# Research on the improvement of the rescuers training facility for the practical performance tests of respiratory protection devices

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**Abstract.** Respiratory protection devices, both compressed air and compressed oxygen based, are subject to certification for placing on the market. The European standards governing the requirements for certification, the manner of conducting the tests are reviewed periodically in order to increase the operational safety of respiratory apparatus in order to cope in any circumstances with the dangers to which rescuers are subjected. The evaluation of the respiratory apparatus from a practical point of view is done by the practical test of performance. The modernization of the training facility according to the latest standardization regulations regarding the practical performance tests is necessary for the certification activity of the respiratory apparatus but it is also useful for the activity of training rescuers, having the role of harmonizing the request of the respiratory apparatus with the effort to which the rescuers are subjected.

## 1 Introduction

The training ground for rescuers aims to require intense physical effort from rescuers to test the body's adaptation to the isolating apparatus. The behavior of insulating aparatus based on compressed oxygen is different from that of devices based on compressed air, especially due to the exothermic reaction produced by apparatus based on compressed oxygen, this reaction occurred during the restoration of oxygen concentration on rescuers by increasing the air temperature during the use of the apparatus. The duration of use of an oxygen-based insulating device usually reaches four hours, the devices being mainly intended for rescuers from the underground mining industry.[1] There are many dangers underground for rescue personnel, from the decrease of oxygen concentration due to its replacement with other gases, underground fires, explosions, collapses, etc. In order to train a rescuer for such conditions, a specific training facility is needed, with possibilities to produce high temperatures, low light intensity, high humidity and the development of a physical effort in areas with limited spaces.

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In the case of insulating devices based on compressed air, the use is easier, the compressed air is not heated in the circuit of the apparatus, the ergonomics of the device is better, the mass of the device is lower, the air quality being much closer to natural air.

Under these conditions, with the use of common cylinders with a volume of 6.8 liters loaded at 300 atmospheres, the use duration of insulating devices based on compressed air in the training facility is about 45 minutes. In case of an event, from entering the damaged area, performing the necessary work and evacuating the injured, the time of use of the device is very limited, and the physical effort at high intensity on a large part of the intervention. There are many areas of activity in the field of surface industry with a risk of toxic, explosive or flammable gases, with different consequences in the event of a technological accident.[2] The activities of the rescue teams will be different depending on the field of activity, the preparation of the intervention is specific to the economic activity and requires different physical effort capacities. In order to prepare rescuers for different specific areas, the training facility must allow different path configurations with variable effort dosage. In order to certify insulating devices, there are specific requirements for the use of devices in the range to be evaluated by rescuers appointed to test them. These tests are included in specific standardized and regularly reviewed procedures. The subjective evaluation of the aparatus includes the evaluation of the degree of difficulty of mounting, the convenience of using the mask, the compatibility with the skin, the fit of the harness, the comfort of using the device, the body degree of freedom, the comfort of breathing, etc.

## 2. Practical performance tests of respirators apparatus

According to the latest standard update on the practical performance, in the training facility, the behavior of insulating devices is tested under specified conditions of use. The activities necessary to be carried out in the training facility, are similar to the specific elements of the rescuers' training, they contain inclined and horizontal displacements, passing over obstacles or through openings of certain dimensions. From the point of view of physical activity with the apparatus, the training facility must be constructed and equipped in such a way that a series of specific activities common to all revisions of the standards of practical performance testing can be carried out:

-walk on the level with full headroom
-walk on the level with a headroom of 1,2m
-run on a treadmill with a variable speed and leveled and inclined
-clawl on the level with a headroom of 0,7m
-crawl through a narrow section after the respiratory protection device was doffed while still using it
-pass upwards through a horizontal square opening positioned at 1,4 m above the ground, without removal of the respiratory protection device
-climb up and down a vertical ladder
-pass through a training gallery with climbing a ladder
-fill a 8 litter capacity container with chippings
-lift a mass of 25 kg via a rope and a puley at 1m above the ground[1]

## 3. Design requirements for training facility

### 3.1 Physiological bases of training

Training is a process of psychophysiological exercises through which an increased efficiency is obtained in the professional activity of rescuers, aiming the specificity of

industrial activity. The maximum efficiency is obtained by raising the functional capacity of the body to the highest degree. For this it is necessary to use the systematic and methodical exercise according to pedagogical rules. The intensity of the exercises used during the training are conditioned by the individual possibilities of the rescuer, by the degree of preparation, by the nature of the exercises, or by the external conditions of development. The training as rescuers aims at learning motor skills, developing the mental and physical qualities of motor activity, skill, will, perseverance, self-confidence, courage, determination, initiative.[4] The sequence and gradation of the exercises are rigorously planned, ensuring to the training a scientific character.

### 3.2 The physiology of warm up

The body's functions must be trained gradually to reach the conditions of maximum mobilization. Comparing the functions of the resting body with those of effort, there is a significant increase in their level during work. The increase consists of: acceleration of the pulse, of the respiration, of the intensification of the sweat secretion, the increase of the body temperature. The intensity varies depending on the following factors: the difficulty of the training, the duration of the training, the intensity of the effort, the state of training and the degree of preparation but also by the personal factors (experience, attitude, motivation).[4]

### 3.3 Training methods

a. Interval training: consists of alternating periods of intense stress without reaching the maximum limit with short periods of reduced stress or rest. Using intense efforts the body is forced to respond accordingly. The activity is then resumed after a short break when the body is in full overcompensation period.

The advantages are as follows:

-the resumption of the effort is done from a higher stage (in the overcompensation phase) which allows a development, a mobilization of the means of adaptation to a higher functional level;

- the break being short, the body is in a state of "warming" (dilated muscle capillaries), which maintains an ideal ratio between $O_2$ intake and $CO_2$ elimination;

- the recovery processes are performed in the first third of the recovery period in proportion of 70%. In short and frequent breaks the recovery is performed to a greater extent;

b. Repetition workouts: are similar to the first variant which is distinguished by the fact that the number of intervals is shorter but the duration increased. Circuit and isometric contraction training exclusively aims to develop strength.

### 3.4 Monitoring rescuers during training

Given the fact that during training performed in the training facility, rescuers are subjected to high physical exertion, parameters such as blood oxygen saturation and pulse are monitored. These parameters are measured continuously throughout the training period with equipment such as the oximeter and the telemetry measurement system. The telemetry system uses a specialized software that allows a continuous recording of the rescuers' pulse through wireless technology up to a distance of approx. 100 meters from the central unit. It should be noted that rescuers, during training, in addition to carrying a respiratory protection device weighing between 14 and 18 kg, are subjected to very difficult actions, created in the training facility, respectively difficult conditions of microclimate (high heat and humidity), toxic environment, smoke, all these being the simulation of real intervention

conditions in case of unwanted events. The training ground is equipment for tracking the movement of rescuers through low visibility environment represented by a thermal imaging camera which is a device used by intervention and rescue personnel in search, rescue and firefighting operations, if visibility is impaired due to poor lighting or smoke conditions. To achieve the harsh microclimate conditions in the training ground, a smoke machine, heat cannons, humidifiers are used to replicate the possible conditions encountered in the intervention. Each rescuer will be given a compression belt with BH3 monitor positioned according to fig. 1.


**Fig. 1.** BH3monitor.

On the monitor, a blue LED point out communication and the orange LED the battery. The monitor is mounted on the compression belt and must be positioned correctly on the body. The belt will be positioned with the monitor on the left side of the chest so as to exert a constant pressure on the body and the red LED (for sensing the heart rate) must flash. If the red LED stays on, it means that the monitor does not detect the heart rate correctly. The entire team of rescuers participating in the exercise will be monitored with BH3 monitors, which simultaneously transmit information to the Omnisense Live monitoring software (fig. 2).


**Fig. 2.** Live mode with 4 monitoring devices.

If the generic physiological parameters are exceeded, the status bar of each rescuer will turn red. Exceedances must be monitored but the rescuer can continue his exercise. If the values by which the generic thresholds are exceeded are very high, the rerscuer in question will be stopped immediately from carrying out physical activity.

In order to simulate the conditions of low visibility and disorientation, an artificial fog that imitates the smoke is produced. From the settings of the smoke machine (fig. 3), the degree of opacity can be set up, using a higher visibility at the beginning of the exercise then decreasing the visibility along the way.

Through the combination of artificial fog and strobe lights and an audio system that reproduces sounds specific to a real intervention, there is an additional stress on the rescuers, in addition to the physical stress of the exercise.


**Fig. 3.** Antari Z 1000 smoke machine.

Surveillance of rescuers' movement in the training ground in the low visibility environment is done with thermal imaging cameras (fig. 4). To monitor movement through the area of confined spaces, their floor is equipped with weight sensors that transmit to the control system information about the occupation of closed spaces.

**Fig. 4.** Images from infrared and visible surveillance cameras.

The control and supervision equipment is unified in a console that simplifies the activity in the training ground from the point of view of the personnel necessary for the supervision of the activity by the personnel involved in the training activity (fig. 5).

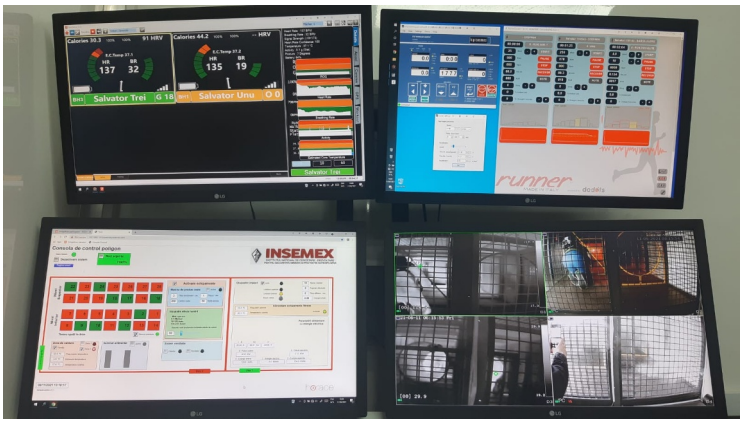


**Fig. 5.** Control panel with active applications.

Using fitness equipment such as treadmills, infinity ladder, stepper, bicycle, impact device, equipped with intelligent effort control systems and integrated in the control software application from the control panel it is possible to monitor the amount of work submitted by each rescuer, the degree of physical training, the response to effort under the protection of the insulating device and the storage of physical parameters for each rescuer and then if necessary the comparison of how physiological parameters have evolved over time for each person. Given the nature of the intervention and rescue activity, it is sometimes possible for the team to intervene following a fire and the intervention of automatic firefighting equipment or their own formations, in which case the working atmosphere will be affected by both high temperature and of humidity. In a polygon the temperature can be increased in a section of it with the help of a group of radiant panels and the relative humidity of the air can be raised by humidifiers.

## 4 Conclusions

The training activity of rescuers in the training ground is complementary to the testing of breathing apparatus in terms of practical performance, any improvement of the material base of the range being useful for both activities, especially from a scientific point of view, for data collection. related to the physiological parameters of the persons who carry out various activities under the protection of the insulating device.

The modernization of the infrastructure of the rescue training ground in terms of equipment necessary for the evaluation of the effort made must be done with equipment equipped with systems for measuring the effort produced, with the possibility to transfer the information collected from each device in a single application to build a unique profile for each rescuer and to record each exercise to compare the evolution over time.

The practical performance tests include subjective evaluations of the users of the devices but also measured values resulting from the testing activity. By collecting this data, practical performance comparisons can be made for devices with similar properties.

By using modern means of monitoring physiological parameters during exercise, the degree of physical training and the ability to cope with intense effort, can be assessed thus contributing to the selection of people compatible with intervention and rescue activities.

By real-time monitoring of the physiological parameters of the team participating in the exercise, the safety of the whole team is increased, the increase above the normal limit of physiological parameters repeatedly for a team member during training, may indicate a

vulnerability to the development of real actions by the risk of compromising the team's intervention and the need to evacuate it.

The use of modern means to faithfully replicate sounds, lights and conditions of variable visibility, humidity, intense heat offers the possibility to familiarize rescuers with working conditions that could encounter in case of dangerous events, increasing the degree of mental readiness for intervention

## Refrences

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