Academic Journal of Science and Technology
ISSN: 2771-3032 | Vol. 7, No. 1, 2023

Research on Dynamic Monitoring Technology for Dengsi Gas Reservoir in Gaoshiti Moxi Block

Huohai Yang, Qingrong Liao

Petroleum Engineering School, Southwest Petroleum University, Chengdu, China

Abstract: The fourth group gas reservoir in the Moxi platform edge zone of Anyue Gas Field is a super large carbonate gas reservoir with edge and bottom water in China. There is no mature development experience in this type of gas reservoir in China, and there is a lack of a systematic dynamic monitoring system. This article focuses on the challenges and key technical issues faced by gas reservoir dynamic monitoring work. Through active exploration, continuous improvement, and innovation of dynamic monitoring technology and analysis methods, a dynamic monitoring system suitable for the four groups of gas reservoirs with lights at the edge of the Moxi platform has been constructed. Five key dynamic monitoring technologies, including pressure and temperature dynamic monitoring technology, production capacity monitoring and evaluation technology, fluid property monitoring technology, water invasion monitoring and identification technology, and well connectivity monitoring and evaluation technology, have been developed for the four gas reservoirs in the Moxi platform edge zone. Scientific and reasonable development measures have been formulated to support the preparation of the overall water control plan for the gas reservoir, It has played a role in ensuring the scientific and efficient development of large-scale edge and bottom water carbonate gas reservoirs.

Keywords: Moxi Platform Edge Zone, Deng4 Formation Gas Reservoir, Dynamic monitoring system, Water intrusion, Key technology.

1. Introduction

The Dengsi gas reservoir in the Moxi block of the Anyue super large gas field in the Sichuan Basin is a high-temperature and atmospheric pressure large-scale lithologic stratigraphic composite enclosed gas reservoir[1]. The storage space is mainly composed of small and medium-sized karst caves and various types of dissolution pores. The overall performance of the reservoir is low porosity, low permeability, and strong heterogeneity[2]. The fourth gas reservoir in the Moxi platform edge zone is currently in the early stage of stable production, and there are problems such as interference between some well groups, poor reservoir seepage characteristics of some gas wells, blockage of some gas wells, water invasion, etc., which result in limited production[3]. The dynamic reserves of the stacked gas wells with well control radii have significant differences in calculation results at different periods, and the dynamic temperature and pressure monitoring system for gas well production is incomplete, There is an urgent need to establish a unified production dynamic monitoring system suitable for the four gas reservoirs along the Moxi platform edge[4].

2. Key Technologies for Dynamic Monitoring of Gas Reservoirs

In response to the actual dynamic monitoring of the four groups of gas reservoirs with lights on the edge of the Moxi platform, through theoretical research and technological integration innovation, five key technologies for dynamic monitoring of the four groups of gas reservoirs with lights on the edge of the Moxi platform have been formed, including pressure and temperature dynamic monitoring technology, production capacity monitoring and evaluation technology, fluid property monitoring technology, water invasion monitoring and identification technology, and well connectivity monitoring and evaluation technology[5].

2.1. Temperature and pressure monitoring process

2.1.1. Conventional pressure and temperature monitoring process

Conventional pressure and temperature monitoring processes include wire suspension well testing, cable testing, coiled tubing, wellhead pressure monitoring, and support tube pressure testing processes. At present, the pressure and temperature dynamic monitoring technology widely used in the Moxi platform edge band lamp four gas reservoir is wire suspension well testing and wellhead pressure monitoring.

The wire suspension well testing technology has been widely applied in the construction of gas reservoirs with high temperature, high pressure, and medium sulfur content, and has formed a relatively complete safety technology and management system for gas well wire testing. The wire suspension well testing technology is widely used in Dengsi Gas Reservoir and has good adaptability.

2.1.2. Permanent underground monitoring process

The commonly used permanent monitoring hardware systems currently include fiber optic sensor monitoring systems, electronic sensor monitoring systems, and capillary sensor monitoring systems.

(1) Fiber optic monitoring system

In the petroleum industry, fiber optic sensors have attracted widespread attention due to their suitability for permanent underground placement, reliable performance, electromagnetic interference resistance, high temperature and pressure resistance, convenient use, and the ability to continuously monitor multiple points on a single line, two-dimensional lattice, or spatial distribution. They have been applied in dynamic monitoring of oil reservoirs and have been proven to have advantages that conventional electronic devices cannot match.

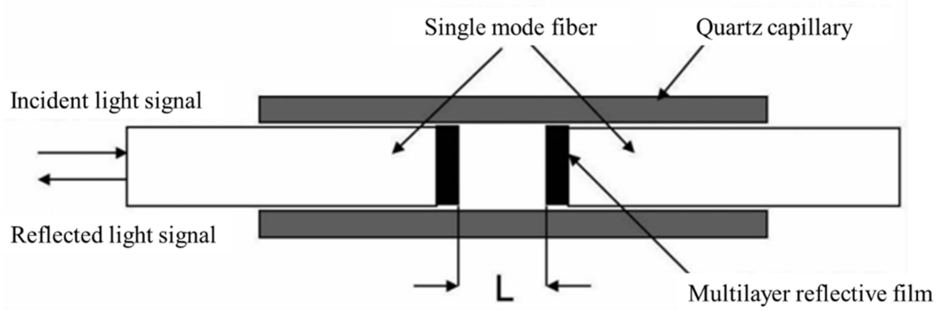

Figure 1. Structure diagram of fiber optic sensor

(2) Electronic monitoring system

The electronic pressure sensor system is mainly used to measure bottom hole pressure, and this technology has become mature. There are many types of electronic sensors, the most commonly used being quartz electronic sensors. Quartz electronic sensors have the characteristics of large measurement range, high measurement accuracy, and fast measurement speed.

Figure 2. Composition diagram of electronic monitoring system

(3) Capillary monitoring system

Capillary monitoring technology is currently relatively complete, with different transmission principles for pressure monitoring and temperature monitoring. The former is a pressure transmitting capillary, while the latter is a thermocouple wire. The monitoring system is divided into two parts: underground and surface. The underground part includes: wellhead crossing device, annular packer, capillary steel pipe, capillary steel pipe protector, and pressure cylinder; The ground part includes: nitrogen gas source, nitrogen booster pump, air compressor, purging manifold, pressure transmitter, wellhead outlet device, data acquisition and control system, etc.

Due to the high testing accuracy, simple underground structure, high temperature resistance, long service life, and easy maintenance of capillary pressure monitoring systems, their application prospects in gas fields are very broad. However, the system is expensive and usually only used to monitor bottom hole pressure, with a relatively limited function, which limits its application in gas fields.

(4) Block applicability analysis

The first implementation of fiber optic monitoring system in China began with the cooperation between Shandong Academy of Sciences and Shengli Oilfield at the end of 2008. Currently, this technology is rarely applied domestically. Due to the high cost of fiber optic permanent monitoring technology, it is not recommended to conduct experiments in the work area.

Electronic monitoring system: This technology is relatively mature and can meet testing requirements, with high stability and reliability. Construction operations and post management are relatively simple. This technology has a wide range of applications and has been successfully implemented 6 times in oil and gas fields in the Sichuan Chongqing region.

Capillary monitoring system: The pressure and temperature transmission media of this technology are different, and the technology used domestically and internationally is usually only used to monitor pressure, which relatively limits its application in oil and gas fields; Moreover, the different transmission media of pressure and temperature lead to significant difficulties in construction and later management, so it is not recommended to conduct this technical test on gas reservoirs in the work area.

Finally, the comprehensive temperature and pressure monitoring system with wire suspension well testing technology and electronic monitoring system was selected as the dynamic monitoring system for the temperature and pressure of the four groups of gas reservoirs with lights at the edge of the Moxi platform.

2.2. Production monitoring process

Production monitoring mainly refers to wellhead production measurement. The commonly used natural gas flow meters in China include orifice flow meters, waist wheel (Roots) flow meters, turbine flow meters, and vortex flow meters[6].

At present, the wellhead production calculation of the four gas reservoirs with lamps at the edge of the Gaomo block is measured through the SGQ intelligent differential pressure flowmeter. The SGQ intelligent differential pressure flowmeter is composed of components such as monocrystalline silicon composite sensors, specialized solar panels, cable outlets, and LCD display screens.

The SGQ intelligent differential pressure flowmeter automatically collects real-time differential pressure, pressure, and temperature signals (platinum resistance temperature sensor) when natural gas flows through the throttling device, and based on the basic principle that the flow rate of the fluid is proportional to the square root of the pressure difference generated by its flow through the throttling device.

Through the SGQ intelligent differential pressure flowmeter for production monitoring, the total daily gas production of 52 wells in the gas reservoir is 10.384 million cubic meters/day, with a single well daily gas production range of 629-388800 cubic meters/day, and an average of 199700 cubic meters/day. Among them, the wells in the Gaoshiti block are 230000 cubic meters/day, the wells in the Moxi block are 187400 cubic meters/day, the daily gas production of 8 wells is more than 300000 cubic meters/day, and the daily gas production of 39 wells is between 100000 and 300000 cubic meters/day. Only 5 wells have a daily gas production of less than 100000 cubic meters/day, The overall gas production is stable.

2.3. Fluid Property Monitoring Process

Fluid property monitoring includes monitoring and analysis of chemical characteristics such as natural gas, wellhead produced fluid, hydrogen sulfide in water, and blockages. Analyze the composition of natural gas and the content of hydrogen sulfide, determine the type, mineralization degree, and ion content of water, and provide basic data for formulating development plans for gas reservoirs. During the development process of gas reservoirs, regular wellhead sampling and testing of gas and water are conducted to analyze the properties of natural gas components and the hydrochemical characteristics of the produced liquid, in order to determine changes in fluid properties and changes in gas well production.

2.3.1. Analysis of Natural Gas Components

The commonly used method for analyzing natural gas components is through gas chromatography. The gas chromatograph mainly realizes data analysis work such as measuring the concentration of gas components and separating gas mixtures.

Gas chromatography refers to the chromatography method using gas as the mobile phase. Due to the fast transfer speed of the sample in the gas phase, the sample components can instantly reach equilibrium between the mobile phase and the stationary phase. In addition, there are many substances that can be used as stationary phases, so gas chromatography is a separation and analysis method with fast analysis speed and high separation efficiency. In recent years, the use of highly sensitive and selective detectors has given it the advantages of high analytical sensitivity and wide application range. When analyzing natural gas components, it is necessary to strictly control various parameters to meet the analysis standards. During the experimental process, it is necessary to control the valve based on the composition and content of natural gas, and analyze and study the liquid present in the carrier gas through the conversion and switching of the valve. By separating the chromatographic column and displaying the results, it is further ensured that the natural gas components can enter their own separator separately and do not react with other gas components, ensuring more reliable and accurate results.

Through natural gas composition analysis, the relative density of natural gas and the content of methane, ethane, CO2, and H2S in 52 wells in the 4 well areas of Moxi Block are close, and it is necessary to unify the necessary conditions for reservoir formation.

2.3.2. Water sample analysis

Production dynamic monitoring requires regular sampling and testing of gas well water production to determine changes in the water production situation of the gas well. According to the sampling location, it can be divided into wellhead sampling and underground MDT sampling. During analysis, ion chromatography is used to determine the ion content and water type of the water sample[7].

(1) Ion chromatography

Ion chromatography is a liquid chromatography method for analyzing anions and cations. Ion chromatography utilizes the differences in affinity between different ions and ion exchange resins in a given ion exchange column for separation. Multiple anions are continuously analyzed qualitatively and quantitatively in a single run program. Ion chromatography, as an important branch of liquid chromatography, has the characteristics of high sensitivity, fast and convenient operation, good stability of separation columns, high capacity, and strong selectivity.

(2) Classification of Formation Water Types (Sulin Classification)

The classification method for formation water types in oil and gas fields in China is commonly used, which was proposed by former Soviet geochemical scientist Su Lin.

Table 1. Characteristic Coefficients of Native Water Types (Su Lin Classification)

Water type	Na^+/Cl^-	$(Na^+-Cl^-)/SO_4^{2-}$	$(Cl^--Na^+)/Mg^{2+}$
Calcium chloride type	<1	<0	>1
Magnesium chloride type	<1	<0	<1
Sodium bicarbonate type	>1	>1	<0
Sodium sulfate type	>1	<1	<0

2.3.3. Analysis of Blockages

About 40% of the wells in the work area currently have varying degrees of blockage, which seriously affects the normal production of gas wells. Therefore, it is necessary to analyze the source and chemical composition of the blockage, increase understanding of the blockage, and take corresponding anti blockage measures to maintain the normal production of the gas well.

At present, the analysis of laboratory blockages includes pre-treatment, burning test, quantitative analysis of inorganic elements, determination of sulfide content, composition identification (infrared spectroscopy analysis), microscopic morphology of scale phase (scanning electron microscopy analysis), qualitative analysis of elements (scanning electron microscopy energy spectrum analysis, X-ray diffraction analysis), and organic matter composition analysis (GC-MS analysis). Infrared spectroscopy analysis can be used to study the molecular structure and chemical bonds of samples, and can also serve as a method for characterizing and identifying chemical species; Qualitative analysis of elements includes energy dispersive electron microscopy analysis and X-ray diffraction analysis: Energy dispersive electron microscopy analysis is mainly used for observing the appearance of samples and analyzing the elemental composition and content of a certain area of the sample, while X-ray diffraction analysis mainly analyzes the inorganic composition of the sample. Gas chromatography-mass spectrometry analysis mainly analyzes the organic components in the blockage sample.

Through monitoring and analysis of blockages, from January 2021 to October 2022, there were a total of 38 wells and 79 well blockages in the Dengying Formation at the edge of the high grinding platform, accounting for 73.1% of the total number of wells. There are mainly three types of blockages: wellhead and surface process blockages, wellbore blockages, and formation blockages. The blockages are mostly solid backflow materials from the underground, causing damage to the throttle valve core and valve sleeve, obstruction in the well passage, and ineffective production, seriously affecting the normal and safe production of the gas well.

2.4. Water intrusion monitoring and identification technology

2.4.1. Early identification technology for water invasion

The water invasion of gas reservoirs is a dynamic process, and its changes must be reflected in dynamic monitoring data. If water invasion is active in a water drive gas reservoir, the movement characteristics of the natural water invasion boundary during the development process will be reflected to varying degrees in the multiple well test analysis curves of gas wells near the water boundary at different times. In actual well testing interpretation analysis, composite formation well testing models and linear discontinuous boundary well testing models are commonly used to analyze natural water invasion boundaries. Conducting well testing tracking and comparative analysis at different stages can determine whether water invasion has occurred in gas reservoirs.

According to the relationship between the investigation radius of the testing well and the distance between the gas well and the gas water boundary of the gas reservoir, water invasion can be divided into three types: early, medium, and late.

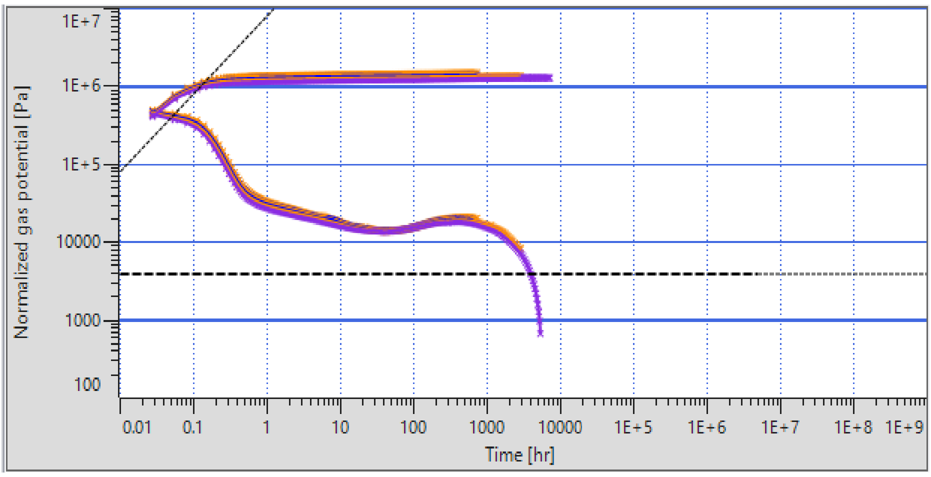

Figure 3. Unstable well testing curves for three scenarios

2.4.2. Criteria for distinguishing water production types

Based on the sampled water from Well Moxi 22 and Well Moxi 022-X2, production performance analysis, hydrochemical analysis, and other methods were used to analyze their ion composition and mineralization. The criteria for determining the water production type of the Dengsi gas reservoir in the Moxi platform edge zone were established, as shown in Table 2.

Table 2. Criteria for Judging Water Production Types

Type of liquid production	Total mineralization degree (g/L)	Cl^-(g/L)	Br^-(g/L)
Formation water	>70	>40	>0.3
Mixed liquid	20~70	15~40	0.03~0.3
Condensate water	＜20	＜15	＜0.03

According to the criteria for distinguishing water production types, the 52 wells in the Dengsi gas reservoir at the edge of the Moxi platform mainly produce condensate water and acid backflow fluid. Currently, the two wells, Moxi 022-X40 and X41, are suspected to be producing layer water, and the water production type is calcium chloride type.

2.5. Interwell Connectivity Monitoring Technology

The commonly used gas reservoir connectivity evaluation techniques in China include early pressure drop monitoring, production performance identification, well control radius comparison monitoring, observation well testing, and well testing monitoring[8]. The application results in the four groups of gas reservoirs in the Moxi platform edge are all good.

At present, more than 150 well to well connectivity monitoring and analysis have been completed for the gas reservoir, with 7 wells experiencing early pressure drop, and a total of 10 well groups with 21 wells experiencing interference. There is connectivity between the periphery and the main body, and there is a significant difference in connectivity between low permeability and high permeability areas.

3. Conclusion and outlook

(1) Based on existing data, it is recognized that the Dengsi gas reservoir in the platform edge zone of the Moxi block is a gas reservoir with edge and bottom water and local sealed water. Water invasion monitoring of the gas reservoir should be combined with static and dynamic monitoring, and the

geological model should be continuously modified to identify water invasion risk wells. Dynamic monitoring of water invasion risk wells should focus on tracking and identifying the production characteristics, and predicting water invasion.

(2) Strengthen water invasion monitoring of gas reservoirs. Starting from three aspects, firstly, strengthen the identification and monitoring of gas and water layers in the early stage of gas reservoir development, and recognize the gas-water interface of the gas reservoir as early as possible through logging, oil testing, MDT testing, etc., to identify water production risk wells; Secondly, during the trial production stage, strengthen the monitoring of water invasion in water production risk wells, select opportunities to carry out unstable well testing, and establish a double logarithmic curve representing the true seepage characteristics of the gas well formation as early as possible. Afterwards, by conducting multiple unstable well tests and comparing the changes in the double logarithmic curve, the goal of monitoring water invasion was achieved. Thirdly, during the stable and decreasing stages, strengthen energy monitoring of peripheral water bodies. By continuously measuring pressure at intervals between observation wells in water areas and conducting unstable well testing at intervals between drainage wells, water energy is evaluated and water control strategies are formulated.

References

[1] Luo Jing, Zhu Suihui, Cao Jian, et al. Dynamic monitoring technical countermeasures for ultra deep and high pressure gas reservoirs: a case study of Qixia Formation gas reservoir in SY structure [J]. Natural Gas Technology and Economy, 2019, 13(1) : 13-15, 81.

[2] Zhang Lei, Hu Ping, Xu Ming, et al. A practical method for monitoring water production performance of gas wells in con-densate gas field: a case study of YAKELA Cretaceous con-densate gas reservoir [J]. Natural Gas Technology and Econo-my, 2017, 11(2) : 18-20.

[3] Zeng Daqian, Peng Xinling, Fu Dekui, et al. Dynamic monitor-ing technology for development of Puguang high sulfur gas field [J]. Natural Gas Industry, 2018, 38(10) : 63-69.

[4] He Liping, Mao Meili, Liao Hongmei, et al. Pressure monitor-ing method and remote well testing technology in Sulige gas field [J]. Natural Gas Industry, 2011, 31(1) : 59-61, 113.

[5] Jia Ailin, Yan Haijun. Development problems and Counter-measures of different types of typical carbonate gas reservoirs [J]. Acta Petroleum Sinica, 2014, 35(3) : 519-527.

[6] Chen Dan, Hou Donglin. Characteristics and controlling fac-tors of Feixianguan Formation gas reservoir in Yuanba gasfield [J]. Natural Gas Technology and Economy, 2015, 9(1) : 4-7, 77.

[7] Li Huaji, Zhang Sheng, An Fengshan, et al. Discussion on gas water distribution in Xu2 gas reservoir of Xinchang gas field [J]. Natural Gas Technology, 2008(2) : 28-31, 94.

[8] Zhuang Huinong. Gas reservoir dynamic description and well test [M]. Beijing: Petroleum Industry Press, 2004.