Pre – Conditioning
A tool to combat Face Bursts at Mponeng

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As the mining depth increases, so do the stresses ahead of the mining faces. Consequently the probability of face bursting also increases. Mponeng is a seismically active deep level mine. Due to the depth and the properties of the rock mass (hard, brittle hangingwall lava), the occurrence of face bursting is a problem. Seismicity accounts for some 50% of all mine fatalities on Mponeng. Over the past few years great improvements have been made in reducing the rock related injury and seismic rates. This was achieved by changing the overall mining layout as well as the support strategy. Although the change in mining layout, from longwall to sequential grid mining, reduced the occurrence and size of the large events, face bursting remained a problem. Considering the seismic fatalities since 1997, 60% were as a result of events below magnitude 1.5 and 30% was attributed to face bursting. As pre-conditioning is currently the only tool available to combat face bursting it was introduced on Mponeng. Since the implementation of pre-conditioning the injury rates have been reduced and specifically the occurrence of on-shift face bursting.

Introduction

Mponeng Mine is situated on the West Wits line of the Witwatersrand Basin, some 70 km south west of Johannesburg near Carletonville. Mponeng produces gold from the Ventersdorp Contact Reef (VCR), a quartz-pebble conglomerate characterised by thick reef terraces separated by thin inter-terrace slope reef. The reef is overlain by hard lava and Quartzite footwall in the majority of the working places. An outcrop of the Booysens shales appears in the footwall of stopes on the eastern boundary of the workings. Mining takes place at an average depth of 2900 m below surface. Mponeng started stoping in the mid 1980's using a Longwall Mining method. In the mid 1990's the mining method was changed to a Sequential Grid Mining Method.

History

Pre-conditioning or de-stress blasting started at ERPM in the early 1950's. Incidence of Rockburst per area mined were reportedly reduced by 36%, severe Rockburst events by 73% and on-shift events dropped to almost zero during the testing period. This was however not accepted by the mines as a viable and safe mining method and subsequently stopped (Roux. Et al 1957).

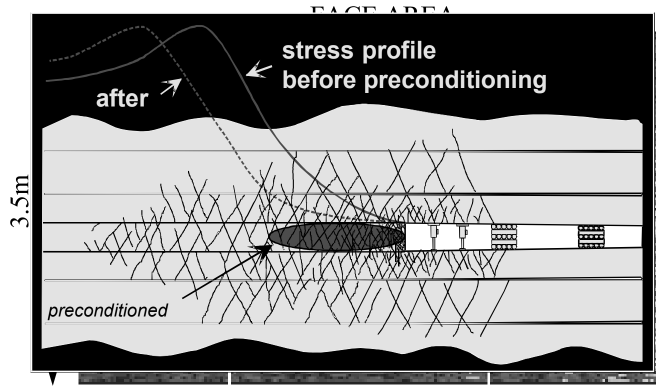
SIMRAC re-investigated pre-conditioning in the late 80's. Long hole, face parallel pre-conditioning tests started at West Driefontein and at Blyvooruitzicht GM in 1990. This was not successful from a production viewpoint as it caused production delays.

Tests on face perpendicular pre-con in a Long wall started at Mponeng (then Western Deep Levels South) in 1994. Although successful it wasn't pursued after the testing was completed. Various attempts were made to do pre-conditioning mine-wide, but it was only in the beginning of the 2000's that it was rolled out and enforced mine-wide (GAP 336).

Pre-conditioning mechanism (face perpendicular pre-conditioning)

Pre-conditioning is aimed at transfering the stresses away from the stope face through remobilising the existing fractures in the rockmass and to prevent the accumulation of strain energy ahead of the working face and therefore reducing the potential for faceburst damage.

Figure 1 Idealised stress profile ahead of a stope and intended stress transfer by pre-conditioning.



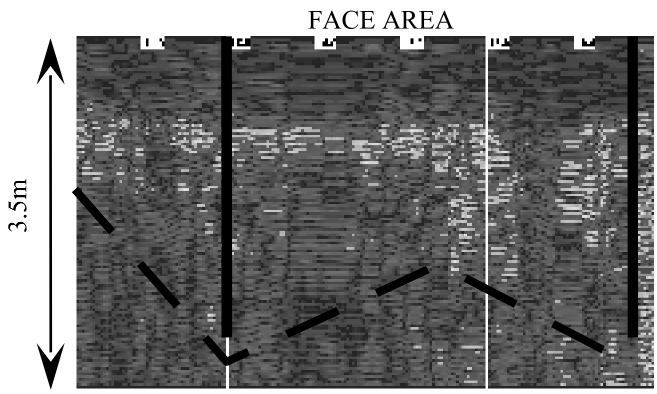


Figure 2: Ground Penetrating Radar (GPR) scan of the fracture zone ahead of a pre-conditioned mining face.

The stress redistribution provides a low-stress cushion ahead of the stope face that is able to absorb energy from distant events (Figure 1,2 and 3).

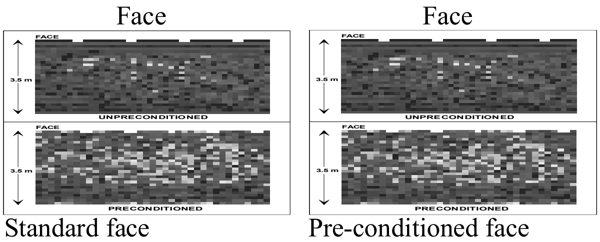


Figure 3: GPR scan of the fracture zone of a pre-conditioned and un pre-conditioned face.

Pre-conditioning involves the setting off of a designed blast ahead of the stope face. This is achieved by drilling holes into the face, at a certain burden, that are longer than the normal production holes. These holes are charged up and blasted with the production rounds. It is essential that the pre-conditioning holes are timed to go off prior to the production holes.

Implementation of Pre-conditioning on Mponeng

Layout

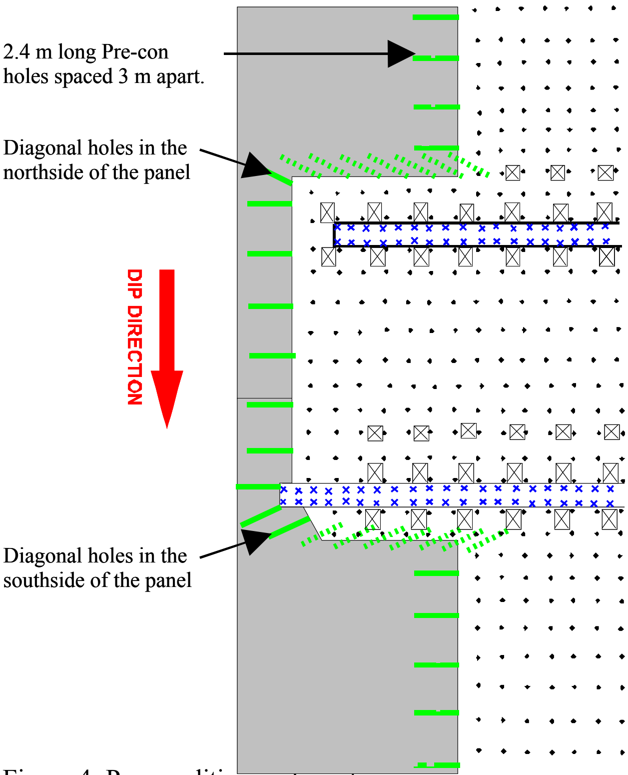


Figure 4: Pre-conditioning layout.

Face perpendicular pre-conditioning involves the drilling and blasting of 2.4 m (min) long face perpendicular holes, 3 m apart with every production round. The row of pre-conditioning holes is drilled in the centre of the face, between the hangingwall and footwall of the stope.

Charging up

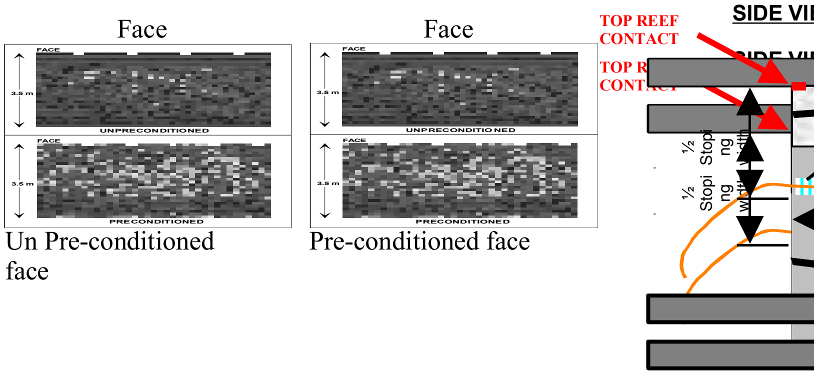


Figure 5: Charging up of the pre-conditioning hole.

Approximately 2/3 (1.4 m) of the drilled hole must be charged with explosives. The detonation of the hole should be by top-priming the explosive charge, to facilitate removal of primers from misfired holes. Stemming of the holes is very important as an effective stemming will maximise the stemming retention time, which will contain the explosive energy in the hole as long as possible. Poor or no stemming can also result in misfires of the production holes. The remaining 1/3 of the hole must be tamped with a competent stemming material.

Detonation sequence

The timing of the pre-conditioning hole relative to the production holes is very important. Mistiming may lead to ineffective pre-conditioning and / or misfires.
The pre-conditioning hole should be timed so that detonation of the hole will take place approximately 1.0 m ahead of the production holes.

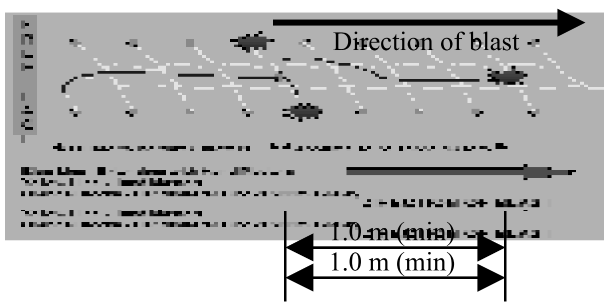


Figure 6: Detonation sequence of the pre-conditioning blast.

Training and Implementation of pre-conditioning.

As the effectiveness of pre-conditioning is reliant on quality of the operation, proper training is essential. Training at Mponeng began during the Value Added Blasting (VAB) training that was done with all the crews on the mine. During this, the teams were trained in the principles and application of pre-conditioning.

Trained production shift overseers were used for a period of 3 months to do on the job training of all the crews. Early and late shifts were done to ensure that the initial examination, charging up and timing of the pre-conditioning holes were done to standard. Pre-conditioning booklets were also distributed to the crews.

An additional bonus incentive is paid to the drillers for drilling these holes. The production overseers must, on a daily basis, book the drilling of the pre-conditioning holes and the workers are paid accordingly.

Auditing and follow-up

As part of the learner miners training program, candidates are required to do a 3 month Rock Engineering phase. During this period they audit the compliance to the stope and development support and pre-conditioning standards. Early and late shifts are done to ensure initial examination, charging up and timing of the holes are done correctly. A pre-conditioning audit checklist was compiled, which is used during the pre-condition audits.

Pre-con Audit Report			Date:	
Miner :			Section:	
Shift Overseer:				
Panel no :				

Distance Between sockets				Distance between new holes				Comments:
S1& S2				H1&H2				
S2& S3				H2&H3				
S3& S4				H3&H4				
S4& S5				H4&H5				
S5& S6				H5&H6				
S6& S7				H6&H7				
S7& S8				H7&H8				
S8& S9				H8&H9				
S9& S10				H9&H10				
S10& S11				H10&H11				
S11& S12				H11&H12				
S12& S13				H12&H13				
S13& S14				H13&H14				

Depth of Socket		People Trained			Sketch of face
S1		Name	Job	Coy No	
S2					
S3					
S4					
S5					
S6					
S7					
S8					
S9					
S10					
S11					
S12					
S13					
S14					

Figure 7: Pre-con Audit Report

The Rock-engineering department and the auditing teams (learner miners) do refresher and on-the-job training continuously as part of the stope audit program.

Problems and Actions

Charging up of the pre-conditioning hole

The initial recommendation was to charge up the first metre of the hole (± 5 cartridges AEL 200 mm Powergel). The primer is then placed behind the explosives, which in theory would give you a 1.2 m charged hole. However with the forcing of the explosives into the holes, this effective charged portion of the hole is much less than is called for.

This resulted in creating a poorly developed fracture zone in the immediate face. Investigations of the pre-conditioning, it appeared to be sub-standard. Only after dressing the face and removing the initial face slabs could the proper fragmented zone around the pre-conditioning sockets be observed.

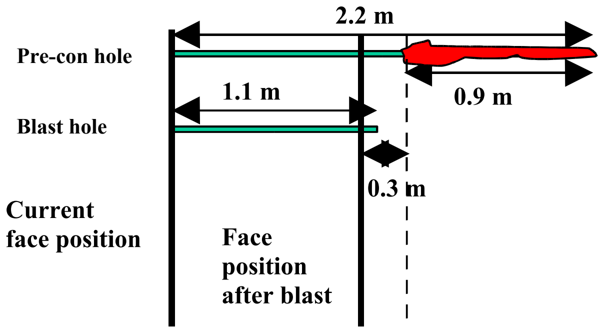


Figure 8 indicates the problem encountered with the pre-conditioning hole detonating in front of the blasted face.

A subsequent change in the standard was made. The standard specifies that the first 1.4 m of the hole must be charged up, including the primer. After charging up of the hole is done, the person in charge must ensure that only 1.0 m of the hole remains that needs to be tamped.

Position of the pre-conditioning hole (high stoping width > 1.8 m)

During 2000, the effectiveness and application of pre-conditioning blasts at high stoping widths was questioned, which resulted in a SIMRAC project (GAP 811). The final report recommended that the pre-conditioning holes be drilled a maximum distance of 0.6 m from the hangingwall to eliminate the occurrence of overhanging faces (Figure 9).

Fig

The dangers associated with overhanging faces are recognised and the creation thereof may not be allowed. There is however a practical implication of drilling a pre-conditioning hole 0.6 m from and parallel to the hangingwall.

Drilling the hole at an angle of more than 14° to the hangingwall will result in the hole being drilled into the hangingwall resulting in hangingwall damage. Due to the length of the stoping airleg, drilling a 2.4 m long hole parallel to the hangingwall can only be achieved by commencing the drilling from the top of broken rock in the panel. This is not possible if the panel has been cleaned.

Another issue was the variable stoping width in a panel, which can range from < 1.0 m to > 2.0 m within a panel. At a low stoping width, a row of pre-conditioning holes is drilled in the middle between the hangingwall and footwall. Having two different pre-conditioning standards within a working panel can cause confusion. A decision was made to drill the line of pre-conditioning holes in the middle between the hangingwall and footwall to eliminate the problems mentioned above and to produce only one pre-conditioning standard.

Pre-conditioning itself is not the root cause of overhanging face. Overhanging faces is also the result of poor blasting practices and therefore it will be addressed as it occurs and removed during the entry examination and before drilling of the production round commences.

Negotiating rolls in the reef.

Erratic and severe dip and strike rolls are encountered when mining the VCR reef at Mponeng. When mining breast the position of the majority of the dip rolls only become known when they are exposed. Therefore no precaution can be taken beforehand. The production crew normally knows of the existence once it is too late. The exposure of rolls or the mining in rolls is often associated with an increase in seismicity as the drilling and blasting takes place inside the hard, brittle Ventersdorp hangingwall lavas. The occurrence of face bursting increases as the lavas are exposed (Figure 10A).

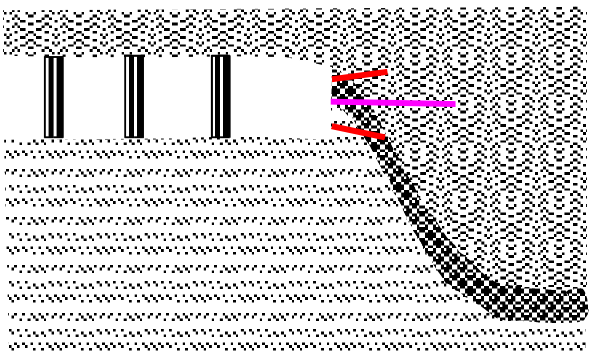


Figure 10A: Drilling into the lava hangingwall with the production as well as the pre-conditioning hole.

Poor hangingwall conditions are encountered with the exposure of rolls, due to blasting damage caused by the drilling and blasting of the production hole into the hangingwall (Figure 10B and C).

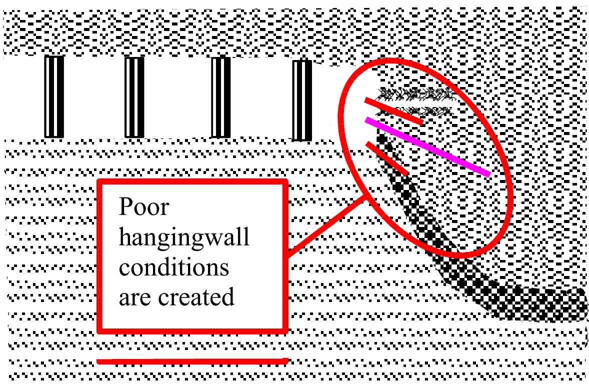


Figure 10B: Continuous drilling into the hangingwall lavas while negotiating the roll creates poor hangingwall conditions.

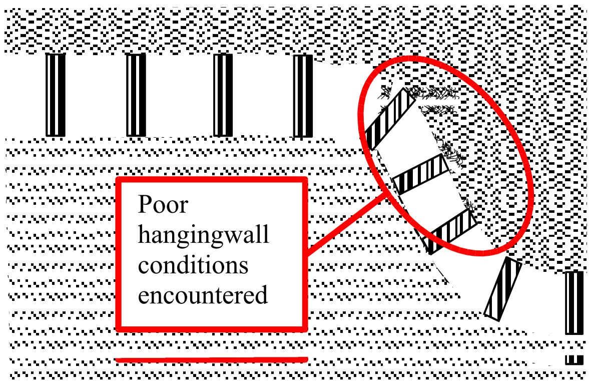


Figure 10C: Poor hangingwall conditions are encountered in the roll.

Additional damage caused by pre-conditioning is questionable. Analysis done by SIMRAC (GAP 030) on the forming of fractures indicates that no new groups of fractures are formed in the hangingwall with the introduction of pre-conditioning. There was a relative change in the abundance of the existing fracture groups. There is an increase of approximately 25% in steep dipping fractures, whilst shallow dipping fractures showed a decrease of 61%. Fractures of intermediate dip showed very little change in abundance between the pre-conditioned and un pre-conditioned areas.

Exposing the lava hangingwall leads to an increase in the occurrence of face bursting. As stated previously, pre-conditioning is the only tool that reduces the occurrence of and the damage associated with face bursting. The support system has to deal with the deterioration of the hangingwall. More stringent support and the use of headboards will provide an increased in areal coverage and support resistance. In some areas pinning of the hangingwall is done.

Locating the Pre-conditioning sockets after the blast.

All sockets need to be examined for misfires after the blasting of a production round. It is even more important that the pre-conditioning holes are examined as they are charged up ahead of the blasted face position. Due to the "freezing" of the broken rock inside the sockets (if pre-conditioning done correctly) identifying and locating of the sockets does become a problem (Figure 11.)

Location of the pre-conditioning sockets is essential for auditing, to ensure a true refection of the compliance of pre-conditioning. In order to alleviate this problem, paintlines, 3 m apart, perpendicular to face are drawn against the hangingwall. These lines are extended with every blast and are an indication of the location in which the pre-conditioning holes would be found.

This was a practical solution to reduce as a lot of time was spent searching for the holes.

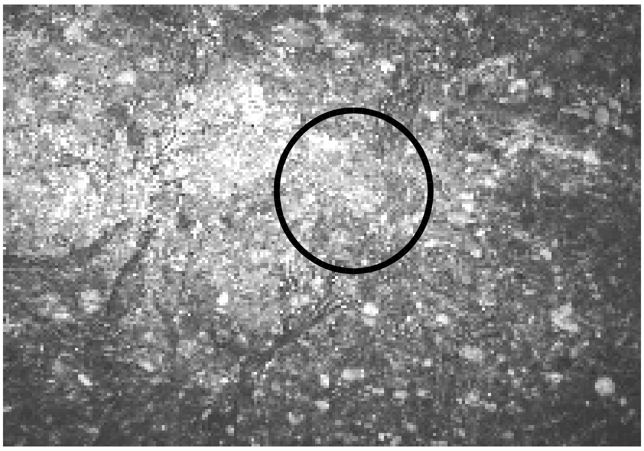


Figure 11: Pre-conditioning socket after the blast.

General

As always there is a resistance to change, “new” concepts and additional work. It is essential that the production crew experience the advantages of pre-conditioning. Once that is achieved they will ensure that it is done to standard. Continuous audits are done to ensure it is done to standard. Where problems are encountered on-the-job re-training is done and disciplinary actions used.

Quantifying the effectiveness of Pre-conditioning

Although implementing pre-conditioning started in the beginning of the 2000’s, it was only in the first quarter of 2003 that a major effort was put into the application of proper pre-conditioning and the re-training of the personnel. It was also in this time that the stope audit system was implemented.
Some of the published additional advantages due to pre-conditioning are:

- Improved hangingwall conditions
- Better stoping width control
- Improved face conditions
- Increased face advance per blast
- Increased drilling rate
- Reduced fragment size of blasted reef
- Increased worker morale

Seismicity and Seismic damage analysis

As seismicity is production driven, the number of seismic events are normalised against the production. A seismic rate is given as the events per 1000 m^2 mined.

Previously published papers indicated the reduction in seismicity since changing from longwall to sequential grid mining. There is however a slight increase in the seismic rate during the past two years, since 2003. This is mainly due to the cutting of some pillars in the lower levels (Figure 12).

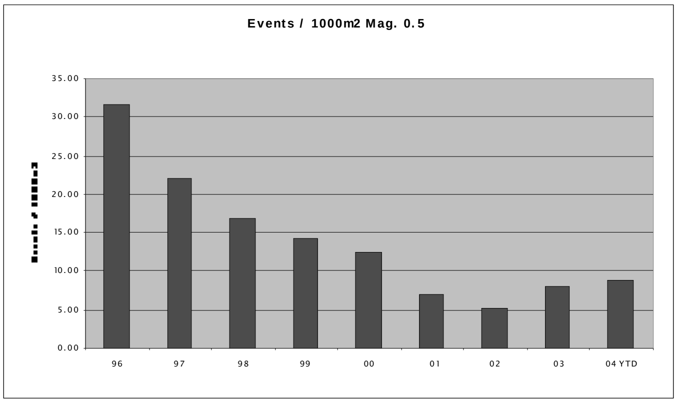
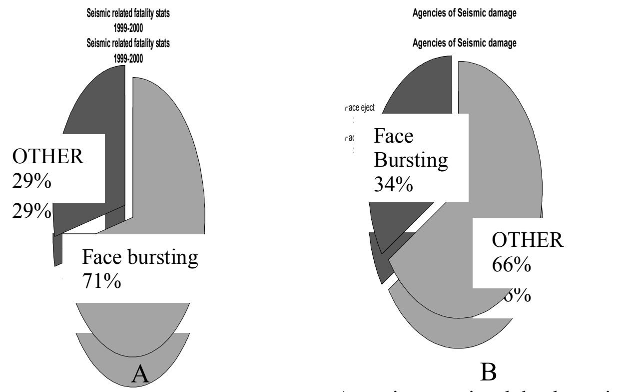


Figure 12: Events per 1000 m^2 mined.

Of the total number of events that occur on Mponeng, and average of 14% is above magnitude 0 and 2% above magnitude 1. Approximately 70 to 100 damaging events (M>1) occur on Mponeng during a month.

Analysis of the damaging events since January 2004 indicates that 34% of the damage is attributed to face ejection (Figure 13B). The remaining 66% was either falls of ground or dynamic closure with no associated face bursting. As this database does not extend further back, these values are compared to the rock related fatalities between 1999 and 2001. As indicated in Figure 13A, 71% of the rock related fatalities were caused by face bursting.



A

Rock related fatalities
1999 - 2001

B

Agencies associated the damaging events M>1

Figure 13: (A) indicates the % of fatalities attributed to face bursting during 1999-2001. (B) Indicates the current % of face bursting.

Evaluating the current damage caused by seismic events (M>1), a total of 574 seismic damage and Fall of Ground Management (FOGM) reports (since January 2004) were analysed. A total of 55% of the cases recorded no damage, 30% only minor falls of ground (< 5m) and 15% damage greater than 5 m (Figure 14).

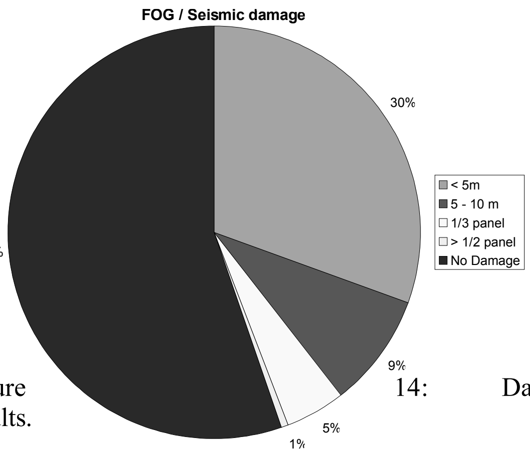


Figure 14: Damage results.

Rock related injuries statistics

Improving the hangingwall and face conditions should ultimately have a positive affect on the safety of the people working in the area and also on the injury statistics.

Figure 15 indicates the improvements in the injury rates since 1999.

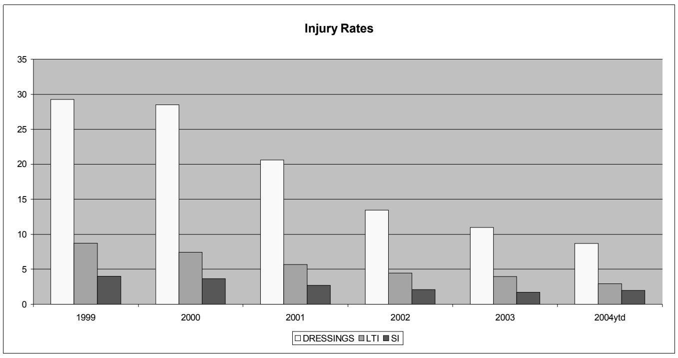


Figure 15: Dressing, lost time injury and serious injury rates.

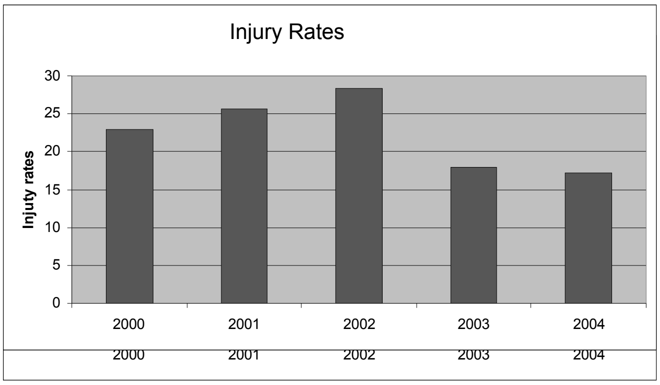


Figure 16: Injury rates (Seismic related injuries / 1000 damaging on-shift events)

As pre-conditioning is aimed in reducing the occurrence and effect of face bursting, the rock-related injuries are normalised against the number of damaging (M>0) on-shift events. An injury rate per 1000 damaging on-shift events is obtained.

Since 2003 there was a marked reduction in the injury rate after a gradual increase up to the end of 2002 (Figure 16).

Production

SIMRAC (GAP 336) indicated a decrease in the drilling times of the production holes but adding the drilling time of the pre-conditioning holes, there is an increase in total drilling time when drilling a 2.4 m long pre-conditioning hole. As the length of the pre-conditioning holes decrease so do the total drilling times (Figure 17).

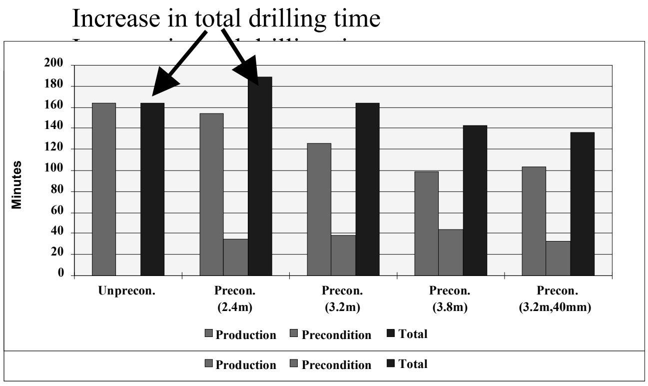


Figure: 17: Drilling times relative to the length of pre-conditioning holes.

As 2.4 m long pre-conditioning holes are drilled, with the increase in the drilling time, a decrease in production is expected. There is a noticeable increase in productivity during the past few years (Figure 18). The implementation of pre-conditioning therefore has had no negative effect on the productivity of Mponeng.

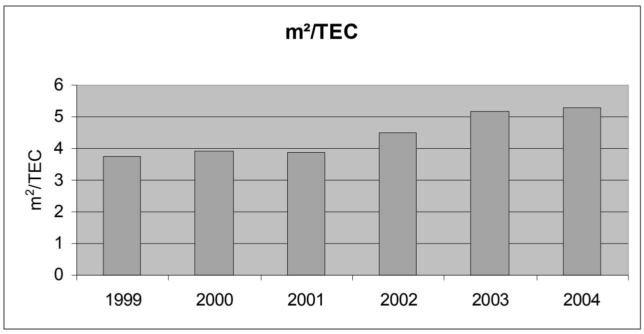


Figure 18: Square metres mined per total employee costed.

Conclusion

Since the implementation of pre-conditioning, there's been a decrease in the occurrence of face bursting during the shift and the number of injuries associated with the seismicity, while it had no negative influence on the productivity of the mine.
Where the hazard of face bursting exists, pre-conditioning is currently the only tool to reduce the occurrence and effect of face bursting and has proved to be very effective on Mponeng

Acknowledgements

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References

McGILL R.B. Strategies to manage seismicity in a deep VCR environment. Second International Seminar on Deep and High Stress Mining, SAIMM, Johannesburg, February 2004.

ROUX, A.J.A, LEERMAN, E.R & DENKHAUS, H.G. 1957. De-stressing a means of ameliorating rockburst conditions. Part 1 – The concept of de-stressing and the results obtained from its application J.S. Afr Inst of Mining and Met. October 101 – 119.

SIMRAC Project GAP 030. Preconditioning to reduce the incidence of face bursts in highly stressed faces, 1996

SIMRAC Project GAP 336. Develop and implement preconditioning techniques to control face ejection rockbursts for safer mining in seismically hazardous areas, 1998

SIMRAC Project GAP 811. Criteria for preconditioning at varying stoping widths in different geotechnical areas, 2003.