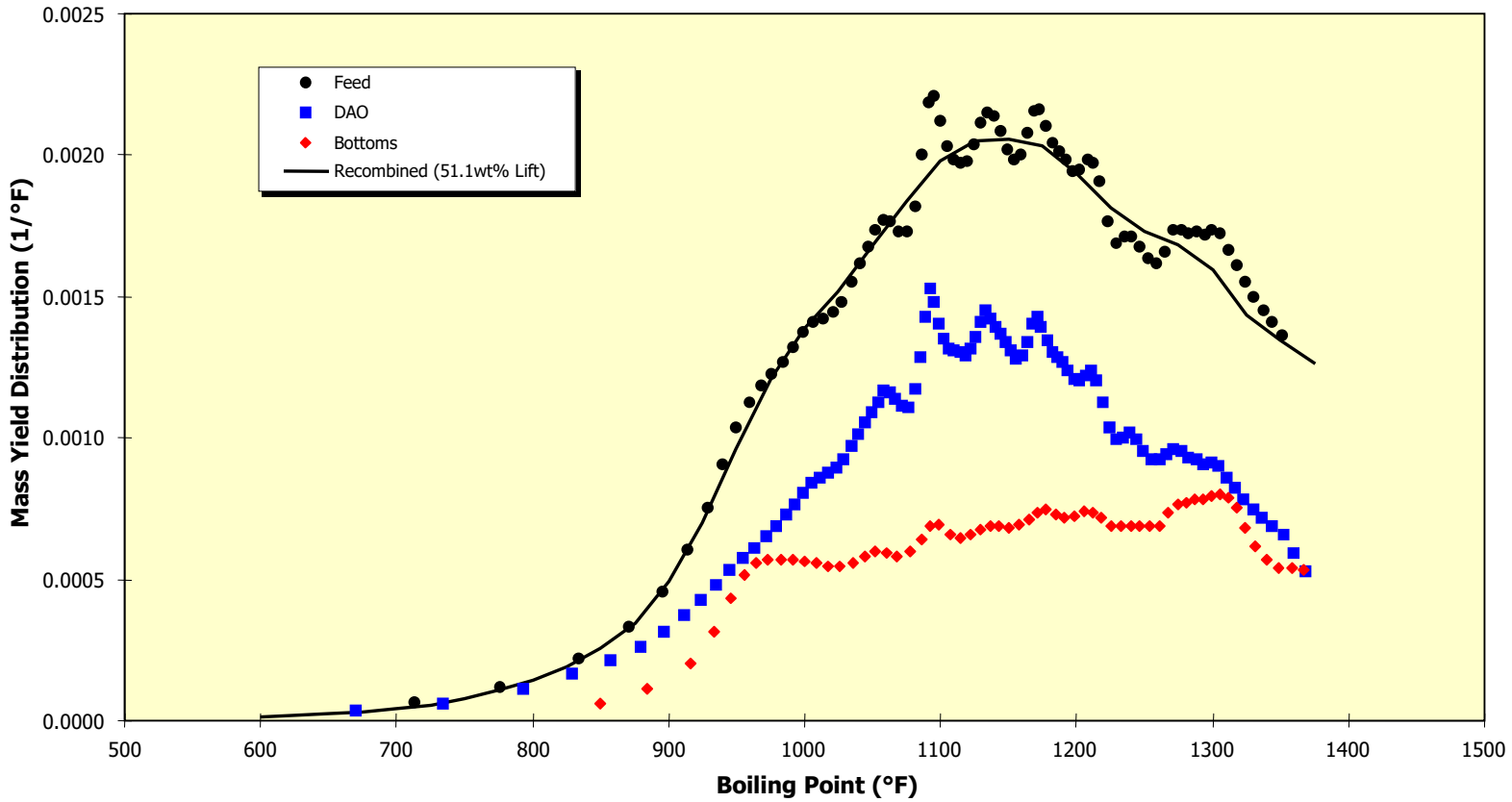
Typical SDA Process



Foster Wheeler SDA process
Hydrocarbon Processing's *2008 Refining Processes Handbook*

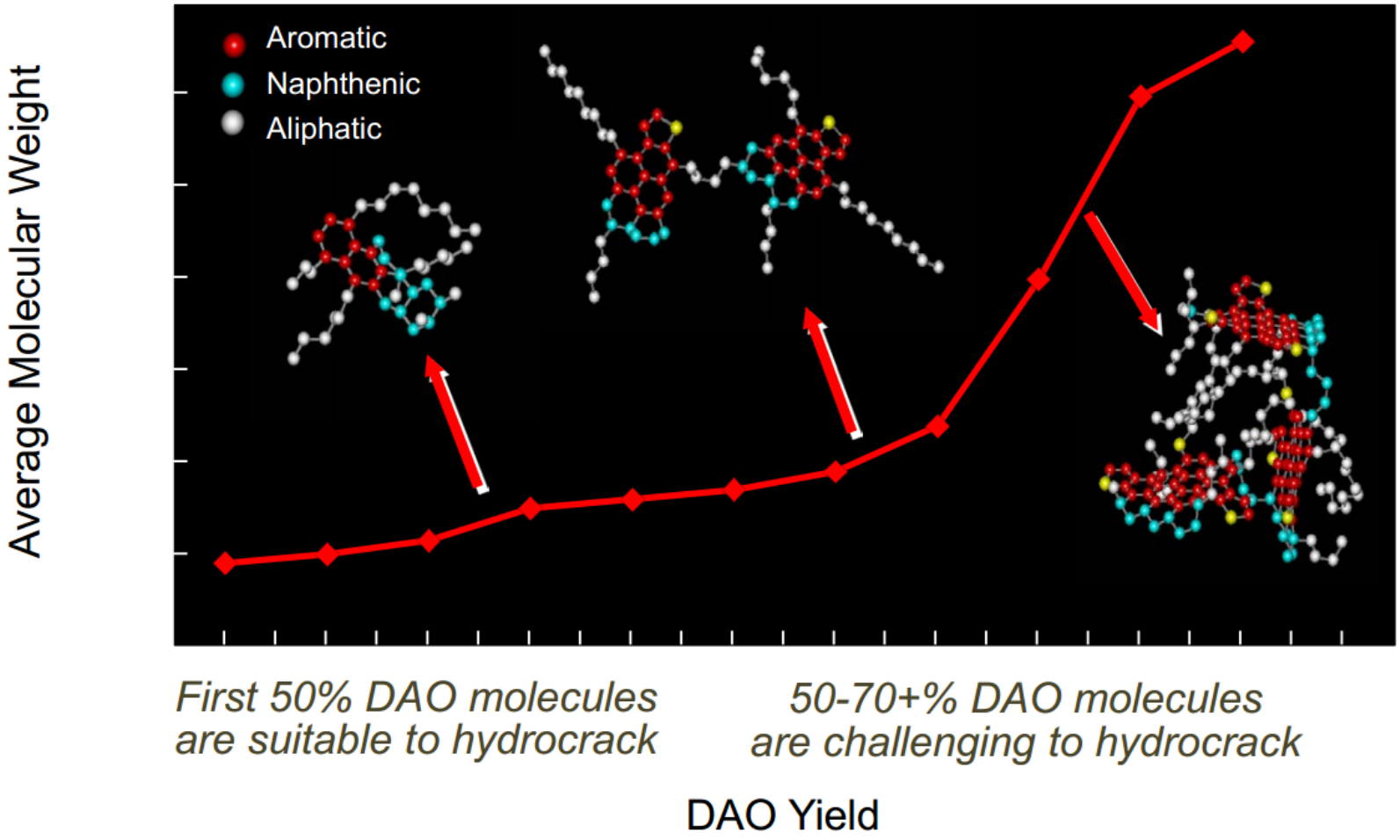
Characteristics of Products

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



COLORADOSCHOOLOFMINES
EARTH • ENERGY • ENVIRONMENT

Characteristics of Products



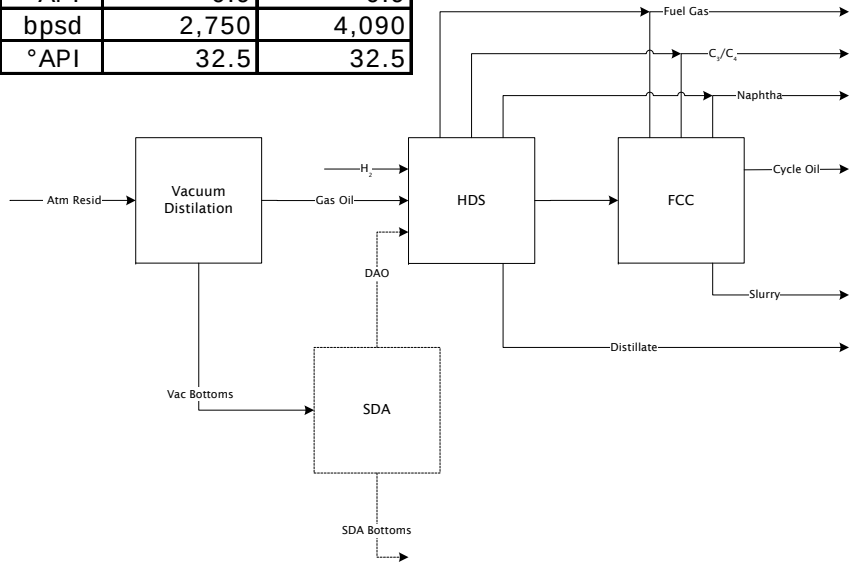
Residue Upgrading Technology Options for Cost Effective Solutions,
Steve Beeston, ARTC 2014, Singapore, March 5, 2014
http://www.fwc.com/getmedia/200f27cb-c130-439e-aa08-51adaca15dd0/Residue-upgrading-technology-options-for-cost-effective-solutions.pdf.aspx?ext=.pdf

COLORADOSCHOOLOFMINES
EARTH • ENERGY • ENVIRONMENT

Integration of SDA into Refinery

		Base	With SDA
Atm Resid Feed	bpsd	50,000	50,000
	°API	15.1	15.1
	wt% S	4.02	4.02
	ppmw metals	69	69
Vac Resid	bpsd	20,000	20,000
	°API	5.6	5.6
	wt% S	5.55	5.55
	ppmw metals	160	160
SDA Bottoms	bpsd		5,400
	°API		-12.6
	wt% S		7.15
	ppmw metals		475
SDA DAO	bpsd		14,600
	°API		11.4
	wt% S		4.84
	ppmw metals		20
Gas Oil	bpsd	30,000	30,000
	°API	22.3	22.3
	wt% S	3.04	3.04
Feed to HDS	bpsd	30,000	44,600
	°API	22.3	18.5
	wt% S	3	3.66
	ppmw metals		7

		Base	With SDA
Feed to FCC	bpsd	27,340	40,651
	°API		24.0
HDS Fuel Gas	Mscfd	4,200	6,310
FCC Fuel Gas	Mscfd	4,430	6,582
Total Fuel Gas	Mscfd	8,630	12,892
HDS C3/C4	bpsd	190	289
FCC C3/C4	bpsd	5,220	7,765
Total C3/C4	bpsd	5,410	8,054
HDS Naphtha	bpsd	260	388
FCC Naphtha	bpsd	15,420	22,927
Total Naphtha	bpsd	15,680	23,315
	°API	54.5	54.5
FCC Cycle Oil	bpsd	7,108	10,569
	°API	25.5	25.5
FCC Slurry	bpsd	1,367	2,033
	°API	0.9	0.9
HDS Distillate	bpsd	2,750	4,090
	°API	32.5	32.5



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

Updated: July 5, 2017

COLORADOSCHOOLOFMINES
EARTH • ENERGY • ENVIRONMENT

Visbreaking

Purpose

- Cut viscosity in ½ of feed (specs for heavy fuel oil)
- Reduces "cutter stock“
- Reduces heavy fuel oil amount

Characteristics

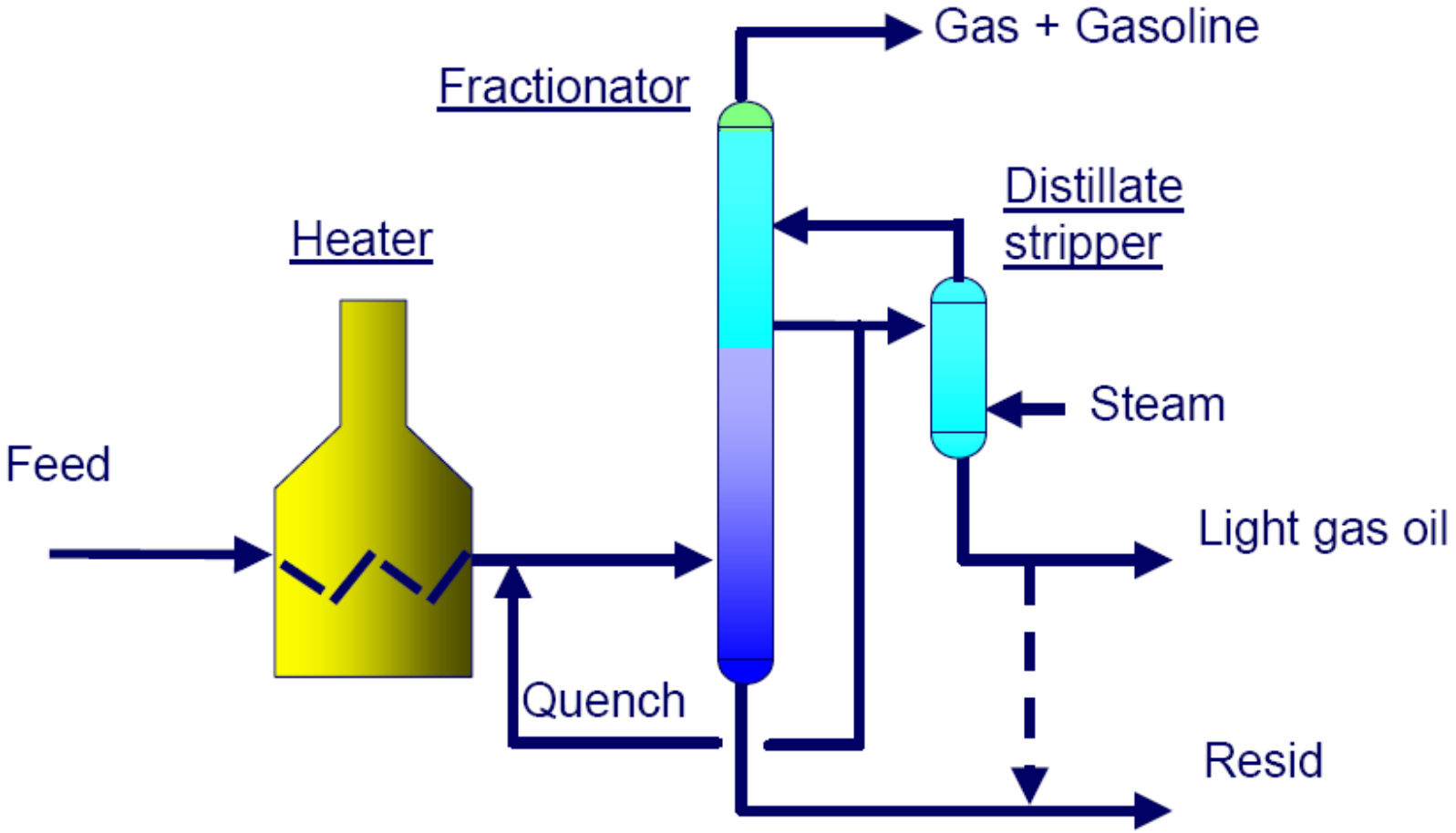
- Relatively mild thermal cracking operation
- Flexible on feedstock quality
- Typically high resin crude oils
- Low capital cost for process

Products

- ~20% feed cracked to light ends, naphtha, gas oil & distillate
- 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

Updated: July 5, 2017

Typical Coil Visbreaker



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

Catalytic Cracking

Purpose

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

Characteristics

- 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

Products

- Light gases
  - Olefins
- Light & Heavy Naphtha
- Light & Heavy Cycle Oils
- Slurry

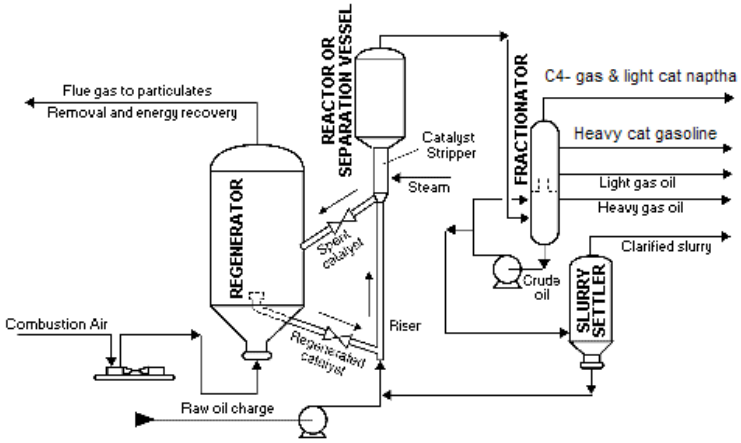


Figure: http://www.osha.gov/dts/osta/otm/otm_iv/otm_iv_2.html

COLORADOSCHOOLOFMINES
EARTH • ENERGY • ENVIRONMENT

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

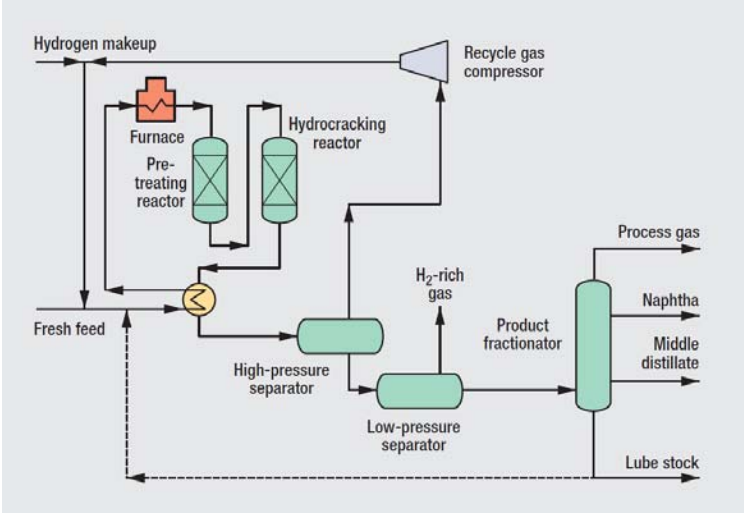


Figure:
Haldo Topsøe process flow
2011 Refining Processes Handbook
Hydrocarbon Processing, 2011

Updated: July 5, 2017

COLORADO SCHOOL OF MINES
EARTH • ENERGY • ENVIRONMENT

Coking

Purpose

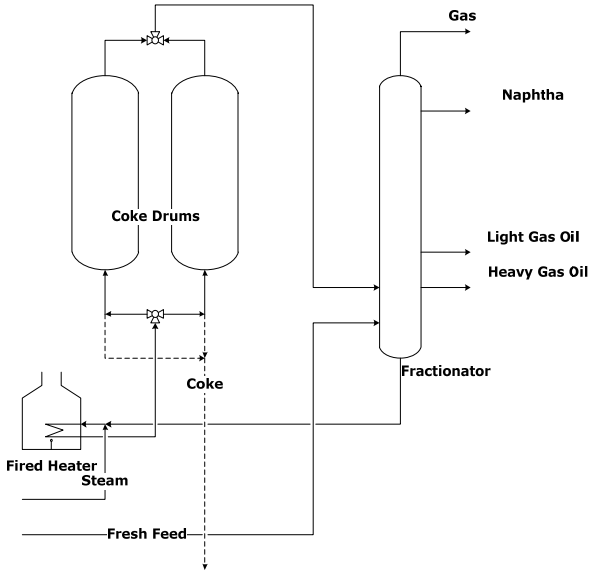
- Create light gases & distillates
- "Carbon rejection"

Characteristics

- Severe thermal cracking process
- Can process a wide variety of feedstocks – high High metals (nickel and vanadium), sulfur, resins & asphaltenes
- Side chains broken off from thermally stable PNA cores
  - PNAs contain majority of the heteroatoms (sulfur, nitrogen, metals)

Products

- Light gases, distillates (naphthas & gas oils) for catalytic upgrading
  - High in sulfur & olefins
- Coke
  - High in sulfur & metals



Updated: July 5, 2017

COLORADOSCHOOLOFMINES
EARTH • ENERGY • ENVIRONMENT

Summary

Updated: July 5, 2017

COLORADOSCHOOLOFMINES
EARTH • ENERGY • ENVIRONMENT

Summary

Reason for “Bottom of the Barrel” processing

- Attempt to get more liquid fuels from the portion of the crude oil that is heavier (of higher boiling point) than the diesel range

Processes

- Physical separations
  - Vacuum Column
  - Solvent Deasphalting (SDA)
- Chemical conversions
  - Visbreaking
  - Coking
  - Fluidized Catalytic Cracking (FCC)
  - Hydrocracking

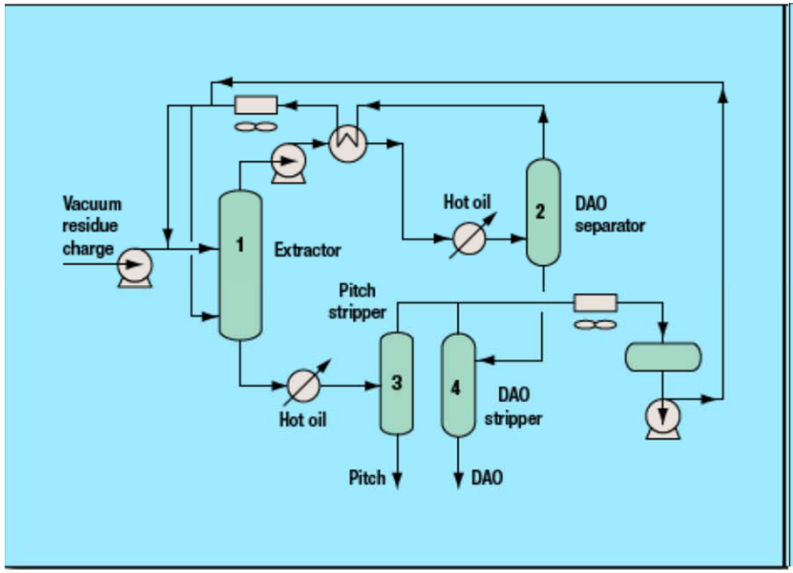
Supplemental Slides

Updated: July 5, 2017

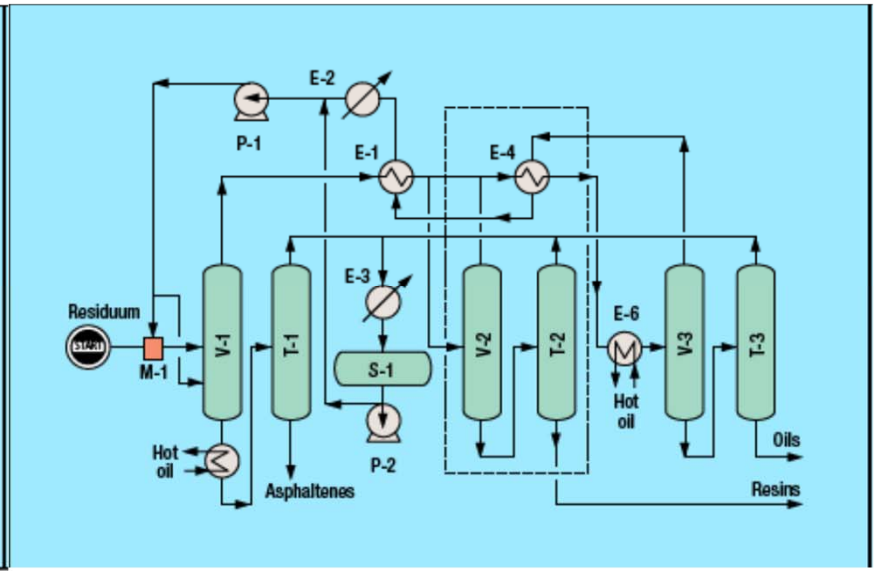
COLORADOSCHOOLOFMINES
EARTH • ENERGY • ENVIRONMENT

SDA Technology Providers

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



Foster Wheeler



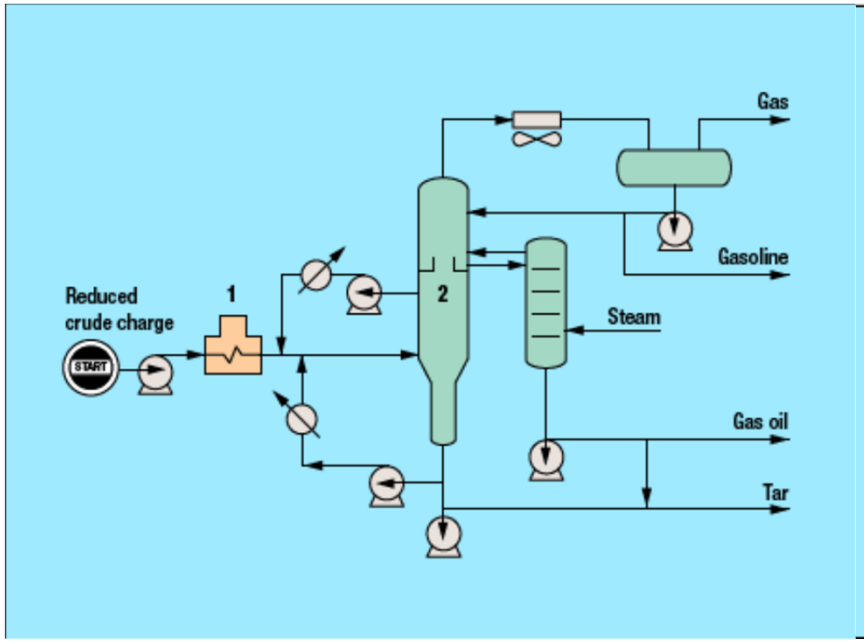
KBR ROSE©

Hydrocarbon Processing's *2008 Refining Processes Handbook*

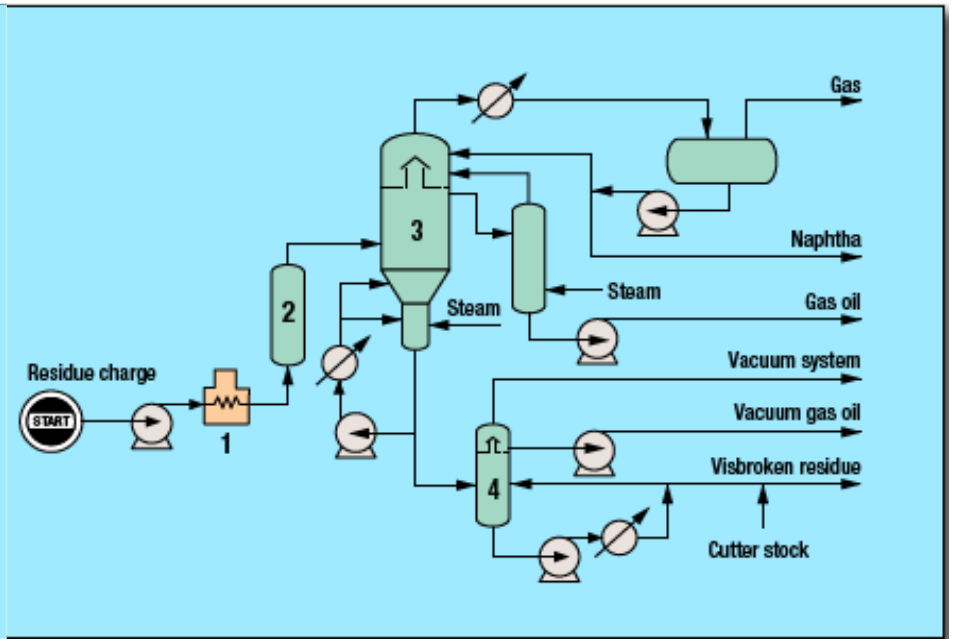
COLORADOSCHOOLOFMINES
EARTH • ENERGY • ENVIRONMENT

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*