Offshore CO$_2$-EOR Pilot Project in Vietnam

5$^{th}$ October 2016
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Atsushi Hatakeyama
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   - CO2 Huff’n’Puff Pilot Test
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1. Introduction
Introduction - JX Nippon

**Energy Business**
- Market share of domestic sales of petroleum products: Approx. 36% *(No.1 in Japan)*
- Market share of domestic sales of lubricant products: Approx. 34% *(No.1 in Japan)*
- Paraxylene supply capacity: 3,120 thousand *tons/year* *(No.1 supplier in Asia)*

**Oil and Natural Gas Exploration and Production Business**
- Crude oil and natural gas sales volume (a project company basis): Approx. 121 thousand barrels/day (B/D)

**Worldwide business activities in such areas as**
- Malaysia, Vietnam, North Sea (UK), Middle East and others

**Metals Business**
- Equity entitled copper mine production: Approx. 170 thousand tons/year *
- Refined copper production capacity: 920 thousand tons/year *
- Electronic Materials: Products with world No.1 market shares

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*1 FY2016 actual  
*2 FY2015 actual  
*3 As of Mar. 2016  
*4 Crude oil equivalent (average daily production from Jan. to Dec. 2015 actual)  
*5 Equity entitled copper production contained in copper concentrate (FY2016 actual)  
*6 Pan Pacific Copper (67.8% equity stake): 650 thousand tons/year + LS-Nikko Copper (39.9% equity stake): 270 thousand tons/year (As of Mar. 2016)  
*7 Profit and loss of Toho Titanium is included in the Metals Business.

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JX Nippon Business Activities

Date of establishment : June 26, 1991
Head office : 1-2 Otemachi 1-chome, Chiyoda-ku, Tokyo
Paid-in capital : 9.8 Billion yen
Number of employees : 949 (as of March 31st, 2016)

Business Activities

The UK North Sea
The U.S.
Canada
Thailand
Vietnam
Myanmar
Malaysia
Indonesia
Australia
Brazil
Papua New Guinea
UAE / Qatar
Japan

Production Exploration Development
# Challenges for CO₂ Reduction on JX Nippon’s E&P Business Activities

JX Nippon continues “Challenges” in accordance with Company Mission Statement “Harmony with the environment”

<table>
<thead>
<tr>
<th>Year</th>
<th>Project Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000~</td>
<td>Zero Flaring, Abu Dhabi</td>
</tr>
<tr>
<td>2007~</td>
<td>Zero Flaring &amp; CDM Project, Vietnam</td>
</tr>
<tr>
<td>2011</td>
<td>CO₂ EOR Huff’n’Puff Pilot Test, Vietnam</td>
</tr>
<tr>
<td>2016~</td>
<td>Carbon Capture &amp; CO₂-EOR Project, USA</td>
</tr>
</tbody>
</table>

*Pioneering CO₂-EOR field application in SE Asia* 

Acknowledged to DOE for this project granted as “Clean Coal Power Initiative Program”

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2. Offshore CO$_2$-EOR Pilot Project in Vietnam
Rang Dong Field, Offshore Vietnam

**Reservoir Description**

<table>
<thead>
<tr>
<th>Reservoir Properties</th>
<th>Rang Dong LM Reservoir</th>
<th>Criteria for Gas EOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reservoir Depth [m]</td>
<td>2,100</td>
<td>&gt;650</td>
</tr>
<tr>
<td>Reservoir Pressure [psi]</td>
<td>3,100</td>
<td>&gt;1,030</td>
</tr>
<tr>
<td>Reservoir Temp. [degF]</td>
<td>196</td>
<td>&gt;90</td>
</tr>
<tr>
<td>API Gravity [API]</td>
<td>38</td>
<td>&gt;31</td>
</tr>
<tr>
<td>Oil Viscosity [cP]</td>
<td>0.76</td>
<td>&lt;5</td>
</tr>
<tr>
<td>Oil Saturation [%]</td>
<td>50</td>
<td>&gt;25</td>
</tr>
<tr>
<td>Permeability [mD]</td>
<td>1-3,000</td>
<td>&gt;5</td>
</tr>
</tbody>
</table>

- The field was discovered in 1994, and has been produced since 1998.
- Current cum. oil production is 200 Millionth bbl.

About 120 km offshore of Southern Vietnam

**Oil Production Rate**
- North WHP Started to Produce
- Central WHP Started to Produce And Started Gas Lift
- East WHP Started to Produce
- Add Water Injector (New Drilling or, Workover)

**Water Injection Rate**
- Water Injection Started
CO$_2$-EOR Project Scheme

To study the CO$_2$-EOR applicability to the offshore oil fields in Vietnam through an international joint study between Vietnam and Japan

**International Joint Study**

*Study agreement under MOU between PVN and JOGMEC*
CO₂-EOR Project History

2007-2010 Phase 1 Feasibility Study

To evaluate the potential and feasibility of CO₂-EOR to Rang Dong field

- **Laboratory Study**
  - Slimtube Test
  - Interfacial Tension Test
  - Swelling Test
  - Coreflood Test

- **Simulation Study**
  - Geological Model Upscale
  - History Match
  - EOS Model
  - Optimized CO₂ EOR

- **CO₂ Source Study**
  - Site Survey
  - Facility Modification
  - Cost Estimation

2011-2014 Phase 2 Pilot Test

To confirm CO₂-EOR effects in actual reservoir
Phase 1: Laboratory Study

1st Feasibility Study

- Slim-tube Test
- IFT Test
- Solubility Swelling Test
- Core-flood Test

- Injected CO₂ and crude form “Miscible (completely mixed and form single phase)” under reservoir condition
- CO₂ flooding yield 2.2 times recovery factor against Water Flooding in Core Scale

Core-flood Test

Swelling Test

- CO₂: 93.1%
- HCG: 72.7%
- Water: 42.4%
Phase 1: CO2-EOR Incremental Oil

Special reservoir model constructed with Laboratory Study results for Evaluation of CO2-EOR Incremental Reserves.

Scenario Assumption
- Import 1.0 Mil. ton CO2 per year for 7.5 years
- Inject CO2 into Reservoir under Miscible Condition
- Recycle Breakthrough CO2 for re-injection.
- Almost all the imported CO2 injected into reservoir in field end.

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Phase 1: Studies for CO\(_2\) Source and Facility Development/Modifications

### 1st Feasibility Study

**CO\(_2\) Source Study & Cost Estimation**

**At CO\(_2\) source**
- Facilities for CO\(_2\) Capture, De-watering & Compression
- Onshore/Offshore Pipelines

**Fertilizer Plant**
- 0.4 Million Ton/Year
- 135 km from Target Field
- 700 Million $ (incl. Rang Dong Mod.)

**CO\(_2\) Rich Gas Field**
- 1.0 Million Ton/Year
- 520 km from Target Field
- 1.0 Billion $ (incl. Rang Dong Mod.)

**At Rang Dong**
- New facility for CO\(_2\) injection and Recycling
- Existing facility to be modified for prevention of corrosion by CO\(_2\).
CO₂-EOR Project History

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2011-2014 Phase 2 Pilot Test
To confirm CO₂-EOR effects in actual reservoir
CO₂ Huff’n’Puff Test - Objectives

Objectives of H&P pilot test

In order to confirm an effectiveness of CO₂-EOR, a small CO₂-EOR pilot test was conducted.

- To Confirm CO₂ Injectivity
- To Confirm Increased Oil Production
- To Confirm Mechanisms of CO₂-EOR

Three Stage Actions

Merits on Huff’n’Puff

- Single Well
- Short Test
- Small CO₂ Requirement
- Minimum Impact to Facility
CO₂ Huff’n’Puff Test - Operation

Test Operation

- DST equips on Rig
- CO₂ injection equips on Vessel
- CO₂ contaminant flow isolated from Existing Production System

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Oil Increment by CO₂ Huff’n’Puff

Oil Rate [bbl/d], GOR [scf/stb]

Water Cut%

Oil Rate

CO₂ Injection

Water Cut

CO₂ Concentration

950 bpd -> 1,500 bpd
+550 bpd (1.6 times)

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Water Cut Reduction by CO₂ Huff’n’Puff

- **Oil Rate [bbl/d]**
- **GOR [scf/stb]**
- **BS&W**
- **Choke Size**
- **CO₂ in Gas**
- **API 60**

**Dates:**
- 5/23
- 5/24
- 5/25
- 5/26
- 5/27
- 5/28
- 5/29
- 5/30
- 5/31
- 6/01
- 6/02

**Legend:**
- **Pre-Flow**
- **Saturation Logging**
- **Saturation Logging while Soaking**
- **Post-Flow**

**Key Points:**
- **WC=50-60% -> 0%**
- **CO₂ Concentration**
- **Water Cut Reduction by CO₂**
- **Huff’n’Puff**

**API 60:**

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CO\textsubscript{2} Huff’n’Puff Test Results

Operation was successfully completed without any operational trouble and HSE issues

CO\textsubscript{2} Huff’n’Puff Test provided following results;

- CO\textsubscript{2} Injectivity
- Oil Production Increase
- Water Cut Reduction
- Oil Property Changes by CO\textsubscript{2} injection
- Oil Saturation Changes before / after CO\textsubscript{2} injection

Feasibility Study and CO\textsubscript{2} Huff’n’Puff test results indicated CO2-EOR is technically applicable for Rang Dong Field
**Alternative EOR Application ~HCG-EOR~**

CO$_2$-EOR can maximize ultimate recovery. However, HCG-EOR is more cost-effective application.

**CO$_2$-EOR**

CAPEX: US$ 1 Bil.

**HCG-EOR**

CAPEX: US$100 Mil.

CO$_2$-EOR project is temporary suspended. JX proceeded HCG-EOR toward commercial application.
HCG-EOR Application in Rang Dong Field

JX also succeeded HCG-EOR Pilot Test since 2012.

JX implemented HCG-EOR as the first commercial EOR since 2014.
3. CONCLUSIONS
3. Conclusions

- JX planned and conducted 1\textsuperscript{st} Offshore CO\textsubscript{2}-EOR Pilot Test in SE Asia, jointly with JOGMEC/PVN in 2011.

- CO\textsubscript{2}-EOR is technically applicable, but economically challenging for Rang Dong due to inconveniently located offshore project. Alternatively, JX has applied commercial HCG–EOR since 2014.

- Technical experiences in Rang Dong Field highly encourage CO\textsubscript{2}-EOR business expansion. JX could achieve FID for Carbon Capture & CO\textsubscript{2}-EOR Project in United States, under “Clean Coal Power Initiative Program” granted by DOE.

- JX continues development of CO\textsubscript{2}-EOR technology for maximizing oil production and reduction of CO\textsubscript{2}.
Thank you for your attention