A new process (VAPEX) for recovering heavy oils using hot water and hydrocarbon vapour

ROGER M. BUTLER and IGOR J. MOKRYS
The University of Calgary
Calgary, Alberta

ABSTRACT

There are extensive deposits of heavy oils in Saskatchewan and Alberta which can only be recovered with low efficiency by conventional methods. Thermal recovery processes using steam, although effective, are uneconomic in many of the Lloydminster-type reservoirs because the deposits are relatively thin and heat losses to the overburden and underburden are excessive.

A new idea is to use a solvent, such as propane, in the vapour phase which can form a vapour-filled chamber within the reservoir. Vapour dissolves in the oil around the chamber and the resulting solution drains, driven by gravity, to a horizontal production well placed low in the formation. The solvent vapour, at or near its dew point, is injected simultaneously with hot water from a horizontal well located at the top of the reservoir. The temperature and flow rate of the water are chosen so that the reservoir temperature is raised to the range of only 40°C to 80°C. As the diluted bitumen drains toward the production well, it interacts with hot water and some propane re-distils upward to dilute further bitumen. There is, thus, a transport of heat from low down in the reservoir to the upper reaches by the evaporation of propane near the bottom and its condensation (dissolution) at the top. This mechanism causes the heat in the water to be distributed through the reservoir, in particular, laterally away from the point of injection.

Results are presented that show the gas/oil and water/oil ratios and the additional oil recovery from a vertical, two-dimensional scaled reservoir model due to propane injection near the end of a hot waterflood. The essential feature of the recovery mechanism and the process conditions are discussed.

Introduction

There are extensive deposits of heavy oils in Saskatchewan and Alberta which can only be recovered with a low recovery efficiency by conventional methods. Primary recovery in the best of these heavy oil reservoirs can yield about 6% of the original-oil-in-place. Waterflooding can improve the recovery but only to an extent of 1% to 2% because of the adverse mobility ratio.

The recovery concept, which is described here, is closely related to the steam-assisted gravity drainage (SAGD) Process which has been discussed in the literature[1-8]. In the SAGD process, a growing steam chamber forms as steam is injected into the reservoir and steam flows continuously to the perimeter of the chamber where it condenses and heats the surrounding oil. The heated oil drains, driven by gravity, to a horizontal well located at the base of the

reservoir. This process is effective and can be economic if the heat (steam) requirements are not too high. The heat requirements can become excessive, however, in thin reservoirs where the vertical heat losses above and below the reservoir tend to be high and also in low-permeability carbonates where the reservoir heat capacity per unit volume of contained oil is high.

One potential means for overcoming the problem of heat loss is to use solvents in place of heat to mobilize the oil. Rather than lowering the viscosity of the oil by heating, dilution with a solvent is used instead. In a recent paper[9], it was shown that the recovery mechanism using solvents is very similar to that found with steam. Whereas with steam it is necessary for heat to diffuse into the reservoir by thermal conduction, the process with solvents involves molecular diffusion. The rates at which the processes occur can be described by analogous equations*.

$$Q = 2\sqrt{2kg\phi\Delta S_o HN} \quad , \text{m}^3\text{m}^{-1}\text{d}^{-1} \quad \dots\dots\dots\dots\dots\dots\dots (1)$$

where N is a dimensionless number defined for the steam process as

$$N = \int_{T_{min}}^{T_s} \frac{\alpha\Delta\rho}{\mu} \cdot \frac{dT}{(T - T_R)} \quad \dots\dots\dots\dots\dots\dots\dots (2)$$

In this equation dimensionally consistent units should be used, e.g.

α = thermal diffusivity, m^2d^{-1}
$\Delta\rho$ = $\rho_{bit} - \rho_{steam}$, kg m^{-3}
T = temperature, °C
μ = bitumen viscosity at T, kg m^{-1}d^{-1}
T_s = steam temperature, °C
T_{min} = a temperature slightly above the reservoir temperature T_R

For the solvent process, N is defined as

$$N = \int_{c_{s_{min}}}^{1} \frac{D_s(1-c_s)\Delta\rho}{\mu} \cdot \frac{dc_s}{c_s} \quad \dots\dots\dots\dots\dots\dots\dots (3)$$

where

D_s = intrinsic solvent diffusivity, m^2d^{-1}
$\Delta\rho$ = $\rho_{soln} - \rho_{solv}$, kg m^{-3}
c_s = solvent concentration, vol. fraction
μ = solution viscosity, kg m^{-1}d^{-1}
$c_{s_{min}}$ = a very small solvent concentration

The rate at which the recovery process occurs with a liquid sol-

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*The equations in this paper are dimensionally consistent. Thus, for example, if equation (1) is to yield Q in m³ per m of horizontal well per day, then k should be in m², g in m/d² and H in m.