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Vertical Single-Well SAGD with Multiple Producers

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Abstract

Performance of conventional, steam-assisted gravity drainage (SAGD) horizontal well completions can be significantly impacted in formations with low vertical permeability and interbedded mudstone layers impeding vertical drainage. Also, because of shallow depth, caprock integrity, and/or thief zone issues, the lower operating steam pressure for SAGD completions can impact its ability to grow the steam chamber vertically in a timely manner. Such performance degradation results in lower production rates and often higher steam oil ratios. A vertical well injector/producer was proposed that consists of vertical, propped planes at varying azimuths installed from the bottom to the top of pay. Steam is injected at the top of the pay and liquids are 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 to 45 days. Reservoir simulations show that the single-well SAGD system's performance is superior to a conventional SAGD completion, achieving greater than $2xNPV_{10}$ (net present value) of conventional SAGD in clean McMurray channel sand. Incorporating multiple vertical producer wells with a single central vertical SAGD injector/producer well, yields system performance far superior to a conventional SAGD completion, achieving greater than $6xNPV_{10}$ of a conventional SAGD completion in clean McMurray channel sand. The oil production rate for the vertical SAGD system with multiple producers is 4x faster than a conventional SAGD completion, with a greater recovery factor, and a lower cumulative steam oil ratio (SOR) of 1.5 compared to 2.5 resulting in a 40% saving in both Capex and Opex. Simulations of the system in variable geology, indicate that the vertical drainage efficiency of the system is virtually independent of geology, provided the multi-azimuth, high permeability propped vertical planes connect the wells hydraulically and are constructed continuously throughout the pay thickness.

Introduction

Shallow-field experiments demonstrated that vertical planes could be injected on azimuth in weakly cemented formations (Hocking 1996). Continuous permeable planes filled with an iron proppant—in some cases, kilometers in length—have been constructed using this technology for groundwater remediation at numerous sites (Hocking and Wells 2002). More recently, shallow-field experiments have demonstrated that multi-azimuth permeable planes can be installed from a single well in weakly cemented formations (Hocking et al. 2008). The technology is not limited by depth, but is limited to formation strength, being that it is applicable only in weakly cemented formations. This process has now been extended to depths greater than 500 m (Hocking et al. 2011a & 2013) and is proposed as a new thermally enhanced well-completion system for heavy-oil and bitumen recovery in unconsolidated sands where conventional thermal recovery methods, such as SAGD and cyclic steam stimulation (CSS) have limitations because of geological issues.

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, because of 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 has been proposed, Hocking et al. 2011a & b, consisting of multiple vertical, propped permeable planes at varying azimuths from a single vertical well, and the well completed as an injector/producer operating in SAGD mode immediately on startup. Steam is injected through a vacuum insulated tubing (VIT) and liquids produced via a parallel production tubing in the same wellbore. Steam-trap control is maintained by an adequate liquid head over the production tubing, as in conventional SAGD. The steam chamber develops immediately at the top of the pay, with performance enhanced because of the full gravity effect on the 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 zero to minimal impact on performance (i.e., production rate and SOR). Also, because the steam chamber