HOSTED BY

ELSEVIER

Available online at www.sciencedirect.com

ScienceDirect

Natural Gas Industry B 2 (2015) 192−197

www.elsevier.com/locate/ngib

Research article

Application of fine managed pressure drilling technique in complex wells with both blowout and lost circulation risks

Yan Ling[a,*], Wu Huisheng[b], Yan Yan[c]

[a] CNPC Chuanqing Drilling Engineering Company Limited, Chengdu, Sichuan 610051, China
[b] East Sichuan Drilling and Exploration Company, CNPC Chuanqing Drilling Engineering Company Limited, Chengdu, Sichuan 610051, China
[c] Drilling and Production Technology Research Institute, CNPC Chuanqing Drilling Engineering Company, Guanghan, Sichuan 618300, China

Received 30 October 2014; accepted 20 January 2015
Available online 10 September 2015

Abstract

Fractured carbonate reservoirs are susceptible to blowout and lost circulation during drilling, which not only restricts drilling speed, but also poses big threat to well control. Moreover, there are few technical means available to reconstruct pressure balance in the borehole. Accordingly, the fine managed pressure drilling was used in the drilling of Well GS19 in the Qixia Formation with super-high pressure and narrow density window, which is a success: ① back pressure in the annular spaces will be adjusted to maintain a slightly over-balanced bottom-hole hydraulic pressure, and fluid level in the circulation tank will be kept in a slight dropping state to ensure that natural gas in the formation would not invade into the borehole in a massive volume; ② inlet drilling fluid density will be controlled at around 2.35 g/cm^3, back pressures in the annular be maintained at 2−5 MPa, and bottom-hole pressure equivalent circulation density be controlled at 2.46−2.52 g/cm^3; ③ during managed pressure drilling operations, if wellhead pressure exceeds or expects to exceed 7 MPa, semi-blind rams will be closed. Fluids will pass through the choke manifold of the rig to the choke manifold specifically for pressure control before entering gas/liquid separators to discharge gas; ④ during tripping back pressure will be kept at less than 5 MPa, volume of injected drilling fluid will be higher than the theoretical volume during tripping out, whereas the volume of returned drilling fluid will be higher than the theoretical volume during the out-tripping. This technique has been applied successfully in the drilling of the Qixia Formation, Liangshan Formation and Longmaxi Formation with a total footage of 216.60 m, as a good attempt in complicated wells with both blowout and lost circulation risks, which can provide valuable experiences and guidance for handling similar complexities in the future.

Keywords: Sichuan Basin; Carbonate rocks; Overflow; Lost circulation; Co-existence of blowout and lost circulation; Multi-pressure system; Fine managed pressure; Narrow density window

Since the exploration and development of Sinian in the Sichuan Basin, the drilling operation has encountered complex lithology, and dozens of uncertain geologic factors, unpredictable formation pressure, multiple pressure systems in vertical direction and local high pressure. It is not possible to achieve effective separation of all complex intervals by using limited casing programs, consequently, two or more alternating high-pressure and low-pressure layers may coexist in the same open hole interval. In addition, production layers are with fracture-pore features. All those mentioned above could cause lost circulation and overflow, narrow drilling fluid density window, the occurrence of both blowout and lost circulation, posing high threat to well control. Currently, there are few technical means available to deal with such complex conditions, and the few technical means available are long in handling cycle, hindering drilling speed and the pace of natural gas exploration in the gas play.

* Corresponding author.
E-mail address: yanl002_sc@cnpc.com (Yan L.).
Peer review under responsibility of Sichuan Petroleum Administration.

http://dx.doi.org/10.1016/j.ngib.2015.07.010

Table 1
Statistics on complexities in Ø215.9 mm section.

Time	Depth/m	Formation	Drilling fluid density/(g cm^3)	Type	Description	Countermeasures
2014-03-02	3845.97	Mao-3	2.15	Overflow	After circulating and observing the well for 10 min, total hydrocarbon content was up from 4.23% to 73.72%, outlet density was down from 2.13 to 1.90 g/cm^3, and fluid level in the circulation tank rose by 0.4 m^3	The drilling fluid density was increased to 2.32 g/cm^3 and the well was restored to normal drilling.
	4013.69		2.24		Average lost circulation rate: 2.4 m^3/h	Drilling and observation
	4017.20		2.24		Fluid level in circulation tank no longer dropped	Drilling went on
2014-03-07	4019.35	Qi-2	2.24	Lost circulation	Hydrocarbon: 1.97% ↑ 4.0%; C_1 1.09% ↑ 2.49%; density at outlet reduced to 2.20 g/cm^3 with no change in fluid level	Drilling continued
	4019.69		2.24		Within 5 min, fluid level increased by 1.1 m^3, total hydrocarbon content: 4.0%↑56.15%; C_1 1.09% ↑ 54.25%, density at outlet reduced to 1.92 g/cm^3	Tripped out drilling string, and shut down the well, at this point, standpipe pressure was 0 MPa and casing pressure was 8.0 MPa; after observation for 18 min, the standpipe pressure was 0 MPa, and the casing pressure rose from 8.0 to 16.4 MPa

1. Basic data of well GS19

1.1. Signs of well intervals with both blowout and lost circulation

With a designed depth of 5520 m, Well GS19 is a preliminary exploration well for the Sinian formations. Its Ø311.2 mm interval was drilled to the depth of 2865.0 m, with Ø244.5 mm intermediate casing installed to the well depth of 2863.8 m (Member Jia-2^3) before cementation. Then, a Ø215.9 mm drill bit was used to the depth of 3845.97 m (Member Mao-3) with a drilling fluid density of 2.15 g/cm^3. The first gas layer show was found in this section, subsequently by using managed pressure circulation through a separator, drilling fluid density was enhanced from 2.15 to 2.32 g/cm^3 to restore normal drilling (Table 1). Later on, the first layer (Member Qi-2) with lost circulation of 2.4 m^3/h was encountered at the depth of 4013.69 m when drilling with drilling fluid of 2.24 g/cm^3. Observation results showed fluid level in the circulation tank stopped dropping at the well depth of 4017.20 m; further drilled to the depth of 4019.35 m, outlet monitoring showed a rise of total hydrocarbon and C_1 content, drop of drilling fluid density and no change in fluid level; 5 min later, when further drilled to the depth of 4019.69 m, fluid level increased by 1.1 m^3, outlet monitoring showed a sharp rise of total hydrocarbon and C_1 content, and drilling fluid density dropping to 1.92 g/cm^3; drilling string was tripped out and the well was closed for 18 min under close watch, during which standpipe pressure was 0 MPa, and casing pressure increased from 8.0 to 16.4 MPa (Table 1).

Comprehensive analysis of lost circulation conditions shows that there is a gas layer at the well depth of 3845.97 m; at the time of lost circulation at a well depth of 4013−4019 m, density of drilling fluid at inlet maintained at 2.24 g/cm^3 with no return loss observed at the wellhead, from beginning to the end, the borehole was filled with drilling fluid with hydraulic pressure remained unchanged, so no natural gas kicked in at the depth of 3845 m. Therefore, the layer with lost circulation at the depth of 4013−4019 m was thought to be the a fracture layer with both blowout and lost circulation. During the drilling of the interval, lost circulation of drilling fluid was observed, and high-pressure natural gas kicked into the well, with more natural gas built up in the borehole and drilling fluid in annular moving upward and expansion of the gas, speed of lost circulation decreased and eventually stopped all together, then overflow and fluid level rise were observed.

1.2. Lost-circulation prevention and well killing performance

1.2.1. Lost circulation control and well killing by using bridging mud

During the first killing, 30 m^3 bridging mud with a density of 2.30 g/cm^3 (concentration of 10%) and 177 m^3 drilling fluid of 2.30 g/cm^3 were injected down the drillpipe to kill the well; the well was circulated under the controlled standpipe pressure of 9.5−20.1 MPa, casing pressure of 9.1−25.1 MPa and pumping rate of 13.6 L/s, with a flame height of 5−10 m. The well killing operation failed due to return loss. The well was closed with casing pressure increasing to 24.2 MPa and standpipe pressure of 0 MPa.

During the second killing, 30 m^3 bridging mud of 2.30 g/cm^3 (concentration of 12%) and 85 m^3 drilling fluid of 2.30 g/cm^3 were injected down the annular. Upon suspension of pumping, casing pressure was 7.2 MPa and standpipe pressure 0 MPa.

During the third killing, 43 m^3 drilling fluid of 2.31 g/cm^3 was injected down the drillpipe, whereas 45 m^3 bridging mud of 2.31 g/cm^3 (concentration of 18%) and 107 m^3 drilling fluid of 2.31 g/cm^3 were injected reversely through the annular.