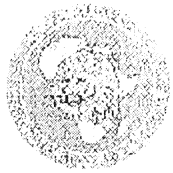

The Status and Prospects of Mine Rescue Technology and Equipment in China

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Abstract: The paper systematically expounds the research and application status of rescue technology and equipment for mine disasters in China in terms of personal protection, rescue & relief work and fire prevention & extinguishing, etc. The trend of development of rescue technology and equipment suitable for safety conditions of coal mines in China is also put forward in the paper.

Key words: Coal Mine · Rescue · Emergency Disaster Relief · Status and Prospect

1. Introduction

With the development of coal industry as well as the more and more importance the Chinese government has attached to work safety in coal mines, mine rescue technology and equipment in China have been improved tremendously. However, the complexity of the country's seam geological conditions has brought about frequent disasters and accidents in coal mines. The ways to do rescue and relief work have become important means to rescue the personnel underground, assure the safe property of the state, reduce and control the disasters and accidents. Over the last decades, mine rescue technology and equipment in China have been playing important roles in mine disaster rescue. The continuous development of new rescue and relief technology and equipment has greatly improved the equipment standards of rescue teams in China. Mine rescue teams are specialized teams to handle mine disasters in coal mines and the rescuers are frontline professionals underground. Currently, there are more than 120 mine rescue teams(including the independent brigades) and more than 21,000 rescuers in total among the large and medium-sized coal enterprises. Early this year, the Mine Rescue Center of the State Administration of Work Safety(SAWS) was established, responsible for the organization, guidance and coordination of mine rescue and emergency rescue all over the country. A complete set of mine rescue and first-aid

system, which is rather perfect and suitable for the conditions of China, was therefore taken shape basically.

At present, mine rescue teams in China are basically equipped with equipments in five categories: personal protective appliances, rescue communication equipment, rescue machines and tools, equipment for fire prevention and extinguishing and checkout equipment for analysis and test. Being a comprehensive research establishment in China's coal industry, China Coal Research Institute(CCRI) has been engaged in the research, development, promotion and application of mine rescue technology and equipment since its foundation in 1957, great contributions have been made to rescue work in coal mines in China.

2. Personal protective technology and equipment

Personal protective technology and equipment are important safeguards for the lives of miners underground. Among them, the self-rescuer, miner's self-rescue system and respirator are typical ones.

2.1 Self-rescuer

Divided into two types of filtration and separation, self-rescuer is one of the important protective devices equipped for underground miners in coal mines in China. In case disasters occur in mines, miners with self-rescuers can effectively prevent the poisonous and harmful gases from harming their bodies. In eighties and nineties of 20^{th} century respectively, China developed AZL40, AZL60 and AZL90 filtration self-rescuer, a series products with protecting time of 40min., 60min. and 90 min. With small volume, light weight and cheap price, the filtration self-rescuer has a big market in coal mines in China as up to 2 million self-rescuers are now in application, accounting for 70% approximately of the total equipment in coal mines. However, with the stricter requirement of the O_2, CO and CO_2 concentration for their applied circumstances, the application of self-rescuers has been limited greatly. With the improvement and perfection of the technology of oxygen self-rescuer, the filtration self-rescuer will be replaced sooner or later.

Starting from sixties of 20^{th} century, China had successfully developed AZG-40, AZG-40A and AG-40B oxygen self-rescuers. They were not put into good operation because the irregularly granular oxygen generating agent had low strength and dust were easy to produce if they were taken along for a long time, which would possibly bring about serious problems such as the self-rescuer on fire and oxygen cutoff. In nineties of 20^{th} century, new development was made to oxygen self-rescuers by employing advanced technology. First of all, the tabular oxygen generating agent of super potassium oxide was successfully developed that had improved the strength of the oxygen generating agent and solved the problem of dust that might bring about fire. Secondly, advanced technology and international standards were employed to design, process, reform and check the

old model of self-rescuer in order to develop the rapid oxygen generating layers of tablets to produce the initial oxygen generation and take the place of oxygen candles. Fushun Branch and Chongqing Branch of CCRI, as well as the coal mine safety instrument factories in Fushun city of Liaoning province, Xi'an city of Shaanxi province and Hunan province, etc. had developed oxygen self-rescuers of multiple specifications. In 1998, the ORS30C oxygen self-rescuer, the microcomputer-controlled check device simulating human respiration, the AJH and AZH30B oxygen self-rescuer were respectively developed according to the standards of European Community. The newly developed OSR30C self-rescuer was checked in the Drager Company, Germany, and the results indicated that the major performance indexes of self-rescuers made in China have been up to the world advanced levels.

2.2 Miner's self-rescue system

The miner's self-rescue system is the oxygen supply device located in the temporary refuge underground. In case disasters of coalburst and gasburst occur underground, miners can make use of the miners' self-rescue system which will provide longer time of oxygen uptake than the portable oxygen self-rescue and enlarge the opportunity of escape as well as extend the time waiting for rescue or replace the self-rescuer consumed for a longer period time of time. In nineties of 20^{th} century, Chongqing Branch of CCRI developed the ZY-J sectional heading compressed air self-rescue system and the ZY-M fully-mechanized face compressed air self-rescue system. Both systems have been applied extensively in coal mines in China, playing important roles in the sector. On December 19, 1989, for instance, a severe coalburst occurred at Face 2201, Jianshan Coal Mine, Yinggangling Mining Bureau of Jiangxi province. 5,000t of coal and 45,000m^3 of gas were burst that turned the airflow to the other direction. 37 miners were working at the burst scene and 36 of them luckily escaped the disaster by timely using the compressed air self-rescue device. The HLG-1 group oxygen supply device, developed by Fushun Branch of CCRI, can provide six miners simultaneously with continuous oxygen supply for 3 hours. Currently, the miner's self-rescue system is on its way to develop a more stable, reliable, convenient and easier system.

2.3 Oxygen respirator

Oxygen respirator is the important personal protective equipment for mine rescue team members. Oxygen respirator is divided into two types, one is positive pressure oxygen respirator and other one is negative pressure oxygen respirator. Starting from fifties of 20^{th} century, negative pressure oxygen respirator had been the major device adopted by the members of mine rescue teams in China. Since negative pressure exists inside the oxygen respirator, both the mouthpiece and nose clip might fall off the face of the rescuer when he breathes. Or when he speaks via the mouthpiece at the disaster scene, the noxious gas might leak into the rescuer's respiratory system from the outside and might get him poisoned or

hurt. In China, there had been up to 116 accidents of self casualty out of the negative pressure respirator and 182 persons were dead. The successfully developed positive pressure respirator had completely overcome the above-mentioned respirator's shortcomings and for sure it would replace the old one step by step. In view of the successful experience of development and application in the USA, Germany and Japan, China imported the Biopak-240 positive pressure oxygen respirator from the USA in 1995. Chongqing Branch of CCRI imported the relevant technology from the German Drager Company and assembled the BG4 oxygen positive pressure respirator in 1997. In the meanwhile, various research establishments and enterprises actively put more investment on development. Fushun Coal Mine Safety Instrument Factory developed HYZ4 oxygen positive pressure respirator. Fushun Branch of CCRI not only reformed the AHY-6 oxygen negative pressure respirator to positive pressure oxygen respirator, but also developed the new type PB4 positive pressure oxygen respirator by equivalently employing the standards of European Community. The Branch also co-developed the KF-1 4h positive pressure respirator with the Japanese Chuanzhong Disaster Prevention and Control Co., Ltd. All these new products laid the foundation of replacing the older generations of equipment by new ones for rescue teams in China.

3. Rescue technology and equipment

3.1 Mine rescue command and communication system

China started the research of mien rescue communication technology at a rather late time. Recently, Changzhou Research Institute of Automation, CCRI successfully developed the KTW1A mine cordless phone system, mine cellular full duplex wireless communication system and KTW2 mine rescue wireless communication system. With these systems, mutual conversation can be made among the four parties of surface and underground commanders, rescue team leaders and rescuers. The service area of communication serves a vertical distance of 1km and horizontal distance of 5m between the underground command unit and portable unit, 50m between portable units and 10km between underground command unit and surface communication unit. Fushun Branch of CCRI also developed the KJT95 mine rescue communication system with rather big improvement in terms of the system's functions, product structures as well as the system's flexibility, reliability and stability. Xi'an Branch of CCRI developed the WLX-1 cableless emergency communication system for rock mass, which had also realized the rescue and emergency communication and dispatch command communication within the circumference of 4km centering on the underground main station.

In view of the disadvantages of the current rescue communication system and the practical needs of disaster rescue and relief, underground communication equipment with full functions, low price and stable performance is now under speedy development. It's also one of the key factors to improve the rescue

standards in our country. Changzhou Research Institute of Automation, CCRI is undertaking the project of Rescue Wireless Communication System and Equipment for Underground Space and Research on Multi-function Movable and Rescue Mine Communication System. The purposes for these projects are to develop a complete set of wireless rescue communication system on the basis of KTW2 mine rescue wireless communication system, which is suitable for the application of underground space and combine well the underground communication with the rescue communication system. CCRI is now conducting research and development on the monitoring and position system for underground personnel, automatic echo position system for trapped persons, accident rescue dispatch and command system and wireless actual-time rescue vision and voice transmission system. Not only the safety information databank on coal mines in China will be established, but also the emergency rescue technology and equipment will be developed, taking the China map network information management system for example. The research and development on these projects are the joint efforts of those managing to improve the unit technology of rescue communication, information, decision-making, command and dispatch a higher and integrated level. As the developing trend of rescue communication, it will powerfully improve the rescue capacity and standards of China.

3.2 Rescue machines and tools

As long as grave disasters occur in coal mines, roadways and equipment underground would be severely damaged and staffs would be trapped. Portable rescue machines and tools are not only important equipment for the rescuers to do rescue and relief work, but also important means to save time for rescue and the lives of the trapped persons.

Rescue drill is the important equipment to open up safety passage and save the lives of the trapped staffs. It generally employs the horizontally directional drilling technology from the surface or underground to rapidly provide the trapped staffs with fresh air and food via the borehole and then enlarge the borehole and rescue them out of the scene. It is considered a quick and effective way to conduct rescue. Learning from the advanced experience internationally and adopting the horizontally directional drilling technology, Xi'an Branch of CCRI is speeding up its development of underground rescue drill with capacity of passing through 50m of the crush zone, opening borehole of ϕ200mm, enlarging borehole of ϕ600mm and borehole depth of 100m. Such drill will be on the market very soon. The Research Institute of Mine Construction, CCRI will adopt the raise boring technology and develop the surface drill and drilling tools, which can drill ϕ200mm boreholes with depth of 200m and the boreholes can be enlarged to ϕ500mm~600mm.

As for other portable drills and tools, CCRI and its branches and institutes have independently developed the flameproof rescue accent light, rescue indicator,

speed self-produced gas-filling rescue stretcher, actual-time gas-produced automatic flameproof and suppressing device, portable measuring instrument for coal mine gas explosiveness, etc. In addition, CCRI will also develop the high-pressure pump supplying oil to the hydraulic drills and tools, hydraulic cutter, portable rescue support, craning air bag, hydraulic metal cutter, mine rescue multi-stage hydraulic prop, measuring instrument for preventing 2nd explosion, movable roadway support, special rescue scraper conveyor and reamers. As long as the drills and tools are successfully developed and the rescue teams are equipped with them, it will be very helpful to increase the rescue efficiency and capacity of the rescue teams in China.

4. **Technology and equipment of fire prevention & extinguishing**

57% of coal mines in China have the problem of spontaneous ignition in coal seams. The repeatedly fire accidents of spontaneous ignition have produced influence upon work safety in coal mines. The technology and equipment of fire prevention & extinguishing have played outstanding roles in prevention and control of fire ignition due to internal and external heat in coal mines. Over the last decades, China has gradually developed its own technology of fire prevention & extinguishing according to the conditions of our country and summarized a complete set of technology of fire prevention & extinguishing, such as by even air pressure, grouting with yellow mud, gel, separating agent, injection of ammonia, and foam as well as the speed sealing technology of fire prevention & extinguishing in the burning area.

The technology of fire prevention & extinguishing with foam has had a big development in recent years, from the initial air and cement foam to inert gas foam, then from the physical foam(mechanical foam) to chemical foam and organic polymer foam and then the solid state three-phase foam and foaming plastics, etc. The technology of fire prevention & extinguishing with foam will play bigger and bigger roles because the poisonless and harmless agent has wide sources and low price and the process is simple and workable. The chemical inert foam material for fire prevention & extinguishing is produced by the chemical reaction of medical liquid. Its extinguishing results integrate the suffocation of inert gas, cooling the foam with water, filling and blocking with foam and inhibition. With different kinds of foam materials, China developed in succession the 2MH-100/200 underground movable fire extinguishing train with inert foam, the DQ series of type 150, 400, 1000 and 20 inert gas fire extinguishing device and inert foam fire extinguishing device, type BGP200 and BGP400 fire extinguishing device with high expansion of foam and JP-VP series foam plastics sprayers.

The inorganic solid three-phase foam can be divided into two types: the filling one and the fire extinguishing one. The inorganic solid three-phase foam for fire extinguishing has the features of quick gel coagulation, rapid strength increase and

high strength, etc. Since it can be piled up directly in a roadway or a cavity, the inorganic solid three-phase foam for fire extinguishing will have vast vistas of application. It is one of the major technical means to fill the cavity, block the leaky wind and extinguish the fire with the foam filling agent. The light and solid foam would the best choice to fill for the cavity produced from roof collapse in roadway or the cavity along next goaf-side in mines underground. The inorganic solid three-phase foam with inert gas can not only play the role of the ordinary inorganic solid three-phase foam, but also release inert gas, dilute the concentration of gas and oxygen of the scene, promote the suffocation of ignition and prevent gas explosion in case the inorganic solid three-phase foam is accidentally destroyed(For instance it is destroyed at high temperature at the early stage of fire extinguishing or destroyed at the sudden weighing after filling). The GFMH series inorganic solid three-phase foam generator has been newly developed. It has three specifications (different flow and pressure) and two types (movable and fixed) and is suitable for mines with hazards of gas and coal dust explosions.

In eighties of 20^{th} century, China started the research on fire extinguishing technology and equipment with inertia of gas nitrogen. Injection of nitrogen is one of the major technical means to extinguish fire in the stope. During the period from the "Sixth Five-year Plan" to the "Ninth Five-year Plan", China carried out deep studies on the fire extinguishing mechanism, nitrogen injecting process and nitrogen-producing equipment. Cryogenic air separation, absorption at varying pressure and diaphragm separation have been the three methods popular in China. Cryogenic air separation was the very first method being used. However, this method had been replaced step by step by the other two methods of absorption at varying pressure and diaphragm separation as it needed large-scale nitrogen-producing equipment, high investment on fixed assets and big permanent workshops. In terms of nitrogen injecting equipment, China had independently researched and developed the MD series underground movable nitrogen-producing device by diaphragm separation. During the "Ninth Five-year Plan", China developed the three series of nitrogen-producing device, which were respectively the JXZD underground movable nitrogen-producing device with carbon molecular sieve, KYZD surface movable nitrogen-producing device and KGZD mine surface fixed nitrogen-producing device. The purity of nitrogen produced by these devices has been more than 97% and the max. nitrogen output was more than 2,000m^3/h. However, the pre-treatment equipment of the nitrogen-producing device by the diaphragm separation technology has been of low automaticity and the lifespan of the diaphragm assemblies was only two years approximately. It still needs further improvement.

5. Conclusion

China will build up a well-off society in an all round way in the first twenty years of this century. The social development has put forward higher requirements to the

safety of the people's lives and property. Accordingly, the rescue standards in coal mines must be improved to a new high. Through the development of the last decades, China's mine rescue technology and equipment can basically meet the requirements of work safety. The mine rescue teams and technical system have been taken shape in China. Yet compared with the advanced countries, China has a big gap in terms of mine rescue technology and equipment. China is still in the stage of development of unit technology, which is far from being perfect. Many problems are not fundamentally solved at all. For instance, the development of large-scale rescue drills, how to accurately position the trapped person or the one in distress underground and how to explore the rescue scene. China should develop its mine rescue equipment towards intelligence and network in order to improve the capacity and standards of its rescue teams rapidly, accurately and effectively. In the meanwhile, it's also an important job for China to share the sources of rescue teams and relief equipment all over the country.

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