High Acid Crudes

Crude Oil Quality Group
New Orleans Meeting

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Objective

- Introduce new commercial High Acid Crudes
- Provide understanding that High Acid Crudes are crudes of opportunity
  - Understand supply and demand balances
  - Review High Acid Crudes commonly sold into the USGC & USEC Markets
  - Understand economics of running HAC’s
  - Identify concerns & problems associated with running HAC’s
What are High Acid Crudes?

- TAN is the industry standard for measuring the acid content in crudes.
- High Acid crudes are defined as those crudes with a TAN of 1.0 or higher.

**TAN IS VERY MISLEADING**
- TAN = Total Acid Number
  - All organic acids
    - Light organic acids
    - Naphthenic acids
  - Any acids present in the crude that have been added during the production process

- While light organic acids do cause some overheads corrosion and other acids can cause other problems, the group of the acids that cause most corrosion in refineries are Naphthenic acids.
- It is believed there are more than 1000 Naphthenic Acid species
  - Some are very corrosive others are relatively inert
  - Different species distil at different temperatures and can concentrate in specific areas in the refinery.
- You cannot determine how corrosive a crude will be or which parts of the refinery it will affect from its TAN
Naphthenic acids are carboxylic acids formed mainly by either aerobic or anaerobic biodegradation:

- **Aerobic biodegradation** - micro-organisms metabolize hydrocarbons (often as their sole source of energy) in the presence of oxygen:
  - Shallow reservoirs e.g. San Joaquin Valley, Duri, Alba other North Sea
  - Reservoirs penetrated by meteoric waters (oxygen containing) e.g. Niger Delta, Gulf of Mexico, Venezuela

- **Anaerobic biodegradation** - micro-organisms metabolize hydrocarbons without the presence of oxygen:
  - Deep water reservoirs where no meteoric waters are present e.g. some Gulf of Mexico, Angola Block 14

- Light Paraffins then intermediate hydrocarbons are biodegraded first leading to heavy oils.
- As light crude production is diminishing and heavy crude production is increasing we will see more HAC’s in the market.
High Acid Crude Balance

High Acid Crude Supply > 1.0 TAN

% of Total Forecast Global Crude Supply

Far East
WAFR
Americas
Northwest Europe
Americas HAC (>1.0 TAN) Production

- SJV (U.S.A. California)
- Inglewood Mix (U.S.A. California)
- San Ardo Blend (U.S.A. California)
- Willmington (THUMS) (U.S.A. California)
- Lobster/Posiden (U.S.A. Louisiana)
- DWS (Mars) (Gulf of Mexico)
- Hoover/Diane (Gulf of Mexico)
- Venezuelan
- Marlim (Brazil)
- Roncador (Brazil)
West Africa (WAFR) HAC (>1.0 TAN) Production

11% of total WAFR production

5% of total WAFR production

Rosalita (Angola block 17)
Dalia (Angola block 17)
Kome (Chad)
Ceiba (Equitorial Guinea)
Kuito + Benguela Heavy (Angola Block 14)
Lokele (Cameroon)
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North Sea HAC (>1.0 TAN) Production

[Diagram showing production levels of various fields from 1998 to 2010, with key fields labeled: Clair, Grane, Leadon, Troll Blend, Balder, Harding, Captain, Heidrun, Alba, and Gryphon.]
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Far East HAC (>1.0 TAN) Production

[Graph showing production trends from 1999 to 2010 for various locations and entities.

- BZ25-1 (Bohai Bay)
- CFD (Bohai Bay)
- QHD (Bohai Bay)
- Penglai
- Shengli
- Liuhua
- Wandoo
- Duri]
Finds in Guantas and Hebron excluded - projects not yet approved
<table>
<thead>
<tr>
<th>Region</th>
<th>Supply</th>
<th>Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northwest Europe</td>
<td>890</td>
<td>920</td>
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<tr>
<td>Mediterranean</td>
<td></td>
<td>180</td>
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<tr>
<td>Americas</td>
<td>4270</td>
<td>4259</td>
</tr>
<tr>
<td>Africa/Middle East</td>
<td>262</td>
<td>25</td>
</tr>
<tr>
<td>Far East</td>
<td>862</td>
<td>620</td>
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<tr>
<td>HAC into Fuel Oil</td>
<td></td>
<td>280</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>6284</td>
<td>6284</td>
</tr>
</tbody>
</table>
HAC are plentiful in most global regions and are increasing their % of total crude supply.

North America absorbs most of this excess.

South America is a net exporter of approx. 2.5 MMbd of crude. A large percentage of this is High Acid crude blends. Approx. 500 mbd is refined in South America, mostly local production.

North West Europe which has traditionally been a net exporter of HAC’s is now balanced (increased refinery HAC runs) :-

- HAC’s from NWE are exported to the USEC, USGC, Mediterranean and even the Far East.
- HAC’s are imported from West Africa & South America.

Capetown is the only African refinery processing HAC’s, while West African HAC production is rapidly increasing and being exported out of the region.
Global Supply/Demand Balance

- The Mediterranean currently imports only approx. 180 mbd of HAC.
  - With increasing West African and Americas production, the Mediterranean refiners are likely to take more HAC.

- The Far East has moved from being a net importer of 25-40 mbd for the refining market to being long due to increased production from Bohai Bay and Penglai. Note approx. 250 mbd of Far East HAC production goes into the burning market. There are now some exports to the USWC. Far East refiners are beginning to process HAC.

- There is no known HAC production in the Middle East (except 1 field offshore Saudi), Mediterranean or the FSU. Fujairah is the only Middle East refinery processing HAC’s.
High Acid Crude Flows
# High Acid Crudes Available to the USGC/USEC/ECC Market

<table>
<thead>
<tr>
<th><strong>South America</strong></th>
<th><strong>NWE</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>◼ Marlim</td>
<td>◼ Alba *</td>
</tr>
<tr>
<td>◼ Venezuelan Blends</td>
<td>◼ Gryphon</td>
</tr>
<tr>
<td><strong>West African</strong></td>
<td></td>
</tr>
<tr>
<td>◼ Kuito</td>
<td>◼ Heidrun</td>
</tr>
<tr>
<td>◼ Ceiba</td>
<td>◼ Captain *</td>
</tr>
<tr>
<td>◼ Kome (2004)</td>
<td>◼ Harding *</td>
</tr>
<tr>
<td>◼ Dalia (2H 2005)</td>
<td>◼ Leadon *</td>
</tr>
<tr>
<td></td>
<td>◼ Clair (4Q 2004)</td>
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</tbody>
</table>

(* Shuttle tanker loaded - freight economics will only make it occasionally possible to arbitrage these crudes.)
### Examples of Venezuelan HAC Blends

<table>
<thead>
<tr>
<th></th>
<th>Bachaquero</th>
<th>Menequita</th>
<th>Pilon</th>
<th>Merey</th>
<th>Laguna Blend</th>
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</thead>
<tbody>
<tr>
<td>API</td>
<td>12.2</td>
<td>21.3</td>
<td>14.5</td>
<td>16.0</td>
<td>23.6</td>
</tr>
<tr>
<td>S</td>
<td>2.71</td>
<td>2.5</td>
<td>1.92</td>
<td>2.49</td>
<td>2.07</td>
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<tr>
<td>TAN</td>
<td>3.65</td>
<td>1.15</td>
<td>1.52</td>
<td>1.24</td>
<td>1.03</td>
</tr>
</tbody>
</table>

Many other custom blends are available.
### Quality & Logistics Brazil/West Africa HAC’s
(producing fields only)

<table>
<thead>
<tr>
<th>Crude Name</th>
<th>Country</th>
<th>Marlim Brazil</th>
<th>Kuito Angola</th>
<th>Ceiba Equitorial Guinea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production 2002 mbd</td>
<td></td>
<td>580</td>
<td>100</td>
<td>120</td>
</tr>
<tr>
<td>API</td>
<td></td>
<td>20.1</td>
<td>20</td>
<td>28</td>
</tr>
<tr>
<td>Sulphur, wt. %</td>
<td></td>
<td>0.75</td>
<td>0.64</td>
<td>0.6</td>
</tr>
<tr>
<td>Pour Point deg C</td>
<td></td>
<td>-40</td>
<td>-29</td>
<td>-48</td>
</tr>
<tr>
<td>UOPK</td>
<td></td>
<td>11.6</td>
<td>11.7</td>
<td>11.9</td>
</tr>
<tr>
<td>TAN, mgKOH/g</td>
<td></td>
<td>1.15</td>
<td>2.2</td>
<td>1.06</td>
</tr>
<tr>
<td>Standard Parcel Size mb</td>
<td></td>
<td>1000</td>
<td>920</td>
<td>1000</td>
</tr>
<tr>
<td>VLCC Loading</td>
<td></td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Terminal Operator Notes</td>
<td></td>
<td>Petrobras</td>
<td>ChevronTexaco</td>
<td>Amerada Hess</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Flexible parcel size from tankage in the Caribbean.</td>
<td>Min pol size 300mb. Min vessel size 80 MDWT.</td>
<td>Min parcel size 350 mb.</td>
</tr>
</tbody>
</table>
## Quality & Logistics NWE HAC’s (producing fields only)

<table>
<thead>
<tr>
<th>Crude Name</th>
<th>Alba UK</th>
<th>Troll Blend Norway</th>
<th>Heidrun Norway</th>
<th>Gryphon UK</th>
<th>Captain UK</th>
<th>Harding UK</th>
<th>Leadon UK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Country</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production 2002 mbd</td>
<td>80</td>
<td>330</td>
<td>190</td>
<td>20</td>
<td>85</td>
<td>55</td>
<td>50</td>
</tr>
<tr>
<td>API</td>
<td>19.4</td>
<td>27.2</td>
<td>28.1</td>
<td>21.3</td>
<td>19.1</td>
<td>19.8</td>
<td>17.9</td>
</tr>
<tr>
<td>Sulphur, wt. %</td>
<td>1.25</td>
<td>0.27</td>
<td>0.43</td>
<td>0.4</td>
<td>0.7</td>
<td>0.63</td>
<td>0.47</td>
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<tr>
<td>Pour Point deg C</td>
<td>-35</td>
<td>-42</td>
<td>&lt;42</td>
<td>-42</td>
<td>-29</td>
<td>-37</td>
<td>-18</td>
</tr>
<tr>
<td>UOPK</td>
<td>11.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TAN, mgKOH/g</td>
<td>1.42</td>
<td>1.03</td>
<td>2.41</td>
<td>4.2</td>
<td>2.36</td>
<td>2.9</td>
<td>3.9</td>
</tr>
<tr>
<td>Standard Parcel Size mb</td>
<td>500</td>
<td>1000</td>
<td>500</td>
<td>450</td>
<td>500</td>
<td>500</td>
<td>425</td>
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<tr>
<td>VLCC Loading</td>
<td></td>
<td>Dedicated shuttle tankers</td>
<td>Dedicated shuttle tankers</td>
<td>Dedicated shuttle tankers</td>
<td>Dedicated shuttle tankers</td>
<td>Dedicated shuttle tankers</td>
<td>Dedicated shuttle tankers</td>
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<tr>
<td>Terminal Operator Notes</td>
<td>ChevronTexaco</td>
<td>Statoll</td>
<td>Statoll</td>
<td>Kerr McGee</td>
<td>ChevronTexaco</td>
<td>BP</td>
<td>Kerr McGee</td>
</tr>
</tbody>
</table>

700 mb parcels may also be loaded. Smaller parcels can be supplied with vessel deadfreight. Transhipment at Nigg Bay or Scapa Flow.

Loads FOB Mongstad from storage in parcels of 500 to 2,000,000 mb.

Transhipment at Mongstad or Nigg Bay or Scapa Flow. 1st cargo mid Nov. Production assay not yet available.
Kuito

KUITO CRUDE SPECIFICATIONS

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Specific Gravity</td>
<td>0.94</td>
</tr>
<tr>
<td>Gravity, API</td>
<td>19.0</td>
</tr>
<tr>
<td>Sulphur, wt%</td>
<td>0.68</td>
</tr>
<tr>
<td>UOPK</td>
<td>11.5</td>
</tr>
<tr>
<td>Acid No., mg KOH/g</td>
<td>2.1</td>
</tr>
<tr>
<td>Pour Point, Deg C/Deg F</td>
<td>-30/-25</td>
</tr>
</tbody>
</table>

- FPSO storage capacity is 1400 mb.
- Export berth is SBM (CALM type buoy) that can accommodate VLCC’s as 1st or 2nd load port making Kuito an ideal coload for other West African grades.
- Max vessel DWT is 320 metric tons, Min vessel DWT is 80,000 metric tons.
- Nominal cargo size is 920 mb, however, parcels between 300 and 920 mb can be loaded.
- Loading rate is 35,000 bph.
- 100 mbd field production
- ChevronTexaco market 51% of total production
- Kuito FPSO vessel is 40 miles from Malongo Terminal.

Specific Gravity 0.94
Gravity, API 19.0
Sulphur, wt% 0.68
UOPK 11.5
Acid No., mg KOH/g 2.1
Pour Point, Deg C/Deg F -30/-25
Kuito in the Refinery

**Advantages**
- Distillates have good cold properties
- Good quality resid. with less than 1% S.
- High VGO yield

**Disadvantages**
- Low cetane index and smoke point in distillates
- High resid. yield
- High Nitrogen content

Typical buyers of Kuito will be refiners with hydrotreating, coking, & visbreaking. Also asphalt refiners & topping/reforming refiners wishing to make 1% fuel oil. Refiners are restricted on quantities of Kuito they can run due to its Nitrogen content.
Captain FPSO vessel is 80 miles North East of Aberdeen in the UK.

FPSO storage capacity is 550 mb.

Delivered by shuttle tankers within UK/Cont.

Nigg Bay and Scapa Flow can be used as a transshipment points for deliveries outside the shuttle tanker radius.

Cargo size is 500 mb.

85 mbd field production

ChevronTexaco markets 100% of total production.

**CAPTAIN CRUDE SPECIFICATIONS**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Specific Gravity</td>
<td>0.9378</td>
</tr>
<tr>
<td>Gravity, API</td>
<td>19.1</td>
</tr>
<tr>
<td>Sulphur, wt%</td>
<td>0.7</td>
</tr>
<tr>
<td>Acid No., mg KOH/g</td>
<td>2.1</td>
</tr>
<tr>
<td>Pour Point, Deg C/Deg F</td>
<td>-27/-17</td>
</tr>
</tbody>
</table>
Typical buyers of Captain are coking refineries, visbreaking refineries, asphalt refineries and cracking refineries. Refiners are restricted on quantities of Captain they can run due to the cetane index of the distillates.
ALBA

ALBA CRUDE SPECIFICATIONS

- Specific Gravity: 0.9233
- Gravity, API: 19.4
- Sulphur, wt%: 1.25
- UOPK: 11.8
- Acid No., mg KOH/g: 1.42
- Pour Point, Deg C/Deg F: -35/-35

- **75-80 mbd Field Production**
- **ChevronTexaco markets 25 mbd.**

- Alba is loaded from an FSU (825 mb storage capacity).
- Delivered by shuttle tankers within UK/Cont.
- Nigg Bay and Scapa Flow can be used as a transshipment points for deliveries outside the shuttle tanker radius.
- Cargoes 500 mb or 700 mb, part cargoes of 200 mb can also be supplied.
## Advantages

- Distillates have good cold properties
- Low CCR i.e. good coker feed
- High VGO yield
- Good Asphalt feed when co-reduced with Maya, Iranian Heavy or similar grades
- Suitable for fuel oil blending

## Disadvantages

- Low cetane index in distillates
- High resid. yield
- Viscosity too low to batch run for asphalt

Typical buyers of Alba are coking refiners, visbreaking refiners, asphalt refiners and fuel oil blenders. Refiners are restricted on quantities of Alba they can run due to its S and the cetane index of the distillates.
ChevronTexaco HAC’s becoming available in the next few years

**Kome (2004)**
- Chad
- Expected start-up 2H 2004 @ 200 mbd
- 19 API, 0.1S, 5 TAN

**Benguela Heavy (2004)**
- Angola Block 14
- Expected start up end 2004 @ 50 mbd
- 24 API, 0.9S, 1.25 TAN
- Likely be exported as part of Kuito stream

**Clair (4Q 2004)**
- UK North Sea - West of Shetland
- Expected start up 4Q 2004 @ 60 mbd
- Export via pipeline to Sullom Voe
- 23 API, 0.5S, 1.2 TAN
Other HAC’s becoming available in the next few years

- Offshore Brazil
- Expected start-up not yet known
- 17.8 API, 0.63S, 1.48 TAN

**Dahlia (2005)**
- Angola Block 17
- Expected start up 2H 2005 @ 200 mbd
- 22.6 API, 0.48S, 1.6 TAN

**Rosalita (2007)**
- Angola Block 17
- Expected start up 4Q 2007 @ 50 mbd
- 22 API, 0.5S, 1.5 TAN

**Grane (2004)**
- Norwegian North Sea
- Expected start-up end 2003 @ 120 mbd rising to 200 mbd in 2005
- 19 API, 0.9S, 2.1 TAN
Summary

- There is a sizeable and increasing global supply of HAC’s:
  - 6.3 million Bbls per day - 2002
  - 8.1 million Bbls per day - 2005
  - 9.2 million Bbls per day - 2010
- There is limited ability or willingness by refiners to run HAC’s
- Most HAC’s not refined in local regions come to North America.
- TAN although the industry standard measure is very misleading
Economics of running High Acid Crudes
# Crude selection (1)

<table>
<thead>
<tr>
<th></th>
<th>&quot;A&quot;</th>
<th>&quot;H&quot;</th>
<th>&quot;K&quot;</th>
<th>&quot;S&quot;</th>
<th>&quot;U&quot;</th>
<th>&quot;G&quot;</th>
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</thead>
<tbody>
<tr>
<td>Gravity (API)</td>
<td>19.4</td>
<td>27.3</td>
<td>19.0</td>
<td>23.8</td>
<td>31.3</td>
<td>22.2</td>
</tr>
<tr>
<td>Sulfur (wt%)</td>
<td>1.3</td>
<td>2.9</td>
<td>0.7</td>
<td>4.0</td>
<td>1.4</td>
<td>3.0</td>
</tr>
<tr>
<td>TBP YIELDS (VOL %)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Butanes and Lighter</td>
<td>0.1</td>
<td>2.9</td>
<td>0.2</td>
<td>1.7</td>
<td>1.8</td>
<td>0.6</td>
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<tr>
<td>Light Gasoline</td>
<td>0.2</td>
<td>5.7</td>
<td>0.6</td>
<td>7.0</td>
<td>5.5</td>
<td>3.0</td>
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<td>Light Naphtha</td>
<td>1.0</td>
<td>8.4</td>
<td>5.2</td>
<td>9.6</td>
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<td>8.1</td>
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<td>Heavy Naphtha</td>
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<td>5.0</td>
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<td>Kerosene</td>
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<td>8.1</td>
<td>8.9</td>
<td>7.4</td>
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<tr>
<td>Atm. Gas Oil</td>
<td>17.5</td>
<td>13.9</td>
<td>16.1</td>
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<td>15.6</td>
<td>12.9</td>
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<td>Lt Vacuum Gas Oil</td>
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<td>11.0</td>
<td>16.3</td>
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<td>24.7</td>
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<td>28.8</td>
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**Run it?** ? ? ? ? ?
## Crude selection (2)

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<tbody>
<tr>
<td>Gravity (API)</td>
<td>19.4</td>
<td>27.3</td>
<td>19.0</td>
<td>23.8</td>
<td>31.3</td>
<td>22.2</td>
</tr>
<tr>
<td>Sulfur (wt%)</td>
<td>1.3</td>
<td>2.9</td>
<td>0.7</td>
<td>4.0</td>
<td>1.4</td>
<td>3.0</td>
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<tr>
<td>Acid Number</td>
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<td>2.1</td>
<td>0.3</td>
<td>0.1</td>
<td>0.3</td>
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<tr>
<td>TBP YIELDS (VOL %)</td>
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<td></td>
<td></td>
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<tr>
<td>Butanes and Lighter</td>
<td>0.1</td>
<td>2.9</td>
<td>0.2</td>
<td>1.7</td>
<td>1.8</td>
<td>0.6</td>
</tr>
<tr>
<td>Light Gasoline</td>
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### Crude selection (3)

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....challenge your assumptions!
Recap...

- Sizeable and increasing supply of HAC
- Limited ability or willingness to run HAC
- Solutions are available to the HAC problem
  - Metallurgy
  - Corrosion inhibition
Increasing supply.... Limited demand

- Acid grades have traditionally traded below the relative refining value versus non acid grades
  - This effect we term the “Acid Discount” or “Refining Benefit”
Acid Crudes - Valuation Methodology

• **Substitute for grades in regular slate**
  - HAC unlikely to be run on batch basis
  - Appropriate choice of substitution grade
    • Characteristics & refining configuration
    • Documented pricing
Alba Valuation

- Assume Urals base slate
  - Substitute 20% for Alba
  - Both priced basis Rotterdam - no freight element
- Refinery configuration: typical sized units for a NWE refinery with FCC
- Products: latest specs, NWE prices
Alba Valuation
Acid Discount - Alba

Alba acid discount Average 1.297
Captain Valuation

- Same method used as for Alba
- Assume Urals base slate
  - Substitute 20% for Captain
  - Both priced basis Rotterdam - no freight element
- Refinery configuration: typical sized units for a NWE refinery with FCC
- Products: latest specs, NWE prices
Acid Discount - Captain

Captain acid discount Average 0.594
• Unlike Alba & Captain, Kuito has no “home” market

• 20% Kuito substitution:
  - for Urals in NWE and Med.
  - for Escravos in USAC (US AtlanticCoast)
  - for Maya in USGC
  - freight is a factor in all cases

• Refinery configurations: Coking in USGC and cracking refineries in all other areas

• Latest specs and prices for each region
Acid Discount - Kuito

Kuito acid discount Average 1.89
Factors which have impacted HAC Market Prices

- Changes in OPEC quotas
- Changing HAC supply/demand balance
  - Increased Marlim Production
- Fuel oil demand for HAC
Rapidly rising oil price; Cold weather, Saudis suggests cuts extension.
US Inventories at 10 yr low
OPEC boosts Output
Increased Marlin production
Bombing of USS Cole
Iraq stops Exports, US Cold Weather
Refinery fires in UK (Killingholme), Canb. & US x 2
Iraq stops exports, OPEC to make up loss
Further Refinery outages
Very weak demand, very mild winter

Refinery outages

Rapid drop in oil price during Dec.
Inventories rising

Iraqi exports rising, further OPEC cut

September 11 Attacks, jet demand plummets

Very weak demand, very mild winter

Alba Acid Discount vs. OPEC Production
HAC Market discounts

• Acid discount has widened:
  – ~ -$0.50 / TAN from 1998 Purvin & Gertz study
  – ~ -$0.75 / TAN from latest study:
    – Increased production of HAC
    – Refinery upgrades have not kept pace
General Market Trading ranges

• Alba       Dtd-5.00 to -2.00
• Captain    Dtd-5.00 to -1.50
• Gryphon    Dtd-2.50 to -1.50
• Troll      Dtd-1.50 to +0.75
• Heidrun    Dtd-2.50 to -0.50
• Kuito      Dtd-5.50 to -2.00
• Ceiba      Dtd-5.00 to -2.50
• Lokele     Dtd-4.40 to -3.20
• Marlim     WTI-5.50 to -2.50
In conclusion

- High Acid crudes may offer value relative to other grades
- Cost of mitigation is relatively low