A conceptual study into the implementation of a centralized blasting system at Samancor's Mooinooi Mine

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Synopsis

The utilization of centralized blasting systems is progressively becoming a feature of the South African mining industry, owing to increased pressure from the Department of Mineral Resources (DMR) to ensure safer blasting conditions. The purpose of a centralized blasting system (CBS) is to ensure reduced blasting-related incidents and to improve the underground working environment for the mine's employees. The brief from Samancor Western Chrome Mines (WCM) pertaining to this study was to explore—at a conceptual level–all variables pertaining to the implementation of the CBS. Studies have indicated that Sasol's SafeBlast™ was preferred due to low overall risks and user-friendliness. Empirical observations, however, indicated that attention should be given to the current shaft-clearing procedure and to the installation of additional transformers. This is required to co-ordinate the power supply from 2 level to 10 level with the required supply of the network slave station. A cost analysis indicated that an electronically initiated CBS will result in a R24 cost increase per panel, which relates to a mere 1% cost increase per panel. This cost, in addition to the R1.1 million capital cost, proved to be negligible in comparison to the possible direct and indirect costs incurred by the mine in the event of a blasting-related incident. It was found that Samancor should conduct further studies incorporating the necessary requirements to ensure a successful transition, while considering all stakeholders on the mine. This study proved that the transition to a CBS would ensure safe and efficient blasting at Samancor's Mooinooi Mine.

Keywords

centralized blasting systems, blasting systems, underground blasting systems, Samancor chrome, central blasting.

Introduction

Blasting at Samancor's Mooinooi chrome mine currently relies on drilling holes with pneumatic jackhammers. The blast holes are charged with Expanfo™, and blasted using a 60-minute stay-a-light delay starter combined with a shock tube and pyrotechnic detonator initiating system. This system is utilized to ensure, as far as possible, evacuation of the entire mine before blasting commences.

Risks other than unintentional initiation of a panel while people are still underground include dangerous gases emitted by the current blasting system. The delay timing of the stay-a-light starter is also influenced by the ventilation in the section, making the system unpredictable. The risks are increased by the difficulty in determining if there were any misfires.

Due to the risks of the current system, the Department of Mineral Resources (DMR) has increased pressure on the mining industry to comply with the Mine Health and Safety Act to promote and ensure safer blasting conditions. These rules force employers to ensure the safety of their employees.

The main provider of Samancor's blasting products is Sasol Nitro. With the implementation of Sasol's SafeBlast™ centralized blasting system (CBS), in conjunction with their SafeStart™ instantaneous electronic starter detonator, Samancor is striving to maintain an optimal safety and production record. The Sasol SafeBlast™ CBS had been successfully implemented on 80 mines throughout South Africa by June 2011.

By converting to a CBS, adherence to the regulations set out in the Mine Health and Safety Act (MHSA) is guaranteed if properly co-ordinated. The improved safety record guaranteed by the use of a CBS therefore emphasizes the necessity of this study.

A detailed conceptual study into a CBS should give Samancor the required information to motivate conversion to a CBS.

Problem statement

A detailed conceptual study needs to be conducted to motivate the conversion to a CBS at Samancor's Mooinooi mine, highlighting the advantages and mine-specific observations associated with the implementation of such a system.

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Objectives

- ➤ Conduct a literature study to illustrate available systems on the South African market, identify and define all components needed for the proper implementation of the SafeBlast™ CBS, and identify associated risks
- ➤ Revise the current shaft clearance procedure and power supply to operating levels
- ➤ Include an estimation to illustrate capital requirements for implementation of the CBS
- ➤ Conduct a feasibility study comparing the current blasting system to the proposed CBS
- ➤ Illustrate blasting management principles to ensure a smooth and successful conversion
- ➤ Make recommendations regarding the possible conversion to a CBS at Mooinooi.

Centralized blasting systems

Centralized blasting is progressively forming an integral part of safe, productive, and environmentally-conscious blasting in the South African mining industry. With the Western Chrome Mines (WCM) section of Samancor utilizing stay-a-light delay starters to initiate blasts, it has become clear that the transition to a cost-efficient and more technologically advanced system is critically important. Safe and efficient blasting forms an essential part of all operations at WCM. Some advantages of the implementation of the CBS at WCM include the following:

- ➤ Reduced risks associated with underground employees coming into contact with potentially harmful gases/fumes emitted by explosives
- ➤ Increased safety on the mine, as all panels can be initiated from a safe location once all personnel have been evacuated from the working places
- ➤ A reduced re-entry period after blasting has commenced, aiming to achieve a re-entry time of two hours compared to the three-hour delay currently practised
- ➤ Substantially fewer misfires resulting from the usage of electronic detonators. The computerized system will also allow for post-blast evaluations and pinpointing of possible problematic areas underground
- ➤ Improved control over seismicity.

The advantages and disadvantages of the current blasting system are summarized in Table I. The CBS is described by Laubscher (2009) as consisting of an electronic backbone which connects a central and safe monitoring and firing point to the mine's entire blasting area. It allows for two-way communication to take place in real time, with an electronic device initiating each blast by means of an electronic starter. The system compromises a blast controller on surface that monitors and reports all data and activities on a real-time system. A communications network down the shaft to each of the control boxes is placed at a safe distance from any blasting effects, but near enough to place the blast under the control of an authorized person. These control boxes then initiate the blast by supplying the correct voltage and coded signal to the initiators via a network of copper or fibre optic blasting cable.

CBS products are produced by major explosives companies and include the following:

- ➤ *AEL mining services*—QuickShot Network
- ➤ *Orica mining services*—i-kon™ CEBS
- ➤ *Sasol nitro*—SafeBlast™ CBS.

Sasol Nitro's SafeBlast™ CBS

The system to be implemented at Samancor's WCM is Sasol Nitro's SafeBlast™ CBS, which is accompanied by the utilization of a SafeStart™ instantaneous electronic starter detonator. This system was selected due to existing business relations between Sasol and Samancor. A detailed study was conducted to illustrate Sasol Nitro's SafeBlast™ CBS. The main system components of the are as follows (Figure 1):

1. The centralized computer running Mine Commander™
2. The network interface unit (NIU)
3. Fibre optic converters
4. The network slave station (NSS)
5. The panel connector unit (PCU), and,
6. The SafeStart™ instantaneous electronic detonator.

Current blasting system

The current blasting system at Samancor's WCM consists of shock tube connected to a pyrotechnic detonator on one end, which is inserted into the blast hole, and a stay-a-light delay at the other end, in close proximity to the face to be blasted.

Inherent safety offered by an electronic CBS

The overall safety of the SafeBlast™ CBS lies with the introduction of the SafeStart™ instantaneous electronic detonator, which greatly enhanced the reliability of detonation. Back-up detonators need not be used and the detonator is resistant to environmental hazards, unauthorized firing, and unplanned initiation, ensuring adherence to the requirements set out by Brinkman.

Table I

Advantages and disadvantages of the current blasting system

Advantages	Disadvantages
More affordable than the electronic initiating system	No definite control over exact detonation time due to inconsistent ventilation affecting the stay-a-light delays
Easy to use, minimal training required	Open flame required to start up the stay-a-light delay
No need for installation of additional equipment, hence no capital expenditure (CAPEX)	Without proper communication, there is the risk of people being in the panel without the person responsible for setting off the blast being aware of it
	Possibility of initiation by foreign elements

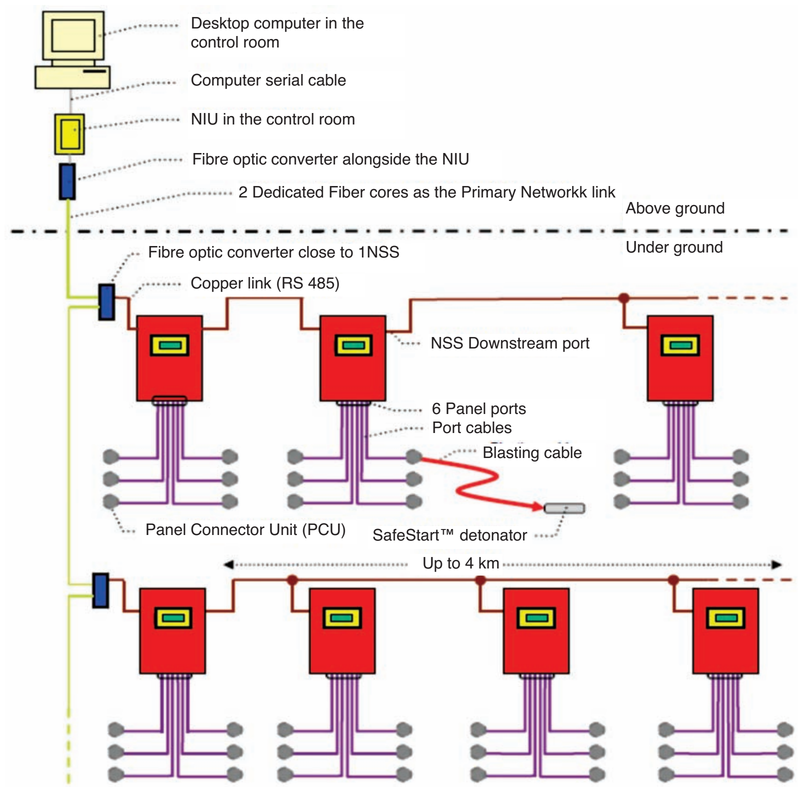

Figure 1—A schematic of the various components of the SafeStart^{TM} centralized blasting system (Sasol Nitro)

Laubscher (2009) further motivates the increased safety after implementation of a CBS, which can directly be related to the use of electronic detonators. Laubscher also states that with in-hole electronic delay detonators, blas occur within split seconds of each other, which initiates a significant energy release in a small window of time. Data recorded by various seismic centres indicate a significant improvement in the seismic footprint of a number of deep-level underground mines.

It should be noted, however, that seismicity in the western Bushveld Complex proved to be much lower than that typically experienced in the Witwatersrand Basin. This was found by Gay, *et al.*, (1995) to be so due to the shallower mining depths, typically less than 1 000 m, the use of closely spaced yielding or crush pillars, and high horizontal stresses. Significant variations in seismic character also exist between various platinum regions, as in the gold regions. Gay, *et al.* found that experience gained from the gold mines cannot be used in the Bushveld mines, as the geotechnical properties and stress regime differ considerably.

Currently, seismicity is not a major problem at Mooinooi, although greater mining depths may increase the magnitude of seismic events such as those experienced by some platinum mines in the region.

A benefit case study of the advantages and effects of using a CBS in a narrow reef mine, was conducted by AEL. Data collected over a 12-month period from geophones installed on the mine indicated a definite change in the pattern of seismic-related events in various sections of the mine.

Seismicity is not a problem at Mooinooi *per se,* but due to mining taking place at increasing depths it is a factor that should be taken into account. Figures 2 and 3 tabulate the results obtained in order to draw a comparison between seismicity before and after the transition to a CBS.

The results clearly show improved frequency control over seismicity in the mine after implementation of a CBS. From the data, the CBS implementation saw a reduction of seismic activity from an eight-hour to a four-hour-window.

Mine-specific observations

The MG1 and MG2 mining areas at Mooinooi are accessed by three decline shafts. The primary shaft is 300 m long; the sub-shaft, which acts as the main access point to 1 level through to 10 level, is 1 375 m long; and the third, which is currently being deepened, will extend to 16 level. With full implementation of the CBS, some concern arises when it comes to the effectiveness of the current shaft clearance procedure. Through observations made, it was found to be inadequate for the safe operating of the CBS. The CBS requires the person responsible for initiating the blast to be sure that the entire workforce is on surface before blasting can commence.

Currently, the system has limited control over people entering the underground workings as the newly-constructed MG2 material decline has no control point and can be accessed through a ventilation door. This negates the control the lamp room officer has pertaining to personnel control. The current control system also does not have any warning system to indicate if people are still underground. The mine is able to get this critical information only by having people clock in at the main shaft before going down the material decline. This unfortunately is not sufficient, as human error

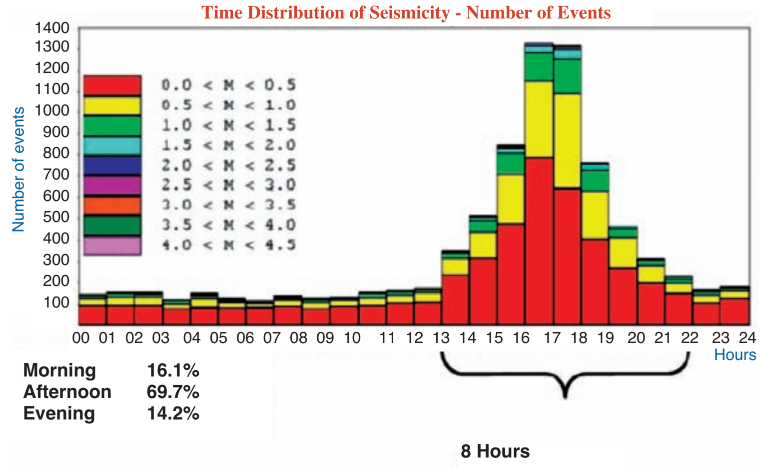

Figure 2—Seismic profile prior to CBS implementation (Goncalves, G., 4 August 2010)

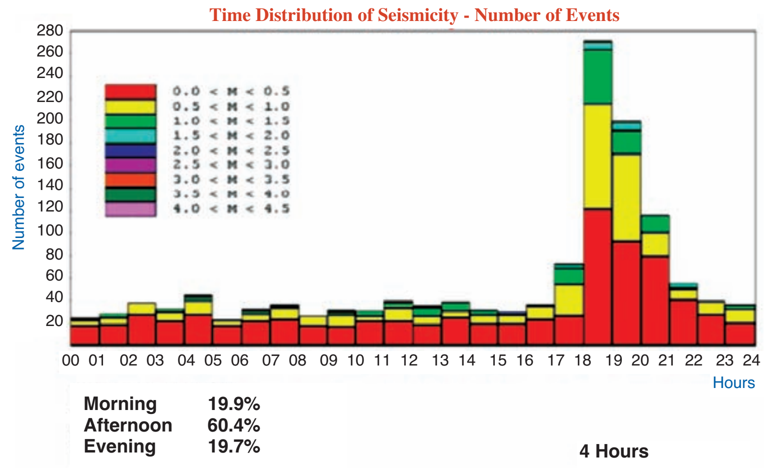

Figure 3—The recorded seismic profile post CBS implementation (Goncalves, G., 4 August 2010)

has a major impact on the reliability of the data, and failure could lead to serious injury or even multiple fatalities. It is therefore of the utmost importance to implement a new automated control system that is situated at each access point to the mine.

Further observations indicated that the mine has an electrical supply of 380 VAC from 2 level to 10 level and 525 VAC from 11 level to the newly-developed 13 level. This proved to be of concern as the CBS's network slave station (NSS) requires a 525 VAC. Installing an additional step-up transformer before each NSS unit will be required. This step-up process can be derived from the induction law, but is beyond the scope of this study.

System risk assessment

A mine-specific risk assessment to determine the possible dangers associated with the CBS installation will assist the mine to concentrate on areas of concern during training of the mine personnel. The risk assessment may highlight possible teething problems that could arise once production commences. This will give management the opportunity to prepare for any possible system errors, and to have a plan of action in place for when an error is encountered.

A risk assessment was performed by Sasol pertaining to the CBS to highlight possible risks that may occur and to confirm that the Sasol SafeBlast™ CBS is simple to use. The risk matrix in Table II illustrate the impact of an event compared to the frequency of occurrence. Values are assigned to determine the level of risk of each occurrence. A risk score of 36 denotes the highest or most significant risk, while a score of 1 denotes the lowest or least risk. These risks are then categorized into a simple ordered system as depicted in Table II.

The matrix is used as a reference to conduct a risk assessment on the CBS to indicate all areas that need to be carefully monitored. The risk assessment was conducted on the following components of the system:

- CBS installation
- CBS surface operations
- CBS underground operations
- Electrical hazards.

It should, however, be noted that these risk assessments were conducted by Sasol using data collected through various trial runs at a number of mines around the country. From the data collected, the risk assessments clearly showed in the risk indices (R) that there is only one risk that falls within the

Table II

Risk matrix quantifying each level of risk (Sasol Nitro)

Risk index	Category	Severity	Weekly	Monthly	Quarterly	Yearly	Yearly	Yearly
19 to 36	High	Frequency of event						
12 to 18	Medium		6	5	4	3	2	1
1 to 11	Low							
Degree of harm/loss								
Catastrophic or greater than R5 million		6	36	35	33	30	26	11
Multiple fatalities or R1–R5 million		5	34	32	29	25	18	9
Fatal or R0.5–R1 million		4	31	28	24	21	16	7
Serious injury or R100 000–R500 000		3	27	28	20	19	14	5
Lost time injury or R10 000–R100 000		2	22	17	15	13	12	3
Dressing case or R0–R10 000		1	10	8	6	4	2	1

Table III

Underground operating procedures (Sasol Nitro)

Miner locks the NSS prior to blast preparation correctly, as per mine procedure
Miner connects the SafeStart™ to the blasting cable after evacuation of hazardous zone, and before attachment of the initiation trunk line to the SafeStart™
Miner unlocks the NSS after completing blast preparation, and once the hazardous zone is clear, he enables the NSS to blast
Miner checks the status of SafeStart™ connections as displayed at each NSS

medium-risk category of 12–18. The remainder of the risks are all low-risk events. A risk other than the operational and system implementation risk shown in Table II, is that any delay in system implementation could lead to failure of compliance as stipulated by the DMR.

Tthe SafeBlast™ CBS is considered to be extremely safe provided that all of the following procedures are followed:

➤ Installation as per the installation manual
➤ Underground operations in accordance with all operating procedures as illustrated in Table III
➤ Associated electrical hazards taken into account
➤ Surface operations in accordance with all operating procedures as illustrated in Table IV.

Cost of installation

Mooinooi mine consists of a network of underground operations. These were identified individually in order to determine their relevance to the CBS installation. These results are illustrated in Table V, indicating the expected total cost of the CBS implementation at Mooinooi mine.

The R1.1 million capital expenditure required to install the SafeBlast™ CBS should not be viewed in isolation, and therefore a feasibility study was conducted. The feasibility study proved that a total blasting cost increase of less than 1% can be expected in comparison to the basic stay-a-light starter detonator system.

The increased operating cost was determined by assuming a total blasting cost of R3000 per panel; then calculating what cost effect the utilization of an electronic starter would have on the total blasting costs. From Table VI a cost increase of R24.00 per panel is expected, which relates to an overall blasting cost increase of 1%.

The minimal increase in operating cost combined with the capital expenditure is completely justified by the improved safety and peace of mind guaranteed by the CBS. Squelch (2001) showed that in 1994 the average cost of compensation paid in the event of a fatality was R462 782.00. Since then, emphasis has been put on increasing safety in the mining industry, therefore this amount has increased exponentially to pressure the mining industry to put preventative measures in place. This figure has inflated to over R2 million per fatality, which justifies the CBS capital outlay.

Table IV

Surface operating procedures (Sasol Nitro)

Control room operator ARMS the blast once the shaft is cleared
Control room operator primes the blast
Control room operator fires the blast

Table V

Software and hardware unit requirements and total cost (Samancor, 2010)

Item	CBS component	Number of units
1	Mine Commander™	1
2	Network interface unit	2
3	Network slave station 525 Vac	23
4	Network slave unit	2
5	Panel connector unit	138
6	Blasting cable tester	46
7	NSU verification jig	1
Software and hardware costs		R706 295.00
Installation costs		R391 497.00
Total cost of CBS		R1 097792.00

Table VI

Starter detonator base price (Sasol Nitro)

Starter detonator base price	
Stay-a-light	R4.28 per starter
Electronic starter pack	R28.00 per starter
Increase	R24.00 per panel

Direct costs such as compensation will be minimal when compared with indirect losses incurred by the mine if issued with a Section 54. While investigation into a blasting related incident is continuing, production on the mine may be brought to a halt for up to 4 days, resulting in revenue losses for the mine. By preventing one such an incident the CBS justifies its expenses.

Management principle

The final, and probably the most important, factor to be taken into account is the blasting management process. Converting to a CBS requires detailed consultation with all stakeholders, at managerial and workforce level. A structured conversion plan must be drawn up to introduce the system to all stakeholders according to Stander, Solomon, and Macnulty (2008). They headed a detailed process of a similar large scale system conversion at the Anglo American Platinum mines and designed roll-out plans for the mine. These plans included the following and should be given close attention, in order to apply similar principles at Mooinooi mine and ensure a smooth and successful conversion.

- Mine site—Human resources training department, SHEQ management, and production departments. The Anglo mines were required to complete a pre-launch orientation of management and workers with respect to the CBS system transition
- Head office—Supply chain; human resources training; safety and health department
- Members of the group project team
- Change management specialist to co-ordinate the transition
- Conversion specialist to embrace collaboration with mine management and direct involvement in the implementation process underground
- Legislative compliance.

In conjunction with these roll-out plans, monitoring programmes are required to ensure feedback on the new system. This will assist management to conduct ongoing assessments and control checks to ensure maximum benefit of the system.

Conclusion

All components of the SafeBlast™ CBS were analysed and assessed. The findings indicated that the system complies with Samancor WCM's safety requirements and meets legislative requirements set out by the DMR.

The current shaft-clearance system was found to be inadequate to cater for safe implementation of the CBS. The MG2 material decline shaft provides entry for employees to the mine without any form of access control data. It is of utmost importance that all employees are on surface before blasting can commence.

The power supply from 2 level to 10 level proved to be below the required voltage of the SafeBlast™'s NSS unit.

A risk assessment conducted by Sasol Nitro showed that the SafeBlast™ CBS is extremely safe and showed only one medium risk, further justifying the CBS implementation at Samancor WCM. A mine-specific risk assessment will be required to highlight issues in association with the mine's clearing procedure. An assessment will highlight issues such as the inadequate shaft-clearance procedures and power-supply problems from 2 level to 10 level.

Additional costs, other than the R1.1 million capital expenditure required to implement the system, will include a minimal blasting cost increase of less than 1% per panel. This is negligible when related to the possible direct and indirect costs incurred by the mine in the event of a blasting-related incident.

The most important factor to be taken into account is the managerial processes pertaining to all the stakeholders involved. A structured system will be required to control the CBS conversion and post-conversion assessments.

Recommendations

- Intensive training conducted by Sasol Nitro should be undertaken by all employees that will be working with the SafeBlast™ CBS. This will ensure that all system operators are equipped with the required tools to operate the SafeBlast™ CBS safely and efficiently
- A fully-automated control system should be implemented at all access points to the mine to ensure sufficient control
- Step-up transformers should be installed together with the NSS units
- A mine-specific risk assessment should be conducted to identify possible site-specific problems pertaining to a CBS conversion
- Mechanical installation should be conducted and overseen as per the Sasol Nitro installation procedures.

Further work

- This study was conducted only at Samancor WCM's Mooinooi division, and further detailed studies should be conducted at the other mine shafts to identify problems that are specific to each division
- The shift cycles must be co-ordinated to ensure that the critical re-entry time is kept to a minimum while complying with the laws set out by the DMR
- A study should be concluded after the CBS installation and commissioning to illustrate the benefits of the system and potential long term cost savings
- Consider the practicality of using a one-time PIN system to further improve the inherent safety of the CBS, placing the manager in control of the entire blasting system.

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