Crude Oil Compatibility and Self-Incompatibility

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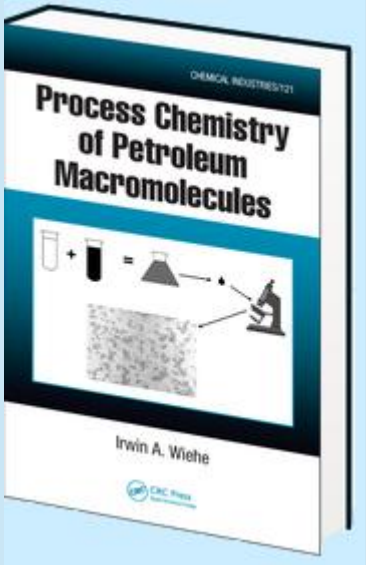
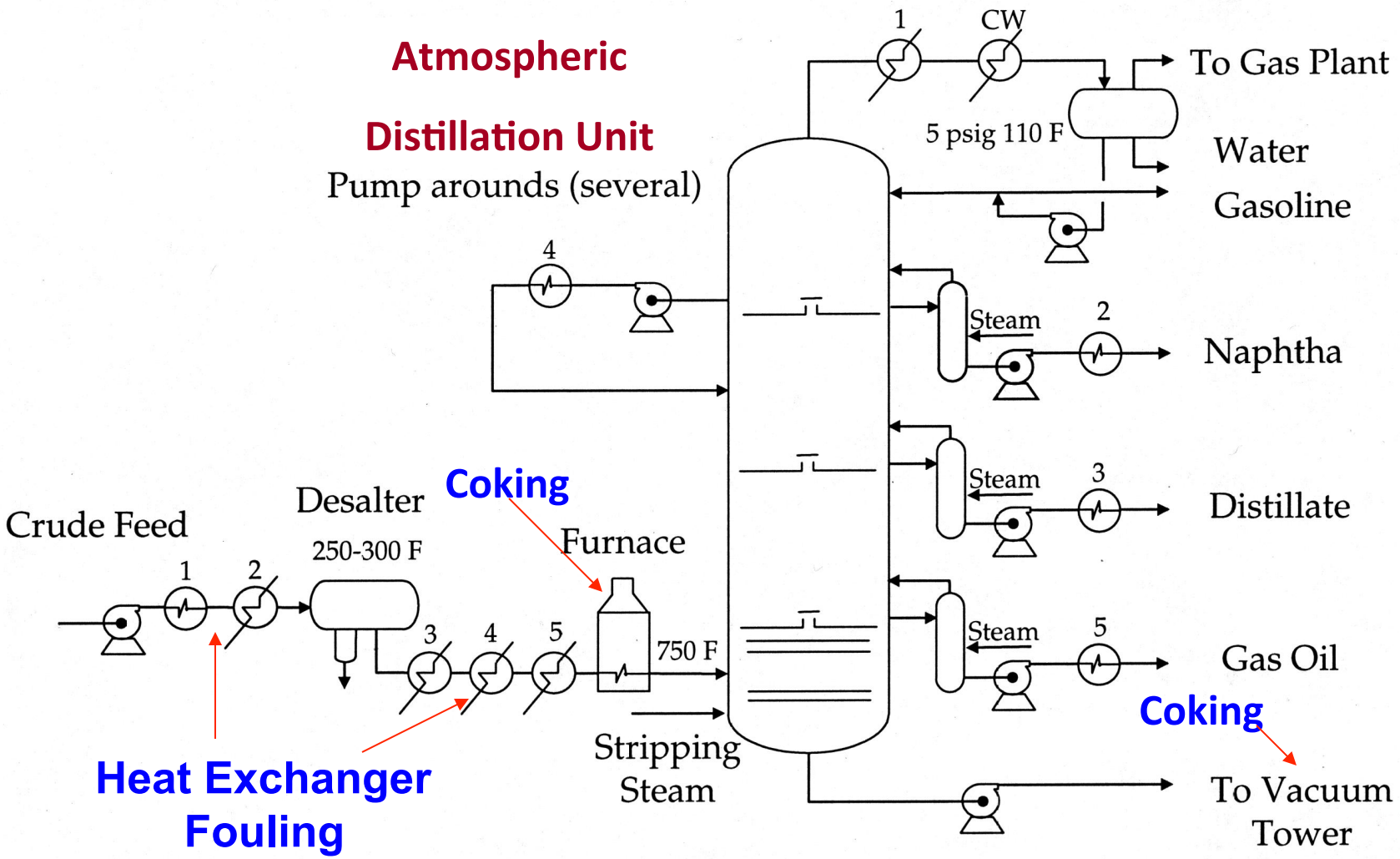
Crude Oil Quality Association Meeting



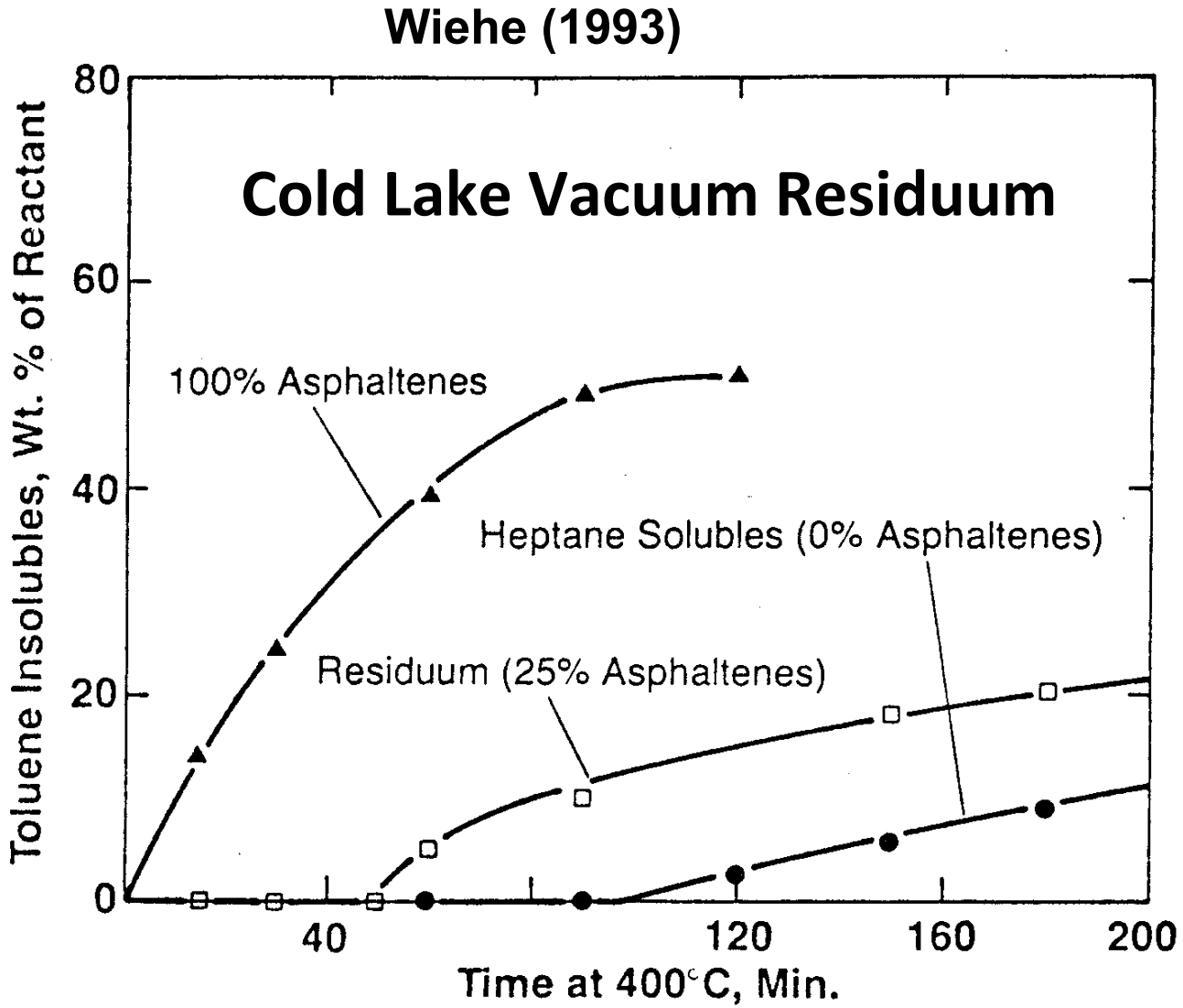
San Antonio, Texas

March 3, 2016

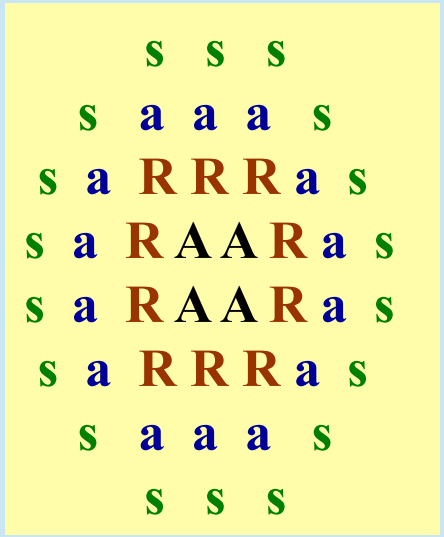
No Longer Should Accept Organic Fouling
(Lemke, 1999: 2/3 Fouling Cost in Crude Unit)



Must Keep Asphaltene Soluble on Heating to Minimize Coke Formation



Physical Model of Petroleum



A = Asphaltenes (Solute)

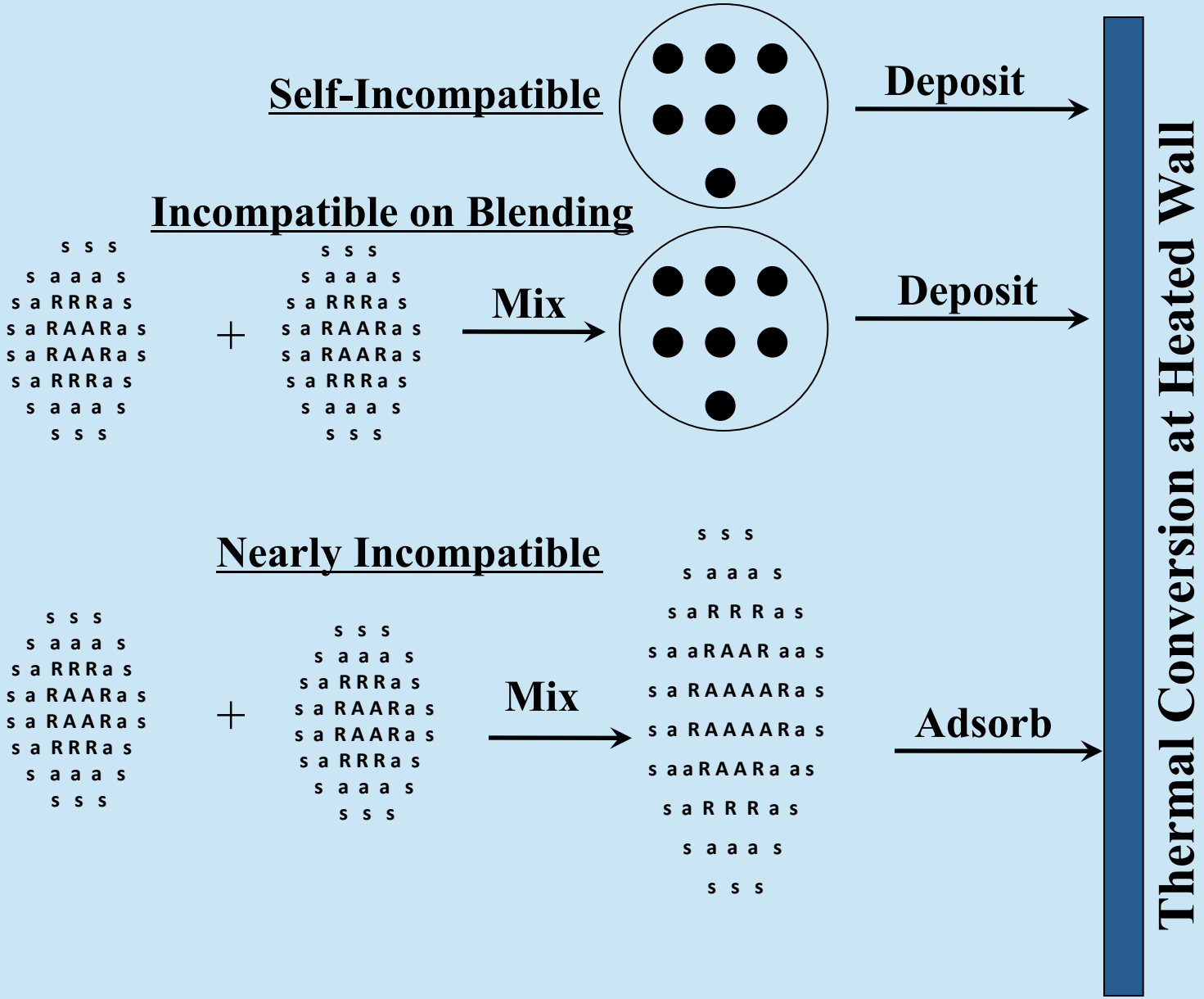
R = Resins (Dispersant)

a = Aromatics (Solvent)

s = Saturates (Nonsolvent)

- **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



Solubility Parameters Put On Toluene - Heptane Scale

δ_f = Flocculation Solubility Parameter

δ_{oil} = Solubility Parameter of the Oil

δ_H = Solubility Parameter of n-Heptane

δ_T = Solubility Parameter of Toluene

$$\text{Insolubility Number} \equiv I_N \equiv 100\frac{(\delta_f - \delta_H)}{(\delta_T - \delta_H)}$$

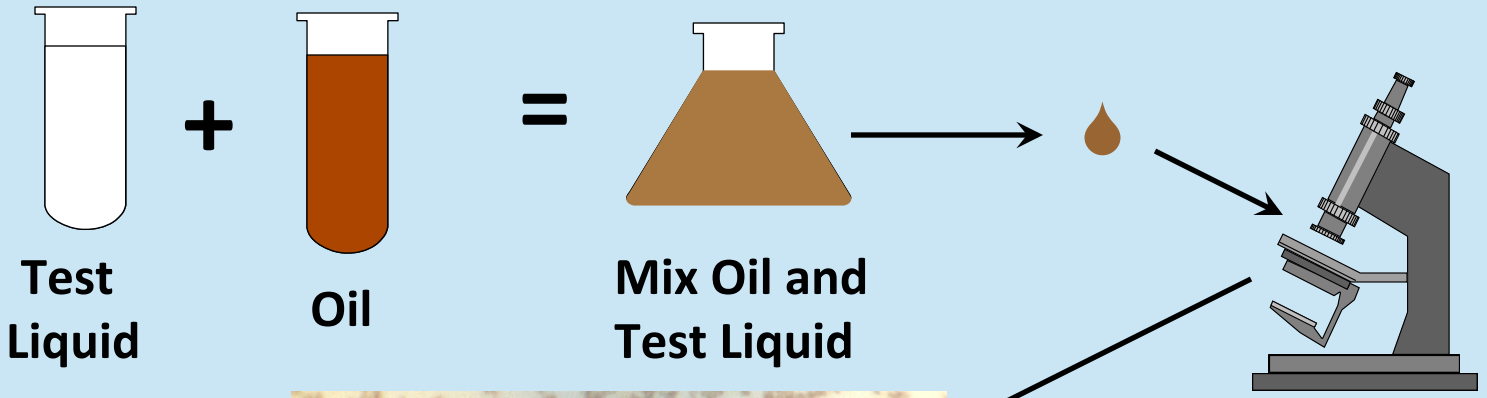
$$\text{Solubility Blending Number} \equiv S_{BN} \equiv 100\frac{(\delta_{oil} - \delta_H)}{(\delta_T - \delta_H)}$$

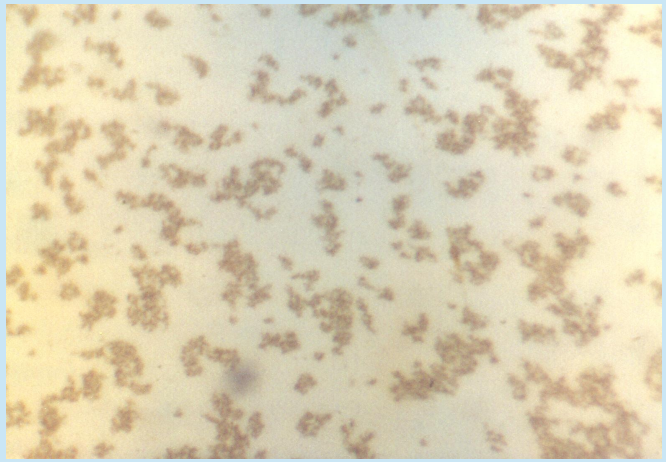
I. A. Wiehe and R. J. Kennedy, Energy & Fuels, 14, 56 – 63 (2000).

US Patent 5,871,634 (1999), Assigned to Exxon (Expires on Dec. 10, 2016)

Measurement of I_N and S_{BN}

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

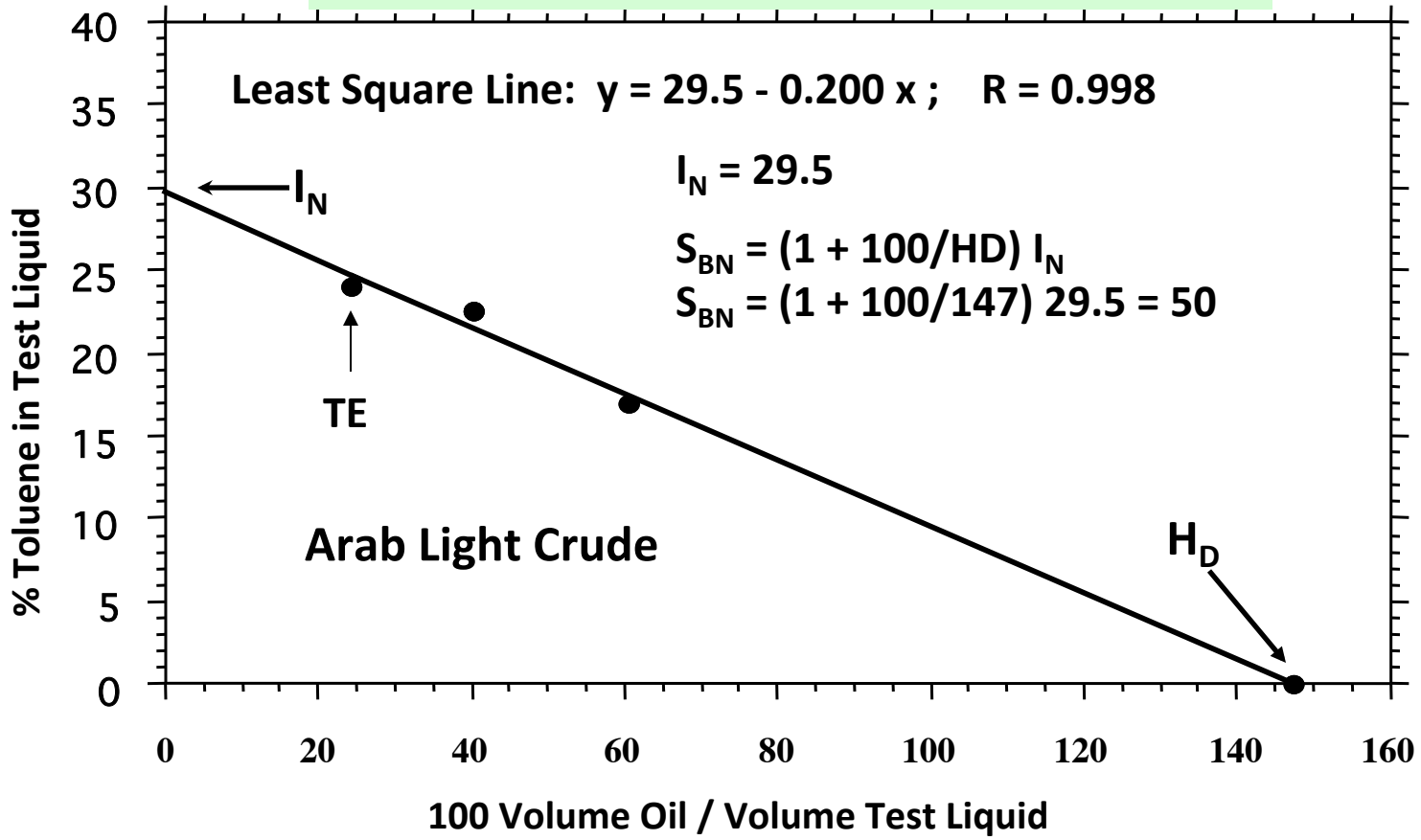




See if Insoluble Chain Agglomerates of Asphaltenes Under Optical Microscope

Data Verifies Linear Relation
Compatibility Numbers Calculated from Intercepts

(Other Tests for Oils without Asphaltenes)

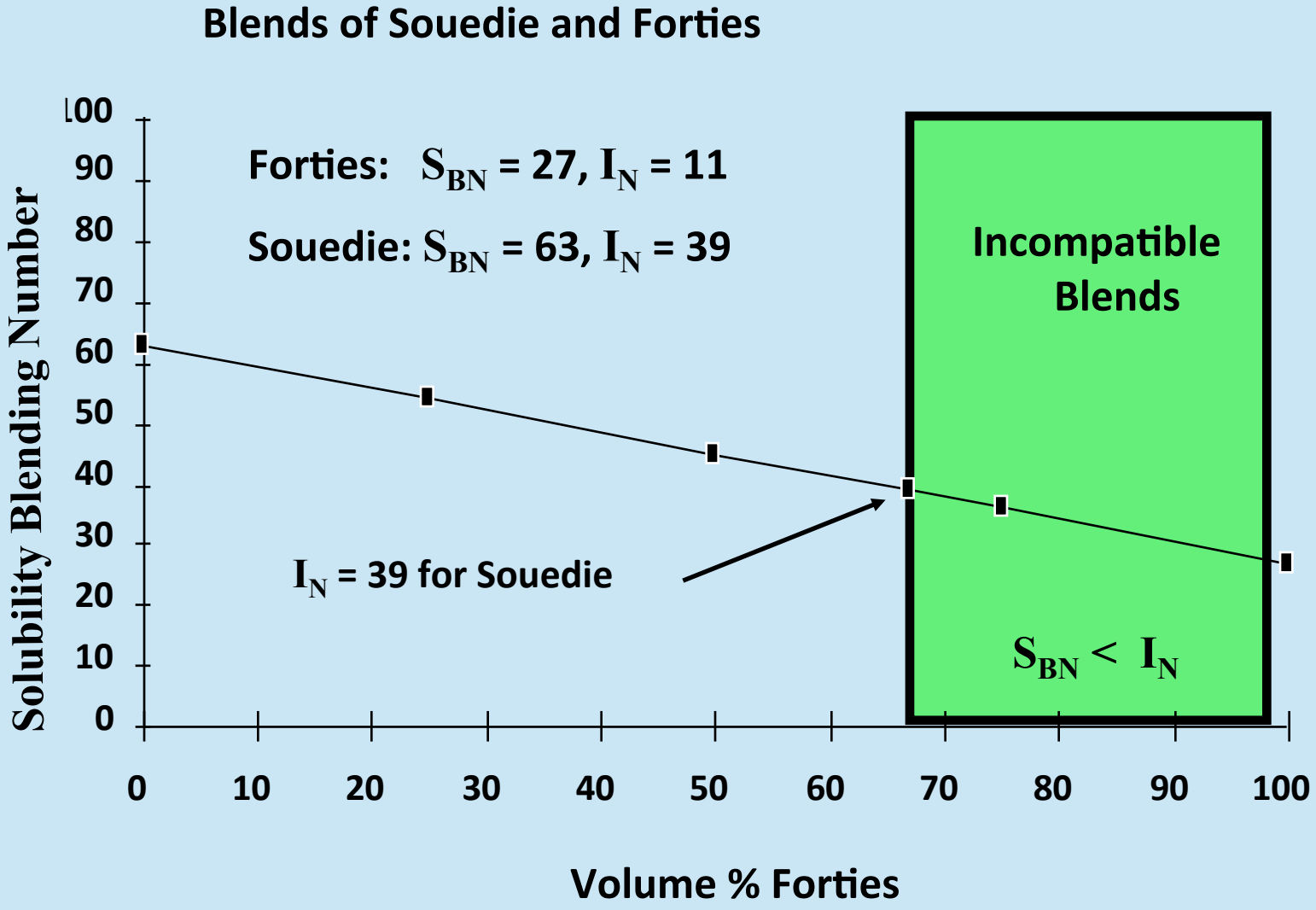


TE = Toluene Equivalence at 2 grams oil and 10 ml mixture of n-Heptane and Toluene

HD = Heptane Dilution: Maximum ml of n-Heptane with 5 ml Oil without Precipitating Asphaltenes

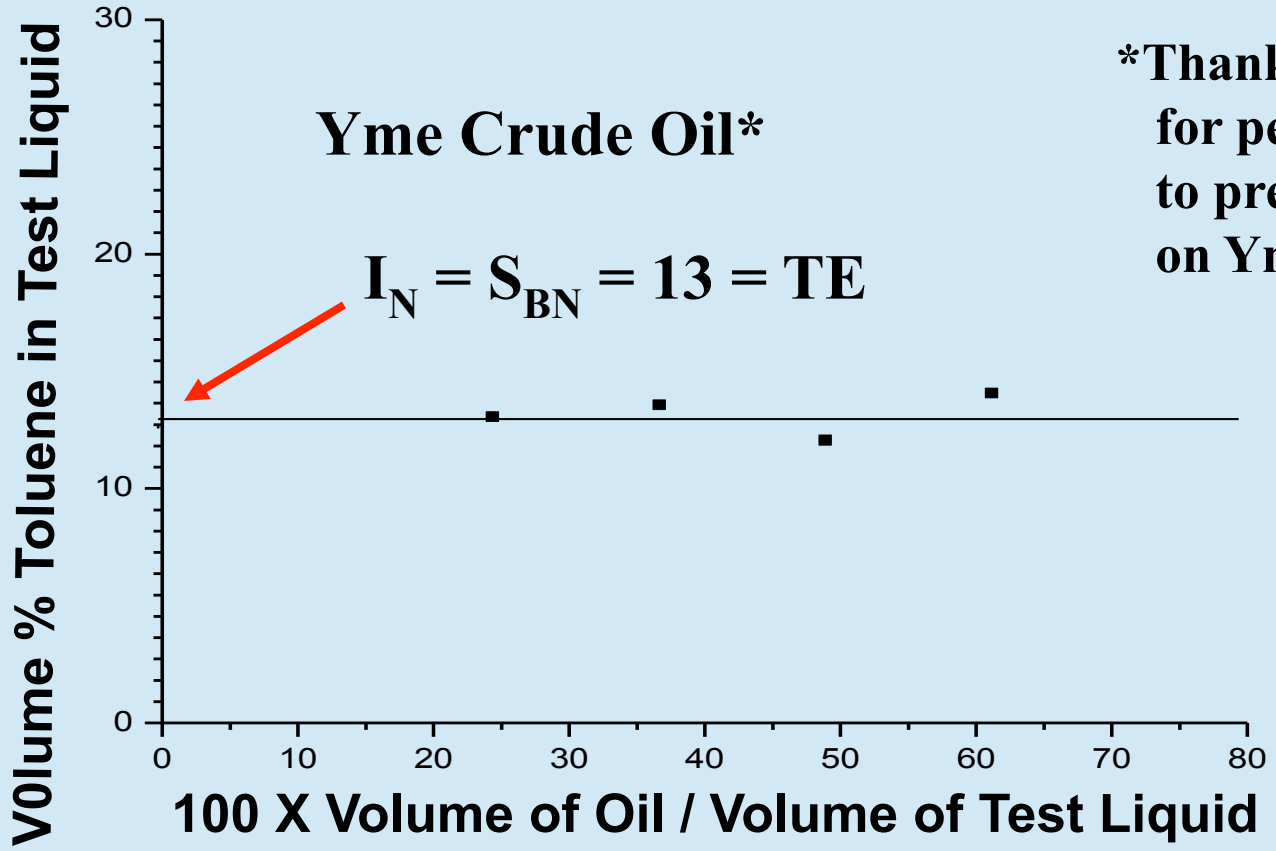
Do Not Mix Crudes in Wrong Order

Compatibility Criterion: Volume Average $S_{BN} > I_N$ of Any Oil



More Than 30 Self-Incompatible Crudes

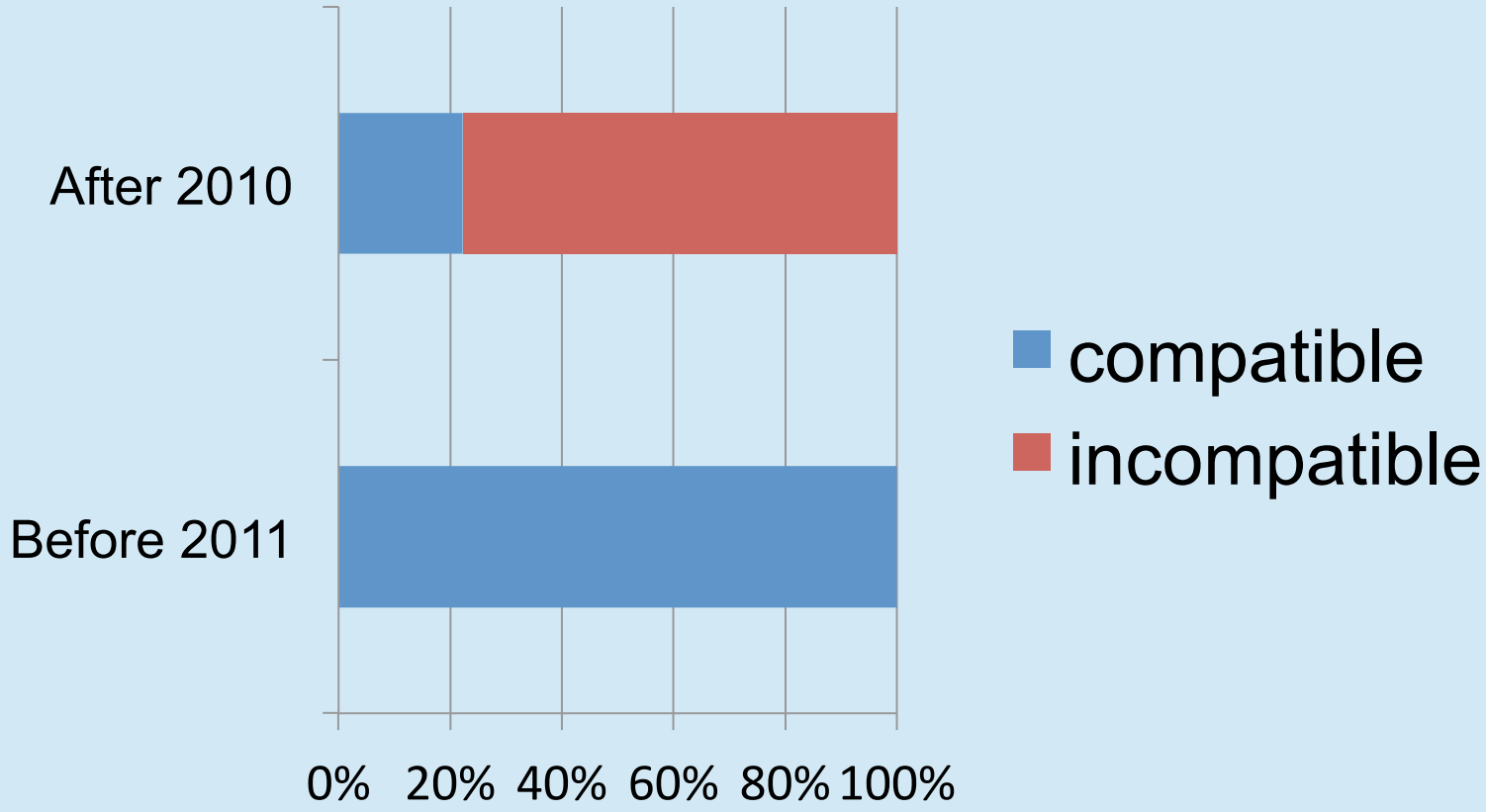
Soluble in 1 Volume of Toluene but not n-Heptane



*Thanks to Statoil for permission to present data on Yme

Isthmus Crude Also Self-Incompatible (Second Most Produced Crude of Mexico)

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?