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TRAINING SCENARIOS FOR MINE RESCUERS AIMED AT SELECTING AND BUILDING RESCUE TEAMS ABLE OF INTERVENING IN MAJOR INCIDENTS

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Abstract: *In mining rescue operations, the practical training of rescue personnel plays an essential role in the selection and configuration of rescue teams that intervene in critical situations, major incidents, accidents or other events occurring in underground mining works. Practical training can be conducted through monthly scheduled practical exercises at rescue stations within a mining unit, as well as through modern training means available at INCD-INSEMEX Petroșani (virtual reality, mobile training facility for rescuers) used in the process of instruction and re-instruction of mining rescuers. Mining rescuers' training level can be quantified through both physical and mental training by their reactions in certain critical situations, which can be created using virtual reality. Furthermore, the monitoring of the rescuers' physiological parameters before, during and after performing the practical exercise is also of particular importance. This monitoring can be carried out through the equipment available in the mobile training facility. The current paper aims to establish complex training scenarios for mining rescuers to select and configure rescue teams that can act in case of explosions, mine fires or other events.*
Keywords: *mining rescuer, training scenarios, virtual reality, mobile training polygon, rescue teams*

1. Introduction

Mining rescue operations require thorough physical and psychological preparation of mining rescue team members, given the risks they face during their underground interventions. While risks in surface activities can be evaluated with greater precision, in underground mining operations, it is very difficult to assess risks, especially in the case of major incidents such as explosions, endogenous fires in coal mines, gas or water eruptions, etc.

In mining activities, during disasters, work accidents or major events, mining rescuers are the ones who intervene (Figure 1). Any other state intervention structure (Emergency Situations Inspectorate, Military Firefighters, SMURD, Ambulance) does not have procedures for underground interventions, they are able to perform interventions only up to the gallery entrance or to the access ways of underground shafts [1].

Interventions are carried out by mining rescuers, members of the mining rescue station that operate at each mining unit, to rescue those caught in the event or to restore normal conditions in the underground. These interventions are often conducted under the protection of closed-circuit breathing apparatuses based on compressed oxygen, which regenerate exhaled air and have an autonomy of 2 or 4 hours.

The closed-circuit oxygen-based breathing apparatuses allow intervention and rescue personnel to operate in the area affected by major incidents without considering the concentration of toxic gases and provide sufficient working time for the intervention [2].

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Mining rescue activities can only be performed by trained and authorized personnel in accordance with current legislation. These personnel are prepared through practical and theoretical training sessions conducted at the rescue station to which they belong.

Fig. 1. Occurrence of a major incident in an underground mine

A crucial aspect of mining rescue operations is the practical training of mining rescuers within rescue stations, which underpins their physical preparedness and is critical to the success of an underground intervention. Besides proper physical training, mining rescuers must also be psychologically prepared to handle critical situations that may arise during their underground interventions.

Monthly practical and theoretical training programs are developed at the rescue stations, including scenarios that can be implemented at each mining unit based on its specific characteristics and the equipment available at the rescue station. These scenarios involve simulating events within mining operations, alerting rescue teams and conducting the actual intervention, as outlined in the training program prepared by the rescue station chief and approved by the unit leader [3].

The Authorization Group for Rescue at INCD INSEMEX Petroșani is equipped with a mobile training facility that includes a fitness equipment area and an enclosed space area. This facility is used in the training and re-training process of mining rescuers, allowing for complex training scenarios to be created, with continuous monitoring of rescuers' physiological parameters and work consumptions. Additionally, the Group is equipped with a virtual reality training system, enabling rescuers to be placed in scenarios that cannot be recreated in reality, such as fires, explosions, working at great heights, etc.

Using these two modern training tools, various training scenarios can be created, highlighting both the physical readiness of rescuers and how they psychologically handle complex events. The current paper presents complex training scenarios for mining rescuers using these modern training tools, monitoring the rescuers' physical and psychological preparedness and thereby building rescue teams that are efficient in disaster interventions.

2. Practical training scenarios for mining rescuers using the mobile training facility

The mobile training facility (Figure 2) is a modern piece of equipment for the practical training of mining rescuers. It is equipped with a compartment containing fitness equipment (infinity staircase, ergometer, treadmill, bicycle and stepper) that subjects the rescuer to intense physical exertion. Additionally, it features a compartment with enclosed spaces, consisting of cages measuring 80 cm by 80 cm, organized in two rows and two levels, totaling a length of 22 meters. These cages are equipped with horizontal, vertical and inclined blockers, as well as duct systems. In the enclosed space compartment reduced visibility atmosphere (by flooding it with smoke), high humidity, elevated temperatures and disaster-associated noises can be created [4].

Fig. 2. Mobile training facility

Thus, after installing and verifying the closed-circuit breathing apparatus based on compressed oxygen, the mining rescuer is registered by the training instructor. A personal record is created, containing personal data such as the rescuer's identification number, name, age, qualifications, the unit they work for within the rescue station, etc. All this information is stored within the information system of the mobile training facility's command console, located in the fitness equipment area [5].

After the rescuer's registration, they are introduced to the equipment in the mobile training facility and shown how to use it. A telemetry system is then attached to the rescuer, allowing for the monitoring of certain physiological parameters (respiratory rate, blood pressure, blood oxygen saturation, the amount of energy expended on the equipment, etc.), which are transmitted directly to the information system.

A first training scenario (Figure 3) involves setting the fitness equipment to predefined parameters (speed and incline of the treadmill, number of pulls on the ergometer, speed of the infinity staircase, distance to be cycled and power on the stepper).

Fig. 3. Rescuer's training in the fitness area

Under the protection of the breathing apparatus, mining rescuers will spend 8 minutes on each piece of equipment. This setup ensures that the rescuers work under the same conditions, but they are differentiated by

the physiological parameters measured (pulse, blood oxygen saturation, blood pressure) and the energy expended during the training (kcal).

After completing the fitness equipment circuit, rescuers are introduced to the enclosed spaces compartment of the mobile training facility. They will traverse the enclosed space course twice: the first time with normal visibility just to get used to the route and the second time with the compartment filled with smoke, providing reduced visibility. Throughout their time in the enclosed spaces, their physiological parameters are monitored via the telemetry system, which displays the data on the control console [6].

At the end of this training scenario, the oxygen pressure in the cylinder is recorded to quantify the remaining time the mining rescuer can use the breathing protection apparatus. For this scenario, the selection of rescue team members is primarily based on the values of physiological factors, which should fall within certain normal limits for intense physical exertion and on their endurance during the exercise.

Another scenario can be created by quantifying the actual time the mining rescuer spends on the training, with specific targets set for each piece of fitness equipment based on their characteristics. The objectives are as follows:

- Infinity staircase: cover a specific distance, with the rescuer choosing the operating speed.
- Ergometer: complete a fixed number of pulls.
- Bicycle: cover a set distance.
- Stepper: set to a performance level (power) between 0-600W, quantifying the energy expended.
- Treadmill: cover a running distance, with the rescuer setting the walking speed of the treadmill.

After completing the exercises in the fitness equipment area, the rescuer moves to the enclosed spaces compartment (Figure 4) and traverses the course three times under conditions of reduced visibility, high temperature (achieved with a 6 kW heater installed in the compartment), and high humidity. In this scenario, the time taken to complete the enclosed spaces course is quantified.

These training scenarios ensure that rescuers are not only physically fit but also capable of handling the challenging conditions they may encounter during actual underground rescue operations. By monitoring their physiological responses and performance, training can be tailored to improve their endurance and efficiency, making them more effective in real-life rescue situations.

Fig. 4. Rescuers training in the enclosed spaces area

In this scenario, mine rescuers are also monitored physiologically through the telemetry system, with values being transmitted to the control console. In this scenario, team members are selected primarily based on the time the mine rescuer has spent training and successfully completing the entire specified route within physiological parameter limits, considering conditions of high exertion.

The two training scenarios using the mobile facility can be continuously improved based on the specific mining area from which rescuers come, type of equipment they use and core functions in which they operate.

It is ideal that the rescue team responding to a major incident includes experienced mine rescuers selected based on their performance in exercises conducted at the rescue station, and ideally, those who are very familiar with the intervention area.

3. Scenarios for practical training of mine rescuers using virtual reality systems

Virtual reality is increasingly integrated into training processes across various fields, and in this regard, INCD INSEMEX Petroșani has equipped the rescue authorization group with 4 virtual reality training devices for intervention and rescue personnel.

Compared to traditional methods of training mine rescuers, virtual reality training provides a superior level of preparation as a modern method that can simulate situations impossible to recreate in real life (such as

explosions, fires, working at great heights, etc.). The equipment used for training scenarios through virtual reality includes controllers, VR goggles, perimeter sensors and hardware equipment on which training scenarios software is installed.

One virtual reality training scenario involves testing a mine rescuer on the assembly and verification process of an isolating apparatus (Figure 3) used during operations. This step is a legal requirement in the intervention and rescue procedures. The scenario quantifies the steps for assembling the apparatus and verifying its parameters, requiring the rescuer to strictly follow the assembly and verification sequence; otherwise, progression to the next stage is impossible [7].

There's also the possibility for the trainer, using the hardware equipment (laptop), to allow the rescuer to proceed from one stage to another without following the correct sequence. At the end of the scenario, the trainer can assess and penalize the mine rescuer for any mistakes made throughout the exercise.

Another virtual reality training scenario for mine rescuers involves navigating through a labyrinth of enclosed spaces (simulating an underground mining network). After assembling and verifying the isolating apparatus, the rescuer enters the labyrinth area, which includes small sections, various blockades, circular tube-like areas and vertical climbing and descending areas resembling mining works. This scenario assesses how well the rescuer reacts to extreme situations involving movement through confined spaces and a diverse range of obstacles, which are typical challenges during major mining incidents like methane or coal dust explosions.

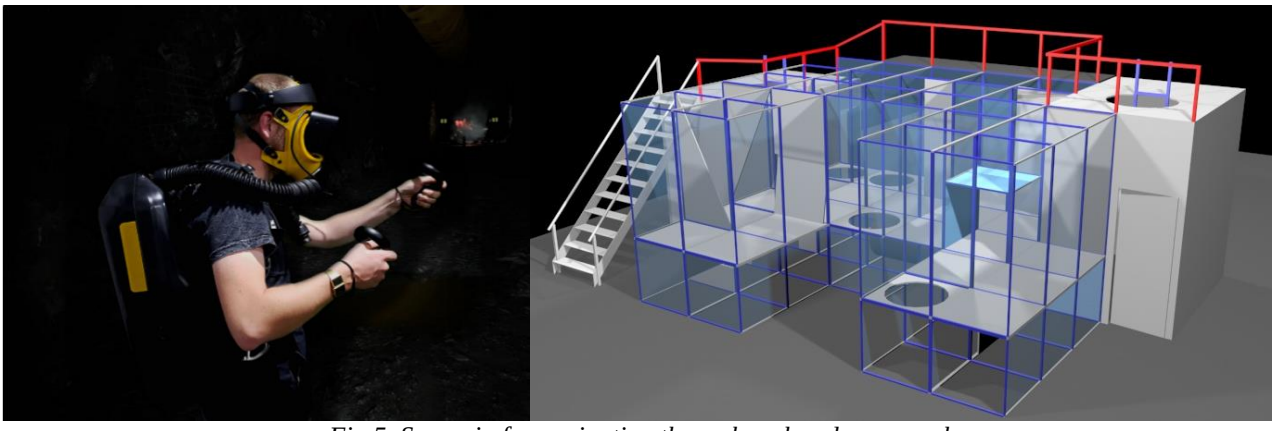

Fig.5. Scenario for navigating through a closed-space polygon

Through the use of hardware equipment, events such as fires or explosions can be generated during the rescuer's journey along the route. This aims to assess the mine rescuer's reaction, behaviour and emotional response in such scenarios, which cannot be reproduced in real life [8].

Within the virtual reality labyrinth, a high-altitude area (approximately 10-15 meters) is simulated, which the rescuer must navigate, potentially challenging those who have not faced such situations in reality.

Using a laptop, while the mine rescuer progresses through the labyrinth, a simulation can increase explosive gas levels beyond normal limits. This tests the rescuer's procedural response, whether they choose to leave the area or continue advancing under these conditions.

Implementing these scenarios using virtual reality and observing the reactions of mine rescuers helps in selecting and training teams for rescue operations, depending on the type and scale of the incident. This is due to the complexity of events that can be simulated through virtual reality, which are impractical to replicate in real-life exercises but only occur during disasters.

4. Conclusions

The practical training undertaken by mine rescuers, in accordance with current legislation and based on the scenarios described in this paper, conducted through modern training methods, will enhance intervention capabilities during major incidents in our country's mines. These scenarios do not replace the practical training conducted monthly at each mining rescue station but represent a complementary alternative using modern equipment to simulate situations beyond daily mining activities.

The mobile training facility's equipment allows for building databases that encompass a mine rescuer's training activities from authorization until retirement. These data highlight their progression or regression during their tenure as mine rescuers at a rescue station. The telemetry system in the mobile facility can monitor rescuers' physiological parameters, a capability not feasible during practical exercises taking place within mines, which can be a crucial criterion in building rescue teams.

Virtual reality provides the most modern form of training for rescue personnel by simulating situations impossible to recreate during exercises (such as fires, explosions, water eruptions, etc.), challenging rescuers both in decision-making and emotional resilience.

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