**Density and Specific Gravity ASTM D 287-92@60 °F (15.5 °C) and 1 atm.**

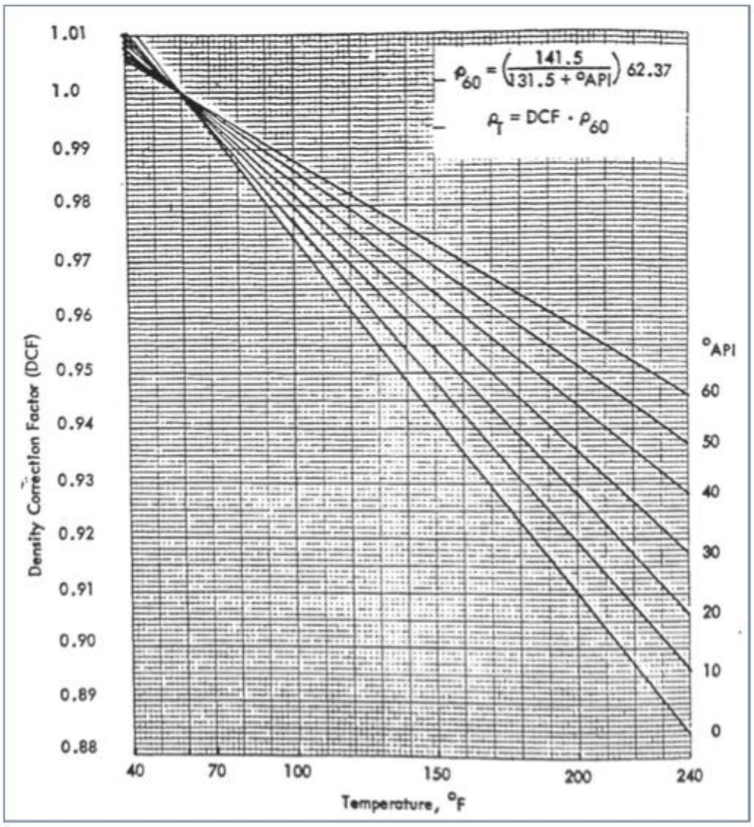
$$SG\ @\ 60°F = \frac{\rho\ of\ liquid\ at\ T}{\rho\ of\ water\ at\ T} \quad (1)$$

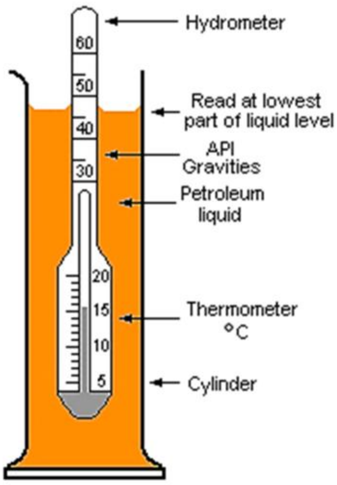
$$SG\ @\ 60°F = \frac{\rho\ of\ petroluem\ at\ 60°F\ \ g/cm^3}{0.999\ \frac{g}{cm^3}} \quad (2)$$

**ASTM D 287-92: API of crude oil and petroleum products by hydrometer method.**

- A hydrometer (a calibrated floating device) is placed in the sample at the specified temperature.
- The depth to which the **hydrometer sinks and comes to rest in the liquid indicates** the relative weight of the liquid.
- The hydrometer reading (**API**) is converted to specific gravity at 15.6°C or API gravity at 60°F using standard tables or figures.

$$API = \frac{141.5}{Sp.Gr.@\ 60°F} - 131.5 \ldots (3)$$




**Coefficient of thermal expansion $\gamma$**

$$SG_{60} = SG_T + [0.000331(T(°F) - 60) \quad (4)$$

**Density at 20°C $d_{20}$**

$$d_{20} = 0.995\ SG \ldots (5)$$

Equation 5 was developed for hydrocarbons **from $C_5$ to $C_{20}$**; however, it can be safely used up to $C_{40}$ with P**RD (percent relative deviation) of less than 0.1%.**

$$\%D = \frac{estimated\ value - actual\ value}{actual\ value}\ x100 \ldots.(6)$$

**Specific gravity of petroleum fractions as a function to $K_w$, API, MeABP and temperature**

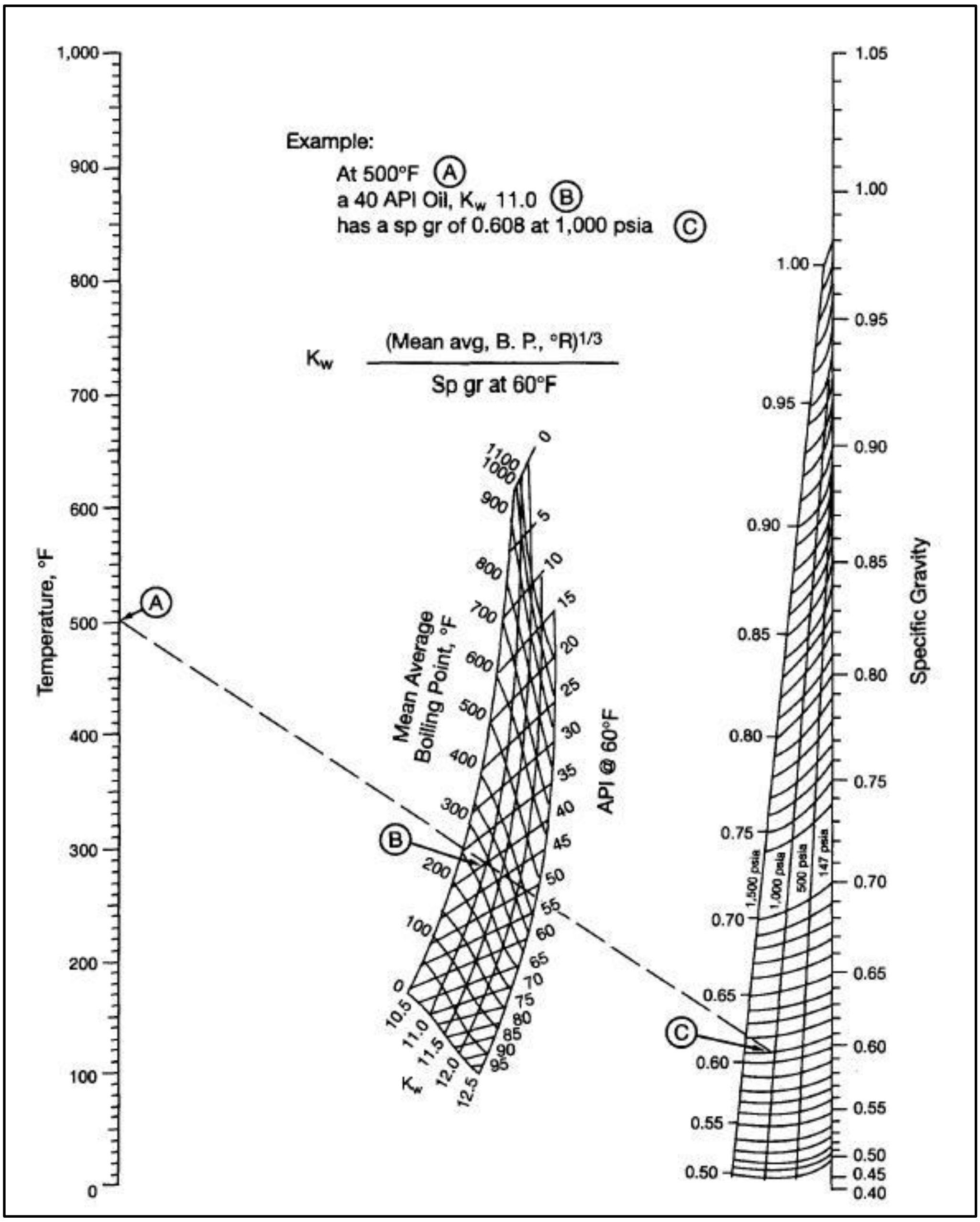



**Figure (1): Correlation between MeABP, Kw, API and specific gravity**

***Riazi-Daubert Methods***

For heavier fractions (molecular weight from 200 to 800) the following relation in terms of kinematic viscosities developed by Riazi and Daubert may be used.

$$SG = 0.7717[v_{38}^{0.1157}][v_{99}^{-0.1616}] \qquad (7)$$

***Predication of Molecular Weight** (Riazi-Daubert Methods)*

- Most oil fractions have molecular weights in the range of **100-700**.

$$M = 42.965[\exp(2.097 \, x \, 10^{-4} \, T_b - 7.7812SG + 2.08476 \, x \, 10^{-3} \, T_b SG)]T_b^{1.26007} SG^{4.98308}$$

- Where M is the molecular weight of the petroleum fraction, $T_b$ is the mean average boiling point of the petroleum fraction in K, and SG is the specific gravity at 60°F.

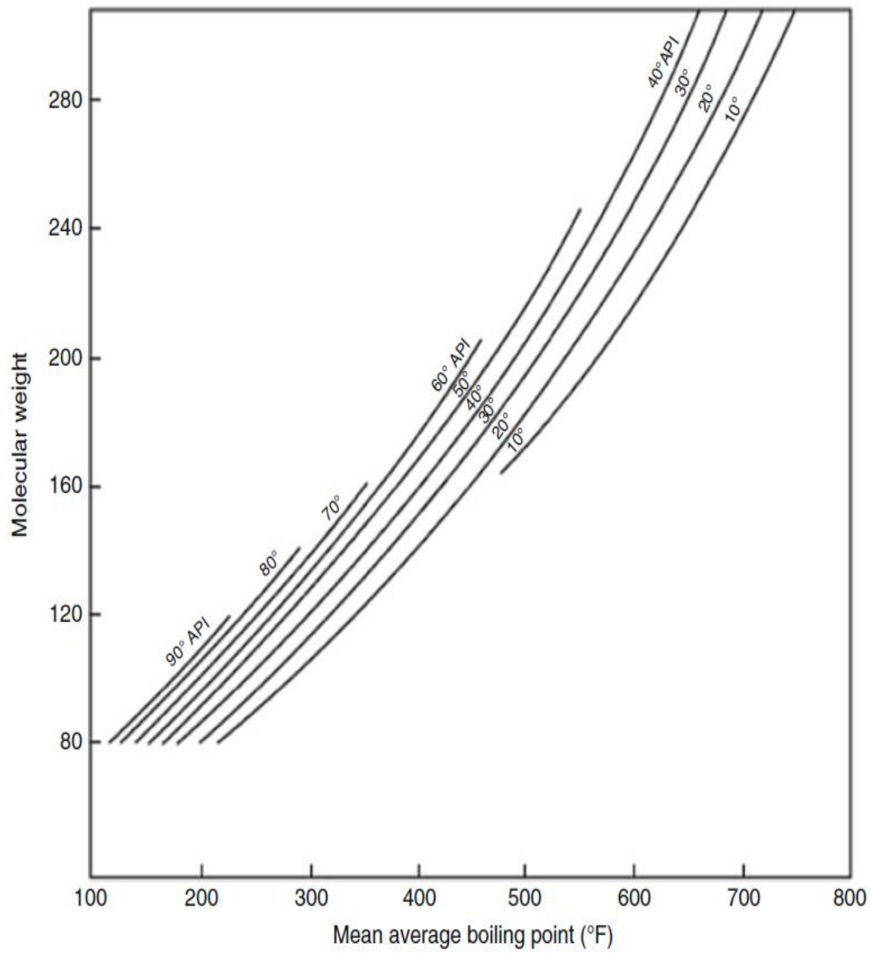



**Figure (2): Correlation between boiling point, molecular weight, and API gravity**

- For heavy petroleum fractions, Riazi and Daubert developed a three-parameter correlation in terms of kinematic viscosity based on the molecular weight of heavy fractions in the range of 200-800: the equation below is only recommended when the boiling point is not available.

$$M = 223.56\left[v_{38}^{-1.2435+1.228SG} \, v_{99}^{3.4758-3.038SG}\right]SG^{-0.6665} \qquad (9)$$

**A graphical presentation of Equation (9) is shown in Figure below:**

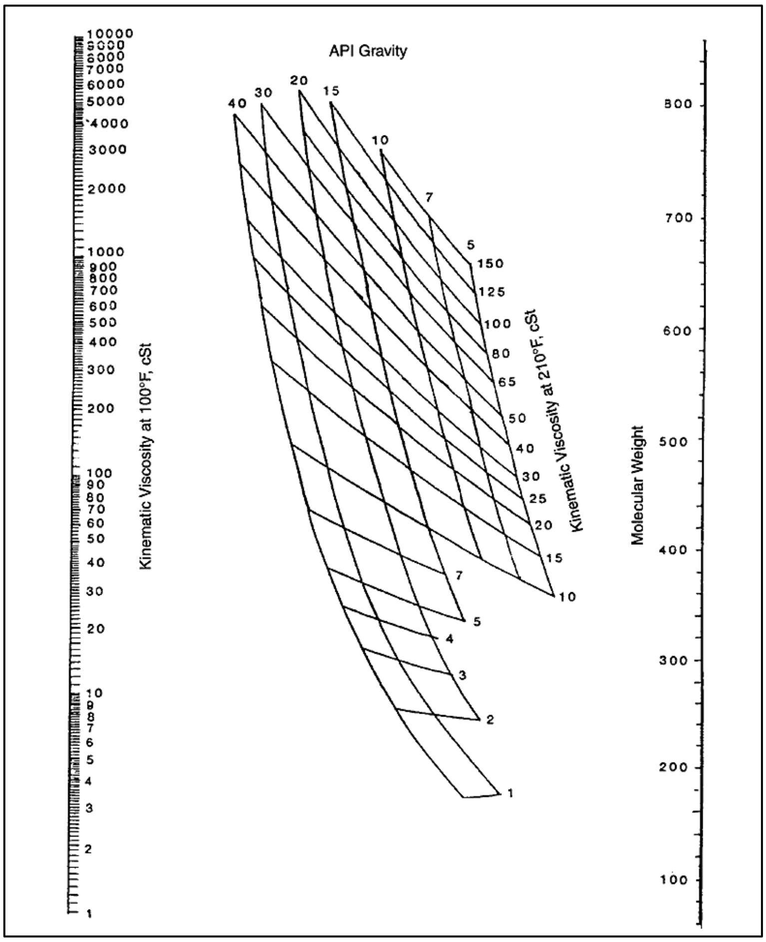



**Figure (3): Correlation between viscosity, molecular weight, and gravity**

**Prediction Average Boiling Points by *Riazi-Daubert Correlations***

- Boiling points of petroleum fractions are presented by distillation curves such as ASTM D86 or TBP.
- There are five average boiling points:
- VABP (volume average boiling point)
- MABP (molal average boiling point)
- WABP (weight average boiling point)

$$ABP = \sum_{i=1}^{n} x_i T_{bi}$$

where **ABP** is the VABP, MABP, or WABP and $x_i$ is the corresponding volume, mole, or weight fraction of component i. $T_{bi}$ is the normal boiling point of component **i in kelvin**.

- CABP (cubic average boiling point)
- MeABP (mean average boiling point)

$$MeABP = \frac{MABP + CABP}{2} \qquad (10)$$

For petroleum fractions in which volume, weight, or mole fractions of components are not known, the average boiling points are calculated through ASTM D 86 distillation curve as

$$VABP = \frac{T_{10} + T_{30} + T_{50} + T_{70} + T_{90}}{5} \qquad (11)$$

Where $T_{10}$, $T_{30}$, $T_{50}$, $T_{70}$, and $T_{90}$ are ASTM D86 temperatures at 10, 30, 50, 70, and 90 vol% distilled.

**Slope of the ASTM distillation curves**

A parameter that approximately characterizes slope of a distillation curve is the slope of a linear line between 10 and 90% points. This slope shown by SL is defined as

$$SL = \frac{T_{90} - T_{10}}{90 - 10} \qquad (12)$$

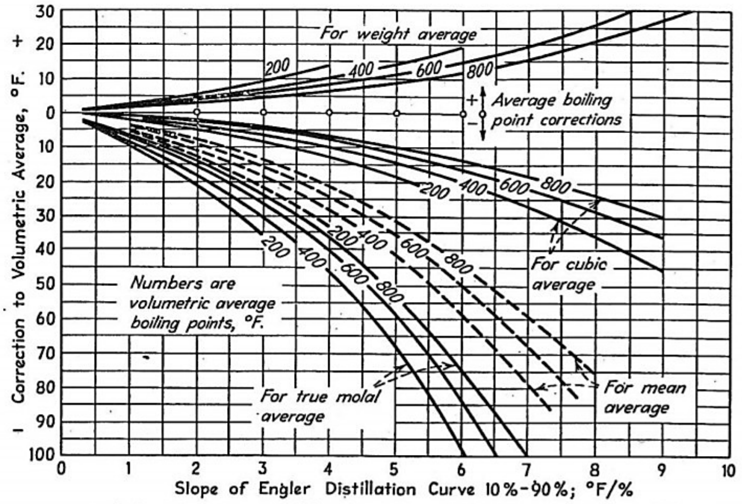



**Figure (4): Average Boiling Points of Petroleum Fractions**

$$ABP = VABP \pm \Delta T \qquad (13)$$

$$WABP = VABP \pm \Delta T_W$$

$$MABP = VABP \pm \Delta T_M$$

$$CABP = VABP \pm \Delta T_C$$

$$MeABP = VABP \pm \Delta T_{Me}$$

ΔT is the correction temperature to **VABP** for each ABP. **All temperatures are in °F**.

- The most useful is **MeABP**, which is recommended for most physical properties as well as calculation of **Watson K**.

**Exercise:** For the straight run SR Naphtha fraction, the experimental **ASTM D86** data with 98.8% recovery vol% are given below. Calculate VABP, WABP, CABP, MABP, and MeABP. Find the base of the fraction by Kw method.

| Vol% Distilled | IBP | 5 | 10 | 30 | 50 | 70 | 90 | 95 | FBP |
|---|---|---|---|---|---|---|---|---|---|
| ASTM D86 °F | 92 | 118 | 128 | 164 | 198 | 230 | 262 | 272 | 300 |

**Solution:**

$$VABP = \frac{128 + 164 + 198 + 230 + 262}{5} = 196.4\ °F$$

$$SL = \frac{262 - 128}{90 - 10} = 1.675\ °F$$

$\Delta T_W = +5°F$ $WABP = 201.4°F$

$\Delta T_M = -15°F$ $MABP = 181.4°F$

$\Delta T_C = -3$ $CABP = 193.4°F$

$\Delta T_{Me} = -5°F$ $MeABP = 191.4°F$

$(MeABP can\ be\ calculated\ by\ eq.\ 10)$

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:

$$SG = a[(T_{10})^b (T_{50})^c] \quad (14)$$

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 |

$$SG = 0.08342[(326.37)^{0.10731}(365.37)^{0.26288}] = 0.7323$$

$$K_w = \frac{\sqrt[3]{651.07\ R}}{0.7323\ @\ 60°F} = 11.840\ \ mixed\ (pf\&N)$$

*Note: To use **Figure 3**, based on the value of $V_{38}$ a point is determined on the vertical line, then from $V_{99}$ and SG, another points on the chart is specified. A line that connects these two points intersects with the line of molecular weight where it may be read as the estimated value.*