Comparative study of the temperature profiles for spontaneous and induced ignition on the pilot area of In Situ Combustion (ISC) on Bare Field of Venezuela

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ABSTRACT

Several evaluations on the laboratory and by reservoir simulation have been carried out in order to determine the best opportunity for the ignition process on the In Situ Combustion Pilot (ISC). The ignition point is critical for every single ISC process, for that reason evaluation of the temperature profiles and the times required for reached temperatures to promote the reactions and the profile on time and distance on the area are critical information to manage in terms to define the best way to ignite on the field. On Bare Field it is planned a Pilot Project to evaluate the impact of ISC mainly to increase primary recovery factor 8% to 20%; the definition of the ignition is one of the most important challenges to ensure the success of the ISC pilot on Bare Field. Some preliminary experimental evaluation has been done at the laboratory to determine the temperature achieved with induced ignition, and those values are compared with the spontaneous profiles and the times required for each case. The results obtained showed that induced ignition take slightly minor times to promote the reactions of ISC and could be visualized that spontaneous take longer times which could be unfavorable to implement a pilot project under this scenario because the risks associated are higher, the opportunity implicit on the pilot is to minimize the risks to evaluate the maximum benefits of this EOR process like the potentiality to exploit and produce its heavy and extra heavy oil by ISC.

KEY WORDS

In Situ Combustion, ignition, reservoir simulation

INTRODUCTION

Venezuela has the biggest reserves of heavy oil in the world in the Faja Del Orinoco Hugo Chavez Frias (PDVSA 2012). The recovery factor in this area can be increased significantly if Enhanced Oil Recovery (EOR) processes are implemented appropriately. In this sense, several EOR processes are being visualized by hierarchization in these area, either chemical processes or thermal processes. In Situ Combustion process (ISC) is one of the thermal processes that will be tested in the Faja Del Orinoco Hugo Chavez Frias due to the highest recovery factors obtained in others fields developed with this EOR thermal process around the world. In this method, air is injected into a reservoir to create a high temperature combustion front that is propagated through the reservoir. The area chosen for the ISC Pilot in Venezuela is the Bare Field located in the northwestern area of Ayacucho, in the Faja Del Orinoco Hugo Chavez Frias, southern part of the Eastern Basin of Venezuela and north of the Orinoco River.

The objective of this study was to show the results from sensitivities through CMG platform between spontaneous and ignition induced by preheating the area with steam injection in order to compare both mainly considering the temperature profiles in the reservoir looking for the best option in order to accelerate the formation of the ignition front in the pilot area to be affected by the ISC process. The reservoir simulation will be validating the results obtained from the laboratory tests.

The results would be the base to choose the best way to generate the ignition in the field for the pilot test.

STATEMENT OF THEORY AND DEFINITIONS

In Situ Combustion (ISC) is a displacement process in which the oxygen contained on air is injected into a reservoir at high pressure and temperature. It reacts with the crude oil to create a high temperature combustion front that is propagated through the reservoir. Ignition can be spontaneous if the crude oil has sufficient reactivity itself at contact with the oxygen at the reservoir or induced by artificial methods (electrical, gas igniters, steam injection). It is the most critical and important stage on the In Situ Combustion process that should be defined carefully. The fuel consumed by the combustion front is a residuum produced by a complex process, where cracking, coking, and steam distillation occurs simultaneously with the combustion front advance. The combustion front is preheated to the combustion temperatures (650 to 1200 °F) as it flows through the rock behind the combustion zone. The Combustion process produces primarily water (as water steam); and CO_2, and CO; flowing ahead with a slow movement. Oxygen not consumed by the combustion front and nitrogen also flows with the combustion gases (Green 1998).

Venezuela has many heavy oil reservoirs; Faja Del Orinoco Hugo Chavez Frias is the most important accumulation of heavy and extra heavy oil in this country. Looking for to increase the recovery factor in this area, PDVSA is planning to implement several EOR pilots and In Situ Combustion is a promising process to be considered for this type of reservoirs. Bare field is the area chosen to apply air injection as the source to generate and complete important data related with the process since previous experiences have been poorly documented, this pilot area is located in the northwestern area of Ayacucho, in the Faja Del Orinoco Hugo Chavez Frias, southern part of the Eastern Basin of Venezuela and north of the Orinoco River. Geographically is located in Anzoátegui state, and covers an area of about 487 km^2 with a length of 27 km and a width of 18 km approximately (see Figure 1). The ISC Pilot Area consists of one vertical injector, two horizontal producers and four vertical observer wells (Anaya 2010).

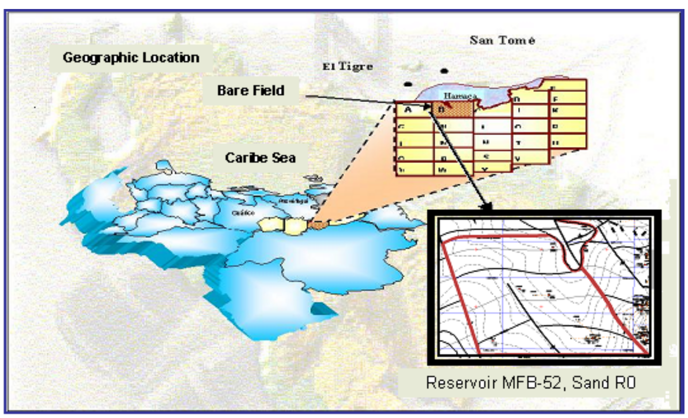

Figure 1. Location of Bare ISC Pilot, Venezuela

DATA AND OBSERVATIONS

Experimental data and CMG's thermal reservoir simulator were used to represent the Pilot area for the Bare field. It is based on Anaya et al work and consists of a corner point grid with 245587 blocks (126x61x33). Figure 2 shows the field simulation model.

After some preliminary studies at the laboratory promoting ignition with steam injection, reservoir simulation has been proved to be the best tool to evaluate the conditions generates at the field which offer the temperature profiles and cumulative production impact more adequate for the pilot in first instance. Looking for the best option in order to accelerate the formation of the ignition front in the porous media, two sensibility cases were studied by simulation model of the reservoir comparing the spontaneous ignition and generated ignition, according the following scenarios:

a) Case A: Spontaneous Ignition, using air as injection fluid in order to promote the ignition through the reaction with the crude oil was studied.

Conditions for this case are following:

Fluid injected: air (79% N_2 and 21% O_2)
Qinjgas: 4 $MMft^3/d$
BHPmax: 2000 psi
Start injection: 01/01/2016
Final injection: 01/01/2021

b) Case B: Promoted or Enhanced spontaneous ignition, using steam injection in order to preheat the area into the reservoir and reach the ignition temperature was modeled.

Conditions for this case are following:
Fluid injected: steam (1000 psi and 0.7 quality)
Qwaterequiv: 1100 bpd
BHPmax: 2000 psi
Start injection of steam: 01/01/2016
Final Injection of steam: 01/02/2016
Start injection of air: 01/02/2016
Final Injection of air: 01/01/2021

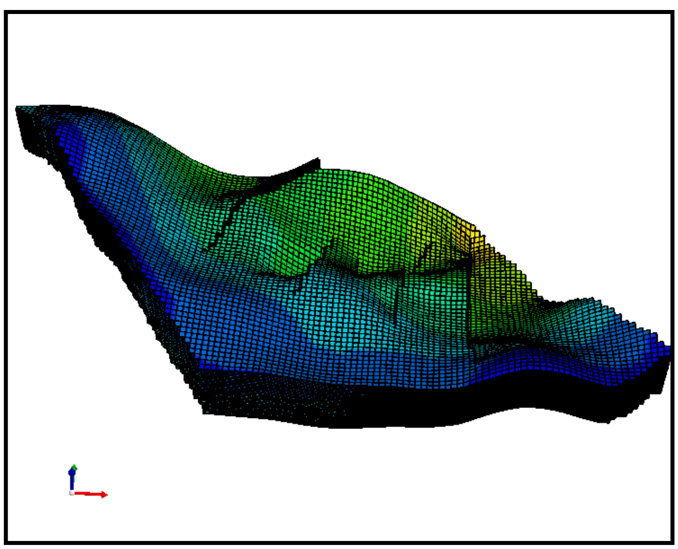

Figure 2. Model Simulation of ISC Pilot in Bare field

RESULTS

Temperature Profiles

Case A: Spontaneous Ignition.

Depending of each case, specific simulation conditions were established in the model. STARS simulator from CMG was used to run the different cases and several results were obtained. They are presented in this section. Case A corresponds to air injection since the injector well is opened and operated. It was established 2016/01/01 as the date of the ISC pilot started according to this sensitivity case.

Figure 3 shows the temperature profile for the injector and four observer wells of the pilot considering this case.

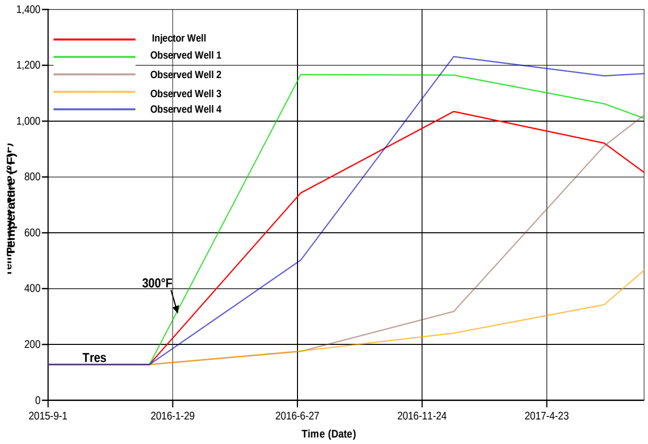

Figure 3. Temperature profile Spontaneous Ignition Case

Case B: Steam Injection for Ignition.

The scenario on the reservoir model considers on Case B consists in a preheating stage by steam injection during the one month (January, 2016). In this case was injected 1100 bpd of equivalent water (steam) at 1000psi and 0.7 of quality assuming at reservoir conditions.

Furthermore Figure 4, shows the temperature profile achieved for the injector and observer wells from the case B.

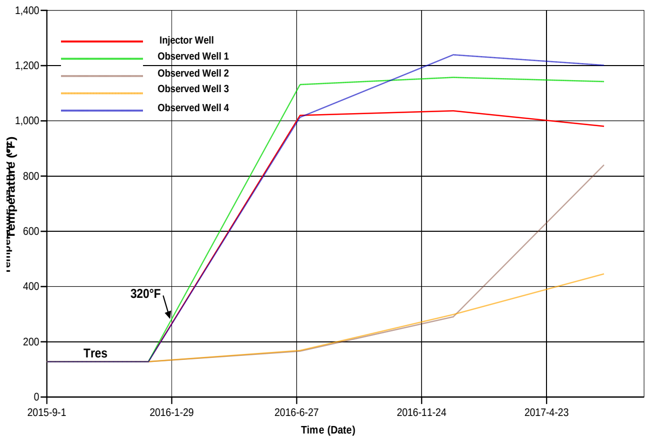

Figure 4. Temperature profiles with Steam Injection for Ignition Case B

Additionally, on figure 5 it is plotted the oil production cumulative until 2018, where for both cases of the production profile showed similar tendency. Cumulated oil also was evaluated in order to confirm the effect of the steam injection during a month in the pilot.

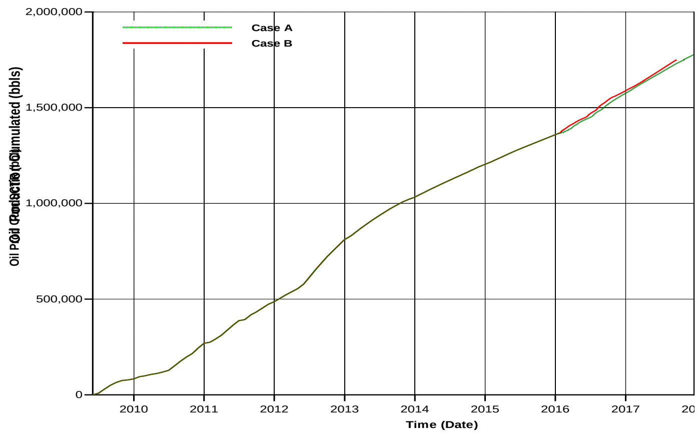

Figure 5. Cumulative oil at 2018 of the CES pilot for Case A and B

Finally, figure 6 shows the effect observed in the reservoir pressure injecting only air or preheating the reservoir with steam (Case A and B, respectively).

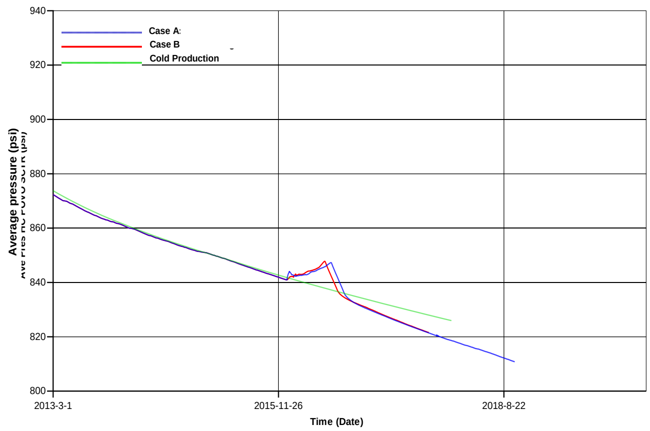

Figure 6. Reservoir Pressure for ISC Pilot under different scenarios

DISCUSSION

Temperature Profile

The Figures 3 and 4 show the temperature profile for Cases A and B. For the spontaneous ignition case (Figure 3), it can be observed how the temperature increases since the first day of air injection (Tres= 129 °F) due to the reactivity of the oil at air contact. At the end of the first month of air injection, either the temperature in the injector well or at the level of observer well 1 is close to 300°F, the observer well 4 only experimented the effect of the injection by reaching temperature close to 200°F. Due to the location of the observer wells 2 and 3 in the pilot area, the effect of the air injection is not evidenced and the temperature doesn't increase during the first month. The Ignition point (600°F), according this chart is reached at March 2016 (three months after the injection started).

Results obtained by steam injection to promote ignition are showed in the Figure 4; these reflect how the steam injection during the first month of the heating stage in the pilot area are similar to the observations for the case A. Temperature is going to increase since the first day of the injection to reservoir temperature (129°F) through the time and at the end of the first month temperature reaches values close to 320°F. In similar way, it can be observed how the effect of the steam injection is not experimented at the level of the observer wells 2 and 3. In other hand, the temperature profile in the observer well 4 increase considerably, comparing with case A, close to 300°F at the end of January, however this preheating is not enough because the ignition point is also reached at March 2016, which is the same behavior observed in Case A. These results validated with the preliminary studies at the laboratory where condition for the ignition point are reached almost at the same time.

Production and Pressure Response:

According Figure 5, oil production is not affected due to the preheating. It can see the same response in production with a little vantage to the Case B, but it is not conclusive. The difference between the two curves is low and the preheating using steam injection does not promote an improvement in the oil production. This supposed to be only affecting the time to reach the ignition temperature.

Finally, according the pressure performance chart showed in Figure 6, both cases A and B promote a pressurization during the first month of the injection and its behavior continues during the next five months, after that, pressure show a decline line similar to the cold production declination.

Final discussion

This work evaluated the impact of the steam injection as method of preheating for the ignition stage in comparison with spontaneous ignition for the In Situ Combustion pilot project in Bare field. Results showed that steam injection used as preheating method will not represent a benefit in comparison with air injection since the beginning of the heat stage of the production, due basically the reactivity between the oil and the air injected.

CONCLUSION

According to the sensitivity cases studied, the following conclusions were reached

1. Spontaneous ignition represented by Case A, from reservoir simulation point of view is a good choice for the ISC Pilot in Bare field because the profile temperature shows how the ignition point is reached 2 months after the air injection started.

2. Steam injection for promoting ignition represented by Case B, has a similar behavior in the temperature profile compared with spontaneous ignition; due to the ignition point is reached close to 2 months after the injection started.

3. The oil reactivity with the air for Bare field would help to reach quickly the ignition point in the reservoir accordingly with kinetic results obtained either from the lab or by reservoir simulation.

5. Oil production is not affected by the use of spontaneous or induced ignition. Pressure response in the ISC pilot is going to increase the first six months, after that, it is going to decline according with cold production declination performance.

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NOMENCLATURE

Bbls: barrels
°F: Fahrenheit Grade
ISC: In Situ Combustion
Km: kilometers
Km^2: square kilometers
Mbbls: thousand of barrels
$MMMft^3/d$: millions of cubic feet per day
Psi: pound square inch
Qinj: injection rate

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