



胜利油田CCUS全流程示范工程

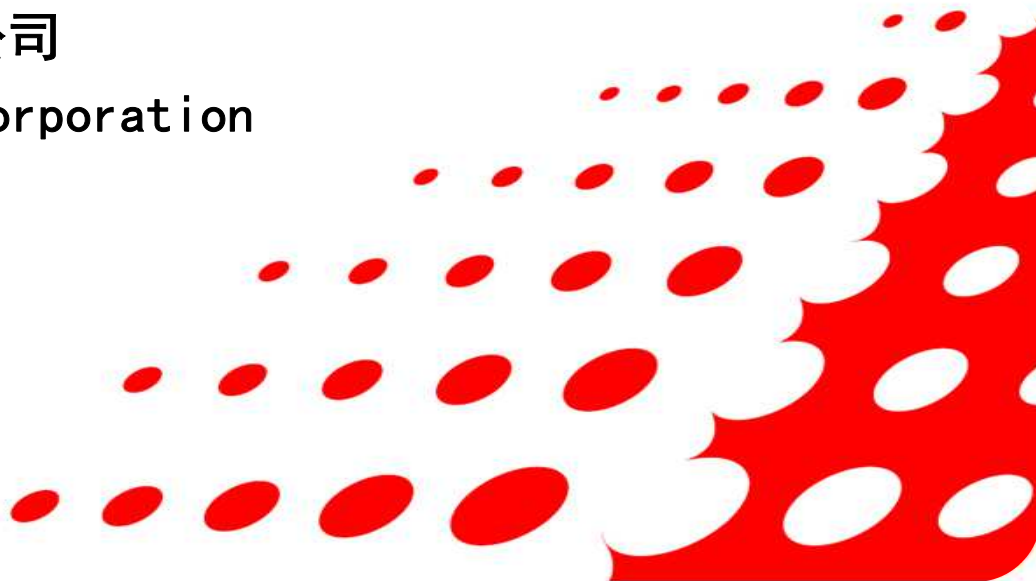
CCUS Demonstration Projects of Shengli Oilfield

中石化石油工程建设有限公司

Sinopec Engineering Incorporation

2014年11月20日

Nov. 20, 2014





汇报提纲 Report Outline

一、项目进展

I. Project Progress

二、面临挑战

II. Challenges



一、项目进展

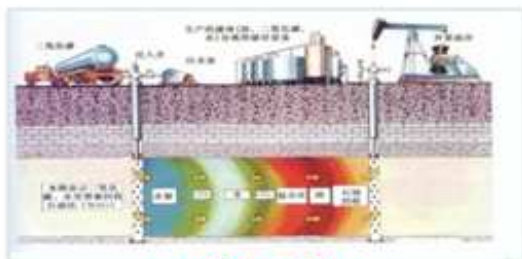
I. Project Progress

中国石化胜利油田紧密结合自身企业特点，在国内外率先开展了以燃煤电厂烟气为CO₂捕集气源、CO₂驱油为主要资源化利用及封存方式的CCUS技术研发及应用示范，实现了原油开采的“绿色无碳*”。

In light of the characteristics of our enterprise, and giving full play to the strength of integration strategy, Sinopec has laid strong emphasis on CCUS technology research and application demonstration, which adopts CO₂ flooding as the major method of resource utilization and storage, achieving “Green Oil”.



燃煤电厂烟气CO₂捕集



驱油与封存



CO₂减排—绿色低碳 环境生态效益

Emission Reduction

---Social & Environmental Benefits

CO₂驱油—提高采收率 经济效益

Enhanced Oil Recovery

---Financial Benefits

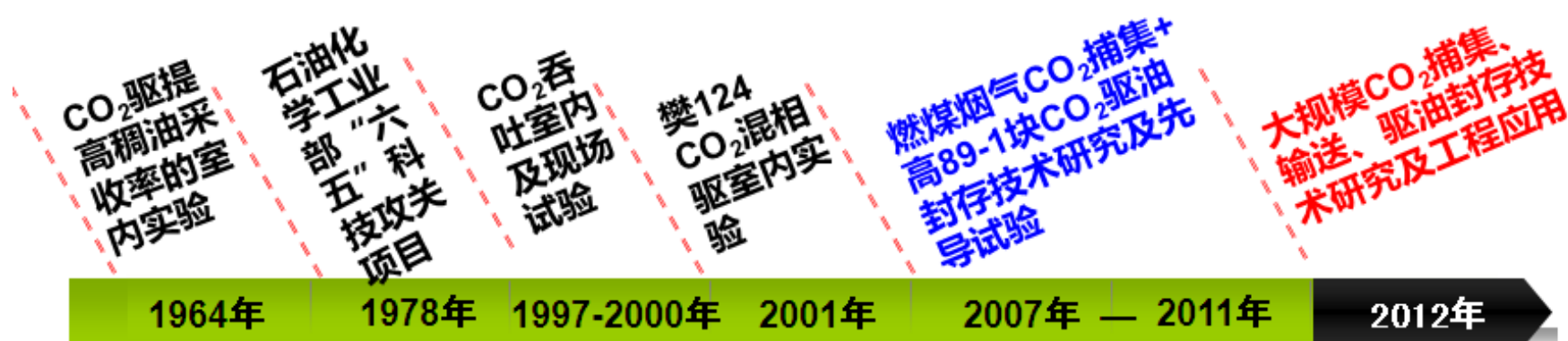
*经概算，消耗1吨原油产生约3.02吨CO₂，在低渗透油田应用CCUS技术，每注入封存4-5.6吨CO₂，可以增产原油1吨，消耗这部分原油CO₂净产生量为负值。



一、项目进展

I. Project Progress

➤ 胜利油田CCUS技术发展历程 History of Shengli Oilfield CCUS since 1964



自2007年起，国家及中石化加大了对胜利油田CCUS技术研发的支持，开展了多项科研课题。

Since 2007, Shengli Oilfield has made great improvement in the technology of CO₂ capture EOR utilization and sequestration

年度	课题来源	课题名称
2008	国家“十一五”科技支撑	烟气CO ₂ 超重力法捕集纯化技术及应用示范
2011	国资委示范工程	特低渗透油藏CO ₂ 驱大幅度提高采收率示范工程
2012	国家“十二五”科技支撑	大规模燃煤电厂烟气CO ₂ 捕集、驱油及封存技术开发及应用示范
2007	总公司课题（重大先导）	低渗透油藏注CO ₂ 提高采收率先导试验
2010	总公司课题	CO ₂ 驱油藏气窜规律及泡沫凝胶堵调技术研究
2010	总公司课题	高含水期CO ₂ 驱注采输系统腐蚀结垢控制技术研究
2011	总公司课题（十条龙）	燃煤电厂烟气CO ₂ 捕集纯化及应用技术研究



一、项目进展

I. Project Progress

● 建成了4万吨/年燃煤电厂烟气CO₂捕集纯化成套装置

Sinopec 100 t/d CCUS Project on Coal-fired Power Plant Flue Gas

将胜利电厂烟气中的CO₂捕集出来，经过压缩、干燥、液化及存储后，通过罐车输送至油区用于CO₂驱油与封存。

Process: capture and purify in Shengli Power plant, compress, dry, liquefy, store and CO₂ flooding



捕集纯化

Capture & Purify
Shengli Power Plant

MSA化学吸
收工艺

压缩

Compress

往复式
三级压缩

干燥

Dry

硅胶吸附

液化

Liquefy

R-22氟利昂
制冷剂

储存装车

Store, Load

真空绝热
储罐

捕集率：80%
纯度：99.5%

出口压力：2.5MPa
出口温度：40℃

水露点
≤ -40℃

液化温度：-20℃

储存压力：2.2MPa
储存温度：-20℃

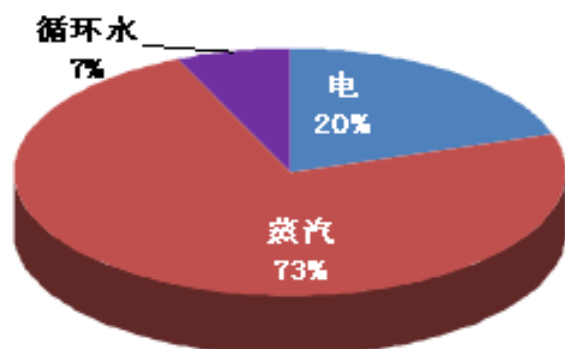


一、项目进展

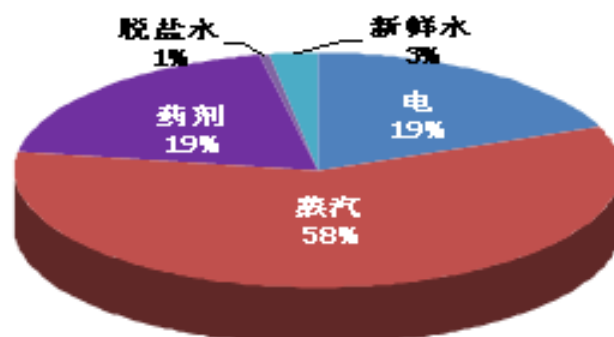
I. Project Progress

- 建成了4万吨/年燃煤电厂烟气CO₂捕集纯化成套装置

工业运行结果 (新型MSA-II高效溶剂) Solvent MSA-II :



捕集能耗： 4.36GJ/t CO₂



捕集成本： 191元/t CO₂

工业运行性能对比

项目	MEA	日本KS系列	胜利电厂100t/d装置
再生蒸汽消耗/(t/tCO ₂)	2.0	1.8	1.6
吸收剂损耗 (kg/tCO ₂)	3.5-6	0.8	<1.0
捕集成本 (元/吨)	295	(220)	191

中石化自主开发的高效CO₂捕集溶剂及工艺比传统MEA工艺再生能耗降低20%，同时吸收剂损耗有大幅下降，捕集成本降低35%，达到国际先进水平。

Sinopec independently developed new capture solvent with 20% reduction of energy consumption, capture cost decreased 35%, compared with traditional MEA capture, achieving international level.



一、项目进展

I. Project Progress

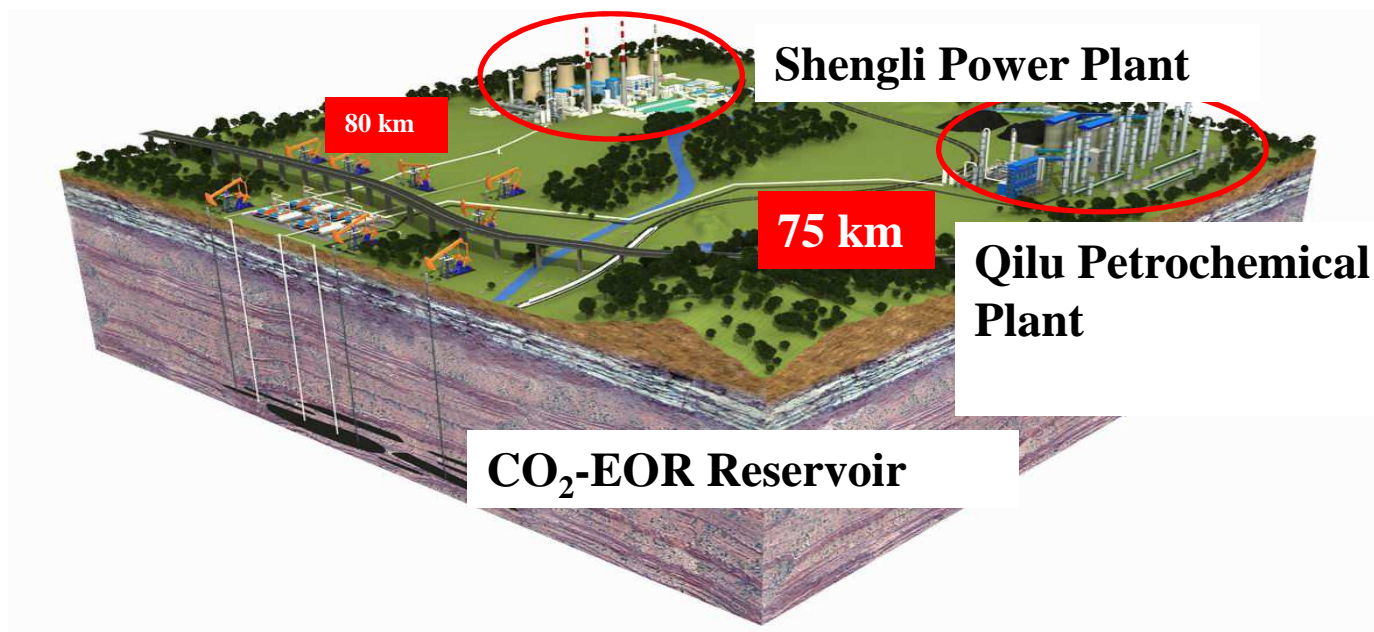
依托现有技术，中国石化建成了4万吨/年燃煤电厂烟气CO₂捕集纯化成套装置和高89低渗透油藏封存驱油场地，目前开展两项大规模CCUS示范工程的研究开发与施工建设：

- (1) 齐鲁石化50万吨/年煤制气尾气CO₂捕集、输送及驱油封存示范工程；
- (2) 胜利电厂100万吨/年燃煤烟道气CO₂捕集、输送及驱油封存示范工程。

Sinopec is undertaking two large-scale CO₂ capture, transport, enhanced oil recovery and sequestration projects under the strong support of the Ministry of Science and Technology:

Part 1: 1 Mton/year CCS-EOR project from Shengli Coal-fired Power Plant flue gas

Part 2: 0.5 Mton/year CCS-EOR project from Sinopec Qilu Petrochemical coal gas





一、项目进展

I. Project Progress

Goals

- Testing and optimization of the developed technology
- Economy assessment of CCS-EOR project
- Security of large-scaled storage project
- Best practice for the construction, operation and management
- Promotion of the commercial application of CCS-EOR



胜利电厂三期低浓度CO₂
(CO₂14%)
Shengli Power Plant Phase III,
Rarefied CO₂(CO₂ 14%)

↓ 1.0Mton/year

化学吸收法
Chemical Absorption Process

胜利油田
Shengli Oilfield



齐鲁煤制气高浓度CO₂
(CO₂90%)
QPEC Coal Gas,
elevated CO₂ (CO₂ 90%)

↓ 0.5Mton/year

低温精馏法
Cryogenic Distillation
Process

胜利油田
Shengli Oilfield



一、项目进展

I. Project Progress

- 1 Mton/year CCS-EOR project from Shengli Coal-fired Power Plant flue gas
 - The feasibility studies on CO₂ capture (the first version) and pipeline have been finished
 - The CO₂ flooding reservoir have been selected(0.35Mt/a)
 - The feasibility studies of CO₂ injection, drilling and production engineering, produced fluid gathering and transportation system are done
 - Project investment estimation
 - Baseline for CO₂-EOR environmental monitoring



一、项目进展

I. Project Progress

整体概况 Introduction

烟气引自电厂三期600MW机组脱硫、脱硝后出口烟道（该机组烟气排量35%），烟气的主要成分为CO₂和N₂，在胜利发电厂进行CO₂捕集、压缩、干燥，得到纯度为99.5%（V%）的CO₂，增压后CO₂管输至CO₂输送首站。
The flue gas comes from the flue gas outlet (flue gas displacement of 35% for this unit) of the **Phase III** 600MW units in Shengli Power Plant after desulfuration and denitrification, with primary components of CO₂ and N₂. The project will be conducted for CO₂ capture, compression and drying to obtain CO₂ with the purity of 99.5% (V%), which will be piped to CO₂ transmission initial station after being boosted.

装置包括三个单元：捕集、压缩、干燥

Device involves three units, namely capture unit, compression unit and drying unit.



捕集纯化

Capture and purification

捕集率≥80%

CO₂纯度≥99.5%

产品量 3300t/d



压缩

Compression

出口压力 11.5Mpa (g)

出口温度 40℃



干燥

Drying

出口压力 11.5Mpa (g)

水露点 <-40℃

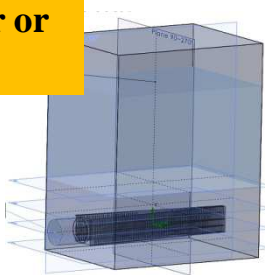
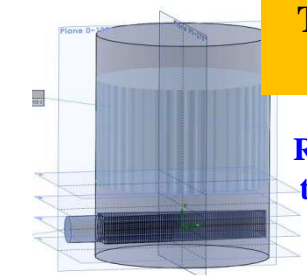


一、项目进展 I. Project Progress

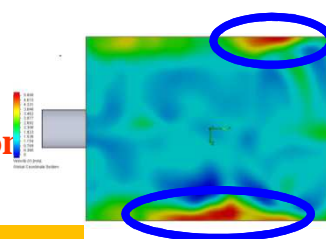
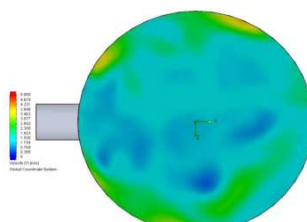
大型反应器设计 Design for large scale reactor

塔型：方塔or圆塔
Tower type: square tower or round tower

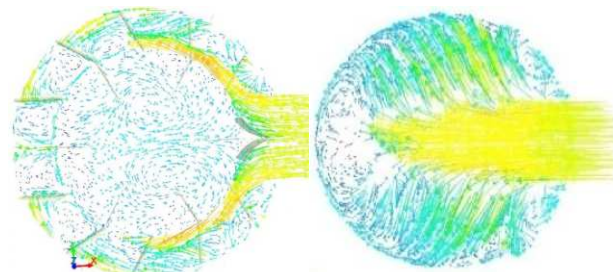
圆塔 Round tower
塔型 Tower type
方塔 Square tower



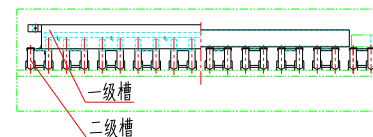
气速模拟
Gas speed simulation



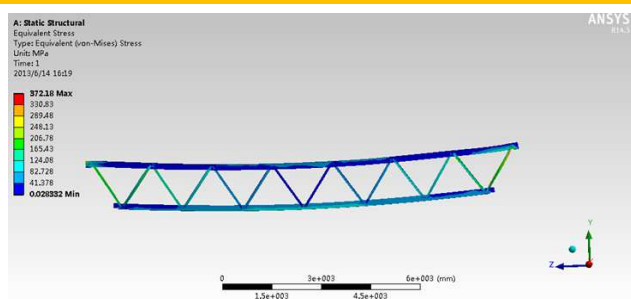
气体分布器优化设计
Optimization design of gas distributor



液体分布器优化设计
Optimization design of liquid distributor

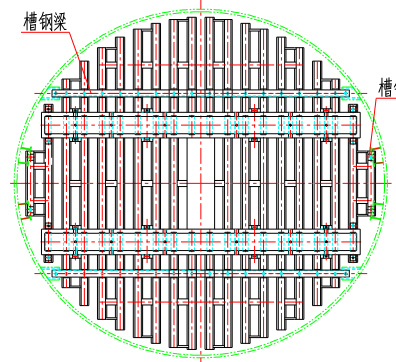


填料支撑桁梁优化设计
Optimization design of packing support frame



填料优选
Selection of packing

序号	填料名称	塔径	填料高度	泛点率	压降
		mm	mm	%	mbar
1	Zupac2.0	12400	15200	63.8	9.39
2	M250.Y	12500	15120	66.2	18.28
3	M250.X	11800	16056	60.9	11.92
4	IR25	14500	15000	65.2	31.95





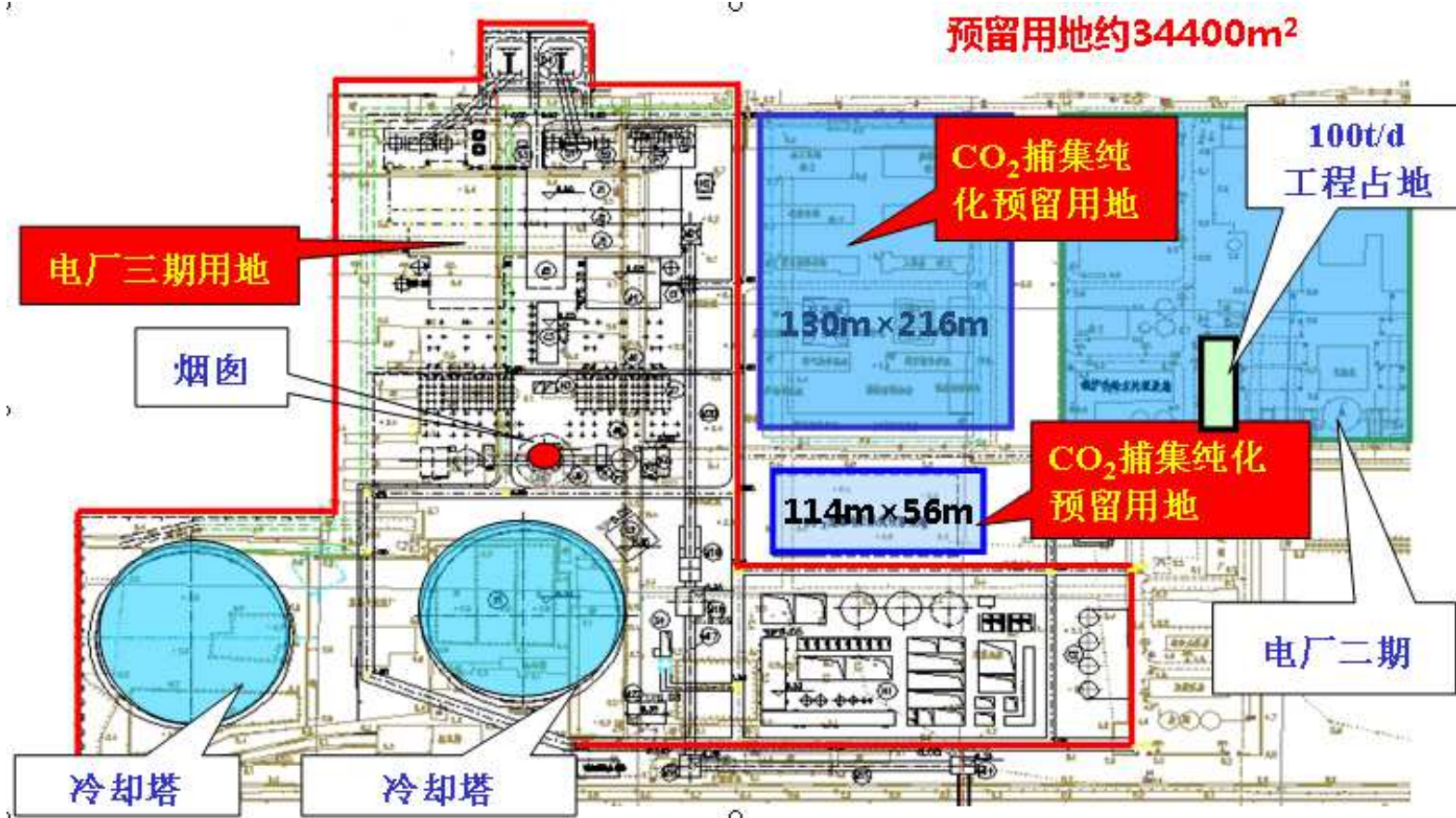
一、项目进展

I. Project Progress

总图布置 General layout

与胜利电厂三期充分结合，预留了工程用地。

The general drawing integrates the practical conditions of the Phase III project of Shengli Power Plant into consideration and reserves construction land.



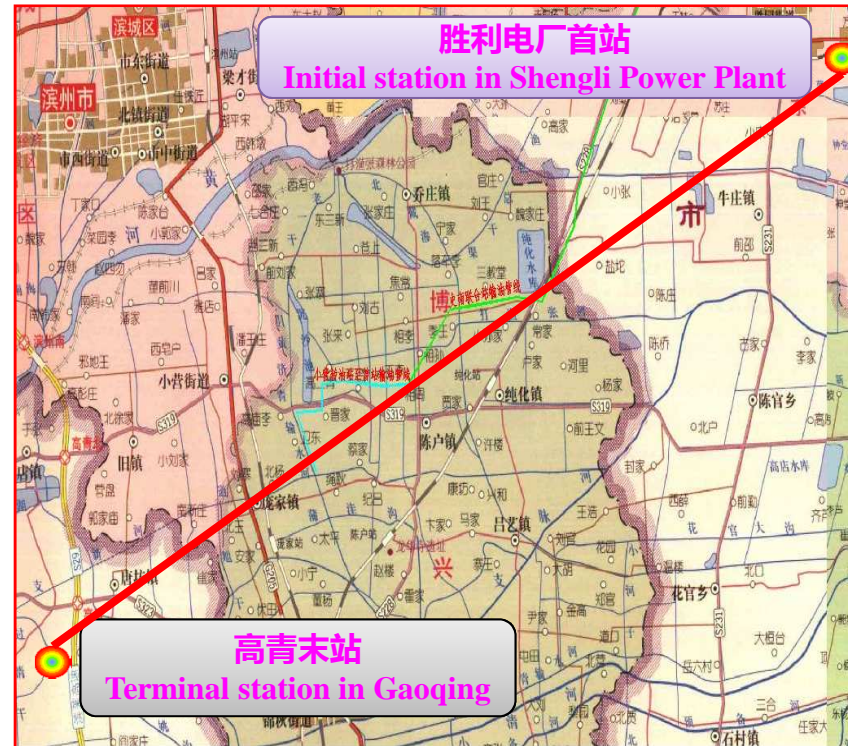


一、项目进展

I. Project Progress

管道输送工程概况 Pipeline Project overview

压力 11.5Mpa (g)
Pressure 11.5Mpa (g)
温度 40℃
Temperature: 40℃
 $\text{CO}_2 \geq 99.5\%$
规模: 100万吨/年
Scale: 1 million t/a



管道工程起点为胜利电厂首站，接收胜利电厂捕集增压后的二氧化碳（99.5vt%），通过长输管道输送至驱油封存区高青末站。

The pipeline project starts from the initial station in Shengli Power Plant and ends in the terminal station in Gaoqing, for receiving and transporting captured and boosted CO_2 (99.5vt%) in Shengli Power Plant.



一、项目进展

I. Project Progress

管道配套安全措施 Pipeline Supporting safety measures

增大管道壁厚、加大管道埋深、在人口稠密区增多阀室；在站场工艺装置区、阀室等处设置CO₂气体检测探测器，检测CO₂泄漏情况并进行现场声光报警；而管道沿线村庄较多，从安全、运营等方面考虑，设置高精度音波泄漏检测系统。

Increase the wall thickness and the burial depth of pipeline; add valve chambers in congested areas; set CO₂ detectors in the process unit area and the valve chambers to detect CO₂ leak and send out sound and light alarm signal; for pipeline with many villages along the line, a high accuracy acoustic leakage detection system is set for safety and operation concerns.





一、项目进展

I. Project Progress

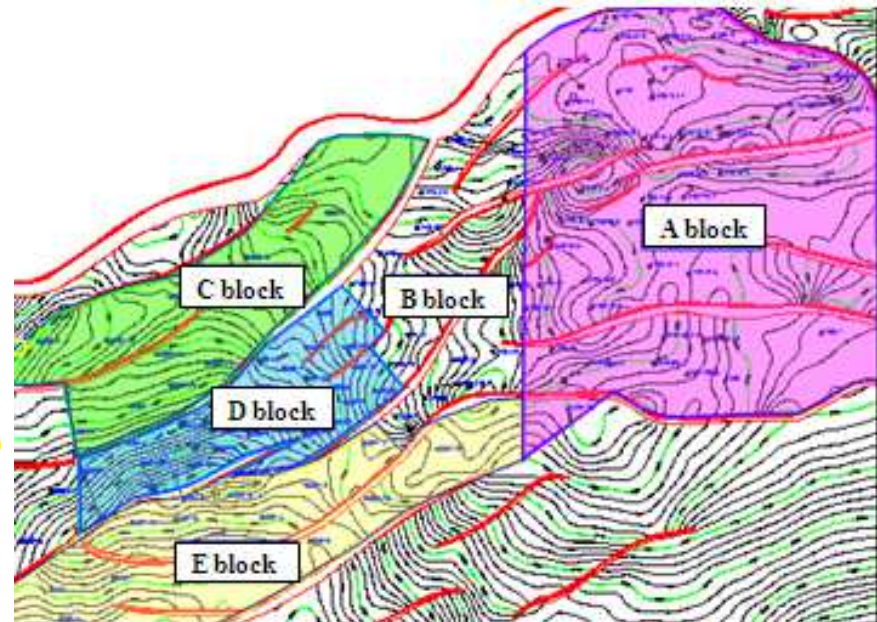
优选了CO₂驱油与封存示范区

Optimized CO₂ flooding & storage demonstration area

筛选原则

Screening principles

- (1) 满足油藏适应性评价标准;
- (2) 具有较大的储量规模, 注气能力达到60万吨/年以上;
- (3) 地质认识清楚, 目前地层压力在混相压力附近;
- (4) 综合含水较低或基本不含水。



示范区: 优选了本项目驱油封存区块。油藏埋深2700-3200m, 含油面积40.3km², 地质储量1450×10⁴t, 渗透率2.1mD, 目前共有完钻井137口。

Demonstration Area: A-E Blocks was finally selected as the flooding & storage block of the Project. This block is located in Gaoqing County, Shandong Province, with buried depth being in the range of 2,700-3,200m, oil-bearing area of 40.3km², geological reserves of 1,450×10⁴t, permeability of 2.1mD, where 137 wells were drilled.



一、项目进展

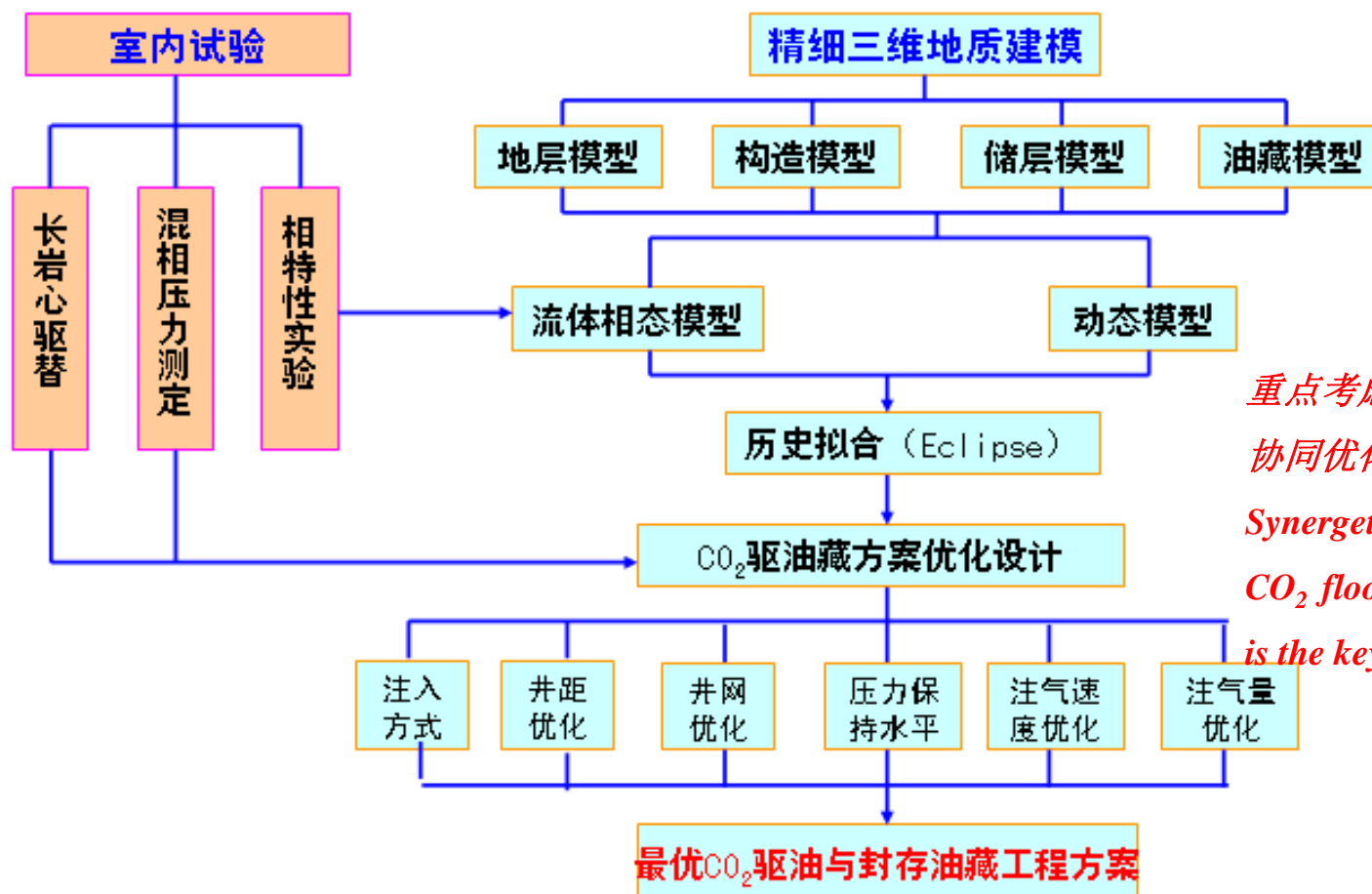
I. Project Progress

CO₂驱油与封存的油藏工程方案

Reservoir engineering scheme for CO₂ flooding and storage

CO₂驱油与封存优化设计流程

Design process for optimization of CO₂ flooding and storage



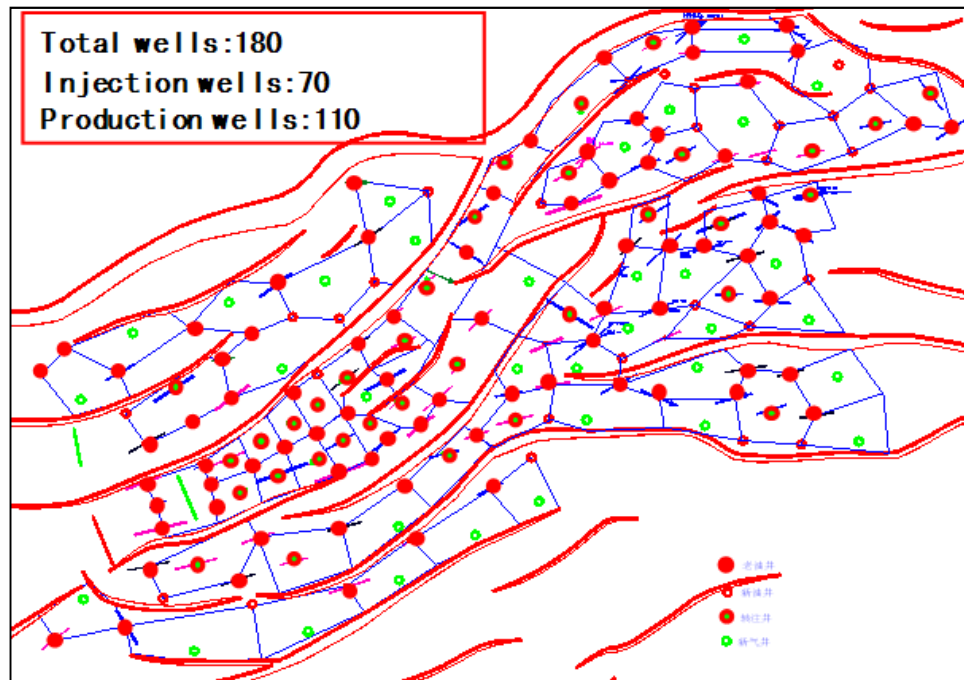
重点考虑CO₂驱油与封存
协同优化

Synergetic optimization of
CO₂ flooding and storage
is the key consideration

一、项目进展

I. Project Progress

- Reservoir development program for CO₂ flooding and storage



It is expected that the recovery percentage will reach 17.4% (elastic recovery rate of 10.7%) with the accumulated CO₂ storage of 366×10^4 t and accumulated oil production of 252×10^4 t to the end of 20 years.



一、项目进展

I. Project Progress

- 研发了三种不同的采出气CO₂回收工艺并进行了现场试验 (CO₂捕集率 > 80%, CO₂纯度 > 95%)

CO₂ recycle process development, CO₂ capture efficiency > 80%, CO₂ purity > 95%



变压吸附脱碳系统

Decarburization by pressure variable absorption

适用于：中小规模

试验规模：1000Nm³/d

运行成本：115元/吨



化学吸收脱碳系统

Decarburization by chemical absorption

适用于：大规模，中低CO₂含量

试验规模：30000Nm³/d

运行成本：120元/吨



低温分馏脱碳系统

Decarburization by low temperature fractionation

适用于：大规模，高CO₂含量

试验规模：75000Nm³/d

运行成本：108元/吨



一、项目进展

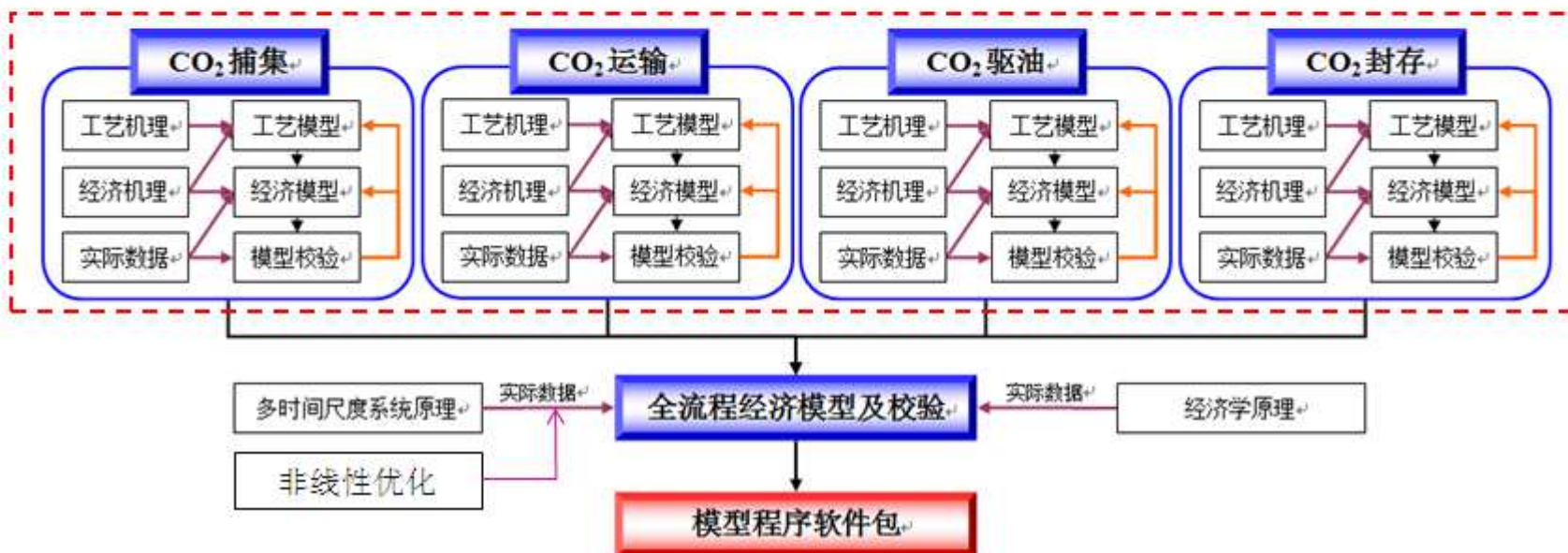
I. Project Progress

CO₂捕集、驱油及封存工程技术经济综合评价

Economic assessment for CCS-EOR

基于工艺机理、经济机理及实际数据建立工艺模型、经济模型，并对模型进行校验，目前已完成了CCUS（捕集、输送、驱油及封存）经济评价模型的建设。

Economic assessment for CCS-EOR contains process model, economic model, and validation based on the mechanisms of process and economy. Until now, economic models for single stage have been built up.



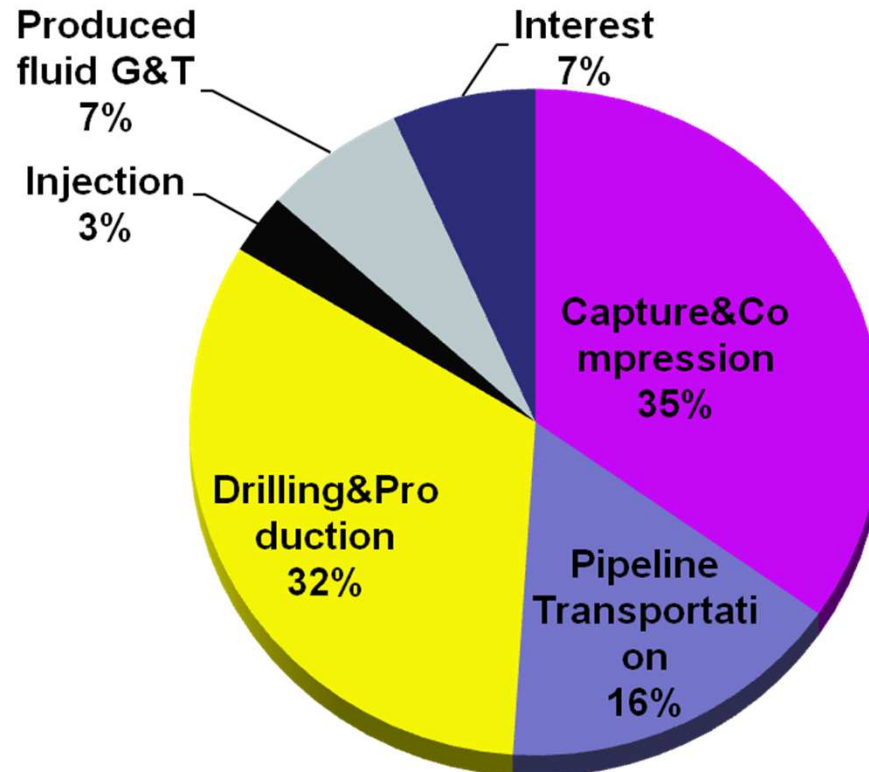


一、项目进展

I. Project Progress

- Project investment estimation

Project investment :1.89 billion RMB





- 注气前**

几十厘米

包气带

3-5米

潜水层

十几米

隔水层

盖层

2500-3000米

油藏

定性+定量：对比注气前后

土壤气

植被

Groundwater

Ground deformations

Air

注气后

The diagram illustrates the qualitative and quantitative comparison of CO2 injection before and after. The left side shows the 'Before' state with a vertical profile of geological layers: 壤土 (topsoil), 包气带 (vadose zone), 潜水层 (aquifer), 隔水层 (aquiclude), 盖层 (caprock), and 油藏 (oil reservoir). The right side shows the 'After' state with CO2 bubbles in the vadose zone and aquifer. The center features a dashed box with '土壤气' (soil gas), '植被' (vegetation), '地面变形' (ground deformation), and '浅层地下水水质指标' (shallow groundwater water quality indicators). Below this is a box with images and labels for 'soil gas', 'Vegetation', 'Groundwater', 'Ground deformations', and 'Air'.



汇报提纲 Report Outline

一、项目进展

I. Project Progress

二、面临挑战

II. Challenges



二、面临挑战 II. Challenges

1、缺乏CCUS相应的法律法规框架

Lack of corresponding legal and regulatory framework available to CCUS

- ✓ 管辖部门及审批程序不明确
- ✓ **Competent department and approval procedure are not clear**

本项目涉及三个行政区的法律、法规关系，同时也涉及能源、环境等多个监管部门。目前CCUS项目的司法管辖权以及CCUS项目审批和监管程序尚不明确，CCUS工程立项、建设及运行监管等存在潜在困难和风险。

The project involves laws and regulations of two administrative divisions as well as several supervision departments like energy department and the environment administration department, etc. At present, the jurisdiction of CCUS project as well as the project approval and supervisory process are still not clear. Therefore, potential difficulties and risks exist in CCUS project approval, construction, operation and supervision and other aspects.

- ✓ 缺乏CCUS相关技术规范
- ✓ **Lack of technical regulations available to CCUS**

我国目前还没有专门的CO₂捕集、输送、封存选址、环境监测的工程标准或规范，在技术评选、立项评审、工程设计及安评、环评等方面存在困难。

So far, there is no special engineering standard or specification on CO₂ capture, transmission, storage site selection and environmental monitoring. Therefore, difficulties exist in technology selection, project approval review, engineering design, safety evaluation & environmental evaluation and other aspects.



二、面临挑战 II. Challenges

1、缺乏CCUS相应的法律法规框架

Lack of corresponding legal and regulatory framework available to CCUS

- ✓ **CCUS项目所有权不明确**
- ✓ **Ownership of CCUS project is not clear**

目前的法律法规体系下，企业及政府承担的潜在风险、项目所有权、减排收益分配权、责任归属等不明确，导致项目承担较大的政策风险、环境风险及经济风险。

The current laws and regulations system has no clear stipulations on responsibilities of enterprise and government in terms of potential risks, project ownership, emission reduction profits distribution and ascription of responsibility, so the project may have high risks of policy, environment and economic.



二、面临挑战 II. Challenges

2、先期示范的大规模CCUS项目面临较大的风险

Risks to the large-scale CCUS project at early

stage

目前，在国内开展小规模的先导或示范项目，企业可以承担，但大规模的CCUS应用，投资较高，即使是对效益相对较好的驱油应用，由于油藏条件与美国、加拿大等国家相比较差，驱油所获增油收益非常有限，在目前的政策体系下，CCUS项目的经济评价较差。另外，随着技术快速进步，CCUS项目成本和投资下降较快，先期投入的工业示范项目会因此承担更多的经济风险，同时由于法规体系的不完善，企业还要承担可能的环境风险。在这种情况下，亟需从国家财税及产业政策上给予先期进行的工业示范项目给予支持，如降低特别收益金、减排补贴、降低贷款利率等等。

At present, enterprises can conduct small pilot or demonstration projects at home, but large-scale CCUS application often require big investment, even in relatively successful oil displacement area. As reservoir condition in our country is relatively poor compared with those in other countries like America and Canada, few benefits can be achieved through EOR by flooding. Thus, CCUS project economic evaluation is negative under the current policy system. Besides, benefiting from the rapid development of technology, the cost and investment of CCUS project are coming down, which may give rise to more economic risks in early industrial demonstration projects. Moreover, due to the inefficient regulation system, enterprises have to bear potential environmental risks. In this case, it is imperative that the industrial demonstration projects shall be supported by state favorable policies in aspects of fiscal & taxation and industrial development, by means of reducing special oil gain levy, offering subsidies for emission reduction, lowering loan interest rate, etc. for example.



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