Extra Heavy Oil and Bitumen
Impact of Technologies on the Recovery Factor
« The Challenges of Enhanced Recovery »
Confusing heterogeneous denominations:

- Heavy Oil, Extra Heavy Oil, Oil Sands, Tar Sands, Bitumen, …

→ need for a simple classification

4 Classes based mainly on downhole viscosity:

- **A Class:** Medium Heavy Oil
  \[25° > d^\circ API > 18°\]
  \[100 \text{ cPo} > \mu > 10 \text{ cPo}, \text{mobile at reservoir conditions}\]

- **B Class:** Extra Heavy Oil
  \[20° > d^\circ API > 7°\]
  \[10,000 \text{ cPo} > \mu > 100 \text{ cPo}, \text{mobile at reservoir conditions}\]

- **C Class:** Tar Sands and Bitumen
  \[12° > d^\circ API > 7°\]
  \[\mu > 10,000 \text{ cPo}, \text{non mobile at reservoir conditions}\]

- **D Class:** Oil Shales
  Reservoir = Source Rock, no permeability
  Mining Extraction only
Heavy Oil (excluding Oil Shales) : 3 Main Categories

Heavy Oil Classification

- **A Class**: Medium Heavy Oil
  - Canada
  - Dalia
  - Tempa Rosa
  - Captain
- **B Class**: Extra Heavy Oil
  - Orinoco
- **C Class**: Tar Sands & Bitumen
  - Wabasca
  - Athabasca
  - Peace river
  - Cold lake
  - Upper & Lower Ugnu
  - Cat canyon
  - Eljobo
  - Boscan
  - El Jobo
  - Varadero
  - Garam Jaruco
  - Chabi
  - Fazenda Belem
  - Alto do Rodrigues 1
  - Alto do Rodrigues 2
  - Boca de Jaruco
  - West sak
  - Lacq
  - Shoonebeck
  - Fomentereuda

API Density vs. Downhole Viscosity (Cpo)
"Heavy Oils" : Resources of 4000 to 5000 Gb (OIP)
Potential Reserves depends on recovery factors

Considerable Potential Reserves : # 500 to 1000 Gb

- equivalent to 50-100% of worldwide conventional oil reserves
- 5 to 10 times (?) the ultra-deep offshore potential reserves
- mainly (80%) in extra heavy oil, tar sands and bitumens
- mainly (80%) in North and South America
- less than 1% produced or under active development

Heavy Oil Reserves

<table>
<thead>
<tr>
<th>Country</th>
<th>Reserves (Gb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Venezuela</td>
<td>270</td>
</tr>
<tr>
<td>Canada</td>
<td>310</td>
</tr>
</tbody>
</table>

Light Oil Reserves

<table>
<thead>
<tr>
<th>Country</th>
<th>Reserves (Gb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saudi Arabia</td>
<td>260</td>
</tr>
</tbody>
</table>
Huge Untapped Resources in Orinoco and Athabasca

Extra Heavy Oils
($\mu < 10,000$ cPo)
Oil in place: 1,200 Gb
(PDVSA estimates)

Tar Sands & Bitumen
($\mu > 10,000$ cPo)
Oil in place: 1,300 Gb
(EUB estimates)
A decisive difference: the geothermal gradient

**Athabasca:**
- T res. # 11°C
- μ > 1,000,000 cPo

**Orinoco:**
- T res. # 53°C
- μ # 1,500 to 3,000 cPo

**Viscosity = f(temp)**

**Cold Production Possible**

**Thermal Production Compulsory**
Production Technologies

1 - Proven technologies
... but with limited suitability or recovery efficiency

- Mining Extraction
- Cold Production
- Huff & Puff
Mining Extraction

- Proven technology
- High Recovery Factor
- Decreasing operating costs:
  - 1980's: > 25 US$/bbl
  - 2002: 8 - 12 US$/bbl
- Limited GHG emissions

BUT:

- Overburden limited to 50-75 m
- Suitable to less than 10% of Oil in Place in Athabasca
Cold Production

- Proven technology
- Fair productivities with horizontal wells (Venezuela) or with CHOPS (Canada)
- Limited investments
- Limited operating costs (2 to 4 US$/bbl)
- Available artificial lift technologies: PCP, rod pumps
- No GHG emissions

BUT:

- Poor recovery factors (# 5 to 10%)
- Unsuitable for bitumens (too viscous)
- Unsuitable for reservoirs with active aquifer
Example of Cold Production: the Sincor Project

ZUATA
8.5° API 200 Kbls/d

Cold Production

JOSE
32° API 180 Kbls/d

Distillation
Hydrotreater

Coker
Hydrocracker

Distillation Hydrotreater

Coker
Hydrocracker

Diluent 70 KBD

12”-20”

26”-36”

Diluted crude 270 KBD

21+200 km

Investment: US$ 4.2 billion
Plateau production: 200 kbd of crude oil
              180 kbd of Zuata Sweet
Oil gravity: 8.5° ⇒ 32° API
Technical cost: < 7 US$/b
Contract duration: 35 years

THE PARTNERS

SINCOR

TOTAL 47 %

PDVSA 38 %

STATOIL 15 %

10
Huff & Puff

• Proven technology:
  • Canada: Cold Lake, Wolf Lake & Primrose
  • Venezuela: Maracaibo & Oriente Basins
  • California: Kern River

• Limited operating costs:
  • 4 to 5 US$/bbl

BUT:

• Limited recovery factors (< 15-20%): only stimulation around wellbore

• Consumption of energy and increase of GHG emissions
Production Technologies

2 - More efficient technologies
... but not yet field proven

- In-Situ Combustion
- Solvent Injection
In Situ Combustion

- Old technology (1960's)
- High Recovery Factor: up to 60%
- Self-generation of energy (coke consumption)
- In situ upgrading (thermal cracking)

BUT:

- Field tested nearly exclusively on light oils
- Not so many successes (operational and safety problems)
- Pattern adapted to extra-heavy oil & bitumen to be found and field tested ...
Solvent Injection

- High Recovery Factor: up to 60%
- Low energy consumption
- In situ upgrading (asphaltene precipitation)
- No boiler feedwater treatment
- Limited GHG emissions

BUT:

- Slow process (molecular diffusivity much smaller than thermal diffusivity)
- Start-up not so easy: need for warming with steam?
- Possible "killing factor": solvent loss in reservoir?
- Not yet field tested: first pilots being launched in Alberta
- Not mature enough for industrial application until some years
Production Technologies

3 - Available efficient technology
... with proven results

• Steam Injection and SAGD
Steam Assisted Gravity Drainage (SAGD)

- High Recovery Factor:
  - up to 60%
- Quick process (high thermal diffusivity)
- Proven technology:
  - several pilots since 1980's in Alberta and elsewhere
  - Mature enough for medium scale field tests

BUT:

- Huge need of energy: 1500 MW for 100,000 bopd !!
- "Killing factor": steam oil ratio (has to be < 3 vol./vol.)
- Large GHG emissions: up to 15,000 Tons/day of CO₂ for 100,000 bopd
- Requires technics adapted to high temperatures (artificial lift, metering, surface pumping, ...)
SAGD: already a reality in Alberta

Phase 1 of Foster Creek (EnCana)

Construction of Christina Lake (EnCana)

Construction of MacKay River (PetroCanada)

Surmont Pilot (Conoco-Phillips / Total / Devon)
SAGD 1st Challenge: To Increase Oil Value

UPGRADED & VALUE OF THE PRODUCT

-100%  -80%  -60%  -40%  -20%  0%  20%  40%  60%  80%  100%

BRENT  ATHABASCA  ORENOQUE  Diluted Bitumen 19°API  Syncrude LR-coking 23°API  Syncrude H-OIL with VR 23°API  Syncrude HDH + 36,3°API  Syncrude SINCOR 32°API  Syncrude H-OIL without VR 32,4°API  Gasoil (145-375°C)  Gasoline (0-145°C)  VGO (375-540°C)  VR 540°C+

Mid Upgrading

-8.5 $/bbl  15.6 $/bbl

Deep Upgrading

-17 $/bbl  17.6 $/bbl
Upgrading: a Balanced Choice

**Thermal Cracking**
- Lower Investment Costs
- Lower Cost of Steam: petcoke may be used as fuel

**Deep Hydrocracking**
- Higher SCO value

**BUT**
- Lower SCO value

**BUT**
- Higher Investment Costs
- High consumption of natural gas for H2 and steam production
SAGD 2\textsuperscript{nd} Challenge: To Reduce Cost of Steam

Combustion of natural gas:
- simple and cheap boiler technology (OTSG)
- reduced treatment of boiler feedwater
- minimized GHG emissions
- limited investment costs:
  - \# 160 MMUS\$ (for 100,000 bopd)

BUT

High operating cost:
3 US\$/Bbl
(gas price ± 3 US\$/MMbtu)
**1st Alternative Fuel: Combustion of Upgrading Residues**

**Combustion of residues:**
- cheaper fuel than natural gas:
- reduced operating cost: 3 → 1 US$/bbl
- avoids stockpiling of residues (pet coke, asphalts)

**BUT**
- Requests specific boilers
- Heavier treatment of boiler feedwater
- High sulphur % → FGD compulsory
- Requires regenerative FGD process to avoid stockpiling of Ca$_2$SO$_4$
- Higher CO$_2$ emissions
- Higher investment costs:
  - 160 → 500 MMUS$ (100,000 bopd)
2nd Alternative Fuel: Gasification of Upgrading Residues

Gasification of residues:

- cheaper fuel than natural gas
- reduced operating cost: 3 ⇒ 1.3 US$/bbl
- avoids stockpiling of residues (petcoke, asphalts)
- allows production of H₂ for hydrotreatment
- easier capture of SO₂ and CO₂
- syngas can be burnt into simple OTSG boilers
- reduced treatment of boiler feedwater

BUT

- Higher investments costs:
  - 160 ⇒ 360 MMUS$ (100,000 bopd)
SAGD 3rd Challenge: To Reduce CO₂ Emissions

Bitumen 100 000 BPOD

Total CO₂: 14 300 tons / day

CO₂
11 000 tons / day

Oil Water separation

Upgrader
Flexicoker case

SCO 88 050 BOPD

CO₂
3 300 tons / day

Pads

Steam Generation

Steam: 43 200 tons/day

Equivalent gas 71.9 MMSCFD

8 - 12 wellpairs / Pad
SOR: 2.5 Vol / Vol
Artificial lift: Gas lift + ESP

Diluent recycle

Diluted Bitumen 19 °API

Natural gas

Water make up

38.5 MMSCFD

82.8 MMSCFD

44.3 MMSCFD

Electrical power external supply

Natural gas: 6 500 tons / day

Nota: CO₂ for bitumen production with only Natural gas: 6 500 tons / day

Nota: CO₂ for bitumen production with only Natural gas: 6 500 tons / day
CO₂ Emissions in SAGD

1 ton CO₂/ton syncrude

Range of possible variation

Upstream
Upgrader
Refining

kg CO₂ / barrel of bitumen

Athabasca SAGD
Athabasca Mine
SINCOR

24
Cost of CO₂ Capture

Today solution: MEA process
- Technical capture cost: $25 US$/T CO₂
- 0.5 T CO₂ emission / T CO₂ captured
= Real capture cost: $50 US$/T CO₂
⇒ +10 US$/bbl !!

Possible solution: oxy-combustion
(concentration of CO₂)

Tax?
- 10 US$/T CO₂ ⇒ +2 US$/bbl
- 20 US$/T CO₂ ⇒ +4 US$/bbl
- 30 US$/T CO₂ ⇒ +6 US$/bbl

Possible solution: oxy-combustion
(concentration of CO₂)
Conclusion: Impact of Recovery Efficiency

Technical cost (US$/bbl)

- Upstream + Downstream + 20 $/T CO₂ tax
- Upstream + Downstream
- Upstream only (no upgrading)

CO₂ Emissions (kg/bbl)

Recovery Efficiency

- SAGD
- Cold Production

ASPO Annual Meeting 2003 - Rueil- 26-27 May 2003
Difficult choice between:

- **current proven technologies:**
  - √ limited costs and GHG emissions
  - √ limited recovery factor (10% max?)

- **emerging “hot” technologies:**
  - √ higher recovery factor (40%+?)
  - √ but: higher cost and higher GHG emissions

A temptation:

- √ Nuclear Energy to produce steam?
- √ But not without drawbacks (especially beyond technology)
The End

Thank you for your attention.