Heavy Oil vs. Light Oil

Legislative Brown bag

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Topics

- Heavy Oil vs. Light Oil – the really big picture
- Heavy Oil Properties
- The Heavy Oil Resource on the Alaska North Slope
- Marketing and Transport Issues
- Heavy Oil Depletion Mechanisms
- BP Alaska Milne S-Pad Pilot
Welcome
World Reserves

- Currently, 90% of production is from conventional oil
- Heavy oil and bitumen are growing rapidly
- Canada and Venezuela together have >35% of the non-conventional oil reserves

Source: MacGregor, 1996 and UNITAR, 1998
Global Heavy Oil

Canada
- 40 years of heavy oil development
- Focus of today's heavy Oil Technologies

Alaska
- Historical light oil focus

California
- Cradle of Heavy Oil Technology
- In twilight period

Venezuela
- Conventional approach to easiest Heavy Oil
- Business climate not inciting innovation and experimentation

Russia
- Decades of heavy oil experimentation but continued focus on light oil

Barrels OOIP
- ~1 billion
- ~10 billion
- ~100 billion
- >1 trillion

Source: JPT, IEA, Schlumberger OFS Marketing
Heavy Oil – Key Properties

• Viscosity (Physical Property)
  ▪ Flows through a reservoir very slowly: wells produce at lower rates than light oil wells
  ▪ Heavy oil developments involve lots of wells
  ▪ Waterflooding is not viable due to the viscosity contrast between heavy oil and water
  ▪ Thermal techniques (e.g. steam) can be effective in increasing recovery but energy balance is an issue and conditions must be just right in the reservoir

• Hydrogen Content (Chemical Property)
  ▪ Heavy oil is depleted in hydrogen relative to light oil
  ▪ Fewer refined products are derived from heavy oil
  ▪ Heavy oil fetches a lower price on the market
API Gravity of some standard crudes

<table>
<thead>
<tr>
<th>Gravity</th>
<th>API Definition</th>
</tr>
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<tbody>
<tr>
<td>40</td>
<td>West Texas Intermediate Light</td>
</tr>
<tr>
<td>33</td>
<td>Canadian Syn-crude Light</td>
</tr>
<tr>
<td>32</td>
<td>Arab Light Medium</td>
</tr>
<tr>
<td>29</td>
<td>Alaska NS Crude Medium</td>
</tr>
<tr>
<td>27</td>
<td>Arab Heavy Heavy</td>
</tr>
<tr>
<td>16 to 24</td>
<td>Alaska Viscous Heavy</td>
</tr>
<tr>
<td>8 to 14</td>
<td>Alaska Heavy Heavy</td>
</tr>
<tr>
<td>10</td>
<td>Water Extra Heavy</td>
</tr>
<tr>
<td>10</td>
<td>Venezuela (Orinoco) Extra Heavy</td>
</tr>
<tr>
<td>9 to 18</td>
<td>Canadian Lloydminster Extra Heavy</td>
</tr>
<tr>
<td>6 to 10</td>
<td>Canadian Athabasca Extra Heavy</td>
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</tbody>
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Gravity ≠ Viscosity

The term “Heavy Oil” is a reference to the high density (API Gravity) of those oils. The measurement that we care most about today is viscosity since that is the property which governs well productivity. Viscosity is not synonymous with Gravity. There is a positive, but very loose correlation between gravity and viscosity that is specific to a given oilfield - but any quantitative transform from API Gravity to Viscosity is a rough approximation at best and there are no transforms or rules of thumb for oils in general.
What is heavy oil?

North Slope Heavy oil is a residue formed from light oil that has lost the small (light) molecules leaving the heavy ones. These form hydrocarbon compounds characterized by long, very complex molecules.

Most of the hydrogen is in the light ends so heavy oil is depleted in hydrogen.

The long molecules of heavy oil impart high internal friction resulting in high viscosity.

A heavy oil model in a Calgary museum
Oil vs. Bacteria

- "Heavy" Oil
- Leaky
- Methane as metabolic waste
- Fault & Spill
- "Viscous" Oil
- "Light" Oil
- Oil Staining from a Pre-existing Trap
- Tilt & Spill

- Permafrost
- Gas Hydrates

- Shallow, Colder & Heavier

- Deeper, Hotter & Lighter

Bacteria - "we love to eat"

Most anaerobic bacteria cannot survive beyond 60°C
Viscosity

- Viscosity is the resistance a material has to change in form. It is commonly described as internal friction.

- Viscosity reduction
  - Heat
  - Dilution (Diluent)
Heavy Oil Export Options

- Change physical properties – Upgrade
- Add heat to TAPS
- **Dilute heavy oil with light oil**

1st Epiphany:
Heavy oil is linked to light oil by Diluent
2nd Epiphany:
Given that linkage, we need to figure out heavy oil NOW - not after light oil
Alaska Fluid Viscosity
Alaska fluids range over a continuum of viscosities

North Slope Oil Fields
Oil viscosity versus Depth

- Mostly Developed
- Starting to Develop
- Potential Future development

**Development sequence**

- Light Oil (like water)
- Viscous Oil (like syrup)
- Heavy Oil (like honey)

**Depth (ft)**

**Oil Viscosity (cp)**

*The term “Viscous Oil” is a home grown, Alaska term. You won’t find it defined in the literature or used outside of Alaska. What we term Viscous Oil in Alaska is referred to as Heavy Oil in the industry.*
Alaska Viscous and Heavy Oil

Beaufort Sea

- Kuparuk
- Prudhoe Bay
- Northstar
- Pt. McIntyre
- Niakuk
- Endicott
- Liberty
- Pt. Thompson
- Meltwater
- Tarn
- Pt. Thompson

Legend:
- 'Light' Oil Production
- 'Viscous' Oil Dev./Appraise
- 'Heavy' Oil Appraise
- Undeveloped Oil
- Undeveloped Gas

0 2.5 5 10 15 20 Miles
Ugnu Structure & Fluid Quality

A

Minimum Case GRV

Maximum Case GRV

B

Temperature

-1,000

-2,000

-3,000

-4,000

0°C

11°C

27°C

8 – 10 API

10 - 12 API

(20,000 – 1,000 cp)

12 - 14 API

35 Miles

BASE PERMAFROST
Stratigraphic and Volumetric Distribution

Heavy oil is found in the shallowest reservoirs (Ugnu), light oil in the deepest.
Heavy Oil Depletion Technology

4th Epiphany:
Other people are making this work!
Horizontal Wells & Motherbores

**Vertical Wells**
- Minimal reservoir contact

**Horizontal Wells**
- Maximum reservoir contact

Piloting at S-Pad

The horizontal well concept is to maximize contact with the reservoir. Horizontal wells are operationally simple as they keep sand out, but recovery factor is likely low and well density must be high to compensate.

**Motherbores - Many Horizontal laterals in one well**
CHOPS Elements

- Unconsolidated rocks
- PCP Pump
- Surface Drive
- Heated Separation Tank
- Sand Disposal

Heavy drawdown against perforations deliberately draws sand into the wellbore along with oil. As sand production continues “wormholes” form in the reservoir collectively representing a multi-fold increase in surface area. Sand production diminishes after an initial pulse but continues at about 5 to 10% by volume for the life of the well.
SAGD (Steam Assisted Gravity Drainage)

The SAGD system is comprised of a well pair with one steam injector placed directly above one oil/water producer. The process is initiated by injecting steam into both wells for a period of months in order to "melt" the interwell space. Subsequently, the lower well is converted to a producer. A "steam chamber" evolves around the well pair and grows up and out with time. When the steam chamber contacts the overburden heat losses increase dramatically and the chamber slows its evolution.

Recovery factors within any given cell are demonstrated at up to 30% and asserted up to 50%. The drilling pattern, i.e., the configuration of cells, is a key driver to bulk reservoir recovery.

Key SAGD technical issues are:
- well length and pattern
- injection pressure
- well design and mechanics
Recovery Methods

- Prudhoe
- Milne Point
- Kuparuk

- CHOPS
- Cold Heavy Oil Production with Sand
- Horizontals & Fish-Bone Wells
- CO₂ & Solvents (Incl. WAPEX)
- THAI
- In-Situ Combustion
- Microbial EOR
- CSS
- Cyclic Steam Stimulation
- SAGD
- Steam Assisted Gravity Drainage

- COLD - PRIMARY
- RESERVOIR HOMOGENEITY
- Not Much Shale
- Lots of Shale

- Low Viscosity like Olive Oil
- High Viscosity like Honey

- OIL QUALITY
North Slope Heavy Oil Accumulation

BP’s Milne Point Heavy Oil Pilot

THERMAL (>20,000 cP)?

COLD &/or THERMAL

COLD (<20,000 cP)?
Heavy Oil Value Chain

Time dependency given viability/longevity of existing architecture is driver of pace

5th Epiphany:

Heavy oil is unlikely ever to be more economic than light oil
Vision vs. Reality

Canadian Design
- Single well tank battery
- Oil, water and solids trucked separately
- Gas burned or vented
- Direct fired heater
- 20+ years experience

Alaska Design
- Safety & environmental constraints
  - No direct fired heaters in tanks
  - No venting of gas
  - No spills
  - Operate safely over a multi-year period
- Unknown fluid properties and behavior
- First of its kind in Alaska
Pilot Location, S-Pad Milne Point Alaska
Milne Point S-Pad Heavy Oil Oil Facility
New BP Heavy Oil Pilot Project, Milne Point Alaska
Viscous and Heavy Oil Appraisal

Present

Time Frame

Future

High

Technical & Commercial Challenge

Very High

Plan

Options

Vision

Viscous Enhanced Waterflood

Heavy Cold Primary

Viscous + Heavy EOR

Thermal
Take Away Messages

• Heavy oil (including Viscous) is a world scale resource base that is intrinsic to the BP Alaska strategy.

• The time for heavy oil is now due to light oil linkage through diluent and infrastructure.

• Heavy oil is a different commodity than light oil with respect to extraction techniques, technical challenges, understanding, environmental challenges and market.

• The technical viability of Alaska Heavy Oil is unknown, so commercial outcome remains large range - must answer technical viability question first.

• BP’s Milne S-Pad pilot is a technology trial and its design and appearance do not necessarily reflect what an ultimate development will look like.