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Paper Title

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Abstract

Lost circulation across permeable, naturally fractured, and depleted formations is a major challenge during drilling and cementing operations.

A major operator in Oman was experiencing dynamic losses across permeable and depleted zones during drilling and cementing the top-hole section. During primary cementing, no returns during cement displacement indicates an important cementing objective was not achieved, which may require remedial solutions resulting in non-productive time and additional costs. In order to achieve a dependable barrier for isolation of hydrocarbon bearing formations, the objective needs to be the development of a system for eliminating or minimizing losses in weaker formations during cementing operations.

This discussion details a tailored loss circulation cement spacer (LCCS) system designed to help provide assurance of the top of cement (TOC) and zonal isolation in areas prone to lost circulation. The LCCS subjected to fluid modeling and laboratory testing including rheological measurements and compatibility assessments prior to the cement job helped to ensure job requirements would be met. The LCCS was successfully deployed in Malih and Abu Tabul wells, helping meet cementing objectives by invading and preferentially bridging against the loss circulation zones.

Introduction

Achieving the desired TOC was a major challenge in the Malih and Abu Tabul fields in Oman due to losses experienced in several wells across highly permeable and depleted zones. It impacted the cementing operation leading to considerable non-productive time, operation and remedial costs. Several conventional spacers and loss circulation materials (LCMs) including particulates and fibers, were used unsuccessfully to cure these losses in these fields.

A new tailored LCCS system was designed for use prior to cement placement in these fields. Various lab tests were conducted to achieve an optimum formulation of spacer to maintain rheological hierarchy of the fluid system. Computational fluid dynamic (CFD) modeling was used to determine the volume of LCCS required for optimum fluid separation to avoid contamination of mud and the cement slurry. Multiple compatibility tests were done to ensure all fluids were compatible. LCCS compatibility optimization can be achieved with drilling fluids; however, it can be challenging to achive compatibility which is essential for LCCS acceptance. Based on all these lab tests and CFD modeling, 8.0 m3 of LCCS was pumped ahead of cement for the top-hole section in Malih and Abu Tabul fields to reduce the formation permeability. During drilling and running casing, an average of 6 m3/hr losses were observed. However, during cementing 100% returns to surface were seen, indicating elimination of downhole losses due to the novel spacer formulation.

Lost circulation categories and LCCS treatment decision tree for Malih and Abu Tabul fields shows the proper loss circulation treatment based on degree of losses severity in Malih and Abu Tabul Fields.

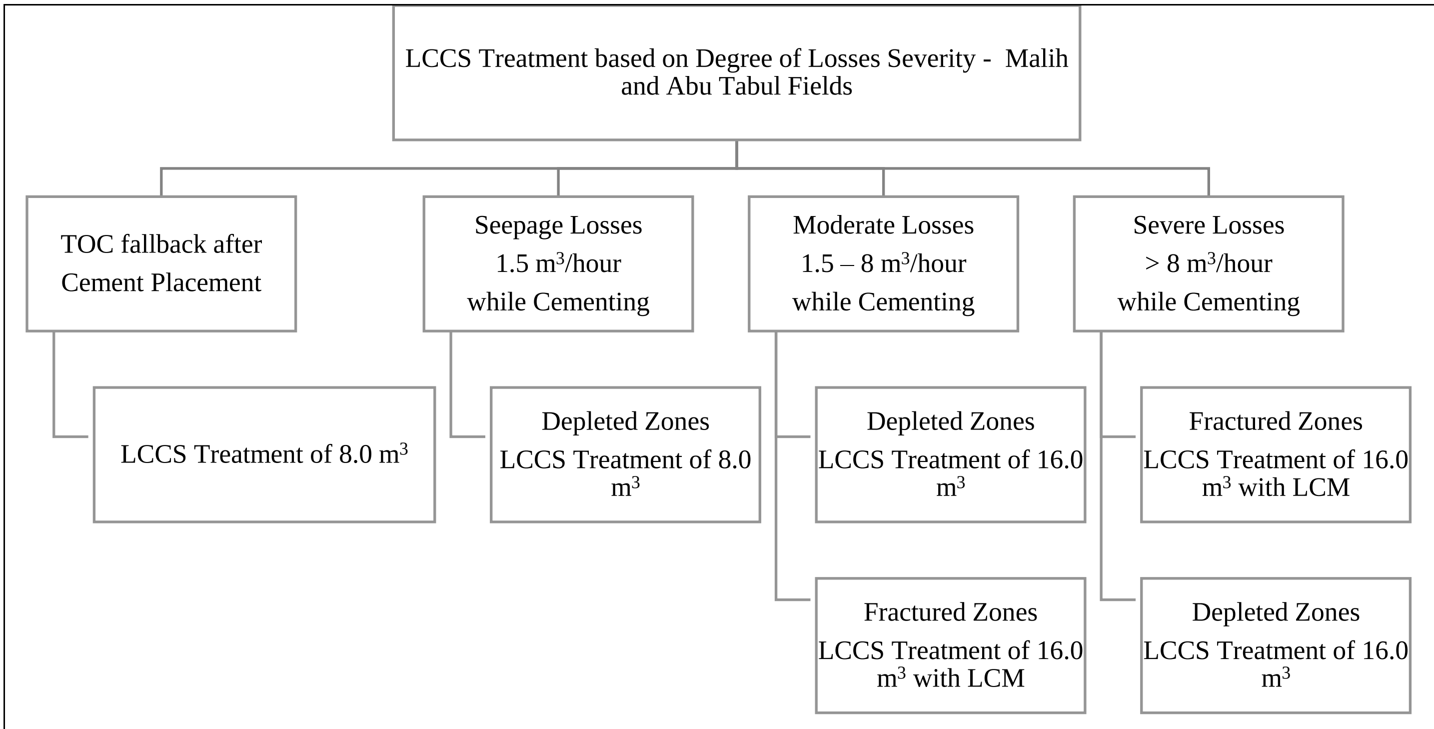

Figure 1: Lost circulation categories and treatment decision tree for Malih and Abu Tabul fields based on fluid modeling and lab testing.

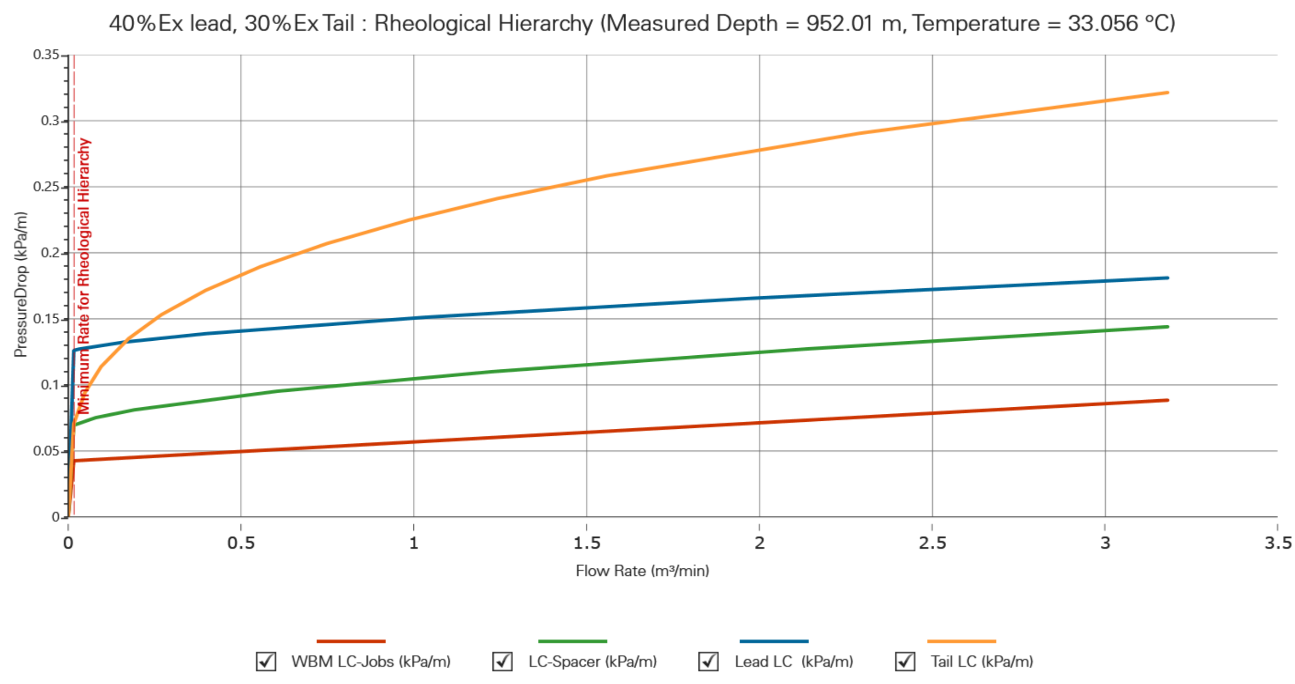

Figure 2: Malih and Abu Tabul top-hole section fluids rheological hierarchy based on CFD.

Table 1: Rheology measurements of LCCS compared to a conventional spacer for top-hole section.

Spacer	Test Temp (degC)	Viscometer Dial Readings (Geometry R1-B1)							
		600	300	200	100	60	30	6	3
1.25 SG LCCS	26.0	70	45	35	30	25	20	13	5
	BHCT-36	75	45	35	30	25	20	15	10
1.25 SG Conventional Spacer	26.0	65	50	40	30	20	15	10	8
	BHCT-36	60	40	35	30	25	20	15	10

Table 2: LCCS compatibility with 1.20 sg WBM for top-hole section.

Test Temp (degC)	Fluid Mixture (% by Volume)	Viscometer Dial Readings (Geometry R1-B1)							
		600	300	200	100	60	30	6	3
BHCT-36	100 % WBM	56	40	28	21	19	14	7	5
	95 % WBM / 5 % LCCS	57	40	28	23	20	14	7	5
	75 % WBM /25 % LCCS	57	41	30	23	20	15	7	5
	50 % WBM /50% LCCS	65	43	30	26	22	15	10	7
	25 % WBM /75% LCCS	72	43	32	27	23	20	11	8
	5 % WBM /95% LCCS	75	45	33	27	23	19	14	10
	100% LCCS	75	45	35	30	25	20	15	10

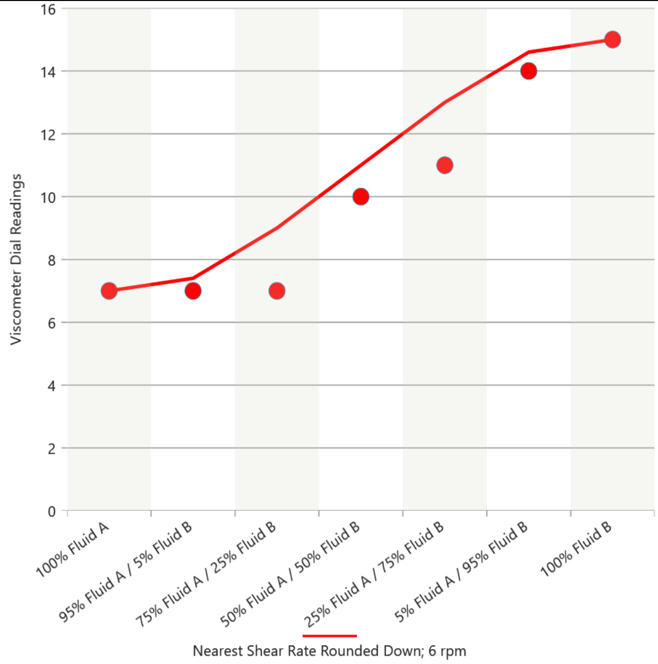

Figure 3: LCCS (Fluid B) compatibility with 1.20 sg WBM (Fluid A) for top-hole section.

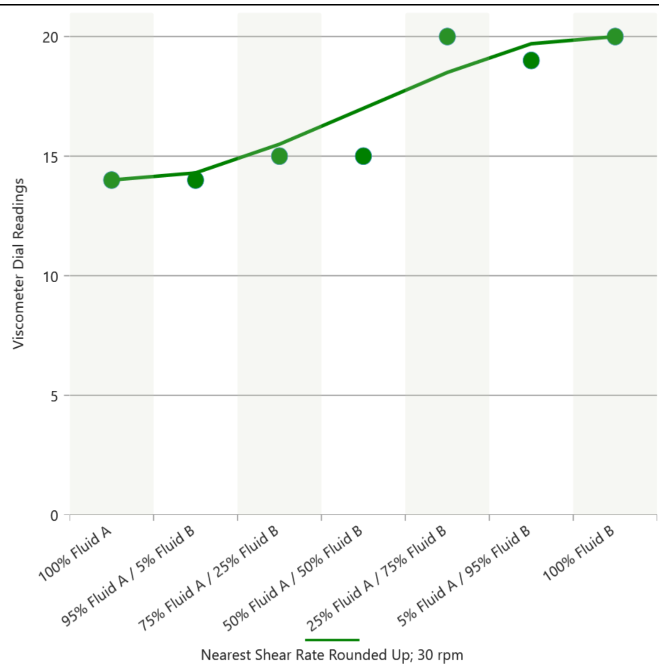

Figure 4: LCCS (Fluid B) compatibility with 1.20 sg WBM (Fluid A) for top-hole section.

Table 3: LCCS compatibility with 1.30 sg lead cement for top-hole section

Test Temp (degC)	Fluid Mixture (% by Volume)	Viscometer Dial Readings (Geometry R1-B1)							
		600	300	200	100	60	30	6	3
BHCT-36	100 % LCCS	75	45	35	30	25	20	15	10
	95 % LCCS / 5 % Cement	78	46	40	33	25	20	17	12
	75 % LCCS /25 % Cement	78	45	42	32	22	16	10	10
	50 % LCCS /50% Cement	80	52	46	34	25	20	15	10
	25 % LCCS /75% Cement	90	60	50	40	35	25	16	15
	5 % LCCS /95% Cement	94	62	57	50	43	23	18	14
	100% Cement		75	60	42	30	20	11	8

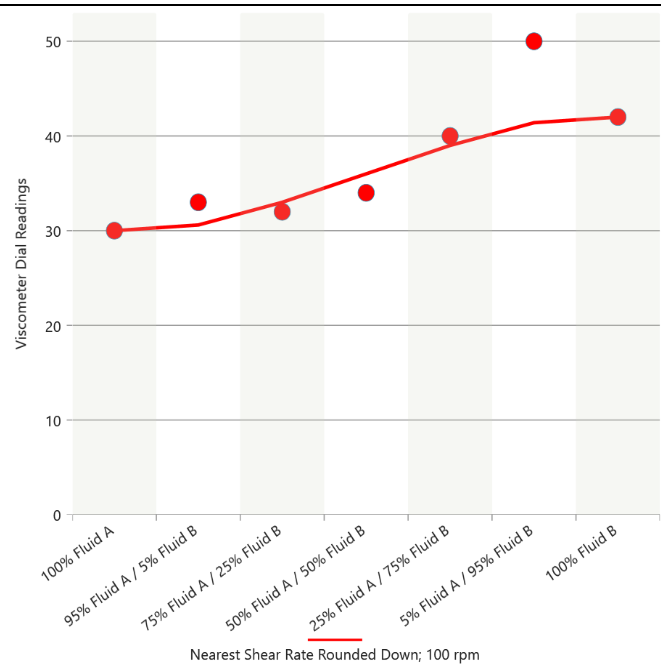

Figure 5: LCCS (Fluid A) compatibility with 1.30 sg lead (Fluid B) cement for top-hole section.

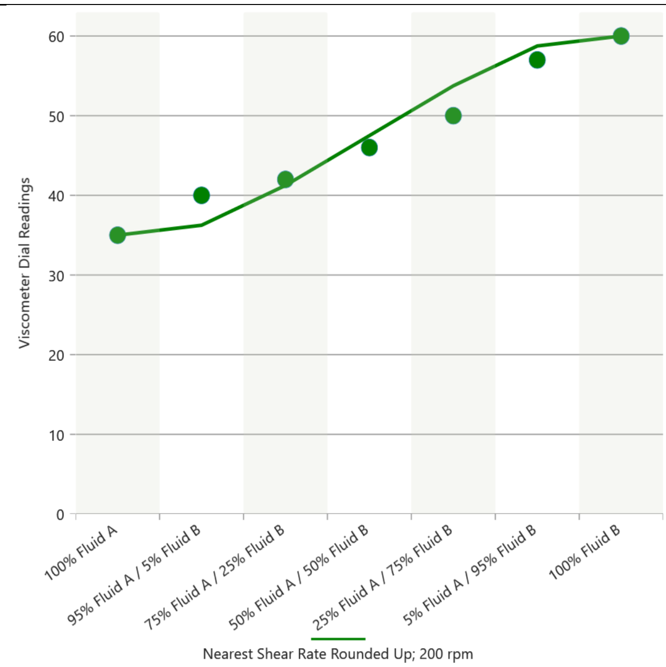

Figure 6: LCCS (Fluid A) compatibility with 1.30 sg lead (Fluid B) cement for top-hole section.

Table 4: LCCS loss test (Lost Circulation Control) with various-permeability cores/slots

LCCS (Kg/m3)	LCCS Density (SG)	Spacer Loss (mL/30 min) at 82°C 1,000 psi		
		60- mesh screen	600-micron slot	1000-micron slot
91	1.25	42	0	0

Fluid	Material / Mixture Name	Particle Safe Passage	Particle Transport Efficiency	Particle Static Suspendability
LC-Spacer	LCM			

Figure 7: Using CFD to to determine the safe LCM concentration in LCCS for moderate to severe losses while cementing for Malih and Abu Tabul top-hole section.

Table 5: Free Fluid API 10B-2 test for LCCS with LCM to confirm partical static suspendability for moderate to severe losses while cementing for Malih and Abu Tabul top-hole section.

LCCS Density (SG)	LCCS (Kg/m3)	LCM (Kg/m3)	Free Fluid %
1.25	91	40	0

Table 6: Pump schedule for Malih and Abu Tabul top-hole section.

Pumping Stage	Stage No.	Density (sg)	Rate (m^3/min)	Volume (m^3)
Circulate WBM	1	1.20	0.95	0.00
Pump LCCS	2	1.25	0.80	8.00
Drop bottom wiper plug	3			
Pump Lead Cement Slurry	4	1.30	0.80	45.20
Pump Tail Cement Slurry	5	1.89	0.80	40.00
Top Plug/Start Displacement	6			
Displace with WBM	7	1.20	1.00	68.90

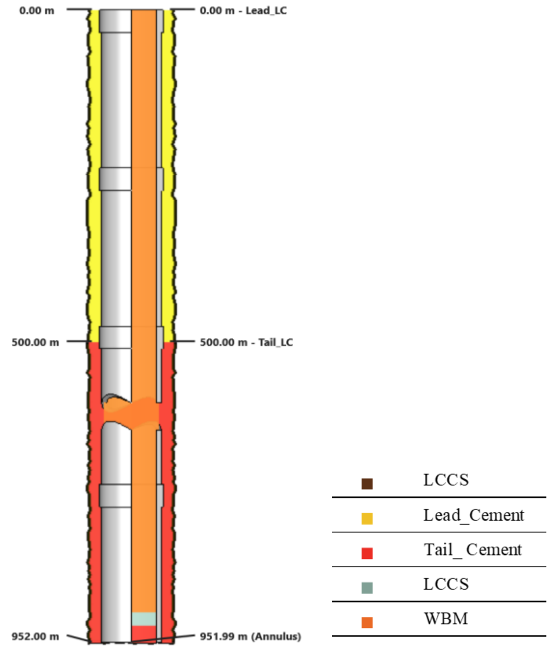

Figure 8: Final 2D Fluid Positions for Malih and Abu Tabul top-hole section.

LCCS Application

This LCCS formulation was used in six different wells in Malih and Abu Tabul fields and resulted in full returns during the cementing job and cement returns observed at the surface were achieved. This solution helped in achieving the cementing job objectives in the primary cementing job and eliminated the requirement of excess cement volumes, top fill cementing jobs, the use of multistage tools and ultimately resulted in improved well economics.

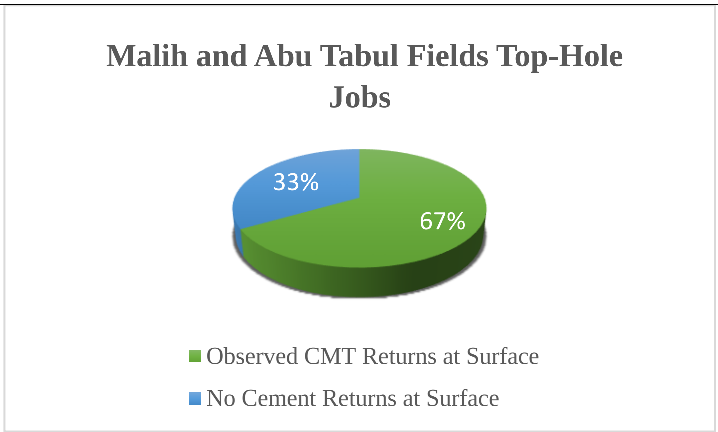

Figure 9: Cement returns of top-hole cement jobs in Malih and Abu Tabul fields. LCCS was used in all jobs with returns. Conventional spacer was used in jobs where no cement returns observed at surface.

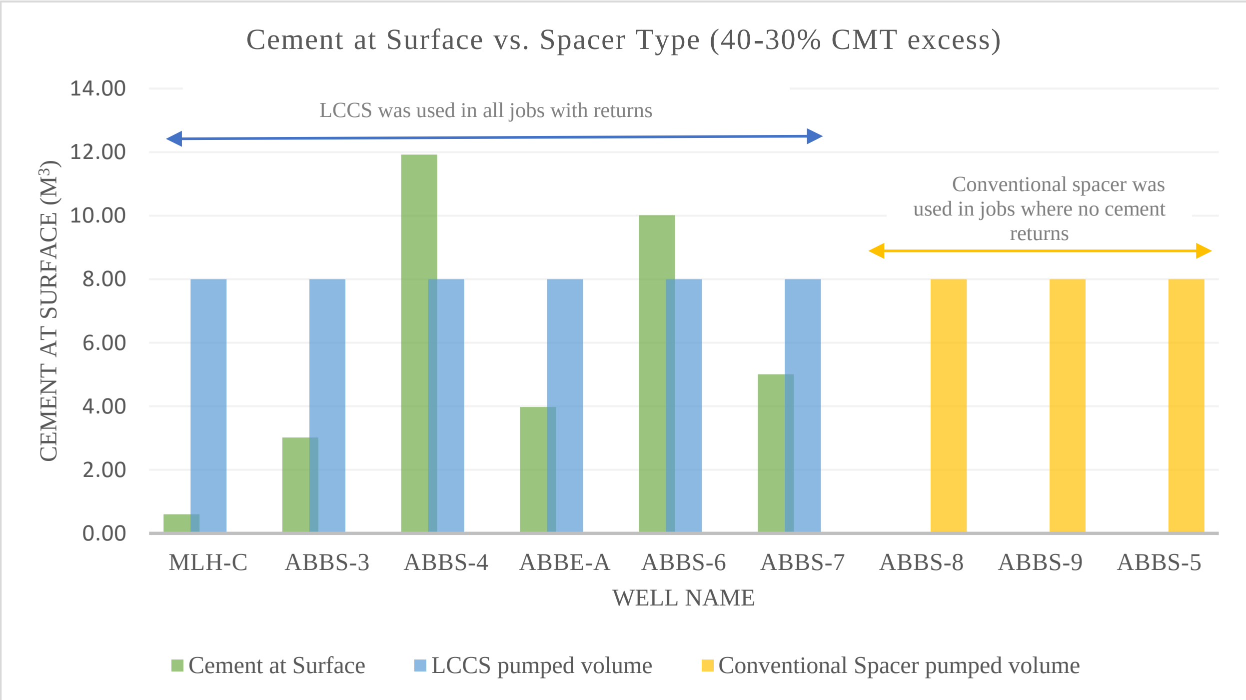

Figure 10: Cement returns in m3 of top-hole cement jobs in Malih and Abu Tabul fields. LCCS was used in all jobs with returns. Conventional spacer was used in jobs where no cement returns observed at surface.

Table 7: A detailed summary of top-hole cement jobs in Malih and Abu Tabul fields

Well	MLH-C	ABBS-3	ABBS-4	ABBE-A	ABBS-6	ABBS-7
Job Type	13-3/8 in Casing					
Hole Size (in)	17.5					
Formation Type (Lithography)	Carbonate, Shaly sand and Sand					
MD (m)/TVD (m)	955	852	948	1020	952	944
BHST (°C) /BHCT (°C)	51/41	46/37	47/38	51/41	46/37	46/37
Loss Type	Dynamic					
Planned TOC /Actual TOC	Surface/ Surface					
Mud Type/ Density (SG)	WBM/1.20					
LCCS Concentration (kg/m^3)	91					
LCCS Volume (m^3) / Density (SG)	8/1.25					
Lead & Tail Cement Density (SG)/ Cement Excess (%)	1.30 & 1.89/30 - 40 over open hole					
Post-Treatment Result	Full Returns during job/ 0.60 m3 cement to surface	Full Returns during job/ 3.0 m3 cement to surface	Full Returns during job / 12.0 m3 cement to surface	Full Returns during job / 4.0 m3 cement to surface	Full Returns during job / 10.0 m3 cement to surface	Full Returns during job / 5.0 m3 cement to surface

Conclusions

The novel LCCS was designed and used to meet the specific job objectives of the 13-3/8 in casing cementing jobs across highly permeable and depleted zones. The LCCS was used to reduce the impact of formation permeability and micro fractures while preventing lost circulation and maintaining wellbore stability during the entire cementing operation. The LCCS used in these jobs has proven to deliver designed cementing placement while eliminating additional complexities in the continued challenge of cementing across formations with a history of lost circulation challenges.

Acknowledgments

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Nomenclature

BHCT: Bottom Hole Circulating Temperature.
BHST: Bottom Hole Static Temperature.
CFD: Computational Fluid Dynamics.
LCCS: Lost Circulation Cement Spacer.
LCM: Lost Circulation Material.
MD: Measured Depth.
SG: Specific Gravity.
TD: Total Depth.
TOC: Top of Cement.
TVD: Total Vertical Depth.
WBM: Water Based Mud.

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