

Closed-loop Extraction Method for the Recovery of Heavy Oils and Bitumens Underlain by Aquifers: the Vapex Process

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Abstract

In previous papers^(1,2,3) the authors described the results of injecting saturated ethane or propane vapours into a scaled two-dimensional model to recover heavy oils and bitumen at or slightly above the reservoir temperature. The results were encouraging. Although the scaled oil production rates were lower than those obtained with SAGD⁽⁴⁾, they showed that it may be possible to recover heavy oils and bitumens economically using this method in conjunction with long horizontal wells. Apart from the low heat requirement inherent in the use of saturated propane, additional advantages derived from vapex are a partial in situ deasphalting and a reduction in the content of heavy metals. The resulting oil can be lighter, of a higher quality and better suited for a direct refining.

In this paper these ideas are expanded further: a development of a closed-loop extraction is described and a technique for spreading the hydrocarbon vapour underneath the oil bearing payzone is proposed to simulate the performance of a planar well. Using this concept the vapour-oil contact is greatly increased and improved production rates are obtained.

The paper discusses scaled physical model results for Peace River bitumen and Lloydminster heavy oil. The mechanism involved is believed to be similar to that which was described earlier on rising fingers of liquid solvent⁽⁵⁾. Experiments are presented that show that the rate of mobilization is a function of the areal distribution of the solvent vapour. The results demonstrate that oil production rates exceed those of the SAGD in spite of the fact that no extraneous heat is injected into the reservoir. This strategy may permit the economic production of marginal heavy oil and bitumen reservoirs.

Introduction

Many heavy oil reservoirs in Alberta and Saskatchewan are thin and underlain by extensive aquifers. Bottom water frequently limits the performance of primary and thermal recovery methods. Primary production is often hampered by rapid water coning, and economic recoveries are limited to about 1 to 5% of the original-oil-in-place. Thermal methods can be inefficient and uneconomical due to excessive vertical heat losses, thin pay zones, high water cuts and steam condensation in bottom water zones.

Underlying zones of high water saturation are also common in bitumen reservoirs in Peace River. In Cold Lake, reservoir fluids tend to migrate through the path of least resistance, i.e., via the bottom water zone, resulting in low recoveries and poor sweep efficiencies. Pilot or commercial thermal recovery operations in these reservoirs are either considered unsuitable or their location

is chosen to maximize net pay thickness and to minimize bottom water thickness. As a result, until now reservoirs with an underlying aquifer have been of a lower commercial value to operators because of low productivities and high water cuts.

It is believed that when employing a saturated hydrocarbon vapour (typically ethane or propane) in conjunction with horizontal wells to mobilize and recover viscous oils and bitumens from formations, the bottom water zone can serve as a means for providing initial injectivity. Since the vapour is injected at reservoir temperature and since it is essentially insoluble in water—while strongly soluble in oil—there are no heat or material losses to the water layer. Furthermore, the mobile water layer will override the lighter diluted oil and assist in moving it towards the production well.

The injection of hydrocarbon vapour into bottom water reservoirs is a cost effective solution that improves chances for an economic return. What is a disadvantage for steam injection becomes an advantage for hydrocarbon vapour.

Another advantage of the vapex approach is that heat losses to the reservoir rock and overburden are negligible. This makes the process attractive for low porosity and/or thin reservoirs as well as for thicker, higher porosity reservoirs. Operation in fractured, low porosity rocks could be of interest.

Experimental Work

Closed-loop Extraction: Method and Apparatus

The experimental work utilized a scaled, vertical, two-dimensional physical model that was confined in a pressure vessel. A diagram of the cell is given in Figure 1 and the apparatus in Figure 2. The scaled model cell was made of reinforced phenolic resin sheets and was vibro-packed with 1 mm glass beads or Ottawa sand (20 – 30 mesh or 30 – 50 mesh). The injector was initially positioned above the production well (experiments without aquifer, Figure 2) or later at the bottom and across the cell (experiments with underlying aquifer). The cell represents a vertical cross-section through a reservoir payzone with horizontal injector and horizontal producer. The cell was equipped with 62 thermocouples to obtain temperature distribution as the heat front due to the dissolution of propane in oil was created and dissipated⁽²⁾. A transparent cell wall made it possible to examine and photograph the undisturbed reservoir at the end of the experiment without opening the cell.

The apparatus for a closed-loop propane extraction without an aquifer is presented in Figure 2. The essential parts of the system are the gas recycle loop and the propane make-up line. The main element of the recycle loop is the propane stripper which heats up

