Large 3D Physical Model at SRC: Realistic Results for Unconventional Hydrocarbon Reserves
Solvent and Thermal Recovery Techniques

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Agenda

- Canadian Heavy Oil and Bitumen Deposits
- Heavy Oil and Bitumen EOR Processes
- Importance of 3D Physical Modelling
- SRC’s Low and High Temperature 3D Physical Modelling Lab Facilities
- Concluding Remarks
Canadian Heavy Oil and Bitumen Deposits

~2,500,000,000,000 BBL (~350×10^9 m^3) of Heavy Oil (8.5-20.0 API gravity) → Alberta and Saskatchewan

15% Fractured Carbonates
85% Unconsolidated Sandstone

Current Primary Production and Proven EOR Methods will leave ~90% behind in the reservoir

Even if 30% of the Canadian Heavy Oil and Oil sands deposits are accessed → Fulfill Canada & USA needs for over 100 years (consumption at 20,000,000 BBL/day (~1.2×10^9 m^3/yr)
Canadian Heavy Oil and Bitumen Deposits

Solvent Concentration, mol% vs. Temperature, °C

- **Reserves**
  - Depth < 75 m: ~200 billion bbls
  - 75<Depth < 200 m: ~600 billion bbls
  - Depth > 200 m: ~1,800 billion bbls

- **Currently Un-Explored**
  - New Process Development
    - SVX
    - Warm/Hybrid SVX
    - SVX-Thin Gas Cap Reservoirs
      - T-SVX
      - ES-SAGD
      - SAS

- **Realms of Surface Mining**
  - Process Optimization
    - Heat and Mass Flow Physical Modeling
    - Heat and Mass Flow Numerical Modeling

- **Reservoir T & P**
  - (10 - 20 °C)
  - (300 - 1500 kPa)

- **Steam Injection T & P**
  - (172 – 240 °C)
  - (850 - 3500 kPa)

- **(>200 °C)**
  - (>2000 kPa)

- **Commercial SAGD Projects**
  - SVX POST SAGD
  - Wedge Wells
  - Isothermal SAGD
  - Adiabatic SAGD
Solvent Vapour Extraction (SVX) Process

- Involves injection of hydrocarbon solvents.
- Their mixtures with non-condensable gases.
- Injected through laterally and vertically separated injection and production wells.
- Composition set that solvent mixture stays in vapour state.

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Recovery Processes for Reservoir Depths Between 75 and 200 meters

Warm Hybrid SVX Process

- Involves injection of hydrocarbon solvents similar well configuration as of SVX processes.
- Elevated reservoir temperature.
- Multiple options of increasing reservoir temperature: hot waterflood, increasing injection and production wellbore temperatures, electrical heating, saturated steam injection with accordance to reservoir pressure.
- Cyclic and continuous solvent injection.
SVX with T-Wells

- Additional horizontal injection well perpendicular to the horizontal production well.
- Placed in top of the reservoir along the width of the reservoir.
- Provides larger area for the solvent to contact the oil and generate an additional diluted oil profile perpendicular to the diluted oil profile of classical SVX process.
Recovery Processes for Reservoir Depths Between 75 and 200 meters

SVX with Thin Cap Rock or No Cap Rock Reservoirs

- One horizontal injection well placed in the middle bottom of reservoir.
- Two production wells laterally spaced and horizontally placed in the bottom corners of reservoir.
- The well configuration is most suitable for thin gas cap or no gas cap.
Expanding Solvent SAGD (ES-SAGD)

- Hydrocarbon solvents with steam are injected in a gravity dominated process similar to SAGD.
- The suitable solvent types are vaporized and condensed with steam simultaneously along the steam chamber boundary.
- The presence of solvent slows the vertical growth of the steam chamber and thus reduces the heat losses.
SVX POST SAGD

- Hydrocarbon solvents are injected at the end of steam injection phase with the same well configuration as of SAGD.

- The injected solvent not only drains the oil from the SAGD swept zone (having 10 to 15% of oil saturation) but also mobilize the oil placed between injector and producer.
**SAGD and ES-SAGD with Wedge Wells**

- Even at the end of SAGD, ES-SAGD or SVX Post SAGD a significant amount of oil is always present that are outside the reach of solvent or steam chambers.
- Wedge wells vertically aligned to the injection and production wells are placed in the wedges of the reservoir.
- Solvent injection or solvent additive steam injection is continued to achieve maximum %OOIP recoveries.
The best tool to evaluate the recovery performance of heavy oil or bitumen EOR processes is numerical simulations.

For accurate and reliable process evaluations or field scale predictions from numerical simulations, tuned numerical models are required with detailed attention to physical phenomenon happening in the real field reservoirs.

The 3D physical modelling is the best way to generate the datasets for tuning of the numerical models.

The data generated from the experiments performed on 3D physical models can capture the physical phenomenon happening in the real field (especially with the third dimension involved).

SRC have the lab facilities to conduct the 3D physical modelling studies of thermal and steam based heavy oil and bitumen recovery processes. These studies are used to perform semi-analytical and numerical modelling of these processes to predict field scale estimates.

1. Low Temperature EOR Processes 3D Physical Model Lab Facilities
2. High Temperature 3D Physical Model Lab Facilities
Overburden Pressure Vessel System

- Pressure rated at 10.5 MPa.
- Temperature controlled between 20 and 60°C.
- Inside diameter = 1.06 m.
- Inside length = 2.5 m (usable).
- Can be rotated 90° from horizontal to vertical for thick vertical sections.
- Uses water for overburden fluid.
Low Temperature EOR Processes 3D Physical Modelling Lab Facilities

3D Physical Model System

- Pressure rated at 5.0 MPa.
- Temperature controlled between 20 and 60°C.
- Use of synthetic or actual field porous media and fluids.
- Resaturation of model with either dead- or live-oil systems.
- Continuous solvent chamber imaging using a grid of 90 thermocouples.

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The Overburden Pressure Vessel

- Pressure rated at 10.5 MPa
- Temperature controlled between 5 and 250°C
- Rotate 90° from horizontal to vertical – *More Geometries*
- Duratherm for overburden fluid – *Low Vapour Pressure*
- Inside: diameter = 1.06 m, Length = 2.5+ meters
- Two Autoclave Doors – *One each end*
The 3D Physical Model System

- Stainless Steel Tub and Weld-on Lid design – *With Bracing*
- NPT Connections for Wells, Imbibing Ports & Thermocouples
- Pressure rated at 10.0 MPa
- Temperature between 5 and 250+°C (Can be higher than overburden)
- Different Model Sizes, Well Types and Locations Accommodated
- Use of Actual Field Porous Media and Field Reservoir Fluids
Live Oil Mixing System

MAWP = 10.5 MPa at 60°C,
Volume = 200 L
Facilitates Pressure-Depletion

TSVX Data Acquisition & Control

SVX Data Acquisition & Control
What We Get From Experimental Studies

✓ Run Parameters and Variables
✓ Oil, Water and Gas Production Rate and Recovery with Time
✓ Gross and Net Solvent or steam Oil Ratios with Time
✓ Gas Composition with Time – *Indicates solvent ‘storage’*
✓ Solvent Material Balance – *Indicates solvent ‘retention’*
✓ Operating Pressures with Time – *Inlet, outlet and differential*
✓ Produced Oil Analysis with Time – *Mol fraction, GOR, density and viscosity*
✓ Original and Produced Dead Oil – *SARA, CND, mol wt., density, viscosity*

The obtained datasets are used to perform:

✓ Analytical Field Scaling – *Solvent Injection/production and oil production rates*
✓ Numerical modelling – *History matched numerical simulation*
What We Get From Experimental Studies

Process Simulation & Scaling:

✓ Semi Analytical modelling – *Two Methods Developed*
  - Explicit Dispersivity Flow Model and Scaling Method
  - Implicit Dispersivity Flow Model and Scaling Method

✓ Numerical modelling – *Tuned Simulation Models*
  - Numerical Simulation modelling → Scaling and predicting field estimates
  - Commercial Numerical Simulators from CMG are used: STARS & GEM

EOS Determination of Solvent Vapour Qualities

Special PVT analysis and Fluid Characterization
Concluding Remarks

- SVX and SVX-based hybrid processes reduce capital and operating costs.
- These processes use less natural gas and produce lower greenhouse gas emissions than thermal processes.
- They are comparatively more environmental friendly.
- These may be the only processes acceptable on the basis of not only economic and technical grounds but also of public concerns.
- Technology development and field scale implementation of these processes is in the best interest of general public as well as oil industry.
- Quality data obtained from 3D physical modelling and reliable and accurate field scale predictions are the most important factors in process and economic evaluation of these processes.
- SRC is playing a major role towards the field scale implementation of these processes.
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