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Geothermal Heating Technology in China

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Key words: geothermal resources; heating technology; geothermal direct heating; indirect heating; cascade utilization; heat pump technology; integrated energy station; economical and intensive utilization mode

ABSTRACT

In this paper, we mainly introduce the history and development of heating with geothermal resources in northern China. We analyze the utilization mode, process flow and the advantages and disadvantages of equipment of geothermal heating technology in details. We advocate the utilization mode of "geothermal indirect heating and recharge-mining" and make full use of heat energy through heat pump, floor heating and other technical means to achieve efficient and intensive utilization of resources. Finally, suggestions on rational, scientific and orderly development and utilization of geothermal resources were put forward.

1. INTRODUCTION

Clean heating is an important part of the national energy production and consumption revolution and lifestyle revolution, and one of the main measures to improve the living environment. There are four distinct seasons in the vast northern areas north of Qinling and Huaihe rivers in China, especially in the long and cold winter, which generally has a heating period of 4-6 months. Residential buildings always use coal-fired boilers for heating.

There is limited influence on scattered rural air. But with the acceleration of urbanization, the residents of the group are more and more concentrated. Due to the large amount of sulfur dioxide, nitrogen oxide and suspended particles, the problem of air pollution is serious.

However, with the acceleration of urbanization, the density of the population increases. As a result of coal-fired heating, a large number of sulfur dioxide, nitrogen oxides and suspended particulates are discharged directly. Air pollution is serious, which brings serious potential hazards to the environment. In the 1980s, the Chinese government promulgated the Regulations of the State Council Environmental Protection Committee on Technical Policies for Preventing and Curing Soot Pollution (No. 011 of National Ring Character (84), "Urban construction departments should synchronously design and construct joint heating as a supporting facility for residential buildings in the planning of heating areas.

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In order to restrict the construction of scattered heating boiler house, it is strictly prohibited to use small coal furnaces for heating in new residential areas [1]. The government begins to pay attention to the cleaning and heating work in the north in winter, push forward the utilization and technical innovation of various green and environmental protection energy, and continuously optimize the policies, improve the mechanism, and comprehensively implement the heating source from the local conditions, comprehensively implement the heating source from the local conditions, comprehensively improve the efficiency of the heating network system and effectively reduce the heating energy consumption of users. The heating and heat sources in northern China are becoming more and more widely used in heating and heating, such as clean and environmental solar energy, wind energy, biomass energy and geothermal energy[2].

The 13th Five-Year Plan of National Renewable Energy Development emphasizes that we should vigorously promote the diversified development of solar energy, actively develop biomass heating, actively promote the utilization of geothermal energy, and increase the exploration and evaluation of geothermal resources potential. This brings a new opportunity for the development of clean heating. This paper mainly introduces the application and development of geothermal resources in regional heating.

2. HISTORY AND DEVELOPMENT OF GEOTHERMAL HEATING

Geothermal resources were mainly used in greenhouse cultivation, irrigation, aquaculture, industrial printing and dyeing, bathing, swimming, physiotherapy and so on. The geothermal battle in the early 1970s marked the beginning of the government's active involvement. In the early 1980s, the funds and equipment assistance of the United Nations Development Programmed and the governments of Italy and Romania enabled China to enter an unprecedented period of high and rapid development in the exploration, development and utilization of geothermal resources.

In 1982, Tianjin, a northern port city, conducted a geothermal heating experiment using heat fluids buried 1064-1106m underground to heat 30,000m^2 residential and office buildings by indirect heat transfer. This was the first geothermal district

heating project in the city. Another exploration in the same period was to use geothermal fluids buried 951-1,316 m to directly heat nearly a 10,000 m^2 school dormitories.

The practice of these two projects proves that the geothermal heating effect is good, and the building room temperature can be maintained at 16-20℃ during heating period. Cost accounting: Although the initial investment of geothermal heating drilling project is high, its operation cost is low and it is economical compared with the total cost of boiler heating[3]. The applied technology research and geothermal related design of these early projects laid the foundation for the gradual scale development of geothermal heating.

In the past 30 years, with the improvement and progress of technical means and related equipment and materials in geothermal utilization, problem-oriented process improvement and economic factors promoting technological innovation in geothermal management, geothermal heating technology and management in China have gradually developed from extensive to intensive. In the northern region, geothermal resources mainly serve different industries such as building heating, domestic water, hot spring recreation and facility agriculture, among which heating is the largest and most important industry, creating very significant economic output value and social benefits.

A medium-sized and large-scale geothermal development project (more than 100,000 m^2) can provide employment to 10-50 people[3], increase workers income, promote the development of real estate and other related industries, and promote the development of infrastructure and other industries. It can not only save conventional energy, alleviate resource shortage to a certain extent, improve people's living standards and quality, and improve the investment environment. Promote the sustainable development of regional economy. Moreover, geothermal resources have the characteristics of recyclable utilization, green environmental protection and low pollution. Its development and utilization can effectively reduce the demand for conventional fuels and emissions of ash, slag, sulfur dioxide and nitrogen oxides, save the cost of urban pollution control, and correspondingly reduce the amount of urban transportation, effectively protect the ecological environment, and have very obvious environmental benefits. Heating enterprises get economic benefits from heating income. Residents use clean and environmentally friendly heat sources. Blue Sky Project and Clean Air Action also provide commendable achievements for one government.

3. GEOTHERMAL HEATING TECHNOLOGY

In China, geothermal heating generally adopts direct, inter-supply, cascade utilization and multi-energy comprehensive utilization.

3.1 Geothermal Direct Heating

Geothermal direct heating means that geothermal fluids pass directly through heat users, and then discharge or recharge. The design of this heating method is simple (Figure 1). This direct heating method was used in the early spontaneous geothermal heating experiments in China. At that time, geothermal fluid was usually discharged after heating by a first-order radiator. The temperature difference of the radiator was the influence of the temperature difference, and the temperature of the geothermal drainage was generally about 50℃.

In order to solve the problem of excessive drainage temperature, the technical department has developed a STZ temperature control valve[4], which controls the temperature of geothermal return water and enlarges the temperature difference of geothermal utilization. A new type of geothermal direct heating system (Figure 2) has been established to form a relatively closed geothermal direct heating and circulation system, and the utilization rate of geothermal energy has been significantly improved.

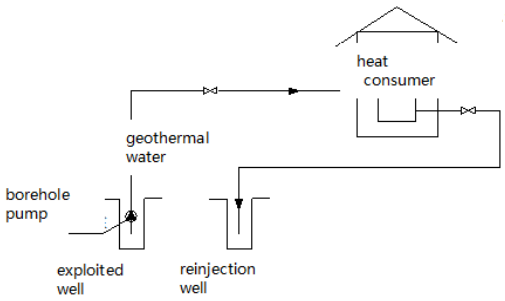


Figure 1 Earlier Direct Geothermal Heating System

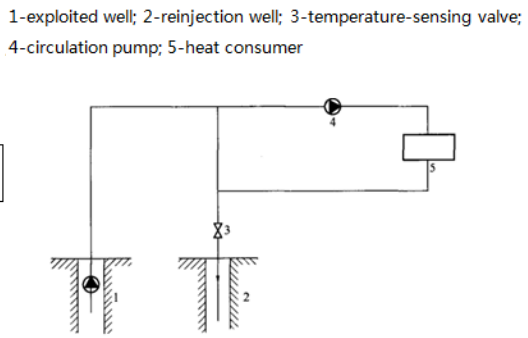


Figure 2 New Geothermal Direct Heating System

Generally, there are some restrictions on the use of direct geothermal heating. First, the corrosiveness of heat fluids reduces the service life of heating equipment pipeline network. Second, the scaling of geothermal pipeline network system affects the heat dissipation performance and reduces the effective heat utilization rate. Third, the hydraulic regulation of direct geothermal heating system is poor. Despite these, direct geothermal power supply has obvious advantages, such as low temperature loss, high heating efficiency and low initial investment.

3.2 Indirect Geothermal Heating

The indirect geothermal heating system (Figure3) is different from the direct one. The thermal fluid does not pass directly through the heat user radiator, but through the heat exchanger, transfers the heat to the circulating water of the heating network, and the geothermal fluid is recharged or discharged after the temperature decreases. Because the geothermal fluid does not pass through the heating network, only circulating water is used in the heat users, so the corrosive protection of radiators is relatively easy to achieve. At the same time, the circulating pump of heating network is mainly used to overcome the resistance along the cycle

system and the pressure of the system is relatively stable. This indirect heating system is usually used in large-scale centralized geothermal heating. The disadvantage is that with the addition of heat exchangers, the temperature of the circulating water entering the thermal user will be lower than that of the geothermal fluid, and the temperature difference between the two reacts with the temperature loss of the heat exchanger.

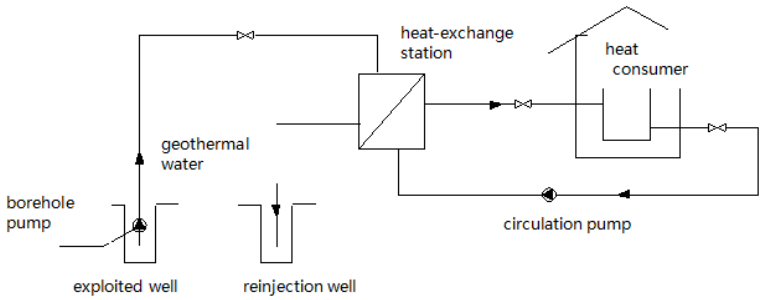


Figure 3 Geothermal indirect heating system

Heat exchanger is the key component of a geothermal inter-supply system. Titanium alloy plate heat exchanger is mainly used in Geothermal Engineering (Figure 4). It has the characteristics of good heat transfer performance, compact structure, flexible use and convenient cleaning and maintenance.

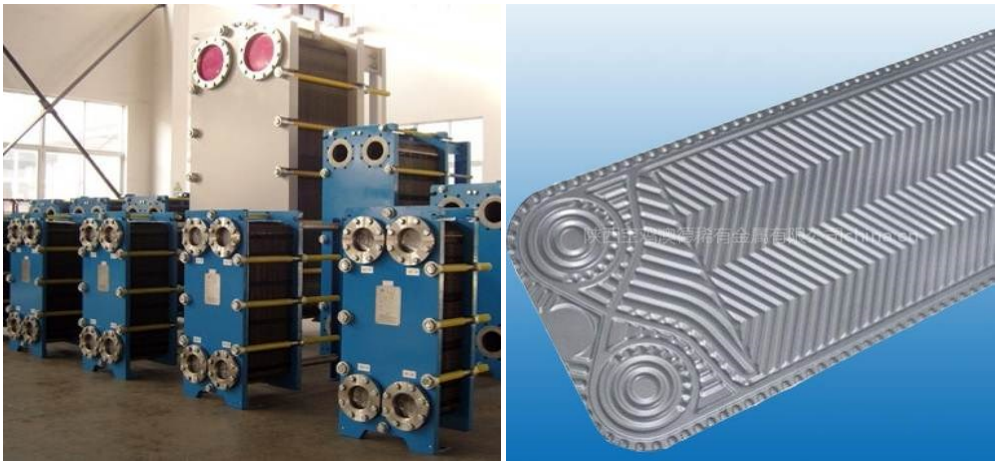


Figure4 Plate heat exchanger

The most important characteristic of the geothermal inter-supply system is "heating without water". This uses heat exchanger to extract heat energy from geothermal fluid. The fluid does not participate in circulation and is not polluted, so as to avoid corrosion of heating pipe network and terminal equipment. After heat transfer, geothermal fluids, as heat carriers, will be recharged after water purification and injected into the original thermal reservoir to form a relatively closed thermal cycle system above and below the ground[3]. This is to achieve the goal of utilizing only heat energy without consuming water, renewable and sustainable utilization. At present, China mainly adopts and promotes this mode of "geothermal inter-supply and recharge mining" for geothermal development and utilization (Figures 5 and 6).

Figure 5 Geothermal Station with Indirect Heating

Figure6 Geothermal Recharge System

3.3 Cascade Utilization

The cascade utilization of energy includes energy consumption according to grade and multiple utilization step by step. In cogeneration of heat and power, high and high temperature steam is used to generate electricity first, and waste heat is used to heat

buildings. According to the demand, energy is used cascade from high to low for many times. With the decline of energy grade, the most economical and reasonable temperature range is found in every energy-consuming equipment. In this way, when the high-grade energy in one device falls outside the scope of economic application, it can be transferred to another device which can use this low-grade energy efficiently, so that the overall energy utilization rate reaches the highest level.

Geothermal cascade utilization is based on the different temperatures of thermal fluids for step-by-step utilization. High-temperature geothermal energy is first used for power generation. Then, it can be used for industrial drying, agricultural seedling breeding, building heating and so on; finally, low-temperature thermal fluids are used for living heat, bathing and so on. After a series of utilization, the tail water reaches about 20℃, so as to maximize the use of thermal energy. If necessary, the heat pump can be added to further improve the temperature grade of the heat source and then be used. By using the heat pump, the temperature of the geothermal tail water can be reduced to about 10℃ Different enterprises have different levels of energy requirements. According to the level of energy demand of each energy-using enterprise, the cascade utilization relationship of energy can be formed (Figure 7). High-level heat source can be reduced to low-level heat source after being used by the higher-level enterprise, and it can be used by enterprises with low supply and demand. The cascade utilization of energy can effectively meet the energy needs of each unit without increasing energy consumption, and greatly improve the energy utilization rate.

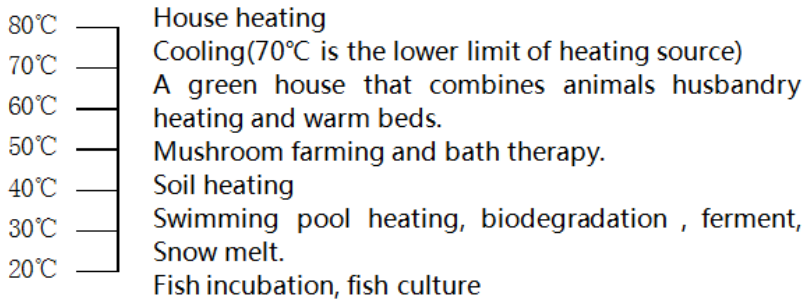
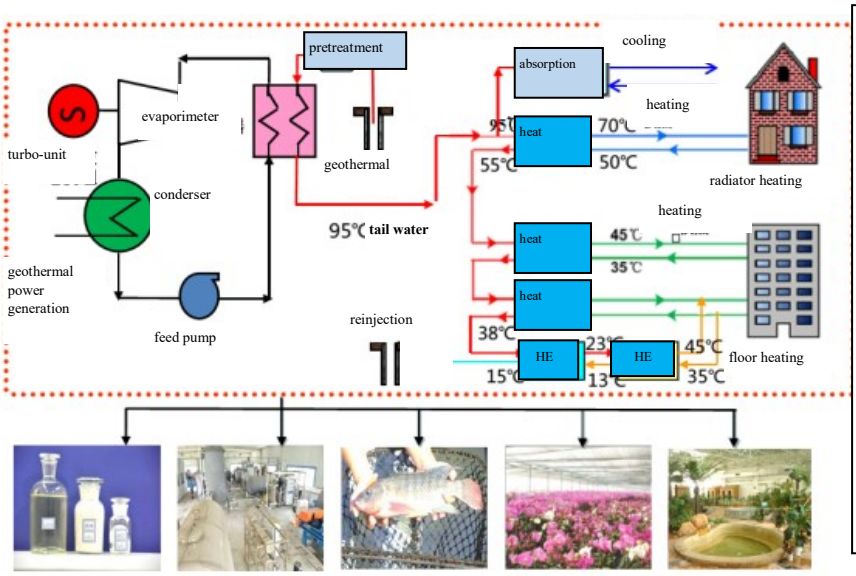


Figure7 Low Temperature Geothermal Cascade Utilization Level

Cascade utilization is an important principle of low and medium temperature geothermal utilization. Geothermal cascade utilization can increase the utilization temperature difference, reduce the drainage temperature of geothermal fluid and improve the utilization rate of geothermal energy. Geothermal cascade utilization mainly includes three ways: heating cascade utilization, heat pump and geothermal comprehensive utilization. In China, the main ways of geothermal heating terminal include radiator, fan coil unit and low temperature floor heating. Geothermal fluids with temperatures of 70-100℃ are used for heating after being replaced by boards. After the tail water used by traditional radiator users and fan-coil users for primary and secondary heat utilization, the water temperature is reduced to about 55℃, 45℃ and 38℃. New technologies and processes, such as heat pump, are used for heating floor radiation users again. The tail water temperature of geothermal energy can be reduced to about 10℃.

Most of the circulating tail water is recharged. Some of the tail water can also provide domestic water for residents according to their needs. It can also supply water for comprehensive fields such as hot spring recuperation, health care and recreation. This has led to the development of geothermal industry in hot spring tourism, catering and hotel industries[5] (Figure 8).



Acording to the idea of "Grade opposite, cascade utilization" , geothermal power generation, high-efficiency heating and refrigeration of buildings,industrial and agricultural production and the cascade utilization of hot spring are realized. So the transformation and utilization of geothermal energy is improved greatly.

Figure8 Geothermal cascade utilization

3.3.1 Cascade utilization of heating modes

Figure 9 Radiator Heating and Floor Radiant Heating

According to the demand of building heating, different heating modes are the preferred cascade utilization modes for geothermal heating (Figure 9).

Radiator heating belongs to the high temperature section of geothermal cascade utilization. The upper limit of water supply temperature is 95℃, the lower limit can be as low as 65℃, the reasonable utilization temperature is 20-25℃, and the outlet temperature of radiator is above 45℃.

Generally, increasing the area of the radiator can increase the temperature difference of geothermal utilization. However, since the average water temperature of heating decreases, the heat release capacity of the radiator decreases, so the design outlet water temperature of the radiator cannot be too low. The fan coil units commonly used in air conditioning have the characteristics of large heat transfer surface area and good heat transfer effect. They are often used for heating and refrigeration in public buildings. Low-temperature floor radiation heating is a kind of heating method which uses the heat storage radiation of the ground itself to distribute heat to the space on the ground by laying hot water transmission cooling coils under the ground. Premature waste heat as heat source to adjust the thermal microclimate of the room. It belongs to building energy-saving technology and has great development prospects and popularization value.

Low-temperature floor radiation heating has many advantages compared with other methods: 1) energy saving; 2) good thermal comfort; 3) can achieve "household measurement, room temperature adjustment"; 4) saving indoor area, flexible layout of indoor space; 5) small investment, mature technology. New materials such as steel pipe, ceramic pipe, copper pipe, PB plastic pipe, rigid polyvinyl chloride dilute plastic pipe and cross-linking pipe can be used as heating pipes for floor radiation heating.

Low-temperature floor radiation heating has been very popular. It is a heating method that uses hot water with temperature not higher than 60℃ as the heat medium, circulates in the heating pipe, heats the floor, and provides indoor heating by radiation and convection through the ground.

Floor heating takes the whole ground as the heat dissipation surface, so that the indoor temperature is evenly distributed in the horizontal and vertical directions, heat is distributed from the ground to the indoor space, the temperature of the upper space is lower, the comfort of the human body is good and energy-saving; the temperature difference between the return water and the floor heating design should not be greater than 10 degrees, and the average temperature from 55℃ to 35℃ is more appropriate.

Therefore, floor heating is an important low-temperature heating mode, which can reuse the waste heat of radiator heating. It can be used in three stages in series at most: 60-50℃, 50-40℃, 40-30℃. It is suitable for the middle and low temperature stage of geothermal cascade utilization. For the heating system using geothermal energy as heat source, the temperature of geothermal tail water after heat transfer is usually 40-50℃, and floor radiation heating is the most suitable step utilization.

3.3.2 Heat pump

Heat pump is a special tool for geothermal cascade utilization. On the one hand, it can absorb the heat from the tail water of geothermal heating, further reduce the tail water temperature and realize the reuse of geothermal waste heat; on the other hand, it can compress heat pump into high-grade heat energy for system heating, expand the scale of geothermal heating, and realize the transfer of geothermal heating waste water from waste heat utilization to heating (Figure 10).

With the help of heat pump, the geothermal heating system breaks through the temperature limit of geothermal cascade utilization and makes waste heat heating a reality. Technically, it is feasible to use water source heat pump to reduce the geothermal drainage temperature below the local annual average outdoor air temperature, so the geothermal utilization rate can exceed 100%.

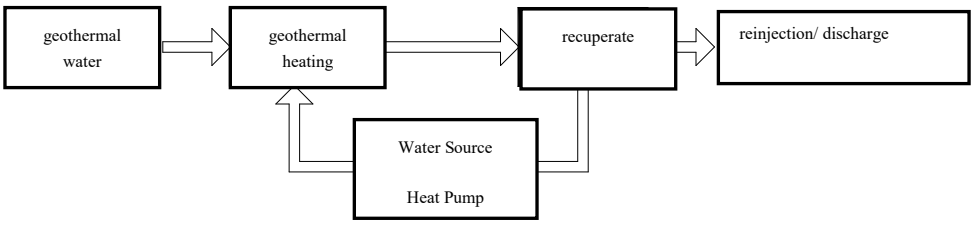


Figure10 Water source heat pump

3.4 Integrated Energy Station

With the rapid development of energy utilization technology, it has become a trend to combine multiple energy sources to form a large comprehensive energy station to provide central heating and Refrigeration Services for the region.

The integrated energy station is to utilize two or more kinds of renewable energy, such as deep geothermal energy, shallow geothermal energy, solar energy, biomass energy, air energy, industrial and amateur heat and conventional energy, etc. (Figure 11) and integrate them systematically through dynamic regulation technology to improve the efficiency of energy development and utilization.

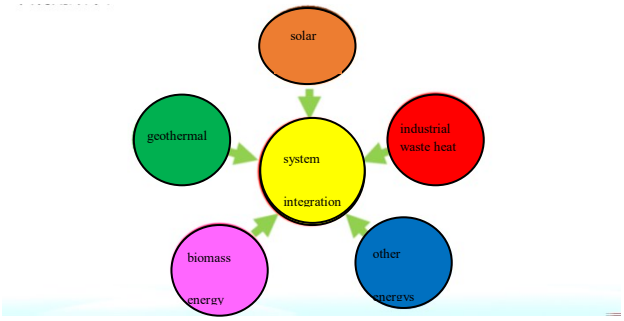


Figure11 Integrated Technology of Composite Energy Utilization System

The earliest comprehensive energy station in Tianjin is the energy station in Area A of Xiqing New Campus of Tianjin University of Technology, which was built in 2008. It uses a variety of energy sources of 185,500 m^2 for building heating, refrigeration and domestic hot water supply. It mainly consists of a pair of geothermal systems consisting of a pair of wells with a depth of 2,170 m and 2,300 m, a temperature of 65°C for water extraction and irrigation, and a heat pump system consisting of 588 underground pipes with a depth of 120 m. And solar energy system, gas boiler system, through the supporting automatic control system, the equipment station will be organically combined with multiple systems, fully achieve high efficiency, energy saving, environmental protection.

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4. CONCLUSIONS AND SUGGESTIONS

Geothermal energy is a renewable and clean energy. In order to maintain the advantages of renewable energy, we must develop it in accordance with the objective output capacity of resources, protect it in development and develop it in protection.

While satisfying the needs of people's life and social development and giving full play to the advantages of resources for the development of economy and the improvement of people's living standards, we should make rational, scientific and orderly use of them.

Firstly, according to the local conditions, resource availability, different temperature, water quantity and quality of thermal fluid, and the type and characteristics of resources, we should choose the appropriate utilization mode to make the development and utilization of geothermal resources reach the optimum combination.

Secondly, attention should be paid to the recharge work. Exploration results show that the thermal resources and unexploited geothermal fluids in the rock skeleton account for 99.5% of the total geothermal resources. Recharge exploitation is the only way to realize the regeneration of geothermal resources. Increasing the number of recharge wells and single well recharge quantity, reinforcing the recharge intensity, avoiding direct discharge, and comprehensively improving the recharge rate are important to realize the sustainable development and utilization of geothermal resources. Guarantee.

Thirdly, there is a need to increase the depth of geothermal comprehensive utilization, improve the geothermal utilization system, and formulate reasonable utilization plan. In terms of utilization technology, cascade and intensive utilization mode should be chosen, heat pump technology should be used to "squeeze out" the heat energy in geothermal fluid, and floor radiation heating technology and fan coil technology should be fully utilized to reduce the tail water temperature as far as possible in the selection of heating terminal equipment.

Lastly, we should strengthen the management of resources, implement strict system of program optimization review, design and construction supervision and mining administrative license, establish perfect industry technical norms, strengthen the construction of mining rights market and post-certification supervision, make detailed short-term and long-term planning, standardize management and overall development.

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