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Design of a new type of mine rescue relay cabin

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ABSTRACT

This paper presents the design of an innovative mine emergency rescue relay cabin, and investigates a detailed comparison of existing shelter facilities, their function, service object, structures, size, and system components with the newly designed mine emergency rescue relay cabin. Air-tightness test indicated a test chamber relief rate of 26 Pa/min, which meets the design requirements. Furthermore, respirator replacement test showed an average time of 73.7 s to replace a respirator. The air cover air supply test indicated an air supply rate of 220 L/min, which is sufficient for the staff replacing the respirator in the emergency rescue relay cabin. The total air supply volume is 9680 L, which can be supplied via two compressed air cylinders of 40 L, pressurized to15 MPa.

1. Introduction

The main shelter facilities of existing underground emergency systems include fixed refuge chambers and movable rescue capsules, both of which possess advantages such as being able to accommodate a considerable number of personnel, complete the internal protection systems, and broad security protection ranges [1–3]. However, several problems are currently hindering the application of refuge chambers and rescue capsules. The existing underground shelter facilities require long construction time, high usage, operation, and maintenance costs, and they are mainly used for the protection of underground workers [4,5]. To resolve these issues, this study investigates the design of a new type of mine emergency rescue relay cabin. Compared with existing underground shelter facilities, the new emergency cabin design has several advantages, such as small size, flexible usage, easy installation and transportation, diversity in protection objects, and low production cost [6–9]. Combined with existing underground shelter facilities, this new type of rescue relay cabin can achieve comprehensive coverage of the underground shelter space, not only lowering the cost of building underground emergency chambers, but also providing timely resources and equipment to underground shelter and rescue personnel, and both improving mine rescue efficiency and reducing casualties.

2. Characteristics

2.1. Application feature comparison

The key feature of existing major shelter facilities, fixed refuge chambers, and movable rescue capsules is the internal life-support system, the main function of which is to provide a safe space for the shelter of personnel waiting for rescue underground [10]. In contrast, the main function of the emergency rescue relay cabin is to provide materials and energy for the mine rescue personnel and shelter personnel to ensure the continuity of the rescue and shelter actions. Overall, the proposed relay cabin provides temporary protection for the rescue and shelter of the workers.

2.2. Comparison of application objects

The application object of existing major shelter facilities, fixed refuge chambers, and movable rescue capsules is primarily the underground personnel [11–14]. However, the emergency rescue relay cabin can not only shelter the underground personnel, but also provide rescue workers with oxygen cylinders, self-help equipment, food, water, communication devices, batteries and energy.

2.3. Structure and dimensions comparison

The average dimensions of a movable rescue capsule in existing shelter facilities are 23 m × 2.4 m × 2.0 m, which can accommodate 30 people. The internal structure is divided into transition area, living area and equipment area. The average dimensions of

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a refuge chamber for 30 people are 25 m × 4.5 m × 3.5 m. The internal structure is divided into buffer areas on both sides and the shelter area in the middle. For the emergency rescue relay cabin to provide energy and supplies for 40 people, the overall cabin dimensions are only 1.52 m × 1.30 m × 1.77 m, as shown in Fig. 1.

The comparison shows that, for the same number of people, the emergency rescue relay cabin has a much smaller size. Further, compared to movable rescue capsules, it can move flexibly along pre-laid tracks by the roadway, allowing for rescue missions near and above the work area, and others near and outside of the mining area along the roadway.

2.4. Comparison of system components

The life-support system of existing major shelter facilities, fixed refuge chambers, and movable rescue capsules primarily includes the following: fire and explosion protection system, closed buffer system, air curtain isolation system, oxygen supply system, cooling and dehumidifying system, monitoring and controlling system, and communication system [15–17]. The main function of the emergency rescue relay cabin is to provide a temporary shelter place and supplies and energy for the rescuers and endangered workers. Therefore, its internal systems consist of a basic protection system, pressurized air supply system, communication and lighting system, supply and distribution system, and power supply system.

2.5. Construction cost comparison

The costs of the emergency rescue relay cabin include material and equipment cost, site transformation cost, and daily maintenance fee. The total cost of emergency rescue relay cabin is far less than that of current shelter facilities according to the market survey.

3. System components

3.1. Exterior structure of the relay cabin

According to the features of the emergency rescue relay cabin and the condition of the domestic underground transportation equipment and roadway sizes, the final shape of the emergency rescue relay cabin is designed to be rectangular, with specific dimensions of 1.52 m × 1.30 m × 1.77 m. The interior dimensions of the cabin are 1.50 m × 1.28 m × 1.75 m. The entire relay cabin is steel welded to ensure a certain degree of strength and weight, thereby preventing cabin body inclination because of shock waves from the side [18]. In addition, the compressive and tensile properties are good. The front of the relay cabin has an explosion-proof door and an emergency switch. Furthermore, necessary interfaces are set up to enable connection with the outside, such as the ventilation port connecting to external air supply devices, water supply port, power supply interface, communication interface, and air vent.

3.2. System components of the relay cabin

The interior of the relay cabin consists of several sub-systems: enclosed system, air cover air supply system, resource system, power supply system, lighting system, communication system and so on.

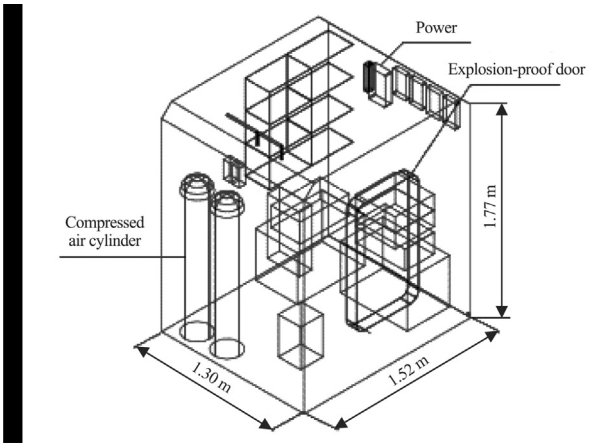

Fig. 1. Internal layout and dimensions of the mine rescue relay cabin.

(1) Enclosed system

The emergency rescue relay cabin has relatively low design requirements in terms of guaranteeing the survival of personnel. The entire cabin body comprises an enclosed system consisting of the steel shell structure and the explosion-proof door. The steel shell of the system body is built with steel welding technology. The front panel located in the tunnel and the explosion-proof door can withstand an impact of 0.3 MPa, and ordinary shock waves. In addition, the relay cabin has a certain degree of airtightness to prevent infiltration of toxic gases. After the personnel entering the cabin, a positive pressure of +200 Pa ± 100 Pa with a relief rate less than 30 Pa/min ± 20 Pa/min is maintained, which is slightly less than that of refuge chamber and movable rescue capsule.

(2) Air cover air supply system

This system is mainly used for personnel to replace supplies. The air cover can be used to cover the upper body to form positive pressure and prevent poisonous gases from entering. In addition, the person can temporarily shelter in the relay cabin. There are two oxygen supply systems for the air cover air supply system: compressed air cylinders and external oxygen supply system. The overall air supply system of the relay cabin comprises compressed air cylinders, compressed air cylinders connectors, external pressure air ports, pressure regulators, airway, pressure gauge, muffler, ventilation isolation bag, and oil-water separator [19–21]. The cabin also has two air covers. One of the two covers is used when the equipment is being replaced, and the other one is on standby. In emergency situations, both can be used together to ensure the shelter of two people.

(3) Resource system

The emergency rescue relay cabin can be filled with respirators, water, food, and first aid supplies based on actual need. In this study, the number of emergency rescue personnel and the safety factor were set to 40 and 1.2, respectively.

(4) Respirator

The emergency rescue relay cabin has 50 chemical oxygen respirators (with a safety factor of 1.2) meeting the equipment replacement requirement of 40 people. The respirators are placed