



MINING INDUSTRY
OCCUPATIONAL
SAFETY & HEALTH



Methods to improve the **Drill and Blast** Cycle in Conventional Narrow Tabular Orebodies in South African Mines:

A Reference Guide



MINERALS COUNCIL
SOUTH AFRICA



VISION

To ensure mining matters for South Africa.



MISSION

To play a leadership role in enabling the South African mining sector to achieve its real potential for investment, growth, transformation and development in a socially and environmentally responsible manner.



VALUES

Members are obliged to conduct their business according to the agreed Minerals Council values, which dictate the minimum standards of conduct required of them in order to become a member of, or remain a member of, the Minerals Council. The five values of the Minerals Council are:



Responsible citizenship



Respect



Trust



Honesty



Accountability

Methods to improve the **Drill and Blast** Cycle in Conventional Narrow Tabular Orebodies in South African Mines:



MINERALS COUNCIL
SOUTH AFRICA

A Reference Guide

CONTENT

List of Acronyms and Abbreviations	3
Acknowledgements	3
1. Introduction	4
2. Aim and scope of the study	4
3. Background to the initiative:	
Why consider improving the Drill and Blast Process?	5
3.1 Safety drivers	5
3.2 Data acquisition	7
3.2.1 Source mine data	7
3.2.2 Interviews and ad-hoc visits	10
3.3 Conclusions from the background information	11
4 Understanding the mining cycle	12
4.1 Key elements within the mining cycle	12
4.2 The timeframe and resource allocation for each element	15
4.3 Management of the mining cycle	15
4.4 The consequences of poor execution of an element/s	16
5 Towards increasing productivity and efficiency of the Mining Cycle	18
5.1 Blast Design	20
5.1.1 Overview	20
5.1.2 Discussion	22
5.2 Technologies to improve the drill and blast cycle	26
5.2.1 Training Improvements – 3D simulation and Virtual Reality	26
5.2.2 Monitoring and review of drilling quality	29
5.2.3 Centralised blasting	29
6 Conclusions	30
References	31

We will treat everyone with CARE, DIGNITY AND RESPECT

LIST OF ACRONYMS AND ABBREVIATIONS

CB	Centralised Blasting or Multiple Excavation Simultaneous Detonation
COM	Chamber of Mines (<i>now Minerals Council South Africa</i>)
COPA	Community of Practice for Adoption
CSIR	The Centre for Scientific and Industrial Research
DB	Drill and Blast Cycle
DMR	Department of Mineral Resources
FOG	Fall of Ground
FOG RB	Fall of Ground due to Rock Bursts
FOG RF	Fall of Ground due to Rock Falls
LH	Learning Hub
LP	Leading Practice
MHSA	Mine Health and Safety Act
MHSC	Mine Health and Safety Council
MOSH	Mining Industry Occupational Safety and Health
PETN	Pentaerythritol Tetranitrate
TARP	Trigger Action Response Program
VRW	Virtual Reality Wall
	Minerals Council South Africa

ACKNOWLEDGEMENTS

The authors wish to thank the following persons and organisations for their invaluable contributions in the preparation of this document:

The MOSH Learning Hub
The MOSH FOG Industry Team
The COM Rock Engineering Technical Committee (RETC)
The MOSH Task Force
Gold Fields Mining: South Africa Region
Sibanye Stillwater: Gold Division
Glencore: Ferroalloys Division
Mr. Chris Sheppard – MOSH FOG Team Sponsor: COO AngloGold Ashanti
Mr. Duncan Adams – MOSH FOG Team Manager 2010-2016
Mr. Andre van Zyl – MOSH FOG Team Manager 2010-2016



**MINING INDUSTRY
OCCUPATIONAL
SAFETY & HEALTH**

We pledged our commitment to the target of ZERO HARM, and that EVERY MINERWORKER shall return from work UNHARMED, EVERY DAY

1. INTRODUCTION

Since the inception of formal large-scale mining in South Africa 120 years ago, the most economically feasible, and productive method of extracting the orebody, has been through blasting operations. In order to garner the greatest benefit from the orebody, the process requires that a fair number of steps be completed and repeated frequently to achieve the required targets. This process has not changed much over time despite there being several significant technological advances and improvements in the mining sector. However, in the last decade, the efficiency and productivity of the drill and blast cycle has come under increased scrutiny and it has become apparent that the quality of the drill and blast has a significant impact on both productivity and the stability of the working areas. In addition, and against the backdrop of the persisting high number of fall of ground (FOG) accidents, the Minerals Council South Africa (MCSA), through the established Mining Industry Occupational Safety and Health (MOSH) Learning Hub's FOG Team, has sought to identify and document a Drill and Blast (DB) reference guide to address this need, and improve the mining industry through this initiative.

In the past, a Leading Practice (LP) is sourced and documented from a single operation or mining company. In this way, the FOG Team would be able to disseminate into industry an already tried and tested methodology or best practice that has proven to be successful at addressing and mitigating a particular risk. However, in the DB case, the absence of a single provider necessitated the sourcing of information from several mining operations and relevant research subject matter. In addition, with the onset of the Fourth Industrial Revolution, new technology solutions and innovations have also been included in the DB Reference Guide. It is envisaged that the use of a combination of sources will ultimately complement the LP and produce an improved effect on the mining industry.

Embedded, and underlying this document, is the MOSH Leading Practice Adoption System. The system remains one of the primary vehicles to attain the safety goals and milestones that mining industry has set for itself. In this light, the Drill and Blast reference guide is viewed as an industry initiative in the quest for ZERO HARM and, that optimal execution thereof will result in significant safety improvements in the industry, especially in the FOG space. It is also envisaged that a number of FOG leading practices will emanate from this reference guide.



2. AIM AND SCOPE OF THE REFERENCE GUIDE

The primary aim of the work is to describe the Drill and Blast (DB) Reference guide for stoping in conventional narrow tabular mines. However, this does not prevent other mining sectors from using the information to improve their drill and blast processes.

The scope of the document is to:

- Describe the Drill and Blast Reference Guide,
- Provide a value case for such a guide,
- Outline the safety trends underlying drill and blast processes,
- Analyse data, procured from industry, that shows the extent of deviations from the standards, norms and procedures for drill and blast,
- Show why improving drilling and blasting will contribute to both production and safety initiatives,
- Provide techniques on how to improve the processes,
- Define the key elements that constitute an ideal drill and blast cycle,
- Show how efficiency and productivity gains can be made within the cycle, and,
- Provide a suite of available products and technologies that can be used to improve the training of personnel, as well as contribute to efficiencies within the DB cycle.

3. BACKGROUND TO THE INITIATIVE: WHY CONSIDER IMPROVING THE DRILL AND BLAST PROCESS?

3.1. SAFETY DRIVERS

Since the inception of formal large-scale underground mining in South Africa, FOGs have been responsible for significant loss of life, permanent disability and serious injury in the mining industry. In the past, the FOG could have contributed as much as 50%. However, since the inception of the Mine Health and Safety Act (MHSA), the adoption of Leading Practices, and a number of Industry initiatives, the number of fatalities have drastically reduced.

But the FOG problem persists!

The Mine Health and Safety Council (MHSC) reported that FOG fatalities contributed 31% of all fatalities in the mining sector in 2015. In 2016, 2017, and 2018, this contribution has steadily increased to 36%, 37% and 27% respectively. In addition, the number of FOG fatalities has also increased. The question therefore begs as to what step change is required to enact a significant reduction of FOG fatalities?

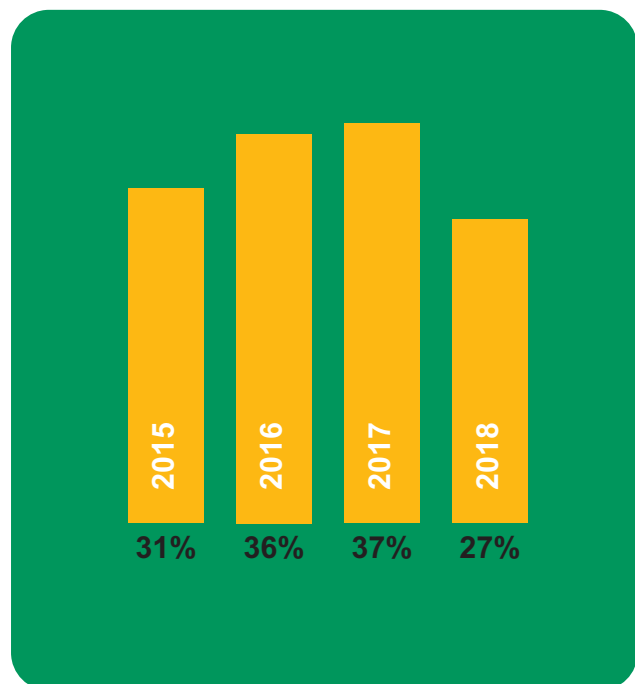
The FOG Team is confident that the **DB Reference Guide will bring about such a step change!**

Figure 1 serves to illustrate the root of the problem...drilling into the hangingwall and detonation of such shot holes in a conventional hard-rock stope. The drilling of and subsequent detonation:

1. Imparts energy into the rockmass,
2. Opens up pre-existing stress fractures,
3. Breaks up competent rock strata,
4. Creates brows and caviats,
5. Reduces compression of the rockblocks,
6. Allows slippage of geological features, extending breaks in the hangingwall, and,
7. Ultimately leads to a FOG.

A study conducted in 2015, revealed that during the years 2013-2014, poor drilling and blasting could have contributed to 47% of all the fatal FOG accidents.

Accurate blasting practices in underground mining environments have been proven to deliver improvements in safety and productivity and should therefore be considered part of the core foundation upon which a mine is developed and operated.
www.miningreview.com



FOG fatalities as a percentage of the total fatalities in the South African Mining Industry (SAMI)



Figure 1: Poor drilling discipline results in sockets in the hangingwall

Similarly, a relationship could be found in the analysis of the 2015-2017 FOG fatality database, where barring non-conformances within the DB cycle contributed to 80% of fatal FOG accidents. Barring is related to drill and blast in the following way:

If holes are not drilled correctly (angle, depth, spacing, burden, etc.), and these holes are detonated, poor hangingwall conditions result. The issue is compounded if the detonation is problematic (sequencing, coupling, tamping, explosive charge). Therefore, if any one of these or a combination of elements are not to standard, the hangingwall becomes susceptible to damage and deterioration. To remedy such “poor ground conditions”, created by the process of poor DB, the mining crew has to utilize valuable time and effort to re-create better hangingwall conditions through the process of barring the loose rocks. This further exposes the mining crew to poor hangingwall and uncontrolled failures may result. In this way,

The sub-standard act has resulted in a sub-standard condition.

Every person going home from work unharmed everyday

3.2. DATA ACQUISITION

3.2.1. SOURCE MINE DATA

In 2015, the MOSH Learning Hub conducted on site research at two source mines; one in the gold sector, and another in the platinum sector. Both were conventional tabular operations. Using the 3 legs of a Leading Practice, Technical Data was from underground stope drilling data; Behavioural Communication concerns were highlighted during interviews with mine personnel; and Leadership Behaviour challenges were identified during ad-hoc visits to the mines and through the interview process.

The data provided invaluable information on aspects that may not have daylighted through a normal risk assessment process and it showed that:

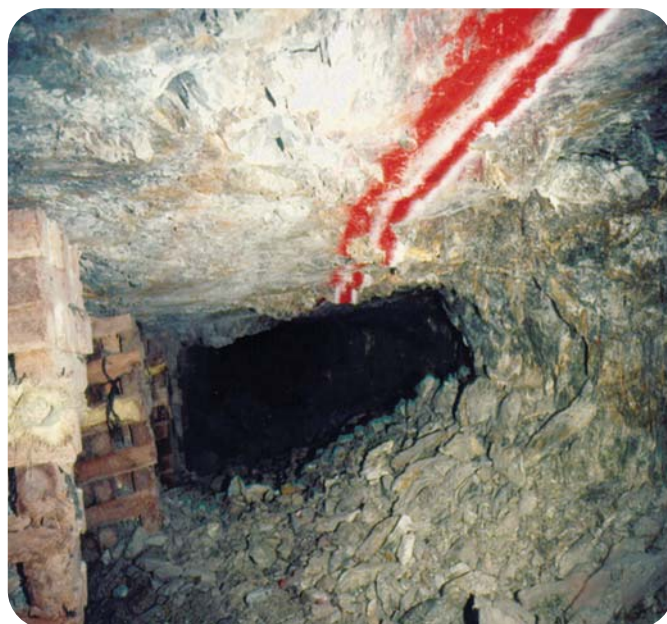
- Many of the FOG problems emanate from the creation of poor rockmass and strata conditions. During the extraction process, these conditions are often caused by unfavourable geological structures and/or high stress zones. However, these geological weaknesses, and many other non-problematic **geological conditions are made worse**, and unstable, by the act of mining. In particular, poor drilling and blasting of the rockmass contributes significantly to the instability and the potential for failure.
- The vibrational and explosive effects, within the confined space of a stope is exacerbated, if **incorrect marking, poor drilling, overcharging, incorrect timing and sequencing**, are practiced. The effect can result in degradation of the rockmass, damage to support elements, which invariably impacts on support performance, and instability in the stope, especially during seismic incidence. The mechanisms of damage from drilling and blasting are clearly **misunderstood** and often controversial.

At the source mines, a short study was conducted to illustrate the extent of the deviations. Figures 2-4 show data on spacing of drill holes, distance of hole to top contact, and distance of hole to bottom contact respectively. Figure 5 shows drill hole depth. The figures clearly indicate that drilling of holes is not being executed correctly:

- (Figure 2) Burdens range between 25-108cms. It is likely that the standard burdens were supposed to be between 40-50cms,
- (Figure 3) Distance of hole collar to top contact ranged between 22-50cms. The required distance would be between 10-20cms. A large distance to the top reef contact would indicate that the reef is being mined closer to the footwall,
- (Figure 4) Distance of hole collar to bottom contact ranged between 15-72cms. Again, the required distance would be between 10-20cms. A large distance to the bottom reef contact would indicate that the reef is being mined closer to the hangingwall, and,
- (Figure 5) Drill hole length ranged between 50-92 cms. This demonstrates the irregular nature of the face that may be expected after the blast. A typical conventional operation would use 1.2-1.5m drill steel, which would give an effective hole length of between 0.9-1.2m.

“The innocent rock mass is often blamed for insufficient stability that is actually the result of rough and careless blasting. Where no precautions have been taken to avoid blasting damage, no knowledge of the real stability of the undisturbed rock can be gained from looking at the remaining wall rock. What one sees are the sad remains of what could have been – a perfectly safe and stable rock face”.

Holmberg and Persson in *Underground Excavations in Rock*; E Hoek & E T Brown (1998)



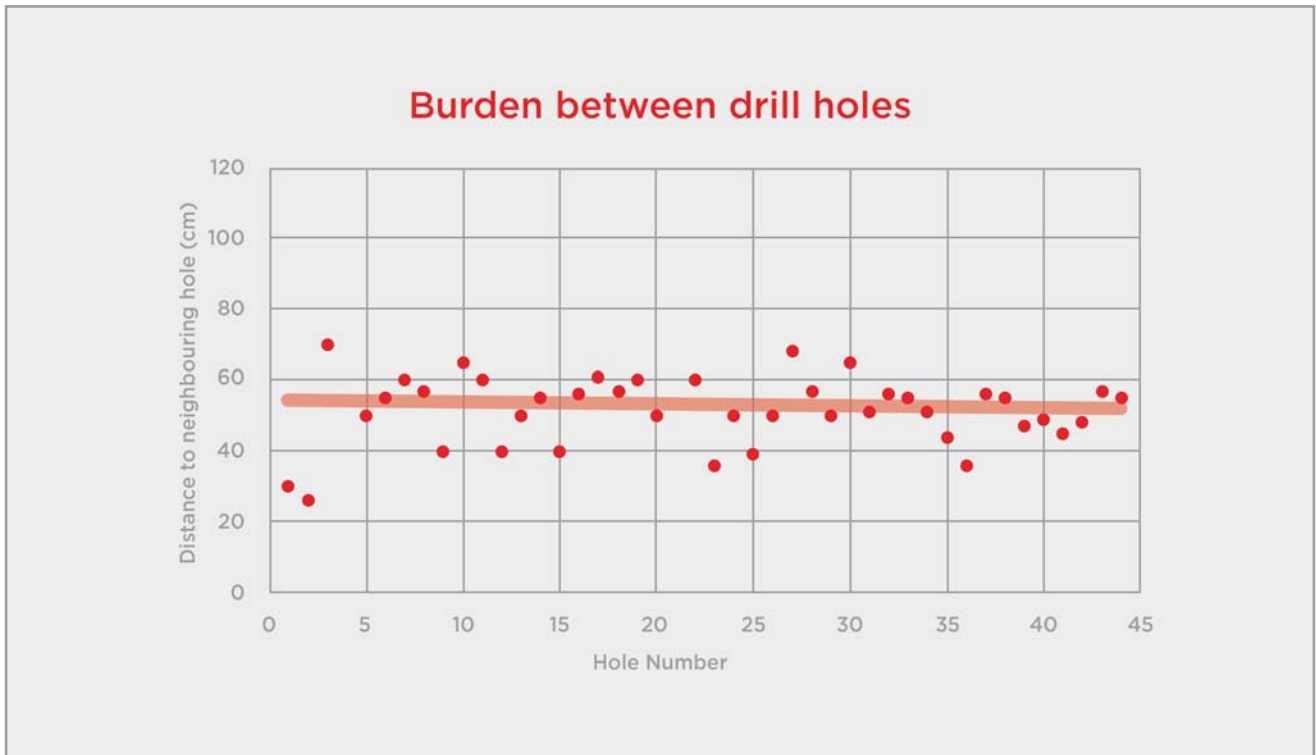


Figure 2. Distance (burden) between drill holes

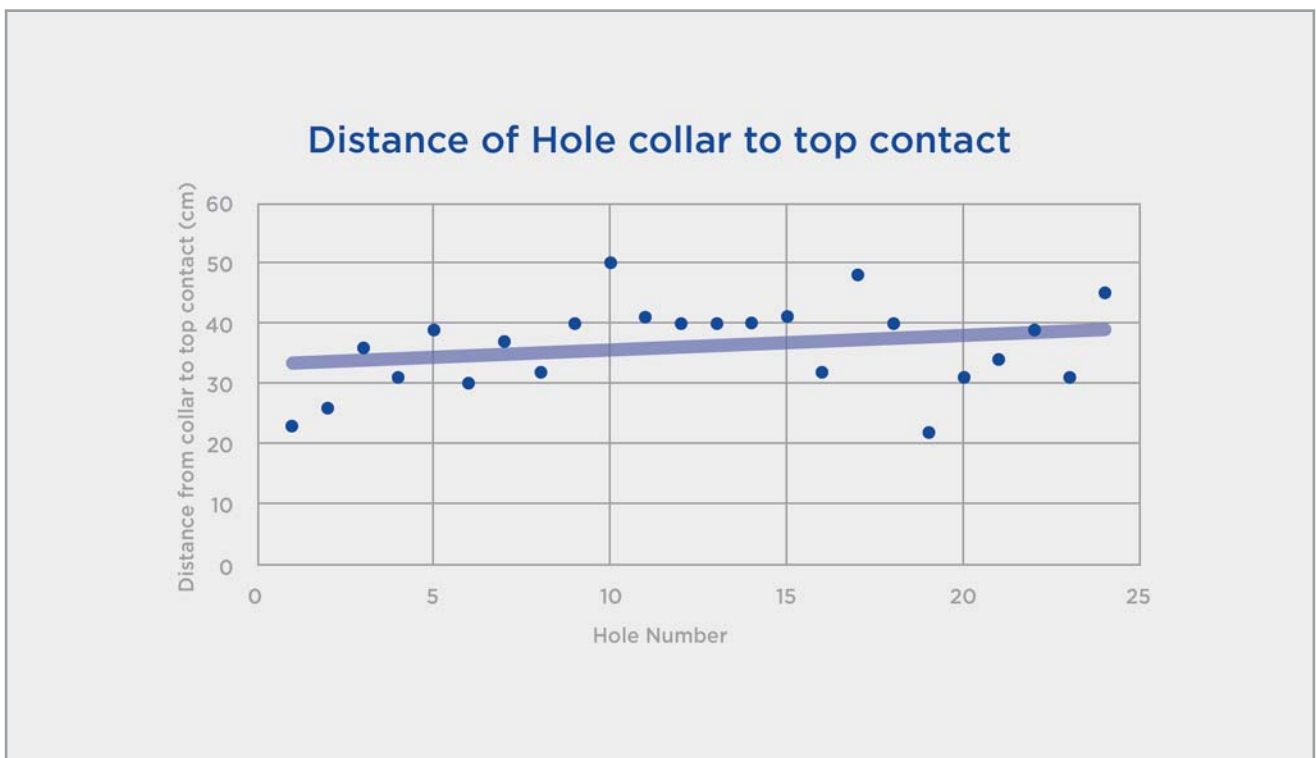


Figure 3. Distance from shot-holes to top reef contact

**“Mining industry growth was greater than that of the national economy”
~Roger Baxter CEO Minerals Council (January 2019)**

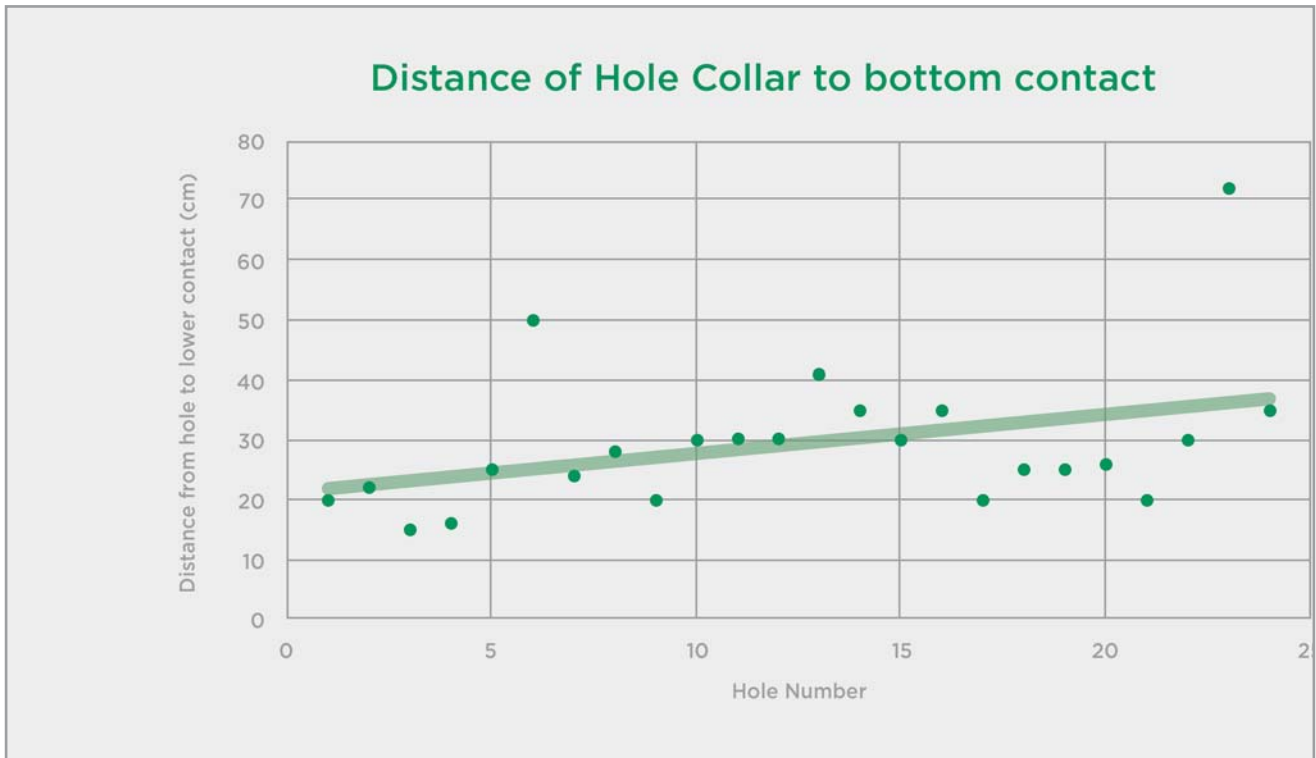


Figure 4. Distance from shot-holes to lower reef contact

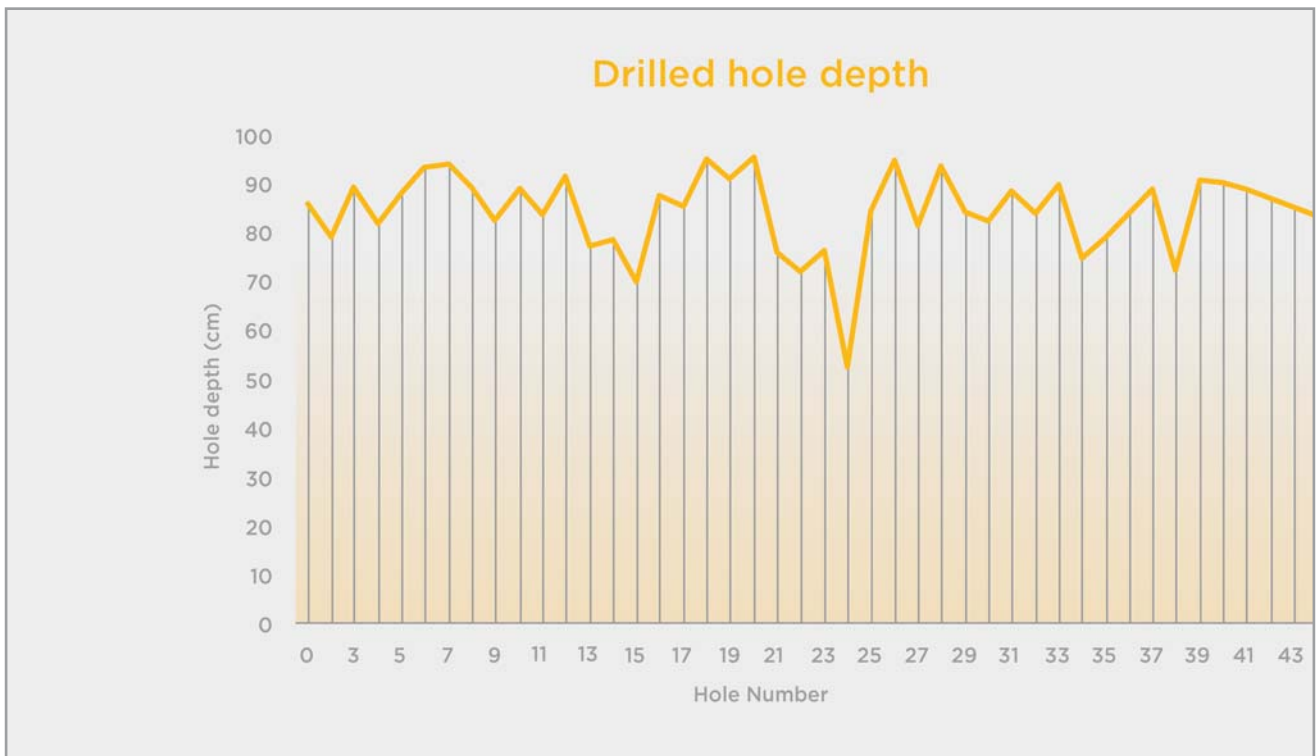


Figure 5. Drill hole depth

If it's not grown, it's mined

3.2.2. INTERVIEWS AND AD-HOC VISITS

Although the underground data acquisition was key to providing a technical frame of reference, interviews and ad-hoc visits (leadership behaviour and behavioural communication) provided another layer of information that shows underlying problems. The data from the interviews and ad-hoc visits are segregated in Table 1 under 5 broad categories underlying the technical deviations involved in the DB cycle:



Here the concepts Design and Technical complement each other but refer to Mine Design and Technical components of Blast Design respectively.

Table 1: Issues raised through interviews and evidence concerning drill and blast practices

Category	Issues raised
Design	<ul style="list-style-type: none"> • Drilling and blasting is done in the same way always – why change? • Different rock types require different explosives types with different delays between shot holes – there is not much evidence/research supporting this hypothesis. • 9-27% of the energy from the explosives is useful energy for breaking the rock; the rest is wasteful energy. • Gullies are not adequate for the broken ore. Ore left in-stope will only be removed during the sweeping stage. • When packs are too close to the face, drill angles are compromised.
Quality	<ul style="list-style-type: none"> • The quality of marking, drilling, charging and blasting affects the mining cycle from the face to the mill. • Fragmentation of the rock impacts the mine call factor but also helps or hinders cleaning and transport. • Top and bottom reef contacts, hole direction lines and elevation lines were not clear and sometimes missing. • Face shape can be compromised by poor execution of the blast design. • The placement and drilling of shot holes is critical to the end result. • Correct positioning (marking), spacing and burden (particularly at toe of hole), correct direction (horizontal and vertical) and length of the holes are all critical success factors. • Inclination or declination of holes results in poor blast. Strata control problems may result in moderate to poor rockmasses at depth. Updip and downdip drilling is often difficult to control. • Support installed too close to the face could result in incorrect angle of drilling. • Relief holes or free breaking surfaces/points are imperative. The break angle of any hole must be maximised. • Sequencing of shot-holes in the blast is critical to minimising misfires and therefore straight faces. • Incorrect drilling and charge timing sequence results in poor muckpile positioning.
Leadership	<ul style="list-style-type: none"> • Inappropriate behaviours by both workers and supervisors encourage non-compliance and the taking of short-cuts. • Crews expressed concern about the lack of coaching by supervisors, management and leadership. • Supervision is critical to success and it is generally lacking. • Resources are sometimes inadequate or available e.g. run out of paint. • No consideration for colour blindness or poor visibility – red marking paint on dark grey face can sometimes not be seen.
Training	<ul style="list-style-type: none"> • Syllabi were good at the source mines. However, trainees are usually tested for ability at the training centres and not competency. • Theoretical aspects of the wider issues around drilling and blasting covered. It seems that the content is available to all who attend the courses. • The poor performance underground indicates lack of comprehension or skill of workers regarding the knowledge conveyed to them. • The lack of underground comprehension may be due to: <ul style="list-style-type: none"> o low education levels; o inappropriate material; o incorrect methods to convey the message; o insufficient experiential and practical learning; and, • There is a need for comprehensive, experiential training to equip people for these jobs.
Technical	<ul style="list-style-type: none"> • The perception is that higher VOD explosives gives more face advance. No consideration is given to the impact on the rockmass if the higher VOD explosives are used incorrectly or inappropriately. • There is a lack of understanding that explosives are expensive and when not used optimally, it is regarded as waste. • Emulsion explosives are safer to handle and only become “unstable” in the hole. They are inertly safer, but more expensive. • Shock-tube does not always fire sequentially and may result in misfires and poor face shapes. • Percussion action is detrimental to both people and machines and should be phased out. • Machines are too heavy and bulky and cannot be held up to drill the top holes at the right angle and the correct depth.

In addition to the issues noted above, some stand-out comments on leadership, during the interview process, included:

- *“Miners/team leaders acknowledge that drilling into the hangingwall and footwall results in unfavourable conditions. However, from underground observations in their areas of responsibility, it is clear that the machine operators do not appreciate this fact fully and/or the miners/team leaders do not understand/care about the consequences of the poor drilling practices. It does not seem to bother the supervisors either.*
- *Teams recognised the necessity for supervisors to conduct compliance and conformance audits, but stressed that they should concentrate on their appointments as health and safety professionals:*
 - o *Supervisors should coach more;*
 - o *Must be available if help is asked for or required;*
 - o *They need to motivate the workers;*
 - o *They should not criticise the miner with the team present;*
 - o *They should give correction and advice when necessary. They should not shout but rather tell;*
 - o *They should do regular conformance checks during the shift rather than doing it after the blast when the result is visible;*
 - o *They need to show interest in each crew member and recognise their leaders;*
 - o *They must develop respect and show care toward their subordinates;*
 - o *They must communicate more with the crews about changes in the organisation, changes in management and/or changes in equipment/support;*
 - o *They should not change plans without consultation; and,*
 - o *Supervisors need to help with ordering of equipment.*
- *The training departments should conduct underground observations to ascertain if the training provided is relevant, is being executed accordingly underground, and whether there is a need to improve such training.*
- *Communication between workers and the supervisors should occur more frequently and they should be kept abreast of changes in the workplace or organisation.*
- *There is generally a perception that production pressures supercede safety concerns. Supervisors need to prioritise safety over production.*
- *Due to the activities on the face, time for drilling and conducting these activities are limited. Supervisors should acknowledge these constraints and help the crews with resolution of these challenges. The crews should form part of the solution.*
- *Supervisors do not connect with their teams and individuals on the team. Supervisors are therefore viewed as distant in their actions and are regarded merely as managers. They need to be viewed as safety intervention facilitators, as well as successful production and productivity experts.”*

3.3. CONCLUSIONS FROM THE BACKGROUND INFORMATION

Against the backdrop of the information provided, there are inherent and deeply rooted technical, behaviour communication and leadership behaviour challenges. Problems exist within the technical, design, quality, training and leadership domains of the drill and blast operation; and it seems that supervisors are not advocating initiatives according to their health and safety appointments.

The following sections will now provide some building blocks to create a more productive and safe operational environment.



Safety and Health: FIRST, ALWAYS and EVERYDAY

4. UNDERSTANDING THE MINING CYCLE

Typically, operations review (or are instructed to review) their operating systems and processes after a significant event/loss. During such a review/audit, root cause analyses are conducted for the loss event; trends are analysed, and remediation is proposed, assessed, implemented and monitored. During this process improvements in the mining cycle are often overlooked. Rather, the consequence of a poor DB cycle is analysed, rather than the root cause of the poor DB cycle.

To ensure that all stakeholders understand which aspects contribute to stability and how each could go wrong, it is important to know:

- i. What the key elements are that contribute to the mining cycle (support, drill, blast and clean) in conventional mines,
- ii. How each element contributes to the mining cycle and relative importance and effectiveness of each,
- iii. The resources (time, equipment, material, human capital, etc.) it takes to conduct/perform each element effectively,
- iv. What the consequences would be if a particular element is not executed properly, and/or if such an element does not conform to a particular standard, procedure, or process, and,
- v. How to improve the training, leadership and development of persons so that persons are able to, and likely to, show appropriate competence in the execution of each element.

4.1. KEY ELEMENTS WITHIN THE MINING CYCLE

Typically, there are 4 broad activities (Support, Drill, Blast and Clean) that have to be conducted in order for a mining excavation/face/end to advance. These are represented as a cycle in Figure 6:

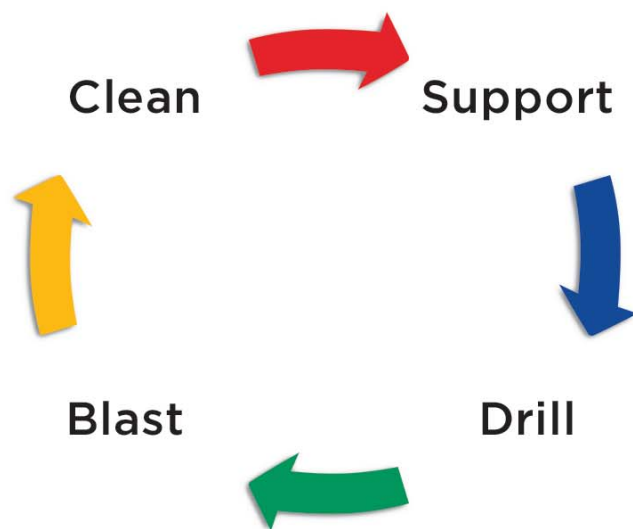


Figure 6: Broad activities within a mining cycle



The cycle may begin at any point but often starts with an unsupported, clean face. The face then has to be inspected and supported (Figure 7). Thereafter, the face is drilled (Figure 8), blasted (Figure 9) and then cleaned (Figure 10). Each activity has several sub-processes or work activities/packages that need to be completed in order to achieve an efficient and successful blast.

The figures show examples of activities that may be present in an operational mining cycle in a conventional tabular mine. There are, therefore, at least 80 processes/activities/tasks in such an extraction sequence, and several operations may still conduct activities that may not be accounted for in these figures.

From a safety perspective, having such a **large number of activities could attract non-conformances/non-compliances** as time constraints may not permit all activities from being conducted efficiently, effectively or to standard. Shortcuts in activities could lead to incidents and accidents. However, standards, procedures and processes are meant to achieve both safety and productivity gains, and as such, if all activities are conducted according to the mine standards and procedures, both should be achieved.

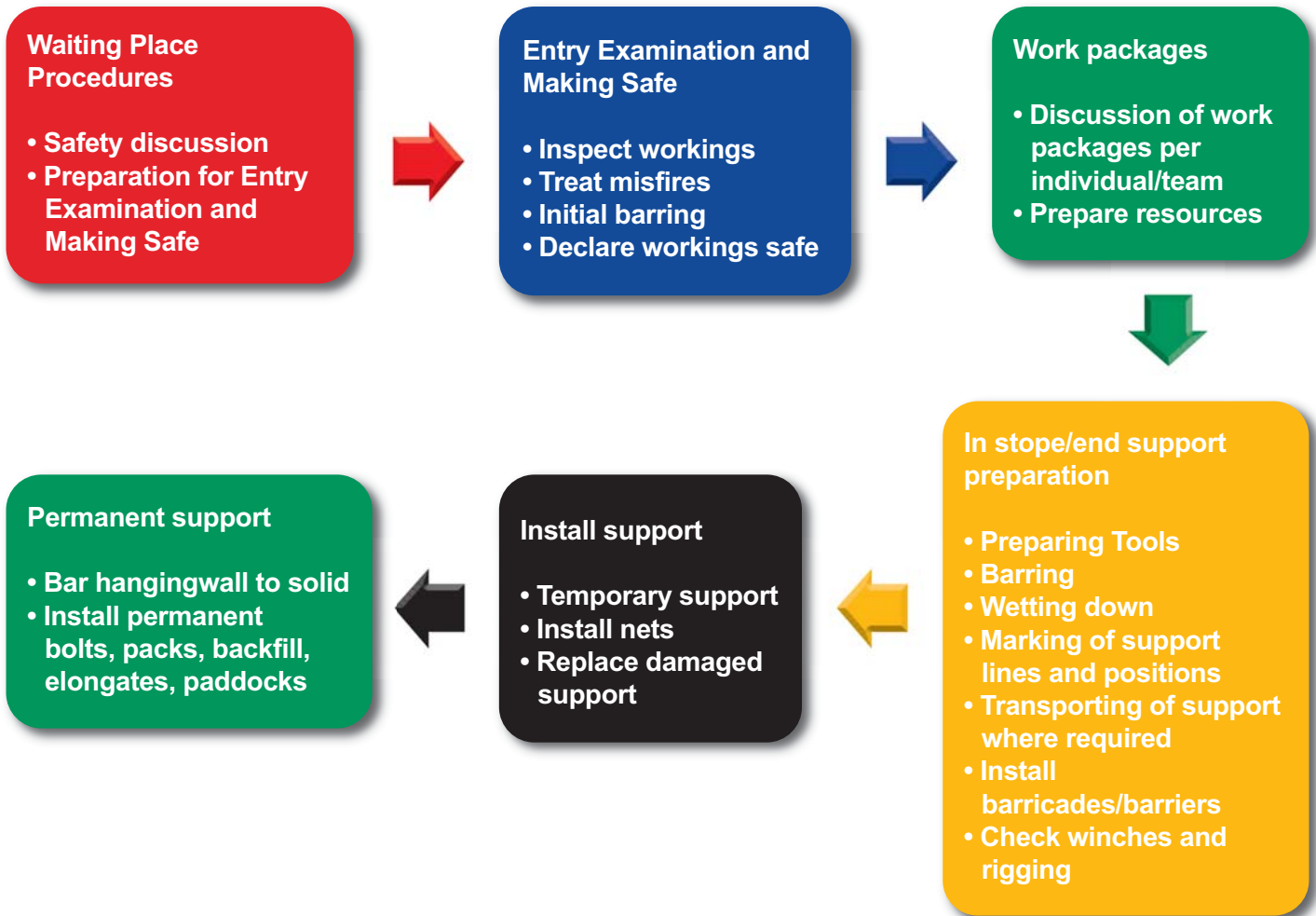


Figure 7: SUPPORT INSTALLATION FLOW CHART



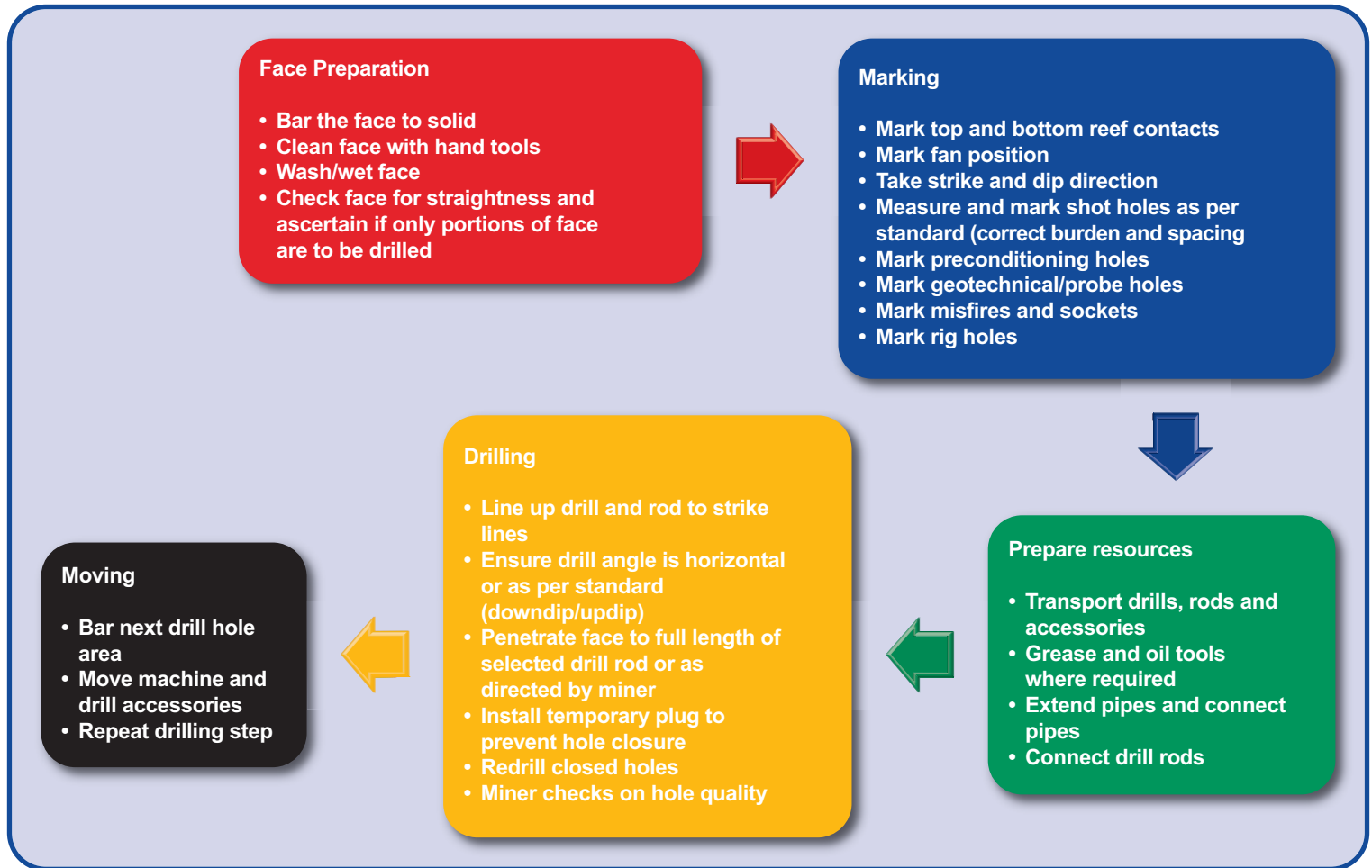


Figure 8: DRILL FLOW CHART

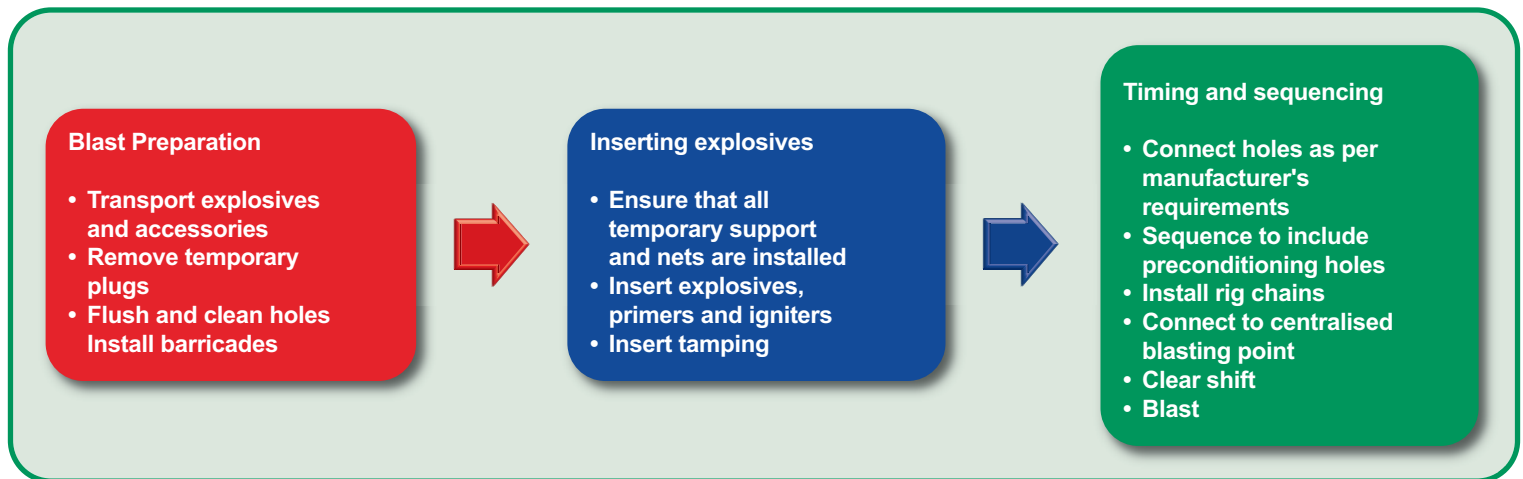


Figure 9: BLAST FLOW CHART



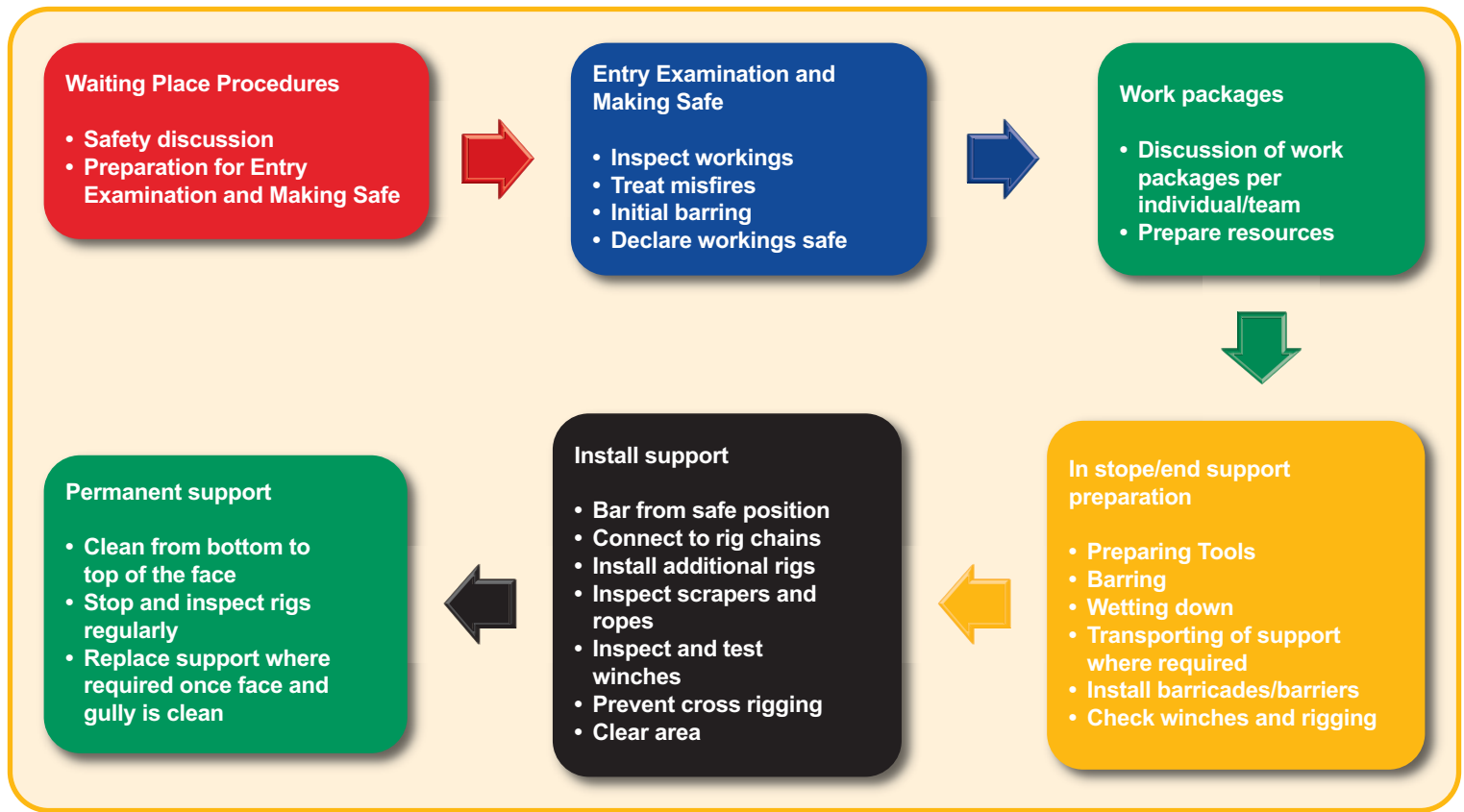


Figure 10: CLEANING FLOW CHART

4.2. THE TIMEFRAME AND RESOURCE ALLOCATION FOR EACH ELEMENT

It is imperative that each operation conducts a proper work study for its mining cycle. Each activity that is completed, according to a set of standards or procedures, will be assessed for a time range. These time allocations would then be fed into the calculation of an overall mining cycle time for that operation. Note that travelling time needs to be added to such a calculation to get an overall timeframe for each human capital resource.

Once the time assessment has been conducted, the required skill set and required resources (equipment and material) can be allocated accordingly. Procurement processes and just-in-time resource deliveries to site can then be advocated.

4.3. MANAGEMENT OF THE MINING CYCLE

In order to manage this process, it is important that the operation utilises a Work Study Program or a Work Breakdown Structure (WBS). The second term is borrowed from the Project Management discipline where each component of a particular project is broken down, assessed, scheduled and managed within strict deliverables, controls and time.

In order to achieve significant gains in productivity and efficiency, the mining cycle on a mine should be managed with similar strict controls. In addition to providing enhanced stability in the rockmass, these controls will also allow financial gains through efficient use of resources and provide opportunities to improve compliance to the regulatory and mandatory activities within the cycle.



4.4. THE CONSEQUENCES OF POOR EXECUTION OF AN ELEMENT/S

At the onset, the value proposition for this MOSH reference guide was to craft and enable a safer environment by understanding the components of the mining cycle and adopting measures to improve each. In so doing, both production and safety is enhanced. However, it is important to inculcate behaviours and leadership traits that illicit the ideal culture. Each person that is responsible in the mining cycle needs to be aware of what the consequences are should a particular element not be performed to the required criteria.

An example of such an intervention would be to help the crews understand what impact poor drilling discipline has on ground stability. If shot holes are marked (Figure 11) correctly, but drilled incorrectly (Figure 12), the detonation of such a hole may damage the hangingwall and/or footwall. This may lead to strata control difficulties and additional barring may be required to attain the required stability. The time taken for the additional barring could have been used for other critical jobs.



Figure 11. Accurate, clear marking of the face to indicate where the shot-holes should be drilled is critical to executing a good blast

ZERO HARM

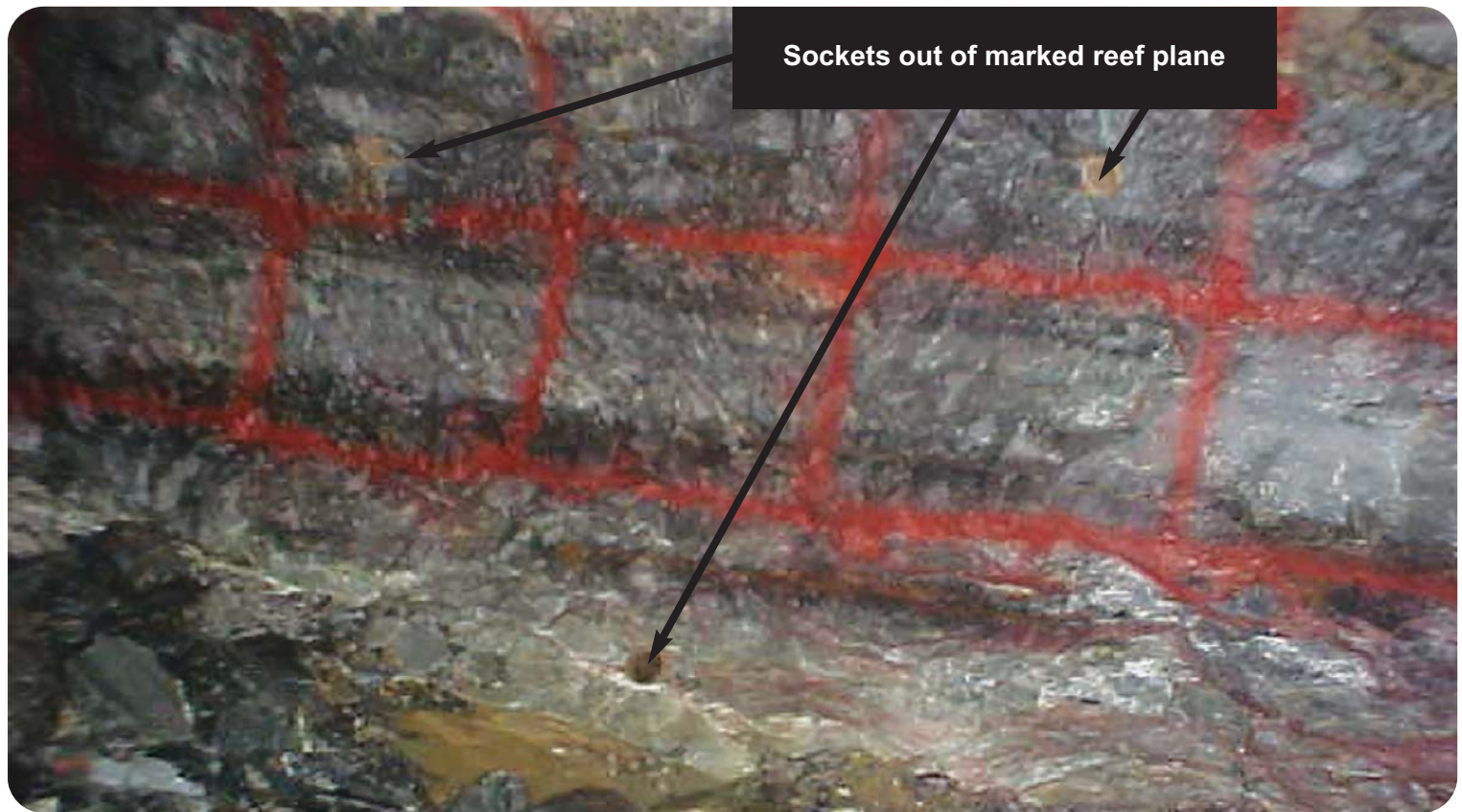


Figure 12. Position of sockets from the previous blast indicating poor drilling angles

In addition, optimal mining practices may have further benefits:

- **Value chain gains**

- o Explosives are used more efficiently in that all the available explosive energy is used to fracture the rockmass. Energy is not “lost” during the blast;
- o The maximum designed advance per blast is achieved;
- o Lost blasts are minimised;
- o Good fragmentation, as designed, will result in the reduction of secondary blasting at the tips and reduced milling costs;
- o Uniform fragmentation also results in improved cleaning times;
- o Damage to support is minimal and therefore replacement of damaged support is reduced;
- o Muckpile position is optimised to ensure more efficient cleaning of the broken ore;
- o The face is blasted more solid and hence less barring (less time) is required therewith increasing the face time available for drilling; and,
- o Mining a stope width as designed reduces the requirement to order additional oversize support units.

- **Business optimisation**

- o Business plans can be achieved. This leads to targets being met and improved;
- o With targets met, crews achieve incentives;
- o Ore is transported regularly so mill efficiency is maintained;
- o Less dilution of the broken ore means reduced waste throughput; and,
- o Human capital and resources are used optimally.

From the discussion, it is imperative that all individuals responsible in the mining cycle understand the consequences of poor execution of the elements within the mining cycle and that it is incumbent on them to eradicate non-compliances.

Safety is our No1 Priority

5. TOWARDS INCREASING PRODUCTIVITY AND EFFICIENCY OF THE MINING CYCLE

Figure 13 shows an ideal DB scene where one can identify that the 4 main activities described in Figure 6, Section 4.1., have been successfully achieved:

- a) **Support** – temporary and permanent support installed; barring completed,
- b) **Drill** – correct marking, correct angle and inclination of drilling, correct position relative to marking clean appropriate equipment used, and ancillary equipment in good order,
- c) **Blast** – previous blast sockets treated; clean straight face; no overhanging face; barricade in place; even footwall, and,
- d) **Clean** – Clean footwall; dust allayed.



Figure 13. Drilling at right angles to a well-marked face, with top and bottom contact lines and drilling direction lines indicated. The angle of the drill is close to parallel to the top contact

To aid in the creation and successful detonation of the stope in Figure 13, the DB practitioner should also use information provided in Tables 2-4. These utilise best practices from other conventional operations, as well as relevant research. For ease of use, the tables are segregated according to the 3 legs of the MOSH LP Adoption Strategy:

- Technical,
- Behavioural Communication, and,
- Leadership Behaviour.

Safety rules are your best tools

Table 2: Mining Cycle Leading Practices from various operations – MOSH Technical components

Category	Leading Practice
<div style="background-color: #e53935; color: white; padding: 5px; text-align: center; border-radius: 5px;">Design</div>	<ul style="list-style-type: none"> • Each blast to be planned/designed. “Powder factors”, explosive type, advance and explosive volume can be detailed based on the Velocity of Detonation (VODs). More information is available in Section 5 of this document • Where possible and if sufficient resources are available, the advancing stope face is to be measured/surveyed after each blast, or in a periodic manner so that the blast engineer may plan the following blasts based on survey data and not data plotted by the miner. • Mine on true dip and strike. Using this technique allows mining to occur along predefined bedding planes. This results in exposure of the same strata, promoting stability as the compressional stress of the rock blocks are maintained. There is also no “cutting” across strata which results in blocky ground conditions. • Squarer hole patterns rather than staggered patterns should be used. • Resources for each blast should be planned timeously and orders for each blast should be expedited optimally. • The gully should be ahead (tight-end heading or advanced strike gully) of the stope panel to provide a breaking surface for the panel blast. • Bulking factors for the rock type should be considered for ore flow. Typical quartzite bulking factors are in the order of 1.6. This is important for gully depth and orepass capacity calculations. • Gullies should be deep enough to carry the amount of the designed muckpile per blast. • Panels lengths should be shorter lower down the raise as the capacity of the orepasses lower down the raise are relatively lower due to their proximity to the cross-cut/haulage. • Typical panel lengths should not exceed 30m, including the tight-end heading or ASG. This will aid cycling of crews between panels, smaller areas of responsibility, and a shorter support, drill, blast and clean cycle. • The support standard must consider if support units will interfere with drilling practices. When packs are too close to the face, drill angles are compromised.
<div style="background-color: #2980b9; color: white; padding: 5px; text-align: center; border-radius: 5px;">Quality</div>	<ul style="list-style-type: none"> • The need for illumination in the stope is often overlooked. This will help with identifying unsafe hangingwall as well as providing additional light to the drillers improving their drilling discipline. • From the daily monitoring information, fragmentation analyses can be conducted and the next blast’s ore can be optimised for the operation. • The daily monitoring should highlight misfires and out-of-sequence firing. • Products that help with levelling of drill machines will aid in alignment/ angles of shot holes. • Burdens and spacings can be improved with the use of measuring instruments, especially laser marking/profiling in development ends. • The supplier should be able to take over the charging and initiation process. • The miner must be able to mark and measure the length/depth, spacing and burdens of shot holes prior to charging up. Deviations should be rectified. • Plot daily advances on a plan. • Review advances periodically to ascertain compliance to the plan and whether targets can be met. • Face shapes and lead/lags can be measured and monitored through a well resourced safety and rock engineering department. TARP processes, as well as timeous relay of information is critical. • Inclination or declination of shot holes when updipping and downdipping should be carefully designed and monitored. • The break angle of any shot hole must be maximised.
<div style="background-color: #27ae60; color: white; padding: 5px; text-align: center; border-radius: 5px;">Technical</div>	<ul style="list-style-type: none"> • Emulsions should be considered. They are more stable during transport and can be pumped in varying quantities. Encapsulated explosives often result in too much or too little charge to move the rock. • In order to reduce the effects of seismicity, centralised blasting systems should be used. • Stemming for each rock type and explosive type should be determined. • Electronic initiation/blasting systems are necessary for accurate detonation sequences. • Drill holes using tapered and appropriate button bits (for the rock type) will result in higher efficiencies and faster penetration of the rockmass. • Technological advances could realise remote drill rigs that will be able to drill to the correct design as well as achieve the required thrust for faster penetration. • The use of Hydropower also facilitates increased productivity. • Thrust adaptations(air-legs) aligned with the drilling is sub-optimal and should be improved for greater penetration speeds and efficiencies. • Percussion drilling should be phased out as it is detrimental to both people and machines. • Appropriate and extension air-legs should be used in order to reach the top holes and drill them to the right depth and at the right inclination and angle. • Consider another colour for marking of the face. Red is not clearly visible in low light environments.

Table 3: Mining Cycle Leading Practices from various operations – MOSH Behavioural Communication components

Category	Best Practice
Training	<ul style="list-style-type: none"> • There is a need for comprehensive, experiential learning/training to equip people for these jobs. • A large Platinum mine is using their team mobilisation programme to give more than theory in terms of Drill and Blast Program. Candidates are shown, amongst other things, the impact of drilling short holes. A grid is marked on the ground and two teams go through the process of mining for a month. The team that drills the correct length holes consistently, moves far ahead of the other team. It is possible to show visually the m² that were gained or lost. • Theoretical aspects of the wider issues surrounding the mining cycle should be covered in the syllabus. • The lack of comprehension or skill of workers should be negated by appropriate cognitive and risk tolerance tools which should highlight job appropriate persons • Additional coaching, mentoring and training for production personnel is advocated so that they may use that skill to check the quality of the drilling.
Messaging	<ul style="list-style-type: none"> • Ensure that the correct methods are used to convey the messages. Take cognisance of education level, graphical information and language • There is a lack of understanding of resources available to the organisation. Ensure that during communication, teams understand wasteful expenditure and how that impacts on the individual and the organisation. Explosives are expensive and when not used optimally, is regarded as waste. • Impact assessments of poor mining cycle conformance on business and remuneration should be discussed with the crews.

Table 4: Mining Cycle Leading Practices from various operations – MOSH Leadership Behaviour components

Category	Best Practice
Leadership	<ul style="list-style-type: none"> • Competent supervision and personnel should be placed in stope. Each should be individually assessed for risk. • Daily review of previous blast or lost blast by all stakeholders. • When marking the face, every driller must accompany the miner throughout his part of the face to: <ul style="list-style-type: none"> o Review the result of the drilling of the previous shift, o Allow him to comment on the holes miners are marking off, and, o Comment on the barring and safety aspects in the drillers’ “area of responsibility”. • Visible Felt Leadership (VFL) visits should attempt to instil the values of the organisation, communicate timeously important and relevant messages to the workforce, connect with people and show interest in their well-being, coach persons if they are doing things incorrectly, mentor persons so that they may achieve higher standards of work, demonstrate commitment, foster respect, improve workplace behaviour, and discourage the taking of short-cuts through culture transformation. • Resources should be available to optimise the cycle.

5.1. BLAST DESIGN

5.1.1. OVERVIEW

The effectiveness of the blast can be attributed to 2 main factors:

- The technical ability of the detonation system to move the rockmass in the desired manner, and,
- The ground reaction to the force applied to it.



Tables 5 and 6 show those elements attributed to each of the factors listed above.

The tables are by no means exhaustive; other elements may also contribute to the detonation.

Figure 14 redistributes the information in Tables 5 and 6 in a visual format. The idea is to remove ore efficiently from its in-situ position, whilst “*minimising energy consumption in comminution*” (Silva, et al, 2017).

“Safety First” is “Safety Always.” ~Charles M. Hayes

Table 5: Explosive Technical elements involved in the blast design and relevant terminology

	Element	Brief description
1	Technical Powder Factor	The relationship between the mass of explosive and the volume of rock to be broken
2	Actual Powder Factor	The Actual Powder Factor is a relationship between how much rock was broken and how much explosive was used to break it
3	Explosive column length	The length of hole with a continuous charge of explosives
4	Borehole pressure	The pressure which the gasses of detonation exert on the borehole wall
5	Relative Density of Explosive	The density of the explosive based on the materials used in its manufacture
6	Velocity of Detonation	The velocity at which a detonation progresses through an explosive
7	Critical Explosive diameter	The diameter of the explosive cartridge or the estimated emulsion diameter when extruded into the hole; the minimum diameter for propagation of a stable detonation
8	Coupling percentage	The relative adhesion between hole diameter and explosive diameter prior to initiation
9	Initiation system	The compatibility of the explosive and the initiation system should be carefully considered to optimise the blast
10	Vibration Control	This control is necessary where there is an effect on surface property; where there is a necessity to reduce Peak Particle Velocities (PPV) during the blast; where blast vibrations may damage electric, electronic and sensitive equipment or where airblasts/overpressures may impact on personnel, excavations and/or material and equipment
11	Stemming Factors	Those factors that are considered when selecting a stemming material to contain the explosive in the drill hole. These factors are stemming length, rock type, charge length, explosive length, hole length, explosive density, burden, etc.

Table 6: Ground reaction elements involved in the blast design and relevant terminology

	Element	Brief description
12	Line drilling	A method of overbreak control which uses a series of closely spaced holes that are not charged
13	Hole diameter	The diameter of the drill hole
14	Burden	The distance between holes in a sub-vertical direction (in a column) in underground excavations
15	Spacing	The distance between holes in a sub-horizontal plane (in a row)
16	The number of shot, perimeter (pre-split; post-split) & preconditioning holes	The number of different types of holes and their relative contribution to safety, stability and productivity of the environment will outline the different explosive loads required
17	The sequencing of the different types of holes	The delays and explosive load in each of the different types of holes will contribute to the success of the blast as well as the overall safety of the environment
18	Stoping width	The height of the excavation where ore blasting is occurring
19	Flyrock / Muckpile Factor	The ideal position for which the blasted ore should be able to be cleaned. The explosive energy should not result in scattering of rock in positions where cleaning is inappropriate. In addition, the type of rock should be considered here
20	Rock Factor	The type of rock to be blasted, including hardness for which an appropriate explosive should be designed
21	Rock Bulking Factor	The volume of resultant rock after blasting. Typical values range from 1.2-2.0 of the in-situ volume
22	Advance per blast	The ideal face advance rate that can be achieved by the blast design; to be read with Stopping width to determine the volume to be mined
23	Panel length	The length of a reef face that can be drilled and blasted
24	Ideal Rock Fragmentation	The size distribution of the rock material required for transportation and processing

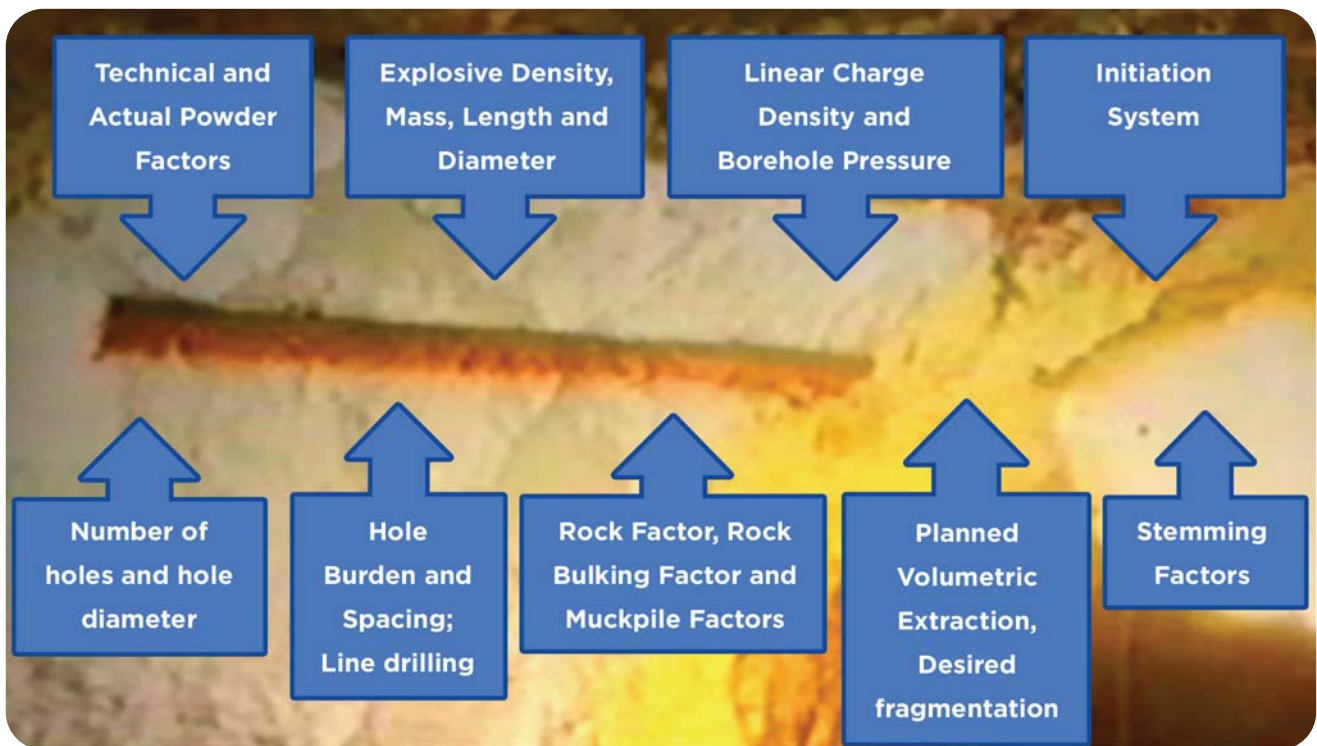


Figure 14. Factors influencing a blast design

5.1.2. DISCUSSION

Whereas a comprehensive discussion and understanding of each of the elements may be beneficial, the purpose of this document is not to provide additional training material for blast design, but to highlight those elements that may have the highest improvement potential for DB. Therefore, variations and exceptions to each of the elements, have to be keenly studied and understood to ensure optimisation of the DB cycle.

Examples of potential improvements may lie in the discussion of the following elements:

- a. **Charge length:** The entire shot hole column does not need an explosive charge. COMRO 1990, studies indicated that only **1/2 to 1/3 of the shot hole** length needs to be **charged**. In addition, this explosive should be inserted from the toe of the hole, as it is further from the free face during detonation and requires more energy to break and heave. The third of the hole near the hole collar is closer to the free face and therefore requires little to no energy to break it – it will heave as the toe breaks. If the entire hole is charged flyrock may damage support units and ground vibration could result in hangingwall instability.
- b. **Advance per blast** - In addition, the mine should undertake an assessment of whether a large advance per blast (1.5-3.5m), or smaller **incremental advances** (<1.0m) are more productive. Factors to be considered would include, the efficiency of the cleaning cycle, the bulking factor of a particular rock type, and what the panel lengths are? Smaller advances result in less broken ore to be cleaned per cycle, resulting in panels being blasted regularly, support being installed timeously, and a **quality blast per day**. In addition, the use of smaller explosive charges result in less gas pressure into the hangingwall, resulting in less fracturing of the rockmass. The excavation is more stable and less barring is required.

SMART - Safety Means Always Remember Teamwork

c. **Rock Factor:** Different rock types require different explosive types with different delays between shot holes. Much work has been done in the surface blasting and coal mining sector, but the technologies have not been researched thoroughly for other underground mines. A surface blasting rock factor consideration is used as an example. Figure 15 shows how an explosive is matched to a particular rockmass characteristic and a stemming length. Table 7 uses an applicable rockmass factor as an input into blast design.

A sub-set of considerations must also be made when considering preconditioning:

- Without production detonation;
- Prior to production detonation; or,
- In sequence with production detonation.

The rock factor and stress related thereto should also be considered when designing line drilling and/or perimeter (pre-and-post-split) blasting.

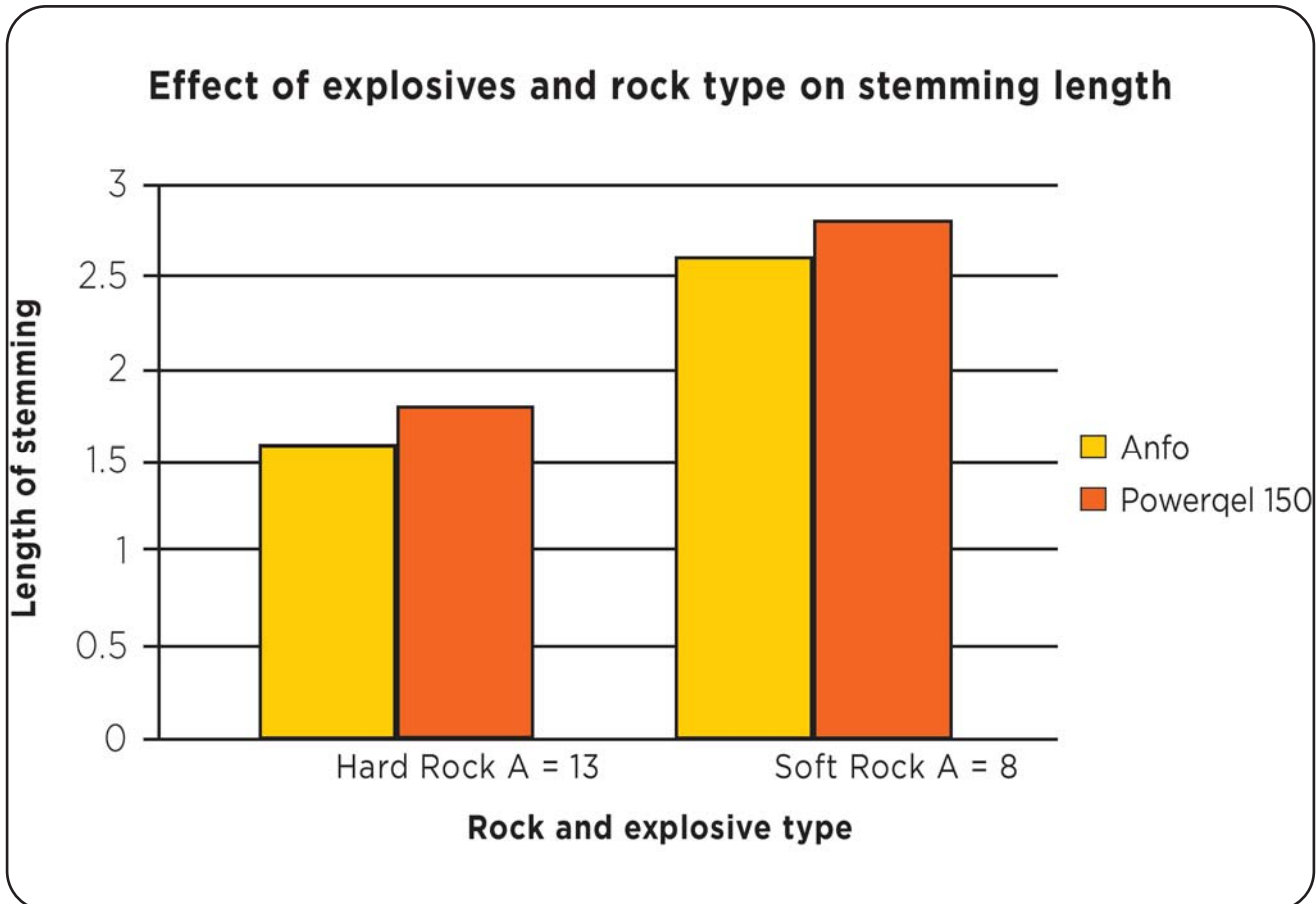


Figure 15. Matching rock and explosive type to required stemming (Explosives Today, 1987, described by Boshoff, 2015)

Table 7. Estimation of Surface Mines’s Rock Factor (Explosives Today, 1987, described by Boshoff, 2015) for blast design

Blasting Category (UCS)	Typical rock type	Rock factor (A)
Hard (+200MPa)	Andesite, dolerite, granite, ironstone, silcrete	12-14
Medium (100-200MPa)	Dolomite, hornfels, quartzite, serpentine, schist	10-11
Soft (50-100MPa)	Sandstone, calcrete, limestone, shale	8-9
Very soft (<50MPa)	Coal	6

d. **Stemming or Tamping** - Boshoff (2015) relates that “the main purpose of stemming is to retain the energy long enough that it was intended for. The retention of energy allows for more work to be done to the rock...” It is therefore imperative that shot holes are stemmed, even when using emulsions.

The **lack of stemming** allows for:

- Blast energy to escape from the hole,
- Waste of explosives, when such explosives are used for tamping,
- Damage to the rockmass, as the excessive energy permeates and vibrates the hangingwall,
- Damage to support as flyrock may dislodge installed support, or render them ineffective, and,
- Damage to stope infrastructure.



Figure 16. Energy blow-out from blast hole as a result of a lack of stemming (COMRO, 1990)

Armstrong (1993) also found that the fragmentation size decreases with increasing confinement of the energy. Hence, more work is done (fracturing) to the rock allowing for smaller size rock fragments. This allows for better transport of the ore, but can also have a negative effect should the fragmentation be too fine, especially in the high value gold deposits.

ZERO HARM

Otounye (1981) found that an “*efficient stemming material is one that rapidly compacts when subjected to high explosive pressures after detonation*”. This means that should the stemming material compact slowly, the gases from the explosives would escape in between the stemming particles before those gaps can be sealed.

Stemming length has also been confined to rules of thumb as there is no clear and concise method of determining an optimal length. Rules of thumb include:

- 1-1.2 x burden length,
- 1/3 of the blast hole length,
- 3 x hole diameter when high compaction aggregates are used,
- 10 x hole diameter when low compaction materials are used, and,
- 20 x hole diameter for a preconditioning hole.

Some of the parameters that need to be considered when selecting a stemming product are:

- *Rock strength* – hard rocks need lower length; soft rocks need longer lengths to take into account hole deformation and spalling at the hole. Figure 16, gives an indication of such differences. For soft rock, the stemming length is approximately 40% more than for hard rock when using ANFO or Powergel 150. Rock factors for surface operations are shown in Table 7. However, the charge length for each is unknown,
 - *Velocity of Detonation (VOD)* – High VOD explosives need a shorter stemming length whereas lower VOD explosives need longer stemming lengths due to an increasing need for confinement,
 - *Strength of explosive* – higher strength needs longer stemming,
 - *Density of explosive* – higher density needs longer stemming, and,
 - *Length of explosive column.*
- e. **Panel length** – If a proper understanding of a blast cycle is understood and the relative timeframes for each component is clearly described, all components can be optimised for the available face time with the number of resources available. Therefore, quality work for each of the elements, listed in Figures 7-10, can be practiced. In this study, the available face time for the resources employed will be known and hence the length of the panel can be deduced to optimise the resources effectively. Hence, if additional resources are employed, face lengths can increase.

5.2. TECHNOLOGIES TO IMPROVE THE DRILL AND BLAST CYCLE

In order to augment and improve the drill and blast cycle, opportunities and technologies exist within the mining supply chain industry. The ensuing discussion will focus mainly on augmenting the training, technical and quality components of the DB cycle.

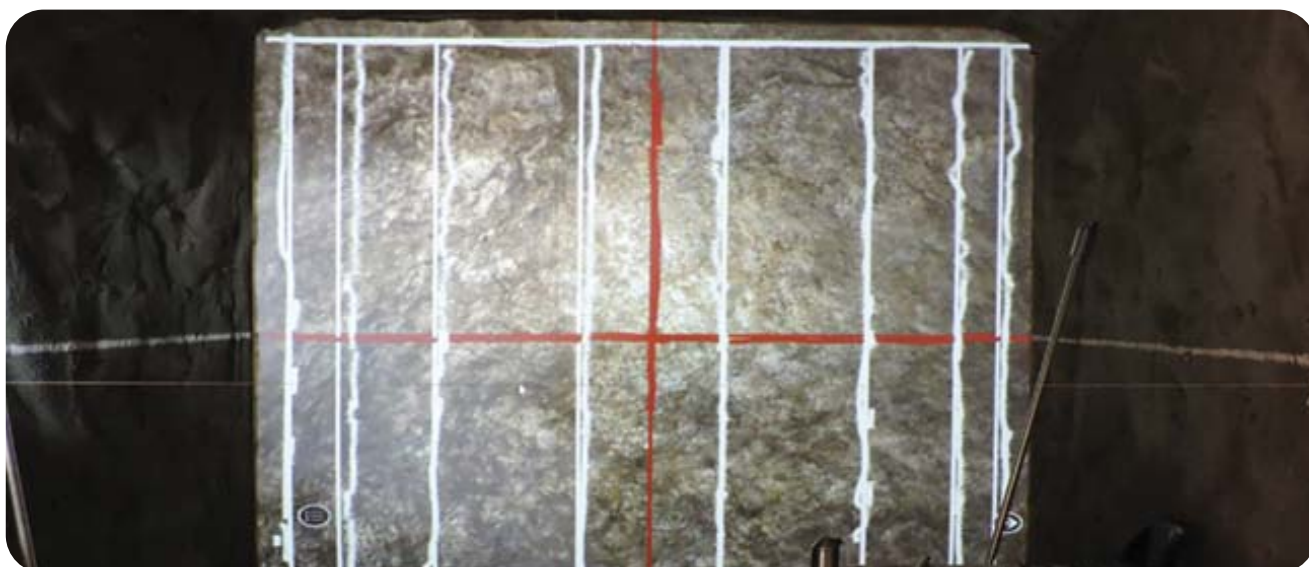
5.2.1. TRAINING IMPROVEMENTS - 3D SIMULATION AND VIRTUAL REALITY

At least 2 South African platinum mines, 1 African mine, 1 South African Mining Industry Supplier and several international operations, use Virtual Reality (VR) training (Figures 17-20). This technology has sprouted increasing opportunities for the workforce to attain and improve their skills. Current VR simulations encompass a projected development rock face (Virtual Reality Wall) where trainees are practically trained on:

1. How to take line and grade,
2. Mark off a blast pattern/burden, and,
3. Sequence the round (timing) to ensure the correct firing of the 'blast pattern' is attained.

This augments the theoretical training and has the following advantages for the blended approach to training:

- The incumbent/trainee is trained theoretically and is then allowed to perform the task on the VR practically,
- It is an immersive experience where the underground setting is emulated. Trainees are encouraged to wear the required underground clothes and personal protective equipment (PPE),
- The activity of the person performing the actions are monitored and can be used to improve the person's capabilities/skills with further interventions,
- Relatively cost effective if compared to how much wasteful expenditure, as a result of poor blasting, can be prevented,
- The ability and competency can be tested immediately. The person does not have to go to the workplace and be tested on site,
- The resources and time taken for the training is minimal, depending on the individual being found competent,
- The system can be configured for each type of blast round,
- A Trigger Action Response Program (TARP) may be added to the VR experience. An example thereof may be geological triggers that could give rise to a FOG,
- The system also allows the trainee exposure to interactive functionalities associated with computers, and,
- After the theoretical and surface practical training is completed, underground assessments can be done to evaluate the effectiveness of the blended training methods. Review and improvements in both the technology and theory can then be done.



Safety rules are your best tools



Figure 17. Virtual Reality Wall (VRW) training in the “classroom” simulating a development end



Figure 18. Virtual Reality Wall (VRW) training – person performing the marking task

“Safety First” is “Safety Always.” ~Charles M. Hayes

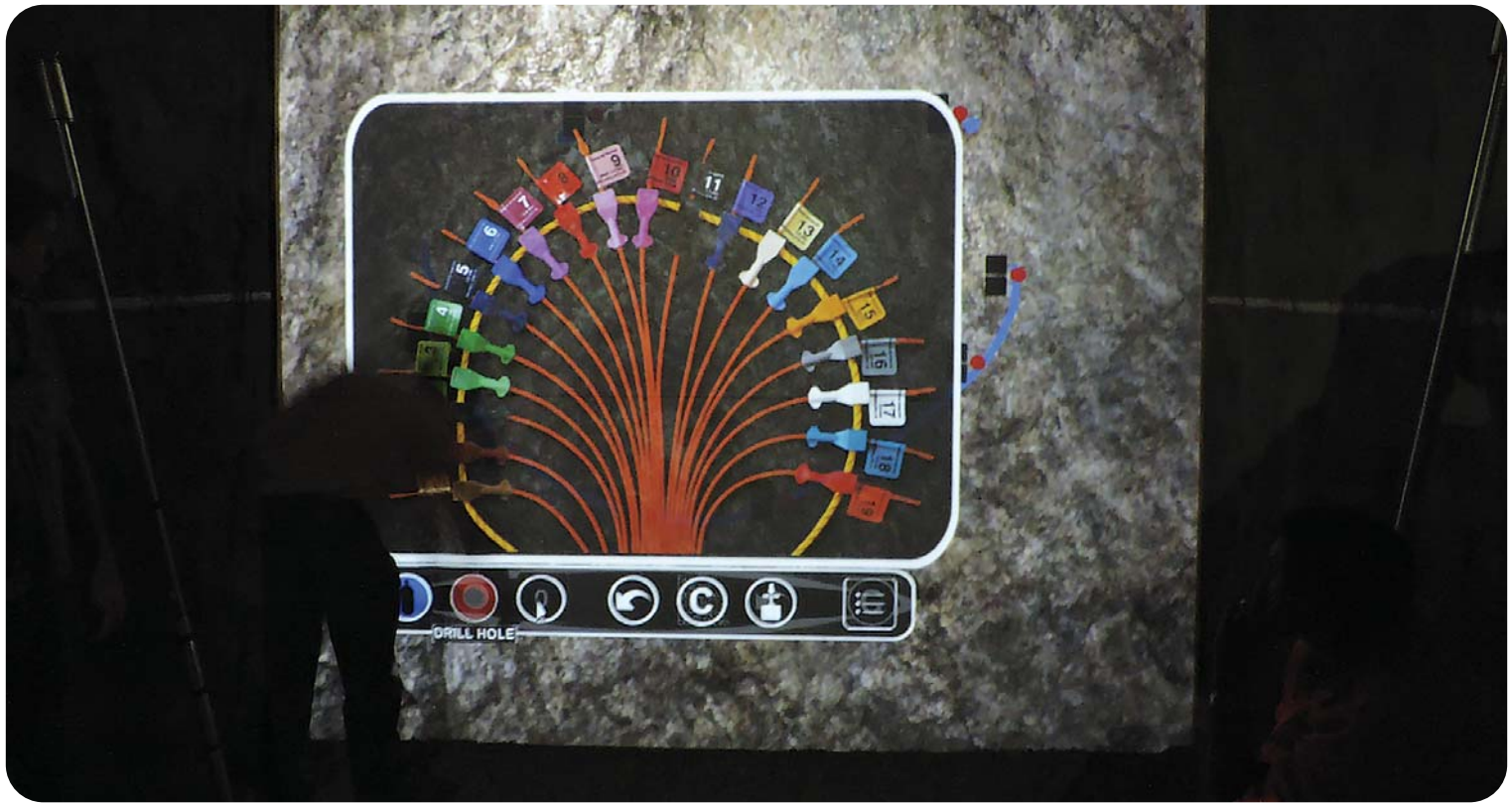


Figure 19. Virtual Reality Wall (VRW) training – person performing the timing/sequencing of the blast



Figure 20. Virtual Reality Wall (VRW) training – showing the consequences of incorrect sequencing on a blast

**Safety is about doing the right thing, even if no one is looking,
because safety starts with me!**

5.2.2. MONITORING AND REVIEW OF DRILL QUALITY

Drill hole quality can be measured after the drilling hole has been complete and cleaned. Surveys of drill holes could include:

- Length – the actual length of the hole can be measured against the design length,
- Width – the roundness of the hole may indicate stress, as well as the quality of the drill steel used;
- Direction – the angle relative to the design could indicate how successful the blast would be, as well as indicating where the muckpile may be;
- Linearity – has the hole deviated significantly over the short distance;
- Elevation – is the hole drilled into the hangingwall or footwall.

These measurements can be captured using readily available measuring tools like a clinoruler and to a lesser extent, a charging stick. The auditor could capture the data on a data processing unit and the information gleaned through this process could be used to give feedback, guidance and coaching of drilling quality to the crew, even before the blast occurs. Through this intervention, the drill crew may be able to understand the consequences of their drill behaviour. The crew may also be able to give feedback on how they may be able to improve and optimise their time to ensure that a good quality blast is obtained.

In addition, there are tools and technologies that do exist to improve drill quality. Although both have been trialled, their widespread adoption has been constrained by perceived cost, the lack of capital to manufacture the units and resistance from the crews. However, for the purposes of completeness, a summary of the tools may be useful.

5.2.3. CENTRALISED BLASTING

The Centralised Blasting concept or Multiple Panel Simultaneous Detonation has been used primarily on the deep level gold mines on the Far West Rand. The concept is described as the detonation of a number of panels/ends and/or stopes on a particular operation at the same time. In addition the concept has been used for detonation of stopes between mines. Inter-mine centralised blasting has occurred between the then Goldfield's (now SibanyeStillwater) Driefontein West Mines Division and Anglo Gold Ashanti in order to reduce the likelihood of regional redistribution of stress on geological features as a result of blasting activity. At the time, panels on the two mines were being blasted in close proximity to each other, along a common boundary pillar. In addition, geological features traversed the mine boundaries. It was hypothesised that should latent blast energies activate these features on the one mine, it may result in rockmass failure on the other before workers had left the workings. From a worker exposure perspective, blasting at the same time meant that:

- Workings were clear of mine personnel by a certain time,
- No blasting would take place before such time,
- A central communication office would alert the 2 mines when workings are clear,
- If there was a delay, both mines would be affected,
- If the day's work was not finished at the recommended blasting time, the workers would not be able to stay to complete those activities,
- Workers are at a lower risk fatigue profile if they only work their normal hours, and,
- It helps with the re-entry period of workers.

Hence, the concept resulted in a more regional effect rather than a local one. Any latent ground motion on geological structures would occur and be concentrated during the immediate period (seismic window) after the blast. The effect would be more general, regional type of destressing as any instability on the regional geological features would be triggered resulting in a theoretically safer working environment when workers are at the face. It also determines when seismic incidences are relatively lower after the blast so that workers may enter the workings.

Centralised blasting is also characterised as regional preconditioning.

SMART - Safety Means Always Remember Teamwork

6. CONCLUSIONS

In pursuance of the need by industry to improve the safety, efficiency and productivity of the drill and blast cycle, the COM MOSH LH FOG Team sourced “best” practices from a number of mining operations, conducted interviews, reviewed relevant subject matter research and tabled innovations that could result in improving the extraction process. It was clear that the understanding of the mining cycle process was imperative to attain these goals - key elements of the Support, Drill, Blast and Clean process were described. The intention is to improve mine training material, as well as workers’ behaviour through consequential thinking. In addition, details on blast design and other technical elements were described to aid the operation in improving their extraction process.

It is envisaged that the adoption of this Leading Practice will undoubtedly lead to significant safety improvements in the industry, particularly in the FOG space where accidents persist. Using the MOSH approach, more reward is gained from understanding of the initiative; documenting best practices from participating mines; and providing guidance on redirecting people’s behaviour so that a culture shift is achieved.

Contact Info:

C. Legodi - MOSH FOG Adoption Specialist
A. Issaka - MOSH FOG Adoption Manager
S. Durapraj - MOSH FOG Adoption Manager
P. Yoyo - MOSH FOG Adoption Manager

www.mosh.org.za

Every person going home from work unharmed everyday

REFERENCES

Blast Design. Retrieved October 20, 2017, from <http://gis.lic.wisc.edu/wwwlicgf/glifwc/PolyMet/SDEIS/references/Dyno%20Nobel%202010.pdf>

Blasting Video footage provided by Chamber of Mines: Brinkman, COMRO, 1990

Boshoff, D., **The development of a blasthole stemming performance evaluation model using a purpose built testing facility**, MSc Research Project, University of Pretoria.

Durapraj, S. (4SV) **Ya Rona Shaft Pillar- the Extraction of the Chase**. Annual Goldfields Mining and Rock Engineering Seminar (pp. 1-32). Unpublished presentation, cited in MSc Research Report: An investigation of Westonia Formation Lavas (WAF) and its influence on the Rock Engineering design at Gold Field's KDC No. 4 (Ya Rona) Shaft Pillar extraction, 2015, University of Witwatersrand, 2015.

Laser marking. Retrieved February 20, 2018, from <http://www.commendium.com/wp-content/uploads/subterranean-3d-scanning1.jpg>

Otounye, **Effect of Hole Stemming Practices on Energy Efficiency of Comminution**, International Journal of Mining Engineering, 1984, 2, pgs. 351-354

Preconditioning. Retrieved October 20, 2017, from <http://www.saimm.co.za/Journal/v100n01p007.pdf>

Preconditioning Photographs, supplied by J. van Zyl, Goldfields, 2018.

Silva, J.D., Amaya, J.G., and Basso, F. **Development of a predictive model of fragmentation using drilling and blasting data in open pit mining**. SAIMM Journal of the South African Institute of Mining and Metallurgy Volume 117 No. 11 November 2017, Johannesburg, pgs 1089-1094.

Stope Drill Rig. Retrieved February 20, 2018, from <http://www.hpesa.com/product-images/water-stope-walker.gif>

Stope Drill Rig. Retrieved February 20, 2018, from https://www.boartlongyear.com/wp-content/uploads/S36_Stopemate_SudBerry_Canada_NAM_6985.jpg

Tose, S.S.J., **Surface Blasting Handbook**, African Explosives Limited, 5th Edition, August 2004

Virtual Reality Wall. Retrieved December 18, 2017, from https://www.miningreview.com/magazine_articles/virtual-technology-training-delivers-best-blasting-practices/

Methods to improve the Drill and Blast Cycle in Conventional Narrow Tabular Orebodies in South African Mines:



A Reference Guide

MINERALS COUNCIL SOUTH AFRICA

I commit to

SAFETY AND HEALTH FIRST,

ALWAYS AND EVERY DAY

#ZEROHARM
www.safetyandhealthinmining.co.za

A poster with a red background. At the top right is the Minerals Council South Africa logo. The text reads: 'I commit to SAFETY AND HEALTH FIRST, ALWAYS AND EVERY DAY'. At the bottom left is the #ZEROHARM hashtag and the website URL. A pixelated graphic is in the bottom right corner.

MINERALS COUNCIL SOUTH AFRICA

We pledged our commitment to the target of

ZERO HARM,

and that **EVERY MINERWORKER** shall return from work **UNHARMED, EVERY DAY**

#ZEROHARM
www.safetyandhealthinmining.co.za

A poster with a blue background. At the top right is the Minerals Council South Africa logo. The text reads: 'We pledged our commitment to the target of ZERO HARM, and that EVERY MINERWORKER shall return from work UNHARMED, EVERY DAY'. At the bottom left is the #ZEROHARM hashtag and the website URL. A pixelated graphic is in the bottom right corner.

MINERALS COUNCIL SOUTH AFRICA

SHOW US YOUR YOUR

National Day of **SAFETY & HEALTH** in Mining 2018

COMMITMENT

by sharing a photograph on The Minerals Council's Facebook Page

@Mine

#ZEROHARM
www.safetyandhealthinmining.co.za

A poster with a yellow background. At the top right is the Minerals Council South Africa logo. The text reads: 'SHOW US YOUR YOUR', 'National Day of SAFETY & HEALTH in Mining 2018', 'COMMITMENT by sharing a photograph on The Minerals Council's Facebook Page', and '@Mine'. There is a ribbon icon and a #ZEROHARM hashtag with website URL at the bottom left. A pixelated graphic is in the bottom right corner.

MINERALS COUNCIL SOUTH AFRICA

We will treat everyone with

CARE, DIGNITY AND RESPECT

#ZEROHARM
www.safetyandhealthinmining.co.za

A poster with a green background. At the top right is the Minerals Council South Africa logo. The text reads: 'We will treat everyone with CARE, DIGNITY AND RESPECT'. At the bottom left is the #ZEROHARM hashtag and the website URL. A pixelated graphic is in the bottom right corner.

