The Progress and Outlook of Integrated CCUS Demo of Yanchang Petroleum

Speaker: Gao Ruimin

China .Research Institute of Shaanxi Yanchang Petroleum (Group) Co., Ltd

SEP 9,2014

陕西延长石油(集团)有限责任公司
SHAANXI YANCHANG PETROLEUM(GROUP)CO.,LTD.

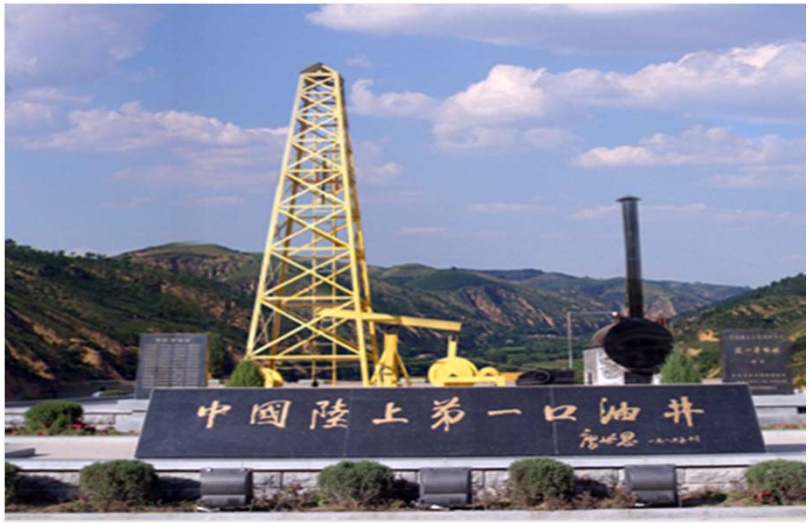
Outline

1. **Profile of Yanchang Petroleum**
2. **Background and Advantages**
3. **Research and Development**
4. **Progress of Field Applications**
5. **Planning**

1. Profile of Yanchang Petroleum

◆ **History：** Shaanxi Yanchang Petroleum (Group) Corp. Ltd is one of the four qualified enterprises for oil and gas exploration in China. The first oil well in mainland China was drilled in this area 108 years ago. It has made an important contribution to the national construction.

◆ **Businesses：** involve oil and gas exploration and production, oil refining, storage and transportation, oil-selling, mining industry, new energy, equipment manufacturing, engineering design and construction, technology research and development and financial service.




油气田勘探


油气田开发

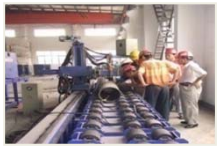

石油炼制


管道运输


油气化工


煤矿开采


油气煤盐化工


装备制造


工程建设


科研与设计


太阳能产业

金融保险

1. Profile of Yanchang Petroleum

◆ Benefits : Yanchang have produced crude oil by 12.54 million tons and refined crude oil by 14.03 million tons in 2013； The sales revenue of 2013 is 186.5 billions, and has entered the world top 500 enterprises.

◆ Resource: Yanchang located in Ordos basin, the proved reserves of oil is 2.5 billion tons, the proved reserves of natural gas is 330 billion m^3 , the proved reserves of coal is15 billion tons.

◆ Objective: Yanchang will have endeavored to realize 500 billion Yuan of operating revenues by the end of “The Thirteen Five-Year Plan”, and entered into the top 300 enterprises of the world.

2. Background and Advantages

Background

◆ **Emission reduction pressure:** With the rapid economic development, as the biggest producer, consumer and emitter of carbon, China is facing the growing pressure of carbon emission reduction.

◆ **Enterprise responsibility:** Coal chemical industry of YanChang releases plenty of high-concentration carbon dioxide, which needs to be handled reasonably.

◆ **Economic development:** As a comprehensive developed enterprise, YanChang realizes economic sustainable development for both northern Shaanxi district and the company itself.

◆ **Problem solving:** During development process, YanChang needs to overcome the problem of low permeability, unstable yields, water shortage and fragile environment .

Through out the development of CCUS project, we must combine "carbon capture-EOR-carbon storage-carbon reduction "together, and it's the inevitable choice of YanChang to realize emission reduction and industry sustainable development.

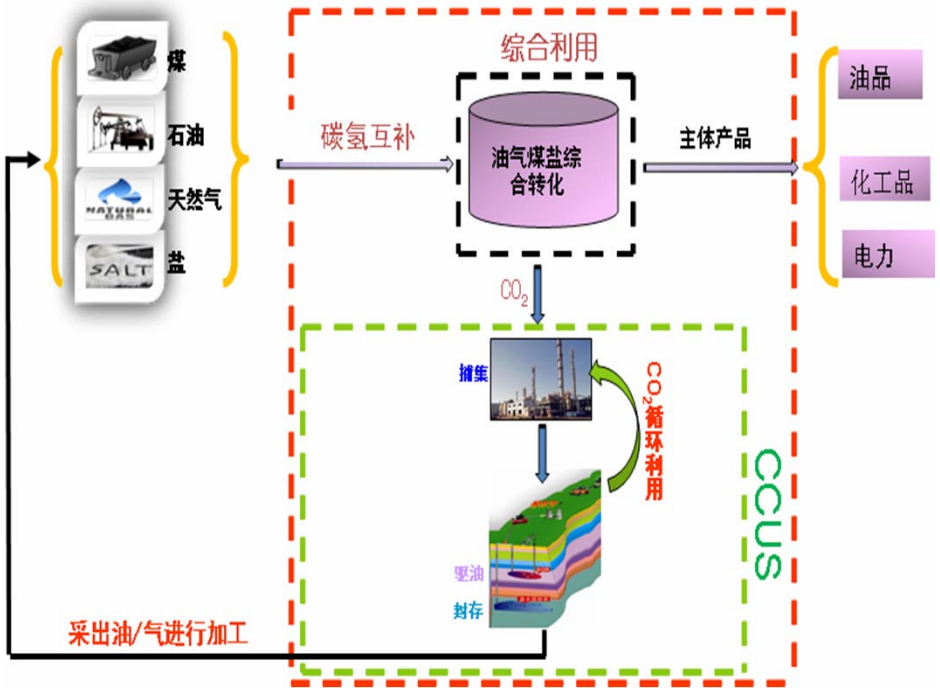
2. Background and Advantages

Advantages

There are abundant coal, oil and natural gas resources belonging to Yanchang petroleum in the north of Shaanxi province, which lays the foundation for the integrated CCUS project.

1)Energy saving and carbon reduction by comprehensively making use of coal, oil and gas

Yanchang Petroleum is rich in resources such as coal, oil, gas, and so on, which can bring complementation of carbon molecules and hydrogen molecules by comprehensive utilization. The innovative jointing of coal chemical and oil&gas Chemical can make CO_2 emission reduce sharply, thereby enhance energy efficiency.



2. Background and Advantage

2) CO_2 capture and transportation with low-cost

◆ The purity of CO_2 that come from coal chemical industry of Yanchang is very high, captured devices adopt Rectisol process with the characteristic of low cost and energy-consuming, the cost of running capture devices is just 18 $.

◆The cost of CO_2 transportation is low because oil field and coal chemical plants locate in the same areas.

3) Broad prospects of CO_2 –EOR

◆Yanchang oil reservoir belong to ultra-low permeability, the oil recovery is 10%, CO_2 flooding can enhance oil recovery by 5-10%, therefore ensure sustained oil production.

◆replacing water flooding with CO_2 flooding can save huge volume of water in north of Shaanxi which is water resource shortage.

◆ benefit of CO_2 –EOR can make up for CCUS cost, so that both social and economic benefits can be achieved.

4） Advantages of CO_2 fracturing and enormous demand

◆ Most of wells need to be fracturing for producing, besides saving lots of water, CO_2 fracturing can increase production by 50%.

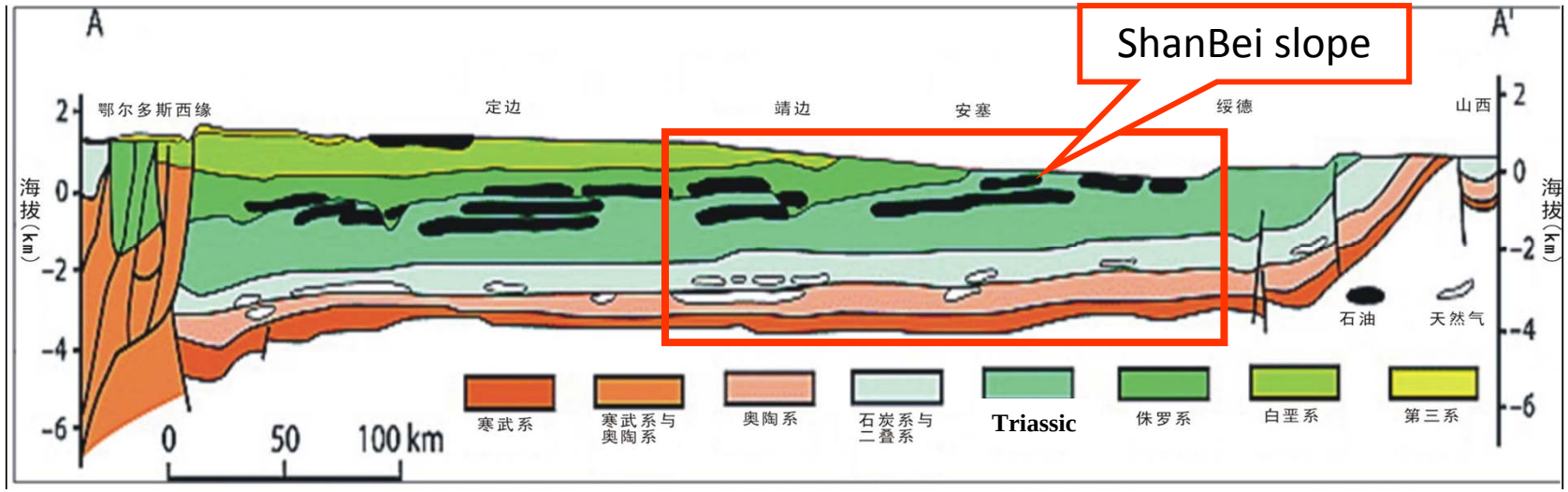
2. Background and Advantages

4) Ample storage volume and Stable geologic structure

◆ The geology of Ordos basin is stable and simple structure with less fault, it is safe for CO_2 storage, and is the most advantageous areas of CO_2 storage in China.

◆ According to preliminary estimate , reservoir can storage CO_2 by 500~1000 million tons and deep brine aquifers can storage CO_2 by 10 billion tons in Ordos basin , Yanchang Oil-field can storage CO_2 by 180 million tons.

◆ The reservoir depth is 1~3Km, it is better for CO_2 injected by supercritical state.



2. Background and Advantage

5) State-sponsored, Corporate attention, International cooperation

◆ State-sponsored： Yanchang Petroleum got supports from National Development and Reform Commission and Ministry of Science and Technology.

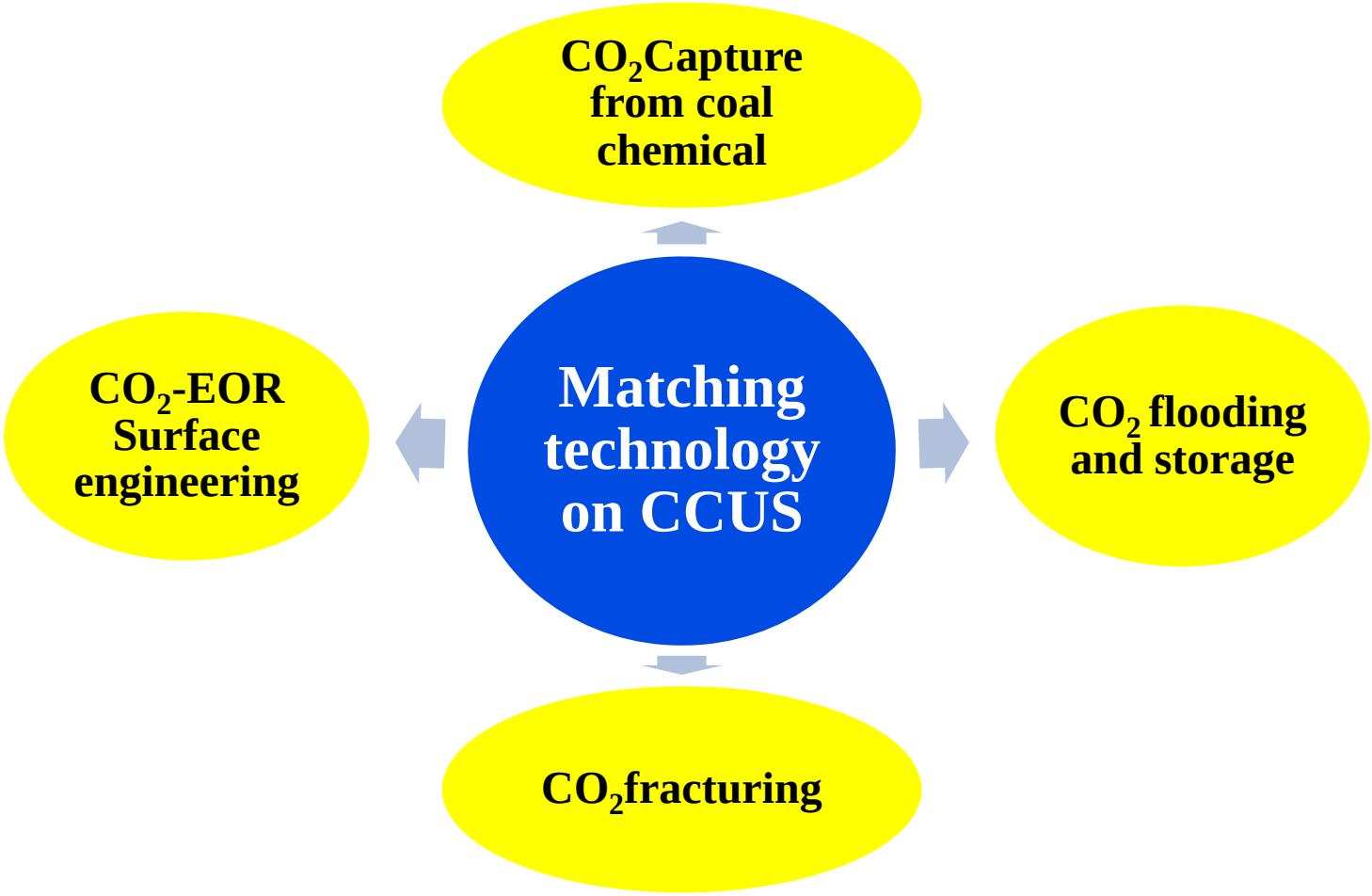
◆ Corporate attention： Yanchang Petroleum invested 300million ￥on CCUS, and established working team.

◆ International cooperation： joined in the US-China Advanced Coal Technology Consortia, and established cooperation mechanism with Institute of global CCUS, University of Wyoming, University of West Virginia, University of Regina, Air Products & Chemicals Corp.

year	sponsor	Relation Projects
2007	Planning of national Supporting technical	**research of CO_2- EOR in low(ultra-low)permeability reservoir (ChuanKou Oilfield)**
2010	Yanchang Petroleum	**research on the matching technology of Yanchang Petroleum CO_2- EOR(300million)**
2011	Planning of national Supporting technical	**Technology Demo of CCS and EOR of Shanbei Coal-chemical Industry**
2012	Planning of national 863	**Key technical research of exhaust gas CCUS of coal-fired power plant**
2013	Institute of Australian canbon capture and storage	**Demonstration Project of Sino-Australian International Cooperation on CCUS Integration**
2013	Shaanxi garverment	**Key technical pilot test of CO_2- EOR in north of Shaanxi**
2014	Yanchang Petroleum	**pilot test of CO_2flooding and fracturing in north of Shaanxi**

3. Research and Development

Since 2007,Yanchang petroleum have researched and developed 4 items of CCUS matching technology under the support of national technical Planning, projects of International cooperation and Yanchang Petroleum Group.



CO_2Capture from coal chemical

1) Build a set of CO_2 capture multifunction pilot-plant

Research and Development a set of CO_2 capture multifunction pilot-plant which aim at low purity CO_2 (about 20%) and producing CO_2 of recapture, separation, purification and reutilization.

Index parameter

capture capacity :200kg/d;

energy consumption:1.084GJ/t;

Technical characteristics: simple technology, high safety factor, low energy consumption, stable performance, low-cost, high purity

CO_2Capture from coal chemical

2) Developed Ⅲ types of CO_2 capture technology

◆Aim at the running coal chemical plant of Yanchang petroleum, developed Rectisol Process technology of CERI by the way of evaporation method, separated and purified no-sulphur Liquid rich methanol that associated with rich CO_2.

◆Aim at sulphur liquid rich methanol , developed Rectisol Process technology of HNU1 by the way of flashing, compression, drying , dehydration, further enhanced capture capacity and reduced energy consumption.

◆Aim at associated gas that come from CO_2 flooding process in JingBian oilfield, developed a set of producing CO_2 separated technology, separate and Purify producing CO_2 in oilfield.

technology	Capacity (t/h)	Purity (%)	energy consumption (GJ/t CO_2)	Traditional energy consumption (GJ/t CO_2)	Cooling water(t/h)
CERI	8.5	99.6	1.24	2.85	134.46
HNU1	22.2	99.6	0.62	2.70	135.5
Capture of producing CO_2	11.09	86	1.08	1.25	

CO_2 Flooding and Storage

1) Built the Criteria of reservoir selection

With taking into account geology, fluid, field development, oil recovery ,GOR and so on, developed criteria of reservoir selection for CO_2 flooding and storage in Yanchang oilfield.

Reservoir	Reservoir number	suitable Reservoir	Not suitable Reservoir	Ratio of suitable Reservoir	Reserves ($\times 10^4$t)	suitable Reserves ($\times 10^4$t)	Not suitable Reserves ($\times 10^4$t)	Ratio of suitable Reserves
杏子川	13	12	1	0.92	10685	10495	190	0.98
靖边	15	14	1	0.93	12341	12071	270	0.98
永宁	5	4	1	0.8	25316	24727	588	0.98
西区	3	3	0	1.00	12012	12011	0	1.00
七里村	8	1	7	0.13	12691	1934	10757	0.15
瓦窑堡	16	11	5	0.69	13924	11142	2782	0.80
……								
total	**178**	**150**	**28**	**0.84**	**219138**	**176274**	**42864**	**0.80**

CO_2 Flooding and Storage

2) Potential evaluation of CO_2 flooding and storage

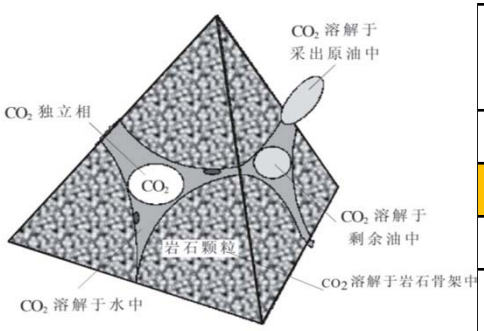
Calculated model of storage capacity

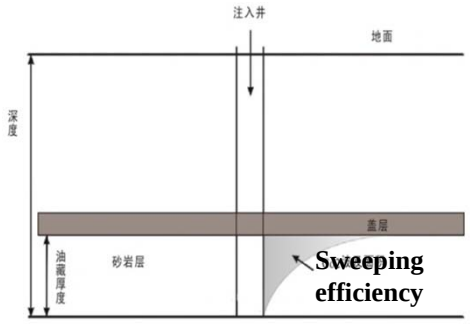
material balance

- Ratio of CO_2 dissolve in Original oil
- Ratio of CO_2 dissolve in stratum water
- CO_2 storage capacity calculated under well closed

Model of potential evaluation for CO_2 flooding

- **Immiscible**
- **Miscible**





num	reservoir	Reserves (10^4t)	Storage capacity(10^4t)	Enhanced recovery(%)	Utilization coefficient	Storage coefficient
1	化子坪区-长2层	1015	265.63	6.99	0.27	0.26
2	乔家洼-长6	931	209.87	4.03	0.18	0.23
3	永宁油区-长6	1333.69	357.41	10.83	0.40	0.27
4	义吴-长4+5、长6	4754.79	1207.39	9.85	0.39	0.25
5	定边--延10	424	145.83	10.83	0.31	0.34
6	郭旗西区-长61	3110	769.90	8.67	0.35	0.25
7	直罗-埝沟-长2	240	62.42	7.43	0.29	0.26
8	南区-湫沿山-长6	278.6	62.80	10.52	0.47	0.23
9	吴起-油沟-长4+5	801	194.25	8.58	0.58	0.56
10	英旺-庙湾-长8	454.41	156.29	5.51	0.16	0.34

CO_2 Flooding and Storage

3) Reservoir engineering methods and experiments evaluation system

- Reservoir engineering methods for CO_2 flooding in YanChang ultra-low permeability reservoir.

  Development geology :Decrypted reservoir heterogeneous and distribution regularity in detail，built the precise reservoir geologic modeling .

  Reservoir evaluation :Analyzed the characteristic of oil productivity, oil-water relationship and development.

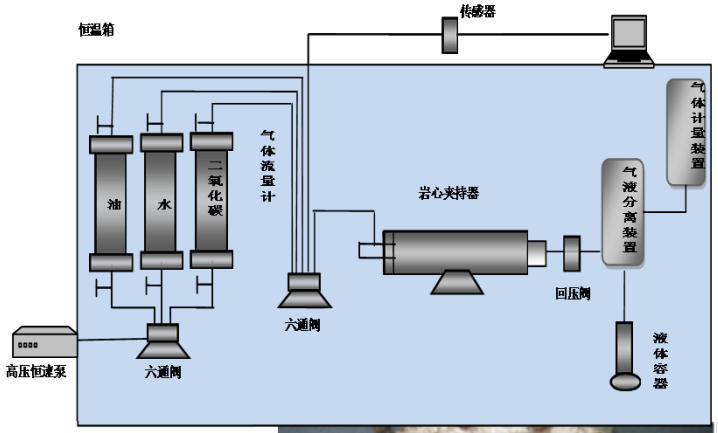
  Numerical reservoir simulation: Built 3-D geologic model of WuQi and JingBian and conducted history matching.

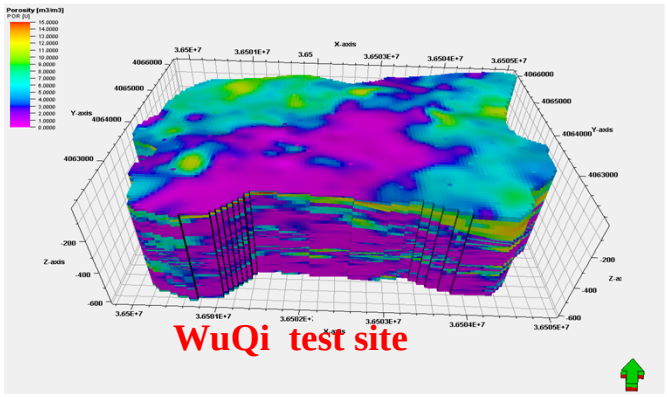
- experiments evaluation for CO_2 flooding

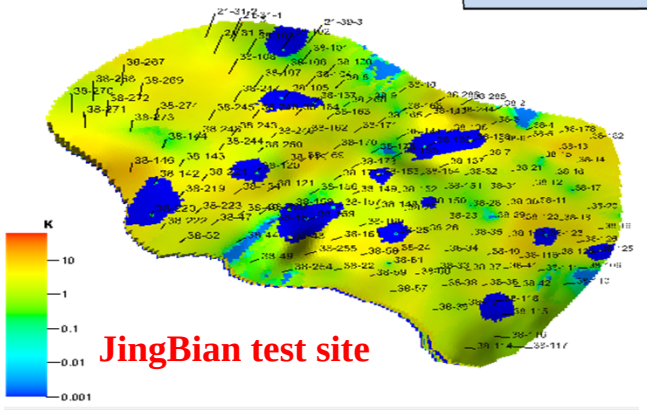
  heterogeneous of core under control

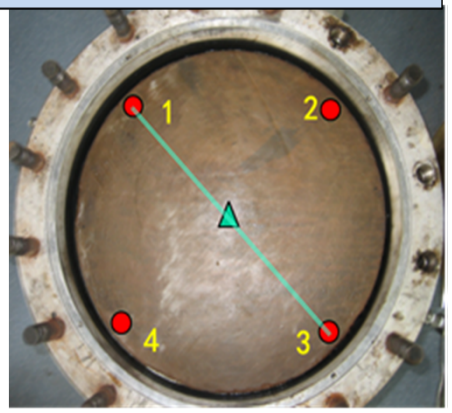
  overlength core for displacement

  large physical simulation with radial low-permeable seepage









CO_2 Flooding and Storage

4）Matching technology and anti-corrosion for CO_2 flooding

- matching technology of injected well

  Improved wellhead and injection string

  Optimized oil tube and packer

- matching technology of produced well

  Optimized the pumping unit,

  sucker rod and oil pump

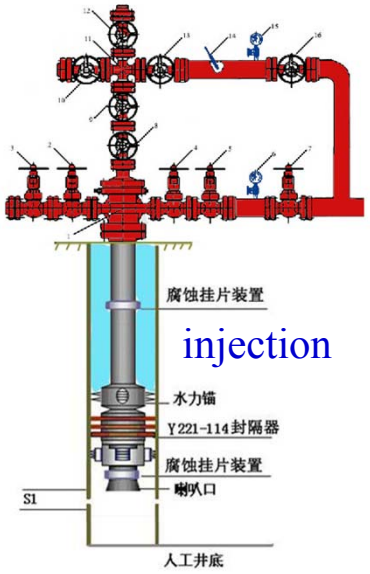
- study of anti-corrosion

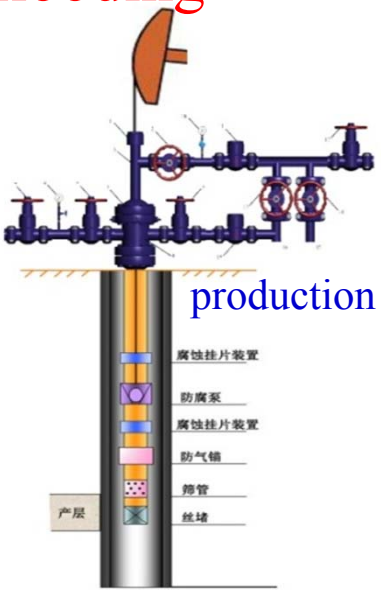
  Injection well :

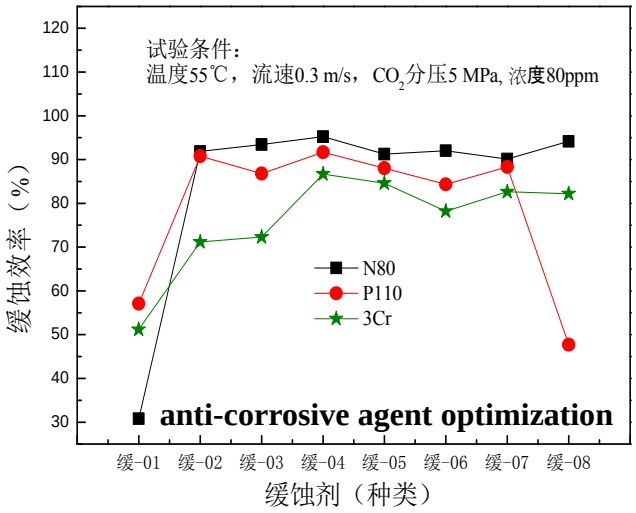
  carbon steel + packer +inhibitor

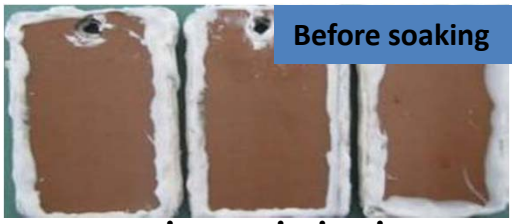
  Production well:

  Comprehensive anti-corrosion +carbon steel +inhibitor









coating optimization

CO_2 Flooding and Storage

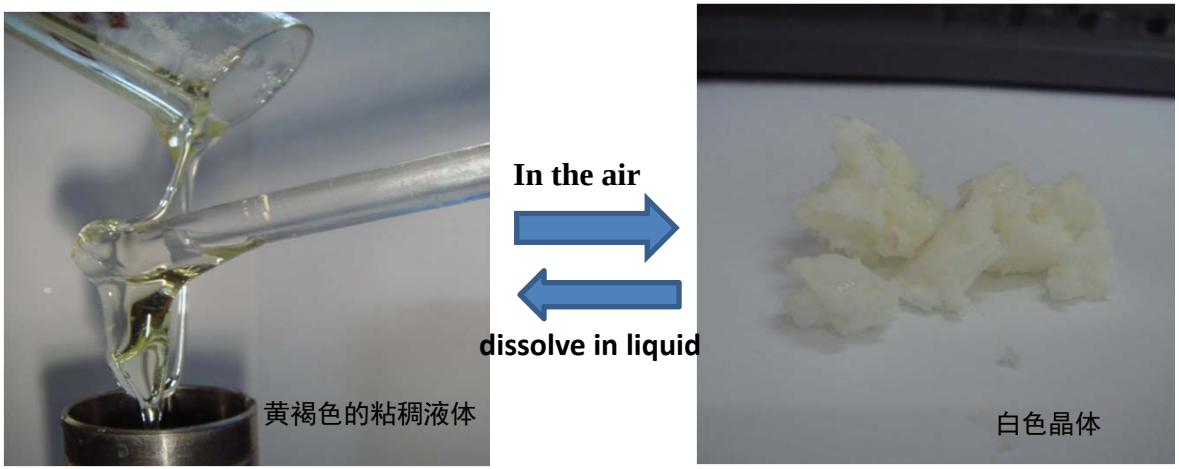
5）Technology of expanding swept volume

- stage 1—WAG
- stage 2—modified starch plug channeling of fracture

  characteristic: high strength and remain stable after gelling
- stage 3—Small molecule amine plug channeling of high permeable formation

  mechanism: ease to be injected and form a salt with CO_2 reacting

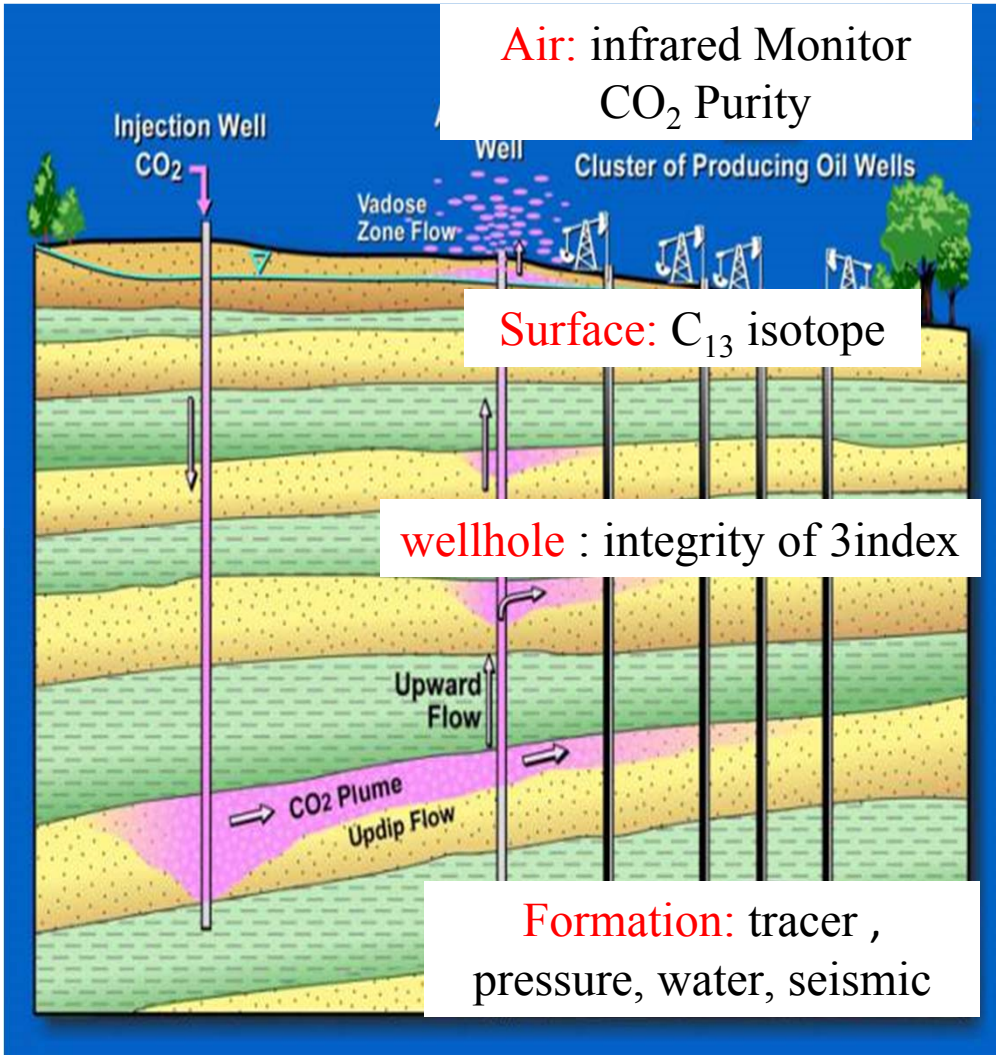
modified starch after gelling



Small molecule amine

CO_2 Flooding and Storage

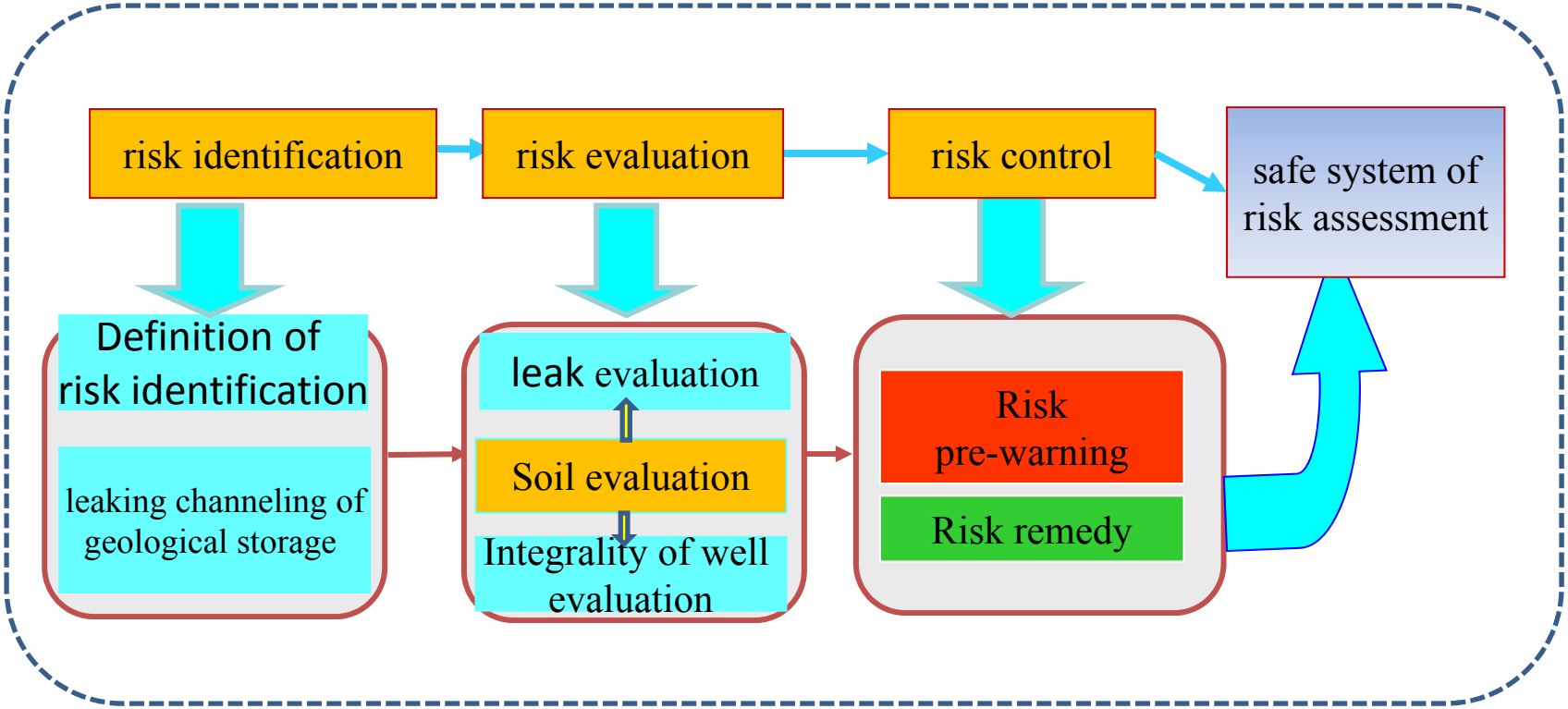
6) CO_2 safety-monitoring technology



Monitoring Program		cycle
injection well	Injection parameters(volume, pressure, temperature)	continuous
production well	production performance	day
	working fluid level	month
	Purity of producing CO_2	continuous
	pressure monitoring	continuous
	component of crude oil	season
	Output profile	2 year
	static pressure	2 year
	water quality	month
	corrosion rate	
reservoir	tracer material	
	formation pressure	
	formation water PH	
	seismic surveillance	
Surface	Atmospheric CO_2 Purity	Half year
	Soil C_{13}	year
	plant growth	Half year

CO_2 Flooding and Storage

7) safe system of risk assessment and methodological flow of pre-warning

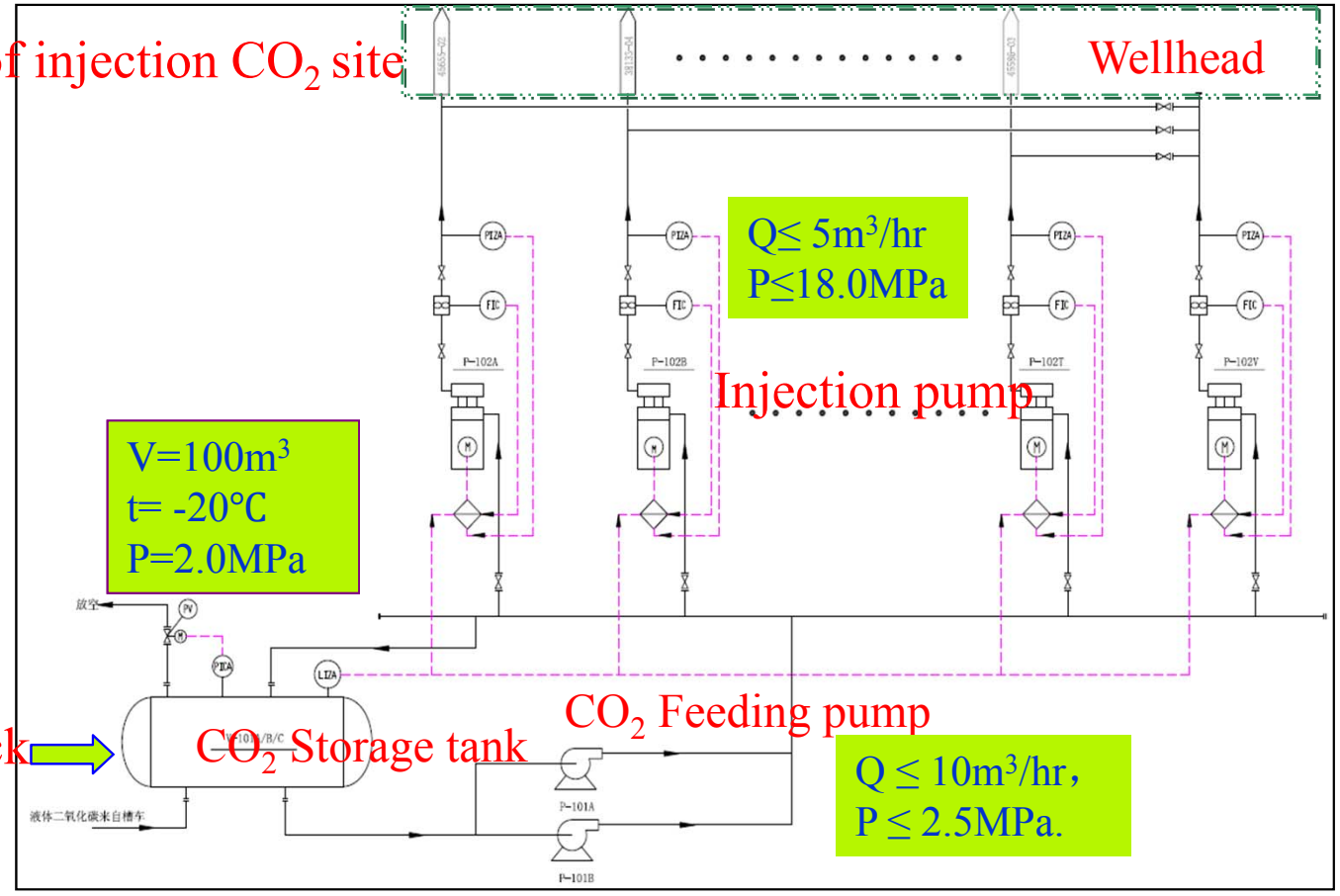


CO_2-EOR Surface engineering

1) Technological process of portable CO_2 flooding devices and field application

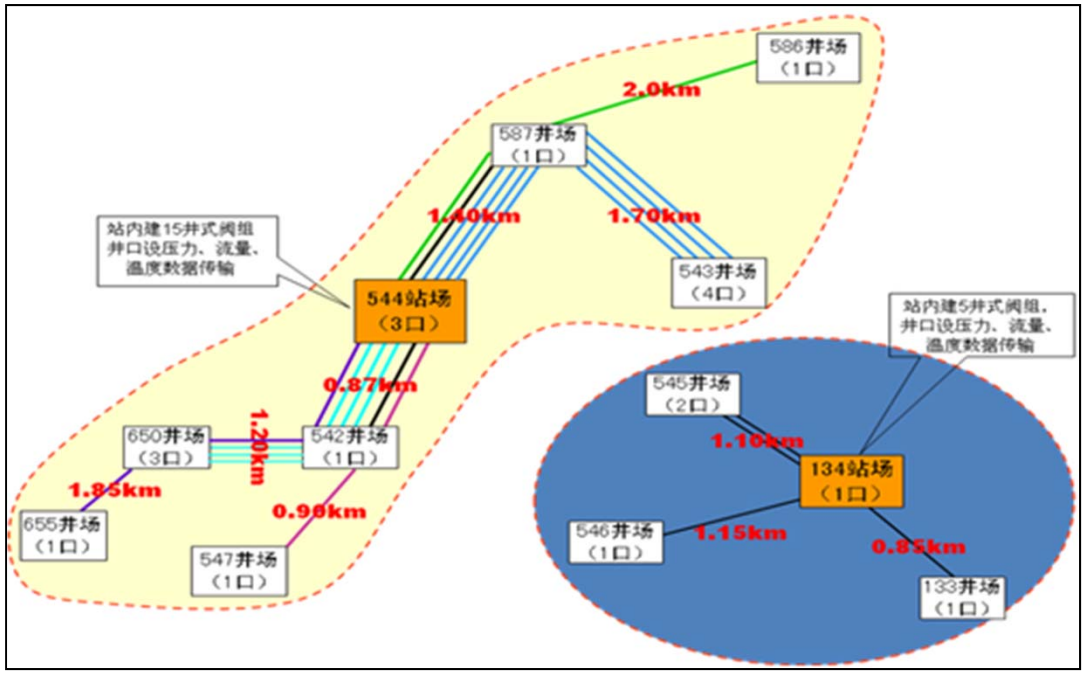
Injection flow of well site : Truck ⟶ Storage tank ⟶ Feeding pump ⟶ Injection pump ⟶ Wellhead

Technology of injection CO_2 site



CO_2-EOR Surface engineering

2) Finished Overall design of CO_2 injected process in JingBian oilfield



- 2 CO_2-injection stations, scale 600m^3/d;
- built 2 new 3km roads;
- 20km injection pipeline;

1#station：locate at 544 well site
4 CO_2 storage tanks : V=100m^3 ;
4 Feeding pumps :2 running and 2standby;
6 Injection pump: 4running and 2 standby;
Meet 15 injection Wells.

2#station：locate at 134 well site
2 CO_2 storage tanks : V=100m^3 ;
2 Feeding pumps :1 running and 1standby;
3 Injection pump: 2running and 1 standby;
Meet 5 Injection Wells.

CO_2 Fracturing

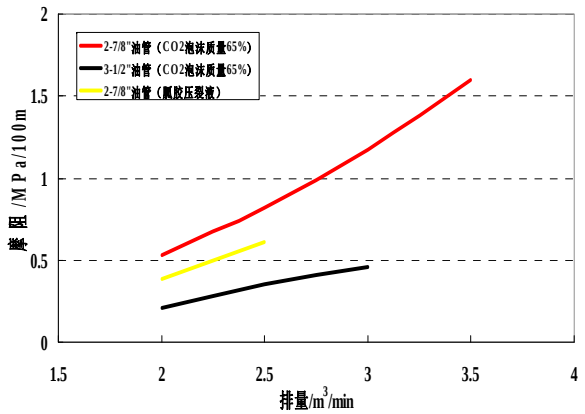
III types of CO_2fracturing developed by laboratory study and field test

1) CO_2 enhanced Fracturing

Combined with the features that liquid CO_2 are high flow-back , low damage and fit for sand fracturing, we developed CO_2 enhanced fracturing tech that use liquid CO_2 first before hydro fracture. This increased the CO_2 fracturing flow-back rate.

2) CO_2 Foam Fracturing

Taken the foam fluid (liquid CO_2:fracturing fluid to a certain proportion with foam quality >52%) as sand carrying agent, injected into the formation. This tech is water saving and low damage to the formation.



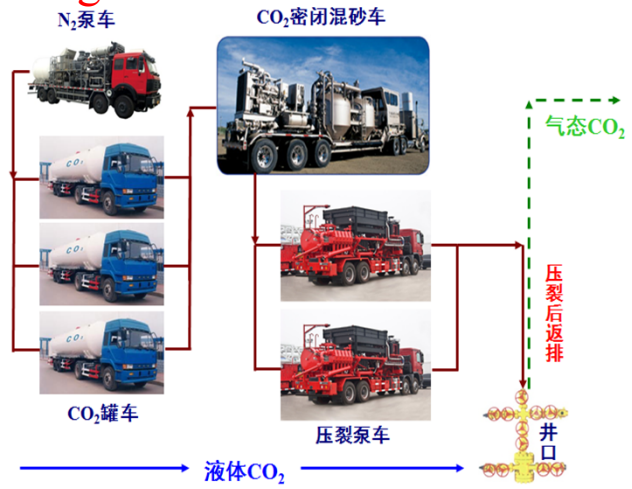
CO_2 Fracturing

3) CO_2 Liquid Fracturing

Fracturing using pure liquid CO_2 as the sand carrying fluid. CO_2 can drained out of formation quickly and completely after fracturing with no damage.

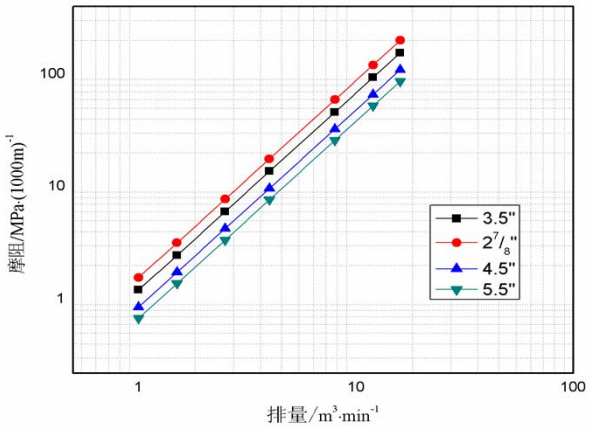
◆ Liquid CO_2 pipe flow test

Evaluated first time the liquid (supercritical) CO_2 flow friction coefficient, dynamic filtration and dynamic sand carrying capability, which gives theoretical support to CO_2 dry fracturing and parameters optimization.



◆ CO_2 dry fracturing optimization

Considering the pump infusion, established the CO_2 wellbore flow friction plate and optimized dry fracturing parameters.



4. Progress of Field applications

After many years of research and practice, Yanchang got the substantial progress on CCUS

1) Jingbian coal-to-chemicals demonstration project

By Hydrogen-Carbon complementary(more carbon than hydrogen in coal and more hydrogen than carbon in oil and gas), Yanchang petroleum carried out world's first oil-gas-coal comprehensive utilization demonstration projects. The project was put into production on 2014 July, with total investment 26.9 billion RMB, 600,000 tons polyethylene and 600,000 tons polypropylene products per year, and achieve an annual emission reduction 4,350,000 tons.

num	JingBian project	Jing Bian	International advanced level	Domestic advanced level	Compared with International level	Remark
1	methanol production(10^4t/y)	180	165.35	153.12	+8.86%	Same material
3	energy consumption(GJ/t)	37	48	50	-23.8%	
4	water consumption(m^3/t)	4.1	10	12	-59.00%	
6	CO_2 emission (10^4t/a)	285	720	720	-60.42%	4.35million ton/a
7	SO_2 emission (t/a)	634	1389	1389	-54.36%	
8	wastewater（m^3/h）	83.4	252.9	252.9	-67.02%	Saving water 10 million ton/a
9	Solid Waste(10^4t/a)	12.8	39.82	39.82	-67.81%	landfill

4. Progress of Field applications

2) Yulin coal-oil co-refining demonstration project

Based on the technology of heavy oil hydro cracking and coal hydro liquefaction, Yanchang petroleum developed coal-oil co-refining tech, which use residue oil, heavy oil, coal tar and low rank coal as raw materials, played a synergistic effect of coal and heavy oil in the reaction, greatly improved resources transformation efficiency and realize an annual emission reduction 1.8 million tons.

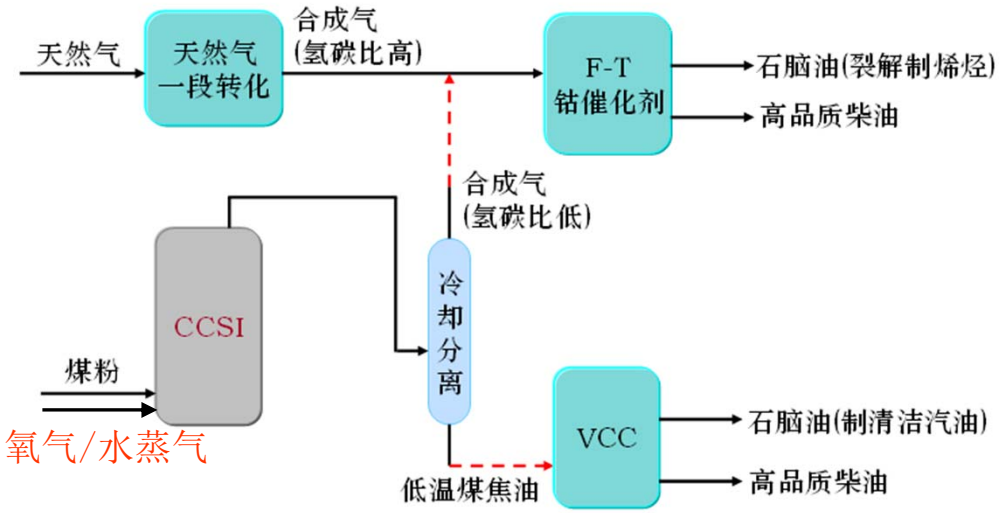
project	scale	Construction investment	Energy efficiency	CO_2 emission	Water consumption
indirect coal to liquid	1million ton/a	>16 billion	40.5%	7.2ton	>10ton/ton-oil
direct coal to liquid	1million ton/a	>12 billion	50.26%	5.2ton	10ton/ton-oil
coal and oil co-refining	0.33million ton/a	≈2.5 billion	70.65%	1.1ton	3.36ton/ton-oil

4. Progress of Field applications

3) Integrated technology of coal tar extraction and synthesis gas in coal (CCSI).

Yanchang petroleum developed it's own integrated coal tar extraction and synthesis gas in coal (CCSI) technology. At present, lab and small scale pilot experiment has been completed; a bigger 36 tons/d pilot device is being designed.

pilot plant



Profit analysis:

Processing 100 million tons of coal per year using CCSI technology:

Raw material cost: 35 billion RMB.

Product value: 236 billion RMB, in which coal tar processing output value are 96 billion RMB and synthesis gas and oil output value are 140 billion RMB.

So, resource added value up to 201 billion RMB.

4. Progress of Field applications

4)Low-cost CO_2 capture devices on coal chemical industry

firstly build a set of 50,000 t/a CO_2 capture device in Yulin Coal Chemical Company , using CERI process directly to separate high purity CO_2 products from no sulfur medium voltage methanol rich liquid.

The 80000 ton/year CO_2 with food grade is produced by Shaanxi Xinhua-Xinke Gas Company, the sub-company of Yanchang Petroleum.

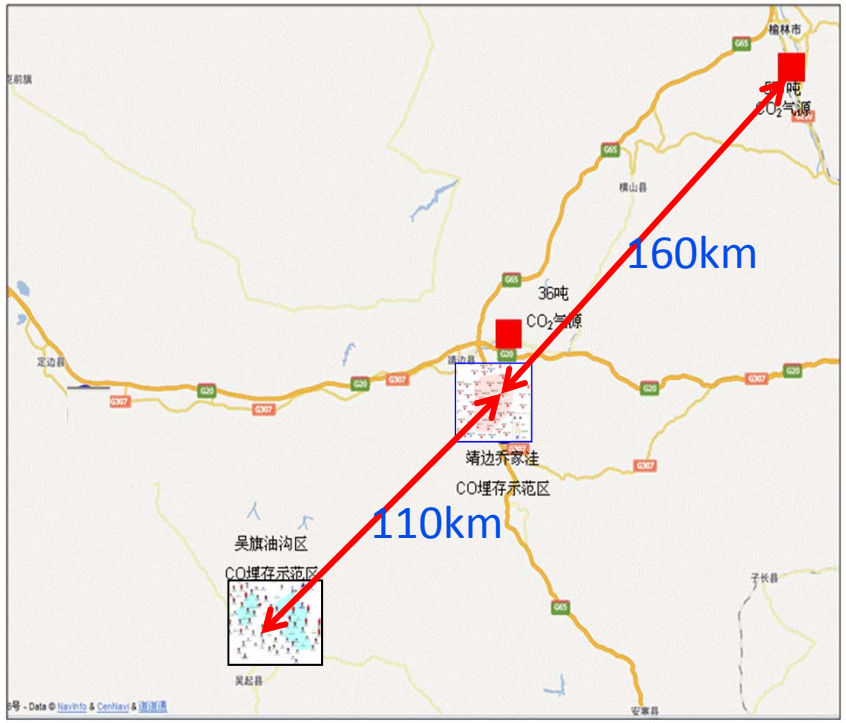
The 360000 ton/year CO_2 capture facility construction project has be started by Shaanxi Yanchang China-coal Yulin Energy Chemical Company, the project will be finished by OCT,2014

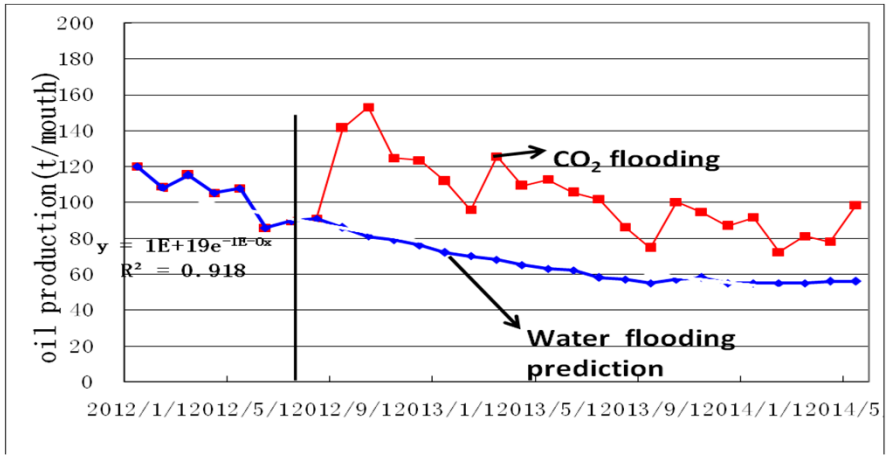
4. Progress of Field applications

5)CO_2-EOR and storage pilot test

(1)CO_2-EOR and storage field test site of JingBian

Stage 1 JingBian pilot test started in Sep 5, 2012, and had cumulatively injected 180 thousand ton liquid CO_2 with 5 well groups, comparing with estimated oil production decreasing rate by waterflooding, accumulated oil production increased by 900 tons. It will increase 16 well groups in 2015, inject CO_2 by 200 thousand ton/a, and storage CO_2 by 120 thousand ton/a.

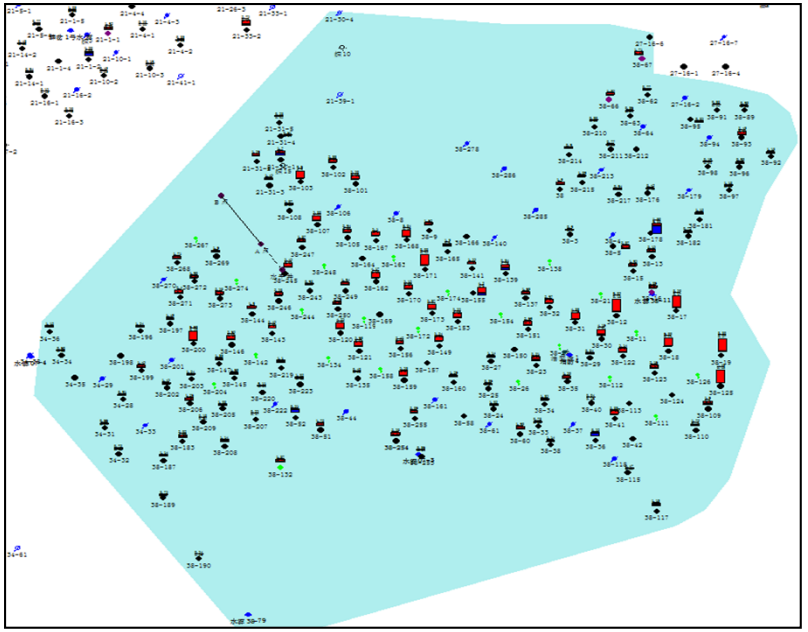


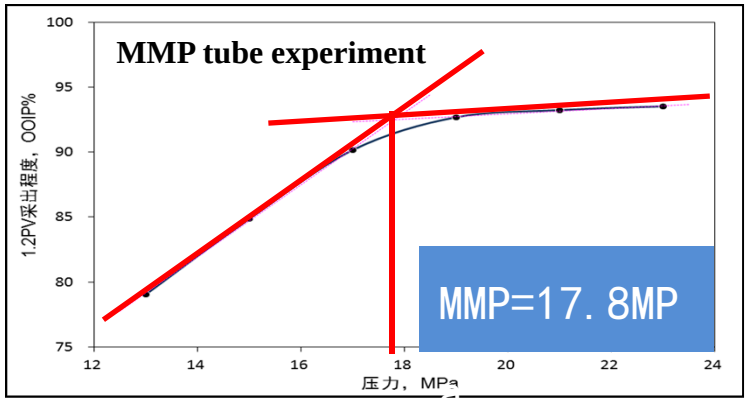


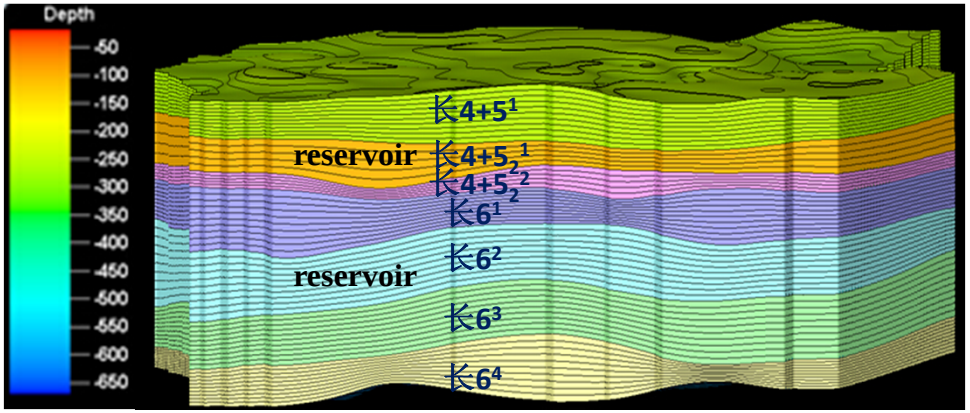
4. Progress of Field applications

(1)CO_2-EOR and storage field test site of WuQi

Stage 2 carried out miscible displacement of EOR in WuQi whose area is 14.8 km^2 , and had started injection in Aug, 2014. It will increase 36 well groups in 2015, inject CO_2 by 300 thousand ton/a, and storage CO_2 by 180 thousand ton/a.





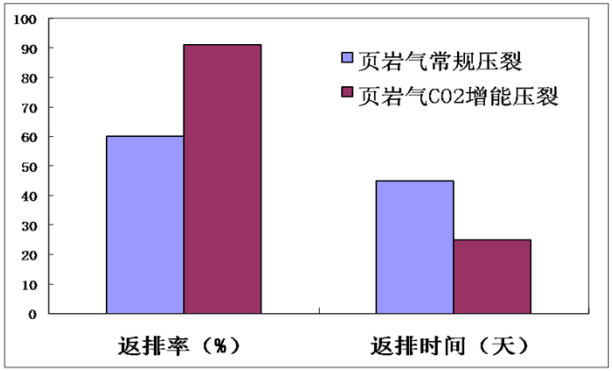


4. Field applications

6)CO_2 fracturing field apply

（1）Shale gas wells CO_2 fracturing： CO_2 fracturing had been conducted at YanYePing3 well , with 767 m^3 CO_2, 728m^3 sand and 20,000m^3 other fracturing fluid. Through this CO_2 enhanced fracturing, single well production and fracturing fluid flow-back rate had been increased.

（2）Natural gas wells CO_2 fracturing： For low pressure tight sandstone gas reservoir, we developed VES-CO_2 foam fracturing technology that increasing the yield obviously. Shi3 well, which applied VES-CO_2 foam fracturing, has increased daily gas production from 6400m^3 to 3,8000m^3, and daily open flow capacity from 2,1500m^3 to 10,0000m^3.



5. Planning

After accumulation of preliminary study and practice, CCUS Planning of YanChang at the end of "thirteen Five-Year Plan" is arranged as follows:

1) Work on allied chemical of coal, oil and gas for carbon reduction; develop clean utilization model of fossil fuel through hydrocarbon complementation and coal refine, reducing more than 1200 tons of carbon a year than traditional coal chemical industry. Focus on the innovation to carry out coal, oil & gas to olefins and coal & oil Co-refinery, significantly reducing carbon and improving fuel efficiency.

◆ **Coal, oil and gas comprehensive translation**: Oil, gas and coal transfer to olefins and hydrogen, producing 600 thousand tons of polyethylene, 600 thousand tons of polypropylene and other products a year.

◆ **coal &oil Co-refinery**： The coal-oil co-refine plant with the scale of 450 thousand tons/a was started in may 2014; The coal tar hydro-refining plant with the scale of 500 thousand tons a year was started in Oct, 2014.

5. Planning

2) Campaign of carbon capture, utilization and storage are arranged as follows:

◆ **capture-**Based on the existing of 50000 tons/a CO_2 capture, carry out the pre-feasibility of CO_2 capture facilities by the scale of 3.5 million tons/a, improving total capture ability to 4 million tons/a.

◆**transport-**Demo and construct a CO_2 pipeline with total length of 200—300 kilometers and delivery capacity reaches to 4 million tons/a.

◆ **flooding and storage-**Construct industrial application base of CO_2-EOR and storage with more than 600 wells, increasing oil production by 1 million tons/a, storing CO_2 by 2.4 million tons/a, enhancing oil recovery by 5%--10%, and realizing recapture and cyclic utilization of CO_2 .

◆ **fracturing-**implement CO_2 fracturing by 100 shale and natural gas wells.

◆ **teamwork-**Develop a managing excellence team of CCUS, which can undertake CO_2 reduction, capture, storage management and technical work, ensuring healthy and steady development of Yanchang CCUS.

5. Planning

3) next CCUS research orientation Of Yanchang

◆CO_2 capture, separation and transportation technology----including optimization and new process simulation of CO_2 capture from coal chemical; economic evaluation of capture-separation technology; liquid and supercritical transportation technology, separation technology of CO_2 from produced oil gas.

◆ Macthing technology for CO_2 storage and CO_2 -EOR----including numerical simulation of the injected CO_2 and optimization of injecting scheme.

◆ Monitoring for CO_2 storage and safe displacement----including monitoring of CO_2 storage and safe flooding; monitoring of gas channeling and gas flooding front; monitoring of injecting dynamic and producing dynamic.

◆ CO_2 fracturing technology

◆ Policy and law for CCUS

Ends

Technical ideas which combined CCUS with EOR is one of an effective way to realize Carbon Reduction. As an important member of energy chemical industry, Yanchang petroleum is willing to enhance communication, and cooperation with the domestic and foreign counterparts, for innovation-driven and comprehensive utilization of resources. It will make new greater contributions for efficient, clean and low-carbon utilization of global petrochemical energy.

Thanks for your advices