Million-Tonne

CO_2 Capture, Utilization and Storage(CCUS)

The Qilu-Shengli Oilfield Project

中国石油化工集团有限公司
SINOPEC GROUP

SINOPEC，CHINA

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Outline

1. Introduction

◆ The Qilu-Shengli Oilfield Project

The largest CCUS project in China.

(1) CO_2 captured from Qilu Petrochemical Company

(2) Through 114.5 km pipeline to Shengli Oilfield for CO_2-EOR and storage

(3) Injected into low permeability reservoirs, expected EOR by 11.6%

1. Introduction

◆ Project timeline

Date	Events
June 9, 2013	CO_2 high pressure miscible flooding pilot test at block G89-1&F142.
June 11, 2021	The preparation of the Qilu-Shengli Oilfield CCUS Project completed, including reservoir engineering, surface engineering, injection and production engineering, and monitoring engineering.
July 5, 2021	Sinopec began the construction of China's first Million-Tonne CCUS Project: Qilu-Shengli Oilfield CCUS Project.
April 4, 2022	Pilot operation of the Million-Tonne CCUS Project.
August 25, 2022	The CCUS demonstration project was fully completed and operated, and runs well up to now.

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Sinopec

One of the largest integrated energy and chemical companies in the world.

Upstream

- China’s No.2 oil & gas producer
- Annual production nearly 40 million tonnes

Refining

- No.2 refining capacity in the world
- Annual refining capacity close to 300 million tonnes, approximately 31% of China's total refining capacity

Marketing

- No.1 distribution network for refined oil products in China
- Gas stations over 30,000

Chemicals

- No.1 ethylene producer in China, No.3 globally
- Annual ethylene output over 13 million tonnes

Trading

- World’s leading crude oil trader

Sinopec has many advantages of engaging in all stages of the CCUS process.

(1) CO_2 capture engineering

- The exhaust emissions from coal gasification are initially captured.
- The captured exhaust is further processed through a series of steps, including cooling, dehydration, liquefaction, and purification using a distillation tower.
- The liquid CO_2 purity ＞ 99%.

Compression unit

Liquefaction purification unit

Propylene refrigeration unit

CO_2 storage unit

(2) CO_2 pipeline engineering

- The Qilu-Shengli Oilfield CO_2 pipeline, 114.5-kilometer long.
- The maximum transmission capacity of 1.7 million tonnes per year.
- The pipeline is under operation.

(3) Surface engineering

The injection, gathering, and reinjection of produced gas has been completed.

Injection system

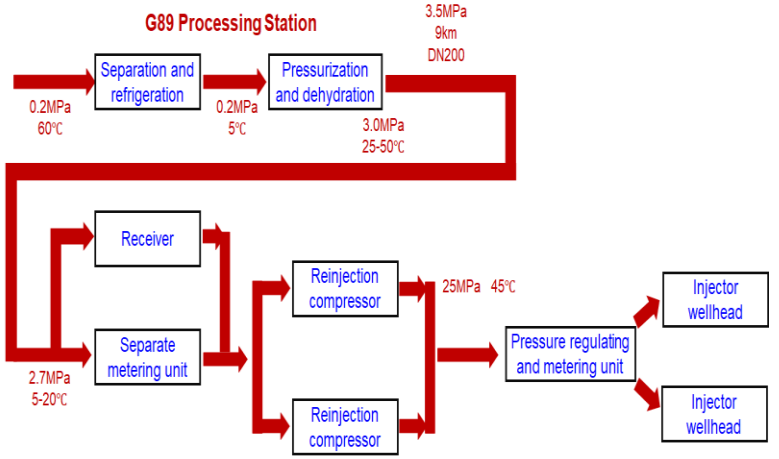
- 15 new injection plants
- Skid-mounted equipment
- Regional information center

Oil gathering system

- 2 regional oil gathering centers East/West, Enclosed produced gas and liquid gathering, and processing system

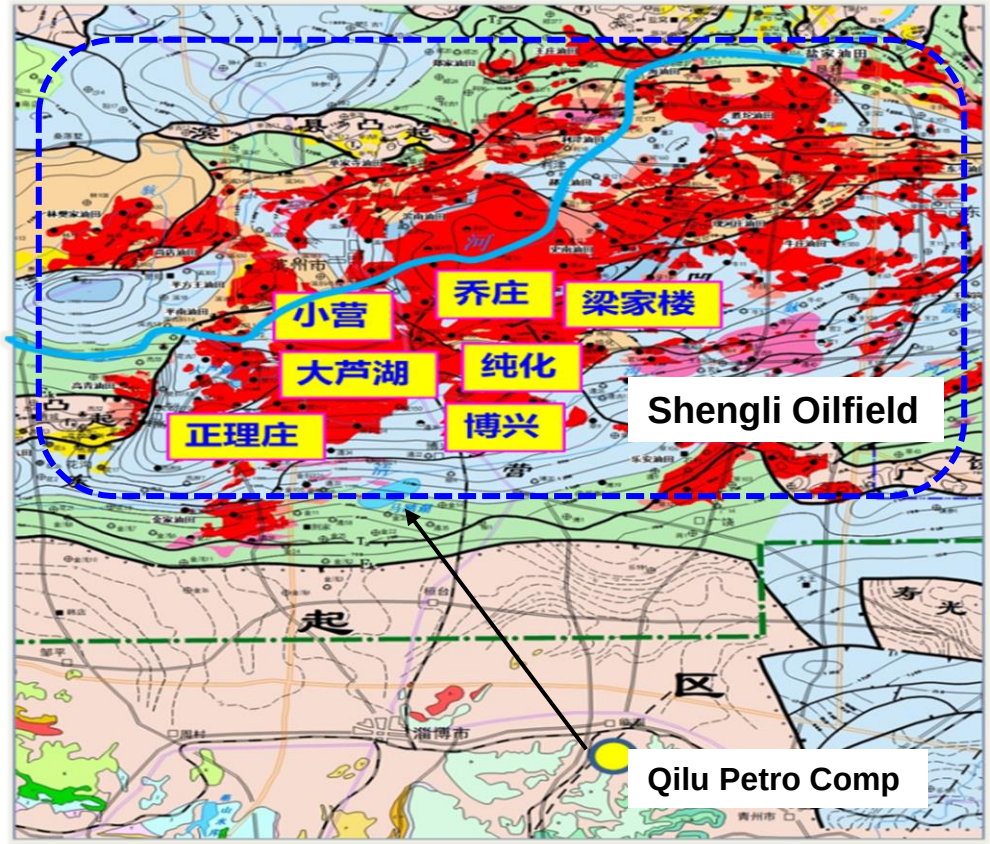
Reinjection system

- Produced gas is pressurized and reinjected to formation



(4) CO_2 flooding and storage engineering

➢**Project site： block G89&F142 in Jiyang Basin**



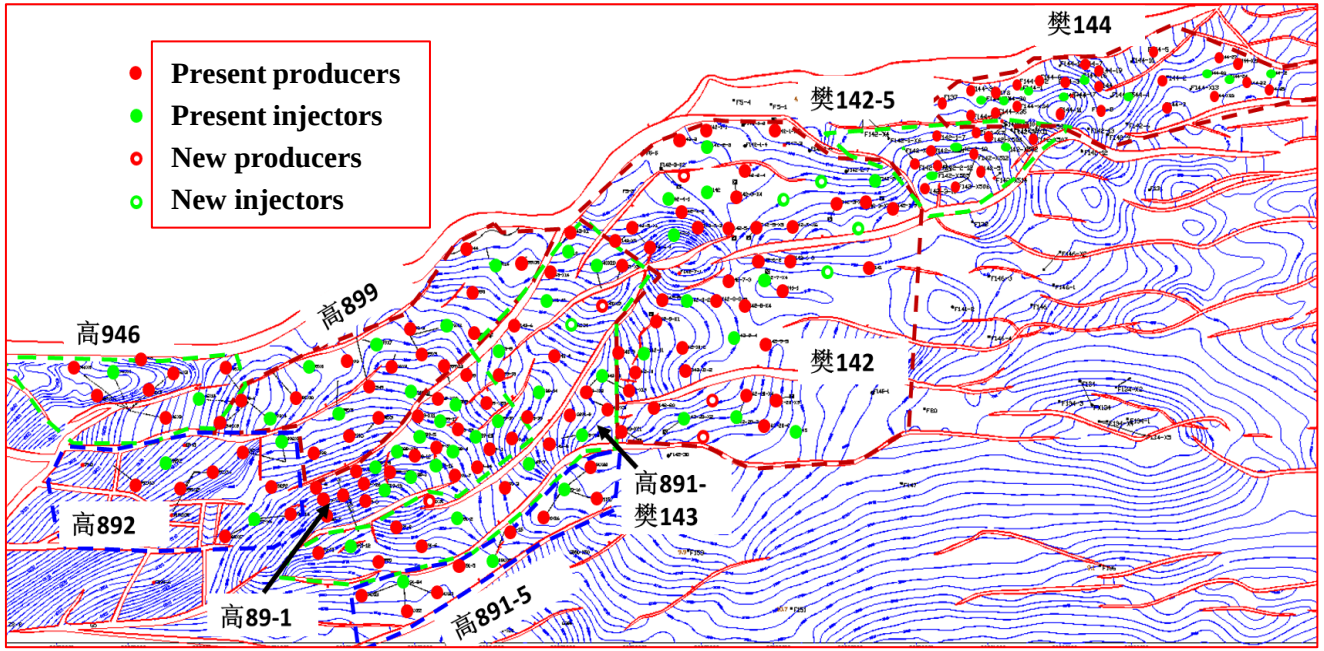
- 48 km^2 area
- Geological reserve 25.62 mts
- Depth 3000-3500m
- Thin layers, low permeability (< 5mD), strong heterogeneity
- Underground viscosity < 3cP.

(4) CO_2 flooding and storage engineering

- 73 injectors 166 producers
- Expected oil production 351,000 ts/yr

- Expected EOR by 11.6%
- Expected incremental oil production 2.97 mts

The Qilu-Shengli oilfield project well pattern



Development technical policies

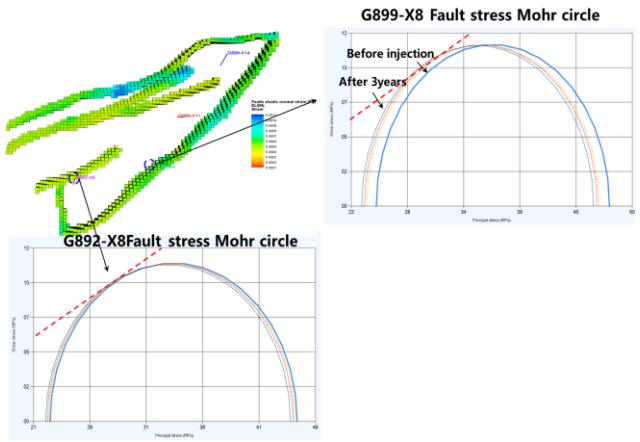
Development method	High-pressure miscible flooding
Well pattern	Irregular area well pattern
Pressure level	1.2 MMP
Injection method	Water alternating gas injection
Injection rate	40-60t/d

(5) Monitoring engineering

- Geological safety: fault and cap sealing ability evaluation
- Well integrity: injection-production wells and cement rings evaluation
- Environmental risks: real-time monitoring of air, soil and water

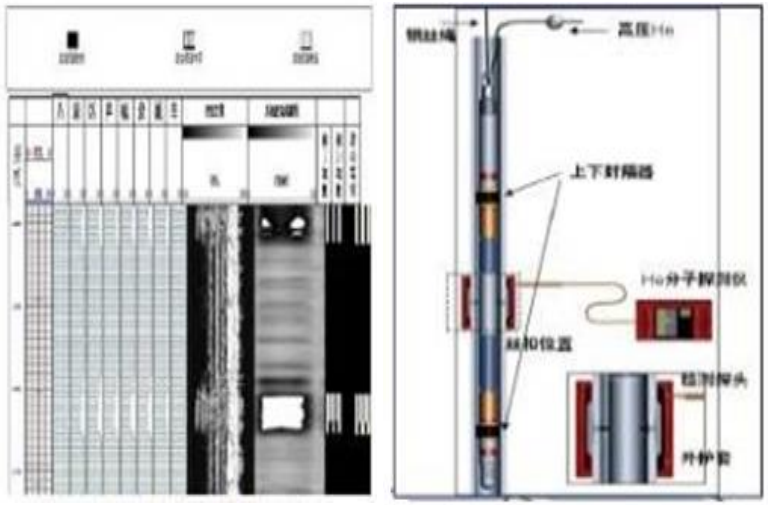
Faults and caps evaluation

Safety assessment of faults



To realize dynamic tracking of pressure field and stress field based on Multi-field coupling simulation. The faults and caps stability was evaluated according to the stress Mohr circle.

Well bore integrity

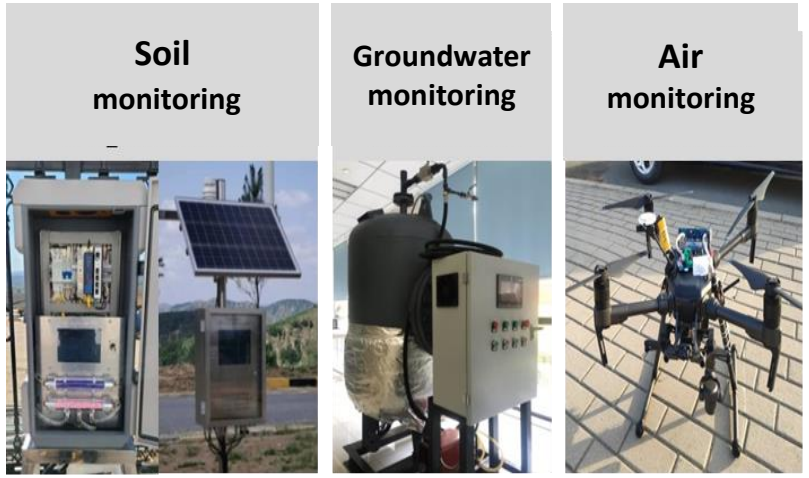


Eight-sector detection

Helium gas seal detection

Quantitative evaluation of casing condition by “40 arm imaging+electromagnetic flaw detection”.

Environmental monitoring



An integrated technology of all-temporal and spatial CO_2 safety monitoring and early warning was constructed.

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(1) CO_2 capture technology

- Low temperature distillation: Propylene refrigeration, -23℃, Pressure, 2 MPa.
- Low energy consumption: waste heat utilization, energy recovery and gas separation pressure optimization, the energy consumption reduce by 10%.
- The capture cost has been reduced by 40%.

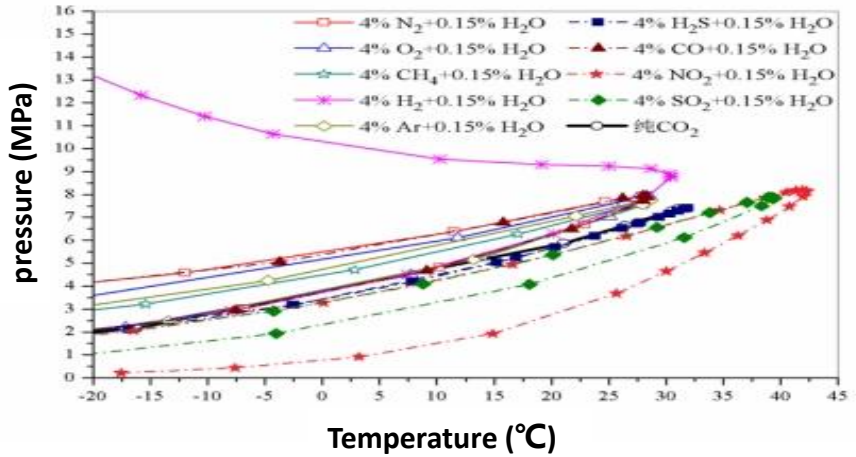
Efficient packing in extraction tower

Waste heat / residual pressure utilization technology

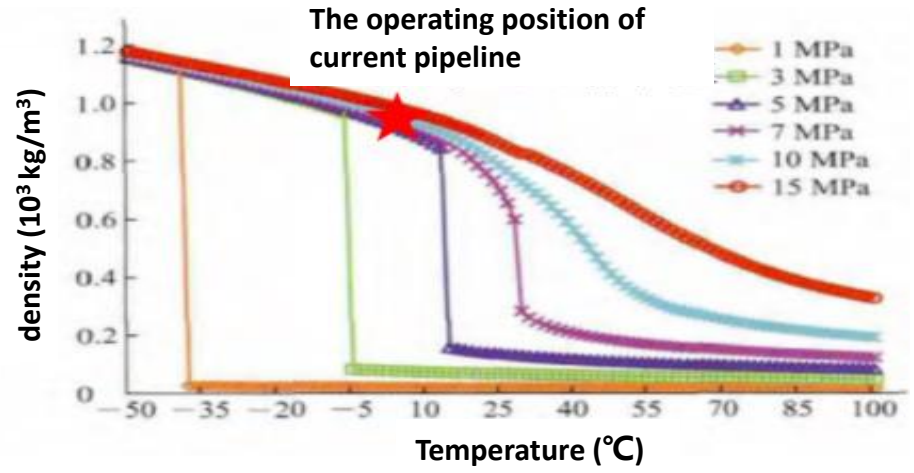
(2) CO_2 pipeline transportation technology

- Designed initial pressure: 10 MPa. End pressure: 9 MPa.
- Pressure control: less than 1.0MPa per 100km.
- Stability of CO_2 phase: prevent the generation of hydrate.

Phase curves with different impurities



CO_2 density curves at different pressures and temperatures



(3) CO_2 injection technology

◆ High pressure injection system

- The first set of equipment in China: storage tank, injection pump, measurement unit, and partial pressure injection.
- The injection pressure reaches more than 40 MPa.

Storage tank

- Automatic stabilized pressure
- Stable constant low temperature

Recycling

Injection

Injection pump

- High-pressure gas-liquid separation device
- High-efficiency airtight injection

Measurement unit

- Improved metering accuracy
- Inject multiple wells at the same time

Injectors

(4) CO_2 flooding and storage technology

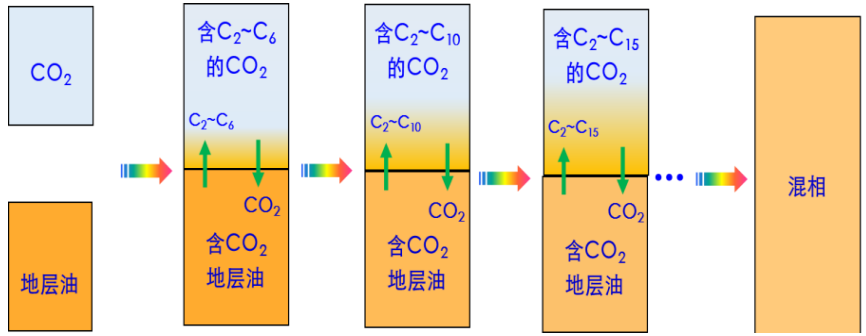
◆ CO_2 high pressure miscibility flooding

Build a high-pressure flooding system, to improve miscibility, expand sweep efficiency more than 30%, greatly increase recovery(>8%) and CO_2 storage.

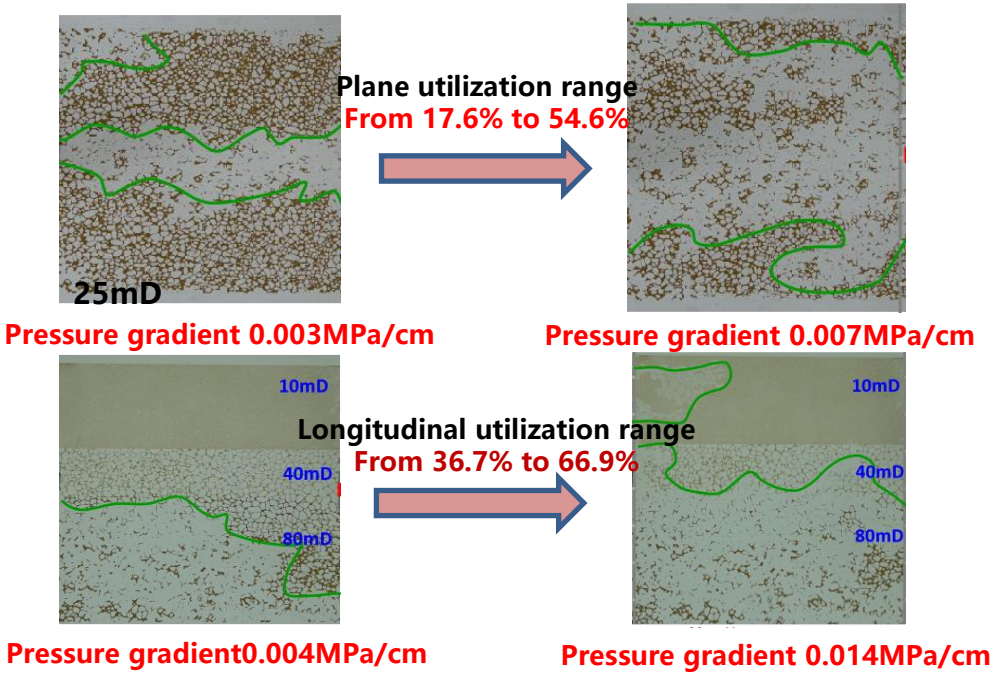
The number and type of hydrocarbons in the gas phase increase.

0.7MMP ➡ 1.0MMP ➡ 1.2MMP

Mainly C_2-C_6	Mainly C_2-C_{15}	Mainly C_2-C_{20}
7.5% in gas phase	15.4% in gas phase	20.8% in gas phase



High pressure gradient can effectively improve the production degree of low permeability area.



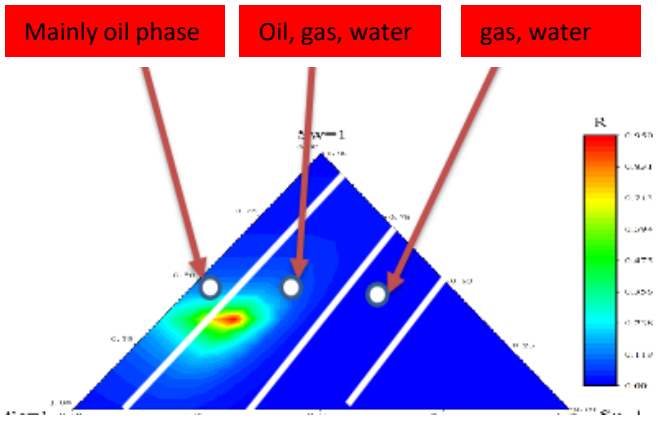
(4) CO_2 flooding and storage technology

◆ Injection optimization

- Gas-water alternating technology: dynamic gas-water ratio, and solves gas channeling.
- The initial injection gas slug was 0.1PV, changed to 0.05PV after 1PV.
- Raise the sweep efficiency by 14% and improve the oil recovery by 11%.

Maximizing the three-phase resistance

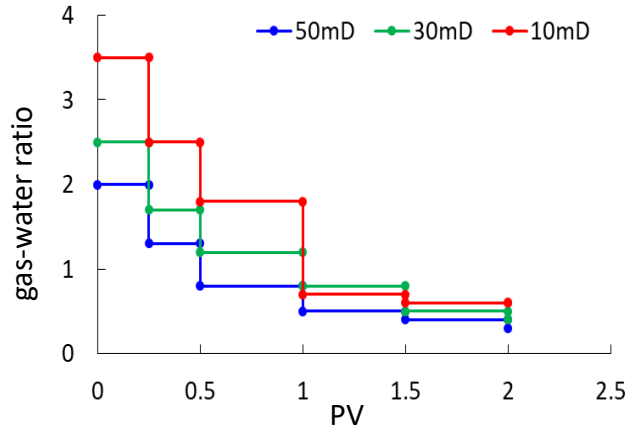
The injection gas-water ratio for the required maximum flow resistance varies depending on the remaining oil saturation



Distribution of resistance for three-phase

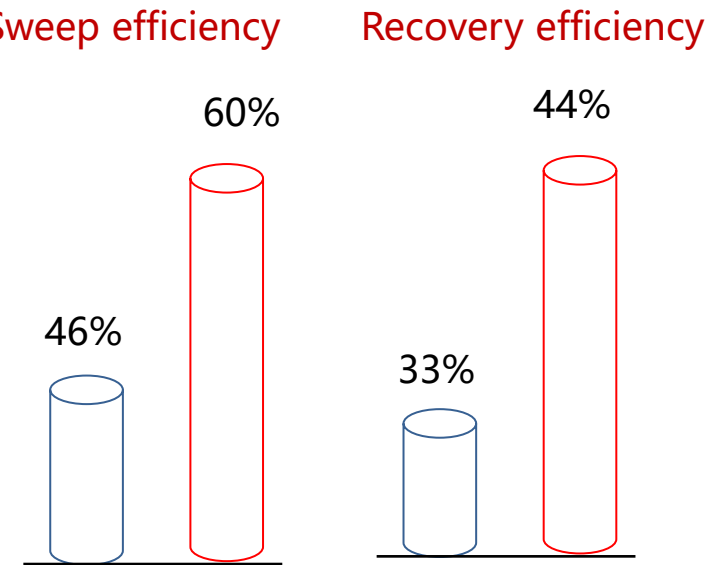
Dynamic gas-water ratio

Adjusting the gas-water ratio to ensure high resistance throughout the entire process



Dynamic gas-water ratio optimization

Expand swept volume



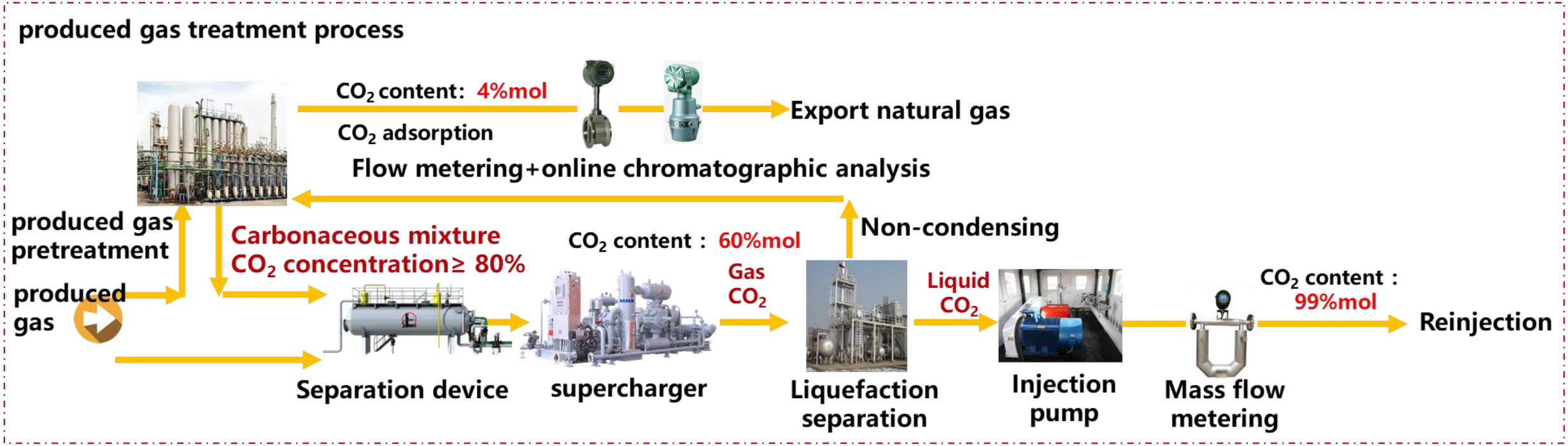
Before and after implementation

Before and after implementation

(4) CO_2 flooding and storage technology

◆ Produced gas reinjection technology

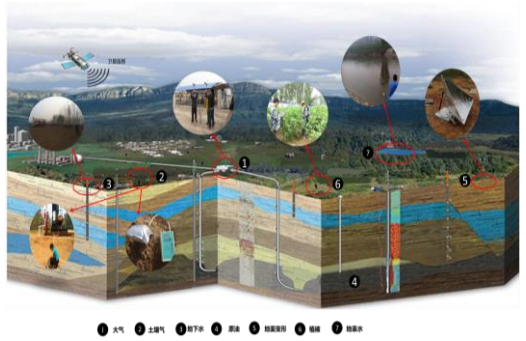
- The technology consists of pretreatment, low-temperature liquefaction separation and low-temperature liquid CO_2 reinjection.
- Produced gas reinjected to formation, the CO_2 dynamic storage rate ＞ 90%.



(5) Monitoring technology

A monitoring system based on reservoir, wellbore, surface, and atmosphere environment has been established to realize real-time dynamic warning and monitoring.

Monitoring area



Vertical:

Atmospheric

Near surface

Deep surface

Horizontal:

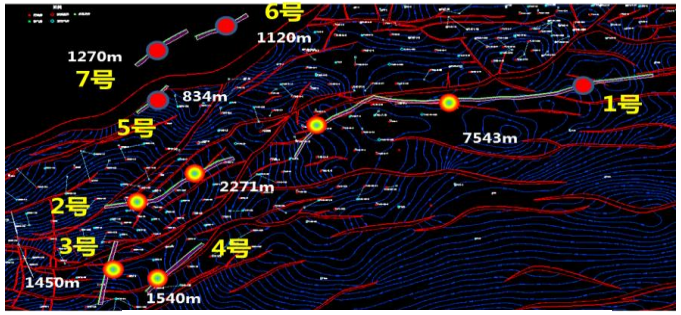
core area (20km×10km)

comparison area (5km outreach)

Monitoring items

Items	Points	Frequency
Atmosphere	Core area: 12; Comp. area: 2 in upwind direction 4 downwind direction	Core area: Online continuous monitoring; Comp. area: 1/mth
Surface-soil gas	Core area(1km)150； Comp. area(4km)40； Stable isotope of C13： 13 around injector.	Background value 1/mth，during injection 1/3mths
Near surface-soil gas, ground water	250m above the fault 1, No.1 fault 8; two fully penetrated faults 2; sampling depth 30m。	Background value 1/mth，during injection 1/mth
deep subsurface	2200m near the fault	Background value 1/mth，during injection 1/mth
Wellbore integrity monitoring	injectors 68、others 30	1 before injection; 10% of injectors during injection period annually
Vegetation (optional)	30km x 17km	Background value 1/mth，during injection 1/3mths
Ground deformation (optional)	30km x20km	Background value 1/mth，during injection 1/3mths

Fault monitoring



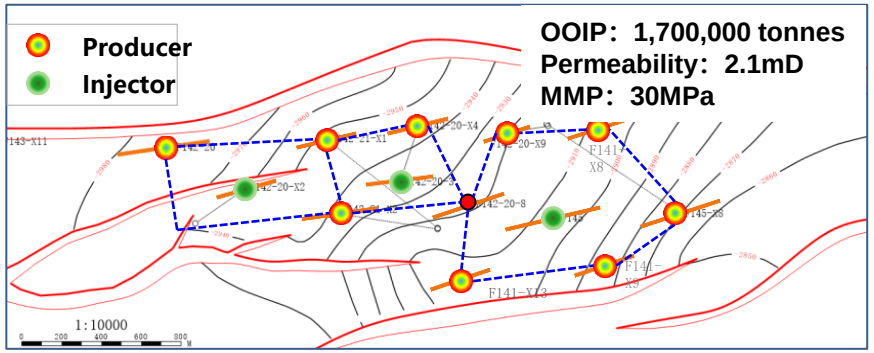
Possible leaking faults

Items	Fault No.	Possible leakage direction	Well	Coordinate	Unit	Installation location
1	1	Southeast	F142-8-2	N37°19'30.70" E117°95'22.65"	Dongsheng Corp. Binbo branch	Southeast corner
2			F142-8-2	N37°14'17.16" E118°05'71.73"	Dongsheng Corp. Binbo branch	Southeast corner
3	2	Southeast	G89-X21	N37°76'32.11" E117°89'44.81"	Chunliang plant. Daluhu Branch	Southeast corner
4			F143-4	N37°57'14.21" E117°91'53.36"	Dongsheng Corp. Binbo Branch	Southeast corner
5	3	Southeast	G891-8	N37°19'11.69" E117°32'62.63"	Chunliang plant. Zhenglizhuang Branch	Southeast corner
6	4	Southeast	G891-5	N37°18'47.82" E117°78'63.19"	Chunliang plant. Zhenglizhuang Branch	Southeast corner

Project benefits

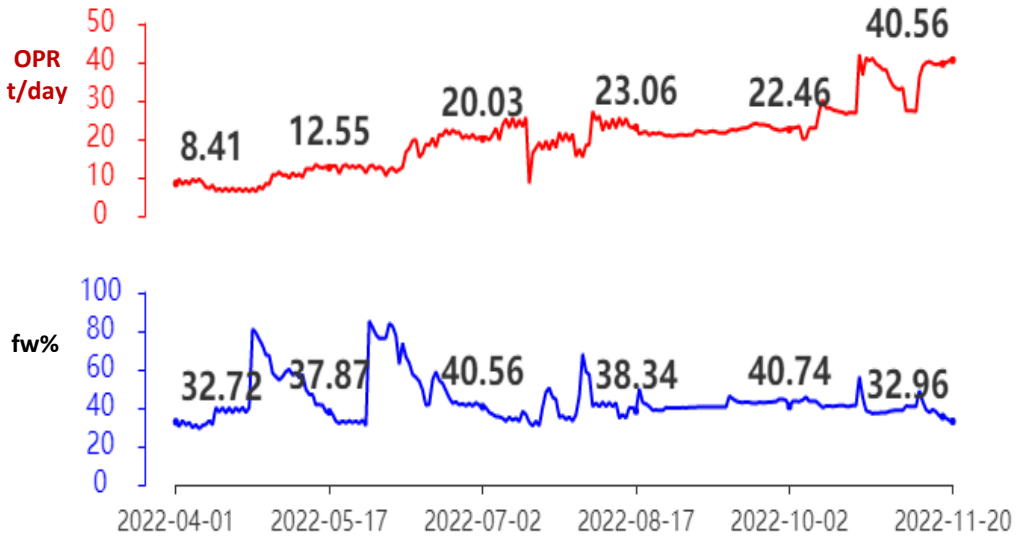
- The daily injection is 1,200-2,000 tonnes, with 0.47 million tonnes of CO_2 injected. The daily oil production is 302 tonnes, with 26,500 tonnes of incremental oil production obtained.
- E.g Fan 142-20, the oil production rate increases from 8 t/day to 40 t/day.
- Operating cost $35/bbl , balancing oil price $65/bbl.

Fan 142-20



- Well pattern： parallel to the direction of main stress and bar sand
- To date, a total of 17,000 tons of CO_2 has been injected

Fan 142-20 production curve



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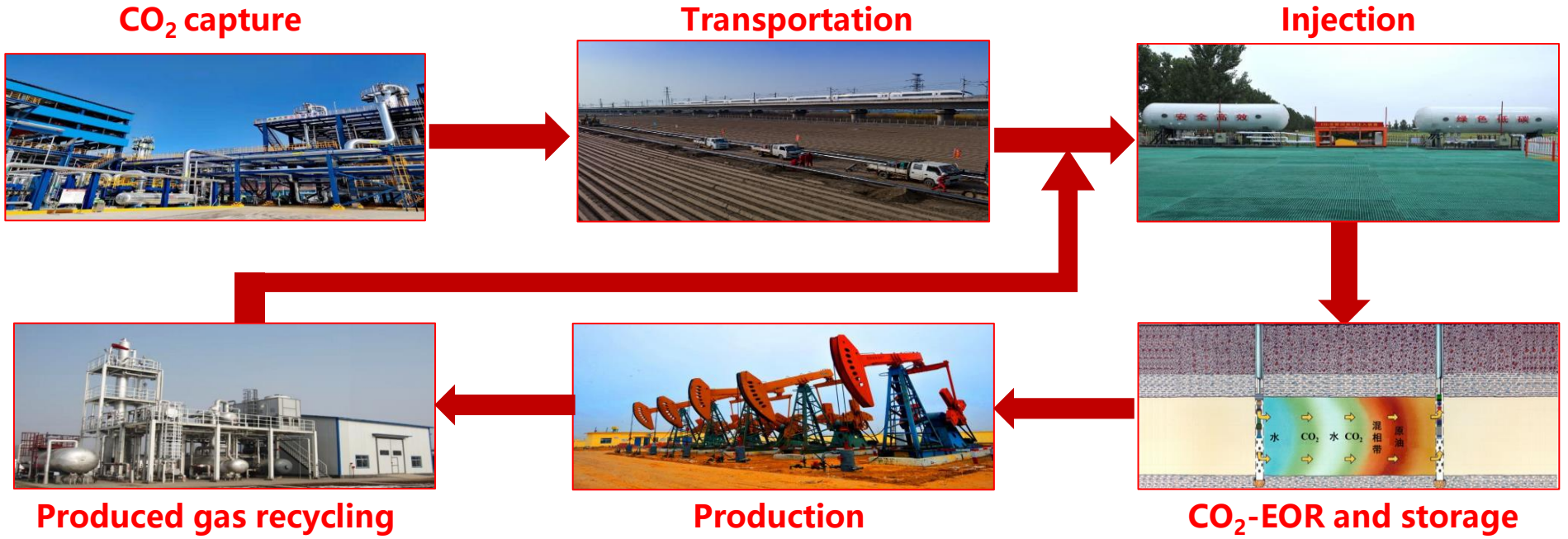
Summary

(1) China has successfully established its 1st million-tonne CCUS demonstration project and the 1st 100 kilometer CO_2 transmission pipeline.

(2) The project design, construction and equipment development are completed by Sinopec.

(3) The Qilu-Shengli Oilfield Project is operated well and safely.

(4) Valuable experiences accumulated for large-scale CCUS projects, rendering support in the construction of hub and industrial clusters in China.



THANK YOU!

CCUS Project in Shengli Oilfield