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Injection of Multi-Azimuth Permeable Planes in Weakly Cemented Formations for Enhanced Heavy Oil Recovery

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Abstract

Stimulation of weakly cemented formations is not a fracturing process as what occurs in hard rocks, since the weak formation has minimal strength and thus basically zero fracture toughness. It has been demonstrated conclusively that vertical planes can be injected in weakly cemented formations, with control of the plane's azimuth and the ability to inject multiple planes at differing azimuths both sequentially and simultaneously in a single well. Laboratory and near-surface experiments involving injection from a perforated casing have yielded random injected geometries that are not repeatable nor develop a planar injected feature. On the other hand, if the casing is dilated during the injection process, repeatable consistent vertical planar injected geometries are formed with control of the azimuth of the injected planes. These experiments have been conducted in the laboratory, at numerous shallow field sites involving excavation of the injections, and at deeper field sites (~50 meters) with the injected geometry determined by real time imaging using the active resistivity method. The specialized casing system is conventionally drilled and cemented in place, sub-surface resistivity receivers installed, the casing dilated during injection and the subsequent injected geometry imaged in real time during the injection process. The application has field demonstrated both simultaneous and sequential multi-azimuth vertical planar injections from a single casing horizon. The method has significant potential in soft rock formations for production enhancement in both shallow gas and shallow heavy oil reservoirs. The paper presents field injection experiments of multi-azimuth injected vertical planar geometries in a variety of weakly cemented formations and describes the application of the method to shallow petroleum soft rock reservoirs, especially for thermal and solvent recovery of heavy oil.

Background

A series of field experiments in loose sands and peat layers, lead to the realization that the azimuth of injected vertical planes could be controlled by the well initiation device, and that the injected plane would remain on azimuth by controlling the rate of injection and the viscosity of the injected fluid. The ability to control the azimuth orientation of vertical injected planes in weakly cemented formations was first demonstrated in a number of shallow field trials in 1992. These early experiments were all excavated to determine the orientation and extent of the injected geometry. For a proof of concept project for the U.S. Army Corps of Engineers, twenty three injected vertical planes were constructed at a site in Vermont, Felice and Hocking (1994). A series of vertical planes were constructed at the site, which is a recent river flood plane composed of sands, silts, clay and gravel. Single and multiple injections were conducted to demonstrate that the technology was capable of controlling vertical plane azimuth orientation, planar extent, thickness and coalescence. The injected planes were initiated in both dry and saturated conditions, with verification of injected geometry based on post test excavation wherever possible, see Figure 1. By 1996 over two-hundred and fifty (250) tests had been conducted at eight sites in a variety of formations and stress conditions with the experiments being either excavated or imaged by surface tiltmeters and downhole active resistivity to verify the extent, orientation and thickness of the resulting vertical injected planar geometry, Hocking (1996).

These earlier field tests utilized an injection initiation device consisting of a driven flat-faced probe with an inflatable packer mounted above the probe, see Figure 2. The first commercial injection initiation device developed in 1996 was a 3.5m tool