Tikrit University

The College of Petroleum Processes Engineering

Petroleum Systems Control Engineering Department

Properties of Petroleum & Natural Gas

Third Class

Lecture 11

By

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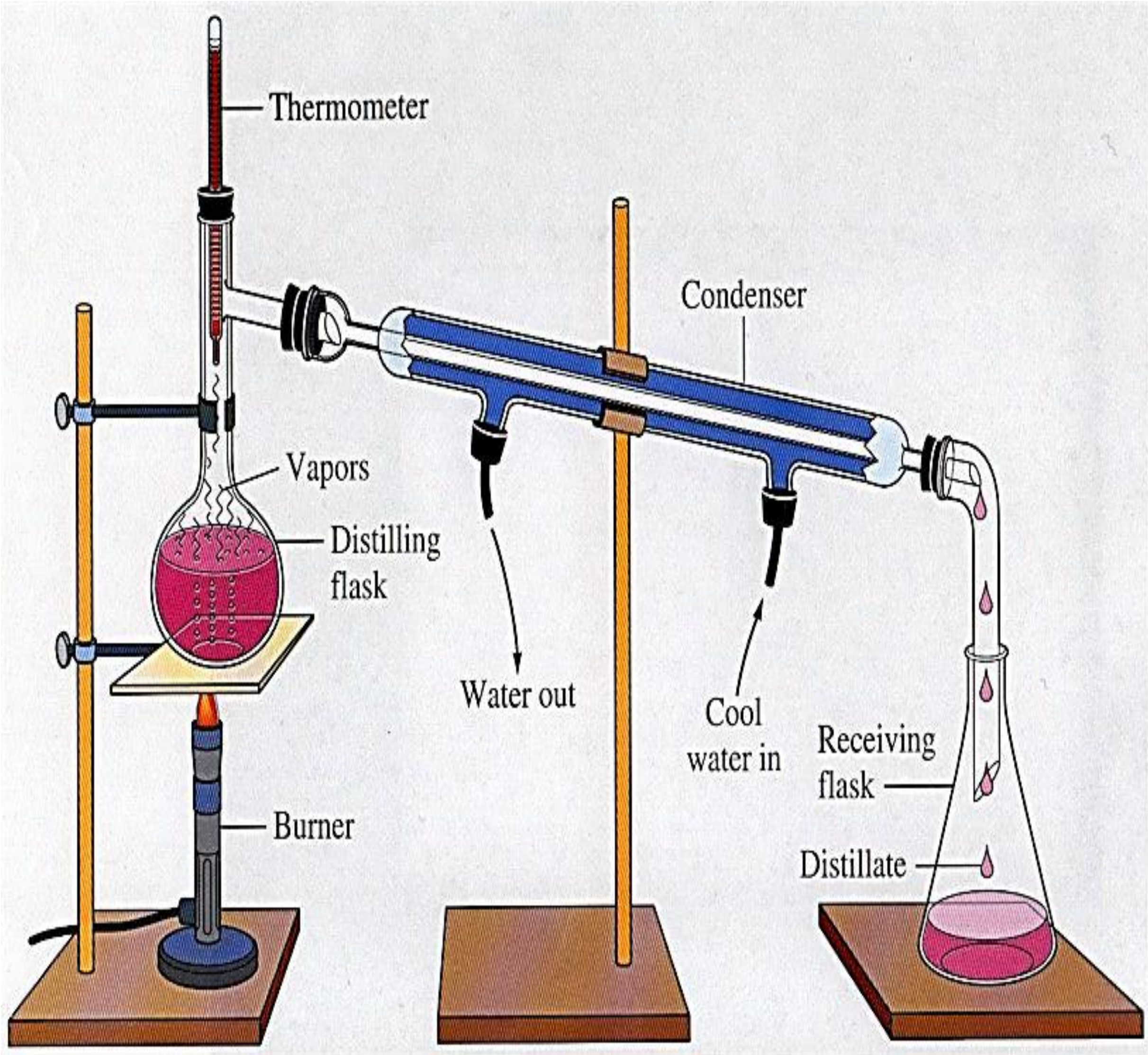
ASTM distillation curves of petroleum products

- The distillation of petroleum cuts is done in a simple distillation apparatus which does not have a fractionation column.
- For light cuts (gasoline, kerosene, diesel and heating oil) the distillation is run at atmospheric pressure under ASTM D86 test.
- For heavier fractions an **ASTM D1160** test at reduced pressure is employed.
- **Distillation is a process** of separating the component or substances from a liquid mixture by selective evaporation and condensation, the process exploits differences in the volatility of the mixture's components.
- **Volatility** is the tendency of a substance to vaporize. Volatility is directly related to a substance's vapour pressure.
- At a given temperature, a substance with higher vapour pressure vaporizes more readily than a substance with a lower vapour pressure.

ASTM D86 distillation apparatus consisting of:

- flask holding the sample connected to an inclined condenser, which condensed the rising vapour. The fractions distilled are collected in a graduated cylinder.
- The temperature at which the first drop of condensate is collected is called the initial boiling point (IBP).
- The end point (EP) is the maximum vapour temperature when almost the entire sample is distilled.



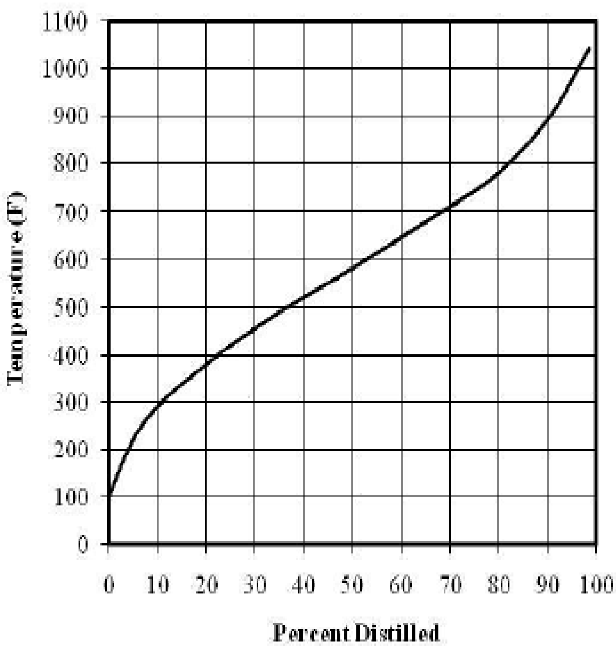
ASTM D86 apparatus

- Heavy petroleum products, which tend to decompose partially or completely vaporized at a maximum temperature of 400°C (750°F) are distilled using the **ASTM D1160** method. It is carried out at pressures between **1 and 760 mm Hg**.

Prediction and Conversion of Distillation Curves

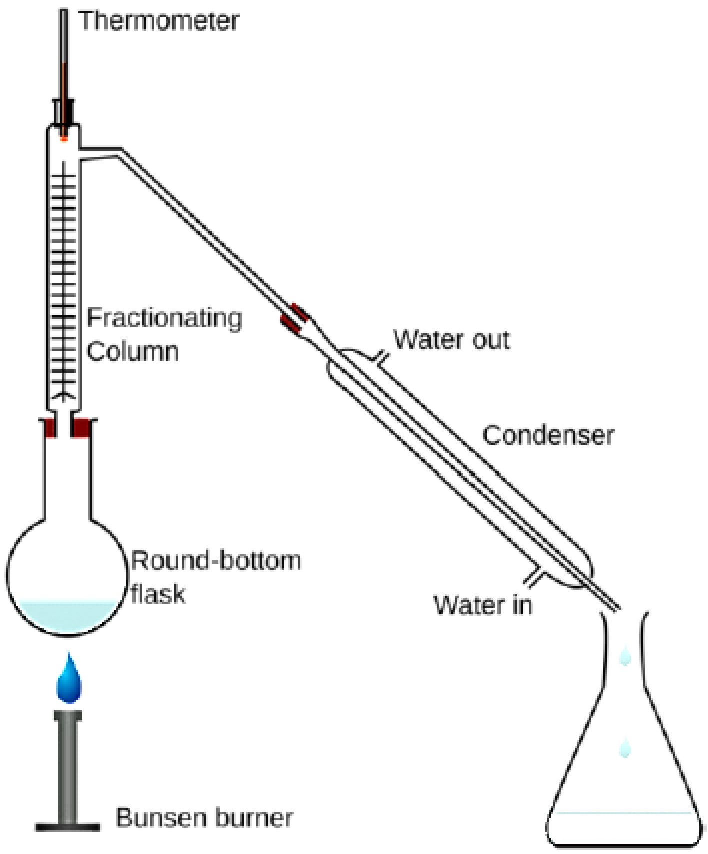
- For a petroleum fraction of unknown composition, the boiling point may be presented by a curve of temperature versus vol% (or fraction) of mixture vaporized based on 100 units of volume.
- The boiling point of the lightest component in a petroleum mixture is called ***initial boiling point*** (**IBP**) and the boiling point of the heaviest compound is called the ***final boiling point*** **(FBP).**
- In some references the **FBP is also called the *end point.***

Vol %	IBP	T5	T10	T30	T50	T70	T90	T95	FBP
ASTM D86 °C									
% Recovery or total distillate TD:									
% Residue: % Loss:									



True Boiling Point Distillation TBP ASTM D2892

- Data from TBP distillation provides more detailed characterization of the volatility of crude oil or petroleum fraction.
- It is performed in columns with 15 theoretical plates or equilibrium stages and a reflux ratio of 5:1.
- The high degree of fractionation in this test gives an accurate component distribution.
- Because the degree of separation for a TBP distillation test is much higher than that of the ASTM distillation test, its IBP is lower and its EP is higher than those of the ASTM D86 test.



TBP apparatus

Conversion between ASTM D86 and TBP Distillation ASTM D2892

Riazi-Daubert Method (API method)

$$T_i(desired) = a(T_i available)^b\, SG^c \quad \text{.................(1)}$$

- Ti (available) is the available distillation temperature at a specific vol% distilled
- Ti (desired) is the desired distillation data for the same vol% distilled, both are in kelvin or Rankine.
- SG is the specific gravity of fraction at 15.5°C and a, b, and c are correlation parameters specific for each conversion type and each vol% point on the distillation curve.
- **ASTM D 86 distillation data do not represent actual boiling point of components** in a petroleum fraction. Petroleum Process engineers are more interested in actual or true boiling **point (TBP) of cuts in a petroleum mixture**.
- If distillation data available are in the form of **ASTM D 86** and desired distillation is TBP, equation below can be used, but for this particular type of conversion value of constant c for all points is zero and the (equation 1) reduces to:

$$TBP = a(ASTM)^b \quad \text{...................(2)}$$

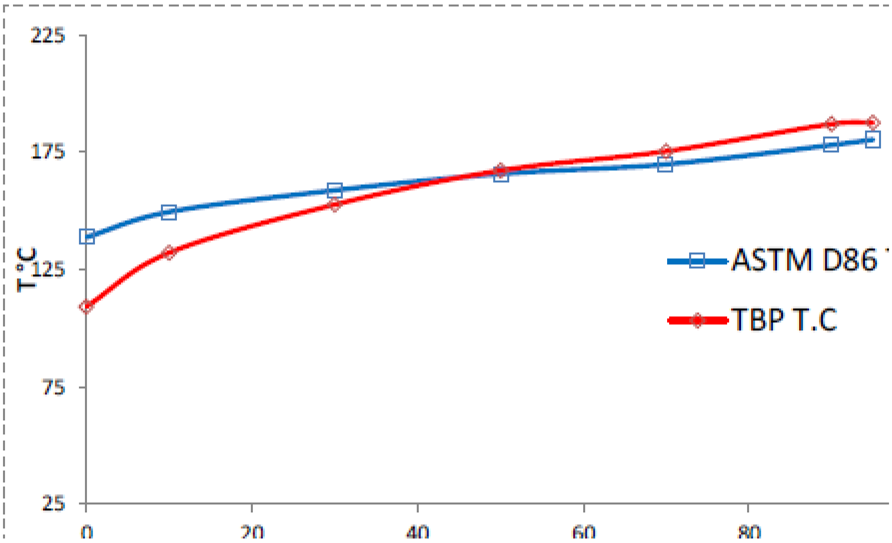
Factors a and b are constants varying with percent of liquid sample distilled as given in the following table.

Vol%	a	b	ASTM D 86 range,[a] °C
0	0.9177	1.0019	20–320
10	0.5564	1.0900	35–305
30	0.7617	1.0425	50–315
50	0.9013	1.0176	55–320
70	0.8821	1.0226	65–330
90	0.9552	1.0110	75–345
95	0.8177	1.0355	75–400

Q1: A naphtha fraction has the following ASTM D86 distillation data. Obtain the TBP curve using the API method.

$$TBP = a(ASTM)^b$$

Vol %	ASTM D86 °C	ASTM D86 k	TBP k	TBP °C
0	**138.8**	411.95	382.4	**109.25**
10	149.6	422.75	405.36	**132.21**
30	158.8	431.95	425.86	**152.71**
50	**165.8**	438.95	440.38	**167.23**
70	169.9	443.05	448.59	**175.44**
90	178.1	451.25	460.25	**187.1**
95	**180.4**	453.55	460.8	**187.65**



$$SL\ (D86) = \frac{178.1-149.6}{90-10} = 0.356℃$$

$$SL\ (TBP) = \frac{187.1-132.21}{90-10} = 0.686℃$$

- **Note that SL less than 0.8, i.e. MeABP = T50= 167.23 °C**
- **Note that if ASTM D86 is needed and TBP values are only available, then one can use equation 2 as follows:**

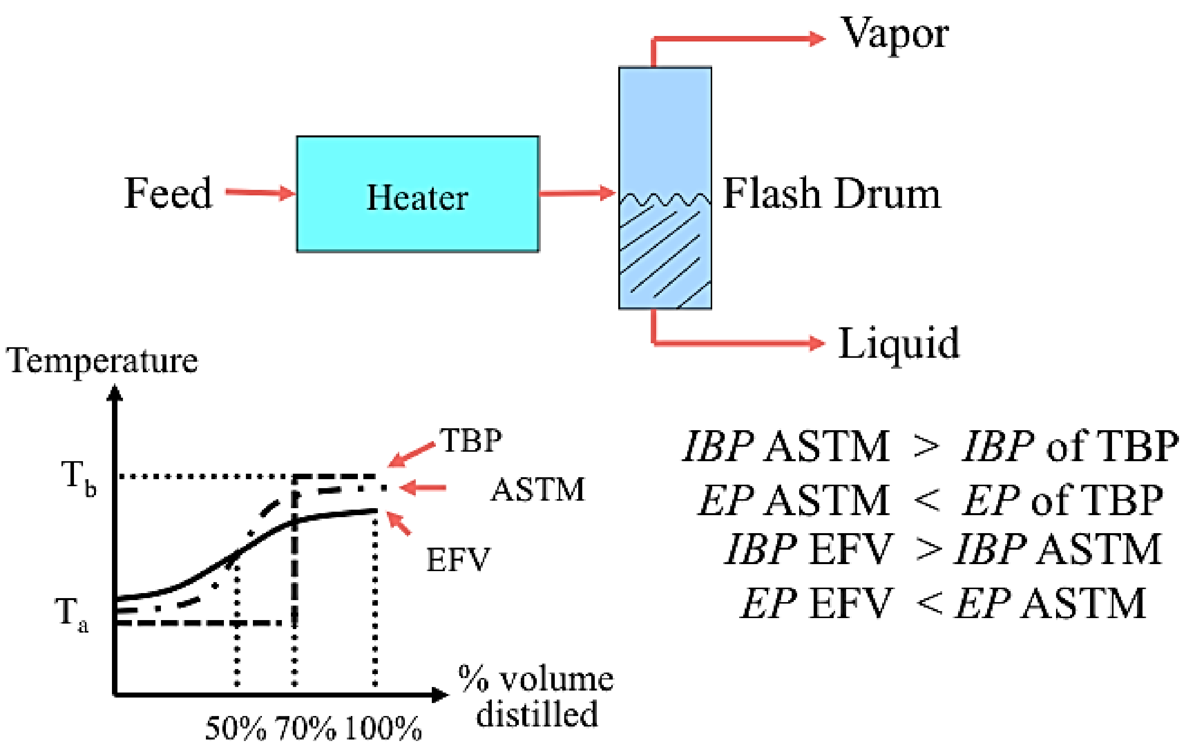
$$ASTM = [\frac{1}{a} * TBP]^{\frac{1}{b}}$$

..................(3)

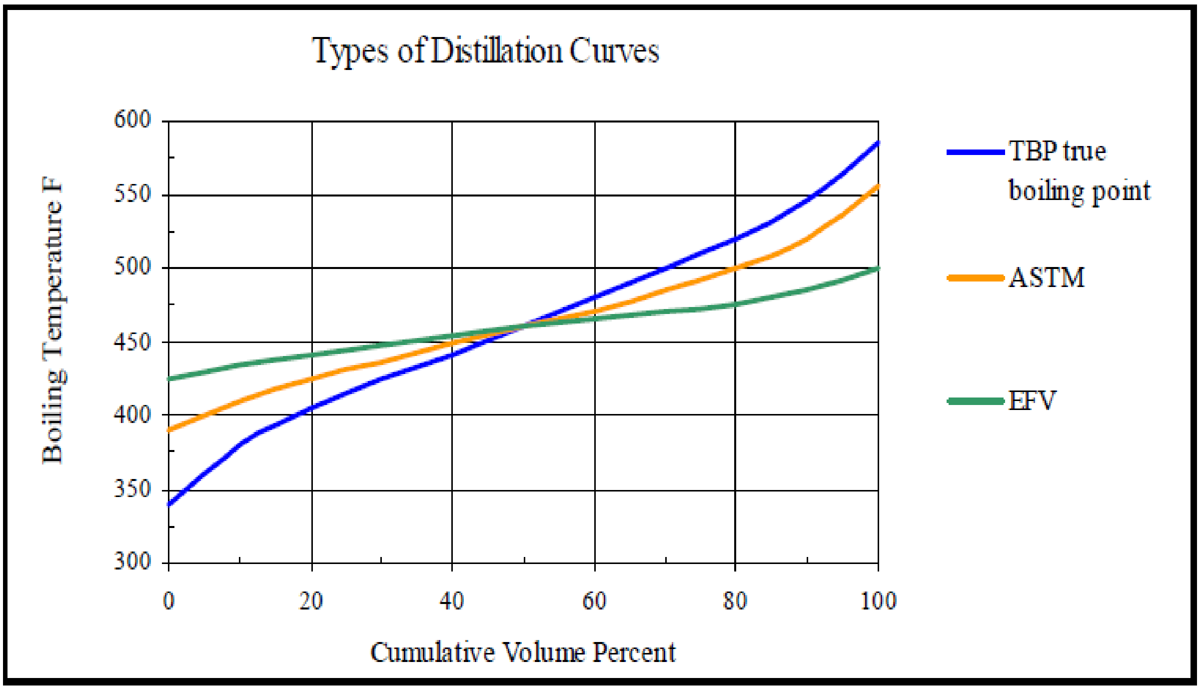
ASTM D 86 and EFV Conversions

- (EFV) is presented in terms of the temperature versus vol% vaporized.
- It involves a series of experiments at constant atmospheric pressure with total vapour in equilibrium with the unvaporized liquid.
- To have a full shape of an EFV curve at least five temperatures at 10, 30, 50, 70, and 90 vol% vaporized are required (five experiments).

- Each EFV experiment involves heating a flowing feed and the separation of the liquid and vapor in a flash drum. A distillation curve may be obtained by conducting this distillation at varying heater outlet temperatures.
- EFV gives the lowest degree of separation between A and B, even lower than that given by the ASTM distillation.
- The EFV **initial boiling point** of the fraction is the **bubble point** and the EFV **final boiling** point is the **dew point.**



Initial Boiling Point (IBP) : 0% distilled)
End Point (EP) :100% distilled)



- EFV distillation curves are useful in the design and operation of overhead partial condensers and bottom reboilers since the EFV temperatures represent actual equilibrium temperatures.
- EFV curves at pressures above atmospheric up to pressures of 15 bar may also be useful for design and operation of vaporizing or condensing vessels under pressure.

$$EFV = a(ASTM\ D86)^b\ SG^c \quad \text{..............}(4)$$

Where constants a, b, and c is given in the Table below:

Vol%	*a*	*b*	*c*	ASTM D 86 range,ᵃ °C
0	2.9747	0.8466	0.4209	10–265
10	1.4459	0.9511	0.1287	60–320
30	0.8506	1.0315	0.0817	90–340
50	3.2680	0.8274	0.6214	110–355
70	8.2873	0.6871	0.9340	130–400
90	10.6266	0.6529	1.1025	160–520
100	7.9952	0.6949	1.0737	190–430

- If specific gravity of a fraction is not available, it may be estimated from available distillation curves at 10 and 50% points as given by the following equation:

$$SG = a[(T_{10})^b (T_{50})^c] \quad \text{.................(5)}$$

where constants *a*, *b*, and c for the three types of distillation data, namely, ASTM D 86, TBP, and EFV, are given in the Table below. Temperatures at 10 and 50% are both in kelvin.

Distillation type	T_{10} range,^{a}°C	T_{50} range,^{a}°C	SG range	*a*	*b*	*c*
ASTM D 86	35–295	60–365	0.70–1.00	0.08342	0.10731	0.26288
TBP	10–295	55–320	0.67–0.97	0.10431	0.12550	0.20862
EFV	79–350	105–365	0.74–0.91	0.09138	−0.0153	0.36844

Q2: Estimate the true boiling point (TBP) and EFV distillation curves of the petroleum fraction having the following ASTM D86 distillation temperatures:

- ❖ Using Riazi-Duabert's method
- ❖ Draw all curves on a single graph indicating IBP, MBP and FBP.

V% distilled	IBP	5	10	30	50	70	90	95	FBP
ASTM D86 °C	193	-	204	215	225	237	251	-	271

Solution:

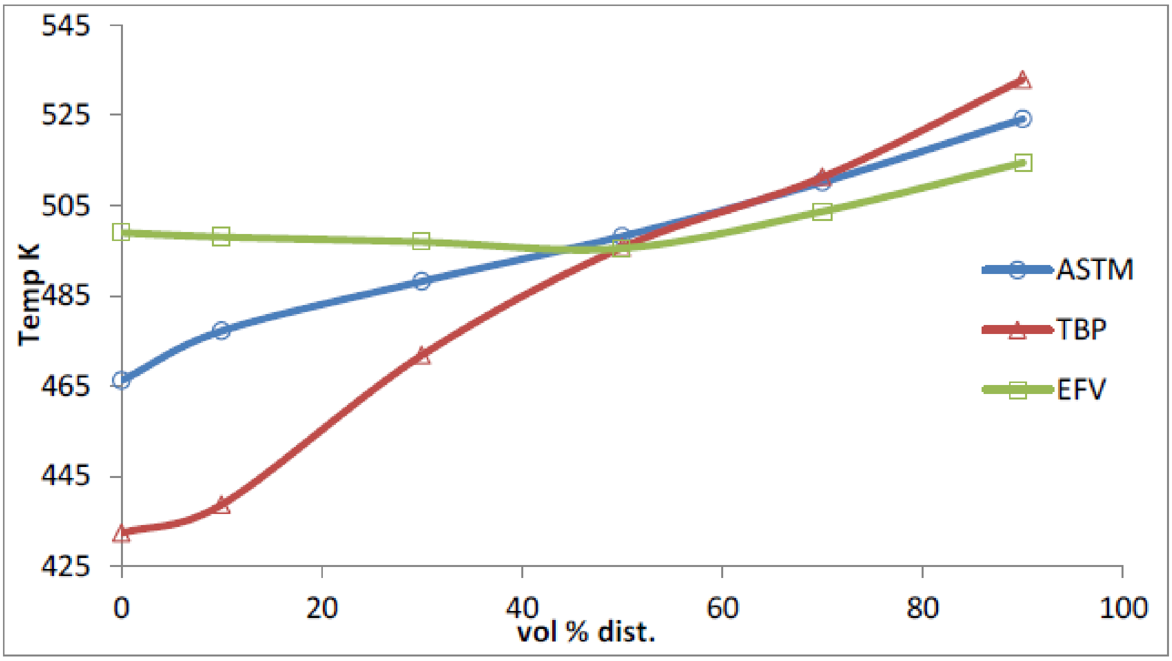
$$TBP = a(ASTM\ D86)^b$$

vol %	a	b	ASTMD86 C	ASTMD86 K	TBPK	TBPC
IBP	0.9167	1.0019	193	466.15	432.337711	159.187711
10	0.5277	1.09	204	477.15	438.652861	165.502861
30	0.7429	1.0425	215	488.15	471.788301	198.638301
50	0.892	1.0176	225	498.15	495.676726	222.526726
70	0.8705	1.0226	237	510.15	511.282159	238.132159
90	0.949	1.011	251	524.15	532.887845	259.737845
FBP 95	0.8177	1.0355				

$$EFV = a(ASTM\ D86\ °K)^b\ SG^c$$

a	b	c	T10	T50	SG
0.08342	0.10731	0.26288	477.6	498.65	0.82786

vol %	ASTM D86 K	EFV	a	b	c	SG
0	466.15	498.9292045	2.9747	0.8466	0.4209	0.827651
10	477.15	498.0052258	1.4459	0.9511	0.1287	0.827651
30	488.15	496.8853822	0.8506	1.0315	0.0817	0.827651
50	498.15	495.4822487	3.268	0.8274	0.6214	0.827651
70	510.15	503.6648071	8.2873	0.6871	0.934	0.827651
90	524.15	514.4622033	10.6266	0.6529	1.1025	0.827651
95			7.9952	0.6949	1.0737	0.827651


545
525
505
485
465
445
425
Temp K
0
20
40
60
80
100
vol % dist.
ASTM
TBP
EFV