Technology & Applications

Unconventional Oil & Gas | Technology & Applications

[ww-shortcode-divider style="thin"]When dealing with unconventional resources, the technical key drivers which have boosted their exploitation are:

1. directional drilling
2. hydraulic fracturing (fracking)
3. thermal EOR (TEOR) processes

These technologies are not at all new to the oil & gas industry, but they have been considerably improved in the last few years both from the operational and economic side.

Directional drilling

Directional drilling is the capability to drill a wellbore deviating its axis from the vertical in a controlled manner.

When producing unconventional reserves, it is common practice to drill a number of horizontal wells through the reservoir to maximize the contact area of the well with the formation.

When producing CBM, the natural fractures of the coal are often sufficient to enable gas flow.

When producing gas or oil shale, hydraulic fracturing techniques have to be used to achieve production.

Hydraulic fracturing

Hydraulic fracturing is a stimulation technique that aims at substantially increasing the permeability of the rock, and, therefore, the productivity of the wells, fracturing it in controlled way.

This result is generally achieved by injecting fluid into the wellbore at very high flow rate and pressure to induce a network of fractures that propagate for a designed volume (stimulated reservoir volume SRV)into the surrounding reservoir rock formation.

The fractures created in shales by this technique tend to generate more complex and branching fracture networks that expand in multiple direction. As result , the standard, simple and single fracture modeling tools of the past do not provide a valid simulation representation of fracture system. The industry replaced for a valid modeling of the complex fracture network with the introduction of the concept of srv. The srv calculation is based on the effective formation volume defined on the location of the microsismic events that are recorded during the stimulation treatmemt.

A) Shale and shale oil

The shale gas or shale oil exploitation process can be summarized as follows:

- Identification of the target shale sequences using conventional geological exploration methods.
- Drilling of boreholes into the target sequence and setting down of the casing.
- Hydraulic fracturing (fracking) of the formation, using pumps at surface, and injecting water (with around 5% of additives, being mainly sand grains) at pressures carefully calculated to overcome the yield strength of the shale so that pre-existing fractures can either opened up or new ones created.
    - Additives typically are: 5% sand “proppant” to

keep physically the fractures open, and 0.1 – 0.2% chemicals to enhance water flow and inhibit unwanted bacterial growth.

- Pumping out back to surface the injected water plus any admixed native groundwater, until the water level in the well drops below a threshold value so that the oil or gas might overcome the water pressure and move from the pores of the shale into the borehole
- Collection of the gas or oil moving to the boreholes to dispatch it to surface facilities for processing and delivering to final users
- Disposal of the pumped water, either to sewer or surface watercourses (following any required treatment), or else by reinjection to a subsurface formation.

Application of horizontal drilling and fracturing for the shale and gas exploitation (Total)

B) Coal Bed Methane (CBM)

CBM extraction process can be summarized as follows:

- Identification of the target coal seams by mean of geological exploration methods
- Drilling of two or more boreholes into the target seam, and a few meters below to create ‘sumps’ beneath the seam floor level:
  - Cementing the casing into place from the strata overlying the coal seam (only the target coal seam is open to the borehole)
  - Several of these wells are likely to be deviated to run horizontally along the coal seams and to carry maximum gas to the vertical production borehole
- Installing pumps with very high lift capabilities into the borehole sumps
- Pumping out the boreholes for depressurizing the

groundwater in the coal seam until the water head in the wells drops below a threshold value so that the gas might be desorbed from the pore walls and move into the boreholes.

    - pumping out has to be maintained until the water level has dropped below the seam floor level before the bulk of the methane will enter the borehole, and this is the reason why overlying strata must be thoroughly cased-out (otherwise more groundwater than necessary would need to be pumped from great depth)
    - gas initially moves from microscopic pores in the coal, and subsequently degasses from dissolution in the groundwater
    - gas travels to the borehole along the face cleat, and when deviated horizontal boreholes are used, these are oriented to run perpendicular to the face cleat, thereby encouraging maximum flow of gas into the borehole

- Collection of the gas moving into the boreholes to dispatch it to surface facilities for processing and delivering to final users

- Disposing of the pumped water (production water) either to sewer or surface water

(following any required treatment) or by reinjection.

In many cases, the low permeability of the coal seam will require the application of ‘stimulation techniques’, and in such cases it is requires :

- Drilling of a directional well ensuring that most of the natural small cracks of the coal are exposed to the borehole wall
- Hydraulic fracturing of the well to increase the coal seam productivity.

C) Natural Gas Hydrates

To produce natural gas from hydrates, it is necessary to dissociate them, and three basic methods are available to reach this target, i.e.:

1. *Depressurization*
2. *Thermal stimulation*
3. *Chemical injection*

These three techniques are all based on the principle of shifting the hydrate condition from the hydrate stable region to the hydrate unstable region.

1. Depressurization Method

- It is currently regarded as the most promising method
- First, the hydrate contacting the free gas layer becomes unstable and decomposes by lowering pressure of the free gas layer.
- Then, the produced gas is collected by wellbores and water remains in the stratum.

Depressurization method (Research Consortium for Methane)

2. Thermal Stimulation Method

- It involves dissociating hydrates by increasing the in situ temperature above the gas hydrate equilibrium point
- Hydrate reservoirs are heated by injecting hot (salt) water or steam
- The advantage of this method is that the hydrate decomposition process and the gas production rate could be controlled by regulating the amount and the rate of the heat injected
- From the economic point of view, this method is not

suitable for exploitation of hydrates in the permafrost region where the ambient temperature is very low and the permafrost layer is thick

Thermal stimulation method (Oil & Gas Journal)

3. Chemical Injection Method

- Inhibitors, such as methanol, ethanol, or brine, are injected to dissociate hydrates in the reservoir
- Because of the injected inhibitors, the formation condition of hydrate phase equilibrium will be changed, making the hydrate system unstable so that it decomposes
- The main advantage of this technique is that the gas production rate can be improved in a very short time
- From the economic point of view, this method is not well promising as inhibitors are expensive.

Gas production from hydrate by the chemical injection method

(Imperial College – UK)

D) Oil Sands

Mining

About 20 percent of currently recoverable oil sands reserves lies close enough to the surface to allow open-pit mining.

The bitumen is produced using a strip mining process similar to that for coal mining.

The overburden (primarily soil and vegetation) is removed, and a layer of oil sands is excavated using massive shovels and moved by pipeline or truck to a processing facility where the bitumen is extracted using the hot water technique.

Today, all sites are integrated mine/extraction-upgrading operations which allow extracting the heavy bitumen and upgrading it to a light crude oil called synthetic crude oil

(SCO).

Oil sands mining extraction and upgrading process (CBS News website)

In-situ Thermal Processes

About 80 percent of the recoverable oil sands deposits are too deep for surface mining and are produced using advanced drilling techniques combined with thermal processes.

In-situ thermal methods consists of heating the deposit to lower the oil or bitumen viscosity, so allowing it to flow and be pumped to the surface. Heat can be supplied to the formation by injecting steam or hot water, or by starting an "in situ" combustion process.

The thermal processes most widely diffuse today at industrial scale are: Cyclic Steam Stimulation (CSS), Steam Assisted Gravity Drainage (SAGD), and SteamFlooding (SF).

Cyclic Steam Stimulation (CSS)

CSS process (or Huff and Puff) is based on producing steam in once-through steam generators and injecting it down the wellbore into the target formation at a temperature of about 300°C and pressures averaging 11 MPa. This pressure is sufficient to cause parting of the unconsolidated oil sands formation so enhancing the fluid flow.

For each individual well, periods of steaming are followed by periods of soaking and then by periods of production, i.e. CSS is a three-stage process operated in this way:

(1) high-pressure steam is injected through a vertical well for a period of time – (2) the reservoir is shut in to soak – (3) the well is put back on production.

Typical initial cycle times are as follows: (1) injection: 4-6 weeks; (2) soaking: 4-8 weeks;

(3) production: 3-6 months.

Typical recovery rates of CSS process are in the order of approximately 25%-30% of the original heavy/oil/bitumen in place.

Left: CSS in horizontal well (Canadian Natural Resources)

Right: CSS in vertical well (Petroleum Communication Foundation)

Steam Assisted Gravity Drainage (SAGD)

The SAGD is a quite recently developed process originally designed for exploiting the Canadian oil/tar sands. Its implementation requires the drilling of a couple of horizontal wells: an upper steam injector and a lower oil producer. They must run in parallel and be some five meters away.

Steam is injected into the sands through the upper well to create a steam chamber that expands vertically and horizontally. The heat is transferred from the chamber to the bitumen, reducing its viscosity and enabling it to flow – by gravity drainage – into the production well where it is pumped with the condensed water to the surface facilities for processing.

In most cases the expected recovery of SAGD process is in the order of approximately 50% of the original heavy/oil/bitumen in place.

SAGD Process (Japan petroleum Exploration Co. Ltd)

For the steam-assisted gravity drainage (sagd) well pairs , drilling operations have become very specialized, requiring specially designed drilling rigs and equipment in order to drill wells more and more efficiently without sacrificing wellbore quality and the production performance.

Logging-while-drilling (lwd) sensors help direct high-angle and horizontal drilling and ensure efficient use of expensive rig time.

Measurement-while-drilling (mwd) technology is used to determine wellpath and position in three-dimensional space. Mwd can establish true vertical depth, bottom-hole location, and orientation of directional drilling systems.*Steamflooding (SF)*

Steamflooding is one of the oldest TEOR processes and was substantially developed by analogy with the water or gas injection techniques.

In the SF process high temperature steam is continuously injected through horizontal or vertical wells. As the steam moves through the formation it loses heat to reservoir fluids (usually very viscous oil and water) and rock, and condenses into hot water, which, coupled with the continuous supply of steam behind it, sweeps and drives the oil toward the producer wells.

The oil recovery is enhanced because of the following mechanisms:

- Heating swells the oil and strongly reduces its viscosity, making it easier its release from the reservoir rock and its flow toward the producer wells
- The high temperature tends to vaporize the lighter fractions of the oil, and as these fractions move into the cooler zones of the reservoir ahead of the steam/hot water bank, they condense and form a solvent bank enhancing the mobilization of the original oil
- The injected steam moving through the reservoir cools and condenses in hot water which displaces the oil behind of it in a way similar to that of a water injection process.

From the field data available from a number of SF projects, it appears that this technique is very effective in oil recovery with rates of the order of 50%, and in some favorable cases even of 70%-75%.

Steam flooding (U.S. Department of Energy, Bartlesville, Oklahoma)

Scottish Government: Report on Unconventional Oil And Gas – 2014

TOTAL : Energies and Expertise – Unconventional gas

Energies: Experimental Simulation of the Exploitation of Natural Gas Hydrate – 2012

Treccani: Hydrocarbon Encyclopedia

IHS CERA: Fueling the Future with Natural Gas – January 2014

Exxon Mobil Corporation: Unconventional Resources Development – Managing the Risks – 2014