Challenges of Mines Rescue in Expanding Mine Operations

Success begins with getting rescue teams to the action quickly and safely. As mining operations develop, the underground workings extend farther from the shaft or portal, and become more complex as they continue to expand. Travel distances and time increase.

Challenge

As mines are constantly growing and expanding so do the challenges for emergency response teams. They have to keep up with the pace that is set by current and future production techniques.
Although mines have now reached depths of several kilometers and their dimensions and complexity are of an entire city, mines rescue still must be able to reach the most remote areas within the mine in a swift and safe manner. The duration of breathing apparatus and physical human capabilities are natural imitations. Therefore alternative methods have to be explored to extend the time under oxygen for mine rescue teams without putting additional stress on the team members. To address this global trend, Dräger, Goldcorp and Paus have partnered together to develop a mine rescue vehicle that allows mines rescue teams to travel for an extended period of time in a contaminated atmosphere without the use of their breathing apparatus, thus extending the range of their mission. By application of current available techniques the safe expansion of production in a mine can be ensured by giving mines rescue teams the capabilities to respond to accidents in a safer and faster way.

With the easily accessible resources getting fewer there is a global trend to search for higher ore grades underground and or continually expanding mines underground to extend the life time. While in some areas this trend has just begun in other countries the mines are reaching depths or horizontal dimensions that pose extreme challenges. (Codelco, 2016)

These include safety relevant topics, such as rock stability, heat and seismicity, but also more basic issues such as distances to the working face, which can become crucial considering the cost to develop a new shaft or decline. To overcome this, there is a is a growing interest in collaboration to drive the development and support of deeper mines and tackle the complexity of underground mining by collaboration between various stakeholders. This is evidenced by the fact that several industry and research groups and networks have formed, e.g. the I2mine project in Europe or the Ultra-Deep Mining Network by the Centre for Excellence in Mining Innovation in Canada. Due to commodity pricing and the trend towards renewable energy metal/non-metal mining will be the driving force behind this development.

An emergency situation only amplifies the challenges as outlined above. Especially in the event of ventilation failure or a fire the increasing air temperature and levels of hazardous gases are major risks that need to be accounted for in any mine emergency plan.
One of the main restrictions to consider is the oxygen time of the closed-circuit breathing apparatus (CCBA) as currently used by mine rescue teams around the globe. Within this time the distance to the incident or location, the assigned task and the time back needs to be covered. With increasing depth or expansion, the distances to overcome become larger thus reducing the already limited operational time.

Mine Rescue Scenarios

Current state-of-the art are CCBAs are rated at 4hrs. While in theory longer duration sets would be possible these would require more bulk and weight thus significantly increasing the strain on the team members. Already today the full duration of CCBA is rarely utilized due to several limiting factors.
A safety buffer is usually utilized in that the twice the time used on the ingoing trip should be allowed for returning to the fresh air base to allow for unforeseen events on the way back.
(Workplace Safety North, 2011) In addition several mine rescue organizations have imposed time restrictions for the usage of CCBA related to the hazards of heat stress. (Workplace Safety North, 2014) Also in the event of reduced visibility through smoke the time required to overcome the distances will be increased by reducing the speed at which people or machinery can move.
The German regulations for escape distances with self-rescue devices derived from numerous tests and incidents may be used as an indicator to illustrate these effects. It shows that even in the event of using a light escape set the distances that can be covered are significantly decreased in higher temperatures, on inclines and declines and considering poor visibility. According to the tables the walking distances have to be reduced by up to 30-50% for each of these factors. Emphasis is put on the fact that if these conditions are combined with longer distances, individual assessment of distances will be necessary. (Bresser, Fuchs, Hermülheim, Langer, Ollesch, Junker, 2007) This certainly holds true for the use of much heavier equipment such as a CCBA-set and carrying full emergency gear.

All these factors combined can easily create scenarios where even with traditional motorized transport mine rescue teams are reaching the limits of covering the complete mine while still having sufficient time left to fulfill their mission in an efficient manner.

This outlines the need for 3 elements in future mine rescue scenarios for deeper and expanding mines:
1. Mine rescue teams need to get to an incident site faster
2. Emergency personnel needs to be protected along the way without having to utilize precious oxygen time of the CCBA in order to be well rested and have sufficient time buffer to fulfill the tasks at hand
3. Safe evacuation of team member and/or mine personnel and egress is a basic requirement however becomes increasingly more important and complex the longer the distance to cover.

To assist mines to tackle these tasks within the Mine Emergency Plan there currently already are a number of concepts available. Portable shelters may be moved along and provide refuge for the miners for a defined time, thus taking time pressure off the mine rescue team. Permanent rooms at strategic locations may serve as a collection point for workers which can help in shortening the period for allocation of missing personnel as well as serve as an extension of the fresh air base.

Solutions

A concept to actually avoid lengthy mine rescue missions is an emergency plan utilizing equipment known as the First Response and Emergency Escape Kit (FREEK). In this scenario especially trained personnel in the mine can access a FREEK station equipped with self-contained breathing apparatus and turnout gear to swiftly fight a smaller fire before it can turn into a bigger incident. In case this cannot achieved the team can pull back to the FREEK station, top off the SCBA cylinders and start the evacuation to a point of safety.
However these solutions have their limitations in that they do not help the mine rescue team get to the incident once a situation requires the immediate response by the team.

For this reason the Canadian mining company Goldcorp explored the options to overcome the hazard scenarios out of their own risk assessment for its deep mining operations. Even with a comparatively modest depth of 1.2 kilometers with a horizontal expansion of 12 kilometers from the ramp access at the mine operation Musselwhite in Canada the time needed to reach the remotest point in the mine with good visibility would have already accounted for 45 minutes. In a traditional vehicle the CCBA would have to be donned and considering the time back only little time would have been left until the time to return. Considering the heat stress limitation as above and poor visibility, basically no further expansion would be possible.
To address this scenario a concept was developed in which an encapsulated vehicle would be used in order to reach a scene without utilizing the CCBA of the rescue team with capabilities to drive in poor visibility, toxic gas and being rugged enough to survive the mining environment.

Together with PAUS, a mining vehicle manufacturer and Dräger, a leading supplier of medical and safety technology this concept was refined and put into reality in the development of the MRV 9000 mine rescue vehicle which has since been subject to evaluation testing under realistic conditions at the Mine Emergency Response Drill of the American Mine Safety and Health Administration (MSHA) in Missouri. (Heuer, 2016)

To suit the requirements of the mine rescue teams a vehicle chassis was chosen that fit the demands regarding size, ruggedness, load capability and climbing power to carry out missions in critical situations with difficult ground conditions. The vehicle was combined with a cassette for transporting rescue personnel and possible patients or persons to be evacuated. Including the drivers cabin it provides space for 6 persons from the rescue staff and two patients, with the possibility to place an additional patient on a stretcher in the cassette. Both the cabin and the cassette are equipped with an air purging system that is independent from the ambient air. The system allows the mine rescue team to access the incident site without using their CCBA set, carrying out their mission and then reentering the vehicle and again purging the vehicle from hazardous substances to egress the mine without the need to use the breathing apparatus.
The breathing air system of the vehicle is designed for a mission scenario with an operating time of five hours with a recharge and turnaround time of 45 minutes to be ready for the next mission.

Additional monitoring systems, such as gas monitoring and thermal imaging systems can be deployed to allow better assessment of the ventilation of the surrounding atmosphere as well as ensuring maneuverability in situations with low visibility. Also an air conditioning system is integrated to help reduce the heat stress. With these elements the vehicle addresses all three elements as outlined above, getting the rescue personnel to the incident swift, safely and rested to maximize the utilization of the breathing apparatus for the actual task and enabling egress and evacuation of personnel from remote locations in a protected manner.

Of course there are limitations to the use of the concept. It might be necessary to be adapted to specifics of the mine where possible, especially height and size requirements need to be considered to ensure a wide operational coverage, sufficient oxygen is necessary for the use of the combustion engine and it is limited to non-coal mines due to restrictions in the ex-protection. Also the proper integration into the emergency plan and training of all involved staff is a crucial element to make the whole concept work in an actual incident.

The paper shows that deep and expanding mines pose extreme challenges for mine rescue teams and thus can limit the safe operation of a mine due to the limits of existing emergency plans. However, through close cooperation of various stakeholders utilizing various sources of expertise from mine operators, suppliers and other institutions tools can be developed that give mine operators options they can pick from to create a coherent safety concept to answer the individual challenges of their mine operation.

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