五环科技股份有限公司
WUHUAN ENGINEERING CO., LTD.

Capture Process Selection and Cost Analysis

for

The First CCS Pilot Project in China

Professor: Pi Jinlin

2010-11-4

WUHUAN'S Engineering Office

五环科技股份有限公司

Wuhuan Engineering Co., Ltd

cags

China Australia Geological Storage of CO_2

中澳二氧化碳地质封存

Brief Introduction to Wuhuan Engineering Co.,LTD

- An national grade design institute with the history of over 50 years; Rank within top 20 engineering firms many times in China .
- Focus engineering fields: Coal chemical,ammonia,NH3 processing, phosphate chemical and synthetic materials industries. Over 50% of NH3, Ur and methanol capacity in China were constructed from Wuhuan's engineering.
- Many significant domestic chemical projects were designed by Wuhuan.
- The annually contract price : RMB 8 billion (EPC and engineering service).
- Professionals (engineers and experts): 1200, including 2 National Design Masters and 37 experts with national subsidy.
- Address: 1019 Minzu Road, Wuhan, P.R. China
- Website: CWCEC.COM

Wuhuan_ Reference of the built large and middle-sized projects (over1000)

Ammonia、Methanol、Coal Chemical、Natural Gas Chemical	*252*
Chemical Fertilizer	*233*
Nitric Acid、Sulfuric Acid、hydrochloric acid	*38*
Caustic soda、Soda ash	*14*
Inorganic salts chemical ,	
Fine Chemical, Food, Pharmaceutical, Chemical pesticides	*41*
Petrochemical、Organic chemical	*30*
Town gas、LPG and Oils storage engineering	*61*

Wuhuan _ Reference of the built large-sized and middle-sized projects (To be continued)

Thermal power engineering	*45*
ASU	*19*
Composite material	*11*
Environmental protection and impact	*86*
City planning and civil architecture	*152*
Project cost estimate	*320*
Project supervision	*53*
Project EPC contracting	*46*

Wuhuan __Awards and Patents

- ***Awards*** ***212***

  Thereinto: National ***40***

  Provincial ***156***

- ***Patents*** ***28***

Welcome Cooperation！ Thanks！

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Content

- Project Overview
- Configuration of Units
- Capture Process Selection / Eng. Schemes
- Investment estimate and Cost Analysis
- Conclusion

1.Project Overview_Background

Project Owner: Shenhua Group

Project objectives:

-- to construct and operate the first pilot CCS project in China,

-- to gain the knowledge and experience of capture, transportation and CO2 storage in aquifers .

-- to provide experience and data support as requested for the construction and operation of commercial CCS project with injection capacity of over million tons /a

Injection Capacity : 10kt/a

1.Project Overview_Background

CO2 Source: Vent gas of Acid Gas Removal Unit of Coal to Hydrogen Plant in CTL Complex with CO2 concentration of 87%

Overall Process: Compression, Purification, Separation, Liquefaction, Transportation, Injection

Project Site: Yijinhuoluoqi , Ordos, in Inner Mongolia, Ordos basin.

--Capture and Liquefaction Units: inside Shenhua CTL

-- Injection and Storage Reservoir : 20km from the Complex

1.Project Overview_Schedule

- July, 2009,

  Shenhua Group entrusted Wuhuan Engineering responsible for project feasibility study, basic engineering and detailed engineering .

- Up to now,

  Engineering completed,

  Installation and construction almost completed,

  Expected to inject CO2 into underground in December of 2010.

1.Project Overview
_Technical and Economical Index

No.	Items	Unit	Amount	Remark
1	CCS capacity	kt/a	10	
2	operation time	Hours/a	7440	
3	CO2 Specification			
	Food grade CO_2	kt/a	10	After completion of the pilot operation
4	Consumption			
4.1	Feed CO_2	k t/a	13.7	
4.2	Power	kWh/h	2322	
4.3	Cooling water	t/h	269	
4.4	LP Steam	t/h	0.5	
5	Capital Investment	M RMB	~2	
6	Cost of CCS	RMB/tCO2	277	41$/t

2.Configuration of Units_Capacity

- Injection capacity：

  13.4 t/h（Food grade/Storage grade liquid CO2）

  322.6 t/d

  10 kt/a

- Operation system：

  Annual operation days： 310 d/a

  Daily operation hours： 24 h/d

  Annual operation hours： 7440h/a

2. Configuration of Units
_ CO2 Product Specification

Product	Design requirements	Remark
Storage Liquid CO2	Purity≥95%	
	Pressure：1.7~2.2MPa.G	
Food grade CO2	Purity≥99.9%	GB10621-2006

2. Configuration of Units _ WBS

- Level 1：

  --Ground facilities (capture and transportation facilities）

  --Underground engineering and monitoring system（storage system)

- Level 2: Ground facilities：

  -- CO2 Compression,

  --Purification,

  --Liquefaction and Distillation,

  --Refrigeration System,

  --Storage and Transportation,

  --Utility distribution

  --Control system

2. Configuration of Units _ WBS

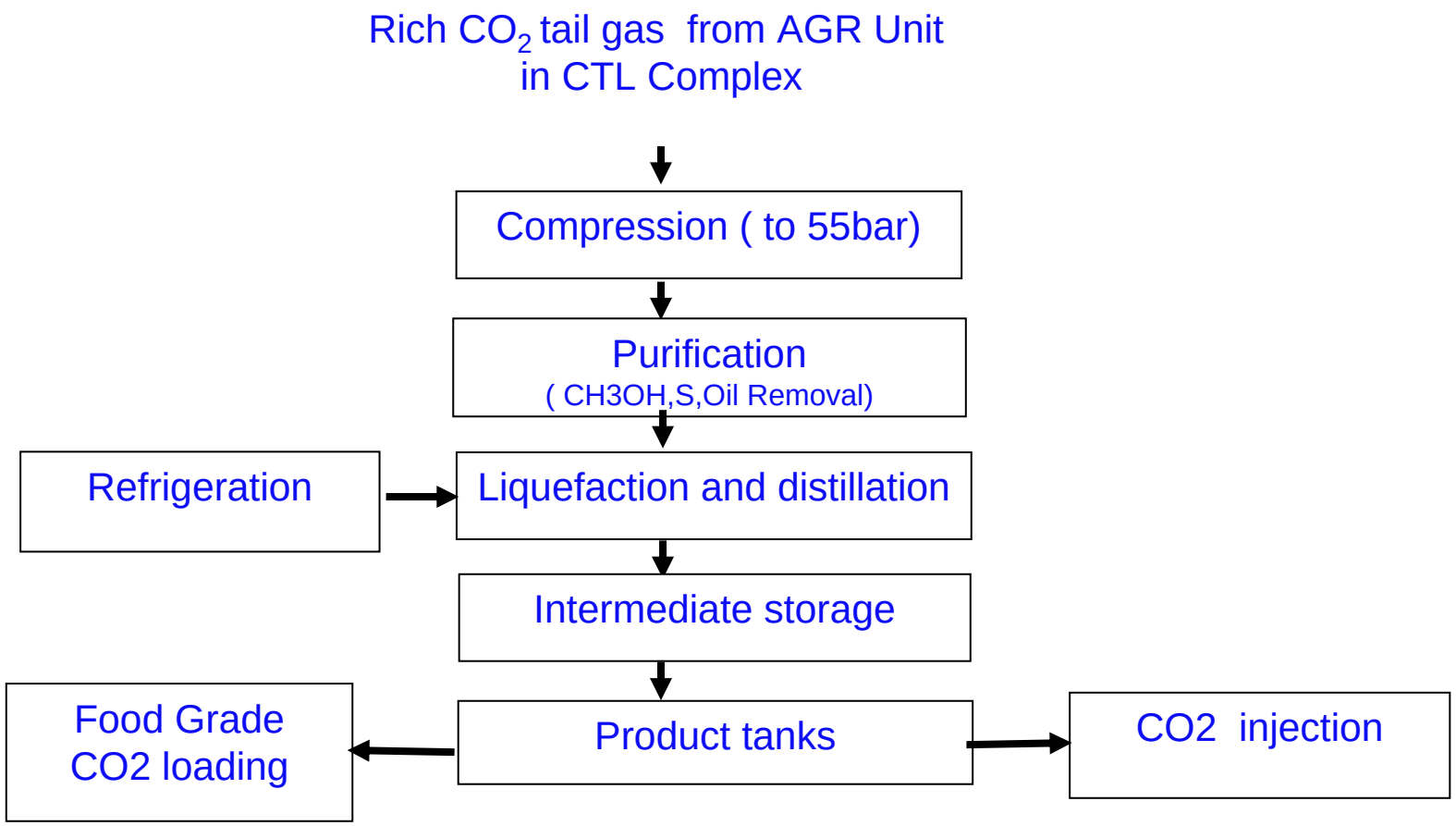
- Level 2: Underground Engineering and Monitoring System:

  --Injection Well

  -- Monitoring Well

  --Underground Storage Reservoir

2. Configuration of Units_ Process Flow Block Diagram



3. Process Selection _ CO2 Feed

	Design data，mol%	Actual data，mol%
T (℃)	25.5	25--30
P(MPag)	0.105	0.08—0.10
CO2	87.938	83--88
CO	0.0178	TRACE
H2	0.17	1.1—1.25
N2	10.503	11--15
H2O	1.358	TRACE
H2S	0.000341	TRACE
CH3OH	0.009955	5—12ppm
CH4	0.001156	0.01—0.02
Ar	0.001182	0.01—0.05

3. Selection of Capture Process

Option 1： Revamping of Rectisol Unit to rise up CO2 concentration

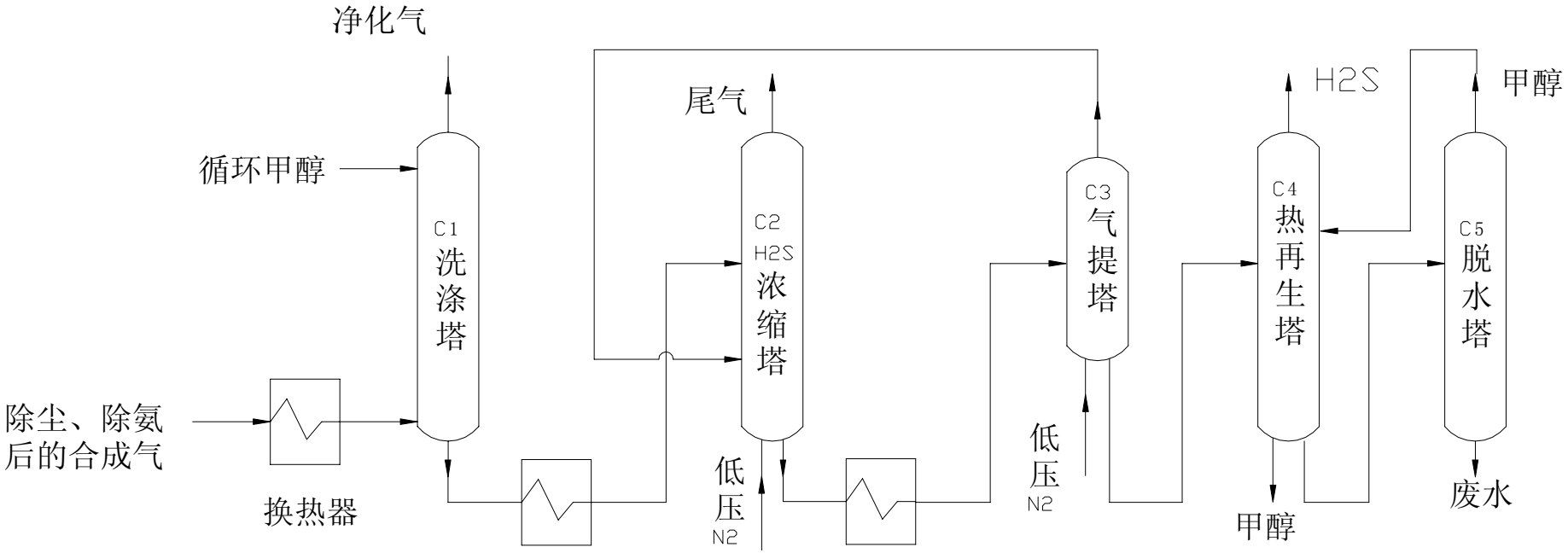
Restore the existing flow into the typical Rectisol process of ammonia industry.

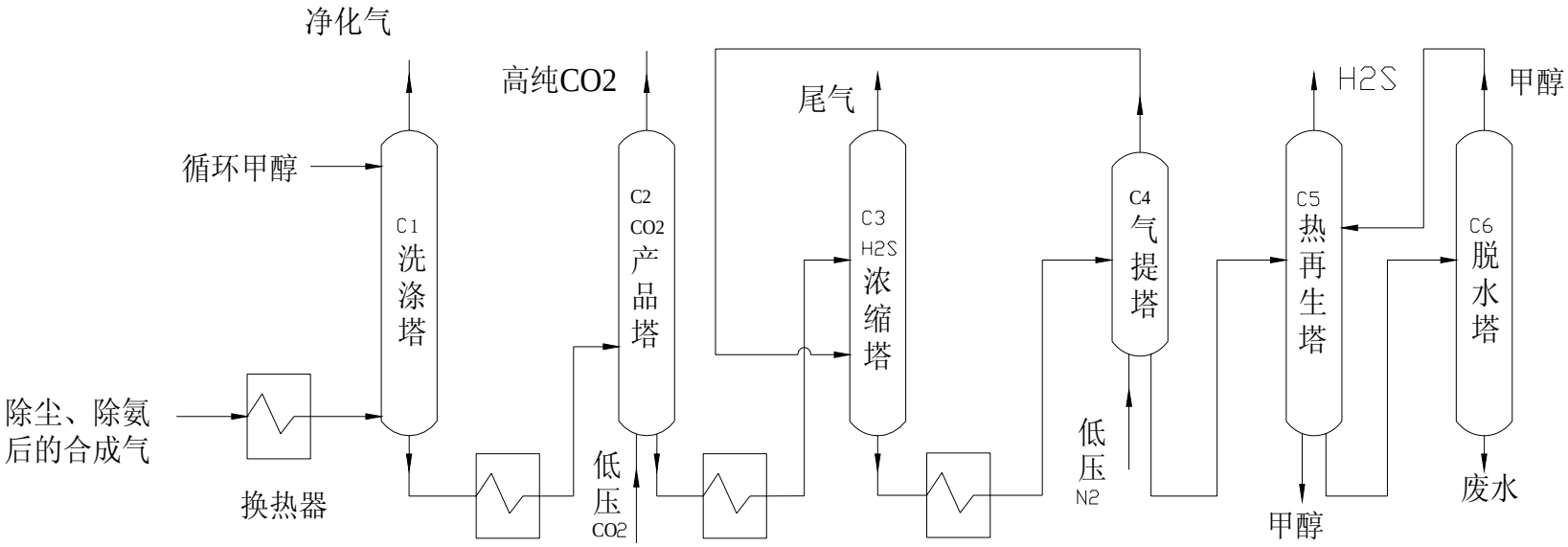
Main revamping including：

--add one CO2 product column（new CO2 column）；

--add one set of spiral wound heat exchanger；

--add one set of LT heat exchanger and LT pump, etc.


净化气
循环甲醇
除尘、除氨
后的合成气
换热器
C1
洗涤塔
尾气
C2
H2S
浓缩塔
低压
N2
C3
气提塔
低压
N2
H2S
C4
热再生塔
甲醇
甲醇
C5
脱水塔
废水


净化气
高纯CO2
尾气
H2S
甲醇
循环甲醇
C1
洗涤塔
C2
CO2
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脱水塔
除尘、除氨
后的合成气
换热器
低压
CO2
低压
N2
甲醇
废水

3. Selection of Capture Process

Option 2：Installation of additional Purification and concentration System

An additional system which adopts TSA and LT distillation technology is installed for purification and concentration of CO2 into liquefied phase.

A typical food grade CO2 process will be employed

_Comparison of Options

Item	Option 1	Option 2
CO_2 Sequestration Spec.	Satisfied	Satisfied
Food Grade CO_2 Spec.	No	Yes
Construction period	＞ 12 months	~10 months
Impact on CTL operation	CTL Complex shutdown for ＞ 12 months	No impact on CTL operation
Layout limit	Limited, no space for additional equipments	Available, to be installed on spare area of CTL Complex.

Option 2 is picked up.

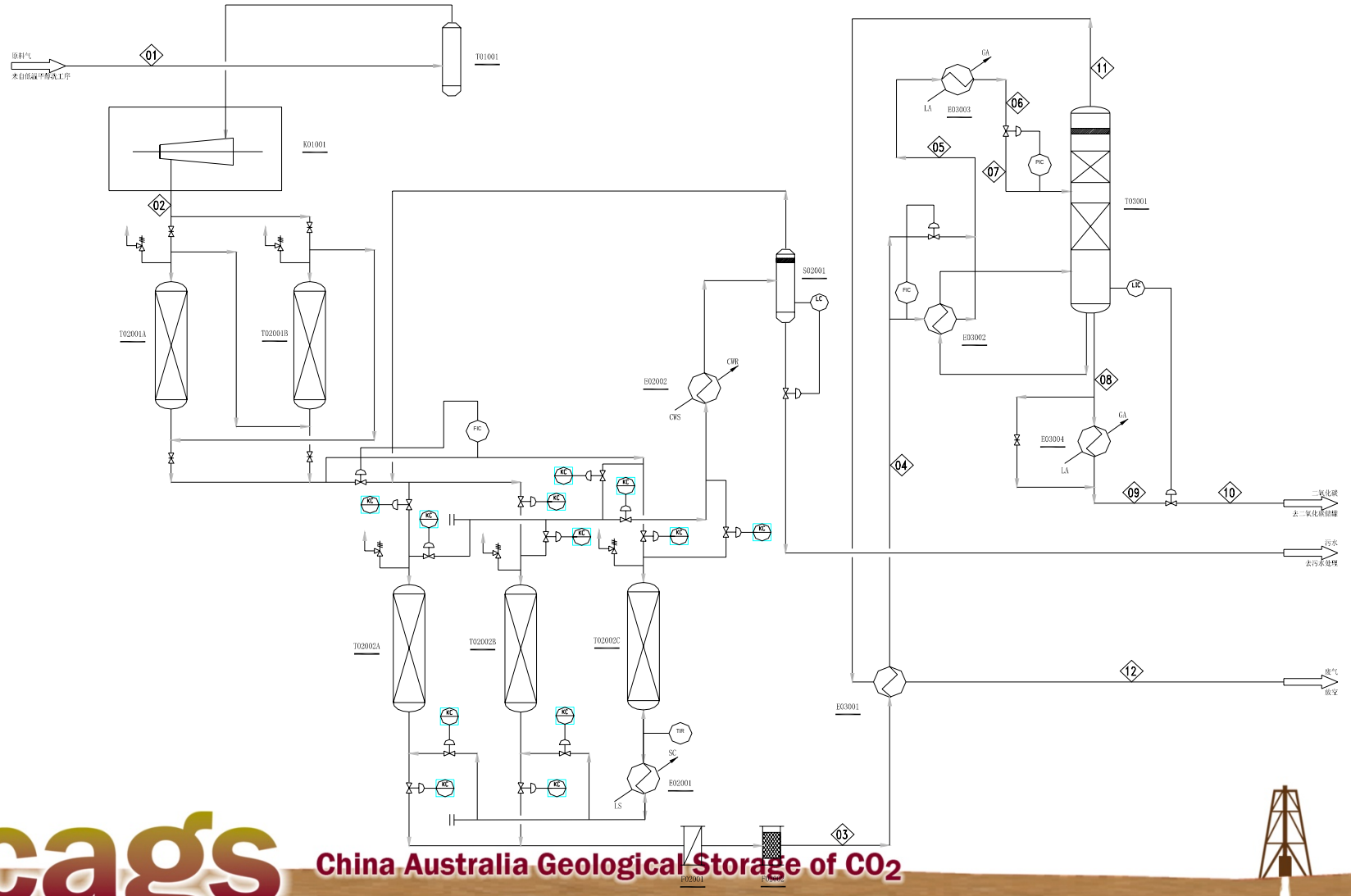
_Pressure Selection of Purification and Liquefaction

Utilities Consumption at Different Liquefied Pressure (On tons of CO2)

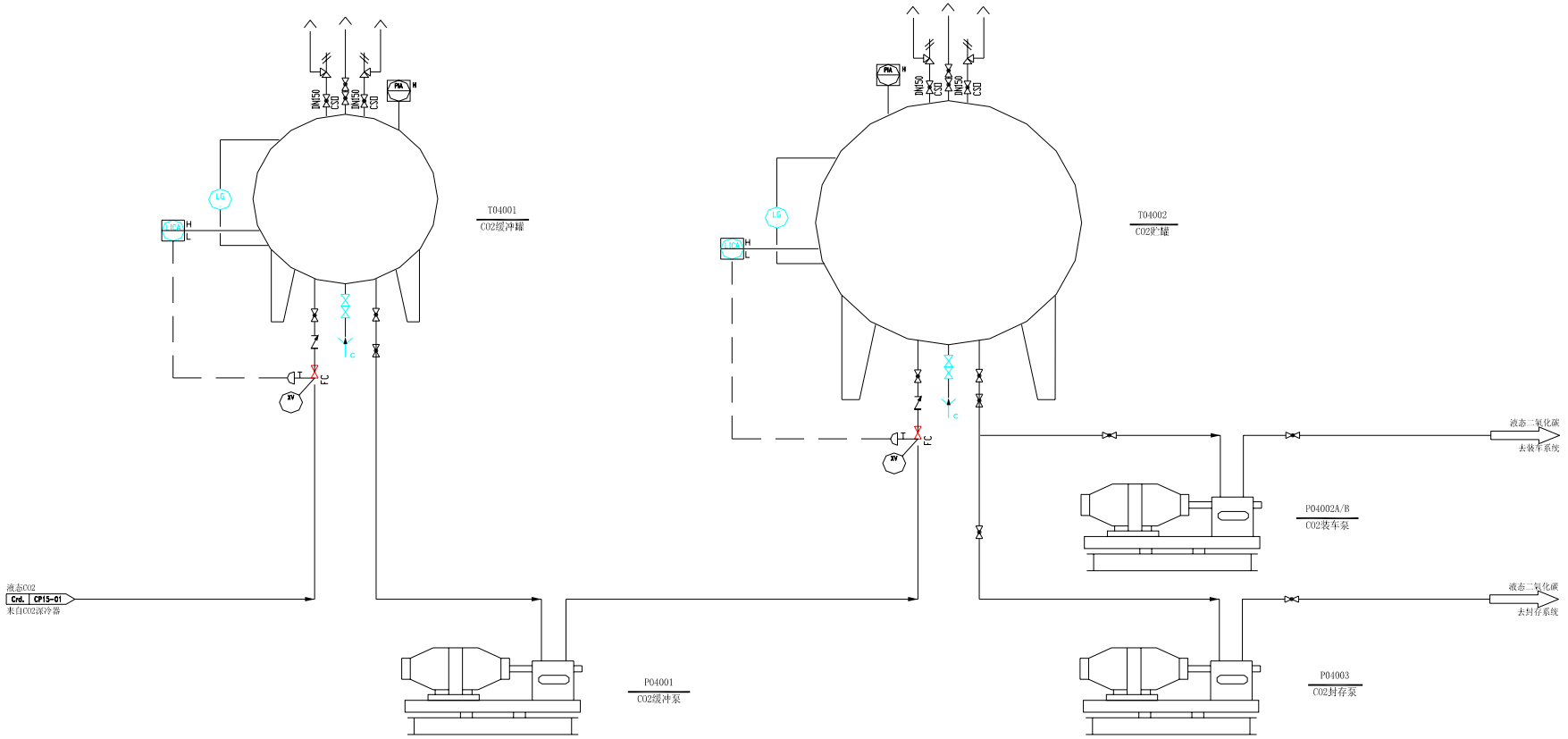
Consumption	Pressure of purification and liquefaction (MPa)			
	2.5	4	5	7.8
Cooling water (△t=12℃) m^3	28.9	22.4	18.8	19.2
Raw gas compression power (kW)	215.9	106.1	107.3	118
NH3 compression power (kW)	60.7	62	49.4	42.6
Total power consumption (kW)	276.6	168.1	156.7	160.6

5.0MPa is chosen for purification and liquefaction.

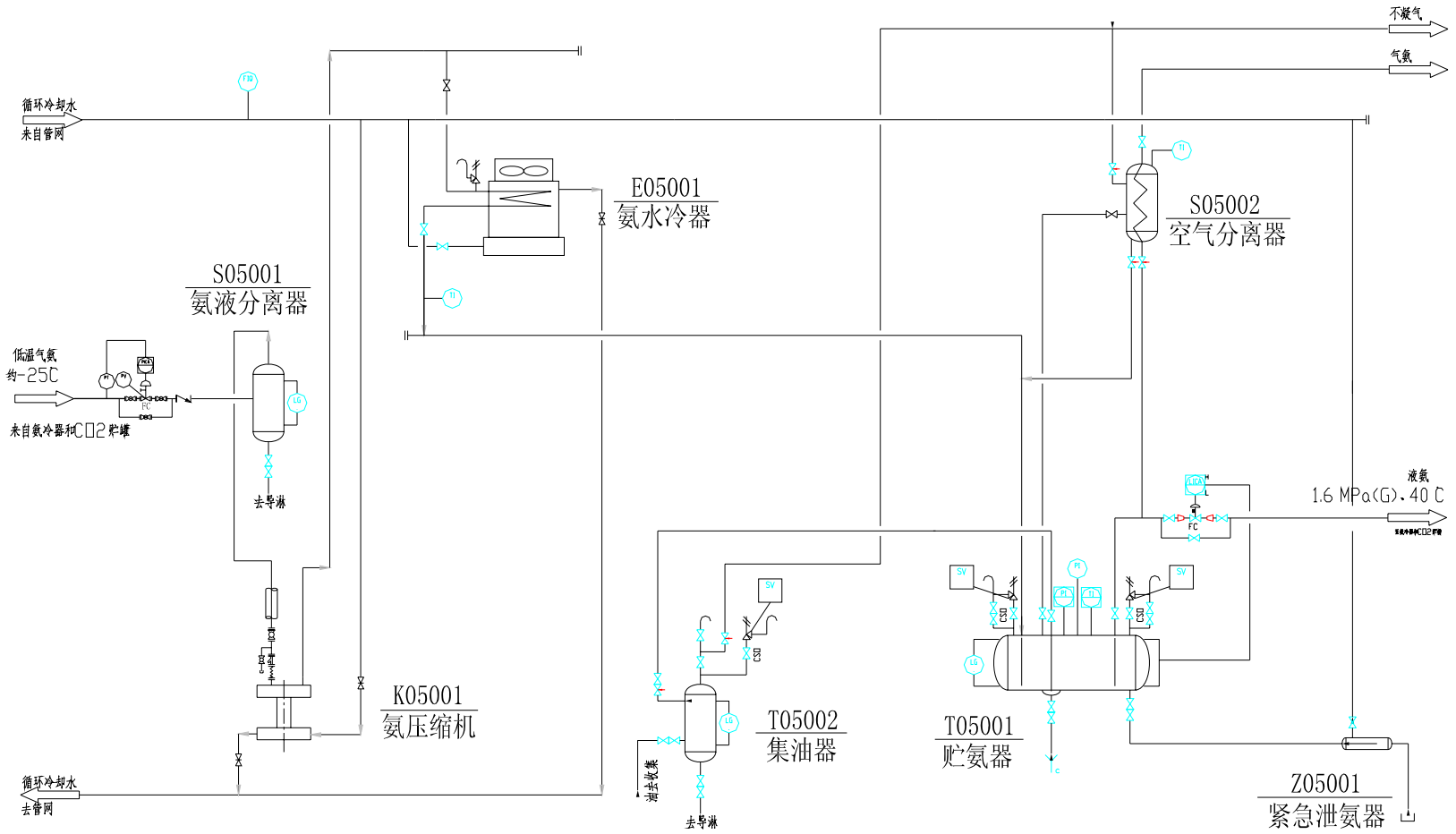
_Process Flow Diagram（compression, purification, liquefaction and rectification)



_Process Flow Diagram（Including transportation and intermediate storage



_Process Flow Diagram（refrigeration system）



_Utilities Consumption

Electricity	220V、50HZ	kW	100
	380/6k/10kV、50HZ	kW	2108
Cooling water	P=0.4～0.5MPa △t=12℃	t/h	254
Steam	T≥180℃	t/h	0.5

4. Capital Investment Estimate

- Total investment of the project: ~2 00 MRMB

including：

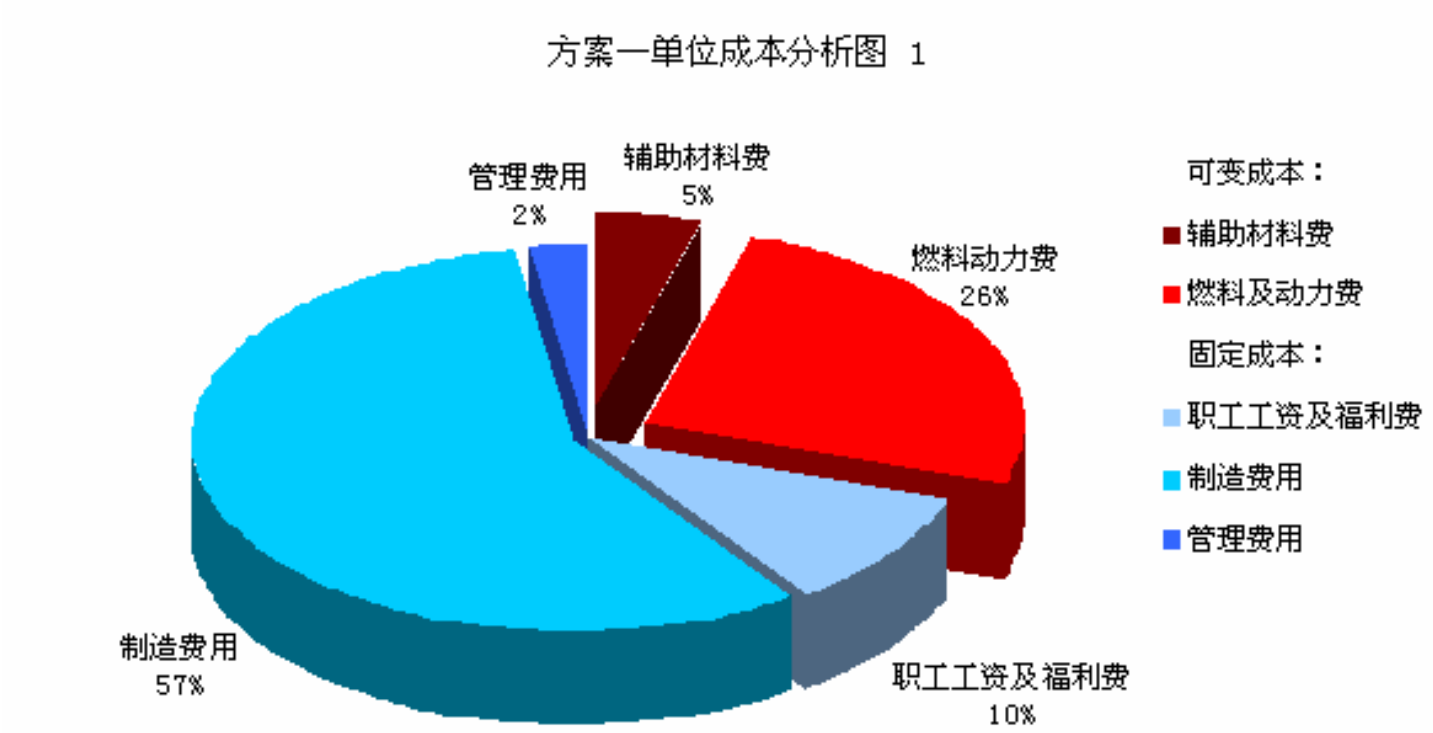
Construction investment ~190 MRMB

_Cost Analysis

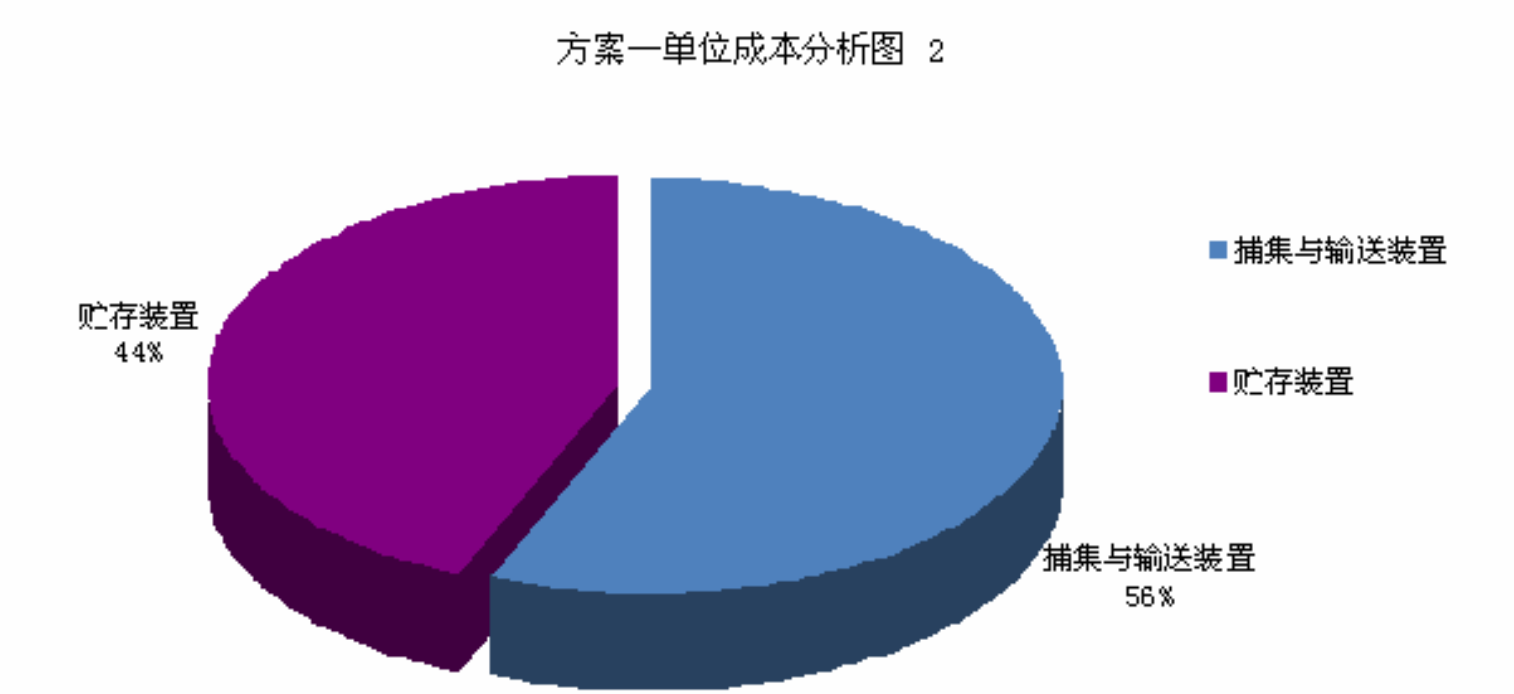
CCS cost	RMB/t CO2	277.12	41$/t

- CCS cost is 41$/t which is lower than 100-120 $/t as estimated for regular CCS projects abroad, which indicates:

--CO2 rich feed from CO2 removal/capture process integrated in a chemical project like CTL benefits the decrease of CCS cost and favors CCS deployment.



The variable cost : 31%，the fixed cost totally is 69%.
The fixed cost goes down as the capacity rises up.
The cost for a commercial project with over million tons/a injection will be lower than 41$/t.



The cost of capture and transportation accounts for 56%, lower than the portion(70-80%)of regular CCS project, while the cost of injection accounts for 44%，higher than the portion(20-30%) of regular CCS project as estimated. As the storage reservoir investment has a little relation to the capacity, the cost for million tons /a project will be lower than 41$/t.

5 Study Conclusion

- ✓ Selected capture process for CO2 rich source is mature and reliable with low operation cost and investment.
- ✓ The cost analysis indicates that CO2 source which is the tail gas from CO2 removal of a chemical complex benefits the decrease of CCS cost.
- ✓ Commercial CCS project is best to focus on CO2 rich sources.

THANKS
FOR YOUR ATTENTION !

Q&A