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Novel approach to enhance the quality of the cement operations in the intermediate section in southern Iraq oil fields

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Abstract

Obtaining high-quality zonal isolation is one of the most challenging tasks for both operators and service companies in southern Iraq oil fields, especially in the surface, and the intermediate casing cementing operation. Different types of cement designed have been proposed and implemented previously, but the vast majority of cementing operation suffering from poor isolation when it comes to cement bond evaluation. Away from traditional cementing design, this paper presents an extensive investigation for the failure of the cementing jobs in southern Iraq fields and propose a comprehensive approach to improve the quality of the formation isolation by using commercial software. The approach was conducted by proposing hydraulic and operational parameters designs, not only depending on hole condition after reaching the casing design point, but also it considers the history of drilling. Since the capability of having good cement job is increasing by ensuring optimum hole condition to get proper formation isolating. The optimum volume/density of spacer, washer, and cement slurry combined with pumping rates should be designed to ensure that maximum equivalent circulation density (ECD) does not exceed the least fracture gradient of the weakest zone in the entire section. Three distinguish cementing designs were proposed based on the severity of the loss circulation while drilling. Cement design parameters were updated and modified hydraulically based on the history of the drilling in the problematic zones. In addition, considerable attention should be paid to the casing placement in which more than 70% standoff is required.

Introduction

Optimization of the primary cement design parameters is a crucial task in the oil industry to ensure sufficient zonal isolation and long-lasting well life (Denney, 2001). These variables are constrained profoundly by the well condition before the cement job being conducted. The narrow margin between the pore and fracture pressures is a substantial challenge when it comes to cement operation. Therefore, the cement hydraulic design should be meticulously optimized to ensure high-quality cement job. Otherwise, the poor-quality cement placement results in a detrimental effect on well integrity and cost. Thus, a comprehensive cementing design examination should be conducted to analyze the causes of the cement problems by considering not only the post cement jobs analysis but also the history of drilling. In this work, the cement operation for the intermediate section in southern Iraq field has investigated, and it can be observed that the vast majority of the wells are suffering from bad zone isolation in this section. Indeed, the bad cementing jobs are not mainly related to the quality of cement being pumped, but it is potentially related to cement procedures and drilling problems. Generally speaking, several drilling problems have been encountered in the intermediate section which has an adverse influence on cementing operation such as lost circulation, hole instability, and hole enlargement (Alsubaih and Nygaard, 2016; Alsubaih et al., 2017). However, several techniques and materials have been implemented to cure the loss circulation while drilling and yet it is frequently observed during the cementing.

To overcome this obstacle, the cement design parameters such as the liquid volumes (cement, and spacer), pumping flow rate, liquid densities, rheological properties and casing standoff have designed to ensure operation parameters less than the fracture gradient of the weak zone. The fracture gradients have been estimated based on the offset well data. Nonetheless, it is varying significantly because of the heterogeneity of the formations. Therefore, it is required to update the cementing design according to the drilling events being encountered. The objective of the paper is to propose optimum hydraulic designs based on the severity of the drilling problems that encountered while drilling. Thus, the cement maximum hydraulic design in terms of ECD does not exceed the minimum fracture pressure being recorded rely upon the drilling events.

The drilling problems in the intermediate section

The intermediate section is drilled via 12 ¼ in. bit and cased by 9 5/8 in. casing to the top of the Sadi zone. The formations in this section are the Dammam, Rus, Um-al-Radhuma, Tayarat, Shiranish, Hartha, and upper Sadi formations. Severe drilling fluid losses were experienced in the Dammam formation due to shaly limestone with high porosity. Some wells in the Rus formation have partial drilling fluid losses, while other wells experience bit damage. Thus, it is necessary to control the drilling parameters such as manipulating low RPM and high WOB (Alsubaih et al, 2018). In Um-al-Radhuma, many wells have tight spots. Therefore, hole reaming may be required. Shiranish formation shows moderate to highly-reactive clay content, which elevates the tendency of bit balling. Although high-pressure sulfur water in Tayarat formation is observed, the drilling fluid weight is usually used to control it in most cases. On the other hand, Hartha formation causes multiple problems like tight spots, partial to severe losses, and stuck pipes in various depths across this formation. The drilling fluid losses do not occur because of drilling fluid weight is larger than the fracture gradient but are caused by the fractured nature of Hartha limestone. The chemical composition of the drilling fluid should be compatible with this rock, and the rheological properties should be designed to avoid any unwanted ECD that causes a dynamic drilling fluid loss in many wells. Ultimately, an intractable cement loss occurs while running the cement job, which has been reported predominantly in this section so that the well integrity is a colossal concern, especially in a sulfurase water zone.

The cementing failure in the intermediate section

The vast majority of oil wells being cemented in southern Iraq oil fields are suffering from bad cement isolation in the intermediate section. These problems are often escalating due to the variety of the drilling events in the intermediate hole that pose poor cement isolation. The loss during cementing in the Dammam and Hartha formations combined with sulfurase water flow in Tayarat are harshly impacting the well integrity and cement quality (Alsubaih and Nygaard, 2016). Therefore, several intervals with free pipe as well as formations communication are dominated observations when it comes to the cement evaluation even though numerous cement design /material being implemented. The lightweight cement, thixotropic cement, foam cement, fiber cement and multi-stage cement jobs are among the most obvious solutions being conducted to avoid loss circulation while cementing. However, the cement quality does not meet expectations in term of zonal isolation because of the detrimental effect of the sulfurase water and loss circulation zones on the cement bond. In addition, the inappropriate selection of the rheological and hydraulic parameters which result in adequate mud and filter cake removal with potential cement contamination. Thus, the cement operation design should be reconsidered by using a recognized design based on the well condition prior to the cement job. Figure 1 shows cement evaluation for randomly selected wells in a field in southern Iraq. It can be noticed, several wells suffering from bad zonal isolation in many intervals especially the interval where the drilling problems are commonly encountered. The investigation of the primary causes of the failure revealed that the problem was related to formation breakdown by an excessive ECD increase during the cementing operation. The main reason for ECD excessiveness is related to use single cement design regardless of the severity of the losses during the drilling operation.

The cement design components

Fluid displacement

Several authors have been investigated the impact of optimum cement displacement to improve the quality of cement behind the casing. The sufficient displacement can be obtained by appropriate management to the following factors; well geometry, mud rheology, densities difference between displacing and displaced fluids, casing standoff, type of the flow regime, casing reciprocating and rotation during/before cement job (Clark and Carter, 1973; Sauer, 1987; Nelson, 2006). The larger annulus clearance, the higher displacement rate that is required to achieve optimum displacement efficiency. On another hand, the lower value of the yield point, as well as the density of displacing fluid compared with the cement slurry, the higher displacement efficiency to improve sheath quality. The casing centralization has a significant impact on achieving symmetrical cement path with sufficient cement in place that leads to adequate zonal isolation. The optimum flow regime can induce satisfactory removal of the mud and filter cake by exerting sufficient friction or drag forces on the mud through conducting turbulent/laminar flow regimes that leads to high cement quality (Huant and crook , 1979). The pipe movements are highly beneficial to prevent the cement from bypasses the narrow sides in the hole and consequently sufficient slurry distribution. However, in poorly centralize casing the fluid tends to flow in the easy path in turbulent or laminar flow lifting the narrow path under plug flow regime, therefore it is more beneficial to use the high-density contrast between the fluids to optimize the cement placement (Mclean et al, 1968). Frankly, optimization all these factors are hardly controlled by the well condition and the surface equipment capability when it comes to the job execution**.** Also, there are no single method or material to improve the cement displacement and consequently the quality rather it is a combination of different factors.

Cement slurry design

The cement slurry is designed to achieve a specific function in term of zonal isolation and casing support by considering slurry properties such as density, rheology, stability, mixability and thickening time. The density of slurry is governed by the mud window, and the required the mechanical properties of cement to some extent such as compressive/tensile strengths, Young modulus, and passion ratio. The density of the fluid in the cement system should follow low to high-density approach in which the density of spacer is heavier and lighter than the cement and mud respectively. The cement rheological properties are normally selected to provide sufficient slurry movability and reduce the friction pressure to decrease the ECD. The remind properties (stability, mixability and thickening time) are out of paper scope, and it is worth to state, there was no cement failure caused by these factors being recording in the area of study.

Methodology

In this paper, the hydraulic and rheologic designs have re-evaluated to maintain the dynamic pressure during the displacement less than the fracture gradient of the weakest zone. This objective is reached by managing the cement design variables that induce equivalent circulation density in the safe operating limit. The equivalent circulation density (ECD) is calculated using WellPlan package within Landmark (a commercial software designed by Halliburton) by applying a selected range of variables that impact the ECD during cementing operation such as densities, rheological properties and pumping rates. The rang of each selected variable where chosen according to the practical experience in the oil field. Also, one at time sensitivity analysis was conducted by changing one design variable in a specific range when the other variable kept constant. The sensitivity star plot was constructed and used as a milestone in obtaining the most sensitive parameters then inferring the optimum design. Three distinguish cementing designs were proposed based on the severity of the loss circulation while drilling. The least induced downhole pressure design should be implemented in case of total to severe loss circulation while drilling. In another hand, the moderate induced downhole pressure design is required to be utilized when there are partial losses for the drilling fluid. Finally, the highest dynamic downhole pressure design is utilized in case of problem free wellbore.

One at time sensitivity analysis

The sensitivity analysis of the cement design parameters to the ECD of cement system has conducted by using Wellplan package by changing one value of a single parameter and keep the other constant. This technique provides a valuable tool to improve the design based on the most sensitive parameters and screen out the less sensitive variables. The star plot was drawn in Figure 2 that shows some parameters are sharply increasing with respected the ECD such as the densities of the lead and tail. Same as displacement rate, the plastic viscosity, yield point, and the spacer volume are proportionally increase the ECD. Nevertheless, the height of lead and tail in the well are negatively impacted the ECD. Ultimately, the cement pumping rate does not influence the ECD, but it is essential to reducing the free fall effect.

The cement design in some offset wells

As mention earlier, serval cement design being proposed by changing the materials, tools, and procedure. Some of these modifications led to an enhancement in the cement quality in some wells but the problem of poor cement is not fully avoided. Because these solutions were applicable with great success in some well but it is not in others. Table 1 show three cement designs for the well being investigated. One stage, multi-densities, and two-stage cement jobs were the most recognized cementing design in the area of investigation. The partial to severe loss circulation are thoroughly recognized through the drilling operation and in the majority of the well during cementing. In other hand, the displacement rate is constant at 10 bbl/min regardless of hole condition and the severity of the losses during cementing. It is desirable to have high displacement rate to improve cement job quality, but great attention should pay to the well condition in which the least fracture gradient does not exceed. The density of the slurries, as well as the top of cement, were altered though most of the wells were utmost suffering from losses while cementing. Table 2 provide rheological information to the cement and the mud being used in the cement design. It is clearly obvious, the yield point values in the one stage and multi densities design are less than the values in the displacing mud. However, the general rule of thumb is to design the cement slurry to have a yield point and a plastic viscosity at least equal to its value in the mud to optimize the displacement. Therefore, the cement to mud rheological properties should be redesigned to follow best cement practice. Two main components have a significant impact on cement displacement; the resistant force represents by the immobility of the drilling fluid and the displacement force employ by the flow energy of the cement system. Thus, to enhance the displacement either drilling fluid should be less resistant to flow and the displacement flow rate has to increase.

Results and discussions

Three cement systems and pumping designs have proposed in this paper to ensure optimum cement placement and improve formations isolation. These designs have chosen to be implemented based on the severity of drilling problems in term of loss circulation during the drilling. The casing standoff in base case deviated well have designed to be more than 80% as shown in Figure 3 and 4.

In all cases, the mud should be condition to have less yield point, and plastic viscosity and button up circulated at least two times prior to the cement job. Table 3 listed the suggested designs that can be utilized as a guideline to enhance the cement placement. In case of partial losses during the drilling, the cement designed to have highest rheological properties and moderate displacement rate 7 bbl/ min. This design can be beneficial to reduce the friction pressure losses and consequently the ECD as illustrate in Figure 5. The moderate displacement rate with the rheological difference between cement and mud lead to better mud displacement. Figure 6 illustrates the liquid rate in and out of the well during cementing in case of partial mud losses cement design. In other hand, same as the cement rheological properties, the displacement rate has minimized to 5.5 bbl/min in order to maintain the ECD below the fracture gradient as shown in Figure 7. This design offers

ECD value less than the maximum ECD while drilling. The mud rheological properties mitigated with a fair contract with cement rheological properties to generate sufficient displacement and mud removal. The fluid rate in and out of the well have displayed in Figure 8. The high displacement rate 11 bbl/min and low cement/mud rheological properties can be valuable in improving displacement when no losses being recorded as shown in Figure 9. For this design, the fluids pumping rate in and out of the hole are illustrated in the figure 10.

Conclusions

The cementing design parameters should be appropriately selected to ensure sufficient zonal isolation. The investigation revealed the vast majority of cementing operation in southern Iraq fields for intermediate section suffering from paramount failure in cement jobs. The hydraulic rheological parameters required to be implemented in a manner to achieve maximum displacement efficiency within acceptable ECD. In this work, three intrinsically cementing designs were proposed based upon the degree of loss circulation severity while drilling. These designs are the least, moderate, and highest dynamic induced downhole pressure designs, that are required to be utilized in cases of total to sever loss circulation, partial loss, and problem free wellbore, respectively. Sensitivity analysis revealed that parameters such as the density of the lead and the tail, displacement rate, plastic viscosity, and yield point, are proportionally increased with respect to ECD, while the cement pumping rate has a zero influence over the ECD. Therefore, key design varables have optimized to increase the probability of have good cement in the intermediate section. This paper consider as first published research to address and resolve such kind of problem in southern Iraq region.

Acknowledgments

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Nomenclature

ECD = *Equivalent circulation density*
WOB = *Weight on bit*
RPM = *Revolution per minute*

References

1. Alsubaih, A. A., & Nygaard, R. (2016, June 26). Shale Instability of Deviated Wellbores in Southern Iraqi Fields. American Rock Mechanics Association.

2. Alsubaih, A., Albadran, F., & Alkanaani, N. (2018, January 29). Mechanical Specific Energy and Statistical Techniques to Maximizing the Drilling Rates for Production Section of Mishrif Wells in Southern Iraq Fields. Society of Petroleum Engineers. doi:10.2118/189354-MS
3. Alsubaih, A. A., Dahm, H. H., & Alsubaih, I. (2017, August 28). History Matching, Sensitivity and Uncertainty Analysis to Improve Wellbore Stability Model Predictions. American Rock Mechanics Association.
4. Denney, D. (2001, August 1). Cements for Long-Term Isolation Design Optimization. Society of Petroleum Engineers. doi:10.2118/0801-0070-JPT
5. Dunn, M.D., Crane, L.R. and Thomas, R.L.: "North Slope Drilling Practices – Ever Adapting to New Challenges." AADE-05-NTCE-07, AADE National Technical Conference, Houston, April 5-7, 2005.
6. Haut, R. C., & Crook, R. J. (1979, January 1). Primary Cementing: The Mud Displacement Process. Society of Petroleum Engineers. doi:10.2118/8253-MS
7. McLean, R. H., Manry, C. W., & Whitaker, W. W. (1967, February 1). Displacement Mechanics in Primary Cementing. Society of Petroleum Engineers. doi:10.2118/1488-PA
8. Nelson, E. B.; Guillot, D.; Eds., Well Cementing. 2nd ed.; Schlumberger: Sugar Land, TX, 2006
9. Sauer, C. W. (1987, September 1). Mud Displacement During Cementing State of the Art. Society of Petroleum Engineers. doi:10.2118/14197-PA.

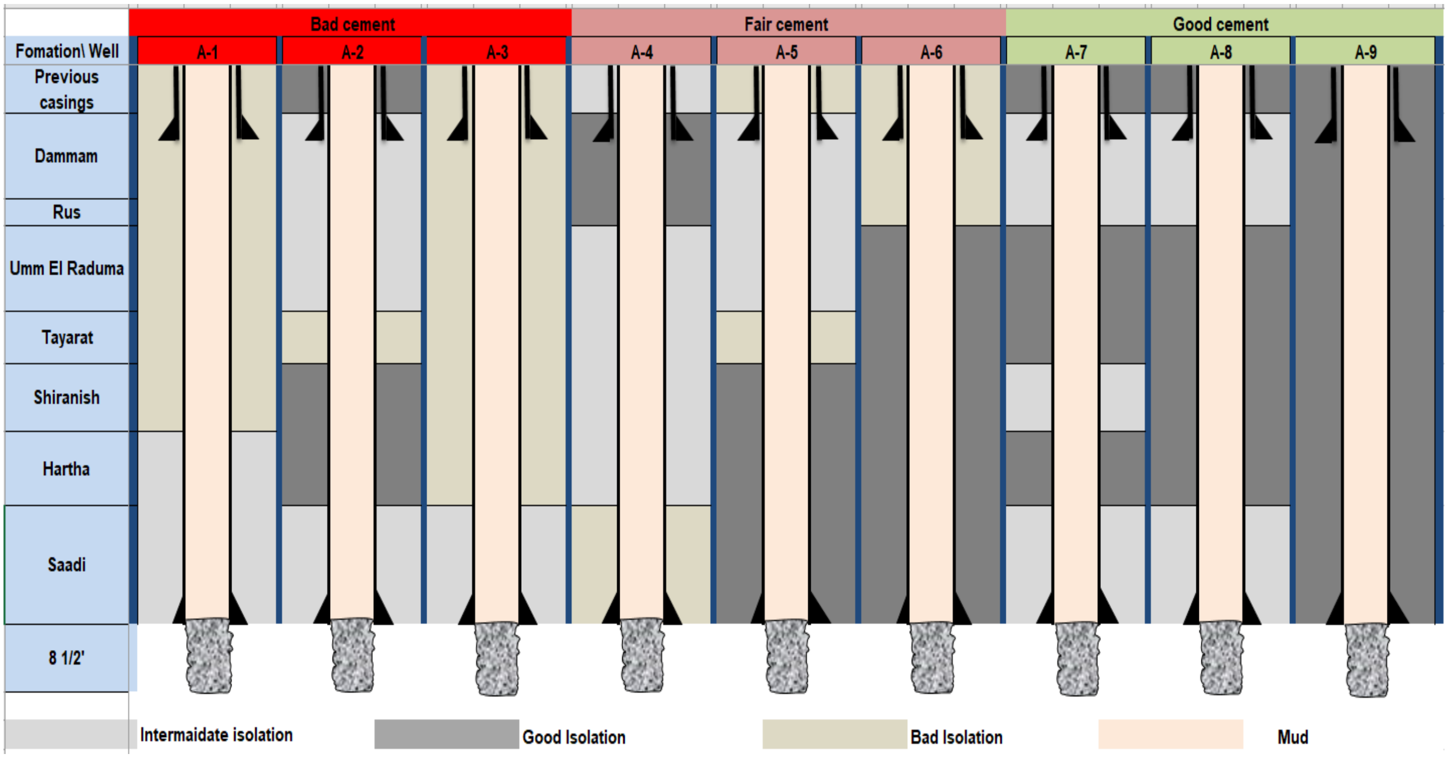

Figure 1: Cement quality evaluation for wells in southern Iraq

Table 1: The cement designs in the investigated wells. where T= Tow stage, O= one stage, and M= multi densities slurries

Well	Type	Cement			Spacer		Washer		Displacement	Losses		Remarks
		Second Stage		First Stage	Volume	Density	Volume	Density	Rate	Drilling	Cementing	
		Lead (sg)	Tail (sg)	Tail (sg)	(bbl)	(sg)	(bbl)	(sg)	(bbl/min)	(bbl/hr)		
A-1	T	1.5	1.9	1.9	50	1.32	NA	NA	10	8 to 48	yes	
A-2	T	1.26	1.9	1.9	60	1.2	30	1.012	10	9 to 19	yes	
A-3	O	1.26	1.9	NA	60	1.2	30	1	10	2 to 5	yes	
A-4	O	1.26	1.9	NA	60	1.2	30	1	10	20 to 50	yes	
A-5	O	1.26	1.92	NA	60	1.2	30	1	8 to 10	15 to 20	yes	fiber
A-6	O	1.35	1.9	NA	NA	NA	73	1.03	10	10 to 50	NA	
A-7	T	1.5	1.9	1.9	50	1.32	NA	NA	10	5 to 25	NA	
A-8	M	1.32	1.9	1.9	70	1.32	50	1.01	10	7 to 15	-	TOB JOB
		INTERMEDIATE	1.75		50	1.32			10			
A-9	M	1.32	1.92	1.9	30	1.32	50	1.01	6	12 to 90	yes	TOP JOB
		INTERMEDIATE	1.75			1.32			6			

Table 2: Cement and mud rheological properties

Cement						Mud			
Slurry		Yield point Ibf/100 ft2	Plastic viscosity CP	Gel 10 sec Ibf/100 ft2	Top of cement M	Density SG	Yield point Ibf/100 ft2	Plastic viscosity CP	Gel 10 sec Ibf/100 ft2
One stage	Lead	19.5	40.5	9	820	1.14	25	17	15
	Tail	19	96	19	1800				
Multi-Slurries	Tail	10.5	79.5	4	1890	1.16	25	15	10
	Lead	12	6	6	surface				
	INTERMEDIATE	28	39	21	920				
	Tail	10.5	79.5	12	1680				
Two stages	Tail	31.5	85.5	4	1850	1.17	23	19	15
	Lead	27	39.5	12	surface				
	Tail	30	87	18	1670				

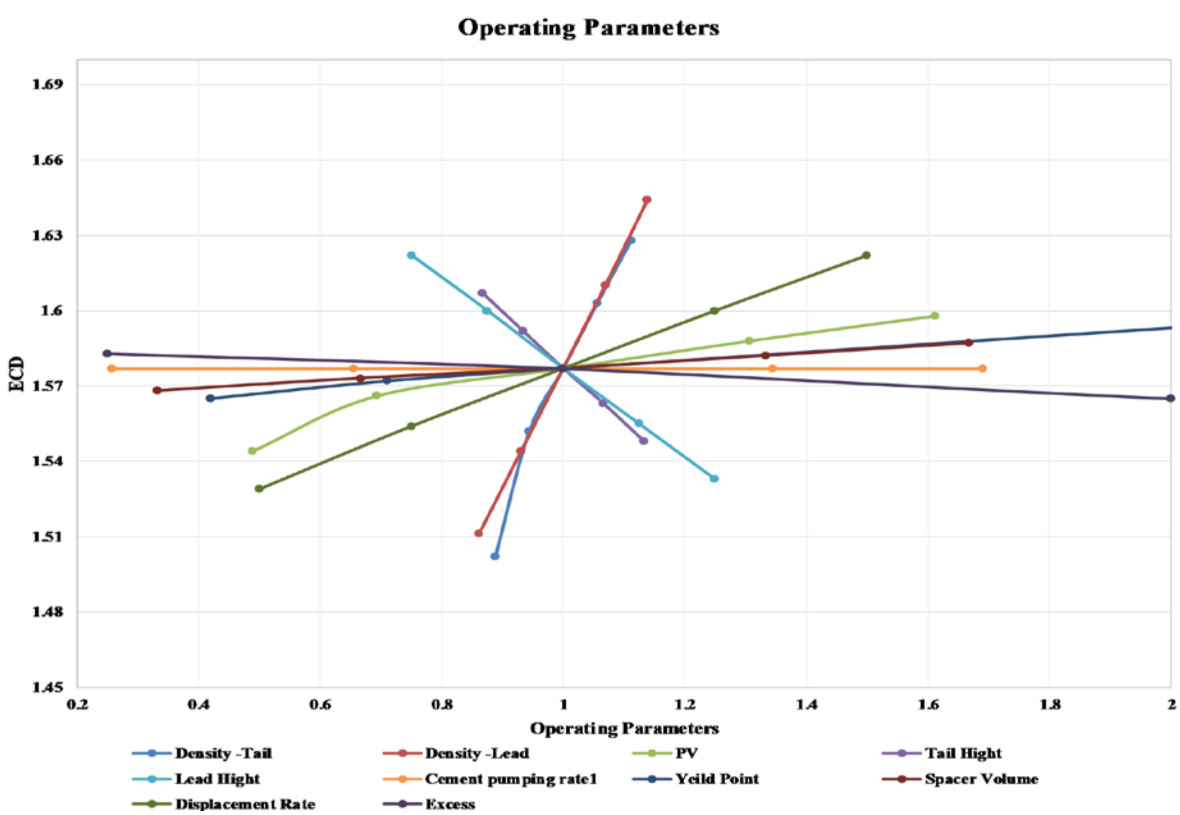

Figure 2: Cement design parameters sensitivity plot

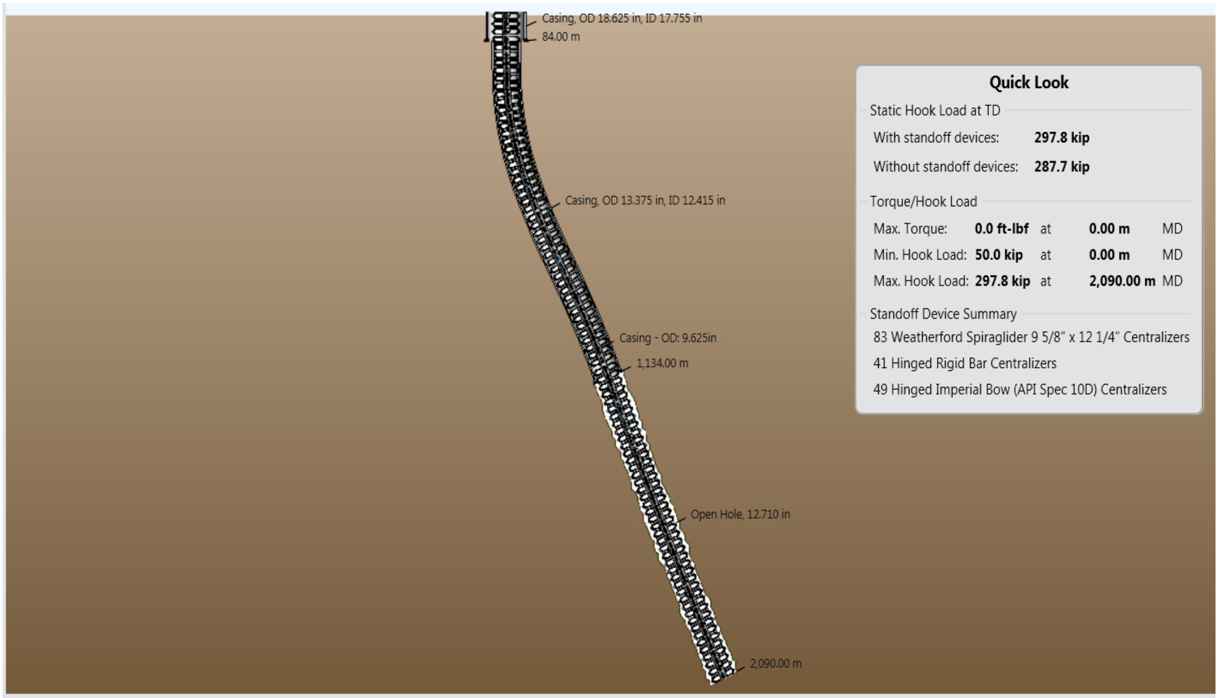

Figure 3: Well profile for typical design

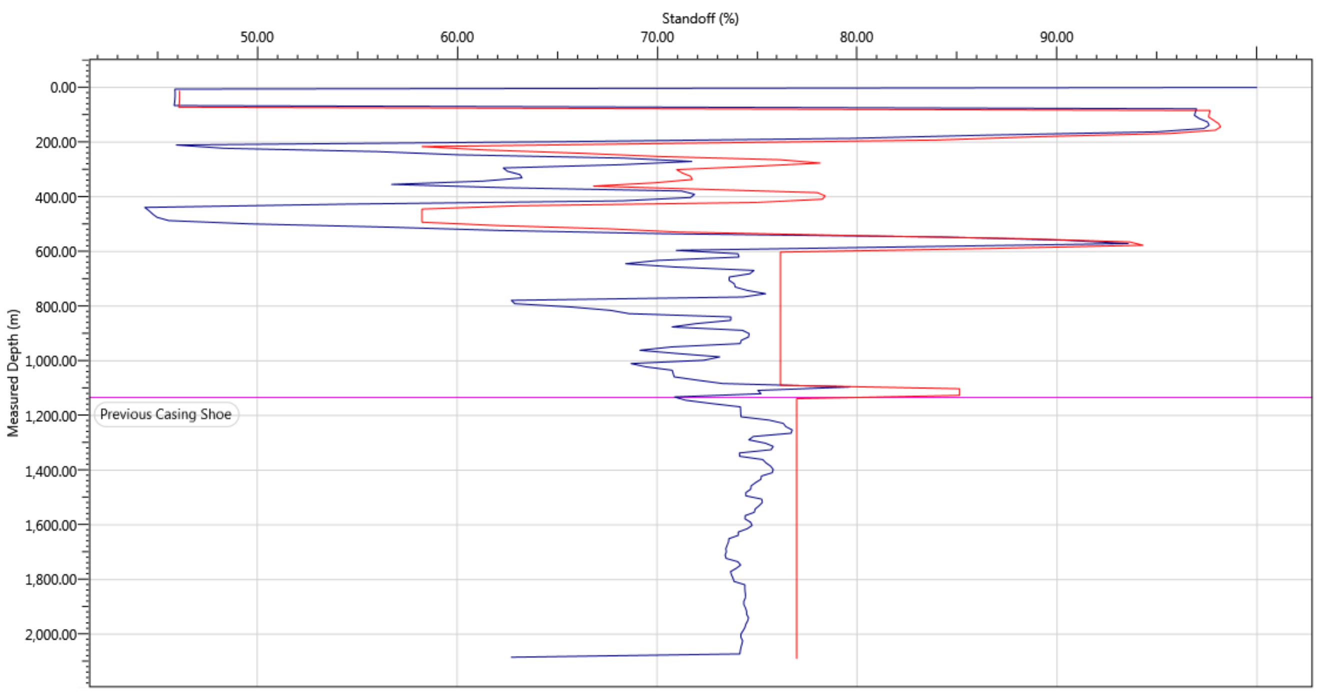

Figure 4: Optimum casing standoff

Table 3: The Proposed cement design to improve cement quality

Cement								Mud			
Slurry		Severity of loss during drilling	Density	Yield point Ibf/100 ft2	Plastic viscosity CP	Pump rate bbl/min	Top of cement M	Density SG	Yield point Ibf/100 ft2	Plastic viscosity CP	Displacement bbl/min
One stage	Lead	Partial Losses	1.45	16	65	7	800	1.14	12	16	8
	Tail		1.85	22	98		1650				
	Lead	severe Losses	1.4	15	40.5	5	900	1.14	10	13	5.5
	Tail		1.8	18	91		1650				
	Lead	No losses	1.55	13	33	9	850	1.14	8	11	11
	Tail		1.85	15	80		1600				

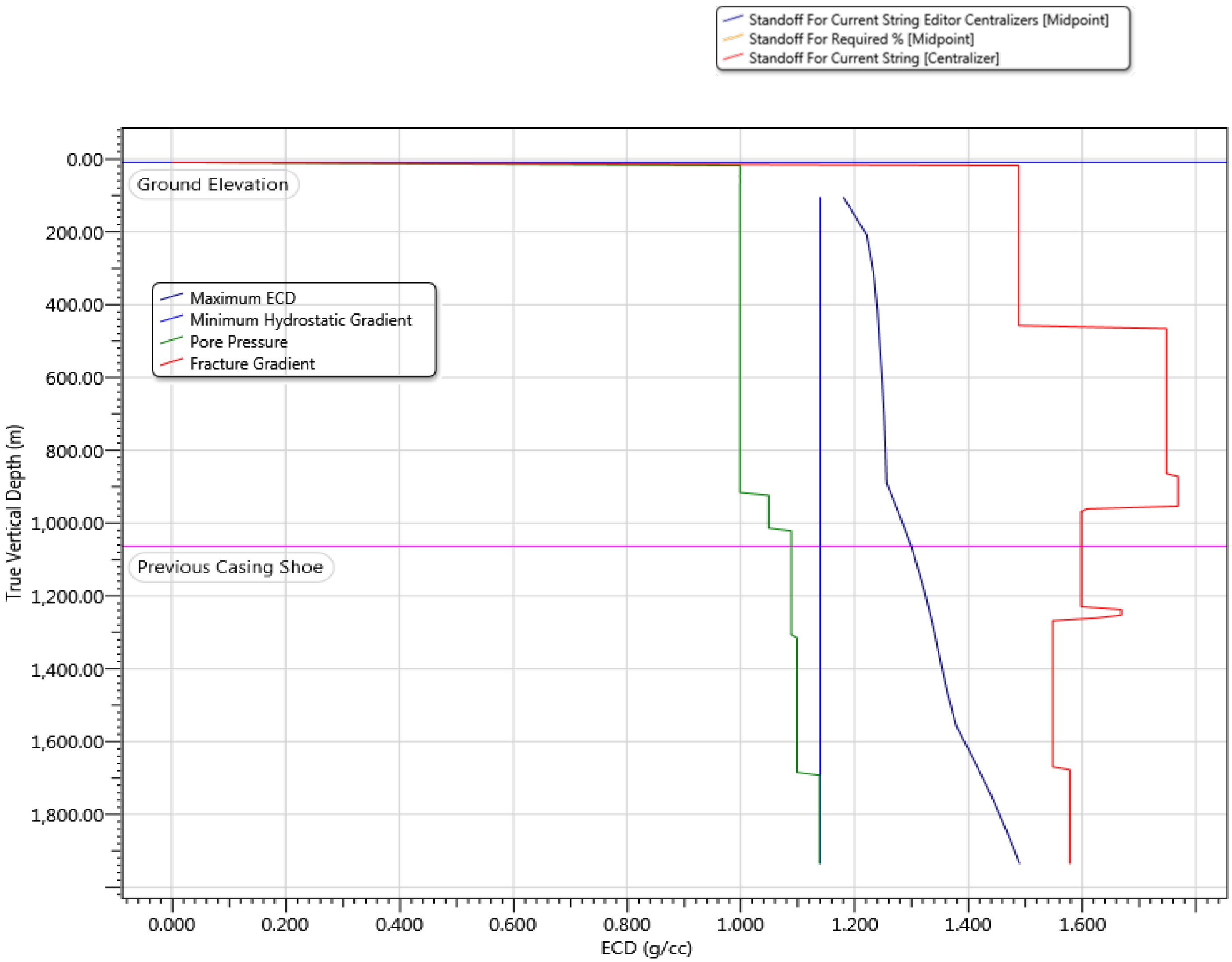

Figure 5: The operation parameters for cement design when partial losses is recorded

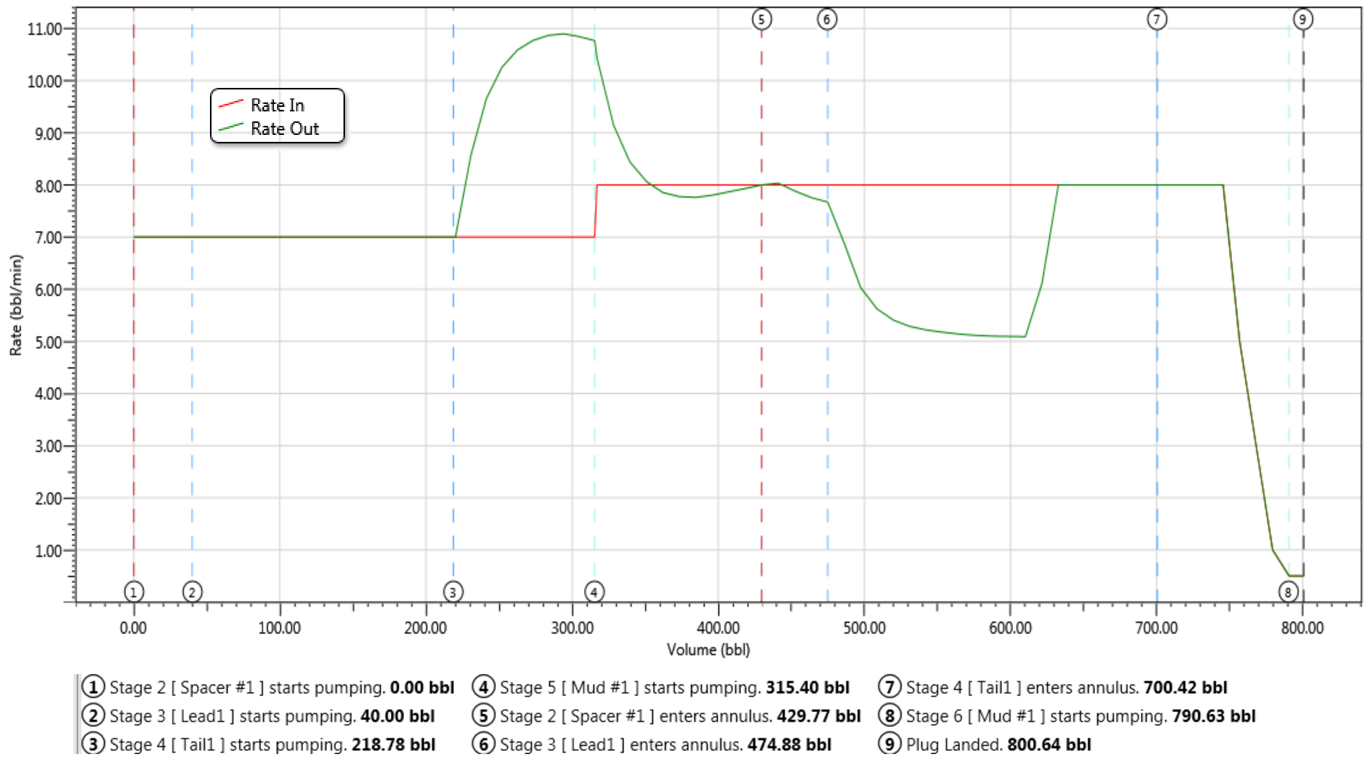

Figure 6: The fluids pumping schedule for partial losses design

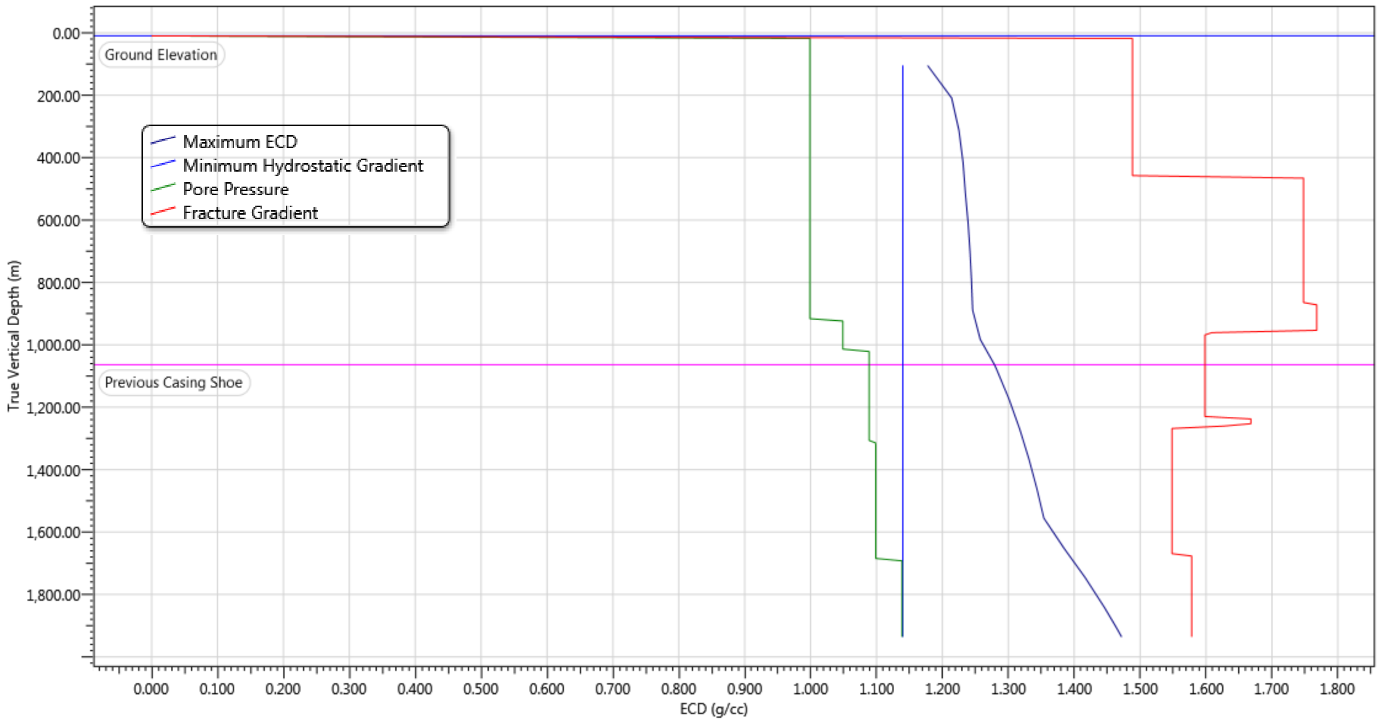

Figure 7: The operation parameters for cement design when complete losses is recorded

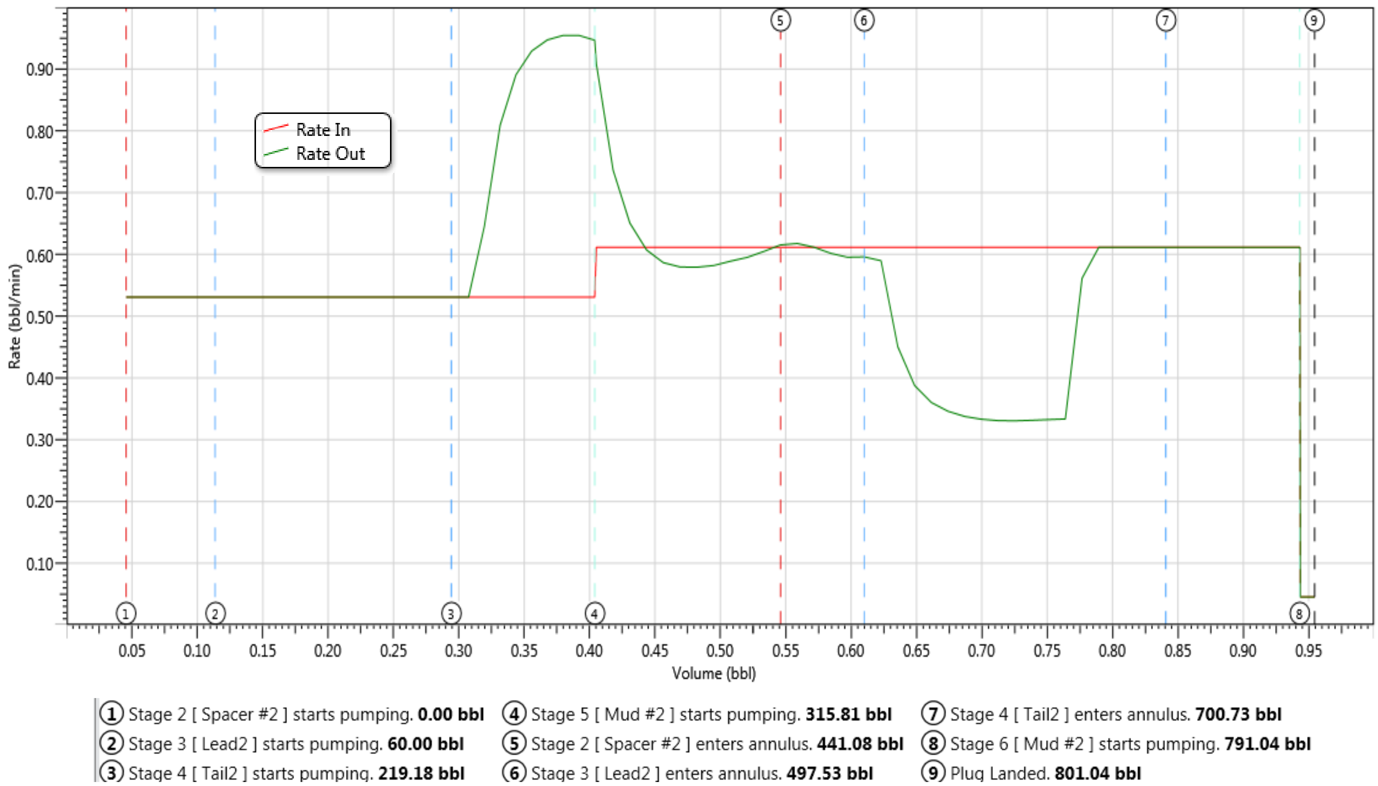

Figure 8: The fluids pumping schedule for complete losses design

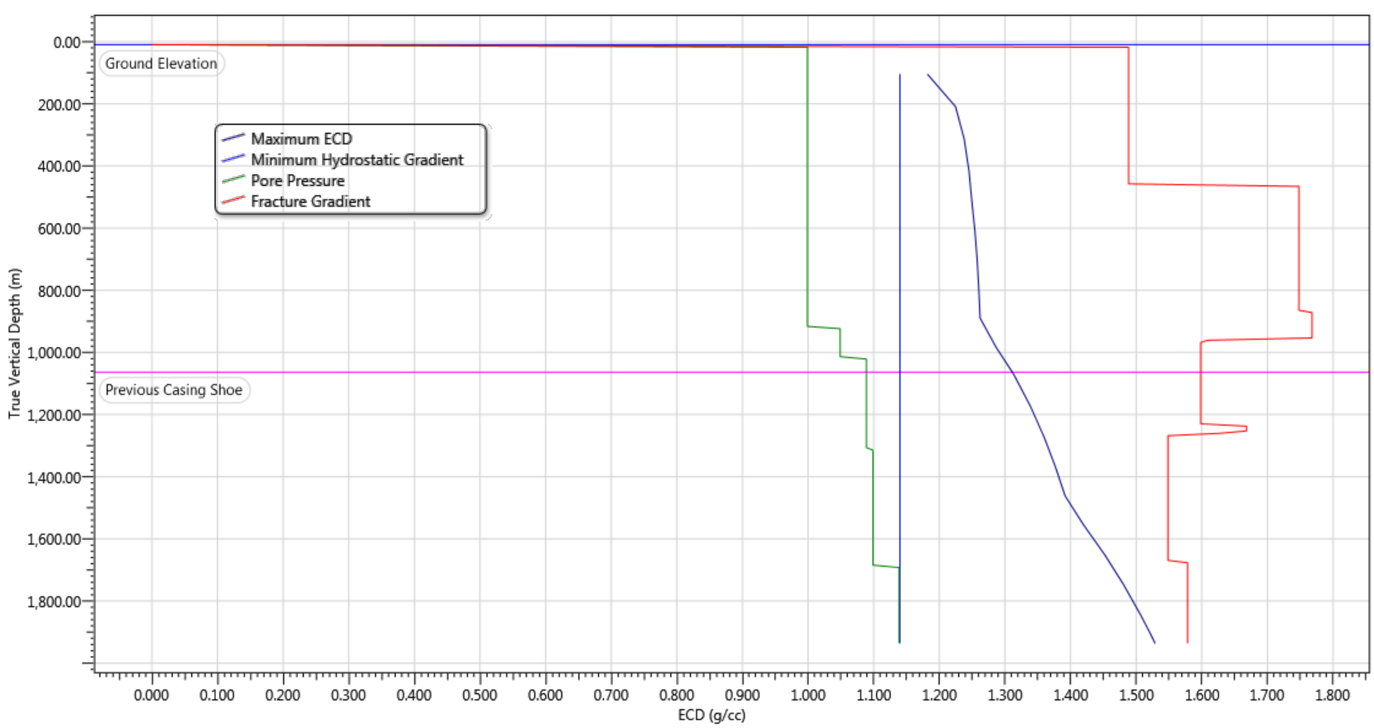

Figure 9: The operation parameters for cement design when no losses is recorded

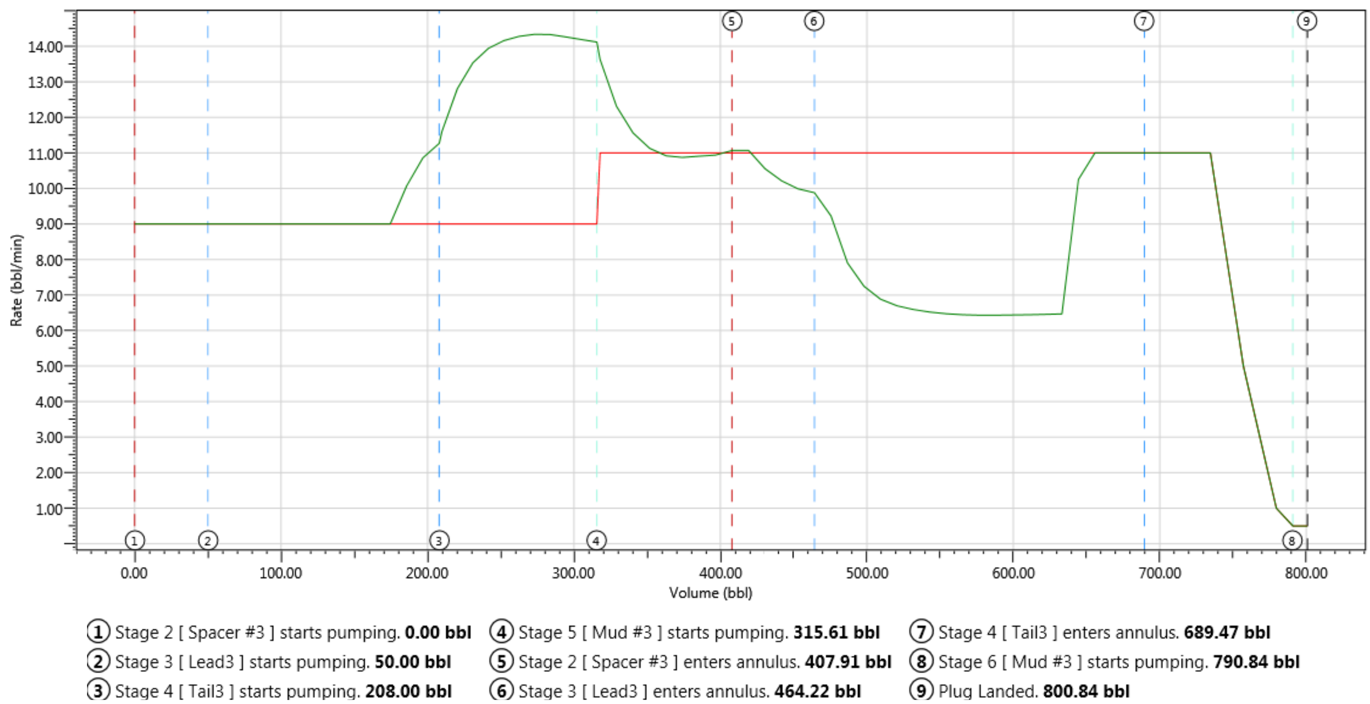

Figure 10: The fluids pumping schedule for losses free design