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Crude Value Enhancement: An Emerging Opportunity for Innovations in E&P?

M. Rashid Khan
Rashid.khan.1@aramco.com
Boom and bust: Perception of our mind?

March 1999 $10/bbl

Oct 2003 $46/bbl
All major organizations missed Oil price forecasts in 1998

Widely Divergent Forecasts Make Planning Difficult

Many books on the topic...

Faults Aug, 2005

The oiloholics
There are many suggested peaks

“Which peak you wish to pick?”

TRENDLINES PEAK OIL DEPLETION SCENARIOS 2005
...compiled by Freddy Hutter ~ www.TRENDLINES.ca

MBD

120
110
100
90
80
70
60
50
40
30
20
10
0


TODAY: 85-mbd >

EXXONMOBIL 2005
OPEC 2004
EIA 2005 (High Price Scenario)
LAHERREY 2005
ASPO 2005
TOTAL 2005 (confirmed URR)
BP 2005 (confirmed URR)
KOPPELAR 2005
IEA 2004
CERA (low URR)
PAST Ver 5.1002
Topics

- Innovation and historical trends in energy usage
- Crude oil quality and its impact on subsequent use
  - “bad actors” or undesirables in crude?
  - human impact on quality? standards of “crude oil”?
- Relation between quality and price
- Traditional upgrading/desulfurization processes?
- Motivation for field upgrading
- Opportunity for innovation
Crude reality

- Is the industry innovative?
- What investment typically goes into production vs. processing?

Where the Gas Dollar Goes?

- Crude Oil 52%
- Federal, State & Local Taxes 20%
- Distribution & Marketing 8%
- Refining 20%

Oil Industry Investment in the U.S.
Is the industry innovative?

Relative R&D performance of Industry leaders for 2003

Pharma/biotech*: $14 b
Intel & Microsoft: $11.5
General Motors: $6
Global oil and gas**: $3
US Oil & Gas total***: $<0.5

*10 Pharma + 3 biotech
**6 Major operators + 5 large service firms
*** US DOE, Fed reporting System 50431-2

Source: Cambridge Energy Research Associates
Does crude oil quality matter?

• Crude oil must be converted yet there is “brick wall” when discussing crude quality
• Quality is impacted during or after production
• Sulfur and gravity do NOT adequately define crude quality; other “bad actors” also impacts crude quality
“Bad-actors” – undesirables in crude oil?

- Sulfur, Density (API Gravity)
- Total Acids (TAN)
- Nitrogen, BSW (bottom, sediment, water)
- Viscosity, Boiling Point
- Carbon residue, metals
- Dissolved $\text{H}_2\text{S}$ or elemental $\text{S}$
- Contaminants introduced
- Precursor for green-house gas (more later)
- Every crude oil is unique
Definitions and impact

- **Sulfur:** Less than 0.7% S = sweet; >0.7 %S = sour, require more processing
- **Acid:** Acidic Crudes (>TAN 1) are highly corrosive at various areas
- **Density (API gravity):** Light crudes are easier to process
Quest for quality

All data show that most new global capacity is sour and heavy

Estimated Quality of Reserves (2005)

- High Acid (Sweet) 2%
- Sweet 19%
- Heavy Sour 16%
- Light/Medium Sour 63%

Source: EIA

Crude Quality by Types

USGC million bbl/day

Source: EIA
Quest for “ultra clean” fuels
diverted capital
Factors impacting crude price

- Declining crude quality
- Changes in product quality specifications
- Little spare crude oil processing capacity
- Investment constraints
- Demand outpacing supply
From production to refinery

Human factors impacting quality: “dilution is the solution to pollution”

- “Crude oil” does not have strict “quality standards”
- Contamination: Cleaning waste, chlorinated solvents, NG liquids
- Alternation: Completion & drilling fluids, production chemicals, additives, etc.
- Blending: Some are not transparent.
- “Dilution is NOT the solution to pollution”
Comments from Crude Quality group

“We are concerned with the increased blending crude with foreign Sour to sulfur and gravity limits and representing them as neat domestic barrels. We are hoping to come to an agreement to push the entire industry to report on a routine basis on all barrels traded. We hope the traders will no longer merely trade on gravity and sulfur.....”

Dr. Khan .......... I would be interested to know the E&P feedback to the downstream on what additives are present in crude oils and ...evaluate impacts of existing and new chemical additives....

Dr. Khan,... the industry has yet to develop a full understanding of the performance of crude oil after it has been significantly changed by the production process.
Crude quality may have many implications

- Corrosion: main cause of pipeline failures
- Case study: costs of pipeline corrosion: $5 - 9 b/y
- In one pipeline alone in USA required > $1b
Options for crude upgrading

1. In refinery (current) “in your backyard.”
2. Field upgrading
3. In-situ, down hole

• Crude is generally converted near the population centers.
• Integration with production may provide synergy, be less energy intensive and be cleaner.
• Leave “bad-actors” at the source.

More field upgrading, less refining

World’s first floating gas refinery
Science for crude upgrading

Add Hydrogen

Remove Carbon

crude

Novel Processes

Combinations
Processes: Visbreaking, Steam cracking, Fluid Cracking, Coking

Fundamentals of carbon rejection
Fundamentals of hydrogen addition

- Cracking in the presence and $H_2$
- Reactions catalyzed by metal sulfides

Processes
Hydrocracking, Hydrovisbreaking
Defining refining

- **Crude Oil**
  - Furnace
  - Distillation Tower (Crude Unit)
    - <90°: Butane & Lighter → Refinery Fuel Gas Processing
    - 90-220°: Straight Run Gasoline → Further Processed to Gasoline
    - 220-315°: Naphtha → Further Processed to Gasoline, Heavy Naphtha for Jet Fuel
    - 315-450°: Kerosene → Further Processed to Jet Fuel
    - 450-650°: Light Gas Oil → Further Processed to Gasoline, Diesel and Fuel Oil
    - 650-800°: Heavy Gas Oil → Further Processed to Gasoline, Diesel and Fuel Oil
    - >800°: Residual Fuel Oil/Asphalt → Further Processed to Gasoline, Diesel, Fuel Oil, and Lube Stock
  - Vacuum Unit
## Crude Types

<table>
<thead>
<tr>
<th>Crude Types</th>
<th>Characteristics</th>
<th>Yields</th>
<th>2004 U.S. Refinery Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweet Crude</td>
<td>34+ API Gravity</td>
<td>2%</td>
<td>8% Propane/Butane</td>
</tr>
<tr>
<td>(e.g., WTI, Brent)</td>
<td>&lt;0.7% Sulfur</td>
<td>36%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Most Expensive</td>
<td>34%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>28%</td>
<td></td>
</tr>
<tr>
<td>Medium Sour Crude</td>
<td>24-34 API Gravity</td>
<td>3%</td>
<td>49% Gasoline RFG Premium</td>
</tr>
<tr>
<td>(Mars, Arab Light,</td>
<td>&gt;0.7% Sulfur</td>
<td>21%</td>
<td></td>
</tr>
<tr>
<td>Arab Medium)</td>
<td>Less Expensive</td>
<td>28%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>50%</td>
<td></td>
</tr>
<tr>
<td>Heavy Sour Crude</td>
<td>&lt;24 API Gravity</td>
<td>71%</td>
<td>32% Distillate Jet Fuel</td>
</tr>
<tr>
<td>(e.g., Maya)</td>
<td>&gt;0.7% Sulfur</td>
<td>22%</td>
<td>Diesel Heating Oil</td>
</tr>
<tr>
<td></td>
<td>Least Expensive</td>
<td>63%</td>
<td>11% Heavy Fuel Oil &amp; Others</td>
</tr>
</tbody>
</table>

Source: IEA
Many field treatment are already viable

Remove H₂S in crude oil in the field; viscosity reduction

- Sour crude have high elemental S (>0.5%), dissolved H₂S
- Maya, Qatar, W. Texas: 200 -350 ppmw
- H₂S is removed in the field strippers, desalters or holding tanks, but elemental S may remain; the easiest way to remove is by upgrading (T, t, catalysts).

![H₂S Concentration Graph]

![Lowering crude viscosity in field Graph]

Physical treatment eased transport

![Petroleum Sludge and Fuel Graph]

US Patent 6,444,117

Basic field upgrading to syncrude

Feed + Catalyst

H₂

Catalyst recycling

Upgraded Products

Separation

Gravity & sulfur during upgrading
In-situ upgrading & recovery of 60% remaining oil

Inject into the reservoir to force additional crude out of the pores in the reservoir rock. Some additives may change asphaltene improving quality and yield.

Pipe dream?

- Upgraded crude
- Reactants Injection
- Value enhancement
- Gravel
- Water
- Crude
- Production wells @ oil zone
- Limestone
- Injection Wells
- Producing Wells

CO₂
Water
Gas
Steam
Chemicals
Oxygen
Integrated gasification: innovative bridge to the future

Sweet crude, chemical, power without GHG emission possible today

Residue $C + H_2O \rightarrow CO + H_2 \rightarrow CO_2 + H_2$

Oxygen

Alternatives:
- Heavy Oil
- SOUR CRUDE
- Petroleum Coke
- Refinery Residues
- Orimulsion
- Natural Gas

Gasification

Combined Cycle Gas & Steam Turbines

Electricity

Steam

Clean Syngas

Hydrogen for upgrading; Chemicals

SULFUR REMOVAL

CO2

Slag

Gasification Power Systems
Field or “mine mouth” conversion of fuel

Opportunity for CO₂ sequestration while making a sweet crude

45,000 ton earth-mover en route to an open-pit mine

Gasifier Unit, Jan 2006,
Source: OPTI Canada Inc.
Growing inventions on upgrading
some of which may be useful near production site or in-situ

131 patents
‘downhole & upgrading’;
181 patent
applications

24 patents on
‘ultrasound+ desulfurization’;
21 applications

133 patents on
‘in-situ & gasification’;
179 patent
applications

145 patents
‘downhole & desulfurization’;
106 applications
Quest for disruptive or radical innovation in energy development

Contribution of technology to economic growth >50%. but this is primarily from PASTEUR QUADRA; Ref: Modified from Donald Stokes, “Pasteur's Quadrant”
IT innovation made oil field into a digital factory

Much of today’s oil is “smart oil.”

$3/gal oil vs $5/gal soda
Finding and supplying crude oil is challenging.

Many innovative successes by E&P, but future successes may be different.
Huge conventional & non-conventional oil sources exist:

Opportunity for E&P innovation in heavy &/or sour resources

-~6-8 Trillion barrels of oil in place

Enhanced Oil Recovery Target

-~7 Trillion barrels of oil in place

Oil Shales 38%
Extra Heavy Oil 23%
Tar Sands & Bitumen 39%

Source: IEA World Energy 2004

Original Oil Resource In-Place: 1,332 Billion Barrels
Remaining Undeveloped Oil Resource In-Place: 1,124 Billion Barrels

Already Produced or Proved Reserves (208 Billion Barrels)
Undiscovered Oil and Reserve Growth (190 Billion Barrels)
Enhanced Oil Recovery (210 Billion Barrels)

“Stranded” Light Oil
Heavy Oil
Oil Sands
Residual Oil in Transition Zones
“Stranded” Oil in Future Resources

Source: Advanced Resources
A major problem for all fossil fuels is green house gas

- Climate changes threaten the world
- Our energy policy must account for it by innovations for CO\textsubscript{2} capture, sequestration
- A major need is to separate the energy content from carbon present in fossil fuels.
- World needs “disruptive innovations” to face the challenges.
To survive we have to adapt and innovate

"It is not the strongest of the species that survives, nor the most intelligent; it is the one that is most adaptable to change."

-- *Darwin (1809-82)*

Mother earth is getting sick
Responsible energy alternatives and energy conservation

- Oil Sands
- Ultra-Heavy Crude
- Ethanol (0.8 b/d)
- Gasification
- GTL
“While people think big oil finds big oil, over the years about 80% of the oil found in the US has been brought in by wildcatters.”

WSJ, “Wildcat Producer Sparks Oil Boom in Montana,” 4, 2006
Innovation in oil industry did “miracles”
Lessens from Kern River: discovered in 1899

- Kern River, after 43 years of operation had “remaining reserve” of 54 million bbl.
- In the next 43 years of life, it produced, not 54 but 730 million bbls.
- In 1986, it had “remaining reserves” of about 900 million bbls.
- Innovation will bring surprises to crude quality and reserves.

Adelman, 1987
Innovation with optimism is the solution

“Everything that can be invented, has been invented.”
-Charles Duell, Head, US Patent, 1899

- Edison 1888: Genius is 99% perspiration
- Prof Dickey 1958: “We usually find oil in a new place with old ideas. Sometimes, we find oil in an old place with a new idea, BUT we seldom find much oil in an old place with an old idea. Several times in the past we thought we were running out of oil, whereas actually we were running out of ideas.”
Concluding remarks

- Society quests for cleaner environment & cleaner fuels
- Crude must be converted to clean fuels, but there is no clear standards on crude quality.
- Human factors impact crude oil quality.
- Concerns are on yield and not on quality; refiners are challenged by supply & capacity constraints.
- The challenge: make cleaner products from poorer feeds.
- Opportunities exist to synergize quality issues while addressing production.
- Disruptive innovation is needed to provide cleaner energy & address carbon & quality aspects of fuels.
Thank you

Be the change you want to see in the world

You are invited to the spectacular natural wonders of Arabian gulf

Rashid.Khan.1@aramco.com

Please send any comments or feedback
Q. How human impacts quality during production?

- There are a number of steps involved before a crude is shipped to the refinery: GOSP followed by pipeline, shipping tank, storage etc.

- Contamination: Tank cleaning solvents, cleaning waste, chlorinated solvents, NG liquids. The cleaning solvent with HCl is very damaging to refinery

- Alternation: Completion fluid containing salt water, production chemical containing acids, drilling fluids, drag reducers, additives, antifoam, etc.

- Blending: Well head, refinery charge etc, but some are not transparent (separation of asphaltenes is one of the concerns).
Steam/Solvent assisted processes

1. Steam-Assisted Gravity Drainage and variations
2. Vapor-Assisted Petroleum Extraction, VAPEX and variations. Advantages of solvent aided over steam only:
   - Lower capital needs
   - Lower emission
   - Lower water usage
   - Some quality improvement

Ref: S. Gupta, EnCana Corp.
Q. Examples of current EOR and in-situ upgrading options

- THAI process converts 10 API oil to 20.6 API; converts asphaltene in the oil.
- CHOPS (Cold Heavy Oil Production with Sand) produces oil along with sand.
- PPT (Pressure Pulsing Technique) increases oil rates of the original oil.
- IGI (Inert Gas Injection) injects inert gas with gravity drainage for pressure maintenance.
- SAGD (Steam Assisted Gravity Drainage) heats the oil to reduce the temperature for vertical drainage, producing the original oil.
- VAPEX (Vapor Assisted Petroleum Extraction): Can provide upgrading by leaving some of the heavier components in the reservoir.