Value added blasting

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Synopsis

Value added blasting is a process methodology that links tasks and processes, with the aim to improve/enhance the technical application of explosives technology and initiating systems, resulting in improved output.

The phases and steps of a typical value added blasting intervention are discussed in this paper. Each step having distinct purposes, principles and methodology. The underlying philosophies and process steps of the programme are described for each step.

This paper gives an account of projects that have been completed in two Anglo American Gold Mines. This will include a description of the projects that were conducted at Vaal Reefs 8 Shaft and Western Deep Levels South Mine covering:

- **The need for blasting improvements**
- **The approach that was followed**
- **The result of the programme.**

The key elements of the methodology

- To deliver higher stoping and tunnelling performance.
- Improved sustainable performance, (Quality Blasting Culture).
- An integrated system of measurement.
- Improvement of both efficiencies and effectiveness.

The flow of the process is centred on the model shown in Figure 1.

Blast performance assessment—analysis phase

Purpose

To analyse the blasting performance of a selected operation, so as to identify and quantify the window of opportunities that create key leverage areas within that specific blasting operation.

Principle

The scope of the assessment includes:

- Historical performances
- Current mining and blasting activities
- Explosives product related performance
- 'Up and Downstream' activities that impact on the blasting operations
- Cause and effect relationships within the operations.

Methodology

A specialized team will proceed underground for approximately three weeks with specially designed data capturing mechanisms to quantify the following criteria:

Marking practices

- Actual versus standard
- Marking patterns
- Marked burdens
- Direction lines
- Marking knowledge of the supervisor.

Principle

To capture the skills knowledge and capacity of the operators when marking off. What tactics do they adopt when confronted with a blasting problem, e.g. undercutting, protection of a fragile hangingwall and reduction of stoping width?

Drilling practices

- Drilling on marked hole
- Dip of drilling
- Angle of drilling
- Drilled burdens
- Toe burdens
- Hole diameters.

Principle

The principle aim of the measurement of these indicators will be to establish the framework in which the operation, (stope or tunnel) is being blasted and the subsequent blasting results.

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Table I

Typical marking off practices (cause and effect)

Cause	Result effect
Wide marked burdens, (90 cm)	Drilled holes not conducive to achieve a quality blast
Incorrect direction lines	Large toe burdens resulting in no proper free face creation that results in damage in the surrounding rock
Different marking patterns, e.g. box versus staggered	Operators not adopting the correct pattern to suit the situation and ground conditions resulting in a dysfunctional blast

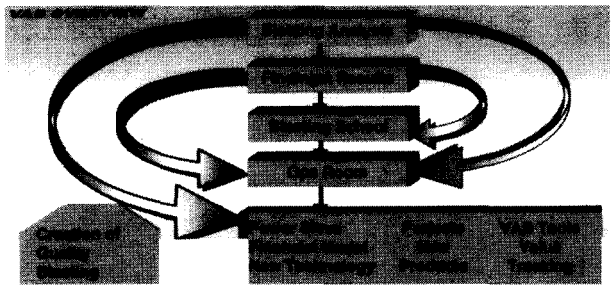


Figure 1

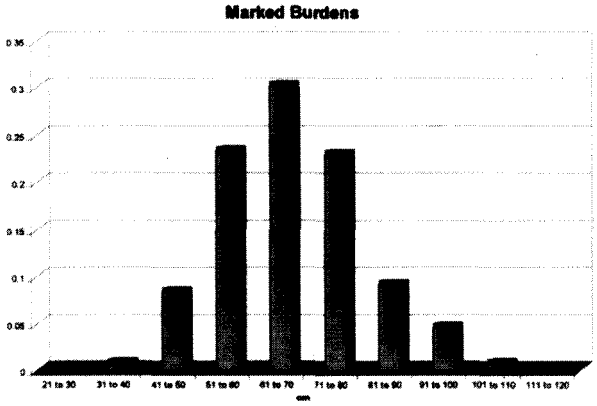


Figure 2

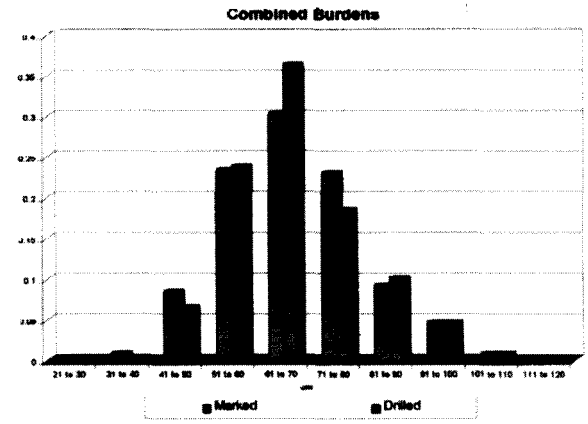


Figure 3

Table II

Typical drilling practices (cause and effect)

Cause	Result effect
Incorrect dip	Bump in face, footwall lifting
Incorrect angle	Bump in the face, hanging-wall damage
Excessive burden	Blow outs, long sockets, loss of advance, no free face, FOG
Short holes	Loss of advance, night shift, cleaning constraints
Long holes	Overburdened blast hole, surrounding rock damage

The predominant scenario that manifests, is the misalignment between actual work behaviour and the understanding of the consequences, of that incorrect work behaviour, e.g. if the toe burdens are drilled at 1,2 m apart, what is the effect on the surrounding rock and the influence of that blasting result on the underground excavation?

Charging up

- Kg/m3 powder factor
- Uncharged length
- Position of primer
- Interconnecting spaces.

Blast performance assessment—behavioural analysis phase

The underlying behavioural processes and philosophy that directs the focus is the following:

Individuals and teams who are aware of the causes and effects of their work practices, and who are conscious of the downstream consequences of these effects, will be more motivated and will perform more effectively.

Introduction

To be effective, stope teams must have:

- The required skills and knowledge
- The opportunity to achieve their targets with the required infrastructure, materials, equipment and resources
- Positive attitudes, perceptions and motivation.

During this diagnostic phase several techniques are applied to evaluate these key human behavioural factors which directly impact upon the actual blasting performance of stope teams. These include:

- Understanding of cause, effect and consequences
- Attitude and perceptions
- Alignment and motivation
- Work behaviours
- The value added by supervision.

The conclusions drawn from these evaluations provide the basis for the design and customization of the training syllabus for the mine.

Understanding of cause and effect

Purpose

To determine the level of knowledge, awareness or

Table III

Typical charging practices (cause and effect)

Cause	Result effect
Incorrect spacing of igniter cord	Out-of-sequence firing
Incorrect priming practice	Inconsistent run-up velocity of detonation of column charge
Overcharging, (ideal and narrow ree stope=powder fact 2,0 to 2,5kg per m³	Typical overcharging powder factors of 3,5 to 5 kg per m³ causing severe damage to excavation

understanding among the different categories of stope workers and their supervisors, of:

- The causes of non-standard conditions attributed to marking, drilling or charging problems
- The effects or consequences of non-standard marking, drilling or charging.

Principle

Individuals and stope crews with a sound understanding of how non-standard work can affect downstream activities and outcomes are more likely to correct their work practices, provided that they have the skill to do so and are motivated to improve their work performance.

Method and approach

Surveys are conducted with a representative sample of stope teams in small groups of each job category. Each group is presented with a series of questions relating to marking, drilling and charging. They are given multiple choice answers to select from. The responses are recorded. The results are graphed and conclusions are drawn about the level of understanding of cause and effect.

Alignment surveys

Purpose

To evaluate the level of common understanding and purpose among stope team members and their supervision regarding their priorities or focus required to improve the quality of blasting in their stopes.

Principle

The hypothesis is that work teams that have a common understanding of the causes and effects of blasting problems and are aligned in terms of what needs to be done to improve their performance, will be more successful than those that are not aligned.

Method and approach

- A sample of stope teams, their miners and shift bosses are surveyed in small groups or individually.
  The group or individual is asked to consider the specific panel or stoping contract in which the stope team works. The analyst shows them fifteen flash cards in random order, describing each flash card. They are asked to arrange the cards in rank order of importance according to priority to improve their blast-related problems.
  The ranking order is recorded and graphed for each group of each stope team as shown in the example (Figure 5). The graphs of each stope team and their supervision are compared and conclusions may be drawn of the degree of alignment or misalignment within each team.
  The flash cards are descriptive with pictures and text. The following fifteen activities which impact on blast quality and blast frequency are most frequently used:
  i. Create a free breaking face.
  ii. Mark the face correctly with proper burdens, grid and direction lines using a 'komba stick' if necessary.
  iii. Drill holes on the mark ensuring full-length holes using correct length and gauge of drill steel.
  iv. Drill holes on direction lines at the standard angle.
  v. Drill top and bottom holes at correct angles towards the hangingwall and footwall.
  vi. Charge each hole with the correct amount of explosives.
  vii. Connect the charged face right pattern, from hole to hole, ensuring correct sequence and inter-connector spacing for proper sequential firing.
  viii. Ensure proper blast containment using effective barricading.
  ix. Good preparation for night shift, ensuring effective rigging and scraping systems.
  x. Move winches closer to the face and/or shorten the pulling distances to tips.
  xi. Improve the condition of gullies, tips and travelling ways for more effective movement of men, materials and ore.
  xii. Move air and water pipes closer to the face.
  xiii. Move mono ropes forward reducing manual handling.
  xiv. Improve the transport and delivery of materials and equipment to the stope and improve the removal of rock and ore from the stope tips to the shaft ore pass.
  xv. Ensure that the stope team does not run short of essential materials and equipment.

The following Figures show the contrasting perceptions of two groups within the same stope team indicating considerable misalignment.

Perception survey—ability, motivation and opportunity

Purpose

To evaluate stope teams and their supervision in terms of their perceptions of the ability, motivation and opportunity of the team to achieve a quality blast at optimum frequency.

Principle

Perceptions are reality for the person or group holding such perceptions. To achieve more frequent quality blasting, stope teams must have the necessary ability, motivation and opportunity.

- *Ability*
  Individuals and stope teams must have all the knowledge and skills to perform effectively.

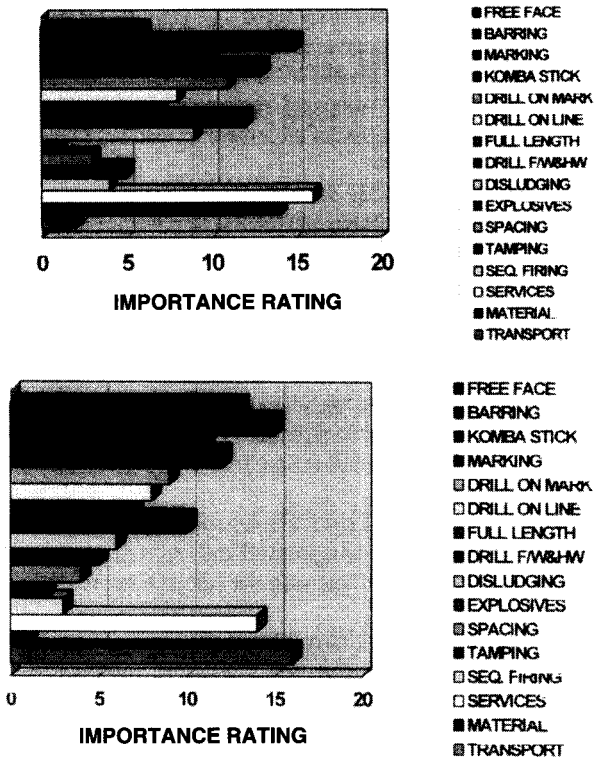


Figure 5

- *Motivation*
  In addition to being able to perform effectively, individuals and stope teams must be willing to perform at optimum levels.
- *Opportunity*
  Individuals and stope teams that have the opportunity to perform optimally have the necessary:
  - resources (labour, materials and equipment)
  - infrastructure (mine design and layout, technology and specialist or support services)
  - capacity (cleaning, tipping, tramming and transportation).

There should not be limitations that are beyond the direct control of the team.

Method and approach

The survey is conducted with a representative sample of all the job categories of stope teams, including the supervision levels.

Each survey participant is given a response sheet with fifty-five questions. Each participant responds to each question in the appropriate block with a 'yes', 'no', or 'uncertain' tick.

The responses of an entire M/O section are processed and represented graphically for each job category as shown in the example (Figure 6), which would represent the perceptions of a group such as drillers.

Evaluation of the value added by supervision to blasting

Purpose

To determine the effectiveness of the role played by the miner, night shift cleaner, team leader and shift boss in the promoting blast quality.

Principle

Supervisors have an important role to play in ensuring that stope teams work to standard, have the skills and are motivated to perform effectively.

Method and approach

The supervisor is accompanied throughout the shift by the evaluator. The time spent on activities is carefully recorded and tallied into categories of supervisory behaviours.

An evaluation sheet and timing device is used. All activity is recorded against time and the total time equates to a full shift.

Categories of supervisory activity

These are varied according to the need. The following are most commonly used.

- *Active value-adding supervision*
  The supervisor engages actively with subordinates on work performance related activity and gives instructions that clearly have, or will have, a positive impact on quality of work.
- *Active non-value-adding supervision*
  The supervisor engages actively with subordinates on work performance related activity and gives instructions but this does not have a positive effect on quality of work, either because of his style, lack of legitimacy or because he gives incorrect or inappropriate instructions.
- *Effective on-the-job training or coaching*
  The supervisor corrects work practices in such a way that work behaviour will be positively influenced and knowledge will be transferred.
- *Ineffective on-the-job training or coaching*
  The supervisor corrects work practices but does not positively influence work behaviour because of his style or approach, his lack of legitimacy, or because he gives incorrect training or coaching.
- *Effective passive supervision*
  The supervisor observes or watches people working but makes no attempt to engage them or to intervene or give instructions because they are working to standard.
- *Ineffective passive supervision*
  The supervisor observes or watches people working and makes no attempt to intervene or give instructions even if they are not working to standard.
- *Inspection*
  The supervisor inspects work that has been done.
- *Planning, administration or logistics*
  The supervisor is not supervising work but is engaged in other necessary activities.
  The evaluations are tabulated in such a way that the analysis may be graphed as shown in figure 7.
  This then is useful to illustrate the supervisory shortcomings particularly where one is able to show an ideal profile against the actual profile. It serves as a means for determining supervisory training needs.

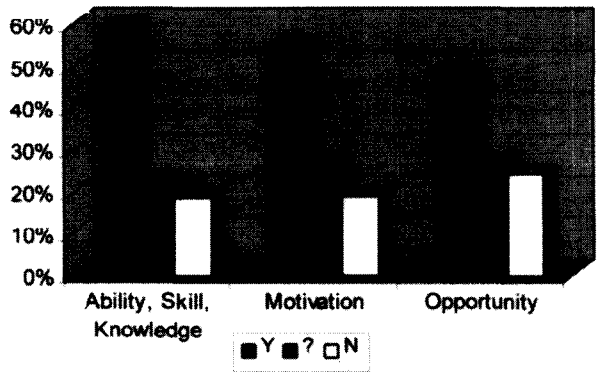


Figure 6

Stoping cycle analysis and the impact on blast quality

Purpose

The purpose of this analysis is:

- To evaluate the effectiveness of the shift activity planning of the miner and the team leader
- To evaluate the control over the achievement of the plan by the supervision and the team members
- To evaluate how well the plan is communicated and understood by all members of the team
- To analyse the extent of the deviations from the plan for the shift and the reasons for them.

Method and Approach

The evaluator interviews the miner or team leader in the stope panel. The interview is structured on a document that lists all the key activities for the entire shift. The supervisor indicates the activities planned for the shift and estimates the time by which each activity will have to begin and end if the plan for the shift is to be successfully achieved. He is also asked to qualify the volume of work planned, such as the number of holes planned per driller, or the number of face metres to be blasted.

Once the estimate for all activities is recorded, the evaluator observes and records all actual start and finish times for all the activities and notes the reasons for late starts and for lost time in each activity. The causes and effects of deviations are analysed and considered for the training needs.

Analysis of findings and their interpretation

Table IV illustrates deviations from plan and shows the reason causing such deviations and the bar diagram gives a visual illustration of what actually happened against the plan.

Summary of blast performance assessment

The driving factors behind the establishment of the blasting practices framework is to get closer to the heart of the blasting problems. The data collected from an assessment will assist Management in the following areas:

- The use of new blasting technology can be assessed. If the basics are not in place the performance of the new technology is not maximized.
- Key blasting indicators associated with the improvement of production can be quantified and dealt with accordingly through effective training. Traditional blast-related training on mines has focused heavily on individual competencies, skills and standards. This served to reinforce the differentiation in roles and functions of the stoping job categories, which, together with separate bonus structures, counteracted efforts to promote effective teamwork.
  Teams were fragmented by the lack of a shared knowledge and understanding of the work practices and methods that would help them to achieve success as a cohesive team. Each member was trained to do his job but was not given an understanding of how his work behaviour could affect other jobs and the performance of the team as a whole. The perspective of cause, effect and consequences was excluded.
  Many mines have reduced the negative impact of job differentiation and specialized training by introducing multi-skilled or multi-tasked teams and by applying team bonus schemes. Individual team members are now more aware of the 'bigger picture' by being party to a wider range of stoping activities and are more in control over their own rewards.
  In the value added blasting programme, stope teams, both traditional and multi-tasked, are given an understanding of the dynamics involved in achieving better quality blasting and impacting on blast frequency as well.

Table IV

Analysis of survey findings

Activity	Cause for deviation from plan	Effect of deviation from plan
1. Crew waiting for timber	Mono-rope breakdown	Late installation of support
2. Drillers waiting for water, etc.	Burst water pipe	Drilling not completed

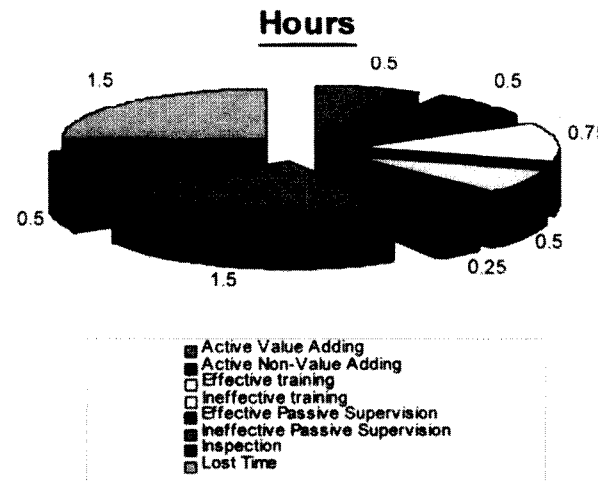


Figure 7

- Focused and directed activities can be mobilized to address the fundamental basics affecting the performance of any blasting operation.
- Supervisors can focus on a strategic business level while the grassroots workers can be empowered to carry out their own tactics to achieve a quality blast once the basics are rectified.

Blasting school

Purpose

The blasting school is the vehicle to create a sustainable mechanism to influence the hearts and minds of the grassroots worker in any blasting operation or activity through the use of skills-based experiential learning combined with understanding of cause, effect and consequences.

Principle

- The blasting school is fitted with large 3-dimensional models and tools to facilitate the understanding and mechanisms behind the science of blasting. The primary aim is to influence the culture or paradigm that has been created around the quality blasting criteria over many generations of miners.
- The blasting school is also the catalyst to ensure that a protracted change occurs in the stope face or tunnel and that the relevant behavioural adjustments are taken seriously by the operator.
- Stope teams can see, through the use of 3-dimensional cause and effect relationships, the relevant paradigm adjustments they must make to ensure a quality blast.
- The neutralization of problems being generated from poor blasting is communicated through tools and processes, to heighten the individual's awareness to

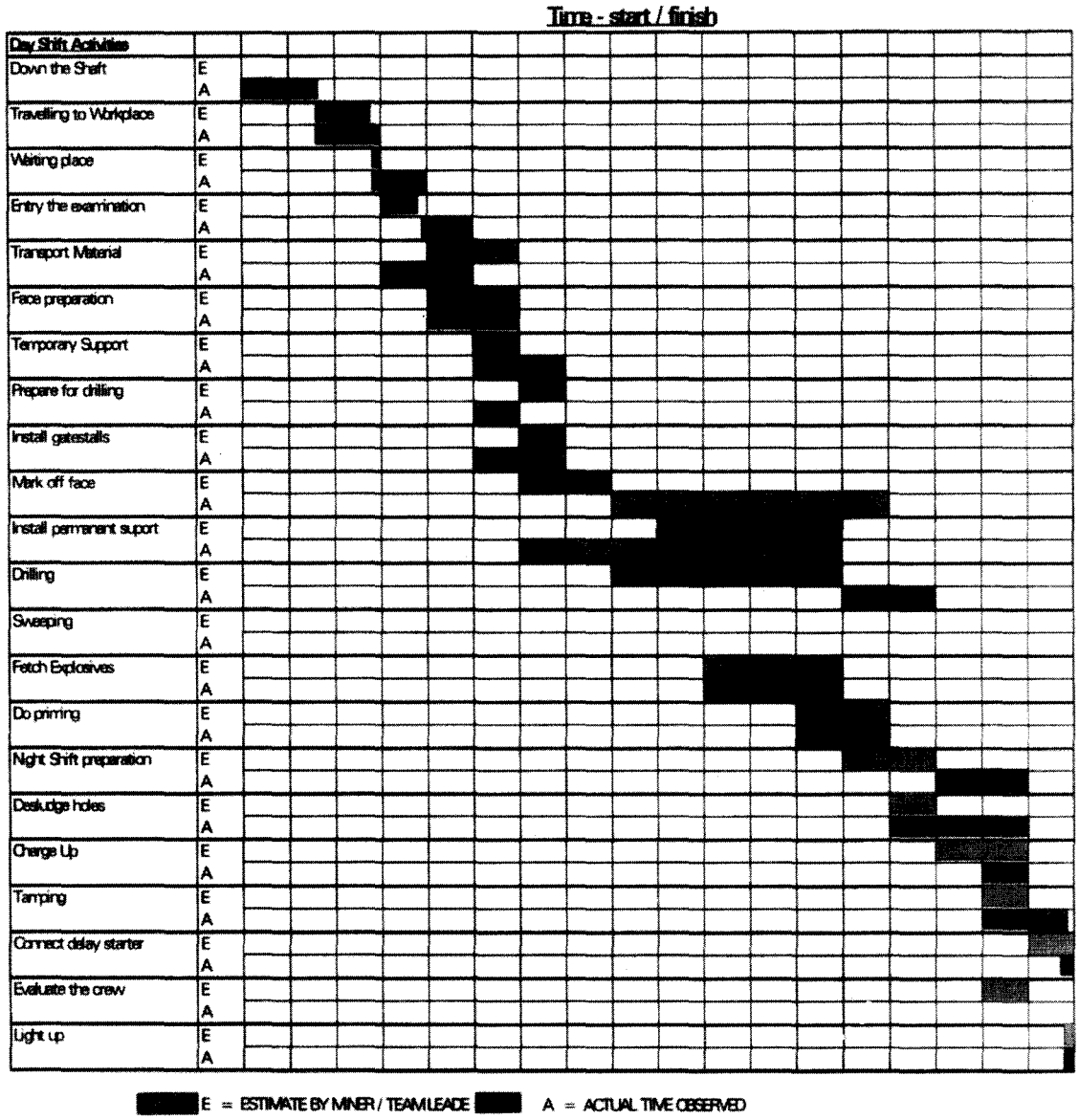


Figure 8

consequences of his poor work practices and the downsteam effects on tips, gullies, tramming, secondary blasting and ore processing.

Methodology

Correcting the blast-related problems normally involves the training of all levels and categories of employees involved in blasting operations. The focus is primarily on stope teams and their supervision where the approach is specifically geared towards mobilizing team energy towards improved blasting through the creation of awareness and understanding of the causes, effects and consequences of their work practices.

Pre-training visits are conducted to identify the actual problems of each team and customize the cause content accordingly. Post-training visits re-inforce the message back in the workplace with on-the-job follow-up and corrective action.

The training facilitators are mainly black and qualified with strong mining backgrounds, combined with specialist explosives and blasting knowledge. Change management experts guide the content and process of training delivery, and ensure the alignment of stakeholders for maximum buy-in and support for the programme at all levels. This contributes to the overall success of sustained improvements in blasting.

Entire crews, including their night shifts and supervisors are trained together as there is a strong emphasis on team building. The training syllabus incorporates business principles understanding which is linked to mine profitability and personal or group rewards.

A facility is permanently installed with models and tools to create an environment of learning and facilitation.

The models capture and illustrate the following dynamics:

- Proper creation of a free face
- Sequential firing and the importance thereof
- Surrounding rock damage and breakages, and the impact of such an occurrence to the holistic operation
- Basic rock mechanics and the dynamics involved when a hole of explosives detonates
- Rectification of blast-related problems and the relevant tactics that must be adopted when faced with:
  - Poor face shapes
  - Falls of ground
  - Proper gully/heading mining
  - Cause and effect of poor marking/drilling and charging up practices
  - Stope activity planning
  - Ratio trees illustrating business principles
- The incongruity between nightshift and dayshift is a dynamic that is exploited to create team synergy around achieving the common goal of a quality blast.

Process

- The intervention is not lecture based, but the method adopted is one of experiential learning through facilitation.
- The intervention is skills based, but with the appeal to all senses built in to the syllabus, for maximum experiential learning benefits.

Table V

Programme contents

A. Introduction

- Personal introductions
- AECI and their involvement
- Programme objective, process and 'house rules'
- Pre-test.

B. Creating the context

- Review of business concepts
  - Profit = Revenue-Cost (taxi business ratio tree)
  - What happens to profit
  - The concept of quality
  - Consequences of non-quality work
- The mine as a business
  - Mining ratio tree
  - Activities to get a quality blast
  - Realities regarding: Production, grade, cost and safety.

C. Quality blasting

- Breaking the ground—How it happens
  - Free face creation
  - Consequences of over burdens
  - Blasting induced damage
  - The standards and why we need them
  - 'Reality check' how are we doing?
- Corrective action
  - Analysing sockets
  - Correct marking
  - Undercutting
  - Fragmentation
  - Brows and faults
- The correct use of explosives
  - Products and their use
  - Sequential firing
  - Charging and connecting
  - Dealing with misfires
  - Secondary blasting

D. Commitment to make the changes

- Post-test
- Workplace communication
- Issues, concerns and next steps

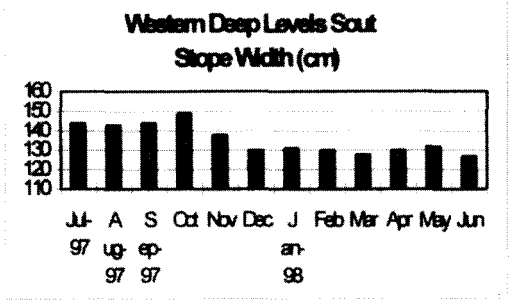
- Stakeholder alignment is the key criterion that must be met, with all Supervisors and groupings being aligned and energized to achieve the purpose of the intervention.

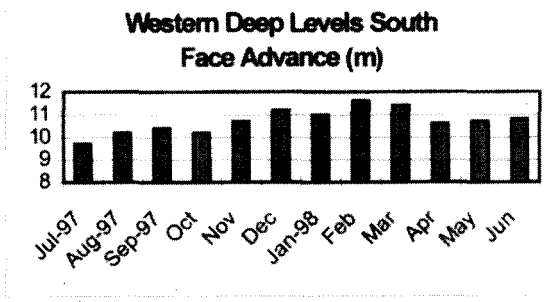
Syllabus

The training syllabus will differ for each mine according to the need. The programme outline (Table V) is a typical example.

Sustaining the change

- The sustaining of such an intervention calls for an interactive strategic partnership with the supplier. This creates an environment for 'value to be created together' through the sharing of knowledge and expertise





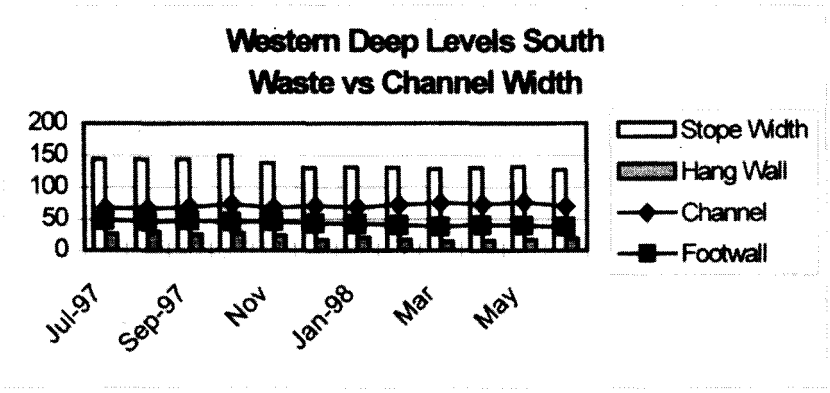


Figure 9

- Ownership and management of the process is a joint responsibility of the two parties to maximize the return on the investment. Ongoing audits and processes adjustments will ensure the process is sustained
- Improved blast quality must be sustained by those most directly involved in blasting operations. The coaching role of the supervisor is reinforced for the purpose
- Re-training and continued follow-up by mine personnel is made possible by the training of mine trainers as VAB facilitators.

Value added blasting projects at Vaal Reefs 8 Shaft and Western Deep Levels South Mine

The objectives and leverage points differ for each mine depending upon the needs and opportunities identified at the analysis stage. The success of each value added blasting project is therefore evaluated differently, according to the objectives and outcomes required. The approach and methodology required also is determined during the analysis and differs with each project.

Western Deep Levels South Mine

Analysis

An evaluation of blasting practices and the associated behavioural issues revealed that a reduction in stoping width and external waste could be achieved through improved work practices. This was also a key objective of the process re-engineering programme that was already in progress on the mine.

Project implementation

Suitable training facilitators were selected from available mine personnel and a blasting school was established and equipped with 3-dimensional models (fibreglass stope mock-ups) and supporting training aides. Facilitators were trained to conduct underground evaluations of stope team training needs, training of crews and post-training follow-up programmes. All stope crews on the mine were then systematically passed through the value added blasting programme.

Achievements

By the time that all crews had been trained the mine had achieved its process re-engineering objectives for reduced stoping width. External waste was reduced and face advance also improved as shown in Figure 9.

Vaal Reefs 8 Shaft

Analysis

It was concluded from the evaluation of leverage areas that considerable financial benefits could be achieved through better blasting practices.

Project implementation

A blasting school was established and an initial round of training was conducted with all crews on the mine. Following subsequent enhancements to the blasting school, a second round of training was conducted with all crews.

Achievements

Vaal Reefs 8 Shaft shows an impressive record of general improvement in production and financial performances over the past eighteen months. Mr John Fulcher and Mr Neville Nicalau have acknowledged the important role played by their blasting school in their achievements. ◆