

“Technical and legal aspects for rescue operation performed in harsh climate condition in Polish copper mines”

1. Introduction

In 2003 and 2004 mines of KGHM Polska Miedz SA have experienced many fire situations. According to the author such fires have led to issues which in coming years will lead to the adequate provision of preparation and preparedness in carrying out a fire fighting effort. Within the mining industry, due to changing conditions, best practice procedures confirm the need of ongoing adaptation of technical and organisational structures. For this reason it cannot be granted that the current best practise process is complete.

The act of fighting fires brings with it considerations that are site relevant and cannot be applied always to other mines situations, however, the cohort of experience (Polish and international) has made its mark within current and developing actions of Polish mine rescue procedures and the technical equipment it utilises.

2. Selected legal aspects within Polish regulations concerning requirements in mining rescue

A revised **geological and mining law** which came into effect on 1st January 2002 (**Act established on 27 July 2001**) and resulting regulations relating to mine rescue operations, specifically these established in **Decree on the 12th June** manage requirements relating to mine incident preparation in the event of a rescue or fire operation. Primarily this has resulted in a requirement that every mine has to have an emergency rescue plan that covers among others the following: ensuring communication (connectedness procedure) for fighting fire, methods of fighting fire, ability to define and categorise regions of the mine that are at risk of fire, a plan for evacuating “at risk” areas, ventilation parameters and all necessary tools and recourses in the event of an operation. The regulation also defines requirements relating to the training of staff at all levels of employment as well as miners.

3. Common-most hazards experienced during rescue operations

Obviously all mine rescue operations, especially those involving fire fighting, are conducted within hostile environments. In observing the development of copper ore exploitation in Poland, it is important to underline issues relating to the worsening forecast of already difficult mine climate conditions. In coming years a large part of excavation will be performed on levels of 1200 m, in rock mass of primary temperatures of about 45 C. The factors that have significant impact on mine rescue and safety of personal in these areas are:

- the harsh climate environment and high temperatures associated with fire fighting,
- poor visibility due to gas and smoke emissions,
- irrespirable atmosphere,
- confined work spaces,
- poor communications between the team, fresh air base and head of operation,

During the process of collecting material for this presentation, the analysis of statistical data representing mining incidents has shown the seriousness of problems associated with increased temperatures. Within the world wide mining industry, most critical incidents especially with rescuers in underground mines have taken place in difficult temperature extremes – similar to those currently represented by copper ore mines of KGHM Polska Miedz SA. Polish copper ore mines are unique due to their

lengthy and complicated ventilation infrastructure and in many areas with a limited tunnel width and height (confined spaces). Such circumstances make it particularly difficult for emergency response teams, particularly in the case of fire which ignites during the absence of personnel. This may impact seriously on the length of time of a rescue operation.

In light of his personal involvement in supervising of mine rescue operations (many of them in difficult environmental conditions), additionally including experiences in supervising underground mining works in areas of expected increased rock temperatures, the author would like to share his experiences and problems encountered at the conference forum. The presented paper will cover in detail the reasons for fire ignition, as well as experiences gained during two of the most difficult rescue operations in copper mines of the last decade.

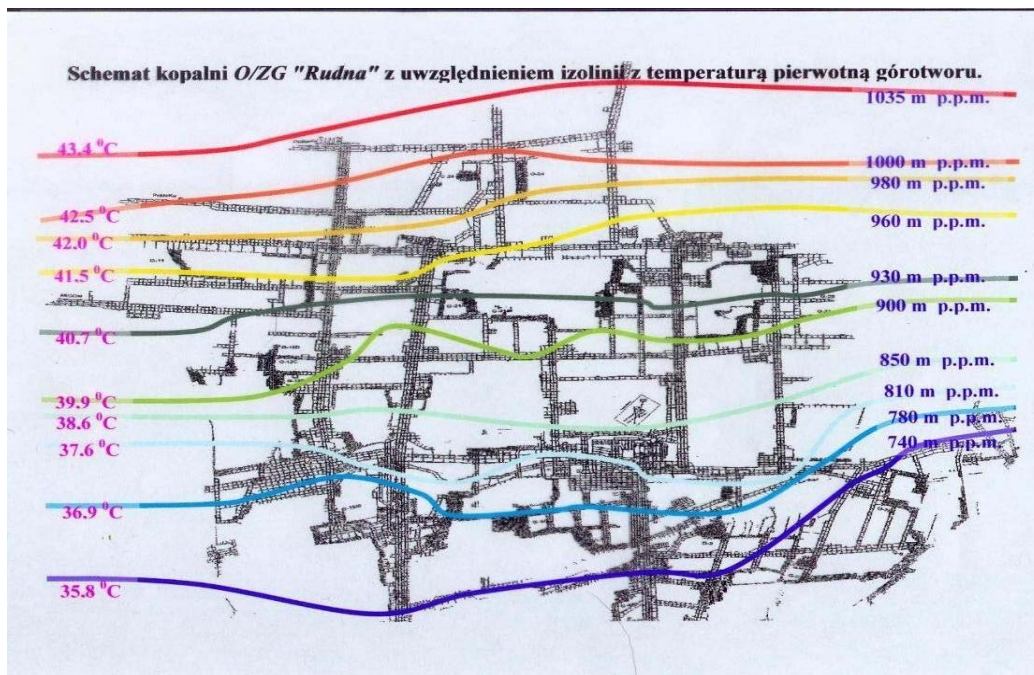


Figure 1: Isotherms of primary rock temperatures in Rudna mine

4. Circumstances of occurred fires, outline of actions, hazards and consequences

Fire of the LHD loader in Rudna mine.

A 6000 m³/min of fresh air had been directed to two sub fields of G-24 division from shaft R-IX, after ventilating the production area it was redirected to both shaft R-V in Rudna Główna at a rate of 2000 m³/min and shaft R-X in Rudna Zachodnia at a rate of 4000 m³/min accordingly.

The ventilations drifts to shafts R-X and R-V are approximately 4,500 m and 5,000 m respectively. The total ventilation system roads for the precinct G-24/3 covers approximately 10 km. The entire length of which had become fulfilled with dense smoke during fire of LHD loader.

On the 8 July 2003 the operator of LHD loader (model LKP, No 187) began mucking out ore from gallery T-150b face and loaded it on two trucks. At about 10.45 he noticed a flash on the front left side of the engine, followed by fire and smoke. Confused by the sudden fire, the operator did not switch the engine off, nor did he

disconnect the electrical supply. He removed the safety pin of fire protection system; however the connector did not work. After a short while the operator of another one loader (LKP No 164) and one of two operators of trucks came to assist him. With the aid of a fire extinguisher they attempted again to put out the blaze, but they were totally unsuccessful.

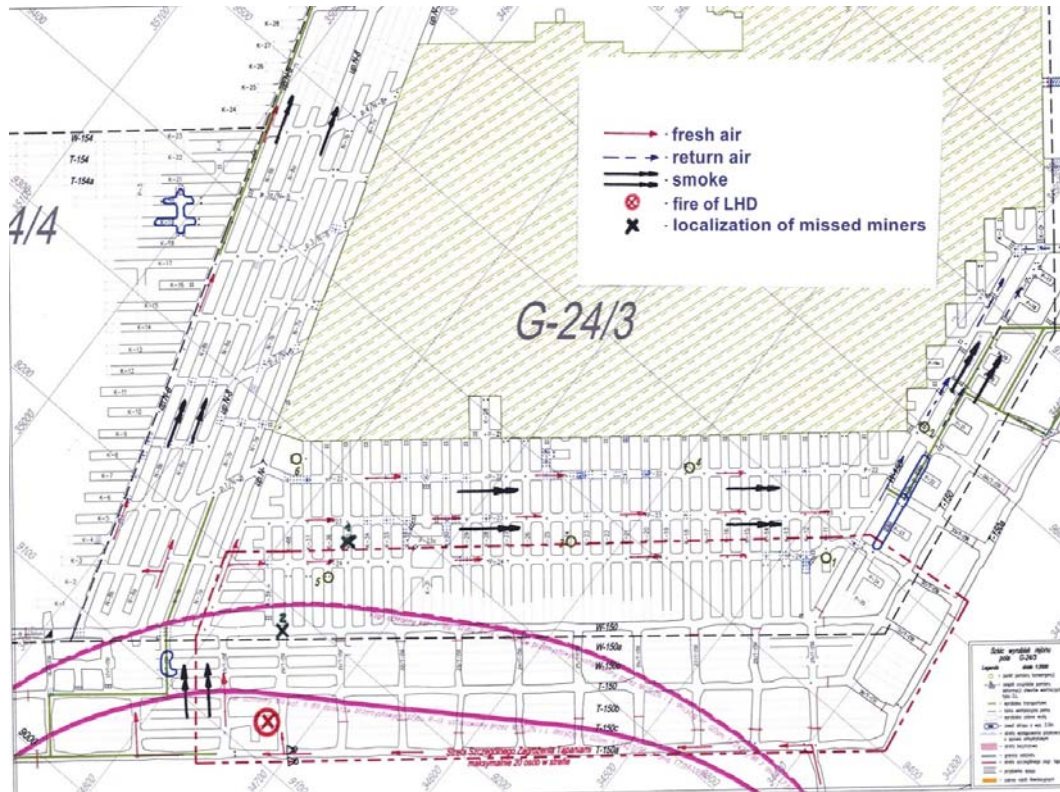


Figure 2: Map's sketch – localization of fire and missed miners

Due to their inability to put out the blaze, the rapid spread of fire and intensifying smoke, the operators retreated from gallery T-150b to the intersection with cross-cut P-19. Due to intense smoke situation at this point the operator of loader No 187 wearied a breathing apparatus and retreated in the direction of gallery T-150a, which was the fresh air inlet for the precinct G-24/3, however in the dense smoke he lost his orientation and he get lost. The other two operators managed to retreat to the local conveyor bin feeder at gallery W-150. From here at 10.54 they raised the fire alarm calling to the mine dispatcher.

On receiving notification of the fire the dispatcher called the rescue teams from JRGH Lubin and informed the mine manager – head of rescue operation. At 11.04 the mine manager has taken responsibility and of head of operation and began evacuation of the mining crews in accordance to standard procedures written in fire plan for mining situation in section G-24/3.

All areas of the site that were potentially threatened by smoke contamination were considered at risk accordingly to the fire plan. The crews from areas at risk were evacuated themselves. There were manned sentry stands points – they were

established near the evacuated site in entrance galleries, for controlling unwittingly accesses to the endangered zone.

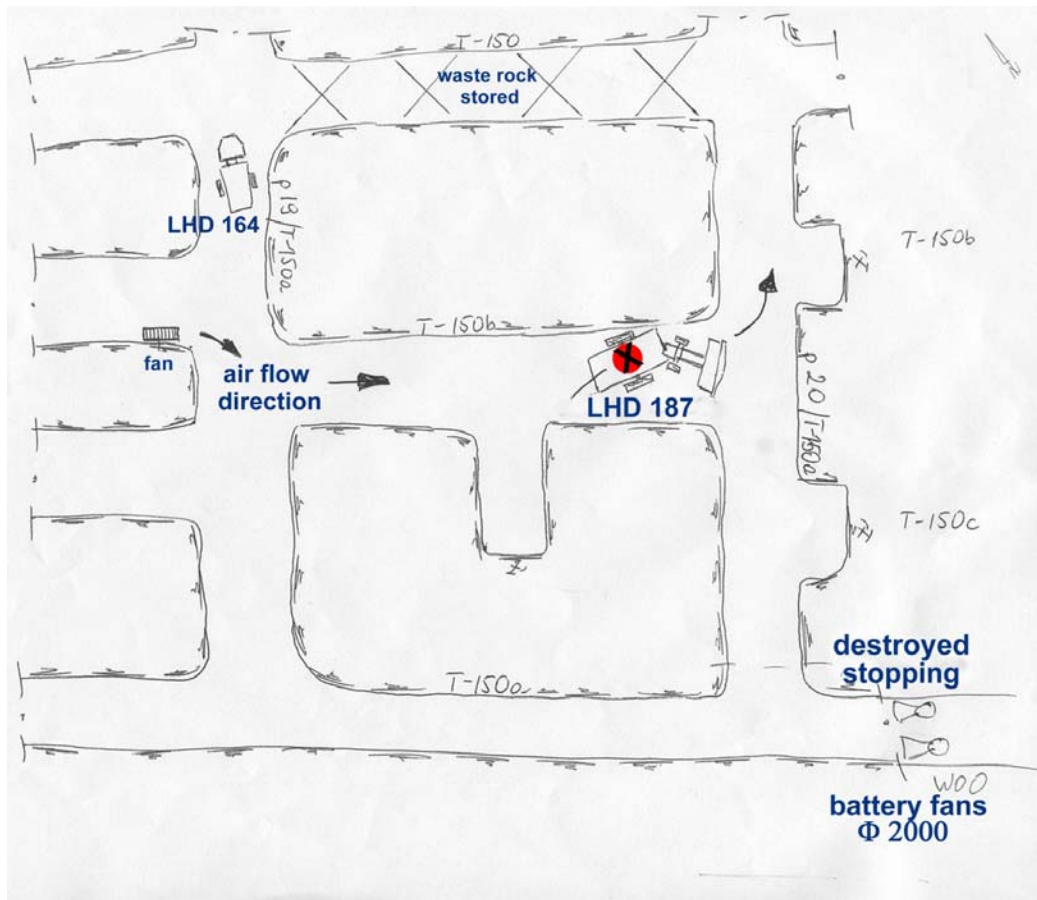


Figure 3: Sketch of workings in area of fire.

At 11.13 (19 minutes after receiving notification of the fire) the operation staff determined that there were 82 workers within the potentially threatened area (this included workers from neighbouring sections). After an hour counting all miners whose have left the endangered area it was stated that there were two workers missed. One of them was mentioned driver of LHD loader and another one was foreman who also gets lost in smoke when he tried to gather miners from all crews for evacuation.

In such situation the head of rescue operation has ordered to penetrate workings of section G-24/3 for accounting missed miners. At 12 briefing officer from fresh air base has informed about full readiness of rescue teams for penetration works. The fresh base was located 750 m from stoppings which separate ventilation system in distinct G-24/3. In vicinity of fire during penetration rescue teams have measured in atmosphere 115 ppm concentration of CO. As a result of switching off of two fans built in gallery T-150a a decrease of air current was noticed and no more then 1000 m/min flew trough distinct. Measured air velocity was between 0 to 0, 2 m/s.

Two teams penetrated the site simultaneously and third team was engaged in extinguishing the fire. Extinguishing of the fire was with water from the fire towers, powered from a hydrant at P-16/W-150 (vicinity of conveyor feeder).

The most difficult problem was penetration of the site for missed miners. The long time unsuccessful search for the two lost workers and elapsed time since the incident began was causing concern.

At 14:55 close to intersection of gallery T-150 and cross-cut P-16 the loader operator was located. At 15:18 the foreman was located close to intersection K-35 and P-24. Both workers were given specialist medical treatment in regards to toxic gas inhalation. The fire was extinguished after 1hr and 9 minutes of active fire fighting by the team. Active watering of the fire place by JRGH was completed at 16:00. The emergency situation was called off after almost seven hours of the initial emergency call, including an analysis of the air quality and also thermo visual observation with infra red camera and insite inspection of the loader.



Figure 4: View of burnt LHD loader



Figure 5: Visibility in light smoke

However, due to a returning fire hazard noticed (smoke, increasing CO) precautionary action of cooling the fire site and associated machinery with water took place until 6:00 the following day. The emergency action was attended by nine rescue teams. Those teams penetrating the mine site did so in accordance with procedures for undertaking a rescue effort by trailing communication cable (ULR). The large number of galleries (room and pillar system of exploitation) to penetrate added significantly to the execution of the operation and showed the disadvantage and weakness of this type of communications for extensive and difficult penetration in complex underground working infrastructure. A specific problem was the disruption in communication and a return one of the rescue team to base, hence requiring trailing of the communications cable anew. It was determined that damaged infrastructure consisted of: 24 V electrical installation, parts and elements of hydraulic system, fuel lines, parts and elements of the hydraulic system, tyres. The hydraulic oil tank was empty and there was, from the bottom of the fuel tank, 300mm of diesel oil remaining. The probable cause for the blaze was an electrical short circuit within battery. It is understood that the short circuit near the starter motor led to the ignition of the cable insulation of the 24V electrical system, and the fuel/air mixture.

This occurred as a result of leaking hydraulic pipe connectors within the steering/operational equipment at the time of the operation of the diesel engine. The diesel engine fan successfully distributed the leaking oil throughout the starter motor vicinity and was also instrumental in the sudden and fast distribution of fire within the starter motor cover, thus engulfing the area in front of the operator's cabin and the cabin itself.

The fire of a timber lining of LP support

On the 21st December 2004 at about 1 pm in incline drift U-24, at an intersection with walkway in road W-234 located in a western region of Rudna mine a timber lining of yielding support LP-7 was ignited. The fire firstly reached drift U-24, and then drifts U-25. Both incline drifts were ventilation roads to exhaust used air from the north-western part of the mine to shaft R-X. Before the fire, the current of air flowing within both drifts was approximately 20300m³/min.

In drift U-24, there was a conveyor belt installed, leading to an ore retention bunker near shaft R-III. The conveyor, 840m long consisted of an anti-flammable belt and had automatic water based fire extinguishing system with hydrants at both the engine and return station and within its length at approximately 100 m intervals. These hydrants were also equipped with fire fighting hand tools. The hydrants and automated extinguishers were supplied by a pipeline that was installed in drift U-23. From the intersection with cross-cut P-2 and up to the intersection with roadway T-243a (1300 m), incline drift U-24 was cased with yielding arched support type LP-7 and from cross-heading P-20 to approximately 35m before cross-heading P-6 (800m), inclined drift U-25 was cased with support type LP-9. The space between concrete poling and rock mass was fulfilled with round timbers. This support was successively replaced with a timber cribs and wooden square lining when the site began showing effects and influence of other nearby exploitations. In November 2004, a “Technical project for rebuilding drift U-24” was developed. This job was tendered to a contractor company.

21/12/2004 saw the ongoing work of the reconstruction at intersection U-24 with roadway W-234. The welder, working on cutting off with oxy-acetylene torch tubes that were to support the roof in site, most probably did not notice that molten metal was dropping onto the timber panelling. On completion of the planned shift task at approximately 10:30, the contractor’s crew left the site.

At the beginning of the second shift at about 13:00, the operator of belt conveyor U-24/L-1 noticed the smell of burning timber and saw smoke within the operating station. He informed the mine foreman of the conveyor transport section. The foreman descended a ladder into drift U-24 and saw open flames at the intersection with roadway W-234. The timber lagging was alight behind the first arch of the LP support. The foreman ordered to his crew to take immediate fire fighting action using the fire hoses and extinguishers (the closest hydrant did not work). The fire was deeply reaching into the timber poling and spreading in the direction of shaft.



Figure 6: Temporary stopping in U-23



Figure 7: Misshapen support in U-24

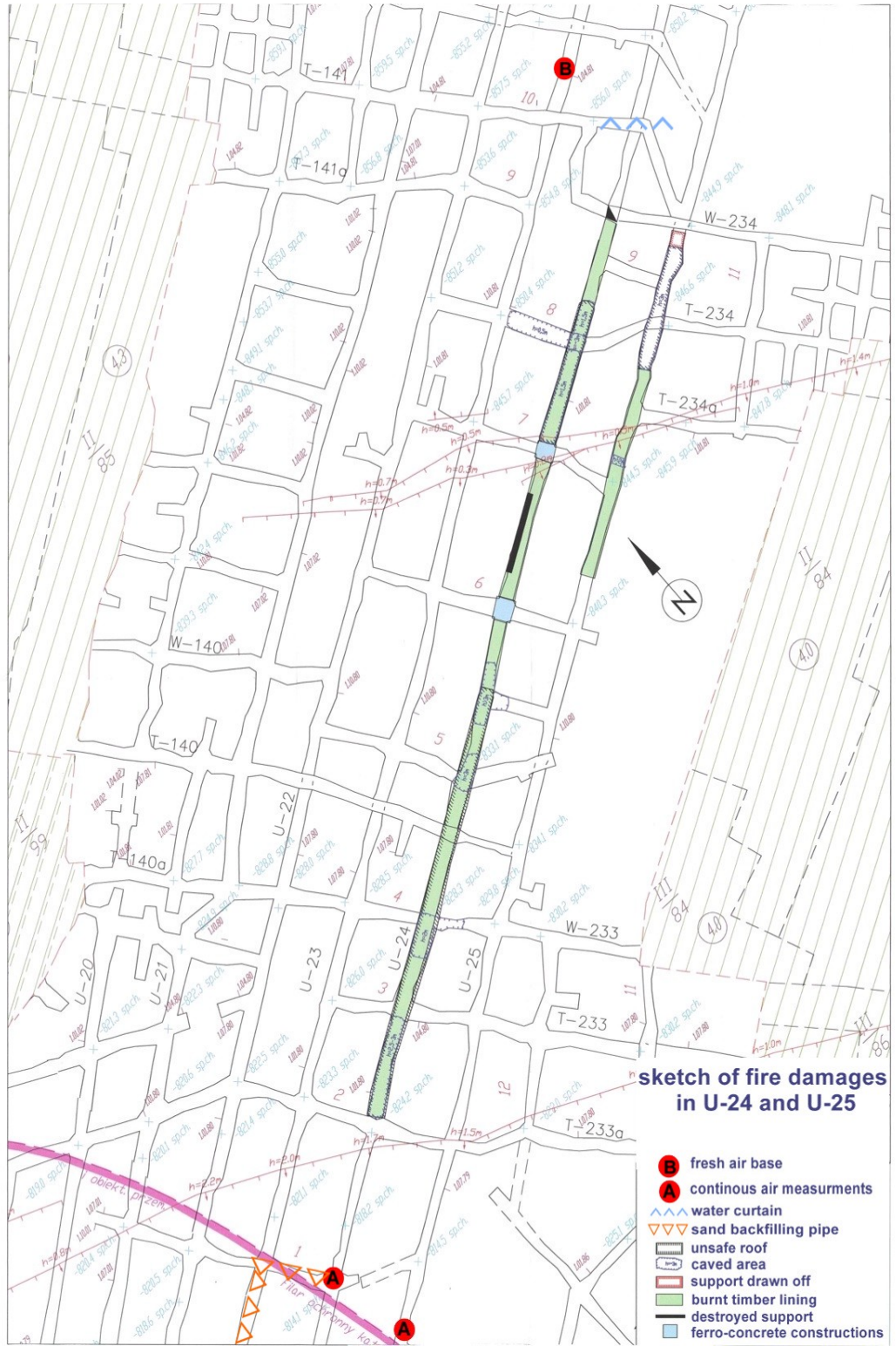


Figure 8: Sketch of fire damages



Figure 9: Timbers beyond poling of support Figure 10: Caving in U-24

As a result of an unsuccessful fire fighting effort, the foreman informed mine dispatcher of the incident who thus began the rescue procedure. After 20 minutes the mine managing director (head of rescue action) resumed the operation. He identified the 'at risk' sector, established sentry points and a rescue fresh air base. At 14:15 the JRGH rescue group (three teams) from Lubin arrived and began extinguishing the fire and cooling the site from within cross-cuts connecting drift U-24 with drift U-23.

On the 22/12/2004 at about 02:00 it was determined that the fire was travelling through cross-cut P-9 towards drift U-25. Active fire fighting within drift U-25 was carried out from cross-cut P-10. The rescue operation depended on the limiting of air flow to the fire by use of temporary air stopping, establishing water curtains within the path of the potential spreading fire in drift U-24 and fire fighting in drift U-25. The goal of this type of action was to stop the fire from spreading in the other direction i.e. against the air current.

Therefore, as well as the temporary stopping in drift U-25, a concrete stopping was erected. From the 23 December another means of cooling U-24 was established by timed allocation of large volumes of water (50 to 100 m³/hour) launched into drift from the stowing pipeline. In the event of continued spread of the fire, the mine was prepared to backfill with sand U-24 and U-25.

In the intersection of cross-cut P-1 with drift U-23 a temperature and air toxicity continuous measuring device was installed in order to measure the physical changes in the 'at risk' area. In both drifts, a continuous digital temperature recorder was installed. On the 24th December a significant drop in CO was recorded in U-24.

The stopping limiting air accesses to the site were dismantled the following day in order to cool the site. On the morning of the 27th December the CO concentration in U-24 dropped to 7 ppm and the temperature dropped to 57°C. The number of rescue teams monitoring the site was reduced to two. On 28 December 2004 the rescue operation was terminated when the measures have confirmed no toxic gases in the air.

As a result of the fire, the timber poling of the LP support in drift U-24 was burnt up to a length of 405 m and in drift U-25, 150 m. Drift U-24 suffered collapse at two sections, lengths of 70 m and 45 m with caving to heights from approximately 1.5 m to 2.5 m and also at three intersections to heights of between 2-3m. Infrastructure suffering fire and/or heat damage included the belt of the conveyor in U-24 (within

the section that was exposed to fire) and energy and telecommunications cables. Within drift U-25, roof rock structure collapsed to a height of approximately 3 m within a 60 m section.

5. Major risk associated with the rescue operation, experiences, remarks

5.1. Heat stress

Experiences gained as a result of these rescue operations underline that the primary threat is heat hazard. Operations within difficult climatic conditions associated with high temperature can lead to disrupted functioning and decline of health of an individual. Symptoms of heat associated stresses during active fire fighting include: weariness, muscle cramps, sudden loss of consciousness, rashes and accelerated fatigue. It is important to note, therefore, that in organising an active fire fighting program within these conditions, time of an individual is limited to not more than 20 minutes – such as in the timber lining fire. Such a situation means that there must be a significant number of personnel available for action at the incident site.

The fire fighting action in drifts U-24 and U-25 was accompanied by a doctor who was responsible for the health of the rescue personnel. Six to eight teams take part in the majority of mine rescue operations, therefore it is difficult to monitor the health of each individual, e.g. regular health reports. Further to this, during the mine incidents described the rescue personnel's constant entering of the 'at risk' site created conditions within the base that made it impossible to keep a temperature balance. Therefore, the potential impacts of the heat stress affected all personnel involved in difficult conditions, but particularly the rescuers. Today this issue requires some considering and the cohort of uncostly procedures should be included within rescue operations plans as soon as possible. Such procedures include the trialling and introduction of monitoring systems for the health of rescue personnel, specifically large numbers of personnel exposed to high stress situations.

Organisational procedures

In the event of such an incident, a number of organisational procedures for ensuring the safety of rescue personnel have been adhered to. For example there has been a selection of a specialist team equipped for action within hot conditions. These people have been monitored in respect to their resistance to heat stress. Considering the variability of people to cope with a difficult microclimate it would be of benefit if the acceptance of new people into the profession would be subject to such scrutiny. In the future, it would also be worthwhile to provide formalised training and acclimatisation procedures for rescue operations within difficult temperatures. It must be underlined that good training is the basis for best practice procedures. This is particularly appropriate for core knowledge principles relating to: heat hazard and its symptoms, undertaking first aid, effect of heat stroke and dangers associated with use of drugs and/or medications in conjunction with heat stress situations.

Technical procedures for limiting heat hazard

The changing and adaptation of structural and engineering systems is limited in terms of improving climatic-ventilation conditions because the rescue operation extends significantly further than the site of active fire. Leading such an operation requires isolating the danger site by limiting its ventilation and simultaneously increasing ventilation within the remainder of the mine. However it is reasonable to say that within Polish copper ore mines, this process may no longer be adequate during long operations and back-up procedures will be required for the cooling of

hazard areas. According to the research of Ludmilla Borodulin, current developments have room for two solutions. The use of mobile air conditioned cabins located near the base or relocatable ventilators with an inbuilt cooling system. There is also the potential for use of heat reflecting screens within close vicinity of the incident, heat retardant clothing for fire fighting crews.

5.2. Communication, lack of visibility

The characteristic feature of mobile equipment, belt conveyors etc. fires is a filling workings with dense smoke and total decrease of visibility. With no visibility a vital priority for rescue teams is to reduce negative results of this occurrence. The fire of LHD loader in Rudna mine has demonstrated a weakness of classic solutions (being in accordance with mining law regulations). The communication system and lack of visibility become evident clearly as the weaker links of rescue operation.

There were undertaken works leading to manufacture by INOWA (subsidiary KGHM's innovation company) an adequate rescue wireless communication system for mining condition existing in room and pillar system working areas. This solution was successfully tested during the yearly fire trial executed in Rudna mine by regional state mining authority (OUG Wroclaw). There are still given careful consideration to a matter of what kind of infra camera (individual or one per team) should be used by rescue teams. It looks that the best solution could be goggle model cameras for member of the team. There is a formal limit forbidding exploiting entire potentiality of the equipment. The rules do not allow to rescuers to split up from the team. But some exercises (and positive results) made with cameras in artificial smoke open discussion about new scenarios of penetration methods in huge room and pillars areas in metal mines. Leaving a matter to proper authorities and not arbitrate what kind of terms are to be executed there is grown an idea how to perform fast penetration in safe way. Moreover gained experiences ascertain us there are no effective rescue operation in fires without accessories like wireless communication and light infra cameras.

5.3. Irrespirable atmosphere

The late catch sight and then the notification of blaze in drift U-24 caused increase of fire to its considerable expansions. The case of fire of timber lining in Rudna mine was an exceptional in whole copper mines history. It gives to raise number organizational, technical and above all logistic difficulties in area of respiratory system protection. In Polish mining industry there are still the most of breathing apparatus in use are the old type W-70 units. Just in beginning of the rescue operation occurrence of complication may be supposed. Nobody was prepared for managing a sufficient technical support base for such big numbers of teams and to carry on rescue activities accordingly to existing procedures. Therefore during the operation occurred a few not standard manners and acting. One of questionable situation was lack of required overhaul medical examination each time rescuers went out into rescue works. Rescue medical officers fulfill only superficial inquiries with rescuers after their arriving to the base. Another one questionable problem took place when rescuers multiple times have used the same apparatus during "rescue shift" i.e. performing in a dozen or several dozen minutes stages rescue works and resting with unwearied apparatus between each successive quit from the base. That situation was outcome as a consequence of vicinity of fresh air base to location of fire as well to harsh hot climate raised in site. With no changes of oxygen cylinder and cartridges of lime soda each rescuer has went into action a few times having certain pressure of oxygen in cylinder – sufficient for planned work. Afterwards investigation and

analysis of operation run indicate that from formal point of view there was not allowed to go beyond the fresh air base not having at least 20 Mpa oxygen pressure in cylinders and to make interruptions in work under oxygen apparatus. Producer toughly has back up own assignation regarding mentioned topics in the instruction. Whole run of rescue operation was performed safely and effectively taking into consideration harsh climate conditions. It had drawn our attention to needs for equipment protecting rescuers in irrespirable atmosphere. Apart modern solution like BG-4 apparatus also apparatuses with pressured air are tested. The aim is to find an apparatus which fulfill requirements for effective works in similar condition met in drift U-24 rescue operation and allow more flexibility.

6. Summary

Author's intention was to pin-point on this forum some problems regarding a specific rescue operation performed in harsh underground climate conditions and to submit this matter for consideration and discussion. A main topic and question is: what should be considered as (also accordingly to the rules) "an adequate promptness and preparedness for rescue operation" for such cases like described above.

Safety in mining costs a lot and insufficient means entail restriction in rescue organization. At the same time possession it self of sufficient means many times does not assure efficient preparedness for certain situations. The process of forming structures and defining serviceable equipment undergoes to verification during critical timeless cases. Unique character of many danger situations makes high demands to people responsible for rescue preparedness. It means for them the permanent necessity of anticipation of any threats and current verification of valuation of hazardous occurrences in order to attain the best possible competent mining rescue organization.

In such situation grows also importance of changes of experiences and improvement of training methods as well as possible forms of practical exercises.