CSCanada
Advances in Petroleum Exploration and Development
Vol. 21, No. 1, 2022, pp. 18-26
DOI:10.3968/12556

ISSN 1925-542X [Print]
ISSN 1925-5438 [Online]
www.cscanada.net
www.cscanada.org

Pengzhou 5-4D Drilling Fluid Technology

YU Jiliang[a],*

[a]Guizhou Shale Gas Exploration and Development Co, Ltd., Zunyi, Guizhou, China.
*Corresponding author.

Received 2 January 2022; accepted 11 April 2022
Published online 26 May 2022

Abstract
Pengzhou 5-4D well is a three-spud directional well deployed by Southwest Oil and Gas company in yadehe structure, Longmenshan Piedmont structural belt, West Sichuan depression, Sichuan Basin. The designed vertical depth is 7545m, the designed maximum well deviation is 89.59°, the actual completed drilling depth is 7150m, and the completed drilling deviation is 91.58°. The strata encountered by the well are Penglaizhen formation, Suining formation, Shaximiao formation, Qianfoya formation, Xujiahe formation, Xiaotangzi formation, Maantang formation and Leikoupo formation. Potassium polysulfonate drilling fluid is used for the first and second spuds of the well, and oil-based drilling fluid is used for the third spud. During the second spud in, Ma'antang formation collapsed and fell seriously, making tripping difficult. After sidetracking, by adjusting the treatment idea of drilling fluid, making rational use of pre hydrated bentonite slurry, using asphalt with different softening points and nano plugging materials, the problem of collapse and falling blocks was well solved, and the operations such as tripping, electrical logging and casing running were safe and smooth. The white oil-based drilling fluid system is used in the third spud in a pioneering manner, and the construction is smooth without downhole complexity, which provides valuable experience for the construction of marine formation drilling fluid in Pengzhou block in the next step.

Key words: Potassium polysulfonate drilling fluid; Collapse and block falling; Strengthen plugging; White oil-based drilling fluid

Yu, J. L. (2022). Pengzhou 5-4D Drilling Fluid Technology. *Advances in Petroleum Exploration and Development*, *21*(1), 18-26. Available from: http://www.cscanada.net/index.php/aped/article/view/12556
DOI: http://dx.doi.org/10.3968/12556

1. BASIC OVERVIEW

1.1 Basic Data

Table 1
Basic data of well Pengzhou 5-4D

Well number	Pengzhou 5-4D well	Geographic location	Yang Liu Cun, Ge Xian Shan Zhen, Pengzhou City, Chengdu City, Sichuan Province
Well type	Directional well	Drilling purpose	layer of Lei 4 section, taking into account layer of Lei 4 section
Designed drilling depth (m)	7545	Actual completed drilling depth (m)	7150
Maximum deviation (°)	91.58	Horizontal displacement (m)	1781.44
Designed drilling horizon	Carboniferous System	Actual completed horizon	Leikoupo Formation

1.2 Wellbore Structure

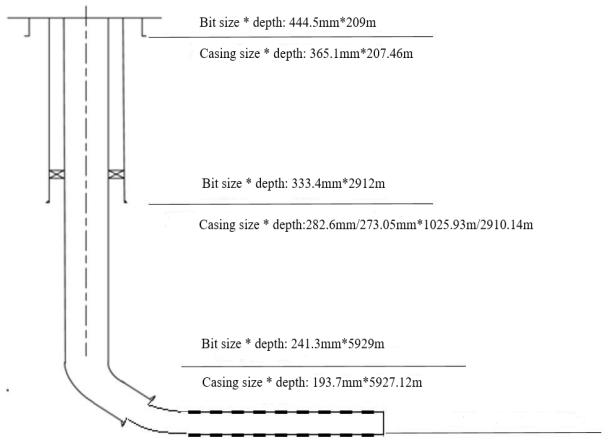

Figure 1
Structure of Pengzhou 5-4D well

1.3 Stratum and Lithology

Table 2
Stratum distribution of well Pengzhou 5-4D

Stratum	Design parameters		Actual drilling parameters		Main lithology
	Vertical depth (m)	Vertical thickness (m)	Well depth / Vertical depth (m)	Drilling depth / Vertical thickness (m)	
Quaternary (Q)	24.00	24	24.00	24.00	
Penglai town formation (J3p)	934.00	910.00	936.00	912.00	Sandstone and mudstone are interbedded with conglomerate
Suining Formation (J3sn)	1299.00	365.00	1300.00	364.00	Sandstone and mudstone are interbedded and gravels are developed
Shaximiao Formation (J2s+x)	1958.00	659.00	1950.00	650.00	Sand mudstone interbedded with conglomerate
Qianfoya formation (J2q)	2117.00	159.00	2084.00	134.00	Sand mudstone interbedded with conglomerate
Baitianba formation (J1b)	/	/	2113.00	29.00	Sand mudstone interbedded with conglomerate
Xu 5 member (T3x5)	2850.00	733.00	2845.00	732.00	Sandstone, mud shale and shale are interbedded, intercalated with coal seam and conglomerate
Xu 4 member(T3x4)	3544.00	694.00	3527.00	682.00	Sandstone, mud shale and shale are interbedded, intercalated with coal seam and conglomerate
Xu 3 member (T3x3)	4430.00	886.00	4430.00	886.00	Sandstone, mud shale and shale are interbedded, intercalated with coal seam and conglomerate
Xu 2 member (T3x2)	5080.57	650.57	5087.00/5078.45	657.00/648.45	Sandstone, mud shale and shale are interbedded, intercalated with coal seam and conglomerate
Xiaotangzi formation (T3t)	5525.85	445.28	5614.00/5528.41	527.00/449.96	Interbedding of sandstone and shale
Ma 2 member (T3m2)	5640.10	114.25	5857.00/5650.49	243.00/122.08	Top mesoclastic limestone
Ma 1 member (T3m1)	5677.00	36.90	5953.00/5682.79	96.00/32.30	Shale with sandstone
Lei 4 member (T2l4)	5694.00(incomplete penetration)	17.00	7150/5729.53	1197/46.74	Dolomite and limestone

Note: Continental strata contain a large amount of shale, especially Xu 5, xu 3, Xu 2 and Xiaotangzi formations contain large sections of carbonaceous shale and coal line.

1.4 Drilling Fluid Performance

Table 3
Performance of drilling fluid in the first spud and the second spud

	Segmented layered drilling fluid system		General performance				HTHP		Rheological properties		K^+ (mg/L)
Well section	System	Layer	ρ(g/cm^3)	FV(s)	FL (mL)	pH	Gel (Pa/Pa)	FL (mL)	PV (mPa·s)	YP (Pa)	
50～209	High bentonite content drilling fluid	Penglai town Formation	1.15	102							
209～1300	Potassium based polymer	Suining Formation	1.20～1.30	30～42	8～10	9～10	2～5/5～12		10～12	5～10	
1300～1800	Potassium based polymer	Shaximiao Formation	1.50～1.80	45～50	5～7	9～10	2～5/5～13		20～25	5～10	
1800～1915	Potassium based polymer	Shaximiao Formation	1.80～1.87	45～57	4～6	9～10	2～5/5～10		20～25	5～10	
1915～2113	Potassium based polymer	Shaximiao Formation	1.88～1.89	50～55	4～6	9～10	3～5/7～15		20～30	10～13	25000
2113～2845	Potassium based polymer	Xu 5 member	1.88～1.93	53～58	4～6	9～10	4～7/7～17		20～30	10～15	25000
2845～3527	Compound salt strong inhibitory polysulfonate drilling fluid	Xu 4 member	1.89～1.90	55～60	2～3	9～10	2～5/10～15		25～30	10～15	30000
3527～4430	Compound salt strong inhibitory polysulfonate drilling fluid	Xu 3 member	1.90～1.92	50～60	2～3	9～10	3～5/10～20	12	25～35	10～15	40000
4430～5087	Compound salt strong inhibitory polysulfonate drilling fluid	Xu 2 member	1.92～1.94	55～65	2～3	9～10	3～5/15～20	12	25～35	12～18	47000
5087～5614	Compound salt strong inhibitory polysulfonate drilling fluid	Xiaotangzi Formation	2.05～2.07	60～70	2～3	10～11	5～8/15/20	10	25～35	15～20	45000
5614～5857	Compound salt strong inhibitory polysulfonate drilling fluid	Ma 2 member	2.07～2.08	60～75	2～3	10～11	4～7/15～20	10	35～45	15～20	45000
5857～5929	Compound salt strong inhibitory polysulfonate drilling fluid	Ma 1 member	2.07～2.08	65～75	2～3	10～11	4～7/15～20	10	35～45	15～20	44000

Table 4
Performance of third spud drilling fluid

Well section (m)	System	Layer	P (g/cm3)	FV(s)	CaCl2 content (%)	Alkalinity (kg/m3)	Sand content (%)	HTHP (mL)	Gel (Pa/Pa)	PV (mPa·s)	YP(Pa)	Solid content (%)	Demulsification voltage (V)	O:W
5929～7150	White oil drilling fluid	Lei 4 member	1.40～1.45	60～75	＞25	2～2.5	≤0.3	≤2	2～5/5-10	25～45	7～12	＜30	＞600	80～85/20～15

2. TECHNICAL DIFFICULTIES

(1) Poor wellbore stability and high collapse risk in multiple well sections: From the upper Penglaizhen formation to the Leikoupo Formation of the target layer, the wellbore instability is easy to occur in the second spud. The formation above Xujiahe is mainly caused by formation hydration and expansion and block falling; In Xujiahe well section, black and grayish black shale fractures are mainly developed, resulting in wellbore instability; The black shale with large well inclination from Xiaotangzi Formation to Maantang Formation collapsed. During the third spud, the reservoir of Leikoupo Formation was broken, the bedding was developed, and the risk of sticking was high. During the construction of horizontal sections of adjacent wells Pengzhou 5-2D and Pengzhou 4-4D, the wellbore was scrapped due to wellbore instability; The third spud bottom section of Pengzhou 8-5D well has a well diameter expansion rate of 91%.

(2) The open hole section of the second spud is very long, and multiple pressure systems exist at the same time: There are many pressure systems from top to bottom, and the pressure gradient from Penglaizhen Formation to Xujiahe Formation changes rapidly; Shaximiao Formation, Xujiahe Formation and Xiaotangzi Formation may encounter fractured high-pressure gas reservoirs. Above Suining Formation: normal pressure section; From Shaximiao Formation to Qianfoya Formation: transition from atmospheric pressure to high pressure; From Xu 5 member to Xu 3 member: stable high pressure section; From Xu 2 Formation to Maantang Formation: pressure reduction section; Maantang Formation and Leikoupo Formation: normal pressure section. Multiple pressure systems exist together, so it is difficult to maintain and adjust the performance of drilling fluid.

(3) High requirements for lubricating capacity of drilling fluid: The second spud has the characteristics of large wellbore (241.3mm), "straight-increase-stability-increase -stability" five section system, large well deviation (greater than 70 °), inclined section length (greater than 1000m), high density (2.08g/cm^3), etc. The reservoir has developed micro fractures and good physical properties during the third spud of Leikoupo Formation, which is prone to sticking. Pengzhou 5-2D well has stuck twice, and Pengzhou 3-5D well has stuck for many times at 7100m, so the drilling fluid is required to have excellent lubrication performance.

3. DRILLING FLUID SYSTEM AND FORMULA

Table 5
Type and formula of Pengzhou 5-4D segmented drilling fluid

Open times	Well section (m)		Drilling fluid system	Formula
	Start	Stop		
Catheter	0	202	High bentonite containing drilling fluid	0.8-1.5% HV-CMC + 4-5% NV-1 + 4% soda ash (soil volume)
First spud	202	2862	Potassium based polymer drilling fluid	3%~5% bentonite + 0.4%~0.6% polymer coating agent + 0.2%~0.5% AP-1 + 0.5%~1% NH4-HPAN + 0.6%~0.8% LV-PAC + 0.5%~1% RH-220 + 3%~5% KCl + 0.2%~0.3% quicklime + barite, etc
Second spud	2862	6072	Compound salt strong inhibition polysulfonate anti sloughing drilling fluid	Upper well slurry + 7%~9% KCl + 0.4%~0.6% quicklime + 0.5%~1% AP-1 + 0.6%~0.8% PAC + 2%~4% SMP-1 + 2%~4% chromium free sulfonated lignite + 0.2%~0.4% polymer coating agent + 1%~2% nano plugging and anti-sloughing agent + 1%~2% film-forming plugging agent + 3.5% QS-2 + 3%~4% sulfonated asphalt + 1%~1.5% DSP-2 + 5% RH-220 + 1% graphite powder + barite, etc
Third spud(side)	4800	5929	Strong inhibition, strong plugging and anti-sloughing drilling fluid	(6-8) % bentonite + (0.3-0.5) % PAM + (0.3-0.5%) AP-1 + (2-3) % multi branched phenolic resin + (2-3) % SMP-1 + (0.3-0.5) % sulfonate copolymer + (1-1.5) % nano plugging agent + (2-3) % high acid soluble sulfonated asphalt
Third spud	5929	7150	White oil-based drilling fluid	White oil + 3%~5% organic soil + 4%~5% main emulsifier + 3%~4% auxiliary emulsifier + 2%~4% wetting agent + 1%~3% quicklime + calcium chloride solution (25%~30%) + 4%~5% fluid loss reducer + 3%~5% plugging agent + 1~2% wellbore enhancer + 1%~2% flow pattern regulator

4. SEGMENTED DRILLING FLUID TREATMENT

4.1 Conduit (0~209m)

The lithology of the conduit is mainly interbedded with unequal thickness of mudstone and sandstone, mainly mudstone. The well section mainly pays attention to collapse and leakage prevention. Technical countermeasures for drilling fluid:

(1) Prepare 120m^3 high concentration bentonite slurry (15%), fully hydrated for at least 24h and wait for use;

(2) Use bentonite slurry for drilling to ensure that the drilling displacement is not less than 50 L/s. follow the

HV-CMC glue according to the sand return to maintain the viscosity of the drilling fluid (> 100s).

(3) After drilling, if there is no indication of wiper trip, thick slurry shall be used to pad the bottom to ensure the smooth running of the conduit.

4.2 First Spud (209~912m)

This drilling mainly encountered Penglaizhen Formation, Suining Formation, Shaximiao Formation, member 5 of Xujiahe Formation and member 4 of Xujiahe Formation. Drilling fluid technical countermeasures:

(1) The drilling fluid in the conduit and polymer glue are used for drilling after dilution, and the viscosity is maintained at 45~50s. After the drill collar is out of the conduit, increase the amount of glue to ensure the safety of the cement sheath at the conduit shoe.

(2) The Penglaizhen Formation contains a large section of mudstone, with strong slurries and rapid viscous shear rise. Use polymer combined with quicklime to control the slurry making to keep the drilling fluid in a low viscosity and low shear state (30-35s).

(3) The middle part of Suining Formation (1000m) was transformed into potassium -based polymer system. Control the content of bentonite (20~30g/L), supplement LV-PAC and LV-CMC for glue protection, and supplement 4%~5% KCl at one time to maintain the K^+ content of 25000mg/L. the properties of drilling fluid after conversion are as follows:

Table 6
Pperformance of drilling fluid after transformation

Well depth (m)	ρ(g/cm^3)	FV(s)	FL (mL)	pH	Gel (Pa/Pa)	PV (mPa·s)	YP(Pa)	K^+(mg/L)
1000	1.25	40	8	9	1/8	10	2	25000

The formation of Shaximiao Formation is prone to hydration, dispersion and collapse. The focus is to strengthen the inhibition of drilling fluid, increase the concentration of polymer glue and timely supplement AP-1. FA367, LV-PAC and K-PAM are added to the glue to reduce water loss, maintain appropriate viscosity and prevent the collapse of coal seam mud shale. According to Pengzhou 5-2D well, the drilling fluid density is increased to 1.90 g/cm3 at the bottom of Shaximiao Formation (1800m), which is conducive to supporting the well wall and well control safety. The performance of drilling fluid is shown in the table below:

Table 7
Drilling fluid performance during drilling in Shaximiao Formation

Well depth (m)	ρ(g/cm3)	FV(s)	FL (mL)	pH	Gel (Pa/Pa)	PV (mPa·s)	YP(Pa)	K+(mg/L)
1000-2100	1.25-1.90	40-55	<5	9	1~5/8~15	10~30	2~15	25000~30000

(4) Qianfoya Formation (2000m) began to supplement wellbore stabilizer, superfine calcium carbonate, film-forming plugging agent, compound anti-slump and fluid loss agent at the same time in order to strengthen the plugging and anti-slump capacity. Drilling to the fifth section of Xu, ensure that the content of sulfonated phenolic resin, ultra-fine calcium carbonate and wellbore stabilizer in the drilling fluid is more than 2%. The viscosity of the funnel is controlled within 52-62s, and the water loss is controlled within 5mL. Use solid control equipment, mainly fine-mesh vibrating screen (160-200 mesh), and the performance of drilling fluid in this well section is shown in the following table:

Figure 4-1
The dropped blocks and coal blocks returned by five groups

Table 8
The performance of drilling fluid in the fifth stage

Well deep/m	ρ(g/cm-3)	FV(s)	FL (mL)	PH	Gel (Pa/Pa)	PV (mPa.s)	YP(Pa)	K+(mg/L)
2100~2912	1.90~1.93	52~62	<5	9	3~5/8~15	30~37	10~17	Above 30000

(5) Completion measures for the second opening: replace the conventional drilling tools to pass the well before the electrical test, fully circulate the large displacement for more than 2 weeks, and prepare a well-

sealing slurry with high performance to seal the well. The formula: well slurry + 1% ultrafine calcium + 1% solid lubrication agent, and the initial cut of the well-sealing slurry is >6Pa. Fully clean the wellbore before running casing and seal with thick lubricating slurry well, making sure the casing is in place smoothly.

Table 9
Drilling fluid performance table after once drilling

Well deep/m	ρ(g/cm^{-3})	FV(s)	FL (mL)	PH	Gel (Pa/Pa)	PV (mPa.s)	YP(Pa)	K$^+$(mg/L)
2912	1.93	62	4	9	4/12	37	14	35000

4.3 Second Open (2912~5929)

The strata drilled in this section are Xujiahe Formation, Xiaotangzi Formation and Maantang Formation. The main problems should be paid attention to collapse prevention, leakage prevention, H_2S prevention, and blowout prevention, especially collapse prevention. The basic idea of drilling fluid treatment is "strong suppression in the upper part, strong plugging in the lower part, and a combination of suppression and plugging in the whole well section".

Drilling fluid technical countermeasures include the following aspects:

System transformation: in the casing, the solid control equipment is fully utilized to purify the ground drilling fluid to remove the inferior solid phase. The MBT (20~30 g/L) was adjusted by diluting the glue solution (polymer + LV-PAC), and SMP-1 and SMC with lower viscosity effect were used as the main glue treatment agents. After further protecting the drilling fluid to reduce water loss, add 3% KCl and 0.5% AP-1 according to the cycle to improve the inhibition of the drilling fluid, and then supplement the plugging agent according to the formula (1% film-forming plugging agent, 1% %QS-2, 1% borehole stabilizer). Finally, organic silicon inhibitor and silicon-fluorine viscosity reducer are used to adjust the viscosity and cut, and gradually convert it into a compound salt strong inhibition potassium polysulfonic anti-slump drilling fluid system. After adjustment, the drilling fluid performance is as follows:

Table 10
Drilling fluid performance before the second opening

Well deep/m	ρ(g/cm-3)	FV(s)	FL (mL)	PH	Gel (Pa/Pa)	PV (mPa.s)	YP(Pa)	K+(mg/L)
2912	1.95	50	3	9	3/10	37	8	35000

Drilling fluid density control: since there are multiple oil and gas layers in this well section, and the coal and shale layers in the third section are prone to serious collapse and block loss, the drilling fluid density of the second opening is 1.98-2.07g/cm3 to ensure the stability of the well wall and the safety of well control. (Adjusting the density is mainly based on mixing heavy pulp according to the cycle week. Heavy pulp density and mixing amount need to be strictly calculated).

Figure 4-2
The dropped blocks of three sections.

Inhibition and anti-slump control: adopt appropriate drilling fluid density to maintain wellbore stability; Keep the K^+ content above 35000 mg/L, and the polymer coating agent content at 0.3% to 0.5%; Using AP-1 to improve the suppressing ability of the drilling fluid ensures that there is no adhesion and no sticking of the back cuttings at the vibrating screen; Using latex asphalt, multi-softening point asphalt, film-forming agent, QS-2, wellbore stabilizer and other treatment agents to play a synergistic effect to form a multi-level and multi-component particle size combination in the system to improve the quality of mud cake, achieve the purpose of blocking and prevent collapse; After entering the third section, every time a new footage is drilled, asphalt + QS-2 + wellbore stabilizer is used to seal the new drilling section during short trips and trips, and the construction idea of "playing one footage to keep another footage" is adhered to.

Rheology Control: Choose barite powder with high quality and low viscosity effect as weighting agent; Make full use of solid control equipment, especially the use of fine-mesh vibrating screen (above 200 mesh) and centrifuge to remove inferior solid phase and keep the solid phase within a reasonable range (the empirically calculated value of solid phase content %=27.35*ρ-23); Use strong inhibitory silicone inhibitors and silicon-fluorine viscosity reducers to adjust sticky cutting, and supplement 1% to 1.5% silicone stabilizers for maintenance when the performance is stable; Standing on the ground is 50m^3 of thin and heavy slurry made of 2% of the soil slurry, 1% to 1.5% (SMC+SMP-1). When the density of the circulating slurry is adjusted, the flow pattern can be adjusted and the high-quality ordinary soil can be supplemented; When the drilling fluid is polluted by CO_2, the lime lye solution prepared with NaOH + CaO

should be properly treated to maintain good fluidity of the drilling fluid. When the well temperature is too high, this solution should not be used. CO_2 pollution has occurred. By adding lime, the stick cut does not drop but rises. At this time, it is recommended to use viscosity reducer, inhibitor or slurry dilution for treatment.

Figure 4-3
The state of drilling fluid treated with lime at 5200 m

Figure 4-4
Drilling fluid state after 5200m dilution treatment

High temperature stability control: The bottom of the second open well is over 140°C and the density is high (ρ2.08 g/cm^3), so the high temperature stability of the drilling fluid is required. Ensure proper slub content (20g/L) and solid content (35%-40%), and reduce the risk of high temperature thickening of drilling fluid due to long-term static; The amount of high-temperature and salt-resistant treatment agents should be sufficient, and the filtration loss control is mainly based on SMP-1, small molecular polymer PANS, and asphalt treatment agents (appropriately matched with emulsifier Span-80 to improve the high temperature stability of the treatment agent), Strictly control HTHP<12mL to improve the high temperature stability of drilling fluid.

Table 11
Comparison of aging properties of drilling fluids at different depths in Well Peng 5-4D

Well deep/m	Aging conditions	Density (g/cm3)	AV (mPa. s)	PV (mPa. s)	YP (Pa)	Gel (Pa/Pa)	FLAPI (mL)	HTHP (mL)
5049	Normal temperature	1.96	44.5	30	14.5	6/18	2	12
	160, 24h	1.96	54	39	16	7/21	2.4	13
5375	Normal temperature	2.03	50	35	15	6/17	3	11
	160, 24h	2.03	60	40	20	7/18	3.2	12
5608	Normal temperature	2.07	55	38	17	7.5/19	3.0	12
	160, 24h	2.07	61	42	19	8.5/21	3.6	14
5724	Normal temperature	2.08	58	40	18	8/20	2.8	12
	160, 24h	2.08	69	47	22	10/28	3.6	15

It can be seen from the above table that at different well depths, the drilling fluid maintained good rheology after being aged at 160 °C for 24 hours, the plastic viscosity and dynamic shear force did not change much. At the same time, the filtration loss at high temperature and high pressure increased slightly, indicating that the system has better inhibition and rheology at room temperature and high temperature. The system performance is relatively stable.

Targeted treatment for the Ma'antang Formation: The shale bedding in the Ma'antang Formation (5600-bottom hole) in this well is easily broken. Before sidetracking, a large number of large and small mixed blocks were returned to the well. It was extremely difficult to trip out each time, and the drilling could not be tripped without turning on the pump. Drilling fluid performance: 2.07g/cm^3, shear force 8/18Pa FL 3.0mL, HTHP 12mL. The footage was barely completed by pushing thick pulp, heavy pulp, carrying with high solid phase pulp, and sealing the section with thick pulp, but the main problem was still a lot of falling blocks. After sidetracking, actively adjust the thinking of drilling fluid. Prepare 50 m^3 of pre-hydrated soil slurry in advance. Before drilling to the layer, supplement the pre-hydrated bentonite slurry according to the cycle (a reasonable content of bentonite can not only effectively improve the temperature resistance of the drilling fluid, but also ensure the suspension and carrying under high temperature, which can make up for the defects that the particle size of ultrafine calcium carbonate is not fine enough and the bridging effect is not ideal). At the same time, it is combined with acid-soluble sulfonated asphalt, multi-softening point asphalt and nano-plugging agent to form a dense mud cake, which can better stabilize the wellbore. Through this series of measures, the problem of block drop was well resolved after sidetracking, and the tripping was smooth, laying a good foundation for subsequent electrical measurement and casing running.

Lubricity control: The excellent lubricity is based on the establishment of a thin, tough and strong high-quality filter cake. After entering the third stage, the filter vector of the drilling fluid is strictly controlled, especially the

HTHP filter vector <12ml; Improve the quality of mud cake by using different particle size QS-2, multi-softening point asphalt and bentonite slurry; Select the temperature-resistant and salt-resistant lubricant (RH220) with good temperature resistance and low viscosity effect as the main lubricant and use it with solid lubricants. Appropriately supplement the emulsifier to improve the emulsification effect of the lubricant to strengthen the lubricity of the system.

Before the completion of the operation, the well is cleaned with a large displacement, and the well-sealing slurry is prepared. The well-sealing slurry formula: well slurry + pre-hydration soils slurry dispersant + 1% SMP-2 + 2% solid lubricant to ensure electrical measurement and casing running smoothly.

4.4 Third Open (5929~7150 m)

Party A decided to use oil-based drilling fluid as a pilot for the third-opening construction in the Pengzhou block after discussion due to the extremely high construction risk in the third-opening well section and the length of the third-opening horizontal section of the well (1800m). The white oil-based drilling fluid showed good wellbore stability, lubrication, anti-seize ability and performance stability during the construction process. The downhole safe tripping is unobstructed, which well verifies the feasibility of oil-based drilling fluids in marine formations.

4.4.1 Basic Formula of Drilling Fluid

Basic formula of drilling fluid: oil-water ratio 80:20 + 3% organic soil + 5% main emulsifier + 1.25% auxiliary emulsifier + 1% wetting agent + 5% plugging agent + 5% fluid loss reducer + 4% alkali Degree regulator + 2% ultrafine calcium 1200 mesh + 2% ultrafine calcium 3000 mesh + 1% nano-polymer plugging agent + barite powder, etc.

Emulsion formula used for maintaining drilling fluid: oil-water ratio 85:15+3% organic soil+5% main emulsion+1.25% auxiliary emulsion+1% wetting agent+5% plugging agent+5% fluid loss agent+4% Alkalinity regulator.

4.4.2 Technical Measures

(1) Preparation and replacement: Prepare 150 m^3 of emulsion in advance according to the formula, and then mix it with the recovered oil-based drilling fluid in a ratio of 1:1 to prepare 260 m^3 of 1.45 g/cm^3 oil-based mud; Replace the conventional drilling tools to replace the slurry. Replacing the water-based drilling fluid (2.00 g/cm^3) in the casing with the recovered oil-based drilling fluid (1.90 g/cm^3) with a similar density, which can reduce the circulating pressure difference; Ensure proper pulp displacement (>1m^3/min) and improve replacement efficiency; After the slurry replacement is completed, the emulsion is mixed in stages to reduce the density, and the performance of the drilling fluid is adjusted to meet the design requirements of three openings, then the formation is drilled.

Table 12
Oil-based drilling fluid performance

Density (g/cm3)	FV (s)	PV (mPa.s)	YP (Pa)	G1/G2	Solid Content	oil to water ratio	Es/V (V)	Alkalinity	Chloride	HTHP 150℃
1.45	86	36	9.5	3.5/8	26%	81:19	692	2.5	28000	1.4 mL

(2) The main maintenance is to supplement the emulsion to avoid the instability of the well wall caused by the large fluctuation of performance.

(3) Control the appropriate drilling fluid density (1.41-1.45 g/cm3) to ensure sufficient support for the formation and prevent differential pressure sticking.

(4) Control the appropriate drilling fluid viscosity (55-60 s) and the displacement to keep a high annular return velocity as the main goal; Regularly conduct special drilling to clean up the cuttings bed in the horizontal section.

(5) Control the drilling fluid HTHP (160 ℃) to be less than 2 mL to reduce the filtrate entering the formation.

(6) The use of asphalt-based plugging materials, ultra-fine calcium, nano-polymer plugging agents and deformable plugging agents [1] can achieve plugging of fractures, rapidly and effectively. Reduce the penetration of filtrate and mud in micro-fractures and enhance the plugging property of the drilling fluid.

(7) The purpose of replenishing the emulsifier in time is to control the demulsification voltage above 650 V and keep the performance of the oil-based drilling fluid stable.

(8) The reserve alkalinity of oil-based drilling fluids is controlled at around 2.5 during the construction of the third opening.

(9) Strengthen the use of solids control equipment, the vibrating screen uses 200 mesh and 240 mesh screen cloth. At the same time, it cooperates with desander, desilter and centrifuge to remove low-density and inferior solid phase.

(10) The formation temperature in this section reaches 155 °C. The content of organic soil in the drilling fluid should be strictly controlled. At the same time, materials with high temperature resistant treatment agents are selected for maintenance treatment to ensure that the drilling fluid system has good rheology and high temperature resistance stability.

5. APPLY EFFECTS

(1) In the first opening, a drilling fluid system with strong inhibition and strong plugging of compound salt was adopted. The construction was smooth and the drilling fluid performance was stable, which reflected the good inhibition and stability of the system.

(2) After the second sidetracking, the Ma'antang Formation solved the problem of the stratum collapsing and falling off by using the bentonite slurry reasonably. The block loss was significantly reduced, the tripping and tripping were smooth, the electrical measurement and casing running were also smooth.

(3) The formation of Sankai Leikoupo was successfully drilled with white oil-based drilling fluid. The whole process was not complicated downhole, and the drilling task was well completed.

6. KNOWLEDGE AND ADVICE

(1) Calcium chloride drilling fluid system can be used in the upper formation: There are large sections of brown mudstone developed in the well section above Qianfoya, which is easy to hydrate and disperse, resulting in serious slurry formation. The drilling fluid density must be increased to balance the formation pressure under the requirement of well control safety due to the presence of shallow gas in the upper part, resulting in a small well diameter expansion rate, a virtual thick mud cake, and multiple wells causing the problem of tripping and sticking. For well sections above 1700m, calcium chloride with AP-1 can be used to control formation slurry. Ensure that the wellbore is clean and properly enlarged to prevent diameter reduction caused by frequent aggravation in the later stage. Specific formula: 3% ~ 4% bentonite + 1% ~ 2% calcium chloride + 0.5% amino polyol + 1% PAC-LV + barite powder.

(2) In the middle and lower part of the two openings, multi-softening point asphalt materials are preferred. Reasonable use of pre-hydrated bentonite slurry can make up for the disadvantage of poor wall-building capacity in high-density wells due to low soil content.

(3) For directional wells with large inclination and large displacement, the plug can be pushed regularly to change the fluid state to clean the wellbore.

(4) White oil-based drilling fluid can well stabilize the wellbore when drilling in limestone formations and reduce the probability of wellbore collapse.

REFERENCES

[1] Qian, S. Y., Xing, J. X., Zhong, L., et al. (2006). Research and application of plugging performance of oil-based drilling fluid. *Drilling Fluid & Completion Fluid*, (5), 4.