Azi-Frac™ Technology

Azimuth Well Stimulation for Enhanced Production in Weakly Cemented Formations

Electric Resistive Heating + Gravity Drainage

Background

GeoSierra introduces the **Azi-Frac** technology, an azimuth controlled well stimulation process for installing vertical planar inclusions in weakly cemented formations on particular azimuths from either a horizontal or vertical well.

The technology was developed from GeoSierra's earlier groundwater remediation expertise, enhanced in a joint collaborative effort between Halliburton and GeoSierra called X-Drain™, and now recently refined and extended to provide the technology in either a horizontal or vertical well for oil field applications.

The Azi-Frac technology involves initiating a vertical fluidized plane on a particular azimuth to form a preferential direction for the injection and propagation of the inclusion from the wellbore. The injection process is not a fracturing mechanism, and is not applicable to hard brittle rock, instead it creates a self propagating inclusion on azimuth in weakly cemented formations.

To initiate the process in a horizontal well, an Azi-Frac open-hole stimulation tool dilates and creates an extension zone in the formation, creating a vertical fluidized plane orthogonal to the wellbore axis for inclusion injection and propagation. For a vertical well, Azi-Frac casing segments are cemented in the well, then mechanically expanded to split the casing and cement along pre-aligned vertical planes, with each propagating vertical wing of the completion stimulated independently by the treatment tooling.

Field trials of the technology have demonstrated that on azimuth, vertical, permeable planes can be constructed from a single well down to depths exceeding 500m. The technology is formation strength limited, but is not depth limited.

Electric Resistive Heating + Gravity Drainage

Azi-Frac vertical propped planes filled with an electric conductive permeable 8/20 proppant are ideal for enhanced oil recovery by single phase electrical resistive heating. The propped inclusions are installed between horizontal wells, between vertical wells or within a single vertical well. A single phase alternating current passes through the inclusions, heating the proprietary proppant by resistive heating, which in turn heats the formation, heavy oil or bitumen by conduction.

Thermal reservoir simulations of the Azi-Frac **E**lectric **R**esistive heating with **G**ravity drainage (**ERG**) system shows the system to be highly productive, efficient, and an environmental clean and sustainable recovery process. The ERG system is targeted to formations and leases where conventional steam assisted gravity drainage (SAGD) is not a viable recovery method, due to depth (shallow or deep), thin pay, outcrop proximity and/or lack of caprock integrity.

The proprietary ERG highly permeable proppant pack consists of differing proppants and fibers depending on the application, e.g. operating effective closure stress, pay thickness, well geometry, etc. The proppant pack can be formulated as an isotropic resistive pack, i.e. horizontal resistivity equal to vertical resistivity, or as a highly anisotropic resistive pack with up to 100:1 in anisotropy. The proppant pack is designed for a particular well layout to achieve a near uniform electric current density over the planar inclusions, thus optimizing the resistive heating of the inclusions, see Figure 1.

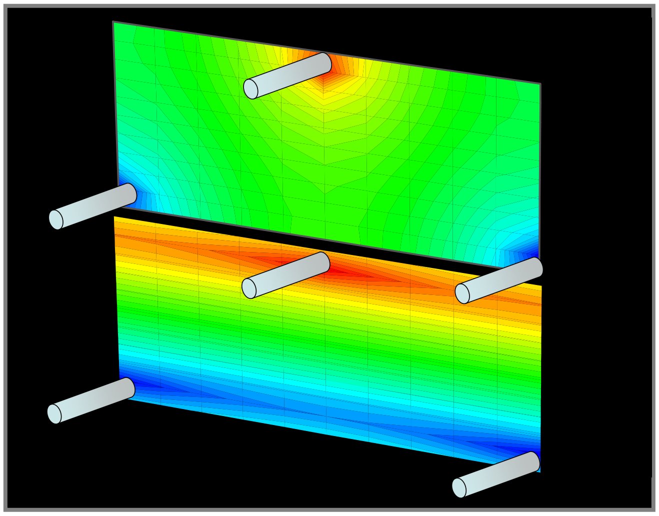

Figure 1: Electric potential contours of ERG horizontal well system: upper isotropic proppant, lower anisotropic 100:1.

Simulations conducted on a variety of ERG system well geometries, involving either horizontal or vertical wells, pay thickness, ambient oil viscosity, etc indicate that computed production rate and cumulative energy oil ratio (CEOR) show that the ERG system is both economically viable and environmentally attractive compared with conventional horizontal SAGD. Operating costs of the ERG system are expected to be similar to conventional SAGD, while capital costs are expected to be significantly less.

ERG Horizontal Wells Athabasca Bitumen

The Azi-Frac technology's inclusions initiated and propagated from a vertical well will overcome vertical heterogeneity more robustly than those installed from horizontal wells. Therefore, the horizontal well layout needs to be optimally placed in order that the inclusions are propagated throughout the full pay thickness.

In a thick Athabasca bitumen deposit in the McMurray formation, an ideal layout of horizontal wells for the ERG system is as shown in Figure 1. The inclusions are first initiated and propagated at 50m spacing in the upper open-hole horizontal well. Following stimulation, the upper well is completed with a specialized slotted liner. The lower horizontal well is then stimulated open-hole, with the inclusions propagating towards and coalescing with the upper inclusions by pore pressure relief. Finally the lower well is completed with a similar slotted liner.

Graphite electrodes are placed in all wellbores, with the lower wells completed as producers with artificial lift, and the upper wells for gas injection for pressure balance and/or to assist drainage. The electrodes are excited with a single phase alternating current, which passes through the inclusions, heating the inclusions by resistive heating, and in turn heating the formation and bitumen by conduction.

Reservoir simulations of conventional SAGD can be highly unreliable due to the difficulty in estimating formation vertical permeability under steam and its significant impact on SAGD performance. The ERG system being virtually independent of formation vertical permeability, enables reservoir simulations to be conducted with a higher degree of confidence, provided the electric conductive permeable planes are installed throughout the full pay thickness.

Reservoir simulations of the horizontal ERG system in Athabasca bitumen 35m thick McMurray formation are shown in Figure 2 along with best performing SAGD with the same reserve base. The SAGD data are from the best performing well pair in Athabasca bitumen in clean McMurray channel sand.

The ERG system outperforms the best SAGD well pair in clean McMurray channel sand by a production factor of 2. The CEOR for the ERG well has been normalized to the equivalent CSOR by equating equivalent operating cost, with the final CSOR shown in Figure 2 being a CEOR of 76kWhr/bbl. The capital cost of an ERG system is expected to be 60-70% less than an equivalent SAGD system.

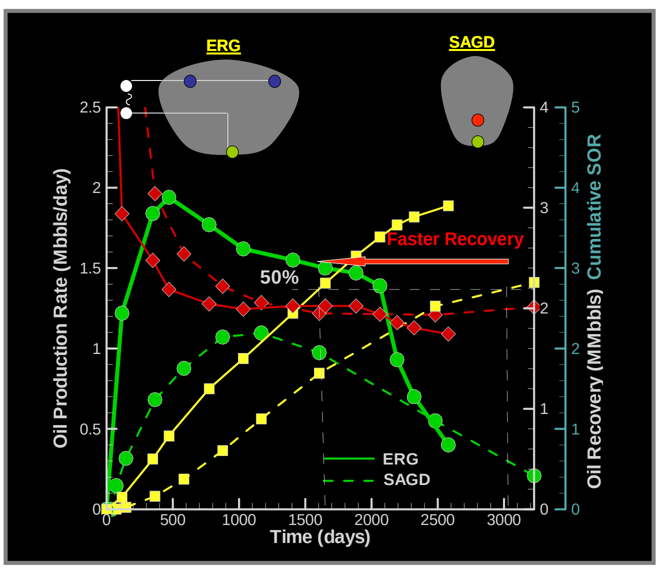

Figure 2: ERG horizontal versus conventional SAGD in 35m thick Athabasca bitumen pay in a clean McMurray channel sand.

ERG Horizontal Wells Heavy Oil

For a thin heavy oil reservoir, the horizontal wells are drilled near the base of the reservoir, see Figure 3. The Azi-Frac inclusions are initiated open-hole, and filled with a high permeable isotropic electric conductive proppant pack.

The alternate wells are stimulated first and completed with a slotted liner. The intermediate wells are then stimulated, thus ensuring that the inclusions propagate towards and coalesce with the neighboring inclusions by pore pressure relief. All the wells are electrically energized, placed on artificial lift and also contain gas injection tubing to assist drainage and provide reservoir pressure balance if required.

The performance of the ERG system in a 7m thick Lloydminster heavy oil reservoir is shown in Figure 3. The CEOR as shown is in hundreds of kWhr/bbl.

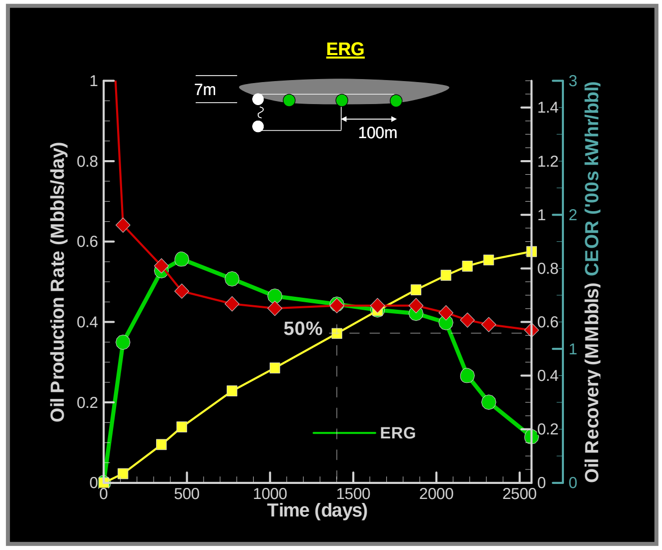

Figure 3: ERG horizontal well performance in 7m thick Lloydminster Group heavy oil reservoir formation.

ERG Vertical Wells Athabasca Bitumen

In shallow thick pay, a vertical ERG system may be the optimum choice compared to a horizontal system, especially if pay thickness varies due to uneven bedrock topography. The ERG configuration could be either a single-well system with a high anisotropic resistive proppant pack, or alternatively, multiple vertical wells stimulated with an isotropic resistive proppant pack between the wells. In all cases, the permeable proppant pack is designed to achieve optimum efficiency for both current density and drainage.

The ERG vertical well systems perform similar to the horizontal well layout, but have a higher capital cost per flowing barrel.

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Azi-Frac™ – is a pending trademark of GeoSierra LLC.
X-Drain™ – is a trademark of Halliburton.