

Doctoral dissertation summary entitled: “Influence of the physical work and microclimate load on closed circuit breathing apparatus operation”

The aim of the thesis was to determine an influence of physical work and microclimate load on closed circuit breathing apparatus operation based on measurements of the breathable air physical parameters and comparative analysis of the results obtained in tests with mine rescuers. Statistics of hazardous occurrences taking place in Polish coal mines and accidents related to them between 2013 and 2017 indicate that the greatest hazards for the working crew and mine rescuers during the rescue operation were underground fires and methane burnings or explosions which supposed 72% of all the hazardous occurrences. Since 1945 the majority of mine rescuers have died during rescue operation from gas explosions and heat strokes. While conducting the rescue operations in coal mines one rule must be followed- mine rescuers should not be put in danger and their death must not happen. However, such occurrences, contrary to the rule, take place. There can be two group accidents indicated- the one that happened at ‘Niwka-Modrzejow’ coal mine in 1998 and ‘Krupinski’ coal mine in 2011, where some of the mine rescuers died during the course of rescue operation.

Commissions, set up by the President of Higher Mining Authority to explain the reasons and circumstances of these accidents, concluded that one of the reasons were particularly difficult working conditions the rescuers had using self-contained closed circuit breathing apparatuses with limited possibility of heat removal due to high air humidity and temperature. Rescue operations in mines are conducted typically in very difficult and very dangerous conditions, that is hot environment, unbreathable atmosphere, gas and coal dust explosion hazard, limited visibility, hard physical work and stress. Every time deeper mine excavations lead to more serious climatic hazard.

Taking into consideration the above mentioned as well as the conclusions Higher Mining Authority Commission made explaining reasons and circumstances for group accidents in the mines, which are related to still current, significant influence breathing apparatuses have on safety and heat comfort of the rescuers while working under unbreathable atmosphere and difficult conditions of microclimate, **conducting the research on influence physical work and microclimate load have on closed circuit breathing apparatuses operation is most certainly justified.**

Analysis of knowledge considering topics similar to the thesis, that is British, German and Polish research, indicated that so far no research has been conducted on the influence of physical work and microclimate load on operation of closed circuit breathing apparatuses used in mine rescue.

In order to establish the influence physical work and microclimate load have on closed circuit breathing apparatus operation, real conditions tests were carried out with participation of mine rescuers equipped with particular breathing apparatus under specified physical effort in designed microclimates at climatic chamber. In each cycle of the tests six mine rescuers took part. The tests were conducted simultaneously on three ergometers placed in the climatic chamber of the Central Mine Rescue Station. During the tests the rescuers were successively equipped with three types of closed circuit breathing apparatus: regenerative W-70 with compressed oxygen and ice, regenerative PSS BG4 Plus with compressed oxygen and ice as well as PSS 7000P cylinder-type breathing apparatus. Apparatuses were chosen for the tests as they are currently used by coal mine rescue services and Central Mine Rescue Unit.

Breathing apparatuses were loaded with established microclimate and variable volume of breathable air flow with different temperature and relative humidity as well as carbon

dioxide content related to physical work and microclimate the mine rescuers experienced in their breathing apparatuses.

The tests were carried out under three microclimates:

- dry thermometer temperature 23 °C, relative humidity 50%,
- dry thermometer temperature 32 °C, relative humidity 85%,
- dry thermometer temperature 38 °C, relative humidity 85%,

and three levels of physical work (effort) mine rescuers had to deal with corresponding to their energy expenditure: 25% of maximum load, 50% of maximum load and no load at all. Time of the test was no longer than 120 minutes and got shortened in hot microclimates. During that time the physical work load was repetitive, that is each load level consisted of constant 5-minute work and followed by 5-minute rest. Physical work load value was established individually for every rescuer on the basis of the VO_{2max} . index values (Maximal Oxygen Consumption).

In total 162 person-tests were performed, 54 tests for each type of the above mentioned breathing apparatuses. During the tests mine rescuers were equipped with breathing apparatuses and performed indicated physical work load in designed microclimates at the climatic chamber. The following physical parameters of breathing air were measured:

- temperature of the dry thermometer and relative humidity of the air inhaled by the rescuers from the apparatuses
- temperature of the dry thermometer and relative humidity of the air exhaled by the rescuers into the apparatuses

To measure the temperature and relative humidity of the breathing air American sensors i-Button were installed.

The course of each test on mine rescuers with breathing apparatuses at the climatic chamber and on exercise stations was as follows:

- preparing the closed circuit breathing apparatus to be used and installing the i-Button sensors either inside the breathing hoses or the mask,
- setting the work load (energy expenditure) on the ergometers calculated individually for each rescuer,
- creating the adequate microclimate in the climatic chamber,
- preparing rescuers for the test: short medical interview and placing the system for ongoing rescuers physiological parameters measurement and archiving,
- conducting tests according to the adapted research plan,
- archiving the measurement results.

Obtained results of temperature and relative humidity of breathable air in the closed circuit breathing apparatuses were presented as a function in time. Statistic tests were carried out; Kruskal-Wallis and median to check if the groups of results differ from each other. The analysis showed that the results vary which means that physical work and microclimate load influence the closed circuit breathing apparatus operation. Also conducted comparative analysis of medium values of the results allowed to indicate the influence physical work and microclimate load have separately on each investigated breathable air parameter in the apparatuses. The analysis demonstrated among others, that the increase of microclimate has more negative influence on breathing apparatus operation than increase of the physical work load, especially when it comes to increase in temperature of the inhaled and exhaled air.

Obtained results used in the comparative analysis allowed to formulate conclusion that an increase of the microclimate had a negative impact on operation of W-70, PSS BG 4 Plus and PSS 7000P apparatuses, because it mainly led to a significant increase in temperature of inhaled and exhaled air.