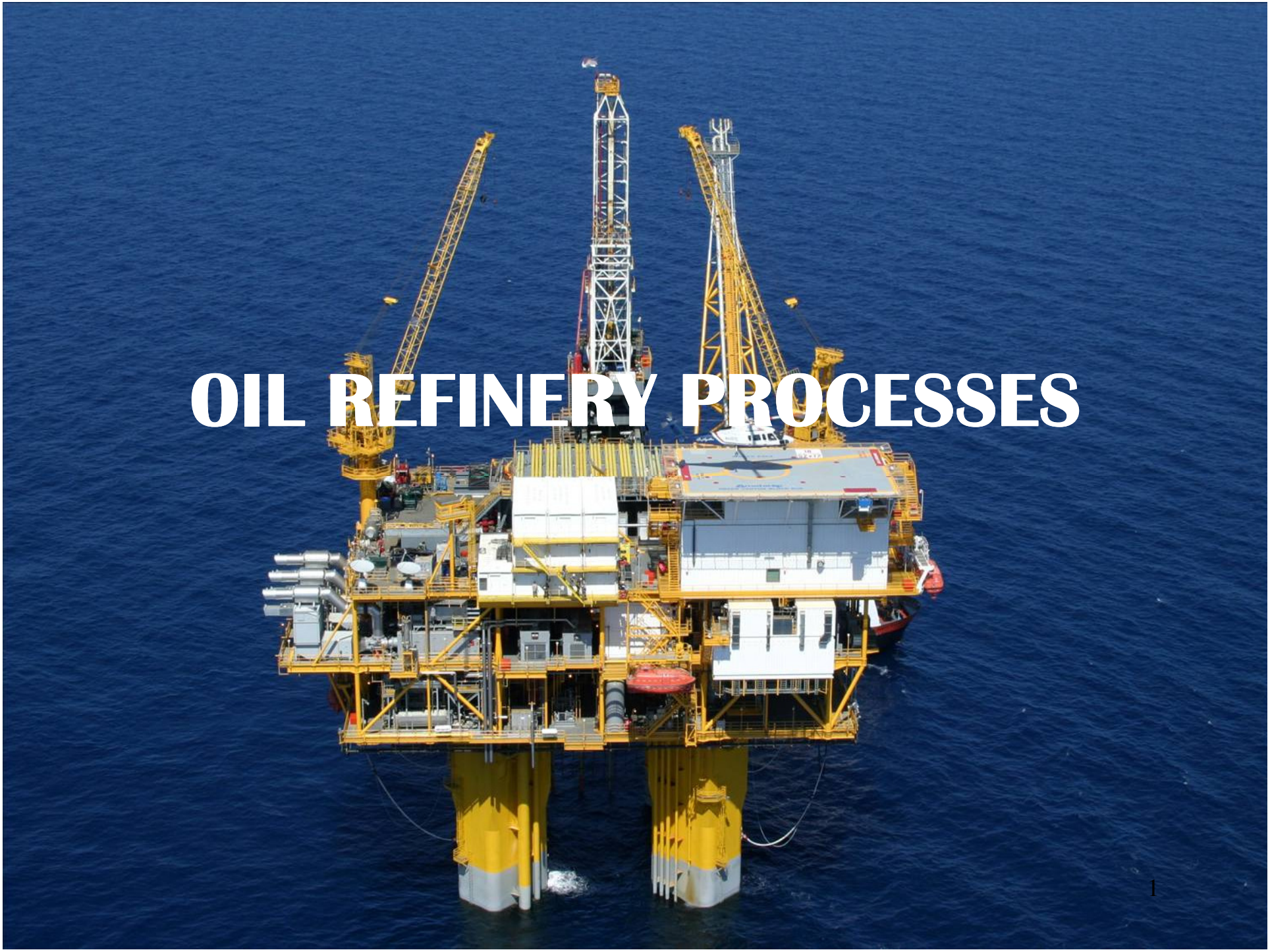
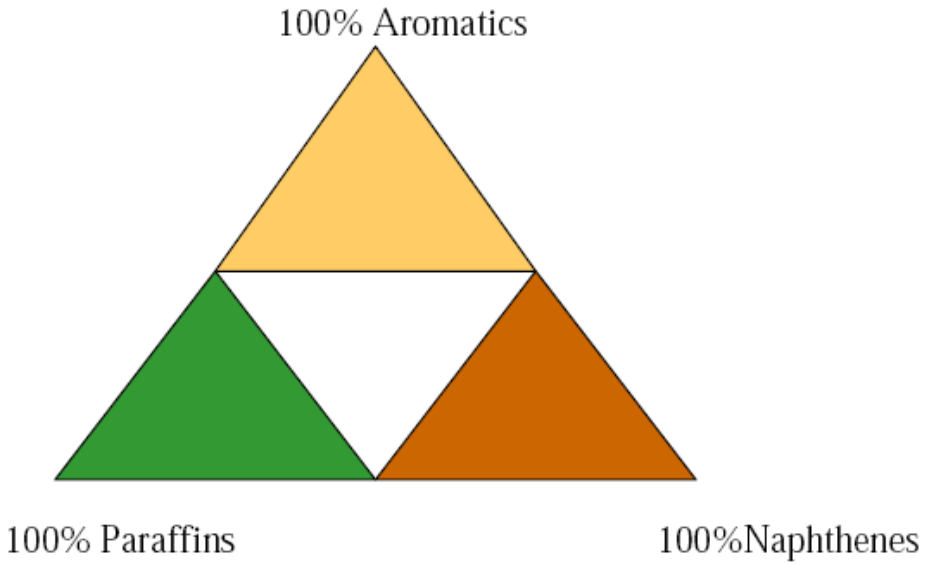


OIL REFINERY PROCESSES

Types of hydrocarbons

- Types of hydrocarbons (parafffins, naphthenes, and aromatics).
- This rating is important to the refinery since the value of the crude oil decreases from classification 1 to 6.



➢ Crude Classifications (in order of decreasing value):

1) Paraffinic Crudes

paraffins + naphthenes > 50%

paraffins > naphthenes

paraffins > 40%

2) Naphthenic Crudes

paraffins + naphthenes >50%

naphthenes > paraffins

naphthenes >40%

3) Paraffinic – Naphthinic Crudes

aromatics < 50%

paraffins < 40%

naphthenes < 40%

4) Aromatic – Naphthenic Crudes

aromatics > 50%

5) Aromatic - Intermediate Crudes

aromatics > 50%

paraffins >10%

6) Aromatic – Asphaltic Crudes

naphthenes > 25%

paraffins < 10%

API

- Crude oils are also defined in terms of API (American Petroleum Institute) gravity.
- Crude Oils API = 10 to 50

$$^{o}\text{API} = (141.5/\text{SG}_{15^{o}\text{F}}) - 131.5$$

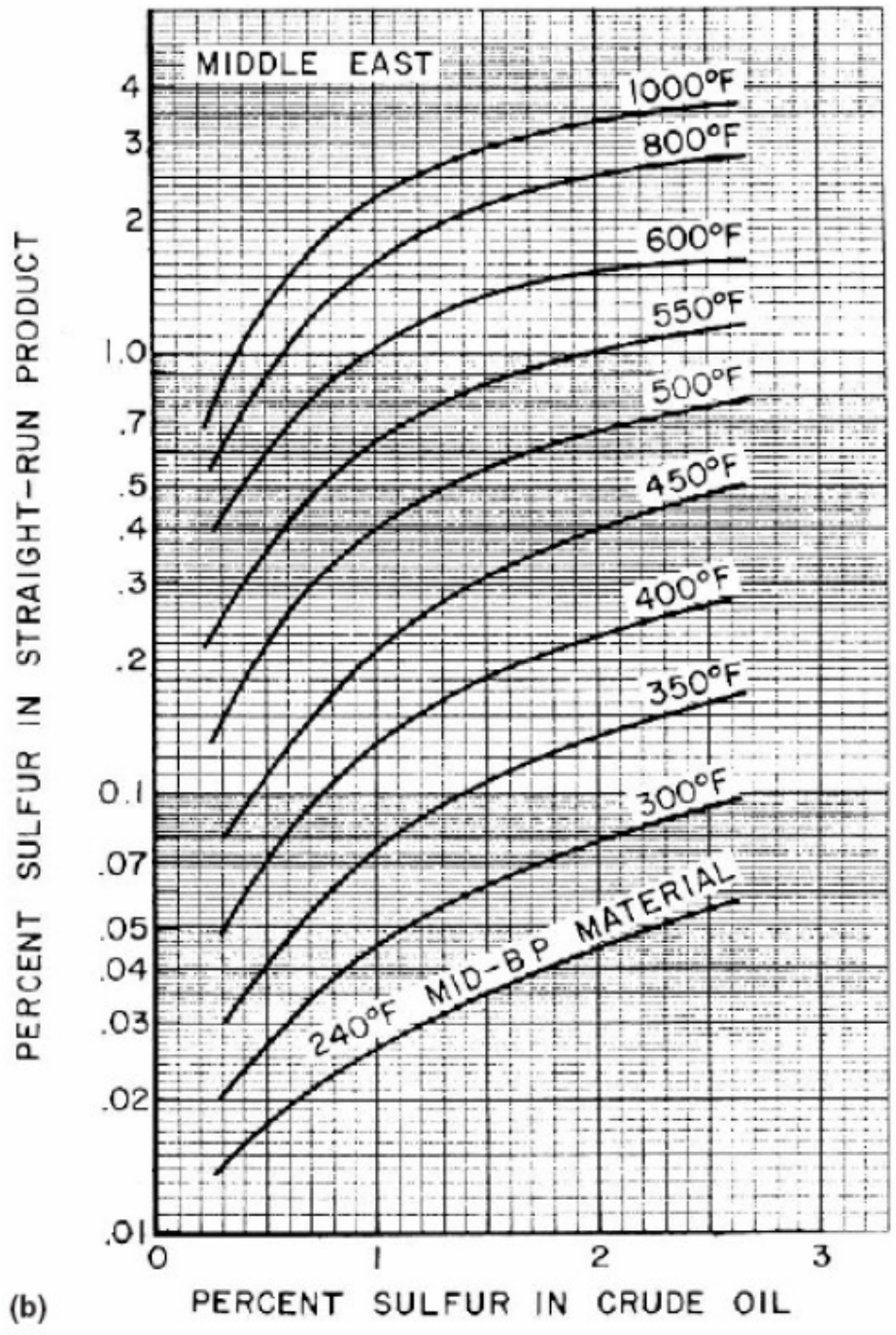
- an increase in API gravity corresponds to a decrease in specific gravity
- The higher the API gravity, the lighter the crude.
- Higher API, more paraffinic crude, higher yields of gasoline (high API gravity, low carbon, high hydrogen).
- Lower API, more aromatic crude, lower yields of gasoline (API gravity of 22 degrees or lower, high carbon, low hydrogen)
- API gravities are not linear and, therefore, cannot be averaged.

Sulfur Content

- The sulfur content is expressed as percent sulfur by weight and varies from less than 0.1% to greater than 5%.

- If a crude has less than 0.5% sulfur in it, it is considered to be **"sweet".**
- If has greater than 2.5% sulfur, it is **"sour".**
- A crude with a sulfur content between these two endpoints is called "intermediate".

- Crudes with greater than 0.5% sulfur generally require more extensive processing than those with lower sulfur content.
- Sulfur content and API gravity are two properties which have had the greatest influence on the value of crude oil, although nitrogen and metals contents are increasing in importance.


MIDDLE EAST
1000°F
800°F
600°F
550°F
500°F
450°F
400°F
350°F
300°F
240°F MID-BP MATERIAL
PERCENT SULFUR IN STRAIGHT-RUN PRODUCT
4
3
2
1.0
.7
.5
.4
.3
.2
0.1
.07
.05
.04
.03
.02
.01
0
1
2
3
PERCENT SULFUR IN CRUDE OIL

(b)

Crude Oil	API Gravity†	Specific Gravity	Sulfur (wt%)	Nitrogen (wt%)
Alaska North Slope	26.2	0.8973	1.1	0.2
Arabian Light	33.8	0.8560	1.8	0.07
Arabian Medium	30.4	0.8740	2.6	0.09
Arabian Heavy	28.0	0.8871	2.8	0.15
Athabasca (Canada)	8	1.0143	4.8	0.4
Beta (California)	16.2	0.9580	3.6	0.81
Brent (North Sea)	38.3	0.8333	0.37	0.10
Bonny Light (Nigeria)	35.4	0.8478	0.14	0.10
Boscan (Venezuela)	10.2	0.9986	5.3	0.65
Ekofisk (Norway)	37.7	0.8363	0.25	0.10
Henan (China)	16.4	0.9567	0.32	0.74
Hondo Blend (California)	20.8	0.9291	4.3	0.62
Kern (California)	13.6	0.9752	1.1	0.7
Kuwait Export	31.4	0.8686	2.5	0.21
Liaohi (China)\	17.9	0.9471	0.26	0.41
Maya (Mexico)	22.2	0.9206	3.4	0.32
Shengli (China)	13.8	0.9738	0.82	0.72
Tapis Blend (Malaysia)	45.9	0.7976	0.03	nil
West Hackberry Sweet*	37.3	0.8383	0.32	0.10
West Texas Intermediate	39.6	0.8270	0.34	0.08
Xinjiang (China)	20.5	0.9309	0.15	0.35

Pour Point, °F (°C)

- a rough indicator of the relative paraffinicity and aromaticity of the crude.
- The lower the pour point, the lower the paraffin content and the greater the content of aromatics.

Carbon Residue, wt%

- Carbon residue is determined by distillation to a coke residue in the absence of air.
- The carbon residue is roughly related to the asphalt content of the crude and to the quantity of the lubricating oil fraction that can be recovered.
- In most cases the lower the carbon residue, the more valuable the crude.
- This is expressed in terms of the weight percent carbon residue by either the Ramsbottom (RCR) or Conradson (CCR) ASTM test procedures (D-524 and D-189).

Salt Content, lb/1000 bbl

- If the salt content of the crude, when expressed as NaCl, is greater than 10 lb/1000 bbl, it is generally necessary to desalt the crude before processing.
- If the salt is not removed, severe corrosion problems may be encountered.
- Although it is not possible to have an accurate conversion unit between lb/1000 bbl and ppm by weight because of the different densities of crude oils, 1lb/1000 bbl is approximately 3 ppm.

Characterization Factors

- There are several correlations between yield and the aromaticity and paraffinicity of crude oils, but the two most widely used are :

1. the UOP or Watson ‘‘characterization factor’’ (KW)

2. the U.S. Bureau of Mines ‘‘correlation index’’ (CI).

- The UOP Characterization Factor, commonly called KUOP, is indicative of the general origin and nature of a petroleum stock.

1. Watson characterization factor

SG: Specific Gravity at 15 C (60 F)

Tb: mean average boiling point (R) (MeABP)

$$K_w = \frac{(T_b)^{\frac{1}{3}}}{SG_{15\,^\circ C\ (60\,^\circ F)}}$$

- The Watson characterization factor ranges from less than 10 for highly aromatic materials to almost 15 for highly paraffinic compounds.
- Crude oils show a narrower range of KW and vary from 10.5 for a highly naphthenic crude to 12.9 for a paraffinic base crude.

2. UOP characterization factor

- Tb transfer to Volume average boiling point (VABP)

$$CI = \frac{87{,}552}{T_B} + 473.7G - 456.8$$

T_B = mean average boiling point, °R

G = specific gravity at 60°F.

- Aromatics would have lower KUOP
- The use of boiling point indicates a relationship to the interactive forces between the molecules.
- The use of specific gravity relates to how tightly the molecules are packed (i.e. density)

- The correlation index is useful in evaluating individual fractions from crude oils.
- The CI scale is based upon straight-chain paraffins having a CI value of 0 and benzene having a CI value of 100.
- The CI values are not quantitative, but the lower the CI value, the greater the concentrations of paraffin hydrocarbons in the fraction; and the higher the CI value, the greater the concentrations of naphthenes and aromatics.

Nitrogen Content, wt%

- nitrogen compounds cause ***severe poisoning of catalysts*** used in processing and cause **corrosion problems** such as hydrogen blistering.

- Crudes containing nitrogen in amounts above 0.25% by weight require special processing to remove the nitrogen.

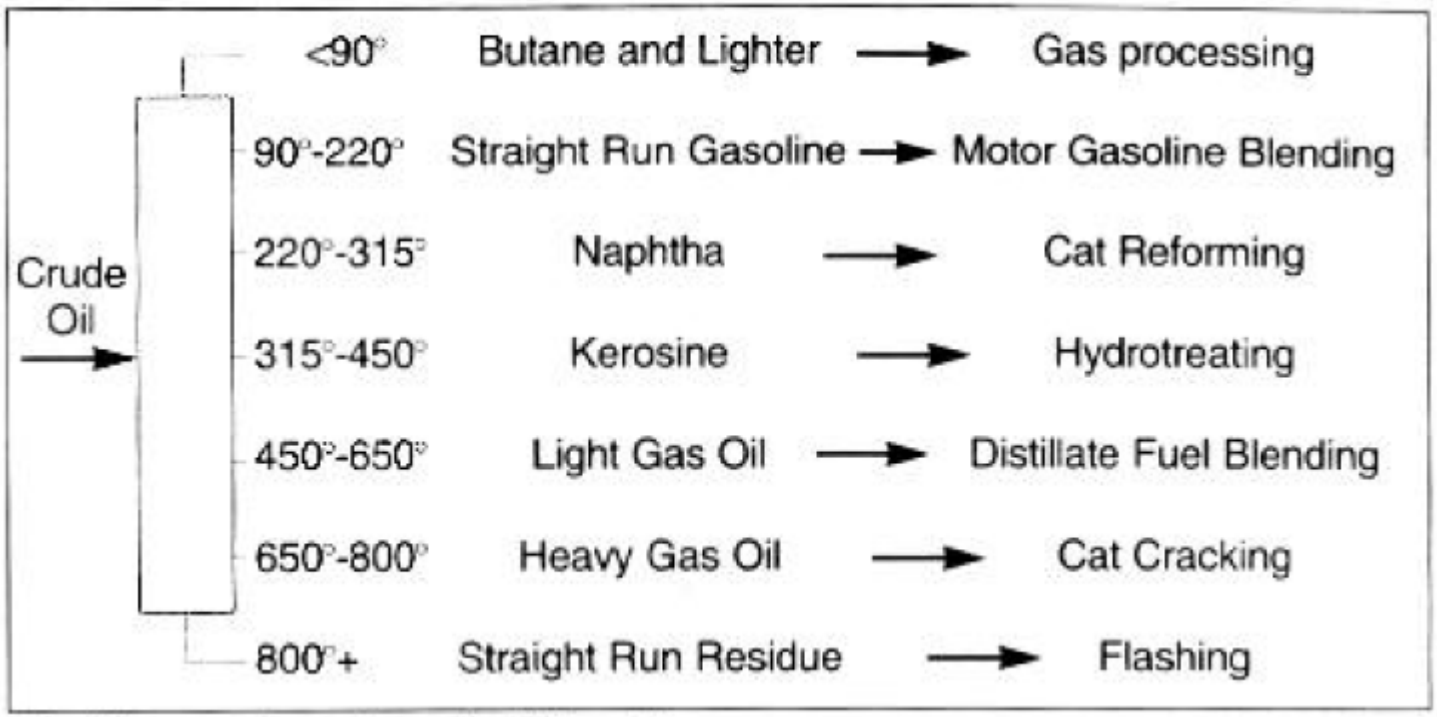
Metals Content, ppm

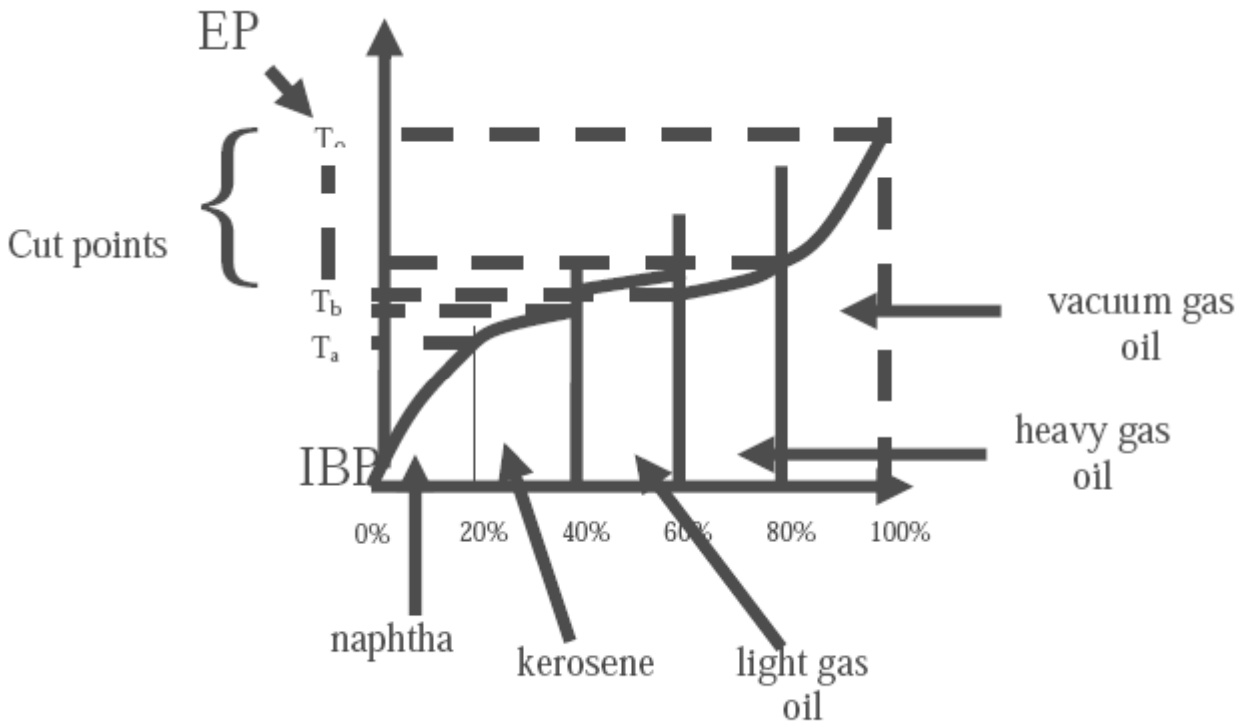
- The metals contet of crude oils can vary from a few parts per million to more than 1000 ppm and, in spite of their relatively low concentrations, are of considerable importance.
- Minute quantities of some of these metals (nickel, vanadium, and copper) can severely affect the activities of catalysts and result in a lower value product distribution.
- Vanadium concentrations above 2 ppm in fuel oils can lead to severe corrosion to turbine blades and deterioration of refractory furnace linings and stacks.
- Distillation concentrates the metallic constituents of crude in the residues, but some of the organometallic compounds are actually volatilized at refinery distillation temperatures and appear in the higher-boiling distillates.
- The metallic content may be reduced by solvent extraction with propane or similar solvents as the organometallic compounds are precipitated with the asphaltenes and resins.

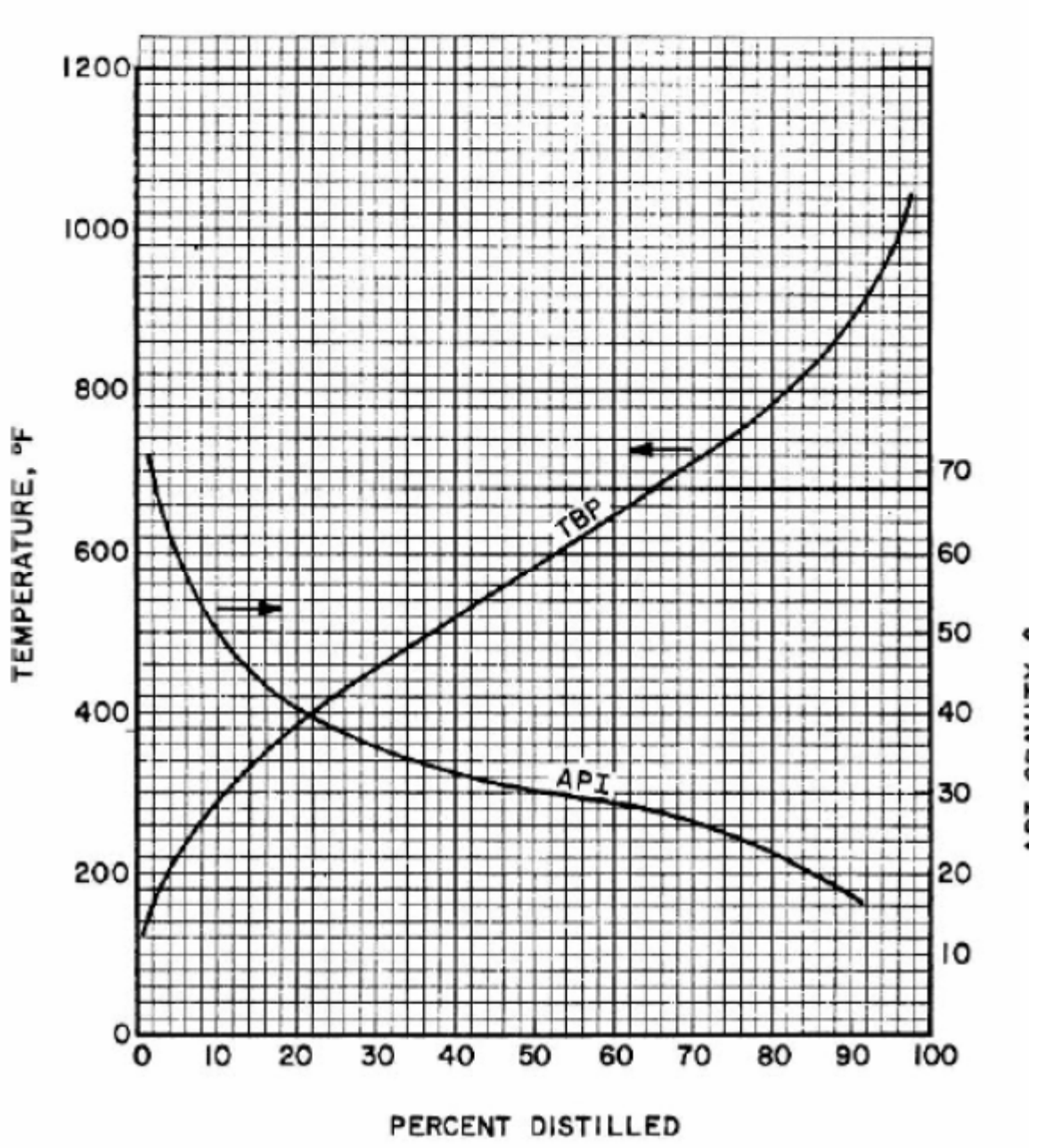
Distillation Range

- gives an indication of the quantities of the various products present.
- The most useful type of distillation is known as a true boiling point (TBP) distillation and generally refers to a distillation performed in equipment that accomplishes a reasonable degree of fractionation.
- There is no specific test procedure called a TBP distillation
- The crude distillation range also has to be correlated with ASTM distillations because product specifications are generally based on the simple ASTM distillation tests D-86 and D-1160.

The TBP cut point for various fractions can be approximated by this Figure.

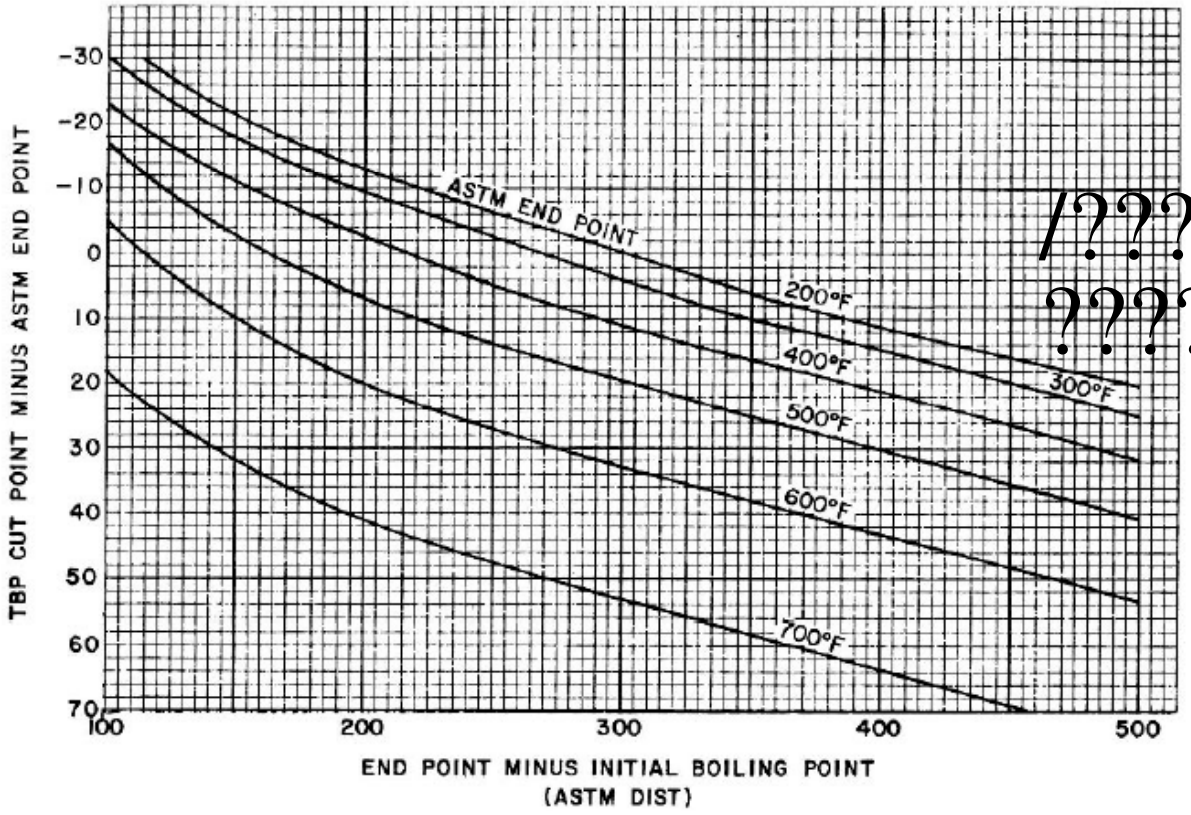



EP
Cut points
T_c
T_b
T_a
IBP
vacuum gas oil
heavy gas oil
0%
20%
40%
60%
80%
100%
naphtha
kerosene
light gas oil


1200
1000
800
600
400
200
0
TEMPERATURE, °F
TBP
API
70
60
50
40
30
20
10
0 10 20 30 40 50 60 70 80 90 100
PERCENT DISTILLED

Distillation Range

The boiling range of the crude gives an indication of the quantities of the various products present.



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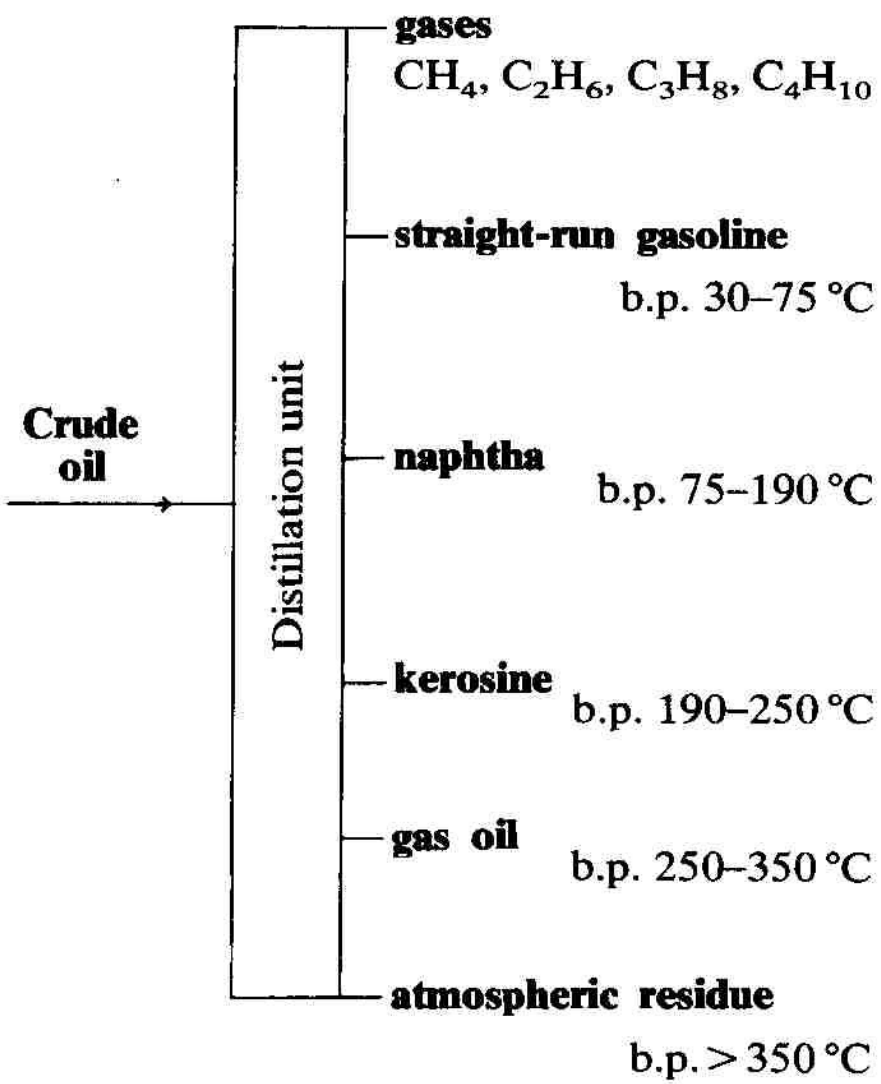

Fuel applications

Refinery fuel. Liquefied petroleum gas (propane and butane).

Has comparatively low octane number. Used for blending in motor gasoline.

Octane number too low for use in motor gasoline. Little direct use as fuel.

Domestic fuel ('paraffin'), jet fuel, tractor fuel.

Diesel fuel, central heating fuel.

Fuel for power stations, ships, and large heating installations.

Hydrocarbon	Octane number[a]		Boiling point (K)
	RON	MON	
n-Pentane	62		309
2-Methylbutane	90		301
Cyclopentane	85		322
n-Hexane	26		342
2-Methylpentane	73		333
2,2-Dimethylbutane	93		323
1-Hexene	63		337
2-Hexene	81		341
Benzene	>100		353
Cyclohexane	77		354
***n*-Heptane**	**0**[b]		**362**
2-methylheptane	13		381
2,2,4-Trimethylpentane	**100**[b]		**372**
1-Octene	35		395
2-Octene	56		398
3-Octene	68		396
Xylenes	>100		≈415
Ethylbenzene	98		410
1,2-Dimethylcyclohexane	79		403
Ethylcyclohexane	41		403
Methyl-tertiary-butyl-ether (MTBE)	118		328
Ethyl-tertiary-butyl-ether (ETBE)	118		345
Tertiary-amyl-methyl-ether (TAME)	111		359
Light straight-run gasoline	68	67	
Isomerate	85	82	
FCC light gasoline	93	82	
FCC heavy gasoline	95	85	
Alkylate	95	92	
Reformate (CCR)	99	88	

[a] Research octane number (RON). The motor octane number (MON) is generally lower, depending on the particular compound. The difference is particularly large for alkenes and aromatics.

[b] By definition.