Physical properties of feedstocks and products

^{o}API

$^{o}API = (141.5/SG_{15^{o}F}) - 131.5$ The purpose of this equation was to extend the range of the specific gravity scale. Crude oil SG changes, although small, may be important.
Crude Oils ^{o}API = 10 – 50

Higher ^{o}API, more paraffinic crude, higher yields of gasoline.
Lower ^{o}API, more aromatic crude, lower yields of gasoline.

Viscosity

Resistance to flow, usually measured @ 100^{0}F in centistokes (kinimatic viscosity)

Pour Point

Measured by ASTM D-97 – temperature at which oil ceases to flow. Diesel may contain waxes, smaller than candle wax, which could solidify in cold weather.

Flash Point

Temperature above which the oil will spontaneously combust. Fractions in vacuum tower are the least combustible. They are the heaviest.

Vapor Pressure

Measured by ASTM D-323. Also know as Reid vapor pressure (RVP). True vapor pressure is usually 5-9% > RVP

Carbon Residue

The solid residue (%wt) remaining after heating to coking temperatures (700-800^{0}C)
ASTM D-524 Ramsbottom Carbon
ASTM D-189 Conradson Carbon
CCR incr. then Asphaltene incr.

Salt Content

Measured by ASTM – 3230 (lb NaCl/1000 bbl)
Desalting is necessary because NaCl content > 10 lbs/1000 bbl leads to corrosion

Metals

Measured by EPA Method 3040 These include Ni, V, Ag, Hg, Na, and Ca. Metals can cause catalyst deactivation and corrosion.

Sediment and Water

Measured by ASTM D – 96 These inorganic particles can lead to operational problems.

Acidity

Measured by ASTM – 664

Sulfur

Measured by ASTM D – 129, 1552, 2622

Sour crudes > 0.5 wt% and sweet crudes < 0.5 wt%. Today it is difficult to find crudes below 1% sulfur.

TBP Distillation Data

Butanes and lighter	55-175 ^oF-
Light Gasoline	175-300 ^oF
Light naphtha	300-400 ^oF
Heavy naptha	400-500 ^oF
Kerosene	500-650 ^oF
Atmosphere Gas Oil	650-800 ^oF
Light Vacuum Gas Oil	800-1000 ^oF
Hvy. Vacuum Gas Oil	1000 ^oF
Vacuum Residue	> 1000 ^oF

Specifications and Environmental Regulations for Gasoline and Diesel

Gasoline-octane number

ON range	Gasoline type
87	Regular
88	Plus
93	Super

Octane # of straight run crude oil is 0 ~ 40

EPA regulations limiting benzene to 1%, aromatics to 10%, and sulfur to 30 ppm

Diesel-cetane nuber

The desirable range for the cetane number is between 40-50

EPA regulations limiting sulfur content to 50 ppm in diesel.

Evaluation of Crude Oil

Evaluation of crude oil is important for refiner because it gives the following types of information:

1. Base and general properties of the crude oil.
2. Presence of impurities such as sulfur, salt, and emulsions which cause general difficulties in processing.
3. Operating or design data. Primarily this necessitates curves of temperature and gravity vs. per cent distilled.
a. Fractionating or true boiling point distillation curve.
b. Equilibrium or flash-vaporization curve.
c. API or specific gravity curve of each fraction distilled.
4. Curves of the properties of the fractions vs. percent distilled (mid per cent curves) or the average properties of a series of fractions vs. Percentage yield (yield curve) by which common realization of yields can by prepared. Among property curves are
a. Viscosity of lubricating-oil fractions
b. Octane number of gasoline fractions.
c. Aniline point of solvents, kerosene, or diesel fractions.
d. Percentage of asphaltic residues.
e. Viscosity of distillation residues.
5. Finished products. Having established the general properties and yield by means of distillation and property curves and exploring the economy of the various break-ups of the crude oil.

Base of crude oil

1)Mallison classification according to residuum:(a material left behind after distillation of fractions.)

Residue > 50% paraffins	Paraffinc base
Residue < 20% paraffins	Asphaltic base
Residue 20-50% paraffins	Mixed base

2)The U.S. Bureau of Mines designated eight base of crude oil

Key Fraction	Boiling point	Pressure	API	Note
No. 1	482-527 ^{0}F	atm.	> 40 (Paraffinic Base) 33 <API >40 (Intermediate Base) API < 33 (Napthene Base)	
No. 2	527-572 ^{0}F 733-779 ^{0}F	(40-mm)Hg 1 atm	> 30 (Paraffinic Base) API < 22 (Napthene Base) 22<API<30 (Intermediate Base)	The presence of wax is noted by cloud point (if below 5^{0}F) it indicates little wax (Wax-free)

3) Specific Gravity and API Gravity:

Specific gravity and API (American Petroleum Institute) gravity are expressions of the density or weight of a unit volume of material.

The specific gravity is the ratio of the weight of a unit volume of oil to the weight of the same volume of water at a standard; both specific gravity and API gravity refer to these constants at 60 ^{0}F (16 ^{0}C).

$$API = \frac{141.5}{Sp.gr.} - 131.5$$

or

$$Sp.gr. = \frac{141.5}{API. + 131.5}$$

Corresponding values of API gravity (0 to 100)

4) Characterization Factor: (C.F), (K)

The most widely used index is characterization factor (Watson, Nelson and Murphy). It was originally defined as:

$$K = \frac{\sqrt[3]{T_B}}{S}$$

In which:

TB is the average molal boiling point (R)

S: is the specific gravity at 60 ^{0}F

It has since related to viscosity, aniline, temperature, molecular weight, critical temperature, percentage of hydrocarbon etc.

K≥ 12.15 (Paraffinic Base)
K< 11.5 (Napthene Base)
K between 11.5-12.15 (Intermediate Base)

5) Correlation Index: (C.I)

Like (C.F) related to boiling point and gravity

$$C.I = \frac{48640}{T_B} + 473.7S - 456.8$$

TB is the average modal boiling point (K)

S: is the specific gravity at 60 ^{0}F

C.I for Parafine =0

C.I for Benzene =100

C.I =0-15 Parafine

C.I =15-50 either Naphtenes or mix (Parafine + Naphtenes)

C.I = above 50 Aromatic

6) Viscosity Index : (V.I)

A series of numbers ranging from 0-100 which indicate the rate of change of viscosity with temperature.

Paraffinic base C.O V.I =100

Naphthenic base C.O V.I = 40

Some Naphthenic base C.O V.I =0

The presence of impurities in the crude oil

1. Sulfur

Difficulties with oils that contain sulfur compounds arise in only three main ways: corrosion, odor and poor explosion characteristics of gasoline fuels.

a) Corrosion: corrosion by finished products presents little difficulty because most products are used at low temperatures. The main bulk of the corrosive sulfur compounds can by removed by treatment with alkalis or the sweetening treatments. In presence of air and moisture the sulfur gases produced during the burning of oil may cause corrosion, as in steel stacks, ducts, and engine exhaust pipes and mufflers.

Real difficulties arise when high sulfur oils are heated to temperature 300 ^{0}F or higher for copper, or 400 0F for steels.

b) Odor : Odor is most obnoxious with low boiling or gaseous sulfur compounds, as H_2S or SO_2 in flue gases, mercaptans up to even six carbons atoms (B.P. of about 400 ^{0}F), sulfides up to 8 carbons atoms (about 350 ^{0}F), and among disulfides only methyl disulfide (B.P. 243 ^{0}F) . This odor is not obnoxious in sweetened products except in certain extremely high- sulfur gasoline.

Percentage of S in crude oil ranges from nearly 0.1 for high API- gravity crude oils as high 5 percentage in a few very heavy crude oils.

Generally crude with greater than **0.5%** S require more extensive processing than those with lower sulfur content.

2. Salt

Salt carried into the plant in brine associated with crude oils is a major cause of the plugging of exchangers and coking of pipe still tubes.

If salt content expressed as NaCl , is greater than 10 lb/1000 bbl, it is generally necessary to desalt the crude before processing.

3. Carbon Residue :

The less the value of carbon residue the more valuable the crude.

4. Nitrogen Compounds:

The nitrogen compounds in petroleum are not of major importance, but they do tend to cause a reduction in the activity of the catalysts used in catalytic cracking and they may assist in the formation of so- called "gum" in distillated or diesel fuel oil.

Crude containing in amount above 0.25 % by weight require special processing to remove the nitrogen.

5. Hydrocarbons Gaseous

The amount of gaseous hydrocarbons dissolved in crude oil is almost totally a function of the degree of weathering that the oil has undergone or the pressure at which it is collected. The percentage of involved when the dissolved gases are lost cannot be stated with accuracy but it is about

$$\text{Liquid vol. \% loss} = \frac{\text{Reid V. P} - 1}{6}$$

If the gas have M.W= 40, the gas amount to about 16.1 ft^3 per 1% loss of liquid.

6. Metallic Content (Ni, V, Cu)

The metal content in crude oil can vary from a few ppm to more than 1000 ppm, disadvantages affect activities of catalyst, corrosion, deterioration of refractory furnace lining and stacks. Can be reduced by solvent extraction with C_3.

Analysis of Crude Petroleum

1) Distillation Curves : When a refining company evaluate its own crude oils to determine the most desirable processing sequence to obtain the required products, its own laboratories will provide data concerning the distillation and processing of the oil and its fractions. The first step in refinery is distillation in which the crude oil separated into fractions according to its boiling point.

There are at least four types of distillation curves or ways of relating vapor temperature and percentage vaporized

a) True-boiling-point (T.B.P): (Fractional, run only on crude oil, batch) .

Distillation characteristics of a crude are assessed performing a preliminary distillation called "True Boiling Point" analysis (TBP). This test enlightens the refiners with all possible information regarding the percentage quantum of fractions, base of crude oil and the possible difficulties beset during treatment operation etc.

True boiling point (TBP) and gravity-mid percent curves can be developed from U.S Bureau of mines crude petroleum analysis data sheet Fig. (1) which is reported in two portions: The first is the portion of the distillation at atmospheric pressure and up to 527 ^{0}F (275 ^{0}C) end point, the second at 40 mm Hg total pressure to 572 ^{0}F (300 ^{0}C) end point. The portion of distillation at reduced pressure is necessary to prevent excessive pot temperature which cracking of the crude oil. The distillation temperatures reported in the analysis be corrected to 760 mm Hg pressure. Generally, those reported in the atmospheric distillation section need to be corrected. The distillation temperature at 40 mm Hg can by converted to 760 mm Hg by use of chart Fig. (2) shows the relationships between boiling temperatures at 40 mm Hg and 760 mm Hg pressure. The gravity mid- percent curve is plotted on the same chart with TBP. The gravity should be plotted on the average volume percent of the fraction, as the gravity is the average of the gravities from the first to the last drops in the fractions. For narrow cuts, a straight line relationship can be assumed and the gravity used as that of the mid-percent of the fraction. Smooth curves are drawn for both TBP and gravity mid- percent curves. Fig. (3) illustrated these curves for the crude oil.

b) Equilibrium or Flash Vaporization (EFV). The feed material is heated as it flows continuously through a heating coil. As vapor is formed it kept cohesively with liquid at some temperature and a sudden release of pressure quickly flashes or separates the vapor from the mixture without any rectification. By successive flash evaporation like this the stock can be progressively distilled at different increasing temperatures. a curve of percentage vaporized vs. temperature may be plotted.

travels along in the tube with remaining liquid until separation is permitted in a vapor separator or vaporizer. By conducting the operation at a series of outlet temperature, a curve of percentage vaporized vs. temperature may be plotted.

c) ASTM or no fractionating distillation: (no fractional , run on fractions) .

It is supposed to be like EFV, a non fractionating distillation system, distinguishing itself as differential distillation. It is a simple distillation carried out with standard ASTM flasks 100,200,500 ml flasks. The data obtained is similar to TBP data

d) Hempel: (Semi fractional).

It is considered as a semi-fractionating type of distillation like Saybolt 's, Where TBP data is insufficient , this can be used.

CRUDE PETROLEUM ANALYSIS

Bureau of Mines Bartlesville Laboratory
Sample 53016

IDENTIFICATION

Hastings Field — Texas, Brazoria County

GENERAL CHARACTERISTICS

Gravity, specific, 0.867 Gravity, °API, 31.7 Pour point, °F., below 5
Sulfur, percent, 0.15 Color, brownish green
Viscosity, Saybolt Universal at 100° Nitrogen, percent,

DISTILLATION, BUREAU OF MINES ROUTINE METHOD

Stage 1—Distillation at atmospheric pressure, 751 mm. Hg
First drop, 84 °F.

Fraction No.	Cut temp. °F.	Percent	Sum, percent	Sp. gr. 60/60°F.	°API 60°F.	C. I.	Refractive index, n_D at 20°C.	Specific dispersion	S. U. visc. 100°F.	Cloud test, °F.
1	122	0.8	0.8	0.673	78.8					
2	167	1.0	1.8	.685	75.1	15				
3	212	3.0	4.8	.725	63.7	24	1.39574	127.7		
4	257	3.4	8.2	.755	55.9	29	1.41796	128.6		
5	302	3.1	11.3	.777	50.6	32	1.42985	135.4		
6	347	3.9	15.2	.798	45.8	35	1.44192	137.8		
7	392	4.9	20.1	.817	41.7	38	1.45217	139.9		
8	437	6.8	26.9	.833	38.4	40	1.46057	140.3		
9	482	8.0	34.9	.848	35.4	41	1.46875	148.0		
10	527	10.9	45.8	.864	32.3	44	1.47679	149.8		

Stage 2—Distillation continued at 40 mm. Hg

Fraction No.	Cut temp. °F.	Percent	Sum, percent	Sp. gr. 60/60°F.	°API 60°F.	C. I.	Refractive index, n_D at 20°C.	Specific dispersion	S. U. visc. 100°F.	Cloud test, °F.
11	392	7.3	53.1	0.873	30.6	45	1.48274	155.2	42	Below 5
12	437	7.8	60.9	.879	29.5	44	1.48474	156.2	50	do
13	482	6.2	67.1	.889	27.7	45	1.49058	152.7	71	do
14	527	5.7	72.8	.901	25.4	48			125	10
15	572	6.9	79.7	.916	23.0	52			280	20
Residuum		20.3	100.0	.945	18.2					

Carbon residue, Conradson: Residuum, 4.7 percent; crude, 1.0 percent.

APPROXIMATE SUMMARY

	Percent	Sp. gr.	°API	Viscosity
Light gasoline	4.8	0.708	68.4	
Total gasoline and naphtha	20.1	0.771	52.0	
Kerosine distillate	--	--	--	
Gas oil	36.9	0.858	33.4	
Nonviscous lubricating distillate	10.2	.879-.895	29.5-26.6	50-100
Medium lubricating distillate	5.8	.895-.908	26.6-24.3	100-200
Viscous lubricating distillate	4.7	.908-.924	24.3-21.6	Above 200
Residuum	20.3	0.945	18.2	
Distillation loss	0			

Figure (1) U.S Bureau of Mines crude petroleum analysis (From Gary and Handwerk, 2001)

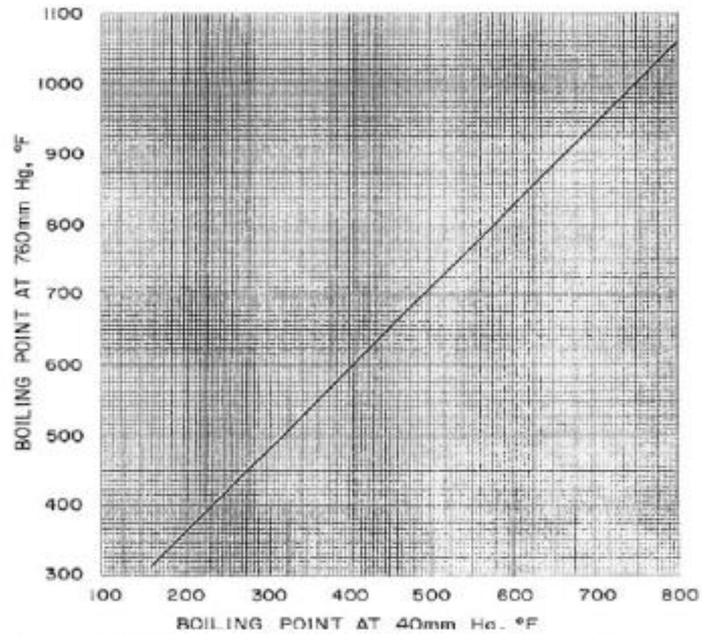


Figure (2) Boling point at 760 mmHg versus boiling point at 40mmHg (From Gary and Handwerk, 2001)

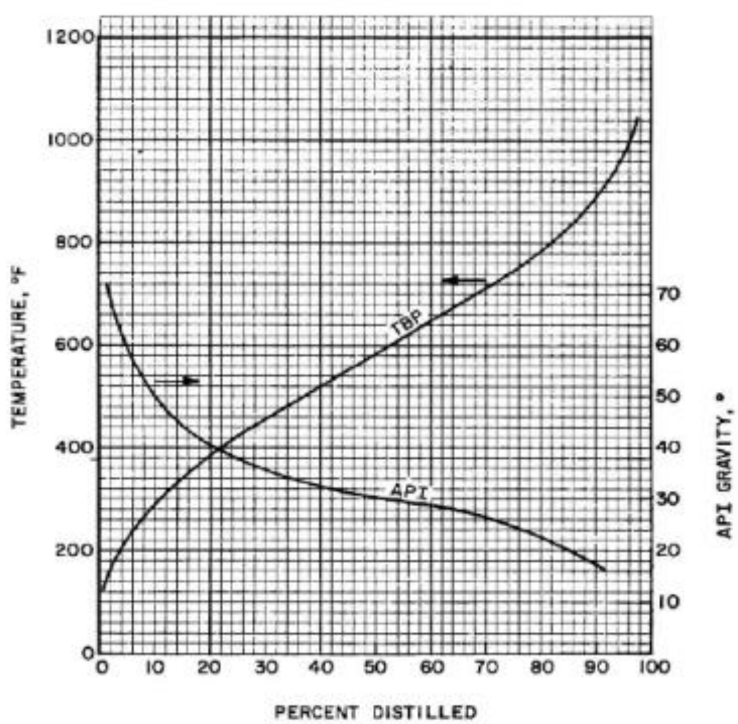


Figure (3): TBP and gravity- mid percent curves. Hasting Field, Texas crude: gravity 31.7 °API; sulfur, 0.15 wt%.(From Gary and Handwerk, 2001)

2) Mid Percent Curves:

The physical properties of an oil found to vary gradually throughout the range of compounds that constitute the oil. Distillation is a means of arranging of compounds these chemical compounds in order of their boiling points. The properties such as color, specific gravity, and viscosity are found to be different for each drop or fraction of the material distilled. The rate at which these properties change from drop to drop may plot as mid per cent curves.

In reality, the specific gravity or viscosity of a fraction is an average of the properties of the many drops that constitute the fraction. If each drop is equally different from the last drop and from the succeeding one, then the drop that distills at exactly half of the fraction has the same property as the average of all the drops. This would be the condition for a mid per cent that is a straight line, but they are substantially straight through any short range of percentage. For a short range of percentage the average property is equal to the property at the mid-point of the fraction. The arithmetical average of the properties of these small fractions is the property of the total or large fraction, or even the entire sample.

Integral- averaging by adding together the properties of a series of short fractions and dividing by number of fractions can not be used on properties that are not additive. Specific gravity (not API gravity) is an example of an additive property, e. g. 10 volumes of an oil of specific gravity 0.8 when mixed with an equal volume of 0.9 specific gravity oil yields a mixture that has a specific gravity 0.85.

Additive Properties	**Non additive Properties**
Boiling Point (T.B.P)	API Gravity
Vapor Pressure	Viscosity
Specific Gravity	Color
Aniline Point	Flash Point
Sulfur Content	
Hydrogen/Carbon ratio	

3) Yield Curves:

If a property is not additive, the property of various ranges of fractions can be determined experimentally by blending and plotting the property value as obtained as a function of yield or amount of blended material.

Crude Suitable for Asphalt Manufacture

If a crude oil residue (750 ^{0}**F mean average boiling point**) having a Watson **characterization factor < 11.8** and **gravity < 35 ^{0}API** , it is usually suitable for asphalt manufacture.

If however, the difference between the K values for the **750 ^{0}F** and **550 ^{0}F** fraction is grater than **0.15**, the residue may contain too much wax to meet most asphalt specification.

Calculation of (K) (Characterization Factor) for The Whole Crude

1. Calculate the TVABP using 20, 50, and 80 volume % TBP temperature.
2. Calculate the 10 to 70% slope of the whole curve.
3. Using a proper correction factor, convert TVABP to TMABP. (or some time given): (TMABP=TVABP-ΔT)
4. Constract a spg mid percent curve and evaluate the spg for the whole crude.
5. K is found as a function of TMABP and spg.

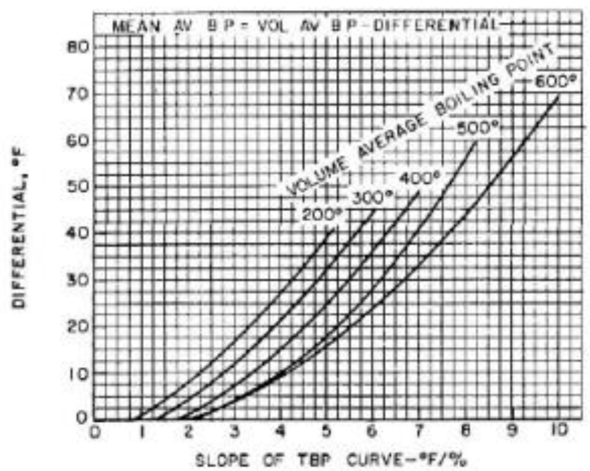


Figure (4): Mean average boiling point of petroleum fractions. (From Gary and Handwerk, 2001)

Estimation of EFV Distillation Curve

A- Estimation of the straight line EFV curve:

1. Estimate of t 50% of ASTM/ TBP using:
2. Estimate the 10 to 70% slope of ASTM/TBP using

$$Slope(ASTM / TBP) = \frac{t_{70} - t_{10}}{60}$$

3. Use Fig. (5) to convert slope (ASTM/TBP) to slope of EFV

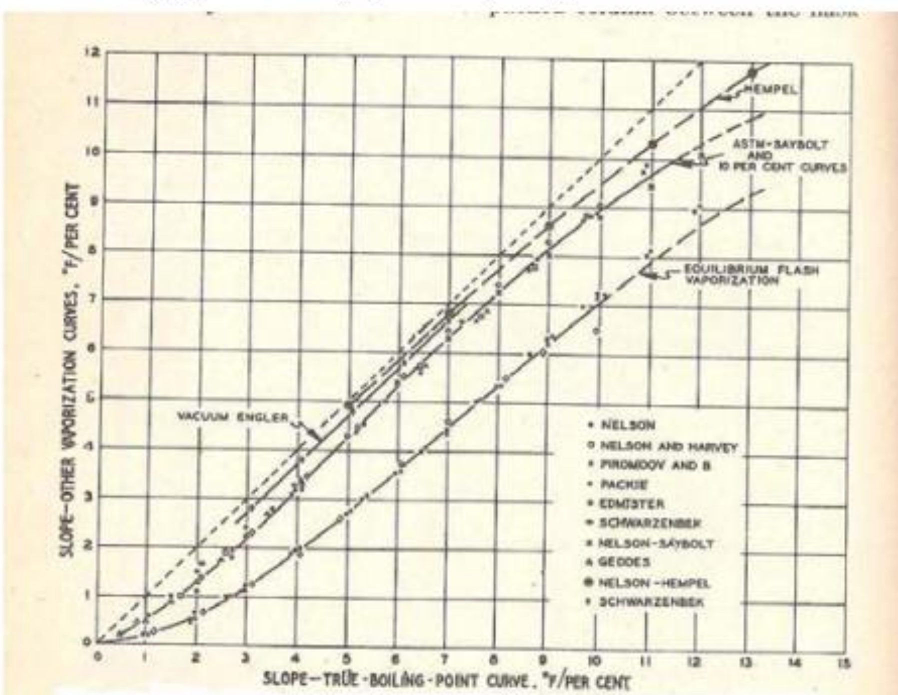


Fig (5): Relationships between the slopes (degrees/ per cent) of various distillation or vaporization curves. (From, Nelson, W. L, 1985)

4. Estimate t 50% of EFV from Fig. (6)

$t_{50\%} = t_{50\%} - \Delta T$

EFV EFV/TBP

5. Draw a straight line through $t_{50\%}$ EFV with slop of EFV.

6. $t_{0\%}$ (bubble point)= $t_{50\%}$ - slope*(50)

EFV EFV

7. $t_{100\%}$ (dew point)= $t_{50\%}$+slope*(50)

EFV EFV

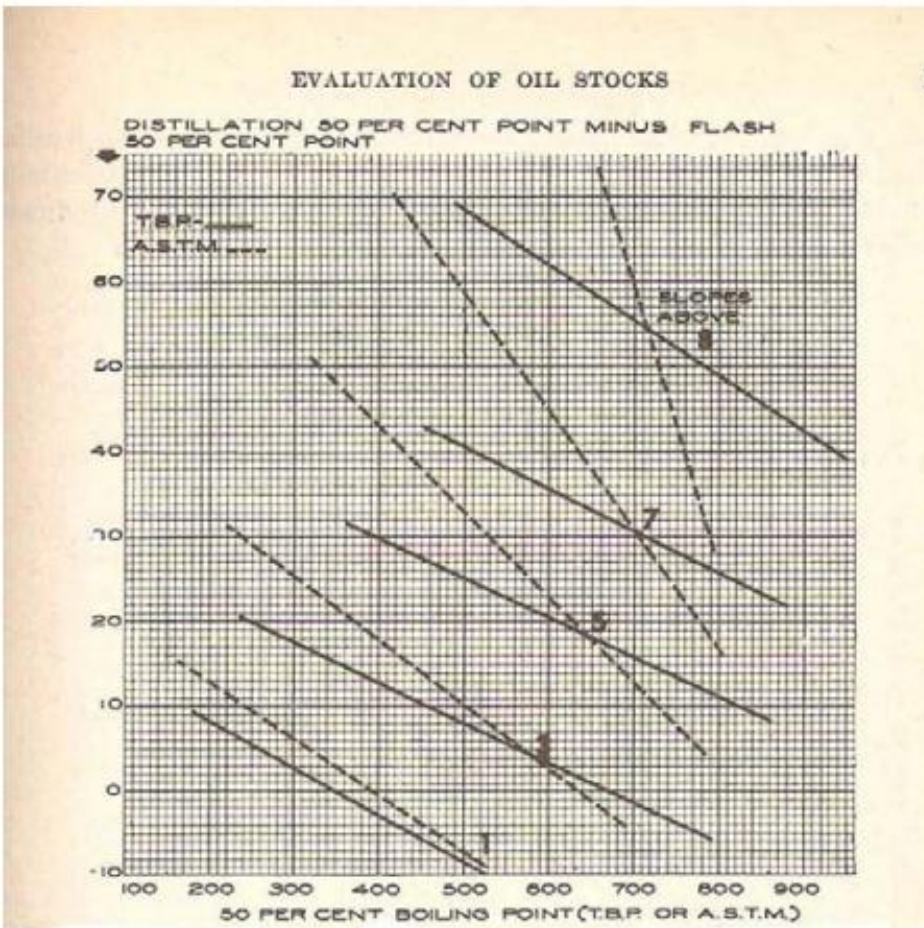


Fig (6): Relationship between distillation temperatures at 50 per cent vaporized and the flash (E. F.V.) temperatures at 50 per cent. (From, Nelson, W. L, 1985)

B. Estimation of EFV Curvature

1. Estimate $t_{50\%}$ (ASTM/TBP)

The proper 50% temperature is intermediate between the temperature on the distillation curve and the temperature on a straight line connecting the 10 and 70 percent points, and usually about halfway between.

2. Convert to $t_{50\%}$ EFV using Fig (6)
3. Estimate the (ASTM/TBP) 10-70 % slope
4. Estimate the EFV slope from Fig (5)
5. Estimate $t_{100\%}$ on flash curve = $t_{50\%}$ + slope *(50)
   $t_{0\%}$ on flash curve= $t_{50\%}$ - slope *(50)
6. Ratio of 10-70 slopes = R
7. Starting at the 10 % and compute the 5 %
   $t_{10\%} = t_{50\%} - 40*$ (slope)
   EFV
8. Slope of (ASTM/TBP) through 5-10 % = r
9. Slope of EFV through 5-10 % = r / R
10. Temperature at 5 % on EFV = $t_{10\%}$- slope * (5)

$$R = \frac{\text{Slope of dist. Curve (10 -70)}}{\text{Slope of flash. Curve (10 -70)}} = \frac{\text{Slope of dist. Curve through short range (r)}}{\text{Slope of EFV through short range}}$$

Average Boiling point

1) Volume Average Boiling Point (TVABP)

$$TVABP = \frac{t_{10\%} + t_{20\%} + ----------- + t_{90\%}}{9}$$

If such data is not available then it may be defined as

$$TVABP = \frac{t_{30\%} + t_{50\%} + t_{70\%}}{3}$$

Where all % are in volumes

2) Weight Average Boiling Point (TWABP)

$$TWABP = \frac{t_{10\%} + t_{20\%} + ----------- + t_{90\%}}{9}$$

Where % are based on weight

3) Molar Average Boiling Point (TMABP)

$$TWABP = \frac{t_{x1} + t_{x2} + t_{x3}}{x_1 + x_2 + x_3}$$

where x_1, x_2, x_3 are mole fractions

t_{x1}, t_{x2}, t_{x3} are corresponding boiling points.

All these boiling point are interconvertable.

Interconvertability of boiling points can be worked out by knowing the slope of distillation curve of a fraction. The method of finding out the slope for ASTM/TBP/EFV is the same

TBP slope is given as $\frac{t_{70} - t_{10}}{60}$ i.e. ^{0}t/ percent; where

70% and 10% are volumetric boiling points on vaporization curve.

The conversion of TBP slope to ASTM or EFV slope can be done with Fig (5)

Example (1) :(Use of Gravity Mid percent Curve) (Nelson p/106)
Compute the spg of a 41.4 API (0.8183 spg) mixed base crude oil from the spg mid percent

Fraction No.	Range of %	spg	Fraction No.	Range of %	spg
1	0 - 5	0.6506	11	50-55	0.8280
2	5-10	0.6939	12	55-60	0.8388
3	10-15	0.7227	13	60-65	0.8498
4	15-20	0.7420	14	65-70	0.8602
5	20-25	0.7583	15	70-75	0.8713
6	25-30	0.7720	16	75-80	0.8827
7	30-35	0.7844	17	80-85	0.8939
8	35-40	0.7958	18	85-90	0.9065
9	40-45	0.8067	19	90-100	0.9340
10	45-50	0.8170			

$$\textbf{Spg of c.o} = \frac{5(0.65+0.69+0.72+0.74+0.76+0.77+0.78+0.79+0.81+0.815+0.82+0.83+0.85+0.86+0.87+0.88+0.89+0.91)+10(0.93)}{100}$$

Computed Sp.gr = 0, 8171, Actual Sp.gr = 0.8183 reasonable check (good for most engineer design work), See fig (7).

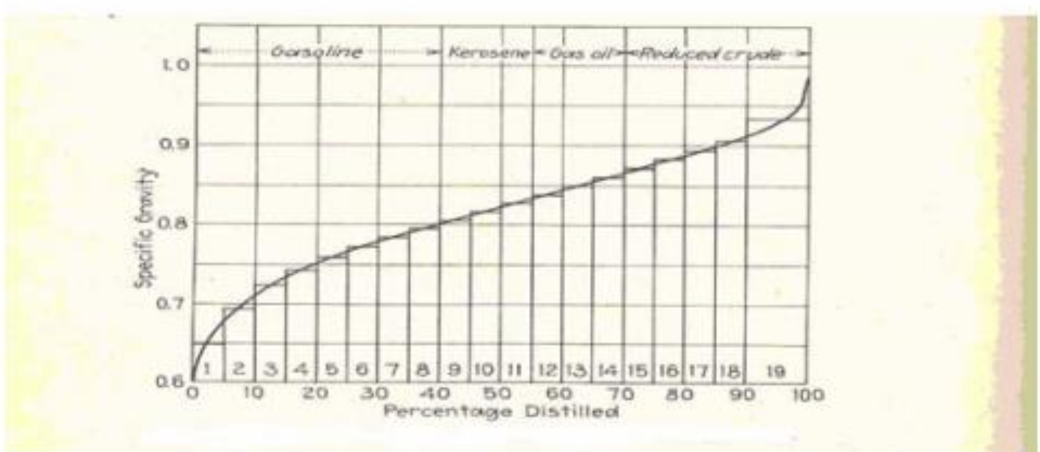


Fig (7): Gravity mid per cent curve. (From, Nelson, W. L, 1985)

Example (2): (Estimate of Flash Vaporization Curve) p/113 Nelson

1) The TBP curve of Fig (8) has a slope (degree/percent) between 10 and 70 percent point of;

$$\frac{t_{70}-t_{10}}{60}=\frac{775-210}{60}=9.4 \text{ Deg/percent}$$

2) According to Fig (5) the slope of EFV curve will be 6.5 Deg/percent.

3) From Fig (9), 50 % percent temperature of TBP curve =576 ^{0}F

4) From Fig (6), the50 % percent temperature of flash curve will be about 64 ^{0}F below of 5) percent temperature of the TBP curve

576- 64 =512 ^{0}F

6) A straight line flash curve can be drawn through 512 ^{0}F with slope of 6.5

Thus at zero percent the temperature=512-50*6.5=187 ^{0}F

At 100 percent the temperature =512+50*6.5= 837 ^{0}F

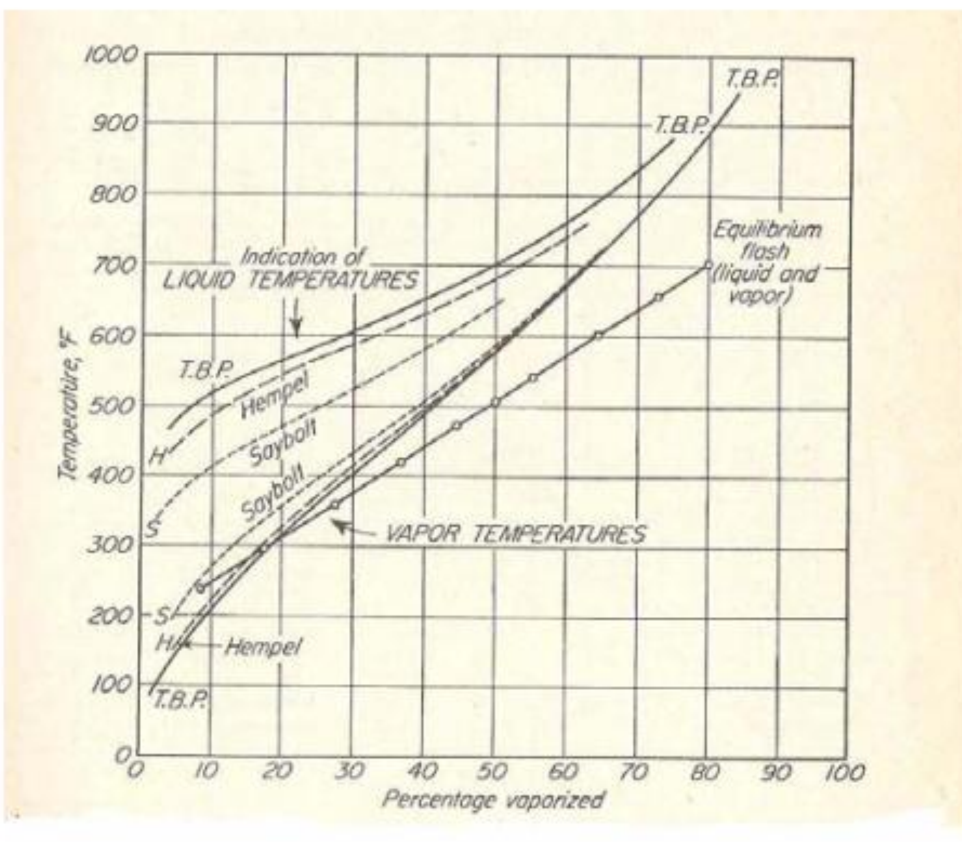


Fig (8) typical liquid and vapor temperature distillation of a 35 API crude oil (From, Nelson, W. L, 1985)

<u>Example (3)</u> :Curvature of Flash Vaporization Curve. (P/119) Nelson.

1) The slope of ASTM, 10-70 percent Fig (9)

$$\frac{430-170}{60} = 4.34$$

2) Slope of flash, 10-70 percent Fig (5) = 2.8

3) The 50 percent point on a straight line connecting 430 and 170 on the ASTM curve is (170+4.34*40) or (430-4.34*20) = 343 ^{0}F

where as it is about 365 on the ASTM curve Fig(9)

A compromise temperature halfway between ,i. e, 354 ^{0}F , is selected

4) 50% on flash curve Fig (6) (354, 2.8) =354-37=317 ^{0}F

100% on flash curve =317+50 *2.8=456 ^{0}F

0 % on flash curve =317-50 *2.8=176 ^{0}F

5) Computing curvature

$$\text{Ratio of 10-70 slope} = \frac{\text{Slope of Flash,}}{\text{Slope of ASTM,}} = \frac{2.8}{4.34} = 0.645$$

6) Starting at the 10 percent and computing the 5 percent point as an illustration

10 % on flash curve : 317-40*2.8=205 ^{0}F

7) Slope of ASTM curve between 5 and 10 % Fig (9)

$$\frac{170-125}{5} = 9.0$$

8) Slope of flash curve between 5 and 10 %

$$R = \frac{\text{Slope of dist. Curve(10 -70)}}{\text{Slope of flash. Curve(10 -70)}} = \frac{\text{Slope of dist. Curve through short range (r)}}{\text{Slope of EFV through short range}}$$

$$= \frac{4.34}{2.8} = \frac{9}{\text{Slope of flash through short range}}$$

Temperature at 5 % on flash curve = 205-5.8*5 = 176 ^{0}F

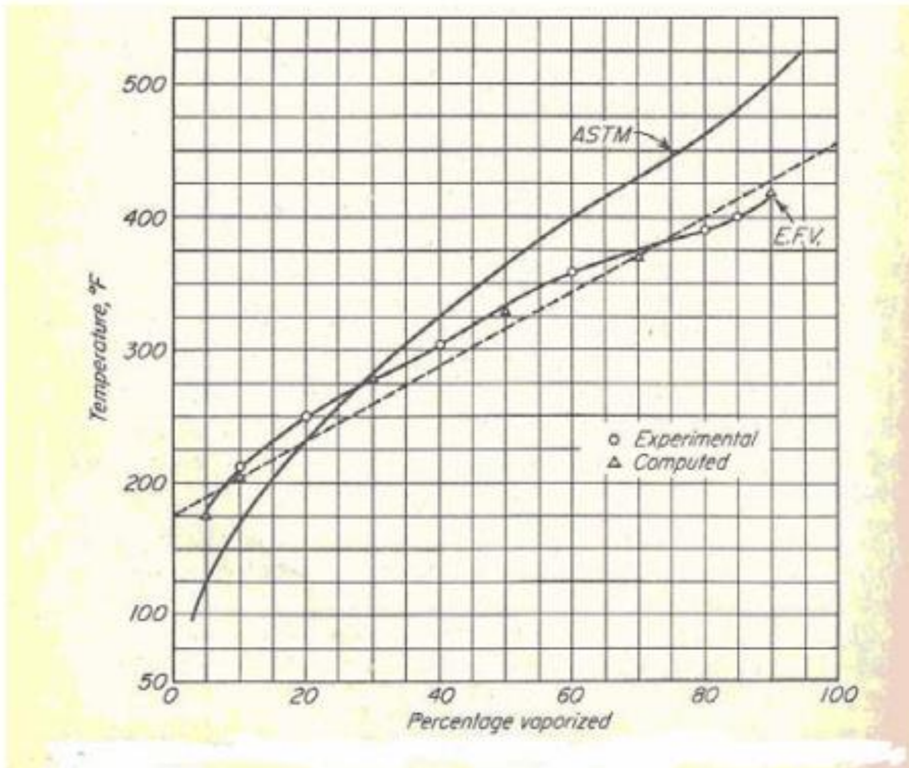
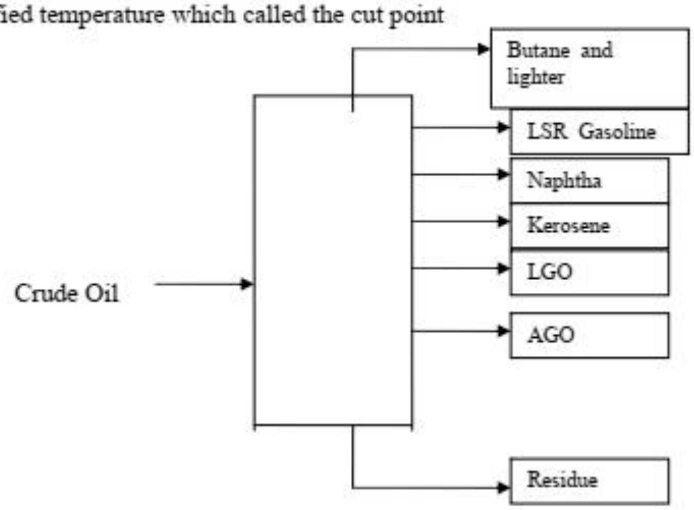


Fig (9): Curvature in the distillation curves of a pressure still distillate. (From, Nelson, W. L, 1985)

<u>Distillation Fractions</u>: All the components that boil between the two specified temperature which called the cut point



Fractions	**Cut points**	**Cut points**
C4 and ltr	< 32 ^{0}C	< 90 ^{0}F
Light Straight Run (LSR) Gasoline	32-105 ^{0}C	90-220 ^{0}F
Naphtha HSR Gas	105-150 ^{0}C	220-300 ^{0}F
Kerosene	150-282 ^{0}C	300-540 ^{0}F
Gas oil	282-425 ^{0}C	540-800 ^{0}F
Residue	425^{+0}C	800 $^{+0}$F

Cut Point

Each fraction has an **IBP** and **EP** on **ASTM** curve because of un efficient fractionation the **IBP** of heavier fraction is interrelated with the **EP** of lighter fraction.

H.W (1): The ASTM data for a pressure distillation are as given. Estimate the EFV curve.

% volume dist.	ASTM (temp. ^{0}F)	% volume dist	ASTM (temp. ^{0}F)
5	125	50	365
10	175	55	380
15	200	60	400
20	230	65	420
25	255	70	425
30	280	75	450
35	300	80	460
40	325	85	480
45	350	90	500

H.W (2): Evaluate the crude oil whose ^{0}API= 35, MABP=600, sulfur%= 0.52%.

H.W (3): 4000 BPD of (35 ^{0} API) crude oil having the given TBP data is available.

TBP ^{0}F	% vol. Distilled	^{0}API	% Sulfur
85	1	110	-
180	13	63	-
385	30	49	0.1
510	50	38	0.3
620	63	23	0.5
750	73	20	0.8
1000	84	17	1.5
1000$^+$	100	11	2.3

a) Draw an assay curve.

b) Evaluate the given crude ; TMABP=TVABP- 120 (^{0} F)

c) Select TBP cut temperature for the products to be obtained from distilling this crude and estimate their yields.

H.W (4) : For the given crude oil ;

a) Evaluate the given oil.

b) Select TBP cut points for the products to be obtained from processing this crude in an atmospheric distillation unit and estimate the %yield for each cut.

% vol. Distilled	TBP (^{0}F)	API	% S
0	40	---	---
20	200	40	0.1
40	280	35	0.18
60	330	30	0.25
80	410	26	0.42
90	500	25	0.68

95	520	20	0.8

H.W (5) : For the given crude oil (31.7 0 API),sulfur percent 0.15 ;

a) Evaluate the given oil.

b) Select TBP cut points for the products to be obtained from processing this crude in an atmospheric distillation unit and estimate the %yield for each cut.

Stage 1- Distillation at atmospheric pressure 751 mm Hg

Fraction No.	Cut Temp. ^{0}F	Percent Distilled	Sum. Percent	Sp. gr. 60/60 ^{0}F	^{0} API 60 ^{0}F
1	122	0.8	0.8	0.673	78.8
2	167	1.0	1.8	0.685	75.1
3	212	3	4.8	0.725	63.7
4	257	3.4	8.2	0.755	55.9
5	302	3.1	11.3	0.777	50.6
6	347	3.9	15.2	0.798	45.8
7	392	4.9	20.1	0.817	41.7
8	437	6.8	26.9	0.833	38.4
9	482	8.0	34.9	0.848	35.4
10	527	10.9	45.8	0.864	32.3

Stage 2- Distillation at atmospheric pressure 40 mm Hg

Fraction No.	Cut Temp. ^{0}F	Percent Distilled	Sum. Percent	Sp. gr. 60/60 0F	^{0} API 60 ^{0}F
11	392	7.3	53.1	0.873	30.6
12	437	7.8	60.9	0.879	29.5
13	482	6.2	67.1	0.889	27.7
14	527	5.7	72.8	0.901	25.6
15	572	6.9	79.7	0.916	22.94
16	-------	20.3	100.0	0.945	18.2