Energy Proceedings
Vol 56, 2025
ISSN 2004-2965

Development and prospect of CCUS-EOR surface gathering and transportation engineering technology in North China Oilfield

Shi Lixin*, Cui Yanli, Liu Yufang, Si Xiaofeng, Li Bingyu, Li Feifei
PetroChina North China Oilfield Branch
(*Corresponding Author: 2292828082@qq.com)

Number：ICCUSC2024-205

ABSTRACT

This paper focuses on the importance of carbon dioxide capture, displacement and storage (CCUS-EOR) and the production stability problems of the gathering and transportation system. Based on the analysis of typical practices at home and abroad, combined with the actual situation of North China Oilfield, this paper proposes the experience and practice of production stability guarantee measures for the CO2 flooding gathering and transportation system in North China Oilfield, aiming to further improve the application effect of CO2 flooding process in North China Oilfield and the safety, stability and flexibility of production and operation.

Keywords: CCUS-EOR, gathering and transportation system, CO2 flooding, anti-corrosion

1. Introduction

Global economic and social development is highly dependent on fossil fuels, and related energy infrastructure will still emit a large amount of greenhouse gases, which will have a serious impact on the climate, environment, economy and society, and the pressure and demand for emission reduction are increasing day by day[1]. With the growing demand for energy and increasing awareness of environmental protection, China made a commitment to the world on September 22, 2020 to achieve carbon peak and carbon neutrality to help achieve the global climate change control goal. However, the stability of the gathering and transportation system has become a key factor restricting its large-scale application.

2. Overview of CCUS-EOR technology

(1) Technical principles and advantages

The mechanism of oil displacement and storage shows that the CO_2 flooding process can achieve the dual purpose of enhanced oil recovery and carbon emission reduction. Dissolved CO_2 in crude oil can increase the expansion capacity of crude oil and improve the fluidity of formation oil. When the formation pressure is high enough, CO_2 can extract the light and medium components of crude oil, and gradually achieve oil and gas miscibility (miscibility), reducing the remaining crude oil in the formation[2]. CO_2 is dissolved in formation water, reacts with rock to form mineralization and solidification, is adsorbed by formation, or is trapped by structure, and can be permanently retained underground (the final CO_2 storage rate of United States oil displacement project is 23%~61%). In the process of CO_2 flooding, part of the CO_2 is permanently stored underground, and the CO_2 is recovered, processed and recycled, and the whole process has zero carbon emissions. When the reservoir conditions are suitable and the CO_2 gas source price is low enough, the CO_2 flooding and storage project (i.e., the flooding CCUS project) will have significant economic and social benefits.

A large number of studies and practices have proved that CO_2 is an effective oil displacement agent, and CO_2 flooding is widely used to enhance oil recovery. In production practice, continuous gas injection, gas flooding followed by water injection, alternating water injection and gas injection after gas flooding or water flooding, and simultaneous injection of gas and water (carbonated water injection) are proposed[3]. Warner (1977) and Fayers

This is a paper for International CCUS Conference 2024 (ICCUS 2024), June 20-22, 2024, Beijing, China.

have shown that alternating water and gas injection is better than continuous injection. Regardless of how CO_2 is injected into the oil layer, the reason why CO_2 can effectively displace oil from porous media is mainly the result of the comprehensive effects of expanding crude oil, reducing the viscosity of crude oil, changing the density of crude oil, acidifying rocks, vaporizing and extracting light components of crude oil, dissolving gas flooding caused by pressure drop, and reducing interfacial tension.

(2) Development status and application prospects

As an important starting point for climate change activities, since the late 80s of the 20th century, developed countries in Europe and the United States have begun CO_2 emission reduction technology research and development and industrial demonstration activities[4].

In the middle of the 20th century, the United States discovered that CO_2, a by-product of its hydrogen production process, could improve the fluidity of crude oil, and obtained the world's first CO_2 flooding patent in 1952, which was the early beginning of CO_2 flooding technology and the technical realization of the predecessor's CO_2 flooding in the 20s of the 20th century. Since 2000, crude oil prices have continued to rise, bringing profit margins to the development of CO_2 flooding technology, attracting a large amount of investment, and increasing the number of new investment projects.

The R&D and application related to CO_2 flooding in Southeast Asia and Japan began in the 90s of the 20th century, and there are only a few CO_2 injection projects so far, but with the large-scale development of offshore high-CO_2 natural gas reservoirs, CO_2 flooding will develop rapidly[5].

The research and development of CO_2 flooding technology in Russia began in the 50s of the 20th century and carried out successful mine tests, because of its rich oil and gas resources and small economic volume, there is no urgent need for the application of enhanced oil recovery technology, and oilfield gas injection is only a small-scale hydrocarbon gas flooding project.

The Middle East and Africa are rich in oil and gas resources. In 2016, ADNOC began to inject gas into the Rumaitha and Bab fields, and in 2018, it began to inject 80x10tCO_2 captured from steel mills into the onshore Habshan oilfield. Algeria has only one pure CO_2 geological storage project, In Salah; According to the current data, the large-scale commercial application of CO_2 flooding and storage technology in the Middle East and North Africa, that is, the large-scale commercial application of oil-flooding CCUS technology, will achieve a breakthrough around 2025.

The target reservoir types of CO_2 flooding in China are mainly low permeability reservoirs, and the enhanced oil recovery range is 3.0%~17%, with an average of about 10%. China's continental sedimentary reservoirs and fluid conditions are poor, the field application scale of gas injection technology is small, the experience accumulation of gas flooding reservoir management needs to be enriched, there is still some room for improvement of CO_2 oil flooding technology, and there is still a large development space for the application of CCUS in the whole process. On the whole, the development level of CCUS technology in China can be divided into three levels: the first level is Jilin Oilfield, Daqing Oilfield, Shengli Oilfield, East China Oilfield, Zhongyuan Oilfield, etc., all of which have the technical conditions for the large-scale application of CCUS-EOR; Changqing Oilfield and Xinjiang Oilfield must be based on the existing mine test, and further expansion of the test can be considered in the near future, so as to verify the feasibility of oil displacement technology and burial, and promote it in the medium and long term; Liaohe Oilfield, Dagang Oilfield, Jidong Oilfield, North China Oilfield, Tuha Oilfield and Southern Oilfield should still focus on technical research and small-scale experiments in the near future, and the promotion and application of supporting technologies should be considered in the medium and long term. Practice shows that in addition to energy conservation and energy efficiency, the development of new and renewable energy, and the increase of carbon sinks, CCUS technology will be an important technology choice for mitigating CO_2 emissions in the future.

3. Analysis of production stability of CO_2 flooding gathering and transportation system

(1) The gas-liquid ratio of produced fluid in CO_2 flooding wells is higher than that of water flooding and chemical flooding, and the volume fraction of CO_2 in produced gas is usually more than 80% and can reach more than 98%. To a

certain extent, the oil output temperature at the wellhead is low and the oil gathering temperature is reduced, resulting in the freezing and plugging of the oil gathering pipeline. At the same time, there is an intermittent sudden increase in the produced gas of the CO_2 flooding ground gathering and transportation system, so the produced liquid gathering and transportation system is prone to unstable working conditions such as gas slug plugging, which causes the flow fluctuation of the downstream treatment facilities of the produced liquid.

(2) The impact of high CO_2 content on the system: the shale gas gas composition contains CO_2 gas, and it is easy to form water accumulation in the low-lying parts of the on-site pipeline, and CO_2 dissolved in water will produce carbonic acid and form an acidic environment. This will cause general corrosion of the pipe and severe local corrosion, the corrosion product is mainly $FeCO_3$, and the reaction is shown in equation (1)~(3).

$CO_2 + H_2O \rightarrow H^+ + HCO_3^-$ (1)

$HCO_3^- + e^- \rightarrow CO^{2-}_3 + H_2$ (2)

$Fe^{2+} + CO^{2-}_3 \rightarrow FeCO_3 + H_2$ (3)

Due to the high CO_2 content in the produced fluid and the combination of produced water, or the water in the water-blended oil collection process mainly used in the cold areas of the north, it will cause certain corrosion to the carbon steel pipelines and equipment of the gathering and transportation system, and with the extension of the development time, the CO_2 content will increase and the corrosion will be aggravated, which will reduce the service life of pipelines and equipment.

4. Safeguard measures for the production stability of CO_2 flooding gathering and transportation system in North China Oilfield

After the oil and gas mixed transportation of 1.0MPag enters the pilot test station, the oil and water are transported to the Lida station through the new oil pipeline for processing, and the gas is reinjected with supercritical CO_2 by the compressor after degreasing, desulfurization (reserved) and dehydration, and the liquid CO_2 is stored in the LCO_2 storage tank by unloading, and then injected into the ground after being pressurized by the feed pump and injection pump.

(1)Targeted improvement of the gathering and transportation process.

① Compared with water flooding, the water content of CO_2 flooding produced fluid decreases, the gas-oil ratio increases significantly, and the oil output temperature of the wellhead decreases. In view of these characteristics, the wellhead process selects a single pipe of oil collection to the pilot test station/metering point for measurement, and each wellhead is equipped with electric heat tracing, while the viscosity depressant interface is reserved. The pressure is lower than 2.1MPa after the electric GLOBE control valve (with shut-off function) is used at the wellhead to ensure the stability of the wellhead pressure and alleviate the influence of high gas-liquid ratio on the gathering and transportation performance.

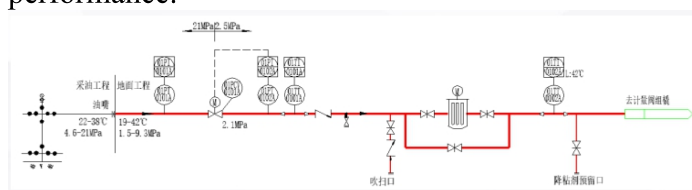

Fig. 1 wellhead process diagram

② The separation method of GLCC+ separator was innovatively adopted, and the experimental device for gas-liquid separation of CO_2 flooded foamed crude oil was designed, which reduced the residence time of crude oil in the separator to 8~17 minutes, which was about 6.4 minutes shorter than that on average, and the particle size of the droplets at the gas phase outlet was reduced to less than 50μm, which significantly improved the separation efficiency and effect.

③ Measurement process

Set up 1 set of metering valve group skid, each single well incoming liquid enters the incoming valve group, through the way of well selection and measurement, the measured single well gas-liquid enters the vertical gas-liquid separator, after separation, the gas-liquid is measured separately, and the rest of the unmetered well incoming liquid is collected and transported through the manifold. The gas phase flowmeter uses a precession vortex flowmeter, and the liquid phase flowmeter uses a double rotor flowmeter.

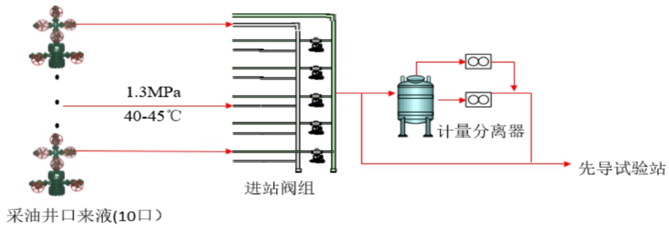

Fig 2: Metrology process

(2) Equipment selection and maintenance

The wellhead produced liquid transported by the oil collection pipeline has high CO2 content and is easy to corrode, and it is easy to freeze and plug in the process, and there is a demand for electrothermal plugging of the pipeline, so the FRP pipeline with strong corrosion resistance is used to ensure stable production. There are two main types of corrosive gas phase pipelines in the station: dry gas pipelines and wet gas pipelines. Among them, the corrosion is carried out under the condition of water content, so ordinary carbon steel can be used for the dry gas pipeline. For wet lines, corrosion is mainly caused by carbon dioxide, hydrogen sulfide, and chloride ions. According to the most demanding working conditions of gathering and transportation, CO_2 content of 99%, hydrogen sulfide content of 534mg/m3 (350ppm), chloride ion concentration of 4000mg/L, temperature of 60 °C, design pressure of 2.5MPa for accounting, ECE (Electronic Corrosion Engineer) software evaluation results show that in accordance with the evaluation principles of ECE and ISO15156.3, 316L can be used safely under this working condition.

5. Conclusions

(1) With the popularization and application of CCUS-EOR technology, CO_2 flooding oil needs to be further studied. According to the development needs, combined with the production and operation of the existing projects, it is urgent to consider the reservoir, oil production and surface engineering as a whole, and implement the prevention and control technical measures of aboveground and underground integration, so as to realize the effective injection of CO_2 and ensure the smooth operation of the production well gathering and transportation treatment system.

(2) By drawing on domestic and foreign experience and combining with its own reality, the production stability guarantee measures of CO_2 flooding gathering and transportation system proposed by North China Oilfield will help improve the application effectiveness of this technology in North China Oilfield and provide strong support for the sustainable development of the oilfield. At the same time, it also provides a useful reference for other oilfields to carry out similar work.

References:

[1] Wang Feng, Li Zheng, Zhang Deping. New progress in CCUS-EOR technology research and practice in Jilin Oilfield[J].Natural Gas Industry,2024,44 (04):76-82.)

[2] Tang Lingjian, Chang Liandong, Cong Cong. Application of corrosion protection technology for crude oil gathering and transportation process in CO_2 flooding block of Y oilfield[J].Surface Engineering of Oil and Gas Field, 2024, 43(02):74-77.

[3] Cao Wanyan. Exploration of Production Stability Assurance Measures for CCUS-EOR Oil Displacement Gathering and Transportation System[J]. Energy Conservation of Petroleum and Petrochemicals, 2023, 13(07): 53-56.

[4] Cao Wanyan. Analysis on the upstream and downstream integrated surface technology route of CCUS-EOR in Daqing Oilfield[J]. Oil & Gas & New Energy, 2022, 34(03):103-108.

[5] Zhao Xuehui, Huang Wei, Li Hongwei, et al. Research Status and Suggestions of CCUS Technology to Promote the Rapid Realization of the "Dual Carbon" Goal[J]. Petroleum Tugitulical Products & Instruments, 2021,7(06):26-32.