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Study on the HEMS Technique to Control Heat-harm and Utilize Geo-thermal Enegy in Deep Mine

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ABSTRACT

With the increasing of exploitation scope and intensity, the shallow resources is getting less and less, which make the deep mining more and more essential. While the exploitation depth getting deeper and deeper, the heat-harm of high temperature becomes one of the main barriers of deep mining, and has seriously impact on the utilize of deep resources. Through the investigation of high temperature coal mine in northern China, three models of high temperature heat-harm mine, that is Jiahe model Sanhejian mode and Zhangshuanglou mode, was summed up. After summarizing the cooling technology of the mine at home and abroad, and analyzing the advantages and disadvantages of each technology and the existing problems, the HEMS (High Temperature Exchange Machinery System) technology of heat-harm control in deep mine is proposed, which put the mine discharge as the cold source. Meanwhile, with the example of JiaHe Coal Mine, this technology of heat-harm control is introduced systematically. It accomplishes its operations by disposing three main workstation that has corresponding functions in different exploitation level, such as the extraction of the refrigerating output by refrigeration equipment, the transportation of the chilled water by closed circulation line, the decompression of the circulation line and equipment by pressure transformation machine, and the heat exchange and cooling of workplace by heat exchange between wind stream and the chilled water. Particularly, the exchanged heat form the workplace is taken to ground heating by the circulating water being acted as a carrier, which reflects the design concept to protect the environment and to reduce the emission of deleterious air. The results of the project illustrate that the HEMS-technology to control the heat-harm is efficient. The temperature of the workplace is brought down to 26-29 centigrade, which is 4-6 centigrade lower than the original, and the relative humidity is 5-15% lower than before. It greatly improves the working environment of the workplace where the heat-harm of high temperature and high humidity lasts for a quite long time. On the other hand, It extracts deep geothermal energy successful replacing ground fired boiler for heating, reducing environmental pollution. And it is worth generalizing in deep mine and related fields.

1. INTRODUCTION

At present, resource crisis and deterioration of the ecological environment are crisis faced by countries of the world. Under dual pressure of international resource crisis and environmental pollution, people of all countries of the world began to think about relations between human race and the environment from the origin of the ecosystems, actively repairing and compensating for the damaged ecological environment, searching for clean, efficient and new alternative energy (such as solar energy, wind energy, tidal energy) to improve energy structure and decreasing primary energy consumption and pollution emissions. As a green geo-thermal energy, deep geothermal energy includes a great deal of thermal energy, and it could turn to be heat-harm if not being explored and utilized. If most mines in eastern China were explored deeper, while exploration depth increasing, the original rock temperature would rise, and high temperature heat-harm on exploration and working face would become more and more serious. High temperature heat-harm would not only do great harm to physical and mental health of mine workers, but also lead to safety accidents, parts of absorbed gas could be released by environmental temperature increasing and then have a great potential safety problems. So it is extremely urgent to control high temperature heat-harm.

This paper, through survey and analysis on deep mines in eastern China, summarizes features of three typical heat-harm mines. On the basis of summarizing and analyzing previous heat-harm control, aiming at the usage of deep geo-thermal energy, successfully develop HEMS, make deep mine heat-harm be resources, while resolving deep mine heat-harm, successfully replace ground coal-fired boiler to achieve the mining area's purpose of saving energy, protecting environment and sustainable developing.

2. THREE TYPICAL HEAT-HARM MODES

According to the data surveyed by China Mining University (Beijing) and China Coal Mine Safety Supervision Bureau for mining area in eastern China, there are 13 mines in Shandong whose temperature on working face is higher than 26^{o}C, among which six mines' temperature on working face is between 26~30^{o}C, 7 mines' temperature is higher than 30^{o}C; in Jiangsu Province there are 5 mines in all whose temperature on working face is higher than 26^{o}C, among which 3 mines' temperature on working face is between 26~30^{o}C, 2 mines' temperature is higher than 30^{o}C; in Anhui Province there are 10 mines in all whose temperature on working face is higher than 26^{o}C, among which 7 mines' temperature on working face is between 26~30^{o}C, 3 mines' temperature is higher than 30^{o}C; there are 12 mines in all in Henan Province whose temperature on working face is higher than 26^{o}C, among which 2 mines' temperature on working face is between 26~30^{o}C, 10 mines' temperature is higher than 30^{o}C (Table 1).

Table 1: Typical high temperature mines distribution in North China

Temperature on working face	Shandong	Jiangsu	Anhui	Henan
>26^{o}C	13	5	10	12
26 ~ 30^{o}C	6	3	7	2
>30^{o}C	7	2	3	10

On another hand, ground heating in mining area is usually supplied by coal-fired boiler, whose efficiency is low and wasting a great deal of one-time energy, and coal-firing emits large number of CO_2 and SO_2, aggravating global warming and environmental pollution. Boiler emission of some typical mining area is in table 2.

Table 2: Coal-firing Boiler Emission of typical mining area

	Coal Consumption	CO_2 Emission	SO_2 Emission
Jiahe coal mine	12500t	19000t	130t
Sanhejian coal mine	12045t	18600t	130t
Zhangshuanglou coal mine	11970 t	17000 t	98.3 t

On the basis of this survey, according to hydro geological conditions and heat-harm of various mines, conclude and summarize three typical mining modes with heat-harm: Jiahe mode, Sanhejian mode and Zhangshuanglou mode.

2.1 Jiahe Mode

This type of heat-harm mines locate at area with normal ground temperature, heat-harm mainly comes from rock temperature rising while exploration depth increasing, representative mines are deep mines with more than 1000 meters depth such as Xuzhou Jiahe coal mine, Huainan Jiulonggang coal mine, Xinwen Sun village coal mine, mainly featuring the following:

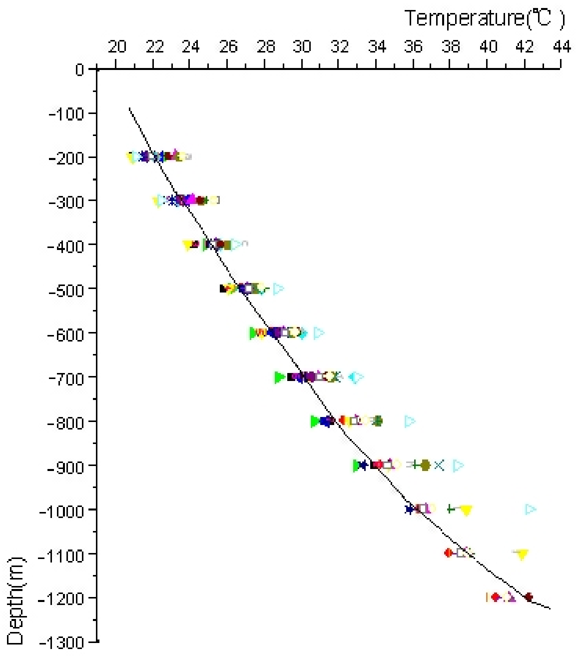


Figure 1: Jiahe ground temperature variation curve.

(1) gradient of ground temperature of this kind of mines with heat-harm is less or near to the average gradient, without heat-harm when explored at superficial part, heat-harm is from ground temperature rising while exploration depth increasing. It could be seen that -800 rock temperature of Jiahe mine is 33~34^{o}C, -1000 rock temperature is 38~39^{o}C, temperature on heading face is as high as35~36^{o}C.

(2) lack of undermine water resource, for example, amount of mine water of Jiahe mine is 95m^3/h~135m^3/h.

(3) use coal-firing boiler on the ground to heat and bath, largely consume resource and seriously pollute.

2.2 Sanhejian Mode

High temperature heat-harm of this kind of mines is due to underground geothermal anomaly and hot water heat, representative mines includes Xuzhou Sanhejian coal mine, No. 8 Pingdingshan coal mine, Chenzhou uranium mine, mainly featuring the following:

(1) gradient of ground temperature of this kind of mines is larger than the average gradient, this kind of mines commonly possesses complete crustal thermal structure and good poly thermal structure. For example, gradient of ground temperature of Sanhejian coal mine is 3.46^{o}C/100m, larger than the average value, whose structure and geological conditions also form good poly thermal structure and crustal thermal structure. It could be seen in Figure 2 that Sanhejian mine's -700 horizontal rock temperature is 37.7^{o}C, -860 horizontal rock temperature is 43.9^{o}C, -980 horizontal rock temperature is 46.8^{o}C. Temperature on heading face is as high as 36~37^{o}C, seriously influencing workers' physical and mental health and production safety.

(2) there is scarce underground cold water as cold source, but it is rich in hot water with high temperature, containing a large number of geothermal resources. For example, flow of water of Sanhejian mine whose temperature is 25~30^{o}C is only 50 m$^{3/}$h, but that whose temperature is 50^{o}C is 1020 m^3/h. Underground hot water further increases heat-harm.

(3) use coal-firing boiler on the ground for heating and bath, resource consumption is large and pollute seriously.

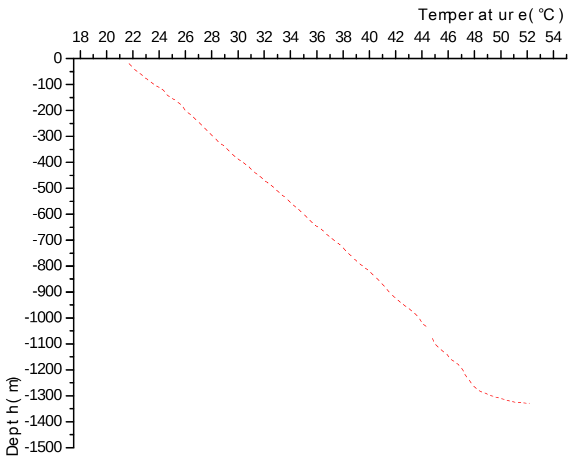


Figure 2: Sanhejian ground temperature variation curve.

2.3 Zhangshuanglou Mode

Gradient of ground temperature of this kind of mines is normal, heat-harm commonly exists at deep part, but this kind of mines is rich in mine water, containing plenty of low-grade cold thermal energy. Representative mines are Xuzhou Zhangshuanglou coal mine, featuring the following:

(1) there is no heat-harm at superficial part of this kind of mines, but while exploration depth increasing, heat-harm becomes more and more serious. For example, temperature on working face of Zhangshuanglou is as high as 36°C.

(2) this kind of mines is rich in mine water, for example, flow of mine water of Zhangshuanglou mine is 1200 m^3/h.

(3) use coal-firing boiler on the ground for heating and bath, resource consumption is large and pollute seriously.

3 DOMESTIC AND ABROAD HEAT-HARM CONTROL SYSTEM

3.1 Central Air Conditioning System

This system cools return water of the unit by spray facilities, sometimes adding auxiliary fans in cooling system, using heat-exchange between wind and water to enhance cooling effect. Cold water of the unit finishes heat-exchanging with intake air flow by passing air cooler, the cooled air flow is conveyed by fans to working face passing wind tunnel and cool the working face. According to the layout form, central air conditioning system gradually developed into the ground centralized and underground centralized modes, Figure 3 is the technology principle diagram. The main problems of this system are large depth, high pressure and high cost; for underground centralized mode, the main problems are heat elimination, weak cooling effect (small circulating water temperature difference, mixed air system) and high operation cost.

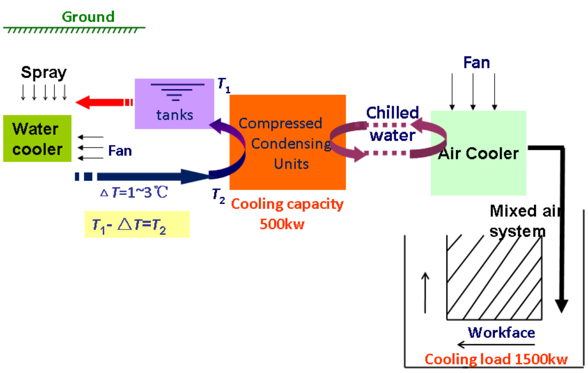


Figure 3: Central air conditioning cooling principle diagram.

3.2 Ice cooling system

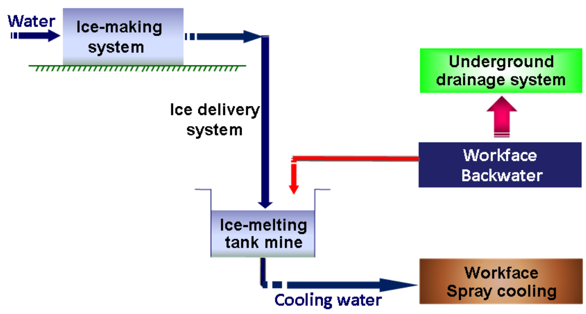


Figure 4: Ice cooling system cooling principle diagram.

The so called ice cooling system is that using granular ice or mashed ice manufactured by ice maker (pack ice must be processed by chip ice machine), conveys it to underground ice-melting pool, uses return water from working face spraying on it to melt the ice, then conveys the cold water to working face and sprays the cold water to reduce temperature. Ice cooling system is mainly comprised with three parts of ice production, ice conveyance and ice melting, Figure 4 is the technology principle diagram. Main problems of ice cooling systems are that ice pipelines are easy to be blocked to break operation off; spray cooling would increase humidity; high operation cost.

3.2 Thermoelectric Glycol System

Thermoelectric glycol technology is that firstly transmitting residual heat from hang gas power plant to lithium-bromide refrigerating machine for first-stage cooling, then transmitting to glycol screw refrigerating machine for second-stage cooling to get glycol solution with temperature of—3.4°C to —5°C. The cooled glycol solution is conveyed to underground cold supply room passing cooling supply pipes to cool water, the cooled water passes air cooler to produce cool air, and the cool air is transmitted to high temperature working face. By using this system, the temperature on heading face reduces from 34°C to 26°C. The temperature of cold glycol solution is —5°C, and only 3°C when reaching heat-exchange system, averagely reducing the temperature of underground working face by 10°C, Figure 5 is the technology principle diagram. The cooling effect of this system is good, but it requires the mine must have hang gas power plant; cold resources must pass second-stage cooling, cold extraction is small; equipments operation is complex, operation cost is high; it is difficult to spread for controlling heat-harm in deep mine.

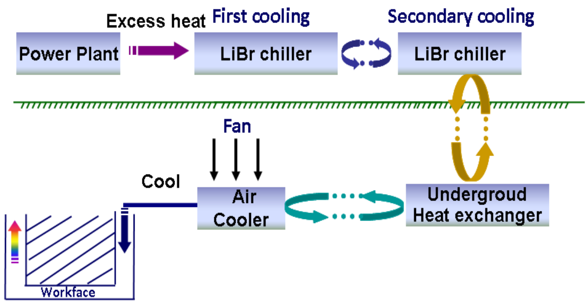


Figure 5: Thermoelectric glycol system cooling principle diagram.

4. HEMS SYSTEM

The above three cooling systems all have a most serious problem, they are all energy consumption systems, simply cooling for cooling, needing to consume plenty of energy in operation, and could not take use of deep mine heat-harm as a resource, wasting the large number of deep geo-thermal energy. Aiming at taking use of deep mine heat-harm, Rock Engineering Research Centre of China Mining University developed HEMS (High Temperature Exchange Machinery System)deep geo-thermal energy usage system relying on China national 973 (2006CB202200) project. Aiming at controlling underground heat-harm and ground boiler heating, this system combines mine water drainage and underground cooling with taking use of heat-harm as a resource, successfully using deep geo-thermal energy to replace ground coal-firing boiler heating, forming a circular green production system with cooling underground and heating on the ground.

4.1 System Instruction

HEMS system uses mine water as the medium, extract deep geo-thermal energy to replace boiler heating on the ground to achieving the purpose of controlling underground heat-harm. Figure 6 is the technology principle diagram. The system is comprised with two parts of underground and on the ground, the underground part includes HEMS-II cooling station, HEMS-I cooling station, HEMS-PT pressure conversion station, HEMS-T heat exchange station and pumping station drainage system, ground part includes regulating pond, HEMS-III heating station and water treatment system. Functions of each station and detailed process are described as following:

(1) HEMS-II cooling station conveys cold energy by water-gas heat exchange to working face to be cooled to control heat-harm, at the same time conveying thermal energy to HEMS-I cooling station.

(2) HEMS-I cooling station conveys the produced thermal energy to HEMS-PT pressure conversion station at the same time conveying cold energy to HEMS-II cooling station.

(3) HEMS-PT pressure conversion station is used for solving liquid high pressure on pipes, at the same time conveying thermal energy produced in HEMS-I cooling station to HEMS-T heat exchange station.

(4) HEMS-T heat exchange station is used for solving high physical abrasion, high mineralization, strong chemical corrosion, and successfully delivers thermal energy to mine water.

(5) Finally convey deep geo-thermal energy to ground regulated pond by underground pumping station drainage system, and convert low-grade thermal energy to high-grade thermal energy by HEMS-III heating station to heat on the ground, the mine water whose thermal energy is extracted is recycled after passing water treatment system and achieving drainage standards.

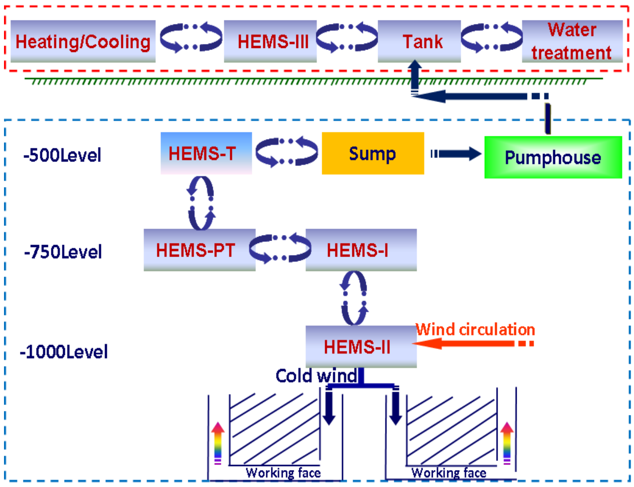


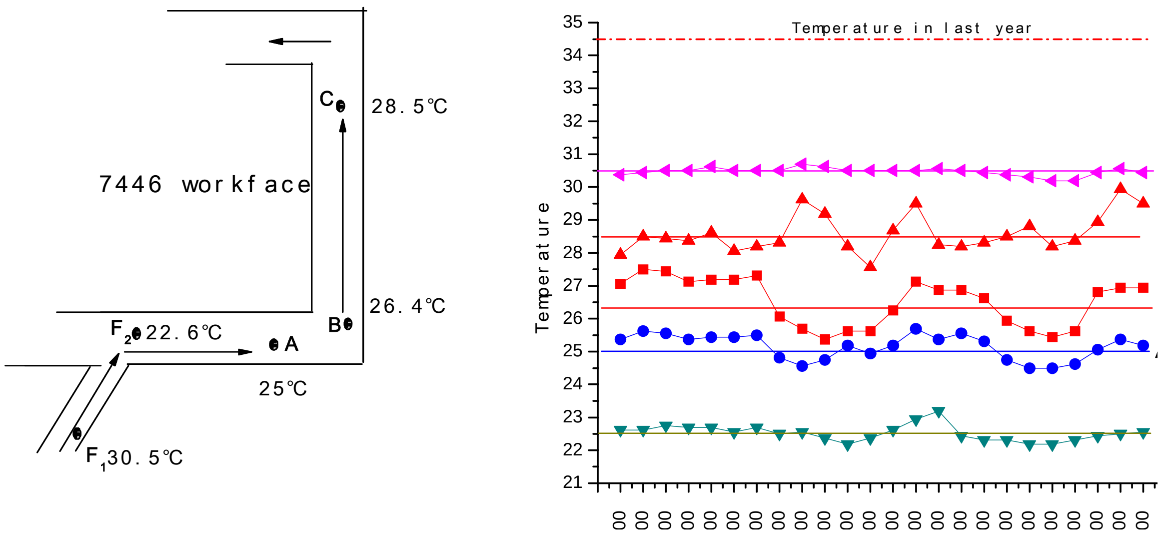
Figure 6: mine water cooling technology and principle.

4.2 Effect Analysis

HEMS system is successfully applied to Xuzhou coal mines such as Jiahe, Sanhejian and Zhangshuanglou, the results shows underground cooling effect is significant, heating on the ground is good. The following is the detailed data.

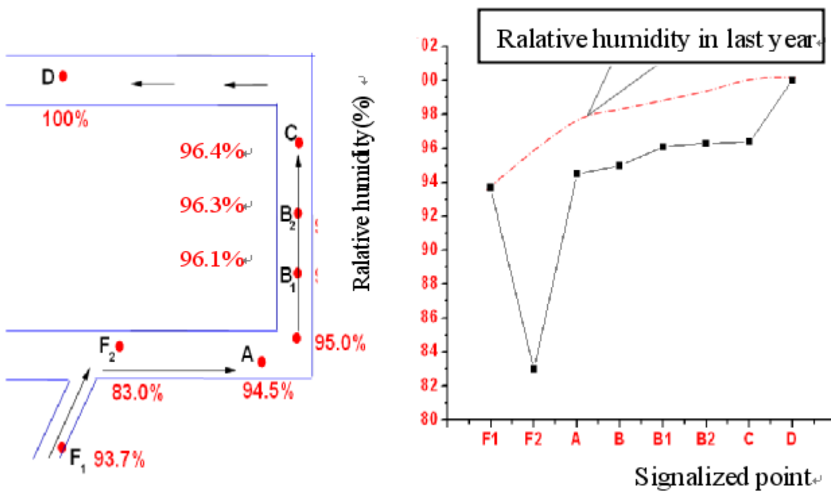
<u>4.2.1 Underground Cooling Effect</u>

In the operation process, there is a great deal of data featuring system operating status on each day. Data shows (Figure 7, 8) that temperature of intake wind on working face is 30.5°C, decreasing to 22.6°C after passing the cooling machine, being 26.4°C when reaching the working face. Controlled temperature at low corner point of working face C is lower by 6°C than that in the same period of 2006, 34.5°C, meeting the production requirements. Analyzing the data of the whole cooling season, temperature decreasing scope is 4~6°C. The system not only reduces the temperature, but also reduces the humidity by 5~10%.



F1 - HEMS-II intake wind F2 - HEMS-II outtake wind A-outside the belt of conveyer B-inside the belt of conveyer C - down corner of working face

Figure 7: 7446 working face cooling effect.



F1 - HEMS-II intake wind F2 - HEMS-II outtake wind A - outside the belt of conveyer B - inside the belt of conveyer B1 - lower part of working face B2 - higher part of working face C - down corner of working face D - return wind of material road

Figure 8: 7446 analysis of relative humidity variation on working face.

The overall running effect shows that controlled temperature on working face is between 26~29°C, compared with average temperature on working face before operating the system, controlled temperature after operating system decreases by 4~6°C, relative humidity of intake wind decreased most after passed HEMS-II cooling device, relative humidity of roadway wind continuously rises when conveyed to working face, the relative humidity at controlling point C is 96.4%, and that at air intake vent is 83%. Relative humidity on working face before operating the system is 100%, so after operating the system the relative humidity decreases by 3.6~17%, largely improving working environment for workers.

4.2.2 Ground Heating Effect

Water temperature supplied for heating designation is 60°C, temperature of returned water is 50°C, Figure 9 is the data of HEMS-III heating unit running for one day. The unit ran normally, fully meeting the heating requirements. Figure 9 shows temperature of water supplied for the unit fluctuates with 60°C, temperature coincidence points of supplied and returned water are automatic off status when temperature of unit reaches the designed 60°C, the unit would restart when heating requirements were not met.

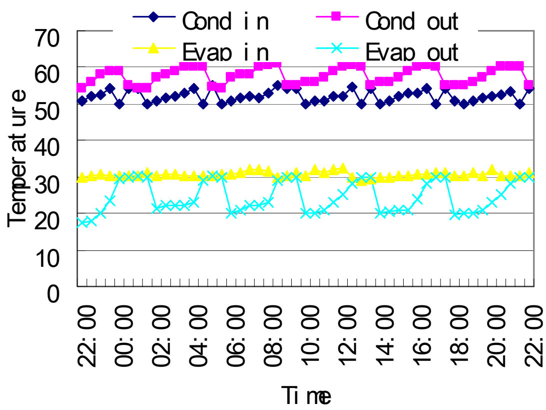


Figure 9: Ground Heating Running Effect.

5 CONCLUSION

In this paper, aiming at deep mine heat-harm and usage of thermal heat, through developing and using HEMS, get the following conclusions:

(1) by analyzing mines in eastern China, summarize the common problems faced by deep mines and deep mine heat-harm control, and energy waste and environmental pollution due to usage of ground coal-firing boiler.

(2) according to plenty of ground temperature variation and hydro conditions analysis of mines with heat-harm, summarize three modes of mines with heat-harm: Jiahe mode, Sanhejian mode and Zhangshuanglou mode.

(3) successfully develop HEMS (High Temperature Exchange Machinery System), this system uses mine water as medium, through exchanging thermal energy, achieve use heat-harm as a resource while controlling heat-harm on working face, successfully extracting deep geo-thermal energy to replace ground coal-firing boiler.

(4) successfully apply to Jiahe, Sanhejian, Zhangshuanglou coal mines of Xuzhou Mining Group. After applying the system, temperature on underground working face could be controlled between 26~30°C, decreasing about 5~7°C, relative humidity decreasing 5~15%, largely improving working environment on working face with high temperature and humidity for a long time. After ground boiler were replaced by deep geo-thermal energy, coal was saved for 10000t, CO_2 emission was decreased for 17000t, SO_2 emission was decreased for about 100t, with significant energy saving and environmental protection effect.

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