Product Blending

Refining processes do not generally produce commercially usable products directly, but rather semi-finished products which must be blended in order to meet the specifications of the demanded products. The main purpose of product blending is to find the best way of mixing different intermediate products available from the refinery and some additives in order to adjust the product specifications. For example, gasoline is produced by blending a number of components that include alkylate, reformate, FCC gasoline and an oxygenated additive such as methyl tertiary butyl ether (MTBE) to increase the octane number.

1- Reid Vapour Pressure Blending

RVP is the vapour pressure at 100 F of a product determined in a volume of air four times the liquid volume. RVP is not an additive property. Therefore, RVP blending indices are used. A commonly used RVP index is based on an empirical method, which is

$$BI_{RVPi} = RVP_i^{1.25} \qquad \text{.......................... (1)}$$

where BI_{RVPi} is the RVP blending index for component i and RVPi is the RVP of component i in psi. Using the index, the RVP of a blend is estimated as

$$BI_{RVP,Blend} = \sum_{i=1}^{n} x_{vi} BI_{RVPi} \qquad \text{.......................... (2)}$$

where x_{vi} is the volume fraction of component i.

Example E9.1

Calculate the RVP of a blend of LSR gasoline, HSR gasoline, Reformate and FCC gasoline. Properties and available quantities of the components are given in Table E9.1.1.

Solution:

As illustrated in Table E9.1.2, the RVP of the blend is calculated through the following steps:

- The volume fraction of each component x_{vi} is calculated and listed in Table E9.1.2.
- The RVP index of each component is calculated. For example, the calculation of LSR gasoline gives $BI_{RVPi} = 11.1^{1.25} = 20.26$
- The volume fraction is multiplied by the index for each component (Table E9.1.2)

From the summation, $BI_{RVP,Blend} = 14.305$, then

$$RVP_{Blend} = (14.305)^{1/1.25} = 8.4 \text{ psi}$$

Hence, the RVP of the blended product is 8.4 psi.

Table E9.1.1 Quantities and RVP values of the blending components

Component	Quantity (BPD)	RVP (psi)
LSR gasoline	5000	11.1
HSR gasoline	4000	1.0
Reformate 94 RON	6000	2.8
FCC gasoline	7000	13.9

Table E9.1.2 Summary of RVP calculations

Component	Quantity (BPD)	x_{vi}	BI_{RVPi}	$x_{vi} \times BI_{RVPi}$
LSR gasoline	5000	0.227	20.26	4.599
HSR gasoline	4000	0.182	1.0	0.182
Reformate 94 RON	6000	0.273	3.62	0.989
FCC gasoline	7000	0.318	26.84	8.535
Sum	22,000	1.0		14.305

Additives, such as propane, i-butane and n-butane can be added to the gasoline blend to adjust the RVP requirements. Example E9.2 illustrates how the amount of an additive is calculated using the method of RVP index.

Example E9.2

Determine the amount of *n*-butane required to produce a gasoline blend with RVP = 10 psi from the components listed in Table E9.1.1. The RVP of *n*-butane is 52 psi.

Solution:

Assume V_{Butane} is the volume flow rate (BPD) of *n*-butane needed to be added to the blend. RVP indices are calculated for all components including *n*-butane and listed in Table E9.2.1.

Table E9.2.1 Summary of calculations

Component	Quantity V_i(BPD)	BI_{RVPi}	$V_i \times BI_{RVPi}$
LSR gasoline	5000	20.26	101,300
HSR gasoline	4000	1.0	4000
Reformate 94 RON	6000	3.62	21,732
FCC gasoline	7000	26.84	187,880
n-Butane	V_{Butane}	139.64	139.64 V_{Butane}
Sum	22,000 + V_{Butane}		314,912 + 139.64 V_{Butane}

The volume is first multiplied by the index and then divided by the total volume. The summation yields the RVP index for the blend.

$$BI_{RVP,Blend} = 10^{1.25} = \frac{314,912 + 139.64 V_{Butane}}{22,000 + V_{Butane}}$$

The above equation is solved for V_{Butane} to be 625.7 BPD, which is the amount of *n*-butane needed to adjust the RVP of the blend to 10 psi.

2- Flash Point Blending

If the flash point of a petroleum product does not meet the required specifications, it can be adjusted by blending this product with other fractions. Flash point is not an additive property and flash point blending indices are used, which blend linearly on a volume basis. The flash point of a blend is determined using the following equation:

$$BI_{FP,Blend} = \sum_{i=1}^{n} x_{vi} BI_{FPi} \qquad \text{……………………(3)}$$

where x_{vi} is the volume fraction of component *i*, and BI_{FPi} is the flash point index of component i that can be determined from the following correlation

$$BI_{FPi} = FP_i^{1/x} \qquad \text{……………………(4)}$$

FP*i* is the flash point temperature of component *i*, in K, and the best value of *x* is -0.06. Another relation to estimate the flash point blending index is based on the flash point experimental data

$$BI_{FPi} = 51708 \times \exp[(\ln(FP_i) - 2.6287)^2/(-0.91725)] \qquad \text{…………(5)}$$

FP_i is the flash point temperature of component i, in F. The flash point blending index is blended based on wt% of components.

Example E9.3

Calculate the blend flash point of the components listed in Table E9.3.1. If the resulted temperature is lower than 130 °F, component D is added to the blend to increase the flash point. Knowing that the flash point of D is 220 °F, calculate the amount (BPD) of component D (SG = 0.95) to be added to adjust the flash point.

Solution:

The flash point indices are calculated using equation (9.6) and listed in Table E9.3.2.

The mass flow rates are calculated for each component based on the given specific gravity and BPD.

For component A $\left(2500\frac{\text{bbl}}{\text{day}}\right)\left(\frac{5.6\ \text{ft}^3}{1\ \text{bbl}}\right)\left(\frac{0.8\times 62.4\ \text{lb}}{\text{ft}^3}\right)\left(\frac{\text{day}}{24\ \text{h}}\right) = 29,120\ \text{lb/h}$

The weight fractions (x_{wi}) are then calculated and listed in Table E9.3.2.

Table E9.3.1 Quantities and flash points of the blending components

Component	BPD	SG	Flash point (°F)
A	2500	0.80	120
B	3750	0.85	100
C	5000	0.90	150

Table E9.3.2 Summary of calculations

Component	x_{wi}	BI_{FPi}
A	0.207	321.36
B	0.329	731.07
C	0.465	106.47

$$BI_{FP,Blend} = \sum_{i=1}^{n} x_{wi} BI_{FPi} = 356.55$$

$$FP_{Blend} = \exp\left(\left[(-0.91725)\times \ln\left(\frac{356.06}{51708}\right)\right]^{0.5} + 2.6287\right) = 117.36\ ^{\circ}F$$

The calculated flash point is less than 130 °F therefore, component D need to be added.

The flash point index for component D is

$BI_{FPi} = 51708\ \exp[(\ln(220) - 2.6287)^2/(-0.91725)] = 12.41$

The blend flash point index is

$BI_{FPi} = 51708\ \exp[(\ln(130) - 2.6287)^2/(-0.91725)] = 218.94$

If W_D is the mass flow rate for component D, then

$29{,}120\ (321.36) + 46{,}410\ (731.07) + 65{,}520\ (106.47) +$

$12.41\ W_D = (141{,}050 + W_D)\ 218.94$

$W_D = 93{,}843$ lb/hr

The volumetric flow rate of component D is 6785 BPD.

3- Pour Point Blending

The pour point is the lowest temperature at which oil can be stored and still capable of flowing or pouring, when it is cooled without stirring under standard cooling conditions. Pour point is not an additive property and pour point blending indices are used, which blend linearly on a volume basis. The pour point of a blend is determined using the following equation:

$$BI_{PP,Blend} = \sum_{i=1}^{n} x_{vi} BI_{PPi} \quad \text{……………………(6)}$$

where x_{vi} is the volume fraction of component i, and BI_{PPi} is the pour point index of component i that can be determined from the following correlation

$$BI_{PPi} = 3,262,000 \times (PP_i/1000)^{12.5} \quad \text{……………………(7)}$$

where PP_i is the pour point of component i, in °R. The pour point of the product, PP Blend , is then evaluated using the reverse form of equation (7).

Another relation to estimate the pour point blending index is the same formula for the flash point with different value of the exponent:

$$BI_{FPi} = PP_i^{1/x} \quad \text{………………………(8)}$$

PP_i is the pour point temperature of component i, in K, and the best value of x is 0.08.

Example E9.4

What is the pour point of the following blend?

Component	BPD	Pour Point (°C)
Catalytic cracked gas oil	2000	−15
Straight run gas oil	3000	−3
Light vacuum gas oil	5000	42
Heavy vacuum gas oil	1000	45

Solution:

The given pour point temperatures are converted to Kelvin then the pour point indices are calculated for each component and listed in Table E9.4. The blend pour point is calculated from the blend index shown in Table E9.4:

$$PP_{Blend} = \left((1697.2/3,262,000)^{1/12.5}\right) \times 1000 = 546\ °R$$

$PP_{Blend} = 86\ °F = 30\ °C$

Table E9.4 Summary of calculations

Component	x_{vi}	BI_{ppi}	$x_{vi} \times BI_{ppi}$
Catalytic cracked gas oil	0.1818	227.3	41.32
Straight run gas oil	0.2727	461.0	125.7
Light vacuum gas oil	0.4545	2748	1249
Heavy vacuum gas oil	0.0909	3093	281.2
Sum	1		1697.2