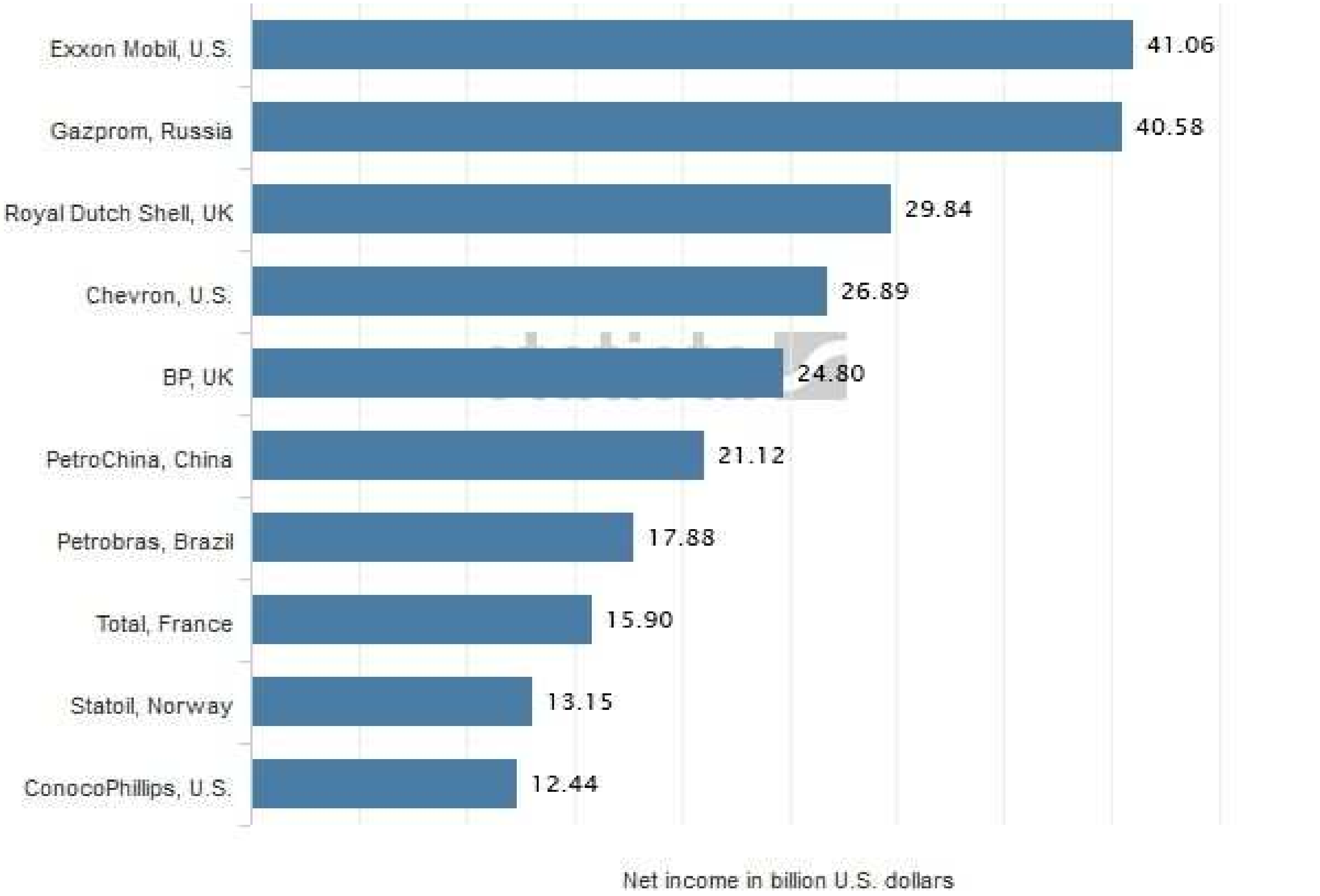
Oil corporations

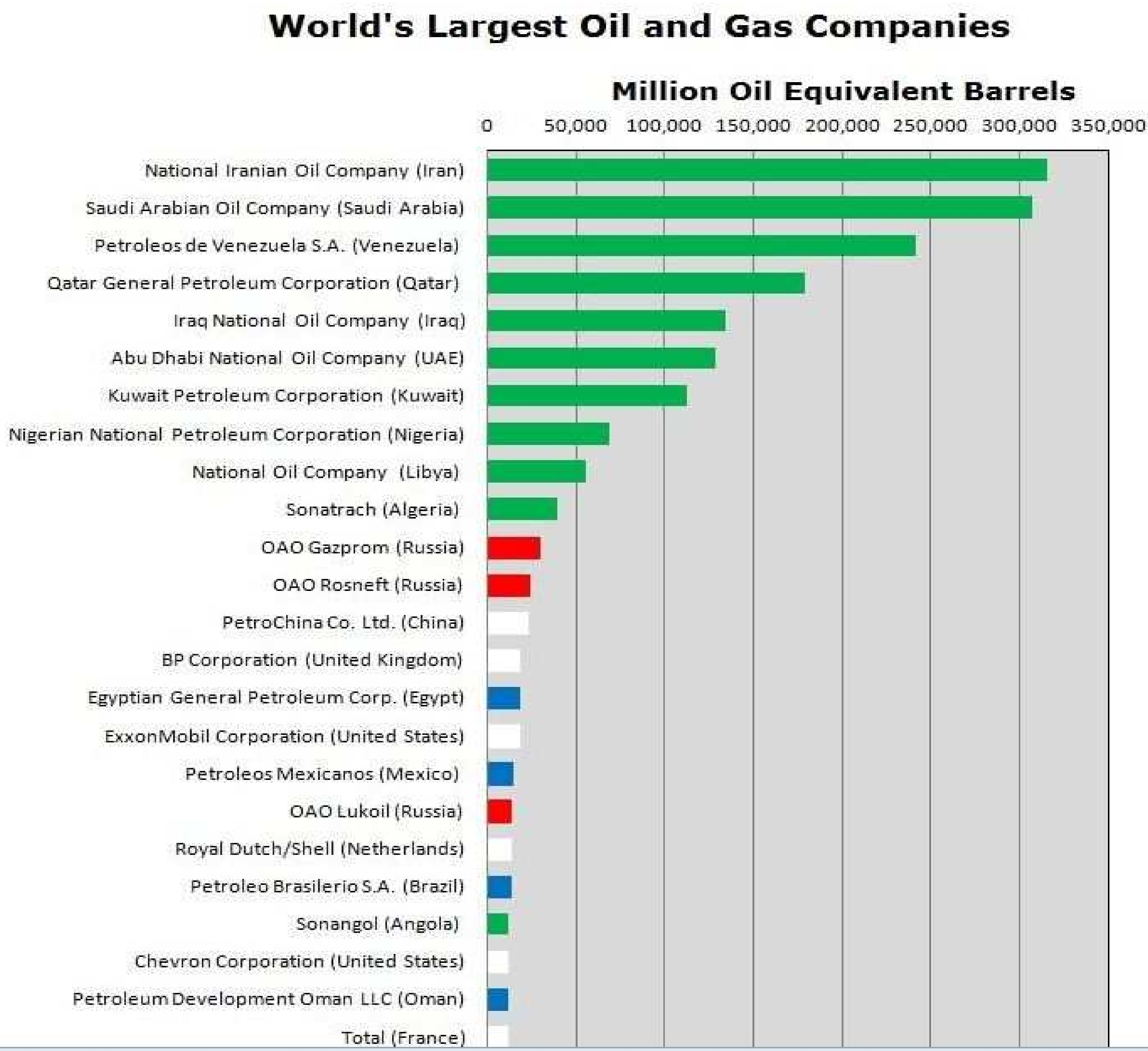
The seven sisters were the following:

1. Standard Oil of New Jersey (Esso), which merged with Mobil to form ExxonMobil.
2. Royal Dutch Shell Anglo-Dutch
3. British Anglo-Persian Oil Company (APOC). This later became BP, then BP Amoco following a merger with Amoco (which in turn was formerly Standard Oil of Indiana). It is now known solely by the initials BP.
4. Standard Oil of New York (Socony). This later became Mobil, which merged with Exxon to form ExxonMobil.
5. Standard Oil of California (Socal). This became Chevron, then, upon merging with Texaco, ChevronTexaco. It has since dropped the 'Texaco' suffix, returning to Chevron.
6. Gulf Oil. Most of this became part of Chevron, with smaller parts becoming part of BP, and Cumberland Farms.
7. Texaco. Merged with Chevron in 2001.

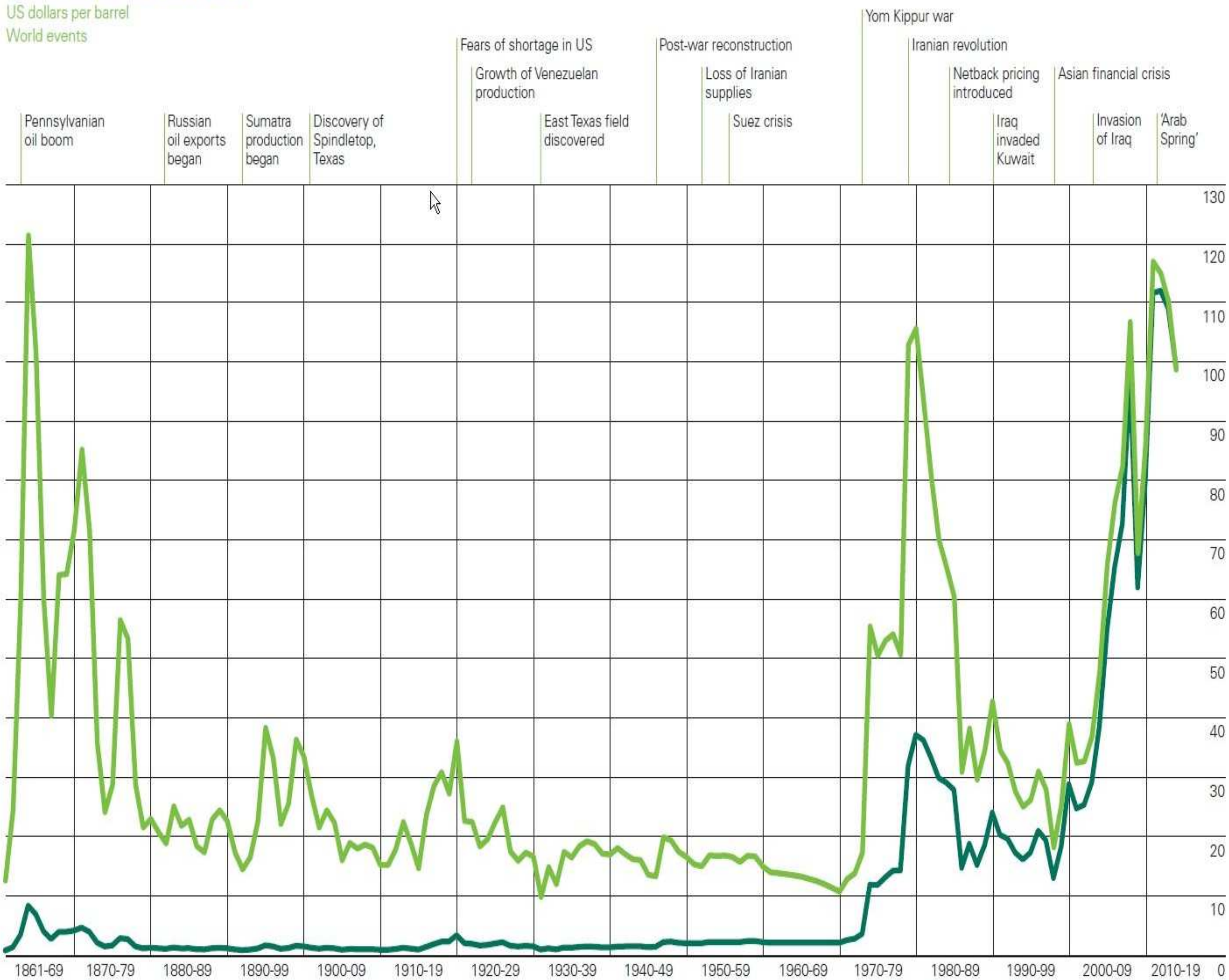
Rank	Company	Global 500 rank	REVENUES $ millions	REVENUES % change from 2006	PROFITS $ millions	PROFITS % change from 2006
1	Exxon Mobil	2	372,824	7	40,610	3
2	Royal Dutch Shell	3	355,782	12	31,331	23
3	BP	4	291,438	6	20,845	-5
4	Chevron	6	210,783	5	18,688	9
5	Total	8	187,280	11	18,042	22
6	ConocoPhillips	10	178,558	4	11,891	-24
7	Sinopec	16	159,260	21	4,166	13
8	China National Petroleum	25	129,798	17	14,925	13
9	ENI	27	120,565	11	13,703	19
10	Valero Energy	49	96,758	6	5,234	-4
11	Statoil Hydro	59	89,224	35	7,526	19
12	Petrobras	63	87,735	21	13,138	2
13	SK Holdings	86	70,717	20	1,505	3
14	Lukoil	90	67,205	23	9,511	27
15	Repsol YPF	92	67,006	10	4,364	11
16	Petronas	95	66,218	30	18,118	41

2012 ranking of the global top 10 oil and gas companies based on net income (in billion U.S. dollars)



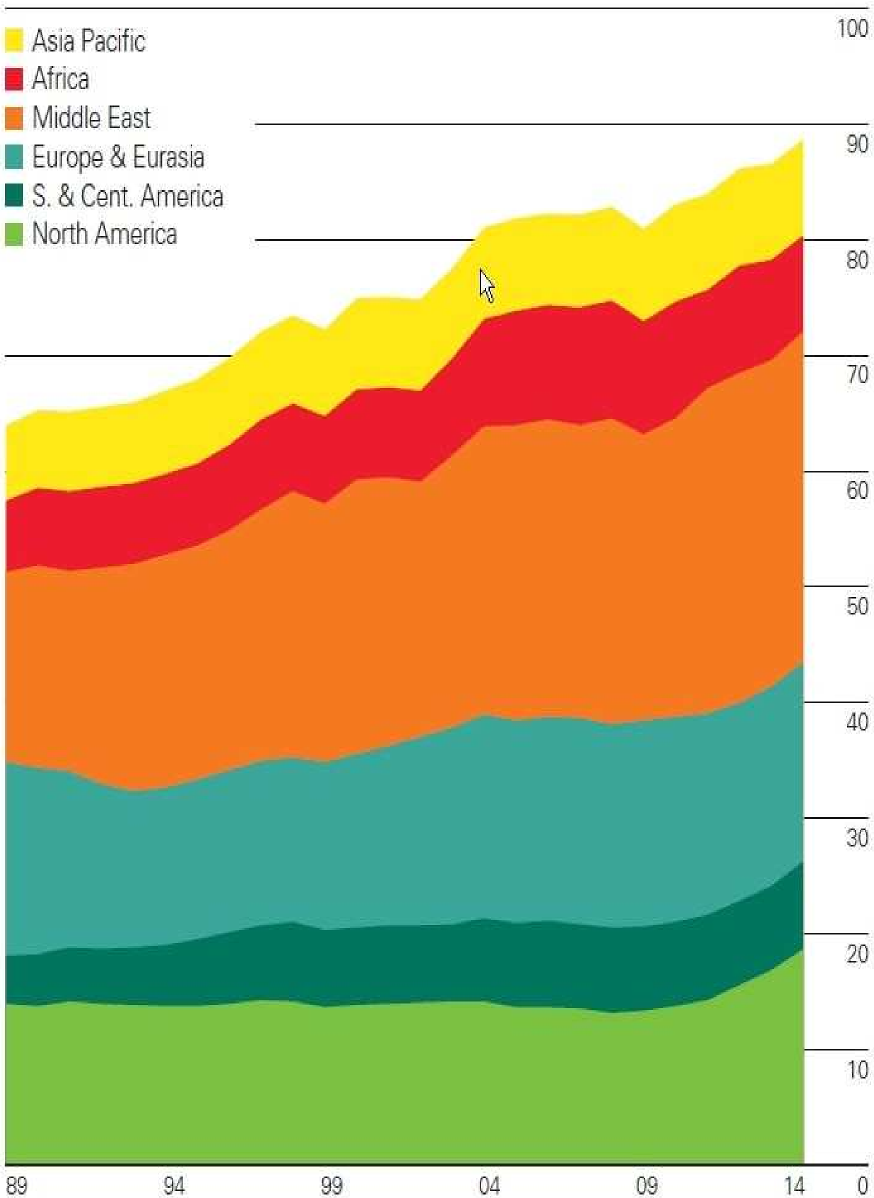

World's Largest Oil and Gas Companies
Million Oil Equivalent Barrels
0
50,000
100,000
150,000
200,000
250,000
300,000
350,000
National Iranian Oil Company (Iran)
Saudi Arabian Oil Company (Saudi Arabia)
Petroleos de Venezuela S.A. (Venezuela)
Qatar General Petroleum Corporation (Qatar)
Iraq National Oil Company (Iraq)
Abu Dhabi National Oil Company (UAE)
Kuwait Petroleum Corporation (Kuwait)
Nigerian National Petroleum Corporation (Nigeria)
National Oil Company (Libya)
Sonatrach (Algeria)
OAO Gazprom (Russia)
OAO Rosneft (Russia)
PetroChina Co. Ltd. (China)
BP Corporation (United Kingdom)
Egyptian General Petroleum Corp. (Egypt)
ExxonMobil Corporation (United States)
Petroleos Mexicanos (Mexico)
OAO Lukoil (Russia)
Royal Dutch/Shell (Netherlands)
Petroleo Brasilerio S.A. (Brazil)
Sonangol (Angola)
Chevron Corporation (United States)
Petroleum Development Oman LLC (Oman)
Total (France)

Crude oil prices 1861-2014



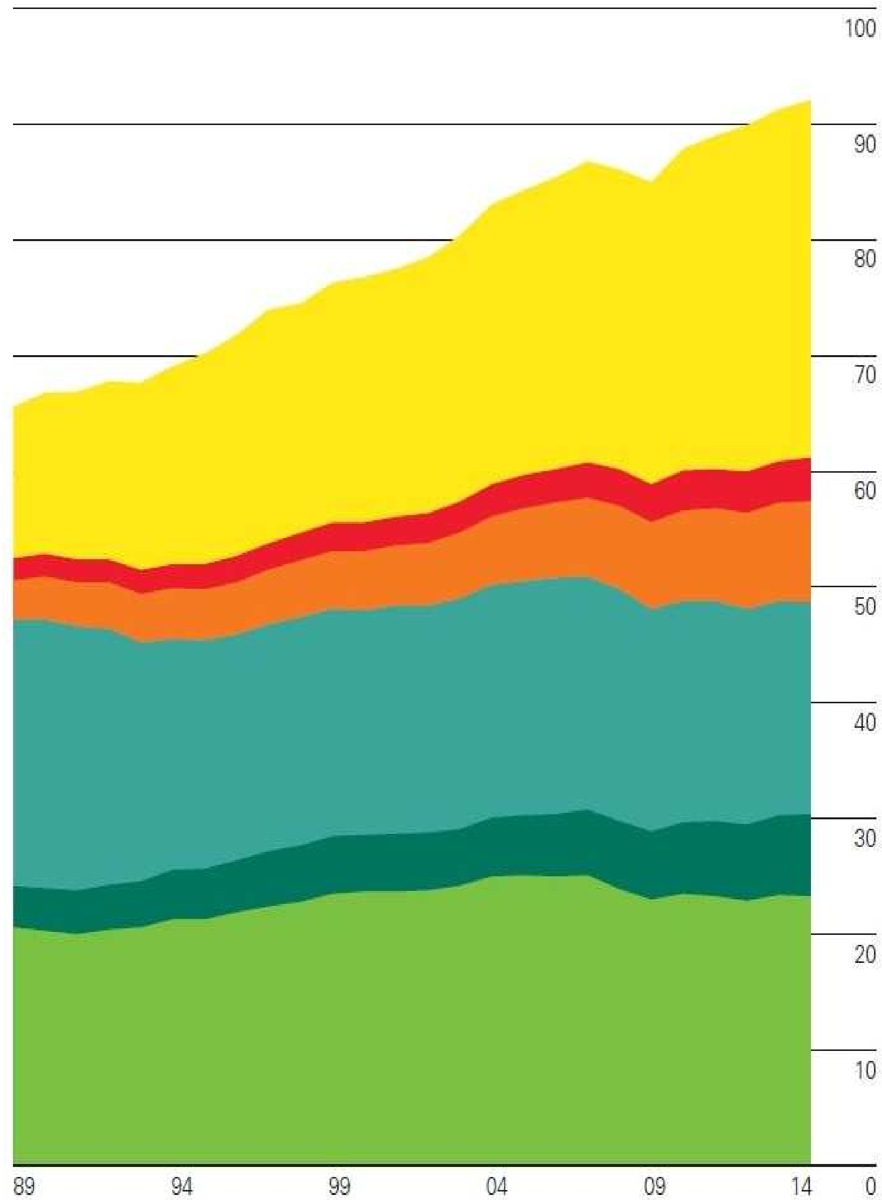
Production by region

Million barrels daily



Consumption by region

Million barrels daily



Distribution of proved reserves in 1994, 2004 and 2014

Percentage

Crude Oil and its Products

הנפט הוא תערובת של פחממנים פרפינים, ארומטים ונפתנים,
עם מעט תרכבות חנקן וגפרית.
הרכב הנפט שונה לפי מקורו.
מוערך שהמקור הקדום היה בעלי חיים+
צמחיה מלפני הרבה מליוני שנים.

בזיקוק ישיר של הנפט מפרידים את הפרקציות הבאות:
גפ"ס
גזולין, נפתה וממיסים
קרוסין ודלק מטוסים
סולר ודלק דיזל
מזוט
שמני סיכה ואספלט.

תהליכי השבחת נפט כוללים:
פיצוח תרמי ופיצוח מימני
פרוס תרמי
אלקילציה
איזומריזציה
פולימריזציה

מבין מוצרי הזיקוק הראשוני של נפט החשוב ביותר הוא הנפתה המשמש חומר גלם לגזולין וכן חומר הזנה לתהליכי יצור אתילן, פרופילן וחמרים ארומטים. את הפרקציה הארומטית מפרידים מנפתה בתהליכי מיצוי.

ממוצרי נפט מפרידים מספר תרכבות נקיות המהוות חמרי גלם לרב מוצרי התעשיה הפטרוכימית:

אתילן

פרופילן

בנזן

טולואן

אורתו קסילן ופרה קסילן

נפתלן

כתחליפים לנפט גלמי מציעים חמרי טבע, בעיקר סוכר, ממנו הצליחו להפיק מוצרים רבים אבל לא במחיר סביר. אצטילן, הניתן להפקה מפחם, שימש כחומר הגלם העיקרי לתעשיה הפטרוכימית בגרמניה במלחמת העולם השניה.

גז סינתזה, תערובת של CO ומימן, הוא חומר גלם חשוב לתהליכים רבים. כיום מיצרים אותובעיקר בחמצון חלקי של מתן או של נפתה בעיקר ליצור מתנול ואמוניה, ניתן ליצר גז סינתזה בחמצון חלקי של פחם. מגז סינתזה מפחם ניתן ליצר חומר דמוי נפט טבעי ומספר רב של תהליכים פותחו למטרה זו ואחדים מתהליכים אלה זכו למספר רב של ישומים, אך מחירי הנפט שצללו עצרו ישומים נוספים.

(141.5/S.G.) - 131.5 = API Gravity

Typical analysis of some crude oils

	Arab Extra Light*	Alameen Egypt	Arab Heavy	Bakr-9 Egypt
Gravity, °API	38.5	33.4	28.0	20.9
Carbon residue (wt %)	2.0	5.1	6.8	11.7
Sulfur content (wt %)	1.1	0.86	2.8	3.8
Nitrogen content (wt %)	0.04	0.12	0.15	—
Ash content (wt %)	0.002	0.004	0.012	0.04
Iron (ppm)	0.4	0.0	1.0	—
Nickel (ppm)	0.6	0.0	9.0	108
Vanadium (ppm)	2.2	15	40.0	150
Pour point (°F)	≈Zero	35	−11.0	55
Paraffin wax content (wt %)	—	3.3	—	—

* *Ali, M. F et al., Hydrocarbon Processing, Vol. 64, No. 2, 1985 p. 83.*

Pour point= The lowest temperature at which a liquid remains pourable

TABLE IV: 2-2. TYPICAL APPROXIMATE CHARACTERISTICS AND PROPERTIES AND GASOLINE POTENTIAL OF VARIOUS CRUDES (Representative average numbers)

Crude source	Paraffins (% vol)	Aromatics (% vol)	Naphthenes (% vol)	Sulfur (% wt)	API gravity (approx.)	Napht. yield (% vol)	Octane no (typical)
Nigerian -Light	37	9	54	0.2	36	28	60
Saudi -Light	63	19	18	2	34	22	40
Saudi -Heavy	60	15	25	2.1	28	23	35
Venezuela -Heavy	35	12	53	2.3	30	2	60
Venezuela -Light	52	14	34	1.5	24	18	50
USA -Midcont. Sweet	-	-	-	0.4	40	-	-
USA -W. Texas Sour	46	22	32	1.9	32	33	55
North Sea -Brent	50	16	34	0.4	37	31	50

	Initial TBP range (°F)	Final TBP range (°F)
Light naphtha	60-90	180-220
Heavy naphtha	180-220	330-430
Kerosene	330-380	480-550
Light gas oil	420-520	610-650
Heavy gas oil	610-650	750-850
Vacuum gas oil	750-800	950-1,050
Vacuum residuum	950-1,050	

2.1 Distillation of crude oil

DE

Fraction	*Boiling range (°C) (at atmospheric pressure)*	*Number of carbon atoms in molecule*	*Approximat by volum*
→ GASES	< 20	1–4	1–2
→ LIGHT GASOLINES OR LIGHT NAPHTHA	20–70	5–6	20–40
→ NAPHTHA (MID-RANGE)	70–170	6–10	
→ KEROSENE	170–250	10–14	10–15
→ GAS OIL	250–340	14–19	15–20
→ DISTILLATE FEEDSTOCKS for LUBRICATING OIL and WAXES, or HEAVY FUEL OILS	340–500	19–35	40–50
→ BITUMEN	> 500 i.e. Residue	> 35	

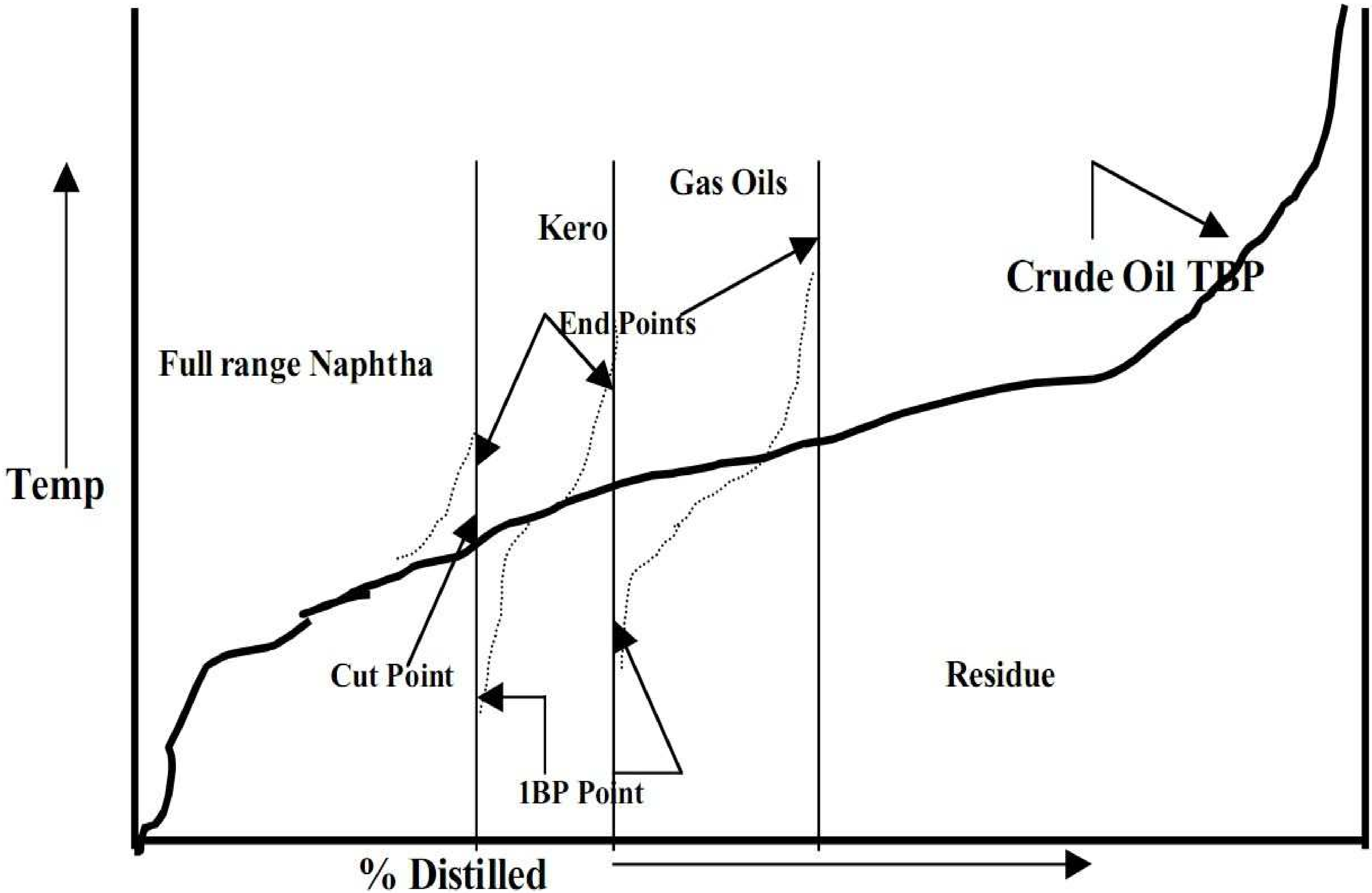


Figure 1.1. Cut points and end points.

Refinery Yield Per Barrel of Oil	
Gasoline	45.8 Percent
Jet Fuel	10.7
Liquefied Gases	3.6
Kerosene	0.3
Distillate	20.9
Residual Fuel Oil	6.8
Feedstocks	2.9
Special Napthas	0.4
Lubricants	1.2
Waxes	0.1
Coke	3.9
Asphalt	3.2
Still Gas	4.8
Miscellaneous	0.5
Shortage (gain*)	-4.9

*The final total product of a refined barrel of crude oil may exceed 1 barrel, since some of the lighter liquids are in a near gaseous state and accordingly take up more volume.

Octane numbers

Boiling points and octane ratings of different hydrocarbons in the gasoline range

Hydrocarbon	Boiling point, °F	Octane number clear: Research method F-1	Octane number clear: Motor method F-2
n-Butane	0.5	...	...
n-Pentane	97	61.7	61.9
2-Methylbutane	82	92.3	90.3
2,2-Dimethylbutane	122	91.8	93.4
2,3 Dimethylbutane	137	103.5	94.3
n-Hexane	156	24.8	26.0
2-Methylpentane	146	73.4	73.5
3-Methylpentane	140	74.5	74.3
n-Heptane	208	0.0	0.0
2-Methylhexane	194	42.4	46.4
n-Octane	258	−19.0*	−15.0*
2,2,4-Trimethyl pentane (isooctane)	211	100.0	100.0
Benzene	176	...	114.8
Toluene	231	120.1	103.5
Ethylbenzene	278	107.4	97.9
Isopropylbenzene	306	...	...
o-Xylene	292	120.0*	103.0*
m-Xylene	283	145.0	124.0*
p-Xylene	281	146.0*	127.0*

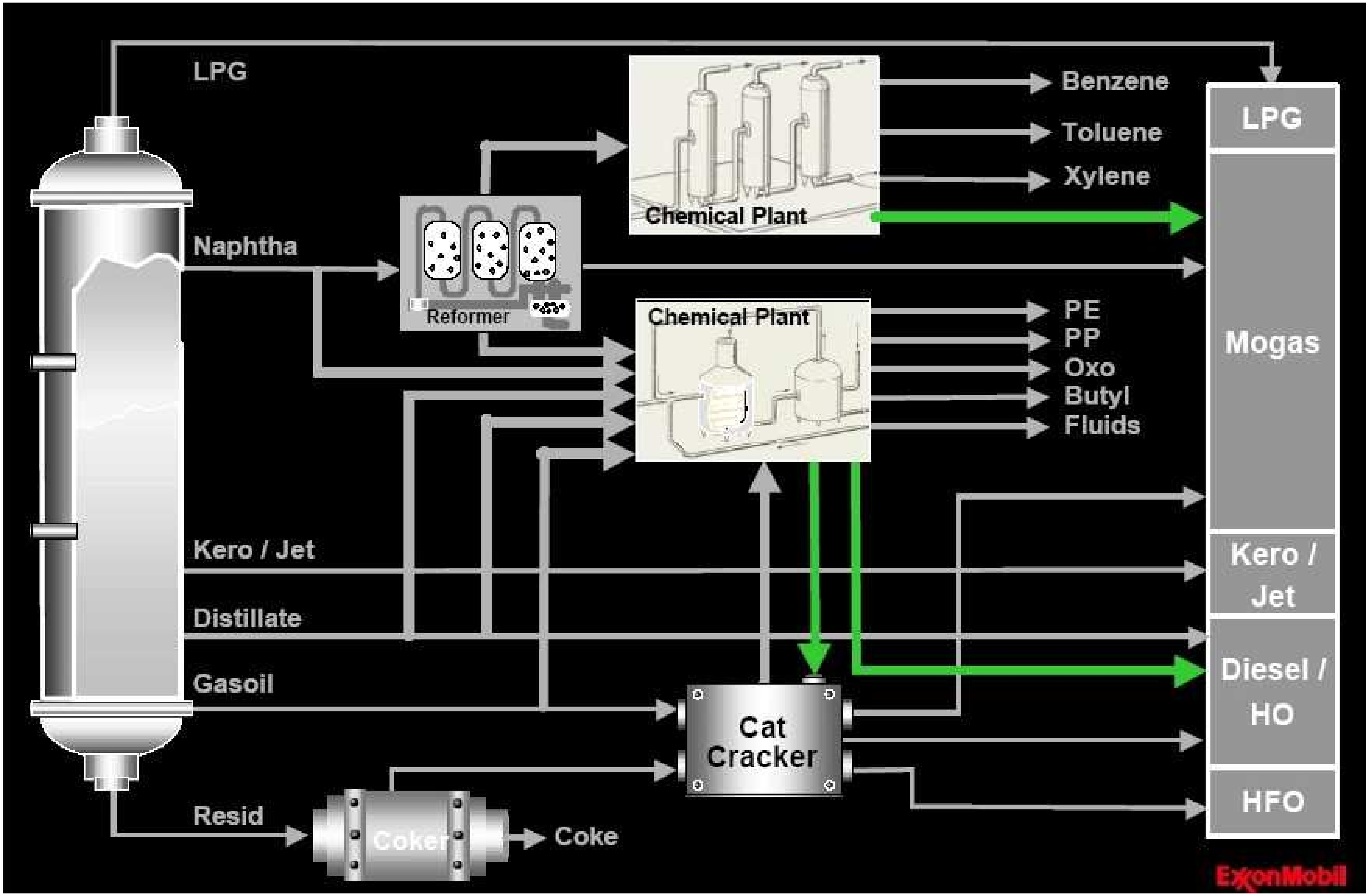
** Blending value of 20% in 60 octane number reference fuel.*

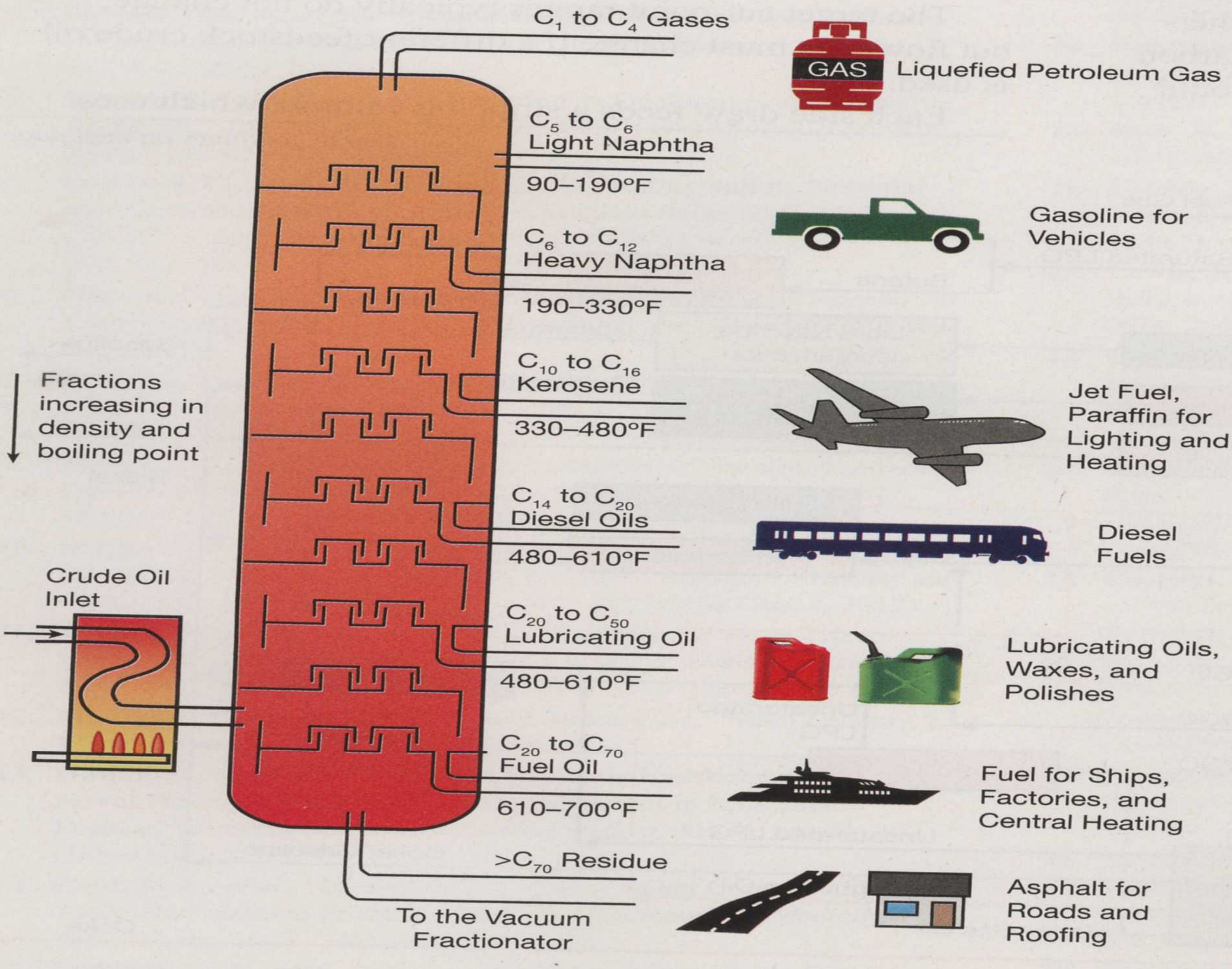
Table 2.12. Oxygenates commonly used in gasoline (subject to phase-out in the U.S.A.)

Name	Formula	RON	RVP psig	Oxygen %wt	Water solubility %*
Methyl tertiary butyl ether (MTBE)	$(CH_3)_3COCH_3$	110–112	8	18	4.3
Ethyl tertiary butyl ether (ETBE)	$(CH_3)_3COC_2H_5$	110–112	4	16	1.2
Tertiary amyl methyl ether (TAME)	$(CH_3)_2(C_2H_5)COCH_3$	103–105	4	16	1.2
Ethanol	C_2H_5OH	112–115	18	35	100

*Wt % soluble in water.

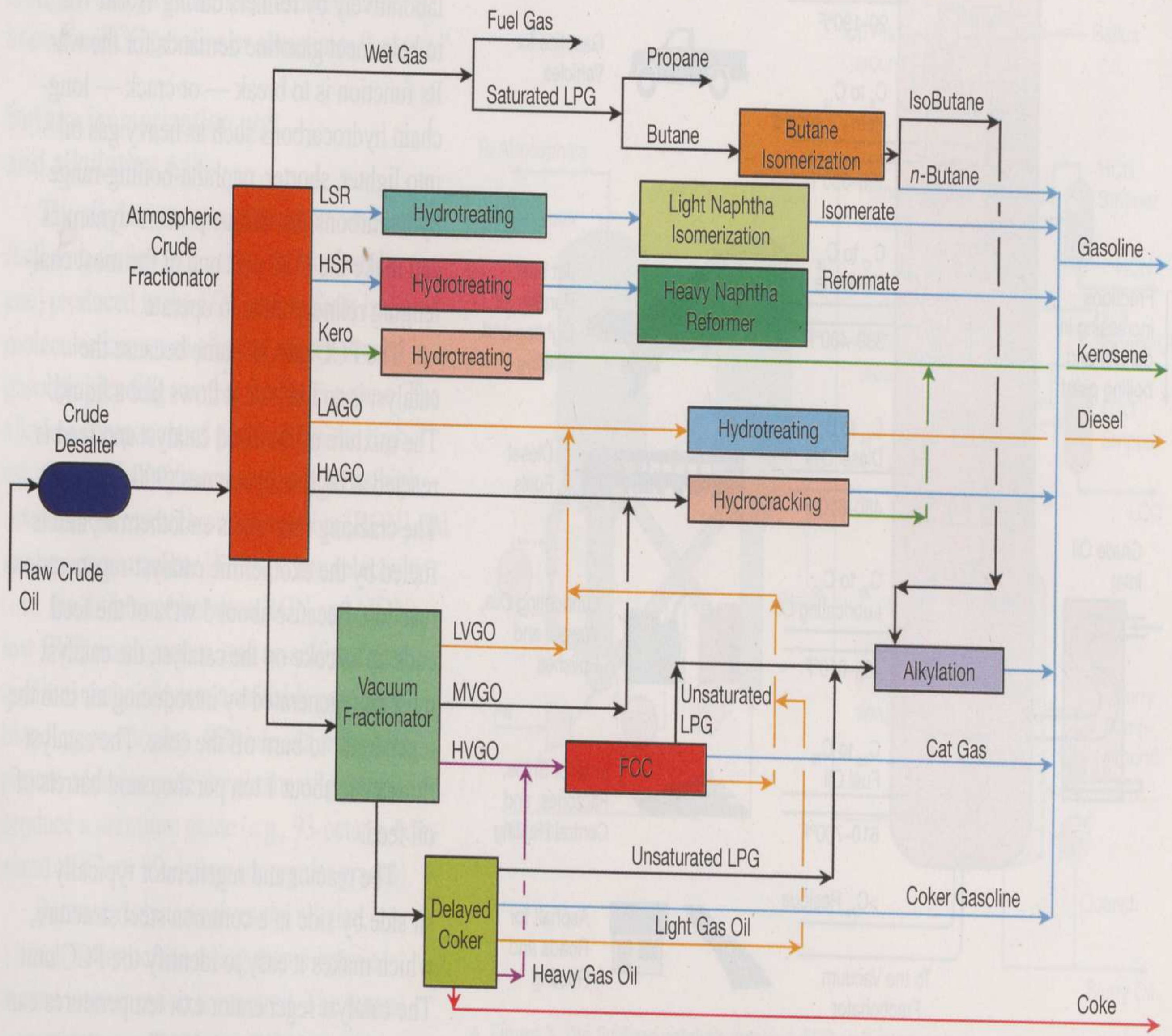
Refining


LPG
Naphtha
Reformer
Chemical Plant
Benzene
Toluene
Xylene
Chemical Plant
PE
PP
Oxo
Butyl
Fluids
Kero / Jet
Distillate
Gasoil
Resid
Coker
Coke
Cat Cracker
LPG
Mogas
Kero / Jet
Diesel / HO
HFO
ExxonMobil

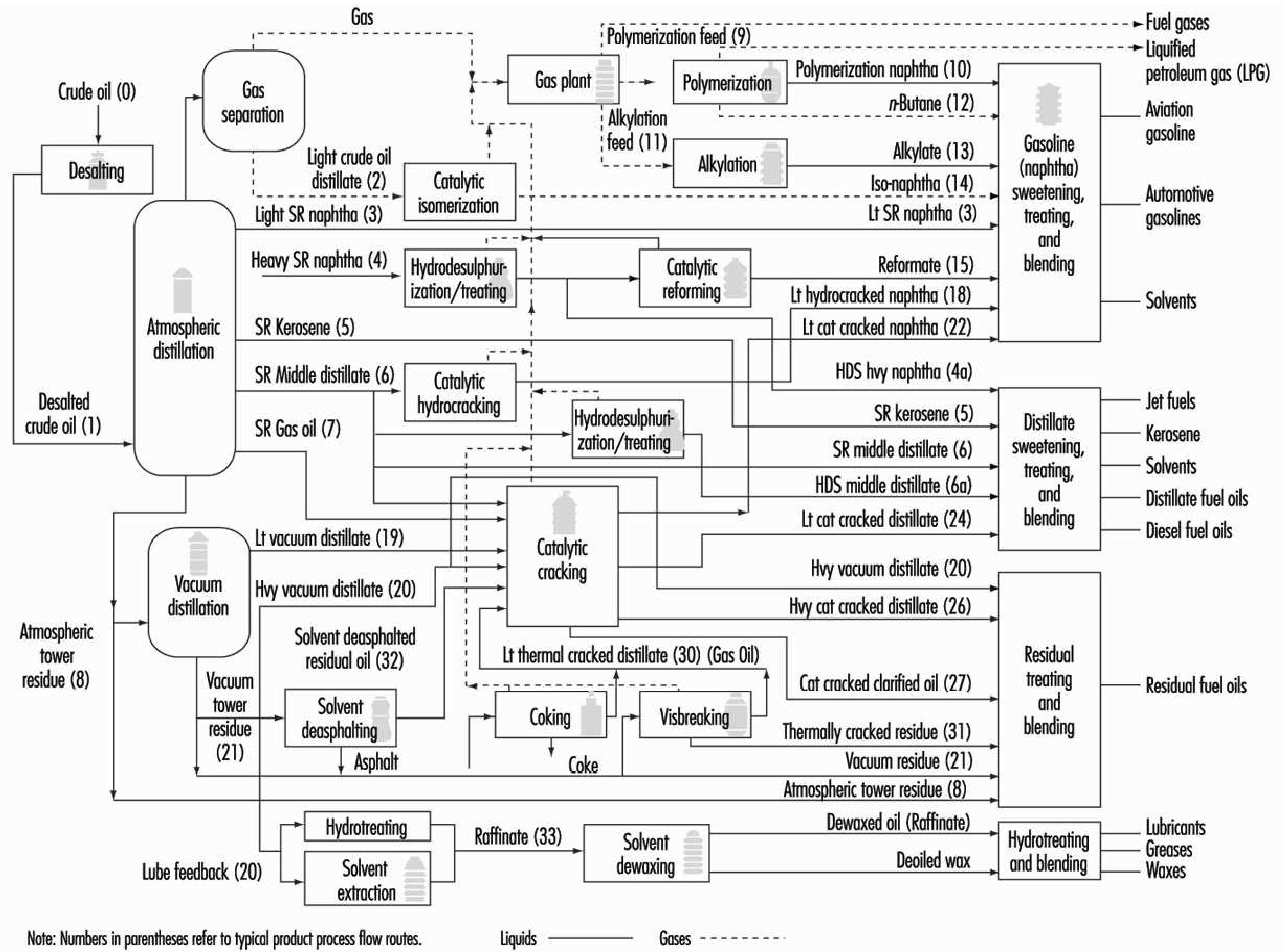


▲ **Figure 2.** One of the first major units in a refinery, the atmospheric crude fractionator

Article continues on next page



▲ **Figure 1.** This refinery flow diagram demonstrates how raw crude oil is converted into fuels. LSR = light straight-run naphtha. HSR = heavy straight run naphtha. Kero = kerosene. LAGO = light atmospheric gas oil.



Note: Numbers in parentheses refer to typical product process flow routes.
Source: OSHA 1996.

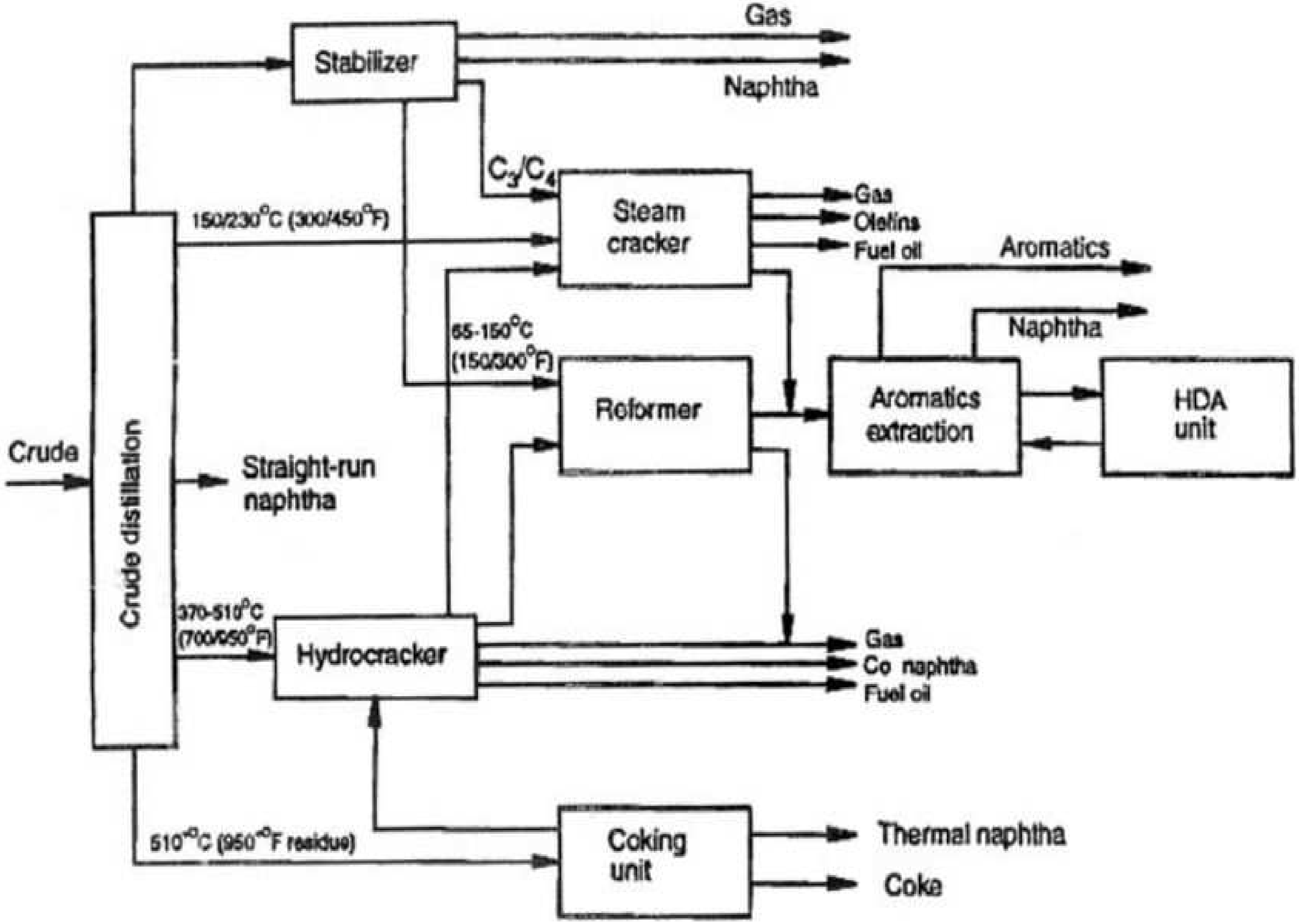
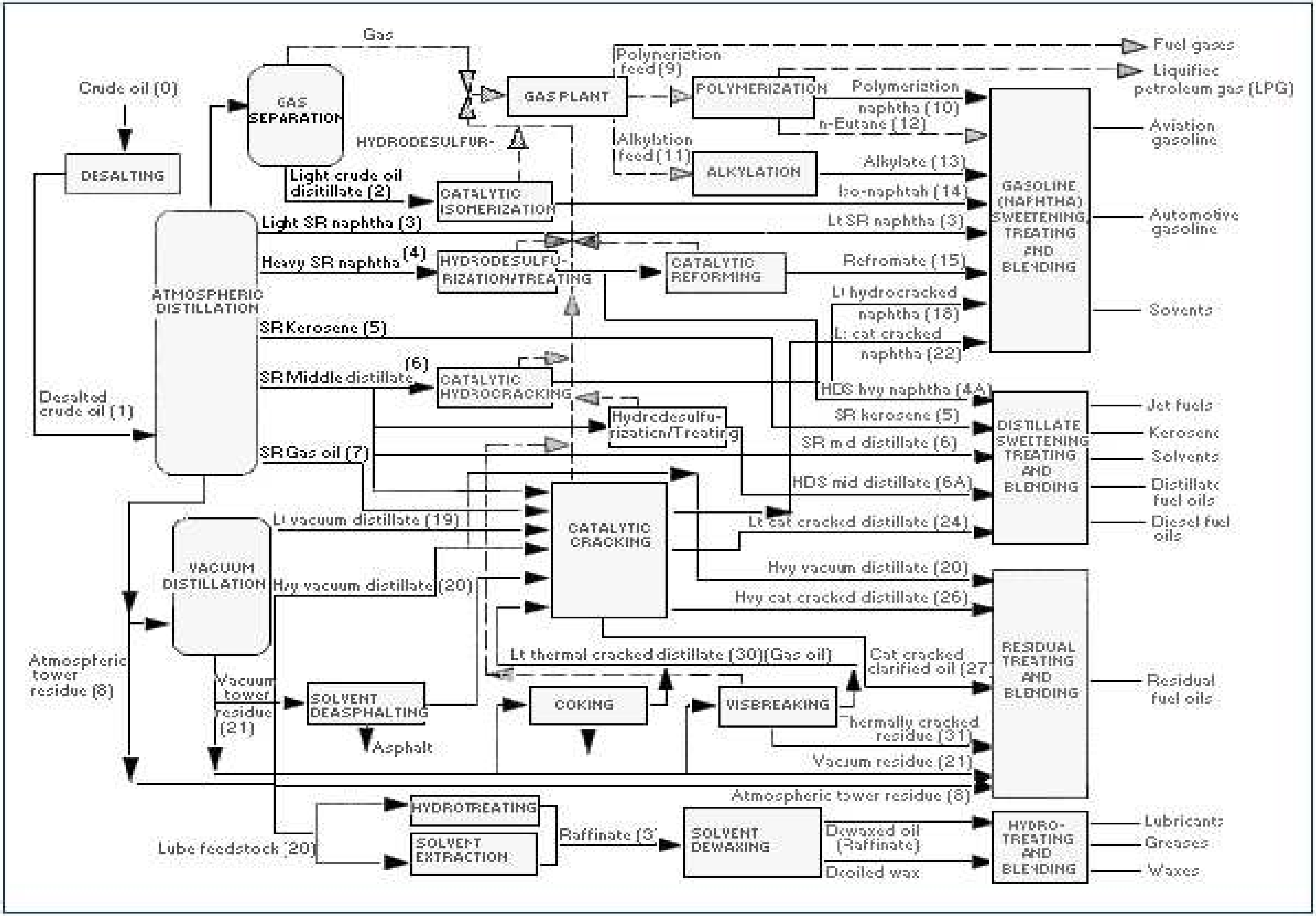
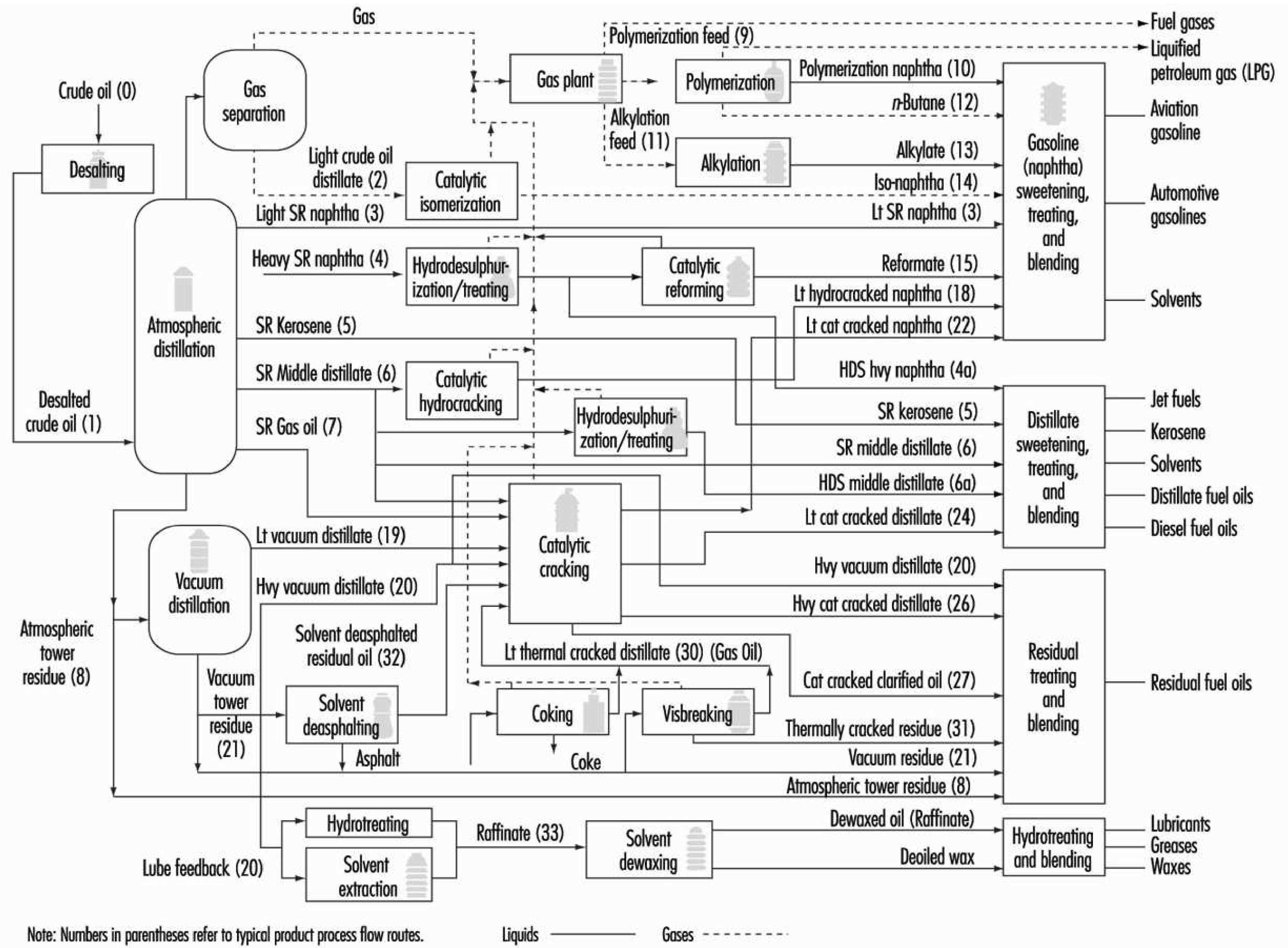


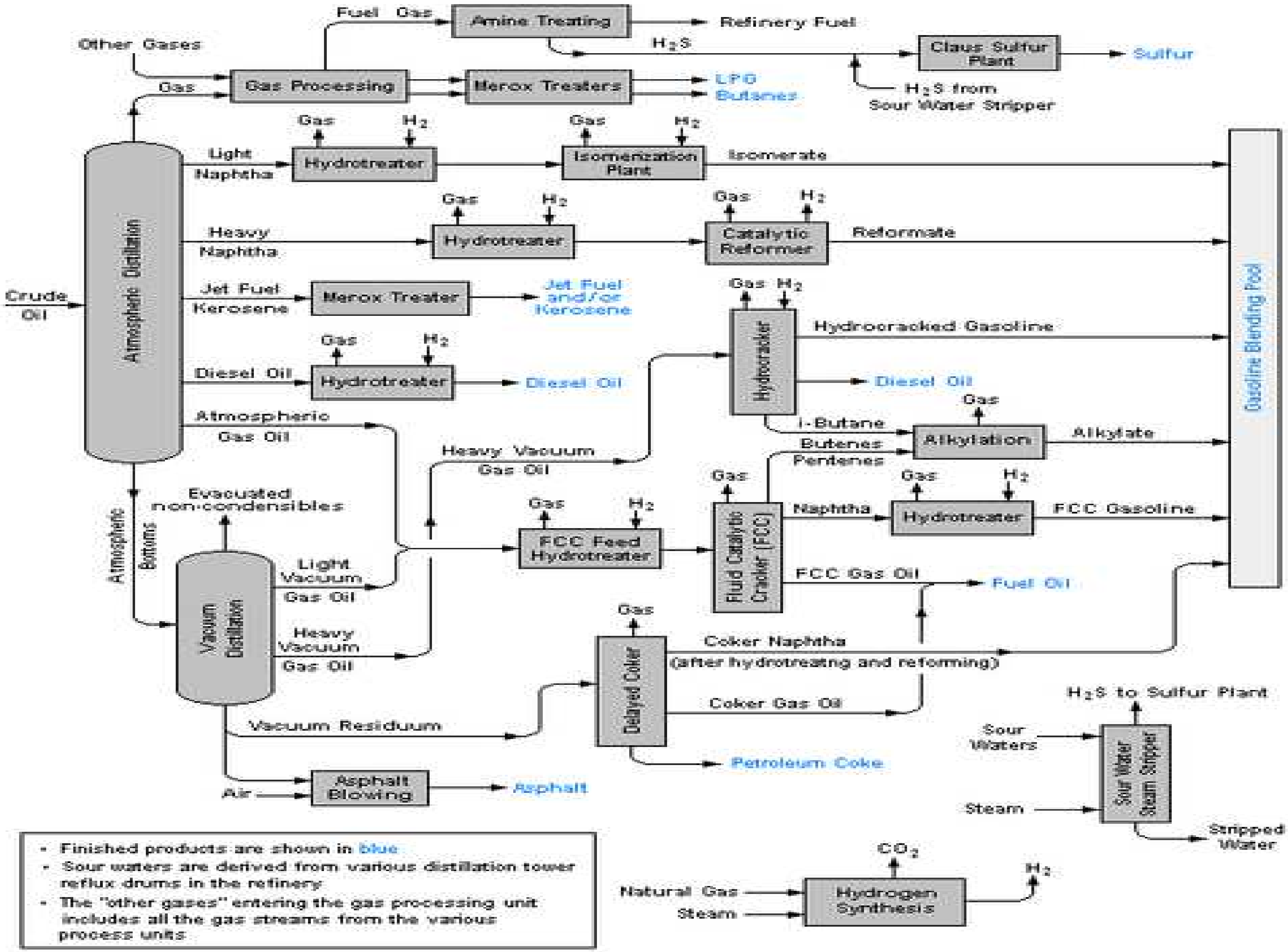
Figure 1.17. A petrochemical refinery configuration.

FIGURE IV:2-6. REFINERY PROCESS CHART.

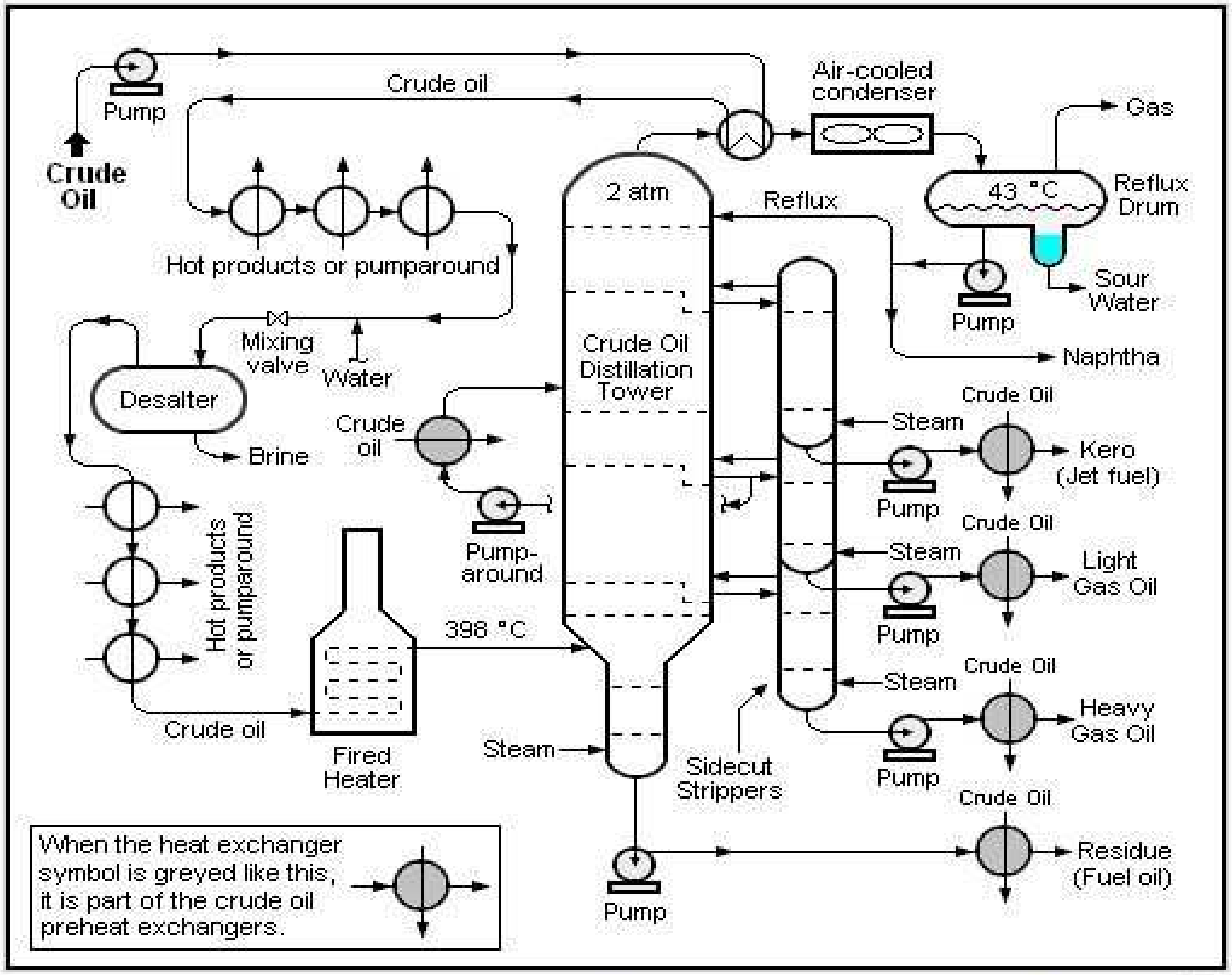




Note: Numbers in parentheses refer to typical product process flow routes.
Source: OSHA 1996.



Fuel Gas
Amine Treating
Refinery Fuel
H_2S
Claus Sulfur Plant
Sulfur
Other Gases
Gas
Gas Processing
Merox Treaters
LPG
Butanes
H_2S from Sour Water Stripper
Gas
H_2
Light Naphtha
Hydrotreater
Isomerization Plant
Isomerate
Heavy Naphtha
Hydrotreater
Catalytic Reformer
Reformate
Crude Oil
Atmospheric Distillation
Jet Fuel Kerosene
Merox Treater
Jet Fuel and/or Kerosene
Gasoline Blending Pool
Hydrocracker
Hydrocracked Gasoline
Diesel Oil
Hydrotreater
Diesel Oil
Diesel Oil
Atmospheric Gas Oil
i-Butane
Alkylation
Alkylate
Heavy Vacuum Gas Oil
Butenes Pentenes
Evacuated non-condensibles
FCC Feed Hydrotreater
Fluid Catalytic Cracker (FCC)
Naphtha
Hydrotreater
FCC Gasoline
Atmospheric Bottoms
Vacuum Distillation
Light Vacuum Gas Oil
Heavy Vacuum Gas Oil
FCC Gas Oil
Fuel Oil
Delayed Coker
Coker Naphtha (after hydrotreatng and reforming)
Coker Gas Oil
H_2S to Sulfur Plant
Vacuum Residuum
Sour Waters
Sour Water Steam Stripper
Petroleum Coke
Air
Asphalt Blowing
Asphalt
Steam
Stripped Water
• Finished products are shown in blue
• Sour waters are derived from various distillation tower reflux drums in the refinery
• The "other gases" entering the gas processing unit includes all the gas streams from the various process units
CO_2
H_2
Natural Gas
Steam
Hydrogen Synthesis



Schematic flow diagram of a typical crude oil distillation unit as used in petroleum crude oil refineries.

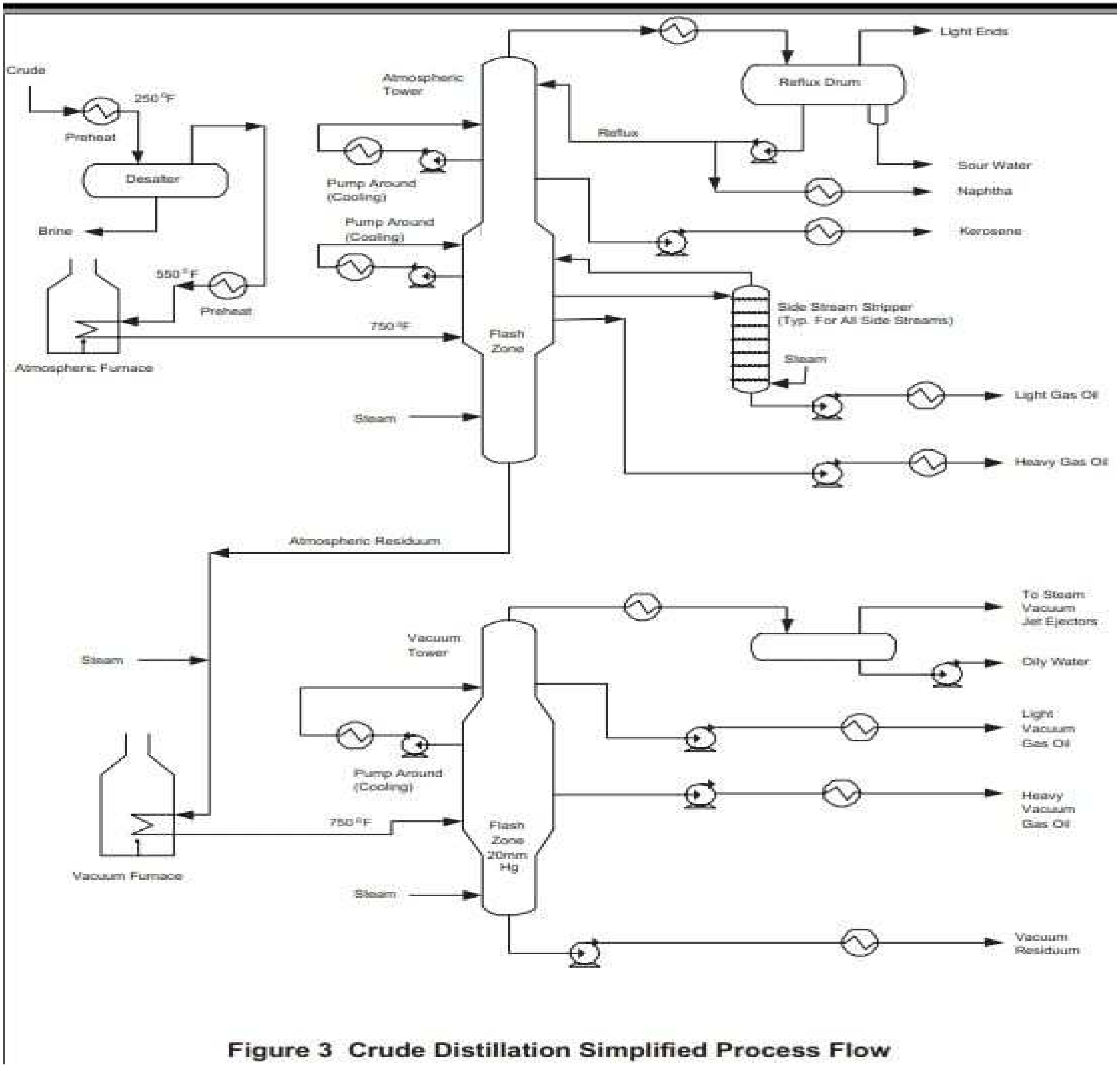


Figure 3 Crude Distillation Simplified Process Flow

Processes and Flowsheets

Process Development since the Commencement of the Modern Refining Era

Year	Process Name	Purpose	By-Products
1862	Atmospheric distillation	Produce kerosene	Naphtha, cracked residuum
1870	Vacuum distillation	Lubricants	Asphalt, residua
1913	Thermal cracking	Increase gasoline yield	Residua, fuel oil
1916	Sweetening	Reduce sulfur	Sulfur
1930	Thermal reforming	Improve octane number	Residua
1932	Hydrogenation	Remove sulfur	Sulfur
1932	Coking	Produce gasoline	Coke
1933	Solvent extraction	Improve lubricant viscosity index	Aromatics
1935	Solvent dewaxing	Improve pour point	Wax
1935	Catalytic polymerization	Improve octane number	Petrochemical feedstocks
1937	Catalytic cracking	Higher octane gasoline	Petrochemical feedstocks
1939	Visbreaking	Reduce viscosity	Increased distillate yield
1940	Alkylation	Increase octane number	High-octane aviation fuel
1940	Isomerization	Produce alkylation feedstock	Naphtha
1942	Fluid catalytic cracking	Increase gasoline yield	Petrochemical feedstocks
1950	Deasphalting	Increase cracker feedstock	Asphalt
1952	Catalytic reforming	Convert low-quality naphtha	Aromatics
1954	Hydrodesulfurization	Remove sulfur	Sulfur
1956	Inhibitor sweetening	Remove mercaptans	Disulfides and sulfur
1957	Catalytic isomerization	Convert to high-octane products	Alkylation feedstocks
1960	Hydrocracking	Improve quality and reduce sulfur	Alkylation feedstocks
1974	Catalytic dewaxing	Improve pour point	Wax
1975	Resid hydrocracking	Increase gasoline yield	Cracked residua

Process name	Action	Method	Purpose
CONVERSION PROCESSES--ALTERATION OR REARRANGEMENT			
Catalytic reforming	Alteration/ dehydration	Catalytic	Upgrade low-octane naphtha
Isomerization	Rearrange	Catalytic	Convert straight chain to branch
TREATMENT PROCESSES			
*Amine treating	Treatment	Absorption	Remove acidic contaminants
Desalting	Dehydration	Absorption	Remove contaminants
Drying & sweetening	Treatment	Abspt/ therm	Remove H_2O & sulfur cmpds
*Furfural extraction	Solvent extr.	Absorption	Upgrade mid distillate & lubes
Hydrodesulfurization	Treatment	Catalytic	Remove sulfur, contaminants
Hydrotreating	Hydrogenation	Catalytic	Remove impurities, saturate HC's
*Phenol extraction	Solvent extr.	Abspt/ therm	Improve visc. index, color
Solvent deasphalting	Treatment	Absorption	Remove asphalt
Solvent dewaxing	Treatment	Cool/ filter	Remove wax from lube stocks
Solvent extraction	Solvent extr.	Abspt/ precip.	Separate unsat. oils
Sweetening	Treatment	Catalytic	Remv H_2S, convert mercaptan

Process name	Action	Method	Purpose
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Solvent dewaxing	Treatment	Cool/ filter	Remove wax from lube stocks
Solvent extraction	Solvent extr.	Abspt/ precip.	Separate unsat. oils
Sweetening	Treatment	Catalytic	Remv H_2S, convert mercaptan

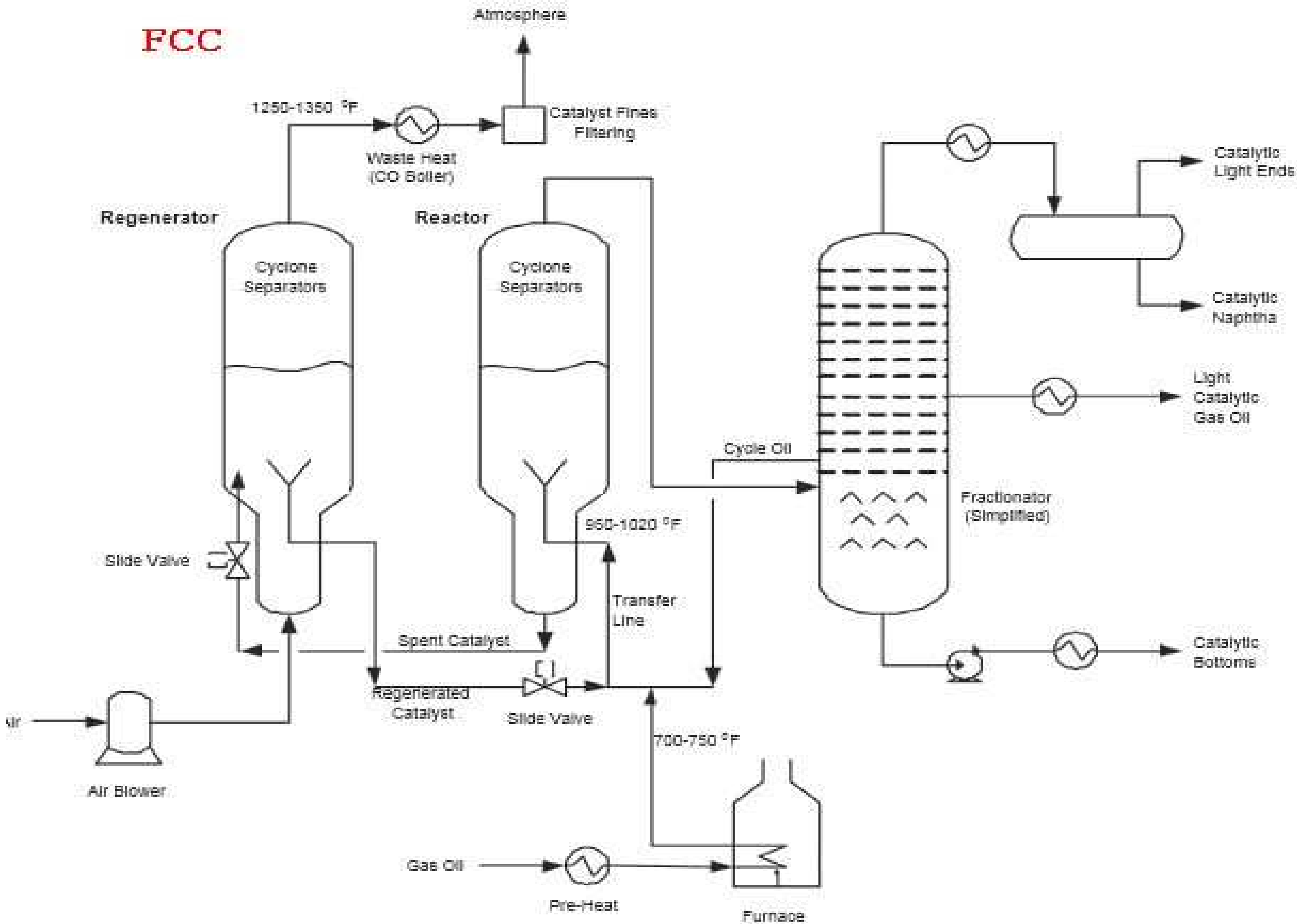
Steam cracking to olefins

Ultimate yields from steam cracking various feedstocks[45]

	Feedstock					
Yield, wt %	**Ethane**	**Propane**	**Butane**	**Naphtha**	**Gas oil**	**Saudi NGL**
$H_2 + CH_4$	13	28	24	26	18	23
Ethylene	80	45	37	30	25	50
Propylene	2.4	15	18	13	14	12
Butadiene	1.4	2	2	4.5	5	2.5
Mixed butenes	1.6	1	6.4	8	6	3.5
C_5^+	1.6	9	12.6	18.5	32	9

NGL=Natural Gas Liquids

FCC


Atmosphere
1250-1350 °F
Catalyst Fines
Filtering
Waste Heat
(CO Boiler)
Regenerator
Reactor
Cyclone
Separators
Cyclone
Separators
Catalytic
Light Ends
Catalytic
Naphtha
Light
Catalytic
Gas Oil
Cycle Oil
Fractionator
(Simplified)
950-1020 °F
Slide Valve
Transfer
Line
Spent Catalyst
Catalytic
Bottoms
Regenerated
Catalyst
Slide Valve
Air Blower
700-750 °F
Gas Oil
Pre-Heat
Furnace

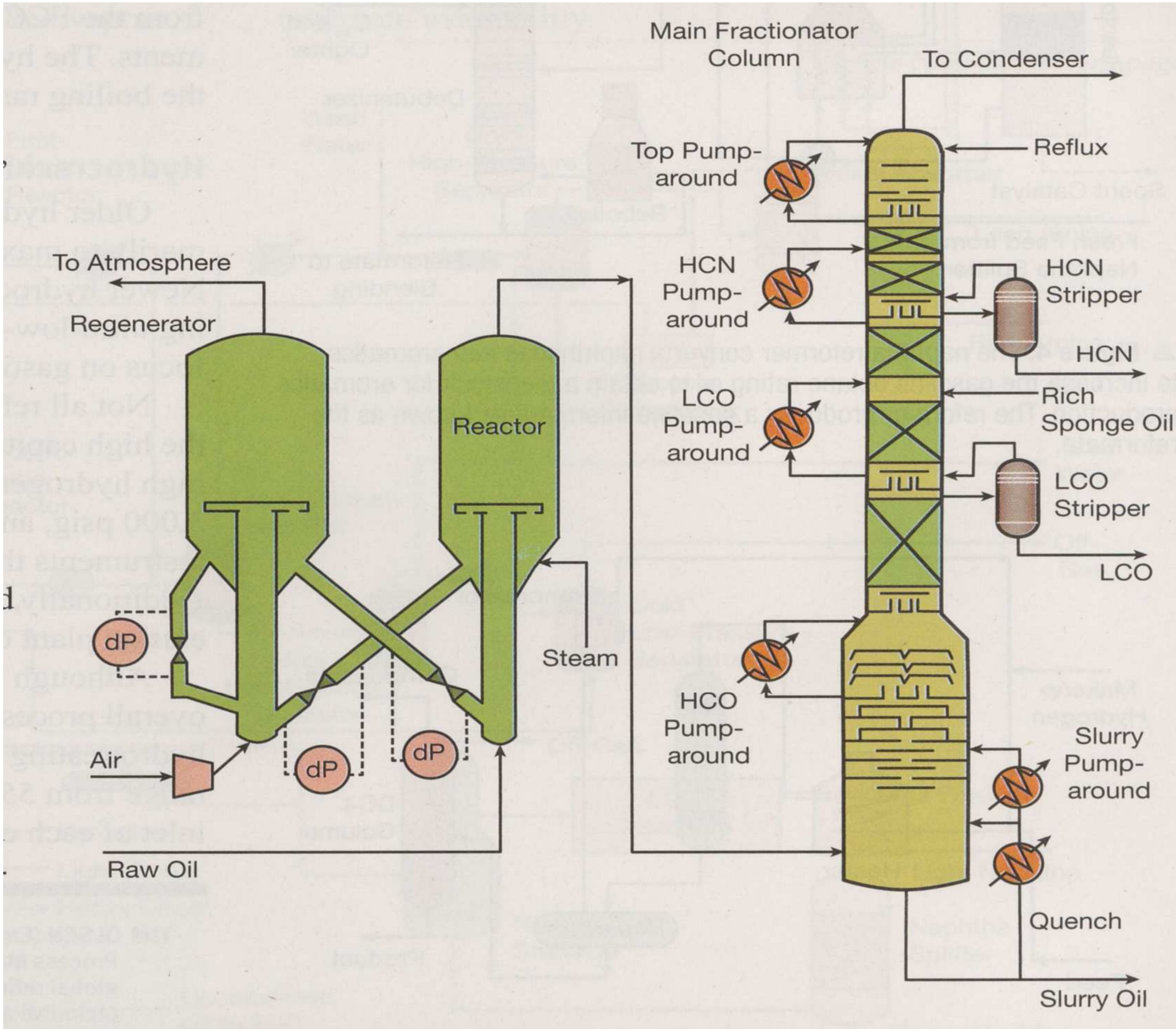
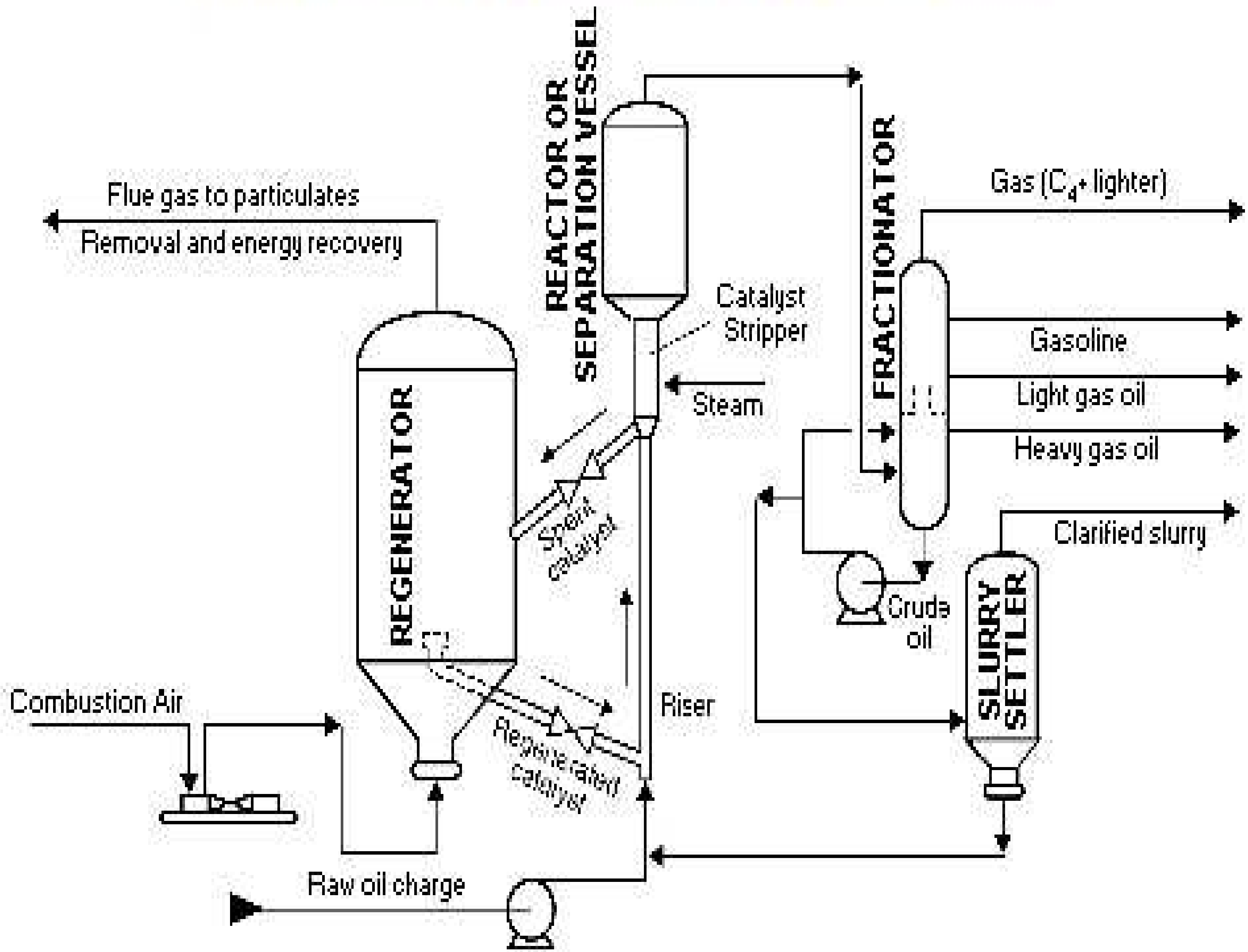

Main Fractionator
Column
To Condenser
Top Pump-
around
Reflux
To Atmosphere
HCN
Pump-
around
HCN
Stripper
Regenerator
HCN
Rich
LCO
Pump-
around
Sponge Oil
Reactor
LCO
Stripper
LCO
dP
Steam
HCO
Pump-
around
Slurry
Pump-
around
Air
dP
dP
Raw Oil
Quench
Slurry Oil

FIGURE IV:2-14. FLUID CATALYTIC CRACKING.



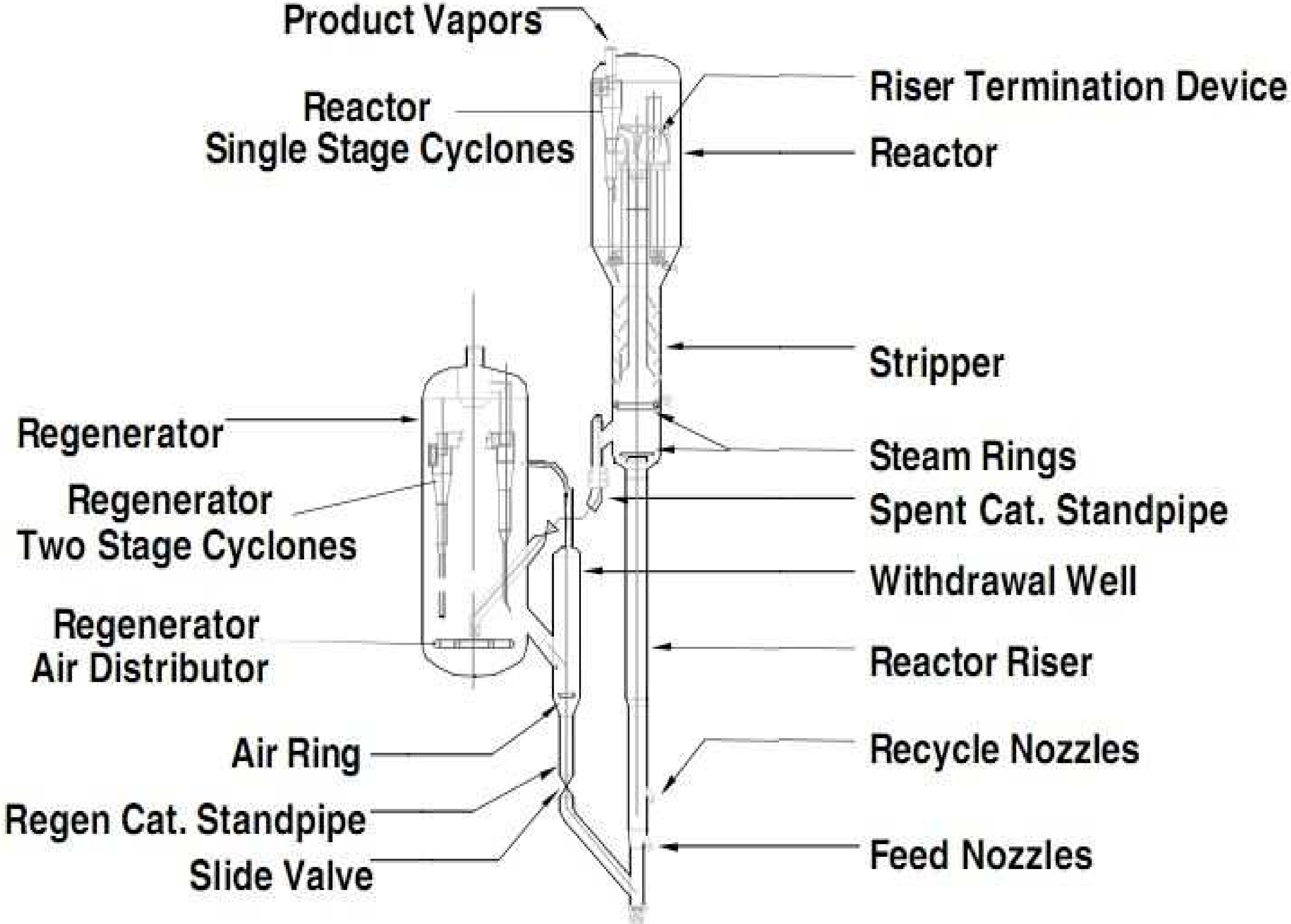


Figure 6.3. Reactor-regenerator of modern FCCU.

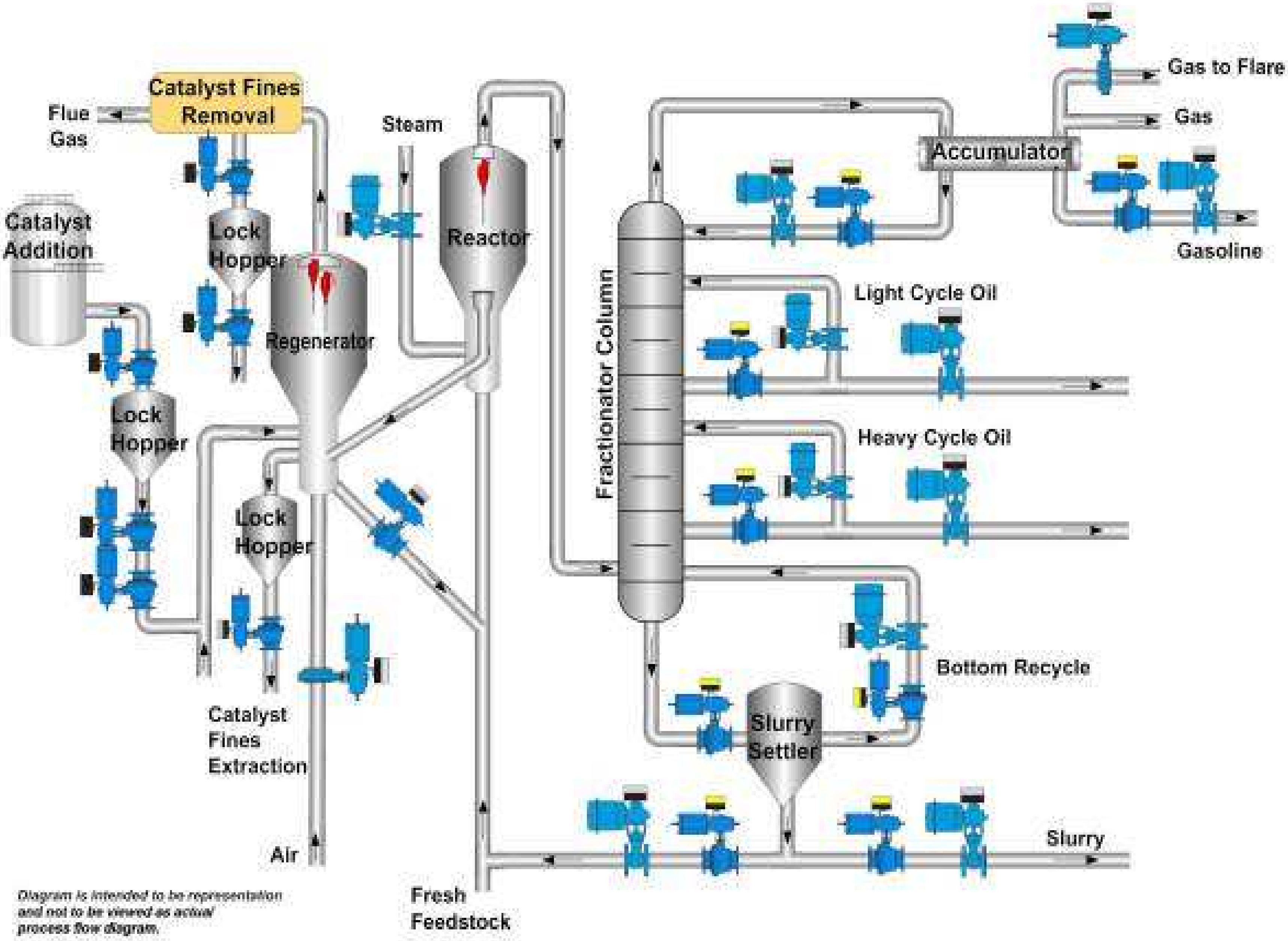
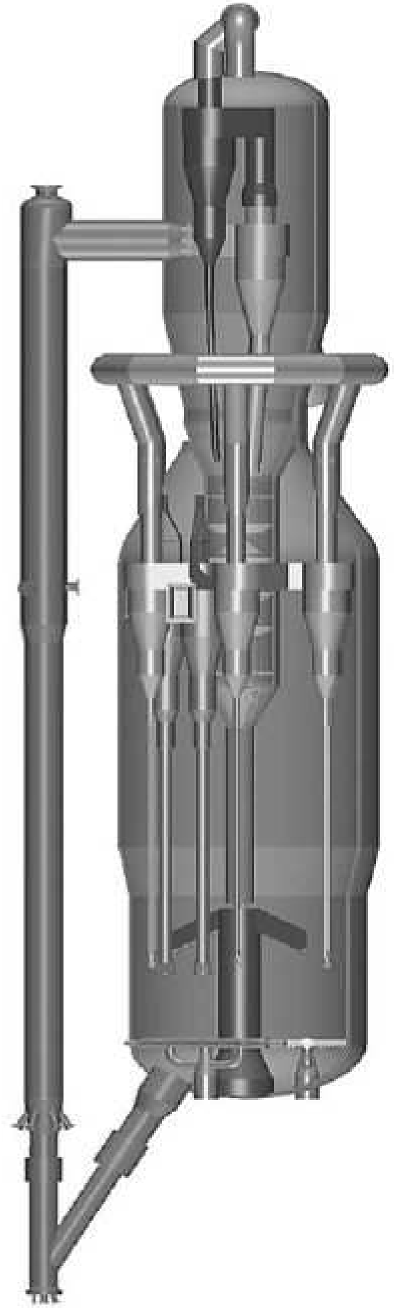


Diagram is intended to be representation and not to be viewed as actual process flow diagram.



Orthoflow FCC converter.

ıg valve.

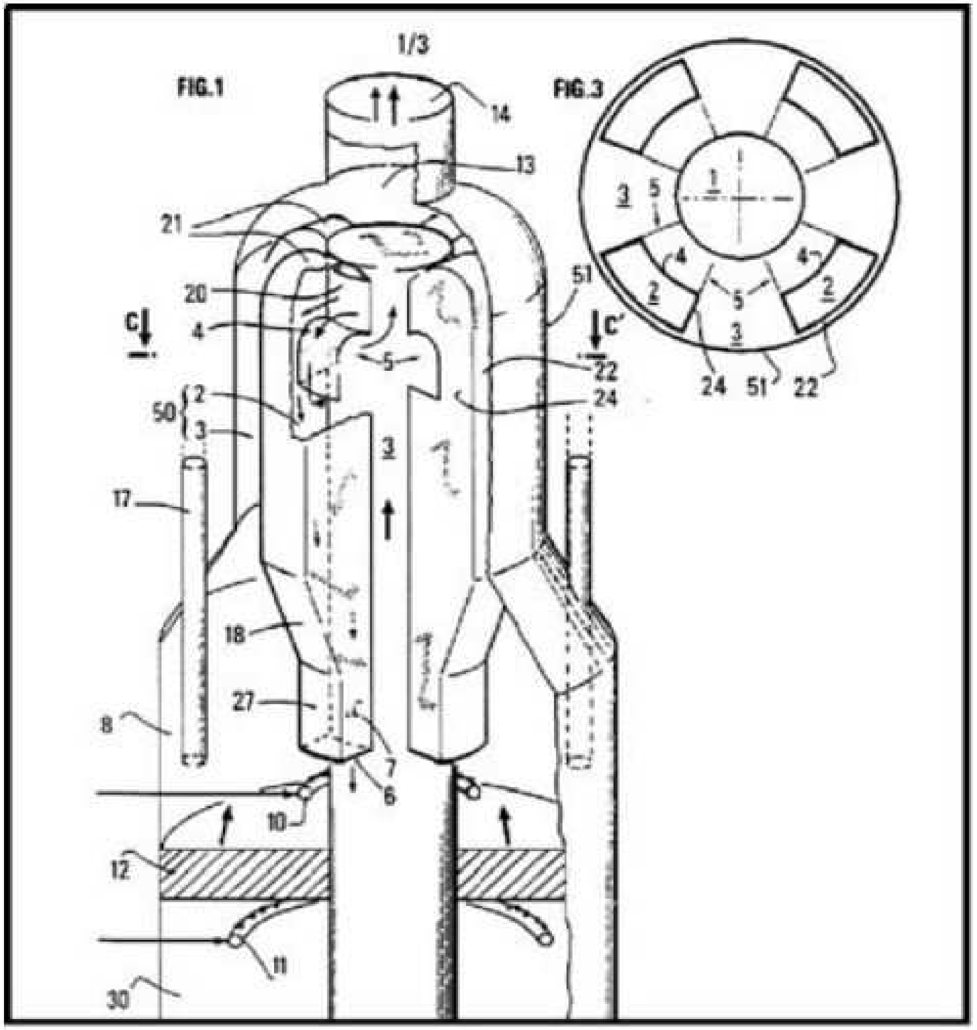
Feed injection cone.

Spent catalyst stripper.

FIGURE 11.2.6 Filtering module.

FIGURE 11.2.7 Droplet separator.

Figure 6.8. Commercial feed injection systems.



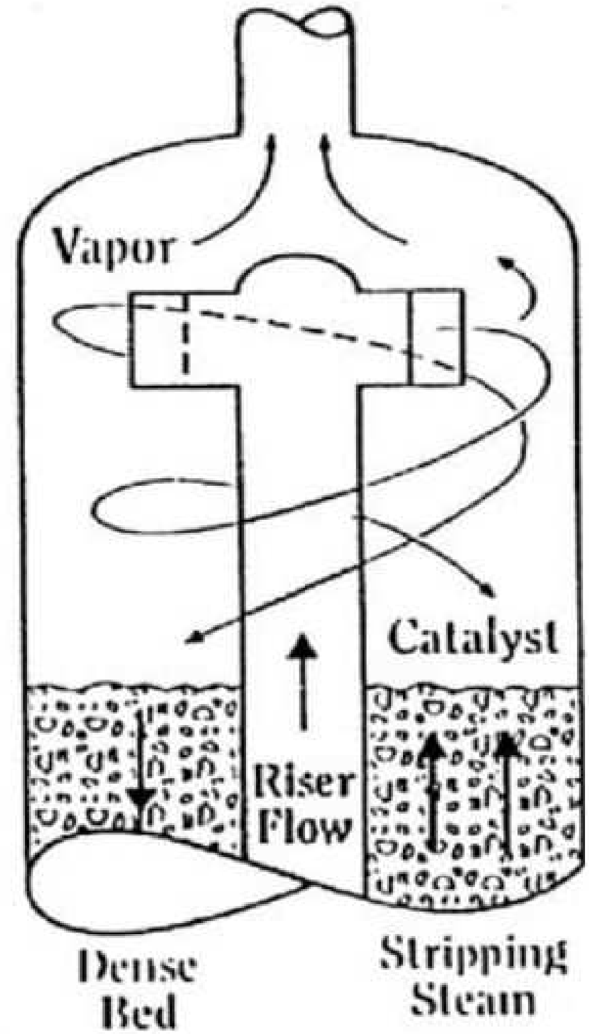
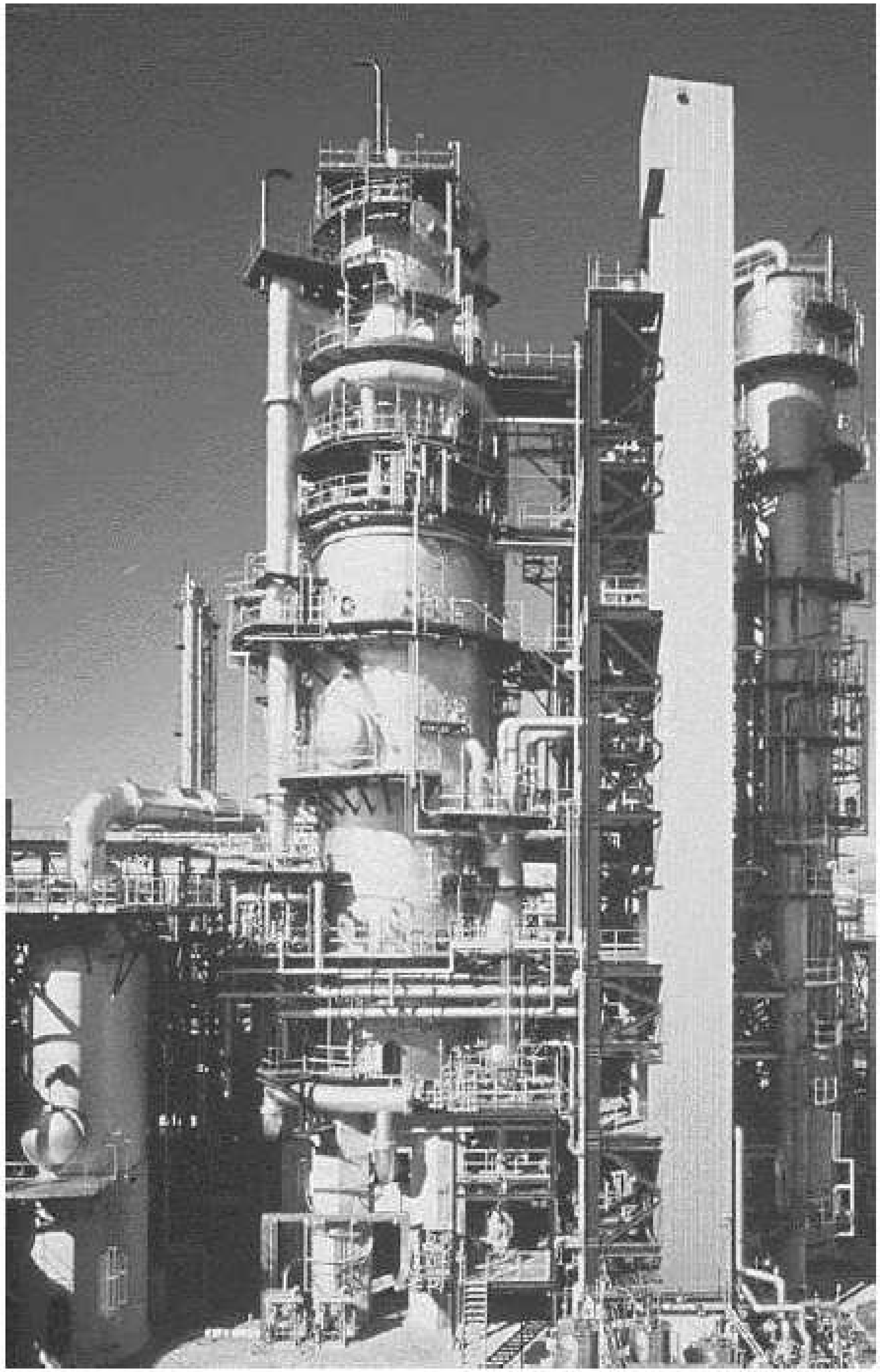
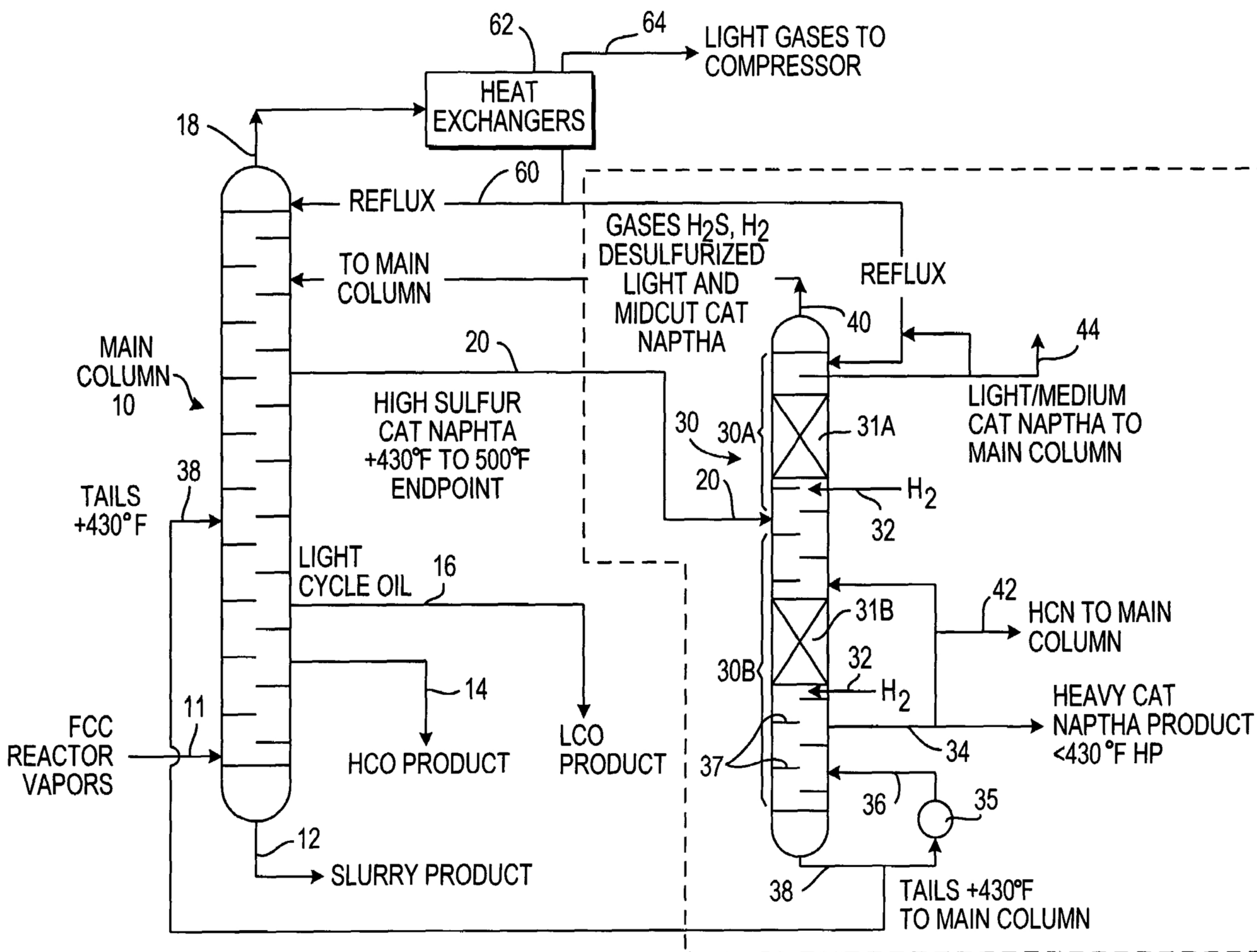


Figure 6.9. Riser separators.

FIGURE 3.4.1 SWI-IFP RFCC unit located in Japan. Photograph shows second- and first-stage regenerators and main fractionator. Note the external cyclones on the second-stage regenerator.



KBR Orthoflow FCC unit.



62
64
LIGHT GASES TO COMPRESSOR
HEAT EXCHANGERS
18
60
REFLUX
GASES H_2S, H_2 DESULFURIZED LIGHT AND MIDCUT CAT NAPTHA
TO MAIN COLUMN
REFLUX
40
44
20
MAIN COLUMN 10
LIGHT/MEDIUM CAT NAPTHA TO MAIN COLUMN
HIGH SULFUR CAT NAPHTA +430°F TO 500°F ENDPOINT
30
30A
31A
20
H_2
32
38
TAILS +430°F
32
LIGHT CYCLE OIL
16
42
HCN TO MAIN COLUMN
31B
32
30B
H_2
14
HEAVY CAT NAPTHA PRODUCT <430 °F HP
FCC REACTOR VAPORS
11
HCO PRODUCT
LCO PRODUCT
37
34
36
35
12
SLURRY PRODUCT
38
TAILS +430°F TO MAIN COLUMN

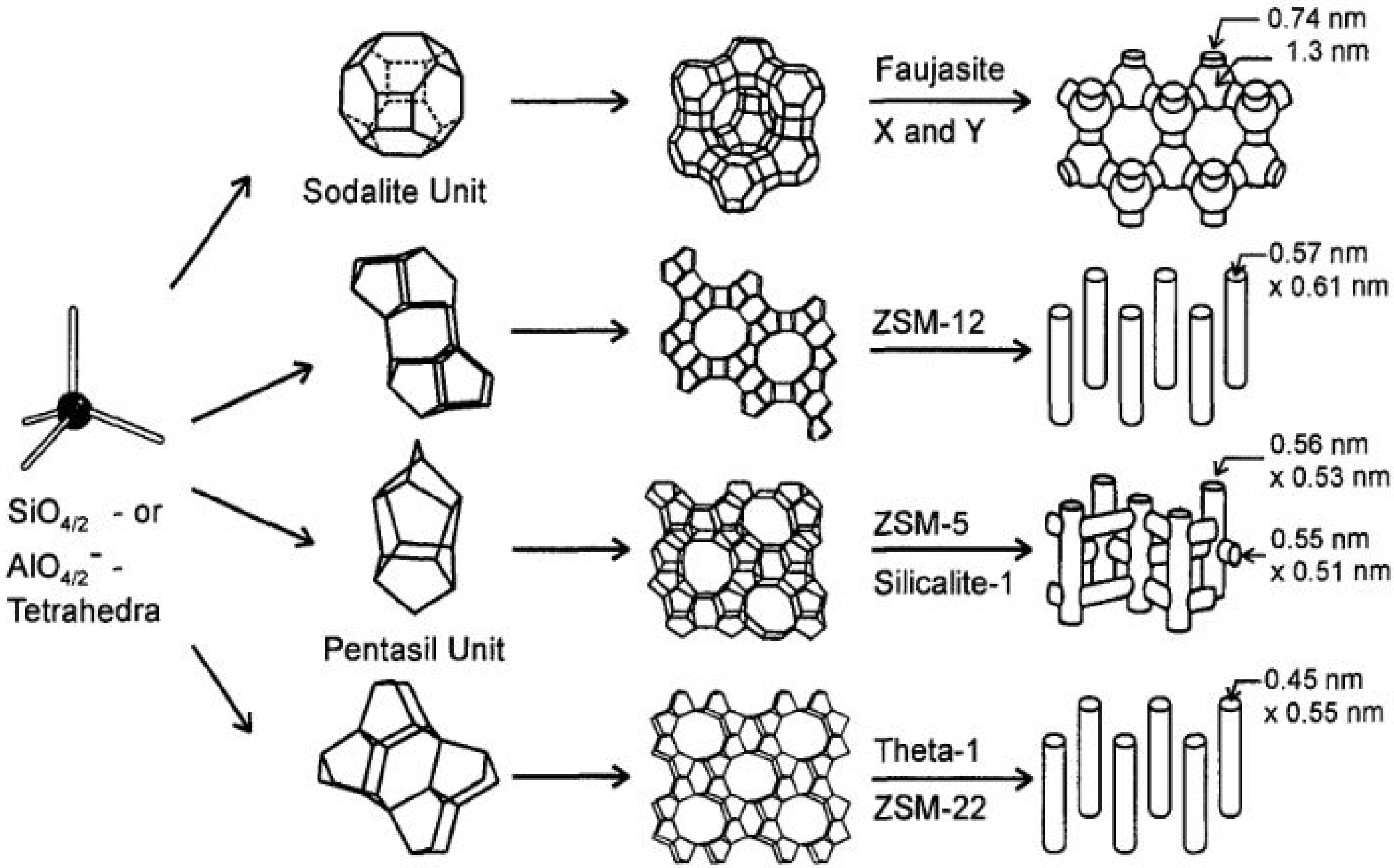


Fig. 1. Structures of four selected zeolites (from top to bottom: faujasite or zeolites X, Y; zeolite ZSM-12; zeolite ZSM-5 or silicalite-1; zeolite Theta-1 or ZSM-22) and their micropore systems and dimensions.

Chemistry of Cracking:

Two general types of reaction occur during cracking:

1. The decomposition of large molecules into small molecules (primary reactions):

$$CH_3-CH_2-CH_2-CH_3 \longrightarrow CH_4 + CH_3-CH=CH_2$$

Butane methane propene

Or

$$CH_3-CH_2-CH_2-CH_3 \longrightarrow CH_3-CH_3 + CH_2=CH_2$$

Butane ethane ethylene

2. Reactions by which some of the primary products react to form higher molecular weight materials (secondary reactions):

$$CH_2=CH_2 + CH_2=CH_2 \longrightarrow CH_3-CH_2-CH=CH_2$$

Ethylene butene

Or

$$R-CH=CH_2 + R'-CH=CH_2 \longrightarrow \text{tar, heavy oil, coke, etc.}$$

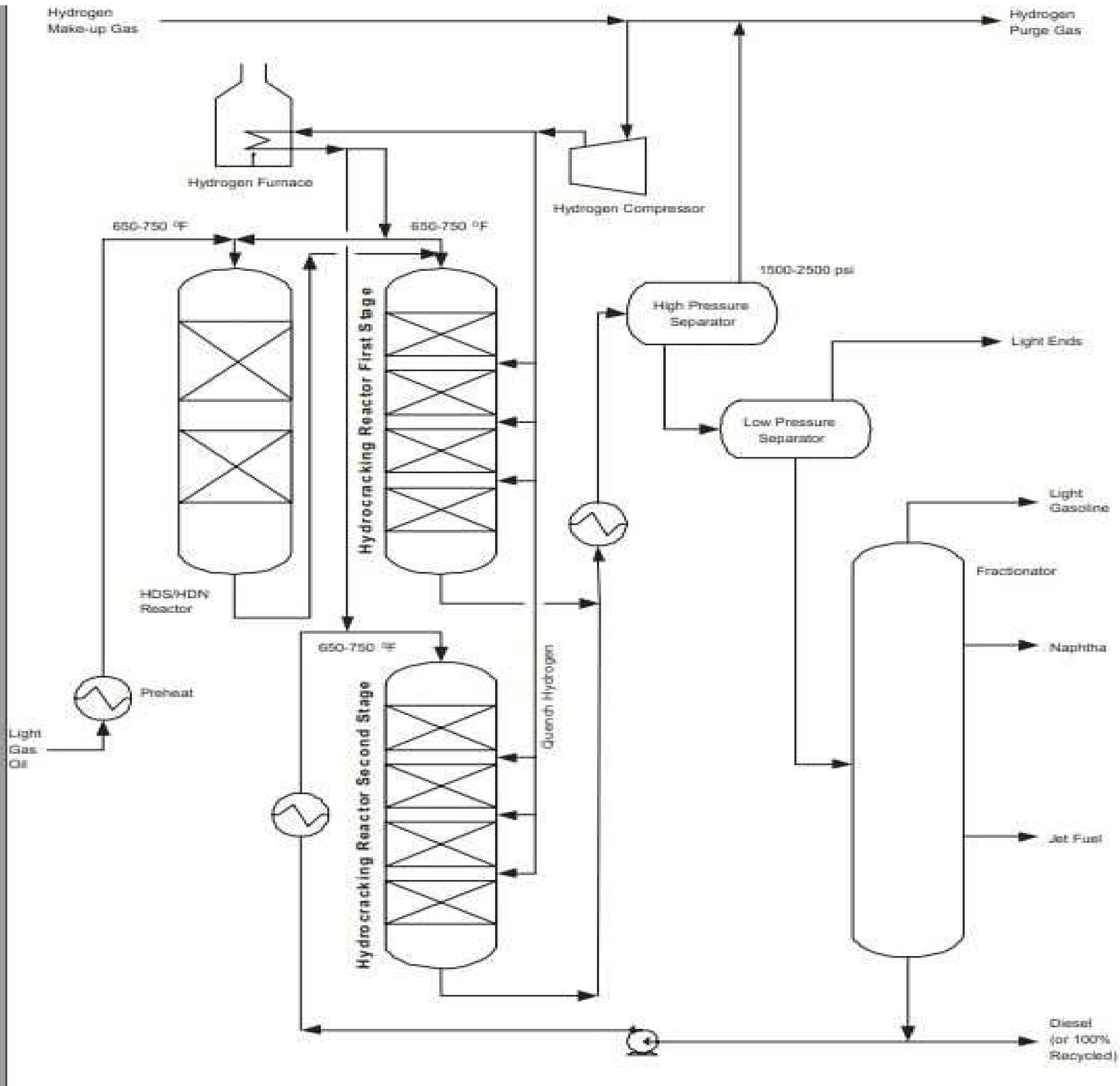
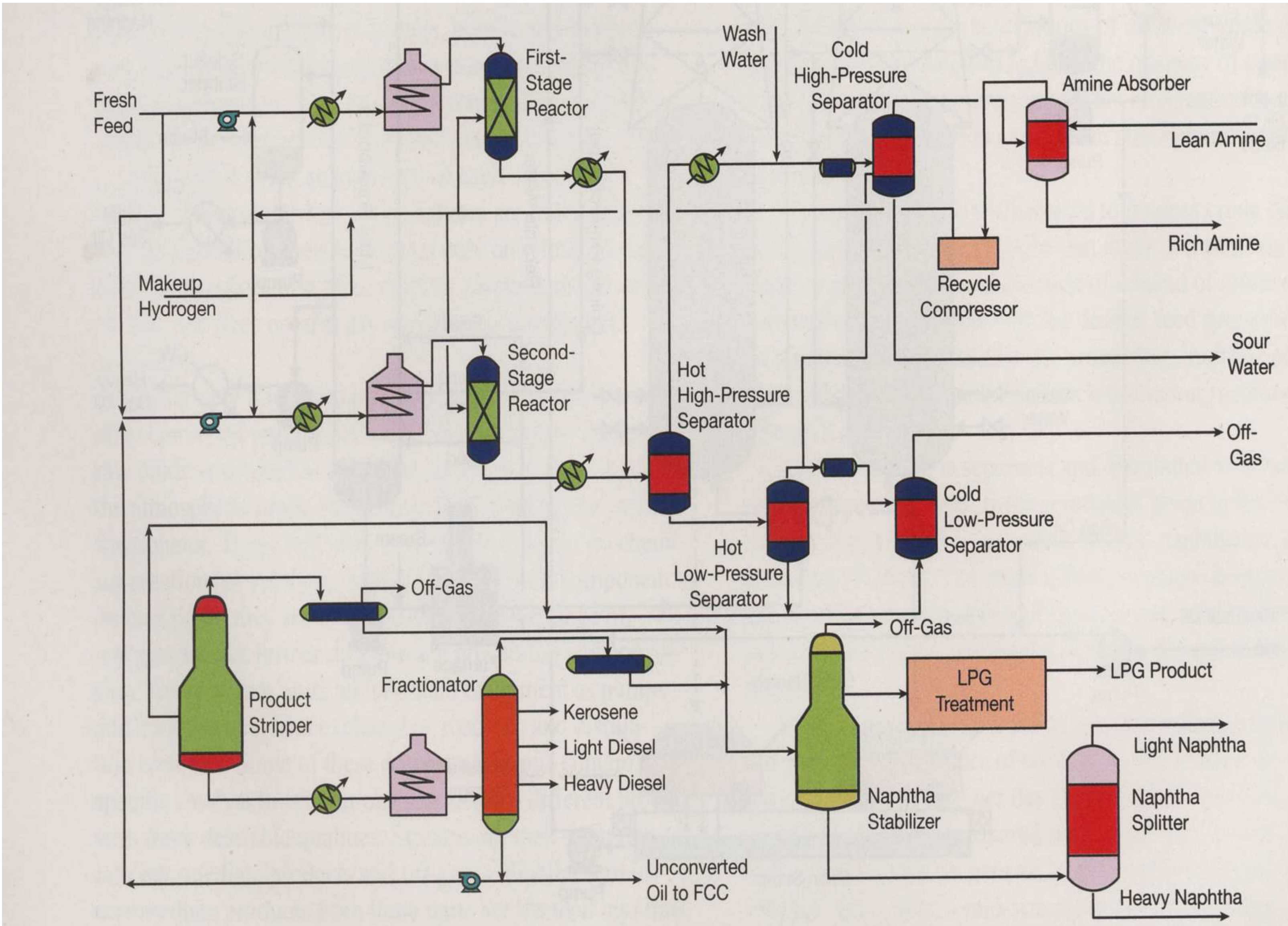
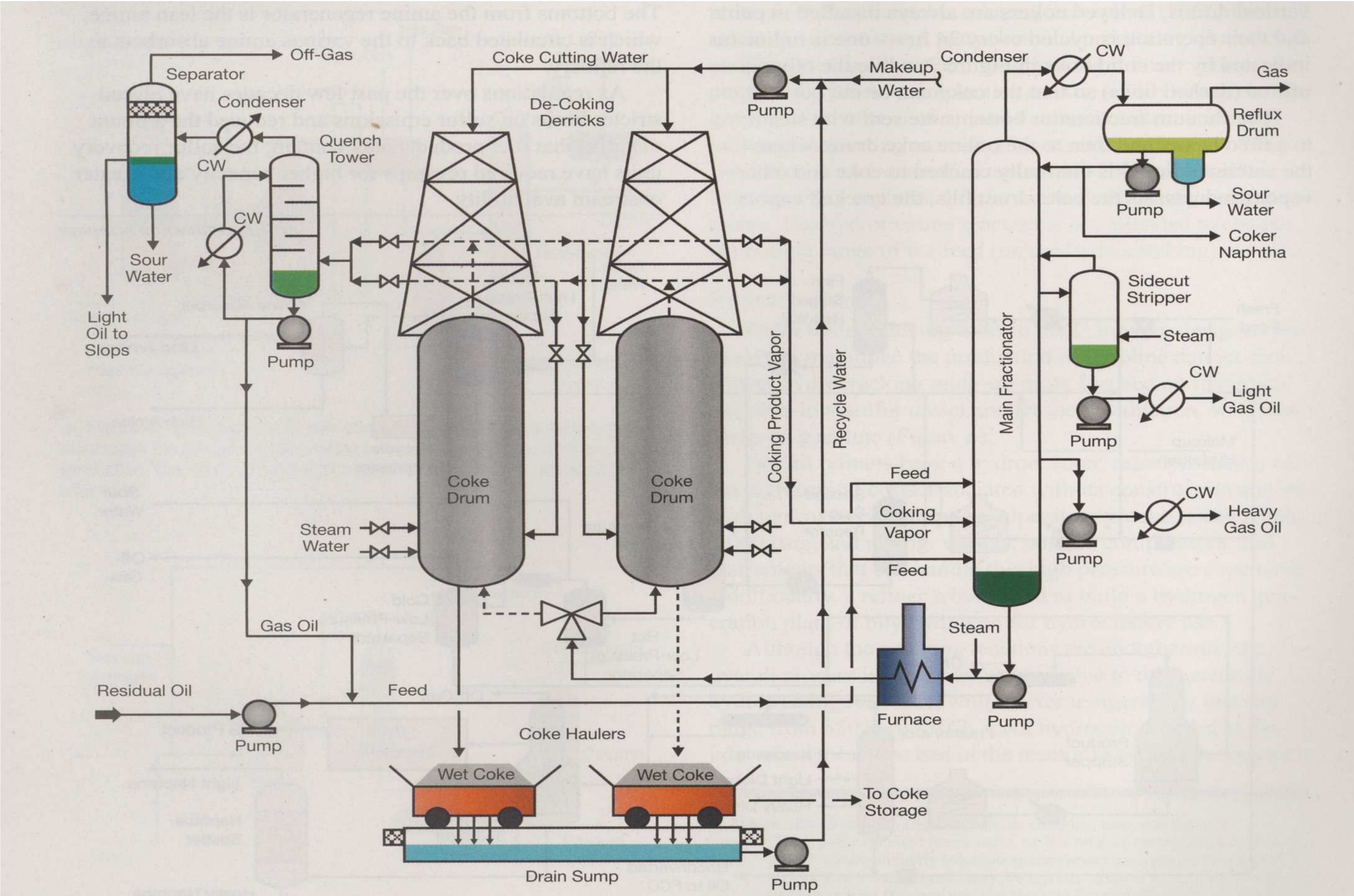


Figure 7 Hydrocracking (Two-Stage) Simplified Process Flow

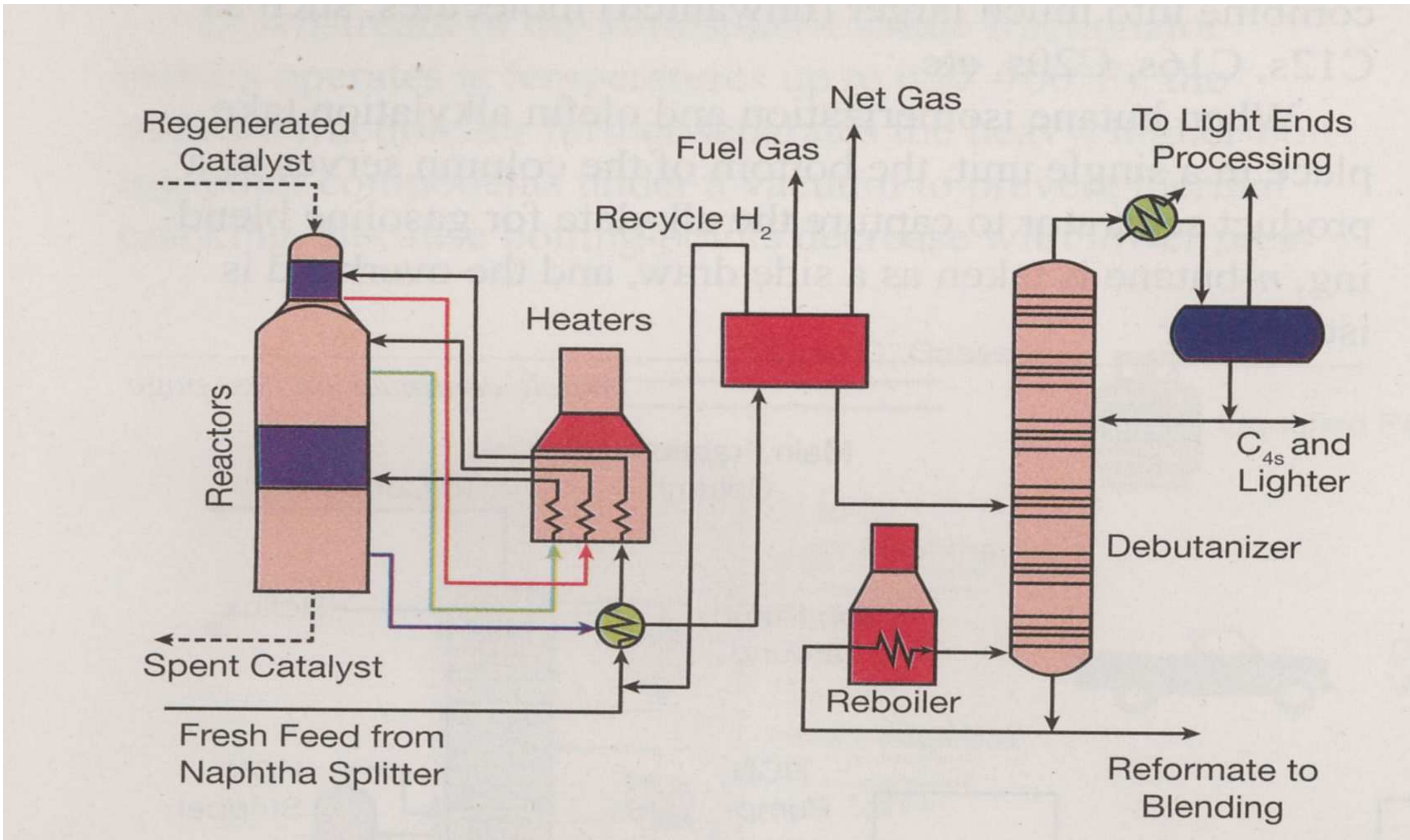
Hydrocracking



Delayed coking



Naphta reformer



Naphta hydrotreater

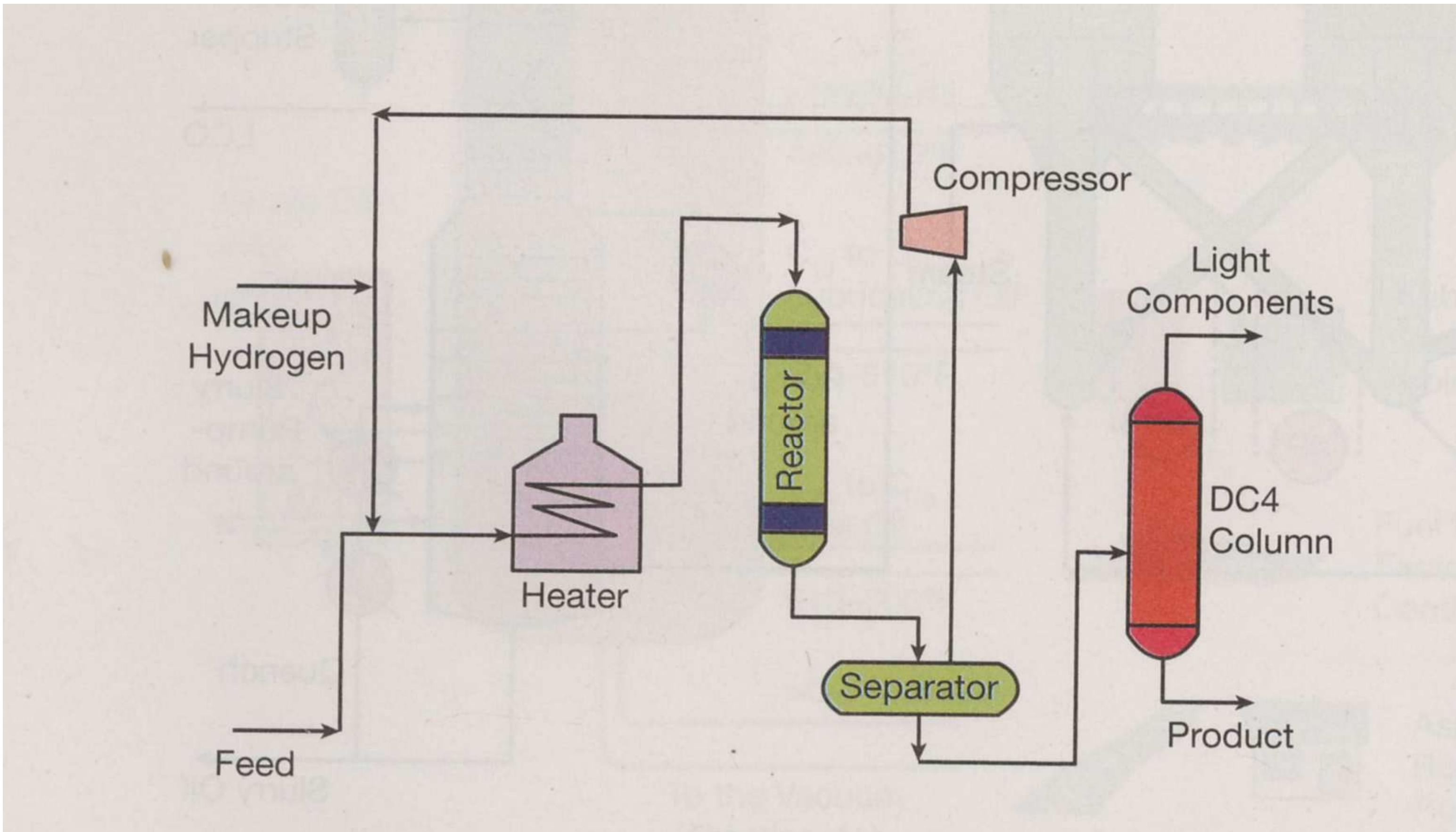


Figure 5. The naphtha hydrotreater removes impurities from the heavy

Markerweek 11-4-2012 p.14

אין יבוא ואין תחרות

בית הזיקוק בחיפה מחזיק בתואר "בית הזיקוק הגדול במזרח התיכון". הוא בעל יכולת זיקוק של 197 אלף חביות נפט ביממה, פי שניים מבית הזיקוק באשדוד.

הנפט הגולמי מגיע לבית הזיקוק בטמפרטורת הסביבה. תהליך הזיקוק שלו כולל את חימום הנפט ועיבויו ברמות טמפרטורות שונות, שנעשה באמצעות כבשני ענק שעל דפנותיהם צינורות שבהם זורם הנפט המחומם. החימום לרמות של מאות מעלות צלזיוס מאפשר את הפרדת חומריו השונים של הנפט על סמך נקודת הרתיחה של כל חומר המרכיב אותו.

מגדלי הזיקוק נדרשים להיות גבוהים, מכיוון שהאדים עולים מעלה. לאחר תהליך האידוי והעיבוי, שלב הזיקוק הבא הוא הפיצוח, שבמהלכו משתמשים בזרזים הנמצאים גם בקנקני סינון המים בריטה ומתקני טיהור אחרים, המזקקים את הנפט ברמה אחת נוספת. במקביל מבצעים "הדחה" - שטיפה של הנפט - המזקקת אותו עוד יותר.

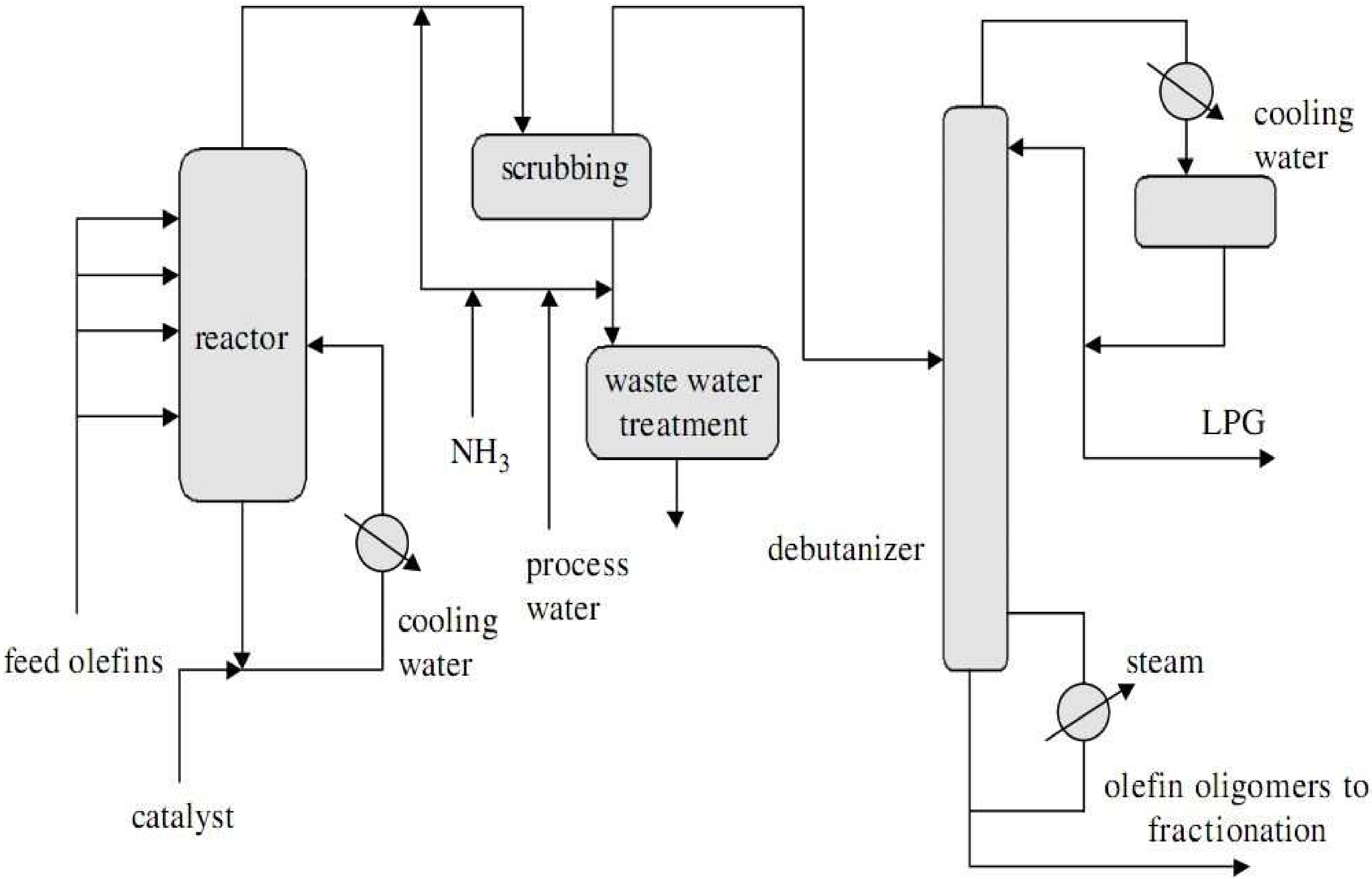
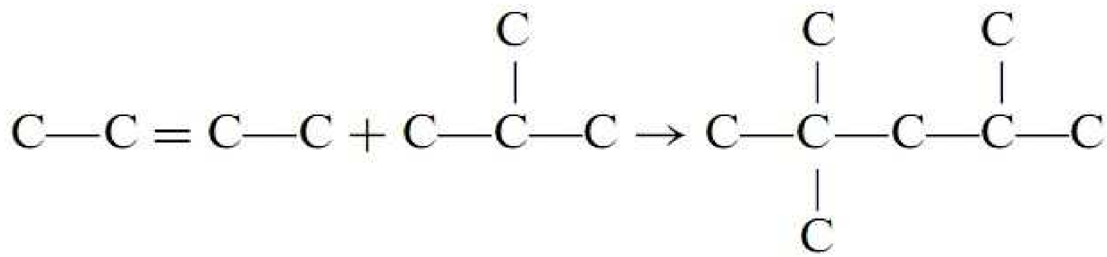


Figure 9.2.7. Dimersol process (IFP).

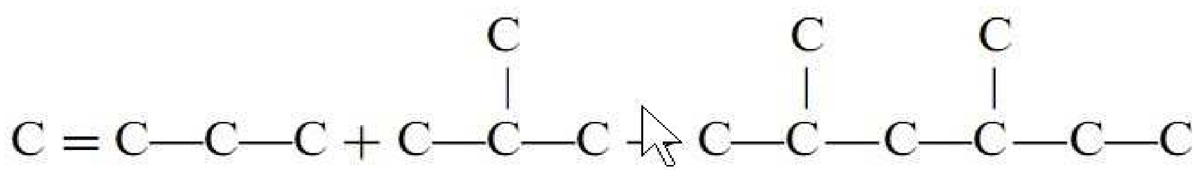
ALKYLATION OF BUTENE-2



cis-Butene-2 + Isobutane → 2,2,4-Trimethylpentane

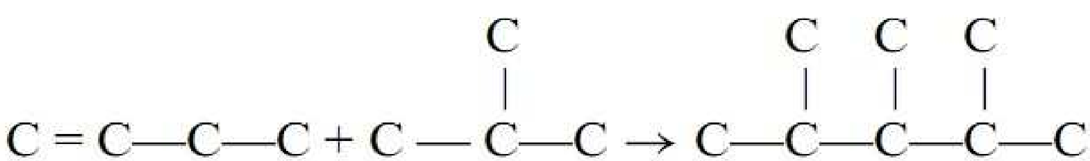
(100 RON)

ALKYLATION OF BUTENE-1



Butene-1 + Isobutane → 2,3-Dimethylhexane

(71.3 RON)



Butene-1 + Isobutane → 2,3,4-Trimethylpentane

(102.7 RON)

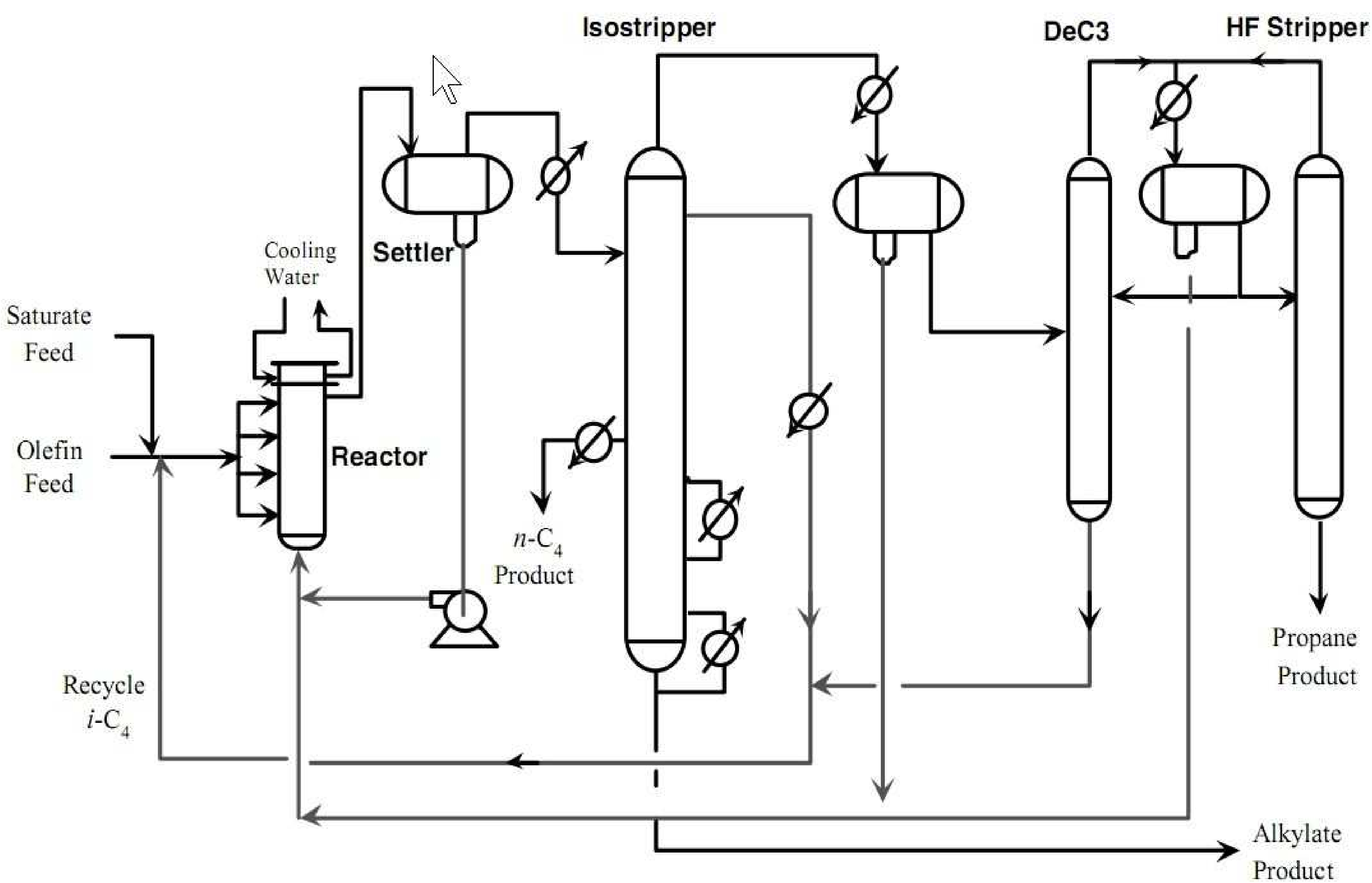


Figure 9.1.2. UOP HF alkylation.

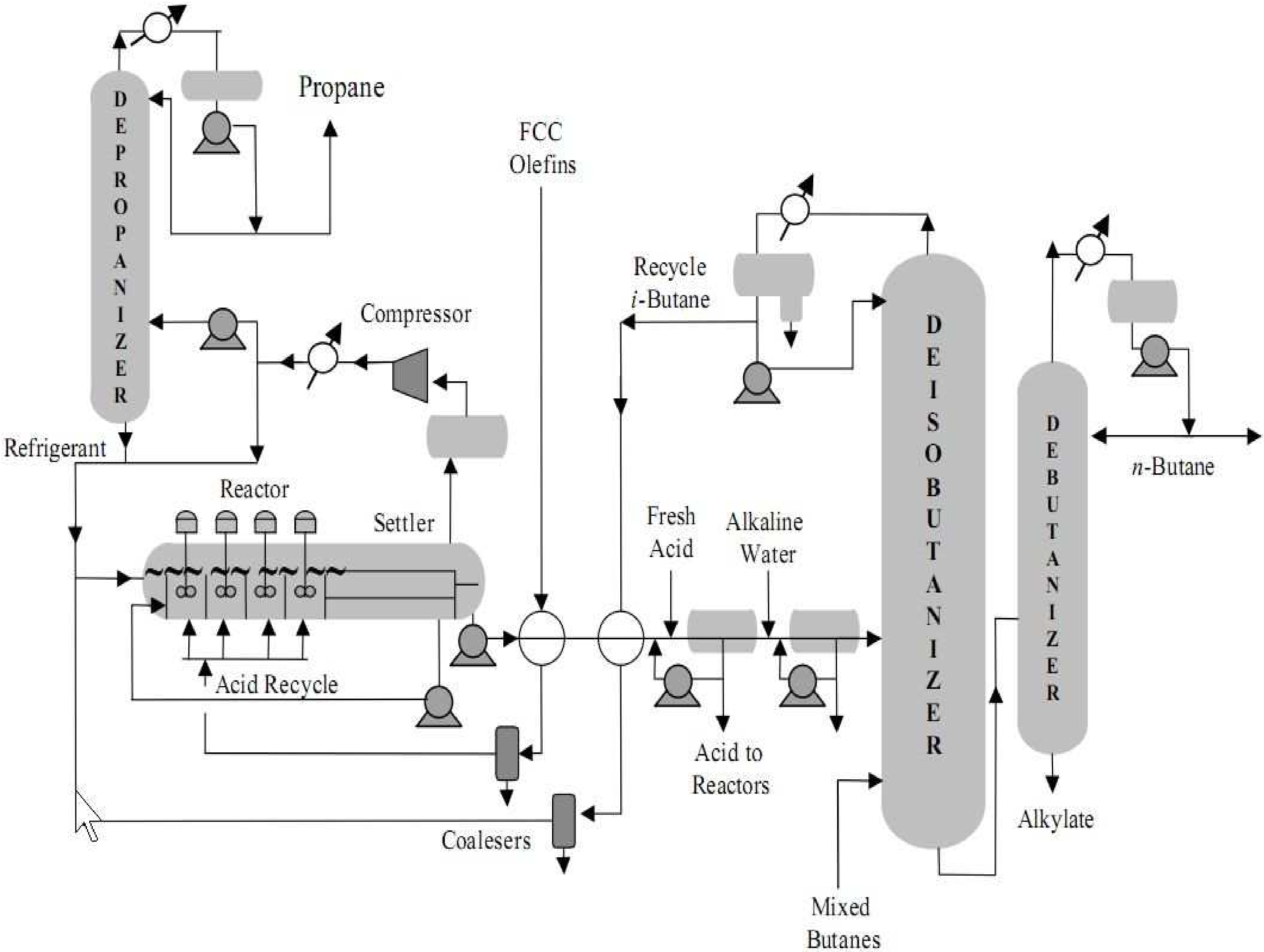
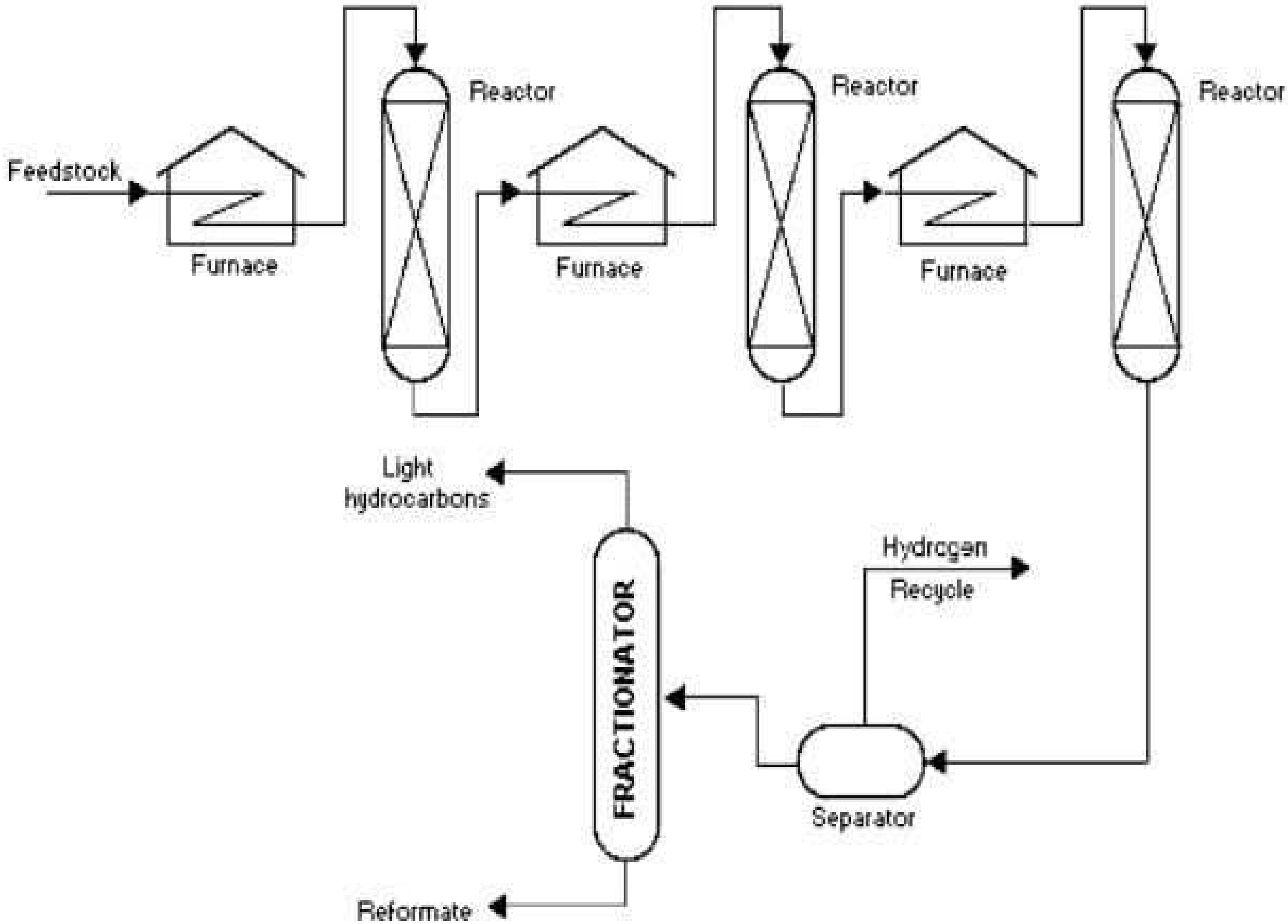


Figure 9.1.3. Cascade auto-refrigerated alkylation process.

FIGURE IV:2-16. PLATFORMING PROCESS.



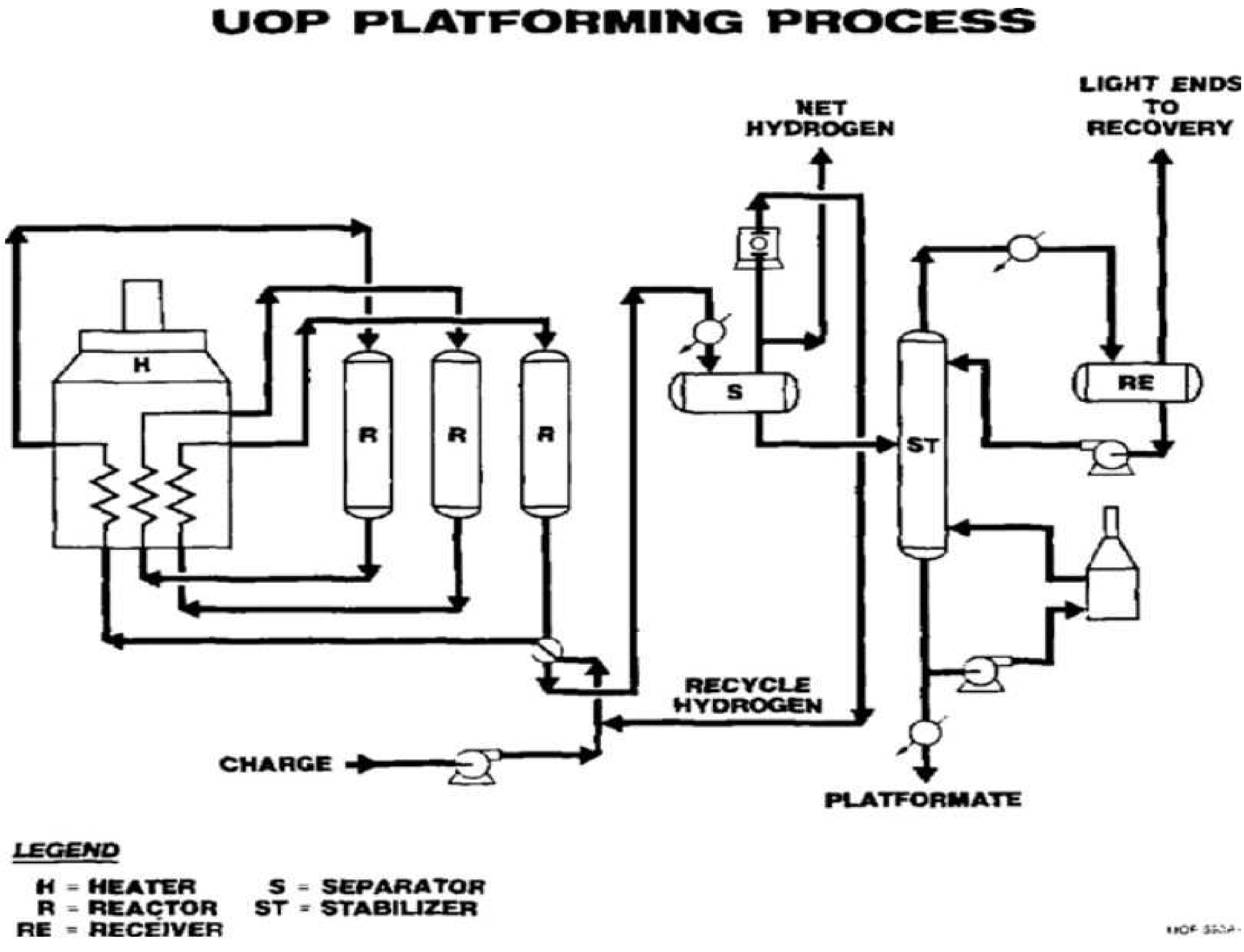


Figure 5.6. Semiregenerative reforming process (reprinted with permission from UOP LLC).

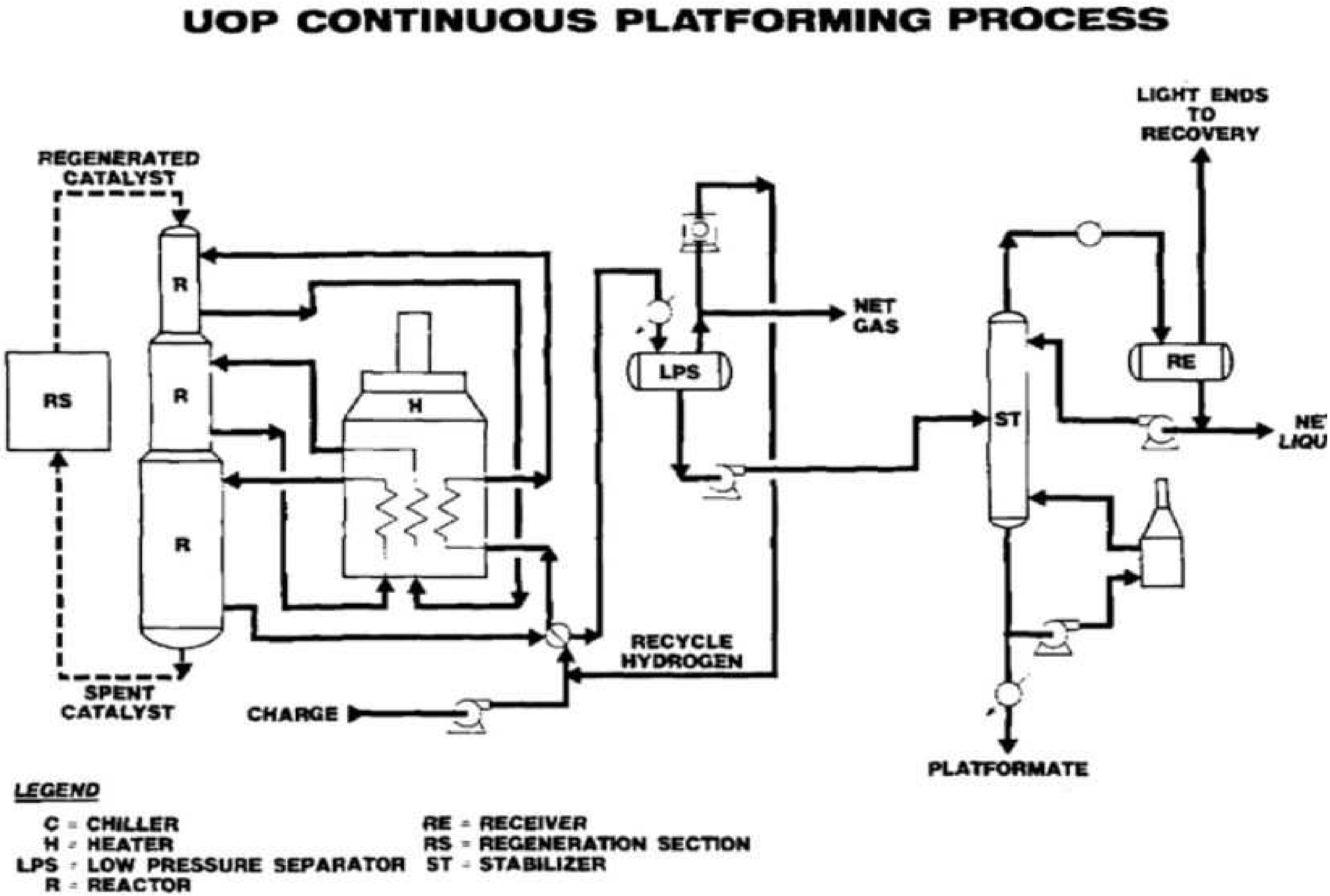


Figure 5.7. CCR Platforming process (reprinted with permission from UOP LLC).

Desulfurisation

Sulfur treatment of gas fractions

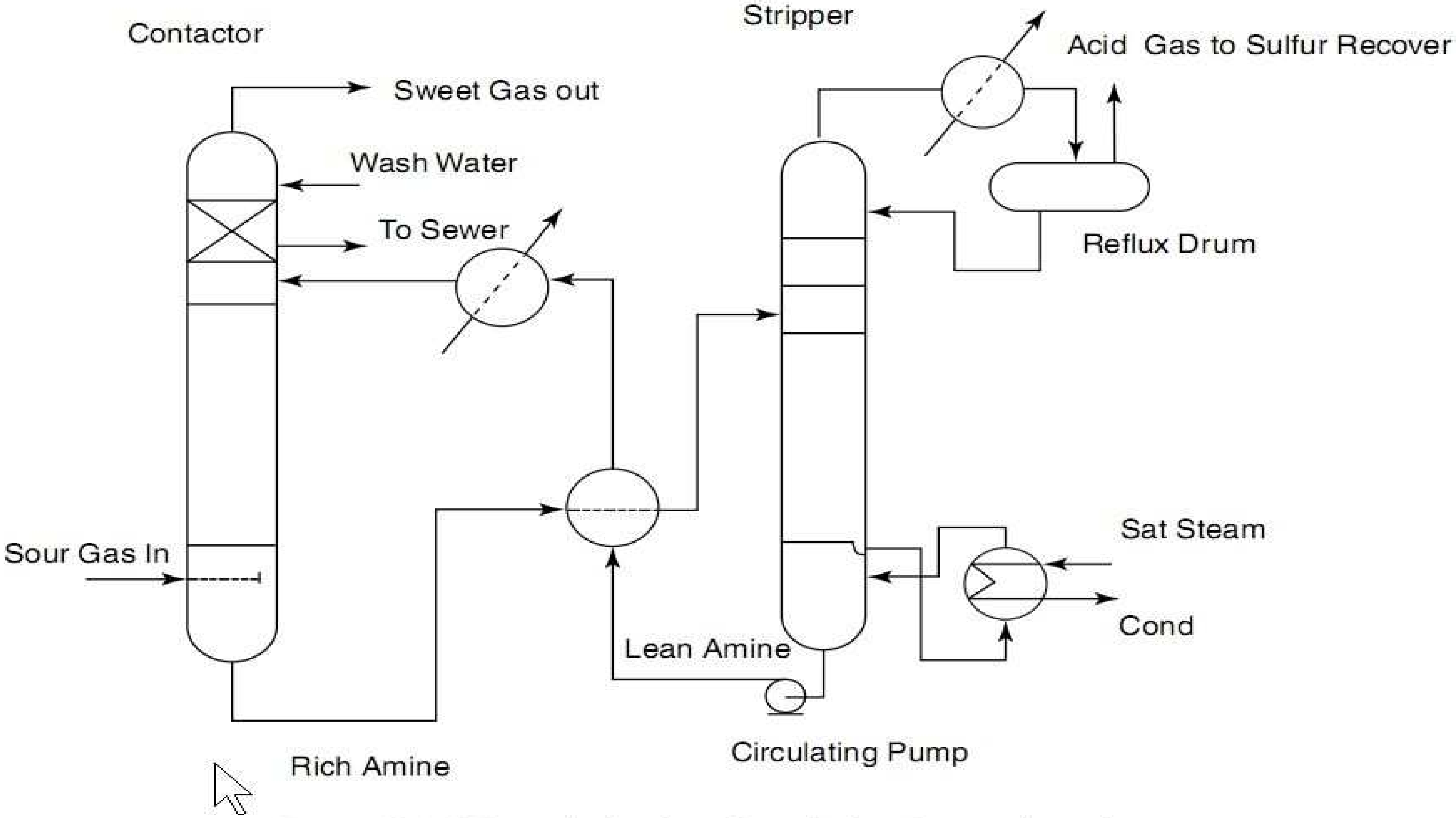
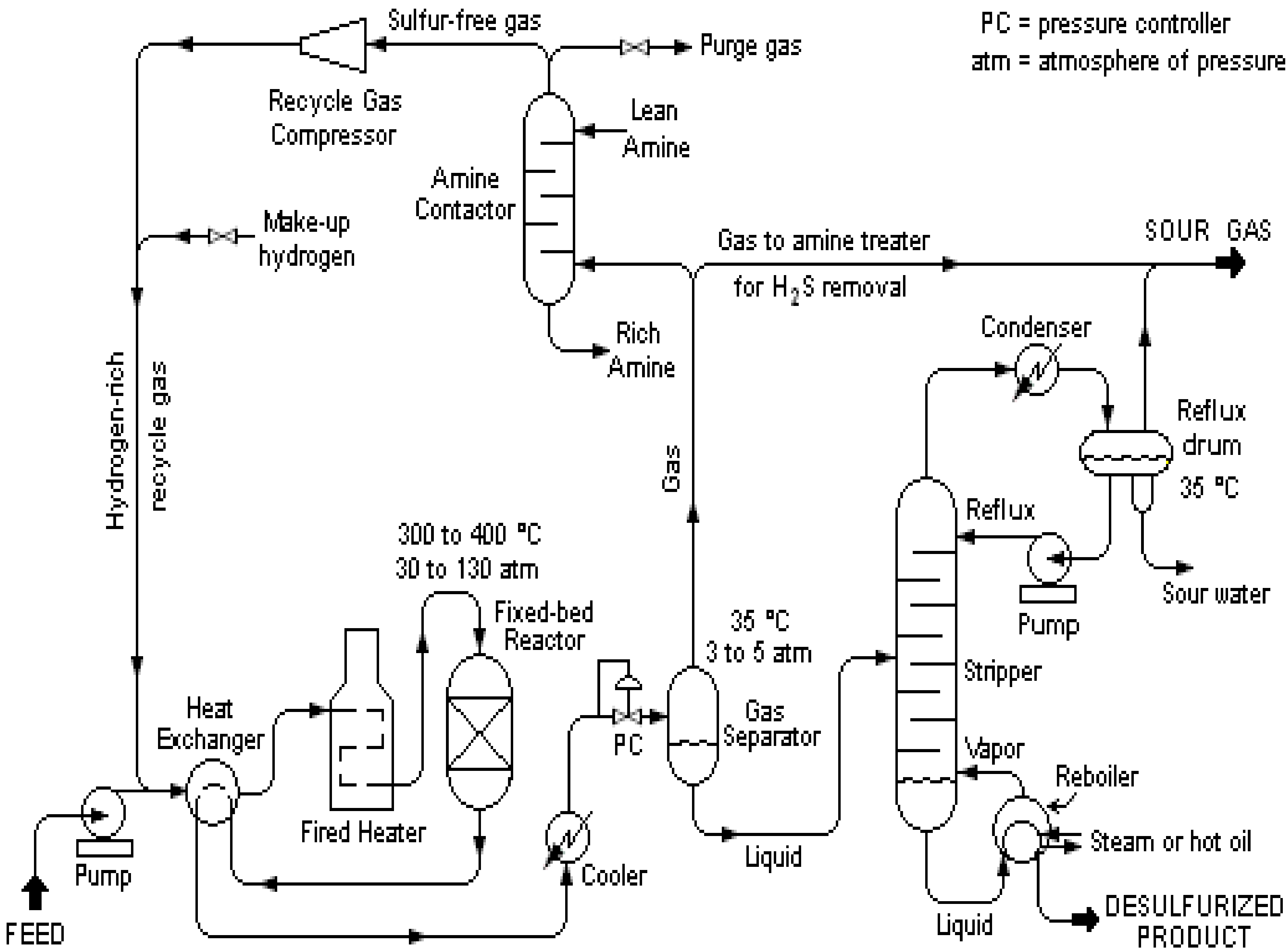


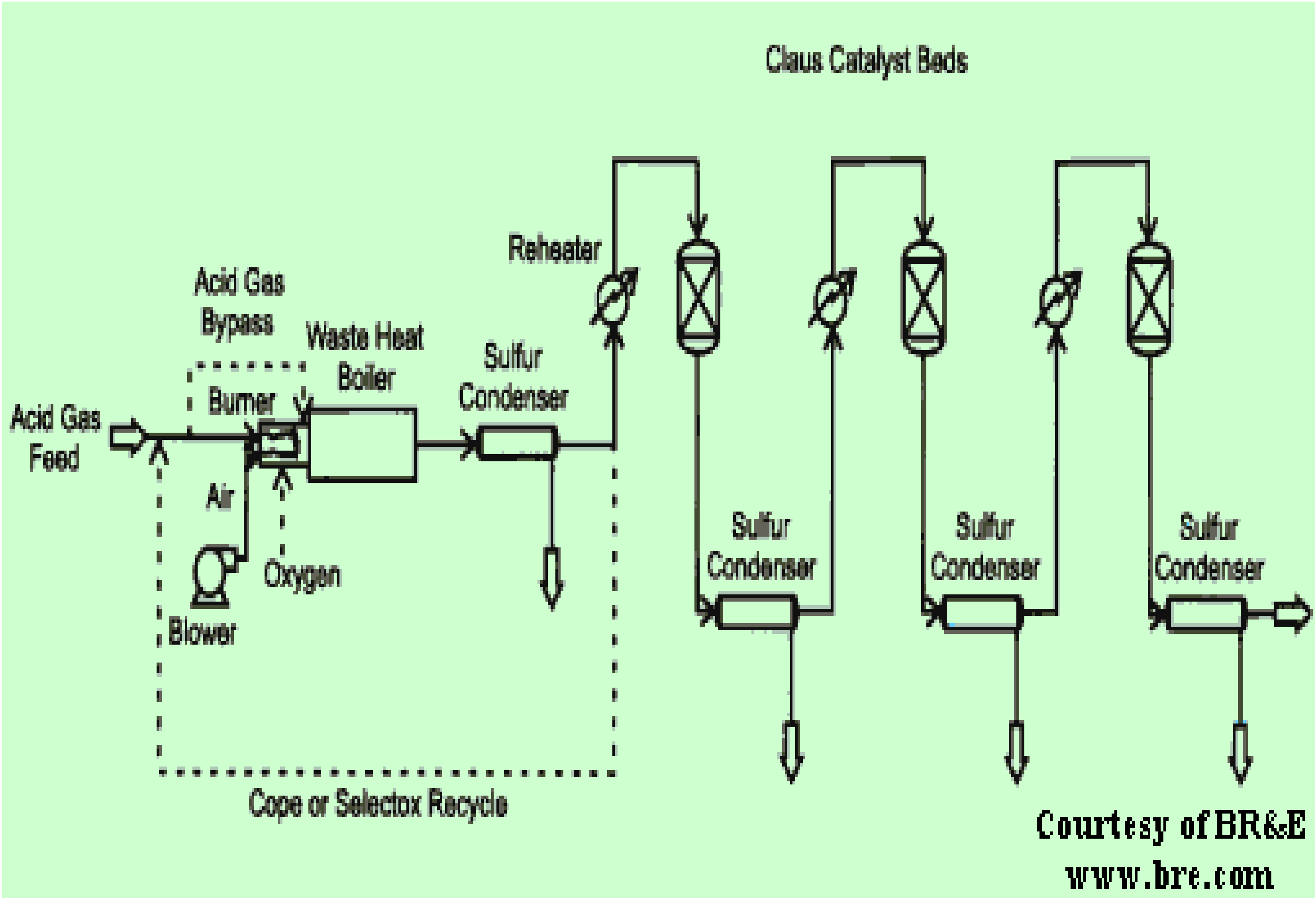
Figure 10.1. Schematic drawing of a typical amine treating unit.


PC = pressure controller
atm = atmosphere of pressure
Sulfur-free gas
Purge gas
Recycle Gas
Compressor
Lean
Amine
Amine
Contactor
Make-up
hydrogen
Gas to amine treater
for H_2S removal
SOUR GAS
Rich
Amine
Condenser
Hydrogen-rich
recycle gas
Gas
Reflux
drum
35 °C
Reflux
300 to 400 °C
30 to 130 atm
Fixed-bed
Reactor
Sour water
Pump
35 °C
3 to 5 atm
Stripper
Heat
Exchanger
Gas
Separator
PC
Vapor
Reboiler
Fired Heater
Steam or hot oil
Pump
Cooler
Liquid
FEED
Liquid
DESULFURIZED
PRODUCT

CLAUS

$H_2S + 2.5O_2 \text{ --> } H_2O + SO_2$

$2H_2S + SO_2 \text{ --> } 2H_2O + 3S$


Claus Catalyst Beds
Reheater
Acid Gas
Bypass
Waste Heat
Boiler
Sulfur
Condenser
Burner
Acid Gas
Feed
Air
Oxygen
Blower
Sulfur
Condenser
Sulfur
Condenser
Sulfur
Condenser
Cope or Selectox Recycle
Courtesy of BR&E
www.bre.com

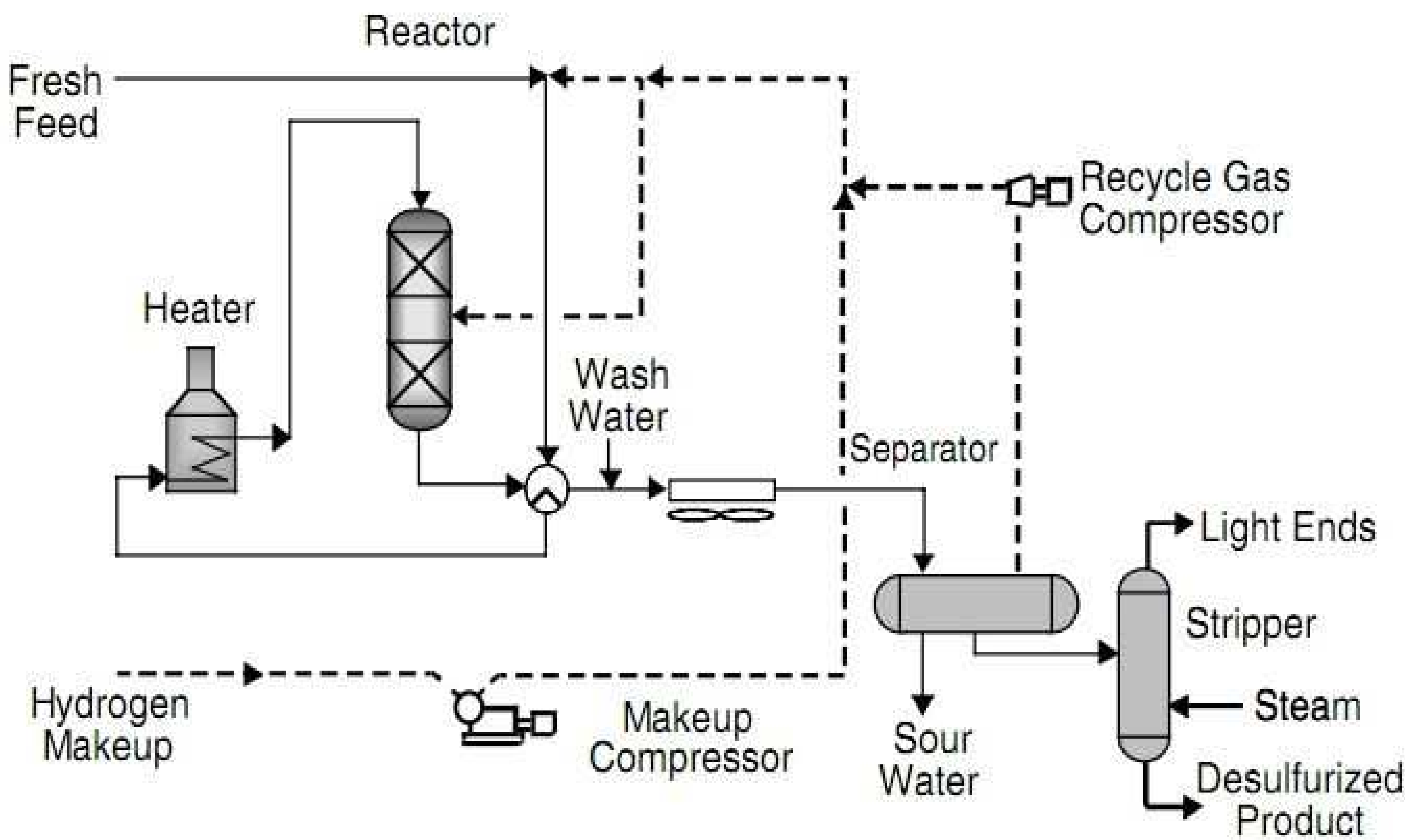
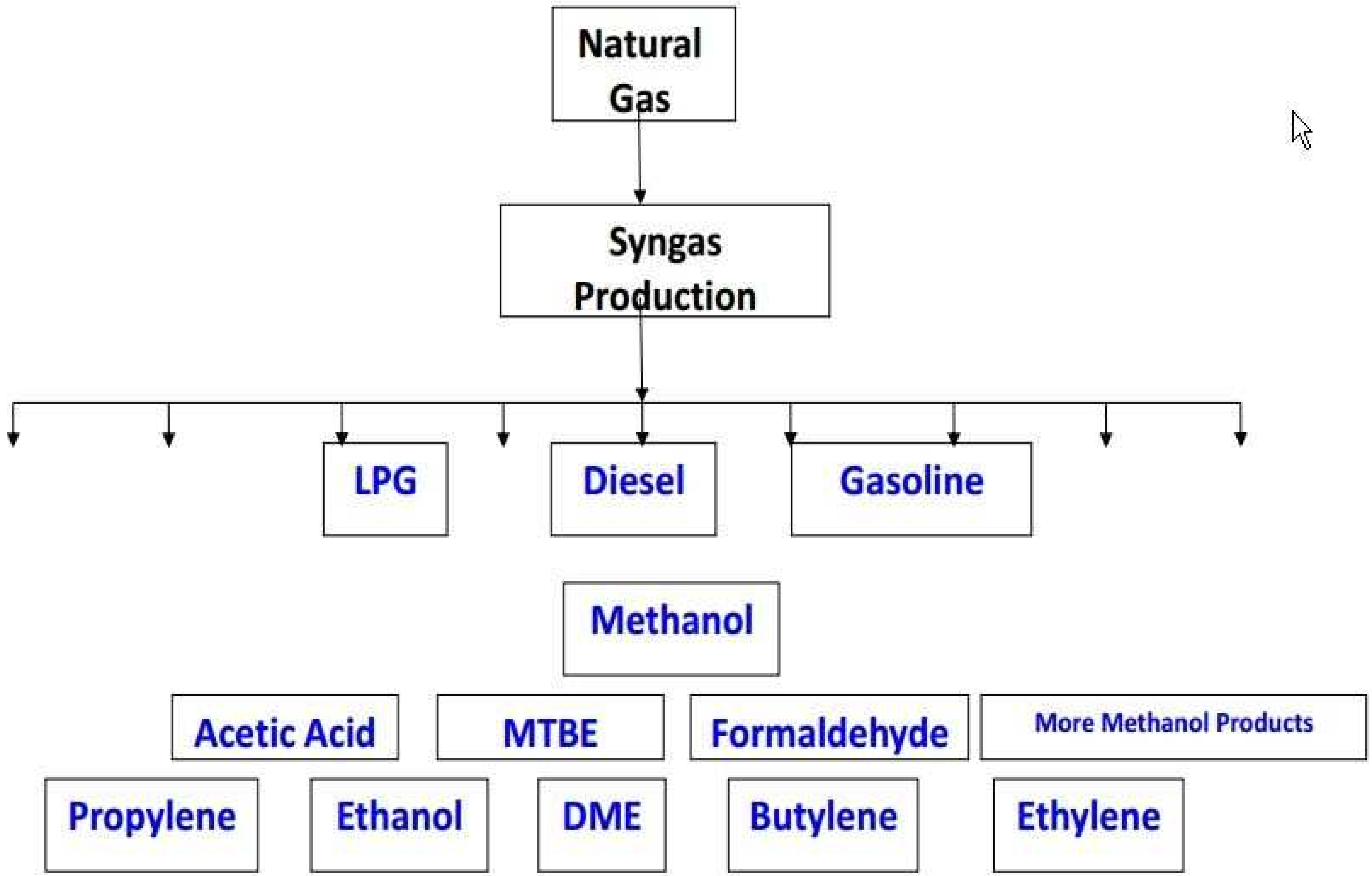


Figure 5.3. Naphtha hydrotreater flow scheme.

מוצרים מגז טבעי



Coal to fuels

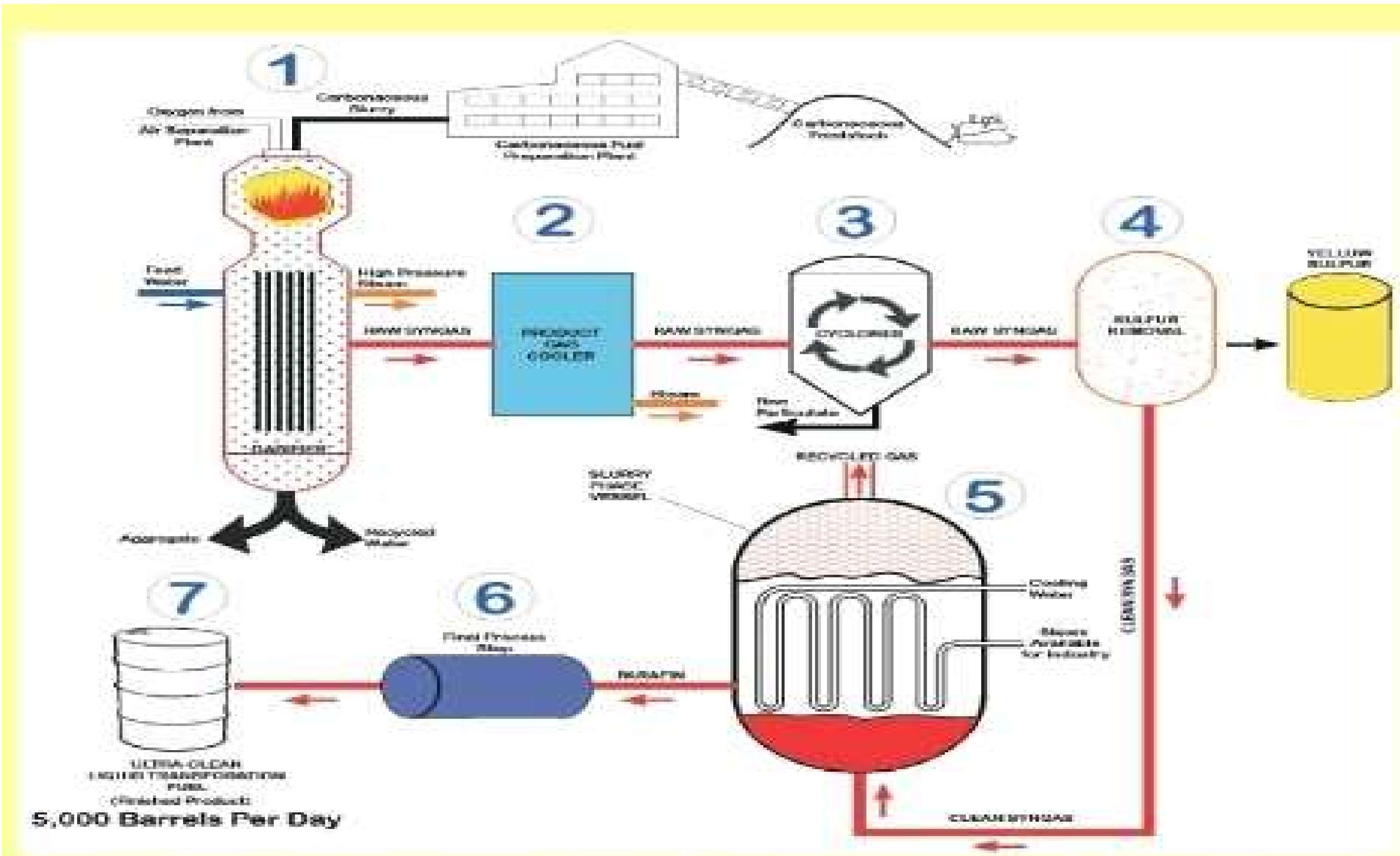
Raw materials

- Coal (high quality)
- Coal (low quality- lignite)
- Shale
- Bituminous sands

Processes

- Coal to liquids
- Coal to syngas
- Syngas to electricity
- Syngas to fuels

Coal to liquids pilot plant



The US Department of Energy (DOE) had an active coal liquefaction program in

Syngas

Early Gasification Milestones

Date	Milestone
1790s	William Murdoch experiments with various types of gas, settling on coal gas as the most effective
1804	Coal gas first patented for lighting
1813	London and Westminster Gas Light & Coke Company illuminates Westminster Bridge with "town gas" lights on New Year's Eve using wooden pipes
1816	Baltimore, Maryland becomes the first U.S. city to light streets with "town gas"
1800s	"Town gas" lighting in factories replaces candles and lanterns, making the night shift possible and ushering in the Industrial Age

Table 2.3 Typical coal liquefaction processes

Process	Typical catalyst	Conditions T(°C)	Conditions P (atm)	Hydrogenation: Prime source	Hydrogenation: Method	Comments
Bergius (original process developed early 1900s)	Iron oxide	465	200	H_2	in liquefaction reactor	Most severe conditions; catalyst discarded
Solvent Refined Coal (Gulf Oil)	Minerals in coal (none added)	450	140	H_2	in liquefaction reactor	Recycle of portion of product liquid to reactor; lack of hydrogenation specificity
H-Coal® (Hydrocarbon Research Inc.)	$CoO—MoO_3/Al_2O_3$	450	200	H_2	in liquefaction reactor	Catalyst ages rapidly
Exxon Donor Solvent	Minerals in coal in liquefaction reactor; $CoO—MoO_3/Al_2O_3$ in separate hydrogenation reactor	450	140	Tetralin in liquefaction reactor. Recycled after hydrogenation in separate reactor		Further hydrogenation of product liquids in separate reactor—catalyst deactivation slow. Typical product yields 0·3 to 0·4 te liquid/te coal feed
National Coal Board supercritical extraction	In separate hydrogenation reactor	350–450	100–200	H_2 in separate reactor		Supercritical gas extraction of portion of coal with PhMe as solvent

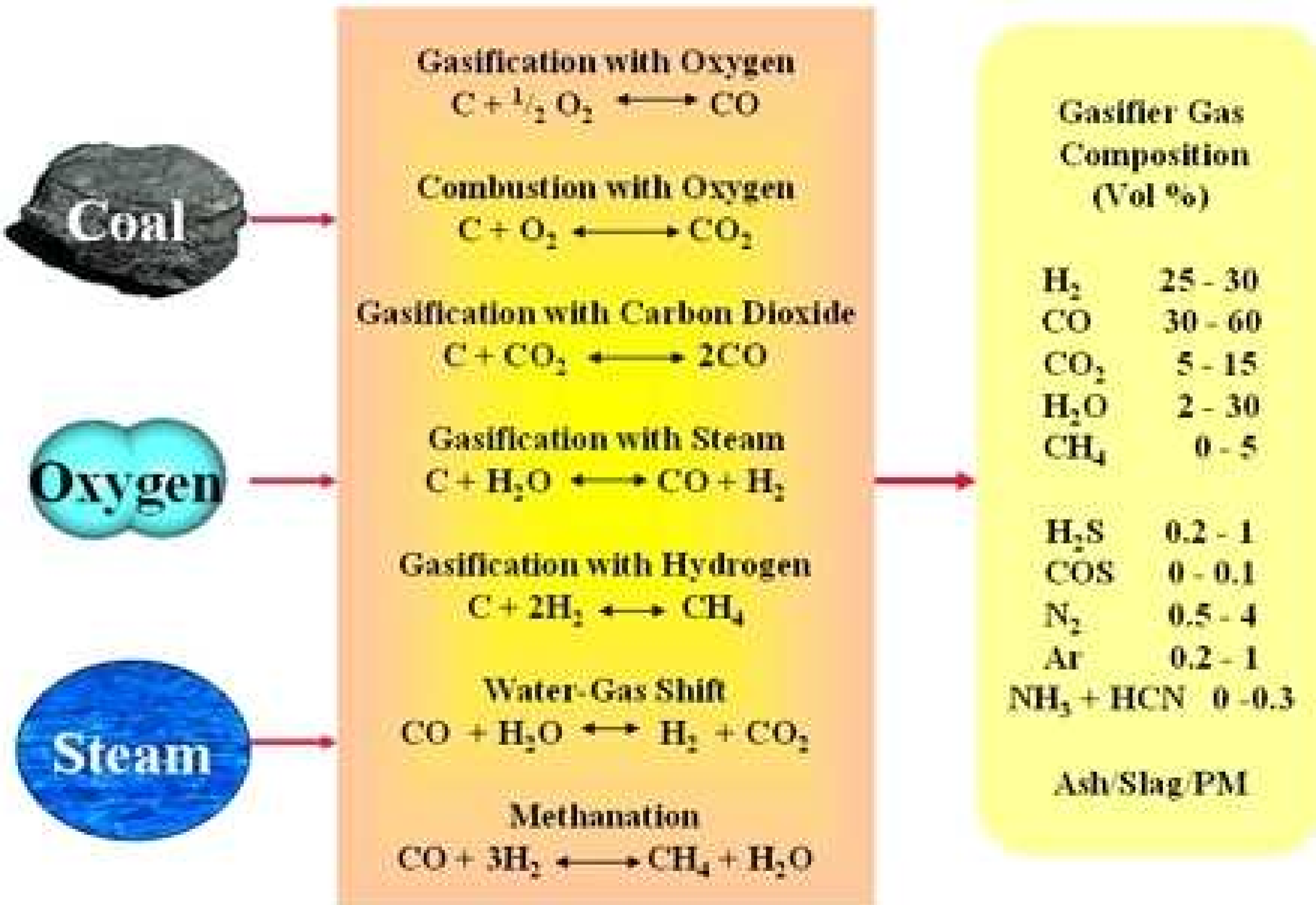
Table 2.4 Gasification processes (commercially proven)*

Process	Conditions	Typical products (vol. %) CH_4	H_2	CO	CO_2	Comments
Lurgi	Fixed bed reactor ~1000°C; 30 atm	12	37	18	32	Production of by-product heavy tar (~1%) restricts coal to 'non-caking' types. 'Slagging Gasifier' under development by British Gas Corporation to enable the difficult 'caking' coals to be handled
Koppers–Totzek	Entrained bed reactor ~1800°C; 1 atm	—	34	51	12	Can handle all coals; high temperatures destroy heavy organic tars. 'Shell–Koppers' pressurized version (15–30 atm) under development
Winkler	Fluidized bed reactor ~900°C; 1 atm	3	42	36	18	Higher pressure process (15 atm) under development
Texaco	Entrained bed reactor ~1200°C; 20–80 atm					Commercially successful process for partial oxidation of fuel oil to synthesis gas being developed to handle coal as coal/water or coal/oil slurries

*The field of coal gasification is in a very active state of development. Nearly 20 other processes at various stages of development have been described; see A. Verma, 1978, *Chemtech* [illegible]

- **British Gas/Lurgi** The BGL process uses an oxygen-blown, moving-bed, slagging gasifier producing raw fuel at 980 F and 395 psia.
- **Destec** The Destec process uses a two stage oxygen blown, entrained flow gasifier producing raw fuel at 1900 F and 412 psia.
- **KRW** The KRW gasifier is air blown producing fuel at 1900 F and 400 psia.
- **Shell** The Shell process uses a dry feed, pressurized, oxygen-blown, entrained flow, slagging gasifier producing raw fuel at 1826 F and 352 psia.
- **Texaco** This is a pressurized, oxygen blown, slagging system producing raw fuel at 2500 F and 475 psia.
- **Transport** This gasifier is still in the developmental stage. Both air blown and oxygen-blown circulating bed reactors were studied using both coal and limestone thus reducing or possibly eliminating sulfur cleanup requirements. The gasifier was designed to produce 1657 F, 395 psia steam.

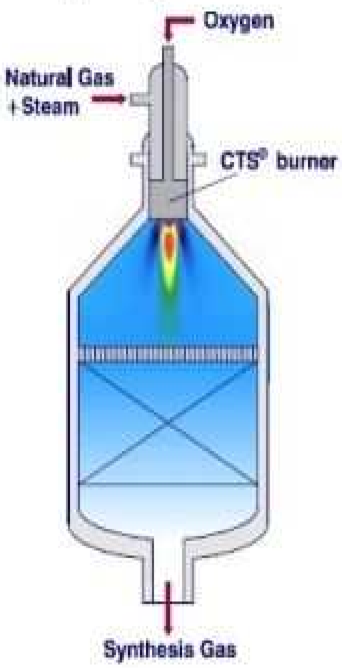
GASIFIER PROCESSES



עקרון ייצור חומרים שונים מגז טבעי הוא הפיכתו לסינגז (H2 +CO), בעזרת קטאליזטור ייעודי:

Steam Reforming 1.1

$$CH_4 + H_2O \rightleftarrows CO + 3H_2 \qquad \Delta H = +206\ kJ/mole$$



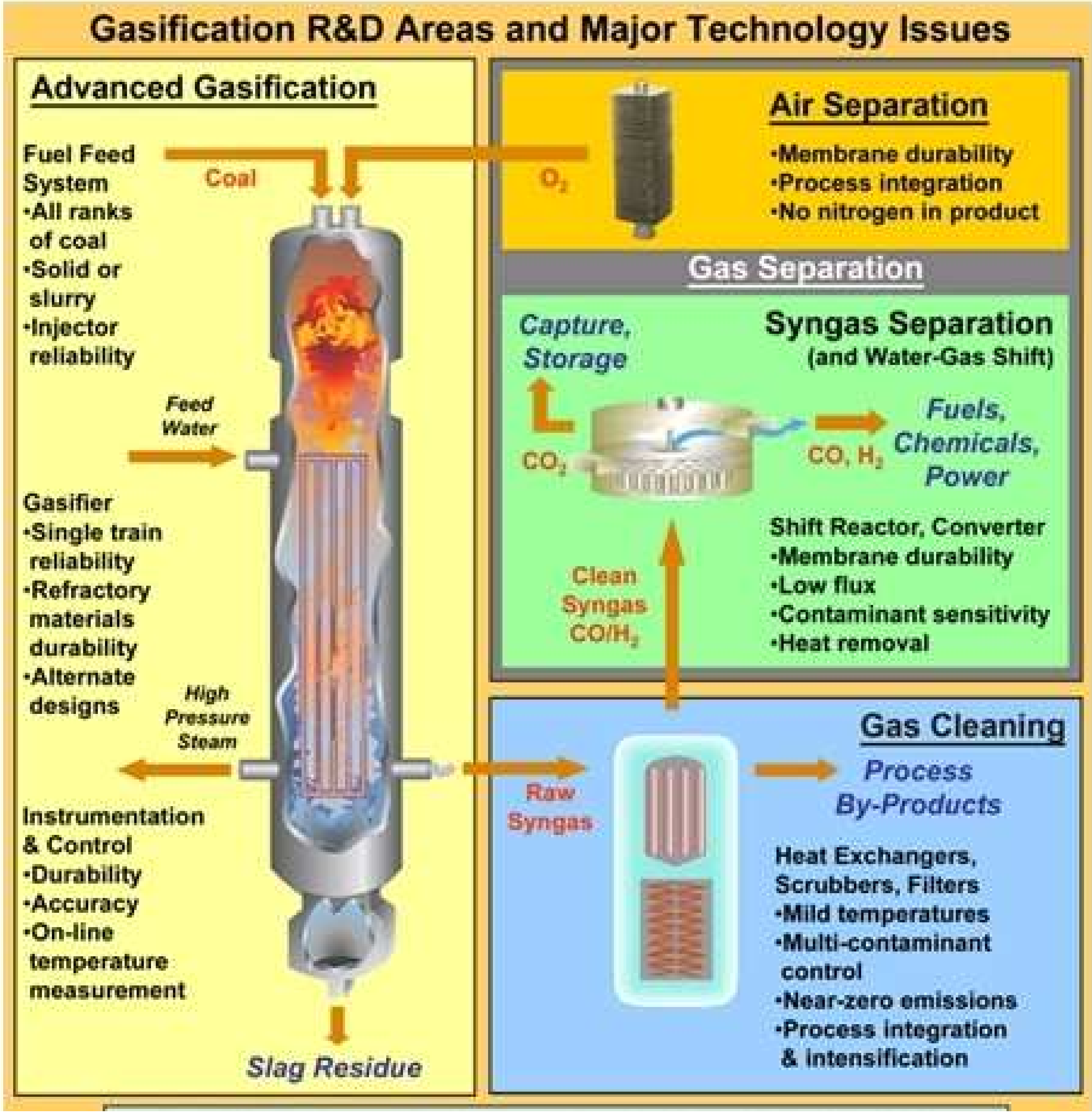
טמפ': 800-850 °C , לחץ: 20-30 אטמ'.
קטאליזטור ניקל.
יחס CO/H2 אופייני הוא 1:3

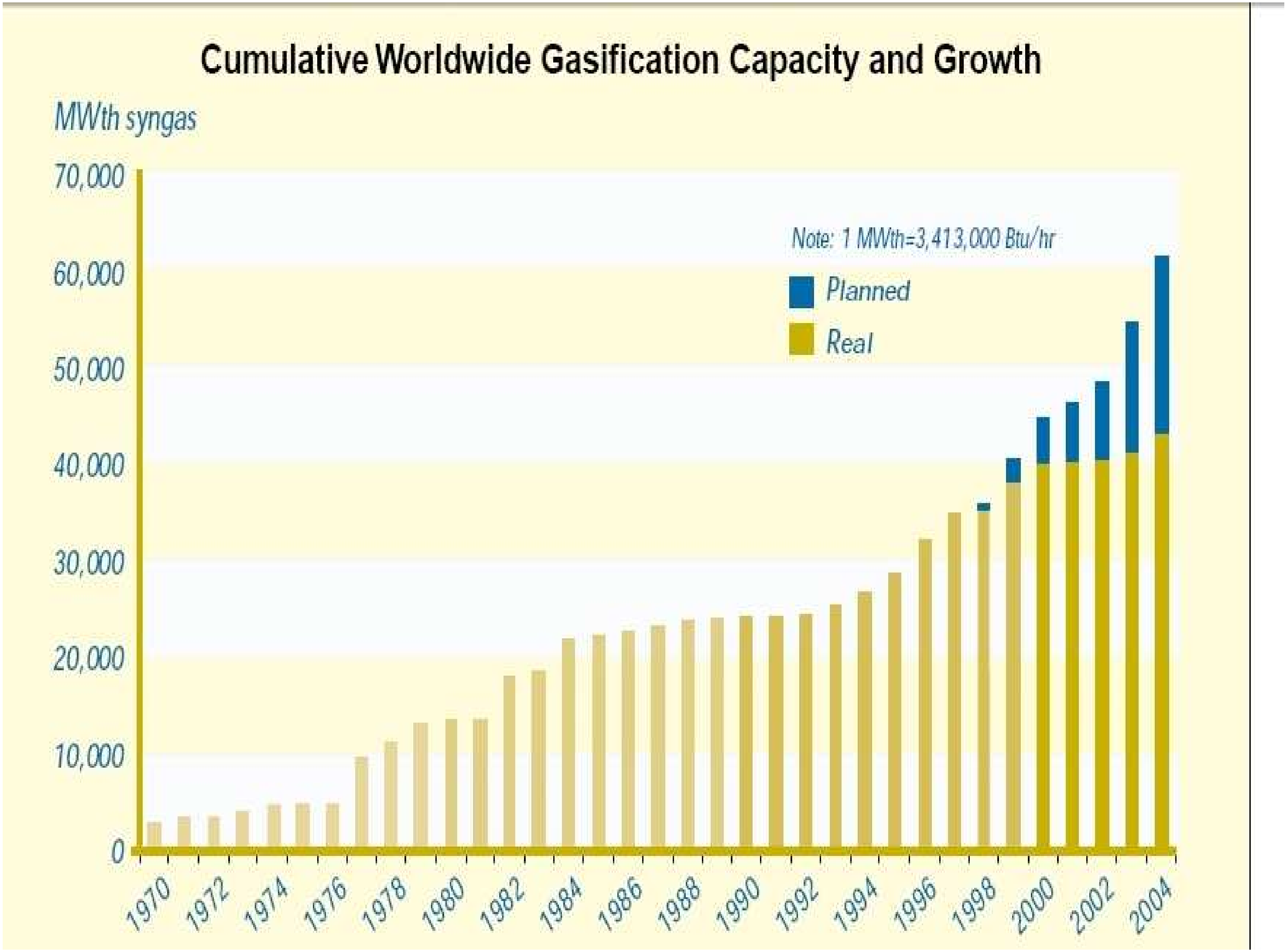
Autothermal Reforming (ATR) 1.2

$$CH_4 + 1/2\ O_2 \longrightarrow CO + 2H_2 \qquad \Delta H = -36\ kJ/mole$$

$$CH_4 + H_2O \rightleftarrows CO + 3H_2 \qquad \Delta H = +206\ kJ/mole$$

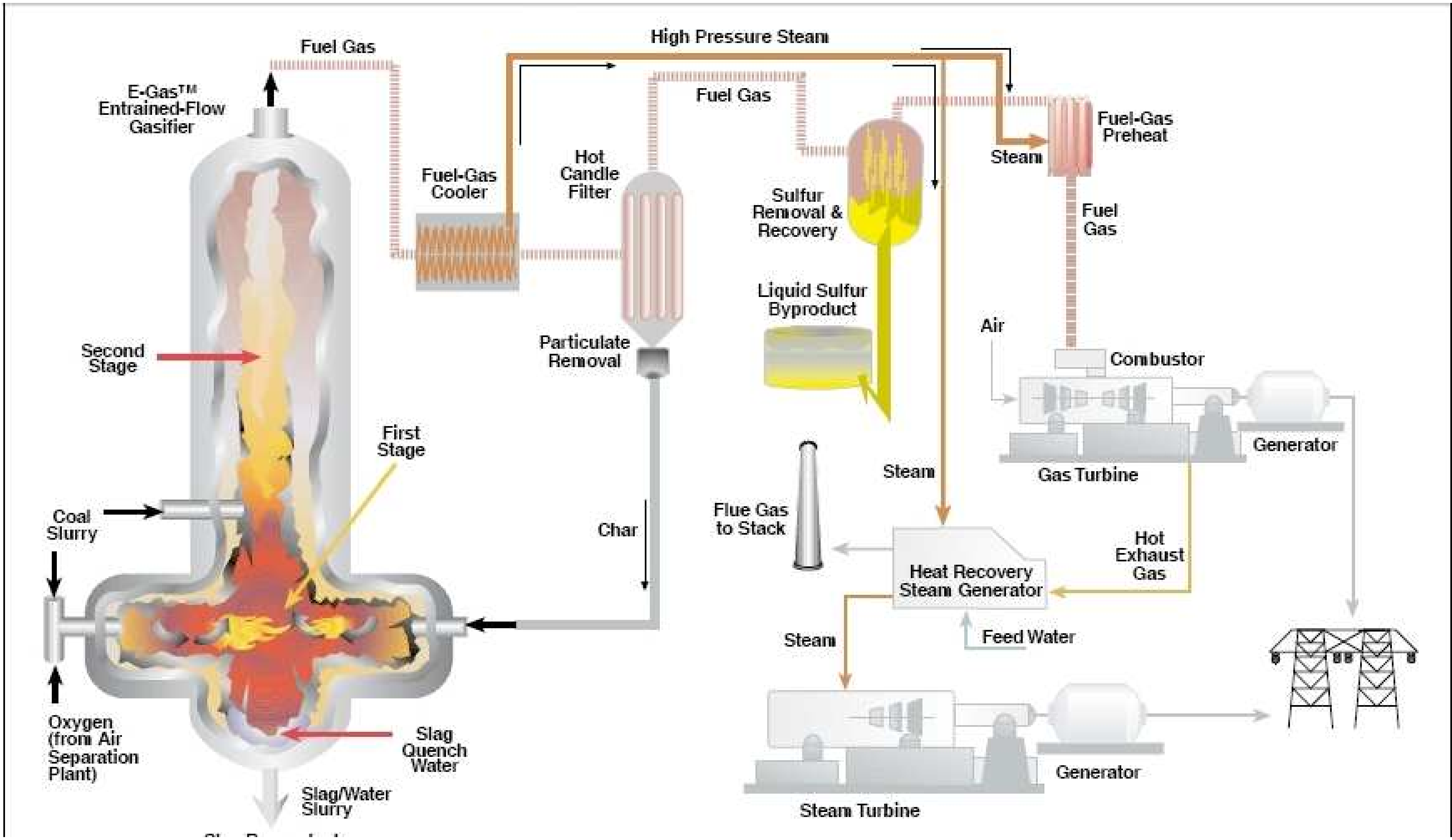
יחס CO/H2 אופייני הוא 1:2


Gasification R&D Areas and Major Technology Issues
Advanced Gasification
Fuel Feed System
•All ranks of coal
•Solid or slurry
•Injector reliability
Coal
Feed Water
Gasifier
•Single train reliability
•Refractory materials durability
•Alternate designs
High Pressure Steam
Instrumentation & Control
•Durability
•Accuracy
•On-line temperature measurement
Slag Residue
O_2
Air Separation
•Membrane durability
•Process integration
•No nitrogen in product
Gas Separation
Capture, Storage
Syngas Separation
(and Water-Gas Shift)
CO_2
CO, H_2
Fuels, Chemicals, Power
Shift Reactor, Converter
•Membrane durability
•Low flux
•Contaminant sensitivity
•Heat removal
Clean Syngas CO/H_2
Raw Syngas
Gas Cleaning
Process By-Products
Heat Exchangers, Scrubbers, Filters
•Mild temperatures
•Multi-contaminant control
•Near-zero emissions
•Process integration & intensification



Cumulative Worldwide Gasification Capacity and Growth
MWth syngas
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Note: 1 MWth=3,413,000 Btu/hr
Planned
Real
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

Syngas to electricity



Syngas to crude

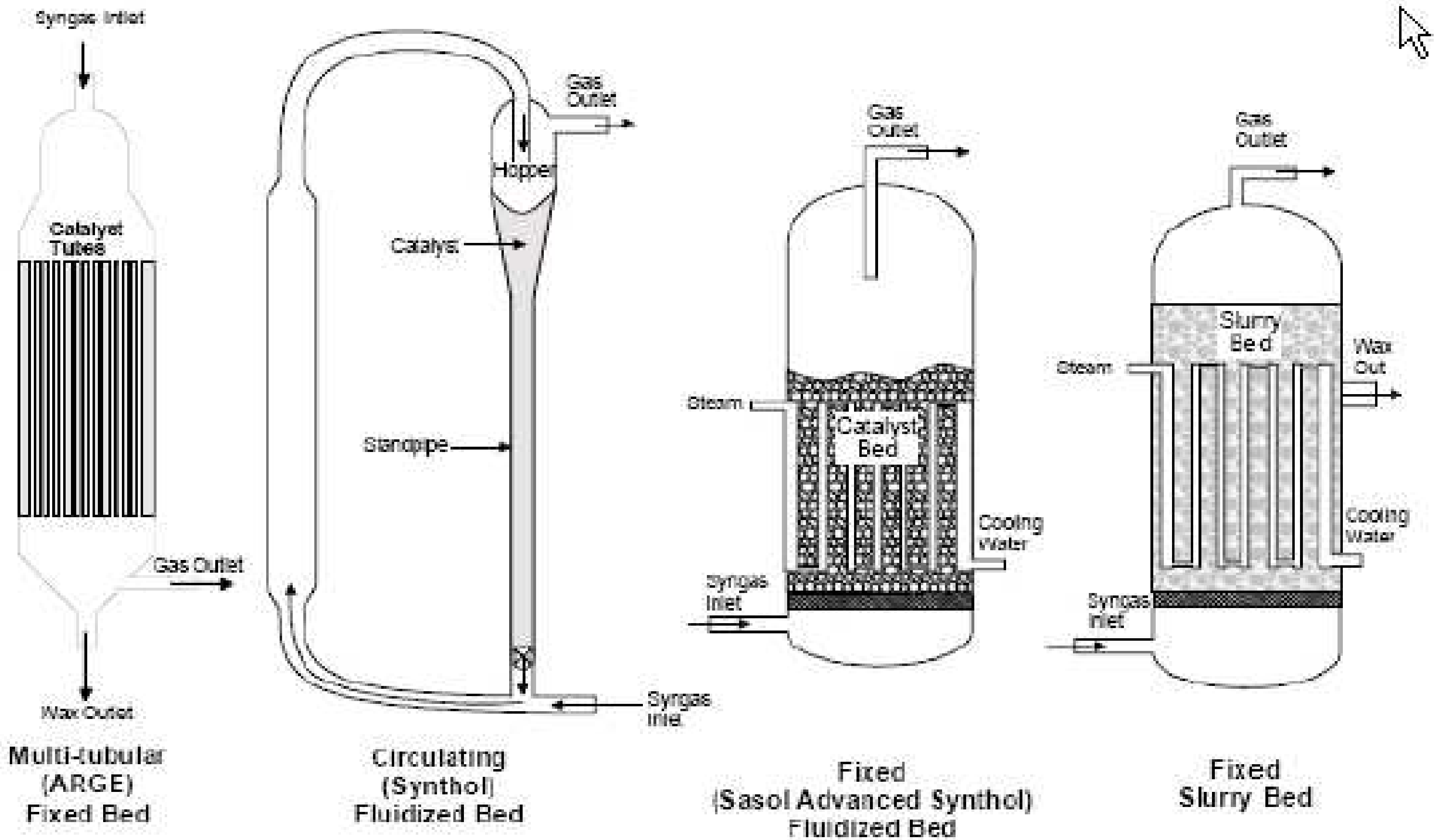


Figure 1: Types of FT reactors

Fischer Tropsch flowsheet