Heavy Oil: Current Status and Recovery Methods

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Topics of Discussion

- Introduction
- Heavy Oil and Tar Sand Deposits
- Current Thermal Recovery Methods
- Bio-Chemical Recovery Methods
- Current US EOR Projects and Production
- Conclusions
Introduction

- Heavy oils are important hydrocarbon resources that are destined to play an important role in the oil supply in the world.
• A generalized classification of heavy oil considers an association of:

  • low API gravity
  • high viscosity at reservoir temperature
  • poor reservoir mobility
  • dark color
• The important question is: how much of this oil is recoverable and what techniques could be applied?

• In order to produce heavy oil through wells, a large amount of heat is needed to reduce its viscosity.
• In the case of heavy oil and tar sands, the recovery factor varies greatly from area to area, depending on the oil and the reservoir characteristics, as well as the technique used.

• Viscosities of the heavy crude's are varies from 100 to 1000 cp at reservoir temperature, while the viscosity of the oil sand is greater than 1000 cp at reservoir temperature.

• Heavy crude's contain 3 wt% or more sulphur, 10 – 30% asphaltenenes, and as much as 2000 ppm of vanadium compounds.
• **Geology** is the single important factor determining the success of a heavy oil recovery project.

• **Large permeability variations** would imply highly uneven distribution of the injected fluid.
• A good reservoir management program for heavy oil recovery is necessary.
Heavy Oil and Tar Sand Deposits

The heavy oil resources of the world total about 10 trillion barrels.

In USA, heavy oil production is nearly 60% of the total EOR production.
• Approximately 25% of the oil production of Canada is from oil sands.

• Tar sands (oil sands) are reservoirs containing crude bitumen.

• The world bitumen resources are more than 4 trillion barrels and are located principally in Canada, 60%; Venezuela, 25%; and USSR, 14%.
• Recovery from California heavy oil reservoirs by steam injection is about **55% of the initial oil in place**.

• In Alberta, recovery is considerably lower – 5 to 25% - because the main recovery method is cyclic steam stimulation.

• **Venezuela** has nearly **two trillion** barrels of heavy oil.

• **Cyclic steam stimulation** has been very successful in Venezuela.
Example of Heavy Oil Reservoirs

<table>
<thead>
<tr>
<th>Field</th>
<th>Country</th>
<th>Oil Gravity</th>
<th>Viscosity, cp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gela</td>
<td>Italy</td>
<td>8–13</td>
<td>80–220</td>
</tr>
<tr>
<td>Duri</td>
<td>Sumatra</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>Darius</td>
<td>Iran</td>
<td>12–20</td>
<td>--</td>
</tr>
<tr>
<td>Harbur</td>
<td>Oman</td>
<td>18–23</td>
<td>--</td>
</tr>
<tr>
<td>Karatchok</td>
<td>Syria</td>
<td>19–23</td>
<td>--</td>
</tr>
<tr>
<td>Bati Raman</td>
<td>Turkey</td>
<td>12</td>
<td>650</td>
</tr>
<tr>
<td>Jopo</td>
<td>Venezuela</td>
<td>8</td>
<td>6200</td>
</tr>
<tr>
<td>Cold Lake</td>
<td>Canada</td>
<td>10–12</td>
<td>100,000</td>
</tr>
<tr>
<td>Kern River</td>
<td>USA, Texas</td>
<td>14</td>
<td>4,200</td>
</tr>
<tr>
<td>Midway Sunset</td>
<td>USA, California</td>
<td>14</td>
<td>1600</td>
</tr>
<tr>
<td>UKCS-3</td>
<td>UK</td>
<td>11–15</td>
<td>150–2750</td>
</tr>
</tbody>
</table>

- Heavy oil resources in the world

<table>
<thead>
<tr>
<th>Region</th>
<th>In Place Oil (Million bbls)</th>
<th>Recoverable Oil (Million bbls)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>2,950,000</td>
<td>213,210</td>
</tr>
<tr>
<td>USA</td>
<td>77,160–127,000</td>
<td>30,065</td>
</tr>
<tr>
<td>Venezuela</td>
<td>700,000–3,000,000</td>
<td>500,000</td>
</tr>
<tr>
<td>Europe</td>
<td>13,196</td>
<td>1,406</td>
</tr>
<tr>
<td>Africa</td>
<td>25,700</td>
<td>1,519</td>
</tr>
<tr>
<td>Middle East</td>
<td>50,000–90,000</td>
<td>4,680</td>
</tr>
<tr>
<td>USSR and Asia</td>
<td>1,131</td>
<td>31</td>
</tr>
</tbody>
</table>

Oman, S.A. and Kuwait not included.

Current Thermal Recovery Methods

- Application of heat to the reservoir rock and fluids, can aid oil production through oil viscosity reduction, thermal expansion effects, increase in sweep efficiency, and possible steam distillation effect.

- Today steam injection is regarded as a well-established oil recovery method, which will become increasingly important in the years to come.
steam injection

The two commonly used forms of steam injection are:

steam flooding or steam derives
cyclic steam injection

A single well operation, injecting steam and then producing oil from the same well, steam injection is called cyclic steam injection, steam soak, or "huff-and-puff".
• In Cold Lake, Alberta, recovery is over 25% or higher.

• In Venezuela, cycling steaming is a well established and recoveries from this process as high as 40% have been noted.

(From Carcona, A: Applied EOR, Prentice Hall, Inc)
Design Criteria

- **Formation depth** may be above 200-400 ft (200 ft in Charco Redondo, Texas) to avoid parting pressure of adjacent formations and should be limited to 5000 ft (Brea, California) due to heat loss.

- Higher limit possible using downhole generators.
• To minimize heat loss, formation thickness should be not less than 30 ft (Slocum, Texas).

• Formation permeability should be high (between 250 and 1000 md) and porosity should be higher than 18 to 20 % (Shiells, California).

• The oil gravity may be in the 12-25 API range with viscosity about 2000 cp at reservoir temperature.
• The upper limit can be decreased to 4000 cp less by cyclic steam injection.

• Steam injection is applied also to **light oils** (Brea, California, with 24° API and 6 cp and El Dorado, Kansas, with 37° API and 4 cp).

• **Oil saturation** at the start of steam injection project should be higher than 40 to 50%.
• It is important to have high enough reservoir pressure to cause rapid movement of oil into the wellbore.

• The quantity of steam to be injected is a difficult parameter to decide about.
• Shallow and dip oil reservoirs, thick pay zones with very good permeability, cheap and high quality water source are some favoring factors to steam injection, while strong nonuniformity, highly water-sensitive clay content, and low interwell communication are adverse factors.
The experience gained from the Kern River Foam Pilots in California, USA, shows that:

- **steam foam** retards steam override and increases vertical sweep.
- **the infill drilling** is necessary to improve the injection-production balance.
- **cyclic steam injection** is still used to clean old wellbore wells.

*(From Carcona, A: Applied EOR, Prentice Hall, Inc)*
The results of the "200" sand, Midway Sunset steam flood in California, USA showed that:

shallow heavy oil reservoirs with poor cyclic steam performances could be developed by steam flooding.

(From Carcona, A: Applied EOR, Prentice Hall, Inc)
More than 50 steam injection field tests have been conducted in tar sand reservoirs worldwide and have demonstrated that steam is an important heat carrier agent in the development of bitumen resources.
- The new approaches to tar sand oil recovery involve
- horizontal wells, using steam plus additives such as surfactant
- combination of mining and petroleum drilling methods.
- Downhole steam generator equipment developed for tar sand reservoirs would also be useful.
In Situ Combustion

A **burning front** and combustion zone is propagated to the producing well by air injection into a well.
• In situ combustion process is applicable for a wide range of oil gravities (8 to 36ºAPI), but commercial success has been possible only in oils that are sufficiently mobile at reservoir conditions.

• **Oil viscosity** may be less than 5000 cp.

• **Forward combustion** is theoretically the most efficient process.
The in situ combustion process has been successfully applied to a variety of reservoirs having depth, between 169 ft (Suplacu de Barcau, Romania) and 11,400 ft (West Heidelberg, Mississippi, USA).

The average thickness between 4 ft (Gloriana, Texas) and 120 ft (Brea Olinda, California).
Pilot Design and Operation

- Pilots play an important role in improving heavy oil recovery, improving developed technology such as adding chemical to cyclic steam stimulation, and developing a new technology such as fracturing tar sand reservoirs.

- They are expensive, but necessary.

- Pilots are in fact research projects run in the oil field.
• The engineer designing a **pilot** and his management need good understanding of what probably can and can not be accomplished considering the **heterogeneity** encountered in heavy oil reservoirs.

• Balancing **pilot** benefit versus cost is of constant concern to the pilot manager.

• **Small patterns** are preferential because **pilot** can be completed in less time.
• It is important to have frequent decision points where data obtained are reviewed and changes in pilot design considered.

• Managers, engineers, operators need to be both experienced in oil field operations and looking for ways to improve the process under test.
Bio-Chemical Recovery Methods

• During the last fifteen years scientific and engineering efforts in the laboratories of King Saud University (Saudi Arabia) and Cairo University (Egypt) has established the basic start for Microbial Enhanced Oil Research technology in the Arab World.
• It is expected that Microbial Enhanced Oil Recovery (MEOR) may recover up to 30% of the residual oil under the Arab reservoir conditions.

• The actual recovery, however, can only be determined through laboratory and pilot tests under field conditions.

• A new technology should be developed to apply MEOR successfully.
There are different forms of microbial oil recovery:

Cyclic well stimulation treatments.

Microbial enhanced water flooding.

Permeability modifications.

Wellbore cleanup.
Recent studies in our laboratories at Cairo University reported some species of bacteria producing polymers and bio-surfactant that can be used in field applications of MEOR processes.

Extensive research is going on today in order to develop a new technology in the area of bio-technological processes that can be used under reservoir conditions of temperature, pressure, rock permeability and water salinity.
Environmental Effects of MEOR

- The *environmental control* of MEOR is of great importance.

- It is *necessary* to prevent any adverse effects on the environment when applying this recovery method.
CURRENT ACTIVE US EOR PROJECTS AND PRODUCTION
ACTIVE US EOR PROJECTS

(From Oil & Gas Journal/Apr. 12, 2004)
US EOR PRODUCTION

(From Oils&Gas Journal/Apr. 12, 2004)
(From Oil&Gas Journal/Apr. 12, 2004)
Conclusions

• The field tests have demonstrated that thermal recovery methods are applicable to heavy oil recovery.

• Cyclic steam stimulation is the most widely used steam injection method for heavy oil recovery.

• A combination of cyclic steaming and steam flood could offer the advantages of each process.
• Improvement of current heavy oil recovery technology is required.

• Development of new technology, such as horizontal well application, mine-assisted heavy oil recovery and microbial methods, is needed.
• **Microbial heavy oil recovery** is a method which can recover more oil at low-cost.

• **Reservoir management** for maximizing economic recovery of heavy oil is essential to the future success of the petroleum industry.
THANK YOU