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Downhole Heating
A New and Robust Re-Creation of a Proven Technology
Outline

- Origins of Technology
- Commercial Heater
- Technology in Action
  - Deployment in Alberta
- Economics – Customer’s Perspective
- Downhole Heater – Other Applications
- Summary
Heaters in Heavy-Oil Plays

**Thermal viscosity reduction**
- Benefits of heaters in long laterals
  - Pump with no Heater
  - Uneven drawdown along the well
  - Significant water coning
  - Pump with Heater
  - Balanced drawdown along the well
  - Reduced water coning

**SAGD pre-heat**
- Heating up near wellbore

**In-situ Upgrading Process**
- Heating up the entire reservoir

**Heat delivery systems**
Commercial Heater
MI Heater Development Program

After extensive development, the Mineral Insulated (Electrical) heater is now commercially viable.
Salamander Heaters: Unmatched in Power, Length and Reliability

- Only cable that can deliver high power at long length without splices, leading to superior reliability
- An order of magnitude improvement over competing technology in the areas of heat and power delivery in harsh environments
- Unique, patent-protected manufacturing process
- Well-suited for subsea flowlines
Technology in Action

Deployment in Alberta
Canada – *In situ* Deployment of Heaters
Asset Description

Geology
- Pay: 20-40 m thick Bluesky formation
- Porosity: 0.24 – 0.26
- Permeability: 500 – 3,000 mD
- Viscosity: 5,000-20,000 cp (pay zone)
- Pockets of crestal gas may exist

Production
- Primary
- Horizontal Wells – single and dual laterals (occasional trilateral)
  - Lateral length: 1,200-2,500 m
  - Liner in only one of the two legs
- Progressing Cavity Pump
Well Trajectory – Dual-lateral Production Well

Oil Saturation: $0.72 < S_o < 0.80$

- Black curves show the trajectory of the laterals
- Heater is installed in the lower lateral
- ‘Stinger’ configuration: 884-m-long heater inside coiled tubing
- Novel cross-over piece tool lead cable from annulus to heater
- ESP cable clamped to tubing at every joint and mid-joint
Downhole Heater – Deployment in Alberta, Canada
Oil Production – Field Data and History-Match

- Well had been cold-producing for almost nine years
  ✓ Ample data to understand/history-match well performance
  ✗ Depleted reservoir energy
Oil Production – Field Data and Model

Conclusions

- Heater performance is not affected by power fluctuations
- Heat in ➜ Oil out, as forecasted by reservoir model (CMG-STARS)
Downhole Heater Economics
Downhole Heating Economics – Customer’s View

Assumptions

- Significantly discounted market price of oil (Western Canada)
- Market value of produced gas is zero
Downhole Heater – Other Onshore Applications
SAGD Downhole Pre-heating – LinkWell

SAGD Pre-heating Benefits

- Accelerating steam injection and thus first oil
  – e.g. SAGD pre-heat
- Improving steam injectivity and conformance
  – Balanced mobility contrast

Steam injection with no heater

Steam injection with heater
Summary

- Salamander Solutions have brought into the market MI cables with an order-of-magnitude better reliability and length for heating of wells and flowlines.
- A 2260-m-long heater assembly was successfully deployed and has been operating for over a year in a dual-lateral horizontal production well that had been cold-producing for nine years.
- Heater has been performing well and production improvement has been within expected range:
  - Oil rate increased by >4X; water cut was reduced.
- Subsurface heat delivery systems can be used in other applications (e.g. SAGD pre-heating, wax removal, subsea lines).
THANK YOU

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Salamander Solutions MI Heater in Coiled Tubing

- Salamander (ex-Shell) have installed ~25 heaters inside coil or strapped to tubing from 15 to 900 meters in US, Canada, and Jordan
- Salamander heaters have undergone extensive testing
- Heater operations have proven to be safe
Downhole Heating – Advanced Reservoir Model

- Temperature versus distance from heated wellbore after ~6 months of heating

![Downhole Heating Graphs](image-url)