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APPLICATION OF CCHP IN DEEP MINE THERMAL HAZARD CONTROL

1. Introduction

With the development of the economy, the demand of energy is increased. But the development of new energy resources can not keep up with the energy demand for the economic growth, which leads to gradually increase the exploitation of fossil energy. More and more coal mines have been deeply exploited, which causes geothermal disasters.

Huainan mining area is a classic representative of high gas mines in China. It has the characteristics such as thick overburden soil, high gas emission, high geothermal temperature, great intensity exploitation and deep level development and so on. So the thermal hazard in Huainan coal mining area is serious [1]. The probability of underground heat accidents is the highest in summer. Due to the influence of ground temperature in many parts of Huainan mining area where the temperature of fresh air reaches to 34°C in working face, and returning current temperature is over 40°C. What's worse, the temperature reaches to 45°C and the moisture is close to 99% in the upper corner. In order to achieve safety and high efficiency exploitation, effective measures must be taken to reduce the temperature.

2. The current status of preventing thermal hazard

2.1. Non-mechanical refrigeration

Non-mechanical refrigeration includes reasonable layout of developing, optimization of ventilation system, increasing air volume, isolating the heat resource, coal seam infusion,

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goaf filling, individual protection and so on [2]. Ventilating system optimization and increasing air volume are economic and effective ways to reduce temperature. But if the predicted rock temperature is over 40°C, enhancing the amount of air can not achieve the target of cooling, which is also a major barrier for aeration-cooling [3]. If non-mechanical refrigeration can not achieve the requirement, the measures of artificial-mechanical refrigeration must be taken.

2.2. Artificial mechanical refrigeration

There are many cooling methods. To some extent, the cooling is in the process of energy transfer and conversion. According to the compensation forms, refrigerating methods are divided into two categories: one utilizes mechanical energy or electric power for compensation and another utilizes heat energy for compensation. At present, there are several kinds of cooling systems as follows:

- Vapor compression refrigeration mainly uses freon and ammonia refrigerant as the refrigerating unit and uses electric power as power system. Freon is eliminated gradually because it does harm to ozone layer.
- Ice cooling system mainly uses ice-water cooling to reduce the temperature, which has been applied to coal mine such as Pingdingshan, Xinwen mining area. If the depth of mine less than 3000 m, using the ice cooling system is neither economic nor energy-saving [4]. So this system can not be popularized widely.
- The refrigerating of vortex tube makes high-pressure airflow vortex in the vortex-tube, and then makes airflow separate into cold and hot airflow. It's applied to some parts of miners' work clothes. But the refrigerating of vortex tube is unlikely to be put into practice widely because of its inefficiency.
- Absorption refrigeration system that depends on surplus heat of plant power has lithium bromide absorption unit, ammonia absorption unit and series compression-type unit, etc. It can be utilized in many high-gas and thermal hazard mines to reduce temperature as wasted heat energy can be used hierarchically [5]. At the same time, water is used as refrigerating fluid in lithium bromide absorption refrigerating machine, which does not harm to ozone layer.

3. Cooling technique of CCHP

3.1. Energy consumption comparison of lithium bromide absorption refrigeration

CCHP is developed on the basis of combining heat and power generation. At present, CCHP is allocated lithium bromide absorption refrigeration machine on the basis of combined heat and power generation in China, making full use of heat source parameter of low requirement. Low-pressure steam over 0.1 MPa and hot-water over 80°C can be used as driving heat source [6]. The CCHP has low primary energy consumption, especially cool-heat and

power generation system with fuel gas and fuel oil, which has high energy utilization. So this system has been used extensively at domestic and foreign. The comparison of operation scheme from several lithium bromide absorption units is shown in Table 1.

TABLE 1
The comparison of operation scheme from several lithium bromide absorption units [7]

Operational mode	Equal to the gross coal consumption rate, g/KW · h
Boiler and single-effective lithium bromide absorption chiller	1218
Boiler and double-effective lithium bromide absorption chiller	687
Direct-burning lithium bromide absorption chiller	526
Cool-heat and power generation unit with fuel gas and fuel oil	322
Cool-heat and power generation system with coal	360
Compression type refrigerating machine	378

3.2. Lithium bromide absorption refrigeration of the gas power generation set

In Huainan, there are 13 coal mines which are large gas mine and the total quantity of gas reaches to 592.8 billion m³ [8]. Meanwhile, the gas content density in Huainan area is reaches to 142 million m³/km², and the highest is reaches to 405 million m³/km² [9]. The total quantity of gas drainage is in Huainan mining group expected to reach to 520 million m³ in 2012 and gas drainage rate is 66%, and usable amount is 134 million m³.

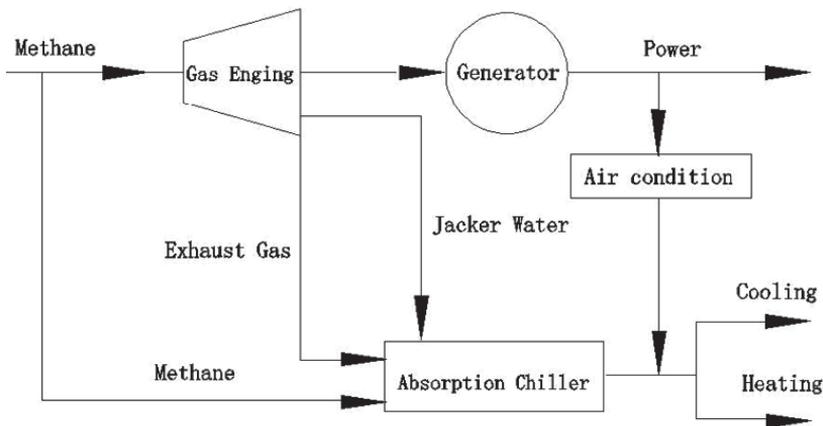


Fig. 1. Schematic diagram of CCHP configuration based on gas engine

As for large gas extraction as well as the high concentration in many coal mines where the thermal hazard is very serious, gas as fuel is used as fuel and the waste heat is used to drive the lithium bromide absorption refrigeration, in order to reduce the temperature in the mine. Meanwhile, the vapor and hot-water are produced by utilizing the waste heat of the boiler to absorb the waste heat of the generator unit to provide heat source to user [10], which is shown in Figure 1. With the development of science and technology, mature generation technology of low concentration gas provides the technical support for making full use of gas.

4. Application of CCHP

4.1. Application of the air conditioning system for mine

Huainan mining group has established the CCHP system of gas electricity-making in Panyi mine since 2008, adopting gas electricity-making unit of internal combustion from DEUTZ. And the generation efficiency reaches to 40%. By absorption refrigeration with waste heat, the annual average cost saving reaches to 48 million Yuan [11]. Cooling system has been established one after the other in mines of thermal hazard control. Especially in Guqiao mine and Dingji mine, where the thermal hazard is very serious.

4.2. Engineering example for CCHP

4.2.1. The degree for thermal hazard

Dingji mine is one of very serious thermal hazard mines in Huainan area. The depth of constant temperature zone is 30 m and the temperature is 16.8°C. The thermal gradient is 2.30–4.00°C/hm, averaged 3.21°C/hm.

This coal mine belongs to the abnormal zone of underground temperature. The average underground temperature is more than 41°C in the level of –800 m, which belongs to the second thermal zone. The average temperature in coal face is 33.2–36.5°C in July. The average temperature in extracting face is 32.0–36.8°C. According to the related measurement data, the temperature in some areas of working face is more than 40°C.

4.2.2. Methane electrical generation and waste heat utilization system

The CCHP project consists of methane electrical generation and waste heat utilization system and air condition system as well as concentrated cooling system in Dingji mine.

The total power of generator is 6.6 MW, and the consumption of the net gas quantity is 31.4 m³ per minute, the waste heat produced by generator is 7.4 t/h, the total power of refrigerator from cooling system is 21 MW. There are six generators of low concentration gas (single-machine capacity is 500 KW), tow generators of high concentration gas (single-machine capacity is 1800 KW), three lithium bromide absorption refrigeration machines (single-machine capacity is 5 MW), three centrifugal refrigeration units (single-machine capacity is 2 MW) and one refrigerant equip with three-cavity (exchanger capacity is 17.3 MW).

In methane electrical generation and waste heat utilization system, more than 30% of gas concentration is delivered to the gasholder with the volume of 10 thousand m³, then the gas fixed pressure from the gasholder is delivered to pretreatment system, and then the gas with filtration dehydration and turbocharged is delivered to generator of high concentration gas. Finally, the high temperature flue gas from generator unit is regard as heat source, producing saturated steam that is 0.6 MPa by waste heat boiler. The power is used as driving force of lithium bromide absorption refrigeration machines in summer and ground heating in mine area in winter. Likewise, the generator of low concentration gas combined with the methane electrical generation and waste heat utilization system also has the same effect.

The electricity of the gas power station is used partly to make up the consumption of concentrated cooling and the rest is transmitted directly to 10 KW power grid so as to meet the power demand. Flow diagram of mine CCHP systems is shown in Figure 2.

4.3. Concentrated cooling system

The lithium bromide and centrifugal series refrigeration have been used in the refrigeration craft of concentrated cooling system in coal mine. The temperature of chilled water is 18°C before entering into the lithium bromide absorption refrigeration unit and the temperature is 5°C after flowing out of the lithium bromide absorption refrigeration unit, and then entering into the electric refrigeration unit. The temperature of chilled water is 2.5°C after flowing out of the centrifugal refrigeration unit. There are three lithium bromide absorption refrigeration units and three centrifugal refrigeration units: the power is 5000 and 2000 KW, respectively. In order to adjust the system load conveniently, three units reserved each other were adopted in the refrigeration. PES, purchasing from Simga Company, is adopted to transmit and distribute the refrigerant in coal mine.

There are many other auxiliary systems. Water treatment system is constructed to ensure the safety of system operation by conducting softening treatment for chilled water and cooling water. The subsystem and device are operated by ground monitoring and supervision system through remote control so as to reduce manual operation.

4.4. Analysis of refrigeration effect

Twenty-six air coolers and 7500 m pipeline were installed in the summer of 2011. Two cooling units are opened when the load is the highest. The cooling flow is about 600 m³/h, and the highest power reaches to 14 MW. The ranges of cooling are two coalface and three coal heading faces and eight rock heading faces, covering all high temperature faces. It turns out that the temperature of major excavating surfaces reduce by 3–5°C and the moisture reduce from 95–100% to 70–90%, which improves the underground working environment and plays a certain role in safety and high efficiency production of mine. Taking 400 KW air-cooler of the haulage roadway in 1422 working face for example, the main parameters of the 400 KW cooler is shown in Table 2, and the effect of the cooler is shown in Figure 3.

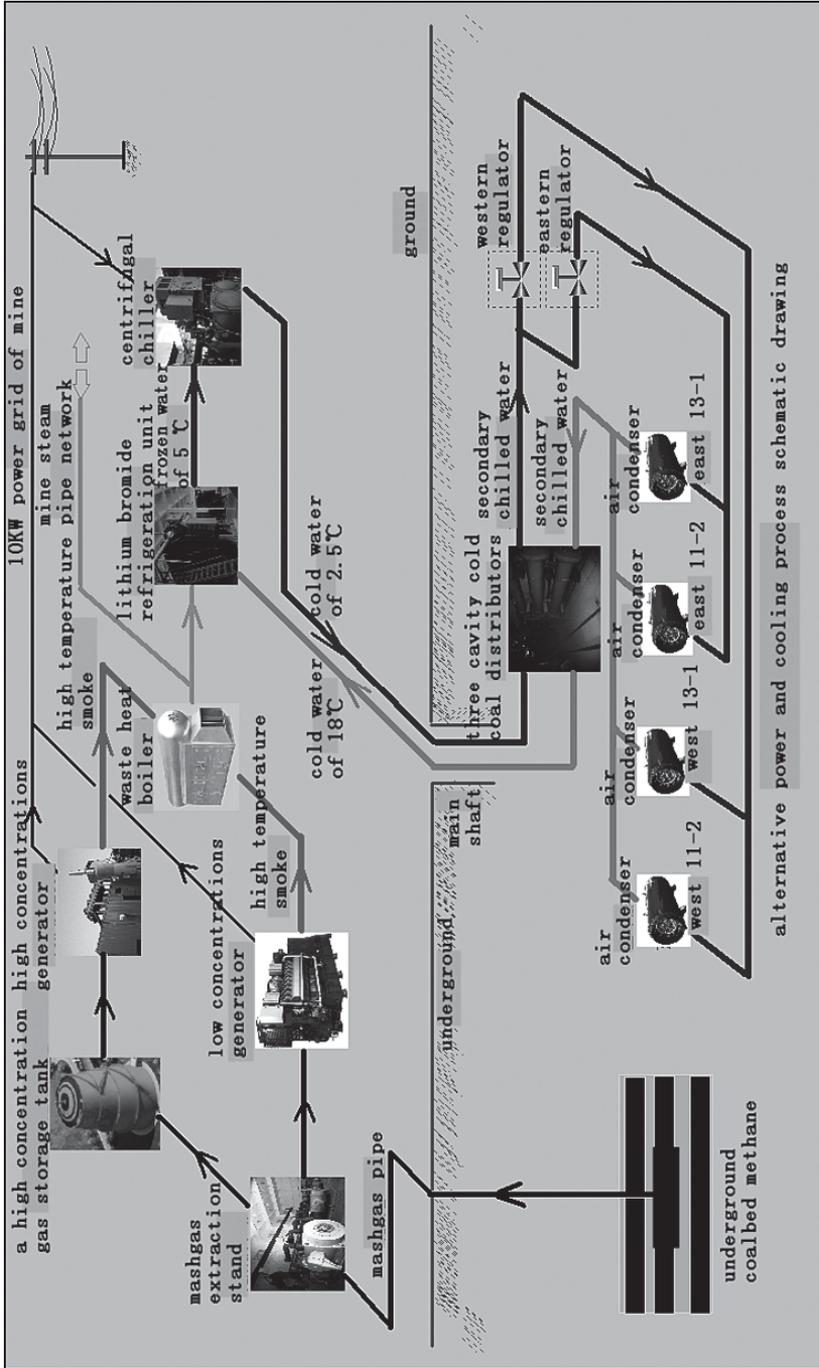


Fig. 2. Flow diagram of mine CCHP system

TABLE 2
400 KW air-cooler of the haulage roadway in 1422 working face

Parameters	Condition.1	Condition.2	Condition.3	Condition.4	Condition.5
Volume of freeze water, m ³ /h	29.4	29.5	29.8	29.4	29.4
Temperature of inlet air of cooler, °C	31.6	31.7	31.8	31.7	31.7
Temperature of outlet air cooler, °C	16.2	16.7	17.2	17.4	17.5
Temperature of inlet water, °C	5.8	5.9	6	6	6.1
Temperature of outlet water, °C	14.4	14.4	14.5	14.5	14.6
Volume of air, m ³ /h	28000	30000	29000	30100	29500
Temperature of 5 m away from cooler, °C	22.4	22.7	22.9	22.8	22.9
Temperature of 50 m away from cooler, °C	26.8	26.6	26.8	27.1	27.4

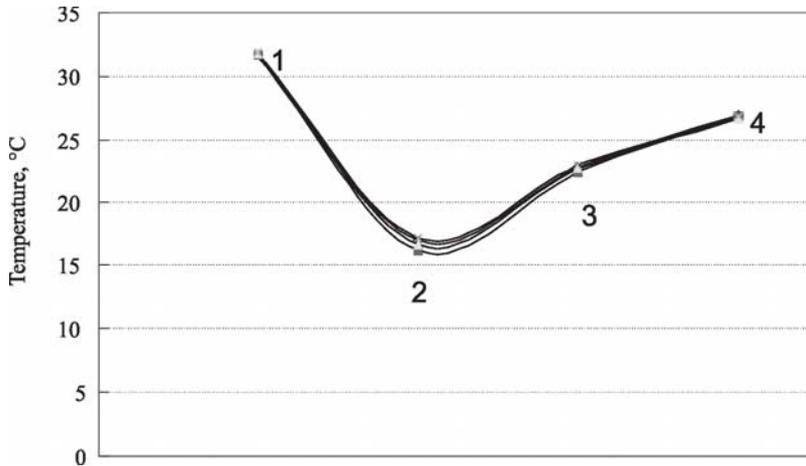


Fig. 3. Refrigeration effect of air cooler of haulage roadway in 1422 working face:
 1 — the temperature of inlet air of cooler; 2 — the temperature of outlet air of cooler;
 3 — the temperature of 5 m away from outlet air of cooler;
 4 — the temperature of 50m away from outlet air of cooler

5. Conclusions

- 1) The gas extraction system has been established in Huainan for the characteristic of high gas reserve, which has relieved the threat of gas hazard as well as made full use of the gas to generate electricity. In addition, the output of plant and heating load were also increased. What's more, the pressure of the power supply could be also relieved in summer.
- 2) In this study, a strategy of CCHP was constructed in using energy hierarchically, which has greatly enhanced the energy utilization ratio and reduced the greenhouse gas emission. The results are consistent with energy saving and emission reduction as well as the national policy to develop conservation-oriented and environment-friendly economy in China.
- 3) The technology of CCHP has been demonstrated successfully in controlling the gas and thermal hazard simultaneously, which also has reduced the cost of cooling. It turns out that the temperature reduces by 5°C and the moisture reduces by 20% in the working face. Moreover, the working environment has been improved enormously. In a word, this CCHP strategy will be promising in the process of thermal hazard control, which also has a certain reference value for some similar situations.

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