Key , and frequently overlooked, facets of effective escape and rescue

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1. Introduction

Should the atmosphere in an underground coal mine become contaminated with noxious gases, smoke, fumes and/or vapors to such an extent that the atmosphere is no longer deemed respirable, employees are instructed to escape to the nearest refuge chamber.

Once in the refuge chamber, employees need to remain there until MRS can affect a rescue operation or the CTC rescue drill can be used to drill a rescue borehole through which employees can be extracted by utilizing a rescue capsule.

The CTC drill was recently used to drill 4x rescue boreholes at Matla and during this exercise certain key aspects where identified that could lead to the success or failure of a rescue operation.

These aspects are often overlooked and as a result might result in fatalities due to a failed rescue attempt. This document will aim to outline these issues so that strategies can be put in place to combat such failures.

2. CTC rescue drill

The rescue drill unit comprises of the T685WS (Pilot Drill) and the T130XD (Main drill rig) and a number of trailers that contain ancillary equipment such as compressors, drill rods, 20t mobile crane and a mobile workshop.

The Pilot drill is capable of drilling a 220mm hole through the soft overburden after which casing is inserted. A 165mm diameter uncased hole can then be drilled to a depth of 300m.

The Main drill is capable of drilling a 750mm hole through the soft overburden, simultaneously inserting a 711mm outside diameter casing with a wall thickness of 8mm up to a depth of 24m. A 635mm and 660mm hole can then be drilled to a maximum depth of 300m.

2. CTC rescue drill

In a typical rescue situation, the Pilot Drill will try to locate trapped personnel (if communication cannot be established with them via existing means) whilst the main drill will drill the main rescue hole through which the rescue capsule will be lowered to extricate trapped persons.

The pilot drill requires a minimum of three operators to deploy and the 165mm hole can be drilled to a depth of 100m within a day involving minimal costs. Mines are required to assist with ground preparation and supply diesel and water

The main drill requires a team of at least eight persons to deploy and a 660mm hole can be delivered safely and reliably at costs considerably lower than commercial rates.

2. CTC rescue drill

It should be noted that the rescue drill used to drill the borehole for the rescue capsule is a massive machine. The machine weighs in excess of 50 tons and as a result, requires a well-prepared access road and area/platform from where drilling can commence. To prepare such an area is a massive undertaking. Before drilling commenced at Matla coal, and this would ring true for all operations, the following preparatory work needs to be conducted:

- The probe drill on its own requires 50mX50m area
- The main rescue drill requires 100mX100M area
- A thorough assessment of the site regarding stability of the surface must be carried out prior to site establishment. If the surface is clayey, as many loads of G5/G6 road mix as may be required must be provided to stabilise the area under and around the machines

2. CTC rescue drill

- A front-end loader must be made available on site, and in wet clayey conditions the biggest available bulldozer must be made available as well.
- Access points to be manned by security guards to prevent unauthorised entry by persons.
- Arrange for security access for CTC Rescue drill team members to mine property e.g. workshops, mine store etc.
- If possible establish communication on site.
- If assembly of the equipment is required after sunset, please arrange portable lighting.
- Establish the location of any heavy mechanical equipment such as cranes (10 ton minimum), road graders, bulldozers, tractors, front-end loaders and water tankers that may be in the district (Provincial Roads Department, erection and construction firms, etc.) and its availability if and when required.
- Arrange accommodation, catering, ablution facilities and drinking water for the teams and technical staff.

2. CTC rescue drill

- If required, assist the RDU team with the provision of items such as picks, shovels, hammers and tools and fittings for pipes etc.
- The RDU will require a minimum of two 2000 litre diesel supply tanks to be available as well as a diesel bowser

Furthermore, and depending on the geological features of the area, the main drill takes approximately 3-5 days to drill a borehole of 90m in depth. (In case of an emergency drilling will be done in two shifts and without stopping and at a rate of 3.5m an hour the 90m hole could be completed in 26hrs.

This time excludes the site preparation, traveling to site and setting up of equipment. After completion of drilling the hole, time must be allocated to remove drill string form the hole and move the drill and equipment from the hole. This process will take another 5 hrs. to complete.

In summary, as it can be seen from the previous few slides, this is a timeous process and plenty of preparation work needs to be done in order to ensure a successful drill operation.

3. Matla rescue trailer – constant supply of respirable air

The rescue trailers purchased are aimed at supporting miners that are trapped underground in a coal mine. The trailer will provide life sustaining supplies through the borehole situated above the refuge bay as long as the drill is operating in the area.

It is fitted with:

- A diesel generator
- A fan to supply air to the trapped miners using power from the diesel generator
- A Spot light
- 4 Bullets
- 2 Jerry cans
- A tower fitted with a winch to lower 4 bullets into the borehole, aimed at supplying trapped miners with food and emergency supplies
- A canopy for the trailer

3. Matla rescue trailer – constant supply of respirable air

The rescue trailer has the capacity to provide miners that are trapped underground with the necessary air and supplies, in order to provide rescue personnel with valuable time to find other means of getting miners out safely.

The fan mounted on the borehole casing, which is activated once a refuge bay is entered, is there to ensure a constant supply of respirable air is delivered to the refuge bay. Furthermore, the purpose of the fan is to maintain a positive pressure inside the refuge bay to prevent the ingress of toxic/noxious gases and smoke.

Most of these fans, in the event of a power failure, can operate for a period of 24 hours by making use of the back-up battery. Should the preparation of the area and drilling of the hole take 5 days – 120 hours – what method will be used to ensure the occupants of a refuge bay are supplied with a constant supply of respirable air once the battery back -up of the casing mounted fan runs out?

The strategy, with the acquisition of these rescue trailers, will be to connect the blower on surface and then force air down the borehole to ensure occupants are safe and the atmosphere remains life sustaining until rescue operations can be initiated.

3. Matla rescue trailer – constant supply of respirable air

Tests were conducted on a 100m length of galvanized pipe to quantify the duty of these blowers and the following results obtained:

A galvanized pipe, 8-inch diameter, was used to conduct the tests on surface. A K-factor (friction factor) of 0.0037 $Ns^2/m4$ was used and the resistance was calculated by making use of the following equation: **$R= (KCL)/A^3$**

Velocities were measured and quantities calculated. By making use of the following formula: **$P = RQ^2$**

The pressure the fan had to overcome to pass a certain amount of air through the casing was calculated and the following obtained:

Area of pipe	0.0314 m^2
Resistance offered by pipe	7508 $Ns^2/m8$
Velocity	5.65 m/s
Quantity	0.18 m^3/s
Pressure	243 Pa

4.1 Sizing of refuge bays – rescue trailer

In the past massive refuge bays were constructed. It was found that the fans we have could not effectively pressurize these refuge bays. Resultantly, calculations were done using the Mine Health and Safety Act as guideline and refuge bays are now constructed as follows:

- 0.6 m² allocated per person
- Based on 40 persons per instance
- 20% allocated for equipment
- 10m² for the rescue drill.
- Total coverage = (0.6x40) + (0.6x40)x 0.2)+ 10m² = 38.8 m²

A pressure test was conducted on a refuge bay. The BP was tested outside and inside of the refuge bay, the fan started and BP tests carried out again. The following was observed:

Size of refuge bay	46 m²
BP inside (fan off)	84.7 kPa
BP outside (fan off)	84.7 kPa
Fan started and ran for 40 seconds	
BP inside (fan on)	84.8 kPa
BP outside (fan on)	84.7 kPa

At a quantity of 0.18 m³/s as supplied by the rescue trailer, and a refuge bay volume of 46m² x 2.5m Height = 115m³, an air change can be affected within 10.6 minutes/ approximately 5.6 air changes per hour.

4.2 Sizing of refuge bays – casing mounted fan

Another refuge bay of 105 m² was used to conduct a similar test. The fan mounted on the casing was running for 11 minutes before a change in pressure was observed.

As it can be seen below, a refuge bay of the correct size can be pressurized by making use of the borehole casing mounted fan. These fans actually had higher quantities than the rescue trailer fans, but this due to the negative pressure created by the main fans.

This is an indication that our current fans will certainly pressurize a refuge bay and provide a life sustaining atmosphere, provided the refuge bay walls and doors are air tight and the refuge bay constructed is of the correct size. However, the challenge is the 24 hour run time, hence the need for an alternative means of pressurizing i.e. the trailers

No	Quantity without Fan running (m^3/s)	Quantity with Fan running (m^3/s)	BP outside Refuge Bay (KPa)	BP Inside Refuge Bay (KPa)
1	0.17	0.86	84.4	84.6
2	0.15	0.80	83.9	84.1
3	0.14	0.83	83.9	84.1
9	0.16	0.82	83.9	84.1

5. Refuge bay diagram, informative plate and designated drill area

It was also found that once on surface, it is almost impossible to identify the correct area to drill i.e. without a sketch/diagram as reference of the layout of the refuge bay underground one can easily drill and hole outside the refuge bay, or drill in the area where employees are seated which might also lead to injuries or fatalities due to fall of ground created by the holing of the drill.

It is therefore of utmost importance to have a dedicated, barricaded, area in a refuge bay where the drill can hole. Also, an informative plate on the concrete plinth of the borehole indicating the depth until holing, geological structure/composition of the area, co-ordinates etc. will be highly advantageous as timelines are dependent on these issues.

As mentioned above, a layout of each refuge bay is critical in ensuring the holings are affected in the correct position.

Now, when standing on surface next to the borehole and using the sketch as reference, one can measure a distance and identify the best position for holing with the rescue drill.

6. 400 kPa doors

Currently, 400 kPa seals are constructed to ensure employees inside the refuge bay are safeguarded in the event of an explosion. However, normal tunnel doors are fitted to these walls.

The structural integrity of the wall is then compromised and the wall can no longer be classified as a 400 kPa structure. Matla has now engaged a company which manufacture 400 kPa certified doors and these are now fitted to our refuge bays.

7. Conclusion

In order to ensure a successful escape and rescue mission during an emergency, there are a few key aspects to be considered. Preparations need to be made before hand to ensure that should an emergency arise the hidden hurdles/stumbling blocks have been considered and addressed. As much as proper construction and life sustainability of a refuge bay is of paramount importance, so too is the issues mentioned above. The size of a refuge bay plays a huge role in the time it takes to pressurise.

Tests have shown that a smaller refuge bay can pressurise within 40 seconds, whereas a large refuge bay can take up to 11 minutes before a difference in pressure is observed.

Imagine waiting a week to drill a rescue borehole and missing the refuge bay? What will another 3 days underground mean for those individuals trapped and their families?

8. Acknowledgements

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Thank you.

Questions?