SPE-185562-MS

Determination of Unconventional Technical Limit on Shale Wells

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This paper was prepared for presentation at the SPE Latin America and Caribbean Petroleum Engineering Conference held in Buenos Aires, Argentina, 18-19 May 2017.

Abstract

The optimization of well drilling is the logical process of analyzing the variables involved in well construction to maximize the efficiency of the operations involved. The philosophy of optimized drilling is based on the knowledge and experience gained in the first drilled well for its learning and application in the drilling of subsequent wells; So that the total cost of drilling is reduced to a minimum. In order to identify those points to be optimized, a methodology of analysis of drilling times (ATP) was developed, which allowed to obtain the actual drilling operations times, non-productive times (NPT's) and normal times for drilling operations. Each of the stages of selected shale / oil gas wells in northern Mexico. Second, we identified the best times, comparable stages and penetration indices (ROP'S) that traversed the selected wells. Finally, the different problems with high frequency indices and best practices were identified to obtain an unconventional technical limit to obtain an optimized baseline for well design and planning.

Introduction

Given the current challenges faced by the global oil industry, strategies should be developed to efficiently, safely and economically drill wells (Velazquez-Cruz, 2003) that generate experiences and knowledge based on the first wells in the area study. Due to the above, the drilling of oil wells requires to beexecuted in the shortest possible time and cost. In this process, day by day knowledge and experiences are generated, which is why, the need arose to develop and implement a new methodology to obtain a Non-conventional Technical limit and thus optimize the well drilling planning from the analysis of Best practices, times, technologies and human resources, based on empirical knowledge.

This paper presents the methodology, its application and results of shale wells in Mexico, as a basis for the planning of future drilling wells in the different study areas.

Theory and Definitions

Throughout the history of the drilling of Mexico, intuitive, empirical and practical efforts have been made to improve the performance of drilling and completion activities. On the other hand, methodologies focused on the same objective have also been applied. As an example, we can mention the project Optimization of Drilling Times, better known as OTP, (Plan Better Rector UPMP PEMEX 1999-2003) that arose in response to a previous study which showed that the time spent by PEMEX in drilling Of wells was high, comparing it with the standard times mentioned, Carlos Osornio (1999). Currently the leading companies worldwide are concerned with finding or developing systems and working methods that allow them to optimize their performance. Such is the case of the concept FEL (frond end loanding). In whose methodology the technical limit is used as an international practice in the planning of wells.

The concept of Technical Limit is new, was introduced fully through Brunei Shell Petroleum, (1998), with the aim of significantly reducing costs in well drilling, without affecting the safety of the processes leading to the termination Of the same wells.

The first well planned and drilled with the concept of the Technical Limit was the Golden Eye, by the Transocean John Shaw, The concept of Technical Limit was used by BSP on developing marine wells, these wells were made with a 40% time saved compared With the history of wells drilled normally, (1999). In México it was implanted at the beginning of the new century (Espinosa-Gustavo, et al, 2014).

Finally, it should be mentioned that the reality of Technical Limit is that it can have a characteristic impact on the reduction of time and cost when planning and drilling a well.

The Technical Limit can be defined as the process to reach optimum performance, reviewing, analyzing and applying the best engineering practices to the drilling and well completion planning operations, serving as the basis for the administration of knowledge in some activity that generates learning and experience. It is a graphic way to see the "best well", to focus on the analysis of best operating practices and determine "what was done and how." figure 1.0.

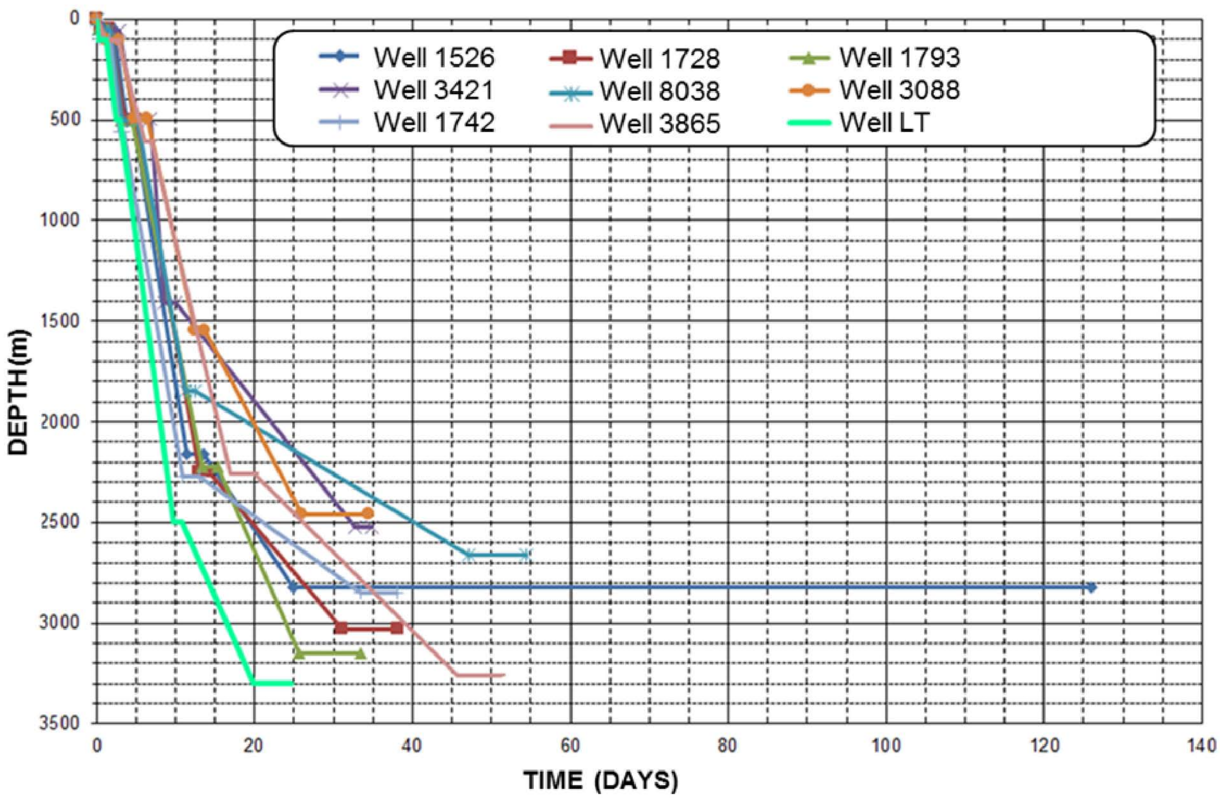

Figure 1—Example technical Limit graphic.

Performing a technical limit analysis aims to reduce time and cost of the drilling process. To establish the technical limit, an analysis of the real time of the drilling and termination operations is carried out, as seen in the figure 2.0.

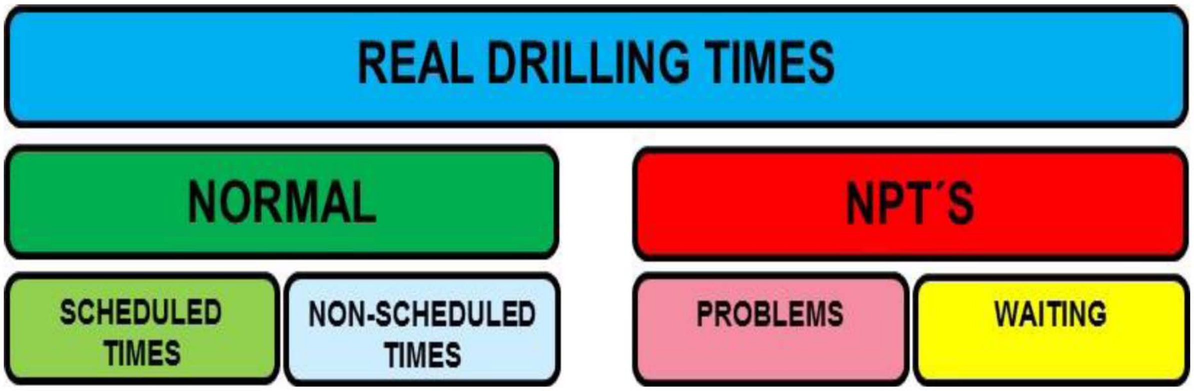

Figure 2—Times drilling times.

Real time is composed of the employee in normal operations and non-productive times. The Non productive times are the traditional NPT's, correspond to the time that is occupied in the development of all those activities that impede the progress of the operations of the well, by operations with problems, Failures and waits.

Normal Times: They are composed by the times in which the well is planned to be drilled and by those not programmed necessary to fulfill the objective

Metodologhy

Process developed TECHLINM Model

He following model represents the workflow to obtain the technical limit.

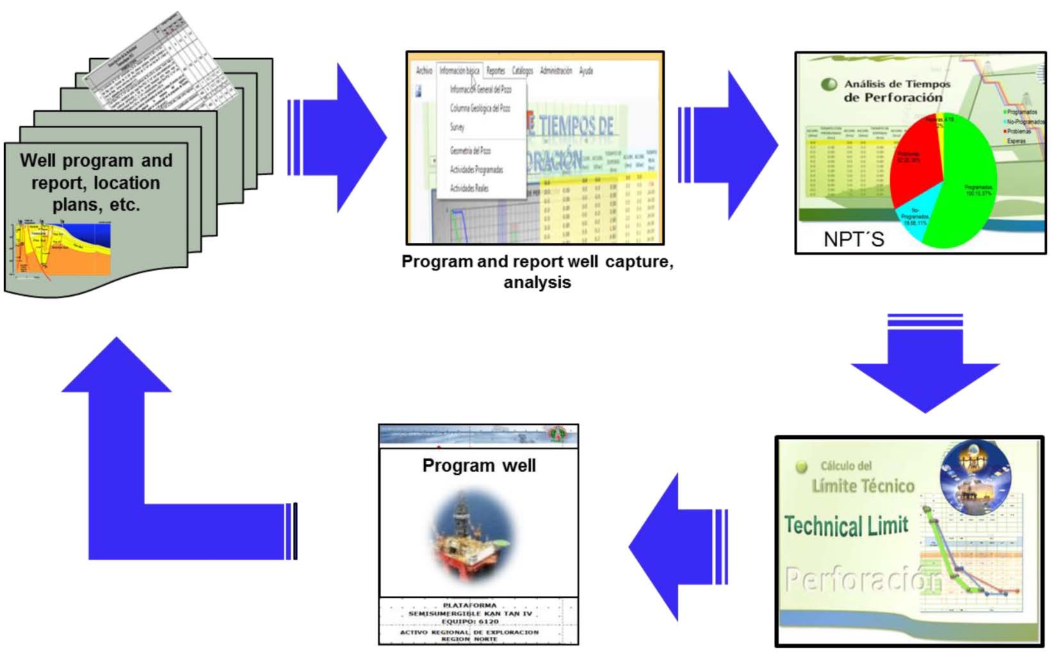

Figure 3—Process developed TECHLIM Model.

In first phase, the wells of the area or field to be analyzed are identified, the necessary information is collected and validated as:

- Compilation of field information.

- Geographical location of the field.
- Field Background
- Geological characteristics
- Number of Perforated Wells
- Daily drill program and report

For the second phase, the distribution and type of wells, their total depth, type of drilling equipment and year in which they were drilled are identified.

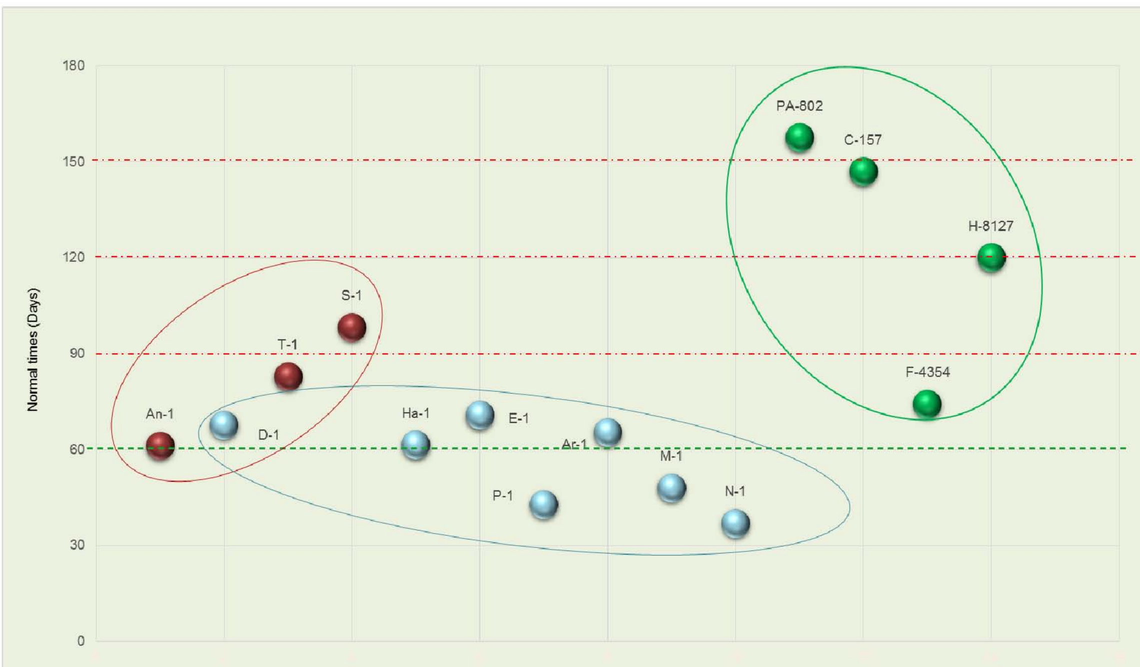

Figure 4—Wells of the area or field and the distribution for type wells.

Subsequently, the wells and stages in which these can be compared are selected and start the capture of the program of activities and daily report of drilling in the software, ATP-IMP V.1.0. ®, It compares the time in which it is estimated to be drilled a well, against the times used in the construction of the well in order to perform the analysis of times, and to obtain the normal times (programmed and non-scheduled) non-productive times (Problems and waits), i. e. the actual drilling times. Figure 5.0.

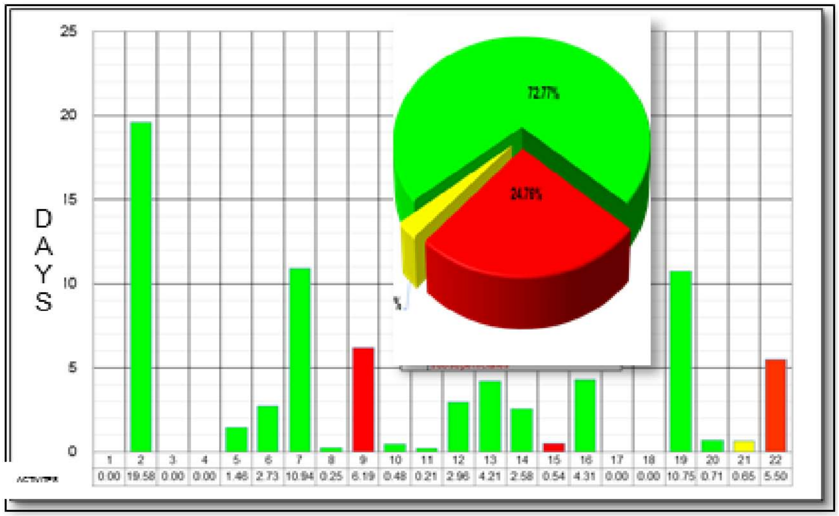

Figure 5—Analysis of drilling times.

In this phase, the information generated in the previous phase is used to identify the deviations and best practices obtained for each well based on the activities that had the least time and those that met the scheduled time. Considers the best documented times of the previous phase (Figure 6.0) and the rate of penetration (EC. 1.0.) to obtain an optimized well which are proposed as the basis of the technical limit for future wells in the area. Figure 7.0.

$$ROP = \frac{Y}{Tr} \qquad \text{Ec.1.0.}$$

Where:
ROP= Rate of penetration
Y= Depth of interval of stage
Tr= Rotation time

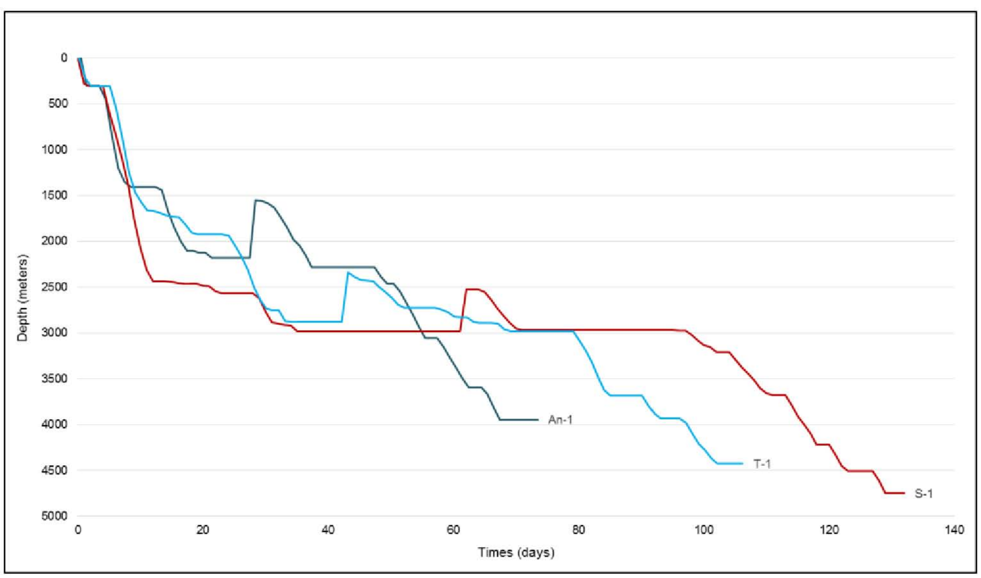

Figure 6—deviations and times obtained for each well.

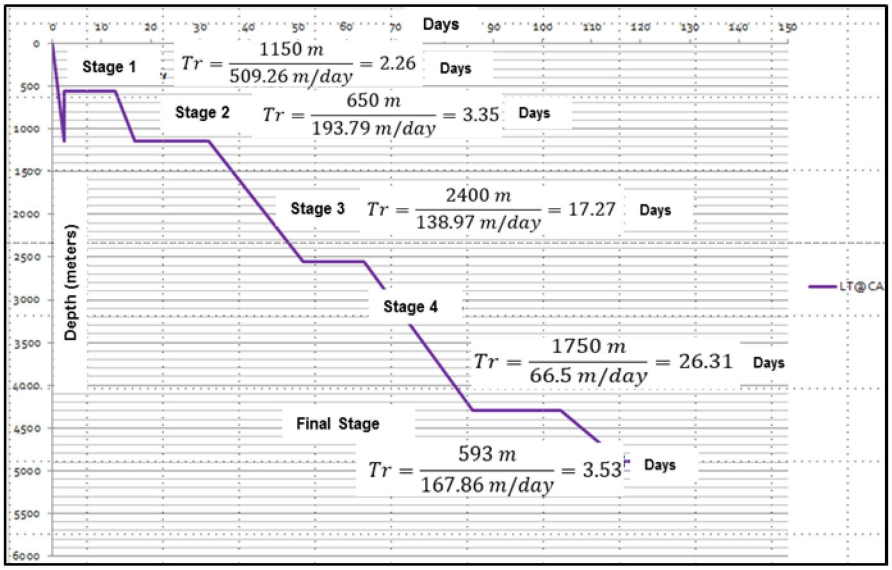

Figure 7—Optimized well and the technical limit.

For the projection of the times of the change of stage we propose the equation 2.0.

$$CE\ [Days] = \frac{CE\ min\ [Days]}{Depth\ CE\ \min[m]} * PDepth\ [m] \qquad \text{Ec. 2.0.}$$

Where:
CE min = Change of minimum stage (CE min)
Depth of CE min = Depth at which this change of stage was made
PDepth = Planned planned depth casing

Limit proposed in well planning

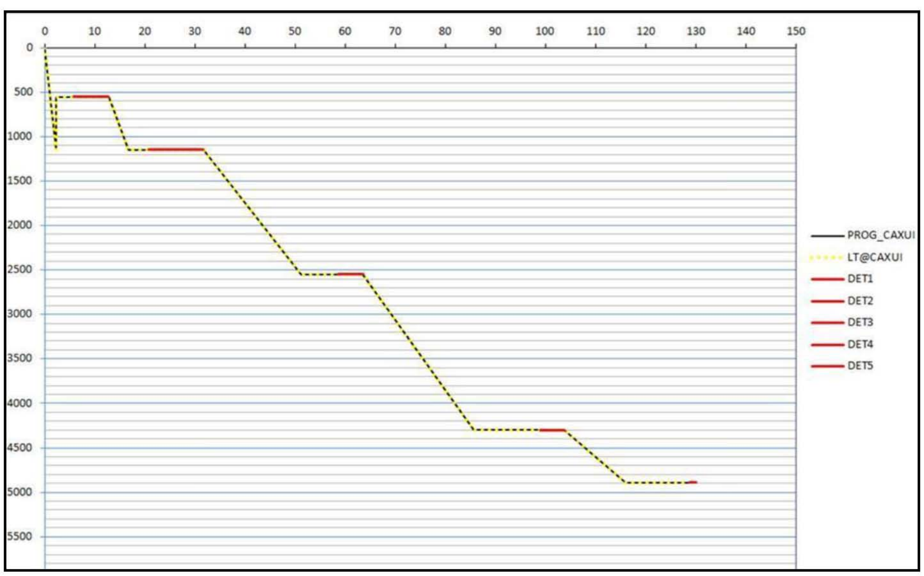

Figure 8—Limit proposed in well planning.

Application and results

The case study was carried out in shale wells with a focus on the formation of Pimienta in Mexico, and considering the following wells:

Table 1—Wells selected to technical limit.

No.	Well	MD	Date	Stage	Casing	Type
1	C-1112	2108	11/07/2010	3	TR 7"	TR
2	C-1113	2071	06/01/2011	2	TR 7"	TR
3	C-1111	2108	12/02/2011	2	TR 4 1/2"	TL
4	C-1185	2007	04/06/2011	2	TR 7"	TR
5	C-1198	2358	23/08/2012	3	TR 4 1/2"	Liner
6	PA-802	4085	23/11/2012	5	TR 4 1/2"	TL
7	C-157	4787	27/07/2013	6	TR 4 1/2"	TL
8	H-8127	4360	12/09/2013	5	TR 4 1/2"	TL
9	F-4354	4150	10/10/2013	4	TR 4 1/2"	TL

Identification of the wells that will be compared for the drilling activity and for the stage change.

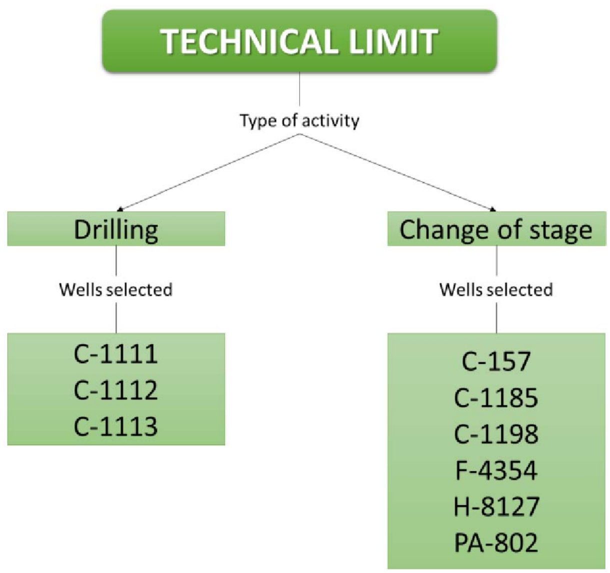

Figure 9—Wells selected for each type of activity.

For the proposed well L-1, 5 stages were planned with the following geometries and depths (table 2.0), which should be considered in the analysis to obtain the times of all comparable stages between the wells in Figure 8.0.

Table 2—Geometries and depths selected for well L-1

Stage	Bit (inches)	Casing (inches)	MD (m)
1	17 1/2"	13 3/8"	58
2	12 1/4"	9 5/8"	1180
3 (**Pilot hole**)	8 1/2"	8 1/2"	2643
4	8 1/2"	7"	2869
5	6 1/8"	4 1/2"	4463

Maximum penetration rate in each perforated formation

The rate of penetration (ROP) was determined using equation 1.0. For each of the formations traversed by wells C-1111, C-1112 and C-1113, to obtain the maximum penetration rate in each drilled formation and to plan to use it in well L-1 as shown in the following figure.

C-1111

ROP (m/h)	Formation	Depth (m)
45.11	TERTIARY	0 1203.95
40.53	MÉNDEZ	1203.95 1272.36
40.65	K. SAN FELIPE	1272.36 1335.05
27.5	K. AGUA NUEVA	135.05 1412.88
16.2	K. TAMPS SUP.	1412.88 1479.03
16.2	OTATES	1479.03 1482.1
14.05	K. TAMPS INF.	1482.1 1900.78
12.55	PIMIENTA	1900.78 1945.91
13.75	J. SAN ANDRES	1945.91 2108.71

C-1112

ROP (m/h)	Formation	Depth (m)
19.37	TERTIARY	0 1125
13.39	MÉNDEZ	1125 1207
45.88	K. SAN FELIPE	1207 1238
17.93	K. AGUA NUEVA	1238 1316
6.45	K. TAMPS SUP.	1316 1400
8.57	OTATES	1400 1401
2.49	K. TAMPS INF.	1401 1825
1.01	PIMIENTA	1825 1869
6.03	J. SAN ANDRES	1869 2090
12.00	ARENISCAS/CUERPO B	2090 2108

C-1113

ROP (m/h)	Formation	Depth (m)
45.11	TERTIARY	0 1202
19.31	MÉNDEZ	1202 1259
14.01	K. SAN FELIPE	1259 1305
6.73	K. AGUA NUEVA	1305 1387
7.32	K. TAMPS SUP.	1387 1473
1.62	OTATES	1473 1475
6.63	K. TAMPS INF.	1475 1895
3.62	PIMIENTA	1895 1931
2.77	J. SAN ANDRES	1931 2057
4.40	ARENISCAS/CUERPO B	2057 2091
11.53	BASAMENTO	2125 2159

New Well L-1

Casing (in)	Formation	Depth (md)	ROP (m/h)
13 3/8"	TERTIARY	1164	45.11
9 5/8"	Mendez	1180	40.53
8 1/2" (Pilot hole)	Mendez	1671	40.53
	San Felipe	1725	45.88
	Agua Nueva	1744	27.50
	Tamaulipas Superior	2003	16.20
	Tamaulipas Inferior	2340	14.05
	Pimienta	2492	12.55
	Pimienta Inferior	2635	12.55
	Tamán	2643	13.75
7"	Tamaulipas Inferior	2010	14.05
	Pimienta	2492	12.55
	Pimienta Inferior	2869.32	7.00
4 1/2"	Pimienta Inferior	4463.3	7.00

Figure 10—ROP values determined for each formation drilled in the three wells and maximum penetration rate well L-1.

Times of change of stage

The times corresponding to the stage changes of wells C-1185, C-1198, Co-157, F-4354, H-8127 and PA-802 were determined and analyzed to identify and select the best times considering similar geometries.

Table 3—Stage change times for each well.

Well C-157

No. Stage	Stage	Chance Stage (days)	Depth (md)
1	20"	6.13	148
2	16"	6.25	926
3	10 3/4"	9.02	1851
4	9 1/2"	3.19	2465
5	7 5/8"	4.25	3008
6	4 1/2"	6.44	4787
	TOTAL	35.27	

Well F-4354

No. Stage	Stage	Chance Stage (days)	Depth (md)
1	16"	4.38	151
2	10 3/4"	5.94	1003
3	7 5/8"	4.75	2608
4	4 1/2"	12.33	4150
	TOTAL	27.40	

Well H-8127

No. Stage	Stage	Chance Stage (days)	Depth (md)
1	16"	5.96	301
2	10 3/4"	6.17	1657
3	9 1/2"	3.27	2885
4	7 5/8"	7.81	3005
5	4 1/2"	2.38	4360
	TOTAL	25.58	

Well PA 802

No. Stage	Stage	Chance Stage (days)	Depth (md)
1	16"	12.29	200
2	10 3/4"	6.65	1034
3	9 1/2"	4.42	2098
4	7 5/8"	6.27	2585
5	4 1/2"	22.02	4085
	TOTAL	51.65	

Well C-1185

No. Stage	Stage	Chance Stage (days)	Depth (md)
1	9 5/8"	4.02	450
2	7"	2.31	2007
	TOTAL	6.33	

Well C-1198

No. Stage	Stage	Chance Stage (days)	Depth (md)
1	9 5/8"	4.79	452
2	7"	2.56	2204
3	4 1/2"	1.21	2358
	TOTAL	8.56	

From the previous analysis of the 6 wells, the wells that had the minimum time in the stage change with their respective depth were determined, table 4.0.

Table 4—Improved stage change times

Well min times	Change of stage min (days)	Depth min (md)
F-4354	4.38	151
C-1185	4.02	1003
C-157	3.19	2465
C-1185	2.31	2007
C-1198	1.21	2358

Projecting the times before the well L-1 the following days are obtained to change the different stages

Table 5—Optimized times for stage change for well L-1.

New well L-1			
Stage	Depth (md)	Stage change (days)	S.C. accumulated (days)
13 3/4"	58	1.68	1.68
9 5/8"	1164	4.67	6.41
8 1/2"	2643	3.42	9.76
7"	2869	3.30	13.07
4 1/2"	4463	2.29	15.36

Technical Limit

So the Technical Limit for the L-1 Well is 33.26 days, as follows:

Table 6—Better times per stage planned for well L-1.

Bit (in)	Casing (in)	Formation	Type Activity	Depth (md)	ROP (m/h)	Time (h)	Time (days)	Accumulated time (days)
17 1/2"	13 3/4"	Tertiary	D	58	45.11	1.29	0.05	0.05
			SC	58	-	40.33	1.68	1.73
12 1/4"	9 5/8"		D	1164	45.11	24.52	1.02	2.76
		Mendez	D	1180	40.53	0.39	0.02	2.77
			SC	1180	-	113.52	4.73	7.50
8 1/2" (pilot)	8 1/2" (pilot)		D	1671	40.53	12.11	0.50	8.01
		San Felipe		1725	45.88	1.18	0.05	8.06
		Agua Nueva		1744	27.50	0.69	0.03	8.08
		Tamaulipas Superior		2003	16.20	15.99	0.67	8.75
		Tamaulipas Inferior		2340	14.05	23.99	1.00	9.75
		Pimienta		2492	12.55	12.11	0.50	10.25
		Pimienta Inferior		2635	12.55	11.39	0.47	10.73
		Tamán		2643	13.75	0.58	0.02	10.75
			SC	2643	-	82.02	3.42	14.17
		Tamaulipas Inferior	TXC	2010	-	4.50	0.19	14.36
8 1/2"	7"	Tamaulipas Inferior	D	2340	14.05	23.49	0.98	15.34
		Pimienta		2492	12.55	12.11	0.50	15.84
		Pimienta Inferior		2869.32	7.00	53.90	2.25	18.09
		Pimienta Inferior	SC	2869.32	-	79.25	3.30	21.39
6 1/8"	4 1/2"	Pimienta Inferior	D	4463.3	7.00	227.71	9.49	30.88
		Pimienta Inferior	SC	4463.3	-	57.12	2.38	33.26

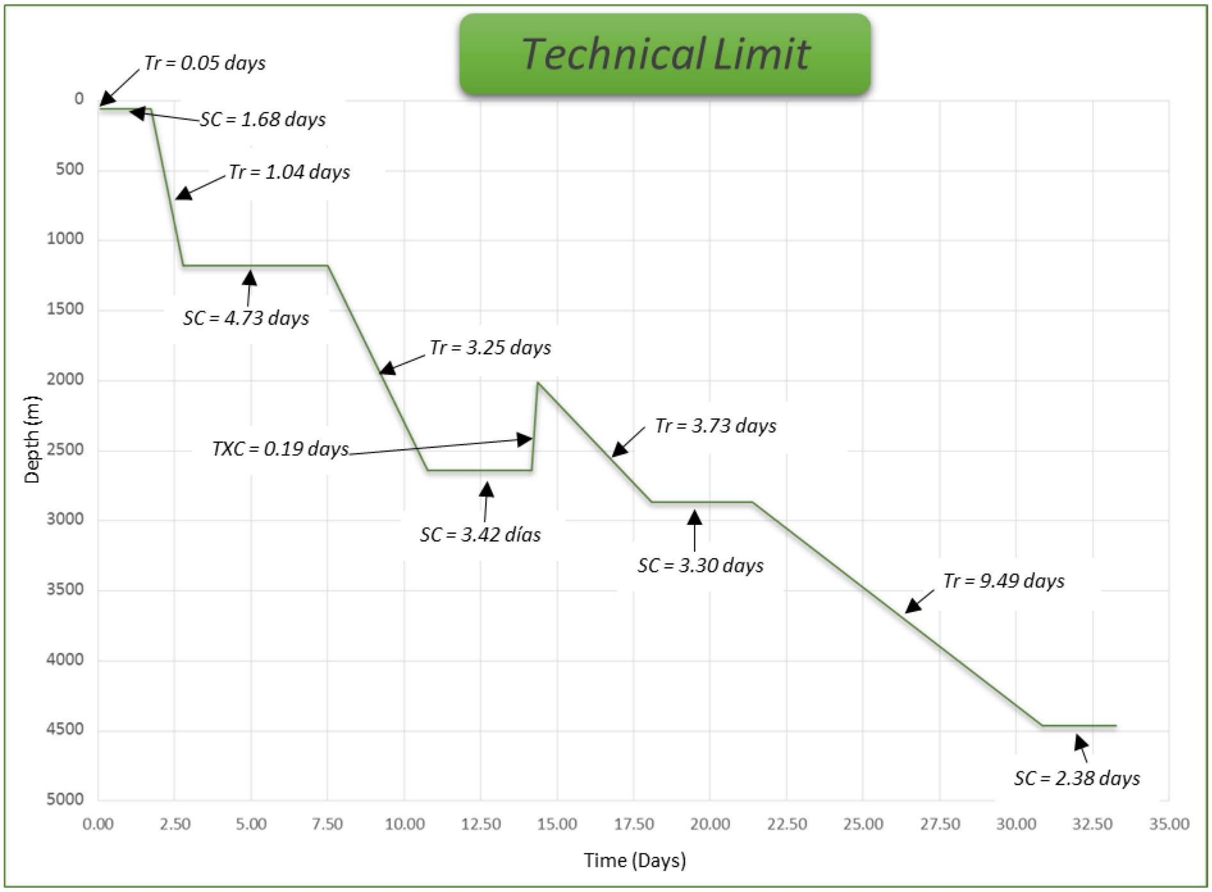

Figure 11—Technical Limit for shalewell L-1.

Conclusions

- Derived from the analysis and application of the methodology was obtained the unconventional technical limit for shale wells with high degree of presicion
- The obtention of the stage changes was relevant for the optimization of the planned well
- The determination of times versus training were key to the optimization of the different stages.
- A new methodology for non-conventional wells was obtained
- The optimization of non-productive times, impacts on the cost of the well

Acknowledgments

The authors would like to thank Instituto Mexicano del Petroleo for support to develop this paper

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