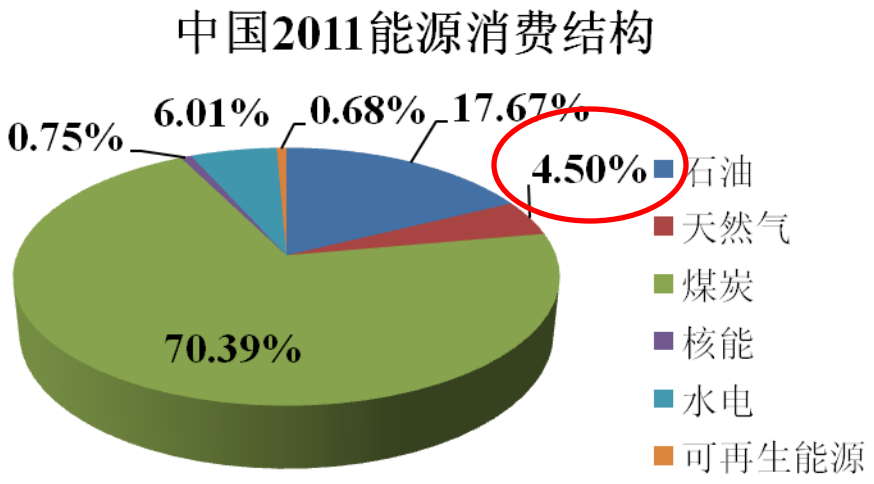
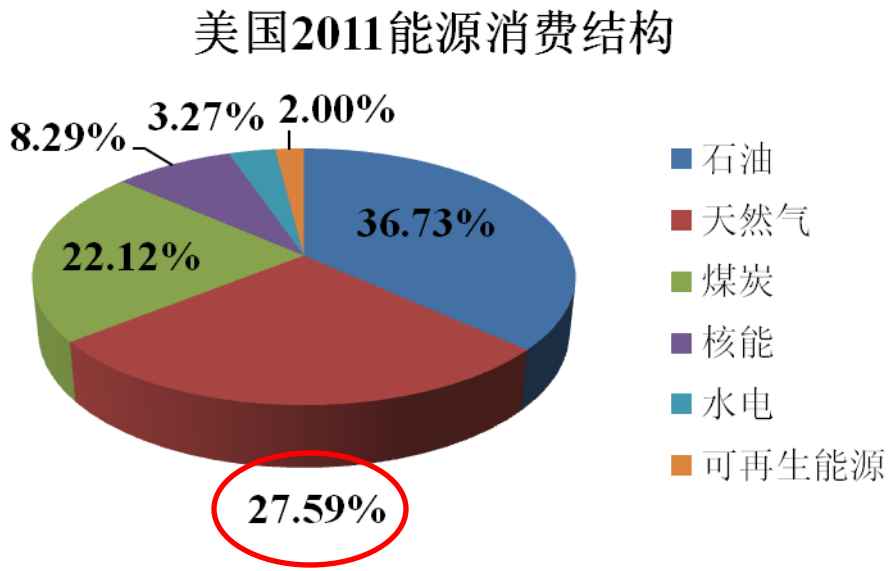
Technology and application of concentrating methane from low-concentration coal mine gas to produce natural gas

Sichuan DKT Energy Technology CO.,LTD.

Contents

Introduction





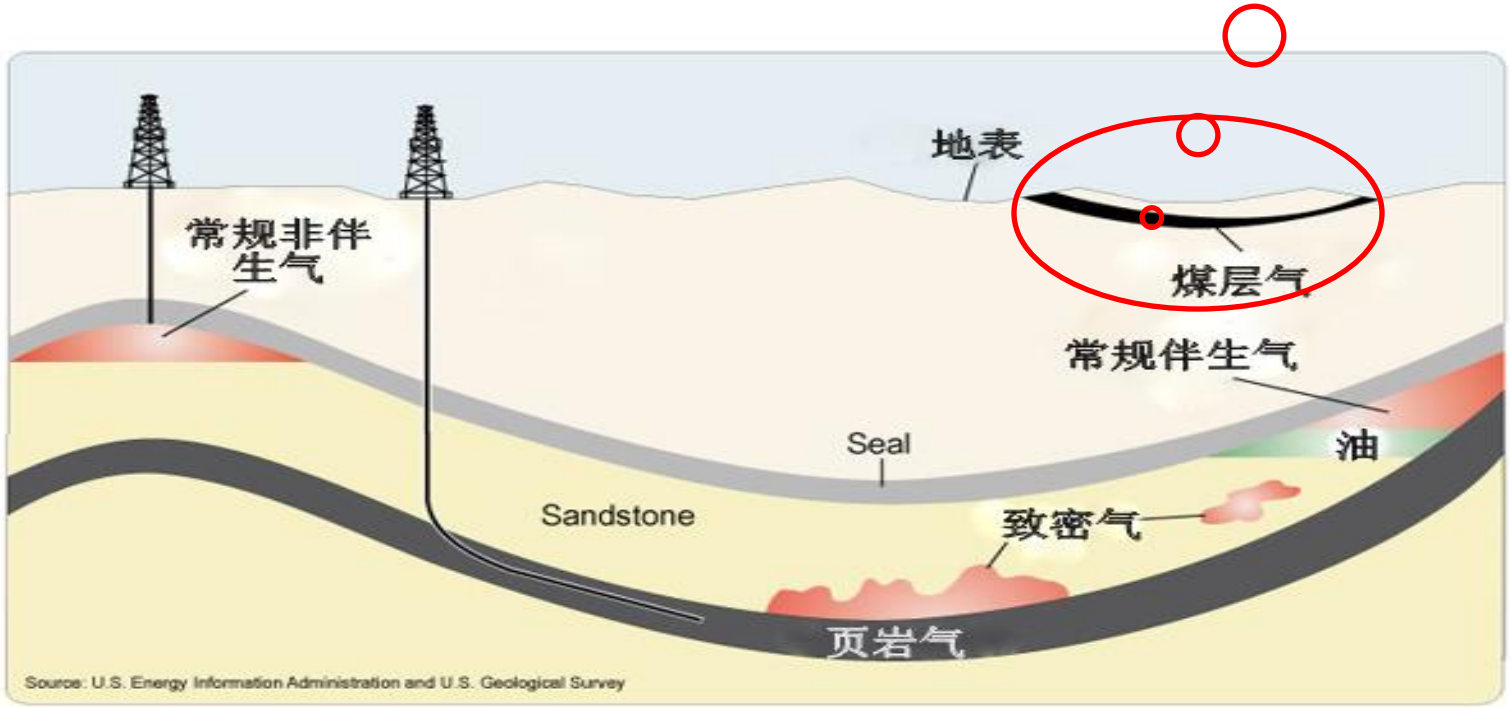
As a clean and eco-friendly high-quality energy, natural gas's proportion in China's energy consumption structure is low (the world average is 23.9%), conventional natural gas production is far below market demand, and the contradiction between supply and demand is obvious.

Introduction

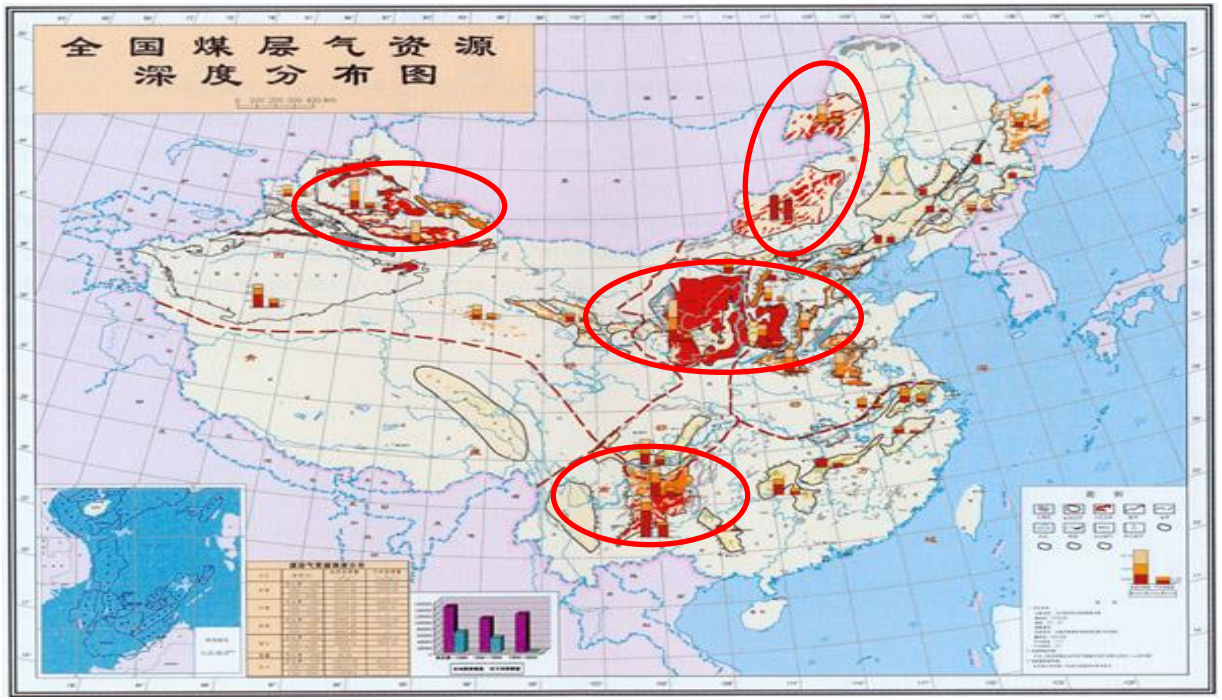
In 2013, natural gas consumption in China was 167.6 billion cubic meters, of which import volume was 53 billion cubic meters, accounting for 31.6%.

Introduction

Its safe recovery means a great supplement to conventional natural gas



Introduction

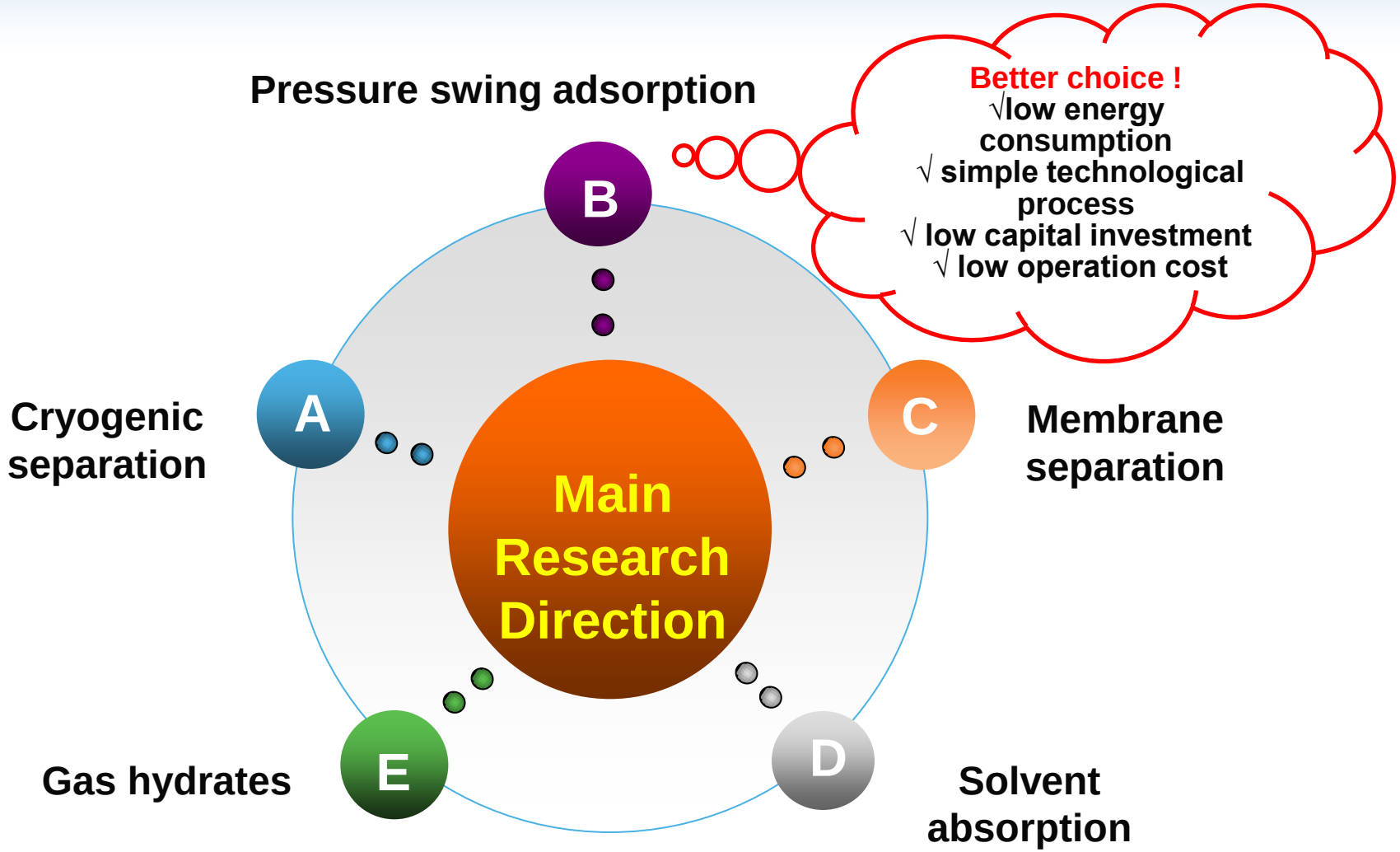


20-30 billion cubic meters of gas has been discharged each year along with coal mining. Equivalent to approximately 350-525 million tons of CO2 greenhouse gas.

If fully recovered to produce clean energy, it is equivalent to 20-30 million tons of refined oil .

2000m-deep shallow CBM geological resource is approximately 36.8 trillion cubic meters, mainly distributed in the north and northwest China. CBM drainage methods are sorted to pre-drainage before mining and draining while mining. CBM content of pre-drainage before mining exceeds more than 90%, but the drainage volume is small, the method draining while mining is mainly used, thus the most drained CBM is featured by low methane content and high oxygen & nitrogen content, **safety factor** becomes the bottleneck restricting its application.

Introduction



Introduction

Technological process safety (safety precautions)

Highly efficient adsorbents

After striving to make technological breakthrough for years, Sichuan DKT Energy Technology Co., Ltd successfully developed **efficient special adsorbents DKT-612 and DKT-613 for gas adsorption deoxidization and methane separation**, as well as **a whole set of process safety measures**. With such a technology, the company has built an industrial demonstration plant for producing oxygen-containing concentrated CNG and LNG at Sijiazhuang Mine in Xiyang County, Shanxi Province, which has been running safely and stably for nearly two years and a half.

Contents

Characteristics of oxygen-containing gas

High gas content in raw material——the content of underground drained coal mine gas reaches 50000Nm^3/h

Low methane content——methane content of most drained methane gas is 10-30%

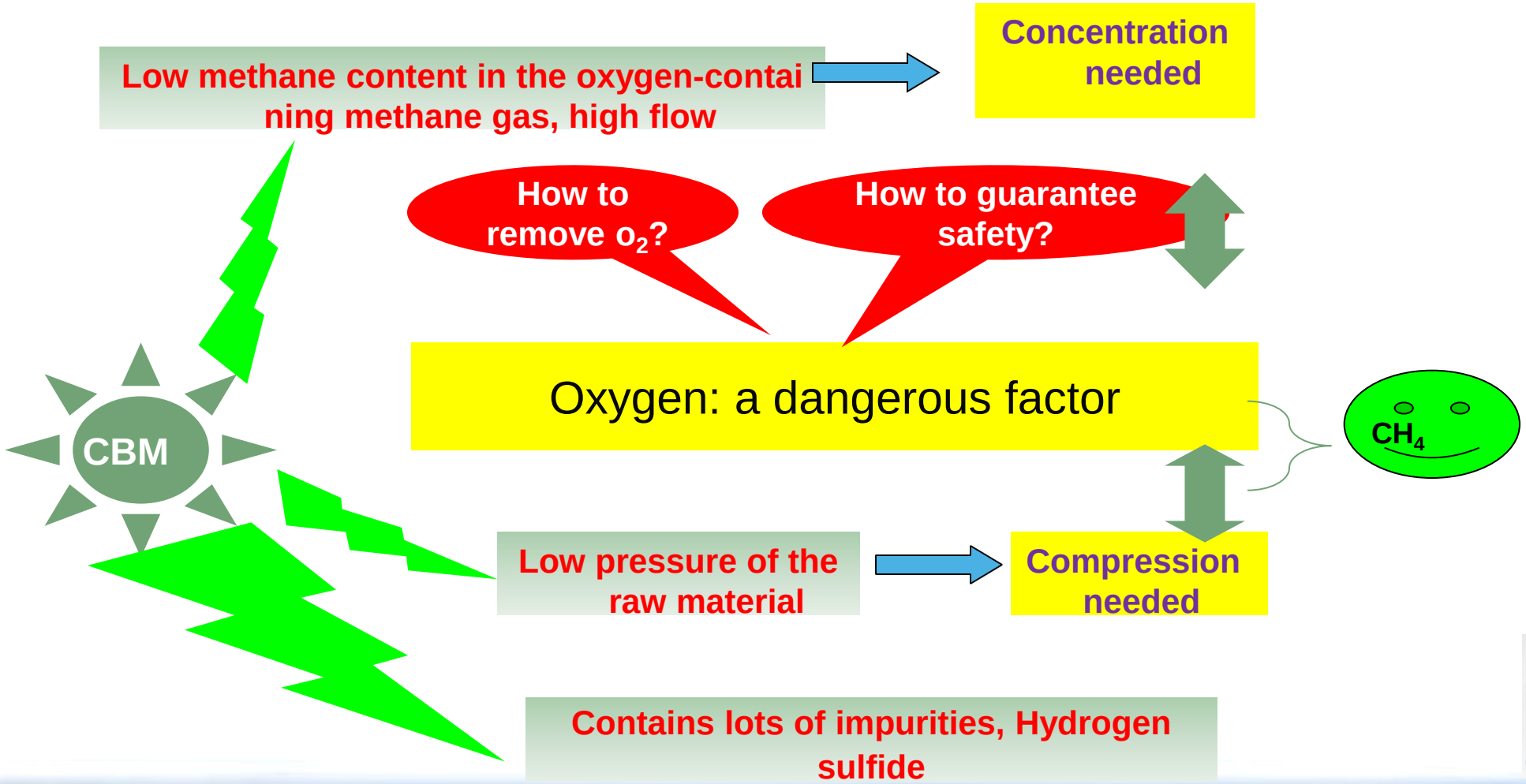
High oxygen content——oxygen content is generally above 12%, it is necessary to enhance the safety

High dust content——contains a variety of dusts, which are easy to plug pipes and equipment, thus impacting service performance and life of adsorbent materials, and may contain harmful substances such as sulfur and water.

Remote geographic position ——other users featured by easy and direct application are unavailable nearby

Process technologies

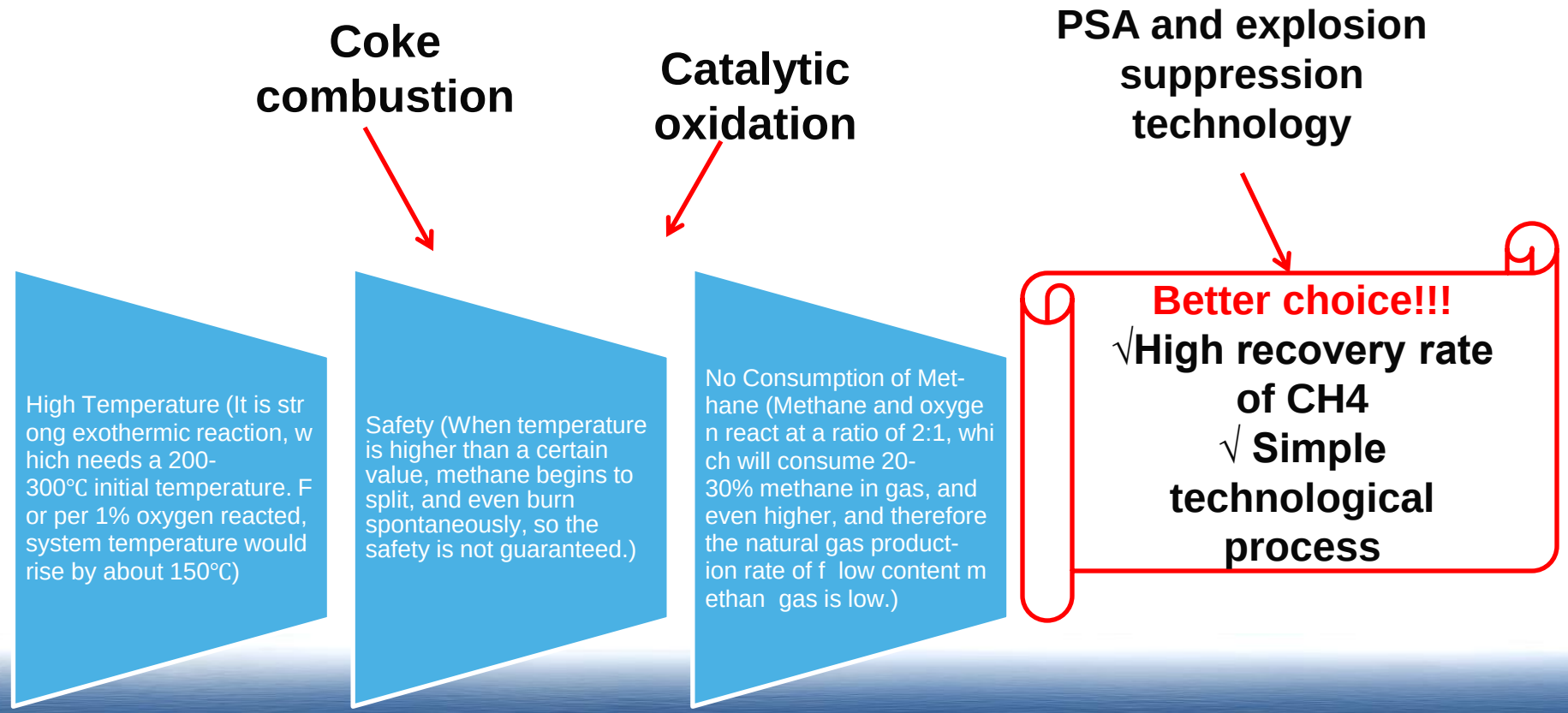
Process safety guarantee



Process technologies

Process safety guarantee

Deoxidation process technologies



Process technologies

Process safety precautions

Passed safety evaluation of Safety Evaluation Center, Nanjing University of Technology (Grade B qualification) and Chongqing Branch of China Coal Research Institute（ (Grade A qualification ）

Process safety guarantee

Units and adsorbent safety guarantee

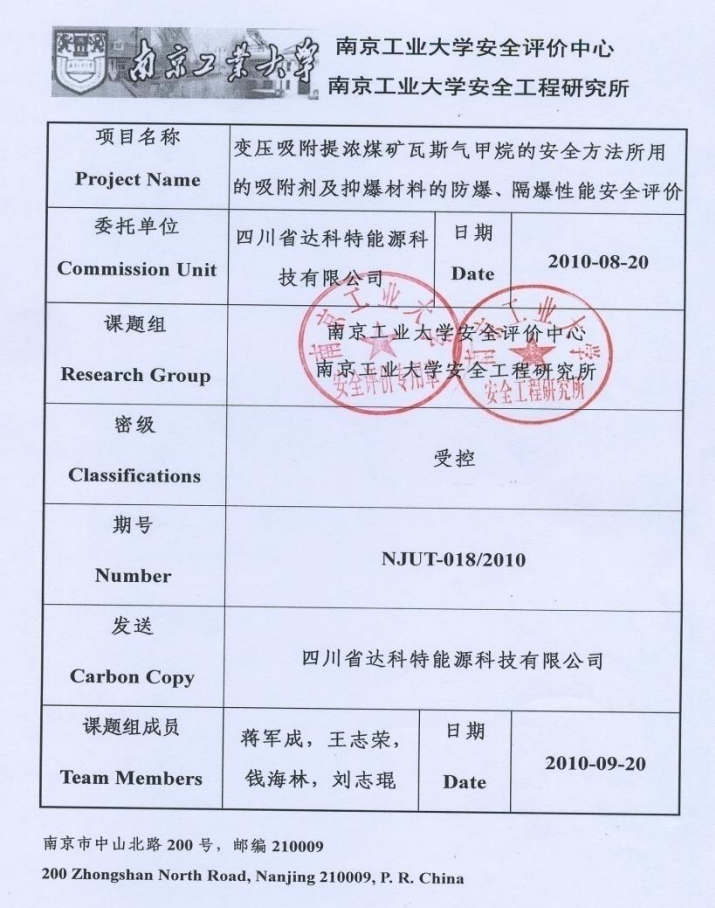
- **Adsorption separation safety:** guaranteed by the adsorbents with good thermal and electrical conductivity which can timely transfer the static electricity and adsorption heat
- **Pipelines and buffer tanks safety:** guaranteed by the explosion suppression material with excellent thermal and electrical conductivity
- **Compression process safety:** guaranteed by the special compressors, very small temperature rise and no sparks during compression process.

Process design safety guarantee

PSA processes: the former process guarantees the latter process safety, they are closely interrelated.

Process technologies

Process safety precautions



南京工业大学安全评价中心
南京工业大学安全工程研究所

项目名称 Project Name	变压吸附提浓煤矿瓦斯气甲烷的安全方法所用的吸附剂及抑爆材料的防爆、隔爆性能安全评价		
委托单位 Commission Unit	四川省达科特能源科技有限公司	日期 Date	2010-08-20
课题组 Research Group	南京工业大学安全评价中心 南京工业大学安全工程研究所		
密级 Classifications	受控		
期号 Number	NJUT-018/2010		
发送 Carbon Copy	四川省达科特能源科技有限公司		
课题组成员 Team Members	蒋军成，王志荣，钱海林，刘志琨	日期 Date	2010-09-20

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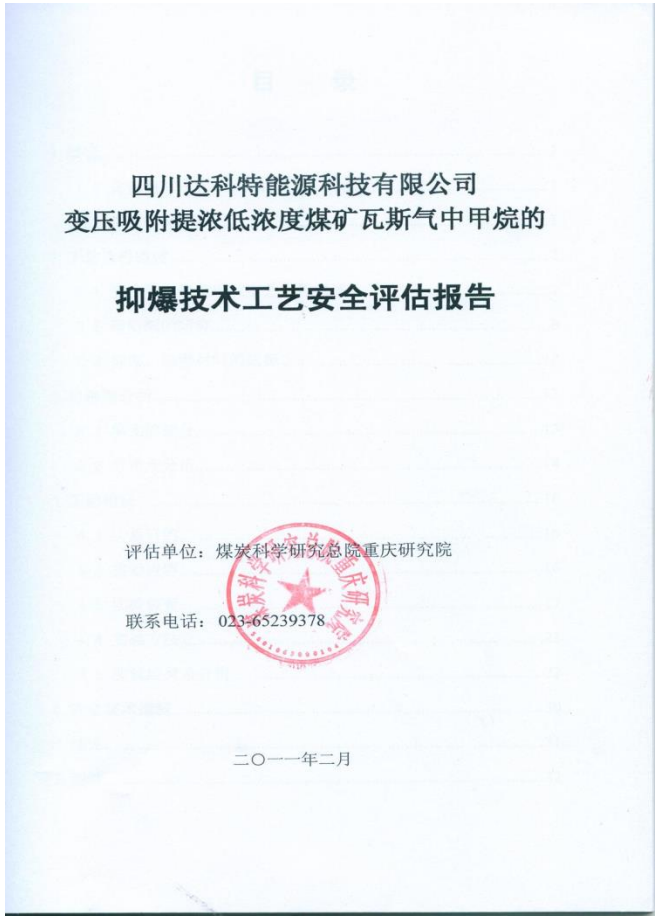


四川达科特能源科技有限公司
变压吸附提浓低浓度煤矿瓦斯气中甲烷的

抑爆技术工艺安全评估报告

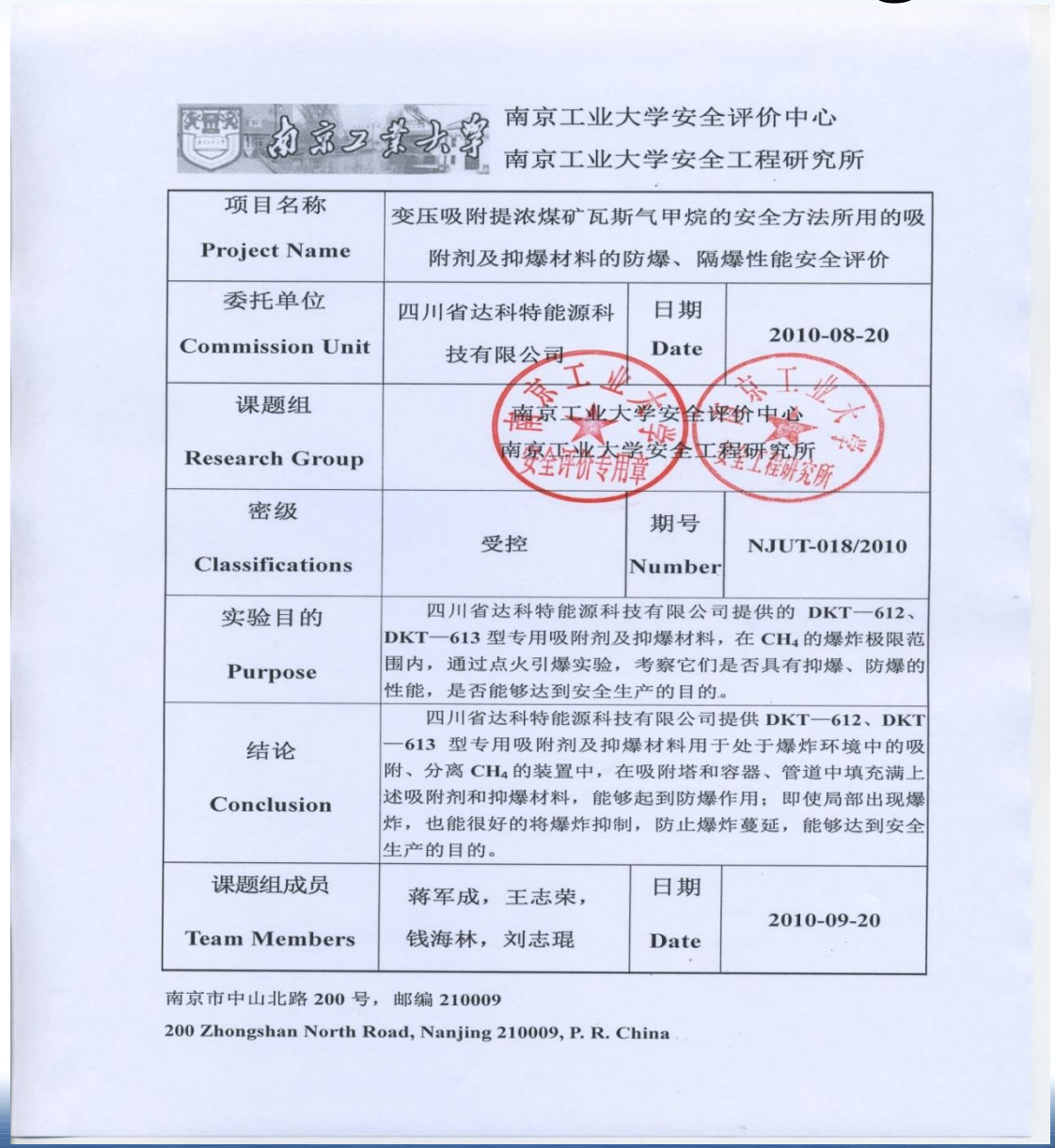
评估单位：煤炭科学研究总院重庆研究院

联系电话：023-65239378

二〇一一年二月

Process technologies

Process safety precautions



南京工业大学安全评价中心
南京工业大学安全工程研究所

项目名称 Project Name	变压吸附提浓煤矿瓦斯气甲烷的安全方法所用的吸附剂及抑爆材料的防爆、隔爆性能安全评价		
委托单位 Commission Unit	四川省达科特能源科技有限公司	日期 Date	2010-08-20
课题组 Research Group	南京工业大学安全评价中心 南京工业大学安全工程研究所		
密级 Classifications	受控	期号 Number	NJUT-018/2010
实验目的 Purpose	四川省达科特能源科技有限公司提供的 DKT—612、DKT—613 型专用吸附剂及抑爆材料，在 CH_4 的爆炸极限范围内，通过点火引爆实验，考察它们是否具有抑爆、防爆的性能，是否能够达到安全生产的目的。		
结论 Conclusion	四川省达科特能源科技有限公司提供 DKT—612、DKT—613 型专用吸附剂及抑爆材料用于处于爆炸环境中的吸附、分离 CH_4 的装置中，在吸附塔和容器、管道中填充满上述吸附剂和抑爆材料，能够起到防爆作用；即使局部出现爆炸，也能很好的将爆炸抑制，防止爆炸蔓延，能够达到安全生产的目的。		
课题组成员 Team Members	蒋军成，王志荣，钱海林，刘志琨	日期 Date	2010-09-20

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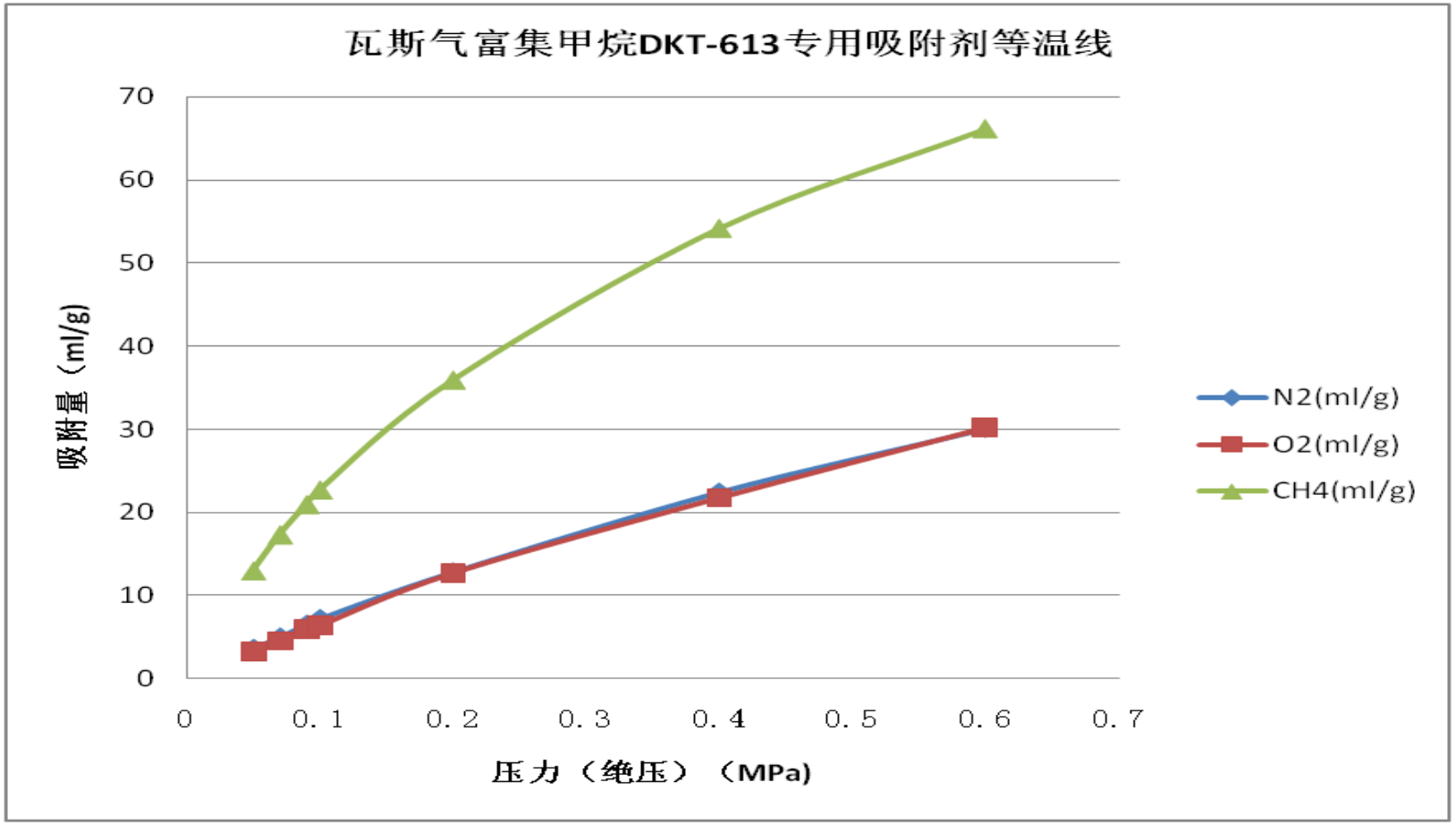
Process technologies

R&D of special adsorbent for methane separation

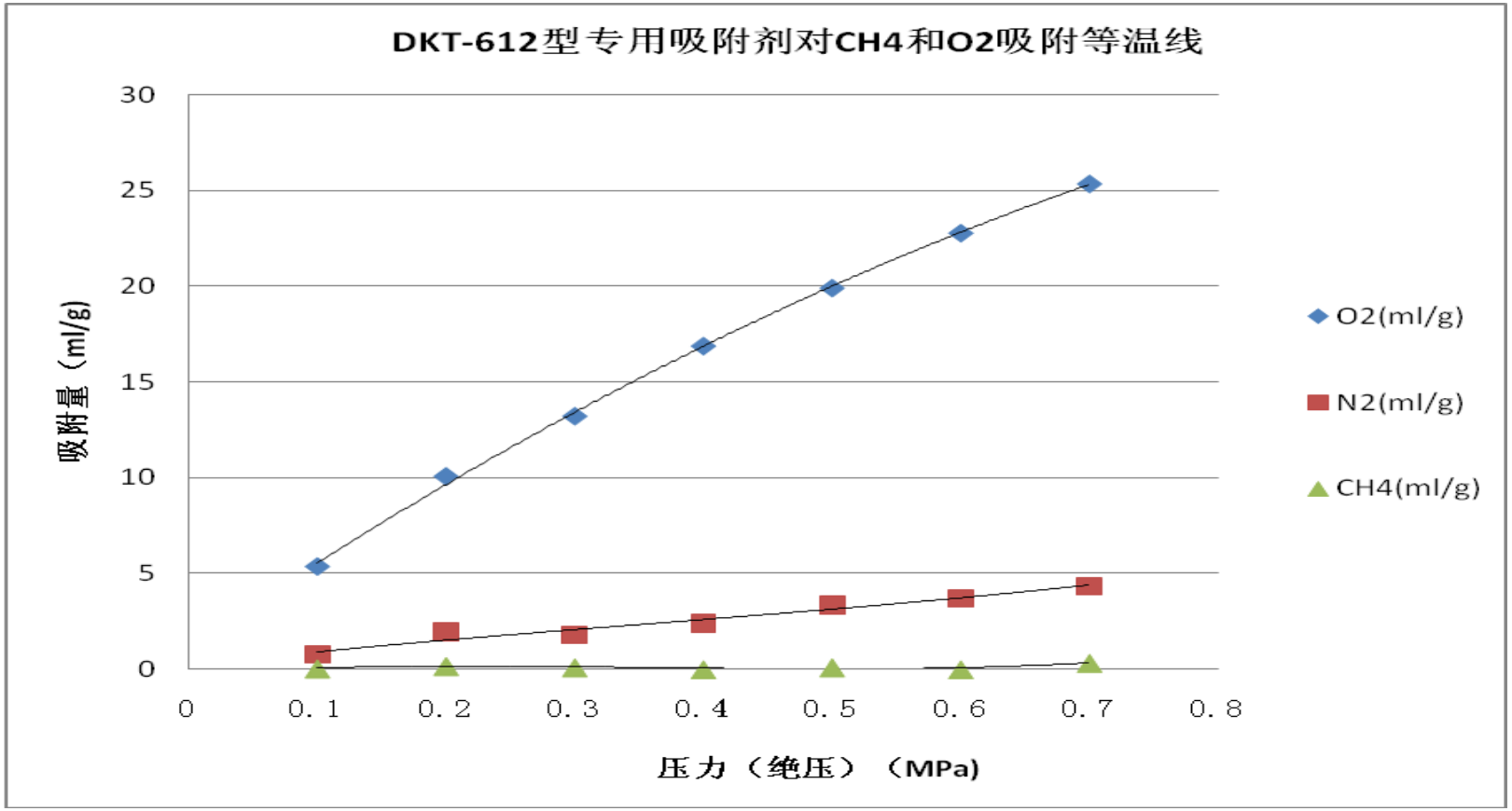


Adsorption isotherm of DKT-613 special adsorbent for separating methane from gas

The developed special efficient adsorbent for methane separation is nearly 50% higher than the conventional adsorbent for methane separation.

Process technologies

R&D of special adsorbent for methane separation



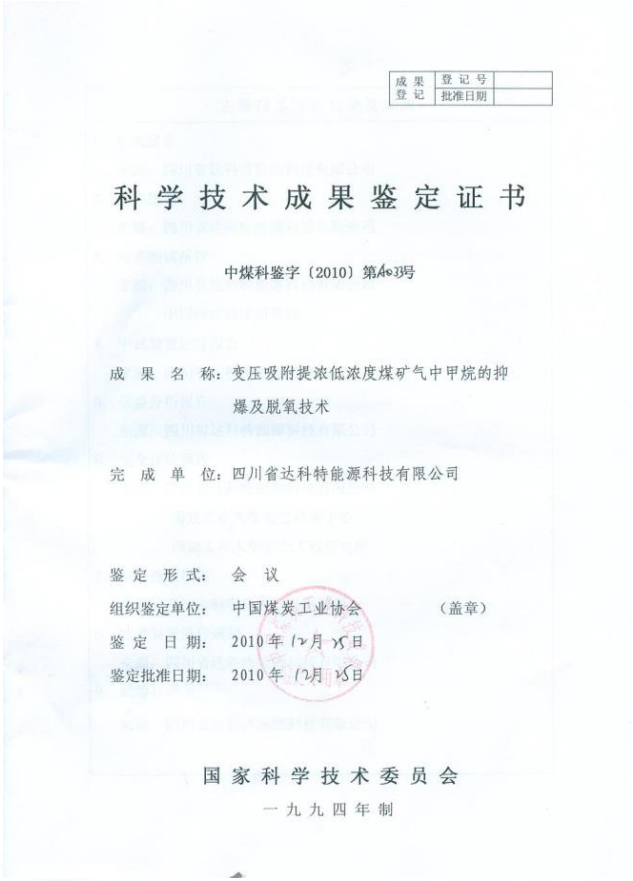
Adsorption isotherm of
DKT-612-type special adsorbent for CH_4 and O_2

High performance deoxidizing adsorbent is able to quickly remove oxygen from gas to ensure safety of methane separation.

Experimental units

Process technologies

It was passed Chinese coal industry technological achievements identification organized by China National Coal Association On December 25, 2010, the technological achievements reached the international advanced level.



成果登记 | 登记号 | | 批准日期 | |

科学技术成果鉴定证书

中煤科鉴字〔2010〕第A-33号

成果名称：变压吸附提浓低浓度煤矿气中甲烷的抑爆及脱氧技术

完成单位：四川省达科特能源科技有限公司

鉴定形式：会议

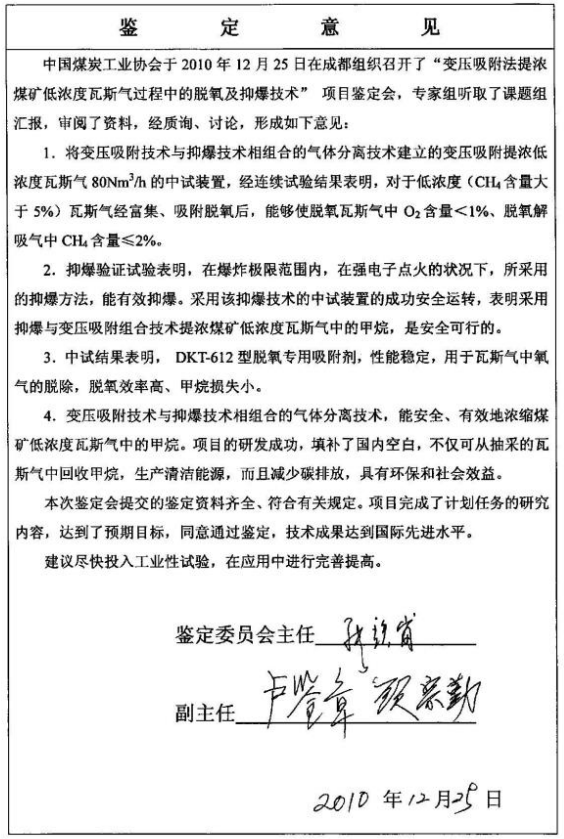
组织鉴定单位：中国煤炭工业协会 （盖章）

鉴定日期：2010年12月15日

鉴定批准日期：2010年12月15日

国家科学技术委员会

一九九四年制



鉴定意见

中国煤炭工业协会于2010年12月25日在成都组织召开了“变压吸附法提浓煤矿低浓度瓦斯气过程中的脱氧及抑爆技术”项目鉴定会，专家组听取了课题组汇报，审阅了资料，经质询、讨论，形成如下意见：

1. 将变压吸附技术与抑爆技术相组合的气体分离技术建立的变压吸附提浓低浓度瓦斯气 80Nm³/h 的中试装置，经连续试验结果表明，对于低浓度（CH_4 含量大于5%）瓦斯气经富集、吸附脱氧后，能够使脱氧瓦斯气中 O_2 含量<1%、脱氧解吸气中 CH_4 含量≤2%。

2. 抑爆验证试验表明，在爆炸极限范围内，在强电子点火的状况下，所采用的抑爆方法，能有效抑爆。采用该抑爆技术的中试装置的成功安全运转，表明采用抑爆与变压吸附组合技术提浓煤矿低浓度瓦斯气中的甲烷，是安全可行的。

3. 中试结果表明，DKT-612 型脱氧专用吸附剂，性能稳定，用于瓦斯气中氧气的脱除，脱氧效率高、甲烷损失小。

4. 变压吸附技术与抑爆技术相组合的气体分离技术，能安全、有效地浓缩煤矿低浓度瓦斯气中的甲烷。项目的研发成功，填补了国内空白，不仅可从抽采的瓦斯气中回收甲烷，生产清洁能源，而且减少碳排放，具有环保和社会效益。

本次鉴定会提交的鉴定资料齐全、符合有关规定。项目完成了计划任务的研究内容，达到了预期目标，同意通过鉴定，技术成果达到国际先进水平。

建议尽快投入工业性试验，在应用中进行完善提高。

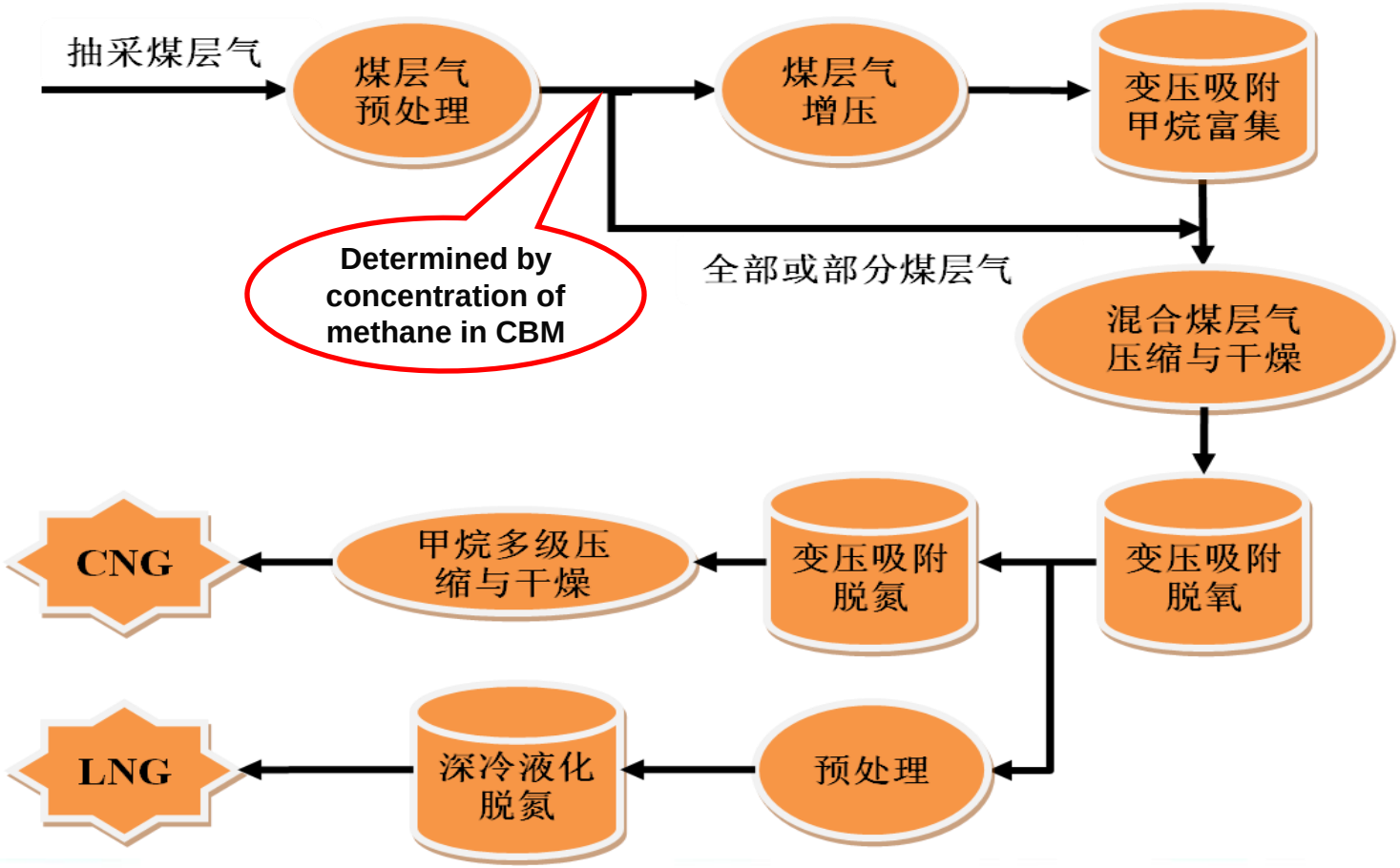
鉴定委员会主任 [illegible]

副主任 [illegible]

2010 年 12 月 25 日

Process technologies

Process technology flow



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Industrial demonstration units

Industrial demonstration project on the above process technologies is carried out by **Shanxi Ruiyang CBM CO.,LTD**, size of phase-I is 35 million square meters / year of **CNG** products, size of phase-II is 50,000 tons / year of **LNG** products. Currently phase-I has been put into operation, phase-II is under construction. The project is the key project supervised by SASAC Shanxi Branch in 2012, total investment is 310 million Yuan, investment of phase-I is 130 million Yuan, total construction area is about 100,000 m^2. In June 2011, the project was started, and achieved **successful one-time test run** on September 10, 2012, **official commercial operation** started on September 20.

Industrial demonstration units

Industrial demonstration units

Industrial demonstration units

Composition of the low concentration oxygen-containing CBM feed gas

Component name	Normal content/vol%	Abnormal content/vol%
CH_4	35（ no less than 30）	20~30
N_2	53.3	65.3~57.3
O_2	11.0	12~14
CO_2	0.7	0.7
H_2O	saturated	saturated

After concentrating through PAS methane enrichment, PAS deoxidation and PAS denitrification, the feed gas is produced to CNG sale (unit CNG's integrated power consumption is **0.98KWH**), **overall methane yield exceeds 95%,** the test results are: **methane content was 98.14vol%, oxygen content was 0.15vol%, nitrogen content was1.71vol%,** all indexes met or exceeded the design criteria, and successfully realized the goal of concentrating low concentration oxygen-containing gas to produce CNG.

Contents

Technological innovations

（1）Adopt adsorption deoxidation for the first time, the adsorbing materials adsorb oxygen only, but not the methane, methane yield reaches 98% during deoxidation;

（2）as special material, the adsorbent could effectively isolate oxygen and methane during the adsorption deoxidation, as adsorption continues, oxygen content in gas phase decreases, the safety is more effectively guaranteed;

（3）the special adsorbent for separating methane and nitrogen is 40% higher than the traditional ones, featured by low energy consumption in methane separation, high methane content and high methane yield;

Technological innovations

（4）Deoxidation adsorbent and special adsorbent for concentrating methane are featured by good explosion protection and suppression functions, the safety performance is recognized by relevant authority, they are designed to be filled in most non-standard equipment of the unit to ensure intrinsic safety of the separation equipment;

（5）Install explosion suppression materials approved by fire department on the pipelines and buffer devices to ensure safety of the whole unit;

（6）Apply 3-stage (or 2-stage) process integration technology recovering and applied by methane in low concentrations gas to produce CNG or LNG.

Benefit analysis

Phase-I project （separate methane from low concentration gas to produce CNG）

Phase-II project (oxygen-containing CBM liquefy LNG 50,000 tons / year)

Remarkable benefits

Environmental protection benefit

Annually use of 70 million Nm^3 of coal mine gas can reduce greenhouse gas emission (converted to 750,000 tons of CO_2), 500 tons of SO_2, 600 tons of NO_2, and 18,300 tons of coal dust

Economic benefit

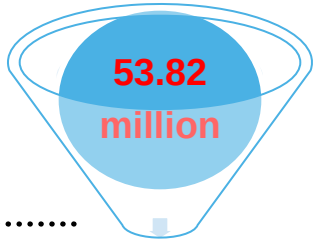
After the project is fully completed and put into operation, the annual sales revenue is expected to reach 280 million Yuan, profit is 140 million Yuan, tax is 35 million Yuan

Social benefit

After completion, the project can directly solve local employment for about 100 people, and indirectly solve employment for about 250 people

Benefit analysis

All cost of phase-I



Annual amortization of house property and land, amortization period is 30 years	*125*
Raw materials, management, financial and other cost	*1650*
Staff cost	*275*
Power consumption	*2450*
Equipment annual depreciation, depreciation period is 10 years, net residual value is 2%	*882*

Analysis based on all cost of actual production operation of phase-I project

Annual output of CNG is 35 million square meters, production cost of unit product is 1.538 Yuan / Nm^3.

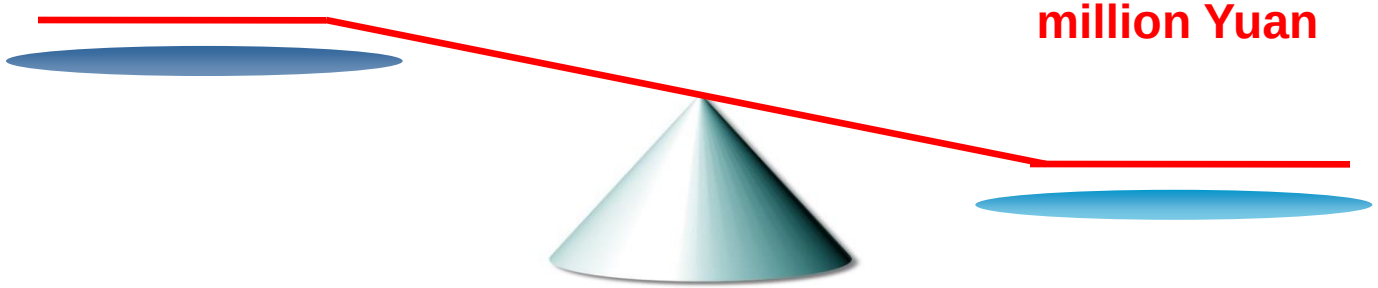
Benefit analysis

According to actual output of phase-I project, annual output of CNG containing 98% methane is 34.77 million square meters), sales revenue is 34.77 × 2.5 = 86.925 million Yuan

Annual sales revenue is 86.925 million Yuan

Profit: 33.105 million Yuan
Rate of profit: 38.1%

All cost is 53.82 million Yuan



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Conclusions

- The world’s first application of PSA technology to remove oxygen in low concentration gas;
- Adopt PSA enrichment, PSA deoxidation and PSA denitrification integrated process to obtain CNG products with purity greater than 95vol%;
- As oxygen contained in low concentration gas, safety of technology process could be effectively ensured through process design optimization, main process equipment selection, special adsorbent selection, analysis equipment control instrument selection and the use of explosion suppression materials, flame arresters and other measures;
- Apply this technology to build a set of industrial demonstration unit for concentrating low-concentration oxygen-containing gas to produce CNG for the purpose of commercial safety operation, and benefit analysis shows that it has significant economic and social benefits.

Problems

- Efficiency of recovery unit is severely affected by gas flow and content. The raw gas covers a small proportion in the production cost, large construction scale will not reach the desired effect, and small one will easily lead to intermittent direct gas venting;
- The overall output value of gas utilization covers a small proportion in output value in coal mines, most coal mines fail to place enough stress on it;
- Local government of construction needs to increase support, the corresponding regulations are not sound;
- National support for the industry is not enough. Currently, there is no construction units like gas generation obtaining corresponding policy subsidies from the state;
- Investment for initial construction is large, financial support for project construction also needs to be put in place.