

# Research Progress and Prospect of CBM Cascade Utilization Technology in China

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**Keywords:** CBM, Cascade utilization, Research progress

**Abstract.** The concentration of methane can play a vital role in choosing the application of CBM (coal bed methane) utilization technology, which can determine the utilization mode as well as the degree of difficulty. In recent years, with the rapid development of CBM utilization industry, especially the breakthrough of the related utilization technology of low concentration coal bed methane, the concept of the cascade utilization of coal bed methane in coal mine has been preliminary formed. Therefore, in this paper, it reviews the current development status of CBM utilization technology in China, making analyses on the main stream of CBM utilization technology at different levels, pointing out the key technical problems that should be solved at once as well as the corresponding solutions, so as to promote the development of CBM cascade utilization technology in China and provide support for the realization of "zero emissions" in the coal mines ultimately.

## Introduction

Making full and comprehensive use of coal bed methane can save energy resources, reduce environmental pollution and promote the coal mine safety production, which also can play multiple role in adjusting the energy structure [1-2]. Usually, as for the use of CBM, it will choose different methods to use according to different concentration of methane. With the increasing emphasis on energy and environment, how to enhance CBM exploitation and utilization efficiency, making CBM industry have rapid and healthy development, so as to realize the "zero emission" of coal bed methane in coal mine will be the chief and most urgent task [3]. Therefore, as the utilization of CBM, it is urgent to combine and match the current existed science and technology reasonably, which should choose the corresponding utilization technology according to the different methane concentration, who also should pay attention to the connection and complementary of utilization technology at different levels, so as to realize the comprehensive effect of cascade utilization of CBM.

CBM cascade utilization technology is a kind of technology that transferring high concentration coal bed methane (the concentration of methane is more than 80%) through the pipe network set directly to the downstream civil or industrial utilization, while medium concentration coal bed methane (the concentration of methane is between 30% and 80%) can produce CNG, LNG through the integrated concentration, meanwhile low concentration coal bed methane (the concentration of methane is between 10% and 30%) can be used through generating power directly, and the extremely low concentration coal bed methane (the concentration of methane is less than 10%) can be used mainly through regenerative oxidation and combustion at the spot, which can form a complete utilization mode, so as to achieve the goal of "gasification mining area".

## The Current Situation of CBM Utilization Technology

**The Exploitation and Current Situation of CBM Utilization Technology in China:** In recent years, with the introduction of a series of policies and measures of the state, the scale of coal mine gas

extraction and utilization is increasingly increased year by year, in 2014, in China the extraction volume of CBM reached to 13.3 billion m<sup>3</sup>, while the amount of utilization reached to 4.5 billion m<sup>3</sup>, but the utilization rate was only 33.8%. The ratio of the extraction of low concentration CBM in Chinese mine is high, and the extraction flow rate, as well as the fluctuation of concentration is large, which can restrict the choice of the CBM extraction technology and the using scale of CBM, the majority of them adopt the method of local use, while the method of gathering use is less. According to statistics, the extraction concentration of CBM is more than 30% can account for 45% of the total amount, while the utilization rate is about 60%, the utilization rate is only about 10% with the concentration less than 30% [4].

The ventilation air methane (VAM), whose concentration is below 0.75% accounted for about 60% of the total emissions, although this part of VAM has great air volume and low concentration, the majority of VAM is still directly emptied and unused, but the development situation of thermal flow-reversal reactor (TFRR) and catalytic flow-reversal reactor (CFRR) technology is good, which can realize the industrialized application. The extremely low concentration CBM which is between 0.75% to 10%, in addition to being as the mixed gas supply at this stage, it can be used basically in the form of gas that can be as the main raw materials. The low concentration CBM which is between 10% to 30%, is mainly used in generating power directly. While high concentration CBM that the concentration is greater than 30% is widely used as the main power generation, civil fuel, which also can be as the form of combustion and chemical raw materials. The heating efficiency of low concentration CBM is about 30%, and its booting rate is about 50%. The concentration and utilization technology of low concentration CBM is still in the application demonstration stage.

**The Mainstream CBM Utilization Technology at All Levels:** (1)Power Generation of CBM. When the concentration of CBM is between 5% and 16%, it is easy for explosion, when the concentration of methane is about 9% it can have the most powerful energy, its speed can reach to 2000 ~ 3000m/s, which can produce great energy at the same time. The direct power generation technology of internal combustion engine of low concentration CBM is using such characteristics of engine to promote it power, so as to implement the conversion from chemical energy to electrical energy. At present, the domestic representative research institutions are as follows: Sheng Dong Group of Shan Dong, Diesel Engine Factory of Jinan, Diesel Engine Industry of Henan and so on. While companies such as DEUTZ AG, German, Caterpillar, USA as well as the other companies in China also can share the market in a large percentage. At present, the power generation industry of CBM in China is developing rapidly and the market prospect is good, but there still exist some problems such as the operating rate is low, the operating cost is high, the economic feature is poor, besides, there are some other issues that are urgent to be solved.

(2)Thermal Flow-reversal Reactor Technology of Low Concentration CBM. The regenerative oxidation technology of low concentration CBM can be mainly divided into two major types: auxiliary fuel utilization technology and main fuel utilization technology. Among them, TFRR is the most mature and reliable technology, there are a lot of testing equipment and industrial demonstration cases. This kind of technology can form the stable gas through VAM and extraction with the mixed hybrid methane that the concentration is about 1%, then the mixed gas can be into the regenerative oxidation device and it can be heated, after oxidation and heat release, with the periodic change of the reversing device, the devices can enter the state of self-sustained and stable operation. By connecting the auxiliary waste heat boiler and the steam generating set, the redundant heat energy can be effectively utilized. The companies that adopt this technology including German DURR, Coal Science and Industry Group Chongqing Institute, Energy and Power Research Center of Chinese Academy of Sciences[5]. In recent years, China has built up dozens of low concentration CBM utilization projects, but most of them are not in long-term operation.

(3)Physical Extraction and Cryogenic Liquefaction of CBM. As for oxygen cryogenic liquefaction and purification of CBM, low concentration CBM can produce liquefaction of LNG production, which belongs to the high value utilization for CBM, thus there is great potential for developing the market, although in recent years in terms of technology, it has made great development, affected by

the investment and high operation cost, it can not form industry with a certain scale, which needs to increase investment in research and development of technology and engineering technology, reduce the overall project investment and operation cost that can rapidly expand industrial scale, so as to improve CBM utilization ratio and realize energy-saving and emission reduction.

To sum up, through years of study on power generation of CBM in coal mine, thermal regenerative oxidation, cryogenic liquefaction and other CBM utilization technology and equipment, it has achieved some progress and achievements, but there still exist some key technologies that can affect the project economic feature and promotion as well as application of the technology, therefore the key technical problems need to be solved in the future.

### **The Key Technical Problems Need Solving**

Focus on resolving the source concentration of CBM and the great flow fluctuations, the concentration CBM that is below 10% should improve the efficiency of thermal regenerative oxidation, while the concentration of CBM is between 10%~30% can carry on purification and utilization in a small scale, the concentration of CBM is above 30% can try to solve purification consumption problem in a large scale, which can form highly efficient and economic CBM cascade utilization technology and equipment, so as to promote the comprehensive promotion and application of CBM cascade utilization technology.

**Solving the technical problem of low concentration CBM with high water content, low power generation efficiency as well as low booting rate:** Research and develop of low concentration CBM with automatic clean dry type fire retardant device and realize the fire retardant device to have automatic cleaning, so as to make the dry type fire retardant device solve congestion problem, as well as the technical problem of affecting generator starting rate; research and develop the waste heat cooling separation dehydration device, adopting the method of using turbine exhausted gas to make low concentration CBM have deep dehydration, so as to improve the power generation efficiency of the generator.

**Solving the technical problem of high energy consumption of low concentration CBM with thermal regenerative oxidation utilization technology:** By means of making research on saving and improving the efficiency of technology, the thermal regenerative oxidation structure and process parameters can be optimized, which can solve high energy consumption of the technical problem of thermal regenerative oxidation system itself. Carrying out the research on heat comprehensive utilization technology, so as to make the waste heat achieve cascade utilization and improve the comprehensive utilization rate of heat energy. Therefore, it can solve the technical problem of poor operation of the system and promote the popularization and application of the thermal regenerative oxidation utilization technology.

**Solving the problem of low concentration CBM with high efficiency of physical extraction and enrichment technology:** High and low pressure alternating physical extraction of CBM enriched technology can use physical extraction pre-concentration method to have fast and efficient purification for CBM, so as to better solve the current problems of CBM such as, big energy consumption of purification equipment, large investment. The adopted physical extraction solvent can not dissolve the following gas such as oxygen, nitrogen and carbon dioxide gas, which can only dissolve the organic gases such as methane molecule, devices are researched and developed to have quick and efficient removal from oxygen, nitrogen and carbon dioxide among CBM, so as to achieve low concentration CBM have quick and efficient clean purification.

**Solving the technical problem of high energy consumption of CBM with highly efficient cryogenic liquefaction technology:** Because low concentration CBM contains oxygen, which can not be liquefied under high pressure purification. Therefore, compared with the conventional high-pressure natural gas, the dew and bubble point is low, which needs lower temperature to have liquefaction and separation, and the lower the temperature is, the smaller the energy efficiency ratio is, the bigger unit power consumption is.

For example, make the raw gas that the concentration of methane is 30% have cryogenic liquefaction, the comprehensive energy consumption per unit can reach to  $2.3\text{kW}\cdot\text{h}/\text{Nm}^3$ . So the energy consumption is a bottleneck for low concentration CBM to have cryogenic liquefaction technology application. Through the liquefaction process of low concentration CBM, optimizing the device parameter matching design, focusing on the research on low concentration coal mixture refrigerant with the nitrogen cycle composite refrigeration containing oxygen liquefaction process technology, so as to reduce comprehensive energy consumption and improve economic efficiency.

### **The Industrial Prospect of Cascade Utilization of CBM**

It is estimated that by 2020 the gap between supply and demand of natural gas in China will reach 100 billion cubic meters and 180 billion cubic meters respectively, the degree of dependence on imports will be from the current less than 20% to 38.7% and 44% respectively. At the same time, according to the Thirteenth Five Year Plan, in the national coal mines, the amount of extraction will reach to 20 billion/  $\text{m}^3$ , the volume can reach to 12 billion/  $\text{m}^3$ .

Therefore, the utilization of CBM industry in China has a huge market and broad prospect. Through the deep research on CBM cascade utilization technology and equipment, it will provide important technical safeguard for the use of CBM in the entire concentration range, which can promote the overall strategic plan, namely" coordinate development, technical support, integrated demonstration, quality and efficiency improvement, cascade utilization".

### **Conclusion**

(1) It analyzed CBM drainage and utilization in China in the recent years, pointing out the reality that the current extraction and utilization rate of CBM is quite different from the anticipated target.

(2) It introduces the ventilation air methane in the thermal regenerative oxidation, coal bed methane power generation, the physical extraction of CBM and cryogenic liquefaction as well as the other multistage mainstream utilization technology of CBM, pointing out the problems that existed such as low efficiency, high energy consumption, poor application effect and so on, so as to state the research necessity of having further development of CBM cascade utilization technology and equipment.

(3) It points out that the market of CBM utilization industry in China is huge and the prospect is broad, through the in-depth research on CBM cascade utilization technology and equipment, it can provide the important safeguard for the entire concentration range of CBM utilization.

### **Acknowledgement**

This study was financially supported by National Science and Technology Major Project of China (2016ZX05045-006), National Natural Science Foundation of China (51574280), Chongqing Frontiers and Application-based Research Program (cstc2015jcyjBX0076).

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