Crude Oil Compatibility and Self-Incompatibility

Irv Wiehe
Soluble Solutions
Irv@SolubleSolutions.com

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No Longer Should Accept Organic Fouling
(Lemke, 1999: 2/3 Fouling Cost in Crude Unit)
Must Keep Asphaltene Soluble on Heating to Minimize Coke Formation

Cold Lake Vacuum Residuum

Toluene Insolubles, Wt. % of Reactant

Time at 400°C, Min.

100% Asphaltenes
Heptane Solubles (0% Asphaltenes)
Residuum (25% Asphaltenes)

Wiehe (1993)
Physical Model of Petroleum

A = Asphaltenes (Solute)
R = Resins (Dispersant)
a = Aromatics (Solvent)
s = Saturates (Nonsolvent)

 Attacks

Asphaltenes Held in Oil in Delicate Balance

- Balance Upset by Adding Saturates and by Removing Resins or Aromatics
- Mixing Oils can Upset Balance to Precipitate Asphaltenes
- Key: Aromatics/Saturates Balance as Measured by Solubility Parameter
Three Modes of Asphaltene Fouling

1. Self-Incompatible
   - Deposit

2. Incompatible on Blending
   - Mix
   - Deposit

3. Nearly Incompatible
   - Mix
   - Adsorb

Thermal Conversion at Heated Wall
δᵓ = Flocculation Solubility Parameter
δₒil = Solubility Parameter of the Oil
δ_H = Solubility Parameter of n-Heptane
δ_T = Solubility Parameter of Toluene

Insolubility Number ≡ I_N ≡ 100 \left( \frac{δ_f - δ_H}{δ_T - δ_H} \right)

Solubility Blending Number ≡ S_{BN} ≡ 100 \left( \frac{δ_{oil} - δ_H}{δ_T - δ_H} \right)

Measurement of $I_N$ and $S_{BN}$

- Blend Oil with Test Liquid (Toluene and n-Heptane)
- Determine Flocculation Points for Oil / Test Liquid Ratios

Blend Liquid + Oil = Mix Oil and Test Liquid

See if Insoluble Chain Agglomerates of Asphaltenes Under Optical Microscope
Data Verifies Linear Relation Compatibility Numbers Calculated from Intercepts

Least Square Line: \( y = 29.5 - 0.200 \times x \); \( R = 0.998 \)

\( I_N = 29.5 \)

\[ S_{BN} = (1 + \frac{100}{HD}) I_N \]

\[ S_{BN} = (1 + \frac{100}{147}) 29.5 = 50 \]

**Arab Light Crude**

\( T_E = \text{Toluene Equivalence at 2 grams oil and 10 ml mixture of n-Heptane and Toluene} \)

\( H_D = \text{Heptane Dilution: Maximum ml of n-Heptane with 5 ml Oil without Precipitating Asphaltenes} \)
Blends of Souedie and Forties

Forties: \( S_{BN} = 27, \; I_N = 11 \)

Souedie: \( S_{BN} = 63, \; I_N = 39 \)

Compatibility Criterion: Volume Average \( S_{BN} > I_N \) of Any Oil

Do Not Mix Crudes in Wrong Order

Incompatible Blends

\( S_{BN} < I_N \)
More Than 30 Self-Incompatible Crudes Soluble in 1 Volume of Toluene but not n-Heptane

**Isthmus Crude Oil**

\[ I_N = S_{BN} = 13 = TE \]

*Thanks to Statoil for permission to present data on Yme

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West Texas Intermediate
Frequency of Self-Incompatibility Increased

Attributed to Contamination or Blending?
Test Procedure Changes with Results

1. Measure Density of Oil in g/ml
2. Mix 5 ml oil and 25 ml n-Heptane
Precipitates Asphaltenes?

- YES
- NO

Particles in Oil? Soluble in Toluene?

- YES
- NO

Self-incompatible Special Tol. Eq. Heptane Dilution & Toluene Equivalence

$S_{BN} = I_N = TE$
$I_N & S_{BN}$

$I_N = 0$
Compatible with Reference Oil?

- YES
- NO

Solvent Oil Equivalence

$S_{BN}$

Nonsolvent Oil Equivalence

$S_{BN}$