CSUG Canadian Society for Unconventional Gas

SPE International

CSUG/SPE 148832

Single-Well SAGD: Overcoming Permeable Lean Zones and Barriers

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This paper was prepared for presentation at the Canadian Unconventional Resources Conference held in Calgary, Alberta, Canada, 15–17 November 2011.

Abstract
Performance of conventional steam-assisted gravity drainage (SAGD) with horizontal well pairs is impacted significantly in formations with high permeable lean zones. These lean zones rapidly halt the vertical growth of the steam chamber, and spread the chamber laterally resulting in water loss issues and a significant impairment of the system to overcome barriers, i.e. low permeable horizontal layers. The operating steam pressure is lowered to reduce the water loss to the lean zone, and this in turns accentuates the impact of any barriers, thus giving rise to high steam oil ratios (SORs) and lower production rates. A vertical single-well injector/producer is proposed that consists of six (6) vertical propped planes installed at varying azimuths from the bottom to the top of pay. Steam is injected at the top of the pay and liquids extracted at the bottom. The well operates immediately in SAGD mode, i.e. the continuous injection of steam and the continuous extraction of liquids, resulting in peak production achieved within 30-45 days. The system is very efficient due to the immediate drainage available from the propped vertical planes, but also due to full gravity drainage height at startup and a favorable steam pressure gradient. Reservoir simulations show that the single-well system's performance with high permeable lean zones within the pay is virtually unimpaired, both in terms of production rate and SOR. Clearly the system's operating pressure needs to be lower to reduce water loss to the lean zone, but due to the top down growth of the steam chamber the permeable lean zone's impact is minimized. The net present value (NPV_{10}) of the single-well SAGD system in 35m thick Athabasca bitumen pay with a 5m permeable lean zone is estimated to be greater than 6xNPV_{10} of conventional SAGD. The single-well SAGD system is much easier to pressure balance and operate than conventional SAGD, resulting in a more robust system provided the multi-azimuth propped vertical planes are constructed continuously throughout the pay height.

Introduction
Horizontal well pair SAGD has limited options to overcome geological variability within the pay zone, e.g. permeable lean zones, shale barriers and low vertical permeability. In many cases, due to the presence of such geological variability, the only option available is to relocate the SAGD well pair and thus not recover those reserves in poor geology. An alternate system is proposed that consists of installing vertical propped permeable planes at varying azimuths from a single vertical well, and complete the well as an injector/producer operating in SAGD mode immediately on startup. Steam trap control is maintained by an adequate liquid head over the production tubing, as is the case in conventional SAGD. The steam chamber develops immediately at the top of pay, with performance enhanced due to full gravity drainage height at startup and a favorable downward acting steam gradient. Provided the propped vertical planes are installed continuously throughout the pay, shale barriers and low vertical permeability have none to minimal impact on performance, i.e. production rate and SOR. Also, since the steam chamber migrates laterally initially and then downward, permeable lean zones have minimal impact on the system's performance. Upward growing steam chambers in conventional horizontal well pair SAGD are considerably impaired due to shale barriers, low vertical permeability and the presence of permeable lean zones, resulting in low production rate and high SOR. If the operating steam pressure must be significantly lowered because of shallow depth, caprock integrity, or water-loss issues, it could result in further impaired conventional SAGD performance greater than due to the slower drainage of the more viscous bitumen at the lower steam temperature. Water- and steam-loss issues can potentially occur in areas associated with top gas, bottom water, permeable lean zones and outcrop proximity.

Approximately 20 years ago, some simple field experiments demonstrated that vertical planes could be injected on azimuth in weakly cemented formations[1]. Continuous permeable planes filled with an iron proppant, in some cases kilometers in length, have been constructed by this technology for groundwater remediation at numerous sites[2]. More recently, shallow field experiments have demonstrated that multi-azimuth permeable planes can be installed from a single well in weakly cemented