NCUT

National Centre for Upgrading Technology

'a Canada–Alberta alliance for bitumen and heavy oil research'

Crude Oil Compatibility and Diluent Evaluation for Pipelining

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Outline

- Background/ Objectives
- Bitumen – solvent Compatibility
- Compatibility - processability
- Asphaltenes stability in different solvent
- Conclusions

Pipeline Transportation - Issues

- Heavy oils/bitumens are too viscous and require diluent for pipeline transportation
- Thermal processing will reduce viscosity (less diluent required) but produces less stable fuel
- Shortage of local diluent for pipeline transportation of bitumen leads to demand for imported and recycled diluent
- Compatibility between diluents and bitumens/heavy oils is an important issue that should be addressed

Objectives

- Investigate the compatibility and stability of virgin and cracked bitumen in:
  - Natural diluents
  - Synthetic diluents
- Diluents ranking for asphaltenes stability in virgin bitumen, cracked bitumen

Feedstocks

- **Oils:**
  - Athabasca Bitumen (AB)
  - Cracked AB (bottoms)
  - Bitumen B
  - Light crude (A)
- **Diluents:**
  - Natural Gas Condensate (NGC) - Dilbit
  - Oil Sands-derived liquid - Synbit
  - N-alkanes

Properties of Diluents

- Natural Gas Condensate (NGC) - Dilbit
- Oil sand-derived liquid - Synbit

	Naphthenes	Paraffins (wt%)		Aromatics
	(wt%)	Iso	Norm	(wt%)
NGC	19.0	40.0	35.0	6.0
Synthetic	28.6	29.1	33.9	8.4

Carbon #	NGC	Syn
4	1.10	3.67
5	38.9	11.1
6	30.6	15.1
7	16.9	17.3
8	7.28	18.1
9	3.15	17.4
10	1.19	11.6
11	0.90	5.72

Properties of the Oils

- Athabasca Bitumen (AB)
- Cracked AB (bottoms)
- Bitumen B
- Light crude (A)

	AB	Cracked AB	Bitumen B	Light Crude
Saturates	20.5	23.6	n/a	61.8
Aromatics	48.5	53.2	n/a	29.6
Polars	12.9	12.7	n/a	7.5
C_5 insoluble	18.1	10.5	17.4	1.2
Total	100	100	17.4	100

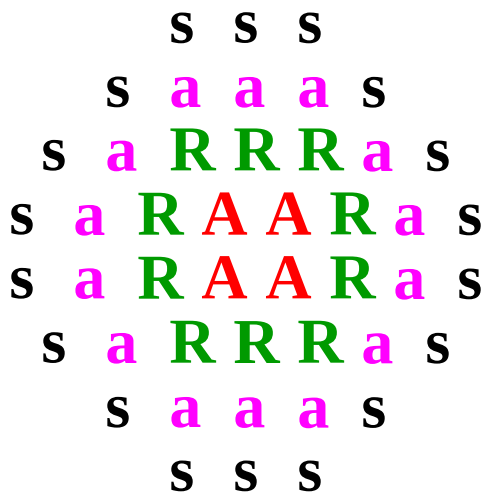
Bitumen – Diluent Compatibility

Asphaltenes Stability – Optical Method

- ASTM D- 7157
- ASTM D- 6703
- ASTM D- 7060
- ASTM D- 7061

Oil Compatibility Model

Colloidal - Solution Hybrid Model of Petroleum



A = Asphaltene (solute)

R = Resins (dispersant)

a = Small Ring Aromatics (solvent)

s = Saturates (nonsolvent)

Upset of this colloidal suspension result in unstable system Asphaltenes precipitation

Fouling

Compatibility Model

Developed by Irwin Wiehe to determine crude incompatibility that causes fouling and coking

$$I_N = \frac{TE}{\left(1 - \frac{V_H}{25d}\right)} \qquad S_{BN} = I_N\left(1 + \frac{V_H}{5}\right)$$

- S_{BN} – Solubility Blending Number – a measure of the oil solvency for asphaltenes
- I_N – Insolubility Number – a measure of asphaltene solubility
- d - Density

For compatible blends: $S_{BN} > I_N$

Laboratory Test
Based on Toluene – Heptane Scale

- TE – minimum vol% of toluene in test liquid (toluene/n-heptane mixture) to keep asphaltenes in solution at a concentration of two grams of oil and 10mL of test liquid

- V_H – the maximum volume of heptane that can be blended with 5mL of oil without precipitating asphaltenes.

Compatibility Model

Predicted solubility numbers for blends

$$S_{BN_{blend}} = \frac{V_A S_{BN(A)} + V_B S_{BN(B)}}{V_A + V_B}$$

Compatibility of Synthetic Diluent with Athabasca Feed

	Solubility (S_{BN})	Insolubility (I_N)	
Synthetic	18.8	0	Non-solvent oil
AB Feed	85.5	28.3	
Volume of Synthetic	Volume AB Feed	SBN_{mix}	P-Value (S_{BN}/I_N)
0	100	85.5	3.02
5	95	82.2	2.90
20	80	72.2	2.55
30	70	65.5	2.31
40	60	58.8	2.08
50	50	52.2	1.84
65	35	42.2	1.49
70	30	38.8	1.37
85	15	28.14	1.02

Compatibility of NGC with Athabasca Feed

	Solubility (S_{BN})	Insolubility (I_N)	
NGC	5.2	0	Non-solvent oil
AB Feed	85.5	28.3	
Volume NGC	Volume AB Feed	SBN_{mix}	P-Value (S_{BN} / I_N)
0	100	85.5	3.02
5	95	81.5	2.88
15	85	73.5	2.60
25	75	65.4	2.31
30	70	59.5	2.17
40	60	53.4	1.89
50	50	45.3	1.60
60	40	37.3	1.32
70	30	29.3	1.03

Compatibility of Synthetic Diluent with Cracked AB Feed

	Solubility (S_{BN})	Insolubility (I_N)	
Synthetic	18.8	0	Non-solvent oil
Cracked Feed	101.1	82.9	
Volume of Synthetic	Volume C-Feed	SBN_{mix}	P-Value (S_{BN}/I_N)
0	100	101.1	1.22
5	95	97.0	1.17
10	90	92.9	1.12
15	85	88.8	1.07
20	80	84.7	1.02

Compatibility of NGC with Cracked AB Feed

	Solubility (S_{BN})	Insolubility (I_N)	
NGC	5.2	0	Non-solvent oil
Cracked Feed	101.12	82.88	
Volume NGC	Volume C-Feed	SBN_{mix}	P-Value (S_{BN} / I_N)
0	100	101.1	1.22
5	95	96.0	1.16
10	90	91.0	1.10
15	85	86.7	1.05

Asphaltenes stability

- Order of addition (blending)
- Local asphaltenes precipitation

Fouling and solubility relationship

- Fouling during crude processing occur at $S_{BN} \leq I_N$
- Solid deposition may occur even if $S_{BN} > I_N$

Compatibility of crudes

	Crudes	IN	SBN	P Value
Batch 1	A	30.64	37.38	1.22
	B	25.90	46.10	1.78
	C	27.64	55.83	2.02
	D	27.92	48.58	1.74
Batch 2	A	30.63	37.37	1.22
	B	27.70	47.09	1.70
	C	27.85	56.25	2.02
	D	29.73	49.35	1.66

Separation of solids by centrifuging

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Fouling of Crudes at 400°C for 4 hrs

Crudes		
A	ΔT	96
	Fouling %	105.09
B	ΔT	63
	Fouling %	49.79
C	ΔT	52
	Fouling %	33.83
D	ΔT	52
	Fouling %	38.19

At 400°C and 3 hours:

ΔT < 15°C low fouling

ΔT 15-30°C medium fouling

ΔT >30°C High fouling

Asphaltenes Stability in Different Solvents

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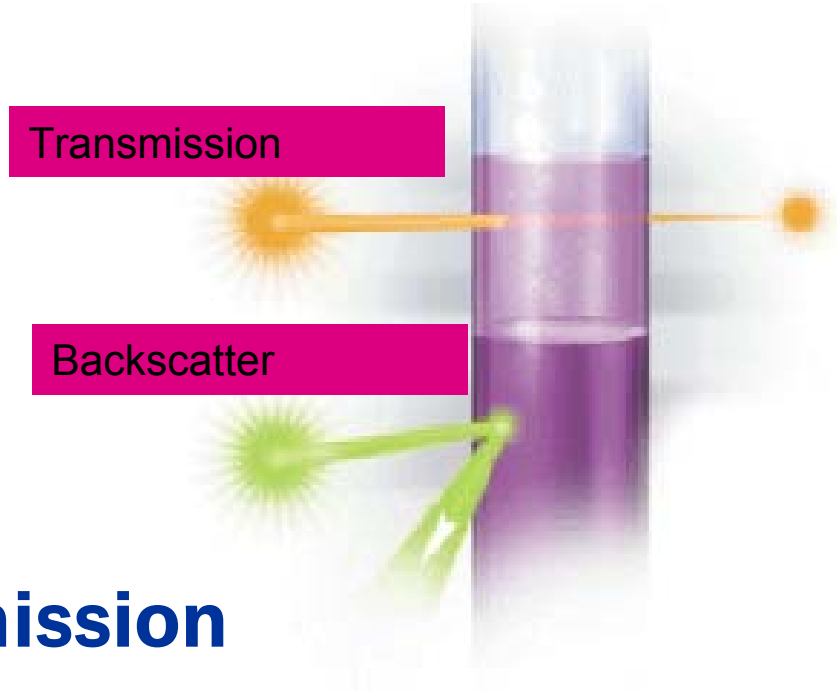
Equipment- Turbiscan AGS

- The Turbiscan AGS is a fully automated near-infra red (880nm) optical scanner
- Capable of fully scanning a sample once a minute with scans at 40µm intervals
- Temperature Control

Turbiscan AGS



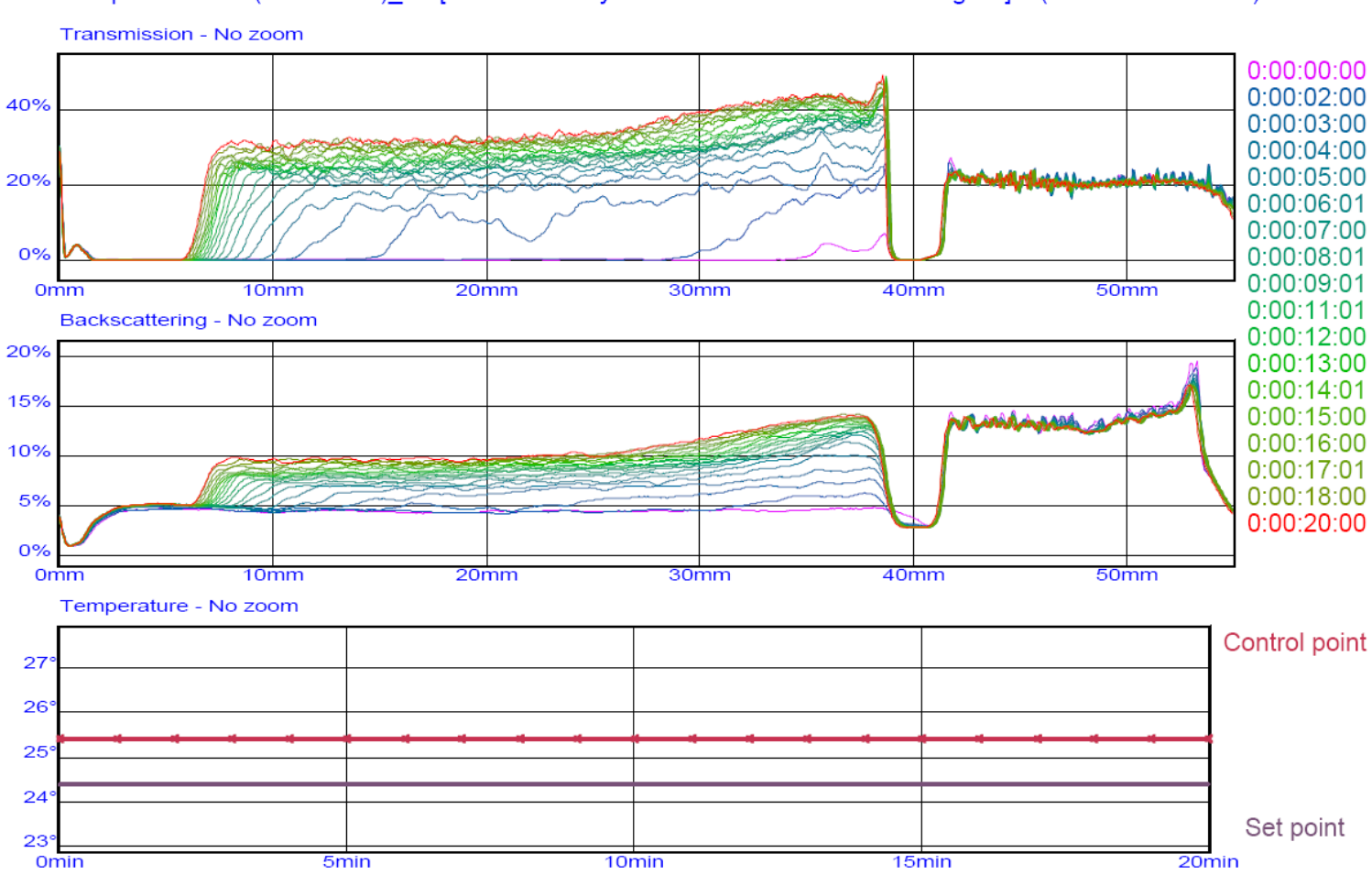
Simultaneous Transmission (T%) and Backscatter (BS%) Profile

Sample Preparation

- **Basic sample preparation modified from ASTM D7061**
  - **10g Oil + 90g Toluene (1:9)**
  - **magnetic stir 1-3hr**
  - **4mL Oil/Toluene + 46mL precipitant**
  - **shake for 6s and immediately add 20mL of solution to vial**
  - **Insert vial for immediate scanning**

Turbiscan Data Output

Cracked Bitumen / Heptane



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Interpretation of Data

- Profile changes are due to changes in the localized concentration of particles and changes in the average particle size
- Separability number (Eqn. 1) (ASTM D7061) can be calculated from data as a measure of stability

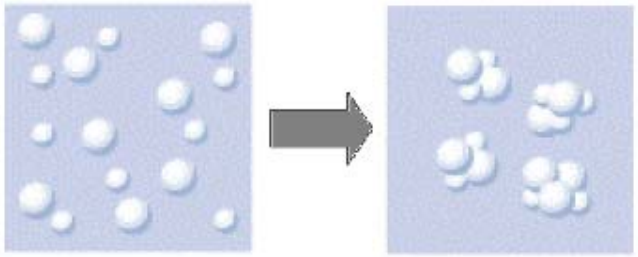
$$\text{Separability number} = \sqrt{\frac{\sum_{i=1}^{n} (X_i - X_T)^2}{n-1}} \qquad (1)$$

where:

X_i = average transmittance for each 60 s,

X_T = average of X_i $\left(X_T = X_1 + X_2 \ldots + X_{16} / 16,\right)$ and

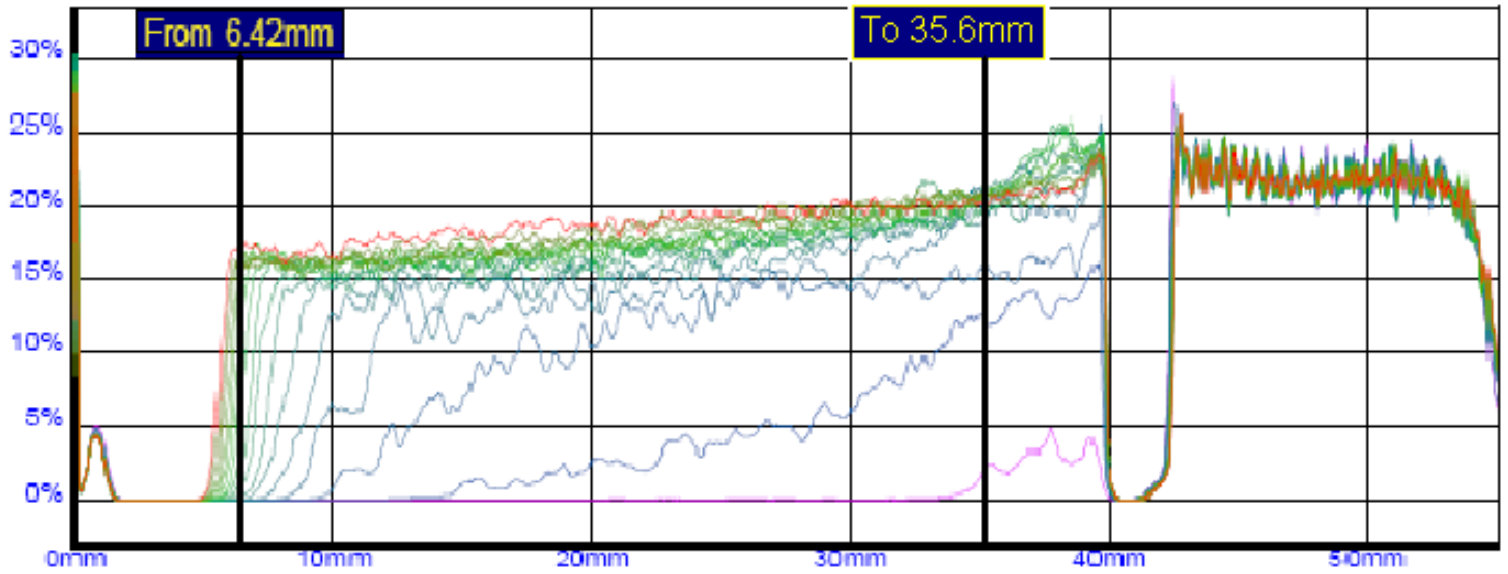
n = the set of replicate measurements (16 in the method).



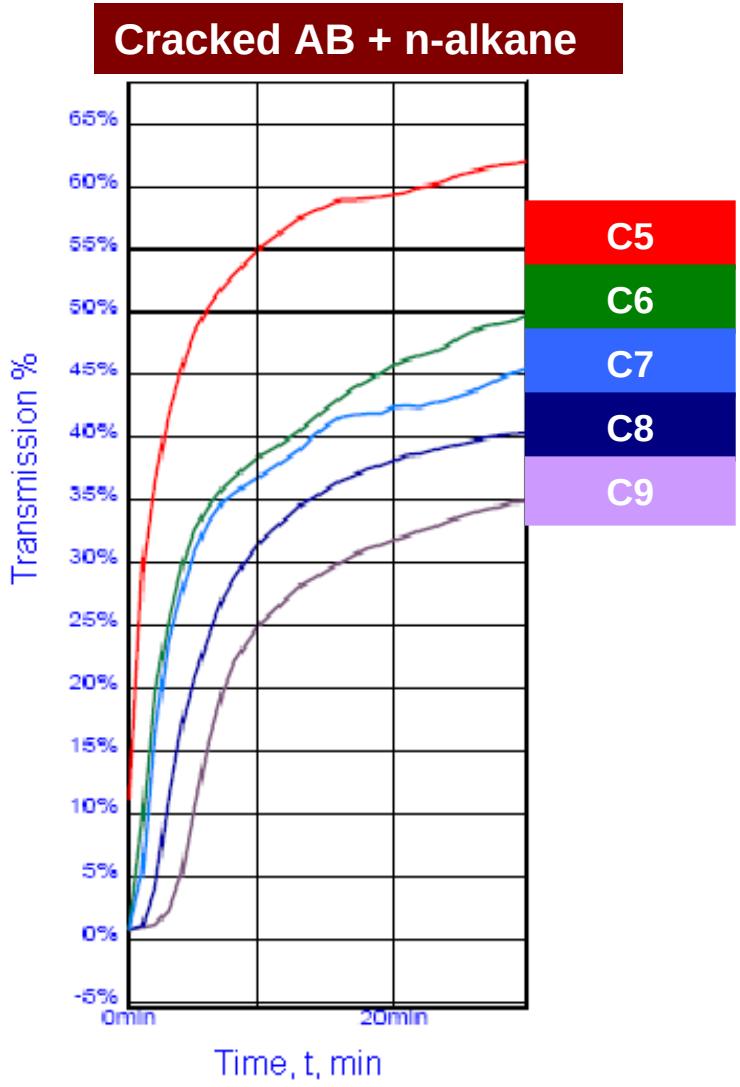
Flocculation

Output Data Manipulation with Turbisoft

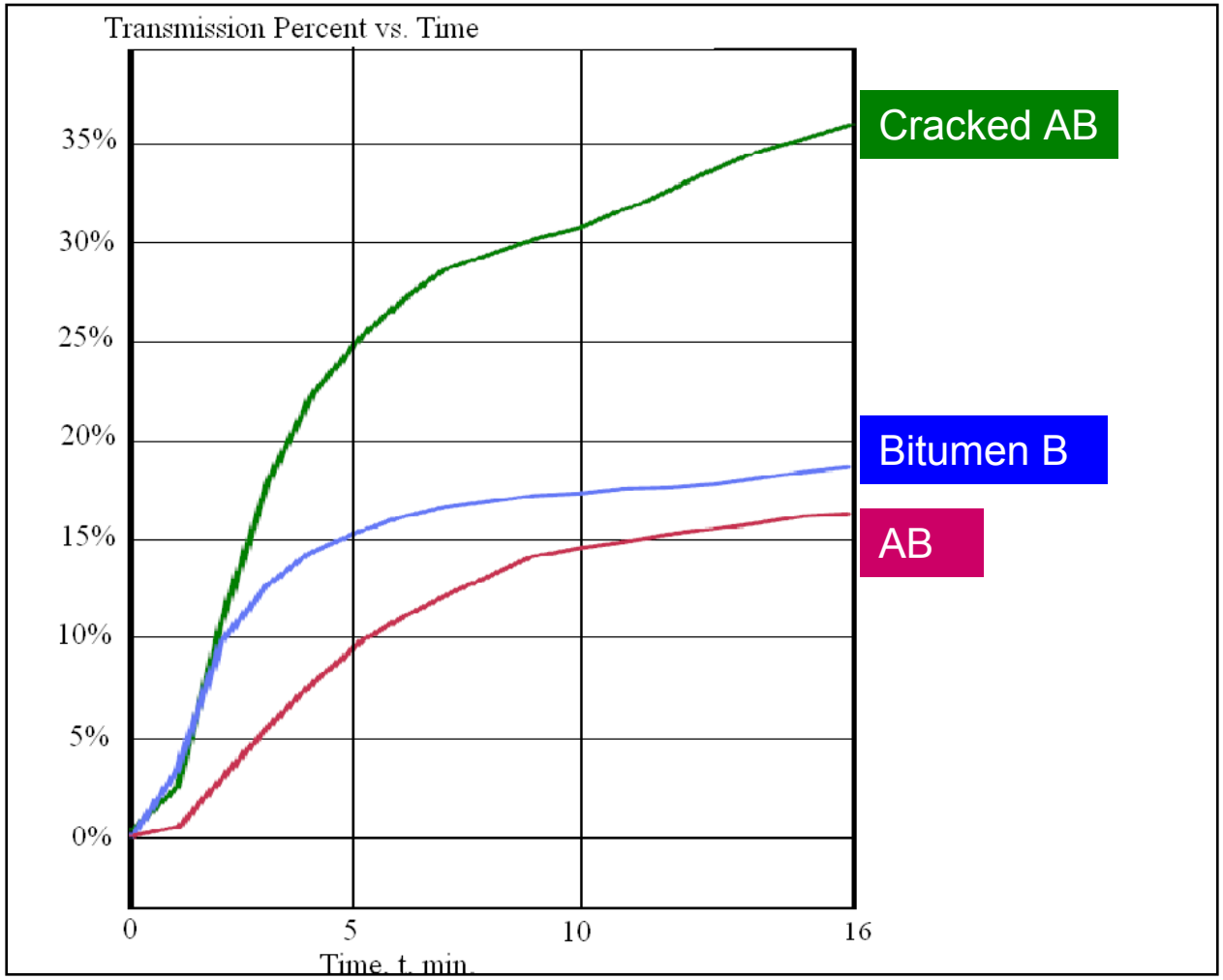
- Average percent Transmission values for each scan can be obtained and plotted versus time



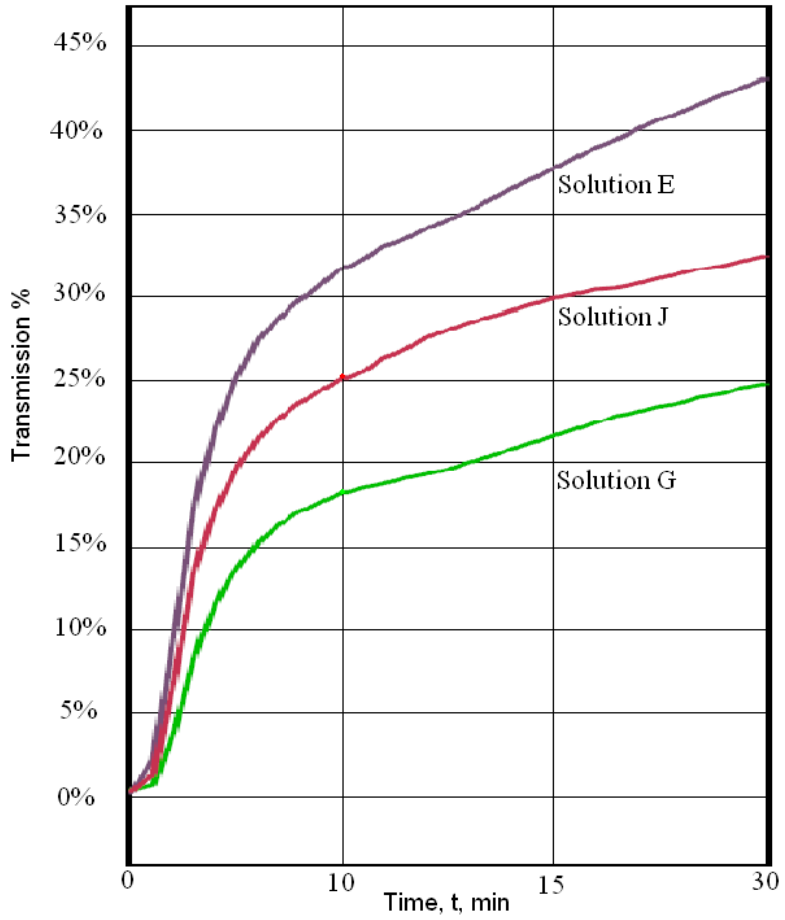
N-alkanes with Cracked AB (1:9)



Comparison of oil stability (n-C_7)



Stabilization of Cracked AB by Maltenes



M/C =0/1 SN = 11.3

M/C =0.5/1 SN= 9.2

M/C =1/1 SN = 6.8

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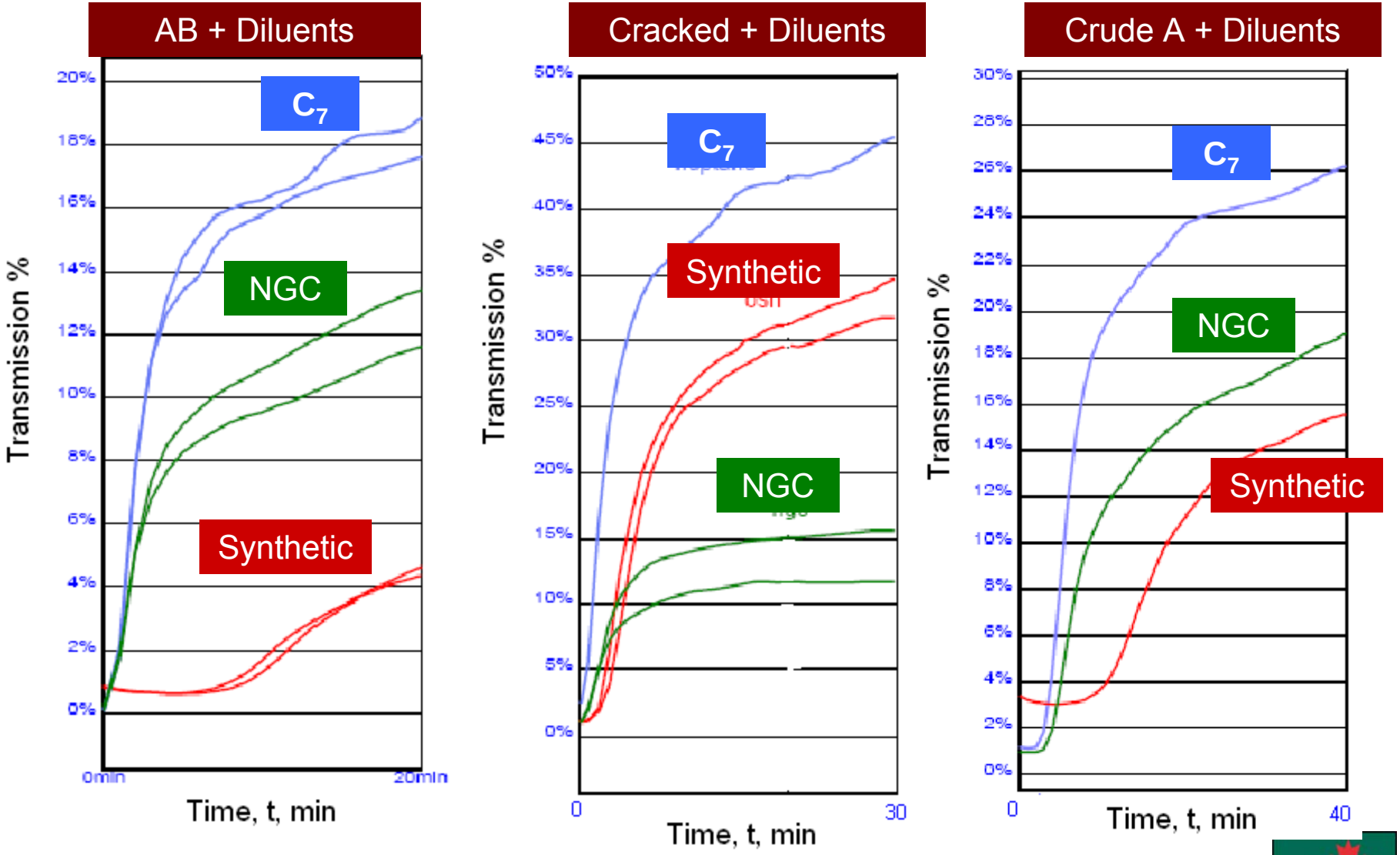
Separability vs Asphaltene Content

- Virgin Oils with higher amounts of asphaltenes are more stable than processed oils
- Light oils with low asphaltenes are unstable

Oil	C_5 Insoluble (wt. %)	Separability Number
AB	18.1	5.4
Bitumen B	17.3	5.5
Cracked AB	10.5	11.4
Crude A	1.2	8.2*

* Light oil - oil/toluene=1:1

Stability Effects of Diluents



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Conclusions

Compatibility data:

- Oil sands-derived liquids are better solvent for bitumen than NGC
- With cracked feed lower volume of both Synthetic solvent and NGC result in incompatibility

Stability data :

- Using an automated Turbiscan it is possible to compare and rank stability of oils and diluents
- Asphaltenes stability studies showed:
  - For cracked feed NGC is a better solvent than oil sands-derived solvent
  - For Athabasca bitumen oil sands-derived solvent is better than NGC

Acknowledgements

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