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"Lessons Learned from Medium and Extended Reach High Pressure Wells in Mexico South."

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Abstract

A drilling performance analysis for multiple high pressure wells was performed on Sen Field, Mexico South. This project belongs to Delta del Grijalva Basin. This field has grown importance for its increasing production on Cantarell's declination. Well design is dominated by medium to extended reach wells. The longest HD achieved is 2,021 meters.

Better drilling performance has been achieved through an analytical approach. Based on the complexity of the wells and its relationship with drilling parameters, new key performance indicators have been outlined. Performance measurement has increased operational productivity.

With this study, technology applications have been validated (drilling bits, MWD and directional systems). A set of lessons learned have been collected. In addition to the new KPI definition, NPT generators have been identified (per section / well / severity / occurrence) in order to develop new best drilling practices and applications.

A systematical and analytical approach has identified the problems faced in selected formations (Encanto, Deposito and Oligoceno). These have presented multiple operational challenges (LIH, fishing operations, contingency sections, sidetracks, etc), which have been mitigated by new technology and best practices.

Our methodology studies the drilling performance through:
1. Offset and subject wells analysis.
2. Drilling program based on the offset information analysis.
3. Detailed event analysis.
4. Drilling performance study.
5. Drilling engineering
6. NPT events and generators.
7. Lessons Learned Database
8. Others: Mudlogging reports, DDR & logs

Introduction

The Sen Oilfield is located at the South East of Mexico, in the State of Tabasco. It covers a complex structural system with compressive strength tectonics in Mesozoic Age with formed thrusts and high dip folds; with a subsequent and extensive Tectonics in Tertiary Age that formed growth-fault with shaly bottom formations.

In addition, an extensive dome of salts in Jurassic Age has become very complex, have been found in Oligocene just at the growth-fault bottom.

Sen Field is a highly faulted and fractured volatile oil reservoir. In terms of connectivity it is highly anisotropic, and the level of anisotropy varies in the field. The matrix is very tight and it is mostly filled with water. The matrix contribution to the oil production is not significant. The fluid storage and flow are governed by the fractures and vugs that are present in the field.

Seismic and structural interpretations are very challenging because geological column prediction has an essential influence in well design. Any error in prediction seriously compromise drilling well success. In the past some wells drilled in Sen Field never could reach TD. Dome salts can be found in Tertiary and Mesozoic Ages and its prediction and hazards mitigation program is essential in project success.

Background

Sen has high production potential and aligned to Mexico production objectives more challenging wells have been drilled in the last 5 years. The challenge includes HP/HT conditions, long displacement, dome salts, lost circulation, diverse lithology, pump rig limitations and geological uncertainty.

Last wells drilled overcome most of the issues above mentioned and others will become more complex as well displacement increase and geological known limits being explored.

This paper analyze the results of Sen 136, Sen 118, Sen 201, Sen 203, Sen 221, Sen 213 and release the most important drilling practices carried by all the parties involved in the planning and execution of these wells. Graphic 1 – Graphic 10.

Surface section – 26" Hole.

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Drilling success starts in 26" Hole [0 m – 1000 m]. Although

drilling this section could look simple at first sight, it caused some headaches during drilling and casing.

Sen 136 had a fish in hole and fishing operation that caused 13 hrs of NPT. According the evidences (excessive bit wear in 5-6-BU-A-F1/16-WT-TD-LOG and stabilizers gauge abnormally wear of 5" - 60 ft; 4" – 70 ft; 2 ¼" – 100 ft) we can infer that problem was related to shock and vibrations in pendulum assembly during drilling, caused tubular excessive fatigue and drill collar body twist-off (10 cm below box) while reaming after casing point was reached.

In addition casing could not be run deeper than 972 meters and circulation was lost and never recovered.

Sen 118 Well, would experience also almost the same problems. Bit wear was excessive [4-2-WT-A-S-1/16"-NO-TD] and stabilizers gauge abnormally wear: 1/16" - 60 ft; 3" – 70 ft; 4" – 100 ft. At 662 meters when running casing, it stuck and could not get free. For this reason an additional casing (16") had to be run to case rat hole and to spend 91 additional hours. Hole quality was very poor – Graphic 2.

Although **Sen 201** would run the same BHA it did not make an undergauge hole as Sen 118 Well. Bit would be POOH with less wear of 1-3-WT-M-E-1-NO-RIG., and with layered and tapered wear stabilizers: 5" - 60 feet, 4" - 70 feet, 2 ½" at 100 feet. No problems would be experienced running casing nor during cement operation – Graphic 3

Sen 203 Well reported a fish in hole while drilling at 848 meters. First stabilizer in the 60 feet pendulum assembly had a body twisted off. Bit wear recorded: 1-1-WT-A-E-I-PN-DTF. NPT would sum 28 hours before back to drilling. No problems running logs nor running casing were experienced. Caliper showed poor hole quality. Graphic 4

Sen 221 Well had the best drilling record with 984 meter in 29:04 drilling hours. Bit wear was negligible: 0-0-NO-A-E-I-NO-TD; and quite low wear blades: 1½" – 60 ft, 1 13/16" – 70 ft, 1/16" – 100 ft. Logs and casing operations were performed fine. Caliper was qualitative the best one. Graphic 5.

Sen 213 failed in showing lessons learned from Sen 201, Sen 221. Surface Section was drilled mainly without problems. Bit and stabilizers wear (2-2-WT-A-E-I-NO-TD ; 1 1/8"- 30 ft; 2" – 40 ft; 2" – 70 ft) were not so severe as occurred in wells Sen 136, Sen 118 and Sen 201 and logs tag bottom without problems. Caliper showed poor hole quality below 160 meters the issues would came in wiper trip. Mud properties were conditioned (S.G. decreased from 1.18 to 1.16) and LCM added to system in concentration up to 140 Kg/m3. Reaming at 373 meters, BHA twist-off in a crossover and 8"x26" Stabilizers with welded blades missed. Fishing operation would spent 36 hours, it would not solve the problem. Next wiper trip did not solve the situation and would accumulate 375 m3 mud losses. String was POOH to run casing. Casing could not run deeper than 428 meters. 16" Casing cased the rat hole. NPT = 168 hours. Graphic 6

We can see that bit and stabilizer with less wear had better caliper and less troubles running casing. We believe strongly that poor caliper is related to low energy utilization through drilling parameters (shock and vibrations). Three of six wells had mechanical problems associated to drill string mechanical failure. For this reason BHA modification should be a must taking in consideration pendular BHA´s is prone to high vibrations. Graphic 7

Intermediate section – 17 1/2" Hole

Due to an additional casings drilled in some wells, then 17 ½" sections were drilled with different pilot bits, intermediate section was drilled with different pilot bit sizes. Common characteristics encountered in this section were drag increments and stuck pipe incidents that calling for mud weight watch out.

Sen 136 drilled 17 ½" hole section with an stabilized assembly from 1000 m to 2850 m. Mud weight had to be increased from 1.46 to 1.61 progressively in order to reduce hole drag. Stick hole and cavings on shakers speed up mud density increment requirements. One roller cone bit (1-1-WT-A-E-2-CT-HR) and one PDC (6 blades – 19 mm) run with 60 feet pendulum assembly to complet the section. Logging, casing run and cementing was run successfully.

Sen 118 Well would start drilling this section with bicentric 14 ½" x 17 ½" (1002 m – 1934 m). Steering assembly with downhole motor and bicentric bit had a very poor directional performance. Caliper showed that it was strongly depending on lithology. Below 1675 meters sandstone decreased as caliper improved. Steering assembly with 14 ½" PDC Bit was run (1934 m to 2994 m) for directional purposes and later hydraulic hole opening would be performed to enlarge it to 17 ½" diameter with acceptable performance. Casing reached bottom and no problems were experienced during cementing.

Sen 201 drilled 17 ½" section from 1000 meters with motor steerable assembly. Directional performace was well to 2,844 when POOH with difficulties (drag 20 – 25 Tons) and downhole motor backed off. Fishing operation took 60 hours. Packed assembly with MWD was run and preventive LCM was added to system until 100 Kg/m3 concentration. It did worked when mud losses started. Pipe stuck happened at 3296 meters drilling depth and during a connection. No up, down nor rotation movements could be done. Circulation had no restrictions. Operation to get free pipe took 106 hours. It included lubricant pills and others for wipe hole and LCM content. Mud density would be lowered from 1.56 to 1.54 during this operation. Casing was run to 3286 m.

Sen 203 drilled 17 ½" section from 1010 meters with motor steerable assembly and roller cone bit. LWD and PWD would be added from 2606 m. to 3300 m. when drag increased until 40 Tons and hole restrictions were experienced, the mud weight was raised from 1.56 to 1.58 and decision of running electrical logs was taken that could reach 3255 meters only. After some time spent while hole conditioning and pipe stuck incidents, mud density was increased to 1.60, hole reported in good shape and casing running decided. It was performed fine with shoe at 3295 m.

Sen 221 Well started drilling from 1000 m to 2395 m with downhole motor steering assembly with PWD and roller cone bit. Packed assembly with MWD and 16 mm 7 blades PDC

Bit was the next run. This run was programmed to 3022 m. Mud density had to be increased to 1.62 to counteract hole drag incremented to 30 Tons. Logs and Casing tag bottom (last 17 meters of casing were run with rotation and circulation). Cementing performed fine.

Sen 213 Well used eccentric hole opener to drill 17 ½" Section and 60 feet pendulum assembly to drill vertical hole to 1800 m. RSS, PWD, downhole vibrations monitoring and LWD were used to drill directional hole to 3145 m. Mud density was increased to 1.60 and synthetic fiber pumped to improve hole cleaning. Hole drag was kept below 8 Tons. Logs were run showing a good caliper. Packed assembly with MWD and eccentric hole opener would continue drilling to 3476 meters. According logs run caliper was perfect. See graph below. Casing was set to 3500 m (final hole opened) and cemented. Graphic 8

At this stage se can state from field results that stuck pipe and hole drag in Sen 136, Sen 118, Sen 201 and Sen 203 Wells was related to not enough mud density. This issue would be in Sen 221 and Sen 213 Wells. In addition Sen 213 was the first well where the enture section was drilled with PDC Bit. Logs were a good example of drilling performance. Downhole vibrations and annular pressure was monitored efficiently with downhole sensors in order to avoid annular overload by cuttings and non efficient use of income energy from drilling parameters applied.

Intermediate section –14 3/4" Hole

Due to hole drag problems could be not overcome at the end of 17 ½" hole section, 14 ¾" – 12 ¼"intermediate section was needed to drill trough potential salt dome to be encountered.

Sen 136 drilled 12 1/4" hole section with motor steerable assembly from 2850 m to 3573 m. Packed assembly with MWD was drilling to 3686 m. at 2.19 g/cc mud density when salt came onto shakers. Increased density according program to 2.24 g/cc. Well was controlled with rotary head MPD but when increased to 2.28 g/cc mud losses started when circulating (at static conditions no losses happened). 40 Kg/m3 of LCM pills could not control lost circulation. Mud losses and well kicking were every day situation. There were cumulative mud losses of 1189 m3 when Liner was decided. Salt was not cased.

Sen 118 Well would start drilling this section at 2994 meters with 12 1/4" and downhole motor steerable assembly. Drilling at 3787 meters with 2.18 g/cc observed 11m3 of mud losses. It added 40 m3 of LCM controlling partially mud losses. At 3970 m started drilling with packed assembly and MWD. In order to control mud losses mud density was decreased to 2.15 g/cc. Drilling was suspended to 4079m to run logs. Then, it was decided hydraulic hole opening. Same was run and start opening hole to 14 ¾" from 3000 meters to 3442 meters in 273 hours. On surface it would be noticed that hydraulic hole opener twisted off on its body. Fish was retrieved after 81 hours of NPT. Hole opening operation continued to 3656 m. POOH and run casing 11 ¾" to 3756 m. Summarizing hydraulic hole opening spent 509 hours.

Sen 201 drilled 14 ¾" opening 8 ½" pilot hole with hydraulic hole opener and steering with RSS, PWD and LWD from 3286 meters to 3822 meters and starting with a mud density of 1.58 gr/cc. Next run would with motor steerable assembly and drilled to 4348 meters. Then, it was run packed assembly with MWD that drilled to 4435 meters with motor steerable assembly. Wireline Logs would be run to identify geological contacts. Last run would be packed assembly with LWD that confirmed casing point. Mud weight ended with 2.14 g/cc. Preventive LCM and fiber plug was pumped during this section with success.

Sen 203 drilled 14 ¾" section with packed assembly and MWD, LWD and PWD from 3300 meters to 4097 meters. Mud density worked from 1.59 to 1.60. 11 ¾" Liner was run to 4093 m.

Sen 221 run drilled and 14 ¾" enlarged hole from 3045 meters with eccenctricc hole opener and packed assembly with MWD. Mud density was 1.80 g/cc and ended with 2.10 g/cc before BHA was POOH at 3528 meters. Downhole Motor steerable assembly would be the next run and drilled to 3845 meters when loss circulation started and mud density was 2.20 gr/cc. Logs were run. Loss circulation applied higher than 100 Kg/m3 LCM. Mud level was 65 meters with 2.14 g/cc mud density. Liner run was decided. It tagged bottom. Cementing was performed without problems.

Sen 213 Well used eccentric hole opener to drill 14 3/4" and MWD from 3530 meters to 4180 m. Mud density was 1.60 and pumping preventive LCM until 30Kg /m3. 11 ¾" liner was run to 4135 meters.

It is very hard to release a general law for this section but some guidelines obtained from experiences above described can be concluded:

- 13 3/8" casing is crutial to prevent drilling in HP Zone with uncase normal pressure formation. It happened basically in Sen 136 Well.
- LCM and fiber products pumped as preventive action is the best action to avoid lost circulation problems.
- Do not overestimate mud weight, once loss circulation is induced by this one, it is difficult to cure.
- Use PWD to watch out carefully annular pressure and take preventive action.
- Use LWD to define casing point.
- RSS is suggested to improve hole cleaning while keeping drillstring all the time in rotation.
- Hole opening after drilling is not the best decision. Sen 118 can give us an example. Hole opening while drilling is tecnology available in these days.
- Salt will determine mud density. It must be done eveything to predict his ocurrence.

Intermediate section –8 ½" - 12 1/4" Hole

Sen 136 drilled 8 ½ " hole section with packed assembly from 3686 m to 4351 m with 2.26 gr/cc. Interval 4325 m to 4345 m had 3 m3 of mud losses. Salt ended at 4320 meters.

Sen 118 Well would start drilling 12 ¼" section from 4079 meters with downhole motor steerable assembly and bicentric bit to 4487 meters with 2.14 gr/cc of mud density. 9 7/8"

casing and cementing were performed without problems. Hole caliper showed that it well was opened more than 12 ¼" but hole quality as showed below. Graphic 9.

Sen 201 drilled 8 ½" hole with motor steerable assembly and 1.85 mud weight from 4448 m to 5128 m. LWD would be run in wiper trip. 67 hours would be necessary for this last run.

Sen 203 – A 8 ½" sidetrack was performed after three attempts. Once sidetrack was done RSS and 10 5/8" x 12 ¼" hole opener was run, drilling from 4275 meters to 4830 meters. NPT was caused by consecutives downhole failure adding unproductive hours to this section. 9 7/8" Liner was run to 4814 and cemented.

Sen 221 run motor steerable assembly with LWD, PWD and vibrations sensors and drilled 8 ½" hole from 3845 m to 4434 m when fish was left in hole because DP pin washed out and twisted off. NPT generated was 56 hours. Next run was packed assembly with MWD, LWD, PWD and drilled to 4500 meters. 7" Liner was run and cemented.

Sen 213 Well used eccentric hole opener to drill 12 1/4" and MWD, PWD from 4180 m. to 4621 m. Next run would packed assembly with 12 ¼" hole opener. Top of salt was detected at 4614 meters Last run of this section was packed assembly with MWD and 12 ¼" hole openerunitocasing point at 4892 meters. Mud density was 2.10. 40 Kg/m3 and fiber was pumped as preventive action against losses. 9 7/8" liner was run to 4889 meters.

Some lessons learned are:

- LCM and fiber products pumped as preventive action is the best action to avoid lost circulation problems.
- Use PWD to watch out carefully annular pressure and take preventive action.
- Use LWD to define casing point.

Production section –5 7/8" - 4 1/8" Hole

Sen 136 drilled 5 7/8 " hole section with motor steerable assembly from 4351 m to 4768 m and 1.90 – 1.83 gr/cc mud density. 5" Casing was run to bottom.

Last section (4 1/8") was drilled from 4968 m to 5324 m lowering mud weight progressively from 1.19 to 1.11.

Sen 118 Well would start drilling 8 ½" section from 4487 meters with downhole motor steerable assembly to 5014 meters with 1.84 gr/cc of mud density. Mud losses had to be controlled. Section was concluded with packed assembly at 5105 meters. Mud density was lowered to 1.80. Liner was run to bottom.

Last section was drilled in 5 7/8" with steerable assembly to 5310 meters. MPD was used because kick off and losses occurred while drilling. Mu density was lowered from 1.21 to 1.13 and then increased back to 1.20 when kicked off ocurred

Sen 201 drilled 5 7/8" with motor steerable assembly when observed mud losses drilling at 5120 meters and 1.20 mud weight . It would end with 0.99 gr/cc at 5397 meters.

Sen 203 – 8 ½" Section was drilled with motor steering assembly and MWD, LWD from 4830 meters to 5360 meters . Mud density was 1.70 during the entire section.

Sen 221 run 5 7/8" motor seteerable assembly from 4500 meters to 4676 meters. Mud weight was increased from 1.18 to 1.70 in order to reduce torque and hole conditioning. 5" Liner was necessary for casing trouble zones.

Well ended at 4857 meters and 4 1/8" hole and 1.10 g/cc with LCM mixed to mud as preventive action.

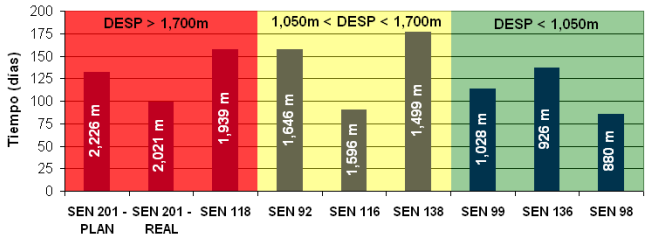
Sen 213 Well ran 8 ½" with motor steerable assembly from 4892 m to 5617 m. Mud density was 1.25. 5" liner was run.

Next section was 4 1/8" drilled to 5907 meters with 0.99 mud density.

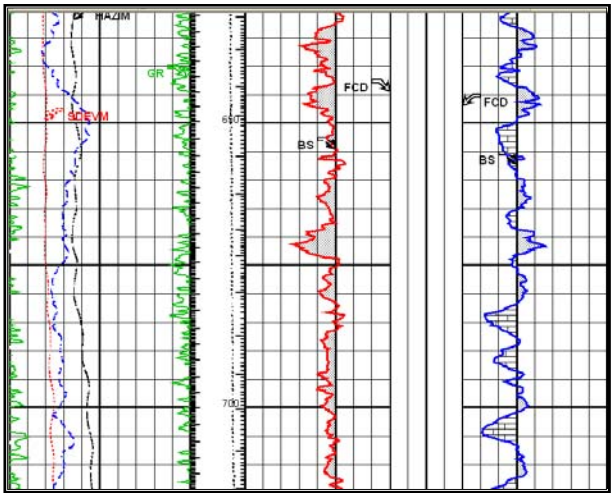
Some lessons learned are:

- Production section has two differentiated zones: high pressure and low pressure zones.
- All technology available: LWD and PWD must used I order to define the casing depths.

Graphics



Graphic 1



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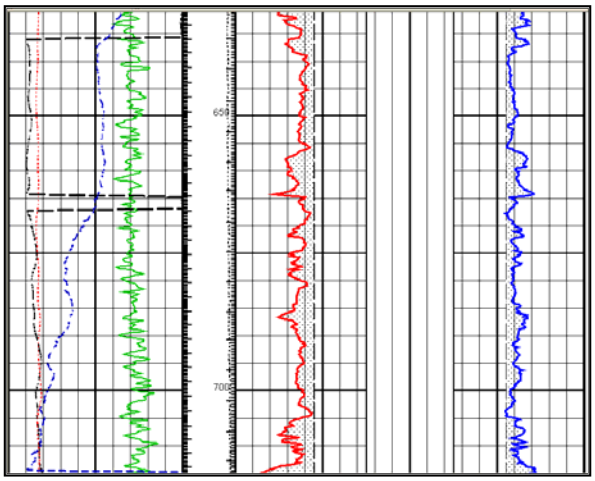

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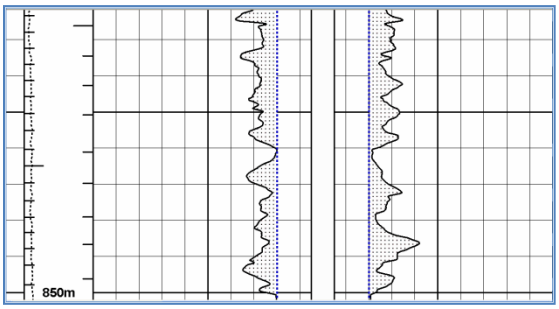

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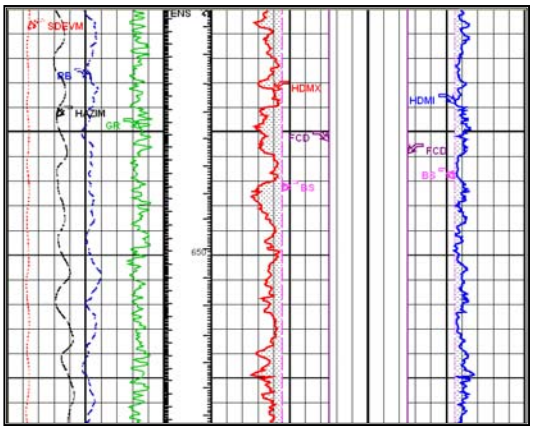

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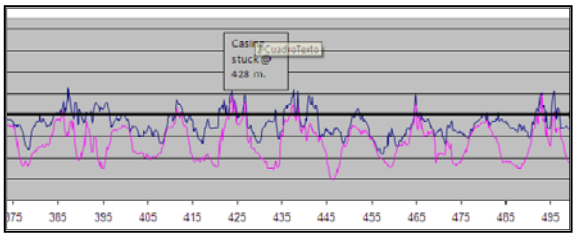

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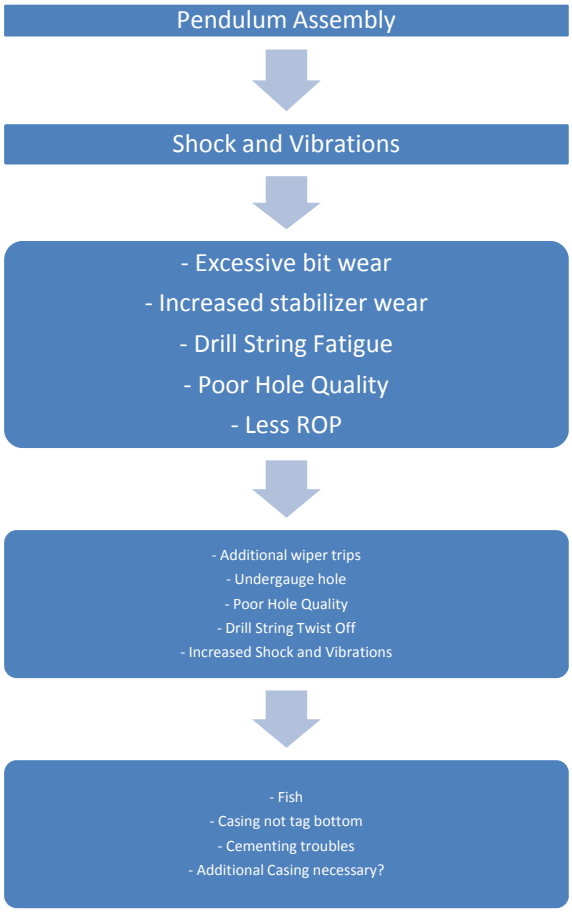

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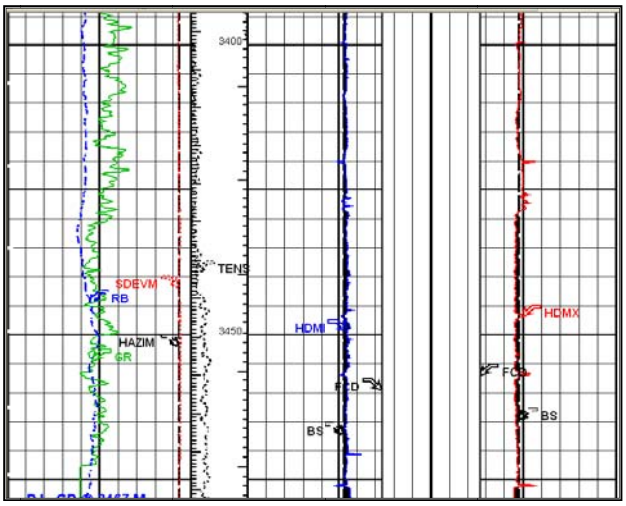

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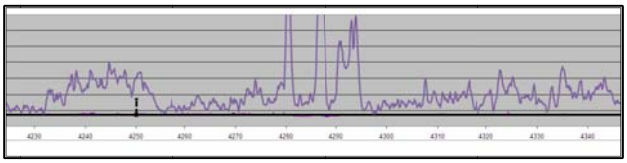
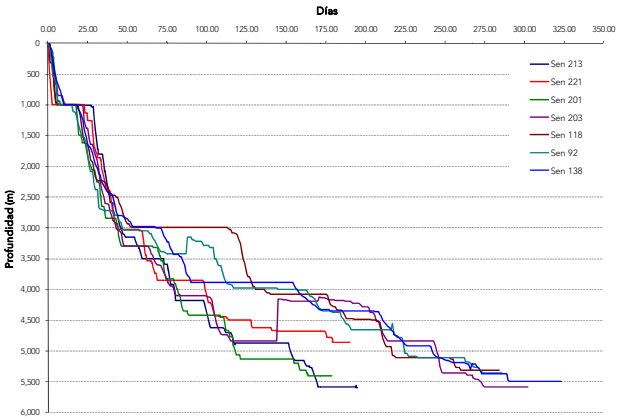


Graphic 9



Graphic 10

Conclusions

1. Due to nature and complexity involved in HP/HT and Medium and Extended Reach Wells as drilled in Sen Field, then it is mandatory to apply PWD and LWD Technology to monitor hole condition and act promptly.
2. Success of the wells started in Surface Hole Section. It is highly recommended follow all the field techniques and fundaments theoretical to get the first casing on bottom.
3. MPD played a very important role in work with narrow pressures where accuracy is essential.
4. Hole opening while drilling (eccentric or hydraulic) has been showed the added value in the success of each drilling phase.
5. RSS provided an added value in surface and intermediate sections.

Acknowledgments

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Nomenclature

BHA = *Bottomhole assembly*
NPT = *Non Productive Time*
gr/cc = *grams per centimeter cubic*
LCM = *Lost Circulation Material*
DDR = *Directional Drilling Report*
TD = *Total Depth*
m = *meter(s)*
POOH = *Pull out of hole*
MWD = *Measurements While Drilling*
LWD = *Logging While Drilling*
PWD = *Pressure While Drilling*
RSS = *Rotary Steerable System*
MPD = *Managed Pressure Drilling*

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