Discussion on dehydration technology of coal mine low-concentration gas reciprocating internal combustion engine

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Abstract. Low concentration gas reciprocating internal combustion engine power generation in coal mine is one of the main ways of gas utilization. This paper aims at the technical problem of low concentration gas power generation efficiency caused by large amount of atomized liquid water carried by gas in low concentration gas pipeline. Based on the analysis of the source of low concentration gas liquid water, this paper discusses in detail research progress of dehydration technology for low concentration gas reciprocating internal combustion engine power generation, and key discusses the mechanical separation method, electric refrigeration method, electric refrigeration combined with cold air circulation method and flue gas residual heat variable temperature method for gas dehydration of low concentration gas power generation.

1. Introduction
At present, the low-concentration gas reciprocating internal combustion engine of coal mines with methane volume concentration between 8% and 30% is the main method of gas utilization. The low-concentration gas power generation of reciprocating internal combustion engines has been widely used due to its advantages such as low gas pressure, wide concentration adaptation, simple and flexible system, and high power generation efficiency [1], and the technology has been rapidly developed. However, due to the limitation of gas source quality and other conditions, the technical problem of flammable and explosive low-concentration gas dehydration with a large amount of liquid water has not been found. A low-concentration gas engine in a coal mine directly affects the thermodynamic combustion and combustion. Reduced efficiency, poor economic operation, even liquid water causes corrosion of pipelines and equipment, freeze damage to instruments, shortened equipment life and large system maintenance workload. Therefore, in view of the large water content of low-concentration gas, it is very necessary to effectively remove the low-concentration gas-gas liquid water.

Low-density methane gas is specialized in dehydration technology research. There are few methods for dehydration in the natural gas industry including solid adsorption, solvent absorption, and low-temperature separation. Solid adsorption uses the porous structure of the adsorbent to absorb water. The adsorbent is water vapor. The solid adsorbent mostly chooses molecular sieves, but molecular sieves are greatly affected by the operating environment pressure and gas temperature conditions [2,3], and they are expensive. High running costs. In the solvent absorption method [4], triethylene glycol...
dehydrating agent is mainly used as an industrial dehydrating agent, which has good hygroscopicity, but has the problems of large investment and complicated process. The low temperature separation method is to use different natural gas and water vapor dew points to separate and separate water vapor. When the temperature drops below the water vapor dew point, water vapor is precipitated. Based on the principle of low-temperature separation, the decomposition technology of double internal combustion engine power generation has comprehensively considered the flammable and explosive characteristics of low-concentration gas, and has developed mechanical separation and dehydration, electric refrigeration dehydration, and electric refrigeration combined with cold air dehydration for low-concentration gas generation. The research progress of flue gas waste heat variable temperature dehydration is described below.

Before 2010, the first cyclone gravity dewatering technology was widely used, and the first generation of low-concentration gas power generation dehydrators was developed. In 2005, the device was first applied in the world’s first installed 3000kW low-concentration gas station in Xieyi Coal Mine of Huainan Mining Group. The TSQ01.00B cyclone gravity dehydrator produced by Shandong Shengli Oilfield Shengli Power Machinery Co., Ltd. is matched with each unit. Relying on cyclone centrifugal force and gravity for dehydration, universal diameter DN200, dehydration efficiency is 60%. The separation effect is better when the gas concentration value is higher than 15%. Between 2010 and 2016, the second type of air-cooled electric refrigeration cold water cooling and dehydration was adapted for use in remote areas of coal mines and was received by on-site users. However, the problem of high energy consumption during operation and the inability to completely remove liquid water made this technology applicable.

Electric refrigeration combined with cold air circulation dehydration and flue gas waste heat variable temperature dehydration are new dehydration technologies that have only appeared in the past three years. Some professional R & D units and power generation users with technical needs have carried out professional research and development and bold exploration, and conducted research on this new technology. Innovative engineering practices. In 2017, Shanxi Yangmei Yangde Coalbed Methane Power Generation Co., Ltd. Pingshu Gas Power Plant designed an electric refrigeration combined cold air circulation dehydration system and a cold air-gas heat exchanger with a mixed gas flow of 7800 Nm3 / h (the gas temperature difference between the inlet and outlet gas is 16 °C, heat load 206kW) 1, 60,000 Nm3 / h cold air fan (full pressure 220Pa, fan power 5.5kW) 1 and air-cooled electric chiller (power 72KW), after dehydration treatment during system trial operation Liquid water content is less than 3%. Compared with electric refrigeration, electric refrigeration combined with cold air dehydration has the following advantages: lower energy consumption (can reduce 40% -50% of all electric refrigeration dehydration power consumption), simple equipment and technology, small size and small footprint.

At the end of 2019, Shanxi Lanneng Coalbed Methane Development Co., Ltd. applied the flue gas waste heat variable temperature dehydration technology developed by the China Coal Science and Industry Group Chongqing Research Institute Co., Ltd. for the first time to its subsidiary Zhulinshan Gas Power Station. Gas mixed flow 6000Nm3 / h, 1 pass DN500 main pipeline 6000 Nm3 / h gas flow temperature reduced from 55 °C to 40 °C, can reduce the water content of 53.21 g / m3, the cooling capacity is 233.8KW, the design and installation of YX500-23H2 One lithium bromide absorption refrigeration unit, one DN900 × 3010mm horizontal gas-water heat exchanger, and one mechanical dehydrator. After dehydration, the temperature of the gas gas reaches below 40 ° C, and the relative humidity of the gas gas is below 78%. Good results can be obtained by cooling and dehumidifying.

2. Low-concentration gas source for generating liquid water

The liquid water in low-concentration gas power generation gas is atomized. According to the measurement of liquid water weighing method, the flow of atomized liquid water is a dynamic change process. Generally, the content of atomized liquid water in the front-end pipeline of low-concentration gas power generation equipment is about 20-50mg. / m3, mainly from the following aspects.
2.1. Ground wet gas drainage system
"Coal mine gas drainage engineering design specification" (GB 50471-2008) stipulates that gas drainage pumps should be wet type. A large amount of liquid and vapor-like liquid water is entrained in the outlet gas of the extraction pump. After being deposited on the bottom of the pipeline, it is collected by the water-seal fire-blocking and venting device at the positive pressure end of the low-concentration gas exhaust side. Part of the vapor mist liquid water enters the gas transmission pipeline and the low-concentration gas engine with the gas flow.

2.2. Low-concentration gas pipeline safety protection system
In order to ensure the safety of the transportation and utilization of low-concentration gas pipelines, the low-concentration gas is converted to water-containing low-concentration gas in the form of steam atomization or two-phase flow, which plays a role of explosion suppression. The specific composition and requirements of the system are described in Technical Specification for Concentrated Gas and Fine Water Mist Safe Conveying Device "(AQ 1078-2009) and" Technical Specification for Low Concentration Gas and Water Two Phase Flow Safe Conveying Device for Coal Mine "(AQ / T 1104-2014) A large amount of gas containing atomized steam and mist-like water passed through the low-concentration gas pipeline to the explosion suppression section of the safety assurance system and entered the low-concentration gas engine, resulting in a decrease in power generation efficiency and engine oil emulsification.

2.3. Ambient temperature difference between pipes
The temperature of gas gas is usually constant at 30-45 °C. Most of the year, the temperature of gas gas exceeds the outdoor ambient temperature. During transportation, the gas gas with 100% saturated relative humidity at the pipe wall meets the outdoor cold source, generating a large amount of condensation and atomization Water, along with the gas, enters the low-concentration gas engine.

3. Low concentration gas dehydration
Mechanical dehydration and electric refrigeration two types of dehydration technologies have been widely used in coal mines for low-concentration gas power generation. Electric refrigeration combined with cold air circulation dehydration and flue gas waste heat temperature dehydration are new low-concentration gas dehydration technologies that have only appeared in recent years. For the future technology development trend.

3.1. Mechanical separation dewatering technology
Most domestic low-concentration gas power generation uses cyclonic gravity dehydration. Low-concentration gas cyclone centrifugal force is used to separate liquid water. The dehydration efficiency can reach 60%. The latest mechanical dehydration with high separation efficiency is multi-principle mechanical separation of liquid water. The principle of flow impact, inertial reflection impact, cyclone centrifugation, and filtration, the dehydration efficiency after separation can reach more than 90%. The system is simple, the investment is small, the safety is high, and the maintenance is convenient. The disadvantage is that some vapor mist water still follows the gas. The air flow enters the power generation system and cannot be completely removed, thereby affecting the low-concentration gas engine.

3.2. Electric refrigeration dehydration technology
The principle of electric refrigeration dehydration is that the compressor of the electric refrigeration chiller unit compensates the power consumption work. The refrigerant continuously absorbs heat from low-temperature objects and releases heat to high-temperature objects. The refrigeration cycle is repeated. That is, the high-temperature and high-pressure R22 Freon coolant gas is converted into low-temperature and low-pressure cooling liquid through thermal equipment such as electric compressors, condensers, and evaporators. The evaporator uses refrigerant water and low-temperature refrigerant to
exchange cold with each other, and the cycle continues. Electric refrigeration chiller consists of electric compressor, condenser, thermal expansion valve, drying filter, evaporator, gas-liquid separator and water tank. Water-cooled chiller or air-cooled chiller are used to cool the condenser with medium air or air for heat exchange. Water-cooled chiller requires more cooling tower water cooling than air-cooled chiller.

The electric refrigeration dehydration system consists of a front mechanical dehydrator, a chiller, a gas-water heat exchanger, and a rear mechanical dehydrator. The technical advantage is that the refrigeration has strong adaptability, can produce cold water below 0 °C, and the system is simple; its disadvantages are high operating power energy consumption, dehydration power consumption as a proportion of power generation, and large noise.

![Diagram of low concentration gas electric refrigeration system](image)

1-front mechanical dehydrator; 2-valve; 3-electric refrigeration chiller; 4-air-water heat exchanger; 5-rear mechanical dehydrator; 6-low concentration gas generator set

**Figure 1. Composition of low concentration gas electric refrigeration system**

### 3.3. Electric refrigeration combined with cold air circulation dehydration technology

Electric refrigeration combined with cold air circulation dehydration is a new type of dehydration technology developed based on air source condensation, electric compression condensation and mechanical separation dehydration. It uses electric compressed refrigerated water and outdoor ambient cold air refrigeration to provide cooling capacity for gas gas cooling and dehydration. It produces cooling capacity to condense and separate saturated water into a low-concentration gas generating set to generate electricity. The refrigeration system adopts different operating modes under different seasonal ambient temperature conditions. When the external ambient temperature is low in winter, the cold air is used to cool the gas to achieve the cooling effect and a large amount of electricity can be saved. When the external ambient temperature is high in summer, electric cooling water Perform heat exchange with gas to achieve the purpose of reducing the temperature of the gas. In the spring and autumn, the combined temperature and dehydration are operated in parallel and in accordance with the outdoor temperature.

The system contains main devices such as a front mechanical dehydrator, an electric refrigeration chiller, an air-water heat exchanger, a cold air fan, a cold air heat exchanger, and a rear mechanical dehydrator. Electric refrigeration combined with cold air circulation dehydration technology has the advantages of lower energy consumption than electric refrigeration, suitable for northern areas with low outdoor temperatures in winter, good safety, high degree of automation, and good adaptability to working conditions. The air heat exchanger is relatively large, needs a lot of floor space, and the control part is complicated.
3.4. Flue gas waste heat variable temperature dehydration technology

The main process technologies of flue gas waste heat variable temperature dehydration include four processes: liquid water filtration-cooling condensation-liquid water filtration-heating and vaporization. The dehydration is based on the low-temperature gas generating unit high-temperature flue gas (usually 550 °C) as the lithium bromide absorption type. The energy source of the refrigeration unit drives the lithium bromide unit to generate cold water to cool the gas, so that the gas is condensed to produce gaseous water. The liquid water is separated and filtered by high-efficiency mechanical dehydration before and after the cooling gas-water heat exchanger, and a small amount of liquid mist passes through. After heating the gas-gas heat exchanger, the liquid becomes gaseous, so as to reduce the relative humidity of the gas after heating, and achieve the purpose of complete removal of liquid water, dehumidification and temperature control. The main equipment involved are a front mechanical dewatering device, a rear mechanical dewatering device, a lithium bromide absorption refrigeration unit, a cooling gas-water heat exchanger, a heating gas-gas heat exchanger, and a flue gas valve.

This method is a new type of low-concentration gas power generation dehydration technology specially developed and promoted during the 13th Five-Year Plan period of the China Coal Science and Industry Group Chongqing Research Institute Co., Ltd., which can achieve a removal rate of 100% of liquid water entrained in low-concentration gas gas and a relative unit inlet The humidity is lower than 80%, the gas temperature is controlled within 40 °C, and the energy consumption of the system is only 1 / 4-1 / 3 of the electric refrigeration dehydration; but it also faces complex system control, and lithium bromide refrigerators in remote areas of the coal mine need to consume a certain number of cycles Problems such as water supply difficulties still need to be studied and solved.

4. Conclusion

Low-concentration gas power generation and stable gas quality and power generation efficiency are the development trends of low-concentration gas power generation technology. Low-concentration gas power generation gas dehydration technology currently mainly includes mechanical separation and
removal, electric refrigeration, electric refrigeration combined cold air circulation, smoke Gas waste heat temperature change method. The four dehydration technologies have gone from simple to complex, from low dehydration rates to high-efficiency dehydration, and they have also developed towards low energy consumption. In the early stage of the application and promotion of this technology, different dehydration technologies should be selected according to the actual site conditions of the project. For example, in areas where there is no water shortage in the plain, priority should be given to the use of flue gas waste heat variable temperature dehydration technology with low energy consumption and good dehydration effect to improve low The economic benefits of concentrated gas power generation and to a certain extent reduce operating costs. The development of low-concentration gas dehydration technology is just in its infancy. In the future, there is still a lot of room for optimization of existing dehydration technologies and methods. In this way, new key technology research is continuously carried out to achieve the energy cascade utilization of low-concentration gas power generation and improve low-concentration. Economic and social benefits of gas power generation.

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