DESIGN OF HIGH-PERFORMANCE WATER BASED MUD SYSTEM WITH AMINE, KCL, ASPHALT & PHPA-BASED INHIBITOR

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Abstract- In this paper, I presented my work on Water Base Mud System. By used of optimum formulation of mud chemicals polyamine, KCL, PHPA (Partially hydrated poly-acrylamide) & Sulphonated Asphalt, these formulations enhanced the inhibition properties of water base mud system. It is the premium water base mud system in API Standard. In a deep well drilling with water based mud system, It is necessary the well stability during drilling, tripping and casing cementing. So we design High Performance mud according to field lithology and according client requirement. We run pilot test with different formulation of HF mud in the Gumpro-Mud lab for optimum mud property which is decided by client ONGC GTO program and well requirement. After run the lab test we get an optimum mud formulation of HF mud system. Which apply in the Western Offshore field of Mumbai-High Basin and well name is B_157N#E, Virtue1 Jack-up Rig.

Key Words*: *Water Based mud system, Mud Chemicals, Mud Properties, Field Location, Well Drilling Data.

1. INTRODUCTION

Drilling fluid compositions vary based on wellbore demands, rig capabilities and environmental concerns. Engineers design drilling fluids to control subsurface pressures, minimize formation damage, minimize the potential for lost circulation, control erosion of the borehole and optimize drilling parameters such as penetration rate and hole cleaning. In addition, because a large percentage of modern wellbores are highly deviated, drilling fluid systems must help manage hole cleaning and stability problems specific to these wells.

2. HOLE SIZE 12.25" SECTION

The objective of this interval was to drill past Limestone/Shale formation and set the 95/8" casing. Drilled down 12 1/4" Hole from 1627 m to 2863m (Section TD).

Tripping during 12.25"section are as follows-

- Trip #1, Wiper Trip: POOH from 1934 m to casing shoe 1627 (Observed tight spots at 1763 m cleared the same by reaming and reciprocation).
- Trip #2, Wiper Trip: POOH from 2280 m to casing shoe 1627 (2084M-2080M, 1924M-1906M, 1840M, 1836M,18011796M,1731M-1728M, 1696M-1694M. CLEARED SAME W/RECIPROCATION AND PUMP OUT 400GPM/430PSI).
- Trip #3, Round Trip: POOH from 2531 m for conventional coring 2529M: SHALE-70%, LIMESTONE 30% (NF/NC). SAMPLE AT 2531M: SHALE: 10%, LIMESTONE-90% (NF/NC). GAS AT MLU Tg max- 1.2% AT 2531M.) Decided to pooh for convectional coring.
- Trip # 4, Round Trip: POOH from 2535.70 m to surface for core recover, coring 4.20 m and core recover 2.20 m.
- Trip # 5, Round Trip: POOH from 2535.70 m to surface for hole enlargement (8.46" core section hole) with 12.25 PDC bit.
- Trip # 6, Round Trip: POOH from 2544.40 m to surface for core recover, coring 8.70 m and core recover 8.20 m.
- Trip #7, Wiper Trip: POOH from 2700 m to casing shoe without any T/pull & H/up.
- Trip #8, Wiper Trip: POOH from 2865 m to casing shoe without any T/pull & H/up.
- Trip #9, Round Trip: POOH from 2865 m to surface without any T/pull & H/up. for Logging, section TD completed.
- Trip #10, Round Trip: POOH from 2865 m to surface without any T/pull & H/up. for hole conditioning.
- Trip #11, Round Trip: POOH from 2865 m to surface without any T/pull & H/up. for 9 5/8" casing and cementing.

Loggings during 12.25"section are as follows-

- RUN LOG-1 (pex-hrla-hngs tool):- Rih Pex-Hrla-Hngs Tool Up To 2864.5m (Logger's Depth). Recorded Main Log 2864.5m – 1626.5m. Repeat Log 2070m– 2000m.
- RUN LOG-2 (dsi-gr):- rihtool to td 2864.5m and recoreded main pass f/2300m to 1626.5m, repeat pass f/2070m to 2000m.

- RUN LOG-3 (fmi-gr):- rih, record repeat pass f/2070m to 2000m. rih tools to td2864.5m, record main pass from 2864.5m to 1635m.
- RUN LOG-4 (cmr-gr):- rih cmr-gr tool to td 2864.5m. Record main pass from 2864.5m- 1639m, repeat pass from 2070m- 2000m.
- RUN LOG-5 (mdt-pq-gr):-Carried out pressure test at depth 2533.7m-3714 psi, 2546.8m-3749psi. Captured sample at 2533.7m. Pressure test in interval (2599-2600m). Contd. c/o pre-test in the intervals (2603-2607.5m, fid at 2607.5m-3929psi, 2635-2636m, 2638.5-2639.5m, 2643-2646m). Pre-test in the interval (1822-1823m).

Casing and Cementation is Lowered 9-5/8" Casing up to 2863m without any problem and cemented as per plan (Casing Shoe at 2863m and F/Collar at 2831m). Observed no mud loss during cement displacement.

2.1 Fluid Selection & Parameters

Mud type are KCl-PHPA-Glycol-Polyamine. The ASAP Water Base Fluid (KCl-PHPA-Glycol-Polyamine) used was designed to provide the optimum mud parameters for drilling 12 1/4'' Phase which helped to control possible problems associated with drilling this type of well such as swelling and dispersion of the clay formations. Optimum mud weight and rheology of the mud system facilitated to stabilize the hole, smooth drilling and trips.

Table -1: Fluid Parameters

Property	Programmed Range	Actual Range
Density (ppg)	9.5 -11	9.8-10.5
Viscosity	45-55	44 -50
PV (cP)	22 - 24	15 -23
YP (lbs/100ft2)	25 - 30	20 -30
6/3 rpm	8 -12/ 6-10	6-10/4-8
Gel0/10	10 -12 /15 -20	4- 9/15-22
Filtration (ml)	<6 ml	6 - 8
Sand (%)		0.1 – 0.5
pH	8.5 -9.0	8.5-9.0
Solids (%)	11 -15	10 – 14
MBT (ppb)	<20	10 -18
KCl (%)	5-7	5 -6

2.2 Mud Summary

This Section was drilled using ASAP KCl-PHPA-Glycol-Polyamine Polymer Mud System. Caustic soda was used for the maintenance of PH. Potassium Chlorideand ASAP PA were the main inhibiting agents of this mud system. PHPA added in conjunction with other chemicals which helped in cutting encapsulation. Chemicals added in requisite quantity to maintain mud rheology and to attain maximum possible inhibition for hole stabilization. XC Polymer (ASAP ZAN) added as a rheology modifier and to maintain low end rheology. ASAPPAC LV and ASAP PAC RG added for fluid loss control. Polymers mixed at a steady rate to avoid formation of fisheyes to minimize the wastage of material.Fluid loss was brought down upto 6.5 ml by end the section. With combined dosage of PAC LV and PAC RG. pH was maintained at pH 8.5 -9.0 with caustic soda. MBT was kept under control <15 ppb by diluting premix mud in active mud and with PHPA premix which helped in encapsulation of clay. Due to occurrence of clay formations, the following chemicals were used to provide very effective inhibition during drilling of 12.25"hole.Initially 6% KCL concentration was maintained till depth of 2863m.Clay hydration was inhibited to an optimum level, as smaller K+ ion is intercalated between two crystal clay lattice units and prevent invasion of water between clay lattice units. PHPA dosage was kept at 3 ppb level. Drilled cuttings were encapsulated by PHPA. Anionic charges of long chain PHPA polymer molecules are bonded with positive surface edge charge of clay particles and thus enable cuttings encapsulation. Polyamine was maintained at 1 -3% while drilling the section; appear to be sufficient to achieve desired inhibition levels. Poly Amine acts chemically as well as mechanically. Chemically, polyamine cat-ion in the molecule replaces Na+ ion in clay lattice through ion exchange and mechanically, the long chain molecule of Polyamine simply adsorbs on the top layers of formation. Both K+ of KCl and Poly amine act chemically to produce inhibition through ion exchange and forming an organic inorganic clay hybrid. The size of the hydrated K+ ion is 2.6 A^0 (Angstroms), whereas the size of hydrated NH4+ ranges from 2.5 A^0 to 7.5 A^0 depending on the type of poly amine used. While drilling, clay / clay stone / shale occurs naturally containing Na+ and d spacing measuring around 9.8 A^0 between clay platelets. Both K+ and polyamine cat-ions can penetrate easily into interstitial spacing.

Clay crystal lattice spacing (due to their size) and replace Na+ and other exchangeable ions in clay lattice through cation exchange mechanism. The resulting exchange brings clay / shale platelets very close reducing the separation potential of shale matrix. The lesser the size of cat-ion being exchanged lesser will be the interstitial gap and more the capability to prevent / minimize swelling potential of clay matrix. Poly amine (due to its size) fits more precisely in crystal lattice of clay than potassium K+ cat-ion effectively sealing interstitial spaces in crystal lattice quickly, preventing fluid invasion deep into the crystal lattice. Polyamine is more or equally effective than K+ in producing same inhibition levels at low concentrations.

2.3 Mud Weight

The mud weight started from 9.8ppg and gradually increased to 10.5 ppg till section TD (1124m). Prior to 1st wiper trip increased mud weight from 10.5 ppg to 11.0 ppg as per instruction from ONGC Base. During wiper trip observed intermittent tight spots so prior to POOH for logging increased the mud weight from 11.0 ppg to 11.5 ppg. The maximum MW of 11.5ppg wassufficient to stabilize the well.

Table – 2: Mud Weight Data

Depth (m)	Mud Weight (ppg)	Remark
1700	9.8	
1900	9.9	
2100	10.1	
2300	10.2	
2500	10.2	
2700	10.3	
2863 (Section TD)	10.2	
2600	10.2	MW constant due to dynamic loss
2600 – 2750 m	10.3	MW constant due to caving observed

2.4 Mud Volume Summary

In this section accumulate and calculate the mud volume according to table.

Table- 3: Mud Volume Data

Volume Summary- (bbl)			
Volume Analysis		**Interval Losses**	
Mixed - Water	1234	Shakers	855.7
Mixed - Base fluid	0	SCE	324.9
Mixed - Chemical Volume	604.7	Discharge	0
Mixed - Weight Material	42.9	Injection	0
Total Mixed	1881.7	Pit Cleaning	520
Mud Received	2372	Evaporation	521.5
Total Volume for Interval	4253.7	Tripping	178
Interval Consumption	3622.9	Seepage/Lost Circulation	1210.8
Interval Balance	2588.7	Behind Casing	0
Volume backloaded	0	Left in Hole	0
Volume transferred to next int.	2576.7		
Consumption Surface – (Vol / Len)	1.25		
Consumption SS – (Vol / Len)	0.34		
Consumption Total – Vol / Len)	1.59		

2.5 12.25" Hole – Mud Properties

Table -4(a): Mud Properties 01 June 2020 to 13 June 2020

PROPERTIES	UNIT	1 8 June 1825 m	2 9 June 1934 m	3 10 June 2227 m	4 11 June 2280 m	5 12 June 2374 m	6 13 June 2531 m
Sample from		FLOW LINE	FLOW LINE	FLOW LINE	ACTIVE	FLOW LINE	Flow Line
Time Taken		05:00	05:00	05:00	05:00	05:00	05:11
Depth	m	1,825	1,934	2,227	2,280	2,374	2,531
Deviation	Deg.						
Flow Line Temperature	°F	108	126	135	135	140	143
Density	ppg	9.9	9.9	10.0	10.2	10.3	10.2
Funnel Viscosity	sec/qt	42	46	43	47	45	46
600 / 300 / 200		50 / 36 / 29	50 / 36 / 30	54 / 38 / 31	73 / 51 / 41	71 / 52 / 42	78 / 56 / 46
100 / 6 / 3		21 / 8 / 6	22 / 8 / 6	21 / 7 / 5	29 / 9 / 7	29 / 7 / 5	33 / 7 / 6
PV	cP	14	14	16	22	19	22
YP	lbs/100 ft^2	22	22	22	29	33	34
Gel 10 sec / 10 min / 30 min	lbs/100 ft^2	6 / 15 / -	8 / 15 / -	5 / 13 / -	8 / 17 / -	5 / 14 / -	6 / 16 / -
'n' / 'k' Annulus	lb*s^n/100ft^2	0.389 / 16.253	0.389 / 16.253	0.44 / 12.457	0.431 / 17.702	0.509 / 11.147	0.485 / 13.899
API / HTHP F/L	ml/30min	6.5 / -	6.5 / -	6.5 / -	7 / -	7 / -	6.5 / -
Cake Thickness API / HTHP	32nd in	1 / -	1 / -	1 / -	1 / -	1 / -	1 / -
pH / Alkalinty Mud (Pm)	-/ml	9.5 / 0.4	9.5 / 0.3	9 / 0.25	9 / 0.2	9 / 0.18	9 / 0.2
Pf / Mf	ml	0.35 / 0.8	0.2 / 0.75	0.2 / 0.65	0.15 / 0.6	0.2 / 0.52	0.25 / 0.61
Chlorides	mg/l	35,000	36,000	36,000	42,000	41,000	40,000
Calcium / Magnesium	mg/l	400 / - /	280 / - /	180 / - /	180 / - /	100 / - /	120 / - /
Total Hardness	mg/l						
Water / Oil	% by Vol.	89 / -	89 / -	88 / -	88 / -	88 / -	88 / -
Solids / Corrected Solids	% by Vol.	11 / 9.1	11 / 9	12 / 10.1	12 / 9.7	12 / 9.8	12 / 9.8
LGS / HGS	% by Vol.	9.1 / 0	9 / 0	10.1 / 0	8.6 / 1.2	7.9 / 1.9	8.7 / 1.2
LGS / HGS	ppb	82.79 / 0	82.28 / 0	91.58 / 0	77.97 / 17.1	71.59 / 28.22	78.81 / 17.37
ASG	SG	2.6	2.6	2.56	2.79	2.91	2.79
Sand Content	% by Vol.	0.2	0.1	0.1	0.1	0.1	0.1
MBT	ppb Eq.	17.5	17.5	16.5	16.5	16.5	16.5
Potassium Chloride	5-9 %						
Polyamine	7 ppb						

Table -4(b): Mud Properties 14 June 2020 to 18 June 2020

PROPERTIES	**UNIT**	**7 14 June 2531 m**	**8 15 June 2534 m**	**9 16 June 2535.7m**	**10 17 June 2539 m**	**11 18 June 2544.4 m**
Sample from		Flow line	Flow Line	Flow Line	Flow Line	Flow Line
Time Taken		14:00	05:00	05:15	05:00	12:00
Depth	m	2,531	2,534	2,535.7	2,539	2,544.4
Deviation	Deg.					
Flow Line Temperature	°F		148	148	150	150
Density	ppg	10.2	10.2	10.2	10.2	10.2
Funnel Viscosity	sec/qt	49	47	45	46	48
600 / 300 / 200		66 / 46 / 35	76 / 54 / 46	69 / 48 / 38	69 / 47 / 35	69 / 51 / 48

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PROPERTIES	UNIT	7 14 June 2531 m	8 15 June 2534 m	9 16 June 2535.7m	10 17 June 2539 m	11 18 June 2544.4 m
100 / 6 / 3		28 / 7 / 6	33 / 7 / 6	29 / 6 / 5	28 / 6 / 5	32 / 5 / 4
PV	cP	20	22	21	22	18
YP	lbs/100 ft^2	26	32	27	25	33
Gel 10 sec / 10 min / 30 min	lbs/100 ft^2	6 / 15 / -	6 / 15 / -	5 / 15 / -	5 / 14 / -	4 / 13 / -
'n' / 'k' Annulus	lb*s^n/100ft^2	0.442 / 14.902	0.477 / 14.079	0.491 / 11.467	0.487 / 11.553	0.553 / 8.297
API / HTHP F/L	ml/30min	6.5 / -	6.5 / -	6.8 / -	6.5 / -	6.5 / -
Cake Thickness API / HTHP	32nd in	1 / -	1 / -	1 / -	1 / -	1 / -
pH / Alkalinty Mud (Pm)	-/ml	9 / 0.17	9 / 0.18	9 / 0.2	9 / 0.18	9 / 0.18
Pf / Mf	ml	0.21 / 0.56	0.23 / 0.58	0.22 / 0.59	0.22 / 0.58	0.21 / 0.6
Chlorides	mg/l	40,000	40,000	40,000	40,000	41,000
Calcium / Magnesium	mg/l	120 / - /	120 / - /	120 / - /	120 / - /	100 / - /
Total Hardness	mg/l					
Water / Oil	% by Vol.	88 / -	87 / -	87 / -	87 / -	88 / -
Solids / Corrected Solids	% by Vol.	12 / 9.8	13 / 10.9	13 / 10.9	13 / 10.9	12 / 9.8
LGS / HGS	% by Vol.	8.7 / 1.2	10.7 / 0.2	10.7 / 0.2	10.7 / 0.2	8.6 / 1.2
LGS / HGS	ppb	78.81 / 17.37	97.16 / 2.79	97.16 / 2.79	97.16 / 2.79	78.41 / 17.21
ASG	SG	2.79	2.63	2.63	2.63	2.79
Sand Content	% by Vol.	0.1	0.1	0.1	0.1	0.1
MBT	ppb Eq.	16.2	15.2	15.2	15.2	15.2
Potassium Chloride	8-9 %					
Polyamine	7 ppb					

Table -4(c): Mud Properties 19 June 2020 to 23 June 2020

PROPERTIES	UNIT	12 19 June 2654 m	13 20 June 2674 m	14 21 June 2774 m	15 22 June 2865 m	16 23 June 2865 m
Sample from		Flow Line	Flow Line	Flow Line	Flow Line	Flow Line
Time Taken		05:00	12:00	05:00	05:00	09:00
Depth	m	2,654	2,674	2,774	2,865	2,865
Deviation	Deg.					
Flow Line Temperature	°F	152	166	166	169	169
Density	ppg	10.3	10.3	10.2	10.2	10.2
Funnel Viscosity	sec/qt	45	45	44	45	46
600 / 300 / 200		69 / 48 / 40	62 / 43 / 38	68 / 49 / 42	64 / 45 / 36	65 / 47 / 39
100 / 6 / 3		28 / 6 / 5	29 / 5 / 4	31 / 5 / 4	26 / 6 / 4	29 / 6 / 5
PV	cP	21	19	19	19	18
YP	lbs/100 ft^2	27	24	30	26	29
Gel 10 sec / 10 min / 30 min	lbs/100 ft^2	5 / 16 / -	4 / 13 / -	4 / 12 / -	4 / 12 / -	5 / 14 / -
'n' / 'k' Annulus	lb*s^n/100ft^2	0.491 / 11.467	0.516 / 8.813	0.544 / 8.415	0.526 / 8.673	0.487 / 11.553
API / HTHP F/L	ml/30min	6.5 / -	6.8 / -	6.5 / -	6.8 / -	6.5 / -
Cake Thickness API / HTHP	32nd in	1 / -	1 / -	1 / -	1 / -	1 / -
pH / Alkalinty Mud (Pm)	-/ml	9 / 0.19	9 / 0.18	9 / 0.17	9 / 0.18	9 / 0.18
Pf / Mf	ml	0.22 /	0.22 / 0.6	0.21 /	0.2 / 0.56	0.22 / 0.6

PROPERTIES	UNIT	12 19 June 2654 m	13 20 June 2674 m	14 21 June 2774 m	15 22 June 2865 m	16 23 June 2865 m
		0.61		0.58		
Chlorides	mg/l	40,000	40,000	40,000	40,000	40,000
Calcium / Magnesium	mg/l	100 / - /	100 / - /	100 / - /	100 / - /	100 / - /
Total Hardness	mg/l					
Water / Oil	% by Vol.	87 / -	87 / -	87 / -	87 / -	87 / -
Solids / Corrected Solids	% by Vol.	13 / 10.9	13 / 10.9	13 / 10.9	13 / 10.9	13 / 10.9
LGS / HGS	% by Vol.	9.9 / 0.9	9.9 / 0.9	10.7 / 0.2	10.7 / 0.2	10.7 / 0.2
LGS / HGS	ppb	90.35 / 13.8	90.35 / 13.8	97.16 / 2.79	97.13 / 2.85	97.16 / 2.79
ASG	SG	2.74	2.74	2.63	2.63	2.63
Sand Content	% by Vol.	0.1	0.1	0.1	0.1	0.1
MBT	ppb Eq.	15.2	15.2	15.2	15	15
Potassium Chloride	8-9 %					
Polyamine	7 ppb					

3. CONCLUSION

Sufficient mud weight is a key to maintain a stable bore hole. Mud Weight increase should be done 0.1-0.2 ppg at a time slowly at regular interval, only as the hole dictates in order to avoid differential sticking. Slow tripping speed should be adopted to avoid surging and swabbing inside the annulus which may destabilize the well bore. Use the maximum Hydraulic capacity (pump flow rate) available, considering well bore stability.

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