Upgrading of Heavy Crude Oil
- Supercritical Water Cracking Technology -

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Manager, Technology Development Center

JGC CORPORATION
The Super Critical Water Partial Upgrading technology has been developed by JGC Corporation of Japan, along with the financial, governmental and technical support of JOGMEC (Japan Oil, Gas and Metals National Corporation.)

Laboratory testing and analysis have been completed and the technology is now moving into the actual demonstration phase set to commence in 2014.
JGC Business Areas

EPC
(Engineering / Procurement / Construction)

Project Development & Investment

EPC
(Engineering / Procurement / Construction)

Up & Mid Stream

LNG

Power Generation

Environmental & Energy Conservation

Refineries

Gas Processing

Industrial

Petrochemicals & Chemicals

Medical Facilities & Research Laboratories

Supercritical Water Cracking
Supercritical Water Cracking

- Background
- Process Advantages
- Supply Chain Benefits
- 5BPD Pilot Plant in Canada
- Summary
Background
Heavy Crude Oil Supply Schemes

Upstream

Diluted Scheme

SAGD

Diluted Bitumen (DilBit)

Diluents

Midstream

Partially Upgrader Scheme

SAGD

Partial Upgrader

Sour SCO

Downstream

Full Upgrader Scheme

SAGD

Full Upgrader

Sweet SCO

CDU, VDU, Coker, HDS

Cokes

Sulfur

CDU, HDS

Cokes

Sulfur

Liquid Products

Liquid Products

Liquid Products

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Supercritical Water Cracking
## Properties of Feedstock and Targets

**Feedstock**
Bitumen

**Product**
SCO

**SCWC**
Refinery
Pipeline

<table>
<thead>
<tr>
<th>Property</th>
<th>Feedstock</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>API</td>
<td>8.3</td>
<td>&gt; 21</td>
</tr>
<tr>
<td>Viscosity@10°C cSt</td>
<td>1,000,000</td>
<td>&lt; 350</td>
</tr>
<tr>
<td>Sulfur wt%</td>
<td>5.15</td>
<td>-</td>
</tr>
<tr>
<td>Ni / V ppm</td>
<td>75 / 194</td>
<td>-</td>
</tr>
<tr>
<td>TAN mg/g</td>
<td>2.48</td>
<td>-</td>
</tr>
<tr>
<td>Olefins %</td>
<td>&lt; 0.5</td>
<td>&lt; 1.0</td>
</tr>
</tbody>
</table>
Results of Direct Observation

Roles of Supercritical Water

1. Thermal Cracking of VR
2. Extracting Distillate and VGO
3. Inhibiting polymerization of asphaltene (coking)

SCW forms layers in the asphaltene micelle
What is Supercritical Water?

Water at a temperature and pressure above its critical point.

SCW has physical properties between liquid and gas.

<table>
<thead>
<tr>
<th>Property</th>
<th>Gas</th>
<th>SC Fluid</th>
<th>Liquid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (kg/m³)</td>
<td>1</td>
<td>100~1,000</td>
<td>1,000</td>
</tr>
<tr>
<td>Viscosity (mPa·s)</td>
<td>0.01</td>
<td>0.1</td>
<td>1</td>
</tr>
<tr>
<td>Diffusion Coefficient (m²/s)</td>
<td>10⁻⁵</td>
<td>10⁻⁷~10⁻⁸</td>
<td>10⁻¹⁰</td>
</tr>
<tr>
<td>Thermal Conductivity (mW/mK)</td>
<td>5~30</td>
<td>20~150</td>
<td>50~200</td>
</tr>
</tbody>
</table>
Bench-Scale Test Unit

Supercritical Water Cracking
R&D Work Plan

Phase 1 Pre-Test
(Mar - Jul 2006)
• Preliminary Test
• Preliminary F/S

Phase 2 Lab Phase
Phase 2.1 (Jan - Dec 2007)
• Optimizing RX Conditions
• SCO Evaluation
• Reaction Modeling

2.2 (Sep 2007 - Mar 2008)
• Test of other heavy oils
• Comparison with conventional technologies

2.3 (Apr - Dec 2008)
• Preliminary Process Design
• Economic Evaluation
• Secondary Conversion Test

2.4 (Jan 2010 – Mar 2011)
• Higher Conversion Test
• Evaluation of Boiler & FDG
• Waste Water Treating

Phase 3 Demonstration
3.1 Pilot Plant 5BPD@Canada (Nov 2011 - Mar 2016)
• Reliability Test
• Scale factor Evaluation
• Semi-Commercial Design

3.2 Semi-Commercial 2000 BPD
Semi-Commercial Plant
• Long Term Operation
• Commercial Design

Supercritical Water Cracking
30,000 BPSD SCWC Scheme

- **Bitumen Heater**
- **Water Heater**
- **Bitumen 30 KBPD (API 8°)**
- **Diluent 14 KBPD**
- **Pitch 9 KBPD**
- **Pitch Cooler**
- **Product Cooler**
- **High Temp. Separator**
- **Low Pressure Separator**
- **Pitch Flash Drum**
- **Low Pressure Separator**
- **SWS**
- **BFW**
- **WWT**
- **Pitch 30 KBPD (API 8°)**
- **Sour Gas Treatment**
- **SCO 21 KBPD (API 24°)**
- **DilBit 44 KBPD**
- **Water 30 KBPD**
- **SAGD System**

Supercritical Water Cracking

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Liquid Yield Comparison

<table>
<thead>
<tr>
<th></th>
<th>Distillate &amp; Lighter</th>
<th>VGO</th>
<th>VR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feedstock</td>
<td>100%</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>Bitumen</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SCW Cracking</td>
<td>101%</td>
<td>46</td>
<td></td>
</tr>
<tr>
<td>Products</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delayed Coker</td>
<td>80% (+ Coke 20 wt%)</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Products*1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*1 includes Coker products and straight run Distillate & Naphtha.
SCWC Plant Footprint

Supercritical Water Cracking
Process Complexity

No. of Equipment

Fractionator  Reactor  Drum  AFC  H/E  Furnace  Pump  Coker  Visbreaker  SCW (Base =100%)
Supply Chain Benefits
Supply Chain Cost

(*WTI:* $80/bbl,  Natural Gas: $4/MMBTU)

<Assumptions>
- Upgrader cost including utility, catalyst, maintenance cost and Depreciation (20yr straight-line).
- Diluents cost: $85/bbl (=WTI +$5/bbl) (30 vol % dilution blend ratio)
- Natural Gas Price: $4/MMBTU (Fuel duty of SAGD Boiler to be 1400MMBTU/hr )
- Pipeline cost : $5/bbl (Fort McMurray ~ Edmonton), $8/bbl (Edmonton~ Houston)
Supply Chain Cost Advantage to Diluted Bitumen
(WTI: $80/bbl, Natural Gas: $4/MMBTU)

- **SAGD Fuel (Natural Gas → Residue)**
  - **No Diluents**
  - **Pipeline Volume Saving (by 40%)**

- **Supply Cost**
  - $12/bbl

- **SCO Premium**
  - $8/bbl

- **Upstream** ⇒ **Pipeline** ⇒ **Refinery**

**Graph:**
- **US$/BBL-SCO**
- **Yield Vol%**
  - SCO
  - Diluted Bitumen
  - VR
  - VGO
  - Distillate
  - Naphtha

**Data Table:**
- **Sulfur (wt%)**
  - SCO: 3.3%
  - Diluted Bitumen: 3.8%
- **API °**
  - SCO: 24
  - Diluted Bitumen: 22
- **Product v%**
  - SCO: 100%
  - Diluted Bitumen: 86%
5 BPD Pilot Plant in Canada
5 bpd SCWC Pilot

Supercritical Water Cracking
5bpsd SCWC Pilot

Bitumen Service Tank

Gas

Knock out Drum:

SCO

Water

Flash Drum:

Receiver:

SCO

Pitch

Low Pressure Separator:

High Pressure Separator:

Gas

Electrical Heater

Reactor

Pitch Flash Drum:

Electrical Heater

Water Tank

Supercritical Water Cracking
Pilot Plant Site in Canmet Facility
Summary
### SCW

**Simple, Clean, minimal Waste**

<table>
<thead>
<tr>
<th>Footprint (Excl. Tank Yard)</th>
<th>SCWC</th>
<th>Delayed Coker</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>![Diagram]</td>
<td>![Diagram]</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Solid Waste (By-product)</th>
<th>SCWC</th>
<th>Delayed Coker</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulfur</td>
<td>![Diagram]</td>
<td>![Diagram]</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>150</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Energy Consumption (API 8° → 21°)</th>
<th>SCWC</th>
<th>Delayed Coker</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Diagram]</td>
<td>![Diagram]</td>
<td>![Diagram]</td>
</tr>
<tr>
<td>1</td>
<td>1.5</td>
<td></td>
</tr>
</tbody>
</table>

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Summary

- **Minimal Waste**
  - SCWC is a partial upgrading technology aimed at minimizing on-site cokes and sulfur

- **Simple Process**
  - SCWC is a simple process applicable for on-site (SAGD) production

- **Supply Chain Advantages**
  - Supply cost improved by $20/bbl
  - Energy consumption reduced by 30%

- **Ready for Demonstration**
  - SCWC Pilot Plant is ready for demonstration

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