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SW-SAGD Pilot Project, in the Well MFB-617, TL Sands, MFB-15 Reservoir, Bare Field. Eastern Basin of Venezuela

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Abstract

Heavy and extra-heavy oil reservoirs constitute the first place of ultimate reserves worldwide, nevertheless its exploitation has become a big challenge for the petroleum industry because of the complexity of the production process, this due to the low mobility of those reservoir oil types under the natural conditions.

One of the greatest reserves of heavy and extra-heavy oil worldwide is in the Orinoco Oil Belt (Venezuela). However, current studies show recovery factor of not more than 3%, even including multilateral and horizontal drilling.

Thermal oil-recovery processes consist of the generation and supply of heat to the producing reservoir, in order to reduce the oil viscosity and to increase its mobility.

One of the new promising technology methods is SW-SAGD, which has reflected excellent results in the Alberta and Lindbergh fields (Canada).

PDVSA E&P recently started-up its first SW-SAGD pilot project to evaluate this technology as a part of its future technological projects which will be developed to achieve higher oil recovery factors in its heavy oil reservoirs. In this project an optical fiber system was permanently installed along a producer well in order to monitor the temperature profile continuously during start-up, initial steam circulation and on production.

The data acquired shows that 1100 ft along the horizontal section were heated during start-up (preheating) in 15 days that is consistent with observation well data.

SW-SAGD technology project applied in the well MFB-617 has been considered successful, increasing 4.3 times its cold production, with a steam oil ratio of 0.30 Ton/STB, exceeding all expectations.

This paper summarizes experience obtained during the development of the first pilot SW-SAGD applied in the Orinoco Oil Belt, specifically in Bare field situated east of Venezuela.

Concepts

SW-SAGD[1] technology requires injection of steam into a horizontal well (injector/producer), creating a steam chamber and reducing the viscosity of the heavy oil. The heavy oil and condensed steam then flow by gravity down into the producer well, from where they are pumped out to the surface.

Introduction

PDVSA E&P started up a pilot horizontal injector/producer well in Bare Field in 2006 as part of its new technology evaluation.

The Bare field is situated in the Orinoco Oil Belt, in Anzoátegui, Venezuela Fig 1, and the TL sands are a 30 ft thick high permeability (~ 7000 mD) reservoir situated 2700 ft below the surface containing high viscosity oil Fig 2. The structure is defined as a monoclinal formation, smoothly dipping towards the north Fig 3. Traditionally the method of development of this reservoir has been cold production; nevertheless the oil recovery factor has not exceeding 3%. So, PDVSA has designed a pilot project SW-SAGD in order to evaluate this process in the Orinoco Oil Belt.

The main reservoir parameters are as follows:

- Thickness = 30 ft.
- Porosity = 30 %.
- Permeability = 7 Darcy.
- Oil Saturation = 80%.
- Original Pressure = 1200 psi. @ 2700 ft.ss
- Current Pressure = 600 psi.
- Reservoir Temperature = 130 °F.
- Original Oil in Place = 108 MMSTB.

SW-SAGD Completion Designed

A big part of the success of SW-SAGD project has been the completion designed on the well MFB-617. This horizontal well was drilled in April 2002 using directional drilling equipment and completed with slotted liners along the reservoir interval. The well has injection tubing to the toe allowing steam to be injected preferentially at the end of the horizontal section. This pipe 2 7/8” is insulated in order to avoid heat losses along the well bore. The production string was completed with tubing 3 ½” set 650 ft above the reservoir top Fig 4.

The downhole instrumentation string consisting of bubble tube and optic fiber in its ¼ inch control line[2] which was adhered to the injection tubing and run all the way along the reservoir interval. Two pressure gauges and four thermocouples are also part of the well instrumentation. This completion had never been utilized for the Orinoco Oil Belt.

Observing the completion diagram from figure 4, the utility of each tool must be detailed: the insulated tubing injects steam into the reservoir and reduces heat losses, the zone separator avoids steam flow back to the surface, forcing steam to penetrate into the reservoir, the dual centralizer keeps both strings centralized minimizing the expansive effects during the injection and the control line protects the optic fiber from the stress as well as replaces it in case of degradation Fig 5.

Project Development

Before SW-SAGD process the well MFB-617 was producing for four years cumulating 563 MTSB (cold production) Fig 6. The average oil production rate was up to 80 STB/D when the well was shut in to start-up the project.

The project development can be analyzed in three phases; the first phase corresponds to the well completion which commenced in 2006 by the rig LGV-100 on June 15th. The work over took 18 days and the well was completed with two strings (one for steam injection and the other for production).

The second phase, we called "preheating" and 100 Ton/Day (80 % steam quality) were continuously injected during 15 days in order to heat the heavy oil and establish fluid communication between the injector well and the reservoir. In this phase, pressure and temperature were monitored by the optic fiber and pressure gauges. Monitoring can be customized. In this test we set up data acquisition at 5 minutes intervals on foot by foot basis along the well.

During the third phase, well MFB-617 was put on production through an artificial lift system know as "Dyna Pump".

According to the data from DTS, the reservoir temperature was 140 °F (t = 0 days) before start-up of the preheating. At the start of the second phase, it was immediately observed that up to 1100 feet of the reservoir interval had 500 °F of temperature, indicating that this zone was 100 % saturated by steam. During the preheating phase (t = 30 days) the steam could heat about ¾ part of the horizontal section (1100 ft), from the toe to heel generating the steam chamber Fig 7. The total amount of steam injected was 3000 Ton equivalent to 266 MMBTU. The oil viscosity reduction can be observed in figure 8.

The horizontal section drilled in well MFB-617; according to its electro-graphics responses has high resistivity and low gamma ray, indicative of clear sand saturated by hydrocarbons of a continuous steam chamber. This suggests that there is no interaction between in-situ clays and the injected steam. Hence there was no adverse impact on development of a steam chamber Fig 9.

Production Behavior

During the injection – production phase, was used a pump unit know as "Dyna Pump", Fig 10. During this phase the pump unit worked at a speed of 3.8 stokes per minute (SPM) and 293 inches of effective length, producing over 300 STB/D. The last production test reported (30-12-07) the well MFB-617 produced 350 STB/D.

It is necessary to emphasize that before the project was started the well produced 80 STB/D, obtaining and profit oil of 270 STB/D by the SW-SAGD technology application. The production decline has been minimizing during the last 15 months that project has been developed Fig 11. Additionally, the continuous steam injection through SW-SAGD technology has had a positive effect on the oil production of the neighbor wells (MFB-637 and MFB-642), indicating that the steam injected has heated the drainage area of these wells. Figure 12, shows a head temperature map from the neighbor wells drilled to SW-SAGD project, where is apparent well spacing is about 150 m.

Conclusion

- It was demonstrated that it is possible to use a dual string completion (steam injection and production simultaneously) in the wells of the Orinoco Oil Belt, being the MFB-617 the first well worldwide in this type of completion to major depths of 3000 feet.

- During the preheating of the well the steam chamber was formed, its length was about 1100 feet of the horizontal section.

- The SW-SAGD technology has reflected excellent results in the well MFB-617, increasing its cold production over 440 % (4.4 times), to steam-oil ratio (SOR) of 0.30 ton/day and minimizing the production decline during the last 15 months of the project.

Recommendations

- To propose new projects applying SW-SAGD technology in order to verify his effectiveness in the Orinoco Oil Belt.

- To apply the SW-SAGD technology in wells with larger horizontal section, such as the big majority of Bare´s Field wells.

- To evaluate the technical and economical feasibility to complete the wells with production casing of 13 3/8" instead of 9 5/8", in order to install a highest capacity pump.

- To be absolutely careful when there is used optical fiber as instrument of monitoring in projects where the temperature of the steam overcomes 500 °F, since it runs the risk of being degraded.

Acknowledgement

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NOMENCLATURE

Ft	=	Feet
Ton	=	Tones
STB	=	Standard Barrels
mD	=	Mili-Darcy
psi	=	Pound Square Inches
°F	=	Fahrenheit
SS	=	Sub Sea
BTU	=	British Thermal Units
SPM	=	Stoke Per Minute
SOR	=	Steam Oil Ratio

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Appendices

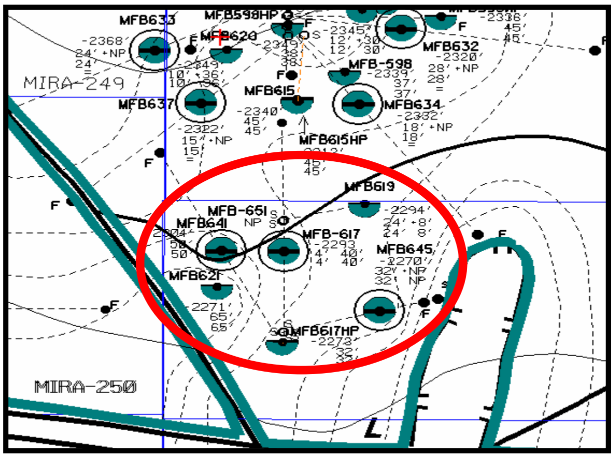

Figure 3: Structural TL Sands Map

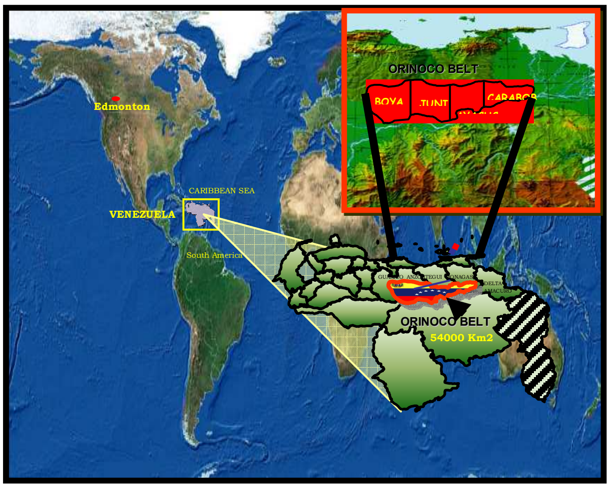

Figure 1: Map of Bare Field

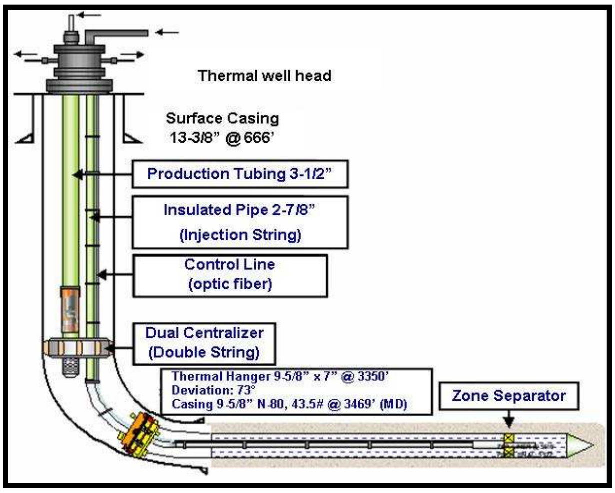

Figure 4: MFB-617. Well Completion Diagram

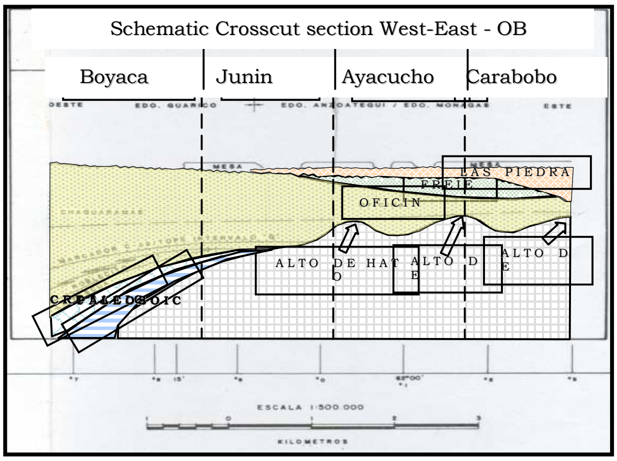

Figure 2: Cross-section of the Bare Field

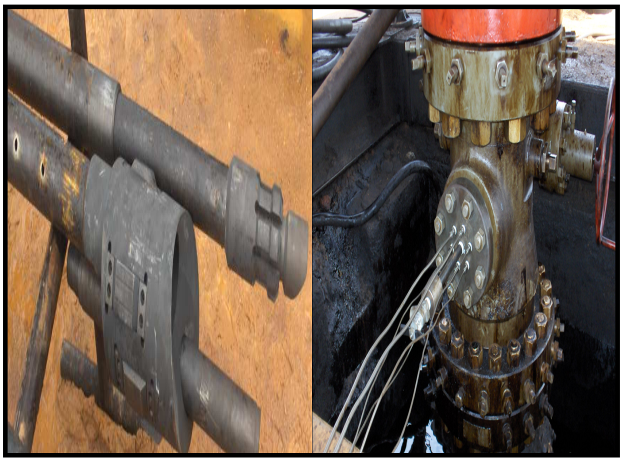

Figure 5: MFB-617. Completion Equipments

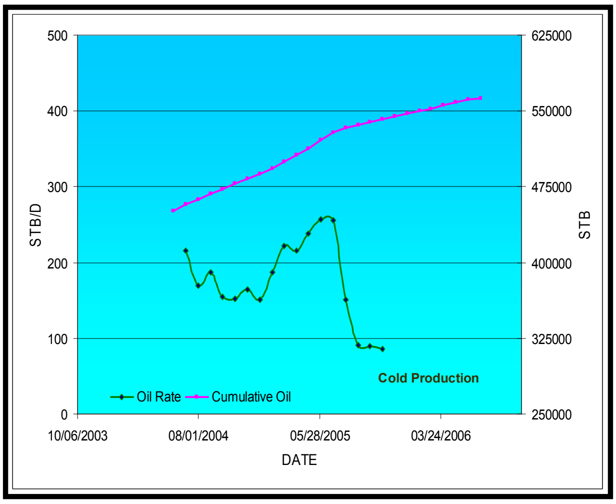

Figure 6: MFB-617. Cold Production History

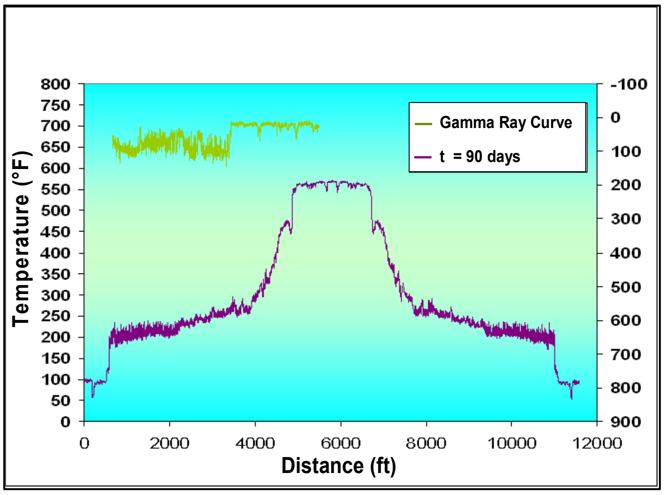

Figure 9: Temperature profile versus lithology

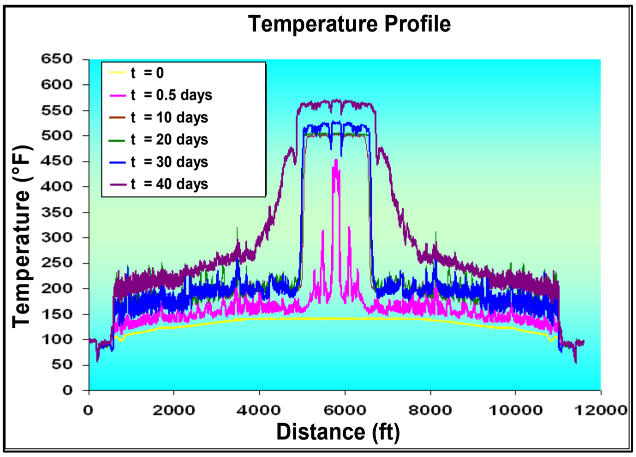

Figure 7: Temperature profile during preheating

Figure 10: DynaPump System

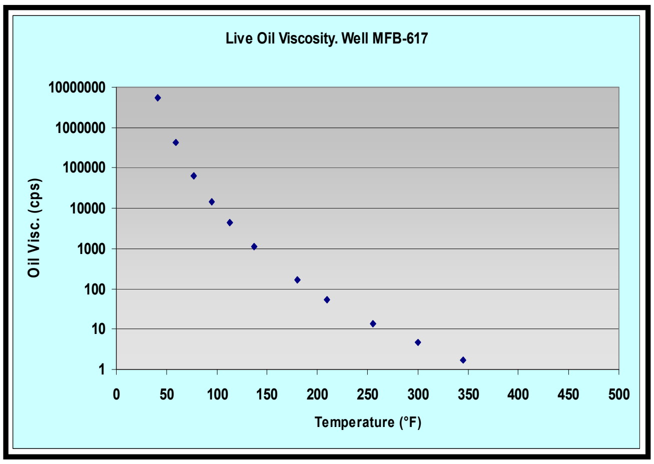

Figure 8: Oil viscosity reducing by thermal effect

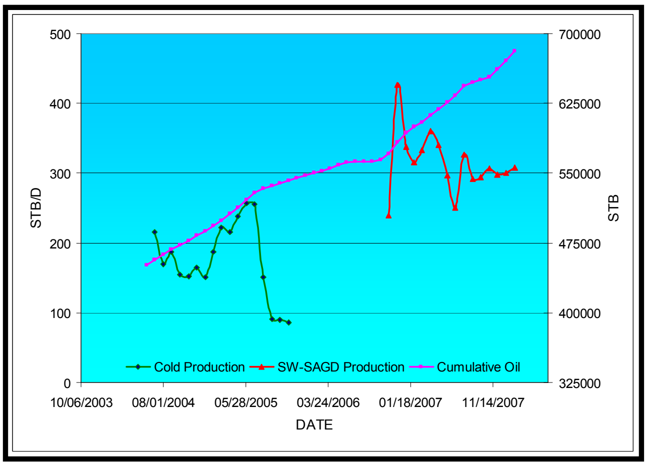

Figure 11: Oil production increasing SW-SAGD

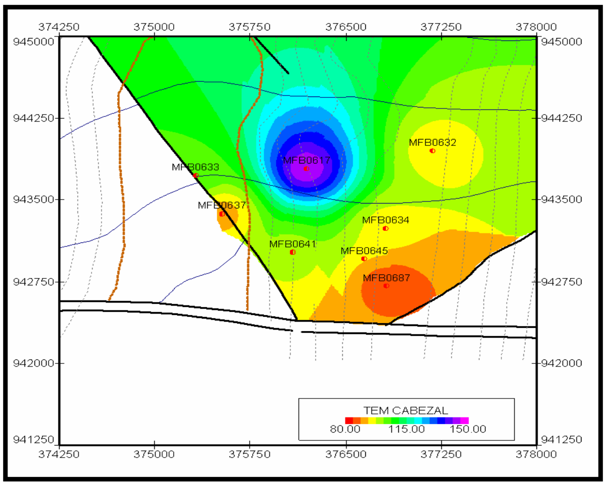

Figure 12: Well head temperature map