**Types of Distillation Curve**

1. **True Boiling point (TBP) Distillation**
   - This type of distillation is commonly used due to the accuracy of the results obtained by this method which is very close to that obtained via real distillation or industrial distillation. In this distillation, there is a fractionation column located between the condenser and the flask. In general, this type of distillation is carried out by two steps: firstly, under atmospheric pressure until 300°C (1% distilled every 2 min), secondly under vacuum pressure (to prevent cracking process and to reduce the boiling point) at 40mmHg (1% distilled every 3-5 min). In this process, the vapor press. temp. is plotted vs. distilled(%) to get TBP curve.

2. **ASTM Distillation**
   - In this type of distillation, there is a fractionation column located between the condenser and the flask. On the other hand, the raised vapor will not be fractionated in this process. This distillation is used with fractions having short range of the boiling point.

3. **Semi-fractionating distillation**
   - In this type of distillation, there will be some fractionating process on the raised vapor via package located between the condenser and the flask.

4. **Equilibrium Flash Vaporization (EFV)**
   - Is a single stage separation technique. A liquid mixture feed is pumped through a heater to raise the temperature and enthalpy of the mixture. It then flows through a valve and the pressure is reduced, causing the liquid to partially vaporize. Because the vapor and liquid are in such close contact until the "flash" occurs, the product liquid and vapor phases approach equilibrium.
Fig. 5. TBP cut point versus ASTM end point
Fig. 6. Crude distillation curve

Fig. 7. TBP and gravity-mid-percent curves
**Average Boiling Point**

1- Volume Average Boiling Point (VABP)

\[ VABP = \frac{T_{20\%} + T_{50\%} + T_{80\%}}{3} \]

\( T_{i\%} \) = Temp. at \( i \) vol. % distilled

For short cut Boiling Point (having short B.P)

\[ VABP = T_{50\%} \]

2- Weight Average Boiling Point (WABP)

\[ WABP = \frac{T_{1\%} + T_{2\%} + T_{3\%} + \ldots + T_{90\%}}{9} \]

\( T_{i\%} \) = Temp. at \( i \) weight. % distilled

3- Molal Average Boiling Point (MABP)

\[ MABP = \frac{T_{x1} + T_{x2} + T_{x3} + \ldots}{x_1 + x_2 + x_3} \]

\( T_{ix} \) = Temp. at \( i \) mol. x distilled, \( x \) is the no. of mole

\[ MABP = VABP + \Delta T \]

4) Slope of Distillation Curve

\[ Slope = \frac{T_{70\%} - T_{10\%}}{60} \]

If the slope < 2 \( \Rightarrow \) Short Cut \( T_{50\%} \) \( \Rightarrow \) VABP = WABP = MABP

Fig. 10 is used to convert Distillation Curve from any type to any type.

Figure 11 is used to find T50% for EFV \( (y_{avix} = T_{50\%(ASTM \ or \ TBP)} - T_{50\%(EFV)}) \)
Fig. 8. Molal average boiling point of petroleum fractions

Fig. 9. Mean average boiling point of petroleum fractions
Also, Differential ($\Delta$) can be estimated from the following eq.

$$\ln \Delta = -0.94402 - 0.00865(VABP - 32)^{0.6667} + 2.99791\text{SL}^{0.333}$$

$$\text{SL} = \frac{T_{90} - T_{10}}{90 - 10}$$

*Fig. 10. Relationships between the slopes of various distillation curves*
Ex) Find \( T_{100\%} \) and \( T_{0\%} \) for EFV if \( T_{50\%(TBP)} = 570 \) and Slope = 9.4.

Sol.: From Fig.10, the slope of EFV curve = 6.6 (at 9.4 TBP)

From Fig. 11, \( \Delta T = 65 \) (at \( T_{50\%(TBP)} = 570 \))

\[ \therefore T_{50\%(EFV)} = T_{50\%(ASTM \ or \ TBP)} - \Delta T = 570 - 65 = 505 \]

\[ slope = \frac{\Delta y}{\Delta x} = \frac{T_{100\%} - 505}{50 - 0} = 6.6 \Rightarrow T_{100\%} = 835 \]

\[ Slope = \frac{\Delta y}{\Delta x} = \frac{505 - T_{0\%}}{100 - 50} = 6.6 \Rightarrow T_{0\%} = 175 \]
Fig. 12. Sulfur content of products from Middle East crude oils
Home work

For a given crude oil; 1- Draw a TBP curve, 2- Evaluate the crude, 3- Find the value of Kw if API=43, 4- Draw a EFV on the same Figure, 5- Find the vol. dis. At 1100F if CCR= 1.8% then draw it, and 6- Find the vol. of the distilled at 1000F.

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<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
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<td>480</td>
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<td>610</td>
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<td>0.82</td>
<td>0.835</td>
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