Application of Mud Cooling System for Gas Hydrate Exploration in Permafrost

CHEN Chen, CHEN Da-yong, FENG Xue-wei

College of Construction Engineering, Jilin University / State Key Laboratory of Superhard Materials / Laboratory of Technology for Drilling Under Complex Condition of Ministry of Land and Resources, Changchun, China, 130026

Received 01 March 2011, accepted 18 March 2011.

Abstract

Mud cooling system is mainly designed for exploration of gas hydrate in permafrost. During the process of drilling, borehole enlargement, gas hydrate dissociation and other issues will happen due to the high mud temperature. In this paper, principle of mud cooling system was described, focusing on the application of mud cooling system for gas hydrate exploration in Mohe basin permafrost. The exploration began on Aug.16, and it took two months to finish the whole exploration. In the end, a 500m hole of Ø108mm was drilled. On the basis of the perfect cooling effect of mud cooling system, the gas hydrate exploration in Mohe was carried out smoothly. In addition, the mud cooling system will provide an effective technical support for future large-scale exploitation of gas hydrate.

Keywords: gas hydrate, mud cooling, permafrost drilling.

1. Introduction

Natural gas hydrate is a kind of compound which is produced under the condition of temperature 0–10°C and pressure above 10MPa [1, 2]. Scientists currently have found a large number of gas hydrates in permafrost, such as the Mackenzie Delta, North Slope of Alaska and Russia, Siberia, Qinhai of China [3,4].

Permafrost gas hydrate exploration mainly takes geophysical methods, such as seismic reflection method, drilling sampling techniques, logging techniques, what's more, drilling of which is the most direct natural gas hydrate exploration technique. However, how to prevent hydrate from decomposing during exploration is the key technical problem [5–12]. During the permafrost drilling process of gas hydrates, a great deal of heat is generated, then the heat will be brought to the surface by cycle of drilling mud. If the mud returned from the drilling hole has a higher temperature than the temperature of gas hydrate reservoir in permafrost, it will cause the borehole (frozen soil or rock) expanding or decomposition of gas hydrates. Therefore, the temperature of mud should always be kept lower than which of hydrate in permafrost while drilling [13–15].

[Fund Support]: Geological Survey of China Geological Survey Project/ Permafrost investigation and assessment of gas hydrate(Project Number:1212010818055)

2. Principle and structure of the mud cooling system

At present, there are several forms of mud cooling system [16]:

(1) Natural evaporative cooling. Since the temperature of mud returning from hole is higher than the ambient temperature, the slurry will flow along the mud tank and evaporative cooling.
(2) Solid with low temperature conducts to cool. Put low temperature solid in the mud pool and cool the slurry though the way of heat conduction.
(3) Forced cooling by mud cooling device. When the returned mud temperature is higher, which indicates the difference of temperature in and out borehole is too large, the cooling device should be utilized [17].

The mud cooling system independent researched and designed by College of Construction Engineering, Jilin University, mainly used for exploration of gas hydrate in permafrost. The mud cooling system consists of two components, namely the refrigerant cooling circuit and mud cooling circuit. Through the refrigeration unit cooling the refrigerant, the refrigerant temperature can reach −15°C.The refrigerant and mud are transported to the coaxial tube heat exchanger in the same time. They exchange heat through the reverse flow heat exchanger. The total heat exchange capacity can be calculated as equation (1) [18,19]. Meanwhile, the key points' temperature of the system need to be detected constantly, and system parameters should be adjusted timely to meet the drilling requirements. The structures of two loops were shown in Figure 1.

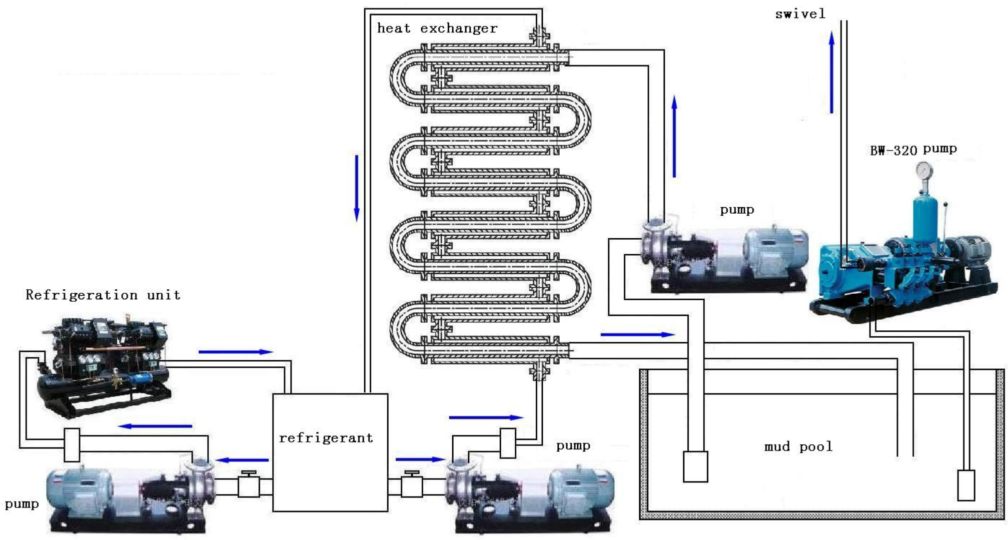

Fig.1. The structure of mud cooling system

$$Q=Mc(t_1-t_2)=(\rho G)c(t_1-t_2)=21.25kw \quad (1)$$

G – flow, 160L/min; C–specific heat, 3.7064 kJ /kg; t_1-t_2 – temperature difference, 2°C; ρ – mud density, 1.0750g/cm^3.

3 Application of mud cooling system for gas hydrate exploration in Mohe basin

3.1 Overview of physical geography in test site

The gas hydrate exploration sites located in Mohe of Heilongjiang Province, China. Mohe is in Daxing'anling Mountain, upper south coast of Heilongjiang river. Construction location was years of permafrost zone with the deepest limit 124 m, generally 60 to 80 meters and the average thaw depth in 0.6–0.7 meters.

3.2 Mud used in the cooling system test

A resistance to low temperature mud with low solid-phase polymer was used in this gas hydrate exploration. Requirements of the main technical parameters of drilling mud as following:

(1) Freezing point of drilling mud was −4°C,

(2) Water loss of drilling mud was less than 4 ml/30min,

(3) The density of drilling mud was 1.07–1.085 g/cm^3.

3.3 Analysis of test data

Test duration: 2010.9.1–2010.9.30

During exploration construction of gas hydrate drilling MK-1 borehole, the mud cooling system had got satisfactory test results. Time curves(as figure 2) of mud temperature had been drawn based on field measured data ranging from 111.30 to 458.10 m.

Fig.2. The temperature ＆ time curve of mud

3.3.1 Analysis of mud temperature curves flowing in and out borehole

As shown in figure 2, average mud temperature flowing in and out borehole were separately 3.13°C(the temperature would reach to 7.5°C without cooling system) and 4.28°C, and average temperature in mud pool was 5.72°C, which met the demands of gas hydrate sampling drilling construction. Because the mud pool without thermal insulation resulted in conducting heat exchange with outside continuously, temperature curve of mud pool appeared fluctuation obviously. Rising temperature in mud pool heated by sunshine aggravated the burden of refrigeration system, especially during 9.10–9.15. And the environmental temperature during 9.20–9.22 was lower, which led the temperature in mud pool to decrease. In addition, new mud needed to be supplied while drilling in leaking formation, owing to the large vertical cracks in the drilling zone. However, temperature of supplied mud was higher usually, which made the temperature in mud pool changing constantly.

3.3.2 Analysis of effects of heat exchange

According to observed test data, temperature curves of pre and post heat exchange between the mud in tube heat exchanger in cooling system and secondary refrigerant were drawn as figure 3. Average temperature of mud flowing in and out exchanger was 1.43°C by calculating, and average heat transfer rate of exchanger was 19.18kW. It proved that the whole system could satisfy the requirements of gas hydrate exploration.

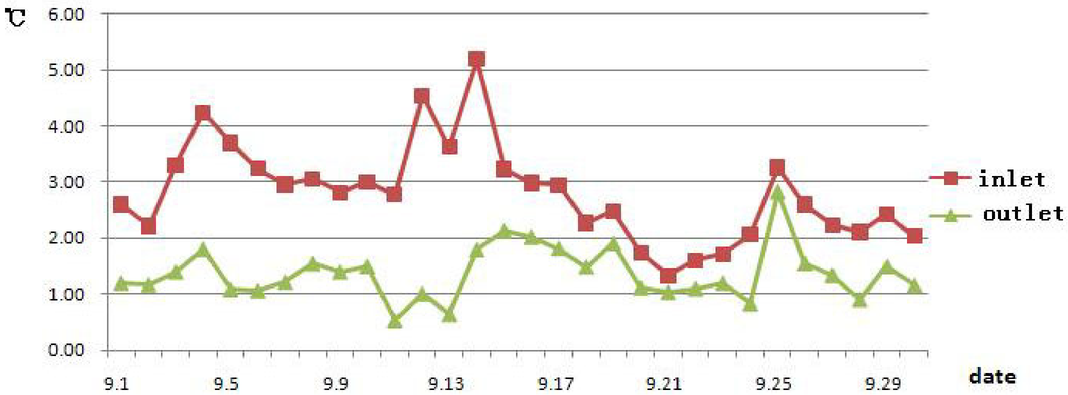

Fig.3 The temperature ＆ time curve of mud heat transfer in heat exchangers

4.Conclusion

This set of mud cooling system has achieved good results in exploration of natural gas hydrate in Mohe basin, which solved hole wall instability, hydrate decomposition and other issues that caused by high temperature of mud. And it has ensured the smooth progress of exploration and construction. After successful application of the mud cooling system in Qinghai 2009 and Mohe Basin 2010, it marks that mud cooling technology has been paid attention to in China, but also offers effective technical support for future large-scale gas hydrate exploration.

[References]

1.Sloan E Dendy. Clathrate Hydrates of Natural Gases[M].NewYork: MarcelDekker,Inc.1990.

2. Sloan E Dendy. Fundamental principles and applications of natural gas hydrates[J].Nature,2003,426(20): 353-359.

3. LONG Xueyuan, YUAN Zongming, Ni Jie.2006.Advances in overseas gas hydrate research and suggestions to China's government[J].Progress in Exploration Geophysics. 29(3)170-177

4. WU Qing-bai, CHENG Guo-dong.2008.Research Summarization on Natural Gas Hydrate in Permafrost Regions[J].ADVANCES IN EARTH SCIENCE.23(2)111-119

5. ZHANG Yong-qin, SUN Jian-hua, JIA Zhi-yao.2009. Research and Application for China Land Permafrost Gas Hydrate Drilling[J]. Exploration Project. 36(S1):22-28.

6. Holbrook W S, Hoskins H, Wood W T , Stephen R A, Lizzarralde D. Methane hydrate and free gas on the Blake Ridge from vertical seismic profiling[J],Science,1996 :273,1840 – 1843.

7. Hyndman R D, Spence G D. A seismic of methane hydrate marine bottom simulating reflectors[J] . J.Geophys. Res. 1992 ,97 :6683 – 6698.

8. ZHOU Huaiyang, PENG Xiaotong, YE Ying.2002. DEVELOPMENT IN TECHNOLOGY OF PROSPECTING AND EXPLOITATION FOR GAS HYDRATES. Geology and Prospecting. 38(1)70-73

9. Hesse R , Harrison W E. Gas Hydrates (clathrates) causing porewater fre shening and oxygen isotope fractionation in deepwater sedimentary sections of terrigenous continental margins[J]. Earth Planet. Sci. Lett, 1981,11:453 – 562.

10. Pecher I A , Ranero C R , Huene. Rvon ,Minshull T A,Singh S C.The nature and distribution of bottom simulating reflectors at the Costa Rican convergent cargin [J]. Geophys. J.Int.,1998 ,133 :219 – 229

11. Gerald R D ,Paull C K,Wallace P. Direct measurement of insitu methane qunatities in a large gashydrate reservoir[J] .Nature,1997,385 :462 – 428.
12. McGee T M.A singlechannel seismic reflection method for quantifying lateral variations in BSR reflectivity[J] ,Marine Geology , 2000,164:29 – 35.
13. DOU Bin,ZHU Yunli,JIANG Guosheng,TANG Fenglin .2004.THE THEORY ON DESIGNING A IN- SITU SAMPLING SYSTEM OF GAS HYDRATE[J]. Geology and Prospecting .40(1) 86-88
14. YE Jian-liang,YIN Kun,JIANG Guo-sheng,TANG Feng-lin,DOU Bin.2003.Key Technique and Countermeasures for Natural Gas Hydrate Drilling[J].(5):45-48.
15. Jiang Guosheng,Ning Fulong, LiZhongwen,Zhang Ling,Xiang Xian chao,DouBin.2001.Inhibition and induction decompostion of gashydrates on drilling procedure [J].Geology and Prospecting,37(6): 86-87
16. ZHAO Jiang-peng,SUN You-ho ng,GUO Wei.2010.Current Situation of Drilling Mud Cooling Technology and Research on a New Type of Drilling Mud Cooling Syste m[J].Exploration Project .37(9):1-5
17. GAO Hang,LIU Hai-tao.2007.Concept Design for Drilling Fluid Cooling System[J].OIL FIELD EQUIPMENT.36 (6):31-32.
18. MENG Xiang-guang.2005.The Establishment of Refrigeration Equipment of Core and the Study of Its Mathematics Model of Gas Hydrate Drilling [D].JiLin University
19. YANG Shi-ming.1987. HEAT TRANSFER[M].Bei Jing:HIGHER EDUCATION PRESS.

Аннотация

Система охлаждения промывочной жидкости в основном предназначена для эксплуатации газовых гидратов в вечной мерзлоте. В процессе бурения, расширения скважины, диссоциация газовых гидратов и другие осложнения могут произойти из-за высокой температуры промывочной жидкости. В статье описывается принцип системы охлаждения промывочной жидкости для применения к добыче газовых гидратов в вечной мерзлоте бассейна Moxe. Эксплуатация начата 16 августа и заняла 2 месяца. В результате была пробурена скважина диаметром 108 мм глубиной 500 м. Благодаря эффекту охлаждения промывочной жидкости эксплуатация газовых гидратов произошла без осложнений. В дополнение данная система обеспечит в будущем возможность широкомасштабной эксплуатации газовых гидратов.

Ключевые слова: газовые гидраты, охлаждение промывочной жидкости, бурение в вечной мерзлоте..

Анотація

Система охолодження промивальної рідини в основному призначена для експлуатації газових гідратів у вічній мерзлоті. В процесі буріння, розширення свердловини, дисоціація газових гідратів і інші ускладнення можуть статися із-за високої температури промивальної рідини. У статті описується принцип системи охолоджування промивальної рідини для застосування до видобутку газових гідратів у вічній мерзлоті басейну Moxe. Експлуатація почата 16 серпня і зайняла 2 місяці. В результаті була пробурена свердловина діаметром 108 мм глибиною 500 м. Завдяки ефекту охолоджування промивальної рідини експлуатація газових гідратів сталася без ускладнень. На додаток дана система забезпечить в майбутньому можливість широкомасштабної експлуатації газових гідратів.

Ключові слова: газові гідрати, охолодження промивальної рідини, буріння у вічній мерзлоті.