

First International Symposium on Mine Safety Science and Engineering

Probing into Design of refuge chamber system in coal mine

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Abstract

Put forward the refuge chamber system composed by permanent refuge chamber, temporary refuge chamber and rescue capsule, which are mutually independent and tightly-coupled, to cost-effectively radiate all the areas with mining activities and protect personnel in mine. In addition, in order to promote the development of refuge chamber system in Chinese coal mine, propose some basically design principles of refuge chamber system and describe the arrangement principles and structure characteristics of three kinds of refuge space in the process of underground refuge chamber system design and construction. It is a significant reference for coal mine refuge chamber system construction in China.

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Selection and/or peer-review under responsibility of China Academy of Safety Science and Technology, China University of Mining and Technology(Beijing), McGill University and University of Wollongong.

Keywords: refuge chamber system; rescue capsule; coal mine; refuge chamber

1. Introduction

With the transformation of economic growth mode in the Chinese coal industry, the production mode and structure of coal industry occurs earth-shaking changes, especially for that the degree of mechanization improved greatly and the production concentration of high yield and high efficiency mine enlarges continually. This new mode of production proposes a new request to the safety and security. Heavy casualties are caused by mine accidents each year in China, which are mainly due to the underground workers poisoning and suffocation death caused by the spread of toxic fumes in the process of the accident ^[1, 2]. The production highly concentration is a Double-bladed Sword, which is not only simplifying the production system but also facing the inconvenience. Coal mine occur disaster, such as fire, flood, explosion and landslides, which often cause roadway congestion and damage ventilation system. And especially if the position of disaster victims is far from the emergency outlet, it will be difficult to evacuate and rescue for underground workers.

The emergency disaster prevention system established in modern coal mine is proposed under circumstances of the above-mentioned background, which aims at effectively reducing losing caused by

mine disaster. The early period of an accident is the most favorable to control accidents and reduce losing. However, regardless of how fast rescue team responses, reaching the accident site needs some time. Therefore, miners made self-help during this period has a multiplier effect to reduce casualties and prevent accidents expanding. Self-help measures of miners include three aspects, including self-help education for miners, equipping with self-help equipment and establishing refuge, establishing a perfect refuge chamber system that can radiate the mining area of which is the key to prevent accidents expanding and reduce casualties.

2. The constitution of refuge chamber system

According to *construction of a complete refuge six systems* notified by State Administration of Work Safety and State Administration of Coal Mine Safety in 2010, mine enterprises must construct complete refuge system including Underground Monitor System, Precise Positioning Underground workers Positioning System, Emergency Escape System, Compressed Air Self-rescue System, Water Supply System and Communications Network^[3], Emergency Escape System of which is the hard core of six system. Emergency Escape System provides the facilities and measures guaranteeing life safety for disaster victims when mine accident occurs. The construction of Emergency Escape System includes providing self rescuer for underground workers, constructing Evacuation Facility, setting up a reasonable evacuation route and establishing scientific contingency plans. Establishing a perfect refuge chamber system which can radiate the mining area is the key to enhance the mine safety support capabilities. The underground refuge chamber system is a relatively independent system which is dependent on a roadway system in mine, including permanent refuge chamber, temporary refuge chamber and rescue capsule. These refuge chambers and rescue capsules are mutually independent and tightly-coupled which forms a complete refuge chamber system, as shown in Figure 1. Refuge chamber system can make survivors in mine disaster enter the nearby refuge and wait for the ground rescue safely when escape routes is blocked or a possible disaster occur once again in a short time. In accordance with the principles of radiating all the mining area, the refuge chamber and rescue capsule should be set by different region and scale, which can make survivors avoid disaster and gain the rescue time. The urgent refuge system composed by the close integration of the underground refuge chamber system, facilities and equipment for disaster prevention, reasonable evacuation route and scientific contingency plans can overcome the oneness of ground rescue and make up for the insufficient rescue time, which will improve the ability of coal mine to withstand disasters and effectively reduce the losses caused by coal mine disasters.

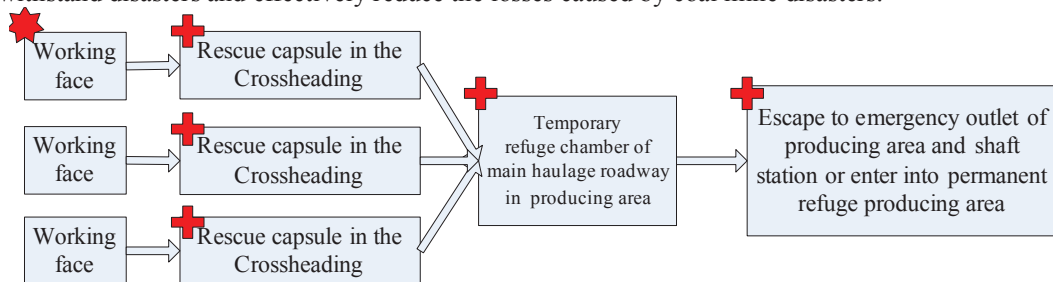


Fig 1 Organization structure drawing of refuge chamber system

3. The design principles of refuge chamber system

The design principles of refuge chamber system can be chosen for mining enterprises according to their characteristics under the principle of meeting the underground workers refuge needs. The design principles are shown as follows.

3.1. Rational arrangement

Based on the characteristics of coal mine disasters and the underground workers distribution of working face, rescue capsule should be arranged in coal face and the heading face. The number of rescue capsule is determined by the number of people in the working face. Temporary refuge chamber is set mainly in evacuation routes in the mining area providing scattered operators along the roadway and mining machinery with refuge space, capacity of which is determined by the distribution situation of workers around the area. Permanent refuge chamber is set mainly near the shaft station and emergency outlet of producing area, regarding as the refuge chamber of the whole mining area or mine.

According to *Construction and Management Interim Provisions for Urgent Escape System in Coal Mine*, the deployment location of rescue capsule and refuge chamber is determined by the following factors: refuge space and accident that protected personnel may face; distance of the work location that staff work away from refuge space; connection of refuge space to its external life support facilities (compressed air, electricity and water); neighborhood situation of refuge space when mine accident occurs; the longest oxygen time provided by self-rescuer and so on. The distribution of rescue capsule and refuge chamber in all mine area is determined based on above-mentioned these factors. A complete refuge network can be built based on the mine refuge route coupled with the refuge chamber system, rescue capsule and refuge chamber of which are mutual coordinated and complementary. Refuge chamber system should service all the places where people work. The distance between refuge place and work place relies on the distance that miner can safely reach by wearing self rescuer when the disasters such as gas explosion, coal and gas outburst and fire occur. It is generally acknowledged that the distance should not exceed 1000m, and the rescue capsule should be arranged under circumstances of blind drift tunneling length exceeding 500m. The layout diagram of refuge chamber system is shown in the Figure 2.

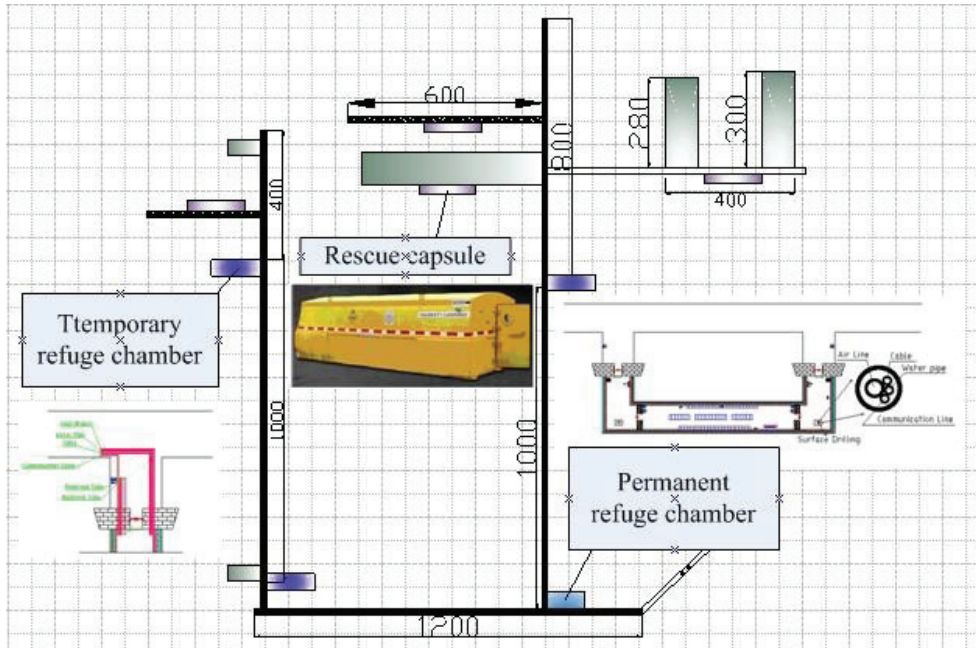


Fig 2 Sketch map of refuge chamber system

3.2. Meeting all the workers

Based on the overseas related experience and the compliance to principle of safety first, number of rescue capsules and refuge chambers should be set to ensure that every underground workers have their own refuge space in their work area when disaster occurs, which need to confirm the one-to-one corresponding relationship of refuge location and underground worker and make reservation for some position.

3.3. Evacuating to safe places within the shortest time

In order to ensure workers enter the refuge space in the shortest time possibly, person in distress escapes should be based on the following principles in view of scattered distribution of underground workers: ① escape distance of all underground workers should not be more than 1000m; ② workers in working face should mainly escape to rescue capsule; ③ scattered distribution workers along the roadway and mining machine workers should mainly escape to temporary refuge chamber; ④ workers near refuge chamber possessing surface drilling should escape to the permanent refuge chamber; ⑤ workers nearest the pit shaft should choose to escape to the ground as soon as possible.

3.4. Facilitating refuge workers to access the refuge space quickly

In order to make refuge workers quickly enter the refuge space, the obvious mark should be made for the location of refuge place along refuge route to guide the refuge workers access the refuge space as soon as possible. The principles are as following: ① In the dark and deep roadway, the luminous flat schematic of roadway and schematic of escape routes should be pasted in the wall every certain distance;

② Solid sound localizer, visual localizer, object localizer, or the combination of these three should be installed near refuge space to guide refuge workers access refuge space quickly.

3.5. Inertial awareness and self-rescue training for workers

Taking into account that the disaster will cause psychological stress, which result in blindly avoiding disaster and confusion, refuge chamber system design should consider the psychological effect of relevant workers including mainly ①instinct to return, ②instinct to evade, ③phototropism instinct, ④ instinct to left and ⑤ instincts to follow. No matter how meticulous the safety protection system is, it relies on people to execute eventually for the most part. So effective self-help education for related workers is an important part of the safety protection system. Underground workers should be familiar with the signs recognition methods of various incidents, judge the location and nature of accident, master the skills and methods of first aid personnel, well know the underground roadway and safety of exports and learn to use self rescuer, especially how to refuge to wait for help when cannot go out of the mine.

4. Design of refuge chamber system

The refuge chamber system is a refuge and transfer station to survive for the survivors in disasters, which are composed by permanent refuge chamber, temporary refuge chamber and rescue capsule. A complete refuge chamber system can increase the possibility of being rescued for the survivors in disasters, make simple first-aid dressing for the seriously wounded, and obtain self-help equipment in reserve, reducing casualties and losses. Therefore, it is particularly important to make safe and rational design.

4.1. Permanent refuge chamber

(1) Basic requirements:

Permanent refuge chambers are mainly set in shaft station and near emergency outlet of mining area, the distance of working face away from which is depended on the specific conditions in coal mine. Generally, it is regard as emergency shelters for the whole coal mine or mining area, and its service life is over 10 years. Permanent refuge chambers should be constructed in stable rock formations, avoiding geologic tectonic zone, high temperature zone, stress anomaly areas and flooding threatened areas in order to ensure that it is not affected by mining during its service life. Non-flammable material should be used to support roadway in the 20 meters range of is and its roof should be integrated. There should be measures of controlling gas emission and preventing gas concentration and spontaneous combustion of coal when it is constructed in the coal seam. And it should be composed by transition room and survival room, adopting two isolated gates structure opening outwards, the transition room of which is between two isolation gates and is equipped with compressed air screen and compressed air spray device, and the survival room of which is within the second isolation gate. In addition, the roadway accessing to refuge chamber safe area needn't be straight, and it can set various curve roads in order to reduce the shock wave hazard caused by gas and coal dust explosion^[4].

(2) Special requirements

Permanent refuge chamber generally possess the drill hole from refuge chamber to ground, the ventilation system of which connects with the compressed air piping line introduced into the ground to achieve that the internal air supply is independent of that of coal mine. In addition, the esophagus roads, communication lines and cables are introduced through ground drill hole to achieve energy, communication and electricity supply, as is shown in Figure 3. The reliability of permanent refuge

chamber is higher than other types of refuge space due to its drill hole directly connecting with the ground, which can provide the ventilation system independent of that of mine and provide resources for survival in refuge chamber continuously when the mine ventilation system is destroyed, prolonging the time to escape for refuge workers and obtaining the more time for the rescue team to arrived at the scene to rescue.

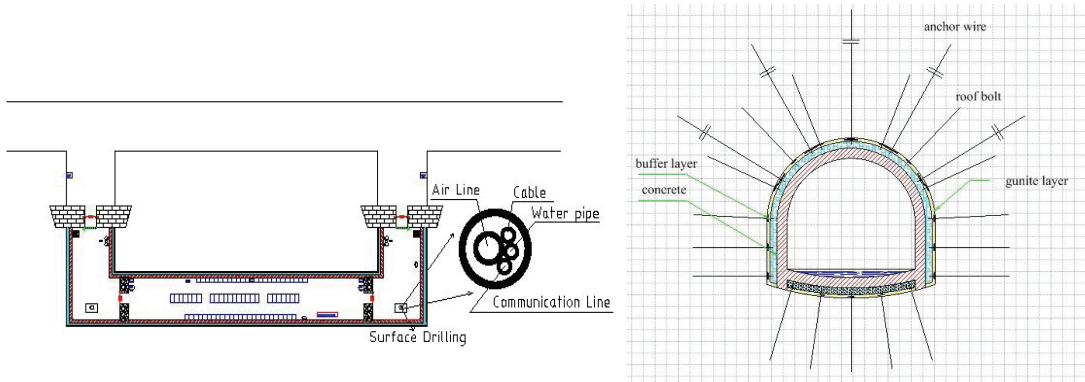


Fig 3 Design and support diagram of permanent refuge chamber

(3) Supporting method

Based on past experience and requirements of *Interim Provisions*, the shape of permanent refuge chamber should be the semicircle, the internal supporting method should be joint supporting method with anchor bar, anchor net and anchor cable, supporting material should be flame retardant, anti-static, anti-high temperature and anti-corrosion and colors of roof and wall should be light. In addition, concrete strength should be not less than C30, steel commonly is used No.3 steel, No.4 steel, or No.16 manganese steel and shot concrete layer, buffer airtight layer and reinforced concrete layer should also be included.

(4) Device in the refuge chamber

In order to ensure the survival of personnel in refuge chamber and the normal operation of equipment, it set up seven large-scale systems, which are protection system of fire and explosion, closed buffer system, air curtain isolated system, oxygen supply system, communications system, monitoring system and ancillary system.

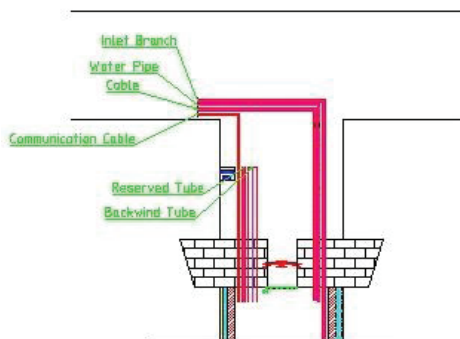


Fig 4 Design diagram of temporary refuge chamber



Fig 5 Design diagram of temporary refuge chamber

4.2. Temporary refuge chamber

Structure design of temporary refuge chamber is similar to permanent refuge chamber. Its overall structure includes functional design, overall structure design, door wall design, internal air circulation

system design, etc. The biggest difference between temporary refuge chamber and permanent refuge chamber is whether the underground lifeline systems are independent of mine. Temporary refuge chamber uses the underground lifeline systems to meet minimum life support, as is shown in Figure 4. Temporary refuge chamber is constructed to reduce the escaped distance of miners, increase the safety factor and solve the establishment problem of permanent refuge chamber under circumstances of geological environment of not drilling conditions. Temporary refuge chamber use the compressed air piping line introduced into underground to supply and replace the air, and in order to assure that the workers in the refuge chamber can still escape to survive in the case of compressed-air system failure, the air-cleaner machinery should be place in temporary refuge chamber to release oxygen while absorbing carbon dioxide that escaping personnel exhaled.

4.3. Rescue capsule

Based on the number of worker in each class, construction cost, quantities and construction period in domestic mine, and taking into account the sudden of accident, refuge of all underground workers can not only rely on permanent and temporary refuge chamber. So for the regions with a number of underground mining activities, rescue capsule can be set to meet the requirements that rescue capsule can advance continuously as the working face advance.

The placement of rescue capsule can be in abandoned roadway and chamber constructed temporarily near working place, as is shown in Figure 5. After the disaster, selecting rightly and entering quickly the rescue capsule are often able to play the well role of ambulance for refuge workers.

Overall promoting application of the refuge chamber system composed by permanent refuge chamber, temporary refuge chamber and rescue capsule, which are mutually independent and tightly-coupled, can cost-effectively radiate all the areas with mining activities and protect personnel in mine.

5. Conclusions

The security production of coal enterprise is a major issue about livelihood, but a lot of major accidents occur frequently in the production system of coal enterprise. To solve this kind of problem, we should initiatively reduce the probability of disasters occurrence through troubleshooting before the disasters, however when the accidents can't be completely eliminated, we also actively build the refuge chamber system composed by permanent refuge chamber, temporary refuge chamber and rescue capsule, which are mutually independent and tightly-coupled, to cost-effectively radiate all the areas with mining activities and protect personnel in mine. In addition, in the process of underground refuge chamber system design, we should comply with these principles including rational arrangement, meeting all the workers, evacuating to safe places within the shortest time, facilitating refuge workers to access the refuge space quickly and considering the psychological factors of staff with the related self-help training.

Acknowledgements

The authors wish to express their appreciation to CUMTB for providing the work with advanced research conditions. The authors are also indebted to the support of National Basic Research Program (973) of China (No.2010CB226801) and State key Laboratory of Coal Resources and Safe Mining.

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