Study and Experiment on CCUS-EOR Technology for Shale Oil in Dagang Oilfield

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Abstract. The recovery efficiency of shale oil depletion development in Dagang oilfield is low and there is no effective technology to enhance recovery efficiency. Through physical simulation and numerical simulation, the technology of enhancing oil recovery by injecting CO_2 in shale oil was studied. At the same time, research on supporting technology of injection and production integration, corrosion prevention and control, production gas recovery and injection is carried out. Through the construction of CCUS-EOR technology system of shale oil in Dagang oilfield, this paper guides the safe and efficient implementation of field CO_2 pumping to enhance oil recovery technology. The results show that the mechanism of CO_2 in shale oil to improve oil recovery is miscibility to improve oil displacement efficiency, dissolution and permeability, plugging extraction and so on. The optimal CO_2 injection volume in a single well is 800–1500 tons, and the best smothered time is 30–40 days. The injection and production integration technology can realize the construction and drainage without moving the pipe string. Three slug corrosion inhibitor filling mode in the process of operation and intermittent dosing mode in the production process can effectively alleviate CO_2 corrosion; Output gas back injection process can realize the recycling of output

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CO_2, and can avoid the corrosion of gathering and transportation system. Field test results show that CO_2 injection is effective in improving oil recovery in shale reservoir. The supporting technologies, such as injection and production integration, corrosion prevention and control, produced gas recovery and injection, have strong adaptability, which is not only conducive to the green and low-carbon development of the oilfield, but also conducive to the realization of the national "double carbon" goal. The implementation of shale oil CCUS-EOR technology has better economic and social benefits. The research results have certain reference significance for the efficient development of shale oil and the green development of oil and gas field enterprises.

Keywords: Shale oil · CO_2 huff and puff · CCUS-EOR technology · Injection and production integration · Corrosion prevention and control · Recall injection

1 Introduction

With the improvement of multi-stage and multi-cluster large-scale volume fracturing technology of horizontal Wells in shale reservoirs, global shale oil production has increased rapidly, and has become the focus of oil and gas exploration and development in the world [1–3]. Although the initial oil recovery rate of shale reservoir is high after staged fracturing of horizontal Wells, the production declines rapidly and the primary recovery is only 5%–10% [4–6]. In recent years, continental shale oil exploration has been carried out in many basins such as Junggar, Ordos, Songliao and Bohai Bay. The shale is mainly composed of low porosity and ultra-low permeability reservoirs. Micro-pore structure is dominated by micro-pore roar [7, 8]. Due to tight reservoir, it is difficult to establish effective displacement relationship between Wells. Conventional EOR methods are not applicable. A large number of literatures show that supercritical CO_2 has the diffusivity of gas and the solubility of liquid. CO_2 has good injection ability in shale oil reservoir and extraction ability in crude oil. CO_2 can reduce the viscosity and interfacial tension of crude oil through diffusion, dissolution, extraction and miscibility in contact with crude oil [9–12]. Therefore, CO_2 enhanced oil recovery technology in shale reservoir can effectively improve shale oil production.

2 Study on Mechanism of Enhancing Oil Recovery by CO_2 Injection in Shale Oil

2.1 Miscible Phase to Improve Oil Displacement Efficiency

It is well known that if CO_2 and crude oil are miscible under reservoir conditions, oil displacement efficiency can be maximized. The minimum miscible pressure test of shale oil in Dagang Oilfield was carried out according to SY/T6573 – 2016 "Experimental Method for Determination of Minimum Miscible Pressure – Thin tube Method". The experimental results of minimum miscible pressure are shown in Fig. 2. According to Fig. 2, the measured minimum CO_2 and shale oil miscible pressure is 36.8 MPa, lower than the current formation pressure (40.76 MPa) and the original formation pressure

(46.29 MPa). It is concluded that CO_2 can be immiscible with shale oil under reservoir condition, which can improve the oil displacement efficiency of shale oil to the greatest extent (Fig. 1).

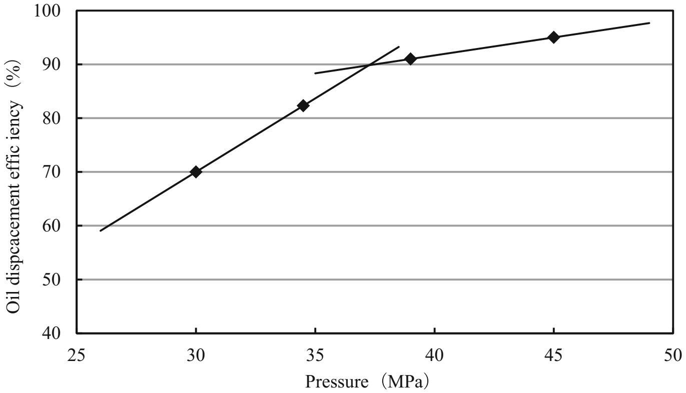

Fig. 1. CO_2 minimum miscible pressure experiment result

2.2 Miscibility Reduces Viscosity and Improves Fluidity of Shale Oil

The viscosity of crude oil was measured under different gas-liquid ratios at reservoir temperature and pressure. As can be seen from Fig. 3, with the increase of gas-oil ratio, the viscosity of crude oil decreases obviously, and the viscosity reduction rate increases rapidly. However, after reaching a certain amount (150 m^3/t), the viscosity changes and viscosity reduction rate slow down. In engineering practice, CO_2 and crude oil constant contact miscible, viscosity is greatly reduced, crude oil liquidity is improved, conducive to the flow of crude oil from the formation to the wellbore; In the lifting process, due to the continuous reduction of pressure, CO_2 will gradually escape from the oil, but there is still a part of the CO_2 dissolved in the oil, low crude oil viscosity conducive to wellbore lifting.

2.3 The Seepage Channel is Expanded by Dissolution and Seepage Enhancement

The corrosion effect of CO_2 combined with formation water on formation rock was studied. The effect of CO_2 on the corrosiveness of rock mineral composition under the condition of reservoir temperature and pressure is studied through rock dissolution experiment. The study shows that CO_2 dissolve mudstone has the largest proportion, has the effect of dissolution and permeability increase 41.86%. Analysis of the main reason for CO_2 water to form carbonic acid, with the dissolution of rock mineral components and acidification to remove the effect of inorganic scale blocking. In the process of CO_2 injection, when the pressure and temperature reach a critical state, the supercritical CO_2 solvent will dissolve organic scale, thus expanding the seepage channel and improving the permeability.

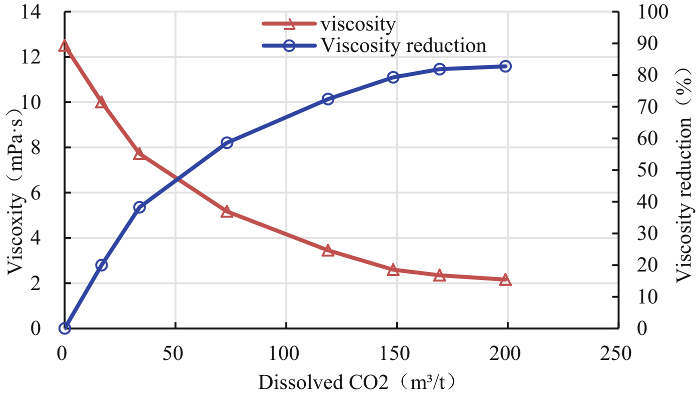

Fig. 2. Variation curves of shale oil viscosity and viscosity reduction under different gas-liquid ratios

In addition, due to CO_2 injection, reservoir formation acidic environment, H+ ion concentration in the solution, the pore surface and clay particles surface of the negative charge to reduce, the pore surface and clay particles between the surface of the exclusion potential energy decreased, therefore, clay particles are not easy to directly from the pore wall surface dispersion off; The remaining H+ after the fixed adsorption of pores and clay particles on the surface is conducive to the compression of the negative double layer, which further inhibits the expansion, dispersion and migration of clay minerals, and consolidates the fluidity of the permeability channel (Fig. 4).

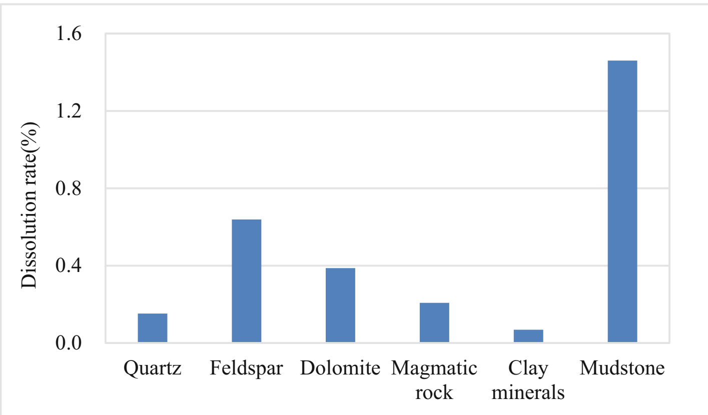

Fig. 3. Experimental results of CO_2 dissolution on different minerals

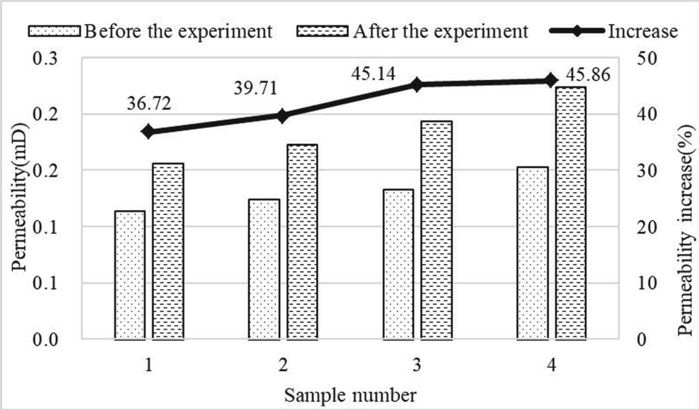

Fig. 4. Comparison of core permeability changes before and after the experiment

2.4 Reduce the Viscosity of Residual Fracturing Fluid and Help Flow Back

At present, the shale reservoir in Dagang Oilfield is put into production by using horizontal well + multistage multi-cluster large-scale volume fracturing. High polymer is the main component of slick water used in fracturing. Polymer solution was used in the field to evaluate the effect of CO_2 on polymer solution. According to the experimental results, CO_2 can greatly reduce the viscosity of polymer solution, reducing the viscosity of 98.25%. The main reason is that the molecular chain of the polymer system is damaged under acidic conditions, and the polymer becomes small molecules, thus improving the mobility. Reflecting to the engineering for CO_2 can greatly reduce the residual fluid viscosity in the reservoir fracturing, improve the residual flow capacity, dredge the seepage channel, conducive to the flow of shale oil, play the role of blocking oil (Table 1).

Table 1. Viscosity data of polymer solution before and after passing into CO_2

State	Initial normal temperature	Reservoir temperature is not CO_2	Reservoir temperature passes into CO_2	CO_2 viscosity reduction rate (%)
Polymer solution viscosity/mPa·s	78.6	62.8	1.1	98.25

2.5 Replenishment of Formation Energy

Under reservoir temperature and pressure, CO_2 is continuously added to the crude oil, and the expansion coefficient and volume coefficient are calculated by recording the volume data after miscible. Figure 3 shows that the volume coefficient and expansion coefficient of crude oil increase linearly with the increase of CO_2 dissolution. When the CO_2 dissolved in crude oil is 198.95 m^3/t, the formation oil volume coefficient is 1.26, which means that the oil has expanded by 26%, and the volume coefficient is 1.44. As CO_2 dissolves in crude oil, it can swell shale oil and increase the elasticity of crude oil. At the same time, it further increases the function of squeezing out the crude oil from the matrix. The CO_2 in the well is heated continuously in the reservoir and expands in volume to further replenish the reservoir energy. After well production, the reservoir pressure drops rapidly, the dissolved gas in the fluid expands rapidly and out, driving the crude oil into the wellbore, forming the internal dissolved CO_2 drive, but also improve the capillary suction effect, resulting in the expansion of the oil drive range, increase the sweep coefficient and single well productivity (Fig. 5).

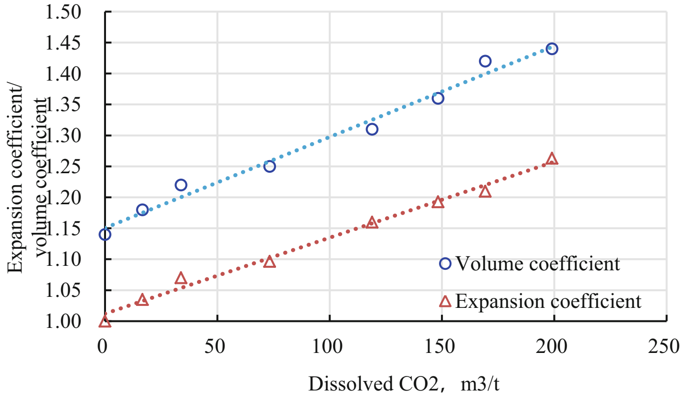

Fig. 5. Change curves of shale oil viscosity and viscosity reduction under different gas-liquid ratios

3 Optimization Design of Injection and Production Process Parameters

In combination with the mechanism understanding, three key injection and production parameters optimization methods such as injection volume, implementation mode and shuttering time were formed through comprehensive analysis of reservoir geological parameters, drilling and well type data, fracturing scale and production data.

3.1 Injection Volume Optimization Design

CO_2 injection volume is an important factor determining the efficiency of shale oil throughput. According to a study on the effect of CO_2 injection on oil increase and oil change (Fig. 6), the amount of oil increase increases as CO_2 injection increases, but the rate of oil change decreases. The reason is that when CO_2 injection is low, the recovery rate of shale oil is greatly increased due to its mechanism of dissolution, expansion, viscosity reduction, and extraction. With the continuous production of crude oil, the remaining oil content decreases gradually, and the CO_2 injected later cannot be fully utilized. At the same time, too much CO_2 makes the volume of crude oil expansion, so that a part of the oil flow to the matrix, increase the CO_2 further to the matrix diffusion resistance, to a certain extent increased the difficulty of mining. When the injection volume is 1,000 tons, the oil increase volume is 1,260 tons, and the oil change rate is 1.26. Combined with the oil change rate, the optimal CO_2 injection volume in a single well is 800–1,500 tons.

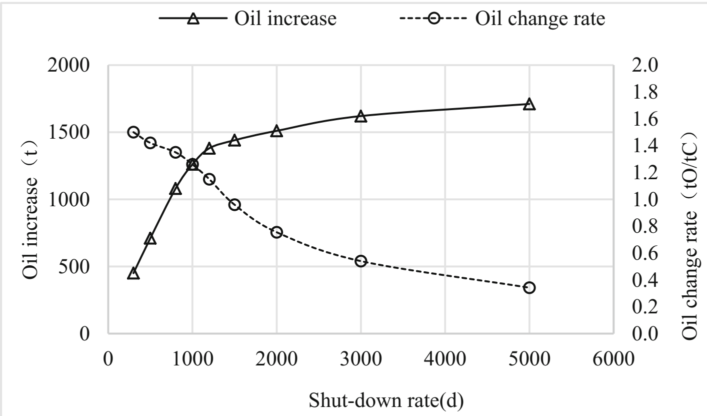

Fig. 6. Relation curve of injection amount, oil increase amount and oil change rate

3.2 Embodiments Design

Combined with the CO_2 injection stimulation mechanism, well connectivity and production data of shale oil, the differentiated implementation mode of single-well self-service CO_2 throughput and discharge, well group CO_2 throughput and discharge cooperative flooding, "CO_2 + water/active water" composite throughput and discharge is studied, which effectively guides different types of shale oil old Wells to implement personalized CO_2 throughput and discharge stimulation technology.

(1) For shale oil Wells not connected with adjacent Wells, the design of a single well self-help CO_2 inhale implementation mode, CO_2 through the wellbore into the formation, through pressure diffusion, give full play to the "CO_2- oil - water - rock" interaction.
(2) For shale oil well groups that can establish displacement relationship, CO_2 huff and puff cooperative flooding mode is adopted. This implementation method can play the dual roles of injection well huff and puff and interwell displacement, and displace the remaining oil around injection well to the vicinity of production well and produce it through huff and puff production wellhead and interwell remaining oil.
(3) For Wells with high recovery rate (total production fluid/fracturing fluid *100%), the "CO_2 + water" compound huff and discharge implementation mode is used. Prior to

the reservoir water replenishment energy, and then inject a certain amount of CO_2, and then inject post displacement water. The multi-effect synergies of water injection energy replenishment, imbibition displacement and CO_2 huff and exhalation increase can be used to improve shale oil recovery.

3.3 Optimal Design of Shut-Off Time

Theoretically, the longer the well is kept shut, the better the recovery. However, when the well is smothered for a long time, CO_2 on oil extraction capacity will decrease significantly, but also increase the production time, reduce the oil well running rate. Therefore, there exists an optimal dull time in actual production. The study showed that the oil gain and oil change rate increased significantly with the prolonged period of shut-off, but the oil gain and oil change rate decreased after 40 days. Therefore, for shale Wells with CO_2 inhalation, the optimal design period is 30 to 40 days (Fig. 7).

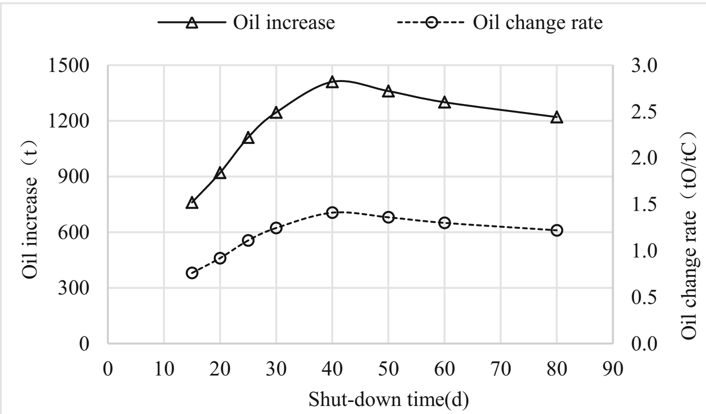

Fig. 7. Relation curve between the time of shut-off and oil increase and oil change rate

4 Research on Supporting Technology

4.1 Injection and Production Integration Technology

Shale oil reservoir has the characteristics of low seepage velocity and easy to be disturbed. Considering reservoir protection, production, economic benefits and other aspects, the use of integrated injection-production technology can realize the immobile column injection CO_2 and lift production. It is beneficial to reduce well killing operations, prevent interference with shale oil seepage flow field and affect production recovery, reduce operation and save operating costs, thus improving economic benefits, and realize casing corrosion protection. Combined with the properties of shale oil, two kinds of injection and production integration technology are supported, which is "pumping unit + hydraulic feedback pump" and hydraulic jet pump.

4.1.1 "Pumping Unit + Hydraulic Feedback Pump" Process

This process can perform CO_2 reverse injection, and can also implement positive injection after lifting the sucker rod. The hydraulic feedback pump wellbore is two pump barrels. When the upper stroke, the lower oil outlet valve closes, the oil inlet valve opens, the liquid on the pump is lifted to the ground, and the liquid under the pump enters the annulus between the upper plunger and the pump barrel. When the down stroke, the oil outlet valve opens, the oil inlet valve closes, and the internal hydraulic force of the loop control enters the pump, generating an upward feedback force on the upper part, reducing the force of the rod column when the pump rod goes down. The process is less affected by CO_2 downhole tools, CO_2 injection can reduce the contact area between CO_2 and casing, minimize the corrosion of CO_2 on casing, great promotion potential.

4.1.2 Hydraulic Jet Pump Technology

The process can realize tubing injection CO_2, reduce CO_2 and casing contact area, minimize CO_2 on casing corrosion. The process can be divided into positive circulation, reverse circulation and concentric double-tube process due to different power liquid channels. Positive circulation power fluid is injected through the tubing and production fluid is discharged from the jacket annulus. Reverse circulation power liquid from the oil jacket annulus injection, output liquid from the oil pipe discharge, can avoid CO_2 on the sleeve corrosion. Concentric two-tube power fluid is injected through the tubing, and the production fluid flows out of the annulus of the large and small tubing, eliminating the need for a packer. In this process, the hydraulic pump liquid volume adjustment range is large, can greatly extract liquid production, but there are problems such as the need for supporting ground process and water injection pump, coordination of power liquid water source and so on.

In general, the above two kinds of injection and production integration technology can basically realize the shale oil multi-round CO_2 throughput immobile pipe string high efficiency lifting, for CO_2 throughput and output stimulation effect provides wellbore protection.

4.2 Corrosion Control Technology

After CO_2 is injected into the reservoir, CO_2 dissolves in water and forms carbonic acid. Under the same pH condition, carbonic acid has a higher acidity and is more corrosive to oil well pipes than hydrochloric acid. In order to further explore the corrosiveness of CO_2 on commonly used pipes, combined with the material of shale oil pipe column made of corrosion hanging sheet, simulate the corrosion environment of CO_2 in Dagang oil field shale oil, carry out indoor corrosion experiments, study the corrosion effect of CO_2 on different materials, and carry out the performance evaluation of supporting corrosion inhibitor. Through the study, the formation of shale oil CO_2 throughput corrosion prevention and control technology.

4.2.1 Comparison of Material Corrosion

CO_2 corrosion effect tests were performed in different materials such as N80, 1Cr, 3Cr, 9Cr, and 13Cr at 130 °C and 40 MPa. According to the test results, the above material on CO_2 corrosion reaction degree, among which N80 corrosion is the most serious, the higher the Cr proportion, the better the corrosion resistance. However, although there was no obvious pitting on the surface of 1Cr material, the corrosion rate reached 2.4 mm/a after weighing, and 9Cr and 13Cr had the best corrosion resistance (Fig. 8).

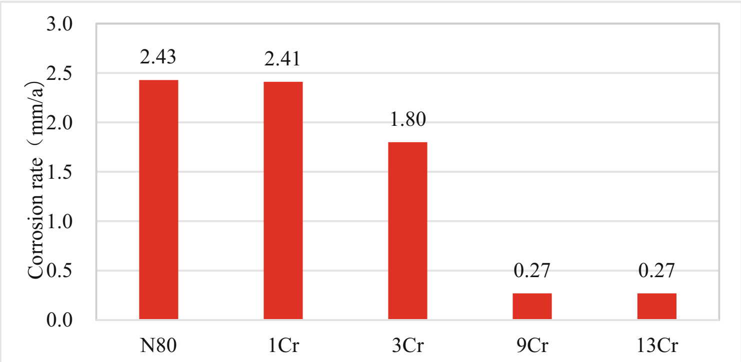

Fig. 8. Corrosion rates of different materials

At present, most pipe strings of shale oil well in Dagang Oilfield are not resistant to carbonic acid corrosion. The design uses the form of adding corrosion inhibitor to alleviate the corrosion of downhole pipe string, carries out the optimization of corrosion inhibitor and dosing process design.

4.2.2 Screening and Evaluation of Corrosion Inhibitors

Four different types of corrosion inhibitors were selected to carry out static corrosion experiments at atmospheric pressure. It can be seen from the experimental results that after adding 200 ppm corrosion inhibitor, the corrosion inhibition effect of 3# and 4# is better, and the corrosion inhibition rate is more than 85%, which is designated as formula 1 and formula 2 (Table 2).

4.2.3 CO_2 Huff and Spit Corrosion Prevention and Control Drug Technology

CO_2 throughput design and construction must choose one or more of the following four ways to implement corrosion inhibitor dosing. The dosing duration of each huff and puff well should not be less than 180 production days after recovery. Four dosing processes have been developed and technical requirements for corrosion monitoring have been established.

(1) Three-stage liquid corrosion inhibitor dosing process. In the carbon injection construction stage, CO_2 injection before and after the design of pre-corrosion inhibitor

Table 2. Static experiment results at atmospheric pressure

Corrosion inhibitor	Dosing concentration (mg/L)	Corrosion rate (mm/a)	Corrosion inhibition rate (%)
/	/	0.193	/
1#	200	0.069	67.3
2#	200	0.053	74.6
3#	200	0.03	85.9
4#	200	0.024	87.9

slug, antifreeze and protective liquid slug, post-corrosion inhibitor slug and other three-stage liquid corrosion inhibitor adding process, with the highest displacement of the pump car into the corrosion inhibitor solution. After 30 production days of huhuatu well stoping, test the corrosion inhibitor concentration in the produced solution every other week. If the concentration of corrosion inhibitor is lower than 100 mg/L, other periodic processes should be used to continue adding corrosion inhibitor.

(2) Periodic addition of solid corrosion inhibitor technology. Periodically from the casing to add solid corrosion inhibitor particles, the first add solid corrosion inhibitor before injecting CO_2, Huatu well after mining every 60 $\pm$ 10 production days add a solid corrosion inhibitor. The dosage of each dosing is two millionths of the accumulated production volume of 60 $\pm$ 10 production days. When there is no pressure in the casing, solid corrosion inhibitor is injected into the casing annulus using a charging cylinder. When the casing is under pressure, solid particle corrosion inhibitor is carried by water and injected into the casing by pump truck.

(3) Periodic adding of liquid corrosion inhibitor technology. Liquid corrosion inhibitors are periodically added from casing for huff and puff Wells where the annulus is unobstructed from head to bottom. After Huatu well recovery, liquid corrosion inhibitor is injected every 30 $\pm$ 5 production days, and the dosage of each injection is two millionths of the accumulated production of 30 $\pm$ 5 production days. When there is no pressure in the casing, the liquid corrosion inhibitor is poured into the casing with a charging drum. When the casing is under pressure, use a pump truck or other pumping equipment to inject liquid corrosion inhibitor into the casing.

(4) Continuous addition of liquid corrosion inhibitor technology. For a huff and dump well with a clear annulus from the wellhead to the bottom of the well, liquid corrosion inhibitor is continuously injected into the casing by means of a storage tank, a dosing pump, and a dosing line. Dosing facilities and lines need to be installed and connected during the period of stifling. The casing is continuously injected with liquid corrosion inhibitor at the start of recovery. The daily capacity of the dosing pump is two millionths of the daily output of the extraction fluid in Huff and spit well.

4.3 Production Gas Recovery Injection Technology

CO_2 discharge well and production stage there will be CO_2 gas output, there are three main drawbacks. First, in the shaft and gathering and transportation system with water and form carbonic acid corrosion metal material; Second, excess CO_2 in the associated gas can affect the quality of natural gas; Third, in the discharge and injection stage, the produced gas should not enter the gathering and transportation system. The use of air discharge and injection will cause greater greenhouse gas emissions, and the safety and environmental protection risks are greater. Therefore, it is necessary to separate, recycle, and reuse the produced CO_2. Not only can the above three problems be solved effectively, but also CO_2 utilization rate can be increased. Aiming at the above goals, the research team carried out the research and field test of the produced gas separation and recovery injection process, so as to form an economical and efficient produced gas separation and recovery injection technology suitable for Dagang oilfield. The process technology is mainly divided into two units.

4.3.1 CO_2 Output Gas Decarbonization Recycling Process

This process consists of a three -phase separator, decarburization unit, liquefied recycling unit, and rebate unit. The gas source treated by a three -phase separator enters the decarbolization unit, first enter the centrifugal water removal tank, rely on gravity impact to remove most of the liquid water in the gas, and after filtering by a coarse filter, enter the screw compressor to make the gas source supercharged As of 1.6MPa, the pressure of the gas source was dehydrated through the frozen dryer, and then entered the activated carbon tank to remove the heavy hydrocarbons above C4 and above. The gas entered the natural gas -specific separation membrane group after multi -stage filtration. Use the selection of membrane materials to infiltrate the characteristics to separate the gas from the gas. The export of the membrane group seepage to the side export obtains a natural gas with a purity of $\geq$90.0%, and directly returns to the natural gas pipe mesh; the membrane osmotic side obtains the osmotic air rich in CO_2, and the permeable air will enter the recycling unit. The osmotic air is compressed and compressed to 2MPa. After dehydration and dehydration, enter the refrigeration compressor, and the temperature is reduced to -35 °C. At this time, most of the CO_2s are liquefied, the liquid CO_2 enters the tank, and the purity of the liquid CO_2 is $\geq 90\%$. At the same time, there are a small part of the non -condensation gas. The main components are natural gas and CO_2. If the gas does not condensed, it will return to the film group imports, separate the circulation, and achieve the "zero" row of the tail gas.

4.3.2 CO_2 Output Gas Reinjection Process

This process can realize the direct compression of the output gas, and the process is simple. After the output of the oil well is separated by three phases, the gas pressure control is controlled within the range of 0.2–0.4 MPa. After drying and removing the hybrid processes, entering the backpack compressor, and finally the supercharged return to the underground. Back compression unit adopts horizontal symmetrical balance to a duplex compressor. The cylinder lubrication form is forced lubrication for less oil. The whole machine uses a single pry layout, which contains compressors, explosion -proof motors, frozen dryers. Qi compression back note. The liquid water generated in each link is concentrated in the sewage tank.

5 Field Test Effect

In total, Dagang Oilfield has implemented single-well self-service CO_2 huff and puff 4 times, well CO_2 huff and puff cooperative flooding 1 well group (3 Wells), "CO_2 + water" complex huff and puff 1 well group (3 Wells). Implementation effect as shown in Table 3, a total of 5250 tons of CO_2, cumulative oil 3814 tons, period of validity 54–442 days, the effective period of the average daily increase in oil 15.99 tons, input-output ratio 1:2.57, oil effect and economic benefits are significant.

Wang Gaoping, Li Kunquan et al. studied CO_2 geologic storage in low permeability reservoir, and gave that CO_2 geologic storage rate was 64.8–73.2% [13, 14]. Combined with CO_2 throughput technology CO_2 backdischarge rate is higher, CO_2 geological storage rate is estimated to be 50%, forecast Dagang oil field can achieve CO_2 geological storage for 2625 tons, has significant social benefits.

Table 3. CO_2 huff and puff effect of shale oil in Dagang oilfield

Mode of implementation	Well	Carbon/water injection (t/m^3)	Stage increase in fuel volume (t)	Validity period(d)	Average daily oil increase during the effective period(t/d)
Single well self-help CO_2 puff and spit	Well 1#: CO_2 well	773	295	208	1.42
	Well 2#: CO_2 well	973	566	180	3.14
	Well 3#: CO_2 well	743	161	237	0.68
	Well 4#: CO_2 well	489	401	199	2.02
Well group CO_2 huff and puff synergistic flooding	Well 5#: Adjacent benefit well	/	1978	362	4.95
	Well 6#: CO_2 well	1004		411	
	Well 7#: Adjacent benefit well	/		442	

(*continued*)

Table 3. (*continued*)

Mode of implementation	Well	Carbon/water injection (t/m^3)	Stage increase in fuel volume (t)	Validity period(d)	Average daily oil increase during the effective period(t/d)
Well group "CO_2 + water" compound huff and puff/drive	Well 8#: CO_2 well	968	413	69 54 290	3.78
	Well 9#: Water injection + CO_2 well	300/10000			
	Well 10#: Adjacent benefit well	/			
Total		5250/10000	3814	/	15.99

6 Conclusion and Prospect

(1) It is clear that CO_2 in shale oil enhances shale oil recovery mechanism by miscibility improving oil displacement efficiency, miscibility reducing shale oil viscosity, dissolution increasing permeability, plugging relief helping backflow recharge and filling formation energy, and forming an optimal design method of injection volume, implementation mode and smoking-time. Field application results show that shale oil filling CO_2 huO2 increase oil effect and economic and social benefits are significant. Carbon storage can be realized at the same time of oil increase, which provides a feasible technical route for the development of green benefits of shale reservoir.

(2) The formation of the shale oil CO_2 enhanced recovery technology as the main body, injection and production integration, corrosion prevention and control, production gas recovery injection and other supporting technology organic integration of CCUS-EOR technology, to achieve the immobile column construction, efficient corrosion prevention and control, CO_2 recycling utilization, conducive to the rapid development of shale oil CO_2 extraction technology.

(3) With the deepening of shale oil exploration and development and the urgent demand of improving shale oil recovery efficiency, CO_2 throughput will be developed from a single well measure to the direction of the whole reservoir. At the same time, in response to the national strategy of "carbon peak and carbon neutrality", the company has actively built the CCUS-EOR demonstration area of characteristic shale oil in Dagang Oilfield according to local conditions, so as to achieve carbon reduction, green and efficient production of shale oil.

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