CSCanada
Advances in Petroleum Exploration and Development
Vol. 20, No.1, 2020, pp. 63-67
DOI:10.3968/12104

ISSN 1925-542X [Print]
ISSN 1925-5438 [Online]
www.cscanada.net
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Brief Analysis on Application of Compound Salt Drilling Fluids

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Received 11 August 2020; accepted 3 October 2020
Published online 26 December 2020

Abstract

The popularization and application of compound salt drilling fluid has become the new normal of drilling in Shengli Oilfield. In view of the problems existing in the exploration period, the construction plan and supporting measures are gradually improved to form a mature construction technology. Compared with the conventional polymer drilling fluid, the improved compound salt drilling fluid not only reduces the hole enlargement rate by 70.61%, improves the ROP by 30.59% and achieves 100% success rate of one-time logging, but also solves the reaming problem in the upper Ng Formation caused by sticking and wellbore stability problem in the lower Es Formation, which is worthy of popularization and application.

Key words: Compound salt; Strong inhibition; Wellbore stability; Speed increase

Zhang, L. (2020). Brief Analysis on Application of Compound Salt Drilling Fluids. *Advances in Petroleum Exploration and Development*, *20*(1), 63-67. Available from: http://www.cscanada.net/index.php/aped/article/view/12104
DOI: http://dx.doi.org/10.3968/12104

1. INTRODUCTION OF COMPOUND SALT DRILLING FLUIDS

1.1 Brief Introduction of Compound Salt Drilling Fluids

In the true sense of compound salt drilling fluids, the inorganic salt components contains not only conventional NaCl and KCl, but also an appropriate amount of Na_2SO_4, $(NH4)_2SO_4$, etc., which are mainly aimed at large sections of salt, gypsum, and mud composite salt layers. The compound salt drilling fluid now used in Shengli Oilfield is evolved on this basis for the internal blocks, mainly using NaCl, KCl and AP-1 as shale inhibitors. Compared with the chemical inhibition mechanism of traditional polymer drilling fluid relying on the bridging and coating of PAM and other polymers, it has additional function of physical inhibition, that is, using high salinity to reduce the activity of filtrate and improve the osmotic pressure of drilling fluid to the formation[1], so as to prevent and slow down the invasion of water phase into the formation mudstone. In addition, through the synergistic effect of the compression of inorganic salts on the bentonite electric double-layer hydration membrane, the lattice fixation of K^+ and the inhibition of amino polyol, the system can improve the ability of inhibiting the osmotic expansion and hydration dispersion of clay particles, and finally achieve the goal of clean wellbore, stable wellbore and less oil and gas damage from the perspective of moderate coarse dispersion.

1.2 Compound Salt Drilling Fluids Formula

According to different blocks, well depths and well types, the current compound salt drilling fluids are mainly divided into two types: low salt type and high salt type, in which the Cl^- content in low salt type is (40000-70000)mg/L, and that in high salt type is (100000-150000)mg/L. The formula is as follows:

(1) High salt type formula (deep exploration wells): 6% bentonite + 0.5% PAM + 0.5% AP-1 + 1.5% WNP-1 + (20-25)% NaCl + (5-8)% KCl + 1% PANS + 2% SPNH + 3% SMP-2 + (3-5)% polyether polyol (2% emulsified paraffin) + 1.5% 4000 mesh $CaCO_3$ + 1.5% 6000 mesh $CaCO_3$ + lubricant + NaOH

(2) High salt type formula (deep production wells): 6% bentonite + 0.5% PAM + 0.5% AP-1 + 1.5% WNP-1 + (20-25)% NaCl + (5-8)% KCl + 1% PANS + 2% SPNH + 3% SMP-2 + (2-3)% high temperature resistant modified asphalt (2%-3% sulfonated asphalt) + 1.5% 4000 mesh $CaCO_3$ + 1.5% 6000 mesh $CaCO_3$ + lubricant + NaOH

(3) Low salt type formula (medium and shallow production wells): (6-8)% bentonite + 0.5% PAM + 0.5% AP-1 + 1% WNP-1 + (3-5)% NaCl + (5-7)% KCl + 1% PANS + 2% SPNH + lubricant + NaOH

1.3 Advantages of Compound Salt Drilling Fluids

First of all, the compound salt drilling fluid has the characteristics of low activity, strong inhibition and non-dispersion, which can improve the success rate of logging and reduce the discharge of drilling cuttings and wastes from the perspective of ensuring wellbore stability and regular well diameter. Secondly, the characteristics of high cleanliness, low solid phase and low viscosity are conducive to the cleaning of the well and the improvement of ROP, thereby shortening the drilling and well construction period and reduce the overall cost of drilling. Meanwhile, the potassium, calcium and chlorine plasma in the fluids can effectively increase the salinity of drilling fluid filtrate, reduce the activity of filtrate[2], and reduce the damage to oil and gas reservoirs.

2. CONSTRUCTION TECHNOLOGY OF COMPOUND SALT DRILLING FLUIDS

2.1 Upper Formation Diameter Control and Hole Cleaning

(1) For wells applied with non-landing process for drilling fluid, the mud used in the first spud left in mud tanks and the casing should be all replaced with clean water before the second opening and make sure all of them are filtered; for wells with large action pit, the mud should be conducted into the action pit during slug cleaning period.

In both cases, after the mud is completely replaced with clean water, add (1-2)% $CaCl_2$, and adjust the mud density to (1.00-1.02) g/cm^3 and viscosity to not more than 28s.

(2) After the second spud, the small circulation drilling method is adopted, and the prepared 10% $CaCl_2$ solution combined with clean water should be added to the mud to achieve the performance of low viscosity, low shear, low solid phase and high water loss. The Ca^{2+} content should be controlled to no less than 800mg/L[3], and mud viscosity should be less than 30s and the density should be (1.05-1.10)g/cm^3. At the bottom of Nm Formation and the top of Ng Formation, the amount of fresh water and $CaCl_2$ can be increased, and mud making should be focused.

(3) According to the well type, formation distribution and tripping time, select a reasonable time (drilling to Ed Formation as far as possible), stop using $CaCl_2$ and start to supplement PAM fluid, keep the effective content of PAM (0.3-0.5)%, and control the drilling fluid performance to density (1.10-1.12) g/cm^3 and viscosity (28-32) s.

(4) When drilling with small circulation technology, the hole enlargement is smaller than that of clean water drilling. At the same time, with the appliance of the non-landing process for drilling fluid, not only can the used mud not be rapidly discarded, but also the difficulty of solid control has greatly increased. Therefore, it is necessary to strengthen the continuous operation of three-stage solid control system, including vibrating screen with more than 120 mesh, desander and double centrifuge.

2.2 Conversion Process of Compound Salt Drilling Fluids

(1) According to the lithology of the block, the conversion time is selected:

① If the lithology of Upper Es3 Formation and the upper part of Middle Es3 Formation is dominated by sandstone and sandy mudstone, compound salt mud conversion shall be carried out in the bottom of Upper Es3 Formation or the upper part of Middle Es3 Formation;

② If the lithology of Upper Es3 Formation and the upper part of Middle Es3 Formation is mainly dark gray mudstone and calcareous mudstone, select the bottom of Es2 Formation or advance to Es1 Formation for mud conversion.

(2) Short tripping operation: While maintaining 1/3 liquid level in mud tank, short tripping operation shall be carried out to ensure smooth borehole in upper easy mud making section and avoid the reduction of the well diameter; if upper mud performance is strictly controlled and borehole condition is good, long tripping operation can be carried out after salt slurry conversion.

(3) Bentonite content adjustment: Determine the amount of water by calculation and small experiment. Control about 60g/L before the conversion and raise the pH to 9.5-10 before the conversion carried out.

(4) Mud colloid protection: The protective formula before conversion is (1-1.5)% WNP-1, 1.5% salt resistant lignite materials and the specific addition amount is determined by small-scale field experiments. After all the preparations are in place, the actual conversion will be carried out on site, so as to achieve the high efficiency and one-time success rate of the conversion as far as possible.

(5) Supplement of inorganic salt: KCl is added first, then NaCl. After adding a slightly higher amount (2-3)% of the inorganic salt than the design, it will be supplemented while drilling. The content of Cl^- in drilling fluid shall be increased to 86000mg/L.

(6) When the viscosity is low after adding salt, add AP-1 to 0.5% in time to enhance the inhibition of the mud. Add an appropriate amount of anti-sloughing materials such as polyols to improve the plugging performance of the mud. If emulsified paraffin is added, the dosage should not exceed 1% to prevent the upper formation from sticking at low temperature.

2.3 Maintenance Points of Compound Salt Drilling Fluids

(1) Strictly control the dosage of viscosity increasing agent. For low salt system, it is necessary to reasonably control the dosage of WNP-1, DSP-2 and other salt resistant polymers. Reduce the use after 2500m. If it is necessary to add, it can be added in the form of liquid, so as to prevent the filtrate viscosity from being too high and affecting the well cleaning. In the middle and later stage, the bentonite content should be maintained as far as possible, and the combination of SPNH and SMP should be added together to control the filtration and rheological properties by appropriately dispersing the soil phase, so as to enhance the toughness and density of mud cake and maintain the low viscosity and low shear state.

(2) In deep wells, bentonite slurry with concentration of (15-20)% should be prepared in advance for standby. Before use, it is necessary to add 0.5% NaOH to raise the pH value to more than 12 and hydrate for more than 24 hours, and then add 0.5% WNP-1 and 1% KFT to prevent the loss of colloidal properties of mud in strong inhibition drilling fluid.

(3) The properties of drilling fluid, filtrate analysis and high temperature rheological properties are regularly detected. If carbonate and bicarbonate contamination occurs in the later drilling section of calcareous mudstone, $CaCl_2$ fluid or cement can be used for adjustment according to the filtrate analysis data[4].

(4) Short tripping should be combined with long tripping. After the conversion of the compound mud, it should be hoisted to the bottom of Nm Formation in time to verify the wellbore, and properly trimmed the well wall in the meantime. If the upper well section has not been trimmed by the bit for a long time, it should be hoisted to the surface casing in time to verify the upper wellbore condition.

2.4 Well Completion

In the aspect of preventing the sound wave of salt mud from being blocked, through a large number of indoor comparative experiments, the formula is summarized as follows.

Tamping fluid: 2m^3 fresh water + (25-50) kg DSP-2+(10-15) kg Na_2CO_3;

Replacement slurry (according to the characteristics of poor colloidal property of salt mud):

Density < 1.40g/cm^3, slurry + 10% water + 0.5% NaOH + 1% SF-1 + 1% KFT

Density > 1.40 g / cm^3 (including liner well), well slurry (bentonite 50-60g / L) + (10-20)% water + (0.2-0.3)% DSP-2 + 2% SMP-2 + 1% SF-1

3. FIELD APPLICATION

12 wells were constructed with the improved compound salt drilling fluid, as shown in Table 1:

Table 1
Wells Applied Improved Compound Salt Drilling Fluid

Well Names	Depth (m)	ROP of Polymer Mud (Adjacent Wells) (m/h)	ROP of Compound Salt Mud (m/h)	ROP Discrepancy (%)	Borehole Enlargement Rate of Polymer Mud (adjacent wells) (%)	Borehole Enlargement Rate of Compound Salt Mud (%)	Borehole Enlargement Rate Discrepancy (%)
Y234	3465	6.99	8.83	26.32	12	3.9	-67.50
Yox932	3726	7.06	9.22	30.59	11.56	9.2	-20.42
Y22-x96	4247	7.43	7.5	0.94	19.02	5.4	-71.61
Yo66-xg29	1655	24.24	25.4	4.79	9.41	5.8	-38.36

Well Names	Depth (m)	ROP of Polymer Mud (Adjacent Wells) (m/h)	ROP of Compound Salt Mud (m/h)	ROP Discrepancy (%)	Borehole Enlargement Rate of Polymer Mud (adjacent wells) (%)	Borehole Enlargement Rate of Compound Salt Mud (%)	Borehole Enlargement Rate Discrepancy (%)
Yo8-x95	2649	22.5	18.4	-18.22	8.06	5.9	-26.80
Tx199	2997	10.15	11.98	18.03	9.91	7.9	-20.28
X11-gx161	2645	17.75	21.26	19.77	6.95	5.5	-20.86
Y22-x98	4310	7.43	9.11	22.61	19.02	5.9	-68.98
YO559-x3	3275	8.51	8.48	-0.35	17.65	7.5	-57.51
X11-xg9	2545	27.31	27.03	-1.03	6.72	2.5	-62.80
Y22-x99	4176	7.43	8.08	8.75	19.02	6.2	-67.40
Fx801	4808	6.99	8.83	26.32	8.24	3.9	-52.67

(1) The average ROP is relatively higher

Compared with the adjacent wells with polymer drilling fluid, the average ROP with the improved compound salt drilling fluid is increased (except for a few wells), with a maximum increase of 30.59%.

(2) The hole enlargement rate is relatively low

From the conversion of compound salt drilling fluid to the completion of drilling, compared with the conventional polymer drilling fluid system in adjacent wells, the average hole diameter enlargement rate decreased by 71.61% at the highest and 20.28% at the lowest.

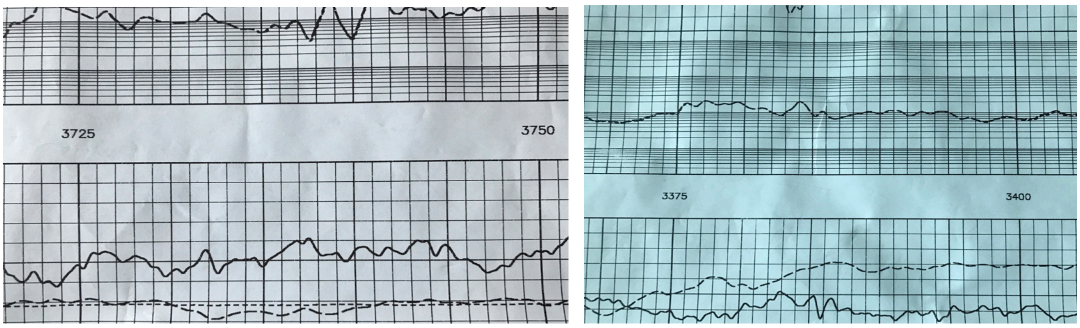

Figure 1 & 2
Logging Curve of Well Y22-x96 and Fx801 (the Dotted Line is Well Diameter)

(3) Wellbore stability

In the wells with compound salt drilling fluid, the Es Formation (especially below the Middle Es3 Formation) is almost free of denudation and block falling. The caliper logging curve is nearly linear and the occurrence of "zigzag" wells is reduced.

(4) Borehole cleaning

Figure 3
The Filter Pressing Process of Non-Landing Process for Drilling Fluid

Figure 4
Sand Return of Compound Salt Drilling Fluid

The viscosity is low and the returning sand of the vibrating screen is slightly sticky. The mesh number of shale shaker in most drilling teams can be up to (150-180) mesh. For the wells with Non-Landing Process for Drilling Fluid, the filter pressing process is smooth. The amount of drilling cuttings returned by scraping and scratching the wellbore after short tripping in the same block is less than that of conventional polymer drilling fluid.

(5) The success rate of logging is relatively improved

In view of the gradual maturity of the compound salt drilling fluid, the overall borehole quality and the success rate of well logging have been improved. One-time success rate of open hole logging of the 12 wells is 100%.

(6) The cost of single well mud materials increases relatively.

Table 2
Unit Cost Comparison of Mud Materials

Wells applied			Adjacent wells			Comparion
Well names	**Mud type**	**Unit cost (m/Yuan)**	**Well names**	**Mud type**	**Unit cost (m/Yuan)**	**Unit cost increase(%)**
Y22-x96	Compound Salt	155.08	Y22-x72	Polymer	120.40	28.8
X11-xg9	Compound Salt	36.00	X11-xg91	Polymer	20.97	20.97
Tx199	Compound Salt	130.70	T174-x8	Polymer	105.99	23.31

4. CONCLUSIONS

(1) Although the polymer drilling fluid is very mature, the cost of single well mud materials, the difficulty of mud conversion and the labor intensity of the drilling fluid are also smaller than those of the compound salt drilling fluid, the physical inhibition mechanism of the compound salt drilling fluid, such as low filtrate activity and high permeability, not only solves the problems of wellbore stability and wellbore diameter control in the mudstone collapsible formations in Shengli Oilfield, but also improves the success rate of open hole logging rate. Therefore, the compound salt drilling fluid can be widely used.

(2) Although the cost of single well mud materials of compound salt drilling fluid is about (20-30)% higher than that of conventional polymer fluid, the overall drilling cost is effectively reduced by increasing ROP, reducing drilling time, ensuring well diameter regular to reduce accident rate, promoting well completion operation and shortening well construction time.

(3) The improved compound salt drilling fluid technology solves the reaming problem caused by sticky formation shrinkage in high permeability formation of Ng Formation and above in the early test, and provides field practice and technical guidance for its popularization and application in Shengli Oilfield and other similar blocks.

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