



HEAVY OIL RECOVERY METHODS

COURSE OUTLINE

This course will cover the reservoir engineering aspects of oil recovery by steam-injection based oil recovery processes, In Situ Combustion (ISC), and primary recovery by Cold Heavy Oil Production with Sands (CHOPS). Therefore, it is a complete course in the sense that primary, secondary and even tertiary recovery of the heavy oil is presented. The emphasis is both on the fundamentals and physical simulation, and on the field applications, including piloting and commercial scale; the largest commercial operations are analysed for each process. Also, the emerging technologies are presented for each category of processes.

A) Cold Heavy Oil Production with Sands (CHOPS)

- Introduction/Background/History, Who invented CHOPS?
- Primary Recovery by Solution Gas Drive (SGD) and Enhanced Solution Gas Drive (ESGD) or Foamy Oil Mechanism; the crucial difference between SGD and ESGD
- CHOPS (Cold Heavy Oil Production with Sand) as a means to activate the ESGD Mechanism/ Progressive Cavity Pumps (PCP) use to sustain CHOPS
- Field Observations; use of PCP's
- Laboratory investigations for foamy oil and CHOPS
 - 1) Foamy oil
 - Micromodels
 - Pressure depletion tests
 - Oil-gas dispersion mobility tests
 - 2) CHOPS
 - Sand production in lab tests; laboratory wormholes and scouring regions
 - Sand transportation within wormholes
- Heavy oil reservoir characteristics making reservoirs amenable to CHOPS exploitation; vertical wells versus horizontal wells (HW) use
- State of reservoir at the end of CHOPS exploitation; assessment of CHOPS related heterogeneities; representation of wormholes in the simulator
- Pros and cons for CHOPS acceptance (thickness criterion); when to opt for CHOPS and when for other approaches. Technical limitations in further advancement of CHOPS
- Example of almost complete information for a field exploited by CHOPS (L. reservoir); other field examples
- Technical means to promote CHOPS exploitation; triggering the generation of wormholes (sand production on demand)

B) Steam-Injection Based Oil Recovery Processes

1. Qualitative Description of Steam-Injection Based Oil Recovery Techniques

- Steam drive (SD)
- Cyclic steam stimulation (CSS)
- Steam Assisted Gravity Drainage (SAGD)

- New approaches
 - SD in line drive configuration, TTH-SD
 - CSS with horizontal wells
 - SAGD with vertical injectors, SW-SAGD
- 2. The Mechanisms of the Steam-Injection Based Oil Recovery Processes**
- Heat losses to traversed and adjacent formations
 - Residual oil saturation (Sor) in the steamed zone
- 3. Basic Laboratory Tests**
- Oil viscosity variation
 - Corefloods (Sor and hot water-oil relative permeability curves)
 - 3-D model tests (vacuum models, TTH models, etc.)
- 4. Design of the Steam-Injection Based Oil Recovery Processes/Performance Prediction**
- Theoretical aspects and modelling – basics. Limitations
 - Cyclic steam stimulation (CSS)
 - Steam drive; single and multisand reservoirs; dipping reservoirs, etc.
 - SAGD; oil sands and heavy oil reservoirs
- 5. Implementation, Operation, Monitoring and Evaluation of steam-injection based processes**
- Conventional steam generation and cogeneration; steam quality, steam-distribution system
 - Injection wells; completion, selective or non-selective injection – injection profile surveys
 - Production wells; inner liners, sand consolidation, etc.
 - Operational aspects/problems (steam injectivity problems, premature break-through, wells stimulation, etc. Interwell tracer surveys
 - Observation wells; temperature surveys; gas and oil saturation logging
 - Coring wells; coring procedures and core analysis
 - Heat management; steam-oil ratio (SOR)
- 6. Optimization of steam injection processes**
- CSS
 - Steam drive (infill drilling, steam followed by water injection, water-alternating steam, steam with foaming additives, etc.
 - SAGD; SAGP, SAGD with off producers, limited steam chamber's height situation, etc.
- 7. Current Status of steam-injection based Projects. Commercial Application**
- The World's Most Significant Commercial Steam Drive Applications, inside and outside USA, including Kern River and Duri field
 - CSS Commercial Applications (USA, Canada, Venezuela)
 - SAGD Piloting and Commercial Applications in Canada

8. Emerging technologies

- CSS; steam-solvent injection (LASER process), steam-air injection, use of HW in CSS operations, etc.
- Steam drive; steam flooding with horizontal fracturing, TTH steam flooding, etc.
- SAGD; ES-SAGD, Fast SAGD, etc.

9. Application of steam-injection based processes to special situations; bottom water or/and gas cap present and fractured rocks

- CSS
- Steam drive
- SAGD
- Some field examples

C) Oil Recovery by In-Situ Combustion

1. Qualitative Description of In-Situ Combustion Techniques

- Forward and Reverse Combustion
- Dry, Wet and Super wet Combustion
- Segregated In-Situ Combustion
- Cyclic In-Situ Combustion (CISC)

2. Mechanisms of the Forward Combustion

- The Main Chemical Reactions. HTO and LTO
- Kinetics of oxidation; Apparent Atomic H/C ratio
- Fuel Availability and Air Requirement

3. The Laws of the ISC Front Propagation

- Dry Combustion
- Moderate wet and super wet combustion

4. Basic ISC Laboratory Tests

- Ramped Temperature Oxidation (RTO) of Oil in Porous Media
- ARC technique
- Combustion Front Propagation in a One-Dimensional Cell – Combustion Tube (CT) Tests

5. Theoretical Aspects and Modelling of ISC

- Analytical Models
- Numerical Models
- Main limitations of the Models

6. Design of an ISC Field Project. Operation Procedures

- Ignition Operation
- Injection Program
- Performance Prediction Methods: Nelson & McNiel, Gates and Ramey, etc.

7. Implementation, Operation, Monitoring and Evaluation of an ISC Pilot

- Screening Criteria
- Line Drive versus Pattern Application

- Choosing the Best Location of the Pilot
- Tracking the ISC front. Gas analyses, BHT measurements, observation wells and coring wells in the burned zone
- Operation/Facilities Problems and Remedies; Burning back the injector, Risk of explosion, Corrosion and Erosion, Emulsion, Sand production, Poor injectivity/productivity, Severe gas production

8. Current Status of ISC Projects. Commercial Application

- The World's most significant commercial ISC applications
- Horizontal wells in ISC processes
- Emerging ISC Processes; Toe-To-Heel Air Injection (THAI), COSH, and Top-Down ISC; Field piloting of the THAI in oil sands and in the Lloydminster heavy oil area