TAGD Field Test Update For AER
January 2015 to December 2015

Presented 2016-04-04
INTRODUCTION

DOVER WEST LEDUC ASSET
TAGD PROCESS
TAGD FIELD TEST
  o Introduction
  o Subsurface
  o Surface
  o Compliance

PLANS
Dover West Leduc Asset
OPPORTUNITY

- Northern extent of well-known prolific Leduc light oil reservoirs, but filled with bitumen.
- 14.8 billion bbl OOIP\(^{(1)}\) (best estimate) in the Leduc carbonate reef (up to 100 m net pay).
- Asset has potential for > 350 000 bbl/d\(^{(2)}\), based on TAGD.

<table>
<thead>
<tr>
<th></th>
<th>Leduc Light Oil</th>
<th>Dover West Leduc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Porosity</td>
<td>5%</td>
<td>15%</td>
</tr>
<tr>
<td>Average Permeability</td>
<td>1 000 mD</td>
<td>&gt;3 000 mD</td>
</tr>
<tr>
<td>Recovery Factor</td>
<td>70%</td>
<td>Estimated &gt;50%</td>
</tr>
</tbody>
</table>

\(^{(1)}\) Discovered (11 600 million bbl) plus Undiscovered.

\(^{(2)}\) Based on management estimate.
AREA MAP OF DOVER WEST

TAGD Field Test

Image of drilling rig
Image of forested area
TAGD Process
TAGD OVERVIEW

THERMAL ASSISTED GRAVITY DRAINAGE

An in situ recovery process, in which:

- The reservoir is heated using a pattern of horizontal heating wells.
- Sufficient temperature is reached such that bitumen will flow by gravity to production wells.

WHAT IT’S NOT:

- NOT just a near-wellbore stimulation process – goal is reservoir-wide heating.
- Does NOT involve flow of electrical current in the reservoir; instead, reservoir heating occurs via thermal conduction.
- Does NOT result in chemical alteration of the bitumen – target temperature to achieve sufficient reduction in viscosity, without cracking the bitumen.
TAGD PROCESS – 3 KEY ELEMENTS

1. Conduction Heating
   Heating reduces viscosity and mobilizes oil

2. Internal Drive
   Internal drive replaces voidage

3. Gravity Drainage
   Mobilized oil flows down by gravity
1: HEATING

Steam injection pressure dictates high temperature

Trade-off between additional energy (and cost) vs. benefit of reduced viscosity

Conductive heating achieves desired optimum temperature

Target temperature achieved via selection of well spacing and heater power input

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AOC Leduc
- Depth: ~280 m ASL
- Temperature: 12°C
- Pressure: 480 kPa
- Leduc viscosity@ 12°C: 13×10⁶ cP

- Steam injection pressure dictates high temperature
- Trade-off between additional energy (and cost) vs. benefit of reduced viscosity
- Conductive heating achieves desired optimum temperature
- Target temperature achieved via selection of well spacing and heater power input
Gas-Oil Gravity Drainage

Voidage Replacement
- Expansion of in-place fluids
- Solution gas evolution
- CO$_2$ generation (dolomite dissolution)
- Connate water vapourization
- Top gas drive from gassy bitumen zone
- Gas injection (optional)
TAGD Field Test Introduction
TAGD FIELD TEST

OBJECTIVES

- Proof of TAGD concept.
- Drill horizontal wells in a fractured, vuggy carbonate.

SCOPE

- 1 horizontal heater well.
- 1 horizontal heater-producer well.
- 4 vertical observation wells.
- Instrumentation to measure downhole pressure and temperature.
No change in 2015
- No change in 2015
TIMELINE

- **June 18, 2010**: Filed TAGD Field Test Application #1653013
- **December 17, 2010**: Received Approval 11546 for the TAGD Field Test
- **January to March 2011**: Drilled And Completed Wells
- **May 2011**: Heating Initiated
- **June 6, 2011**: Received Approval For Early Production
- **July 21, 2011**: Received Approval 11546A Extend Project Life
- **October to November 2011**: Production Cycle #1
- **February to April 2012**: Production Cycle #2
- **September 5, 2012**: Received Approval 11546B for the Addition of Submerged Combustion Evaporator
- **October 25, 2012**: Received Approval 11546C for the Addition of Submerged Combustion Evaporator Tank
**TIMELINE**

- **November 27, 2012** | First Evaporation
- **December 2012 to February 2013** | Production Cycle #3
- **September 19, 2013** | Received Approval 11546D for the TAGD Pilot Project
- **October 17, 2013** | Filed Amendment for Gas Injection Test
- **October 31, 2013** | Received Approval 11546E for the Gas Injection Test
- **December 10, 2013** | MARP approval for the TAGD Pilot Project
- **January 2014 to February 2014** | Conducted Gas Injection Test
- **June 2014** | Began Production Cycle #4
- **December 2014** | Began gas co-injection
Production Cycle #4 2015

- Pumping between 2 m$^3$/d to 30 m$^3$/d of fluid.
- 798 m$^3$ of bitumen produced in Cycle #4.

Test Successfully Completed

June 2014 to May 2015

September 2015
## OBIP APPROVAL AREA AND OPERATING PORTION

<table>
<thead>
<tr>
<th></th>
<th>Area</th>
<th>Thickness</th>
<th>Rock Volume</th>
<th>Porosity</th>
<th>Bitumen Satur.</th>
<th>Net-to-Gross</th>
<th>OBIP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(m²)</td>
<td>(m)</td>
<td>(m³)</td>
<td>(%)</td>
<td>(%)</td>
<td>(frac)</td>
<td>(m³)</td>
</tr>
<tr>
<td>TAGD Field Test Area</td>
<td>647 500</td>
<td>83</td>
<td>53 500 000</td>
<td>14.2</td>
<td>86</td>
<td>0.96</td>
<td>6 272 000</td>
</tr>
<tr>
<td>Approval Area No. 11546</td>
<td>3 940 000</td>
<td>75</td>
<td>312 615 000</td>
<td>14.7</td>
<td>89</td>
<td>0.94</td>
<td>37 000 000</td>
</tr>
<tr>
<td>Operating Portion</td>
<td>2 000</td>
<td>12</td>
<td>24 000</td>
<td>15</td>
<td>88</td>
<td>1.00</td>
<td>3 170</td>
</tr>
</tbody>
</table>

**OBIP** = rock volume × porosity × bitumen saturation × net-to-gross

Net Pay cutoffs are:
- < 6% porosity
- > 20% $S_w$
- > 10% $V_{shale}$
No change in 2015.

No petrographic analysis were completed to identify minerals that could impact the scheme recovery.
No change in 2015
Net pay ranges from 66 to 86 m in the approval area.
STRUCTURE MAP OF TOP OF BITUMEN PAY

- No change in 2015
- The top of the bitumen pay is the eroded Leduc Formation.
- The structure for the top of the Leduc ranges from 281 to 292 m ASL in the approval area.
STRUCTURE MAP OF BASE OF BITUMEN PAY

- No change in 2015
- The base of the bitumen pay is the top of the Cooking Lake open marine unit.
- The structure for the top of Cooking Lake open marine unit has a uniform southwest dip and ranges from 192 to 216 m ASL in the approval area.
No change in 2015

There are five cored wells in the approval area including the type well 1AA/06-08-095-18W4/0.

Adjacent wells around the approval area have been cored.

Routine core analysis measured the porosity, bitumen saturation, and permeability ($k_h$, $k_v$, and $k_{\text{max}}$).

Select cores have been CT scanned to understand the porosity-permeability relationship.
No change in 2015
- No change in 2015
- 4D monitor survey acquired Q4 2012.
- 0.8 km² total area being monitored.
- Original 2010 survey being used as baseline.
- Time delay map of the Beaverhill Lake surface between the 4D monitor survey (2012) and original (2010) survey.
- Time delay results show no correlation to TAGD Field Test.
No change in 2015
Producer is heated to accelerate thermal communication between wells
ARTIFICIAL LIFT

STEAM-RATED BOTTOM HOLE INSERT PUMP:

- landed at 80° inclination.
- pumped with hydraulic pumping unit.
- pump was changed in September 2013 to help minimize gas locking issues.
- have pumped between 2 and 30 m³/d with new pump.
- flow assurance heater maintains 70°C uphole.
- dip tube attached to bottom of pump to lower intake point and achieve a more uniform in-flow.
- performed well
o Base oil introduced in observation wells to reduce temperature smearing effects due to reflux
INSTRUMENTATION OBSERVATIONS

Heater Well
- Fibre DTS data began to deviate from thermocouple data in April 2012.
- Fiber is now reading erroneously higher temperatures in majority of the heated section of the well.
- 1 failed thermocouple point.

Heater-Producer Well
- Fibre DTS data agree well with thermocouple data.
- 5 failed thermocouple points.
- Bubble tube has failed. Currently bubbling natural gas down casing annulus for pressure measurement.

Observation wells
- Convection in wellbore annulus is smearing temperature readings
- OB4 well has 2 failed thermocouple points.
Instrumentation tied to central data acquisition system for remote real-time monitoring and control from the field and Calgary
TAGD FIELD TEST PRODUCTION SUMMARY

- Heating from January to September in Heater well and Heater-Producer well.

- Production Cycle #4 (June 2014 to May 2015).
  - Pumping from 2 to 30 m³/d fluid
At caprock depth of 340 m TVD, fracture pressure estimated to be 7 300 kPa (i.e. 21.5 kPa/m).

Minor increase in pressure due to heating at producer; no change in pressure at observations wells in gas-bitumen zone.

All observed pressures well below maximum operating pressure of 5 100 kPa as specified in the Application.

No heave monitoring was conducted.
- Heater running at full power.
- Heater producer limited by maximum temperature.
Thermocouple data used to monitor heater temperature as fiber readings have become unreliable.
Based on transients observed when heaters are shut off

Non-uniform rock-face temperature along well potentially due to:

- Porosity variations along well
- Refluxing in build section
- Fluid phase distribution along well
OBSERVATION WELL TEMPERATURE

- Observed peak temperatures lower than expected from simulation.
- Convective smearing of temperatures.
HEATING PHASE – PRESSURE CHANGES

![Graph showing pressure changes over time for Heating and Production phases. The graph includes data points for Heating #1 to #5 and Production #1 to #4. There are markers indicating heaters and shut-in periods. The x-axis represents years from 2011 to 2015, and the y-axis represents pressure changes in kPa. The graph shows a significant drop in pressure changes over the years, with a notable peak in 2012.]

- **(P - P_i)**, kPa
- **Heater-Producer BHP**
- **100040809518W400_OB2 @ 224.5 m ASL**
- **Heaters Shut-in**
- Liquid rate controlled by pump
- High oil cut at start of each cycle
- Mobile water likely from disposal in 7-4

- Criteria for start up of each cycle varies in each cycle based on observations during heating, and predictions from history match
- Maximize oil recovery and initial oil cut
CYCLE #4 - MAJOR EVENTS

- Production shut-in
- Gas injection
- Gas co-injection
- Pump speed reduction
- Pump speed increase
- Staged Pump speed increases
  To maintain liquid rate

Heater Outages

Production shut-in; gas injection

Oil Cut, %

Liquid Rate, bbl/d
**Objective:**

- Understand the impact of gas co-injection on the TAGD process, particularly its role in providing additional voidage replacement for the gravity drainage process.
- Gas injection during shut-in is expected to accelerate fluid redistribution by gravity drainage, and reduce the period of shut-in required between cycles.

**Scope:**

- Inject up to 1000 m³/d of natural gas into the casing of producer well during subsequent cycles.
- Injection may be conducted during both shut-in and production conditions.
- The maximum injection pressure will be 1800 kPa.
- Impact of reduced relative permeability to oil due to gas injection offset by benefit from additional voidage replacement. High vertical absolute permeability would allow for gravity drainage.
RECOVERY FACTORS TO DATE

- Recovery factors (RF) have assumed a drainage box of 12 m H x 8 m W x 250 m L.
- RF only an estimate as system is unbounded.

<table>
<thead>
<tr>
<th>OBIP</th>
<th>RF (Year end)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 170 m³</td>
<td>46%</td>
</tr>
</tbody>
</table>
ENERGY VS CUMULATIVE OIL

Cumulative Oil recovered, m³

Cumulative Subsurface Energy Input, TJ
KEY LEARNINGS

**Cycle 1**
- **Objectives:**
  - Investigate early production potential
- **Observations:**
  - Produced more oil than expected; watered out at the end of cycle
- **Learnings & Implications:**
  - Oil mobilized at lower temperatures than expected
  - Need to operate cyclically to minimize water production

**Cycle 2**
- **Objectives:**
  - Determine heating time required to re-establish oil production
- **Observations:**
  - Fiber DTS showed oil production from toe and water from the heel
- **Learnings & Implications:**
  - 3 months heating is too short to establish gravity drainage between wells
  - Pump intake changed to achieve uniform inflow in HZ

**Cycle 3**
- **Objectives:**
  - Demonstrate gravity drainage from upper well
- **Observations:**
  - High initial oil cut with gradual decline
- **Learnings & Implications:**
  - Inter-well gravity drainage demonstrated

**Cycle 4**
- **Objectives:**
  - Validate forecasts
  - Test ways to increase heater power
- **Observations:**
  - Heat Transfer Fluid reduced temp in Heater well
- **Learnings & Implications:**
  - Higher heater power

**Cycle 5 Objectives**
- Increase inter-well temp to commercial target
- Test gas co-injection to enhance drainage
2015 KEY OBSERVATIONS

- Cycle #4 was by far the best cycle. Oil production continued at gradually declining rates for 12 months.
- Interwell temperatures were close to the TAGD target temperature of 150°C.
FIELD TEST PLOT PLAN

<table>
<thead>
<tr>
<th>TAG</th>
<th>EQUIPMENT DESCRIPTION</th>
<th>WIDTH</th>
<th>LENGTH</th>
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<tbody>
<tr>
<td>S100</td>
<td>100% - 200% - 300%</td>
<td>1000</td>
<td>2000</td>
</tr>
<tr>
<td>S200</td>
<td>200% - 300% - 400%</td>
<td>2000</td>
<td>3000</td>
</tr>
<tr>
<td>S300</td>
<td>300% - 400% - 500%</td>
<td>3000</td>
<td>4000</td>
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<tr>
<td>T100</td>
<td>100% - 200% - 300%</td>
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<td>2100</td>
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<tr>
<td>T200</td>
<td>200% - 300% - 400%</td>
<td>2100</td>
<td>3100</td>
</tr>
<tr>
<td>T300</td>
<td>300% - 400% - 500%</td>
<td>3100</td>
<td>4100</td>
</tr>
</tbody>
</table>

- No change in 2015
FACILITY PERFORMANCE

Generally stable and predictable battery performance

- Well pumping for ~139 days in 2015.
- Tubing production routed to separator.
- Solution gas is separated and sent to flare.
- Bitumen / water mix sent to production tanks.
- Emulsion trucked off site to sales.
- Submerged Combustion Evaporator operated to evaporate some of the produced water.
- Electrical power is generated on site.
- No steam generation.
2015 POWER CONSUMPTION

<table>
<thead>
<tr>
<th>Month</th>
<th>Power Consumption (MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>410</td>
</tr>
<tr>
<td>February</td>
<td>430</td>
</tr>
<tr>
<td>March</td>
<td>473</td>
</tr>
<tr>
<td>April</td>
<td>437</td>
</tr>
<tr>
<td>May</td>
<td>440</td>
</tr>
<tr>
<td>June</td>
<td>425</td>
</tr>
<tr>
<td>July</td>
<td>419</td>
</tr>
<tr>
<td>August</td>
<td>402</td>
</tr>
<tr>
<td>September</td>
<td>282</td>
</tr>
<tr>
<td>October</td>
<td>30</td>
</tr>
<tr>
<td>November</td>
<td>31</td>
</tr>
<tr>
<td>December</td>
<td>9</td>
</tr>
<tr>
<td>Monthly Average</td>
<td>317</td>
</tr>
</tbody>
</table>
2015 NATURAL GAS CONSUMPTION

![Bar chart showing monthly natural gas consumption with fuel consumed and gas injection categories.]

- January: 278 m³
- February: 249 m³
- March: 268 m³
- April: 246 m³
- May: 235 m³
- June: 214 m³
- July: 211 m³
- August: 189 m³
- September: 117 m³
- October: 29 m³
- November: 35 m³
- December: 14 m³
- Monthly Average: 173 m³
No change in 2015
No Changes to methodology

Bitumen and Water Production:
  o Daily tank gauging and manual water cut measurements.
  o Total fluid production meter FIT-0100 used as reference meter.
  o Additional verification will be through trucking and third party processing.
  o Evaluating new technologies: 2 Phase and 3 Phase BS&W analyzer.

Gas Production:
  o Solution gas measured from the produced gas meter at the separator.
  o Casing gas measured from the produced gas meter on casing line.
2015 PRODUCED OIL

<table>
<thead>
<tr>
<th>Month</th>
<th>Produced Oil [m^3]</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>46</td>
</tr>
<tr>
<td>February</td>
<td>87</td>
</tr>
<tr>
<td>March</td>
<td>65</td>
</tr>
<tr>
<td>April</td>
<td>65</td>
</tr>
<tr>
<td>May</td>
<td>31</td>
</tr>
<tr>
<td>June</td>
<td>0</td>
</tr>
<tr>
<td>July</td>
<td>0</td>
</tr>
<tr>
<td>August</td>
<td>0</td>
</tr>
<tr>
<td>September</td>
<td>0</td>
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<tr>
<td>October</td>
<td>0</td>
</tr>
<tr>
<td>November</td>
<td>0</td>
</tr>
<tr>
<td>December</td>
<td>0</td>
</tr>
<tr>
<td>Monthly Average</td>
<td>24</td>
</tr>
</tbody>
</table>
Produced water was disposed through evaporation to atmosphere or was trucked with the emulsion.
2015 PRODUCED GAS

Period Solution Gas Produced / Flared (m³)

- January: 0.4
- February: 0.1
- March: 0.1
- April: 0.1
- May: 0.1
- June: 0.0
- July: 0.0
- August: 0.0
- September: 0.0
- October: 0.0
- November: 0.0
- December: 0.0
- Monthly Average: 0.1

Legend:
- Blue: Total Solution Gas Produced m³
- Orange: Total Solution Gas Flared m³
2015 GREENHOUSE GAS EMISSIONS


<table>
<thead>
<tr>
<th>Source</th>
<th>Total GHG Emissions, t CO₂e/y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combustion</td>
<td>4,590</td>
</tr>
<tr>
<td>Flaring</td>
<td>0</td>
</tr>
<tr>
<td>Venting</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>4,590</td>
</tr>
</tbody>
</table>
SULPHUR RECOVERY

- No Change
- The produced gas samples indicated no detectable $\text{H}_2\text{S}$.
- Sulphur recovery is not required for this test.
TAGD Field Test Compliance
May 8th, 2015 - AOC submitted application to inject 1 000 m³/d of natural gas into producer well 100/06-08-095-18 W4M

August 14th, 2015 - Experimental Scheme Approval No.11546F was received for Gas Co-Injection

September 21st, 2015 - AOC successfully concluded the TAGD field test

September 28th, 2015 - AOC submitted notification to the AER regarding field test conclusion
AOC confirms compliance to:

- Experimental Scheme Approval No. 11546F
- EPEA Approval 298764-00-00

AOC has not started reclamation as the project is still active.
REGIONAL INITIATIVES

AOC is a funding member of the following:

- Oil Sands Community Alliance
- Joint Oil Sands Monitoring Program
- Wood Buffalo Environmental Association
- Alberta Biodiversity Monitoring Institute
Plans
The TAGD Field Test has met or exceeded all objectives
AOC terminated the TAGD Field Test in September 2015
AOC has received approval to construct a TAGD Pilot:
  o Approval 11546D received from AER on September 19, 2013
  o Approval for the MARP received from AER on December 10, 2013
  o EPEA Approval 298764-00-00 received from AESRD on December 17, 2013
  o AOC may re-use some of the Field Test facilities for the TAGD Pilot
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