The posibility analysis of high-pressure drilling in Block A in Field F

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Abstract: The drilling and shut-in regulations for peripheral oil fields currently follow the standard of the old area of placanticline,i.e.,the wellhead pressure of water injection wells within 600m of the drilling well is reduced to below 3MPa before drilling. The regulations did not take into account the depth of the target formation, structural development, reservoir properties and oil and water well connectivity in the peripheral oilfield, which made it difficult to relieve pressure in most of the wells and resulted in longer drilling and shut-in cycles and greater impact on production. In order to minimize the impact of drilling and shut-in on field development and to explore drilling and shut-in limits and standards suitable for peripheral fields, drilling tests were conducted in Block A for infill wells. The feasibility of high pressure drilling in the peripheral low permeability oilfield was analyzed by analyzing the drilling site conditions, the quality of post-completion cementing and the logging data of the completed wells under different pressure conditions.

Keywords: Drilling pressure low permeability feasibility

1. Problem formulation

Peripheral oilfield drilling and shut-in regulations currently follow the old area of placanticline's standard, i.e., the wellhead pressure of injection wells within 600m around the wells to be drilled is reduced to 3MPa, and within 300m to 2MPa or less. With the gradual development of the oilfield, the regulation has restricted the development drilling progress and affected the demand for capacity building. First, the cost of pressure relief input is large, with a cumulative investment of * million yuan in 2015-2016; second, the slow progress of pressure relief, according to the current F Oilfield, it takes an average of 3-4 months to reduce to below 3 MPa, and individual wells take more than half a year. Third, the statistics of 3-7 MPa pressure relief wells average 630 square meters of water released from a single well, affecting the effect of pre-injection in the block. Fourth, the long pressure relief cycle affects the block to resume the injection cycle and affects the rate of recovery of liquid production in the block. Fifth, our plant has limited capacity to receive liquid, and the joint stations are operating at full capacity, so there is often nowhere to release liquid from injection wells.

With the further development of the oil field and the implementation of infill wells, it is timely to develop a set of drilling standards suitable for the peripheral oil field, to add a boost to the peripheral oil field production and stable production, so it is necessary to conduct high-pressure drilling tests to explore the drilling boundaries and standards suitable for the peripheral oil field.

2. Overview of the test block

Block A is located in the northern part of the F Oilfield and is mainly a front verge subfacies in delta. It was put into development in 1993 using 300×300m inverted nine-spot area well network, producsing oil area *km^2 and geological reserves*$\times 10^4$t. The block has rapid lateral phase change of sand body, low drilling encounter rate, prominent planar contradiction and large difference in development effect between wells, and local scattered infill was carried out from 2005 to 2008. As of the end of December 2015, there were 165 oil recovery wells with 106 open wells and 85 water injection wells with 30 open wells. After years of development, the block has contradictions such as high integrated water content of 76.9% and low oil recovery rate of 0.3%. In order to mitigate the contradictions of block development, an overall infill adjustment is planned to be implemented for the block in 2017. In terms of program deployment, three types of infill adjustment are adopted by combining the characteristics of different regions. Block A has 84 planned infrastructure infill oil and water wells in 2017, of which 82 new wells (75 infill oil wells and 7 infill water wells) will be drilled. In order to reduce the loss of formation energy, economic efficiency and time cycle due to drilling off standards and improve drilling and shut-in efficiency, the preferred block A was prepared in 2017 to carry out the infill well drilling test and study the drilling and shut-in limits and standards in this block.

3. Countermeasures for high-pressure drilling implementation

In order to ensure the effectiveness of the test and at the same time ensure the safety of drilling, work was carried out on both geological and engineering aspects.

3.1 Prediction of pressure conditions at encrypted well sites

Table 1 Classification statistics of infill test wells in block A

Drilled Wells Classification	Risk Grading	Is the water well connected	Connected injection wells Pressure classification (MPa)	Total number of wells (number)	Number of wells drilled in batches (number)		
					1 batch	2 batches	3 batches
Normal Drilled	/	No	/	15	15		
		Yes	P≤3.0	32	32		
Test Drilling	Low Risk	Yes	3<P≤5.5	12	12		
	Medium risk	Yes	5.5 <P≤7.0	10	5	5	
	High risk	Yes	P > 7.0	13			13
Total		/	/	82	64	5	13

Both reservoir engineering and reservoir numerical simulation methods are applied to predict the pressure conditions at the infill well site in Block A. Based on the prediction results, the wells were drilled and run reasonably.

During the drilling process, MDT logs have been performed on six infilled wells, and the pressure error is within 5%, indicating that the pressure prediction is in line with the actual rate.

Table 2 Comparison of measured pressure and predicted pressure in Block A

No.	Well number	Test Well Type	Predicted pressure (MPa)	Actual measured pressure (MPa)	Error (%)
1	A	No water well connection	14.72	14.6	-0.82
2	B	Less than 3MPa	15.58	15.7	0.77
3	C	Medium risk wells	19.11	18.2	-4.76
4	D	High risk wells	24.38	23.3	-4.43
5	E	High risk wells	24.32	24.5	0.75
6	F	High risk wells	20.59	21.37	3.7

3.2 Optimization of mud density for different pressure conditions

High density will increase solid content, sand content, viscosity, water loss, thick filter cake, pressure leakage, damage to oil and gas reservoirs, wear drilling tools, power consumption, lower drilling speed, and slow drilling rate. The low density does not allow for effective rock dust discharge, so the mud density should be appropriately adjusted according to the specific well depth and pressure at the time.

During the test drilling in Block A, the mud density was adjusted according to the field conditions in a timely manner to achieve the goals of capacity liberation, cost reduction and casing protection.

Table 3 Mud density under different pressure conditions

Test type	No. of wells (pcs)	Predicted pressure coefficient (MPa/100m)	Density of drilling fluid (g/cm3)
No water well connection	15	1.00	1.37
Less than 3MPa	32	1.02	1.44
Low risk	12	1.30	1.51
Medium risk	10	1.35	1.48
High risk	13	1.61	1.54
Total	82	1.22	1.46

During the drilling process, the mud density of 25 wells was adjusted 38 times in close cooperation with the drilling company.

Table 4 Statistics of drilling fluid density in different pressure and different range of wells

Stage	Total (mouth)	Within 300-600m range						Within 300m range					
		5-7 (MPa)	Average density (g/cm3)	3-5 (MPa)	Average density (g/cm3)	3 (MPa)	Average density (g/cm3)	5-7 (MPa)	Average density (g/cm3)	3-5 (MPa)	Average density (g/cm3)	3 (MPa)	Average density (g/cm3)
Initial period	10	3	1.43	1	1.45			4	1.53	1	1.55	1	1.49
Mid-term	31	3	1.4	2	1.38	6	1.36	6	1.54			14	1.4
Later period	36	4	1.33	4	1.44	8	1.4	6	1.6	8	1.5	6	1.47
Total	77	10		7		14		16		9		21	
Average density			1.38		1.42		1.38		1.56		1.5		1.42

3.3 Supporting work measures

In order to ensure safe construction during the drilling process, various supporting measures were developed during the process.

Geological aspects: First, cooperate with the Oilfield Development Department to conduct injection well drilling and shut-in tests in Block A. The pressure range of injection wells was relaxed and the pressure of injection wells in Block A required less than 7 MPa. Second, before the start of drilling with the drilling site managers to implement the injection well pressure, not higher than 7 MPa. Third, the drilling fluid density is calculated according to 7 MPa and additional according to the well control management rules. Fourth, collect the actual drilling of the well and make reasonable adjustments to the drilling fluid density according to the actual drilling conditions. Fifth, the drilling team construction is prepared with heavy slurry and barite powder, and oil and gas water intrusion is found to increase the drilling fluid density in time to prevent complications from occurring. Sixth, regular meetings with the Development Department, drilling company designers to summarize and exchange, to determine the next work arrangements.

Solidification: First, after the electrical logging , the original drilling tool must be through the well, 50 meters above the top of the oil to the bottom of the well carefully scribe, remove the virtual mud cake, while verifying the after-effects, determine the density before solidification, to ensure the pressure of stable oil and gas layer. Second, through the well cycle, deal with the drilling fluid performance, not less than the drilling displacement to wash the well for more than 2 weeks, stable performance after the start of drilling and casing. Third, gradually test the promotion of interface enhancers to improve the quality of cementing. Fourth, the drilling process of oil and gas water intrusion, timely adjustment of the construction plan and cementing program. Fifth, promote the application of DCK quick-setting and early-strength cement slurry system.

4. Effectiveness of high-pressure drilling implementation

By the end of September 2017, 77 encrypted wells were completed in Block A. Compared with the previous drilling off, the drilling off time in Block A was reduced by 3 months.

4.1 Drilling site situation

77 encrypted wells were completed (including 2 scrapped wells) and no drilling accidents such as well collapse, well leakage and well surge were reported during the drilling process.

4.2 Well cementing quality

During the drilling process, the predicted pressure coefficient effectively guided the drilling fluid density ratio. From the statistical results of 75 wells cemented, the overall cementing quality of 64 wells was good, with a quality rate of 85.33%.

Table 5 Statistical table of cementing quality of wells drilled at different pressures and in different ranges

Stage	Total (wells)	Quality wells (wells)	Within 300-600m						Within 300m					
			5-7 (MPa)	Quality wells (mouth)	3-5 (MPa)	Quality wells (Number)	3 (MPa)	Quality wells (Port)	5-7 (MPa)	High quality wells (Port)	3-5 (MPa)	High-quality wells (Number)	3 (MPa)	Quality wells (Number of wells)
Initial period	10	9	3	3	1	1			4	3	1	1	1	1
Mid-term	29	24	3	2	1		6	6	5	3			14	13
Later period	36	31	4	4	4	3	8	8	6	5	8	5	6	6
Total	75	64	10	9	6	4	14	14	15	11	9	6	21	20
Quality rate (%)	85.33		90		66.67		100		73.33		66.67		95.24	

4.3 Logging quality situation

Under the high pressure environment of the formation, there is some influence on the logging curve information, mainly in the following ways.
First, high amplitude in the microelectrode curve with small or no amplitude difference, showing a differential layer characteristic or similar to the calcareous layer.
Second, no negative anomalies or very small negative anomalies in the natural potential, similar to the calcareous layer.
Third, the sonic time difference has increased compared to the equivalent layers.
Fourth, the well diameter curve is slightly increased compared with the sandstone layer, and the well diameter curve of the poor layer has a dilation phenomenon.
In response to the influence of high-pressure layers on logging, methods such as up-and-down comparison of this well and sand prediction of the adjacent well were adopted to improve the accuracy of logging interpretation. 75 wells were completed, with a statistical development sandstone thickness of 11.8m and an effective thickness of 3.7m (including 0.3m in the same layer), which is not much different from the development of the surrounding old wells, after deducting the influence of factors such as well placement area.

4.4 Benefits

Statistics of the whole area drilling off 95 wells, according to the pressure classification 54 qualified wells, 41 unqualified wells, including 5-7MPa 19, 4-5MPa 9, 3-4MPa 13, according to all will be to 3MPa or less drilling calculation, saving costs 1.37 million yuan.

Table 6 Cost savings of 41 wells in Block A

Pressure Reduction	Pre-drilling 5-7MPa wells			Pre-drilling 4-5MPa wells			3-4MPa water wells before drilling			Tanker Cost	Cost savings Total cost
	Number of wells	Cycle time	Pressure relief Frequency	Number of wells	Period	Pressure relief Frequency	Number of wells	Period	Pressure relief Frequency		
5-7	19	7	2							800	212800
4-5	19	15	1.5	9	15	1.5					504000
3-4	19	20	1	9	20	1	13	20	1		656000

Compared with the previous drilling operation is not limited by water injection and pressure relief, which can further optimize the operation. In addition, the average drilling and construction period is shortened by 42 days, and the well is put into production 42 days earlier than before

5. Conclusion and Understanding

From the 77 completed encrypted wells in Block A, the following conclusions and understandings were initially obtained from the implementation of drilling within a reasonable pressure range.
Conclusion:The implementation of high-pressure drilling in Block A of Oilfield F is feasible.
Awareness:
(1) Block drilling is feasible at less than 3MPa in the 300m range and less than 7MPa in the 600m range.
(2) The logging response characteristics are slightly affected after completion drilling, but it does not affect the interpretation effect.
(3) The quality of cementing after completion drilling can be guaranteed under current technology.
(4) The disadvantage of not being able to optimize the drilling run due to high pressure is avoided.
(5) Effective control of in-plant cost expenditures.

(6) Promotes the process of capacity building.
(7) Reduce the impact of water injection and resume water injection in advance, playing a positive role in restoring the block's liquid production capacity.
(8) It can be further promoted in other oil fields of our plant on a trial basis.

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