"Inaccessible Heavy Oil and Bitumen Extraction, Upgrading and GHG Emissions - A Technology Roadmap"

Recovery Methods

Purpose: To identify potential areas of research which would be needed to realistically assess the viability of various proposed recovery processes at various stages of oilsands production, and potential for use of low cost, low energy intensive technology.

Background:

The target resources for this roadmap are:

- All in-situ oilsands and unconsolidated heavy oil deposits, both undeveloped and those considered to be "Inaccessible".
- Thick and rich, dolomitized and fractured carbonate formations 3-50 m thick at depths of 150-300 m.

The bitumen contained in these reservoirs has very high viscosity at reservoir conditions. In order to produce it at economic rates it is necessary to lower the viscosity. This can be accomplished in three ways, adding heat, adding a diluent or modifying the bitumen by a process such as in-situ upgrading. As a result of its high viscosity, bitumen is nearly solid at reservoir conditions and blocks the movement of any fluids through the pore space. This is a significant constraint as most recovery processes depend on the injection of a fluid into the reservoir and many depend on the movement of fluids through the reservoir.

Recovery Processes:

1. Heat Addition

The most common method of heat addition is the injection of a hot fluid such as steam or hot water. In the steam drive process, steam is injected into a well and the heated fluids are produced from one or more adjacent wells. This process is ineffective for bitumen reservoirs as the heated fluid must move through the cold reservoir where the bitumen blocks the pore spaces.

In the cyclic steam stimulation process, steam is injected into a well for a period of time, the well is left to soak and the hot fluids are then produced from the same well. The process is then repeated a number of times. Because of the limited injectivity, the steam must be forced in at high pressure. This creates "fractures" which also provide a return path for the heated bitumen and the condensed water. As steam temperature is directly proportional to the steam pressure and a minimum temperature is required to mobilize the bitumen, this process requires a relatively deep reservoir to contain the required steam pressure. In an appropriate reservoir, this is an initiating process. As recovery levels are limited to 20 – 25%, a follow up process is required to achieve high recovery levels.

Steam Assisted Gravity Drainage (SAGD) involves two closely spaced, parallel horizontal wells. A steam chamber is formed above the top well which acts as a steam injection source. The hot fluids flow by gravity to be produced from the lower well. An advantage of SAGD is that once the chamber is initiated, it is only necessary to heat a thin layer of bitumen on the walls of the chamber. The heated bitumen then flows by gravity to the producing well, exposing another layer of bitumen to the hot steam. Although lab studies show recovery levels of 70% or more for SAGD, commercial field tests have not progressed far enough to validate these levels. Again some follow-up process will be required to achieve full recovery as well as to recover the heat remaining in the steam chamber. SAGD can also be an initiating process. With the close spacing of the two wells, steam can be circulated in both wells to provide initial mobility by conduction heating.

In in-situ combustion, air or oxygen is injected and a portion of the bitumen is burned to generate heat in the reservoir. In the standard combustion process, air or oxygen is injected into a well creating a combustion front around the well. The heated fluids are produced from adjacent wells. Here again the movement of the heated bitumen is restricted by the cold bitumen. Consequently this process is more suitable as an intermediate process where the bitumen has been preheated and/or flow channels have been established in the reservoir.

A modified form of in-situ combustion is Toe to Heal Air Injection (THAI). Air or oxygen is injected into a vertical well with the hot fluid produced from a horizontal well. The combustion front moves out from the vertical well with the hot fluids moving down, by gravity, to the horizontal well. As this eliminates the need to move the heated fluids through the cold bitumen, THAI can be an initiating process.

Electric heating is a potential means of heating the reservoir without the requirement to inject a fluid. This can involve inter-well resistance heating, downhole heaters, microwave heating or RF heating. Because the generation of electricity is a relatively inefficient process, electric heating is more likely to find application as a means of preheating the reservoir or reducing the flow resistance around a production well rather than as the primary means of mobilizing the bitumen.

2. Diluent Addition

Diluent addition involves the injection of a gas or liquid which, when mixed with the bitumen, will lower its viscosity. This type of process is attractive because of the lower energy intensity involved and the potential for reduced green house gases, however, there are some constraints. In order to be effective, the diluent must contact the bitumen, mix with it and reach equilibrium. As a result of the lack of mobility of cold bitumen, this type of process will generally require the reservoir to be preheated. This could be accomplished with a non-invasive process such as electrical heating or diluent addition could be applied as an intermediate or supplemental process following a thermal recovery process.

One application of diluent addition that could be applied as an initiating process, although it would require some pre-heating, is Vapex. This process is similar to SAGD but the injected material is a solvent rather than steam. Once a small chamber is formed using steam, injection is switched to a solvent. The solvent moves through the bitumen free chamber and contacts and equilibrates with a thin surface layer of bitumen. This diluted bitumen then flows by gravity to the production well exposing a fresh layer of bitumen to the solvent. This process has been demonstrated in the lab but has not yet been publicly demonstrated in the field.

The application of diluents to bitumen recovery, whether as a primary recovery mechanism or as an additive to steam, is a complex process. The diluent required is a function of reservoir and fluid properties as well as operating conditions such as temperature and pressure. This means that the appropriate diluent must be selected for each situation. In many cases a single diluent will not meet the requirements and a blend of two or more diluents must be used.

3. In-Situ Bitumen Upgrading

One form of in-situ bitumen upgrading involves the injection of a catalyst. As this process also involves contacting and mixing of the catalyst with the bitumen, it would be applied as an intermediate or supplemental process.

An alternate to catalytic upgrading is in-situ deasphalting. Here a solvent such as propane is injected to drop out some of the asphaltenes and lower the bitumen viscosity. This could be a stand alone process or an additional benefit to a solvent based recovery process such as Vapex.

In-situ upgrading is also an additional benefit to the combustion recovery process. As the combustion front moves through the reservoir, the lighter ends of the bitumen are distilled off, thermal cracking takes place and the coke product is consumed as fuel. The resulting, produced oil, has a much lower viscosity than the original bitumen.

Another mechanism for in-situ upgrading is bioconversion or bacterial upgrading. The process depends on microbes that can convert the bitumen to lower viscosity oil or methane. These microbes may be naturally occurring or injected into the reservoir. As additional nutrients are normally required for this process to take place at reasonable rates, these must be injected. As it is a relatively slow process it would most likely be applied as a final “clean up” process.

Recovery Process Application:

No one in-situ recovery process will be applicable to all reservoirs and no single recovery process will be able to access all the bitumen in a given reservoir. To achieve maximum recovery it will be necessary to apply a combination of different processes. For example a steam based recovery process followed by in-situ combustion, followed by in-situ upgrading, followed by bioconversion of the residual hydrocarbons. This type of sequential recovery will require careful planning to ensure that the optimum sequence and timing is applied.

Supporting Technologies:

One of the objectives of this roadmap exercise is to find means of reducing energy intensity and green house gas production while still maximizing recovery. One possible area for improvement is the production of steam for steam based processes. Most steam is now produced in once through steam generators where natural gas is burned within the shell of the unit and water is converted to steam in tubes that run through the shell. These units are not 100% efficient with a considerable amount of heat lost with the stack gases.

A multi-step system could be more efficient. Initial heating of the water could be accomplished in solar heating units which are very efficient up to about 40^o C. Alternately the initial heat input could be from geothermal sources. Other processes could then take the water to the required operating temperature. There are a number of options which need to be assessed to determine the most effective systems for each recovery process.

Another option is to use direct heating of the water. Here the water is contacted directly by the flame and the products of combustion are injected with the steam. This process has a number of advantages. The water does not have to be treated. The unit can utilize a variety of fuels. All the produced heat is injected, no stack gas losses. The CO_2 and other products of combustion are injected, reducing direct green house gas emission to the atmosphere, providing additional drive energy and reducing the bitumen viscosity through solution of the injected gases. Some areas of concern that need to be addressed are corrosion, potential negative effects of injecting the combustion products and the means of handling the combustion products that are produced with or dissolved in the bitumen.

Recovery Process Monitoring:

Gathering operating data is important for the effective operation of any recovery process but it becomes critical when sequential processes are being implemented. The data is not only needed for process operation and control but is vital for the effective selection and design of any follow-up phases. Operators should measure rates and volumes for all produced materials including oil, water, gas and sand. The composition of the gas stream should be measured on a regular basis. Reservoir temperature and pressure and produced fluid temperature should be monitored. The size and shape of the steam zone, steam chamber or other affected zone should be determined by 3D seismic or other means.

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