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The Latest Generation of the Electronic System enhanced Safety and Productivity

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Abstract

Digital blasting systems represent a new, enabling step forward in mining process optimization, providing the mining industry with different ways to improve operational efficiency or even to develop new extraction methods. The new features of the systems also reinforce both the security and the safety of the blasting process. At this point in time; the second decade of the commercial use of electronic detonators, we introduce the fourth generation system; DTSP. As the need for efficiency increases in the mining and construction industry operations, Davey Bickford has adapted its technology to meet this demand. As the use of the system is taken up by many companies, the achievable benefits are more extensively monitored and accepted in many blasting operations. Two principal points are explained in this paper. Firstly; new system features such as RFID, GPS, multiblasting, synchroblasting, remote blasting through wireless networks, etc. are explained. Secondly a number of case studies are used to demonstrate the value added by these technologies, for the mining operations. These case studies include a large open cast mine in North America as well as a number of surface quarries where electronic initiation has been adopted for specific reasons, including safety, environmental compliance, productivity, and economic concerns. The current initiation techniques are described, as are the Key Performance Indicators used in the quantification of benefits and justification process. While emphasis is placed on the opportunities that the technology offers, constant consideration is always given to the practical aspects of the blasting process, which will ultimately drive the success or failure of this program.

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1. Introduction

In this digital age, the explosives industry is experiencing a smooth transition from traditional pyrotechnic delay initiation system to high tech pyrotechnical initiation system. However, the evolution has been initially slowed by the perceived higher costs and the relative complexities of the emerging system. But now, many operators found that the new systems provide the opportunity to reconsider many old practices and have demonstrated that the productivity and safety benefits achieved far outweigh the end user total cost.

The digital technologies provide the user with enhanced safety, security and ease of use, together with "operational" benefits such as reduced vibration, better fragmentation and muck pile distribution, leading to higher productivity and lower mining costs.

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The electronic technologies provide four basic features: operational safety/security, detonation reliability, accurate timing and the use of a very short delay period, of up to 1ms. The last two points lead a rational improvement in the quality and efficiency of the blasting. In fact, the concept "accurate timing" maximizes the use of available energy and ensures the proper displacement of the muckpile. The possibility to implement very short delay periods permits the interaction of waves between boreholes, and so increases blast effectiveness.

Today's blasters have panels of electronic blasting systems available to choose from. Each of the existing systems has unique characteristics and functional capabilities which distinguish them from their counterparts. Rather, the conventional electric or non-electric detonators designs differ very little from one manufacturer to the other in many respects. With conventional systems, when it comes to the testers or shooters, technologies involved are fairly "standard", allowing shooting boxes or initiators to fire products from any manufacturer.

This study presents the features of new electronic system developed by Davey Bickford and presents two case studies showing how the electronic system can improve the mining operations.

2. New Technologies for enhanced Safety and Security

Even if all existing Electronic Blasting Systems are complying with International Safety Standards and they have the same fundamentals components as the "digital timing", they still different in their architecture in particularly the way how the safety constraints have been approached in their design.

Beginning with their product development, manufacturers have chosen different fundamental principles for addressing safety issues: one or two capacitor design for the detonator electronic chip, different connector and inherent safety are examples of such basic principles (Figure 1).

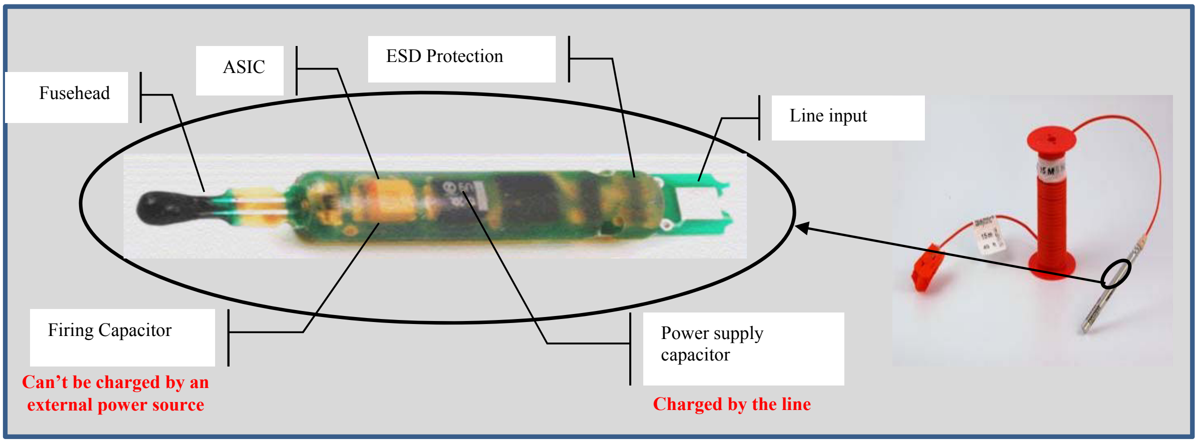

Fig. 1: Davey Bickford electronic detonator

The safety concept of Davey Bickford was to separate the communication circuits from the firing circuits in the detonators using 2 capacitors. The first capacitor will be used only for the communication such as reading the ID and the second for the firing in order to better insulate the latter from external stimuli. In addition to the built-in safety characteristics of the detonators, inherent safety consists in making it physically impossible for the on-bench tester to prematurely detonate a detonator, both by hardware and software limitations. This is generally achieved by limiting voltage and/or current output of on-bench testers. Here again, manufacturers solutions for limiting the consequence of this "power" limitation over the testers performance in terms of the number of detonators that can be tested simultaneously, differ significantly from one system to another.

All of the electronic detonator circuits are protected from external electrical aggression, thanks to passive components such as resistors or transient voltage suppression diodes. In addition to that minimum basic protection, Davey Bickford developed a sophisticate mechanism involving active components, called "smart shunts" for protecting the fusehead until final firing time (Figure 2).

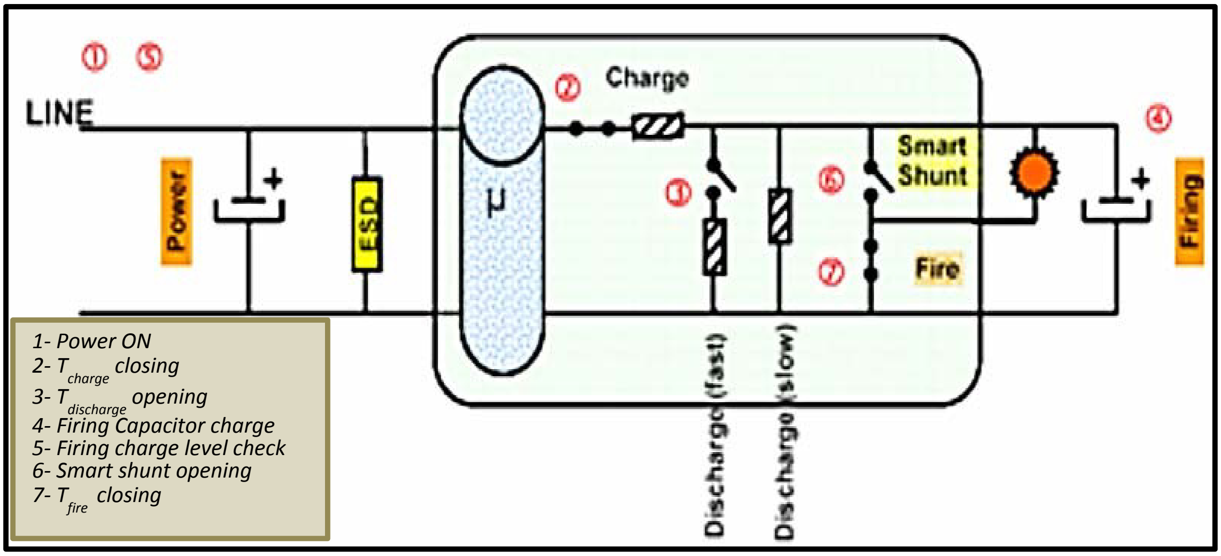

Fig. 2: Davey Bickford safety concept: 7 steps before detonation

These different approaches and proposed solutions resulted in various safety designs released on the market as well as real differences in product sensitivity against external disturbances (ESD, EMI, and Lightning) that can also be observed on the field. That being said, the user must still observe standard precautions and avoid all such hazards, and it is always useful to remind the user that lightning is a threat to any blasting operation, regardless of the initiation system in use.

The electronic detonators can be traced due to the unique identifier embedded into the silicon chip. Anticipated regulations known under the "Track and Trace" standards may improve the traceability of explosives by adding a label/bar code/data matrix on each single detonator, explosive cartridge or piece of detonating cord, but nothing could be more reliable than a permanent tracer programmed into the chip like the unique ID code of each electronic detonator.

3. New Technologies for New Performance

The explosives industries don't have the same needs. For example, a quarry which would fire fifty holes each week will not have the same requirements as a large mining operation which might daily detonate five to ten blasts totaling over 2500 holes within a 20 minutes window between shifts. This way, the manufactures propose different equipment with different features which correspond to each operation. Consequently and to answer to the customer's requests, we observe recently the integration of high technology in initiation equipment, such as the wireless technology. But here again, there are notable differences between the available systems.

Wireless remote firing capability is one of the most new features improving the safety as well as the productivity. This technology, eventually combined with "repeater" devices, not only extends the distance between the actual firing location and the blast area, but also allows parallel firing procedures of several blasts from the same firing point at the same time. Recent developments such as the multi-blast feature, consisting of parallelizing several firing procedures and thus simultaneously remotely controlling several blasts, have been very well received in the mining industry, significantly reducing the time the mine is idle during blasting operations.

To challenge the size of the blast using conventional non-electrical detonators which is theoretically infinite, the manufacture propose to the market to multiply the number of remote controlled firing boxes. Here again, blast synchronization technologies vary from one manufacturer to the next.

The electronic blasting equipment offer to the engineer the possibility to design the blast as he want not as the equipment allow it. The critical feature is not only programming the detonators at the desired timing but also on the transfer of blasting information to and from various system components. This feature is not only for transferring blast plans from bench programmers to firing units but also for downloading/uploading history files or software upgrades. Various solutions are proposed, from no transfer at all to total wireless data transfer with either Infra-red or RFID technology, a USB port, or cables.

RFID provides several advantages in addition to its wireless performance. Since an RFID tag doesn't require embedded energy to be read, it has recently been implemented for exchanging data between system components, whereas the transfer is achievable even if the equipment is accidentally damaged or if the batteries become depleted. An RFID tag can also be used as a "security key" for controlling unauthorized access to the firing procedure.

The integration of Global Positioning Systems (GPS) technology into the blast design process is now becoming more widely accepted. The ability to import “as drilled” or “as designed” hole coordinates via drill navigation or stand-alone real time GPS into blast design software, allows the engineer to create a very accurate 2-dimensional layout of the blast. For critical blasting applications, the new Photogrammic technique or laser profiles can be merged with borehole path data to create extremely accurate 3-dimensional blast design models. This gives unprecedented control over the design and final execution of the blast.

GPS, Photogrammic and Laser Profiling are also being used to help measure and quantify blast results. These and other emerging technologies are now being implemented on a daily basis in many of the more advanced blasting operations. The following brief case studies are examples of how science and blasters’ intuition successfully converge with technology to help produce safer and more efficient operations.

4. Case Study #1 Conversion from Two-Pass Overburden Removal to Cast Blasting at Simplot Phosphates

In this part, we will bring the work of Cassidy McAllister and al.. We will explain the opportunity give it to the Simplot Phosphates mine to attempt a cast of 44% .

4.1 The past

Simplot Phosphates produces high quality phosphate fertilizer through open pit mining. The operation near Vernal, UT began as a three-pass mining process carried out with drill and blast followed by the combined effort of shovel-truck and dozer material removal. Due to the three distinct geologic formations present, the original mining operation was accomplished in three passes: 1) 21.4 m (70 ft) high cover bench, 2) 12.2 m (40 ft) low cover bench and 3) phosphate ore, as shown in Figures 3 and 4. Each mining pass included drill and blast followed by truck and shovel removal of overburden waste. The first two passes removed the overburden and the final pass mined the relatively hard phosphate ore for processing at the mill. Vertical blastholes were employed in all of the mining passes.

The Vernal operation operated for many years with pit widths averaging 100.65 m (330 ft) wide with and overall cast-to-final (overburden placed by explosives in its final location) that was order of ~7% of the total overburden moved annually. Some single blast attempt a cast of 15% cast, this way the engineer recognized the potential benefits of casting and began studying the possibility to implement the process.

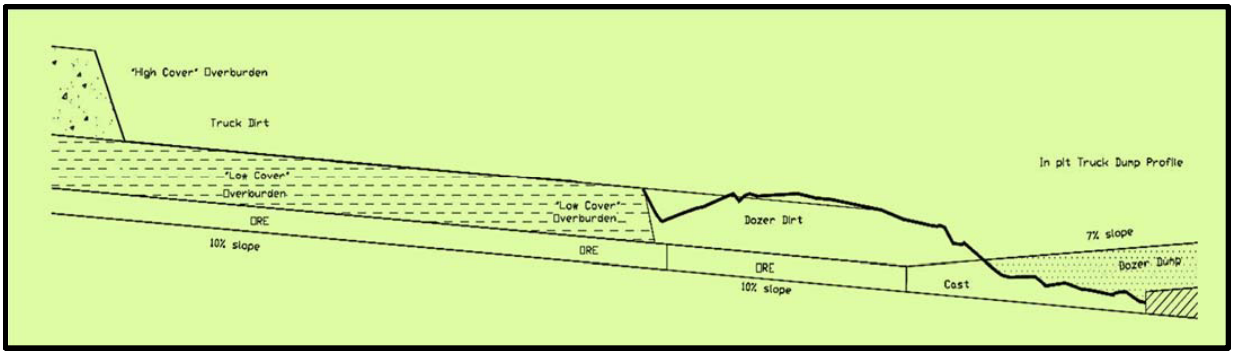

Fig.3: Typical Cross section of 3 pass mining sequence (Mc Allister and al., 2012)

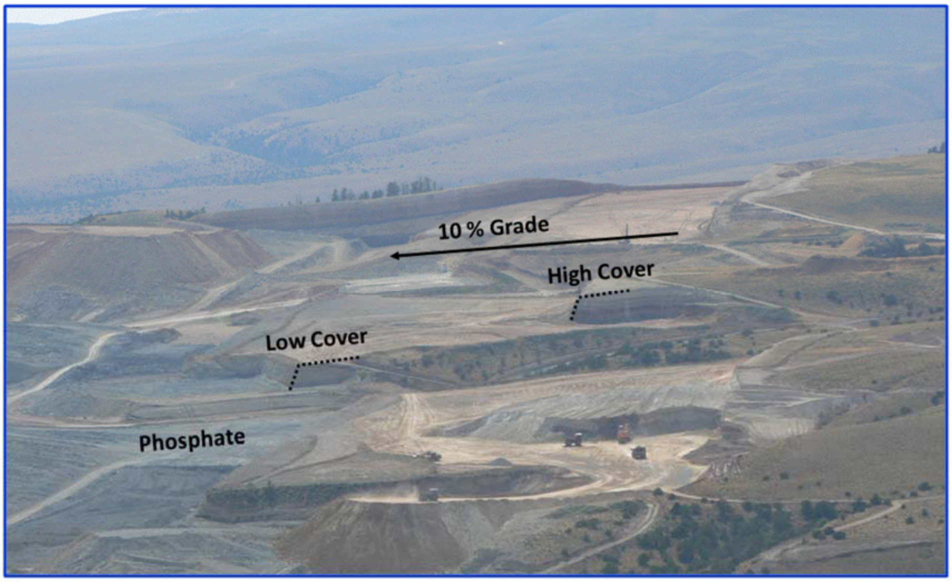

Fig.4: Three pass mining process, high cover, low cover and phosphate ore. (Mc Allister and al., 2012)

4.2 The proposed change

The first change made was changing pit widths from 100.65 m (330 ft) to 73.2 m (240 ft) which allow the cast to final of single blast went from 15% to 20% and the cast to the final for the year 10% considering the two layers (high cover 21.4m (70ft) and lower cover 14m (40ft)). The second major was to shoot the two covers together. The bench height was 30.5m (100ft), pit width 73.2 m (240ft), 11 rows, 6.7m x6.7m (22ftx22ft) burden and spacing, 222 mm (8 ¾ in) diameter vertical holes with PF =0,74 kg/m3 (1.25lb/BCY). These shoots were success and averaged a cast to final of 28%.

4.3. Study on conversion to cast blasting

A study was begun to assess the feasibility of cast blasting including the mechanics of the overburden movement and the anticipated benefits. The mechanics of the overburden movement were evaluated using the computer code, DMC (Distinct Motion Code) (Preece, et al, 1993).

The parameters used by Mc Allisters and al. in the simulation of the cast of the two layers (low and high) with DMC model are presented in the Table 1 and shown in Figure 4. The cast-to-final predicted was 36% and was encouraging enough the engineer to pursue the remainder of the study, including the economic impact.

To valid the model, Mc Allister and al., 2012 performed two simulations, first with the low layer and the second with high layer. The DMC model profiles were then overlaid in AutoCAD with surveyed typical shot profiles proving the DMC model accurate.

Table 1: Blast Design Parameters for Cast Blast Study

Bench Height	32 (105)
Borehole Depth	35 (115)
Explosive Type	ANFO
Stemming	6.7 (22)
Borehole Diameter	270 mm (10.625 in)
Hole Angle	25°
Burden	7 (22)
Spacing	8 (26)
Pattern	Staggered
Number of rows	7
Detonator Pyrotechnic/	Electronic
Detonation Delay Time Hole to Hole	17/12 ms
Detonation Delay Time Row-to-Row	125 ms

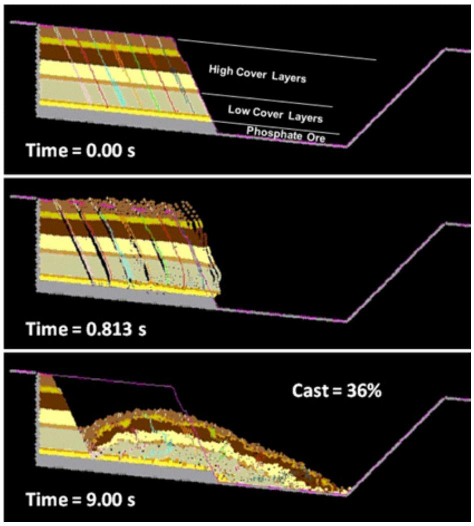

Fig. 5: DMC modeling of the high and low cover blast (Mc Allister and al., 2012)

4.4 Electronic Detonator Cast Blast

The final step in the conversion process was the change from pyrotechnic detonators to electronics. The best typical pyrotechnic blasts used 17 ms hole to hole delays and increasing approximately 100 ms row-to-row delays. The first electronic detonator cast blast were performed with 12 ms hole-to-hole delays and increasing the row-to-row delay at 125 ms. This change in timing and the accuracy of the electronic detonators resulted in another increase in the cast-to-final from 37% to 44%. Figure 6 shown the evidence of the increase. Both the pyrotechnic and the electronic detonator shots were in the same pits with very similar bench heights making an accurate and fair engineering assessment possible.

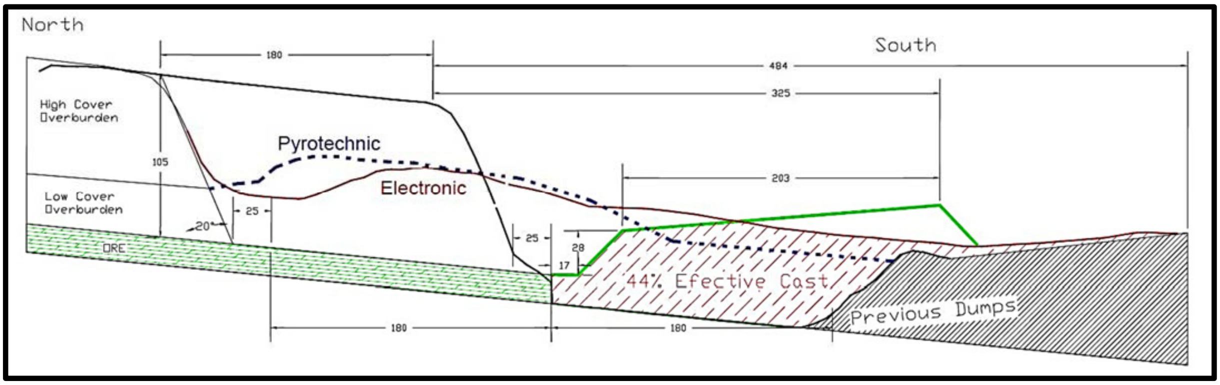

Fig. 6: Cross section of electronic detonator shot, shown with pyrotechnic profile in the background (all units in ft) (Mc Allister and al., 2012).

4.5 Conclusion

Simplot Phosphates has successfully converted their mining operation from a two bench overburden removal operation into an efficient single bench cast blasting operation. Simplot has been successful in increasing their overall cast-to-final overburden at their operation from ~7% to ~32% annually. Since the implementation of electronic detonators Simplot has been able increase record cast blast efficiencies from 37% cast-to-final with pyrotechnic detonators to 44% cast-to-final with electronic detonators. Electronics detonators will defiantly be a strong part of Simplot’s future blasting designs.

5. Case Study #2:Coal Open Pit Casting

The Coal companies in the northern region of the Powder River Basin in southeast Montana have developed the most effective cast blasting operation in the USA by using a good drilling, good blast design, good loading practices and right product.

Even if they had a good fragmentation and cast percentage, they decide to implement the electronic initiation to reduce their vibration levels in order to comply with mine's good neighbor policies. The collected PPV's data with electronic initiation shot shown a cutoff 40% (on all three axes) compared to pyrotechnic initiation. Blasting complaints have since dropped off significantly.

The cast percentage has increased from around 35% to 38%. However, this is very close to the optimal cast for this operation. Although it may seem counterintuitive to some, any additional cast would require that material be pushed back into the pit in order to build the pad for the dragline to sit. Due to the pit width and depth and the swing radius of the dragline, the optimal standoff distance off the coal is about 80' (25M). If the dragline pad was any lower, (Figure 2.) it would be unable to swing high or distant enough to spoil the remaining material adequately.

The benefit of the electronic initiation is not only on the increasing of the percentages of the cast in place but also on the after shot profile. In fact, the uniform surface area obtained by greater control of muck-pile displacement allow a fast and easy build of the dragline pad with less man hours and tractors time as well as the returning the equipment to actual production work.

Table 2 : Layers Technical Data/Blasting Method (Wm. J. Reisz,and al., 2012)

Blast Design Parameter	Value m (ft)
Open Pit Coal	Overburden Casting
Bench Height	461 (150)
Bench width	55 (180) constant
Bench typical length	460 (1500)
Bench Volume	1.15 Mm3 (1.5 M yd3)
Borehole Diameter	200-250mm (7 ¾ - 10 in)
Explosive Type	Bulk 40/60 emulsion/ANFO blend
Pattern	Staggered + Presplit line
Number of rows	5
Burden	10.4 (34)
Spacing	8.5 (28')
Borehole Diameter	0.27 (10.625in)
Hole Angle	25°
Detonator	Electronic
Detonation Delay Time Hole to Hole	17ms
Detonation Delay Time Row-to-Row (2&3)	200ms (656ft)
Detonation Delay Time Row-to-Row (4&5)	300ms (984ft)
Pre-split line (fired with main blast)	fired in groups of 10 holes per 17ms
Powder factor	.59 kg/m3 (1.0 lb./yd.3)
Explosive mass	680 000 kg (1 500 00 lbs)
Initiation	Double primed top and bottom

Fig. 7 : Open pit casting operation of 150' (45M) face.

As previously mentioned, prior to using the electronic detonators, fragmentation was very acceptable. However, since employing the electronics, the dragline cycle time has decreased. More consistent fragmentation and looser digging has allowed the dragline to run under less strain, i.e. smoother and faster swings with a much higher bucket fill factor, all of which leads to higher (yd3/hour) productivity.

The electronic system has been easily integrated to the mine operation. The wire is enrolled on the spool which makes the loading of the primer faster in the deep and angle hole. Performing the test on the bench for each detonator before the explosives loading and the stemming as well as the test before starting the blasting procedure, make the check up more concrete and efficient.

Even on a very large blast, the programming, tie in and testing is done in a very short time. A number of programming options are available. In this case, the auto-incremental option is preferred. The blaster can simply walk from hole to hole, connect the programming unit to each detonator and accept the proposed firing time or choose another. Meanwhile, during the programming process each detonator is being tested for programmability, communication errors, and current leakage. This provides reassurance for the blasters and allows them the opportunity to segregate or correct if possible any reported cutoffs or errors. In the end, the blasters can lunch the firing procedure from safe place where he can observe his blast, control the blasting limit area.

6. Conclusion:

The electronic initiation system is not the magic bullet, a poor drilling, planning, blast design and loading practices give us poor results as well as we use the latest technologies. At the same time, many misperceptions delay the development of the system such as electronic system is: only for the vibration control, complicated to use, we can obtain the same results as conventional system, too expensive to use, take much time/work.

There are numbers of case studies showing that electronic system presents news opportunities to the explosives industries to better perform their operations and at the same time this system can be adapted to the different request formulated buy the users.

Acknowledgements

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