Field Production and Heater Test Project

Amended Experimental Scheme Approval 11487A
Progress report: Long Horizontal Heater Test (LHT)

2013 Performance Review to AER

January 22nd, 2014
Key Messages

- This progress report focuses on the Long Horizontal Heater Test (LHT) results. LHT is one of the two pilots in the Amended Experimental Scheme Approval 11487, Shell’s Field Production and Heater Test Project. The Water Assessment Test (NFTw), the other pilot included in the amendment, is currently in the initial heat injection phase. NFTw is also operated at the same location and should be completed this year. These two tests constitute the 1st Step pilots to de-risk the application of the In-Situ Upgrading Process (IUP) technology in Grosmont.

- LHT was successfully completed on December 16th, 2013. LHT results confirm the commercial heater design to be used in the IUP technology that enables the recovery of extra-heavy oil and bitumen resources. IUP technology has been demonstrated in a sandstone reservoir (Project Viking at Peace River, Experimental Scheme Approval 9874) and it is proposed as the primary recovery method for the Grosmont carbonate reservoir.

- LHT results exceeded expectations, demonstrating robustness during thermal cycles and confirming expected heat injection rates required by the recovery process.

- LHT was executed and operated with no impact to the environment. HSSE monitoring was conducted and mitigation plans were defined and implemented to respond to incidents, when required.

- Challenges during the drilling campaign delayed the start of pilot operation. LHT start-up was delayed ten months while NFTw was delayed eight months as compared to the project schedule submitted in the scheme amendment application of December 7th, 2010.

- LHT abandonment will be conducted tentatively in 2015, pending on NFTw completion.
Today’s Agenda (following Directive 54)

I. Subsurface Issues related to Resource Evaluation and Recovery
   1. Background to the In-Situ Upgrading Process (IUP) and de-risking strategy
   2. Geology/Geosciences
   3. Drilling and Completions
   4. Artificial Lift – N/A*
   5. Instrumentation in wells
   6. Seismic
   7. Scheme performance
   8. Future Plans

II. Surface Operations, Compliance and Issues not related to Resource Evaluation and Recovery
   1. Facilities
   2. Measurement and Reporting – N/A*
   3. Fresh water and brackish water sources and uses – N/A*
   4. Water treatment technology (problems/successes) – N/A*
   5. Water and waste disposal wells and landfill waste – N/A*
   6. Sulphur production – N/A*
   7. Summary of environmental issues
   8. Statement confirming compliance with all conditions of the approval and regulatory requirements

* Not Applicable: no fluid injection or production as per pilot design.
Value Proposition

In Place Bitumen
6 – 10 °API

Low Recovery of Low Value Bitumen

Current Recovery Method – Cyclic Steam Stimulation

Working to Improve Recoveries

25% Recovery

High Recovery of High Value, Upgraded Product (30 – 49 °API)

Relative Revenue

CSS: 25% Recovery x 50% WTI = 12.5

IUP: 50%+ Recovery x 100% WTI = 50+

Leave low value bottom-of-barrel behind

Dist
VGO
Resin
Asph

Naphtha
Jet & Diesel

Heavy Gas Oil
What are the Grosmont 1st Step Pilots?

IUP

Subsurface, Water impact on Energy Balance

Recovery Efficiency, Energy Balance, Product Quality

Commercial Heater de-risking

Project Execution Costs and Timing

System Uptime, Product Stability

Unlock Grosmont

The LHT and NFTw tests constitute the 1st Step pilots to de-risk the application of the IUP technology in Grosmont.

Test-to-Commercial (T2C) Philosophy:

- Learn by doing: clear, sequential, meaningful, value driven steps
- Prepare “commercial” option, demonstrating that technology works and risks can be mitigated
- Progress appraisal and field testing to inform acreage retention decision by lease expiration
- Address non-technical risks properly to ensure successful commercial development
LHT Pilot: 1st De-risking Step for Grosmont

- Key uncertainties for IUP technology de-risking in a carbonate reservoir:
  - Long-term heater reliability in resource
  - Pressure and temperature response along heater as function of time
  - Deployment of longer heaters (> 610 m)

- LHT Pilot objectives
  - **Mechanical integrity** – Investigate thermal stresses and buckling of long horizontal heater in open-hole wellbore.
  - **Heater/subsurface interactions** – Investigate open hole friction, short-term geomechanical risk, thermal stability, heater hot spot management.
  - **Heater deployment** – Demonstrate feasibility of running a fully coiled heater assembly into long horizontal open hole in Grosmont.
  - **Operational learnings** – Joint effort of Gasmer heater team and Canada wells, completions and operations teams; demonstrating deployment and effective heater control strategies.

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<thead>
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Location Map: Shell Leases in Grosmont

Pilots location

Shell leases
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Regional Data

Regional Upper Devonian Cores
(NISKU, UIRE, UGM3, UGM2, UGM1, LGM)
as of June 2012

Shell
- Nisku
- Upper Ireton
- Upper Grosmont 3
- Upper Grosmont 2
- Upper Grosmont 1
- Lower Grosmont

Laricina
- Nisku
- Upper Ireton
- Grosmont D
- Grosmont C
- Grosmont B
- Grosmont A

Wells:
- Shell drilled 59 wells
- 62 Legacy wells

3D Seismic:
- Appraisal 3D 104 km²
- Pilots baseline 3D 3.1 km²
Upper Ireton Reservoir Characteristics

- Dolomite with thin silt laminations, brecciated zones, corrosion intervals
- Depth 300 m
- Temperature 11°C @ 320 m
- Pressure 1.4 MPa @ 320 m
- Bitumen saturation 80-90%
- Porosity 22-35% (Matrix)
- Horizontal matrix permeability range 20-200 mD; fracture permeability range 2-20 Darcies
- Bitumen viscosity 1,800,000+ cp
- Regional hydrology & water chemistry show that water is contained within the HC trapping system
LHT Trajectory and Facies

Ireton-A Units

A6
A5
A4
A3
A2
A1
A0

Fractured Laminated Dolomite

LHT target landing

Top UGM3
LHT Composite Well Log

Horizontal Section
3D Seismic, Lithology and Fracture Interpretation

LHT well

Kunc/top Nisku

PEF, calcite

Grosmont

Breccia

Dolomite

Fracture Intensity

UIRE
LHT, Sinkholes on Semblance Slice

Semblance Slice Near Top Grosmont
### Pilot Seismic Acquisition 2013

#### Survey Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>User Defined</th>
<th>Calculated (Approximation)</th>
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<td>Bin Size (m)</td>
<td>5m X 7.5m</td>
<td>Source Density (# / sq. km 1,067)</td>
</tr>
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</table>

#### Challenges:
- Simultaneous Operations
  - Drilling / Completions / Construction
- Weather
- Short timeline
- Roads (AlPac)
- Limited Pad access (rig matting)
- Caribou Protection Plan (early in – early out)
- HSSE! Keeping everyone safe is Goal #1
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- Well landed, as planned, within the UIRE A1 and A2 layers
- Drilled within 0.5m of the planned trajectory

10009-34-090-23W40 LHT
LHT Well Diagram

Long Heater Test (x1 well)
Well Name: LHT
As-Built: 16 January 2013

Intermediate Instruments:
Pressure:
- (2) Gauges (ported inside)
- (1) Bubble tube (ported inside)
Temperature:
- (2) Thermocouple pts (embedded one each in pressure gauges)

Canister Instruments:
Temperature:
- (24) Thermocouple pts (duplex)
- (1) Fiber Optic DTS: 0.25” line

Surface Casing:
Size: 13-3/8”
Weight: 54.50 lb/ft (81.10 kg/m)
Material: K55
Connections: STC

Intermediate Casing:
Size: 9-5/8” OD
Weight: 40 lb/ft (59.53 kg/m)
Material: L80 IRP (TN80SS)
Connections: LTC

Heater Canister (coiled tubing)
Hole size: 7-7/8”
Size: 4.5” OD
Weight: 0.25” wall thickness
Material: Tenaris HS-70

Well Objective:
1) To provide conduit to deploy heater in 4.5” canister
2) To provide pressure measurements throughout the heating period at the shoe of the well

Pressure gauges (cemented):
(2) x 3/16” cables
Ported to casing ID

Bubble tube (cemented):
(1) x 3/8” tube
Ported to casing ID w/ rupture disk

DTS Fiber:
(1) x 1/4” cable
Temperature Rating: 700 °C

Thermocouples:
Behind intermediate: (2) pts imbedded in pressure gauges
In canister: (12) x 1/8” MI cables, duplex

Depth reference: KB = 549.22 masl, GL = 544.20 masl
(LHT-3) Final Survey
# LHT Subsurface Thermocouples & Pressure Sensors

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<td>LHT1-PE-29</td>
<td>LHT #1 WELLHEAD (CANISTER)</td>
<td>n/a</td>
</tr>
</tbody>
</table>
Data Flow

PI Collector

Fiber Optics

Thermocouples

Bubble Tube

Display

SCADA

Shell Network & PI System

Selected Data

Office Workers / Surveillance / Scientists

DTS Server

Summary Data

DATA

DATA

ION Electrical Data

Thermocouples

Bubble Tube

ERE Pressures

Operator HMI

Selected Data
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</tr>
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<td><strong>Heater/subsurface interactions:</strong> frict., short term geomech risk, hotspots</td>
<td>Complete</td>
</tr>
<tr>
<td><strong>Heater deployment:</strong> demonstrate long heater open hole deployment</td>
<td>Complete</td>
</tr>
<tr>
<td><strong>Operational learnings:</strong> PT &amp; UA joint effort, eff. heater control strategies</td>
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196 days online  
128 days at high heat injection rate  
27 days at 650 °C

**Key Results:**

- A 610 m commercial MI heater concept has been demonstrated for Grosmont
- Program exceeded pilot objectives of 4-month test plan, capturing learnings originally estimated to take 12 months of heating.
LHT Deployment Learnings

- Force and drag data recorded during deployment of 610 m heater

- Estimated dynamic friction force:
  \[ F_{μd} = 6713 \text{ kgf} (14800 \text{ lbf}) \]

- Estimated static friction force:
  \[ 8727 \text{ kgf} < F_{μs} < 10070 \text{ kgf} \]
  \[ (19240 \text{ lbf} < F_{μs} < 22200 \text{ lbf}) \]

- Friction factor is in the range:
  \[ 0.18 – 0.21 \text{ (cased hole)} \]
  \[ 0.24 – 0.30 \text{ (open hole)} \]

- Observations and sensitivity studies suggest that heaters longer than 610 m can be successfully deployed

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![Sensitivity study (LHT dynamic friction)](image-url)
- Two pressure gauges and one bubbler tube set above stage collar in annulus
- Reservoir pressure operating limit set conservatively at 3310 kPa considering 4157 kPa maximum
- Pilot started in January. Power generation issues affected continuous operation and were solved in July.
- Ramped up heat injection using power control mode until shifted to manual temperature control mode to manage developing hot spots (as per operating procedure). This indicates that formation cannot take the maximum heat injection rate for an extended period of time and should stabilize at a lower value.
- Heater and instrumentation endured various thermal cycles without any major issues to date. Fiber optic for temperature sensing failed at expected threshold.
- Pressure behavior confirms the expected bitumen banking process for plugging the fracture network.
- Heat injection control has been demonstrated as an effective way of managing hot spots.
- Heater temperature progression has exceeded expectations. Time to boil off water was less than predicted by models, which has allowed observation of behavior post-boil off and approximation to design temperature as well as heater mechanical integrity at full operational temperatures.
- Four-month operation at high heat injection rate achieved.
Heat injection control has been effective to manage the maximum temperature. Hot sections have not gone beyond the maximum operating temperature and they become more evenly distributed with time:
- Localized high temp. areas develop quickly (↑) and later spread (→→)
- Remaining colder sections gradually heat up (↑)

Locations where hot areas initially developed can be correlated to some geological features.
• Initial hottest section is dominated by calcite with no breccia and limited fractures.
• Homogenous heat pattern is observed at high temperature and extended time.
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   4. Artificial Lift – N/A*
   5. Instrumentation in wells
   6. Seismic
   7. Scheme performance
   8. Future Plans

II. Surface Operations, Compliance and Issues not related to Resource Evaluation and Recovery
   1. Facilities
   2. Measurement and Reporting – N/A*
   3. Fresh water and brackish water sources and uses – N/A*
   4. Water treatment technology (problems/successes) – N/A*
   5. Water and waste disposal wells and landfill waste – N/A*
   6. Sulphur production – N/A*
   7. Summary of environmental issues
   8. Statement confirming compliance with all conditions of the approval and regulatory requirements

* Not Applicable: no fluid injection or production as per pilot design.
Future Plans

- LHT pilot will continue running while the heating phase of the NFTw pilot is completed since the power generator turndown ratio is not low enough to operate NFTw without LHT.
- Decommissioning, Abandonment and Reclamation (DAR) of both pilots will be conducted once the NFTw pilot is successfully completed. DAR activities are currently planned for 2015.
- Data acquired during the pilots will continue to be analyzed and used to calibrate the reservoir models. Based on the outcome of this analysis, Shell will define the way forward in terms of further piloting activities.
Today’s Agenda (following Directive 54)

I. Subsurface Issues related to Resource Evaluation and Recovery
   1. Background to the In-Situ Upgrading Process (IUP) and de-risking strategy
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Plot Plan
Operations Timeline

- LHT and Facilities mechanical completion – December 2012
- Facility and LHT Start up – January 2013
- LHT shutdown due to G5000 generator mechanical issues (intermittent heater operation from February – July 2013)
- LHT re-started in August 2013
- Facility and LHT Operating smoothly from August 2013 to Present
Operations Support

- Operations and support staff accommodations located at the pad facility
- Operations coverage 24/7 at site
  - 12 hour day shift / on call during off hours
  - Minimum 2 people per shift rotation
    - On site supervisor
    - Electrician/Instrumentation
- Support staff based in Calgary and Houston
  - Heater Team, Reservoir Team in Houston
  - HSSE, SD, Surveillance, Wells, Finance in Calgary
  - Operations and ERP support from Peace River In-Situ organization
Facility Modifications

- 5 diesel tanks removed from service
  - Tanks 1001 and 1010 due to pinhole leaks in tank wall
  - Tanks 1013, 1014, 1015 not required for operations
- Diesel Filter skid modifications to improve operations
  - Drain valves modifications to allow for filter changes
  - Install site gauge and EHT to the filter skid drain tote
  - Replace filter canister PSV’s to PRV’s
- Change recycle line from TK 1001 to TK 1012
Today’s Agenda (following Directive 54)

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Environmental Monitoring Programs

All results from 2013 environmental monitoring programs collected for baseline understanding & potential future commercial EPEA\(^{(1)}\) regulatory applications.

There are no environmental impacts nor Grosmont business actions required from monitoring results.

**Air Quality** Monitoring

- 1 Passive Station on Pad A installed in March 2013
- Monthly Air Sampling completed in 2013; Monthly sampling to continue in 2014

**Shallow Groundwater** Monitoring (< 20 m from ground surface)

- 3 shallow monitoring wells installed in March 2013 (1 on North side, 2 on South side)
- 3 sampling events completed in 2013; Quarterly sampling to continue in 2014

**Surface Water Quality** Bi-Annual Sampling on Lake Chipewyan

- 3 shallow monitoring wells installed March 2014 (1 on North side, 2 on South side)
- Finalizing Report of 2013 data and trending analysis of data collected from 2007
- Bi-Annual (~ May & Sept) Sampling Events ongoing in 2014

**Wildlife (Caribou)** Surveys

- Spring & winter wildlife/caribou baseline surveys completed
- There were no Caribou sightings reported within Grosmont Lease
- Program complete. Reports will support future Grosmont Caribou Recovery Management Strategy

\(^{(1)}\) EPEA: Environmental Protection and Enhancement Act
Waste Volumes

- GFL Liquid Waste Slave Lake Facility (Duece Disposal Services)
  - Lube oils /diesel / glycol: 1650 Litres
  - Oil filters: 440 Kg
  - Oily Rags: 360 Kg

- Tervita Services Slave Lake Facility
  - Contaminated Water: 555 m³
  - Contaminated Snow: 532,000 kg
Environmental Incidents

- Berm Failure – surface water runoff released prior to testing – no environmental impact
- Sodium Silicate / Calcium Nitrate spill (drilling materials), which resulted in large clean up work due to material spread across pad surface during spring thaw – materials and contaminated water/snow cleaned with no environmental impact off pad
- 2 Glycol spills < 0.1 m³
- 3 generator engine oil spills within building containment (36 liters)
- 2 diesel spills within diesel tank farm and skid containment
Today’s Agenda (following Directive 54)

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Compliance

- To the best of Shell’s knowledge, Operations at Experimental Scheme Approval No. 11487A (Grosmont) are consistent with all conditions of the approval.

- Decommissioning, abandonment and reclamation of the pilots will be conducted following the guidelines of the applicable Directives.