An Interdisciplinary Response to Mine Water Challenges - Sui, Sun & Wang (eds)
©2014 China University of Mining and Technology Press, Xuzhou, ISBN 978-7-5646-2437-8

New Technology for Reusing Mine Water in Underground Goafs and its Engineering Applications

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Abstract Based on the successful application of a new technology on underground mine water reuse in a certain mining area, the application process, application conditions and safety technical measures taken in reuse of mine water in goafs are summarized in this paper. The results show that, by injecting the mine water produced in the mining process into the goaf where a waterproof sealing wall is established and where the water is deposited, filtrated and stored as production and living water resources for mining area, the problems of water supply and sewage discharge in this mining area were effectively solved, and meanwhile many environmental, economic and social benefits are achieved, which provides a reference for other mining areas or mines with similar conditions in terms of safe water reuse in underground goafs.
Keywords reuse of mine water, goaf, application conditions, technical safety measures, waterproof sealing wall

Introduction

China is a great power of coal production, and water resource is a key restriction factor in coal exploitation. In the large mining areas of the state-key-planned 14 large-scale coal bases, the phenomenon of water resources shortage occurs in different degree, especially for mining areas located in the drought northwest regions with little rain. With the unceasing expansion of the production scale of mining areas, on the one hand, the production and living water consumption increases year by year, on the other hand, the original source of water supply is increasingly dried up, the contradiction between supply and demand of the mining production and living water has become increasingly prominent.

At present, the traditional mine water treatment method is to drain the underground mine water from the underground sump to the ground surface, at where the water is treated by the water regulation pool and the mine water treatment station arranged on the ground surface; after reaching the reuse requirements of water quality, one part of water is used on the ground surface, the other part is returned to the underground for use. The disadvantages of this model are: large infrastructure investment, high lifting and operation cost of mine water, and coverage of big land area, etc.

To solve the existing problems in the mine water reuse in the traditional model, in more than a dozen of mines in a northwest mining area, the mine water produced during the production was injected into the mine goaf for precipitation, filtration and storage. By taking a series of safety technical measures, the purification, filtration, adsorption and storage of the mine water were achieved, and the treated water can be used as mine production and living water, while ensuring normal production of the mining area. Under the condition of making full use of underground mining space, the problem of water supply and water drainage in the mining area are effectively solved.

Research of new technology for reusing mine water in underground goafs

Application process

Reusing mine water in underground goafs is a kind of new technology for mine water treatment. The main impurities to be removed in the water shall be determined according to the actual terrain and geological conditions of the underground goafs and the application of

the mine water after treatment. Then the mine water is injected into the high lying area of the goaf to lead it to flow by itself. Because the coal gangue in the goaf has the functions of filtration, adsorption and purification of mine water, the water during flow can be purified through physical and chemical actions such as filtration, precipitation, adsorption and ion exchange as well as authigenic mineral etc., which is then collected in the low lying area of the goaf for use as production and domestic water above and under the mine shaft.

Taking the mine water as an utilization target, the treatment process is as follows: drain the water into the collecting basin (water sump) through the corresponding drainage facilities; after collecting and regulating actions of the collecting basin, drain it into the goaf through a pipeline or stratum borehole; after purification in the goaf, remove Fe^{2+}, Mn^{2+} etc. from the purified water through an underground water treatment system, then supply water to the locations where the water is needed; in this way the mine water is treated and reused as purified water. Fig. 1 shows the specific process.

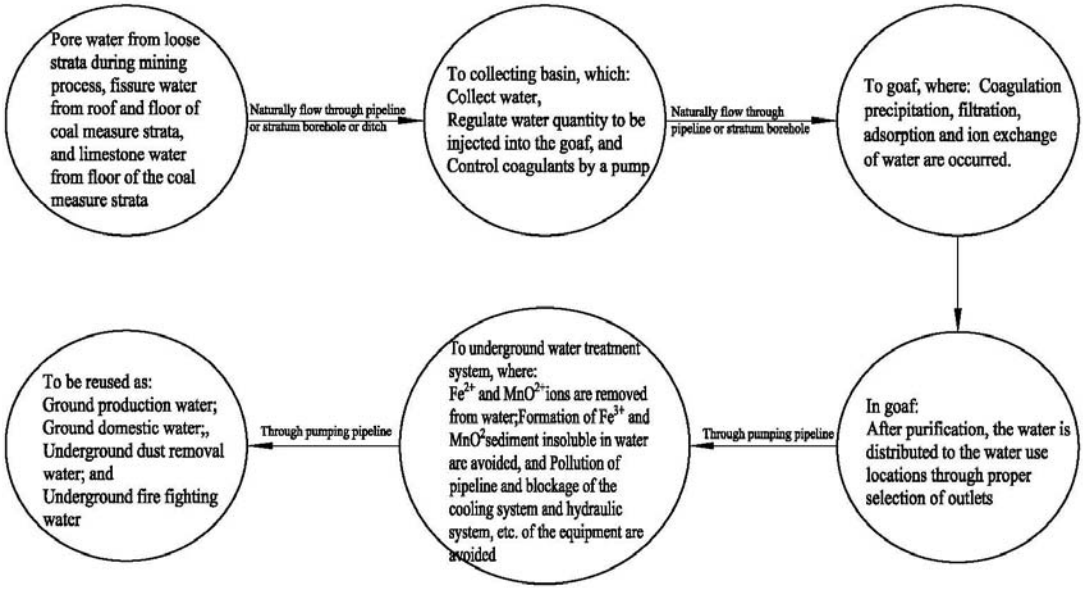

Fig. 1 *Process flow diagram for mine water reuse in underground goaf*

Application conditions

The underground treatment for mine water shall be conducted based on local conditions, taking many factors such as the topographic and geological conditions of the underground goaf, the position of the goaf and the impact of working face mining, etc. into consideration. It is recommended to implement it in the underground goafs with simple hydrogeological conditions first.

Topography of the goaf

The goaf for underground water reuse shall have certain elevation difference, so as to inject the mine water from the high lying area to the low lying area of the goaf. Affected by the terrain height difference, the mine water will flow from high to low, during which the coal gangue in the goaf will filtrate, adsorb and purify the water. Through the drainage facilities arranged on the sealing wall located at the corresponding drift in the goaf, the water after

precipitation and purification is fed through the pipelines to the locations above or under the shaft where the water is needed.

Geological conditions

The underground goaf for mine water reuse shall meet special geological structure requirements; in this sense only a few of mines are qualified. It is forbidden to use goafs with structural damages, where the top and bottom aquifer water may crush into the goaf due to tectonic rupture, or the water stored in the goaf may crush into the up and down coal beds stoping face under the influence of structure, resulting in flood disasters.

Position of the goaf

In order to ensure safe and reliable underground water reuse, meanwhile not to affect other underground production working faces, the goaf for underground water reuse shall be located in the lower part of the area that has been stoped, so as to prevent water stored in the goaf from endangering the safety production of the mine due to various uncertain factors.

Impact from mining of working face

Due to coal seam mining, the stoping face will affect the roof stability. Along with the advancement of the working face, the pressure on the working face will appear, and the first weighting and periodic weighting of the roof will appear, too. The roof weighting will have a devastating effect on the structure and stability of waterproof sealing wall, and meanwhile affect the waterproof coal (rock) pillars retained around the walls, which will greatly affect the safe and stable operation of underground water reuse of mine water in the goaf.

Technical measures for safety

There are numerous factors affecting safe and reliable water reuse in underground goafs. The technical measures for safety shall be taken from such aspects as the waterproof sealing wall structure, the conditions of rocks, water head height of water storage area, monitoring system, etc, so as to ensure safe and reliable treatment of mine water in underground goafs.

Structure of waterproof sealing wall

The waterproof sealing wall is located in the corresponding drift to separate the water storage and reuse area and the normal production area in the goaf. Its main purpose is to serve reuse of mine water. The wall mainly withstands the hydrostatic pressure effect slowly injected into the goaf; for the water storage height up to 50 m water head in the goaf, the wall has to withstand a hydraulic pressure of 0.5 MPa. As the single structure plain concrete waterproof sealing wall has relatively large strength by itself, the compressive and shear strength effected on the whole wall by the water body in the goaf is within the withstanding scope of the wall's main load-bearing structure, which can satisfy the safety requirements under the condition of smaller water pressure. The structure of the waterproof sealing wall is shown in fig. 2.

In addition to the strength of the wall itself, the main factors that affect the reliability of the sealing wall and underground cavern are also related with the factors such as engineering geological properties of rocks around the wall body, properties of water body and magnitude of the pressure, reserved size of waterproof coal (rock) pillars, wall construction quality and maintenance situation, etc.

Conditions of rocks

As the waterproof sealing cavern is formed by the waterproof sealing wall and the rocks, its strength and stability will depend on both. Because the waterproof sealing wall is generally located in the coal drift in the goaf, where the strength of coal seam is lower and the fissure is

developed, adequate waterproof coal pillars shall be reserved on both sides of drift in accordance with the related requirements in Provisions for Coal Mine Water Prevention and Control.

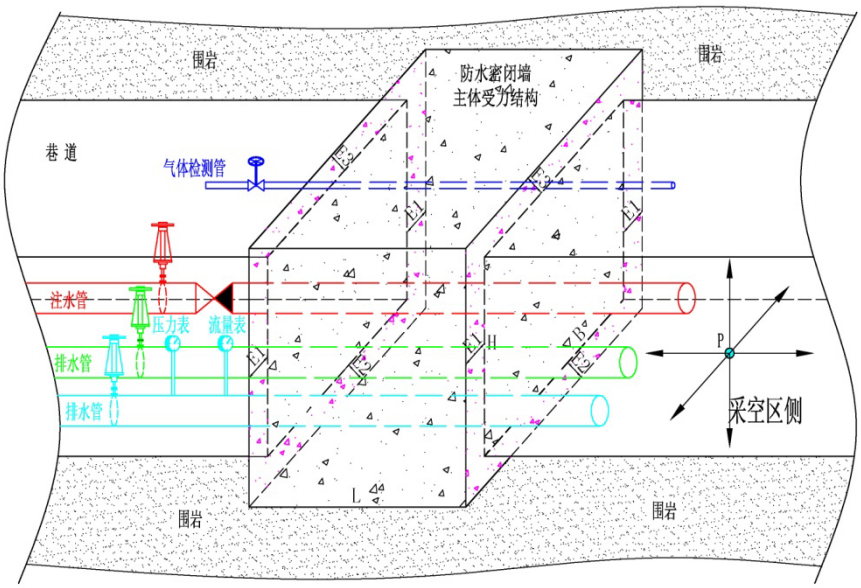

Fig. 2 *Structural Diagram of Waterproof Sealing Wall*

The dimensions of the waterproof sealing wall are calculated by referring to the calculation formula for waterproof gate wall, as follows:

Calculate the depth E required for the cavern to be embedded into the masonry of the rocks according to the compressive conditions of rocks

$$\gamma_0\gamma_c PS_1 = RS_2 \qquad (1)$$

Where, P – safe water pressure withstood by the waterproof sealing wall, MPa;
γ_0 – importance coefficient of the structure;
γ_c – influence coefficient of slotting construction on the rocks;
S_1 – total area of the wall end against the water subjected to water pressure, m^2;
S_2 – load-bearing area of the wall acting with the rocks, m^2;
R – compressive strength of the rock mass, MPa, $R=\xi_a \times Rc$.
R_C – compressive strength of the rock, MPa;
ξ_a – coefficient of rock fissure, the value is deduced as shown in table 1.

Table 1 *Rock fissure coefficient*

Joint development degree	Undeveloped	Relatively developed	Developed	Developed very much
ξa Coefficient of fissure	＞0.75	0.45～0.75	0.45～0.75	＜0.45

Calculate the thickness L of the main load-bearing structure of the cavern wall based on the shear condition of the rocks

$$\gamma_0\gamma_c PS_1 = S_3\tau \qquad (2)$$

where,

τ - allowable shear strength of the rock mass, MPa;
S_3 - rock mass area withstanding the shear, m^2;
Other formulas and parameters are the same as above.

According to the dimension parameters of the waterproof sealing wall determined by the wall rocks strength, the wall and the rocks form an organic whole to resist the water pressure effect in the goaf. If the wall is arranged in the rock stratum with relatively developed joints, fractures and karst and the fault fracture zone, the rocks shall be reinforced by grouting.

Height of water head in the storage area

The safe water head height that the waterproof sealing wall and the cavern can withstand shall be determined in combination with the requirements of the underground mine water and production and living water demand, and according to the strength of the rocks; only the water head is within the range of safe water head height that the rocks strength can withstand, can the safe and reliable operation of the water storage & reuse in the goaf be ensured.

Monitoring system

In order to ensure that the water head height in the water storage reuse area in the goaf is within the range of safe water head height that the wall rocks strength can withstand, the equipment and facilities such as gas detection tubes, drain pipe, water injection tube and pressure gauges shall be provided on the wall for dynamic monitoring of water level and water pressure in the water body of the goaf, strictly controlling the water level and reasonably controlling the injection quantity and displacement, and preventing the overrunning of the underground water level.

Field test and application prospect

Field test

The hydrogeological conditions of a certain mine is relatively simple. At the lowest position of the goaf where the working face has been stoped and stable, two working faces are selected to carry out mine water underground re-treatment. The waterproof sealing walls are set in the crossheadings and main roadways, as shown in the scope of purple boxes in Figure 3; and the shadow part in the figure is the mine water stored in the goaf. Since the working face goaf is the joint mine water reuse area, the waterproof pillars are set around the working face goaf, the goaf water line distributes along the height direction of “three zones” only in the goaf. The monitoring systems are set up on the related walls to monitor the goaf water line, while guaranteeing the safety production of mine, the combination of supply and drainage of the mine is also realized. It is learned that in 2013, through underground mine water reuse, the mine saved sewage treatment fee of RMB￥1.25 million, water rate of RMB ￥5.3 million, and the pollutant discharge fee of RMB￥100,000, thus the earned direct economic benefits of RMB￥6.65 million. While solving the mine water resources reuse problem, it has also achieved good economic and social benefits.

Application prospect

The mines with relevant conditions can inject the sewage produced in the process of production into the goaf for treatment as the source of mining production and living water, through the isolation function of the sealing wall, the purification and storage of the mine water can be realized, and at the same time it is ensured that the normal production in the production mining area is not affected. Under the condition of making full use of underground mining space and effectively excavate the potential of the internal water treatment of the mine, the mine water after treatment can be directly used as mine production

water; and after simple ground treatment, it can be used as living, industrial and green water; after advanced treatment, it can be used as drinking water, which has effectively solved the problem of water supply and water drainage in the mining area.

The successful application of this technology in multiple pairs of mines in the northwest China has effectively achieved the combination of the water supply and water drainage of the mine water, and comprehensive utilization, and brought good environmental, economic and social benefits. For other coal bases and mining areas with contradictions of water supply and water drainage of the mine water, it has a good exemplary role and the necessity for promotion.

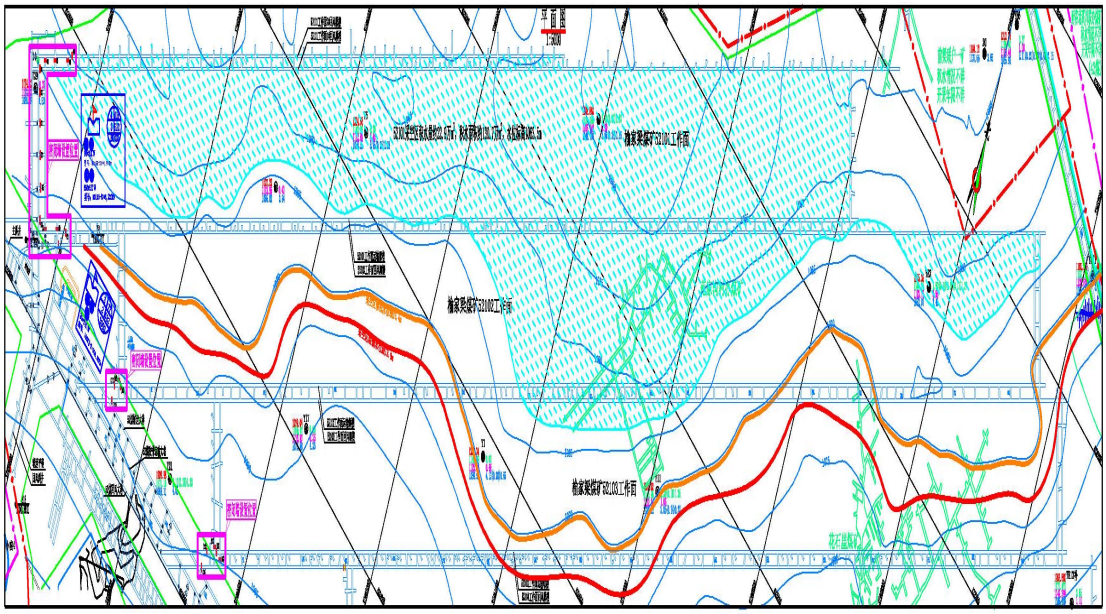

Fig. 3 *Plan of mine water underground reuse in a certain mine*

Conclusions

The effect of using underground goafs for mine water storage & reuse is obvious. Through special application technologies, combined with certain application conditions, and effective safety technical measures, the goals of mine water treatment in underground goaf and application of mine water resources can be effectively achieved, and meanwhile many environmental, economic and social benefits can be also achieved. It is feasible in theory and achievable in technology for the mine water treatment in underground goaf. For the other mining area with similar shortage of water resources of this research mine, this new technology can be applied and bring outremarkable comprehensive benefits. This new technology can effectively combine the water supply and water drainage of the mine water to ensure the coal safety production and realize the mode of sustainable development and utilization of water resources.

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