Thermal evaluation U1,3 MFB-53 Reservoir, by implementing a system of temperature monitoring wells completed with fiber optics and thermocouple belonging to the SAGD pilot project. Faja Petrolifera Del Orinoco.

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Abstract

Petroleos de Venezuela SA, is pushing as one of its goals in the medium and long term to assess the feasibility of applying recovery technologies for heavy and extra heavy crude, this in order to increase the recovery factor of fields belonging to the Faja Petrolifera del Orinoco (FPO). The SAGD process is a thermal recovery method applied in fields of heavy and extra heavy crude, which supplies to the reservoir the amount of thermal energy required to reduce oil viscosity. Right now, it has been obtained the first positive results from the study of the application, from a production rate of 280 bbl/day (without heating) up to 800 bbl/day as a result of steam injection by August 2010, being large part of this success linked to the constant monitoring of temperature changes occurring within the reservoir.

In the SAGD project, one of the variables to be monitored more closely is the temperature, as in thermal processes plays an important role when framing any strategy. This is implemented new monitoring techniques, getting into the steam injector well (MFB 773), depth sensors (thermocouples type K) to study the temperature along the same and thus monitor critical processes, adjust parameters and adapt to the circumstances of each day. In analyzing the temperature behavior of SAGD Project, through sensors in the steam injector, was achieved by evaluating 5 stages in about 120 days. The data provided in the study, helped analyze the temperature variation at reservoir conditions before, during and after steam injection, this being actual results could be extrapolated, with some adjustments, to future thermal recovery projects in the FPO. Through observer Wells it could be determined the thermal behavior of the reservoir at a given distance of the SAGD wells, knowing initially that the original reservoir temperature is 137 ° F, obtained by the first temperature profiles before injection steam. After a period of continuous injection of steam, injection rates varied from 100 to 400 TON / D and a volume of steam injected 11.000 TON accumulated, the temperature in the reservoir reached maximum values of 163 ° F average, meaning an increase of 23 ° F at that distance from the steam injection.

In any thermal recovery project, one must analyze the behavior of the same along the reservoir and thus to predict the amount of heat transferred to the formation with a higher degree of certainty, obtaining optimization process steam injection future will be implemented in the F.P.O and the world.

Introduction

SAGD process is a thermal recovery method, applied in fields of heavy and extra heavy oil, which is generated in the reservoir the amount of thermal energy required to reduce the viscosity of oil, Much of the success of the application of this process in the F.P.O is linked with the drilling and completion of the array of wells at depths greater than 3000 feet, where the parallelism and spacing between them, cementing and completion design are critical.

The first SAGD pilot project developed in the Orinoco Oil Belt in Venezuela, specifically in the Ayacucho area - Bare FIELD by a conventional arrangement of wells MFB-773 (injector) and MFB-772 (Producer) and 3 wells observers (MFB-685 , MFB 785 and MFB-784). These wells were completed at the reservoir U1, 3-53 MFB, reservoir site consisting of unconsolidated sandstone rich in quartz, with variable amounts of detrital clay, ideal for this project because of its excellent petrophysical properties, porosity exceeding

30% permeabilities ranging up to 7,000 MD. Currently, this being evaluated by estimating increase gradually in subsequent years the number of pairs SAGD.

Figure No. 1. Geographic Location SAGD Pilot Project - Orinoco Oil Belt.

Although much of the successful implementation of this process in the F.P.O is related to the drilling and completion of the array of wells deeper than 3.000 feet, where the parallelism and spacing between them, and cementing completion design are critical factors, too, must keep track depth of the pressure data and temperature sensors thrown installed bottom in accordance SAGD wells, in order to determine the effectiveness of the steam chamber within the reservoir.

The study conducted through the implementation of sensors background in SAGD project, is based primarily on monitoring the temperature and variation in the injected steam it in turn will display the changes that occur at the reservoir. To this was included in the project completion thermocouples, which are based on a measurement system consisting of two conductive wires of different alloys joined at one end. Applying junction temperature of these metals generates a voltage is very small (millivolts), which increases proportionally with temperature difference of the two together, giving immediate reliable and easy to read.

Development

Completion of the project SAGD wells.

The project is comprised by two horizontal wells, one injector of steam and one producer. The MFB-772 producer well was drilled using navigation tools MWD-LWD, drilling 2,120 feet of achieving 100% horizontal section net oil, this well was completed with mechanical pumping equipment, using pump-F 5-1/2 insertable AHRF "x 3-3/4" x 3 "x33 ', with a lifting capacity of 3,000 barrels of fluids. By applying the estimated drain SAGD technology 2 MMstb, with an initial potential of 1,500 SBD. Is strapped down to a tail pipe 2-3/8 "pressure and temperature sensors in addition to fiber optics, this in order to monitor the effect of steam injected along the horizontal section of the well. Also, got a capillary tube 3/8 "to fund chemical injection. (Fig. No. 2)

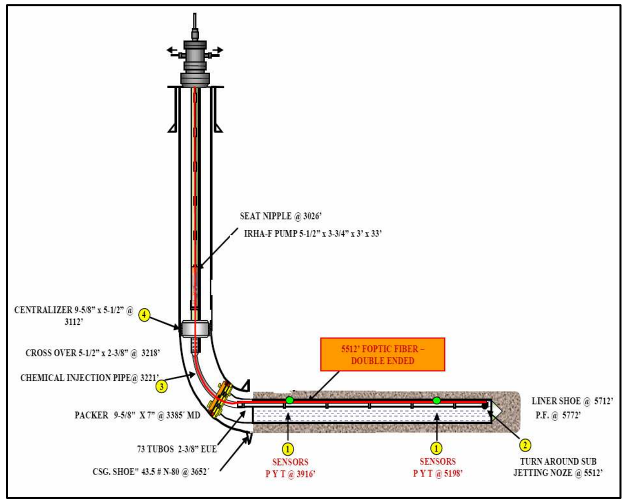


Figure No. 2. Mechanical diagram of Producer well MFB 772 SAGD Pilot Project.

Later the injector was drilled, whose name is MFB-773, with 5.778 feet lof total depth with 1.998 feet of horizontal section 100% of net oil sand, with a vertical spacing between wells of 34 feet. This was completed with pre-insulated pipe 4-1/2 "x 3-1/2", which has shown excellent results in reducing heat losses in the well, in addition to injection valves selectively (70% steam rate in the Toe and 30% in the heel). Were introduced temperature sensors (thermocouples) in the horizontal section, strapped to the pre-insulated pipes, in order to monitor the temperature variation in the reservoir. (Fig. No. 3)

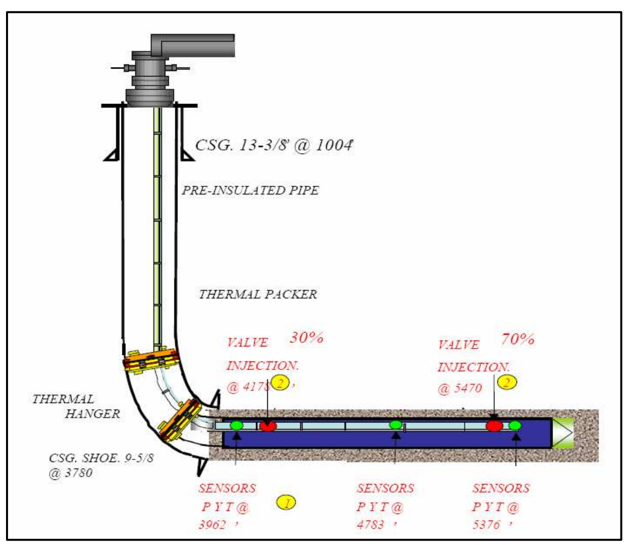


Figure No. 3. Mechanical diagram of the Well of the SAGD Pilot Project.

Approximately 60 meters apart in the area sailed by the pair SAGD (MFB-772 and MFB-773), 3 wells were completed as observer of the project (MFB-685, MFB-784 and MFB-785), in those wells sensors were installed bottom type thermocouples and optical fiber, this in order to determine the behavior of heat in the reservoir and the calculations for heat transfer (figure 4).

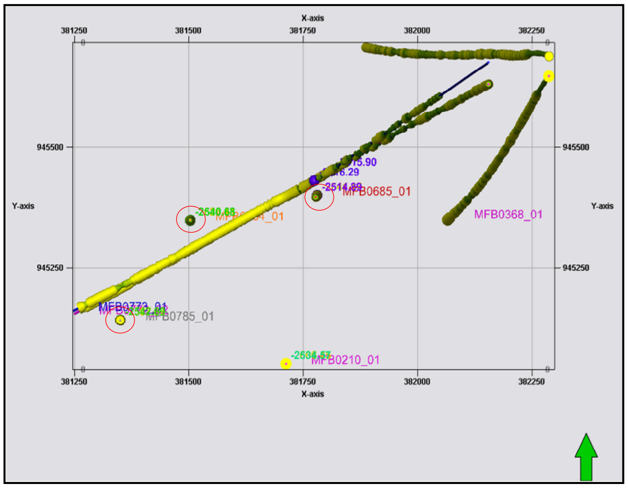


Figure N ° 4. Distribution of wells in SAGD project.

The following figure is a graphical representation of the current path of the wells to sand level goal (U2, 3), which shows the configuration of the array located between them.

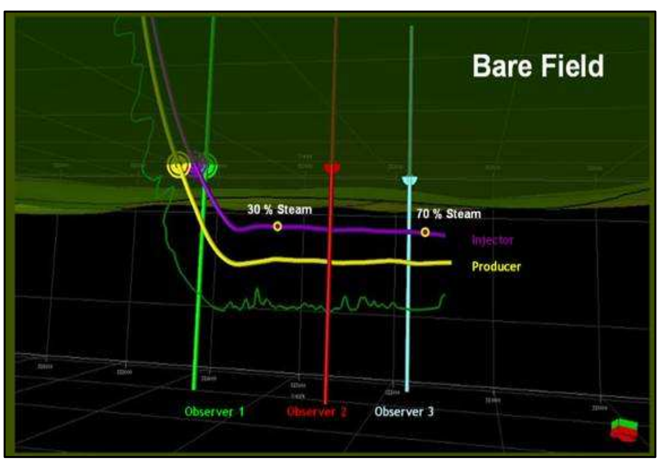


Figure N ° 5. Current trajectories well - SAGD Project.

Applied methodology

In the interpretation of thermal data obtained from sensors background in SAGD project, it was necessary to divide the study into two phases, the first of which was achieved interpret the Data Type Thermocouple sensors implanted in the MFB-773 injector well and the second is to analyze the obtained data Fiber Optic completion of the wells and Observer MFB 784 y MFB-685.

PHASE I. WELL INJECTOR - DATA FROM THERMOCOUPLES.

In the study of variation of temperature in downhole steam injector SAGD project, were evaluated in 5 stages approximately 120 days (Figure N ° 6).

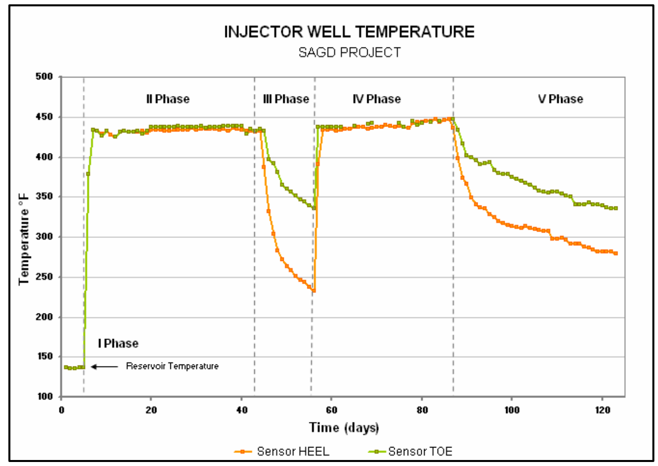


Figure No. 6. Temperature Chart on bottom of Well MFB 773 (INJ) SAGD project.

The analysis stage validated the initial reservoir temperature and the variations that occur in background by volume of steam injected in stage I corroborates the initial temperature, in order to evaluate possible changes that occur when injecting steam in stage II were injected approximately 3.805 tons of steam in 40 days with constant rates of 100 Ton / Day, according to the design completion steam is distributed in the toe 70% and 30% in the heel, with injection temperature averages about 500 ° F, in stage III were analyzed readings obtained after stopping the injection of steam around 10 days, highlighting a decline in bottom heat, in stage IV, continuous injection of steam temperature of 550 ° F average, which was monitored for 31 days, noting that sensitivities were performed on the injection rate, which verified the temperature variation that occurs in downhole pumping from 100 tons / day, up to 400 Ton / Day About 7.385 tons were injected steam in the last stage (V), stopped steam injection for 35 days, where the temperature change was analyzed was generated according to sensitivities made in the previous step.

Period I "Assessment Bottom temperature before injection of steam"

Was conducted to study the behavior of the reservoir prior to steam injection, obtaining readings of the temperature around 137 ° F, the objective of this stage was to corroborate the initial conditions and have a certainty of the changes occurring in the background after steam injection (Fig. N ° 7).

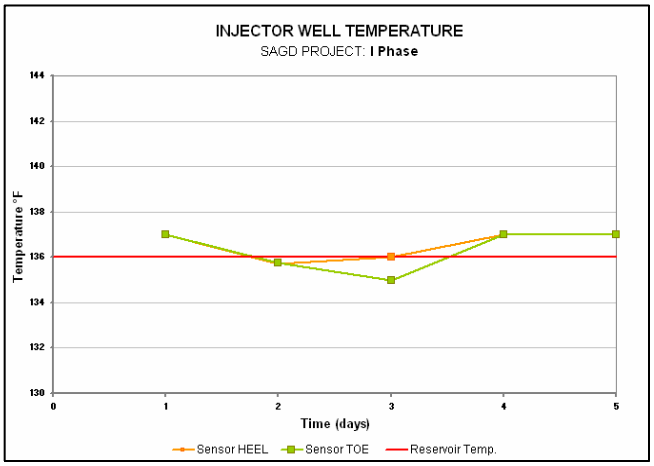


Figure N ° 7. Temperature Chart I stage

Period II "Assessment Botton temperature during steam injection."

At the start of steam injection sensors recorded an immediate increase in temperature at the bottom of the injector MFB 773, yielding similar readings in both the heel and at the bottom of 430 ° F within 10 days. Subsequently there was an increase in temperature to a greater extent at the tip of the well, due to the greater distribution of steam in this area, so that there is a greater volume accumulated in this area, clearly visualizing the linear increase of temperature in both points , considering that was injected at a constant rate and the volume injected was little, so it was not possible to stabilize the system and visualized more heat at a point in the other (see Fig N° 8).

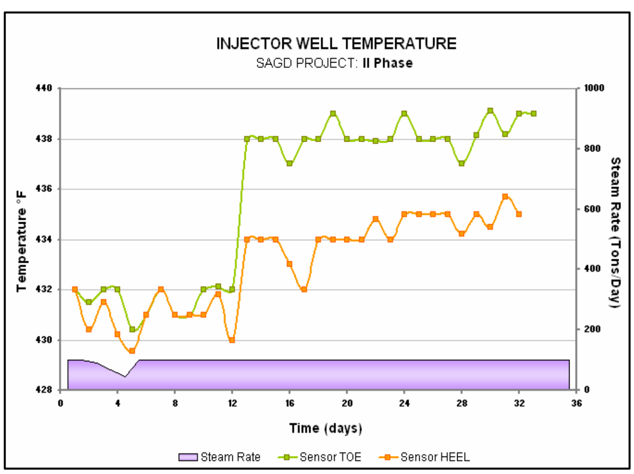


Figure No. 8. Temperature Chart II stage.

Period III "Evaluation of the temperature by stopping the injection of steam."

After cessation of steam injection, it is envisioned that in the first 5 days, heat loss occurs pronounced in the bottom of the well, with the highest proportion in the heel as a result of the smaller amount of steam injected, this decline is due to sudden temperature differential is generated by stopping the injection, then there is a moderate loss of heat, therefore, to study the data was taken from the day where it stabilized temperature drop (Fig. No. 9).

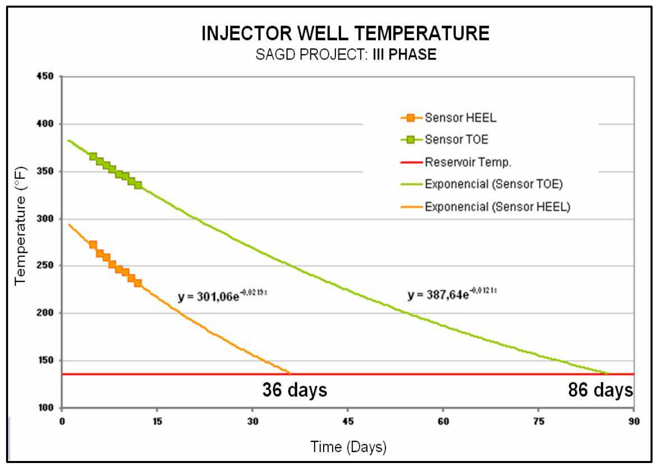


Figure N ° 9. Temperature Chart Stage III.

This information was used to extrapolate the temperature trend in background to the original conditions of the reservoir, obtaining results that allow us to infer the amount of heat lost in training to obtain the initial conditions, it is estimated that approximately 36 days the temperature in the heel be close to the original and in case of the tip in approximately 86 days.

Period IV. "Evaluation of the background temperature during steam injection by varying the volume of steam injected."

The stage behold the sensitivity analysis in tons injected daily, displaying a linear increasing in temperature downhole, this is due to accumulated heat in the formation and increased injected volume. (Fig. No. 10).

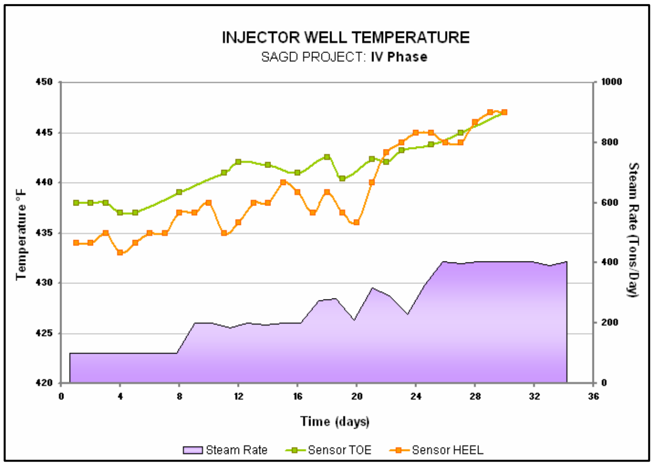


Figure No. 10. Temperature Chart Stage IV.

Noting that in the early days of evaluation behavior is similar to step II, the temperature reached at the tip is greater than in the heel, by increasing the injection rate in the last 8 days, the temperature in the heel and the toe will become equal to maintain the same tendency, it is important that these operating conditions the system is equalized, so it is shown that a volume, rate and a given time is obtained temperature stabilization in different injection points.

Period V. "Final Evaluation of the temperature by stopping the injection of steam"

By stopping the injection losses were evaluated taking into account temperature sensitivities and made as much steam injected, therefore the methodology was adopted in stage III for analysis. (Fig. No. 11).

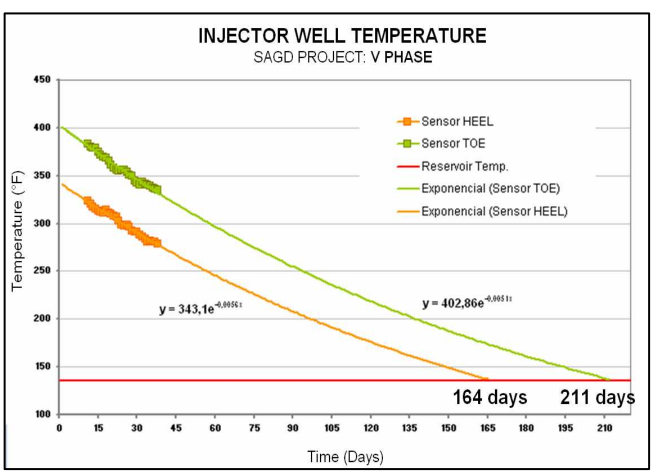


Figure N ° 11. Temperature Chart V Stage.

In the results can be seen that there is less heat loss at both ends of the completion of the well, due to increased accumulation of steam in two points, allowing future visualize the thermal behavior and demonstrated that a greater amount of steam injected heat losses are less. Additionally it was possible to predict the time when the reservoir reaches its original temperature: 175 and 128 days or so for the toe and heel respectively, noting increased maintenance of the temperature at the bottom for a while longer.

PHASE II. WELLS OBSERVER - FIBER OPTIC DATA.

As Phase I, we proceeded to define time intervals, according to the events of injection and / or production that have occurred since the project began, but in this case only identified three major periods occurred in the pair SAGD (MFB-772 producing well and injector MFB-773): a normal first stage injection-production to 100 tons / day, represented by the letter "a", a sensitivity study period with injection rates "B", and a final period of cooling steam injection stop "C", which is our period of study.

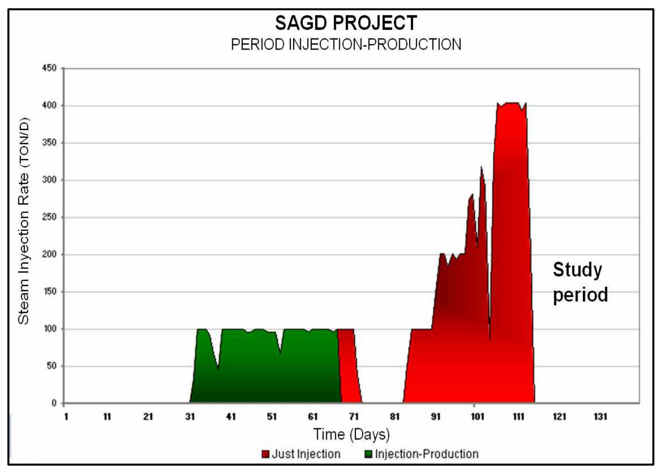


Figure N ° 12. Periods of injection and / or Production.

At the end of November 2009, starts a study of variation of temperature by means of sensitivities of the steam injection rate (period B), during the continuous injection of steam through the well MFB-773, in order to verify the proper functioning of Fiber Optics and determine the optimum injection rate for a heating or temperature increase in the production well, starting with the rate of 100 tons / day to achieve injection rates of 400 tons / day. For this study, it was considered the last period "C", to find the degree of decrease of temperature in this area of the deposit after steam injection stopped after a rate of 400 tons / day.

Study interval - length of optical fiber.

Mainly selected temperature interval data obtained in the most important observers wells, which is the range where the optical fiber is in direct contact with the formation.

We selected a fiber optic line to include the complete range of sand U2, 3 (3.110 '- 3.187'). To do this, as explained in the previous section, we determined the length of cable between surface equipment and wellhead DTS, which is getting about 274 feet in well MFB-784.

Through a graphical representation of the completion of the wells, it could define the study interval of temperature, which is understood from the first point of contact of the optical fiber with the formation (3384 ') to coming out of it (3.542 ') for their return. Knowing that the fiber length to the depth of TAS is 3.458 '(well MFB-784).

Mathematical evaluation of readings of optical fiber profiles.

Intervals were established to determine optimal length arithmetic averages of temperature, starting with 50, 100 and 150 feet, where it was observed that it was feasible to calculate the average or representative, as the standard deviation of the original data from its mean was almost negligible, being in many cases less than 5% of the mean. With this method most representative graphs were obtained that allow determining temperature changes in time intervals after steam injection stopped. (Figures No. 13 and 14).

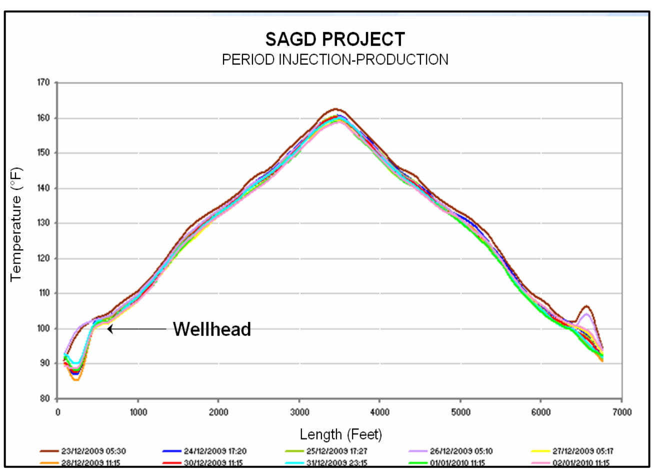


Figure N ° 13. Temperature Profile Standard - Average 150 feet.

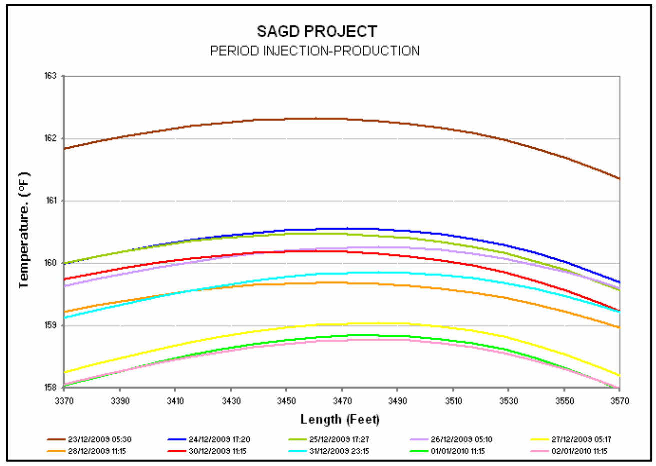


Figure N ° 14. Standard Temperature Profile - Average 150 feet.

In these graphs, we observe that the trends of the curves are smoother than in the graph of the original profiles. Using these new graphics display was achieved minimum temperature changes through the optical fiber profiles in wells observers.

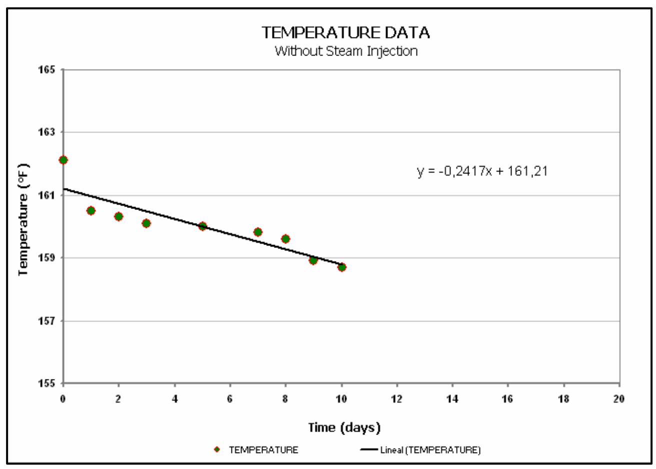


Figure N° 15. Distribution of average temperature in the range of sand.

Figure No. 15 shows a minimal decrease in temperature of 0.244 ° F / day. However, although the methodology applied to the profiles is desirable to identify small changes in temperature in the wells observers Fiber Optic interval in contact with the formation of only 84 feet in descending and ascending 84 feet (return) as described above. For this reason, it determined that the most representative distance for this interval arithmetic, was 15 feet higher because at that distance, very few points were obtained for a graph representative and less than it was possible to observe changes temperature (similar to the initial graph). In addition to verifying the results obtained using the above methodology.

The temperature variation graph for each 15 feet into the formation, shown an example (Figure No. 10), shows the changes of temperature using standard profiles every day in the first interval of sand (15 feet).

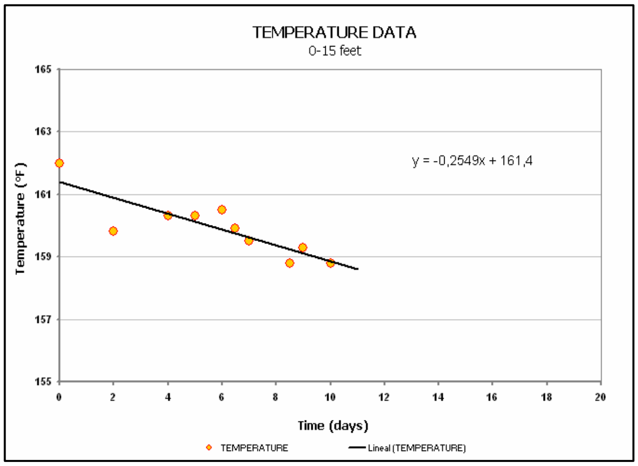


Figure N° 16. Distribution of Temperature in the first interval of sand.

From there, it was determined that the degree of temperature decreasing for the first interval of 15 feet, taken from the training is 0.2232 ° F / day, similar to the overall average value obtained.

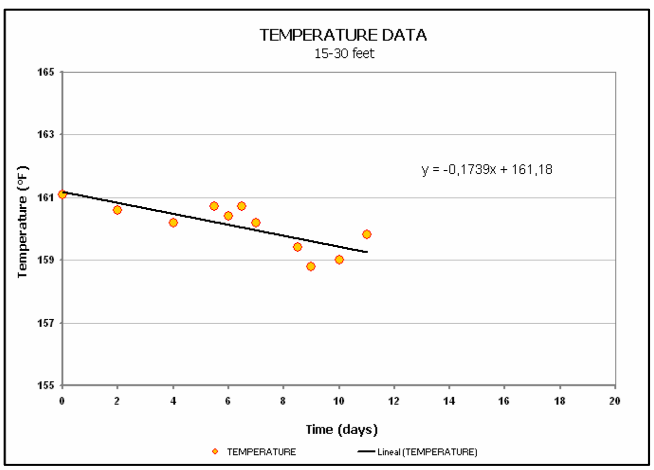


Figure N° 17. Distribution of Temperature in the first interval of sand.

For the next interval of 15 to 30 feet, the degree of temperature decreasing is 0.1799 ° F / day, something different than the first, this due to the heterogeneity of the sand.

Thus, following the same procedure was performed for the following ranges from 30 to 75 feet. Below is a table of values of degree of temperature variation for each of the intervals analyzed.

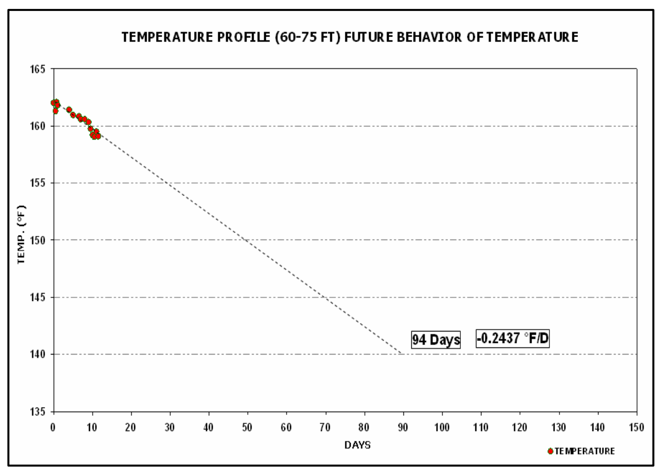
Table 1: Levels of variation in temperature interval.

SAND INTERVAL (FT)	TEMPERATURE GRADIENT (°F/DAY)
0-15	0,2549
15-30	0,1739
30-45	0,1236
45-60	0,1800
60-75	0,2437

Behavior of temperature variation.

The graph for the last interval (Figure No. 18), linear regression was more fit or more relationship among the data. For this reason, was used to predict the future behavior of temperature versus time in training for the area where wells are located observers

According to thermal analysis conducted, it was determined that the degree of heat dissipation is low (Figure N ° 18), which was expected once stop the injection of steam into the well MFB-773 (Injector-SAGD Project). This indicates that stabilization is achieved in a time period of approximately 94 days according to the mathematical model designed.



The above chart shows the variation of temperature versus time. The maximum temperature reached was 162.62 ° C and after about 11 days, the temperature was in the order of 159.3 ° F, thus determined that the temperature at a rate of 0.2437 declined ° F per day. In the graph above is able to observe the behavior of temperature forecast, with which it was determined that the time required to reach the original temperature of the reservoir is approximately 94 days.

Conclusions

• In Period IV of Phase I, we obtained a thermal equilibrium at both points of steam injection at a rate and time.

• Through the Portal of the injector well is determined by the temperature regressions take approximately 86 days to the toe and 36 days in the heel, to reach its original condition.

• In Stage V, was determined by the temperature regressions take longer more than 160 days to reach its original condition.

• The highest temperature recorded in the observation well was 163 ° C, after a steam injection rate of 400 tons/D and an accumulated volume of steam injected from 11.000 TON.

• Repetitive oscillations in the profiles of temperature, was not possible to observe small changes in function of time.

• Steam does not move uniformly in the reservoir.

Recommendations

• Verify the ability to download a larger number of thermocouples in the completion, in order to monitor progress with greater certainty of the steam chamber.

• All thermal recovery project, there must be at least one well completed observer monitoring system temperature, to observe the behavior of the steam in the reservoir.

• Improve data obtained by optical fiber, reducing repetitive oscillations along all the way to identify small changes in temperature versus time.

• Evaluate the temperature variation in the wells observers of the project in all periods of injection-production developed in it.

• Progressively increase steam injection rates and keep them for a long time.

• Monitor project sensitivities in injection rates with active producing well.

• Evaluate the possibility of designing the completion of the steam injector with 3 injection valves (Tip, Middle, heel).

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