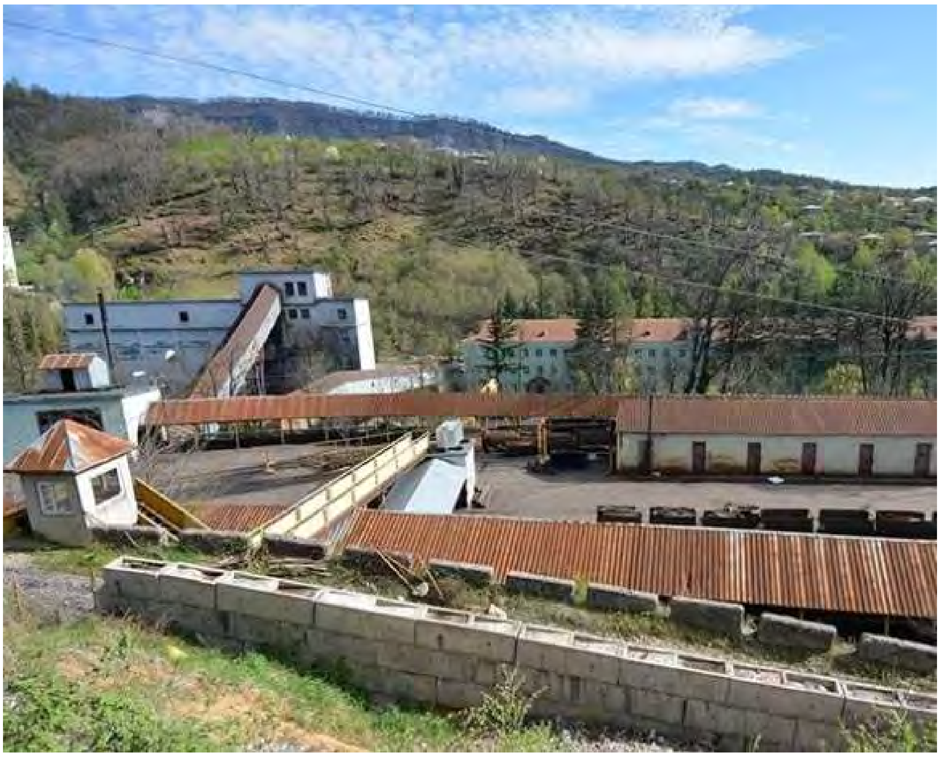
DMT GmbH&Co.KG, Germany

REPORT

HEALTH & SAFETY AUDIT OF MINDELI MINE, GEORGIA

FOR

MINISTRY OF INTERNALLY DISPLACED PERSONS FROM OCCUPIED TERRITORIES, LABOUR, HEALTH AND SOCIAL AFFAIRS OF GEORGIA



To:	Ministry of Internally Displaced Persons from Occupied Territories, Labour, Health and Social Affairs of Georgia, 144 Akaki Tsereteli Avenue, Tbilisi 0119,
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Report No.:	8116431089/2
Prepared by:	Artem Chayka, John Alstead, Rüdiger Baltz, Dietmar Plum, Rolf Steffes

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TABLE OF CONTENTS

LIST OF ANNEXES

LIST OF TABLES

LIST OF FIGURES

0 EXECUTIVE SUMMARY

DMT GmbH&Co.KG ("DMT" or "the Consultant") undertook a health & safety audit of Mindeli Mine in Georgia ("Mindeli" or "the Mine") contracted by the Ministry of Internally Displaced Persons from the Occupied Territories, Labour, Health and Social Affairs of Georgia ("the Ministry" or "the Client").

The main aspects of the audit are:

- Review of the mine operations;
- Review of the current H&S standard and respective regulations;
- Risk assessment;
- Introduction of the state-of the art practices to control the risks; and
- Development of an action plan (road map) for improving H&S standard at the mine.

Mindeli coal mine has been in operation for over 150 years. During the DMT visit, coal production was currently stood down due to the incidents in the past year, which have resulted in two explosions of methane, claiming a total of 10 lives, and seriously injuring several other people.

Production Method: "modified longwall", but more similar to the pillar and stall method with very little mechanization (hand held drills, so-called Turmags, strata boring machines, and small section being worked by steel chain conveyors. Sections are connected by chute roadways. The roadways and seam drifts are steel arch, workings in seam are wooden prop supported.

Observation during the underground visits:

- Brand new warning signs;
- Several areas of broken roof and sides in the roadways that needed dressing down and re-supporting;
- Haulage track standards could be improved;
- Low safety standard awareness, by workers, supervisors and management;
- Unhealthy working conditions and – procedures;
- Lack of firefighting equipment;
- etc.

Several hazardous issues were found to arise from the risky work processes, for example:

- Production of Methane and other gases;
- Lack of temporary support between the supports in both the roof and sides on the coal face;
- Working in confined spaces and very narrow man riding chutes and winzes;
- Working at height, and with difficult footing on unsafe makeshift working platforms;
- Dealing with unusual circumstances such as cavities, spalling of the sides;
- Manual handling and transport of materials;
- Use of hand tools;
- No hydrants, fire control;
- Ventilation derangements by men and shot firing; and

- Inadequate stationary lighting.

Hazard- and Risk Control

The following reasons for risk acceptance were reviewed:

- Failure to understand the risk of the working situation;
- No regard for safe actions;
- Greed;
- Fear;
- Idleness.

Improving Risk Management:

Two gas explosions happened recently showing deficits in the risk management. Therefore, risk management had been stepped up. Since then Mindeli management strived to ensure that assessments are suitable and sufficient and consider all foreseeable issues pertaining to an activity, together with compliance with whatever regulatory burdens are placed upon them.

Training measures are to be updated and extended and the safety approach has to be subsequently audited internally.

Plan- Perform-Improve-Monitor; it has been suggested by DMT that every single activity undertaken at Mindeli mine should follow this same process, so that systems of work are continuously being introduced and reviewed and updated as the work at the mine evolves. It incorporates consideration of both systems and human behavioral aspects of what can go wrong, and how they can be successfully addressed.

Setting limits of what is acceptable; the safety goals need to be re-addressed and standards upgraded and implemented all over Mindeli Mine.

Decision making capacity: Another process that needs to be established clearly is the limit of everyone's technical and decision-making capability. For this purpose a traffic light system had been suggested by DMT. Supervisors need to work to this 'traffic light' system. In this system, the supervisor is given clear guidance on what his actions should be in reaction to changes.

Recent Fatal Accidents:

Shot firing and subsequent gas explosion; A root-cause analysis showed gross disregard of principal safety measures, as prescribed in the mine safety documents (no ventilation, no methane measurements, no backfill of dangerous cavities to avoid gas accumulation, no clear headcount to ensure all workers were out of the danger zone).

A second similar incident occurred 10 weeks later for similar reasons, showing clearly that "no lessons were learnt".

Primary Cause:

- There was gas present in the area.
- Blasting ignited the body of methane.

Secondary Cause:

- The presence (or possible presence) of the cavity were gas accumulated.
- Disobeying the rule to evacuate before blasting.

Further Possible Causes:

- The rules were general, leaving the decision to be made by the officials open to their interpretation of them.
- The procedure at the mine does not include suitable arrangements for the cleaning out of coal debris.
- The colliery supervisors and workmen were predominantly from a close-knit community in the immediate location of the mine. It could reasonably be surmised that there might be an element of peer pressure when supervisors make decisions, which will directly affect the earning, potential of face workers.
- Basic calculations of estimated cycle time and production available time supplied by the mine indicated that there was a negative variation between targeted and the potential tonnage.

DMT drew up a concise set of *incident specific recommendations.*

Accident and Incident Investigation:

Benefit to be drawn from any accident or incident is a determination that arrangements will be put into place so that they will not be repeated in the future.

Clearly, explosions caused the most serious accidents, followed by accidents related to use and operation of mechanical equipment.

DMT conducted an assessment of the different level accidents. However, the reporting and accident management is insufficient and often misreported.

It became clear that there is not a robust accident reporting process at the mine. Presumably fatal accidents, and some of the major accident data will be correct. These are events which cannot go unnoticed. In contrast, the evidence from the lower impact accidents is simply being missed. This has the effect of skewing the statistics. It also makes any analysis of causes and effects virtually impossible.

H&S Responsibility and Structure:

Georgian H&S legislation related to mining appears to be rudimentary. Emphasis is on personal safety features, neglecting safe workplace organization and safe technical equipment.

DMT illustrated the need for a framework policy, which at the very least complies with the minimum acceptable arrangements necessary for the safe operation of the mine, to protect personnel from harm, and also to protect the business, based on the British HASAWA system, including structured training of staff, emergency and first-aid procedures and accident management.

H&S Training:

DMT suggested that training functions at Mindeli should follow a process that can be separated into five steps. The main aspects of the audit are:

- Allocate responsibility for organizing Mindeli's training scheme;
- Identify who should be included in the scheme;
- Identify what training is required to fully serve Mindeli's requirements;
- Determine how to execute the training scheme; and
- Audit the effectiveness and review the requirements of the training scheme.

Shotfiring Procedures (Blasting):

Blasting procedures fall into the three main categories

- Management and control of explosives and detonators;
- Use of explosives and detonators;
- Process of firing shots.

DMT assessed the existing blasting procedures, identified improvement measures to consider and suggested procedures to ensure safe blasting.

Ventilation, Fire- and Explosion Protection:

Mindeli's Ventilation Department is managed by a ventilation engineer. 27 ventilation deputies are available to fulfil all ventilation tasks as there are no workers directly assigned to the ventilation department.

Overview of the main tasks:

- Ventilation and ventilation systems;
- Mine monitoring;
- Outgassing, spontaneous combustion and rock- / gas outburst;
- Explosion protection and safe operation of electrical systems;
- Fire protection and dust control;
- Monitoring of blasting operations; and
- Monitoring of H&S at working places.

Escape plans. Vanishing points are marked in the escape route plan, however a mine rescue brigade does not exist. The central mine rescue service is located in the city of Tkibuli, 30 minutes' drive away.

Ventilation system. Ventilation measuring system is in place, ventilation of the Mindeli Mine is carried out by suction through a main ventilation system installed at the return air shaft, auxiliary ventilation in the road heading is carried out utilising electric fans.

Gas emission is calculated by the ventilation department of the workings based on historical gas content determinations. Gas inflows from the seams in the hanging wall and the footwall areas are estimated, gas measurements are taken regularly and following the accident in April 2018, stationary air measuring devices were installed underground.

For *explosion protection* water pockets as explosion barriers.

Coal dust suppression is essentially limited to spraying with water or water/air mixtures.

For *fire protection* underground, a combined system of regularly arranged water supply points, hydrants, hoses, spray jet pipes as well as fire extinguishers is required. The current measures at the mine are rudimentary.

Escape and rescue points as well as all installed telephone facilities, including phone numbers, are shown in the escape route plan.

Roadway Repair:

DMT visited most of the lateral and face roadways. The rock roadways suffer rather from inadequate support system and insufficient support quality and long periods without maintenance than from ground pressure.

The roadway repair process is back ripping involving:

- Removing the loose material from the roof & floor and installing 3 m roof fall protection shield;
- Removing and loading of the rock material under the protection application;
- Setting the temporary support and withdrawing the damaged arches; and
- Installing the new support and lagging.

Rock and Gas Outbursts:

At Mindeli Mine rock burst occurrences are favored by the complex mining situation. DMT suggested a set of measures to minimize the occurrence of rock bursts.

Alternative Mining Methods:

Alternative mining methods potentially suitable at Mindeli Mine are:

- Soutirage mining method for steep coal seams;
- Cut and fill stoping;
- Short- and longwall mining; and
- Auger mining.

Route back to the coal faces:

To restart production, several other activities are required to allow the face to operate. The drift transport, the blind shaft, the in-seam transport system, the mineral clearance system, the materials handling system, the control of explosives, and more. To restart production, all associated service systems need to be scrutinized in the same manner to ensure adequacy prior to restarting production. It is not sufficient to simply eliminate the immediate issues that caused the two explosions at Mindeli.

The process outlined by DMT in this report does not consider H&S to be a separate activity from operations rather that it is an integral part of the plan as a whole.

1 INTRODUCTION

DMT GmbH&Co.KG ("DMT" or "the Consultant") has been assigned by the Ministry of Internally Displaced Persons from the Occupied Territories, Labour, Health and Social Affairs of Georgia ("the Ministry" or "the Client") to undertake a health & safety audit of Mindeli Mine in Georgia. This will is required as an important part of the current safety improvement process at the mine. The main purpose of the audit is to prepare an independent assessment of the health & safety risks to the mine, provide recommendations on systematic control measures and risk reduction as well as develop a concept for improvement of H&S system to the Western standard.

The main aspects of the audit are:

- Review of the mine operations;
- Review of the current H&S standard and respective regulations;
- Risk assessment;
- Introduction of the state-of the art practices to control the risks; and
- Development of an action plan (road map) for improving H&S standard at the mine

This report summarises observations and findings of two DMT visits to the mine, discussions with the specialists on site and DMT review of the documentation available. The shaft review results are provided in the separate report.

1.1 MINDELI MINE LAYOUT

Mindeli coal mine has been in operation for over 150 years. During the DMT visit, coal production was currently stood down due to the incidents in the past year, which have resulted in two explosions of methane, claiming a total of 10 lives, and seriously injuring several other people.

The most recent method of production is referred to as longwall, but is really more akin to the pillar and stall method.

Before cessation of operations, three such faces were in production, together with associated development work, also in-seam.

A level drift, from the mine surface, leads to an underground shaft, which lowers down to the working horizon. The drift facilitates and transports men and equipment via a locomotive train. These are all then transport down the shaft, and from here to the operating points by rail.

All mineral from the mine is transported by rail in coal tubs, via a separate skip shaft. Each of the two skips has a 7 tonnes capacity. There are no belt conveyors underground.

1.2 MINDELI MINE PRODUCTION METHOD

There is virtually no mechanization of the face process, and the system is labour intensive. The only powered tools used to win the coal are compressed air hand drills (Turmag) and picks, and a type of strata boring drilling machine, similar to a methane boring type machine, used to drill pilot holes for the coal faces.

In addition, there are small section steel chain conveyors to remove the coal to the loading points. The means of coal removal from the working coal face is gravity, the working face providing a chute roadway which is also a connection between the working levels, for both coal transport and personnel.

Steel arch supported roadways, driven in seam, first block the coal faces areas out. From the lower level, face chutes are driven up at full dip (45 degrees) The methane boring type machine, fitted with an extended drill bit, augers a pilot hole to begin to form the face chute, and this provides a free space into which the remaining coal is drilled and blasted. Wooden props and bars, half lap notched at their ends to form a rudimentary but efficient connection between the two components, progressively support the excavation.

From the base of the chute, a small steel chain conveyor carries the coal to the delivery point.

DMT has reviewed all the production and development operations assessable. In addition DMT has inspected the service shaft hoisting facilities at the mine.

2 UNDERGROUND VISITS

The underground visits were very informative demonstrating health & safety standard of the operations and H&S attitude at the mine.

The mine is comparatively basic in its production methods, and very labour intensive, but this should not detract from its ability to uphold good standards.

Starting at the inset to the workings, at the foot of the blind shaft, it was immediately apparent that an amount of work had been carried out to bring, particularly signage, up to a better standard. This was gratifying, as it demonstrates two things. First, the mine recognises the importance of the visit, from the aspect of concentrating on safety measures and second it tends to demonstrate that personnel at the mine know what will be looked for on safety inspections. However, it also demonstrates that for the rest of the time, when there are no visitors, the mine is satisfied to settle into a more comfortable paradigm, where signage doesn't really mean anything because no one really takes much notice of it. If a mine team is going to post up an instruction in the mine, then they must be sure that they will enforce that rule, otherwise the sign will have the opposite effect to that intended. A redundant sign indicates that there is no intent to enforce the rule.

It was also obvious that although there were several of areas of broken roof and sides in the roadways that needed dressing down and re-supporting, this was not considered necessary at Mindeli. When the first of these areas was identified and questions asked by DMT, the answer was 'oh, don't worry about that, there are plenty of those types of areas here'!

Continuing inbye along the transport road, it was clear that haulage track standards could be improved. The track was being held in position in the roadway in many areas by means of various types of wooden boards wedged against the legs of the steel arches that support the roadway. In addition, the infill between the track sleepers was very poor for the most part, and missing completely in many areas. When the mine team was questioned about all this, the reply was that the roadway would be replaced before locomotives ran along it, and that anything that went that way in a vehicle was currently being pushed by hand. Later DMT were told that a refurbishment of the road was part of the programme of work during the cessation of production.

This pre-supposes several issues;

First, the track was in use for locomotives prior to the stand down, on poorly installed track.

Second, the mine team is aware that the system is inadequate because they have scheduled it for improvement, so they knowingly demonstrated to the entire workforce who travel there that expected standards are low.

Third, the mine team continues to allow everyone who walks this road to risk stumbling, slipping, falling injuries daily. These injuries could foreseeably range from cuts through to broken bones, again demonstrating to the workforce that low standards and makeshift solutions a 'make do' attitude are acceptable at Mindeli.

Finally, by allowing men to push vehicles over the distances in question to get safety-based materials inbye demonstrates a willingness to risk muscular skeletal injuries as a matter of course.

There was also evidence at several rail switches and direction changes that ‘homemade tools’ were in use. By this it is meant that there were carefully stored items in the vicinity where they would be used to help the track vehicles around turnings to help prevent them leaving the road and causing a derailment of the whole or part of the train of vehicles, items such as flat sections of steel, various types and lengths of bolts, etc. Of course, such an event could be high risk if persons are nearby, or the cab of the locomotive meets the side of the roadway. In addition, the process of re-railing such a train is a hazardous process when ad hoc methods, and the ‘tricks of the trade ‘are employed.

One concerning aspect along the roadway at an unsealed roadway end, which was sealed further inbye. When asked why the road was simply not sealed at the fresh air source in the tunnel, the mine team said that it was necessary to do this for some reason that was not understood by DMT. When asked how the mine would access the inbye site to carry out work in a long stub in an old return with no ventilation, DMT were informed that personnel wearing self-contained breathing apparatus would carry out the work. DMT suggests that this should not be normal practice, as it is fraught with hazards, putting men in BA into a potentially hazardous situation, and asking them to carry out work at the same time.

On the day of the visit there was a team of 6 men, being supervised by two officials, and these men were engaged in a cleaning up operation in the face gate road, described as preparatory work. Work stopped when the visiting party arrived, so it was not immediately obvious what they were doing. Presumably they were tidying the visit route. If this was the case, DMT consider that they could have been better deployed on more pressing issues.

Continuing to the coal face, the gate roadways seemed to be standing well, and comfortable to travel in, albeit that there was no heat, dust or other issues that could be present during production. The face itself, pitched at 45 degrees and wooden timbered with no temporary roof side support between the supports was a different proposition. On the visit it seemed comfortable enough, but in the working conditions might be an entirely different environment.

Several hazardous issues arise from the process, for example;

- Production of Methane and other gases
- Lack of temporary support between the supports in both the roof and sides on the coal face
- Working in confined spaces
- Working at height, and with difficult footing
- Dealing with unusual circumstances such as cavities, spalling of the sides
- Manual handling and transport of materials
- Use of hand tools
- Fire control
- Ventilation derangements

There was no evidence of any use of restraint (such as harnesses for example). Presumably the drillers simply stand with their feet on the existing support or place boards across the face chute to support themselves as they drill and stem up the holes. Because the face chute has such a small cross sectional area, then it would be likely that 3 men working in this small area would cause some ventilation derangement at certain times of the day.

Fire in a mine is difficult to deal with, as by the very nature of the ventilation system, the air that is required to continue to ventilate the workings, also serves to continuously feed the fire. Add to this the problems of products of combustion on the downwind side, and it becomes immediately obvious that a fire is a major hazard to the mine personnel and infrastructure. The largest coal mine in Europe that produced up to 3 million tonnes in one year was lost in 2013 as a direct result of a fire in the return of the face, thankfully without the loss of any lives.

When DMT enquired about firefighting equipment at the face, there was no hydrant available in the water range. Also, there were no firefighting hoses, which had apparently been sent out of the mine for ‘safe keeping’, as they ‘kept being taken away’. The mine team’s risk assessment of this was that a fire would be detected before it became a problem, and there would be adequate time to get equipment to it before it became a problem. This is not an acceptable situation, and the workforce is being shown that safety rules do not need to be complied with.

An ad hoc ‘working platform’ was observed at one development area adjacent to the coal face. This was situated above a steel conveyor, and ventilation ducting for auxiliary ventilation of another part of the mine passed immediately in front of the heading stub. The stub had only advanced about a metre in depth, and so shotfiring was taking place directly next to the ventilation ducting.

There were several issues of concern with this area.

First, the ‘platform’ was rudimentary, consisting of a haphazard assortment of wooden planks supported by the coal face at one end (the end sitting on the friable coal face), with the other end sitting on pipe ranges.

DMT were informed that this arrangement was in use to facilitate setting of the initial steel support arches at the breaking in stage of the development. Workmen would have lifted heavy steel sections, on a makeshift platform, around 1.5m above the ground, over a steel conveyor, adjacent to an auxiliary ventilation duct.

When asked what possible effects that shotfiring here might have on the ventilation ducting and the subsequent effects on the place it ventilated, DMT were informed that makeshift protection was available to protect the ducting.

When DMT enquired if a more considered way of protecting the only air supply to the area affected, they were informed that this would not be effective, and would get damaged anyway. This demonstrates a lack of forethought, a lack of care for safe systems of work and a lack of planning at Mindeli.

The most striking part about this issue, however, was the total lack of awareness of the unsuitability of this arrangement for the job in hand. Although preparations had been made for the visit, this ‘platform’ had been left in place, indicating that there was no realization that the platform was not fit for purpose.

Another explanation might be that people there have never been asked these types of question before, or if they had, there were no potential repercussions, for unsafe acts.

This was confirmed by the self-made driver seats DMT observed in a loc. When asked the mine has shown the new locs with the proper seats operating in parallel to the old loc.

Figure 1 Self Made Loc Seats

Stationary lighting were found only at one working place underground, which obviously increase the risk of accidents and incidents under unsafe mine conditions.

Any of the inclined workings (winzes and chutes) are equipped with any man riding arrangements. The inclined workings showed extreme narrow (up to 30-40 cm) passages for men.

These and other examples identified underground demonstrated the attitude to H&S at the mine. Obviously, not much time and no huge investment is required to eliminate those hazards, but discipline and wiliness of the mine to change.

3 HAZARD AND RISK CONTROL

The definition of a hazard is; “a potential source of danger”. Personnel at the mine who are sufficiently trained, competent, qualified, and accredited to perform this function, should classify anything that has the potential to do harm as a hazard.

Risk is a measure of the possibility of a hazard doing or causing harm.

A Risk Assessment is an assessment of the likelihood of harm occurring, and an identification of the personnel that will be affected. Then control measures can be installed to reduce the risk of harm to an acceptable level. Risk Assessment can be a daunting prospect when first introduced to a workplace; concepts can become confused and cloud its introduction. Risk assessment should be practiced until it becomes part of the thinking process at Mindeli.

Some people have a natural affinity with risk assessment, they find that it is a process that they can identify easily with and possibly already (if unconsciously) use. Others may have more difficulty. The ones who ‘get it’ need to be identified by management, and used as advocates to roll out the programme, particularly if they are influential at Mindeli.

The people to guard against most are those who latch on to risk assessment as a way of justifying any action through this process. It should be made clear that carrying out a risk assessment is not a passport to doing anything that anyone might wish to do.

Training will be necessary for all management and supervisors for the process to be effective. At a later stage the workforce could also be trained in risk assessment.

Appendix 1 and 2 shows a suitable template for use by mining personnel in the formation of formal risk assessment.

3.1 IDENTIFICATION AND ASSESSMENT OF THE RISK THAT A HAZARD PRESENTS

All activities have inherent hazards. Whether it is filling a car with petrol at a petrol station, or firing a round of shots on a face, there are hazards involved. An exploding petrol station could be just as devastating as an explosion in a coalmine. Virtually all petrol service station pumps in the UK are unmanned, and the public has no choice but to drive in and fill up their tank themselves, but they do not regularly blow up petrol stations as a result. The reason why they do not is that the hazards of novices handling petrol have been recognised, and an assessment of the risk of these hazards with the potential to cause loss of life or property have been identified and reduced to a very low, acceptable level. Hence no one can say that it will never happen, but the likelihood is extremely low.

The assessment of risk is not limited to just hazardous industries, which includes mining. Mining is a process, and as such most of what will occur should be foreseeable.

But it is necessary to go beyond this certain knowledge and explore the ‘what ifs?’

Thus, it is necessary to use all the experience and knowledge, and foresight of all concerned to identify all the hazards that the mine will, and may, face.

Some hazards will have a greater potential to cause harm to people and the mine than will others, but it is difficult to convince a man nursing a broken thumb that worse things could happen to him (just at that moment!) There is a spectrum of hazards, ranging from major hazards to minor hazards.

Coal explosions, gas explosions, ignitions, fires and spontaneous combustion, rock bursts, gas outbursts (in no particular order of importance) fall into the major category. They are hazards that have the potential to do large- scale damage.

The assessment of the risk of these hazards, and the actions that need to be put into place to reduce them to an acceptable level, is paramount in defence against them.

The mine is currently closed for production because the risk of the hazard of a gas explosion occurring was not assessed sufficiently. This must be rectified to enable the face to restart. If it is not presently possible to reduce the level of risk to an acceptable level then the face should not be allowed to operate until it is.

An acceptable level, in this case, would be that another explosion is so remote a possibility that it could be deemed almost not to exist. The possibility of an explosion is not therefore denied completely, and so other safeguards such as additional explosion proof barriers, and the enforcement of the correct position of firing rounds of shots must be put in place to safeguard personnel in the remote possibility of an explosion.

This is not the only hazard facing the mine, and all other issues also need consideration. Otherwise the mine will continuously go from one disaster to the next, reactively finding out what went wrong, instead of proactively avoiding these issues before they occur.

Similarly, if events or circumstances change and cause a previously low risk activity to undertake a change, then the consequences of that change need to be carefully considered, and plans put into place to again reduce the risk to an acceptable level.

The process of hazard recognition is not a single activity, but a continuous one, which recognises change, and makes the right decisions for the control of the change on a continuous basis.

For example; consider a set of support rules which have been agreed by all interested parties, and have been posted and are being worked to. One day, a fault appears in the face of the development. This is likely to require additional support, and the requirements of the support rules have been altered by circumstances. This should be recognised by the supervisors, and, if beyond their remit, should be flagged to senior management for advice. Above all, the area should be made safe or ‘fenced off’ until such time that a decision is made on the way forward.

3.2 WHY DO PEOPLE AT MINDELI TAKE RISKS?

Some people like to take risks. Base jumpers, mountain climbers, all types of extreme sportsmen take huge risk. In general, so that they can continue to enjoy their sport and the rest of their lives, they put in place measures to avoid the risk they are taking to a level that allows them to survive. If they are successful at this they survive. If not, then they die. It is that simple, it is their choice. If they do not affect anyone else then that is fine. But this is not the case. The mountain rescue helicopter team put themselves in danger to attempt to rescue them, the emergency services have the unpleasant task of recovering their remains, their family loses a loved one, the list of people affected goes on. It is neither fine nor simple.

Mining at Mindeli is not an extreme sport. It is a process undertaken to produce coal, and its sale, to make money. In return the people who go and get the coal are paid for this. They are not being paid to take risks nor to risk being killed; they are paid to do a job of work.

People at Mindeli Mine (and everywhere) take risks for various reasons, or a combination of these reasons. Arguably these reasons fall under 5 main headings;

- Failure to understand
- No regard for safe actions
- Greed
- Fear
- Idleness

Each one in the correct circumstances can have the potential to do harm to people and/or property. Mindeli management needs to recognise these issues as hazards, assess the level of risk that they represent, and put control measures into place to prevent them.

In this discussion, it is intended to be site specific to the mine, and therefore will sometimes make uncomfortable and difficult reading. It is an attempt to get to the root of the problems, and to try to make sure people do not continue to be hurt at Mindeli by a process that they rely on for their livelihood.

No single factor will explain the reason for people taking risks, often there will be a combination of these factors, but they will always be the root cause.

3.2.1 FAILURE TO UNDERSTAND

Men who are ignorant of the rules are either lawless (rule-less), or they make up their own laws (or rules). All the men who positioned themselves where they did before each explosion carried out their own informal risk assessment of where they should be when the shots were fired. As it transpired, this risk assessment was nowhere near to being adequate. Because these issues need a great deal of forethought, it is not realistically possible for the men to make an informed decision based on a flawed risk assessment, and therefore it is necessary to have rules which are well thought through beforehand.

It may be that the men did not understand the rules, or could not read them for various reasons when they were shown to them. They could be illiterate, but pretend to read them to avoid embarrassment. They may not be able to read print without spectacles. They may not be able to grasp the meaning of the rules, but pretend that they do, again to avoid embarrassment.

The way that concepts and ideas are presented is very important, and time should be spent not only in instructing, but also in questioning and listening and checking understanding. The process should not merely be a means simply of getting a signature on a piece of paper. Several times at Mindeli, management argument relied on the fact that men had signed a statement to say that they understood the rules. All this means is that there is lots of stored paper, with lots of signatures on them, which does not achieve the necessary result.

For both underground visits and shaft inspection DMT received a brief training in the use of self-rescuer equipment before going underground, and a brief outline of the area to be visited. Also, during the underground visit, notices showing emergency egress routes were observed on the walls of the mine roadways, but no mention of these emergency procedures was made during the briefing. In an emergency it may not be possible to assist a visitor, and this small fragment of knowledge may become very important in an emergency situation.

It may be that there was an assumption that experienced consultants did not require in- depth training, and because they were being accompanied on the visit by experienced staff they did not need to know much detail, but the training was rudimentary to say the least. What can be said for certain was that it was far more basic than any other training that DMT had experienced before.

There was no discussion of the ‘do’s and don’ts’ in the mine. A projector present in the room was not employed which might have helped, particularly with several different languages being used in the room. If this was an example of training at Mindeli Mine, it is understandable if men there often do not understand the rules.

3.2.2 NO REGARD FOR SAFE ACTIONS

Mining is often a tough difficult job, which relies on determination and skill, and there are often people who cannot be relied on to look after their own, or other people’s safety. It should be possible at Mindeli for their colleagues to tell these individuals that they are doing wrong.

The ‘good lads’, who always get a result, no matter what. Who know the ‘tricks of the trade ‘and how to do the ‘wrong thing the right way’. The ‘go getters’ and the ‘arse kickers’ have a place in mining, but these can be very dangerous people in the wrong situation, at the wrong time, and in the wrong circumstances.

One of the ways in which a visitor to a mine can quickly gauge the safety culture is to observe what people do, and also what they do not do. The most visual display of a strong safety culture is the habitual wearing of Personal Protective Equipment (PPE). The mannequin in the glass case in the concourse at Mindeli demonstrates the PPE to be worn underground. This includes; a helmet and boots, a lamp, oxygen self-rescuer, location-monitoring chip, but does not include the requirement to wear protective glasses or gloves. The explanation for this was that there was no mechanised coal cutting so no need for safety glasses, and people could not 'get on' with wearing gloves. In this way Mindeli mine fails to recognise the risk of injuries to eyes and hands, in a mine which relies more on manual handling and hands on work than the clear majority of mechanised coal production throughout the world.

Underground, a group of men were spoken to, and were asked why they were not carrying their self-rescuers on their person. DMT were informed that the rule at the mine was that it was acceptable to have them within 5m of their person when working. There is at least an opportunity here for men at Mindeli Mine to break a rule.

It would be important to know where the self-rescuers of the men involved in the two incidents were discovered in the subsequent investigation.

If there are people at Mindeli who cannot see a better way of working, who refuse to work within the rules, then they need to be weeded out if they cannot change.

If these people, already in situ at the mine, cannot be convinced to work in a different way, and cannot be changed, then they need to be let go, and changed out for people who will.

'Change the people, or change the people.'

3.2.3 GREED

Greed is not simply a thirst for more money. In this context, it is an overwhelming desire to get more; more coal, more medals, more cash, more consideration, more status, more time, more, more, more.

Greed can blind people to what is staring them in the face. If there is a hazard, the craving for more can outweigh the risk involved. After all, just a little tweak of the rules, and Hey Presto! Job done!

In both explosions at Mindeli, greed played a part. The workmen were paid a production bonus, but the supervisors were not. Why then, Mindeli management asked DMT, would the supervisors take a risk to earn the men more money?

This is an unfortunate question, whichever way it is viewed. If it is genuine, then the person asking the question is being naïve. If not, then the same person prefers not to acknowledge the truth; that greed was hand in hand with peer pressure in each instance. The latter reason for apparently not understanding the supervisors' actions is probably even more damning than the former.

Reward actions that improve safety. Mindeli would be a safer place to work if the supervisors were all greedy to make the men work safely, if the men were greedy to look after themselves and each other properly without taking short cuts, and the Management was greedy to reward good safety as well as good production? Consider a bonus scheme that rewards supervisors for making people (and themselves) work safely, and within the rules.

3.2.4 FEAR

How does fear motivate men who face real hazards daily, who do tough and demanding work, and are tough enough and resilient enough to make their living that way?

Fear is a strange motivator for taking risks. It depends on what motivates the individual, and his own personal aspirations and goals, and the fear of not achieving them. Mineworkers may fear injury, which is a healthy attitude, but someone who fears the loss of a job more, or loss of face or status, or loss of reward, or the fear of direct threat may decide to throw his safety to fate to avoid whatever he fears more.

Peer pressure is a more insidious form of fear. Man is a social animal, and most people fear exile from society, even if they know that that society is functioning outside of the rules. Some people at Mindeli mine are being coerced into doing things that they do not want to do because they want to fit in, not rub people up the wrong way, become the subject of criticism, a social pariah, a pain in everyone's side.

Mindeli management asked, 'why would a supervisor take risks for the workers to earn more bonus?' This possible factor may go some way to answering that question.

What the Mindeli management needs to be aware of more than any other factor is that they lead the way in the formation of the safety culture of the mine. If they do not lead by example by not accepting any breaches of rules, by not walking past things that are obviously wrong, by not 'going away for five minutes while we get this done, you don't want to see this', by not questioning why there are 'home made' devices in use, not looking beyond what they are being told, not relying on signatures of people on instruction sheets to prove they know what they should be doing, then they cannot expect the people at Mindeli to respect the rules, or them, because they do not demonstrate that they respect the rules.

3.2.5 IDLENESS

Can a man who arises early in the morning, before most people even consider waking up, and goes to work in an uncomfortable, dirty, hostile environment, to earn money to support himself and his family ever reasonably be labelled as lazy or idle? Idleness is a state which people slip into to make life easier for themselves if they can, or if the conditions are so bad that they are forced into it. Miners all over the world always find the 'easiest' way to do things. And if this easiest way circumvents the rules, then that will be the way it is, until someone in authority puts a stop to it.

The reason why the shot masters were understood to not withdraw themselves to the correct firing station was described as laziness. This is conceivable, but do we truly believe this to be the root cause of the incidents?

3.2.6 INERTIA

Inertia can be defined as;

'A property of matter by which it continues in its existing state of rest or uniform motion in a straight line, unless that state is changed by an external force.

"The power required to overcome friction and the inertia of the moving parts"'

Mindeli mine is in an extreme state of inertia. On occasions when suggestions of how improvement and new initiatives might be applicable to the mine, these normally met with an immediate barrage of reasons why they would not work at Mindeli. Every mine is unique and has its own set of circumstances, but they are not so dissimilar in the hazards they face, and the ways that these can be controlled.

Mindeli needs to open its mind at all levels to new concepts and ideas. If Mindeli always does what it always has, then it will always get what it always got before. The section later in the report 'The route back to the coal face' suggests some of the ways in which Mindeli can become a more inclusive and co-operative place to work regarding the safety culture.

3.3 HOW AN INCIDENT OCCURS

James Reason, Professor of Psychology at the University of Manchester, first put forward the proposition that 'the human error problem can be viewed in two ways: the person approach, and the system approach'

His contention was that the conditions required to circumvent all the defences, barriers and safeguards incorporated into a corporation's rules and training of its personnel, could be illustrated by the 'Swiss cheese' model of accidents. Figure 2 illustrates this concept.

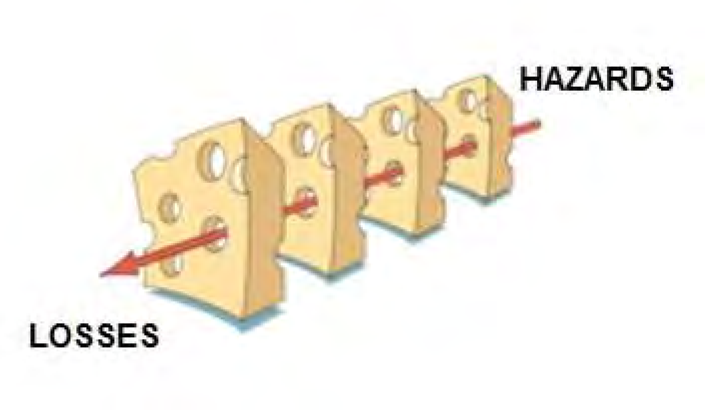

Figure 2 "Swiss Cheese" Model

Only when holes in systems and behaviour can align through rule breaking can the accident or incident escape through the holes that would otherwise be blocked by suitable safety tools and behaviours being employed. It is often the case that several factors need to align in an incident to allow this to occur.

Reason continues; 'Effective risk management depends crucially on establishing a reporting culture. Without a detailed analysis of mishaps, incidents, near misses, and "free lessons," we have no way of uncovering recurrent error traps or of knowing where the "edge" is until we fall over it.

The complete absence of such a reporting culture within the Soviet Union contributed crucially to the Chernobyl disaster'

Accidents and incidents at Mindeli should not only to be reported, but also investigated. This is onerous, and from some people's perspective pointless and a waste of time. But how often do people say, 'I knew that was going to happen', or' that was bound to happen someday' after an event has occurred?

The table below details some of the systematic and behavioural issues that led to the explosions.

Table 1: Systematic and Behavioural Issues

Failure Mechanism	Failure Type
There was gas present, which was not detected or dealt with	Systems and Behaviour
There was a source of ignition	Systems and behaviour
The personnel were not in the correct position	Systems and behaviour
Trained people who should have recognized the hazards did not act appropriately	Systems and behaviour

If any one of these factors had been thwarted by the correct systems and behaviour being in place at that time on that shift, then the incidents may not have occurred, or if they had, may not have had such serious consequences. If the instruction to stop work because of the cavity had been applied, if the decision to not fire the shots had been taken, if the decision to not fire from the wrong place had been taken, then the explosion may not have occurred, or if it had, then possibly only property, and not lives, might have been lost.

4 IMPROVING RISK MANAGEMENT

Because two gas explosions have occurred recently at the mine, this should not confine management hazard recognition at Mindeli to risks surrounding explosions. The other hazards present at Mindeli are many and varied, witnessed by observations made during the underground visit.

It is the responsibility of Mindeli management to ensure that assessments are suitable and sufficient and consider all foreseeable issues pertaining to an activity, together with compliance with whatever regulatory burdens are placed upon them.

However, hazard recognition is not the whole story. There are two more stages to this process, and these stages are missing at Mindeli Mine.

Firstly, the rules must be taught to the people carrying them out, and probably more importantly, in complete agreement between both parties that they are workable and applicable- that they are practicable. The process of drawing up the rules at Mindeli should be an inclusive one, which caters not only for compliance with safety legislation but also allows the job to be carried out in the way described. This goes a long way towards ensuring that the rules are abided; there should be no reason not to if they are good rules. Bad rules are those that everyone knows are impracticable, and inevitably these will be ignored, and new ad-hoc ones put in place, with inevitable dire consequences.

The next stage is auditing. When a new set of rules is put into practice both parties need to be on site when the job is being carried out to ensure that unforeseen issues are catered for, to ensure that the process can be carried out both safely and efficiently. This is where the real art of management comes to the fore, using the knowledge and skill of all parties to devise a workable solution. This is still part of the planning stage.

Audit of the operations should not be a once only activity. Auditing of the work places should be frequent and continuous. Appendix 3 shows a suggested template for auditing mining activities . This is intended to prompt auditors to recognise deficiencies in existing systems, and a process to remedy these. It considers both system and human behaviour issues.

When a workable plan has formulated, agreed, seen to work, and accepted by all parties, then the next stage can be entered. The work can begin, with cycles of work being completed according to the planned system. Strict adherence to the plan should be monitored by the supervisors on site, and in turn reported accurately each shift that compliance is taking place.

Changes in circumstance may well raise new hazards, and the supervisors need to be very clear from management guidance the scope of their powers in addressing these new hazards. There should be a limit to the level of decision that can be made ‘on the spot’. This may call for a complete cessation of production until management can initiate a suitable and sufficient solution (outlined in the section ‘Traffic lights’ later in the report) The supervisor should not be in fear of reprisal for stopping the job in these circumstances; instead he should be praised and thanked for carrying out his job properly.

In addition to looking for changes in circumstances, whilst operations progress normally, audits checks of the process should continue to be made on site to ensure an overview of compliance with the prescribed process.

4.1 PLAN, DO, CHECK, ACT

This is the ‘Plan, Do, Check, Act’ process (Figure 2) Every single activity undertaken at Mindeli mine should follow this same process, so that systems of work are continuously being introduced and reviewed and updated as the work at the mine evolves. It incorporates consideration of both systems and human behavioural aspects of what can go wrong, and how they can be successfully addressed.

Figure 3 Plan, Do, Check, Act Continuous Improvement Cycle

- Safety Policy — Risk Assessment
- Planning — Organization
- Methods of Work — Supervision
- Methods of Work — Reporting
- Support rules etc. — Tool box talks
- Review performance — Audit
- Reassess the plan — Investigate accidents
- Worker consultation — Investigate incidents
- Learn from mistakes — Investigate near misses

For the process of Plan, Do, Check and Act to be effective, certain management operational and safety tools need to be established to complete each element of the process. These tools are what drives the process, and individually contribute to it. The diagram above demonstrates examples of the types of tools which contribute to each section of the process. The process should be continuous, and several rotations may be necessary when establishing a new system or project.

The tools incorporate operational and safety tools, demonstrating the link between the two. Safety should not be a separate subject, it should be like the veins in a body, running through each part, and integrating with each system.

Arguably the most important element of this process is the safety tool known as risk assessment (RA).

Risk assessment assesses the risk presented by the hazards recognised during the planning stage. Each possible risk is itemised, and the level of risk assessed as low, medium, or high dependent upon the potential to do harm. For each separate risk identified, measures that can be put in place to reduce the risk to an acceptable level must be identified.

4.2 'DRAW THE LINE'

The term to 'draw the line' is very pertinent to Mindeli's present situation. The term means 'to set a limit on what one is willing to do or accept'.

Mindeli stand on the brink of a turning point in its history. There is an opportunity to start afresh. However, the line must be drawn once and maintained, there can be no retreat from it, and no new line drawn for anyone's convenience. Everyone at the mine needs to understand where the line is drawn, and respect it.

In times of war men become 'battle hardened'. When their colleagues and friends are lost, that becomes accepted as part of war. The senses become numbed, and things that were never acceptable before become everyday. Mindeli is not at war, it is mining coal, and the line should be drawn appropriately. Men often see or hear of mining accidents and secretly believe that that could never happen to them. This is some kind of deluded defence barrier against the hazards that surround them. There should be no doubt in anyone's mind that it is perfectly possible for all personnel to perform their duties, and return home safe to their families when the shift ends.

4.3 TRAFFIC LIGHTS

Another process that needs to be established clearly is the limit of everyone's technical and decision-making capability. When a team of men is working several thousands of metres away from the surface, with no immediate management control, their actions are very much in their own hands. The culture that needs to be established at the mine is that the right way 'is the way we do things here'. The first line of defence against failure to act this way should be the supervisor immediately in charge of the operation.

To achieve this, the supervisor must be clear about his limitations regarding his reaction to changes in the environment. To this end, supervisors need to work to a 'traffic light' system. In this system, the supervisor is given clear guidance on what his actions should be in reaction to changes, as illustrated in the table below. This example is simplistic but appropriate to Mindeli faces. This can be elaborated, and is an example. This does not replace risk assessment. It is a type of risk assessment itself, and is provided to assist supervisors to understand what type of behaviour is expected of them.

The boards could easily be provided on the mine operational districts as a constant point of reference for supervisors. If people are not clearly told what is expected of them, how do they know what is management's expectation of them?

Table 2 Traffic Light System of Responsibility Level Recognition

Situation level	Change Criteria	Required reaction
Green	• No cavities • No gas • Ventilation normal	Continue working to the plan
Amber	• Roof becoming friable • Rise in methane • Blockage to proper ventilation	Take appropriate action within the rules to rectify the situation. If this escalates to a point not covered by rules move to the Red stage.
Red	• Gas levels at or> 1% • Cavity on face>0.3m • Ventilation derangement • No correct equipment	Stop the operation immediately. If appropriate, remove all personnel from danger, *and any other personnel in other areas that also might be affected*. Seek assistance from the next tier of supervision. If this is not available continue up the ladder of supervision until clear guidance on how to proceed is received.

5 RECENT FATAL ACCIDENTS

On 05 April 2018, on the back shift, the coal face was prepared for shot firing.

What the mine is reasonably confident of, from the position of the bodies of the men who lost their lives, is that none of the officials in charge of the district shift supervisors, and only one of the workmen in their charge withdrew to the correct position of safety (the firing station) as prescribed within the method of work drawn up by the mine team.

We do not know categorically from the subsequent investigation why the ignition of methane occurred. We only know that an ignition occurred somewhere inbye of where their bodies were found, and the direction in which the pressure wave travelled.

From evidence supplied by one survivor, who was the section chief, shift supervisor and was positioned close to the men who subsequently were killed, the fire chief decided to fire the round from a position much closer to the face than prescribed, and with workmen even further inbye of him, even nearer to the face.

The ventilation chief, whose duty it was to determine the methane content at the face before allowing shotfiring, was also killed, and was with to the fire chief at the time of the incident.

The significance of the supervisors' positioning, recognised during the subsequent investigation, was that there was an extensive cavity in the roof of the face adjacent to where the round of shots was fired. It was reasonably, but not conclusively, assumed that this was the area that contained the body of methane that exploded, the supervisors should have stopped production due to the presence of the cavity, according to the rules of the mine.

The cavity was reported to be 6m in height. The mine said that the probe provided for methane detection above the normal roof height were 3.5m fully extended.

The mine stated that they had provided all the officials a method statement (known at the mine as a 'passport') which included an instruction that in these conditions, the rule was to seal off the affected area with air tight seals, and subsequently inject the whole area remotely using the sand slurry piped into the mine for this purpose.

There is also a theory at the mine that a/ some shot hole/s were not correctly stemmed to the correct depth using the prescribed material. It was speculated that this could have allowed the shot/s to backfire, igniting an accumulation of gas. It was reported that there was not a coal dust explosion.

On 16 June 2018, again on the back shift, the coal face was drilled and the shot holes charged ready to fire.

As was the case in the first incident, the position of the men, who lost their lives in the explosion, shows clearly that the fire chief and all the rest of the men and officials from the face, and those working in the adjacent development heading, all failed to withdraw to the prescribed place of safety to fire the round, that is, the shotfiring station.

The investigation concluded that an ignition of methane originated from the point at which the round of shots was fired, but unlike the first incident, the pressure wave of the explosion could pass both ways along the intake and return roadways. It appears to be only due to fortune that the fatality count was not higher. Again, it is reported that there was not a coal dust explosion.

Again, the fire chief had positioned himself just outbye of the face, and again was one of the deceased.

Much was made of the fact that experienced men numbers were on the decline at the mine, and this was put forward to DMT as one possible reason that accidents were happening. But the fire chief was around 60 years of age, and experienced, so this does not seem to hold true. In addition, the leading workman, who was over 50 years of age, was also killed by the blast. The leading workman's position description, DMT were told, includes carrying out audits on the face to ensure compliance with all the rules.

The fact that the mine suffered a second explosion at the mine within months of the first is cause enough for concern, but that the fact that the circumstances were so similar is of note. Obviously, the hard lessons learned in the first event were not taken on board, at least by the fire chief, who once again put himself directly in the line of fire.

This may also beg the question of how well the details were communicated following the first disaster, and new knowledge embedded in the rest of the mine.

Discussion with management revealed that the incident plan might not be accurate in one respect, that a cavity adjacent to the position of the round of shots was present at the time of the explosion.

5.1 CONCLUSIONS SPECIFIC TO INCIDENTS

The incidents shared many similar factors. There were several failures that led to the incidents;

Primary Causation:

- There was gas present in the area in which the round of shots was fired which was sufficient in volume and concentration to be ignited and then explode.
- The fact that the explosions occurred when the round of shots was fired would on balance of the evidence indicate that shot firing was the source of the ignition of the body of methane.

Secondary Causation:

- The presence (or possible presence) of the cavity and the hazards that it represented were, for some reason or reasons, either not recognised or ignored.

- The rules about where to withdraw all personnel to, and where to fire the round from, were ignored for some reason or reasons.

Further Possible Causation

- The rules were general, leaving the decision to be made by the officials open to their interpretation of them. Also, the mine did not recognise the potential to circumvent the rules and did not ensure their correct application through suitable auditing by suitably trained, qualified and authorised persons.
- The procedure at the mine does not include suitable arrangements for the cleaning out of coal debris (dust) or for the checking for breaks within the length of the open shot hole, or for the detection of methane that might be present in it. This might mean that methane feeders could lead to a body of gas in the coal large enough, and of sufficient percentage by volume to cause the explosions.
- The colliery supervisors and workmen were predominantly from a close-knit community in the immediate location of the mine. It could reasonably be surmised that there might be an element of peer pressure when supervisors make decisions, which will directly affect the earning, potential of face workers.
- Basic calculations of estimated cycle time and production available time supplied by the mine indicated that there was a negative variation between targeted and the potential tonnage.

5.2 RECOMMENDATIONS SPECIFIC TO INCIDENTS

- The provisions for the detection of methane need to be more extensive and more rigorous. Better arrangements are required to facilitate the detection of gas, by introduction of simple practical ways of sampling difficult to reach areas, such as cavities, longer probes for example.
- It is not sufficient for the mine to tell people that if there is a cavity then to seal the face off. This is too simplistic, and leads to confused decision making on the job. What is the definition of a cavity?
- Particularly in the case of an open shot hole prior to charging, there is a need to remove the debris in the hole using a specified tool provided for this purpose. Any breaks in strata within the shot hole need to be detected, again with a specified tool, and potential methane feeders in the hole detected through this and by measurement of methane percentage by volume within the hole, and the rules need to make suitable and sufficient provisions for these factors.
- Particularly in the case of cavities, the mine has two options. Either, abandon the area, and ensure that the rules leave no room for speculation and are rigorously applied, or fill the cavity in such a way that methane is not present, and continue mining. Materials and techniques exist and are commonly used throughout the world that can perform this task efficiently to allow rapid continuation of production. These techniques might be considered impracticable when a financial appraisal of the benefits gained against the cost incurred is made.

- As there have been two ignitions of methane associated with shotfiring activities, in a very short interval, the question of what has changed in recent times should be investigated? Has the nature or quality of the coal changed as the mine has progressed? Has the methane content increased? To examine these potential variables a scientific audit of these factors should form a substantial part of the recognition of hazards whenever the mine is forming a new coal face area. This audit should recognise all the hazards involved before production commences, and these should be repeated on each occasion, to replace the 'rubber stamp' approach to passports. They should be site specific, and consider all the hazards specific to that area.
- The chip system (which is still not yet fully rolled out) for the continuous detection of the position of all personnel in the mine could be a very good tool in helping ensure that personnel remove themselves to the safety of the shotfiring station before rounds are fired. However, there is presently potential to circumvent the system. Figure 4 shows the chip housing fitted to all cap lamp cables, and the way that it is secured. It only requires a standard star key to remove this device. Once removed the position of the person is whatever the chip indicates, and may not represent their true location. A means of locating and securing a tamperproof system must be found, and discussion with the chip system manufacturer's representative on site indicated that this would be possible in several ways, offering more security against tampering. This would be an example of 'thinking beyond the fix'.

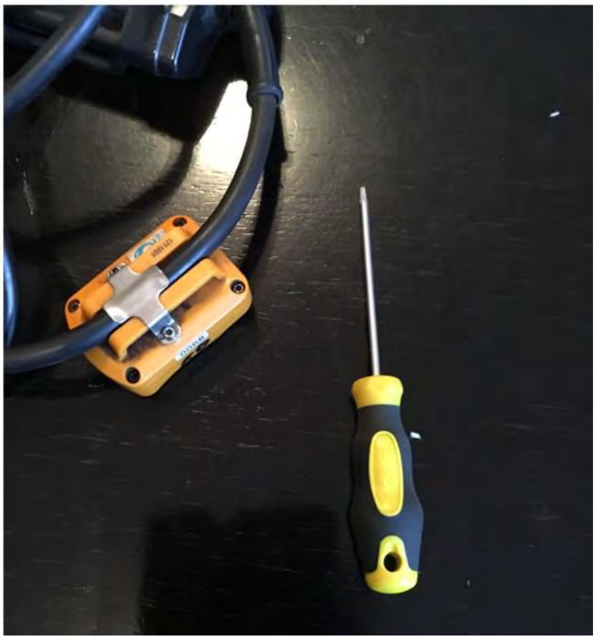

Figure 4 Personnel Position Chip System and Removal Tool

- Another example of neglecting to think beyond the fix, is the use of two types of explosives employed at the mine. The mine team are very clear that the two types exist to be used in two very different applications at the mine, namely in stone, and in coal. The coal explosive is very much 'weaker' than that used in stone, because of the relative volatility of the explosives. Using the coal explosive in stone would not likely be successful. Using the stone explosive in coal would potentially result in a disaster in terms of fire and explosion. It would however, if misguidedly used in coal, have a much more destructive effect. The rules of the mine should be such that it is impossible for the wrong type of explosive to be used in coal. Given that the accidents both occurred on back shifts (when senior management presence is not apparent?) it was suggested to DMT that the reason for people making mistakes might be attributable to some physiological problem due to broken sleep patterns. This is not without merit. It is may also be that the common factor is that there is not the same amount of oversight on those shifts. To facilitate better oversight of 'backshifts' the management team should either be augmented by additional personnel, or, through reorganisation of the existing structure, better control operations on those shifts.

- A review of cycle time should be undertaken, to ascertain if the planned tonnage from each unit could be achieved within the available time. This assessment should include allowances for all delays and breaks in order to realistically evaluate if the cycle can be carried out in the correct way and repeated often enough in the time available to achieve the planned tonnage. Otherwise it might be the case that the reason people at Mindeli are taking short cuts (for example, not withdrawing correctly) is that they feel, for whatever reason, that they are achieving better effectiveness in an unacceptable manner.
- Perhaps the only fortunate factor of the incident was that the explosion did not propagate a coal dust explosion. The mine is adamant that amount of coal dust on the roof sides and walls of roadways is kept to an acceptable amount by regularly washing down the walls with mine water. When questioned, the mine agreed that there was no specific scheme to cover this hazard prevention operation. So it is not certain that this procedure is adequate. This should be rectified immediately, and a suitable scheme put in place to cover the schedule, monitor the compliance, and ensure its adequacy through reporting and auditing. Auditing should consist of regularly collecting samples of the dust present from the roof, sides and floor of each zone of the mine on a continuous basis, and in this way constantly monitoring the validity of the scheme. An alternative method widely used in coal mining throughout the world is to spread non-toxic, inert stone dust onto the surfaces of the roadway, reducing the incendive content of the dust there to an acceptable level. This would be of the order of 80% non-combustible dust in any sample taken to audit the system.
- The mine employs water bag barriers as a defence against explosions of methane and coal dust. Whilst these are effective, they should only be used as a 'last resort' measure to contain an explosion.
- The diagrams produced after the first explosion shows that the pressure wave front reached the designated position of the shotfiring station. If this is correct it may be necessary to review the location that men should withdraw to, in order to fire shots on the coal face.
- During the discussions there was some confusion over the accuracy of the incident drawings, particularly with respect to the alleged presence of a roof cavity at the point of the explosion ignition. In such serious circumstances such an important detail cannot be omitted, and this must not be allowed to continue in any accident reporting, since the main objective of any investigation is to ascertain the root cause of the incident, so that it can be eliminated by further actions, thereby eliminating repeat incidents.

- Any of the inclined openings has men riding arrangements in place. Installing of those arrangements (e.g. chair lifts, pull ropes, etc.) will save workers' time and effort to move to the safe place when blasting.

All the above practical recommendations are relatively simple to introduce. They will inevitably incur cost. Little will be achieved if there is no financial support for all these schemes. However, far more difficult to address are the issues of human factors. No matter how many rules are put in place, if the risk acceptance level of the mine and all associated with it continue as they were when the mine presumably reopens, then more incidents will follow, because people will continue to take risks, for their own reasons. This cannot be allowed to happen. The fact that both shot firers were killed in separate incidents and their, and several workmen's positions, when they died, strongly suggests that the culture of rule breaking was strong amongst the supervisors, and the workmen. When the mine restarts for production, when all the recommendations have been addressed, there will need to be a period of intense supervision. Obviously, the current level of supervision of the activities has been insufficient for safe operation. For this reason, an additional layer of supervision will need to be put into place for an extended and open - ended period. This level of supervision must be technically competent, suitably qualified, and perhaps above all, immune to peer pressure. They must be supported in their decisions from the highest possible authority, and supported by whatever external services are available. They must be allowed to be immune from internal and external pressures to break rules, and want to achieve the target, because after all this is the point of the exercise in the first instance. To manage this balancing act, they need to be trained and have accredited competence as well as supported, particularly in hazard recognition and the assessment of the level of risk that these hazards represent, and they must be able to put actions in place to reduce the risk to an acceptable and safe level. Above all, they must be on site, next time the exploder button is pressed. The additional level of supervision should be the Management team.

6 ACCIDENT AND INCIDENT INVESTIGATION

The only benefit that can emerge from any accident or incident is a determination that arrangements will be put into place so that they will not be repeated in the future, and that the pain and suffering experienced by those involved will not be visited on anyone else. This is a duty of all people at all levels.

It is not possible to avoid incidents and accidents in a reactive way for events that never really took place. By this it is meant that any investigations into such events at Mindeli must unearth the most likely causation of them. Some conclusions will be straightforward and obvious, and others will be identified on the balance of evidence. Because of this, the people investigating the events must be selected for their experience, knowledge, and determination to get to the 'root cause'.

This term 'the root cause' involves finding the real reason for an accident or incident. For example, if a man is reported to have a twisted ankle, then a simple overview of the accident might conclude that he was clumsy. The accident is not life threatening, and on the face of it seems fairly straight - forward. However, during questioning the man about how his injury occurred, it transpires that he was cutting a board to use as a platform to stand on to allow him to set a support arch at the face of a development heading. He was making this as there was no purpose designed platform available on site, and so he was forced to use his discretion and make a platform which was supported at one end by the coal face, and the other on the pipe range. During this work he slipped off a board and fell around 1.5m. Fortunately, the steel conveyor beneath the makeshift platform was not running at the time, and he fell onto this, twisting his ankle in the process.

Such an investigation opens up information about the way in which this particular work was being done. From a 'clumsy' accident it has now been detected that there are issues of supervision, working at height, temporary support, provision of equipment, lack of planning and risk assessment, training, working in confined spaces, personal positioning, and isolation of equipment. All these issues would have been recognised had the job been correctly planned, and the accident could have been avoided.

Of course, if the man said instead that he had merely tripped, then the person investigating has a more difficult task, because if he suspects from the man's answers and body language and his own experience that this was not the case, then his questions must be devised to arrive at the real cause. In addition, if there are witness statements for the accident and a supervisor's report these will all have to correspond to confirm or deny his story.

Gathering statistical information about accidents and incidents is also important. Trends in types of accidents can provoke the mine team into introducing new or improved safeguards. For example, if all accidents were being properly reported and investigated, then the numbers of say hand injuries might lead to a decision to make the wearing of gloves mandatory. If the evidence is not available, then how can the team convince the supervisor (spoken to by DMT) that he should wear gloves, when he is adamant that he just cannot 'get on' with wearing them? This should not be his decision; it is that of the Manager what PPE people wear. The supervisor is sending a message to the workmen, 'we shouldn't need to wear gloves if we don't want to'. But if statistics and good sense show that he should wear them that is the Managers decision. After all it will be the Manager, and not the man, who is blamed if the man has an infected injury, and loses his hand because he was not made to wear appropriate PPE.

Discussing hand injuries in such depth may seem frivolous to some people, when there are a lot more hazardous issues in mining than a cut hand. But it is at this level of consideration where the bedrock of the safety management process at Mindeli should be based. A zero tolerance attitude to unsafe acts and behaviour would ensure that hand injuries are kept to a minimum. Statistically, for every several hundreds of unsafe acts and minor accidents there will be a more serious, or even worse, outcome to an accident or incident.

As far back as 1931, Herbert William Heinrich, an assistant superintendent in the engineering and inspection division of Travelers Insurance Co. in Hartford, CT, proposed from statistical evidence of real world accidents, that there was a relationship between the number of unsafe acts, and the number of fatalities suffered in an organization; he constructed the 'accident triangle' shown in Figure 5.

What this is meant to demonstrate is the precept above, that for any given number of accidents and injuries and unsafe acts there will be a less but worrying number of 'near misses', and eventually all these will result in the ultimate failure of the management process, a fatality. If this precept is accepted, then an uncomfortable conclusion arises with respect to Mindeli's situation;

'How many unsafe acts were undertaken at Mindeli to reach the stage where so many lives were lost?'

Of course the people and the Government recognised this, and that is why the production at the mine had been halted for some seven months, but consideration of Heinrich's proposal would indicate that there were a staggering number of unsafe acts undertaken prior to, and during, the terrible events of 2018, and this is why it is vitally important to imbue a reporting, and investigative, culture at Mindeli with respect to accidents and incidents.

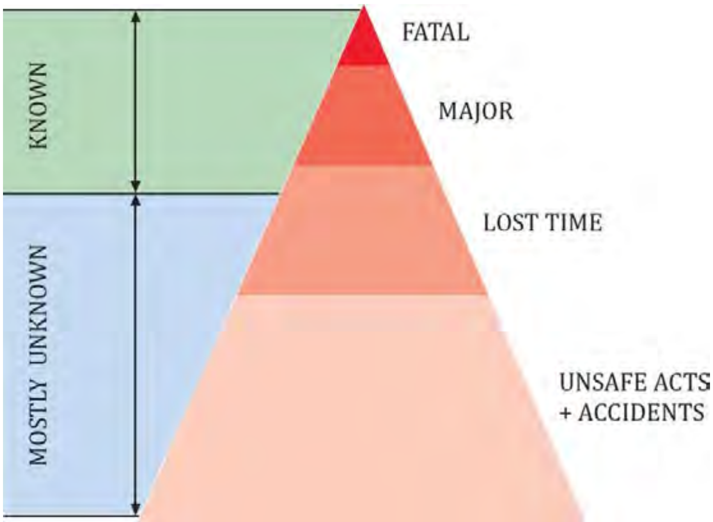

Figure 5 Heinrich Triangle

The tables below, supplied to DMT by the mine show the numbers of 'light, severe, and fatal accidents for a 12 years' period from 2007 to the present day

Table 3 Accidents by Reason

Factors	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Roof Falls & Similar			5	1	4	1	4			1	3	3
Equipment & Mechanism	1	1		4		4	5	4	4	3	6	5
Men falling		1				2	2				3	
Falling of things												
Electrical	1											
Explosions				15	6	2	1	6	1	1		19
Other		1					1	2		2	1	
TOTAL	2	3	5	20	10	9	13	12	5	7	13	27

Table 4 Accidents by Severity

Year	total	light	severe	fatal
2007	2	1	0	1
2008	3	2	1	0
2009	5	3	1	1
2010	20	2	10	8
2011	10	10	4	5
2012	9	3	6	0
2013	13	2	9	2

Year	total	light	severe	fatal
2014	12	4	6	2
2015	5	3	1	1
2016	7	6	0	1
2017	13	7	0	6
2018	27	14	3	10

6.1 ANALYSIS OF ACCIDENT RECORDS PROVIDED

In the 12-year period recorded, there have been a total of 37 fatalities at Mindeli.

In total, there have reportedly been a total of 126 light, severe, and fatal accidents at the mine.

If correct, this would indicate a percentage of fatal accidents of the whole number of accidents of 29%. This would mean that the chances of an accident resulting in a fatality was just over 1 in every 3 accidents. This cannot possibly be the case.

Regarding Heinrich's triangle; thousands of unsafe acts and minor accidents occur for every single fatal accident.

What the records demonstrate is that there is not a robust accident reporting process at the mine. Presumably fatal accidents, and some of the major accident data will be correct. These are events which cannot go unnoticed. In contrast, the evidence from the lower impact accidents is simply being missed. This has the effect of skewing the statistics. It also makes any analysis of causes and effects virtually impossible. The purpose of gathering substantial evidence about accidents is to allow the management team to start to predict where attention should be concentrated with respect to types of accident and occupation, and even geographical area. Without this information, no such proactive work can take place, and any response to accidents and incidents will be reactive at best.

6.2 NEAR MISSES

Many people drive on the roads. Those that do, or those who have been a passenger in a vehicle, are well aware of what is meant by the term 'a near miss'. The kind of event that has you crawling up the back of your seat when you see what is happening immediately in front of you; then in an instant the danger is passed, and relief takes over, and the incident quickly forgotten. That is a near miss.

The benefit of recognising, and not forgetting, near misses is twofold; first it reveals to the observer what might have happened, but fortunately didn't; and second it allows us to take this new found knowledge and use it to prevent it happening again, instead of causing an actual accident.

People investigating accidents and incidents should always be open to the possibility that a particular injury might have led to a much more serious outcome.

Consider the example used earlier of the man who sprained his ankle after falling from his 'home made' platform. If the accident had not been as simple as it turned out, there could easily have been more dire consequences. The man could have fallen onto a moving conveyor, he could have lost his grip on the steel section arch and injured his colleagues in the process, he could have deranged the ventilation to the adjacent workings by knocking down and parting the auxiliary ventilation ducting, he could have fallen on his head and had a far more serious accident. In the event, he had a sprained ankle, which, if left unreported would not have been investigated, and the hazards would not have been flagged, and the near miss, which next time could result in a fatal accident, would have been quickly forgotten. This would be waste of valuable information.

7 H&S RESPONSIBILITIES AND STRUCTURE

Unfortunately a comprehensive outline of the H&S responsibilities of management at Mindeli Mine and the administration of these responsibilities was not available in English to DMT. This section of the report will concentrate on the fundamentals of what should be considered as a minimum to ensure the safe operation of all activities.

7.1 INTRODUCTION

DMT were given to understand that the extent of H&S legislation has limited scope under Georgian Law at the present time. This is not available to DMT in English, however, this does not exempt the company from legal and moral responsibility to their employees, as evidenced by recent events.

To protect personnel from harm, and secure the success of the business, a management safety process must be in place, which is demonstrably maintained, and practiced.

Responsibility for H&S at Mindeli should belong to each individual; for their own, and each other's safety and welfare. In the UK, all employees have a legal obligation under the 'Health and Safety at Work etc. Act, 1974' (HASAWA) to "take reasonable care for the health and safety of himself and of other persons who may be affected by his acts or omissions at work"

In the UK, this obligation to safety on the employee does not detract from the employers duty to "ensure, so far as is reasonably practical, the health, safety and welfare of all his employees" HASAWA continues to specify the extent of the employer's duty, in terms of maintenance of equipment and systems of work, risks associated with handling, storage, and transport, together with those involved in information, instruction, training, supervision, and the provision of a safe working environment. This is in addition to specific legislation pertaining to mining.

HASAWA is not specific to only mining in the UK. It caters for all types of workplaces, and the types of issues that Mindeli has been having difficulty embedding. These issues are therefore not unique to Mindeli, and by following prescribed processes, Mindeli can operate more safely.

It should be clear that DMT are not suggesting a wholesale adoption of all this legislation. The intention is to illustrate the need for a framework policy, which at the very least complies with the minimum acceptable arrangements necessary for the safe operation of the mine, to protect personnel from harm, and also to protect the business. Nothing should prevent anyone at Mindeli from improving on this minimum requirement when they see the need.

7.2 CONTROL OF RISKS IN THE BUSINESS

The first step is to create a Health and Safety Policy Document for Mindeli, which not only tells all employees and others about the commitment of the company to H&S (the Policy Statement), it also sets out clearly who in the company is responsible for what, and how they are to address those responsibilities.

The structure should be audited to determine how best to organise the management team to mirror the requirements of the H&S Policy Document. For example, the areas of responsibility for the mine can be split geographically, or by activity, dependent on which suits the business best. How the various functions, such as mechanical and electrical engineering fit into this must also be reviewed to ensure that all parts of the mine, and all activities are fully addressed, and that there are no areas for which there is either overlap, or gapping in the administration. Overlaps can result in confusion, or at worst neglect, as is the case with gaps.

Position descriptions, like those already seen by DMT Mindeli, must be tailored to comply with each position in the structure. The role of each position must also define the requirements placed upon it to provide the guidance necessary for the execution of all activities within the scope of the position. This requires a two-way process to be described in the policy document between the Operations and Service functions.

The Health and Safety Policy will only be effective if it is applied rigorously, and is regularly reviewed on at least an annual, or requirements basis (i.e. In the event of significant change).

The owner of the company should appoint a competent person to assist them in meeting their H&S duties. Competence would require suitable qualification, experience, and capability to be able to perform the role adequately.

It is not practicably possible to remove all risk. Risks in mining are common, and Mindeli is no exception. Every mine in the world has risks specific to it. There is no such thing as 'an easy' mine. Mindeli is not unique in this respect; it simply has a unique set of problems, as do all mines. Once this axiom has been accepted, the Mindeli can set to work sorting out their H&S issues, and determine what measures need to be put in place to control the risks.

For every activity undertaken at Mindeli, the management team must determine what might cause harm to people, and what steps need to be taken to reduce these hazards. This is known as Risk Assessment (RA). UK law (Management of Health and Safety at Work Regulations 1999) demands that suitable and sufficient numbers of risk assessments are performed in the workplace by suitable numbers of suitably trained people.

Figure 6 shows an extract of the management organogram provided to DMT by Mindeli, detailing the Safety Director's department. DMT agrees that the specialist functions suitable to the director carrying out his role efficiently are within his jurisdiction.

What is of concern, however, to DMT is that it was perceived that these Service functions might appear be operating exclusively and separately from the Operational Workstream in the formulation and provision of 'Methods of Work', (MOW). DMT is also concerned that auditing by any Service or Operational function is not sufficient to ensure compliance even with existing company rules.

The Safety Department should act as the 'policemen' of the H&S system, ensuring that current MOW's and risk assessments (RA) are in place and understood, but not necessarily providing all the documents themselves. The people who should provide them are the Operations Managers, who have intimate knowledge of what the tasks are, and how they expect the jobs to be performed.

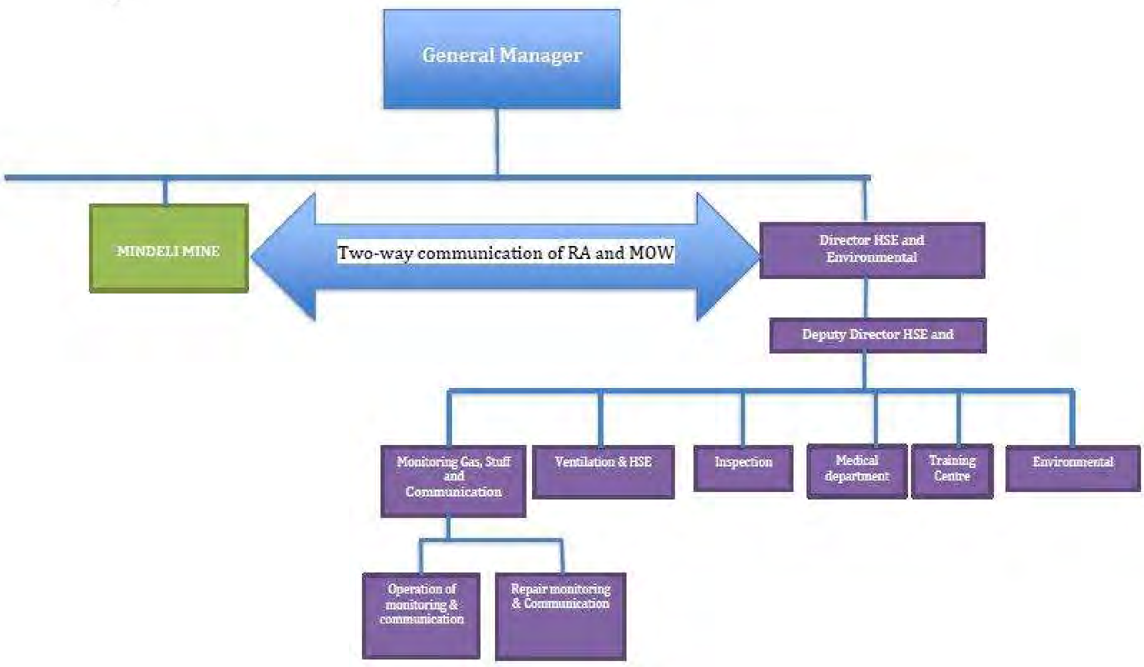

Figure 6 Management Organogram

The Safety function should assist and advise, but should not have the responsibility of provision of these documents, instead they should audit, and report as such in the event of the absence of documents.

The process of developing the documents should be an inclusive one. The people carrying out the work should have input into the final guidance. This can be facilitated more easily by the operational functions that have daily contact with the workforce.

More formal consultation with the workforce is necessary to properly create an inclusive forum about H&S. In this forum, the management team can listen to the workforce representative's thoughts about the H&S content of the work that they do, how risks are controlled, the best ways of supplying training and information to them, and provide feedback on the successes and failures of the H&S measures at Mindeli. Such consultation needs to be a two-way process allowing management and the workforce (including supervisors) to raise concerns and help form H&S management decisions.

The supervisors and the workforce are inextricably connected with the everyday operations at Mindeli, and can be a vast resource of knowledge if consulted correctly, allowing this knowledge to enhance the decision-making process, and to demonstrate to all employees that H&S is now a major function at Mindeli, which runs throughout every aspect of all operations there.

7.3 TRAINING AND INFORMATION

It should be self-evident that the purpose of creating a framework for safety management, which includes documents prescribing the way in which the work is to be achieved, should be fully understood and accepted by the people carrying out the work.

Training of personnel in H&S management is dealt with in detail elsewhere in this report.

The flow of Information is paramount in 'getting the message across'. Visual displays are in use in the entrance concourse at Mindeli, showing employees messages that the management team wishes to advertise. This is good, and needs to be refreshed regularly so that the message does not become stale.

Lots of signage was seen by DMT particularly underground, and this needs to be maintained and more importantly to be enforced for it to have effect.

The mannequin showcase in the concourse also provides a visual display of the personal protective equipment that management expects all employees to use. Unfortunately, in DMT's opinion, it does not fully demonstrate that this is the result of a thorough risk assessment of the hazards at the mine. There are no eye, hearing, or hand protection components that such a RA would demand. This point is fundamental to the safety of Mindeli; not until everyone working at Mindeli recognises the significance of these omissions will the people of Mindeli move onto addressing the other fundamental shortfalls in hazard recognition at their workplace.

Through these very public omissions in hazard recognition, the management is displaying to the workforce, and the world in general, that a suitable and sufficient risk assessment has not been performed for the most fundamental and visual requirement at the mine.

7.4 ARRANGEMENTS FOR EMERGENCY, FIRST AID, AND ACCIDENTS

Given the lack of sufficient information regarding accident statistics, DMT is unable to provide any assessment of the factors involved in the accidents that will likely be happening at the mine. DMT has only seen the headlines of such a report, which shows that there have only been two fatality free years at Mindeli since the mine re started in 2007, with several years including multiple fatalities.

Reporting and recording of accidents is of prime importance to the management's understanding of why and how accidents are happening, so that they can be prevented. The best ways in which this information can be gathered and analysed is through supervisors' reporting, and by people attending the medical facilities for first aid. People should be encouraged to seek first aid, and there should be no stigma attached to this.

When emergencies have occurred there has been need for the support of external emergency services, and mine personnel have supplied immediate support for victims of incidents. Best practice in emergency organisation makes arrangements for part time teams of rescue personnel to be included in each shift that the mine operates who are fully trained in all aspects of rescue, and augment permanent emergency services in the event of an incident. In normal times these people will be part of normal operating teams of men.

The mine should have a clearly defined emergency plan, and this should make arrangements for the prompt evacuation of all personnel from the mine, the assistance of personnel affected, and the control of the possible types of emergency that the mine may face. These arrangements would be drawn from recognition of the hazards that are foreseeable, and the assessment of the risk of them. The risk assessment will form the basis from which the suitable arrangements for the emergency procedure are based.

Best practice also requires that sufficient numbers of personnel trained in first aid should be present in the mine on every shift. The simple way to comply with this is to train all supervisors accordingly, and any other numbers of workmen required by such a scheme. The mine should also have arrangements in place for the swift evacuation of injured personnel, and their treatment during extraction.

8 HEALTH AND SAFETY TRAINING AT MINDELI

The training function at Mindeli should follow a process that can be separated into five steps. The main aspects of the audit are:

- Allocate responsibility for organizing Mindeli's training scheme;
- Identify who should be included in the scheme;
- Identify what training is required to fully serve Mindeli's requirements;
- Determine how to execute the training scheme; and
- Audit the effectiveness and review the requirements of the training scheme.

8.1 RESPONSIBILITY FOR H&S AT MINDELI

Responsibility for H&S at Mindeli is not the sole jurisdiction of the Safety Director, or his department. Ultimate responsibility for safety lies with the directing mind of the company, but it is difficult for this directing mind to control the actions of a person performing an unsafe act, thousands of metres away, underground, in the middle of the night. It is almost impossible to control the spontaneous wrong-doings of all individuals, what can be done is to create a culture and control measures that do not engender unsafe acts, and actively prevents them through the right kind of peer pressure and management process.

When the shotfirers involved with both explosions took the steps that ultimately led to their demise, they blatantly disregarded their training, for their own reasons. If a rigorous 'training needs' audit had been carried out of the shotfiring procedure, this could potentially have revealed a need for wholesale retraining at Mindeli.

The Safety Director and his department must be the policemen of the H&S system,

Actively seeking out and advising on best practice, casting a global eye over other mining and similar process industries with common issues. The Safety Department must monitor all the normal environmental and H&S aspects, but also actively seek out alternative solutions and best practice external to the mine.

H&S training is not a disparate subject. H&S training is an integral part of the universal training programme that should be embedded at the mine, as there are safety aspects in all subjects that are trained. Training per se and H&S training should not be separated into finite areas. It is more appropriate to ensure that 'Training' includes all H&S aspects of the subject being taught.

When the face supervisor told DMT that there was no firefighting equipment on the face, this could not feasibly have been in compliance with the firefighting training that someone in his position should have been given. Firefighting is standard training in all walks of industry, the lack of realisation that the absence of such essential equipment was a hazard demonstrates that H&S training cannot be segregated into a separate subject.

It is appropriate that training should fall within the Safety Director's department at Mindeli, to ensure effective identification of safety training needs, and the fulfilment of these needs through suitable training packages, to fully assist Management in ensuring that Mindeli is a safe place to work.

8.2 WHY PEOPLE SHOULD BE TRAINED IN H&S AT MINDELI

If a company does not train its workforce, then the company cannot reasonably expect the work-force to know how the company wants them to act and operate at work.

People who are new to a job or industry need to be taught the basics correctly, without any ambi-guity. There should be no grey areas, because shortfalls in communication, and ambiguous guid-ance at this stage can result in long-term wrong actions.

If a recruit to mining were to be placed with a team of men at Mindeli, would they previously have encouraged him or her to work in the way that their training dictated, or in the way into which the team had slipped in the absence of refresher training, and audit?

Experienced workers require a different approach, although the principles of accuracy remain. Normally, during their training, experienced workers are being reminded of the way in which the corporate body requires them to work, and 'refresher training' is an opportunity to further embed the right ways of thinking, and right any wrongs which may have inadvertently been committed in the past.

Training experienced people in something new is a combination of the two, and will probably be more of a two-way discussion between the trainer and the trainees. In Mindeli's case it is proposed to achieve something different from the norm. It is proposed to teach experienced workers to stop working in the way that they did before, which was previously accepted at the mine, and to adopt totally new ways of working. This is a challenging, but not impossible, task.

Being experienced may mean that the workforce at all levels is likely to be less open to new ideas. They may be resentful that anyone would think that they do not understand how they are expected to do the job that they have been doing for several, possibly many, years. For this reason, the trainers must be given the tools to convince people from the start that there really is a correct way to do things, and that is the way at Mindeli. The trainers need to impress upon them that there is a need to change, and conquer the hearts and minds of their audience as quickly as possible. Groundwork should be done previously to the onset of training and during DMT's proposed first week of introductory outlines of the 'Company Safety Policy' and 'The Way Forward'.

It is not sufficient to start training for re starting production without a well-planned schedule. The trainers will need to know the best way in which to carry out their task. The schedule will be based upon the need for training, and this will be identified, as discussed later, from several sources.

Training should not only be limited to the classroom, and trainers need to visit trainees in their working environment to continue to embed the right way of thinking (according to the companies wishes) In Mindeli's case, on site assessment will be integral to re starting the mine.

8.3 PERSONNEL REQUIRED TRAINING IN H&S AT MINDELI

The answer to the question, ‘who needs training at Mindeli?’ question is simple, but far reaching; everyone at Mindeli should be re trained, from the top to the bottom, to some extent or other. How to identify this is again discussed later.

The section of this report dealing with ‘The route back to the face’ suggests a route map for re starting production at Mindeli. The main tenet of this discussion is around how to ensure that one operation starts safely and methodically without further incident, and how to roll this process out to the remainder of the operations.

The Management team must shoulder the responsibility and the burden of this task. But how can everyone be sure that these people have the tools and the skills to take on this enormous challenge? The answer is that they must be trained to ensure that they do. These are highly skilled individuals, experts and they are being challenged to take on a new role, leading the rest of the workforce down a new and so far, untrodden path.

The Management team needs to learn new skills, principally in hazard recognition, and in assessment of the risk of these hazards. They may well be quite aware of many of these hazards, but lack the tools or the time to do something about them. They must learn a new way of managing. If some of the existing management prove themselves unable, or unwilling, to undertake this transformation, then they will have to be replaced by others that are able and willing.

There is also a training requirement for the management team in Performance Analysis. The Management team could not demonstrate to DMT that they had knowledge of the time that it takes to complete a cycle of work in an operation. The reason why this could present a safety issue is; without this knowledge the number of cycles achievable in a given time cannot be assessed, and so targets may be too high (or low) resulting in an unrealistic expectation of the outcome of an operation. This might have the result of operators taking ‘short cuts’. Mining is a process industry, and the outcome of the process will inevitably depend on how many cycles can be completed within the available time.

Hazard recognition can in turn be passed on to the supervisors and workforce both through retraining, and by example from the management team. The ideal opportunity to demonstrate a determination to change will come through the initial steps taken to re start the first production face, when everyone at the mine will see the Management team’s determination to provide a solution to their issues and problems, through an inclusive way of retraining an experienced workforce. Not just talking at them, but discussing and arguing about ways in which the job can be done safely and efficiently, or not at all until it can be done safely. This combined wealth of experience can formulate a solution if the need is great enough, and there will never be a greater need than at present.

The supervisors and workmen need to understand the company Health and Safety Policy, and how they contribute to it, and how H&S will be managed, together with specific training in the hazards at Mindeli, and how the Management team intend to control those hazards.

8.4 THE PROCESS OF TRAINING PEOPLE AT MINDELI

Having demonstrated the commitment of Management in the ways described, people at the mine should start to appreciate that training is important; not a paper exercise, not a back-covering activity, but an integral part of the safety and health, and wealth of Mindeli.

DMT's recommendation is to recruit a high profile individual, expert in training, as Training Development Manager, on an interim basis until all interested parties are convinced that the training function is properly established and can maintain its momentum.

Gap analysis should identify what skills the business needs compared with what it already has, and a training program set out that closes this gap in an efficient and timely fashion.

Training operates in a similar way to a computer. If the information input is flawed, then the resultant output will also be flawed. The people providing the training would preferably have mining experience, and understand their subject, but they are not likely to be experts in mining, electrical and mechanical engineering. The people who run the mine, the Management team, are the people who must provide the information that is to be taught by the people who are expert in teaching. In this way, the Management team should achieve their goal of having a skilled workforce with the knowledge of all aspects of mining that the Management require to manage the mine safely and efficiently. The provision of this quality information from the Management team may also raise a training issue in itself.

Importantly, the process of training should be an inclusive one. Workmen's representatives should take part in the discussions about, and formation of, the training roll out. This ensures that various factions are confident that their concerns have been represented in the formation of the program. If a person helps to create a rule they are far more likely to adopt and follow it than if it is just handed to them without consultation.

DMT observed 'home made' tools at a trunk roadway junction transport track turning, The workmen involved with this know intimately the problems associated with navigating this bend, and the ways in which they can be overcome. If these systems can be included in a safe scheme of work, which is then taught to all transport workers, the problems have been solved in such a way that no one needs to 'ad lib' processes because the official process is 'fit for purpose'.

The haulage system installed at the entrance to the face access roads showed evidence of misuse of the system, and also had potential for further misuse in getting heavy materials from the main track onto the rope haulage system. The people who work there have invented their own 'coping' scheme of work. If the problems can be engineered out and a proper scheme of work introduced, and included in the relevant training schedule, this should again remove the need to vary from the official method of work.

The workforce is a huge resource of often untapped knowledge about how things really operate underground, and if this resource is tapped and used to create safe workable systems of work, the need to commit unsafe acts diminishes as quickly as they are replaced by good management process, and become part of the basic training scheme for the people working on the relevant activities.

The risk assessments created to deal with the hazards identified in each operation will also guide identification of training needs.

In both the incidents in 2018, several layers of hazard reduction could have prevented the tragic outcomes. Obviously, the ignition of the methane could have been avoided by not firing the round of shots in the presence of the gas. But if something unforeseeable had caused the explosion, despite all the recommended checks and inspections, 'thinking beyond the fix' would include safeguards such as observation of exclusion zones, and explosion barriers situated in suitable positions. The DMT ventilation report about Mindeli is critical of the sporadic use of these barriers. Barriers have been proven in theory and in practice to do their intended job in the event of an explosion. A thorough risk assessment of these hazards would identify a training need for the erection of suitable barriers in the correct positions.

Another indicator of these needs is normally accident, and ill health statistics. However, there has been a noticeable lack of statistical information on accidents at Mindeli shown to DMT. Gathering this database must commence from 'day one', in order that future statistics can be used to fend off future incidents.

Awareness training should be provided for Directors, Managers, and Supervisors and should include;

- How to Manage H&S requirements
- Who is responsible for what aspects of H&S?
- How to identify hazards and evaluate the risk of the hazard, and how to put measures into place to control them

Training should initially be prioritized to gain the most benefit in the immediate term. The face re commencing production is uppermost in people's minds at present, but the face workers must be able to get to and from their place of work safely, and be sure that all the supporting systems (winding, transport, ventilation, emergency egress, etc.) are similarly equipped to also allow the working face to operate safely in addition to systems in use on the coal face itself.

When the training needs have been identified, and training completed, the first operational activity can be initiated. It is proposed by DMT that one pilot operation is established before any other operations recommence. From a training aspect, this will allow the management team (assisted by the training department) to audit the success of the training that has been imparted by the method described. The audit should address the following;

- Do the supervisors and workmen display understanding of what has been taught?
- Has the training given them the ability to work safely without risk?
- Is the job being carried out in the prescribed manner?
- Can the job be carried out in the prescribed manner?
- What do the people carrying out the task think of the training that they have received?
- Is there a further training need?

- Was the best and most suitable training process used?

Ensuring training has been understood is essential. ‘Training until competent’ allows selected experienced workmen tasked with guiding people new to the job to decide that the ‘new’ worker is competent to carry out the job safely. These experienced workers must previously have been trained to assist them to make an informed decision. Formal auditing of the training is essential, particularly on the job when the actual work is being carried out.

From the outset, recording of training completion is important, both to demonstrate that the training has been given, and to allow the mine to draw up a programme of refresher training for everyone at the mine, on at least an annual basis.

The record of training of each individual is also an essential tool in shift deployment, as shift supervisors can cross reference individual’s records to ascertain that they are not being deployed to a job for which they have not been trained.

8.5 REFRESHER TRAINING

Training is not a ‘one hit ‘activity. By the very nature of mining, new demands are continuously being experienced, and solutions are constantly being found to meet these demands. Also, there should be a process of continuous improvement in every aspect of the mine, to try to maximise the potential, be it for safety, production or other aspects. Continuous Improvement training will be a training requirement.

To keep pace with these constant demands, training must also continue to evolve to allow the overall training function to encompass all aspects of the mine. This means that there will be two main streams to training; training of new systems, techniques and processes, and reinforcement of the training that has already been imparted.

Future plans for Mindeli production will bring with it opportunities for people to learn new skills, and recognise new hazards. Equipment manufacturers have a large role to play in the introduction of new equipment, and instruction for operatives in its use. Any future contracts for the purchase of mechanised equipment must include a training package provided by the manufacturer, and a scheme of training on site on the job until competence in the use of the equipment is assured by the manufacturer’s representatives, and confirmed by audit.

Best practice in refresher training takes groups of people out of the mine environment and spends a full ‘Safety Day’ working to a planned programme of re training. This will have safety as its main emphasis, and as well as reminding people about the use of self-rescuers, and all other safety systems they need to be reminded of, the forum can be used to deliver and discuss safety topics prevalent at that time. The day must not be allowed to become tedious for the audience, and discussion and participation should be planned and encouraged.

The composition of the groups is flexible. Having a team of men who normally work together as a team can have some advantages, but these are probably outweighed by the advantages of a collection of workmen and officials from a cross section of the mine, as different aspects of safety can be brought out which would not be aired by a team who always work together. It is also an opportunity for the Manager to join the group for a short while to reinforce his safety message for Mindeli first hand to small groups of people, further demonstrating ‘from the top’ his commitment to H&S at the mine.

Appendix 7 demonstrates a typical training schedule and content for a British coal mine.

9 SHOTFIRING PROCEDURES

Shotfiring procedures fall into the three main categories:

- The management and control of explosives and detonators
- The use of explosives and detonators
- The process of firing shots

The outline of the procedures present at Mindeli is as follows:

9.1 EXISTING SHOT FIRING PROCEDURE AT MINDELI MINE

1. Prior shift task meeting the shot firer undergoes medical assessment at the mine (blood pressure, heart rate, alcohol).

2. Each shift meeting starts with a safety instruction, which is then confirmed by signature.

3. A mine district, which requires shot firing prepare a shift order for shot firing according to the short firing passport (plan and method of statement). The head of blasting department, who deploys a short firer for the task, approves this. The short firing order, signed by both head of blasting and the shot-firer, is then documented and approved by the shift head of the mine.

4. The shot firer receives explosives and detonators in the underground explosives magazine according to the shift order. After this has been documented in both the order and in the explosive journal the shot firer receives the firing machine and 200m (each section underground is equipped with a trunk cable) of the cable, and the shot firer assistant (a worker from the district applied for blasting) receives the explosive and transport these to the face.

5. The section shift supervisor reports the face is ready for charging and blasting. The shift supervisor adds the names and ID numbers of the workers responsible safeguarding the safe distances to the shot-firing place to the order. Following this the responsible workers move all the individuals to the safe place determined in the short firing passport.

6. The shift supervisor measures methane concentration together with the shot-firer. Following this the shot firer gives the warning (1 whistle) and starts charging of the boreholes. The short firer and his assistance undertake charging. Once the charging is completed both move to the safe place. The shot firer gives the second warning (2 whistles) and firers the shots.

7. After the blasting the shot firer waits 30 minutes allowing the face to be ventilated and examines the work place searching for misfires. If any misfires has been detected the shot firer gives the third signal (3 whistles), which allows the work at face can be continued.

8. If any misfires has been detected the shot firer calls his assistant. They defines the direction of the missed shot and drill an additional borehole parallel to the misfire not closer than 30 cm. The parallel borehole will be then blasted according to 6 and 7 above.

9. After completion of the shot firing work the shot firer documents in the order the amount of explosive and detonators spend. The order is then signed by the shift supervisor.

10. The order is then added to the records in the explosive magazine.

11. If any received explosive couldn't be used, the shot firer gives it back to the explosives magazine, which is to be confirmed by both the shift supervisor and the magazine.

The mine uses two different types of explosives for coal (Metanodatonit) and rock (Super Pover). Detonation velocity is about 3,000 m/s for the coal explosive and 5,500 m/s for the rock one. Detonation transfer distance is 3 and 1 cm respectively. Both of the explosives types are classified as category 4 under Georgian standards. Although DMT does not have the details of the specific standards, the consultant understands this type falls under the permissible explosives. DMT has reviewed the key parameters of the explosives and found these suitable for use under the mining conditions. However, it is worth to consider (trade-off of the technical details, test explosions, etc.) whether utilising an explosive of the higher class 5 will increase safety of work at the mine. A shift task for a shot firer is always either rock of coal. In a mixed (coal and rock) face coal explosives are used. Thus the mine excludes a shot firer has both rock and coal explosives at once.

Plans for drilling and blasting are prepared by the mine planning department for the individual work places. Georgian short firing standard and rules defines both mathematic and safety by using minimal distances between the drill holes:

- For coal 0.6m
- For rock 0.3 m

Based on density of the material (up to 2 t/m^3, 2 to7 and over 7t/m^3). The chief of mine planning distributes the drill holes within the cross-section of a working according to the minimal distances. Inclination of the drillholes is taken always the same. Length of the boreholes is designed based on the experience of the mine. According to the chief of mine planning the length of the drillholes is controlled by the drilling workers in production faces. Basically, the workers drill through the coal until the rock. Amount of explosives per a shot is gained from experience. Once the plan is developed, 3 test shot firing prescribed by law to determine the optimum explosives load and borehole pattern. The worker are instructed about the passport details in the shift meetings.

The key safety rules here are for safety distances:

- no less then 200 m for production operations;
- over 150m for horizontal roadways and up to 10 degree inclination of short firing working;
- 100m for the workings with inclination over 10 degree.

This is regardless the direction of the working up cast or downcast. Every individual has to be in a roadway with intake air.

The key safety rules for stemming:

- Stemming minimum length in coal is 50% of borehole length for 0.6-1 m boreholes.

- Minimum borehole length is 0.5 m in rock and 0.3 m in coal.

The mine typically uses 1 m stem. Stemming material is mud.

NOTE DMT questions about safety requirements caused a discussion between the mine and the project shareholders from the ministry and mining inspector. It took a long time to find out the key parameters. The law appears to be very confusing to interpret even for the engineers dealing with this every day.

If the shot firing passport has to be modified e.g. reacting to a change of geological conditions, the entire design process will start again with redesigning, test explosions, etc. In this case the people would be redeployed to other operation until the passport is modified, tested and optimised. However, according to the chief of mine planning those modifications are rather typical for cross-cuts and a sudden change of geological condition is rather a nonsense.

DMT has reviewed the shot firing procedures above and found these reasonable. To assist the effectiveness of H&S considerations, the manager's scheme should, as a minimum, include the following detail.

9.2 MEASURES TO CONSIDER

In order to safely and efficiently charge shot holes, certain equipment is required by the shot firer. He should have a tool entirely made of wood for use in charging and stemming the shot holes. He should also have a scraper for cleaning out the hole, and a break detector, both of which can be incorporated in the same tool.

In addition he should be given a shotfiring apparatus (exploder) authorised for use at the mine, and a suitable shotfiring cable of adequate length to reach to a place of safety (the shotfiring station) from where the shots can be fired. Only this equipment should be used for the purpose of firing shots. No additional wire should be used for connecting any detonator leads to each other, or to the cable described, or to the exploder. None of the cables or connections must be able to connect with any other source of electricity. Insulated hangers should be used to carry, and insulation sleeves should be used at any 'open' connection.

Mindeli is specific with regard to the shotfiring patterns to be used in each operation. Detailed plans are provided to the operational teams at the commencement of the shift. This also applies to the length of the holes, weight of charge and depth of appropriate stemming.

During drilling of the shot holes, if breaks are detected, the person drilling the hole should bring this to the shotfirer's attention, so that he does not charge the hole. Similarly, if during testing of the hole using the break detector, if a break of more than 3mm in width is detected then the hole should not be charged.

Only the prescribed explosive for the job in hand should be used. There are two types of explosive in use at Mindeli, one for coal and cross measures, and another for stone. The persons in charge of the underground magazine and the shotfirers must all be aware of the differences, and the appropriate use of each type.

Before any shot is charged, a test for gas should be made which covers the whole group of shots, plus all accessible places within 10m of every shot hole, the edge of the waste and at the mouth of each shothole. The maximum percentage of methane by volume permissible [at any of these points where measurements are taken] to allow shots to be fired at Mindeli was reported to DMT as 1%, which allows a high factor of safety [methane explodes at between 5-15% by volume] If more than 1% methane is detected, or if the shotfirer is aware of any circumstances that may cause the level to rise, then this should be dealt with in the prescribed manner, and the shotfirer should delay charging of the holes. It should be noted that within 10 m of the holes certainly includes the roof, and particularly in any cavities, and must be complied with even if ladders and extended probes are necessary. If this is not possible, then again the charging of the holes should not take place at that time.

When the round of shots has been drilled and stemmed in the manner prescribed, the shotfirer is responsible for ensuring that all personnel are aware that shotfiring is about to commence.

Immediately before retiring to fire the round, a test should again be made of the same areas, around the holes, 10m away where accessible, and at the waste edge. Again if >1% is detected, or if it is not possible to test, the round should not be fired.

It may be appropriate to provide these sentries with a visual signal of their assumed authority. One way in which this could be achieved would be to have a red translucent cover for their helmet lamps, so that anyone approaching them knows and understands instantly their task.

The shotfirer must also be satisfied that all persons are withdrawn to the appropriate distance for the safety zone, including him. The supervisors should, anyway, keep a written record of persons in their zone, and arrangements should be in place to ensure that any other persons not deployed to the zone, but visiting it, do not do so without the knowledge and permission of the supervisor to 6enter the zone.

In addition, the personnel location detectors adopted at the mine could be a useful in detecting people within the zone who may not be known about. This should form part of the scheme, but should not be solely relied upon. All persons at the mine must observe discipline when entering the face. A simple numbers check board at each entrance to the face could form part of this discipline.

The shotfirer uses a whistle signaling system to warn of the commencement, and the initiation of shot firing. Firing circuit continuity should be checked before being coupled to the firing circuit. If the continuity of the circuit is not continuous, then the circuit must be checked for breaks, rectified and re tested. If successful, then the round can be fired. If not then the schedule should contain instructions on how to proceed.

After firing, the rule is to wait for 30 minutes before anyone reenters the exclusion zone. This should be more than an adequate time lapse to ensure that there are no delayed hazards as a result of shotfiring.

10 VENTILATION, FIRE AND EXPLOSION PROTECTION

10.1 ORGANIZATION OF VENTILATION

The ventilation department of the Mindeli Mine is managed by a ventilation engineer. A total of 27 ventilation deputies are available to fulfil all ventilation tasks as there are no workers directly assigned to the ventilation department.

Overview of the main tasks:

- Ventilation and ventilation systems;
- Mine monitoring;
- Outgassing, spontaneous combustion and rock- / gas outburst;
- Explosion protection and safe operation of electrical systems;
- Fire protection and dust control;
- Monitoring of blasting operations;
- Monitoring of H&S at working places.

There is no temperature and humidity monitoring in place. According to the mine, temperature underground is about 23 degrees. This corresponds with the findings of the DMT mine visits. However, DMT recommends establishing temperature and humidity monitoring underground on the regular basis considering growing depth of working.

10.2 REGULATION

For the audit, safety and occupational safety regulations available at Mindeli Mine were not provided in translated form. List of rules followed by Mindeli Mine includes:

- Technical safety regulations for coal mines. Decision of the Georgian Government No. 449 of 31.12.2013;
- Technical regulations for explosive work. Decision of the Georgian Government No. 432 of 31.12.2013;
- Standard requirements for security. Georgian National Agency for Standardization and Metrology 2016;
- Standard requirements for blasting safety. Georgian National Agency 2012;
- Instructions for calculating the ventilation quantities of existing coal mines. M. Nedra 1975.

10.3 ESCAPE AND RESCUE

Vanishing points are marked in the escape route plan. For each of the illustrated vanishing point numbers, there is a corresponding escape and rescue plan.

10.4 MINE RESCUE BRIGADE

Currently, there is no rescue service at the mine and no training was provided for the staff on fire-fighting or first aid. The central mine rescue service, which is send for in the case of an accident, is located in the city of Tkibuli. Therefore, the emergency response time often exceeds 30 minutes. The external rescue service is provided by the VGSCH. The rescue strategy in case of an accident comprises two key elements:

- Rescue of persons;
- Handling of the accident.

Emergency first response underground is carried out by untrained mine workers. At the surface, there is a medical station with trained nurses present 24/7 and able to provide first aid. A doctor is not on site and needs to be called in case of an accident.

10.5 VENTILATION SYSTEM

The ventilation plan has the task of providing a quick and immediate overview of all underground mine workings and their ventilation. This plan provides a basis for assessing the correlation between accidents and measures of ventilation of a mine or certain parts of a mine. It also allows quick orientation underground and identification of escape routes based on well elaborated escape and rescue plans.

At Mindeli Mine, ventilation data is recorded according to a uniform scheme. In the mine working, regular hand measurements are carried out at regular intervals:

- During each shift: gas measurements with hand-held devices in the workings, recorded in a form, and signed by the ventilation deputy;
- Daily: measurement of the air distribution in the workings, and recording of results in ventilation tables;
- Weekly: Analysis of air samples;
- Every 6 months: Recording of the air distribution in the entire mine building (additional measurements during the commissioning of new workings, and road headings).

The measuring program covers the following parameters:

- Air velocity;
- Ventilation cross-section;
- Volume flow (calculated);
- CH_4 content;
- CO content; and
- CO_2 content.

After the events of April 2018, a monitoring system was installed in the mine, which allows remote transmission, and offers the possibility to visualize all measured values in a control room. Air velocity, CH_4 content as well as CO content are now continuously measured. Thus, the basis is created to capture the rates of outgassing in the workings and road headings.

Ventilation of the Mindeli Mine is carried out by suction through a main ventilation system installed at the return air shaft, with a total amount of 4,520 m³/min and a negative pressure of 1,668 Pa. As of November 2018, the main ventilation system consists of 2 centrifugal fans type BUD-2,2 with one fan as reserve. Alternate operation of the fans usually follows a schedule approved by the mine's technical manager. Switching between fans takes place outside working hours.

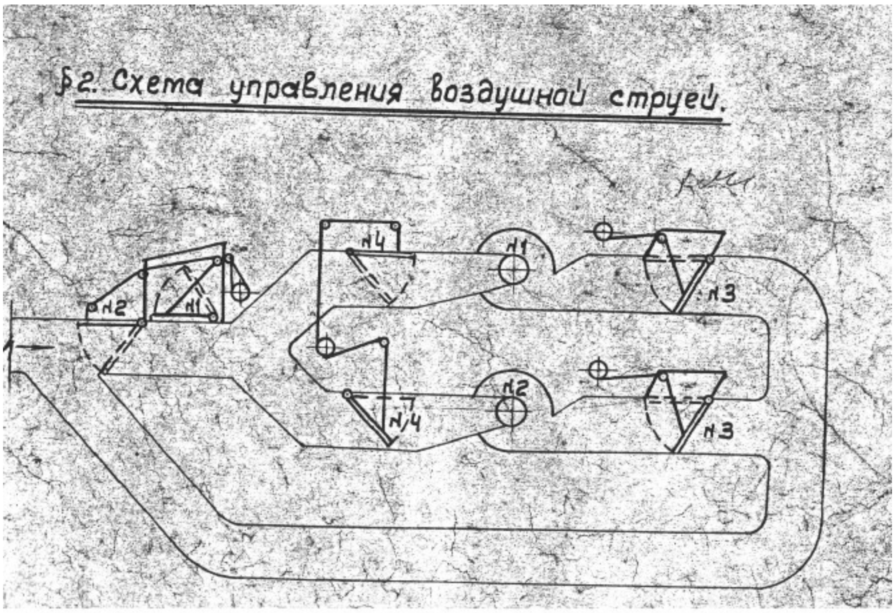

Figure 7 Arrangement of Centrifugal Fans at the Surface

The characteristics curve of the fan from a test bench is provided by the manufacturer dating back to the year 1961. After the installation of a fan, a new characteristic curve has to be determined. The curve usually changes due to the installation conditions, the flow conditions, and due to wear of components, especially the blades. It is therefore mandatory in Germany to redefine the fan characteristic curve right after installation, and then every 5 years. With an up-to-date curve, it is possible to make reliable statements about changes in volume flow and pressure.

The fresh air enters the mine through the intake shaft, the Pulp shaft, and 2 adits on level + 582 m, which are connected to the surface. The upper horizon at the Mindeli 3 shaft has a connection to surface, which allows an airflow of 545 m³/min) into the mine. The fresh air supply of the workings takes place at level + 300 m, + 275 m, and + 175 m levels, while level + 350 m is used to dissipated the return air.

At present, no ventilation pressure measurements are conducted in the mine workings. The most recent measurements date back to 1991.

To assess the stability of the mine ventilation, pressure measurements of the total mine are important. Realistic resistance values of the airways can only be calculated through the pressure decrease inside drifts and at the face. The actual pressure distribution inside the mine is required to assess, for example, a reversal of the ventilation in existing roadways, which might be cause by changes of the fan operating point, construction of new roads or connection of new workings as well as damping of field parts and especially by fires. The escape and rescue concept is based on these assessments.

The minimum and maximum speed of air is regulated according to safety standards. In mine workings, the minimum speed is 0.25 m/s, while the maximum speed 4 m/s should not be exceeded. In the main roadway, up to 8 m/s, and in the fan drift, up to 15 m/s are permitted. Investigations in German coal mines have shown that a minimum speed of 0.5 m/s is necessary to prevent the accumulation and stratification of methane at the roof.

10.6 VENTILATION LAYOUT

Mindelis extraction sections are worked out on retreat using U ventilation scheme. The problem of ventilation and gas emission is illustrated (Figure 8) using the example of a U- layout.

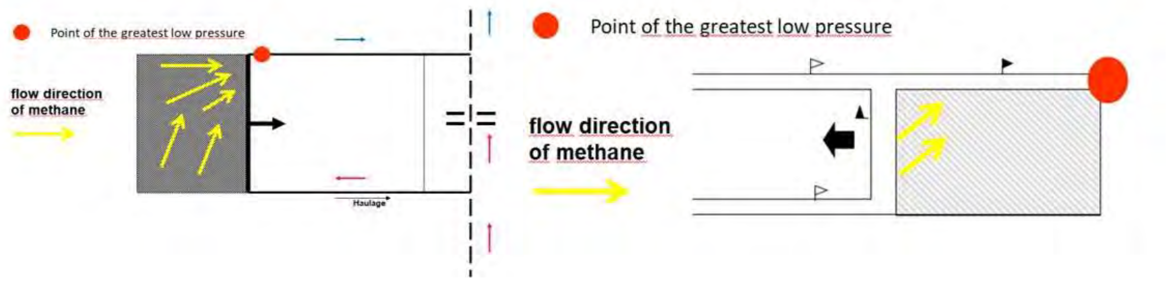

Figure 8 U vs Y Ventilation

Due to the negative pressure generated by the main fan, the methane flows in the goaf in the direction of the greatest low pressure. In retreat workings, the gases flow in the direction of the face. Consequently, highly flammable gas concentrations and explosive gas mixtures are in the immediate vicinity of the mining machines and the mining face, and are therefore a source of ignition.

After several ignitions in U-retreat workings at the beginning of 1990, U-retreat mining was permitted in the German coal industry, particularly in gas-rich deposits.

The advance ventilation system shows a different flow behaviour. Gasses from the goaf are sucked from the mining face by the negative pressure of the main fan flowing in the direction of the return air roadway. Consequently, highly flammable gas concentrations and explosive gas mixtures are removed from the mining machines.

Thus one of the sections impacted by the recent accident applied U-ventilation. The methane from the goaf flowed in the direction of the coal face, creating a high risk potential.

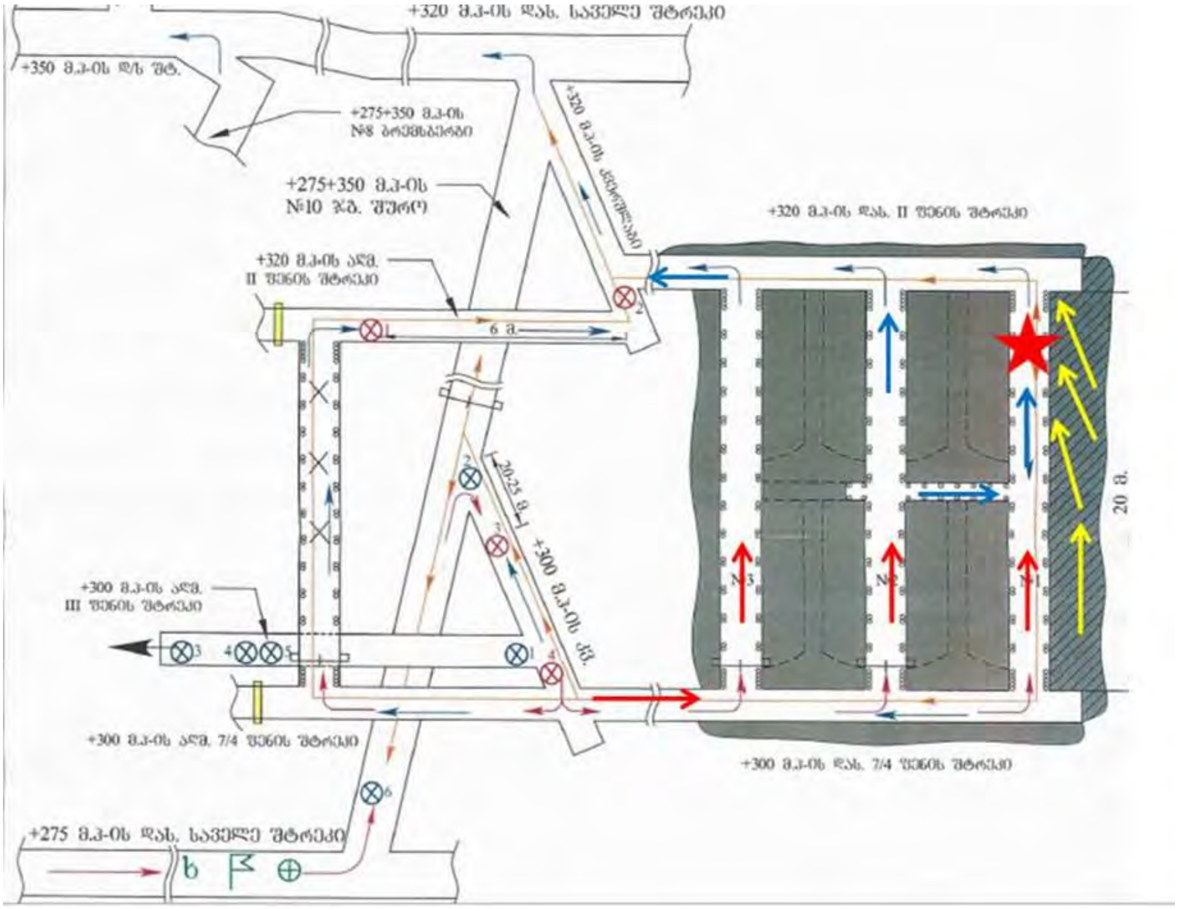

Figure 9 Methane Flow Direction and Ventilation in Mine Working no. 1.

Level + 275 m and + 320 m were drifted with cross-sections of 7.9 m² to 9.2 m². From the connecting road between level + 275 m and + 320 m, the tail gate and loader gate were driven into the seam.

185 m^3/min of air were fed into the working via the loader gate, which had a cross-section of 6.2 m^2. By ventilation doors located in roadway No. 2 and No. 3, road No. 1 was supplied with 110 m^3/min in the lower half, and 155 m^3/min in the upper half of road. With a cross-section of 2 m^2 in road No.1, the air velocity at the face reached 0.91 m/s and 1.3 m/s.

The roadway No. 2 was rated at 60 m^3/min, road No. 3 at 15 m^3/min. Due to the low flow velocity, there was a high chance of stratification of methane in the hanging wall area. The same applied to the fracture space of the goaf area.

10.7 AUXILIARY VENTILATION

The blown auxiliary ventilation in the road heading is carried out utilising electric fans. There are electric fans of the type BM-4, BM-5, and BM-6 available, with the following diameters: 400 mm, 500 mm, and 600 mm. The road heading is ventilated with 2 - 5 m^3/s depending on the type of fan.

The maximum distance between the end of the duct and the working face should be less than 5 times the root of the cross-section of the roadway. Based on a cross-section of 6 m^2, the maximum distance is 12 m.

10.8 GAS EMISSION

The coal-bearing unit lies between massive sandstone benches and reaching a thickness of up to 60 m.

The average thickness of each individual coal seam encountered within the mining area is listed in Table 5. Seams I to V are fairly close together reaching an overall thickness of < 50 m

Table 5 Average Coal Seam Thickness.

Coal Seam	Thickness [m]
I	0.41
II	4.00
7/4	3.03
0,9	3.61
III	7.58
0,9	2.67
IV	6.51
V	0.45

The ventilation department calculates the gas emission of the workings based on historical gas content determinations. Gas inflows from the seams in the hanging wall and the footwall areas are estimated.

Since both current gas content determinations and calculations of real degassing values were not provided by the mine, an example of a procedure for calculating the gas emission is described in the following paragraph.

When excavating a seam, the unmined seam sections in the hanging wall and in the footwall subsequently emit gases depending on their distance to the working seam. For the calculation of the total gas emission inside the workings, these additional gas emissions have to be considered as well, and added to the values calculated for the working seam. The results are then compared with the real gas emission encountered during the mining phase. The real gas emission is calculated applying the so-called final calculation of gas emission, which is based on continuously recorded methane and air volume flow data, including the dissolved amount of coal.

Gas emission calculations for the additional emission are based on hypothetical outgassing areas and degrees. This includes the definition of zones in the footwall and the roof of the working seam releasing methane as a function of their distance from the working seam by the degradation action.

Therefore, these additional outgassing zones are assigned mathematical functions via the degree of outgassing, which means that the gas content of seams in hanging wall and footwall is reduced depending on the distance to the working seam. The following example illustrates the gas emission range for a longwall, which was calculated using the program *Flügge* for the hanging wall area, and *Koppe* for the footwall area. The emission reaches 100 % up to a distance of 20 m in the hanging wall and 10 m in the footwall area.

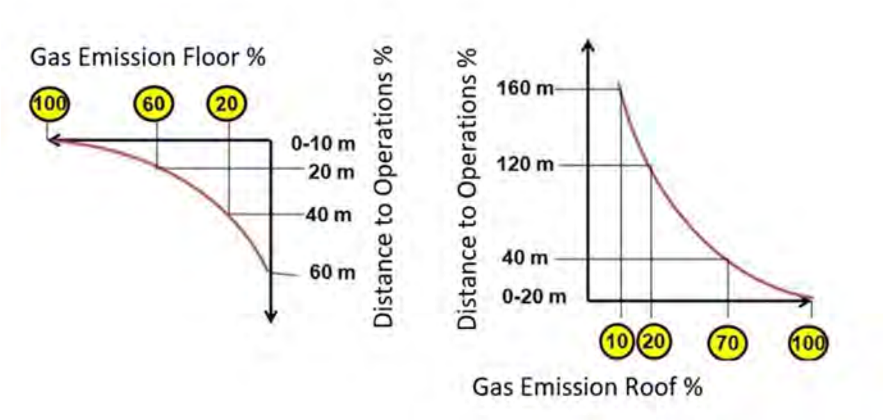

Figure 10 Gas Emission in Longwalls

For the deposit in Georgia, the gas emission areas and gas emission degrees must first be determined by means of post-calculation. Through determination of the gas content of the coal seams in the hanging wall and the footwall areas, the gas emission range and the degree of gas emission into the neighbouring seams during mining can be identified. Based on these results, reliable calculations of the gas inflow from the working seam as well as additional gas emissions can be conducted to determine ventilation requirements.

10.9 GAS CONTENT MEASUREMENT

The determination of the gas content is essential for the evaluation of the gas emission. The measurement procedure is described in chapter Gas Outbursts of this report.

The necessary prerequisites for forecasting the Gas Emission are:

- Gas contents of all seams within the mining area, including the gas content of hanging wall and footwall areas;
- Geological information about the coal-bearing unit, including the overlying and underlying sandstone;
- Current coal production (per blast and per day);
- Current ventilation flow conditions in the working areas;
- CH_4 content of the intake air.

The necessary prerequisites for postcalculation of the real gas emission are:

- Stored data of the CH_4 content of the air, and the volume flow (in m^3/min) in the working area measured over a period of several days;
- Temporal assignment of the dissolved amounts of coal to the methane peaks generated by blasting operations;
- Methane pre-pollution of the mine;
- CH_4 content of the intake air.

Figure 11 below shows an example of the methane volume released in a road header drift, with a pre-load of 0.52 % CH_4. Between 12.30 pm and 5.30 pm, 1,685 m^3 of additional methane have been released into the road header section.

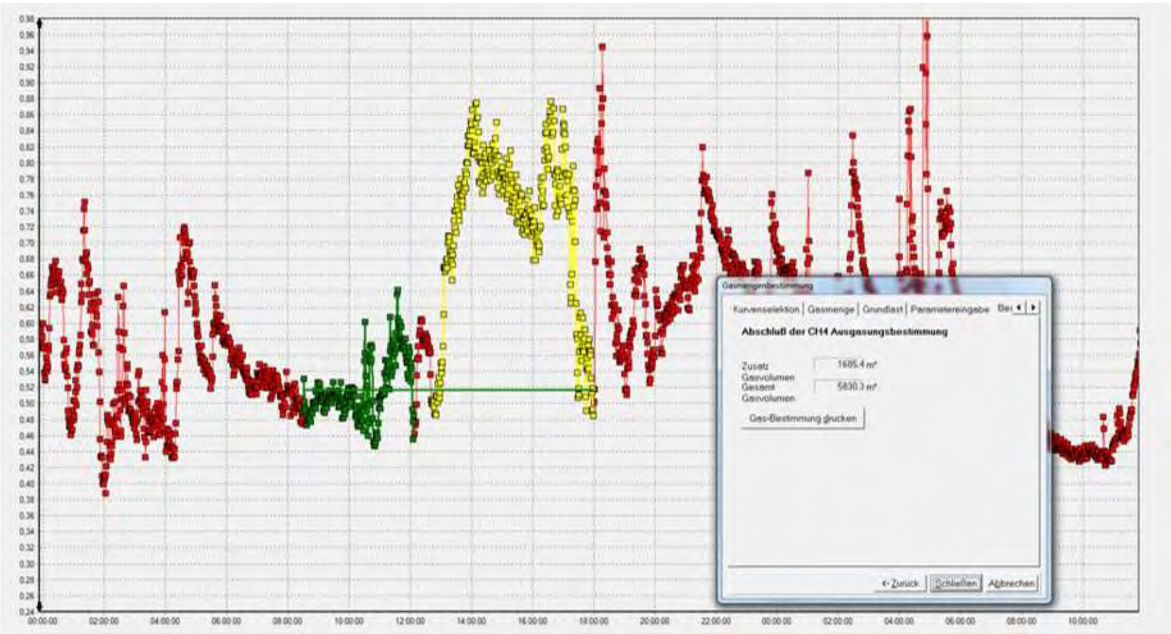

Figure 11 Postcalculation Real Gas Emission

10.10 MINE GAS MONITORING

Following the accident in April 2018, stationary air measuring devices were installed underground. The measured values are transmitted remotely and are visualized at the surface in a control room. Green marking means that the values are within the allowed range, while red markings indicate that the limits have been exceeded or fallen below this range. Figure 12 illustrates the monitoring of the total return air flowing from the working areas to the exhaust shaft, in which the fan is installed.

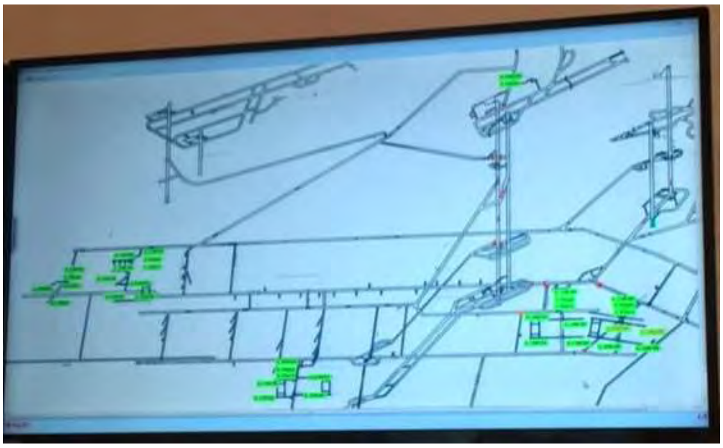

Figure 12 Visualization Monitoring Control Room

Inside the mine workings, the loader gate and tail gate are monitored by methane devices measuring the CH4 and CO content as well as the speed of the total return **Fehler! Verweisquelle konnte nicht gefunden werden.**air flow (Figure 13)

Figure 13 Monitoring Layout Underground

The auxiliary ventilation is monitored with a methane meter installed inside the roadway.

The following measuring systems were installed in the mine:

CH_4- device: GJC4 type MJC4/3.0L

- Measuring range: 0 – 4 %;
- Measuring principle: Catalytic black and white element for mine gas sensor;
- Warning signals: Warning 0.8 %, Alarm 1.3 %.

CO- device: GTH1000

- Measuring range: 0 - 1000 ppm;
- Measuring principle: Electrochemical sensor;

Velocity-device: GFW15

- Measuring range: 0.4 - 15 m/s.

Once the maximum mine gas concentration is reached, the monitoring system shuts power supply of the operations down and the people deployed exit the operations. The operations can be re-commissioned after the prescribed measures on mine gas reduction has been successfully undertaken.

10.11 CALIBRATION OF GAS MEASURING INSTRUMENTS

The measuring systems are calibrated twice a year in a laboratory belonging to the mine. Calibration gases with different concentrations can be purchased from a test gas manufacturer:

- Methane with concentrations of 1 %, 1.5 %, and 2 %;
- Carbon monoxide with concentrations of 20 ppm and 250 ppm;
- Synthetic air.

For correct display of measuring results, regular calibration of the measuring systems is required. In the German hard coal mining industry, gas measuring systems are checked and calibrated at regular intervals: weekly by measuring equipment worker, monthly by ventilation deputy, and once a year by an expert. The data transmission system and the correct display of the values in the control room are included in the tests. Gas devices should be calibrated underground to exclude environmental factors such as temperature and static pressure affecting the readings. When calibrating methane measuring systems, the alarm signal occurring if the measuring range is exceeded should be tested using a methane concentration of approx. 30 %.

10.12 DATA TRANSMISSION AND SECURITY CONTROL ROOM

A data transmission system of type RS 485 is used. With the help of this system, parameters like the concentration of methane and carbon monoxide, the air velocity as well as personalization data are transmitted, and stored for one month. In addition, the dispatcher's conversations with subscribers also are recorded and stored for one year.

The system offers the possibility to calculate the amount of methane released during mining. The example in below shows the mining operation 1-10 and the CH_4- device 004A11 (pink curve) located at the tail gate of the working area. The Y-axis indicates the CH_4 content, while the X-axis indicates the time. In this case, the time period between 01/11/18 and 30/11/18 is visualized. The CH_4 displays of the devices in this mining operation peaking up to 4% should be questioned.

Figure 14 CH4 Peaks in Control Room

10.13 EXPLOSION PROTECTION

Explosion barriers (water trough barrier) prevent the propagation of an explosion into further sections of the mine by dissipating the water contained in them over the entire section of the roadway. When triggered by the pressure wave of an explosion, these containers release water extinguishing the flame front.

An explosion protection plan showing the locations of built-in water barriers is available at the mine. According to this plan, explosion barriers are only present sporadically. A systematic arrangement of these barriers throughout the mine to safeguard workings and drifts is not recognizable. For example, in working 2-8, two explosion barriers are installed in the return crosscut at level + 350 m. In contrast, nor barriers have been installed at the intake crosscut at level + 275 m, which serves as a coal transport route. Another major hazard is coal dust, which is also present in the loader gate. During a methane explosion, this swirling coal dust can lead to a blow-up explosion causing a considerably larger pressure surge. Sufficient protection of the working area is therefore mandatory.

Methane and coal dust explosion tests at Tremonia Mine in Germany have demonstrated that at least two explosion barriers are required to sufficiently extinguish flames and prevent the explosion from continuing. Consequently, a systematic arrangement of these explosion barriers throughout the entire mine building is required.

The mine uses water pockets as explosion barriers. Extensive explosive tests with water barriers were carried out with at the Tremonia test mine.

- Split barrier installed in all roads of the workings and drifts;
- Concentrated barriers installed in all other roadways;
- Water barriers must be erected on all sides and as close as possible to line crossings, and as early as possible during the excavation;

Water trough barriers consist of several containers (trough group) with a capacity of 80 l each. A trough group is defined a certain number of troughs within a section of a length of max. 3 m. It may consist of one or two rows of troughs arranged transversely to the longitudinal direction of the route in a row troughs.

Type 3.1 - Concentrated barrier:

In a concentrated barrier, trough groups are combined in larger numbers. The individual locks are arranged at fixed intervals from each other. The minimum length of a barrier is 20 m. The amount of water in each of the barrier is 200 l/m² of the cross-section, or 5 l/m³ of the track volume, relative to the barrier length. The barriers are installed at 400 m intervals starting at a maximum of 75 m from crossings and branches. The maximum distance to the working face in the case of drives should not exceed 320 m. However, the first barrier should be installed after 200 m.

Type 4.1 - Split barrier:

In a split barrier, the trough groups are evenly distributed over the entire length of the route. The amount of water contained in the barrier is 1 l/m³ of track volume between two adjacent trough groups (consisting of one or two trough rows each). The trough groups are arranged at distances of a maximum of 30 m from each other, and from crossings and branches.

The maximum distance from the working face of drives and struts should not exceed 120 m. The permissible maximum distances in a trough row are:

- Distance trough 1.20 m;
- Between two troughs 1.50 m;
- Sum of the horizontal distances 1.80 m;
- Trough bottom - floor 2.60 m;
- Trough bottom - roof 2.00 m.

A maximum of 50 % of the troughs may be arranged longitudinally. The troughs must not be covered with built-ins by more than 50 % of their surface area, or by other troughs less than 0.50 m vertically. The width of a trough group with its trapped traits as a percentage of the section width is:

- At least 35 % up to 10 m²;
- At least 50% up to 15 m²;
- At least 60% over 15 m².

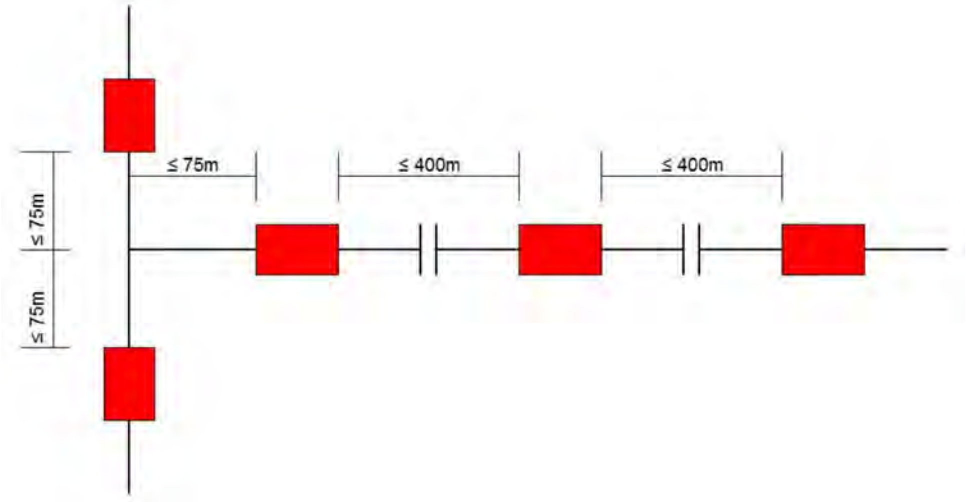

Figure 15 Locking a Branch Line.

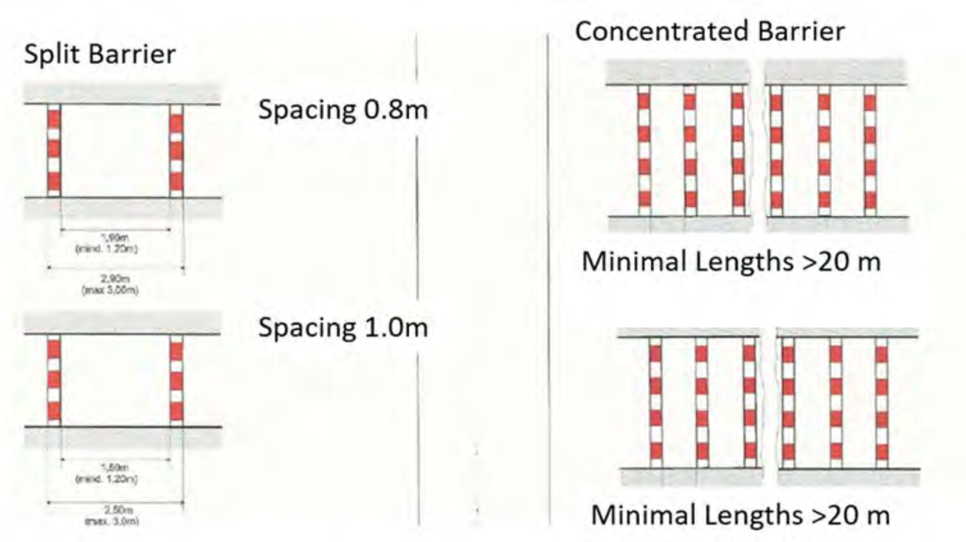

Figure 16 System of Split Barrier and Concentrated Barrier.

The pressure reduction depends on the internals and branches. In addition, it should be noted that the build-up of explosion pressure is reduced again only after the extinction of the flame (this can be caused either by a barrier or fuel shortage). The pressure reduction is then dependent on internals, branches and a characteristic for each output pressure half-value.

The accidents of April 2018 show that employees were injured until the crosscut at level +275 m. According to the mine, the employees were mainly killed and injured by the blast. A higher explosion pressure based on coal dust explosions can have seriously injured and killed people further away from the crosscuts.

10.14 COAL DUST

There are a number of measures to prevent dust. These are essentially limited to spraying with water or water/air mixtures. Deposited coal dust should be eliminated as much as possible. Inevitable residual deposits of coal dust are rendered immobile by means of dust binders (hygroscopic salt solution based on calcium or magnesium chloride) or, if possible, within the technical limits of this process, alternatively rendered inert by means of a scattering of 80 % by weight of rock dust to 20 % by weight of coal dust.

Testing of the measures is carried out by a specialist (fire and explosion protection climbers) or by explosion protection helpers. These exams take place at least once a month. The results of the examinations are documented and brought to the attention of the responsible persons so that, if there are any deficiencies, these can be remedied immediately. This is also documented.

Sampling points are established to test the effectiveness of the rock dust spreading method. Dust samples are examined by a specialized office (accredited testing laboratory).

The explosion hazard of coal dust is given in fluidized form.

10.15 FIRE PROTECTION

The fire protection plan shows the pipelines and water outlets. During DMT's site visit, no fire extinguishers were seen underground. There is also no information on extinguishing equipment stored underground.

For effective fire protection underground, a combined system of regularly arranged water supply points, hydrants, hoses, spray jet pipes as well as fire extinguishers is required, which is based on experiences of the German hard coal industry. For adequate supply in the event of a fire, a minimum water volume of 400 l/min at 1.5 bar flow pressure is recommended to be stored at each pick-up point of the underground deluge system. In shafts connected to the surface, a minimum water volume of 50 l/min per m² should be available. For the location of water supply points from stationary water pipes, an arrangement in the mine building is recommended, which enables quick accessibility from the infrastructure without the help of any additional equipment. It has proved to be advantageous, to have an impact-side attachment at a height of about 1.5 m. Water hydrants should be installed the following areas:

- At stops of shafts;
- At all roads and crossings;
- At belt conveyors and fixed bends;
- At tunnelling machines;
- Intake air side before special fire loads; and
- In functional rooms.

Distance and arrangement of water supply points, hoses, and jet pipes must be adapted to the danger character of the respective mine workings. The extinguishing agent (water) is mainly stored in belt conveyor lines, diesel rooms, and near operations with a risk of gas burns. At each water point, a spray steel pipe including C-hose and transition piece shall be provided. In addition, an attachment near hydrants is recommended. In particularly exposed areas, the deployment of fire extinguishers is still recommended.

Exposed areas include:

- All electrical installations and operating rooms;
- Stationary electrical installations;
- Rooms for storage of flammable liquids;
- All other operating rooms;
- Road heading machines;
- Gas-fire endangered faces;
- Mobile diesel and electric vehicles.

In the intake roadways, in the vicinity of shafts, there should be fire extinguish trains or fire extinguishers available. By way of derogation, fire-fighting equipment may be kept ready for transport at the surface if the conveyors of the shafts are permanently available. Fire protection along electrical installations must be ensured with fire extinguishers.

10.16 SELF-RESCUER ZYX 45

The pressure-oxygen self-rescuer is a device that meets Chinese standards but does not meet European standards. A maximum escape time of 45 min should be possible.

10.17 ESCAPE AND RESCUE

Escape and rescue points as well as all installed telephone facilities, including phone numbers, are shown in the escape route plan. For each vanishing point, there is a corresponding escape and rescue plan. In the plan, the responsibilities and contact persons are listed as well as escape routes for the worker to the surface, and the way for the mine rescue team to come to the vanishing point.

10.18 SUMMARY AND RECOMMENDATIONS

Assessment of ventilation and outgassing was not possible on the basis of the mine visit. It also has to be noted the data provided and the way the mine calculates the required amounts of air for the gas emission are not sufficient.

For an audit of the ventilation, plausibility checks of the current ventilation network are necessary. Since there is no calculated compressible ventilation network at the mine, a current pressure measurement of the entire mine is required. This would also be the basis for building a ventilation network. Compressive ventilation network programs are available worldwide. On this basis, the stability of the ventilation can be calculated and ventilation planning can be carried out. Previous accidents show that methane was not sufficiently diluted by the amounts of air in the mining workings. We recommend maximizing the amounts of airflow during mining until reliable calculations of the gas emission are available. According to the mine, the main fan capacity can be increased to a maximum of 7,680 m³/min. For new workings in unmined areas with a maximum of gas emission, a parallel operation of the two centrifugal fans should also be considered, and their effects on mine workings should be tested.

The calculations of the required air quantities of the mine are based on non-loadable gas contents and hypothetical gas inflows. At Pasport III Slice-265-230, a methane flow of 0.9 m³/min is used for the calculations. In other calculations, gas contents of 12 m³/t are used for the volume air flow calculations. These values do not correspond to the real outgassing ratios. These values are used to calculate a continuous inflow of gas over 24 hours.

In longwall faces are mined with plough or shearer loader, the gas flow in the ventilation is continuous, which is why a 24 hour calculation is acceptable. In the case of discontinuous blasting, the amount of air needed to dilute the methane and the amount of gas produced must be calculated from the gas inflow dissolved per blasting. It should be noted that the gas flow comes not only from the working seam but also from the seams in the hanging wall and footwall, and from the goaf area.

Air movers (Figure 17) ca be installed at the face entrance in the gates, especially in medium-gates as this can help to flush out gas in the goaf.

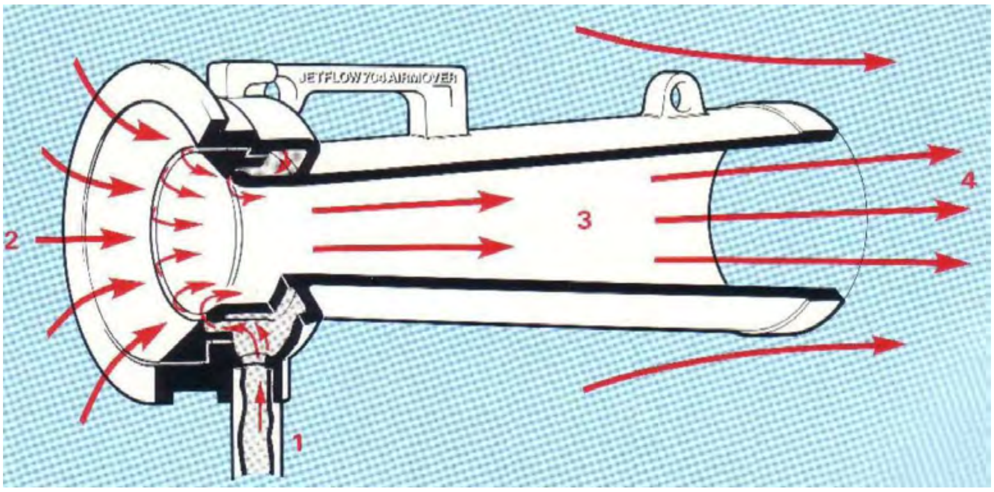

Figure 17 Airmover

The minimum speed within seam sections should be > 0.5 m/s to prevent stratification of methane.

To evaluate the gas emission the following parameters are required: gas contents of all seams, stored measurement data for CH_4, air speed, ventilation cross sections at the location of the methane devices, and times of blasting with the dissolved amount of coal over a period of several days.

Monitoring the mine with stationary measuring equipment was an important step towards improving mine safety. The evaluation options must be used intensively. The basics for post calculation of the real outgassing are available.

Gas content determinations of all seams should be carried out promptly.

For each mining operation, precalculations of the real gas emission must be made in order to determine reliable methane streams for the calculation of the air quantities.

Gas emission forecasting of new mine workings should be created.

10.18.1 GAS DRAINAGE

The possibility of installing a gas drainage system must be checked (Figure 18). With the extraction of methane, the risk of ignition can be significantly reduced.

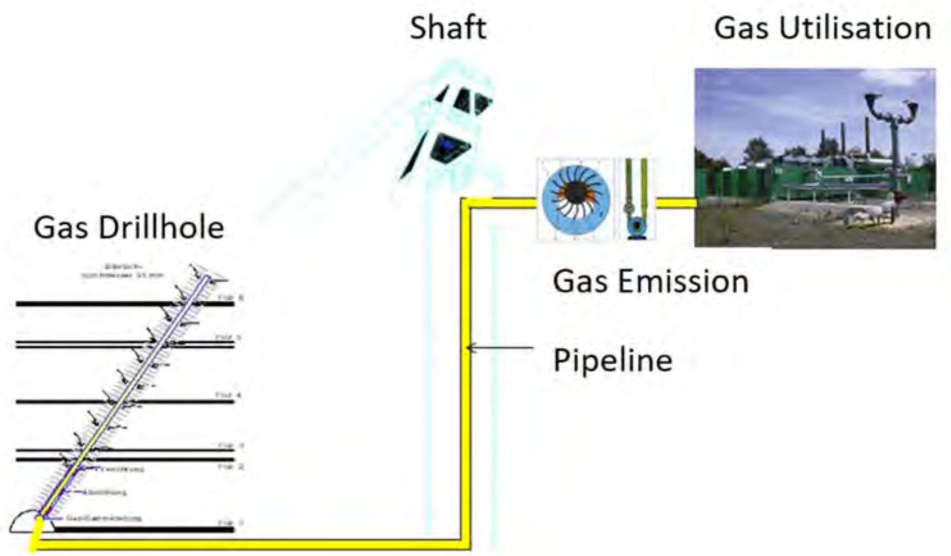

Figure 18 Gas Drainage System

Boreholes from the upper crosscut can be drilled in the goaf and in the hanging wall and footwall of the workings. The existing gas in the goaf and the gas from the additional gas emission could be drained with this system. To prevent larger amounts of methane accumulating at the sandstone bank in the hanging wall, boreholes leading from the cross cut to the sandstone bank should be created.

These boreholes are connected to a collecting pipe in the cross-cut so the gas can be extracted via further pipelines to the surface. Figure 19 shows a gas extraction system with a water ring pump, which routes the extracted gas to the recycling process. Compact mobile combined heat and power plants are used in the German hard coal mining industry to generate energy. The plants are completely installed in two containers ready for operation. A standard plant requires 340 m^3 of methane per hour generating 1.3 MW of electrical power and 1.6 MW of thermal energy.

Figure 19 Compact Mobile Power Plant

10.18.2 CHANGE OF VENTILATION LAYOUT

Since the crosscuts are in the immediate vicinity and parallel to the mining gates, a Y-advance lay-out should be considered. There should be connections from the higher crosscut to the tail gate at regular intervals. These connections can be used behind the face as gas emission window. The tail gate provides additional air for the dilution of methane. Through a gas drainage hole drilled from the crosscut at level + 320 m, the methane flow to the longwall can be minimized. Using this layout, only the gas inflow will be sucked out of the hanging wall and footwall areas.

This ventilation layout in combination with gas drainage is the standard for gassy coal seams in Germany. However, application of the Y-layout requires a proper isolation of the mined out area. This will require an improved backfill material as discussed in section mining methods of this report. To reduce the risk of spontaneous combustion, gas emission windows (roads or boreholes), which are no longer required, should be sealed. The connecting road or a borehole of the crosscut at lev-el + 320 m in the tail gate section can be used to fill the goaf. Fly ash or a liquid building material mixture can be filled into the goaf via a pipeline from the + 320 m crosscut to reduce the risk of spontaneous combustion significantly. The availability of appropriate building materials can be clarified with e.g. HeidelbergCement.

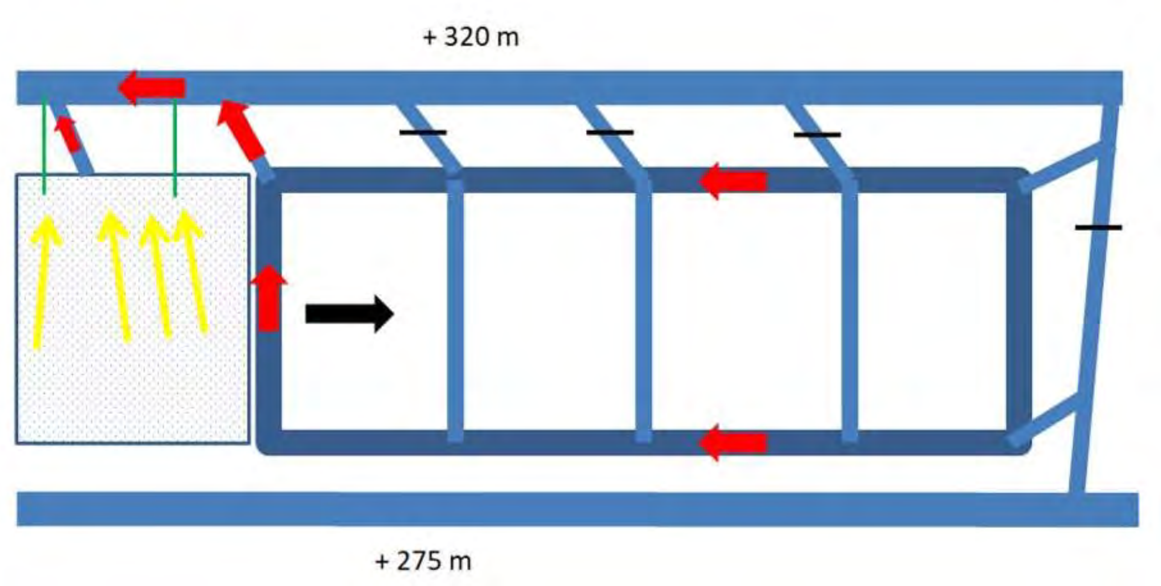

Figure 20 Y-Ventilation Layout

10.19 EXPLOSION PROTECTION

Explosion barriers are not available in the mine to a sufficient extent. All mining operations have to be secured with compact barriers installed at intake and return crosscuts of the workings. In order to minimize the run length of an explosion and the explosion pressure, additional split barriers installed in the workings are recommended.

The explosion pressures, which occurred during the accidents on 05/04/18 and 16/04/18, could not be determined. Since mine workers have been severely injured within a distance of only 100 m from the ignition point, an explosion with limited ignition potential can be assumed. Higher explosion pressures are usually the result of larger amounts of methane and coal dust. Investigations in the German coal industry have shown that with a 2 bar explosion safety distances up to 1,000 m are necessary to exclude personal injury.

Development of an explosion protection plan is required, which contains the water barriers with detailed information.

10.20 FIRE PROTECTION

On the basis of the mine visits and the fire protection plan DMT recommends:

The cross-sections of the water pipes must be dimensioned in such a way that a water volume flow of at least 400 l/min at a static overpressure of at least 1.5 bar is available at any time from the hydraulically most unfavourable point of the pipe network. The static flow overpressure must not exceed 15 bar.

For effective underground fire protection, a combined system of regularly arranged water supply points, hydrants, hoses, spray jet pipes, and fire extinguishers is recommended based on the experience in German hard coal mines. All workers of the mine should receive fire extinguishing training. For an early detection of mine fires or self-ignition, and their assessment, continuous monitoring of the CO content of the mine air or the combustion gases, including computer-based recording and evaluation as well as hand measurements with appropriate gas meters, is recommended. The CO monitoring warning value should normally be set to a CO content below 10 l/min, and the alarm value to a maximum of 20 l/min above the CO basic load normally present in the respective air flow. The measured values of the CO measuring equipment have to be displayed and transmitted to and registered at a permanently occupied control room. At this control room, a ventilation plan with the essential ventilation characteristics and details of the CO measuring equipment must be kept up to date.

As a rule, at least one mine rescue worker in development and at least two mine rescue worker in production should be present at each shift.

The inspections of the arrangements by the supervisory authority have to be carried out at shorter intervals.

10.21 ESCAPE AND RESCUE

In the case of an emergency, all persons underground must be able to be warned immediately from a permanently staffed office at the surface, and be able to report this to themselves. For this purpose, suitable signal or communication facilities are provided.

The operational life of a self-rescuer have to cover the longest escape time on foot (in shafts escape with the emergency drive if necessary), which is required to safely reach a fresh air stream or an escape chamber with self-contained breathing air supply.

Escape routes are signposted or clearly defined (escape always in the direction of the ventilation flow). All workers should be trained to recognize signs of an accident, and to be able to self-rescue by knowing about escape routes and the right behaviour during the escape. These safety instruction are to be repeated regularly.

A sufficient number of staff should regularly trained in first aid. This could be done by the nurses in the medical station. Organizational and technical measures regulate the transport of injuries underground, as well as the alerting and, if necessary, the arrival of a doctor.

For immediate assistance in the case of an event, especially with harmful gases, a rescue team is to be established as part of deployed workers. The headcount, training, equipment and application principles are to be determined according to the risk nature of the mine in the respective operating phase.

Alarm, escape and rescue plans as well as operational principles and measures in the case of accident are to be laid down in writing. They also have to be updated and communicated to the staff on a regular basis, and kept accessible at a central location underground. The same applies to the necessary rescue work documents, such as equipment, switching, piping, weather management and telephone plans.

11 ROADWAY REPAIR

Failure mechanisms in underground mine openings like roadways or production sites are principally controlled by the rock mass characteristics and the underground stresses. The effective stresses depend on the ambient pre-mining stress regime, which is controlled by the lithostatic rock pressure (gravitational force) and tectonic forces, and its disturbance by the mining operations. The rock mass conditions depend on the mechanical parameters of the rock itself and the discontinuities within it. Additional parameters which influence the stability of underground excavations are mainly the water pressure, dynamic forces like seismic accelerations e.g. from earthquakes, and installed support.

Depending on the conditions and parameters, the failure of the rock mass are either structurally controlled by the existing discontinuities (e.g. joints and bedding planes) or by the strength of the rock until it breaks, or a combination of both elements. To identify which mechanism is anticipated, detailed knowledge on the geotechnical characteristics is required.

Tests on the strength of the rocks had been conducted at Tkibuli Mine. According to the results of tests on samples from the West and East areas of the mine, the claystone has an average compressive strength of 17 MPa and can be classified as weak. Sandstone has a strength of 28-67 MPa in average, which characterizes medium strong to strong rock.

Discontinuity conditions like roughness, filling, aperture, persistence and continuity are unfortunately not available. Also information on their orientation and spacing, that describe the degree of disintegration of the rock mass, are not present for any further assessment.

In the current mining depth of about 650-850 m, the pressure load and stresses may exceed the rock strength especially of the weak claystone, so that it breaks according to the existing stress situation around the underground openings. Stress-controlled failure prevails, but is of course also affected by structural elements. In the stronger layers, i.e. in sandstone, the prevailing failure mode is controlled not by breakage of the rock itself, but structurally by displacement along the existing discontinuities in the rock mass. The discontinuities, i.e. natural fractures like bedding and joint planes, form geometrical blocks (wedges) that may slide or fall into the roadway or excavation as single blocks or as collapsing block assembly. Whether this happens, depends on the geometrical situation (of discontinuities and excavation) and the shear parameters, as well as other forces like gravitational (unit weight), water conditions and the installed support (e.g. steel arches, rock bolts etc.). While the conditions are site-specific and locally variable, stability calculations have to be made very individually. Therefore it is necessary to investigate the structures (discontinuities) in the rock mass both beforehand as well as during excavation / roadway driving and to adapt the support scheme accordingly.

In the area of Tkibuli Mine, according to global stress data, stress direction is mainly SSW-NNE. It is associated with compressive forces and thus thrust faulting. Unfortunately, measurement data on the stress conditions at the mine are not available.

For this reason we recommend to conduct stress measurements to verify direction and magnitude of the principle stress components. This can be done by in-situ stress measurements. There are a number of different methods available. Stress directions can be analysed e.g. from geophysical optical/acoustic borehole logging by interpretation of breakouts at the borehole wall. However, this method does not provide information on the amount of stress. Other techniques that allow also to determine the local stress conditions are for example overcoring of a triaxial strain cell and hydraulic fracturing methods, which are performed in drill holes. Depending on the location of the holes, primary in-situ stresses can be determined. Local stress measurements can be done by flatjack tests. It provides an easy method that does not require knowledge about the elastic rock parameters, but result are easily influenced by stress relocations due to the disturbance of the rock mass by the underground excavations.

Based on the data on the rock mass conditions, discontinuities and rock pressure, which need to be acquired, a geotechnical model should be build and kinematic and numerical analyses done to assess the stability of the underground excavations.

DMT visited most of the lateral and face roadways. The rock roadways suffer rather from inadequate support system and insufficient support quality and long periods without maintenance than from ground pressure. The in-seam roadway are often heavily affected by both poor support and rock pressure. Both the lateral and face roadways have numerous instable intervals with broken or missing lagging, deformed support elements or significant roadway deformations (Figure 21). These can result in a fall of ground or even failure of support exposing the people in the workings to high risks.

The mine applies steel arches (27 kg/m profile) with wooden and concrete lagging for the lateral and face roadways and wooden props and bars for extraction workings and winzes. Once height of a roadway has been reduced to 1,9 m and/or the passage for men has reduced to less than 1 m the piece of the roadway have to be repaired. The mine monitor the roadway conditions in terms of compliance to the official standard on the annual basis. Based on monitoring results the mine develops annual plans for repair of the roadways. Table below shows the total roadway meters, which are not in compliance with the standard.

	2015	2016	2017
Meter	412	402	470

Table 6 Length of Unsafe Roadways

DMT recommend to extend the geotechnical monitoring system including measurements in rock. Determination of the rock and support deformation, and stress concentrations. Description of the original geotechnical and geotechnical conditions, such as the strata formation and structure or rock pressure, will provide a strong base for further improvements. These includes all of the measuring procedures that are used to monitor the changes in the cross section of the roadway in the course of its use. Establishing a roadway deformation monitoring system will provide a strong base for understanding of rock breakage mechanism and for improving of the support system at all stages of the mine operation.

The lateral and capital roadways are repaired by the specialist roadway repair department comprising of some 30 men. According to the head of department most of them have over 30 years of experience in underground mining. Face roadways are maintained and repaired by the production departments. Typically 3-4 workers are deployed to a roadway repair site. These are supervised by a shift official, responsible for one or several sites. The work on roadway repair is undertaken in the early and noon shift only.

The work is performed based on passport, developed by the head of technical planning department. This includes a very brief method of statement, a drawing of the reduced cross-section and the target cross-section of the roadway. The method of statement is introduced to the workers, which they confirm by signature. According to the head of repair department the team is instructed in H&S on daily basis. However, no written plans, instructions or records are available.

The roadway repair process is back ripping involving:

- Removing the loose material from the roof & floor and installing 3 m roof fall protection shield;
- Removing and loading of the rock material under the protection application;
- Setting the temporary support and withdrawing the damaged arches; and
- Installing the new support and lagging.

The roof falls are fixed by filling with wooden cribs. The method of work, guidelines and safety instructions are included in the passport of similar content to those discussed above.

Figure 21 Damaged Roadways at Mindeli Mine

11.1 BACK RIPPING RULES

Back ripping present particular risks to those working with support systems. Several serve and fatal accidents occurred in back ripping operations in e.g. German and British mines has been caused by insufficient planning of the process and the tools & supplies. In addition, insufficient safeguarding of the operations and deficiencies in work supervision has contributed to the accidents.

The method of work presented in the Mindeli Mine's passports is a half of a page description of both back ripping process and the safety requirements. The associate passport drawing shows only the old and the target cross-section of the roadway under repair. Even a qualified specialist with in-deep experience in back ripping and brilliant imagination would hardly understand how the individual operation is to be performed and, what hazards are to be considered and what measures are to be undertaken to be safe at each step. The head of roadway repair told DMT he and the department supervisors would give detailed instructions to the workers on daily basis on both methods of work and safety requirements. Then the experienced workers train the beginners at work. However, no examples of the safety requirements, which the department head instructs his team in daily, could be given to DMT.

A detailed method of work supplemented with the specific work related safety instruction including dos and don'ts (back ripping rules) will provide a strong base for understanding the safe work procedures. In addition developing such a step-by-step method of work by the head of repair and his team will probably identify a lot of hazards hidden under the current general work instructions prepared by the planning department, which not practically involved in performing the work. The experience of the officials and workers who will have to implement the back ripping rules will be helpful in drawing up the rules, and the manager should seek their views on the form, content and practicability of the rules. Managers need to prepare them in a form that can be readily and easily understood. They should consider showing a draft of the rules to officials, workers who will have to implement them, and safety representatives, to check that the rules are clear and that they can understand them.

The back ripping rules should incorporate requirements for safe methods of work. These will be based on risk assessments (Appendix 6). For most coal measures strata, the likelihood of a fall from unsupported roof, face or sides is high. Therefore, in drawing up a safe method of work, managers should consider:

- length of time workers have to spend close to open ground from which a fall might occur;
- likelihood that falling ground might strike a worker; and
- consequences of that happening.

Associated risks should also be taken into account, such as handling or operating supports and machinery, maintenance of ventilation, safe operation of transport systems, etc.

To be sufficient the method of work must contain enough information to describe:

- step-by-step procedure that mine workers should follow to safely implement the measures:
- how to withdraw supports safely;

- where are the positions of safety while undertaking each operation;
- what measures to take, including what additional support to set, to ensure that any fall in the back ripping area does not destabilise other roadway supports;
- support-setting procedures, including temporary support measures;
- what are the arrangement for lighting, signalling and communication;
- what equipment to use; and
- how any equipment or services within the roadway are protected while back ripping is in progress.

It is advisable to use detailed layouts, simple drawings, diagrams or photographs explaining what is required at each stage of the back ripping operations. Drawings or diagrams that show only the end result, for example the arrangement of steel work, are neither suitable nor sufficient as method of work. Figure below gives some examples from the UK coal mines.

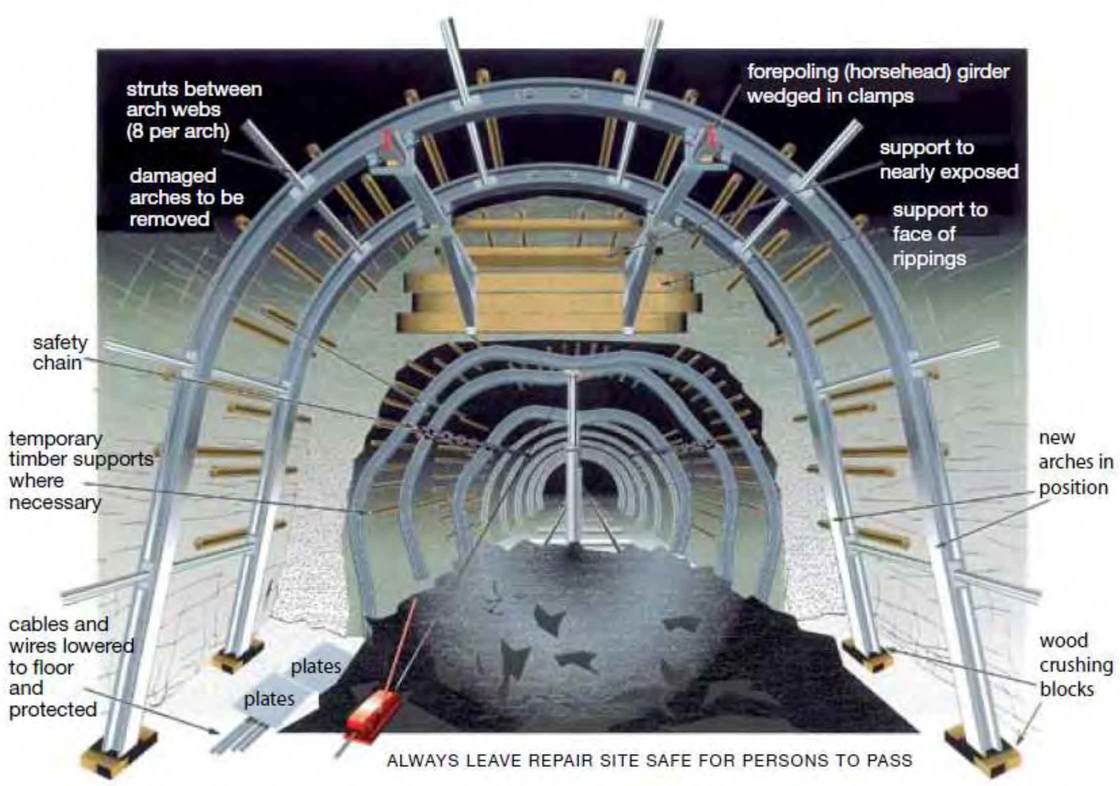

Figure 22 Typical Layout of a Back Ripping in Arch Roadway[1]

The following practical guidelines will be useful for developing of the safe method of work on back ripping:

Supports may be withdrawn safely from a distance by using a rope block, such as a tirfor. The attachments to anchor the blocks and to connect the rope to the support should be strong enough to withstand the expected load and should be fastened so that they do not slip.

To prevent other supports falling uncontrollably when one support is withdrawn, at least four supports beyond the back ripping should be tied together; for example, by using tensioned chains.

Fishplates and struts should be removed before drawing off. These may be under stress and back rippers will need to take steps to ensure that the plates and struts do not violently spring out and cause injury when the fish bolts are removed. For fishplates, a long bolt should be inserted in place

[1] Source: Guidance on the design installation and use of free standing support systems including powered supports in coal mines, HSE 2002

of the first fish bolt removed. This should give enough play to allow the fish plates to release when the remaining bolts are removed, but to stop them springing and causing injury. If struts are likely to spring violently, they can be restrained with a short safety chain before removing the strut bolts.

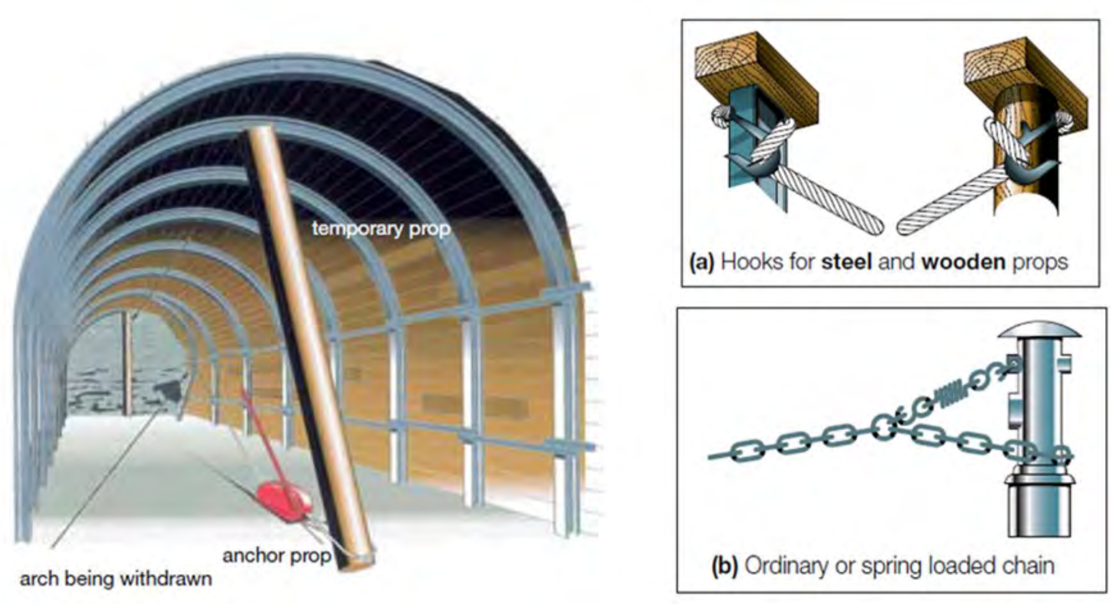

Figure 23 Withdrawal of Supports[2]

Where supports are very distorted and the fish bolts or struts cannot be removed manually, it may be necessary to crop them and remove the arches using powered equipment. This should only be done as part of a planned, closely supervised operation.

Horseheads, drop-arms and boards should temporarily support the exposed ripping face as soon as possible after workers have completed the temporary support necessary to protect themselves against falls from the roof and sides.

Any cavities above the new supports will need to be packed as soon as possible. This is one of the riskier stages of the support-setting operation and needs to be carefully planned. Where packing is to be inserted manually, it is best to cover the centre of the roof member first and place the packing material from beneath. The remaining covering can then be progressively installed and packed, working towards each side.

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[2] Source: Guidance on the design installation and use of free standing support systems including powered supports in coal mines, HSE 2002

Temporary side support should be used, where necessary, to enable the sides to be flanked off so that the legs can be safely set, covered and packed.

Pump-packing several arches at once can significantly reduce the time people have to spend close to exposed ground and should be considered as an alternative to manual packing. However, it will still be necessary to place a layer of packing bags or fibre blocks behind the covering sheets to protect people against falls until the packing material can be pumped in.

Newly installed supports should be spaced at the same intervals as the ones being withdrawn or, where a manager wishes to set more support to reduce the chance of further deterioration, at reduced intervals.

It is advisable to have available several sets of struts of non-standard lengths to allow the position of the new supports to be adjusted if necessary, to keep the amount of exposed ground to a minimum.

In a roadway under repair, any equipment and services that cannot be removed need to be adequately protected. Pipe ranges should be lowered to the floor and covered over. Power and communications cables should also be lowered to the floor and appropriately protected to prevent them being damaged by falling debris.

Support rules need to be readily accessible at all times to people who have to follow them. They may want to refer to them before going down the mine or at any time during the shift. Copies of all sets of rules in force at a mine must be posted in the covered accommodation. Copies of the rules, or relevant extracts from them, applying to a particular place (or places) should also be posted at the entrance to part(s) of a mine to which those rules apply. They should be posted in a position where they can easily be seen and read. To meet this requirement in practice, the rules, or relevant extracts of the rules, could either be:

- posted sufficiently close to the place(s) to which they apply; or
- issued to individual workers and officials.

The manager or some other senior member of the management structure should spend some time at the working place to assess whether the support system is adequate and each stage in the cycle of operations can be safely achieved. In order to do this, it will be necessary to look at what the workers do at each stage in the cycle of operations and assess the risks to them.

Rules must be regularly reviewed to check that they are still relevant to the operations being carried on, and, if necessary, revised. The rules should also be reviewed, and if necessary revised, after:

- any fall of ground accident;
- any fall of ground, not a part of normal operations at a mine, which results from a significant failure of ground control measures; and
- anyone (whose duties include implementing the rules, or ensuring that the rules are implemented) informs the manager that the rules cannot be complied with.

11.2 SUPPORT, TOOLS AND TECHNIQUES

Mindeli Mine applies wood cribs for controlling the roof falls. The timber mats are layered systematically to form vertical columns filling the roof fall cavity. The wood cribs are constructed manually. While constructing the wood cribs in a roof fall cavity the people often work under unsupported and unstable roof of the cavity. This is especially the case when dealing with the bigger cavities. These require high cribs, which are not even possible to erect from a safe position under the adjacent support.

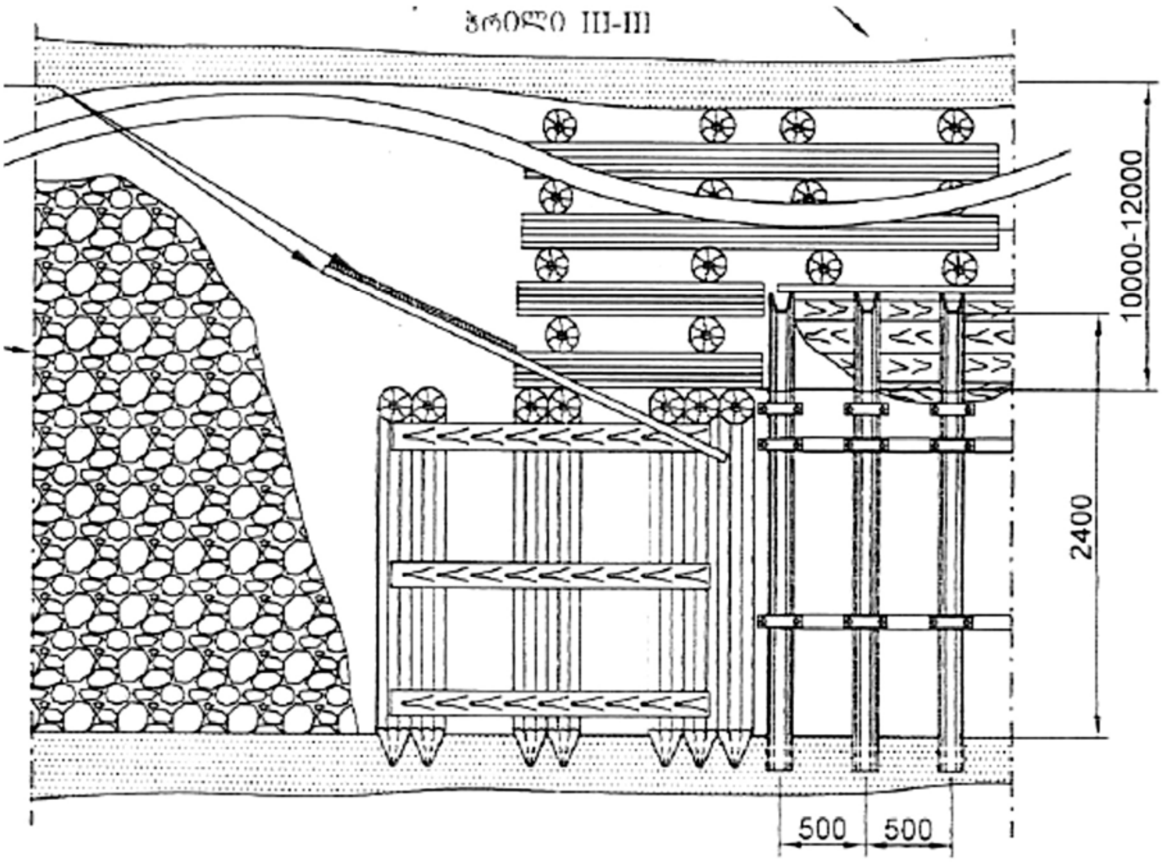


Figure 24 Mindeli Mine Wood Cribs

Alternatively, roof fall cavities can be filled with instant foam or concrete material (Figure 25). The foaming two component phenolic resin systems can be pumped into the fall cavities avoiding any men working under unsupported roof. In addition to ground stabilisation the foams also prevent accumulating mine gas in the cavities, which can't be achieved by using wood cribs. Foaming cavity filling chemicals are state-of-the art in the underground mining. The leading manufacturers are Minova, BASF and A.WEBER S.A.S.

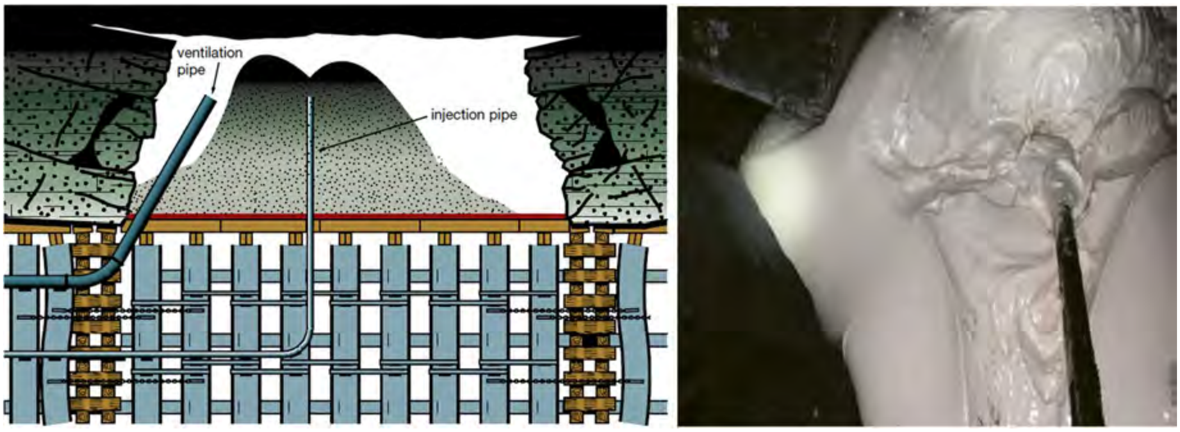
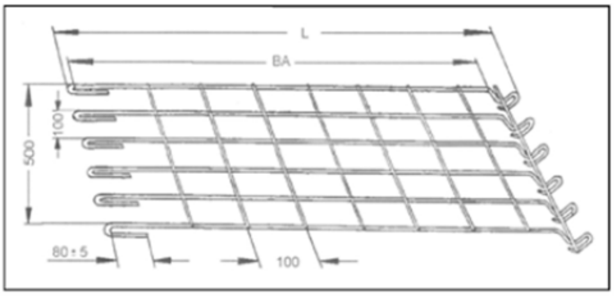


Figure 25 Filling Cavities[3]

While visiting the underground operations DMT has passed many roadway pieces with missing or broken lagging. Undoubtedly, those risky areas could be fixed by installing the wooden lagging, which appears to be a standard at the mine. However, utilising the wire mesh panels (Figure 26) will increase productivity of roadway repair and maintenance and prevent injuries by fall of stones in the roadways.



The installed lagging

Maximum resistance:	305 kN
Maximum deformation:	154 mm
Work capacity of lagging	47,2 kJ

Figure 26 Flathook Lagging[4]

Mindeli Mine applies mutlislice mining. Thus, standing support systems will be the most (and only) suitable for the in-seam roadways. However, a major part of the lateral roadways in rock appears not to be significantly impacted by abutment pressure. It is worth to consider whether roof bolting may be a cost effective and safe alternative to the reused arch supports being the current standard at the mine.

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[3] Source: Minova, HSE

[4] Source: Coal Mine Roadway Support System Handbook, HSE 2004

12 ROCK AND GAS OUTBURSTS

In the worldwide discussion about the phenomenon of rockbursts and similar events it becomes clear that there are always different ideas, classifications and evaluations of the incident forms. For a better understanding, the DMT definition is presented below, as the classification of the various event types was not clear in the discussion at the Mindeli Mine either.

A rockburst is a strata phenomenon, in which the coal or, sometimes, the rock ruptures into underground openings with an explosive impact accompanied by damage effects to underground openings.

A seismic event without damages is not a rockburst.

Every rockburst is accompanied by aloud reported and a ground tremor – a seismic shock. On the other hand, the great majority of ground tremors induced by mining are not due to rockbursts. The following individual factors have an influence on the development of earth tremors (seismic event):

- Influencing factor 1: Strata make-up (stress and deformation behaviour);
- Influencing factor 2: Depth/rock pressure;
- Influencing factor 3: Anisotropy of the stress field;
- Influencing factor 4: Tectonic position of the seam plane (synclinal formation);
- Influencing factor 5: Seam thickness;
- Influencing factor 6: First seam extraction in a particular panel;
- Influencing factor 7: Effective face length;
- Influencing factor 8: Zones affected by earth tremors; and
- Influencing factor 9: Areas with an increased number of earth tremors.

The term is, however, descriptive and rather self-explanatory: coal bursts into mine workings from the sides, roof, floor, this happening suddenly and in an explosive manner. Other terms used internationally are bumps, mountain bumps, air blast, or simple bursts.

The rockbursts in coal mines are violent failures of the coal seam, causing ejection of broken coal and often taking the form of an abrupt movement of the face or sidewall. Table 7 below shows the main differences between rockburst and gas/coal outburst:

Table 7 Differences Rockburst vs Gas/Coal Outburst

Rockburst	**Gas/coal outburst**
Primary cause is rock pressure	Primary cause is gas pressure
Primary elastic energy is released	Primary gas energy is released
Breaking is fiercely, ground motion intense	Breaking is slower, ground motion slight
Secondary the coal releases gas	Secondary the gas ejects coal or rock
Coal is mostly coherent (coarse)	Coal is mostly finely to finest textured
Often backward side walls are affected	Only proceeding coal faces are affected
Mechanical destruction is generally vastly	Mechanical destruction is slight to not any
Deformation of the mining is heavy	In general no deformation of the mining
No cavern	Formation of cavern in coal face

Rockburst	Gas/coal outburst
Solution area between seam and hanging layers	Sometimes settlement of hanging layers
Possible connection with tectonic disturb	In general connected to tectonic disturbance
Progress abruptly	Development takes a few seconds or minutes
No indication through noise development	Often noise development prior to event
Occur often in backward side walls	Occur only at recent, not degased faces
Occurrence also in stationary services	Occur only on working at recent faces

Figure 27 Rockburst vs. Gas/Coal Outburst

12.1 ROCKBURSTS

The current depth of mining or the coverage is to be described as sufficient for a possible rockburst hazard with regard to the rock pressures. Due to the dip of the seam and the increasing rock cover, the depth will increase significantly from currently 800 m to 1,400 m in the future. Thus, the rock pressure increases successively.

The necessary geological conditions for the formation of a rockburst are basically fulfilled. The entire seam of about 60 m is located between two massive sandstone layers.

However, a closer look at the distances of the sandstone banks to Seam 2 and Seam 4 reveals that the distances of the solid bank to the upper Seam 2 are larger than to the lower Seam 4. In the upper built Seam 2 the distance to the sandstone bank is about 13 m and in the lower built Seam 4 the distance of the sandstone bank to Seam 4 is about 9 m. The layers above Seam 2 contain Seam 1 and the lower layer contains Seam 5. The lower strength of these layers and the thicknesses between Seam 2 and 4 and the sandstone bank are normally too large to transfer high pressures to the built seams for the formation of a rockburst.

The parameters of the rock properties provided in 1990 do not refer to the Mindeli district and are therefore not representative for the assessment. The strength values of the sandstone are given as 23 - 33 MPa. These are the highest values mentioned in the table. If the compressive strength is within this value range for Mindeli Mine, the sandstone strengths would not be high enough to transfer critical pressures to the seam.

Due to the complex mining method of pillar recovery, the geometrical situation results in residual pillar situations that increase the rock pressure in some areas. Thus, the conditions for a possible rockburst hazard are basically fulfilled by the depth, area by area solid surrounding rocks as well as additional pressure caused by the excavation geometry. The sum of these factors has apparently led to two rockbursts.

Since, depending on the situation, Seam 2 or Seam 4 was mined or will be mined as the first seam in the mining development to depth a very favourable situation for rock pressure reduction is created and thus a protective seam effect for the subsequent seams. The concentration on a possible rockburst hazard is therefore on the first preceding seam.

As the roadway drivage and the extraction of the coal are currently carried out by drilling and blasting, the situation is favourable in terms of personal protection. In both cases, the miners stand withdrawn at a safe distance if the specified regulations requirements of 160 m - 200 m are fulfilled.

The last large rockburst occurred in 1976 and the last medium rockburst in 2011. Since then, according to the mine management, there have been no further rockbursts. Thus, the mining method can be described as favourable in terms of avoiding rockbursts. Earth tremors caused by active mining should not be described as rockbursts, but as normal fracture reactions caused by active mining that lead to seismic events.

Two rockbursts has occurred in Seam 4. Obviously the focus is on a possible rockburst hazard at Seam 4. After the great rockburst in 1976, seam infusion was successfully introduced to reduce the stresses in the seam. Since mining has been carried out under equivalent geological and geometrical conditions for a long time, the difference in the coal properties of the individual seams may have to be sought.

Moisture in the coal may be of particular importance. The natural moisture content of coal is given as 5 - 7 %. The present analysis of coal from 2007 shows an average natural moisture content of 7.5 % (Alex Stewart analysis). Based on DMT laboratory tests on various types of coal, it became clear that a moisture content such as is to be found in the Mindeli Mine coal significantly reduces the coal's tendency to rockbursts.

As an effective method for stress reduction within the seam, the Mindeli Mine also carries out seam impregnation as a preventive measure to increase the moisture content of the coal to 9 - 10 %. If a homogeneous moisture penetration of the coal is achieved, the measure has a very favourable effect on the reduction in the coal.

The system long-term infusion system at Mindeli Mine and German standard is described in detail below.

The method of seam infusion for stress minimization is very effective as a preventive measure when used correctly. Infusion plan at Mindeli Mine:

- Drilling every 50 m from the lower rock drift.
- Arrangement of a borehole fan so that all seams are reached
- Drill hole diameter 75 mm
- Drill hole lengths between 55 and 65 m
- Cementation of the infusion jet over the first 15 to 30 m
- Infusion pressure 100 - 180 bar
- Infusion duration 2 - 4 weeks
- Increase of humidity to 9 - 10 % (target moisture)
- 45 litres water per m³ coal

In the following comparison of the Mindeli Mine and German standard systems, it is not only the implementation that is important, but above all the control of whether the goal of homogeneous moisture penetration has been achieved. The indicated natural humidity in the coal of Mindeli Mine can already be described as very high at 5 - 7 % (Alex Stewart analysis in average 7.5 %). The indicated infusion period of 2 - 4 weeks appears relatively short. However, the impregnation pressure of 100 - 180 bar is high. If the infusion has reached its goal can only be determined by continuous moisture analyses. Therefore, DMT recommends to carry out a continuous, systematic investigation of the coal moisture before and after infusion in all seams and at various points.

To achieve an even distribution of the water throughout the coal, the infusion process should last a considerable time, and the fluid pressure should not be so high as to open cracks along which the water will flow back. This draws the distinction from short-term infusion, which is directed at fracturing the coal by hydraulic pressure. In practice the two modes of infusion can be combined to some extent. That is why the data reported for long-term infusion are rather varying: the duration of infusion ranges from a few hours per borehole to several months, and fluid pressure ranges from 1 to more than 40 MPa.

The natural limitations to the method result from high rock pressure. This has two reasons. First, no boreholes sufficiently regular for infusion can be drilled in high-stress zones, and second, the densely compressed coal is hardly able to take in enough water through pores or interstices – permeability decreases with increasing compression. Long-term infusion should therefore be applied before high stresses have developed in the respective area of the seam. The most promising approach is to estimate how much water can be absorbed by the coal and to inject this volume rather slowly, controlling the flow rate instead of the fluid pressure.

DMT recommends:

- Infusion should begin several months before the extraction of the respective part of the seam, even a year or longer may be advisable.
- Infusion should terminate before the borehole is affected by the abutment pressure ahead of the extraction face, normally before the face has come closer than about 30 m.
- Infusion time per hole should be several months.
- Preferable are low fluid pressures and flow rates of only up to 5 litres per minute.
- Depth and spacing of the boreholes can be determined from the volume of coal to be moistened and from the volume of water which can be absorbed by that coal. The holes are often between 15 and 100 deep m and 20 to 40 m apart.

- The volume of absorbable water is of the order of 10 to 50 litres per cubic metre of solid coal.

Apparently the rank of the coal is of influence whereas the relationship to porosity is not always distinct. Some values found in laboratory tests are listed below. Underground, under compressive stress, the coal will probably absorb less water because of reduced permeability. On the other hand, 1 or 2 % increase in moisture content may already be enough to eliminate burst danger.

Long-term infusion can be carried out independently of coal mining operations and is also effective in reducing dust concentrations during subsequent extraction. The method has not worked in all instances, but an attempt can often be made without any risk and at comparatively low cost. A disadvantage is the deterioration of roof or floor strata sensitive to moisture.

Table 8 Rank, Porosity and Absorbable Water for Coal

Volatile matter (%)	Porosity (%)	Absorbable water (l/m³)
<10	6-8	40-50*
10-18	4-7	20-40
20-28	3-5	20-25
30-35[5]	6-8	10-20

In two DMT research projects, analyses have been carried out on the subject of "Reducing the risk of rockbursts by water infusion in the coal". The positive influence of the water on stress reduction in coal has been known for many years from laboratory tests. In these research projects, the infusion success was examined in the laboratory for different seams. In addition, the water distribution and the degree of saturation in the infused seams were investigated. In laboratory tests, different seams with different degrees of moisture penetration were tested on the test rig with respect to their distressing behaviour. All coal samples examined were easy to infuse. The saturation humidity levels achieved were between 2.5 and 6%.

Cracks and macropores in the coal act as primary flow paths on which the infusion water is brought to the porous core zones. There is a relationship between the pore volume and the degree of coalification such that the cavity supply of gas-fired coal is 54 litres per tonne of coal, decreasing to 46 litres per tonne of coal for gas coal and to 38 litres per tonne for fat coal and rising 52 litres per tonne for anthracite. Up to infusion pressures of 75 bar, the carbon structure remains unchanged and the permeability remains constant. The permeability rises sharply from 75 – 120 bar, albeit without destroying the structure. High watering pressure causes expansion of the primary flow paths and induces the far-reaching distribution of the water on the cracks. With advancing coalification and an increase in the degree of break-up of the various types of hard coal, gas-flame coal has the highest strength level of 24 - 33 MPa, gas coal a medium strength level of 15 to 23 MPa and fat and forge coal the lowest strength level of 8 – 12 MPa. The strength of anthracite increases slight-

[5] *Mindeli Mine values

ly to 12 to 13 MPa. Regardless of its degree of maturity and origin, every coal has a high energy storage capacity and shows a strong impact tendency in the experiment. The distress behaviour of non-infused coal in the case of distress boreholes on the test bench at pressures greater than 60 MPa is characterised by sudden pressure drops and dynamic events. The strength behaviour of all types of coal is influenced by experimental infusion. The compressive strength under uniaxial and triaxial test conditions is significantly reduced. The energy storage capacity decreases in favour of plastic deformation. Infusion transforms impactable coal into an impact-resistant state. The distress behaviour of infused coal is free of sudden pressure drops and dynamic phenomena.

Due to the successful practical application in the German hard coal mining industry, the research results and the test rig investigations in the laboratory described above, it can be said that the infusion of the coal is effective.

In relation to the current mining method and the mining layout at Mindeli Mine, this prevention method is a suitable method. The decisive factor, however, is continuous monitoring of success. For this purpose, coal samples have to be systematically taken again and again and the moisture analysed. Only in this way it is possible to make an assessment and possibly make corrections regarding impregnation time, impregnation pressure, water quantity and borehole arrangement.

From laboratory and underground tests it is known that a large-area increase in the natural water content of the coal by 2% can reduce the stress build-up near the coal face in the seam and/or facilitate excavation.

In the future, the seam pitch of Mindeli Mine will change. This will probably require a change in the mining method. In this context longwall mining can be considered.

The following requirements must be met for large-area infusion of the coal:

- Homogeneous seam structure – rock layers (>10 cm) prevent the uniform moisture penetration of the seam
- Longwall face lengths > 300 m cannot be reached with infusion boreholes from the roadways (maximum borehole length < 100 m +/- 50 m)
- Coal must be able to absorb water (laboratory test)
- Direct roof layers must not be water-sensitive - difficulty of roof control (laboratory test)
- Bed layers must not display any swelling capacity – difficulty of longwall face control (laboratory test)

Using an infusion example at a German mine, the following infusion data were determined in a seam with a thickness of 1 meter:

- Quantity of infusion water for each borehole: 46 to 586 m³, on average 189 m³
- Infusion time per borehole: 3 to 13 months, 8 months on average
- Quantity of infusion water per m³ of coal: 11.5 to 147 l/m³, on average 47 l/m³
- Water content of coal before infusion: on average 1.4% from 141 samples
- Water content of coal after infusion: on average 2.5% from 117 samples

In comparison it becomes clear that with the indicated natural moisture at Mindeli coal of 5 - 7.5 % is already the favourable basic conditions are present, provided that the data can be confirmed up to-date and for all seams.

12.2 GAS OUTBURSTS

The gas content in the coal is about 15 m³/t in a depth range of 650 m - 700 m. The last gas content determination dates from the 1980s and is therefore no longer representative. The gas content is expected to rise up to 20 m³/t with the increase in depth to 1,400 m.

According to the mine, no gas outbursts have been detected so far.

Assuming the gas content of 15 m³/t (last from the 1980s) and the determined volatile components from the analysis of 2007 (Alex Stewart analysis) with an average of 30 % as given, a gas pressure will be of 30 bar. The orienting sorption isotherm shown below (Figure 28) clearly shows how high the gas pressure is for a gas content of 15 m³/t, as specified by Mindeli Mine, and for 30 % volatile matter.

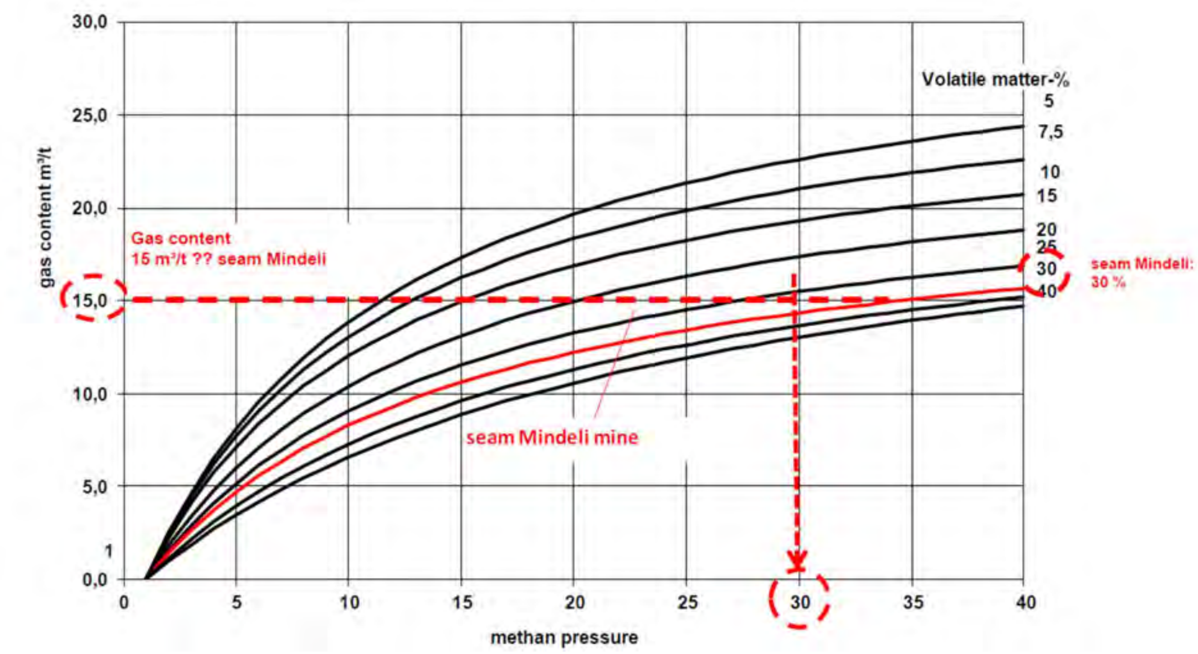

Figure 28 Sorption Isotherm

The gas pressure of approximately 30 bar in the compact, undisturbed coal is probably not able to cause a gas outburst. In the undisturbed coal there is rather a successive basic outgassing. In areas of faulted zones, however, the assumed gas pressure is capable of causing a gas outburst or gas coal outburst. Therefore, the focus must be on areas with faulted zones where gas exploration drillings are required.

Since, as already described above, the first seam to be mined or mined in the development of mining to depth is Seam 2 or Seam 4, depending on the situation, a very favourable situation for gas reduction also arises here. This results in a protective seam effect for the subsequent seams. Concentration on a possible gas outburst hazard is therefore on the first leading seam and in particular on fault areas.

Since faulted zones in roadway driving cannot be detected at an early stage, the German standard requires an exploration drilling program with a gas content of >9 m³/t. The aim is to avoid uncontrolled approaching to a faulted zone and the sudden release of gas or gas with coal. Further measures can be proposed on the basis of current, concretely determined gas contents of the individual seams at Mindeli Mine.

12.2.1 LABORATORY TESTING COAL MINDELI MINE

On the mine underground visit on 09.11.2018 at Mindeli Mine, a coal sample was taken from the side wall in the mining operation. The property of the desorption of the coal sample was investigated. The result of our laboratory analysis shows that the Mindeli coal has a gas outburst coal class 2 related to the sampling site. However, the sample had a too high ash content of >10 %. A high ash content falsifies the result. Therefore the result of the laboratory analysis is unfortunately not useful.

Mine			Mindeli Mine				
Sampling Date			9.11.2018				
Size			0.5 – 0.25 mm				
Sorption Pressure			0.5 bar				
Sample Nr	Sample	Ash [%]	q01 [m^3/t]	kt	V [l/(min*t)]	r2	kt class
1	1	16.6	0.99	0.83	168.7		

kt class	kt	
0	0.61-0.68	Normal coal
1	<0.61	Compact coal
2	>0.68-0.75	Stressed coal
3	>0.75-0.82	Gas Outburst Prone Class 1
4	>0.82	Gas Outburst Prone Class 2

Figure 29 Laboratory Analysis of Coal Sample, Mindeli Mine

12.2.2 LABORATORY TESTS (GERMAN STANDARD)

The coal characteristic desorption value kt is an indicator for methane releasing rate of a coal sample. The value is dimensionless. It is the tangent of an angle of inclination of a straight line, which gives a description of time laps of methane desorption flow in a double logarithmic coordinate plane.

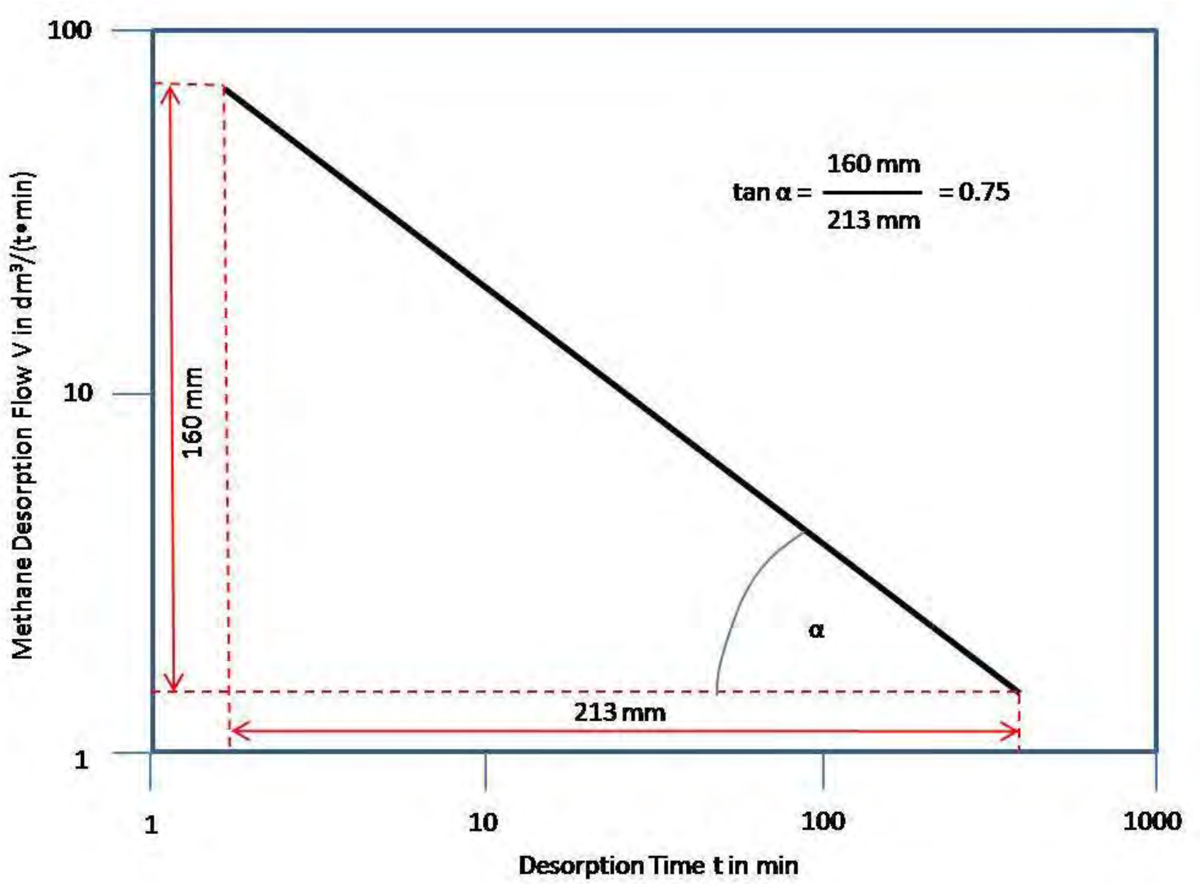

Figure 30 Desorption Graph

$$\tan\alpha = \frac{\log V_a - \log V_b}{\log t_a - \log t_b}$$

V_a Methane desorption flow applied to one ton of coal, at the moment t_a
V_b Methane desorption flow applied to one ton of coal, at the moment t_b
t_a, t_b Moments a and b during methane desorption period

Table 9 Coal Classification Based on kt-Value

k_t-class	k_t-value	Coal classification
0	0.61 – 0.68	Normal coal
1	< 0.61	Compact coal
2	> 0.68 – 0.75	Stressed coal
3	> 0.75 – 0.82	Gas outburst coal class 1
4	> 0.82	Gas outburst coal class 2

Rock has k_t-values greater than 1. It cannot bind gas by sorption, so that there is just free gas present. The gas is set free immediately after depressurizing.

The q_{01}-value is an indicator for methane releasing rate considering the desorbable gas content of the coal. The value has the unit m^3/t. It is the fraction of the desorbable gas content getting out of coal in the first minute after decompression from sorption pressure in balance. It is determined by the formula

$$q_{01} = \frac{V_1}{1000 \bullet (1 - k_t)}$$

A sample is crushed to a grain fraction of 0.40 to 0.63 mm. An inertia of 5.5 g of the crushed sample is put into a sample vessel and the vessel is applied into a condenser bar desorbometer (Figure 31).

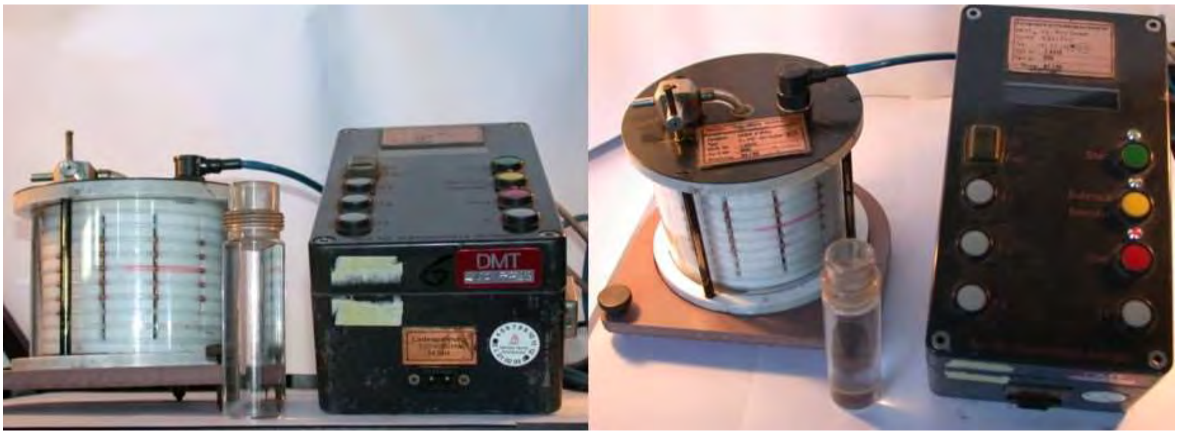

Figure 31 Desorbometer and Sample Vessel

The sample is subjected to an overpressure of 5 bar. After decompression the gas set free by the sample moves a liquid bladder to an appointed distance within an appointed time period. The reader (calculation device) calculates the V1-value and the kt-value.

Determination of the values bases on the "Betriebsempfehlung für den Steinkohlebergbau Nr. 26 – Bestimmung des Gasinhaltes von Kohle[6]", published by Verlag Glückauf, Essen (Germany) in 1987, by order of Landesoberbergamt NRW[7].

[6] Recommendations for coal mining no. 26 – Determination of the gas content of coal"

[7] Inspectorate of mines in North Rhine-Westphalia, Germany

12.2.3 GAS CONTENT

German mines usually do gas content tests using the fast desorption method according to German standard. This executed according to a guideline issued by the mine operator RAG and accepted by the mine inspectorate. Recently, the method has been brought to ISO standard as well (ISO 18871:2015). The procedures of sampling and lab testing have been developed by DMT. The target of developing this procedures was achieving results of gas content tests as soon as possible on a sufficient level of confidence. This is essential when using gas content tests for the gas outburst risk assessment and short to mid-term planning of gas drainage and ventilation. The German fast desorption method generally allows using samples taken by underground in-seam drilling, surface or underground core drilling or sampling by hand from the coal face, conveyors or stock piles.

According to the German standard there are following terms defined:

- Gas content: The gas content is the gas volume per coal mass [m³/t]. Depending on the gas composition the gas content can be sub divided into e.g. methane content or carbon dioxide content. The gas content is referred to normal conditions (273 K and 1013.25 hPa).
- Total gas content: The total gas content q is the sum of the gas content at normal conditions (q1bar value) and the desorbable gas content. The total gas content includes both, adsorbed gas and free gas.
- q1bar value: The q1bar value is defined as the gas content remaining in methane atmosphere at normal conditions (at a balanced partial pressure).
- Desorbable gas content: The desorbable gas content qdes is the maximum fraction of the gas content desorbing in methane atmosphere at normal conditions at a balanced partial pressure.

A special sampling method has been developed which allows quick sampling from a defined position within the borehole. In-seam drilling is executed using pneumatic driven drilling equipment and hollow auger drill rods. Coal cuttings are removed from the borehole during drilling by conventional flushing with compressed air. For sampling at a defined position, the coal is sucked through the drill rods. This is achieved by using an ejector placed between the drill row and the compressed air supply. The coal cuttings are transferred from the deepest point of the borehole into a collection vessel within the ejector device within a few seconds. Using this equipment, coal samples can be taken from more than 20 m distance from the coal face which is suitable regarding touching coal with the virgin gas content. By sieving the coal cuttings to a fraction of more than 2 mm, a grain size is selected which allows reduction of the gas lost during the sampling process to a minimum. The whole sampling process requires maximum 2 hours and minimizes interruptions of heading or longwall operations.

The gas content test is basing on determination of Q1, Q2 and Q3 gas volumes similar to the Australian and US standard. Q1 is the gas lost during sampling. When applying in-seam drilling, this are one or two minutes in total. This volume is recalculated based on the subsequent Q2 measurement. After recovery, the sample is sealed in a bottle of defined volume (usually 1 liter) and send to the laboratory immediately. In the laboratory, Q2 is determined by measuring the gas composition in the sample bottle. The lost gas Q1 is calculated based on this initially released gas volume, the time elapsed between removing the coal from its origin position and sealing, the time elapsed between sealing and Q2 the measurement and an average value of the desorption rate or kt testing. The rate of desorption for the > 2 mm fraction is very similar for different coal types. Considering the short sampling time, this simplification allows accuracy on a suitable level. In exceptional cases as mylonitized coal, the desorption rate is higher. In such cases a higher desorption rate may be used in the calculation of Q1. In cases of uncertainty, also desorption tests can be executed for certain coal types.

After measurement of Q2, the coal sample is immediately crushed down to microscopic size, resulting in total release of adsorbed gas. The gas is captured by using a measurement cylinder.

According to the German standard, the gas content refers to ash free mass. Hence, the weight and ash content of the sample is measured. The gas content is calculated for standard conditions. This is done by recording temperature and barometric pressure at each step of the procedure and subsequent normalization of the measured gas volumes.

The equipment for sampling is described in detail in Figure 32 below. An appropriate laboratory is of course required for the evaluation of the samples[8].

Figure 32 Coal Sampling Arrangements for Gas Content

Today, the method is used in Germany, Kazakhstan, Turkey and Mexico. Although small samples are used, parallel tests using the US standard D7569-10 (in turn close to the Australian standard AS3980) has shown sufficient analogy. Compared to core testing it provides more flexibility in sampling.

[8] The laboratory is not discussed in this report. If further information is required DMT is pleased to provide this.

Operation:

1) Drilling: During drilling the borehole is washed by compressed air. Compressed air is flowing via a bypass, the circulating head and the hollow drilling rods into the borehole.

2) Sampling: For sampling, compressed air is flowing through the ejector. The ejector is providing negative pressure within the ejector body. By this, coal cuttings from the borehole are sucked via drilling rods and circulating head into the ejector body. Coal cuttings are captured within the ejector body.

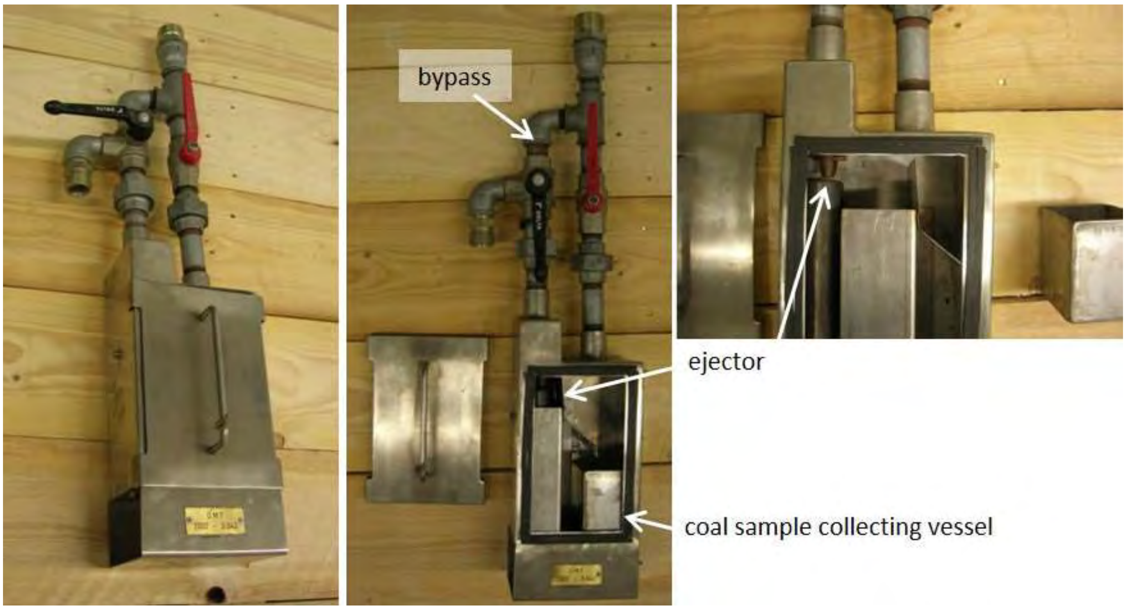

Figure 33 Ejector

Coal samples of ~10 g are filled into the bottle at the drilling location. The bottle (Figure 34) is sealed and transported to the laboratory. The size of the bottle is 1 liter. The rubber plug is pushed into the opening of the bottle body and fixed by the screw cap. Steel pipe, rubber hose and valve are connected to a hole in the rubber plug. They are used in the laboratory for recovery of gas released by the coal sample.

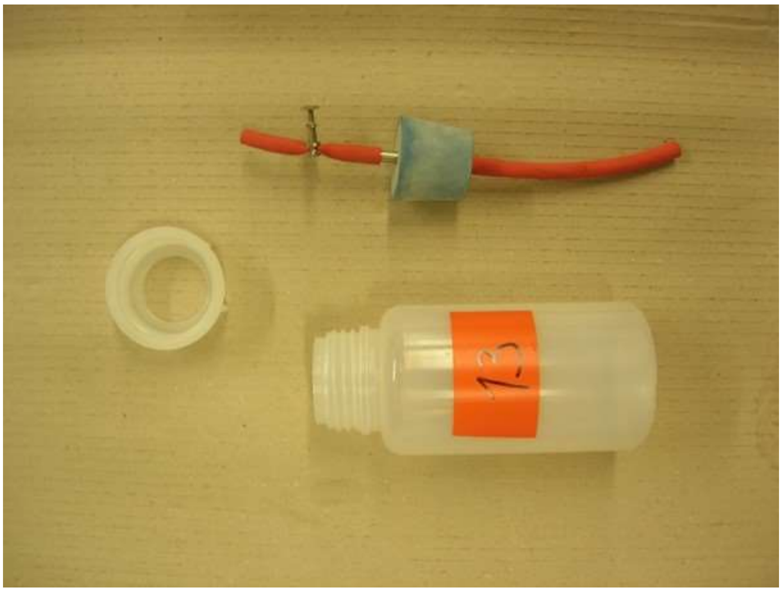

Figure 34 Coal Sampling Bottle

12.3 SUMMARY AND RECOMMENDATIONS

The necessary geological conditions for the formation of a rockburst are basically fulfilled. The entire seam of about 60 m is located between two massive sandstone layers.

However, a closer look at the distances of the sandstone banks to Seam 2 and Seam 4 reveals that the distances of the solid bank to the upper Seam 2 are larger than to the lower Seam 4. In the upper mined Seam 2 the distance to the sandstone bank is about 13 m and in the lower built Seam 4 the distance of the sandstone bank to Seam 4 is about 9 m. The layers above Seam 2 contain Seam 1 and the lower layer contains Seam 5. The lower strength of these layers and the thicknesses between Seam 2 and 4 and the sandstone layer are normally too large to transfer high pressures to the mined seams for the formation of a rockburst.

Due to the complex mining method of pillar recovery, the geometrical situation results in residual pillar situations that increase the mountain pressure in some areas. Thus, the conditions for a possible rockburst hazard are basically fulfilled by the depth, area by area solid surrounding rocks as well as additional pressures caused by the excavation geometry. The sum of these factors has apparently led to two rockbursts.

Since, depending on the situation, Seam 2 or Seam 4 was mined or will be mined as the first seam in the mining development to depth a very favourable situation for rock pressure reduction is created and thus a protective seam effect for the subsequent seams.

The concentration on a possible rockburst hazard is therefore on the first preceding seam.

12.3.1 CONTROL OF ROCKBURST HAZARD

- Continuous determination of the natural moisture content in the coal to assess the risk of rockbursts.
- Continuous determination of the moisture content in the coal after infusion and assessment of whether the objective of increasing the moisture content in the coal has been achieved.
- In the area of the first seam without substructure or superstructure prognostic drilling should be carried out according to the present regulations.
- Future assessments of the hazard situation using a numerical model to visualise the pressure zones in the coal and the loosening zones in the rock formations.

Currently, no further measures for the early detection of stress zones are being implemented. According to the mine management, it is planned to resume predictive drilling as a monitoring procedure with the increase in depth.

Whether predictive drilling will be necessary in the future and, above all, in which areas, can be determined on the basis of numerical considerations, current and continuous moisture analyses and further exploitation planning.

12.3.2 CONTROLL OF GAS OUTBURSTS

- Mindeli Mine should be able to continuously determine the gas content in order to carry out a concrete hazard assessment. In the complex mining situation, there are very many areas which probably have different gas contents. Correct, further measures can only be proposed if the correct gas content is known. The sampling procedure for determining the gas content and the laboratory analyses can be discussed in detail with DMT.
- On the basis of the gas content of 15 m^3/t mentioned by Mindeli Mine, exploration drillings in gate roads are therefore necessary at first, as a gas eruption in fault areas is possible due to the gas content.
- This applies in particular to the first seam to be mined, since the subsequent superstructure or substructure results in good pre-degassing for the subsequent seams. However, these situations must first be systematically checked by determining the gas content. Then together with DMT a drilling program can be created.

Mindeli Mine must be able to continuously determine the gas content or has to commission to determine it in order to be able to carry out a risk assessment. In addition to the regular determination of the moisture content of coal for the risk assessment of the rockburst hazard and the continuous determination of the gas contents, a much more frequent close coordination with the mining authorities and/or experts is required.

13 ALTERNATIVE MINING METHODS

Mindeli Mine's production strategy comprises a LOM mine plan for individual seams supported by production and development schedules providing a base for the company's business model. DMT has reviewed the LOM mine plan along with the individual layouts for the seams proposed for extraction and found these reasonable and achievable. Proposed face performance of some 5,500 t/month on average does not exceed historical production rates regularly achieved. Annual roadway development supports the increasing production. Total drivage meters related to face production increases consequently from some 7.5 m/1,000 t in 2018 to 16 m/1,000 t in 2020 providing for sustainable development of the mine. DMT considers these plans to be realistic.

The long-term projection until 2036 proposes keeping annual production at the level of 700,000 t ROM extending mining operations to the Shaorssky field. This also includes construction of a conveyor drift from the surface. The drift equipped with a belt conveyor will be the main coal haulage route to the surface replacing the current shaft hoisting system. The mine is aware of the required capital and has planned for this accordingly. As usual in Georgia detailed planning is done for 5 year periods, while long-term planning is more conceptual. The plan does not foresee any significant changes from one 5 year plan to the next, which will be optimised and adjusted based upon the experiences during operations.

The mining method currently applied at Mindeli Mine bears major risks associated with:

- Blasting of some 40-50 kg of explosive almost each shift at one production face in gassy environment,
- Installing of the face wooden support (props and bars) and resetting the props damaged by shot firing,
- Dealing with roof fall and cavities in production operations,
- Large amount of manual work to be performed in small (1x1.5 m) and steep (up to 45 degrees) chutes.

Because of the above hazards and other risks associated with the mining technique the mine is looking for the suitable alternatives, which can eliminate and/or reduce the hazards resulted from the current method of mining.

Mindeli Mine has tried several mining methods (longwall, sublevel caving) back in the 60-is and 70-is. Although the mine could achieve production face outputs over 1000 t/d, the trails has failed at coal fires in the gob resulted from failure to control spontaneous combustion. Thus, the main criteria for the alternative mining methods are:

- Control of spontaneous combustion;
- Minimum of drilling and blasting; and
- Stable supported workings.

Mindeli geological conditions (seam thickness up to 60 m and seam dip up to 45°) are not typical for underground coal mining. However, there are several mining methods successfully used at the coal mines, which can be considered as a suitable alternative for the mine. Considering the design criteria set above, the mining methods based on extensive use of drilling and blasting (e.g sublevel caving, etc.) cannot be considered as the suitable alternative. Since any caving mining method without backfilling will not ensure efficient isolation of the broken coal and rock in the gob, these can also be excluded due to spontaneous combustion hazard. Bearing this in mind, DMT considers the following mining methods as the potential alternatives to the current mining technique at Mindeli Mine.

13.1 SOUTIRAGE

Soutirage mining method has been used for extracting the steep coal seams of over 5 m thickness at Vouter Mine in France (Lorrain) from until 1990-s.

Figure 35 shows a typical layout of a soutirage production section. The coal production faces are blocked-out by winzes connected by the laterals with the ventilation horizon and haulage horizon. Coal is extracted in the long roadway-type exploitation openings. Coal at the face is cut by a modified roadheader. The roadheader rides on the pontoon carrier, which is laid on the backfilled floor. Coal cut by the roadheader is loaded onto the armoured face conveyor and transported to the winze.

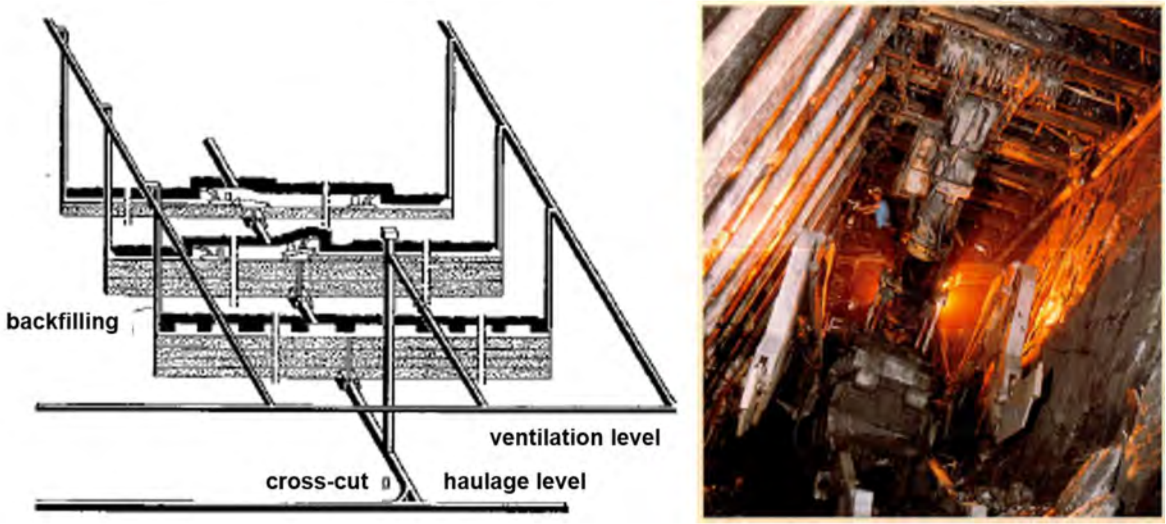

Figure 35 Soutirage Layout

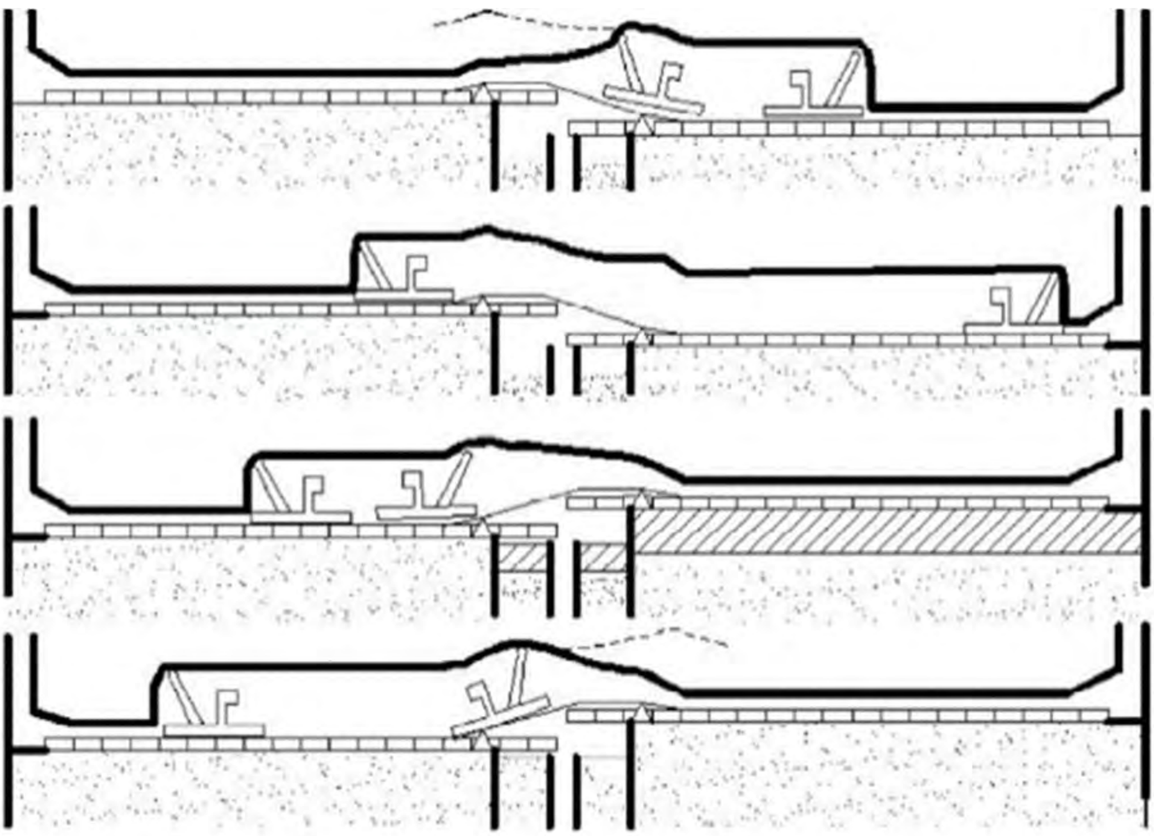

Figure 36 Soutirage Mining Technique

Once the cutting machine has extracted the full length of the exploitation opening the roadheader moves to the adjacent one, and the mined out working is filled with the sand based backfill material pumped under the pontoons.

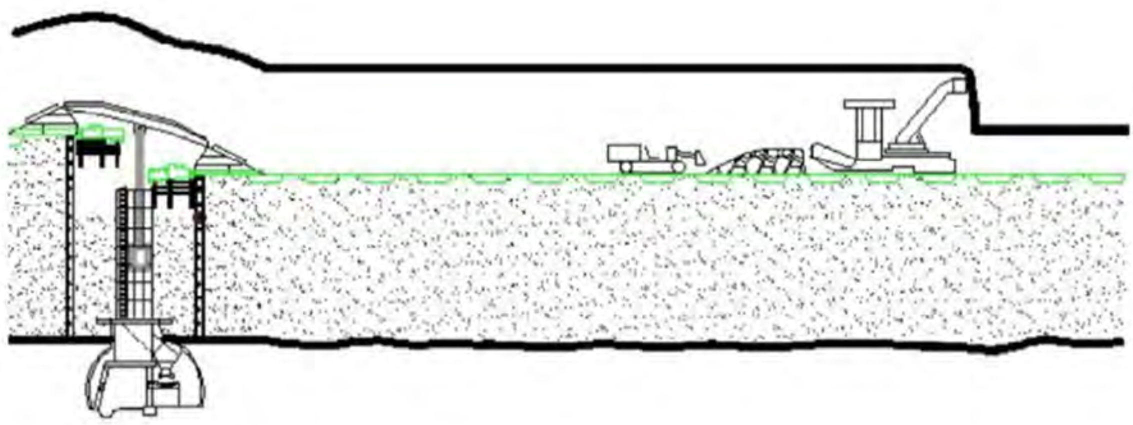

Figure 37 Soutirage Backfilling

Soutirage mining will provide an effective control of spontaneous combustion in the gob. The mined out area is filled with water and sand preventing entrance of oxygen and coal oxidation. Because of the seam thickness reaching up to 60 m at Mindeli Mine the sides of the exploitation opening will have to be isolated by e.g. spraying some 3-5 cm of light concrete or similar material. In addition, the length of the extraction openings can be selected to ensure that the exploitation time of an opening is less than incubation period of potential spontaneous combustion in the particular seam.

Vouter Mine could achieve average production rates of 250 t/d from an exploitation opening utilizing soutirage mining in a 5 m steep seam dipping between 50° and 90°.

13.2 CUTT AND FILL STOPING

Similar to soutirage the method utilizes the roadheaders for coal extraction. The exploitation panel is blocked-up by two or more entries providing ventilation, transport and other services to the production faces. The panel entries are connected with a set up (pillar) roadway (Figure 38). Short extraction openings are driven from the pillar roadways. Coal is cut in the extraction openings by the roadheaders and transported by the chain convenors or bucket loaders to the pillar roadway. Once an extraction opening has been minded out the roadheader moves to the next production face, and the opening is filled with the backfill material (similar to those used at Mindeli mine). The length of the extraction openings can be selected to ensure the production life of an opening is below the period of incubation and self-combustion, which e.g. is 2 months at the minimum for the upper seam II.

Hirschberg Mine in Germany has achieved average production rates of some 200 t/d from a face applying the cut and fill method in 7 m thick lignite seam. Similar results has been achieved at the mines in Poland.

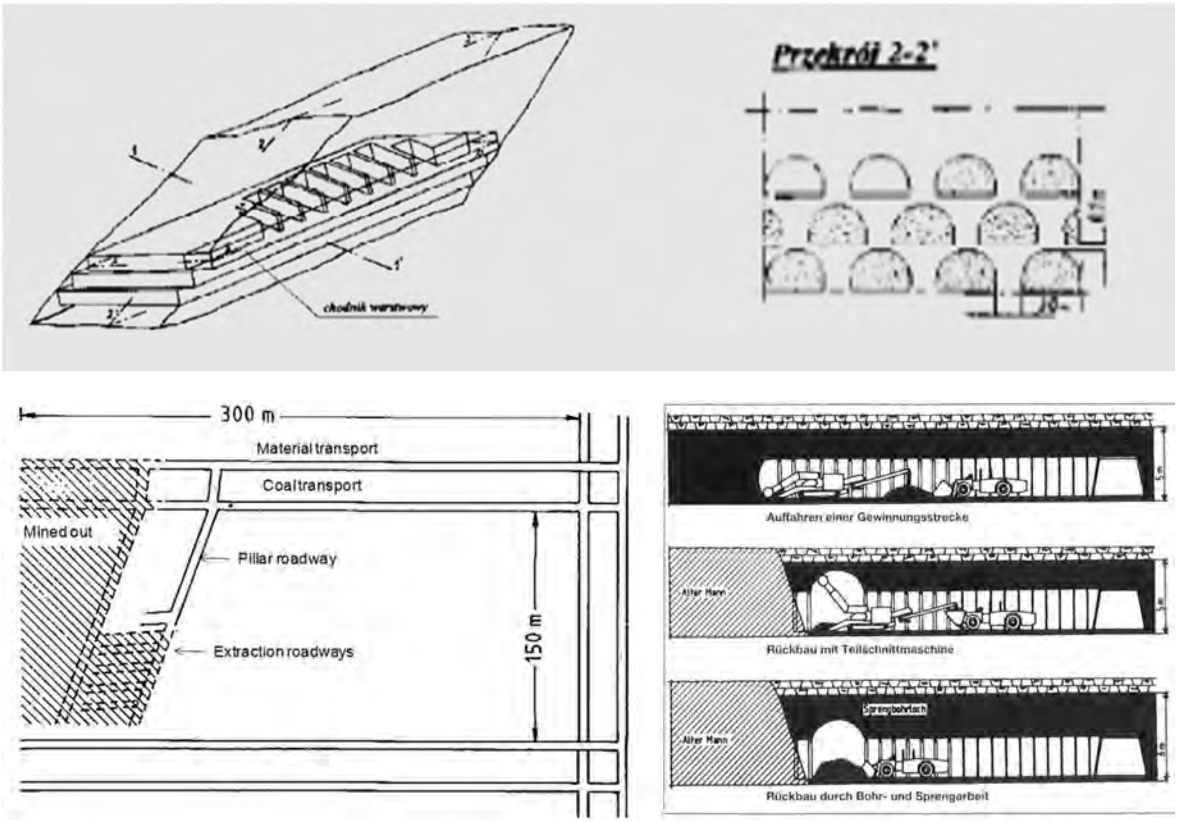

Figure 38 Cut and Fill Layout

13.3 SHORTWALL MINING

Mindeli Mine applied shortwall mining in the 1970-s. According to the mine two shortwall panels has been mined achieving outputs up to 1.200 t/d. The third panel has been lost because of a mine fire probably resulted from spontaneous combustion in the mined out area. Unfortunately, no details are available on the shortwall layout applied. However, DMT assumes a possible mine fire reason can be failure to properly fill and isolate the cavities in the gob behind the longwall with sand-water mixture.

It is worth to consider applying shortwall mining with the improved system for control and prevention of spontaneous combustion. DMT experience in gob backfilling in German coal mining (e.g. Walsum Mine) shows that it is crucial to fill the cavities and fractures in the gob not only in the seam level, but also above the coal seam level (Figure 39). This can be achieved by pumping the backfill material under 8-12 bar pressure through the trailing pumps in the gob and controlling viscosity of the mixture. Alternatively, backfilling material can be pumped both from the shortwall behind the powered roof support –to fill the gob- and from the additional roadway driven above the longwall to fill the cavities and fractures in the roof.

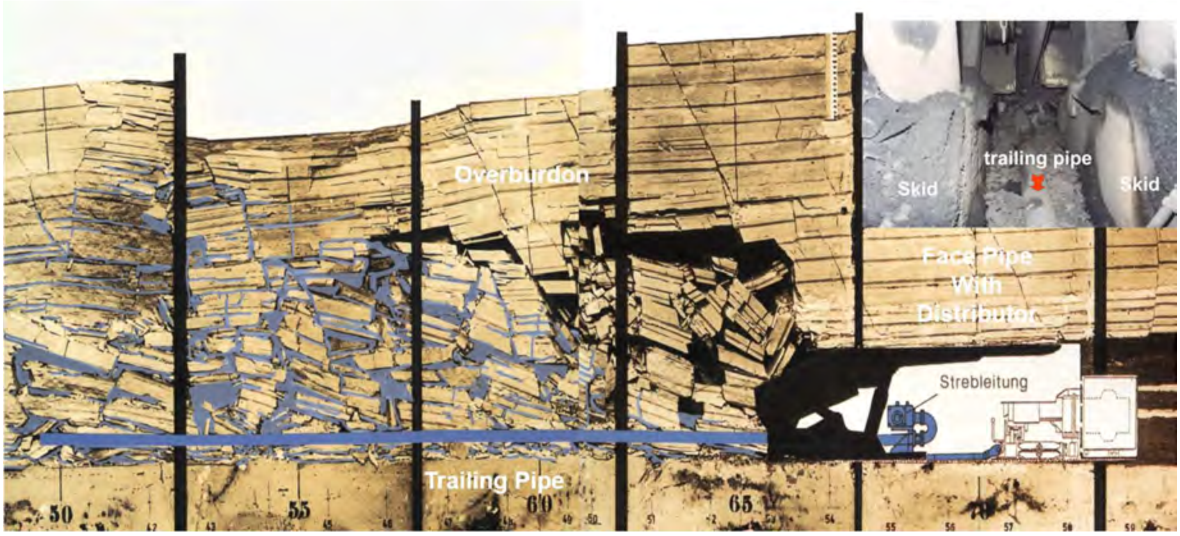

Figure 39 Principle of Gob Cavity Filling

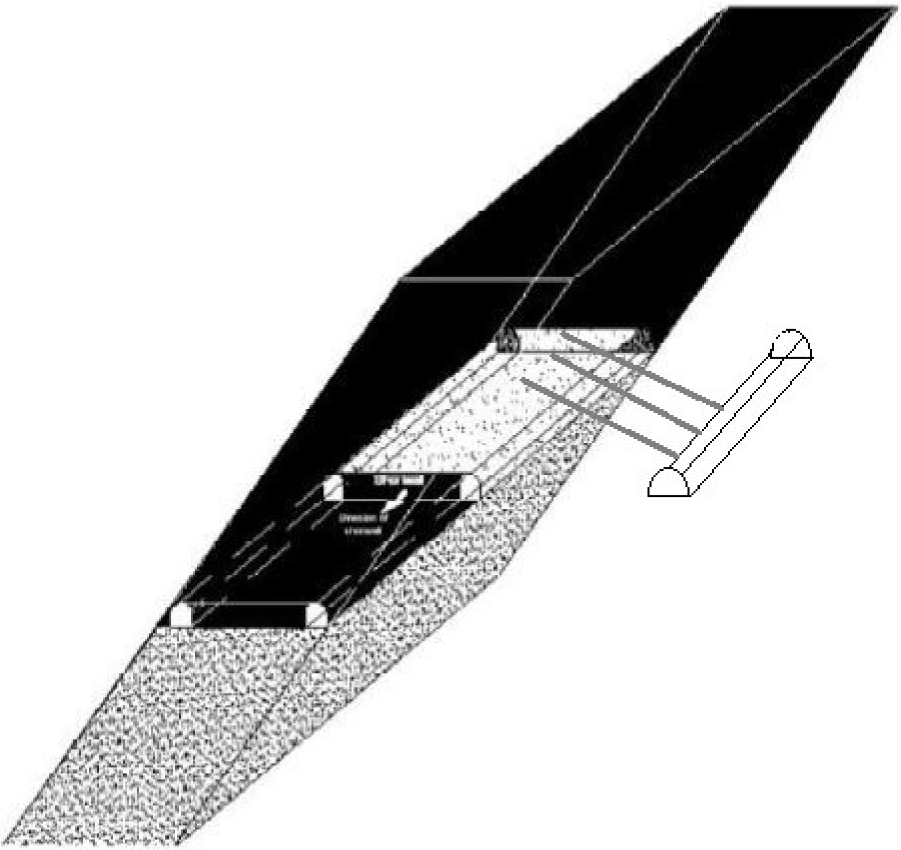

Figure 40 Shortwall Equipment Package

Experience of DMT backfilling laboratories shows that significant improvements of gob isolation quality can be achieved by optimising the recipe of the backfill material. DMT experience in development and testing of various backfilling mixtures for underground mining shows that particular regard should be given to viscosity and fluidity of the backfill (Figure 41). It is advisable to test various recipes of the backfill by adding e.g. fly ash or similar pulverised waste from cement industry to the sand backfill currently used at the mine.

Figure 41 Backfill Pressure & Viscosity Control, Walsum Mine

The incubation period for spontaneous combustion of Mindeli coal ranges from 2 month in seam II up to 5 months for the lower seams. Thus, an effective way of controlling the spontaneous combustion risk will be limiting the panel length by the maximum face advance within the incubation period. In this case the shortwall equipment will be salved and moved to the next panel after advancing e.g. 500 m within 60 days and the old panel will be sealed and backfilled.

Short wall mining is a proven mining method for underground coal mining. DMT assumes the daily production rates between 2,000 and 3,000 t can be achieved from a shortwall face under Mindeli Mine conditions.

13.4 LONGWALL MINING

There are a plenty of examples of successful extraction of the steep coal seams by means of longwall mining. Erin Mine in Germany has run several langwall faces dipping at 45°, some longwall faces have been operated in the UK and Poland. China still utilises longwall equipment packages under conditions similar to those at Mindeli Mine.

Technically, the only mining direction along the strike can suit at the mine (Figure 42). Mining dipdown would prevent backfilling of the gob, and mining on full rise would bear the risk of coal falling from the face.

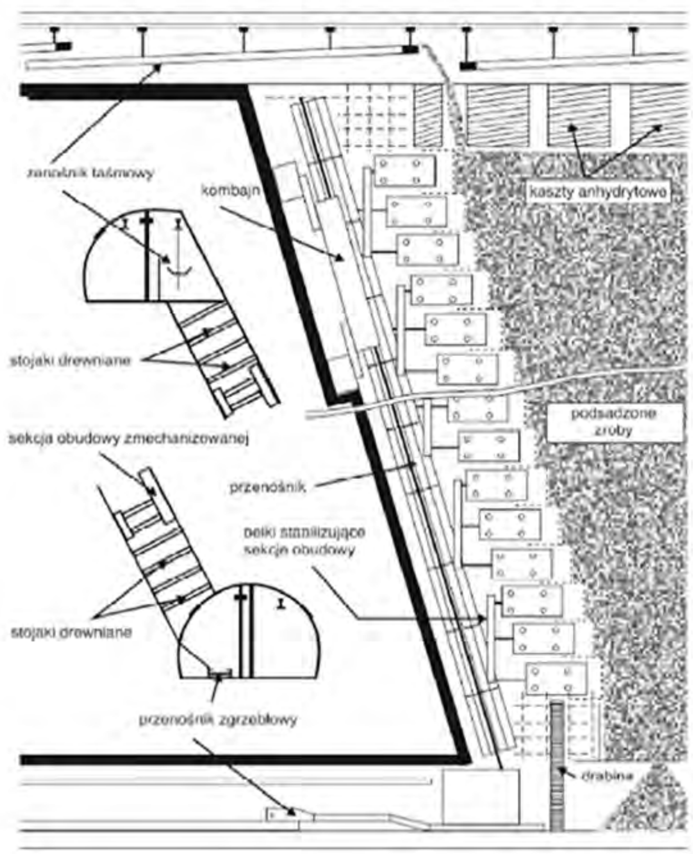

Figure 42 Longwall Layout Steep Seam

According to the mine some pilot lonwalls have been tested at the mine in the soviet era. Similar to the shortwalls these has failed because of the mine fires. DMT recommeds further elaboration of the lonwall mining option in combination with the measures for controlling and preventing self combustion discussed for the shortwalls above.

DMT assumes face output of some 5-7 thousand t/d would be reasonable under Mindeli mining conditions.

13.5 AUGER MINING

Mindeli mine has designed an auger mining prototype equipment set tailored for the conditions at the mine (Figure 43).

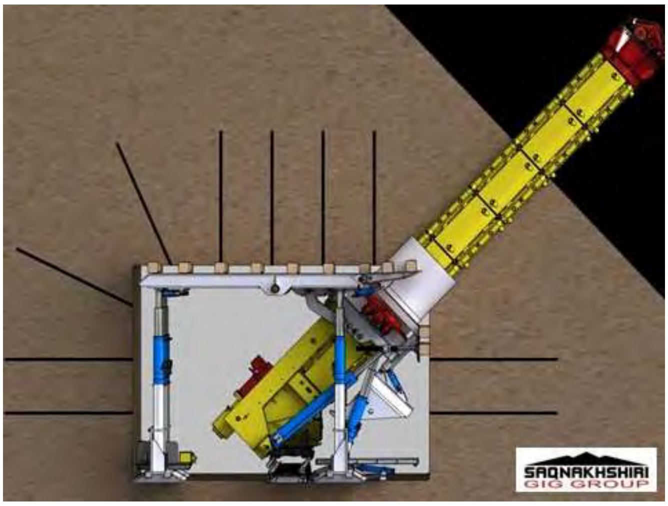

Figure 43 Auger Mining Design Mindeli Mine

Undoubtedly, the proposed system would reduce or eliminate most of the high risks associated with the current mining method. Because of a low productivity and high space requirements, auger mining is rather used in open pit mines as a supplementary method. Particular for Mindeli conditions ventilation arrangements and a proper ignition suppression system has to be installed to control gas explosion risks.

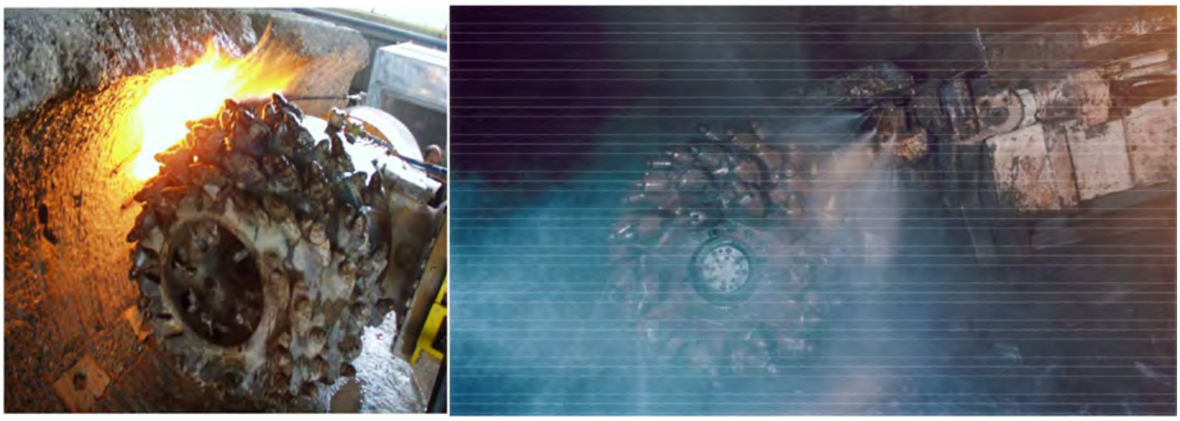

Figure 44 Ignition Suppression System

The alternative mining methods discussed above will potentially reduce and/or eliminate major risks the current system bears. Thus, it is advisable to consider replacing the current drilling & blasting extraction method by a method exploiting coal mechanically. The plans to replace the existing shaft hoisting system by a new convening system constructing the drift will undoubtedly contribute to further H&S improvement. This is in particular sensible considering the shaft hoisting requires a heavy refurbishment program.

The options defer both in terms of investments and in terms of production. Thus, a detailed trade-off of the methods will identify the most suitable alternative for the mine. In addition to the safety, technical and cost consideration the trade-off has to consider availability of the markets for coal production to justify the investments in the long-term prospective.

14 ROUTE BACK TO COAL FACE

The speed at which Mindeli can recommence mining is dependent upon the speed at which the recommendations agreed could be implemented.

The first stage of changing the management process at Mindeli is for the Board to agree a Safety Policy for the business. A Safety Policy sets out in writing the business's commitment to health and safety, and should clearly state who does what they do, when they do it, and how they will do it. This must be communicated to the supervisors and workforce.

DMT have been consulted to make recommendations based upon knowledge and experience drawn from other safety cultures. The recommendations will be considered by Georgian safety and mining experts, regarding their suitability to the administration of the mine.

The process of implementation of the recommendations will be central in ensuring the successful implementation of the chosen initiatives selected to improve H&S at Mindeli. Such a process will need clear and disparate stages.

To this end, all the supervisors and mineworkers, and other personnel at the mine should attend a formal presentation of the safety policy, to demonstrate the intent of management to introduce a suitable H&S management system.

Once this has been completed, say over 4-5 days as each shift/group is initiated, then the process of ensuring that all documentation required for the operation of Mindeli is in place can commence. It is essential that this must be an inclusive process in which all interested parties have an input in order to arrive at a workable, safe conclusion.

The hazards inherent in each activity must be identified, as well as those that affect the whole of the mine.

The risk assessment documents can then be created, (which will confirm or deny the suitability of the existing documentation). Such documentation will include;

- Manager's rules (transport, support, ventilation, fire, spontaneous combustion prevention, shotfiring, explosives etc.)
- Method statements (or Passports) telling people how to do each job
- Ensuring compliance to all existing legislation

The Management team will dictate the length of time that this process occupies, and external assistance would likely benefit this part of the process both in terms of time and content.

To restart production, several other activities are required to allow the face to operate. The drift transport, the blind shaft, the in- seam transport system, the mineral clearance system, the materials handling system, the control of explosives, and more. To restart production, all associated service systems need to be scrutinized in the same manner to ensure adequacy prior to restarting production. It is not sufficient to simply eliminate the immediate issues that caused the two explosions at Mindeli. Without adequate management process in each activity, the next potential disaster could arise anywhere. Mindeli already had a catastrophic management control failure in recent times in the skip winding shaft. A runaway train of vehicles meeting a shift change, or a coal dust explosion propagated by a gas explosion, or flooding stopping the main ventilation circuit could all result in major incidents.

When the above work is completed, to the satisfaction of all interested parties, and the plans signed off by the Manager of the mine, then teams of auditors should go underground and audit the systems dynamically to ensure the suitability and sufficiency of them. This must be carried out under strictly controlled conditions. For instance, during transport of vehicles and all the associated activities along the transport routs, no persons other than the immediate operatives and the audit team should have access to the area.

If the rules are confirmed by audit to be suitable and sufficient, then they should be officially signed off, and until something changes in the future, this is the way that these systems must be operated from that point in time.

The audit teams should consist of suitable senior management, supervisors of the area, and workmen who operate there.

When the supporting systems to the coal face have been signed off as suitable and sufficient, Mindeli can then turn its attention to planning the re-commencement of production on one coal face.

The process used for the supporting activities should be repeated for this first coal face, and an iterative process adopted until all parties are confident that every avenue has been explored to ensure that the systems of work are correct, and cater for all eventualities. Other than this, they should also cater for arrangements for control in circumstances that may arise later (the traffic light system previously described would assist in this)

When the systems for the coal face are agreed, proven to be adequate, and signed off, then attention should turn to the second production area, incorporating the lessons learned in the first area, but still going through the audit and supervision process to highlight any issues specific to that area.

In the same way, the third production area can then be dealt with, and in turn the associated development works.

Eventually, when the mine is returned to full activity, this process of audit and change must be continued to continuously identify changes that require consideration.

In addition to formal audit, there are several ways in which safety issues can be flagged up.

Inclusion is the key. This will help promote a reporting culture at the mine. No matter how much time management spend underground; they will not be able to witness many of the actions and decisions made, which may influence the level of risk present at Mindeli.

The types of meetings that might be considered to enhance this type of behaviour include:

- Safety steering committee- a group of people selected from a cross section of the mine population, including mineworkers' representatives, who go underground on a regular (say monthly) basis together on an agreed rota of visits to take in the whole of the mine at least annually. This team audits what they see, and formally report their findings, and more importantly agreement is made with management on how solutions will be instigated, together with an agreed timeframe. Very senior management should fully involved in this process
- Annual safety refresher training- groups of around 20 workmen from a cross section of the workforce spend one day out in a classroom environment going through a set programme of issues that they should be aware of, the issues at the mine, and their thoughts on what could be done to improve safety. For example, refresher training about self- rescuer use, and PPE could also be included in this meeting.
- Supervisors weekly shift team meeting- once per week, the (say) afternoon shift attend a meeting with the Manager to go through issues at the mine, discuss safety issues, and pass on information that helps to improve the safety culture. The communication should be two- way, and used as a valuable barometer of safety issues at the mine.

15 CONCLUSIONS

It was evident to DMT, throughout the data gathering process, that the mine is in immediate need of a significant root and branch change in the management of health and safety, the safety culture at the mine, and a revision downward of the level of risk acceptance of the business. This was pre-empted quite rightly by the mine being stood down from production for over seven months in order to investigate ways in which these changes can be quantified and put into place.

During the interviews and meetings at the mine, and the underground visits, it was made apparent to DMT from peoples' responses that neither the management team, nor the supervisors or workmen are aware of what the solution to their problem might look like. Compared to other more advanced mining businesses, Mindeli is encapsulated in a time when people did virtually as they wished in the pursuit of their goals. There is no place for this type of behaviour in modern business, and the Government has confirmed their agreement with this precept in taking the action that has been taken.

To start the process of change in the administration of H&S at Mindeli, a management process should be agreed, and followed. The process recommended by DMT begins with the formation of a Safety Policy, set by the business's Board, clearly demonstrating the way in which H&S will be controlled and administered. There must be a commitment, that the likelihood of incidents that have occurred in recent times being repeated is so low as to be considered negligible. In order to ensure this, a substantial amount of work must be undertaken; not least the work involved in changing peoples attitudes to risk taking, and to the safety culture at Mindeli.

Without such a commitment, it would be wrong to advise a continuation of operations, knowing that a failure to invoke change will inevitably result in further incidents.

With the Safety Policy (the keystone of a H&S process) in place, key personnel at Mindeli should be trained in the process of hazard recognition, assessment of the risk of the hazard, and the implementation of control measures and dynamic auditing of all activities. This process will inevitably reveal the 'weak spots' in existing management systems.

There will be concern that these 'new' processes will hinder the operational activities. What the mine will find in reality, is that when the new way of working is established, the mine becomes more efficient and more productive.

Table 10 below summarise a pool of measures to be undertaken to improve the health and safety standard at the mine to an acceptable level.

Table 10 H&S Improvements

Short-Term	Mid-Term	Long-Term	Comment
Install fire extinguishers and fire fighting arrangements underground	Install men riding arrangement in winzes and chutes		
Review of cycle time to ascertain	Refurbish control and Safety System of shaft hoisting		if the planned tonnage from each unit could be achieved within the

Short-Term	Mid-Term	Long-Term	Comment
			available time
inert stone dusting	Fix shaft cable fastening		to prevent coal dust explosion
Improve PPE	Inspect & renew the shaft cables		eye, hearing, or hand protection
Set accidents and incident investigation and analysis process	Provide redundancy to the shaft hoisting barks		
Improve incidents & accidents reporting	Refurbish electrical system of the shaft hoisting		Report all incidents and light accidents
Create a Health and Safety Policy Document	Refurbish shaft monitoring system		
Appoint a competent person to manage H&S change	Establish "traffic lights" system		suitable qualification, experience, and capability to be able to perform the role adequately and independently
Introduce & undertake Risk Assessment	Consider additional layer of supervision		
Train mine management			
Establish risk controls for each individual mine operation	Consider increasing minimum air speed up to 0.5 m/s		drift transport, the blind shaft, the in- seam transport system, the mineral clearance system, the materials handling system, the control of explosives, and more
Establish safety meetings at the mine	Calibrate gas sensors underground		
Develop methods of work clear defining safe procedures	Pressure measurement of mine		The people carrying out the work should have input into the final guidance
No training without written instructions & handouts	Improve & extend training		examine success of the training
Introduce scrapers for cleaning out the blasting holes	Regular gas content measurements		
Determine characteristic curve of the main fan	Train & establish mine rescue team		
Establish wearing of self-rescuer always on their person	Consider using foam for dealing with roof falls		
Consider a bonus scheme for making people and work safely	Introduce wire mesh lagging		to exclude environmental factors
Establish leading & managing by example in terms of H&S	Trade-off suitable mining methods		
Check stability of the ventilation	Install air movers		
Define real gas emission			
Address landings at the switches clear and unique			

Short-Term	Mid-Term	Long-Term	Comment
Establish new inclusive H&S planning system			
Elaborate potential of changing ventilation layout		Install methane drainage	
Improve barriers explosion protection			
Establish longer probers for methane sampling			mine workers
Signpost escape routes			
Establish reporting standards for critical repairs and maintenance			
Reflagging and supporting the roadways			
regularly determine natural moisture of coal			to assess the risk of rockbursts
Forecast drilling for the protection seams		Apply numerical modelling for rockburst assessment	to assess the risk of rockbursts
Refurbish stairs and rests		Gas outbursts drilling based on gas content survey	
Renew shaft hoisting documentation			
Inspect the gears of the shaft winders			
Establish equipment repair recording			
Fix shaft cable fastening			
Introduce tools for detecting the shot hole breakers			
Find a mean of securing a tamperproof system			
Establish regular temperature and humidity monitoring underground			
Establish roadway deformation monitoring and stress concentration forecast	Undertake geotechnical logging of a drillhole and geotechnical survey of the faces	Conduct stress measurements underground	To verify direction and magnitude of the principle stress components
Establish geotechnical & deformation monitoring system		Develop a geotechnical mine model	Kinematic and numerical analyses to assess and plan stability of the underground excavations
	Trade-off class 4 and class 5 explosive		

The process outlined by DMT in this report does not consider H&S to be a separate activity from operations; rather that it is an integral part of the plan as a whole. What must be resisted is the tendency in this kind of situation to run a ‘parallel system’, with the old system continuing, and the new system becoming a ‘paper exercise’

Project Team

Ulrich Ruppel	Project Director
Artem Chayka	Project Manager, Mining Engineer
John Alstead	H&S Expert, Mining Engineer
Rüdiger Baltz	Rock Bumps and Gas Outbursts Expert
Torsten Gorka	Geotechnical Engineer
Dietmar Plum	Mechanical Engineer
Rolf Steffes	Ventilation Engineer
Dr. Hanspeter Tomschi	Environmental Engineer, Geologist

DMT GmbH & Co KG

Ulrich Ruppel

Artem Chayka