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JOURNAL OF THE EXPLOSIVES SAFETY AND TECHNOLOGY SOCIETY (VISFOTAK) INDIA, DEALING WITH SAFETY AND TECHNOLOGICAL ASPECTS OF THE EXPLOSIVES INDUSTRY

2017

World record of firing 6690 electronic detonators in a single blast at The Kansanshi Copper Mining Project in North – West Zambia; on 27th Sept . 2017

2016

Australia's largest controlled electronic detonators blast in 2016 by firing 5,665 detonators in 2,683 blast holes generating greater operational efficiencies.

Cover Feature : Electronic Blast Initiation System (EBIS) : Status in India

The application of digital electronics across the critical rock blasting triad over time, illustrated above, has brought the blasting process, on one integrated common digital platform, forever transforming the exposives business paradigm. The programmable Electronic detonator Blast Initiation System(EBIS) is veritably the 'linchpin', poised to become the most preferred blast initiation system over the conventional pyrotechnic system.
The cover feature provides a global over-view and discusses prospects in India.

MISSION STATEMENT

"To proactively establish a sustainable interface between all major constituents of the Explosives Industry : The Users, the Regulatory Bodies, the Manufacturers, the Academic and Research Institutions, et.al., in order to foster and promote modern concepts and practices, relating to Safety and Technology of Explosives."


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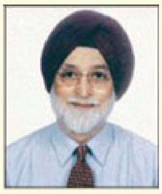
EXPLOSIVES SAFETY & TECHNOLOGY SOCIETY

Editorial...



" We are what we repeatedly do.Excellence then is not an act but a habit – Aristotle "

I was privileged to participate in a conference at Canadian Industries Ltd(CIL), Montreal , Canada, in 1969 where Dr.R.F. Favreau , Research Consultant with CIL , , presented his pioneering work on ' Computer Modeling of Rock Blasting' on 'Energy – Mass- Time' relationship in the three stages of rock breakage process , viz ,the detonics of the explosives ; the high pressure /energy outgoing shock wave to condition the rock mass by inducing fractures in the rock mass ; and finally the breakage and the movement of the rock mass under the influence of exceedingly high pressure of the expanding explosives gases .

However , in retrospect , it was only half the battle because howsoever sophisticated a blast design model be , it still has had to contend with imprecise pyrotechnic delay detonators - the only initiation systems available until recently , due to long delay time and larger scatter of the pyrotechnic delay element . This fundamental discrepancy is now resolved with the development of programmable 'Electronic Detonator' , that replaces the pyrotechnic delay element with an' integrated circuit on a chip' within the body of the detonator , programmable to deploy an unprecedented range of delays from as low as 1ms delay time to as high as 1000 ms , with precision and accuracy to within 0.01% of nominal delay time ; thus enabling a revolutionary step forward to a new programmable digital paradigm of 'rock blasting technology ' affording different ways to improve operational efficiencies or even to develop new extraction methods . The 'cover page' provides some dramatic illustrations in this regard .

A global overview of the growth of EBIS .,beginning with an idea in the 1970s and its progression to a mature technology by the turn of the century, has been presented in the 'cover feature ' .

From India's perspective, China provides an excellent example of how a purposeful industrial policy framework facilitated adoption of electronic detonator technology . To quote from a publication of the Ministry of Industry and Information Technology of China , *" The industry management department of civil explosives and the explosives flow management department (Ministry of Public Security) jointly published a series of policies and guiding documents encouraging companies to develop the application of electronic detonator and industrial development and a favorable development trend has been established "* .As a result , the requirement for electronic detonators grew in a short period from around 1 million in 2015 to 30 million in 2018 !!

Whereas , we have merely scratched the surface in India . The demand for electronic detonators at this juncture is about 0.5 million and projected to grow to about 1 million by 2020 ; whereas , a conservatively estimated potential unmet requirement presently is of the order of 10 million ? Clearly , we need to quickly break out from the present business mould of treating explosives products merely as saleable commodities , and by extension , the blasting process becoming commoditized with predominant emphasis on ' unit cost cutting' , instead of productivity led volume and cost efficiency . The following quotation from Bill Gate's seminal book –'Business @ the Speed of Thought ' , hopefully would lend the requisite impetus :-

"Chances are your company has a sizable investment in technology , and is realizing only 20% of its potential benefits .You are probably viewing hard ware and software as a way to solve specific problems, But like a living organism , an organization functions best if it can rely on a nervous system that will instantaneously deliver to the parts that need it . In clear non-technical language 'Business at the Speed of Thought ' shows you how a digital nervous system can unite all systems and processes under one common infrastructure, releasing rivers of in formation and allowing your company to make quantum leaps in efficiency, growth and profits "

Sooner the better , and no less !!

Best wishes for 2019

Ardaman Singh

CONTENTS

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COVER FEATURE & SUPPLEMENTS

COVER FEATURE

ELECTRONIC BLAST INITIATION SYSTEM (EBIS): STATUS IN INDIA

1.0 INTRODUCTION

"The electronics innovations in weapon development after the second World War, pioneered at Los Alamos, USA, amongst others, duly found industrial applications in many industries including the mining and quarry industries".

Thereafter, over time, with advancements from 'Mechanical and Analogue Electronics', to Digital Electronics, viz, 'Digital Logic Circuits, Digital Information and Communication technology, alongside the proliferation of digital computers, duly heralded a new 'Digital Age', popularly known as 'The Third Industrial Revolution'!

To quote Bill Gates from his seminal book 'Business @ the Speed of Thought':– "If the 1980s were about quality and the 1990s were about re-engineering, then the 2000s will be about velocity." Correspondingly, therefore, "The 'Quality' improvements and 'Business Process 'improvements will occur far faster".

And, sure enough, the past decade or so, witnessed a number of innovative 'break –through' technologies; for example, Nanotechnology, Quantum Computing, the Internet of Things, Robotics, Artificial Intelligence, 3D printing, etc.; and exponentially, Lo and Behold, the dawn of the "Fourth Industrial Revolution " - the phrase first propounded by 'The World Economic Forum' in 2016, that is poised to profoundly impact the modern industrial businesses!

1.1 Whereas, in the context of the explosives industry and its business constituents of mining and construction Industries, respectively the application of digital electronics over time across the critical rock blasting triad of Drilling, Blast Design and Blast Initiation, is chronicled in Table-1.

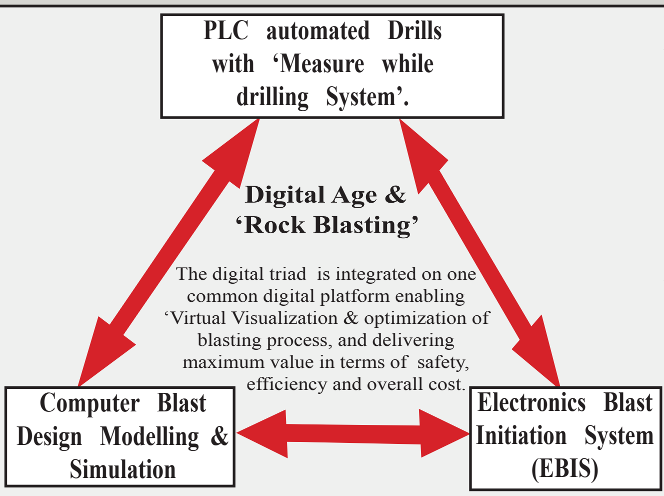
Table 1: Chronology of application of digital electronics in Drilling and Blasting

Period	Application
1970s	• Lang and Favreau introduce Computer Modelling of Blast Design • Electronic sequential Blasting Machine introduced. • First electronic seismographs developed by Dallas Instruments.
1980s	• Beginning of the Development of Programmable Electronic Delay Detonators. • Laser profiling of benches for blast design and analysis developed in Britain.
1990s	• PLC operated drills for surface mining , GPS hole spotting
2000s	• Commercial induction of Programmable Electronic Delay Detonators. • Digital Age of Virtual Visualization of Drilling & Blasting Process Design and Performance.

1.2 Commensurately, for the first time since the turn of the century, the digital age has brought the rock blasting triad on one integrated digital platform, forever transforming the explosives business paradigm from the traditional focus on explosive products as saleable commodities, to an enormously 'value – adding' experiencial business economics of 'Virtual Visualization and Optimization' of delivery and performance of product systems and services, specific to a customer, in order to deliver maximum value. See Box-1.

1.3 However, barring a few notable exceptions, the explosives industry and its major business constituents, have largely remained conservative and very slow to change and adapt to the digital age. The cover feature provides a global over view, and discusses the prospects of EBIS in India?

Digital Age & 'Rock Blasting' (Smart Blasting Solutions with Precision and Reliability) **Box - 1**



The programmable Electronic Blast Initiation System (EBIS) is the veritable the 'linchpin' of the digital framework, endowing unique attributes of 'accuracy and precision' over a wide range of delays from 1ms to 10,000ms with increment of 1ms., within an accuracy range of 0.01 % of nominal delay. Thus, the available option to deploy small inter- hole delay has vastly opened up the scope for "practical use of wave propagation and dynamic fracturing of rock through overlapping, interaction and superposition of shock waves", and consequently enormous benefits across all the major operational domains, viz:-

- Improved environment impact control ;
- Accurate and consistent control over rock breakage viz, fragmentation, throw , swelling and loading out.
- Improvement in mining efficiency and productivity by enabling larger blasts than hitherto feasible; and not the least,
- Overall, resultant improved 'Cost Benefits'.

(The "Cover Feature" is an 'In-House' contribution, as part of the running serial on "Challenges and Issues" of the Explosives Industry - Editor)

COVER FEATURE

2.0 Evolution of EBIS as a 'Mature Technology' :

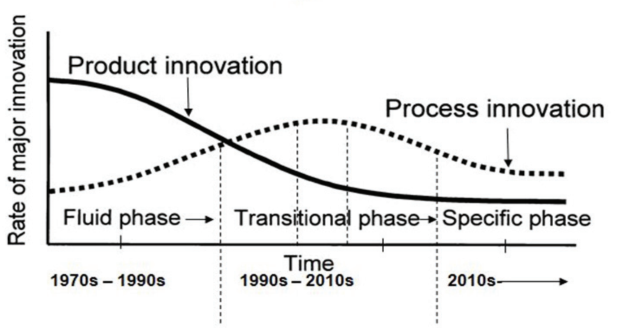
The idea of 'electronic detonator' was first mooted in 1973 at the Kentucky Blasters Conference in the USA; whereas, the race to develop a commercial electronic detonator probably dates from the 1983 ISEE meeting in Dallas, at which Paul Worsey presented a paper on the concept. It took well over two decades, for the EBIS technology to fully evolve and mature; the various dynamic phases of developments based on literature survey, are presented in Box-2.

Evolution of EBIS

Box - 2

1. The chronology of the various dynamic phases of development of EBIS on 'Utterback-Abernathy Dynamic Model, see Fig-1 below:

Fig-1



1.1 Fluid Phase: (early 1970s –to late 1990s)

- Conceptualizing the product specification factoring the competition; and over time, a dominant design emerges that wins the allegiance of the market.
  It took well over two decades to reach this stage vis-à-vis EBIS.
- High on the expectations of the EBIS were

  - they would be ultra safe, owing to the ability to code the firing circuit to only recognize secure signals., and the blasters would welcome the ability to check out the readiness to fire, and fix any faults

  - that of precision: it was generally acknowledged that pyrotechnic delays suffered from timing scatter.; though a sizeable constituency also felt that pyrotechnic delays were good enough.

  - It was hoped they would also be cheap in the expectation of high volumes of electronic chips consumed in blasting.

1.2 Transitional Phase: (1990s to early 2010s)

Once the dominant design is established, the focus shifts to manufacturing competence and eventually a 'proto type' of the new product system emerges which has the potential to challenge the established competing products in the market, for example the cap-fuse, and shock tube blast initiation systems opposite EDIS.

1.3 Specific phase (2010s – present times)

It devolved primarily upon the strategy for marketing the product; the focus entirely shifting towards developing appropriate application processes and systems that provide maximum scope for the realization of the full potential of benefits from the new product. As the technology matures, focus increasingly shifts to cost rationalization, ie, on scale economics and on process innovation to drive out cost and improve productivity. Eventually, a new operational technology emerges that has the potential to challenge all the by now established rules – and the game is disrupted.

2. South Africa's pioneering experience as an example :

The following excerpts from the paper; 'Nine Years of Blasting Experience with Electronic Delay Detonators, by Claude Cunningham, Consulting Mining Engineerm African Explosives Ltd (AEL) (2003) provide a fascinating narrative of South Africa's experience, amongst the pioneering countries:-

- *"In South Africa, the narrow reef gold and platinum mines were using well in excess of 200 million capped fuse units per year – over a million per production day – and there was general agreement that misfires and out-of sequence firing with these units was causing significant losses for mine owners Whereas, such a large user base would be a distinct advantage for precise electronic detonation technology."*
- *"However, the challenge of producing a detonator that could be fired safely and easily by a microchip turned out to be a great deal harder than had been anticipated. The key reason was probably that the electronics experts took time to connect with the conditions in which the systems would have to work. People not exposed to the harsh realities of mining could hardly anticipate how technologies that worked for automobiles and industrial electronic appliances would be completely inadequate once explosives, rock and mining pressures were involved."*
- *"For example, it took AEL seven years from launching its Expert Explosives project in 1986, to offering its first product to the mines. By this time the vision of a cheap system had evaporated, not only with the cost of seven years of intensive development work, but also with the realisation that non-negotiable expense is tied to the strong, high quality components required for the safety and robustness issues. This resulted in a time of hard thinking: if the system was too expensive for narrow reef applications, then the high volumes upon which the concept had been launched could not be tapped. It was quickly evident that the units should be introduced to mining applications in which the cost of the units was minimal relative to the volume of rock moved, and the benefits of using them would handsomely repay this investment.*

3.0 Global perspective of EBIS emerging as a mature technology with proven benefits :-

Electronic detonators come in three firing impulse modes harnessed to the micro chip module within the detonator tube, viz, firing impulse from a 'shock- tube' system, from wired electric system, and wireless system employing ultra low frequency signals, respectively; and correspondingly affording a wide scope for the application of EBIS .from small scale blast capability with shock tube system to large blast capabilities employing wired / wireless systems.

3.1 Acceptability

By all available indications, EBIS is poised to become the dominant preferred blast initiation system, as illustrated by the following developments :-

3.1.1 World record for most electronic detonators fired in a singe blast at The Kansanshi Copper Mining Project in North – West Zambia; on 27th Sept . 2017

The blast involved 6 690 electronic delay detonators, successfully initiated using BME's AXXIS digital initiation system. See Figs 2 and 3 below:-

Significantly, it was preceeded in 2015 by the then in-house blast record using 4144 electronic delay detonators in a single blast.

Fig - 2

Fig - 3

3.1.2 Australia's largest controlled electronic detonators blasts at Daunia Open Cut coal mine situated in the Australia's largest coalfield – the Bowen Basin – in the state of Queensland (2015 and 2016). See Figs 4 and 5 below :-

2015 : A world record for the largest blast when it successfully initiated 4303 electronic detonators in a single blast to break 2.8 million cubic meters of overburden.. The mine chose the electronic blast initiation system in response to its faulty ground conditions . If not well controlled , faults tend to slide over each other during a blast ,;when using non-electric detonators there is a possibility of the product being snapped by this movement of the ground before it can be detonated resulting in a misfire These misfires are eliminated with electronics as the detonators operate as a stand alone entity the instant the fire button is pushed. The benefits of electronic detonators enabled the mine to conduct larger blasts , generating greater operational efficiencies by reducing the number of mine stoppages every time blasting is conducted ., and additionally achieving blasting optimization.

2016 : Yet another record blast was conducted by firing 5,665 detonators in 2,683 blast holes, generating greater operational efficiencies by reducing the number of mine stoppages that must take place every time blasting is conducted, improving safety and productivity with the world's first wireless electronic blasting system.

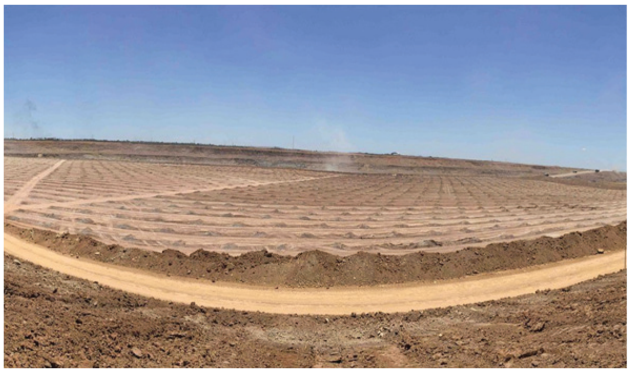


Fig - 4

Fig - 5

COVER FEATURE

3.1.3 Successful wireless implementation in Australia and Canada (2017)

"Two production trials have been executed recently to validate and prove the benefits of the technology. The first production blast took place at the Glencore operated Ernest Henry Mine (EHM), a large Sub Level Cave (SLC) operation in North West Queensland, Australia.

During the trial, 30 rings were pre-charged with WebGen™ well in advance of the cave and then initiated from Mine Control on the surface. WebGen™ eliminated the need for mine site personnel to work near the brow to hook up the blasts, and also demonstrated that lost brows would not remain a production risk. The system was easily integrated into their current method of operation with no misfires or production delays.

In a second production blasting trial at Goldcorp's Musselwhite Mine in Northern Ontario, Canada, five temporary rib pillars were pre-charged using Orica's WebGen™ primers.

The main body of the ore panel was blasted and extracted first while the temporary rib pillars held back the waste rock backfill. The inaccessible ore pillars were then blasted. The introduction of this technology delivered reduced dilution, increased truck fill factors and improved overall productivity."

3.1.4 SWEBREC Report (2013): Improved blasting results through precise initiation – results from field trials at the Aitik Open pit mine (See Fig - 6)

Fig - 6

Aitik is the largest copper mine in Sweden. Approximately 31.5 mt of ore is mined and concentrated here every year. A few relevant abstracts from the report are presented below:-

"Production blasting in mining industry mainly consists of drilling blast holes in particular patterns, charging them with certain amounts of explosive and finally detonating them in a specifically designed sequence. The initiation sequence has been of significant importance since the mechanism of rock breakage by blasting in large scales, e.g. bench blasting, compels the blast holes to be initiated in a specific way. The sequence should be designed in a way that compressive shockwaves, produced by detonation, find enough time to reach the free face and their tensile reflections reach the rock and break it in tension. Such constraint is due to the fact that available detonation caps had not been developed to handle very short time intervals of wave propagation speed. In addition to that, large scatter of delay time in conventional pyrotechnic caps did not permit blast designers to consider theories of dynamic fracture mechanics and wave propagation in practice."

"New horizons opened up on practical usage of wave propagation and dynamic fracturing theories when reliable electronic detonators became available in the late 1990s. These detonation caps are now capable of delay times down to 1 millisecond and are of higher precision compared to conventional caps. The availability of electronic caps permitted the theories of overlapping, interaction and superposition of shockwaves to be put in practice. Precise initiation with short delay times has been practiced in many countries (Australia, Chile, United States, New Zealand, etc.) and has resulted in noticeably better fragmentation, throw, swelling and digability, hence considerable savings."

- *"The bench with inter-hole delay time of 6 ms resulted in the lowest crushing energies among all trials. The bench resulted in more boulders and coarser fragmentation than the second reference bench and other benches. However, different shooting angles of images for different trials introduced uncertainties about the fragmentation analysis."*
- *"The bench with inter-hole delay time of 3 ms gave the finest fragmentation among all trials. All examined values, i.e., x50, x80 and xmax showed improvements compared to the other benches. Although the x80 and xmax values are significantly smaller, the improvement of the mean fragment size is negligible. On the other hand, the crushing energy of the rock was the highest among all trials."*

3.1.5 UN Model Regulations for Dangerous Goods:

New entries for electronic detonators in the UN Model Regulations have been approved, made effective from 2019 . For more details in this regard, please refer to the article titled "UN Decisions and the Explosives Industry" appearing later as a 'Supplement', contributed by the Institute of Makers of Explosives (IME), USA, who effectively steered the Explosives Working Group appointed at the UN to deal with this task .

3.1.6 The Institute of Makers of Explosives (IME), USA :

The IME have prepared an excellent set of 'Guidelines for the Application of EBIS , updated in 2017; certain excerpts are presented in Annexure-1 for ready reference.

COVER FEATURE

3.2 Current demand for EBIS in major explosives producing countries:-

3.2.1 USA:

a) This is where the idea of EBIS was first articulated.

The latest published data on the market for explosives and accessories is available for 2015 only, see Table-2; the demand for EBIS in 2015 was around 6 million nos. constituting about 15% of the total requirement of initiating systems.

Table 2: Market for Explosives and Accessories in the USA-2015

Item	Qty
1. Explosives (Tonne)	
* Permissibles	249
* Other high explosives	47,200
* Blasting agents and oxidizers	1,990,000
TOTAL	**2,040,000**
2 Detonators (Nos)	
* Electric	3,250,000
* Nonelectric	30,300,000
* Electronic	5,680,000
* Other	387,500
TOTAL	**39,600,000**

b) The demand for EBIS has since grown as evident from the sequence of the 'Evaluation and Certification of the EBIS Production Units "carried out by OSHA till 2017 at the request of the various manufacturers. See Table 3.

Table 3: Electronic Detonator Blasting Systems Evaluated by OSHA

(This table only contains companies who have contacted MSHA in order to evaluate and list their electronic detonator blasting systems. The electronic detonator blasting systems listed below have been evaluated)

Sr. No.	Detonator System	Detonator Manufacturer	Evaluation Date
1.	Daveytronics® Electronic Detonator System	Advanced Initiation Systems	August 2004
2.	I-KON™ Electronic Detonator System	Orica USA Inc.	August 2004
3.	Dan-Mar Electronic Detonator Blast Initiation System	Dan-Mar	September 2005
4.	Dyno-Nobel Hot Shot Electronic Detonator Initiation System	Dyno-Nobel	August 2006
5.	Uni-Tronic™ (Models 335 and 500) Electronic Blasting System	Orica USA Inc.	November 2006
6.	Austin Electro*Star (E*Star) Electronic Detonator Blasting System	Austin	March 2007
7.	Digishot™ Electronic Detonator System	Dyno-Nobel	March 2008
8.	Uni-Tronic™ 600 Electronic Detonator	Orica USA Inc.	May 2012
9.	AXXIS G II Electronic Detonator System	BME	August 2017

3.2.2 South Africa:

The following published data is indicative of the evolving preference for EBIS in South Africa

2011 : *Open Pit mining and quarry operators werte largely unaware of the entire range of realizable benefits of EBIS, and therefore losing opportunities to reduce operating costs and increase the efficiency of down stream crushing, screening and milling operations*

2015 : *Electronic detonators were fast becoming an integral part of effective mining processes;*

2017 : *South Africa DetNet, a gtlobal leader in electronic initiation products launched a break through technology (CE4Commander) with the potential to take to take blasting to the next level.*

3.2.3 Australia

- *"Electronic detonators have been commercially available to the Australian quarry industry since the late 1990's. After an initial phase of somewhat modest growth, the off take has picked now, following greater realization of the all round benefits of EBIS by the mining industry, as demonstrated by the example of Boven Basin Coalfield, earlier stated."*
- There is another significant example provided by Rio - Tinto Group in Australia, as per the following information obtained through reliable sources:-

  "Rio Tinto Group operates 10 large iron ore open-caste mines in Western Australia, and produce about 350 million tones of high grade iron ore. They decided to convert to 100% EBIS in October 2017, and in six months thereafter, the consumption of EBIS doubled from earlier 40% shatre to 80 %, and expect to fully convert to EBIS before the end of 2018, at a total consumption of 1 million nos in a year. The primary motive for change over was greater safety, followed by the objective of attaining productivity improvement and reduction in costs"

3.2.4 China

The following data drawn from the publications of the 'Ministry of Industry & Information Technology of China' with respect to the development status of electronic detonator technology, clearly shows China leading by far globally in the application of EBIS.

- The growth of EBIS in China is shown in Table- 4 below:-

Table 4 : Growth rate of EBIS in China

Year	Demand (Million Nos)	Growth
2015	1.2 million	
2016	1.8 million	50 % over 2015
2017	8.0 million	340 % over 2016
2018	30.0 million	275 % over 2017

The current share of EBIS in delay initiation market is 40%; the rest held by shock tube system; whereas, the electric pyrotechnic delays were phased out .by 2006.

- *"The research and development of electronic detonator started from the 1980s. In recent years with the stimulus of the market needs, and increase in the R&D activities on E-Detonators, there are more than 20 professional chip companies in the fray for e-detonator technology."*
- *"The industry management department of the civil explosives in China (MIIT) and the explosives flow management department (Ministry of Public Security) jointly published series of policies and guiding documents encouraging companies to develop the application of electronic detonators. A favorable development trend of E-detonator has been formed in China."*

Clearly, there is a definitive industrial policy framework put in place, rigorously carried out and monitored by the Ministry of Industry & Information Technology, China vis-à-vis adoption of new explosives technologies.

4.0 Status of EBIS in India

4.1 Current:

a) A reliable indicator of the status in India is provided by the Tender Document of the Coal India Ltd(CIL), specifying the requirement of explosives and accessories in 2017-18 and 2018-19, respectively; and the requirement envisaged for the opencast coal mining projects, supposedly the market for EBIS , is presented in Table-5, which represents close to 80 % of the country's requirement of explosives in this category.

Table 5: Requirement of Explosives and Accessories for the open cast projects in CIL

Sr. No.	Explosives/ Accessories / Initiating System	2017-18	2018-19
1.	Bulk Explosives (t)	602,725	703,213
2.	Large dia. Cartridge explosives(t)	75,184	83,397
3.	Accessories/ Initiating Systems:		
	* Det. fuse ('000 m)	933015	105184
	*Cast Boosters (t)	2150	2482
	* Cord Relay ('000m)	1839	1898
	* Non-Electric Detonator ('000m)	151892	178011
	* MS Connectors (' 000 nos)	129	134
	* Electronic Dets (' 000 nos)	439	460

As seen, the requirement for Electronic detonator, makes up a very small share amongst the initiation systems currently deployed by CIL. The application of electronic detonators is limited to blasting operations in areas close to dwellings / important structures, etc. in order to mitigate / control environmental hazards / damage from blasting.

Given this trend, the total demand for EBIS in the country at this juncture is estimated to grow to about 1 million only by 2020.

4.2 Prospective:

There are presently only two manufacturers in the country with a consolidated annual capacity of about a million; that is to say, in the overall context, very early days for EBIS in India?

4.2.1 Estimate of immediately available potential demand for EBIS in 2019:

a) The estimated demand for industrial explosives including initiating explosives, by the various consuming industries, viz, mining, quarrying and civil construction projects, etc in 2019, is shown in Table - 6.

Table 6: Demand for Explosives and Accessories in 2019

Consuming Industry	Packaged Exp. (MT)	Bulk Expl. (MT)	Detonators (Mill.Nos.)	Det.Fuse (Mill.Mtrs.)	Cast Booster (T)
Coal	110768	793153	86	105	1913
Iron Ore	40000	15000	15	24	40
Limestone	67000	4000	17	30	40
Lead & Zinc	5000	17000	6	3	35
Uranium	2500	-	4	1.5	-
Bauxite	6000	-	1.5	2	-
Lignite	4000	12000	-	7	22
Copper	3000	4000	0.6	3	8
Tunnelling Const/ Quarries	160000	8000	430	270	14
TOTAL	**398268**	**853153**	**560.1**	**445.5**	**2072**

b) A reliable basis for EBIS demand is the consumption of cast boosters and correspondingly the equivalent numbers of 'in – hole primer charges' deployed for blasting and thus, indicative of prospective requirement for electronic detonators.

COVER FEATURE

Cast boosters are available in two sizes – 100 g and 250 g - respectively; and for this estimate, an average consumption rate of 200g per 'in-hole' primer charge , has been assumed , and accordingly , the prospective demand for EBIS at this juncture is at least , of the order of 10 million nos . See Table - 7.

Table 7: Potential requirement of EBIS in 2019

User Industry	Cast Booster (t)	Equivalent prospective requirement of Electronic detonators (mill.no)
Coal	1900	9.50
Iron Ore	40	0.20
Lime stone	40	0.20
Lead & Zinc/ Copper	40	0.20
Lignite	20	0.10
Const./ Quarries	15	0.075
Total	2055	10.275

4.2.1 The Way Forward:

There are many an imponderable, briefly discussed below:-

a) Historical context: Though India is currently amongst the major industrial explosives producing countries, it is also an unfortunate reality that the Indian market has persistently trailed behind the global trend by a long margin, with regard to timely induction / adaptation of new emerging explosive blasting technologies. See Table - 8.

Table 8: Asymmetrical Explosives Technology Paradigm in India

Emergence of New Technologies	Induction in India
* Emulsion Explosives(1969)	1980s
* Emulsion-ANFO Blends (1971)	1990s
* Shock Tube Non-Electric Detonators (1974)	1990s
* Digital Technologies:	
- Laser profiling of benches , GPS Hole spottin and automated drilling and related 'measure while drilling services-1990s	??? (No evidence yet)
- Electronic Detonators -1990s	2010s
- Blast design modeling and simulation (Virtual visualization/ optimization of drilling and blasting processes.)	???? (No evidence yet)

The above asymmetrical paradigm has had serious economic ramifications of heavy 'Opportunity Cost' to the country's exchequer, which is the cost of a particular product system in use measured in terms of the value of the next best alternative which is forgone or not chosen ?

Surely , a serious matter of concern for all the stake holders.

b) Commodity Syndrome: Once again referring to the CIL Tender Document, and given the technology matrix as it exists today, the explosives products are merely deemed as saleable commodities, and so by extension, the blasting process is commoditized with predominant emphasis on 'unit cost cutting', opposed to productivity led volume and cost efficiencies, as evident from the following observations :-

- The technical specification for EBIS merely stipulates – "Electronic Detonators – Brand name, strength, delay timing", which would suggest that EBIS is treated merely as one of the initiation products, on differential unit cost basis alone; and
- The punitive provision of a cap on the 'Powder Factor (PF)', without correspondingly prescribing the optimal requisite drilling/ blast design/ blast initiation processes , specific to every mining project; suggesting thereby that every production activity is managed in isolation on its own and not as a part of an integral production system.

c) Global Survey on Productivity in Minining: Now come the Hard part

In the above context of commoditized explosives business paradigm in India, it is instructive to provide relevant excerpts from the Global Survey on " Productivity in Mining: Now come the Hard Part " conducted by Sustainable Mineral Institute / Ernst Young Global Ltd in 2017., presented in Box- 3, for ready reference.

COVER FEATURE

Excerpts from the 'Executive Summary 'of the Global Survey on 'Productivity in Mining : Now come the Hard Part " by Sustainable Mineral Institute / Ernst Young Global Ltd (2017) Box - 3

The executives we interviewed told us that productivity is the number one challenge in the mining sector and is firmly on the CEO's agenda. The expected declines in labor, capital and material productivity all occurred, but an additional factor of economies of scale has played a big role in the decline. Many have found that productivity decreased as operations got larger, and that it was difficult to manage the complexity of these large operations, particularly given the additional challenge of high turnover and lack of staff experienced in focusing on driving efficiency. The growth in mining operations has resulted in complex structures and inadequate functional collaboration.

1. **The integration gap — the reality of the productivity issue**

   Many "productivity" initiatives to date have been focused on cost cutting, which have led to some modest, short-term results, but our survey participants acknowledged that what needs to be done now is more complex. Our view is that mining companies should move beyond point solutions, and adopt an end-to-end solution to transform the business. We believe there is a need to ensure that each part of the business is optimized, not on its own but as part of a business system. We have titled the lack of this as "the integration gap." A number of the executives interviewed highlighted this gap and their desire to close it. Addressing integration is a key challenge for improving productivity, and requires an approach that breaks down the silos and adopts an end-to-end perspective. We believe this is achievable by changing the culture to empower the workforce and finding new solutions to existing problems, and using data and technology to support this.

2. **Sustaining end-to-end transformation through culture**

   Technology can break down silos and enable new working practices to evolve. Only with good data can companies understand what good performance looks like, and companies that successfully use data outperform their peers by 20.[3]

3. **Sustaining end-to-end transformation through culture**

   The critical role people will play in transformation was highlighted around three key themes:

   Engagement — empowerment, flexibility and self-direction

   Measurement and reward — aligned to productivity measures not headline outcomes

   Ongoing talent management — requiring systems thinkers to manage complexity

4. **The way forward**

   Productivity is a CEO issue and therefore needs the CEO to lead and drive end-to-end transformation to solve the issue. As a first step towards transformation, we recommend a refresh or review of operational strategy to help to change the focus of the business and start to change culture.

5.0 Conclusion :

5.1 Finally, The taste of the pudding lies in the eating!

The major user industries, in particular the Coal; India Ltd., have to force the pace and avail the technological dividends of the 'Digital Age.

China provides an excellent example of how a purposeful industrial policy framework facilitated adoption of electronic detonator technology;

5.2 The asymmetrical technology paradigm in India has been the subject of deliberation of this Journal in the past, and it is important to recap the recommendations made then for necessary course correction, as follows:-

i) **4th Edition (2009): Cover Feature- "Explosives and Environment"**

"A permanent Nodal Agency for 'Explosives-Environment Stewardship : it's not only about 'Control and Regulation' which task is vested in the Department of Explosives, Government of India, but much more about ensuring an integrated development of the explosives industry in close concert with the 'state of the art' globally at any given juncture"

"There already exists an institutional frame work of an Explosives Development Council, mandated under the Industrial Development and Regulation Act,1951, which has been moribund, and not functional at all for a very long time"

"It is recommended that the 'Explosives Development Council' should be revived, restructured and accorded a permanent tenure, with full representation of all the relevant entities, and that the Council is duly mandated to act as a Nodal Agency for stewardship of the explosives-environment paradigm as a 'Holistic System'"

ii) **5th Edition (2010): Cover Feature – "Value Chain Analysis of Open Pit Mining"**

"The urgent necessity for a paradigm shift in the methodology of 'value management' of mining projects, and further, for such a shift to come about, both the mining industry and the explosives industry would need to collaborate" .

iii) **6th Edition (2011): Cover Feature – "Emerging Dividends from 'Technology-Safety Interface' of Modern Industrial Explosives : Why India has lagged behind the global trend"**

"The role of the consuming mineral industry constituting over 80% of the market, and predominantly made up of large public enterprises, notably amongst them the Coal India Ltd, which is the largest consumer, is extremely critical."

-Editor

COVER FEATURE

References:

1. Nine Years of Blasting Experience with Electronic Delay Detonators : Claude Cunningham, Consulting Mining Engineer African Explosives Limited (2003)
2. Electronic Delay Detonators – A unique Solution to Pertinent Mining Problems, Raphael Banda, African Explosives Zambia Ltd (2003)
3. An African Story : William McFerren, Pragasen Moodley, Det Net Solutions (2005)
4. A review of the benefits being delivered using electronic delay detonators in the quarry industry - David Miller, Technical Services Engineer NSW Drew Martin, Senior Technical Services Engineer WA Orica Quarry Services (2007).
5. Improvements in Blasting Technology at Cliffs Natural Resources, AlaKoski, et al (2007)
6. A review of the benefits being delivered using electronic delay detonators in the quarry industry - David Miller, Technical Services Engineer NSW Drew Martin, Senior Technical Services Engineer WA Orica Quarry Services (2007).
7. Electronic Detonators : A step forward in Blast Vibration Control - W.J . Birch, T.J. White and S. Hosein (2010)
8. The Latest Generation of the Electronic System enhanced Safety and Productivity - Sami Kara[a]*,William R. Adamson[b], William J. Reisz[c],R;Davey Bickford USA Inc.,USA (2013)
9. Implications of the Dominant Design in Electronic Initiation Systems in the South African Mining Industry - FRANCOIS C. SMIT and CARL W. I. PISTORIUS (1998) “SYMPHOS 2013”, 2nd International Symposium on Innovation and Technology in the Phosphate Industry
10. A review of the benefits of Electronic Detonators (Article in Rem Revista Escola de Minas), 2013
11. Field Testing and Analysis of Blast Utilizing Short Delays with Electronic Detonators; University of Kentucky, USA (2013)
12. Productivity in mining : Now comes the hard part - A Global survey, Sustainable Mineral Institute (SMI),(2014-15)
13. Electric delay detonators – benefits and growth prospect in India; Manoj Latwani, et al, Solar Industries (India) Ltd. (2016)
14. Electric delay detonators – benefits and growth prospect in India; Manoj Latwani, et al, Solar Industries (India) Ltd. (2016)
15. Fragmentation : Better Blast, 46 International Mining, March, 2016
16. Improved blasting results through precise initiation – results from field trials at the Aitik open pit mine: Swebrec, 2017
17. Electronic Detonators Blasting System Evaluated – OSHA, USA (Updated till 2017)
18. Electric Detonator Technology and Industrial Development in China: Ministry of Industry & Information Technology of China (2017)

COVER FEATURE

Annexure - I

SELECTED EXCERPTS FROM 'ELECTRONIC BLAST INITIATION SYSTEM(EBIS) GUIDELINES' PREPARED BY THE INSTITUTE OF MAKERS OF EXPLOSIVES(IME), USA

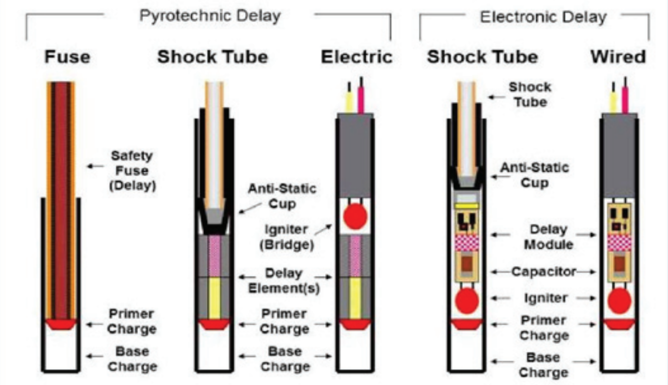
Electronic Detonators : NOT Electric and NOT Non-electric

The functionality, risks, and safety benefits of electronic systems are not fully understood by all potential users. Some of this misunderstanding stems from the fact that the technology, components, and communication protocols used in electronic systems are not found in pyrotechnic-based technologies (fuse caps, electric and nonelectric systems).

Additional confusion stems from the inaccurate assumption that because both technologies incorporate wire as a lead, they must, therefore, be similar technologies. Even though electronic detonators (typically) utilize wire and / or wire harness components in their technology, these should not be confused with standard electric detonator technologies, especially in areas where response to stray / induced current, continuity testing, static electricity, and RF energy is identified as a hazard.

Further complicating matters, some existing government regulations and/or industry guidelines covering initiation systems may not be applicable or appropriate to electronic systems. Often, meaningful regulations specific to electronic systems simply do not exist. This can result in additional confusion for current and "would-be" electronic system users.

Fig.1 Basic Detonator Construction



For the foreseeable future, existing electric detonator regulations may continue to be mistakenly applied (or misapplied) to electronic detonator technologies. To recognize the actual risks associated with EBISs, a basic understanding of the physical construction of the system components, starting with the detonator, is essential. Users should then develop a full understanding of all the test equipment, programming units and firing devices to fully appreciate the risks unique to electronic systems and to ensure the safe application of the technology.

After completing a training and education program, users will have a better appreciation of the enhanced level of protection and blast control capability offered by electronic systems. Users will also understand more fully that every electronic system design is different and that "not all electronic systems are created equal."

Users should ALWAYS know and fully understand the design capabilities and features of their EBISs. The physical construction of an electronic detonator is the primary reason that electronic detonators should not be confused with electric or nonelectric detonator technologies. As seen in Figure 1, the electronic detonator wire leads do not attach directly to a match head or bridge wire, unlike electric detonators.

It is the direct connection to the match head or bridge wire by the external wire of an electric detonator that makes an electric detonator susceptible to initiation from static, stray current and/or RF energy in the field. IME SLP 20, Safety Guide for the Prevention of Radio Frequency Radiation Hazards in the Use of Commercial Electric Detonators (Blasting Caps), was specifically developed to address the sensitivity of electric detonators to RF energy.

In addition to a physical separation from the bridge wire, electronic detonators generally have several other components as part of the design that further increases the level of protection from extraneous electrical energy sources and the risk of premature initiation.

Some of these protection devices include:

- a spark gap device to protect against static discharge events (high voltage spikes from static build up on personnel, equipment, etc.)
- the use of current limiting resistors
- detonator shell construction (Faraday cage - RF energy)

In addition to an electronic detonator's design and construction, EBISs have other built-in features that provide a further level of safety and security that may not be found in other systems. EBISs incorporate a logic component in the detonator design in the form of a microchip technology or an ASIC (Application Specific Integrated Circuit) that provides not only a "logic" protection from premature initiation, but also provides a level of timing control and security from unauthorized use. Generally, the built-in logic circuits will allow operators to limit and control who can use the system though passcode protection. Most will also require a "physical key" to gain access to firing circuits, which increases the level of security by limiting the use of equipment and detonators to ON LV authorized and fully trained blasters. The photos below show a cut-away of a typical electronic detonator as well as the full assembly with special connectors.

COVER FEATURE

On-Bench Field Testing and Programming Equipment

Electronic and electric initiation system technologies vary significantly in the manner a detonator can be tested in the field prior to use. Users of electric detonators are familiar with the use of a "Blaster's Galvanometer" to test for continuity as well as the level of resistance for each detonator and branches and circuits that are used while tying in a blast. While the galvanometer provides some level of continuity testing to ensure lead integrity following the borehole loading and stemming process, the testing is simply a measure of resistance in ohms of the wire lead and match-head or igniter.

Electronic detonators provide a much higher level of detonator and circuit testing capability due to the type of interrogation that can take place with the use of ASIC devices and microprocessor technologies within the electronic detonator. This fundamental difference in technology allows users to not only check circuit integrity; the bench tester can actually conduct a "two-way" communication with an individual detonator or a series of detonators. This communication can provide the user with a significant level of information as well as the ability to program the detonator. The electronic bench testing unit which often may be called a "logger", "tagger", or "programmer" unit by individual manufactures, will provide the user with circuit tests to ensure communication with the detonator (wire breakage, leakage ranges, circuit board test protocols, match-head existence), as well as facilitating the programming of delay times and sequences of individual detonators. The methodology, sequence and type of communication varies between each manufacturer due to proprietary technologies, but EBISs, using "On Bench Testing and Programming Equipment," provide a much higher level of information and communication capability than conventional electric or nonelectric initiation systems.

Typically, loggers, taggers, and testers can be used to test one detonator (as a pre-circuit test) prior to, during and after the borehole loading process. These on-bench testing units also can provide users with the ability to test a group of detonators, a series, and / or the entire blast allowing a blaster to check individual detonator information, the number of detonators in a circuit, and the full system integrity of a blast.

It should be noted and understood by users that all "On Bench Testers" are designed (and required) to be "inherently safe" devices. Inherently safe designs require that all electronic testing and communication is always done at a voltage and current level that is below the level needed to charge and fire a detonator. The tester by design does not have the capability to produce or deliver a high enough energy to fire a blast or a single detonator. This design feature, as well as the other detonator design features make electronics nearly impossible to accidentally fire from extraneous electrical energy found in normal mining, quarrying and construction activities, and provides users of EISs the highest possible level of safety and security.

It is the "On Bench" communication and interface between electronic detonators and the associated testing equipment that has allowed some users to refer to electronic detonators as "Smart Dets." Users can certainly have a much higher level of confidence in their ability to ensure "good" detonators are available following the loading and stemming process or, at a minimum, where suspect misfires could be anticipated and communicated prior to the blast. The systems today are also designed with proprietary methods of securing the communication and require passcode technologies and protocols to ensure that ONLY qualified and properly trained personnel use the systems. Although many users call these technologies Smart Dets or Smart Systems, they are only as smart as the users providing the programming and timing designs for each blast.

Some examples of "On Bench Testing Equipment" are shown below:

Scanner

Logger

Logger

Tagger

Electronic Blasting Machines

Following the successful "on bench" testing and programming of all electronic detonators in a blast, a specifically designed blasting machine must be used for firing the blast. As with all electronic systems, a proprietary blasting machine must be used with each manufacturer's system. Blasting machines have unique design features and communication protocols that must be followed to ensure safe and reliable system level tests, final programming, charging and firing of the shot. Only fully qualified and trained personnel should attempt to use these systems.

Electronic blasting machines are the only devices designed to provide password protection, programming capability as well as the energy levels needed to charge the detonators in a circuit and send a fire command. It is the charging capability of the blasting machine that sets the units apart from all other field equipment for electronic detonators. They are not considered inherently safe devices, and as such, users must: ALWAYS clear the blast area of personnel, vehicles and equipment prior to hooking up to the firing device or blast controller. Refer to IME's SLP 4 for other electronic initiation system ALWAYS and NEVERS.

Electronic blasting machines generally have the same characteristics and capabilities to test and interrogate electronic detonators as "on bench testers." They also have the ability to test, interrogate and program the entire system or all units within a blast. This full scale testing is made possible by the blasting machine's ability to communicate at a higher energy level which provides an adequate energy level for reliable communication as well as for charging of all firing circuits. Generally, a two-way communication is needed for full system testing as well as full charging of the individual detonator's communication and/or firing capacitors. This allows for the reliable performance of the manufacturer's system wide tests prior to the final charge and fire commands being sent.

Many systems will require both password protected firmware and/or software interfaces for the user as well as a physical key or manual device to ensure no accidental firing can occur. As mentioned above, each system is specific to a manufacturer's design and users must understand and follow all protocols to ensure reliable, safe and secure use of electronic blasting machines.

Typical Electronic Blasting Machines

COVER FEATURE & SUPPLEMENTS

SUPPLEMENT - 1

ELECTRONIC DETONATORS - HOW SAFE ARE THEY?

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In recent years use of electronic detonators in blasting has increased multifold as they are very precise in their timing and enable more options of using complex blasting patterns. The benefits of such blasting are claimed to be greater output, throw as desired, less vibration, less fly rock ,better fragmentation etc. Apart from these advantages there is a belief that electronic detonators are extremely safe as compared to the electric detonators well known in the industry. This assumption however needs a more precise definition as to the safety aspects.

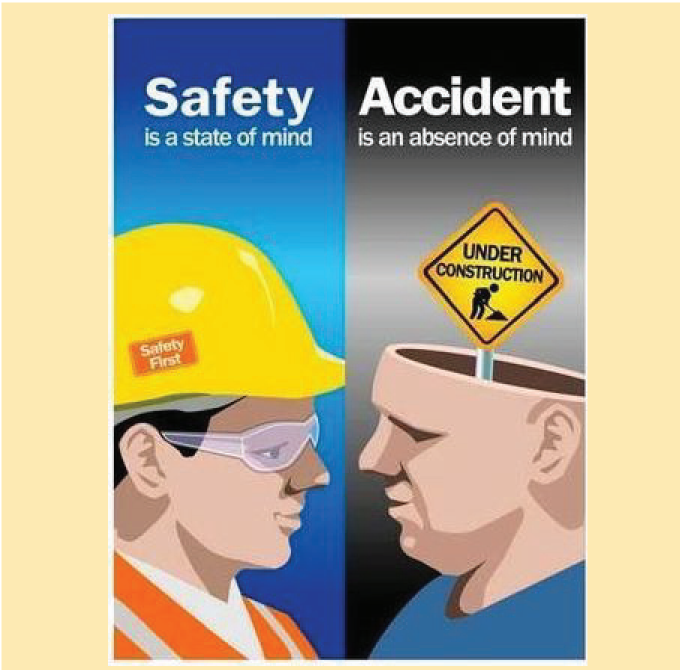
The extra degree of safety claimed in electronic delay detonator is mainly due to the elimination of the delay train inherent in the electric delay detonator. The delay train consists of pyrotechnic chemicals and elimination of the delay element filled with these pyrotechnic chemicals some of which are high energy highly active chemicals and metals leads to greater safety in the manufacturing operations. As far as the end user is concerned the electronic detonator because of its design provides a greater degree of safety to initiation by stray currents be it man made or by nature. It also prevents misuse to a great extent as it can be initiated only by unique blasting machines and they can also be RFID tagged for identification purposes. Details are well described in the user guidelines issued by IME Bulletin in June 2017.

Somehow the fallacy that electronic detonators are much safer than regular ones in all operations of manufacture, storage and transport has crept into the minds of many in the explosives industry and the end user. It is therefore necessary to state the facts concerning this issue.

Electronic detonators as they are being made today use similar filled shells as electric detonators .Most of the electric delay detonators use filled shells containing PETN as the base charge and Azide/Styphnate/Aluminium mixture as the primary charge for initiating the base charge .Since similar filled shells are used to make electronic detonators it is difficult to accept that the electronic detonators have a greater degree of safety than the electric detonators in manufacture, storage and handling especially where influence of friction and impact play an important role in the risk potential. Thus it is necessary that all the statutory rules and regulations in regard to manufacture, storage and transportation applicable to electric detonators also will apply to electronic detonators.

Any detonator be it electric or electronic, instantaneous or delay can achieve a greater degree of safety only when its more sensitive component is replaced by a less sensitive one. Thus elimination/substitution of ASA by a less sensitive primary explosive filling to initiate the base charge is the way towards making safer detonators. Some of the manufacturers in the industry have taken this step by replacing ASA with less sensitive chemicals. These latter have shown increased safety margin. But still there is scope for attaining even greater safety. This is achieved only in the NPD-Non primary detonator-where the primary highly sensitive ASA has been replaced by a secondary explosive like PETN itself. This is achieved by going through a deflagration to detonation process(DDT). So far I think only Nitro Nobel has introduced such a product*.

In the interest of the explosive industry, for manufacturing and delivering to the end user a safer detonator, it is essential that it moves away from using ASA or such other initiating compounds just like the phasing out of manufacture of NG explosives.



SUPPLEMENT - 2

ELECTRONIC DETONATORS IN INDIA: CHALLENGES AND OPPORTUNITIES

By Narendra Mathurkar
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1.0 INTRODUCTION

Initiating devices are the critical elements in blasting operations for mining and construction activities. They perform the functions of transmission and control of the firing signals to the explosive charge in controlled manner with pre-set delay time.

Detonating Fuse with cord relay, Electric delay detonator, Shock tube or NONEL detonator are some of the prevalent conventional Initiating devices used for blast initiation in India. However, recently, Electronic Detonators (EDs) are being put to use by several mining companies because of the numerous advantages of EDs over the conventional initiating devices but, at present, they are primarily used in India for vibration control. Despite the huge potential it has been a slow adaption of technology as ED poses many challenges to manufacturers as well as to the user industry. These challenges are discussed in detail in this article.

2.0 INDIAN SCENARIO

(1) USER: India's entry into this field has been rather late. Leaving aside a few trials, EDs got acceptability in the Indian market in last 8-10 years only. At present it is being deployed mainly for vibration control. However, they are a few mines which have realised the true potential of EDs and have converted most of their initiating requirements to EDs. Overall, the Indian mining industry is now getting ready to embrace the technological benefits of Electronic detonators.

(2) MANUFACTURER: With increased knowledge and experiences sharing due to world wide connectivity, technological advancements in electronics, and acknowledgment of the fact that the usage of electronic detonator is going to expand rapidly - Indian manufacturers are increasingly showing keen interest and ready to invest in this technology.

EDs in India are presently provided by four companies, three of them having manufacturing facilities within India. As compared to the world leaders in this technology, Indian companies are still in early stages of electronic detonator design and substantial work still to needs to be done.

3.0 PRE DESIGN CHALLENGES

Even before the work for ED design can be started, the major challenges facing the Indian manufacturers are:

- **Lack of information, prior art** – The product is very specific in nature and very few companies have the technology. The number is probably less than ten, worldwide, excluding China. For obvious techno commercial reasons, these companies have kept the design patented and closely guarded.
- **Multi disciplinary expertise** - It is a niche product requiring multi disciplinary efforts, namely in, electronics, mechanical, chemical technology and mining. Most of the manufacturing companies have either hired professional electronic design house or has a team of experts in electronics.
- **Long time sustained efforts** – The development phase can be rather long due to lack of prior information. For design, no set guidelines are available except for safety aspect. There is a need for co-ordinated efforts by persons from varying engineering disciplines.
- **High investments** – Companies worldwide had to put millions of dollars in R & D alone. Also the fact that there is no assurance of returns within the expected time period further acts as a deterrent for the explosives companies in India. Of course any investment needs to be judged only by the returns it could generate.
- **High cost of the product** – The basic cost of ED is about 100 times higher than the conventional pyrotechnic initiators. Market in India has always been cost sensitive to the cost of the items. Companies may find it very hard to justify such a high difference in the cost. It requires sustained, co-ordinated, marketing efforts with case studies to establish and to prove the overall cost benefits of using EDs.
- **Difficulty in testing** – The product requires time to time testing during the development phase. The very nature of product requires a scheduled plan for testing with safety clearances. This can be painstaking and time consuming as many permissions are required from multiple agencies and regulatory bodies.

- **Significant marketing and technical sales efforts** – Though the users world over have acknowledged the benefits of EDs the concept is relatively new in India. The benefits of this technology needs to be marketed properly and proved. Blast initiation using EDs is quite different and requires systematic blast plan d beforehand. ED is a mere tool which offers unprecedented flexibility and precision. User training – As a corollary to the point above, the distinct nature of product means significant efforts towards making the user aware of the concept of conducting a blast. In India, typically, the on-site jobs are mostly handled by unskilled labours with little technical background. Even for the trained personnel, adapting them to blasting procedure using ED requires big efforts. The sheer volume of this necessitates deployment of a large team of trained personnel by the suppliers / manufacturers. In fact, at least during initial couple of years, the blasts will need to be conducted by the supplier themselves.
- **Significant efforts towards educating the regulating authorities as well**.
- **Manufacturing and Test facilities** – Though ED is a detonator similar in structure to pyrotechnic ones, at least on the outside, there are many differences in manufacture, assembly and testing. This means having a separate assembly line within the existing setup. Again initial investments and running costs need to be taken into account.

4.0 ELECTRONIC DESIGN – FEATURES REQUIREMENT

The heart of the ED is electronics and its design and development should consider following points (The heart of the ED is electronics and following points need to be addressed for its design and development):

- Conceptualizing : Defining the system of ED with control devices like Logger, Tester and Blaster. Each of the constituents has a specific use and its design is primarily based on making the system user friendly, easy to operate, safe and reliable. The whole design philosophy of ED is based around ED design in conjunction with the peripheral devices. A balance needs to be worked between maximum number of ED in a blast and harness wire line length.
- Incorporating features in hardware and software that would facilitate easy, faithful and quick setup for delay assignment, hole location, blast planning and overall operation. It is product conceptualization and requires significant efforts in design as well as user interaction.
- Design of ED hardware and software
- Chip - Miniaturizing the electronics to mount it on PCB and accommodate it in a shell of about 6 to 7mm internal diameter.
- Distribution of firing energy to individual detonator rather than sending a high energy impulse during instance of firing.
- Two wire bidirectional signal and power transmission.
- Long line operation, often extending to several hundreds of meters. Multidrop configuration operation. The ED can be added/clipped to laid out pair of harness lines.
- Intelligent processing capability within the ED to facilitate communication with external units,
- Unique ID to each detonator. Since EDs are programmable for delay times, each ED requires a Unique ID number to identify itself within the network.
- High and multiple levels of condition based safety interlocks
- A precise count down timer
- Energy storage and gate circuit to initiate the fuse head
- Method for checking fuse head
- Deploying enough measures to facilitate manufacturing process checks and identify process defects.
- Provision for Stress withstand capability like EMC, ESD, Overvoltage, Impact, Vibration etc.
- ASIC or Microprocessor : Use of ASIC or discrete components including microprocessor. This is a major decision which needs to be taken. Some companies start with discrete and proceed to ASIC as the volume grows up. While a majority of them start with ASIC design itself. Microprocessor design offers flexibility and adaptability to changes, lower initial investment but higher complexity and challenges in assembly. Also such design is prone to market forces for costs, availability and 'end of life' possibilities. On the other hand, ASIC offers lower per unit cost, relatively easy assembly process, greater features possibility. But the initial cost investment is very high and no possibility of features change.
- ASIC process : It is a lengthy and costly process. Typical time required to convert a working design to ASIC can be about 1 to 2 years. Also no semiconductor foundry (fabrication facility) is available in India.

5.0 OTHER ASPECTS

Apart from electronics, there are many other aspects which need to be taken into consideration, studied in details and applied correctly and efficiently. Some of them are:

- Conceptualisation the overall functioning of the ED, It is a major task and requires close and a detailed study of the existing practices in mines, ED design and commercial viability.
- ED SHELL : Design of a shell which can accommodate the electronics but at the same time compatible with standard fittings like cast booster.
- LEAD WIRES : Twin wire procurement or manufacturing. The wires need to be extremely robust to withstand the mining environment and particularly stemming. The wires could be in spool form or Z fold. The other end of wire need to be terminated in connector for harness wire connection.

- Selection of proper gauge and type of lead wire and harness wire.
- Fuse Head – It needs to be fulfilling the time scatter requirement to achieve the desired time accuracy levels.
- Wire spools, Wire soldering, fuse head soldering, plug design, crimping and packaging are the significant aspect which need to be addressed.
- Being operated by unskilled personnel means the system has to be simple to operate and 'idiot proof'.
- As always for any explosive containing product, Safety is of prime concern. Sufficient measures and handling instructions need to be devised and implemented.
- The 'Blasting window' is very small, mostly due to work pressure. Any system developed has to be reliable and quick enough to be laid out and connected. This remains a big challenge as ED requires repeated/ multilevel checking of detonators for its presence and correct status. Blasting In-charge is always keen to complete the job safely and as quickly as possible.
- The ED chip manufacturing process is also a big challenge for explosives companies as miniature components handling requires automated assembly machines. This again can be costly affair. The assembly line setup requires a detailed study of available machinery and additional SPMs required to streamline the manufacturing process. Involves significant investments and help of team of experts in electronics assembly lines.
- Protection of design IPR and Patents. This requires knowledge of filing patents through patent attorneys. The fact that there are more than fifty patents world over regarding ED does underline importance of this aspect. Any infringement and legal suites can easily break a smaller company.

6.0 OPPORTUNITIES

Despite all the challenges, Indian companies have invested in electronic detonator technology and are quite keen to expand the scales of manufacturing and use of EDs. This is basically because ED is a premier product and if implemented correctly can be a huge success. -. Usage of ED with proper planning and execution can greatly increase the efficiency of mining operations in India. These new EDS can be also be effectively used for road, tunnel construction, building demolition and controlled blasting.

It offers unprecedented levels of precision, safety and secure blasting which has prompted a country like China to replace all electric detonators with EDs.

7.0 CONCLUSION

Despite several challenges in its design and development, ED offers a huge opportunity for Indian explosives manufacturers. The present requirement of ED in India is quite small when compared with the global requirements but the requirement of EDs in India is likely to multiply in future and the demand will not a limiting factor in capacity building or upscaling the production. What is required is the willingness to understand various aspects of the technology and bring out reliable and cost-effective EDS for the use of mining and allied industries.

8.0 KEYWORDS & DEFINITIONS

- ASIC - An application-specific integrated circuit (ASIC), is an integrated circuit (IC) customized for a particular use, rather than intended for general - purpose use.
- Blaster [Electronic blasting machine]– a blasting machine designed specifically to communicate to a full series of electronic detonators in a blast that also has the capability to communicate, interrogate, and program as well as charge and fire the device(s).
- Chip –a assembly on Printed Circuit Board (PCB) in which the inter-connecting conductors and miniature electronic circuit components have been placed, printed, etched.
- Electric detonator – A device having a nichrome wire bridge coated with initiating explosive and with or without pyrotechnical delay element. It uses direct electrical energy from the device's leads to initiate the device.
- ED, Electronic detonator – any device containing an initiating or primary explosive that is used for initiating detonation in another explosives material and utilizes an integrated circuit and/or micro processing technology to provide communications, energy control and storage capability, timing delay information and commands in order.
- EMC – Electro Magnetic Compatibility. Radio Frequency (RF test). The ED system should neither cause other system to fail due it its own RF generation, neither it should malfunction under influence of RF generated by other devices.
- ESD – Electro Static Discharge, Discharge of static electricity generated within human body due to friction.

  Fuse head – A nichrome bridge wire coated with ignition compound
- Harness wire – the wire used to connect ED end on the surface to Blaster.
- Logger – a term used to describe a type of "on-bench" or field instrument designed to communicate with, record and/or program into, specific information for an electronic blast initiation component or detonator.
- Microprocessor - a computer processor which incorporates the functions of a computer's central processing unit (CPU) on a single integrated circuit (IC), or at most a few integrated circuits.
- SPM – Special Purpose Machine designed specifically for a given task.
- Tester - a term used to describe a type of "on-bench" or field instrument designed to communicate with, record and/or program, specific information for an electronic blast initiation component or detonator.

UN DECISIONS AND THE EXPLOSIVES INDUSTRY

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UN Consultant, Institute of Makers of Explosives(IME), USA

1.0 Summary

This paper reviews the changes in the UN Model Regulations, the Globally Harmonized System of Classification and Labelling, and the Manual of Tests and Criteria as they pertain to the explosives industry. IME participates in the fora related to these instruments. The key changes adopted during the recently completed 2017/2018 biennium include the creation ofadditional entries for electronic detonators, revision to an entry for ammonium nitrate, and a new test for AN emulsions, water gels and suspensions.

2.0 Introduction

Within the United Nations, there are two bodies whose work significantly influences national and international regulations worldwide. These are the Sub-Committee of Experts on the Transport of Dangerous Goods (TDG) and the Sub-Committee of Experts on the Classification and Labelling of Chemicals (GHS). The former develops model regulations related to the transport of dangerous goods including classification, packaging, marking, labeling, placarding, shipping papers, and other transport related activities. The latter develops recommendations for classification and provision of hazard information in the form of labels and safety data sheets for all work activities including transportation (deferring to the TDG), manufacturing, storage, distribution, use, and so forth.

A sub-group within the TDG is its working group on explosives that provides technical support related to the classification and testing of explosives under both the TDG and GHS systems. Due the specialized nature of issues related to explosives that arise at the TDG, they are assigned usually to the EWG that meets separately from, but concurrently with, the TDG. The EWG also consults with the GHS on issues related to physical hazards of explosives. The outcome of this work is reported back to the relevant sub-committee at which time a decision is taken whether to adopt or reject a proposal or to request additional information be developed before the proposal is considered further.

The two sub-committees work on a biennial basis and that work results in amendments to the following documents:

- Recommendations on the Transport of Dangerous Goods, Model Regulations (TDG, ST/SG/AC.10/1)[2] – related to transportation of dangerous goods, this manual addresses subjects such as classification, security, packaging, and hazard communication. The document serves as the basis of national and international regulations on the transport of dangerous goods.
- Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria (TDG/GHS, ST/SG/AC.10/11)[3] – this document provides logic for classification of dangerous goods under the TDG and GHS systems. The document also provides tests and criteria to support those classifications.
- Globally Harmonized System of Classification and Labelling of Chemicals (GHS, ST/SG/AC.10/30)[4] – Deferring to the TDG system where applicable, this document provides classification criteria for chemicals in all sectors including transport, manufacturing, storage, distribution, and use. The document also globally harmonizes communication elements used in hazard communication including labels and safety data sheets.

3.0 IME's participation

Various groups participate in the work of these subcommittees including member states (also known as "experts"), observer nations, UN specialized agencies, other international bodies, and non-governmental organizations (NGOs). All groups are allowed to present proposals, comment on proposals and participate in various working groups; however, only the "experts" have the right to vote on proposals.

The Institute of Makers of Explosives (IME) participates as an NGO on both the TDG and GHS sub-committees. IME's participation is led by its UN Consultant and, presently, two subject matter advisers, Dr. Noel Hsu (IME member company Orica USA, Inc.) and Dr. Jackson Shaver (IME member company Special Devices, Inc.). IME is an active participant in the work of the EWG as well, with IME's UN Consultant serving as the working group's secretary.

4.0 2017/2018 Recap

The following presents a summary of work addressing explosives and related matters completed in the 2017/2018 biennium. It should be noted that the work of the two sub-committees extends well beyond the subject of explosives; however, this paper only addresses those proposals addressing explosives.

1. **Electronic detonators** – Based on a proposal from the NGO Australian Explosives Industry & Safety Group (AEISG), the TDG sub-committee, on the recommendation of the EWG, adopted three new entries to distinguish between electronic and electric detonators To accomplish this, the TDG:
   - Added 3 new entries into the Dangerous Goods List (DGL) of Chapter 3.2 of the Model Regulations. Once published in the 21st Revision of the Model Regulations (expected in mid-2019), these entries will appear in the DGL as shown in Table 1.
   - Added UN 0512 and 0513 to the indicative list of high consequence dangerous goods found in Table 1.4.1 of Chapter 1.4 (Security Provisions) of the Model Regulations. Since all Division 1.1 explosives are included in the list, it was not necessary to add UN 0511 to the list.
   - Modified the definition of "Detonators" found in Appendix B of the Model Regulations to include a reference to electronic detonators. Beginning with the 21st Revision, the definition will appear as follows:

     Detonators

     Articles consisting of a small metal or plastics tube containing explosives such as lead azide, PETN or combinations of explosives. They are designed to start a detonation train. They may be constructed to detonate instantaneously, or may contain a delay element. The term includes:

     DETONATORS FOR AMMUNITION and DETONATORS for blasting, ELECTRIC, NON - ELECTRIC, and ELECTRONIC programmable.

     Detonating relays without flexible detonating cord are included.
   - Added a new definition to Appendix B to describe electronic detonators. That definition will read as follows:

     DETONATORS, ELECTRONIC programmable for blasting

     Detonators with enhanced safety and security features, utilizing electronic components to transmit a firing signal with validated commands and secure communications. Detonators of this type cannot be initiated by other means.

2. **UN 0222 Ammonium nitrate** – Based on a proposal from IME, the TDG subcommittee amended Special Provision (SP) 370[5] of Chapter 3.3 of the Model Regulations to clarify to what types of ammonium nitrate (AN) the 1.1D entry UN 0222 applies. The revised SP will read[6] :

   370 This entry only applies to ammonium nitrate that meets one of the following criteria:

   - Ammonium nitrate with more than 0.2% combustible substances, including any organic substance calculated as carbon, to the exclusion of any added substance; or

   - Ammonium nitrate with not more than 0.2% combustible substances, including any organic substance calculated as carbon, to the exclusion of any added substance, that gives a positive result when tested in accordance with Test Series 2 (see Manual of Tests and Criteria, Part I). See also UN 1942. This entry shall not be used for ammonium nitrate for which a proper shipping name already exists in the Dangerous Goods List of Chapter 3.2 including ammonium nitrate mixed with fuel oil (ANFO) or any of the commercial grades of ammonium nitrate.

3. **New test for UN 3375** – Extensive research was carried out by IME's member company Orica on the Koenen Test, which demonstrated thatfor certain ANEs this test generates false positives.Based on a proposal from IME and Canada, the TDG subcommittee added a new test to Test Series 8 to evaluate ANEs[7] suspected of yielding false positives in the 8(c) Koenen test due to high water content and/or the presence of low volatility oils. The new test, designated "8(e) Canmet/CERL Minimum Burning Pressure (MBP) Test", will only be used to evaluate those ANEs that fail the 8(c) test and meet criteria of

Table 1: New Electronic Detonator Entries

UN No.	Name and description	Class or division	Subsidiary hazard	UN packing group	Special provisions	Limited and excepted quantities		Packagings and IBCs		Portable tanks and bulk containers	
(1)	(2)	(3)	(4)	(5)	(6)	(7a)	(7b)	(8)	(9)	(10)	(11)
0511	DETONATORS, ELECTRONIC programmable for blasting†	1.1B				0	E0	P131			
0512	DETONATORS, ELECTRONIC programmable for blasting†	1.4B				0	E0	P131			
0513	DETONATORS, ELECTRONIC programmable for blasting†	1.4S			347	0	E0	P131			

Figure 1: New boxes added to MTC Figure 10.4

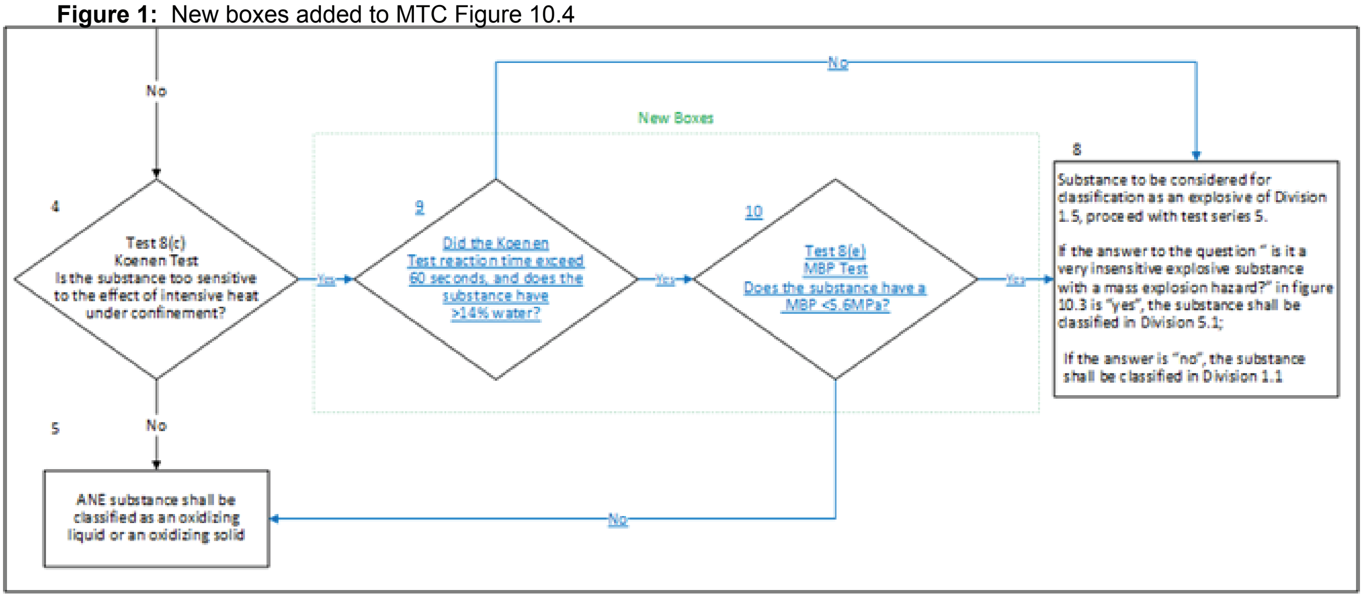
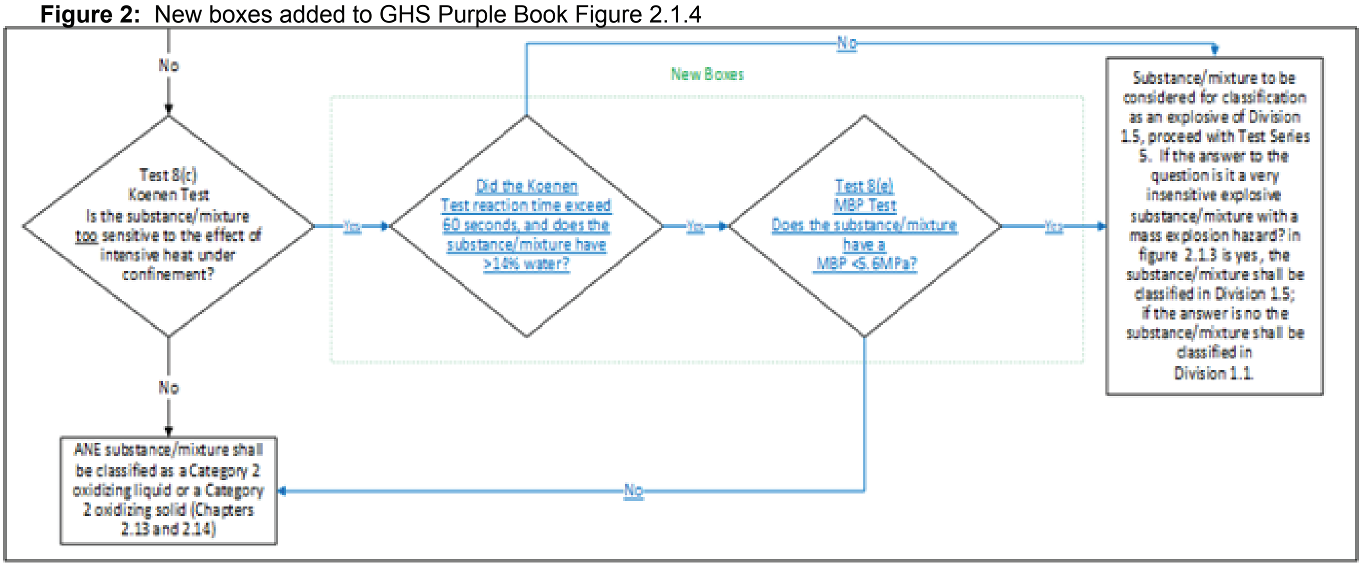


Figure 2: New boxes added to GHS Purple Book Figure 2.1.4



reaction time and water content. Several amendments to the MTC and the GHS Purple Book were required to add the 8(e) test:

- Amended the last sentence of SP 309 of Chapter 3.3 of the Model Regulations to read as follows:

  Substances shall satisfy the criteria for classification as an ANE of Test Series 8 of the Manual of Tests and Criteria, Part I, Section 18 and be approved by the competent authority.

- Inserted the 8(e) MBP test into the ANE classification flowchart in Figure 10.4 of the MTC (see Figure 1).
- Inserted the 8(e) MBP test into the ANE classification flowchart in Figure 2.1.4 of the GHS Purple Book (see Figure 2).
- Amended MTC Section 18.1 to add appropriate references to the 8(e) test:

The assessment whether a candidate for "ammonium nitrate emulsion or suspension or gel, intermediate for blasting explosives (ANE) is insensitive enough for inclusion in Division 5.1 is answered by series 8 tests and any such candidate for inclusion in Division 5.1 should pass each of the three types of tests comprising the series 8(a), 8(b), and 8(c), or if the substance failed the 8(c) and the substance had a time to reaction in 8(c) longer than 60 seconds and a water content greater than 14%, the series 8(a), 8(b), and 8(e). The test types are:

Type 8 (a):	*a test to determine the thermal stability*
Type 8 (b):	*a shock test to determine sensitivity to intense shock*
Type 8 (c):	*a test to determine the effect of heating under confinement*
Type 8 (e):	*a test to determine the effect of pressure on combustion*

- Added the 8(e) test to the list of Series 8 tests in MTC Section 18.2:

Test Code	Name of Test	Section
8(a)	Thermal Stability Test for ANE[a]	18.4
8(b)	ANE Gap Test[a]	18.5
8(c)	Koenen Test[a]	18.6
8(d)	Vented Pipe Tests[b]	18.7
8(e)	CanmetCERL Minimum Burning Pressure (MBP) Test[a]	18.8

- Amended MTC Section 18.6.1.4 to indicate when the 8(e) test can be used if a false positive is suspected in the 8(c) test:

  The result is considered "+" if three negative (-) results cannot be achieved within a maximum of five tests. In such a case, the ANE candidate may either be assigned to the class of explosives or, if the time to reaction exceeds 60 seconds and the substance has greater than 14% water, it can be subjected to Test 8 (e) (as described in 18.8) to determine whether it may be classified in Division 5.1.

- Added the new 8(e) test procedure as section 18.8. Too lengthy to be reproduced here, the procedure may be found in the 54th Session EWG Report, UN/SCETDG/54/INF.50, Annex 3, Amendment 5 (begins on page 15), available at: http://www.unece.org/fileadmin/DAM/trans/doc/2018/dgac10c3/UN-SCETDG-54-INF50e.docx

4. **New test and data to evaluate nitrocellulose** – Based on proposals from the NGO European Chemical Industry Council (CEFIC), the TDG adopted new tests and data for evaluating the stability of nitrocellulose:

   - Added two special provisions to Chapter 3.3 indicating when tests should and should not be applied:

     393 The nitrocellulose shall meet the criteria of the Bergmann-Junk test or methyl violet paper test in the Manual of Tests and Criteria Appendix 10. Tests of type 3 (c) need not be applied

     394 The nitrocellulose shall meet the criteria of the Bergmann-Junk test or methyl violet paper test in the Manual of Tests and Criteria Appendix 10.

   - Added SP number 393 to column 6 of the DGL for entries UN 0340, 0341, 0342 and 0343.

   - Added SP number 394 to column 6 of the DGL for entries UN 2555, 2556, 2557 and 3380.

   - Added Appendix 10 (Stability Tests for Nitrocellulose Mixtures) to the MTC. Appendix 10 provides test method for determining nitrocellulose stability. Too lengthy to reproduce here, the complete text of this new appendix may be found in the consolidated list of draft amendments adopted during the 51st – 53rd sessions, ST/SG/AC.10/C.3/2018/65, beginning on page 57, available at: http://www.unece.org/fileadmin/DAM/trans/doc/2018/dgac10c3/ST-SG-AC.10-C.3-2018-65e.docx

   - Reworded Section 51.4.5.1 of the MTC to read, "A compilation for the test results and classification data for more than 200 industrial nitrocellulose products is given in Appendix 11."

   - Added Appendix 11 (Compilation of classification results on industrial nitrocellulose for the purposes of supply and use according to GHS chapter 2.17, which can be used for the classification of Industrial NC products) to the MTC. Too lengthy to reproduce here, the complete text of this new appendix may be found in the consolidated list of adopted texts, ST/SG/AC.10/C.3/2018/64, beginning on page 2, available at:

     http://www.unece.org/fileadmin/DAM/trans/doc/2018/dgac10c3/ST-SG-AC.10-C.3-2018-64e.docx

5. **Use of the MTC in the context of the GHS –** over the past two biennia (2015 – 2018), the EWG was engaged in a review of the MTC with the intent to broaden the applicability of the document from solely transport-related to applicability for all sectors within the GHS system. The goal of the review was to remove references to "transport" except where essential, make the document applicable to both TDG and GHS purposes, and not affect current transport classifications. The review was completed at the end of the 2017/2018 biennium and will result in the publication of a 7th revision of the MTC. As this work continued through the last meeting of the biennium (TDG 54th session), and last minute corrections and amendments were made during that session, a clean version of all the amendments is currently pending. Readers are encouraged to look for Addenda 2 (ST/SG/AC.10/46/Add.2) to the TDG/GHS Committee report (ST/SG/AC.10/46) that, once published, will be available at:

   http://www.unece.org/trans/main/dgdb/dgcomm/ac10rep.html

6. **Review of GHS Chapter 2.1 –** also over the past two biennia, the EWG has been engaged with a GHS informal correspondence group (ICG) to review Chapter 2.1 (Explosives) of the GHS Purple Book. The mandate of this review was to review the technical criteria for assignment of explosives within the GHS to make that classification system appropriate to all sectors covered by the GHS without consequential changes to the current classification system in transport. By the end of the biennium, a 2-category classification system for GHS purposes was proposed and generally agreed by the EWG and ICG with Category 1 being those explosives that, for whatever reason, have not been assigned a transport classification and Category 2, those explosives that have been assigned a transport classification. Category 2 would be further divided into three subcategories: 2A (high hazard), 2B (medium hazard) and 2C (low hazard). In general, criteria have been tentatively agreed; however, this work will continue into the 2019/2020 biennium.

7. **Others** – The previous sections of this paper discuss major additions and amendments to the Model Regulations, the MTC, and the GHS resulting from the work of the EWG. Other amendments were also considered and adopted during the 2017 / 2018 biennium:

   - Added Division 1.6 to the indicative list of high consequence dangerous goods found in Table 1.4.1 of Chapter

1.4 (Security Provision) of the Model Regulations.

- Amended the outdated reference to "ISO 12097" in section 2.1.3.6.4(b) of the Model Regulations to read "314451-2 using a heating rate of 80 K/min". Section 2.1.3.6 deals with exclusion from Class 1 and section 2.1.3.6.4 provides the criteria for such an exclusion.
- In the Spanish edition of the Model Regulations, amended the description for "Charges, shaped, flexible, linear" (UN 0237 and UN 0288) to read "CARGAS MOLDEADAS LINEALES FLEXIBLES".
- Removed an unnecessary reference to para. 2.1.1.1(c) contained in Section 2.1.3.3.1 of the Model Regulations:

  If the substance is manufactured with a view to producing a practicalexplosive or pyrotechnic effect, it is unnecessary to conduct Test Series 1 and 2.
- Amended Section 16.5.1.4(c) of the MTC to better define what criteria should be used in determining what means of initiation to use when performing the 6(b) test on non-intentional explosive substances:

  Substances not intended for use as explosives, but provisionally accepted into Class 1, should be tested using whichever initiation system gave evidence of a mass explosion in a type 6 (a) test.

5.0 2019/2020 Biennium

The following summarizes those items that have been included on the EWG work program for the current biennium:

1. **Review of test series 6.** The mandate of this review is to remove over specifications, redundancies, impractical specifications (due to limited or no availability of test materials), and to otherwise provide improvements to the test series drawing upon decades of experience performing the tests and assessing test results.
2. **Improvement of test series 8.** Work will continue with a goal to improving the 8(c) Koenen Test used for classifying ANEs into UN 3375 (Division 5.1) and seeking practical improvements or alternatives to the 8(d) Vented Pipe Test used for evaluating the suitability of ANEs for containment in tanks as oxidizing substances (i.e., UN 3375).
3. **Review of tests in parts I, II and III of the Manual of Tests and Criteria**. Nothing specific has yet been identified for this item.
4. **UN standard detonator**. The current standard detonators, described in Appendix 1 of the MTC are no longer commercially available. Additionally, there are two versions (European and USA) of the detonator. The goal of this review is to develop a single specification that will meet the use requirements for a standard detonator and that will be readily available to those performing sensitivity tests on explosives.
5. **Review of packing instructions for explosives**. Nothing specific has yet been identified for this item.
6. **Application of security provisions to explosives N.O.S.** Nothing specific has yet been identified for this item.
7. **Test N.1 for readily combustible solids.** Nothing specific has yet been identified for this item.
8. Review of Chapter 2.1 of the GHS Purple Book. The work will continue to refine the GHS classifications generally agreed during the last biennium and to develop appropriate label and SDS specifications. Once that is complete, a rewrite of the chapter will be undertaken. Presently, the goal for completion is the end of the 2019/2020 biennium. This project will be led by the ICG chair (Sweden) with input, as needed from the EWG.
9. Energetic samples. Nothing specific has yet been identified for this item.
10. Issues related to the definition of explosives. Nothing specific has yet been identified for this item.
11. Review of packaging and transport requirements for ANEs. Nothing specific has yet been identified for this item.

6.0 UN Website.

Details of the work of the TDG and GHS sub-committees can be followed by reviewing the information available at UN's Dangerous Goods website. There, one will find information regarding meetings and meeting documents (agendas, report, working papers, and informal papers), bodies involved in the work, and publications. The website is available here: http://www.unece.org/trans/danger/danger.html

7.0 About the Author.

Active with IME since 1985, David Boston has served as IME's UN Safety Consultant since 1995. He has been an IME board member since 1992, has served as chairman of IME's Transportation & Distribution Committee, Safety & Health Committee, UN Committee, GHS Subcommittee, and several other working subcommittees.

During his tenure as IME UN Safety Consultant, David has served as head of delegation on both the United Nations Sub-Committee of Experts on the Transportation of Dangerous Goods (TDG) and Sub-Committee of Experts on the Globally Harmonized System of Classification and Labelling of Chemicals (GHS). He also serves as secretary of the TDG's Working Group on Explosives. Among other things, David was instrumental in IME's recognition by the TDG and GHS as a Non-Governmental Observer (NGO), the TDG's inclusion of a harmonized identification marking standard in that Sub-Committee's Model Regulations, and the TDG's acceptance of a non-explosive classification for ammonium nitrate, suspension, and gels.

David holds a BA in Business Administration and has worked in the explosives regulatory compliance field for more than 40 years. He founded (1993) and is president of Owen Compliance Services, Inc., the regulatory compliance division of IME member company Owen Oil Tools LP.
Born and raised in the Dallas/Fort Worth, Texas area, David still lives in the North Texas area with Patty, his high school sweetheart and wife of over 40 years. He enjoys landscape and wildlife photography in his spare time.
David can be reached at +1 (817) 551-0660 or dboston@ime.org.

Selected Abstracts from the Proceedings of "Fragblast - 12" (2018)

Lowering Cost of Mining with Wireless Detonators, the Latest Initiation Innovation

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Orica

ABSTRACT

The innovation of WebGen initiation system is in the delivery of electronic timing to blasts without wires in the blast hole. It eliminates the biggest failure mechanism of initiation systems, in wires and tubes. It also has major safety and productivity benefits. True wireless detonators, where there is no physical connection (wire/tube) between the firing transmitter and the receiver in the primer of explosives, eliminates risks and processes in Sublevel Cave mining and also dilution in Sublevel Open Stopping trials, but the opportunities for innovation in mining methodologies are wider than these. This paper explores new mining methods where the mining process has been adapted to realize the benefits that true wireless initiation systems can bring to lower mining costs while increasing security and safety of explosive use. New mining methods are being developed to sustainably exploit resources of an orebody. These developments can be driven from orebody characteristics, but also can be driven by opportunities that Orica's latest wireless initiation system brings, whereby no physical connection (wire or tubing) is present and no "hook-up" process is needed. Once the explosives are charged into the blast holes, the blast charges can be isolated from access through permanent stemming or distance from access. This eliminates the high-risk process of tying in from the blasting cycle. The charging processes can now be easily automated, thereby excluding personnel from hazardous environments, reducing labor costs and the mining cycle times can be shortened increasing productivity. New methodologies will be discussed with reference to wireless initiation's impact on mining costs, security and safety. Initial applications have been underground based but new manufacturing techniques and development of the product will see this initiation system used in all areas of mining including surface, demolition, underwater and deep well applications.

Vibration Modelling and Mechanisms for Wall Control Blasting

D. P. Blair

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ABSTRACT

A vibration waveform superposition model has been developed specifically for wall control blasting. In this model, vibrations are predicted over the flat blast zone towards the wall base, and then up over the surface of the wall itself. This requires the use of 3D coordinates (x, y, z) over the mine pit shell in order to calculate the total distances from each blasthole to a specific monitor station. The monitors are located on a uniform grid (in x-y coordinates) and vibrations predicted at (x, y, z) points typically at 201 x 201 stations. This enables a contour of vibration over the pit wall surface, and examples are given. Random fluctuations are imposed on each blasthole seed emission using low discrepancy Sobol numbers, and the duration of these fluctuations is automatically determined from an energy criterion applied to the seed waveforms. Furthermore, the scatter associated with the delay times, charge weight fluctuations and randomizing the transverse component of vibration are all imposed using independent Sobol numbers. Due to the large range in relative distances involved, an approach is also given for a seed waveform morphing method to yield smooth changes in seed waveforms with distance; this is more realistic than assuming constant seeds or seeds that change according to uniform attenuation models. Single blasthole models are also used to show the potential of centre-priming and air-decks to reduce wall impact. The association between vibration and wall damage is also considered. In this regard, it is typically assumed that there are other wall damage mechanisms, such as gas penetration and bulk movement; however their role is questioned.

Implementation of 100% used oil to replace fuel oil in emulsion manufacturing for energy conservation at PT. Kaltim Prima Coal

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[1] PT. Kaltim Prima Coal, Indonesia
[2] PT. AEL, Indonesia

ABSTRACT

PT. Kaltim Prima Coal produces roughly 10.4 million litres of used oil per year, which originate from the repair activities of equipment performed at the different workshops. One of the solutions to recycle used oil is to manufacture emulsion explosives. In 2016, the level of used oil in emulsion manufacturing at the KPC operations reached 80% used oil and in 2017, the level was increased to 100%. Laboratory-scale trials are conducted with emulsion technology to prove that the quality of emulsion (stability, crystallization) meets the standards for a minimum period of seven days. The successful trials were validated as the VODs was over 4500 m/s, P30 fragmentation 80% and digging time below the 12 seconds target. The results of the trials proved the viability of the utilization of 100% used oil in the KPC operations, the highest level reached to date in Indonesia.

Emulsion Characterization with Cylinder Test and JWL Parameters Determination

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ABSTRACT

A microspheres-sensitized emulsion, to be used in blasting tests in the SLIM project, is characterized by means of the cylinder test. This test measures the expansion of a copper tube after the detonation of an explosive charge inside. A total of 8 tests have been made with two diameters (50 mm and 100 mm) and two densities (1.18 g/cm3 and 1.03 g/cm3) in a 2×2×2 test matrix. The influence of density and diameter on the expansion energy has been studied, showing that the density affects but the diameter apparently does not, which suggests that this explosive, at the densities studied, behaves close to ideal already at 50 mm. The Jones–Wilkins–Lee (JWL) equation of state parameters have been obtained for this emulsion at the densities and diameters tested. These parameters have been validated with LS-DYNA Lagrangian models, with an outstanding correlation between the model and the test results. The JWL parameters are being used for the explosive modelling in rock blasting tests simulations.

A Pit to Gate Multivariable Cost Control Model

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[2] Centre for Exploration Targeting, School of Earth Sciences, University of Western Australia

ABSTRACT

The mining industry requires accurate choice of blasting decision variables (including for example drill hole spacing and blast charge), so as to minimise the combined cost of drill & blast and crushing (ore prep) operations. This issue is relevant both in designing new plants and in continuous process improvement for existing plants. We present a model and a corresponding mathematical method to find the best apportionment of investment between blasting (fragmentation) and process (crushing) costs to provide the overall lowest cost of production and thus maximise downstream contribution for new and existing plants. This paper considers the process from mine to gate, assigning optimal values to the relevant decision variables. Case studies of ore fragmentation optimisation previously presented have been on a local level and addressed sub-system optimisation. This paper considers a mathematical methodology, providing a generic tool that considers the overall process as a total system. The method will be demonstrated using a hypothetical worked example, considering the solution to a common situation of fragmentation versus process investment.

Improving Downstream Performance Through a Highly Flexible Energy Explosive

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MAXAM Terra Solutions, Madrid

ABSTRACT

In times of scarce resources, declining ore grades and demanding environmental and safety commitments, sustainable mining strategies are a key for long term mining. This scenario raises the concern of how efficiently the energy is used in all unit operations and processes, especially in the comminution phase. Any mining, quarrying or excavation can be regarded as a set of interconnected processes, where energy is consumed in a sequence and where the performance of downstream operations is potentially influenced by the initial energy input. From this viewpoint, the influence of blasting on other unit operations is well known. The conscious use of an explosive with adjustable energy outputs in a certain rock mass strongly contributes to reduce the total energy consumption in the mining processes by improving downstream energy use. The controlled release of the detonation energy contributes to maximize rock fragmentation and heave during blasting process. This paper explores the use of a non-aluminized adjustable energy explosive for blasting and its role on performance of downstream unit operations in mining applications. This watergel bulk explosive has highly flexible energetic properties and a broad range of densities. Finally, some practical cases studies show how the energy released by the explosive during a detonation improve the unit operations downstream by lowering loading time, increasing the haulage efficiency and improving crushing and milling performance.

Study on the Influence of Long Term Frequent Blasting Vibration on Buildings and Human Body

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[2] Southwest Jiaotong University, Chengdu, P.R. China

ABSTRACT

The blasting vibration will affect neighboring buildings and human, the safety value of blasting vibration is clearly defined. However, in the actual project construction, although the vibration on the buildings within the standard range, there are still concerns, complaints, or even blocking, because of the impact of blasting vibration. This has a negative impact on social harmony and progress of the project. In order to find out the cause of the problem, the blasting operation points were tracked for a long time, and a large amount of data were obtained by means of blasting parameters recording, blasting vibration monitoring, building damage observation and household physical and psychological investigation. Comprehensive analysis of the data shows that, although the blasting vibration in the standard range will not affect the safety of the building structure and the surface, long term frequent vibration can cause damage to buildings and form apparent damage. Based on the analysis of the influence of blasting on buildings and human body, it is concluded that the control value of long term blasting vibration velocity is 0.2 cm/s. The results are meaningful for the establishment of long term frequent blasting vibration control standards, and to resolve the contradiction between 'disturbing' and 'disturbed'.

RECENT PATENTS OF INTEREST (2018)

EXTENDED BULK EXPLOSIVES AND METHOD OF MAKING

Inventor(s): FIRTZ MICHAEL ALAN [US] ± (Firtz, Michael Alan)

Application(s): FIRTZ MICHAEL ALAN [US] ± (Firtz, Michael Alan)

Classification: **- international: C06B21/00; C06B23/00; C06B31/28; C06B45/02**
- cooperative: C06B21/0091; C06B23/003; C06B31/285; C06B45/02

Application number: US201715463236 20170320 Global Dossier

Priority number(s): US201715463236 20170320

Abstract of US2018265426 (A1) - 2018-09-20

ABSTRACT

A resulting extended bulk explosive and the process for preparing and blending oil shale particulate with bulk explosives is provided, whereby the extending bulk explosive reduces its detonation velocity. The process includes the proper preparation of oil shale granulates to gain different cost effects and performance levels with predetermined blending percentages. The oil shale granulates may be crushed, screened, dried and prepared for blending in accordance to the disclosure of the present invention.

AUTONOMOUS SYSTEM FOR INITIATING INDUSTRIAL EXPLOSIVES

Inventor(s): PETROV YURIJ SERGEEVICH [RU]; ROGACHEV LEONID VIKTOROVICH [RU]; SAKHANSKIJ YURIJ VLADIMIROVICH [RU] ±

Application(s): FEDERALNOE GOSUDARSTVENNOE BYUDZHETNOE OBRAZOVATELNOE UCHREZHDENIE VYSSHEGO OBRAZOVANIYA SEVERO KAVK [RU] ±

Classification: **- international: F42D5/055**
- cooperative: F42D5/055 more

Application number: RU20170139823 20171115

Priority number(s): RU20170139823 20171115

Abstract of RU2665582 (C1) - 2018-08-31

ABSTRACT

FIELD: blasting operations.SUBSTANCE: invention relates to blasting, in particular to electrical charge explosions, and can be used in mining, construction and other areas. Autonomous system for initiating industrial explosives includes an external power source, a microcontroller and a switching device. Solar battery is used as an external power source, and the autonomous system is additionally equipped with a battery controller, a battery, a storage capacitor, an electronic key, a unit for monitoring the parameters of the electric blast circuit. Solar battery is connected to the battery controller, the output of which is connected to the storage capacitor, and the outputs from the battery controller are connected to the battery and the microcontroller, wherein the outputs from the battery and the microcontroller are connected to the inputs of the battery controller, and the output from the storage capacitor is connected to the switching device. Output of the battery is connected to the electronic key the input of which is connected to the microcontroller and the output from the electronic key is connected to the input of the unit for monitoring the parameters of the electric blast circuit the output of which is connected to the microcontroller. Output of the microcontroller is connected to the input of the switching device. Output of the switching device is connected to the electric blast circuit, which is connected to the unit for monitoring the parameters of the electric blast circuit.EFFECT: technical result consists in increasing safety and failure-free operation in dust and gas hazardous conditions and in eliminating sparking.1 cl, 1 dwg

SPECIAL REPORT

IME

Institute of makers of explosives

The safety and security of the commercial explosives industry since 1913

ISSUE BRIEFS (2018)

We are presenting below a selected set of 'Issue Briefs' that were prepared by IME during 2018, to assist the Legislators and the Regulators in formulating policies and standards with regard to Safety and Security of commerce and use of explosive products in the USA. This forms a part of the continuing serial on IME Issue Briefs, started with the 10th edition of the Journal.

Editor

1.0 ATF Rulemaking

Issue: Does ATF's reliance on interim final rules (IFR) disregard congressional intent for issuing explosives regulations?

Background: Federal Explosives Law obligates ATF to take into account industry safety and security standards when issuing rules and requirements. The commercial explosives industry has endeavored to fulfill this obligation through the development of industry best practices for safety and security, participation in relevant standard- setting organizations, and forums for training. We have offered ATF recommendations that we believe will enhance safety and security through participation in the rulemaking process, in the Bureau's research efforts, and in other standard setting activities.

Discussion: ATF currently has several open rulemakings of interest and concern to the explosives industry. The oldest was proposed in 2003. It resulted from the enactment of the 2002 Safe Explosives Act (SEA) and was issued as an "interim final rule" (IFR). IFRs are enforceable without public input as to the effect of the rule on the regulated community. Subsequently, IME raised a number interpretative questions and concerns about the IFR provisions which are critical to the continued commerce of commercial explosives. Although Congress has directed ATF to address these long-standing rulemaking concerns, ATF continues to delay the projected date for finalizing this IFR.

In the absence of rulemaking that is capable of keeping up with new developments and practices, industry must rely on interpretive guidance and variances from rules to conduct business. While we appreciate the Bureau's accommodations, these stop-gap measures do not afford the protections that rulemaking would provide the regulated community, nor does regulation by variance allow the oversight necessary to ensure that all parties are being held to the same standard of compliance. These regulatory tasks may be at odds with ATF's vision as a law enforcement agency, but they are critical to the lawful conduct of the commercial enterprises the Bureau controls. In addition, the continued reliance on an IFR runs counter to the spirit of section 610 of the Regulatory Flexibility Act. Section 610 directs agencies to review rules within ten years of the publication of final rules. Although the SEA IFR has been in effect over 14 years, it has not been subject to public review to determine whether or not changes to requirements are warranted.

Recommendations: ATF should not rely on IFR as a regulatory tool. The Bureau should re-open the rulemaking petition filed by industry, and should otherwise, allow stakeholders to submit comments to update and clarify IFRs that have been pending for years.

2.0 DOT's Jurisdiction to Regulate the Transportation of Hazardous Materials

Issue: Should DOT's jurisdiction to regulate hazardous materials loading, unloading and handling be clarified?

Background: The commercial transportation of hazardous materials is highly regulated under national uniform standards which account for a commendable safety record, despite moving millions of tons of material over 1.2 million times a day. Statistics show that of the approximately 4,400 deaths and about 2.9 million injuries to workers each year in America, on average, less than 10 deaths and 24 major injuries are attributable to hazmat transportation workers. Hazardous materials "transportation" is defined to include the loading, unloading and storage incidental to the movement of these materials. "Hazmat employees" include those that "load, unload, or handle hazardous material."

Discussion: A reformatting error, codified in Federal Hazardous Materials Transportation Law (FHMTL), grants Occupational Safety and Health Administration (OSHA) and DOT overlapping jurisdiction with respect to the handling of hazardous materials transportation. This overlap undermines the statute's goal of regulatory uniformity for hazmat transportation, and has led DOT to relinquish jurisdiction in areas related to loading, unloading, and handling. Duplicative and/or inconsistent regulation of this activity confounds industry's compliance efforts. OSHA made one attempt to rewrite rules concerning explosives transportation under this new authority, but aborted the effort. The erosion of a single-source, uniform regulatory framework is exacerbated by the fact that the Occupational Safety and Health Act allows differing State requirements. Subsequently, the National Transportation Safety Board (NTSB) and the Chemical Safety Board (CSB) both have recommended that DOT reassert its regulatory authority for loading, unloading, and handling. Most recently, after a series of rail incidents, the Rail Safety Advisory Committee (RSAC) is also recommending that DOT step in to reregulate private rail sidings and transloading facilities.

Recommendations: IME supports efforts to clarify DOT's authority by eliminating overlapping jurisdiction for handling criteria, restoring DOT's primacy to this critical area. At the same time, OSHA authority for the protection of employees responding to a release of hazardous materials should be preserved. OSHA continues to share jurisdiction with DOT for hazmat employee training, as was the original intent of Congress. Any additional expansion of OSHA's overlapping jurisdiction must be resisted because it would greatly complicate industry's ability to comply with different safety standards.

3.0 Ammonium Nitrate Detonability Question

Issue: Is ammonium nitrate (AN) prill a Class 1 explosive or not?

Background: Since the tragic 2013 incident at West, TX involving AN, some assert that AN has a TNT detonability equivalence of 0.72, a metric closely approaching the globally-accepted value of "ANFO" (ammonium nitrate fuel oil), a Division 1.5 explosive[1]. Others assert that the technical grade of AN (TGAN) used in the explosives industry is inherently "explosive" while the fertilizer grade (FGAN) used in the agricultural industry is not.

Discussion: AN is a stable, noncombustible chemical compound. The chemical structure of TGAN and FGAN is the same, NH_4NO_3. The only difference is the density of the finished prill. TGAN is less dense than FGAN.

AN is not an explosive. It has been classified as an oxidizer by the U.S. Department of Transportation (DOT) and by the National Fire Protection Association (NFPA) based on prescribed tests[2].

While AN prill is not an explosive, it can detonate under extreme conditions such as shock from an explosion or intense and sustained heat because it contains an ammonium molecule (NH3) which acts as an inefficient fuel – meaning that there is not enough fuel to consume all the oxygen supplied by the NO3 molecule. In a fire, AN can melt[3] at 337 F° and decompose at 410 F°. This physical change increases the likelihood of a thermal explosion. Likewise, AN that is exposed to a shockwave from an explosion may be heated from the extreme compression to the point of decomposition and may detonate if the pressures are high enough and sustained long enough. When melted, there is no difference between FGAN and TGAN.

Determining a TNT equivalence based on this inefficiency has produced a range of results. The highest theoretical value in this range, based on the Thermodynamic Code "TDS", predicts a 0.42, not a 0.72, TNT equivalence. This means that the maximum amount of energy that could be expected from a detonation of AN would be no more than 42% of same amount of TNT[4]. Other subject matter expert sources have predicted ratings as low as 0.25 TNT equivalence[5]. The explosive inefficiency of AN also accounts for the fact that not all product will contribute to the detonation.

Recommendations: Additional studies and testing may validate or lead to reducing the TNT equivalence for AN. Until testing shows otherwise, AN prill, if managed properly, is an inert material which will not detonate. In the meantime, emergency responders should be trained not to attempt to fight that have engaged AN and to evacuate at-risk populations.

1. Blast Effects Caused by Explosions, US Army, London, 2004. The explosive value of ANFO is 0.75 TNT equivalence.
2. DOT classifies AN prill as a Division 5.1 oxidizer meaning that "the material may, generally by yielding oxygen, cause or enhance the combustion of other materials." NFPA uses four ratings for oxidizers that cover materials capable of increasing the burning rate of combustible materials and which may cause spontaneous ignition when in contact with a combustible material. Under this system, AN is a Class 2 oxidizer, with "4" being the most reactive.
3. AN does not burn. It is its own oxygen source.
4. "Ammonium Nitrate – Fertiliser, Oxidiser and Tertiary Explosive," Dr. Martin Braithwaite, 10OCT2008. "Army Field Manual 5-250," 15JUN1992, pgs. 1-2.
5. Loss Prevention Data Sheet 7-89, FM Global, APR2013, predicts 0.33 TNT equivalence; Good Practice Guide for the Safe Storage of Solid Technical Grade Ammonium Nitrate, SAFEX, MAR2014, predicts 0.33 TNT equivalence; and the U.S. Chemical Safety Board in a letter to EPA on Docket EPA-HQ-OEM-2014-0328, 29OCT14, pg. 4, predicts 0.25 TNT equivalence.

4.0 Fumes from Blasting

Issue: Should the Department of Interior's Office of Surface Mining Reclamation and Enforcement (OSMRE) promulgate a standard prohibiting visible emissions from blasting operations?

Background: In April 2014, WildEarth Guardians (WEG) petitioned OSMRE to consider a rule to prohibit the production of visible nitrogen oxide (NO_2) during blasting operations for coal mining activities. IME believes that such a standard would be unattainable on a reliable and consistent basis.

Discussion: The detonation of explosives involves a chemical reaction that unavoidably results in the production of certain gases. While steps can be taken to help reduce the production of gases, they cannot be eliminated altogether. During blasting operations, ideal conditions are rarely, if ever, encountered. The contamination of the explosives products with ground or surface water and drill cuttings, reactivity of the explosives with the rock or other materials being blasted, instability within boreholes, and subsurface geological formations will impact emissions. All of these frequently encountered and largely uncontrollable elements affect the explosive quality and chemical kinetics of the product.

While attempts can be made to minimize emissions, the environmental variables discussed above cannot be eliminated or influenced in a manner that would allow the categorical "prevention" of visible emissions in all cases. There is no way to prospectively determine, from a technical or scientific perspective, whether all conditions affecting blasting will be optimum from shot to shot.

In addition, we do not agree that varying opacity of visible emissions generated by blasting can be equated to the concentration of NO_2 in the "cloud." Because of the inherent difficulties involved in obtaining direct measurements of particular gases in post-blast emission clouds, opacity monitoring has been used as a fall back measure to alert workers and the public of the presence of some amount of NO_2. Opacity is not, however, an accurate means of determining actual concentrations of the chemical. Color perception is highly subjective and is influenced by numerous other factors including the intensity of the sunlight, the perspective/location from which a visible emission is viewed, the presence of other particulates in the ambient air, and the background against which an emission is viewed. It cannot be used as a measure of regulatory compliance.

Existing regulations administered by OSMRE, EPA, and MSHA also safeguard mine employees and surrounding communities. These regulations, in tandem with the voluntary efforts of mine operators in implementing extensive administrative controls operate in unison to successfully ensure the safety of workers and the public.

Recommendations: IME recommends that mine operators continue to work with blasters within the confines of current regulations, augmented by administrative controls, to minimize emissions. No additional regulatory action is necessary at this time.

5.0 Permissible Explosives Approvals

Issue: The government has lost its ability to ensure a safe supply of permissible explosives for the nation's coal miners.

Background: In 1913, the U.S. Bureau of Mines (USBM) was created to address a rash of fatal coal mining explosions by developing and encouraging the use of safer "permissible" explosives. Today, USBM's regulatory heir, the Mine Safety and Health Administration (MSHA), does not have the ability to evaluate the safety of these products.

While permissible explosives usage declined with the advent of mechanical means of coal removal, the market has stabilized, and today, about 4.5 million pounds of permissible explosives are consumed in the U.S. annually. Most of these products are used for development of coal mines and disposal of rooffalls to ensure adequate ventilation where mechanical means of accomplishing these tasks are impossible. Permissible explosives are unique in that they generate a lower temperature, and a shorter duration flame. These qualities lower the probability of igniting methane or coal dust, a potentially disastrous event.

The only way to evaluate these critical safety-related properties is to conduct elaborate tests. The government has not conducted these tests for over 18 years, the equipment is in disrepair, and the corporate knowledge needed to conduct the tests is slipping away into retirement. The government laboratory where permissible testing was conducted for 80 years has decided to abandon not just permissibility testing, but all explosives-related research.

Discussion: This situation must be corrected:

- MSHA does not have the ability to evaluate whether the explosive products being used in the mine met regulatory specifications.
- MSHA has the regulatory authority to conduct quality control testing by taking samples from mines and testing them but, with no adequate laboratory, cannot. Ironically, MSHA has called into question the applicability of certain approvals; demanding that the approval holder prove the explosive will perform as originally approved, something MSHA should be doing on its own. IME believes that such activity is vital to ensuring a safe supply of permissible explosives.
- There are only three locations in North America (NA) that manufacture MSHA-approved permissible explosives and only two in the U.S. One of these locations has the only plant in NA that can make permissible dynamite. Plant accidents, shut downs, and other incidents could combine to shut down all or most of the domestic supply of approved permissibles. This would create dependency on foreign-made explosives without the ability to test them and ensure they meet US standards.
- Without the ability to test new permissible explosives, future improvements in explosives technology will be kept out of coal mines.

Recommendation: Congress should explicitly fund MSHA to reestablish a location where the permissible tests can be conducted and to provide continuing annual funding to support the effort.

6.0 Strengthen OSHA Regulations Covering Ammonium Nitrate (AN)

Issue: After more than 45 years, should the regulations covering manufacture and storage of AN under OSHA rules found at 29 CFR 1910.109(i) be updated?

Background: After the 2013 tragedy of the West Fertilizer explosion and fire, later to be determined by the ATF to be intentionally set, IME worked with the Chemical Safety Board (CSB) to educate the CSB on industry practices as they investigated the matter. IME also worked with safety organizations and our industry partners to determine if there was room to improve the current regulations.

Since 1971, the manufacture and storage of AN has been regulated under OSHA rules found at 29 CFR 1910.109(i) that specifically address the unique properties of this material. There has been no known accidental detonation of AN where a facility has been compliant with this OSHA standard.

In addition, AN is subject to a number of other ATF, EPA, DHS, and DOT safety and security regulations and advisories. The insensitivity of AN renders the material highly unlikely to mass-detonate during manufacturing, storage, and transportation. DOT acknowledges AN's insensitivity, classifying it as a Division 5.1 oxidizer and listing it as a "Table 2" not "Table 1" material. The "technical" grade of AN (TGAN) used in the explosives industry has the same chemical composition as the "fertilizer" grade of AN (FGAN) used in agriculture; only the density of the prill is different. AN, in either form, is not self-reactive and does not pose a threat of an accidental release of energy or fumes unless subjected to substantial and sustained heat (e.g., fire) or shock from high explosives.

Discussion: EPA considered expanding the Risk Management Program (RMP) to cover AN, eventually deciding against it. OSHA has determined in several prior rulemaking actions that AN-based blasting agents do not pose the type of threat that PSM requirements are intended to address. Nevertheless, according to the latest Regulatory Agenda, OSHA continues to review if pure AN should be subject to the extensive Process Safety Management (PSM) requirements.

While these governmental bodies conducted their reviews of AN, IME, the safety and security arm of the commercial explosives industry, developed and published Safety Library Publication

Number 30 (SLP-30) describing the best practices used by the explosives industry to safely manage AN. SLP-30 can be found under publications at www.ime.org.

Recommendations: SLP-30 captures all relevant federal regulations and industry best practices in one document. IME continues to believe that existing regulations, if followed, are protective of workers and the public, with two major exceptions. OSHA's 29 CFR 1910.109(i) regulations should be updated:

(1) to require noncombustible materials for bins and structures used to store AN; and,

(2) to train emergency responders to evacuate at risk populations when fire has engaged the AN, not to attempt to fight such fires. The current regulations, as evidenced by a 45-year safety record of no accidental detonations, have proven effective for decades. By updating the regulations IME hopes to keep workers and the public safe for the next 45 years.

7.0 Taggants In Explosives

Issue: Should taggants be mandated in commercial explosives?

Discussion: Taggants can refer to two types of marking technologies. Detection taggants are used to detect explosives before detonation. Identification taggants are intended to be used to trace explosive materials to their source before and after detonation.

The Antiterrorism and Effective Death Penalty Act of 1996 (ATEDPA) requires detection agents for plastic bonded explosives (PBX). These agents enhance the detection of PBX which has historically been used by terrorists around the world. It is possible to add these detection agents to PBX without compromising their intended performance. IME supports the marking of PBX with detection agents. However, identification taggants present a different story.

From time to time, efforts are made to require identification taggants in explosives. The ATEDPA mandated a study of the feasibility of placing identification taggants in industrial explosives. The Bureau of Alcohol, Tobacco, Firearms, and Explosives (ATF) was tasked with this responsibility and The National Academy of Sciences (NAS) was contracted to conduct a third-party examination.

IME has worked closely with both the ATF and NAS to ensure that industry data was available to complete the study. The NAS report, completed and issued in March 1998, concluded:

> "At today's level of threat, it is not appropriate to require commercial explosives to contain identification taggants … All of the taggant technologies currently available raise concerns about long-range environmental consequences, effectiveness in law enforcement, safety issues, and costs."

The ATF issued an Interim report in March 1998 and also concluded:

> "At this stage of the Study it is clear that … there are remaining complexities surrounding the issue. Any effort which is to have a measurable impact on the prevention and investigation of bombing incidents must be an integrated one, involving the effective regulation of explosives and explosive materials, the effective enforcement of those regulations, and the effective application of cutting edge technologies."

IME's position is consistent with these findings:

- Less than 1 percent of the bombings in the United States involve commercially manufactured high explosives.
- Identification taggants can dangerously increase friction sensitivity when added to the manufacture of high explosives, and their benefit to law enforcement is disputed as taggants may complicate the investigation and prosecution of bombings.
- The substantial costs associated with placing taggants in commercially manufactured high explosives are not justified by the minimal benefits.

Recommendation: Any mandate for the addition of identification taggants must be based on sound science and a cost-benefit analysis. It is not in the best interest of the industry, public, the environment, or law enforcement to mandate identification taggants in commercial explosives at this time.

8.0 Drone (Unmanned aircraft Systems/UAS) Safety & Security

Issue: What safety and security concerns about the operation of drones justify federal control and regulation?

Background: The use of drones and advances in UAS technology are on the rise. Currently, drones are beneficially used by a wide range of industries. The explosives industry relies on drones to assess the safety of re-entering post- blast sites at mines and quarries. Critical infrastructure, including explosives manufacturing sites, benefit from the use of drones to inspect process pipes for leaks, examine flare stacks for maintenance issues, and even assess tanks when it would be too dangerous for a person to enter. Drone technology that would safely allow flight beyond the line of sight of operators and use at night are examples of technological advances that would greatly benefit industry.

Despite their potential beneficial uses, there have been numerous incidents of drones conducting unauthorized flights over critical infrastructure. Some fly- overs may be by unknowing hobbyists. However, drones can be used for surveillance or mapping of a critical infrastructure site. Drone video footage of our nation's critical infrastructure has been posted to websites such as YouTube without consent of the owner/operators of the facility. As such, bad actors could use this information for nefarious purposes, including to attack critical infrastructure. There are also real and present safety concerns with unauthorized drones flying over or making contact with a critical infrastructure facility. A drone that crashes, or if it is armed, could cause significant damage and injury.

State legislatures across the country have been actively moving UAS legislation forward. In 2016, at least 38 states considered legislation related to UAS, and 22 states passed legislation or resolutions, or issued executive orders related to UAS. While state engagement is welcome, a patchwork of differing state laws and regulations will ultimately make compliance more difficult—for both UAS manufacturers and users.

Discussion: In response to these concerns and needs, Congress set the stage for a streamlined, national policy approach on the use of drones when it enacted P.L. 114-190, the FAA Extension, Safety, and Security Act of 2016. This legislation streamlines the processing of applications for commercial operation of UAS, sets up procedures for flying beyond line of sight, and a process to restrict airspace over critical infrastructure from unauthorized UAS flights. In the meantime, we are concerned that FAA is falling behind in its implementation of UAS provisions in the act, including how "critical infrastructure" is defined.

Recommendation: We support the safe use of drones and we do not want to limit this new innovative technology. However, as Congress considers legislation for a long-term authorization of the FAA Act, we request thee items:

(1) Preserve the language included in P.L. 114-190 Sec 2210(c)(2), to direct FAA to use DHS' definition of "critical infrastructure" rather than use scarce resources to invent another competing definition;

(2) Ensure that there are appropriate penalties for those who violate restricted airspace above critical infrastructure with UAS overflights; and,

(3) Define under what circumstances the owners of critical infrastructure may legally disable rogue drones that are perceived to be a direct threat to the safety of employees or the public.

Only safe worker can
make a CONTRIBUTION.
Are you?

Worker Participation Can Help Create Safer Workplaces

It is important to engage workers at all levels in establishing, implementing, and improving safety and health in the workplace. Workers should understand that they are a valuable partner in making their workplace safer and be encouraged and able to communicate with management about hazards on the job.

(Courtesy OSHA News Letter)

SPECIAL REPORT

SAFEX INTERNATIONAL

Safex International

Safex Incident Notices: October, 2017 to October 2018

Summary				
	Activity			No. Of Incidents
*	Fixed Plant Manufacturing:			
		HE		3
		Explosive Accessories		5
				8
*	Mobile Manufacturing Unit (MMU):			-
*	Handling:	Within Plant Area		-
		Outside Plant Area		-
*	Storage:			-
*	Transportation:		Vans	2
			MMU	-
				2
*	Waste / unused explosives disposal, etc.			-
				TOTAL 10

Almost all the incidents were due to human errors arising from lack of due diligence during supervision/lack of awareness.

-Editor

1 INCIDENT TITLE: Transportation Event (ANE) USA

When did it happen? July 12, 2018

Who experienced it? Carrier for Orica USA Inc

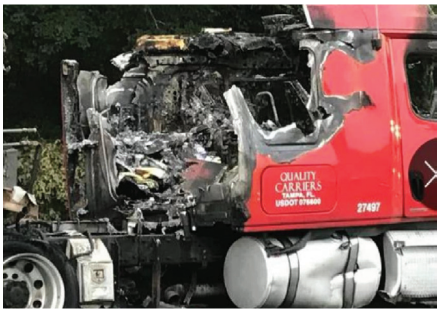
Where did it happen? Highway I-85 in South Carolina

What material was involved? AN emulsion, UN 3375

What happened? Tractor pulling the tanker trailer blew its front tire. The driver lost control of the vehicle crossing the median striking three other vehicles en route. The cab caught on fire while crossing the median.

Why did it happen – theory? Blown tire created an instability that the driver could not correct.

What was the impact? Minor injuries to the carrier driver and the struck vehicles' occupants. Residents were evacuated to a 1-mile radius. The AN emulsion in the tank was transferred to another tanker once the fire was put out.



2 INCIDENT TITLE: Fire during Transport of AN Solution:Australia

When did it happen? April 22, 2018

Who experienced it? Orica

Where did it happen? North Meekatharra, Western Australia

What material was involved? AN solution in ISOtainers.

What happened? The driver (contractor) smelled smoke while in transit. The smoke was from fire engulfing the cabin area. The driver safely parked the vehicle, disconnected the prime mover from the trailer, and left the area. The emergency response team was contacted, and they arrived a short while thereafter.

Why did it happen – theory? The most likely cause of the fire, as investigated by the contractor, was an electrical fault in the prime mover. The exact source and location of the fault was however not identified.

What was the impact? No injuries. The prime mover was a write-off, and there was fire damage to the front of the trailer.

3 INCIDENT TITLE: Air Blower Explosion, Mexico

When did it happen? Saturday, August 12, 2017

Who experienced it? Austin Star Detonator

Where did it happen? Lead azide drying building in Matamoros / Mexico

What material was involved? Dust of lead azide

What happened? Explosion of an air blower in the dust exhaust system of the lead azide drying building.

Why did it happen – theory? In one of the bays of the lead azide drying building, a malfunctioning air blower had been replaced with a new blower that was inappropriate for this area (incorrect spare part). This blower was operating with a higher air flow compared to the others installed in the ventilation system and due to its design allowed lead azide dust to accumulate. The system had been cleaned sporadically, but not after a regular maintenance schedule. After the incident, additional filter gauzes were installed in the ducting. All relevant procedures were reviewed and updated.

Why did it happen – theory? There were no injuries. The material damage was limited to the air blower and its mounting structure.

4 INCIDENT TITLE: Fusehead Initiation - Spain

When did it happen? Not available

Who experienced it? MAXAM

Where did it happen? MAXAM Initiation Systems (Quality Laboratory)

What material was involved? Preparing rejected seismic fuseheads for testing in the Quality Laboratory

What happened?

While the Quality Inspector was preparing rejected fuseheads for testing, an initiation of 24 fuseheads took place.

The box with the fuseheads is made of static dissipative plastic and is divided into 12 compartments capable of taking 25 fuseheads each as a safety precaution to minimise the effect of the explosion in case of accidental initiation.

The Quality Inspector uses a magnet to extract the fuseheads from the compartments. This method has been used for years without incident.

The initiation occurred as the magnet was introduced into the compartment to extract the fuseheads.

Why did it happen – theory?

It is difficult to determine with absolute certainty what the root cause of the incident was. Three scenarios were analysed:

Electrostatic Discharge

- • The employee was wearing the required PPE and clothes. Conductivity of shoes was checked at the start of the shift.
- • The surface of the table and the matting were correctly earthed to dissipate static.
- • Although the humidity was below the recommended value of 65% ,redundant measures were in place to ensure there was no spark from a sudden electrostatic discharge.

Mechanical Impact or Friction

- • The magnet did not impact the fuseheads by dropping or similar.
- • One possibility could be a fusehead impacting the magnet due to the attractive force. As this force has been applied in the same way over many years with no negative outcome, the likelihood of this hypothesis

Comment

Actions to Prevent Reoccurrence

- **Use of magnets has been discontinued and removed from plant.**
- **Box design have been changed to allow manipulation of fuseheads without magnets.**

5 INCIDENT TITLE: Fusehead Initiation:Sweden

When did it happen?	April 09,2018
Who experienced it?	Orica Sweden, Gyttorp Site
Where did it happen?	Room for cutting of fusehead reel
What material was involved?	Fusehead pyrotechnic material
What happened?	While the operator was lifting a fusehead reel to be placed into the cutting machine the reel underneath it was stuck to it. The stuck reel released very shortly thereafter and ignited when it fell onto the reels beneath it. The result was a rapid ignition of the fallen reel, the remaining 12 reels on the transport cart, as well as the reel in the hands of the operator. The rapid ignition of all these reels produced a deflagration within the room.
Why did it happen – theory?	The energy from impact and friction from the falling reel contacting the reels beneath it was sufficient to ignite the fuseheads and result in a deflagration.
What was the impact?	The operator, who was outfitted with fire-resistant clothing sustained a laceration to the forehead and a broken right arm from the event. The room was damaged although the damage was limited since the blowout panel functioned as designed.

6 INCIDENT TITLE: HMX Explosion:India

When did it happen?	June 19 at 18:50.
Who experienced it?	Solar Industries India Ltd.,India
Where did it happen?	HMX Manufacturing Plant
What material was involved?	HMX
What happened?	During the second shift at around 6.50 PM in PP6 (HMX Manufacturing plant) , a loud sound was heard . No production work was in progress. But the recovery operation of solvent in the Crystallizer was going on. There was a reported choking in the outlet line of pressure filter and the filtration process was stopped for the previous 2 days. To clean the outlet line, the operator, and his helper were engaged. The helper reportedly tried to clean the line after removing the viewing glass at mezzanine floor. During the cleaning process there was an explosion. The helper sustained serious injuries on the right part of his body and was immediately rushed to the hospital in Nagpur by ambulance but expired on the way. There was no injury to the other operator.
Why did it happen – theory?	The most probable cause could be the use of excessive force in trying to clear the choke in the pipeline. Details would be available once the investigation, which is going on, is completed.
What was the impact?	There was no major damage to the building or other equipment inside the building. Nearby buildings were also not affected.

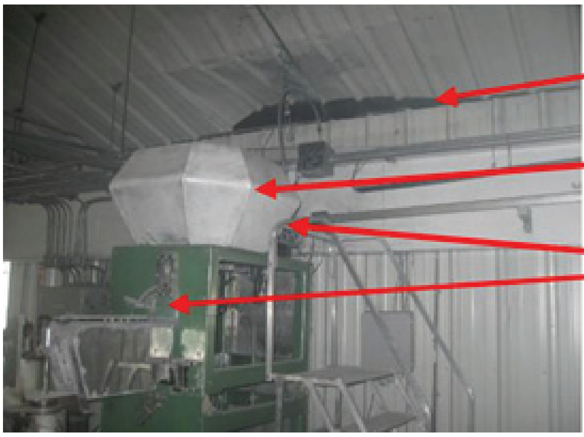
7 INCIDENT TITLE: Hopper Detonation: Texas, USA

When did it happen?	Tuesday, August 8, 2017 at 1:30am
Who experienced it?	Austin Star Detonator Co (ASD)
What material was involved?	Shock tube in process of manufacture HMX/AL mixture – 200 grams
What happened?	Immediately following a spool transfer the Shock tube initiated from a slap and shoot inside the take up. The propagation was towards the powder feed unit. The Initiation reached the dosing system and detonated the powder feed unit with approximately 200 grams of HMX/AL mixture.
Why did it happen – theory?	The snagger, a component of the take up machine, did not hold the tail end of the spool as it began winding and slapped the machine base at a high speed resulting in the "slap and shoot". A guillotine safety system designed to cut the shock tube before the propagation could reach the dosing system had failed due to a faulty electrical component. After review it was concluded that the guillotine system, although it was integrated into the shock tube line safety interlocks, lacked redundancy in the electrical design, and did not indicate if all components were functioning.

Tube initiated from a "slap and shoot"

Latching electrical component failed due to corrosion

What was the impact? No injuries to personnel. The dosing system was damaged along with minor damage to the ceiling and walls.



Damage to Ceiling / Walls

Hopper Shroud (1" Metal)

Damage to Feed System

8 INCIDENT TITLE: 26 October 2018: Germany -Black Powder Incident

When did it happen? Friday, October 26 ,2018 at 09:00 am (local time)

Who experienced it? WANO Schwarzpulver GmbH

Where did it happen? Kunigunde Black Powder Plant

What material was involved? Black Powder

What happened? An initiation took place in the roll crusher phase of the Black Powder manufacturing process during normal operation.

Why did it happen – theory? The possible causes are still under investigation and we are collaborating with the authorities to learn about the causes. An investigation team of experts are working on the incident. More information will be gathered when the investigation is completed.

What was the impact? One employee incurred severe burns and was immediately transferred to a special hospital, where he's receiving medical treatment.

9 INCIDENT TITLE: Fatal Incident at Chemring Countermeasures, UK

When did it happen?	August 10 approximately 17:00 hours
Who experienced it?	Chemring Countermeasures UK
Where did it happen?	Salisbury, UK
What material was involved?	MTV (Magnesium / Teflon / Viton)
What happened?	During mixing process an event occurred, cause unknown, resulting in deflagration.
Why did it happen – theory?	The event will have probably involved solvent and MTV composition.
What was the impact?	Major event, two people injured, one fatally.

10 INCIDENT TITLE: Lead Azide Dust Explosion, Mexico

When did it happen? January 24, 2018 at 1:00 pm

Who experienced it? Austin Star Detonator

Where did it happen? Detonator loading line, Matamoros / Mexico

What material was involved? Lead azide dust

What happened?

After scheduled equipment maintenance on a detonator loading line, a maintenance operator identified that one of the door interlocks was not active. The door could not be closed due to a misalignment. After an unsuccessful attempt to close the door manually, the operator resorted to strike the door with the plastic handle of a set of hex-wrenches (explosive material had not been expected in this area). The second strike resulted in an explosion (small amount of lead azide dust) propelling the lower frame downward with sufficient force to cause a leg injury.

Why did it happen – theory? The silicon sealing between the aluminium frame and the acrylic screen was inadequate and allowed dust to accumulate over time. Dust accumulating was intensified due to the dust control system allowing a dust containing airflow towards the door. The door became misaligned due to a broken rivet to tighten the frame parts.

What was the impact? 1 injured person (leg), limited material damage

SCIENTIFIC / TECHNICAL PAPER

RELATIVE REACTIVITY OF SELECTED EXPLOSIVE FORMULATIONS

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ABSTRACT

Nano-porous silicon-based explosive formulations are currently being explored, with the aim of replacing lead-based primary explosives. Nano-porous silicon combined with oxidisers, form energetic mixtures. It is known that the reactivity of porous silicon explosive formulations is influenced by the amount and type of oxidiser used in combination with porous silicon.

Related studies showed that, on exposure to ambient air, freshly etched porous silicon becomes progressively oxidised. Studies related to this investigation have shown that the shelf life of porous silicon based explosive formulations could be dependent on the level of oxidation of the nano-porous silicon. More resent work, on porous silicon explosive formulations, showed degradation of the thermal sensitivity of such formulations after prolonged storage.

In this study, different oxidisers were used to manufacture nano-porous silicon-based explosive formulations. This study describes the influence of oxidation on the thermal sensitivity of these nano-porous silicon explosive formulations.

A new test method, to better show the difference in response characteristics between energetic mixtures, was developed. This study intends to introduce this novel method and its application characterising the reactivity of selective explosive mixtures.

1.0 Introduction

The use of nano-porous silicon in exploding or detonating compositions only started in 2002 after the accidental discovery of the explosive property of porous silicon (Sailor, 2006) [1]. The use of porous silicon as an ingredient in detonating compositions followed thereafter. The development work of nano-porous silicon-based explosive formulations aims to replace lead-based explosive formulations like lead azide and lead styphnate (Subramanian, et al., 2009) [2]. Lead-based primary explosives are ubiquitous in detonator products used in the commercial mining explosives industry. Porous silicon-based explosive formulations include mixtures of nano-porous silicon with a wide range of oxidizers. Sodium perchlorate((SP) ($NaClO4$)), lithium perchlorate ($LiClO4$), barium perchlorate ($Ba(ClO4)2$), ammonium nitrate and gadolinium nitrate are some of the oxidizers used that are described in the literature. Pentaerythritoltetranitrate (PETN), cyclotrimethylenetrinitramine (RDX) and cyclotetramethylenetetranitramine (HMX), have also been used, as oxidisers mixed with nano-porous silicon. Loni, et al. also showed that, on exposure to ambient air, freshly etched porous silicon becomes progressively oxidised (Loni, et al., 1994) [3]. More recent work on porous silicon explosive formulations, related to this study, showed degradation of the reactivity of the nano-porous silicon-based explosive formulation after a prolonged storage.

A novel method of characterising the reactivity of the explosive mixtures will be used to demonstrate ageing characteristics and the influence of density on the reactivity of nano-porous silicon formulations. This study will further describe the influence of different oxidisers on the relative reactivity of porous silicon explosive formulations.

2.0 Experimental

The experiment was conducted on nano-porous silicon based explosive formulations using nano-porous silicon treated with different oxidizers. The porous silicon membranes were prepared from 6 inch silicon substrates by electrochemical anodization using hydro fluoric acid (HF) - methanol electrolyte. The membranes were subsequently ball-milled in an air environment, using a zirconia grinding medium. This method yielded a particle size distribution, where 10 percent (D10) distribution is equal to or less than (≤) 4µm, 50% D50 ≤ 24µm and, 90% D90 ≤ 86µm. (Loni, 2011) [4].

Nano-porous silicon explosive formulations were prepared by mixing selective oxidisers with the nano-porous silicon. Saturated solutions of the selected oxidizer were preparedusing an organic solvent. Saturated solutions were prepared by dissolving the oxidiser in dry, high purity acetone. Hygroscopic oxidisers were dried under vacuum at 50 degrees Celsius (^{o}C) for 24 hours to ensure that they were dry before being used to prepare the afore mentioned solution.

The solvent, containing the oxidizer, was added to the porous silicon in such a manner that the selective mixtures of different oxidiser to fuel ratios could finally be obtained. The mixtures were air dried (through evaporation) whilst being refined simultaneously by hand using a dry, bone spatula. The refining continued until a consistently fine powder was obtained. After refining, the formulations were dried in an oven under a vacuum (0.7 mega pascal (MPa)) for 3 hours at 55 ^{o}C.

The different mixtures were then evaluated by exposing the samples to heat. A laboratory hotplate was modified to produce the heat for this set of experiments. The hotplate was modified in such a manner that the temperature could be controlled to be within a tolerance of ± 1.0 °C. The modified hotplate was calibrated to determine the temperature on a specific, pre-selected position on the hotplate. This was done to ensure that all the samples were exposed to a similar rate of temperature change. These temperature measurements were collected by measuring the temperature inside an aluminium cup in 5 second time intervals. The temperature of the hotplate was 400 °C.

A sample, of the formulation to be evaluated, was put on a specific position of the heat source. A noise meter (decibel meter) was positioned 150 millimetres (mm) horizontally from the sample and 140 mm above the sample. The time taken, for a reaction to occur, was measured using a standard, calibrated stop watch. This time is the time measured from the moment the sample was placed on the hotplate and is stopped the instance a reaction is obtained. This test set-up allowed for the measurement of the noise level and the time taken for a reaction to occur. Figure 1 show the test set-up.

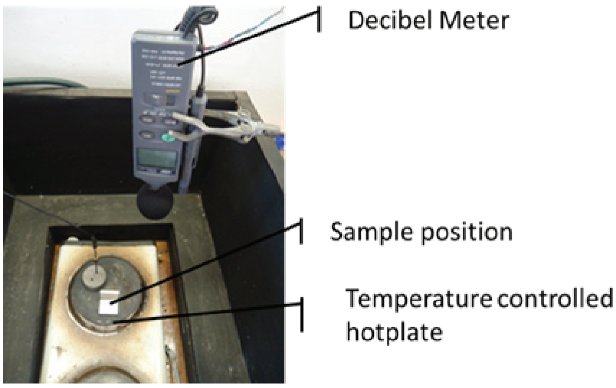


Figure 1: Generc thermal reactivity test set-up

Variables that could influence the results include sample mass, silicon (Si) to oxidiser ratio and the rate of temperature change. These variables were controlled by:

- keeping the rate of temperature change as constant as possible,
- predetermining the Si to oxidiser ratio and keeping this ratio constant, and
- determining the influence of sample mass on the magnitude of the noise reading.

The optimum sample mass,which showed the least effect on the noise reading, was determined. A sample mass of between 0.030 gram (g) and 0.040 g was used for the samples that were tested. The responses obtained were scientifically defined by the following three factors: the time to reaction, the temperature at the reaction and the noise level of the reaction. The time measured, for a reaction to occur, can be indicative of the sensitivity of the formulation towards heat. The temperature at reaction refers to the temperature at which a reaction is noted. The noise level can be related to sound over-pressure (Szendrei, 2010) [5]. The sound overpressure can be related to the over-pressure generated by the reaction.

The tests described in this paper will cover ageing characteristics, the effect of density on the reactivity of the nano-porous silicon-based explosive formulations and the difference in reactivity when using selected oxidisers.

2.1 Development of relative reactivity

To better compare the difference in reactivity of the nano-porous silicon-based explosive formulations, a relation was developed between the noise generated by the reaction and the measured time to reaction. The postulated relation is referred to as relative reactivity (Rr) [6]. The term relative reactivity used here refers to a level of reactivity relative to a specific temperature (the initial temperature of the hotplate).The postulated argument is based on the understanding that, the higher the noise that has been produced the more brisant the explosive formulation is assumed to be. The heat sensitivity of the formulation is a function of the time it took the formulation to react upon exposure to specific thermal stimuli. It must be noted here that it is acknowledged that activation energy is part of the decomposition reaction mechanism it is not incorporated into the Rr determination. The relative reactivity of a formulation that produced a high noise and a long time to reaction cannot be higher when it is compared to a formulation that produced a high noise and a short time to reaction. This problem was overcome by increasing the difference between the noise and time values in the equation. The noise was increased tenfold, and the inverse of the time measurement was used.
This gave equation 1:

$$R_r = \delta^{10}\,(1/\alpha) \qquad \textbf{Equation 1}$$

With R_r being the Relative reactivity, δ the noise measured in decibels and α the time to reaction measured in seconds. Equation 1 was used to calculate the relative reactivity using the noise and time measurement data.

2.2 Ageing characteristics of nano-porous silicon-based explosive formulations

Two different oxidisers were used to manufacture eight different explosive formulations. These formulations were stored in a desiccator for a period of one year and tested at different time intervals. The oxidisers used were sodium perchlorate (SP) and nitriminoterazole (NT). The samples were positioned on a preheated hotplate. Time was measured, starting from when the sample was placed on the hotplate and stopping when a reaction was noted. The sound that was generated by the subsequent reaction was also measured. The formulations evaluated are given in table 1.

Table 1: Explosive Formulations used in ageing characterization

Formulation	Oxidiser	Binder (%weight)	NT* (% weight)	Oxidiser-to-porous silicon ratio
T1	NT	Wax (18%)	-	3 : 1
T2	NT	Nitrocellulose (NC) (11%)	-	3 : 1
T3	NT	-	-	3 : 1
T4	NT	Wax (5%)	75%	3 : 1
N1	SP	Wax (18%)	-	1.4 : 1
N2	SP	NC (11%)	-	1.4 : 1
N3	SP	-	-	1.4 : 1
N4	SP	Wax (5%)	75%	1.4 : 1

*Additional nitiminoterazole was added to the nano-porous silicon based explosive formulation

2.3 Effect of density on the reactivity of the nano-porous silicon-based explosive formulations

Only nitriminoterazole (NT) was used as the oxidiser in order to prepare the nano-porous silicon-based explosives formulation. The oxidiser to fuel ratio used was 3 : 1 on mass balance. The selected explosive increment was consolidated using a hand-press. Samples of the explosive formulation were consolidated to be at different densities. The formulation was consolidated to be at the following densities (gram / cubic centimetre (g.cm-3)), 0.71, 1.99, 2.07, 2.11, 2.22, 2.25, 2.52 and 2.60. The samples were positioned on a preheated hotplate. Time was measured, starting from when the sample was placed on the hotplate and stopping when a reaction was noted. The sound that was generated by the subsequent reaction was also measured.

2.4 Reactivity determination ofnano-porous silicon-based explosive compositions

Sodium perchlorate, barium perchlorate, lithium perchlorate, PETN, NT and HNS were mixed with nano-porous silicon in stoichiometric ratios. The nano-porous silicon sample with a specific surface area (SSA) of 176 m-2.g-1 and a pore volume of 0.39 cm-3.g-1 was used for all samples. Mass-to-mass ratio between the porous silicon and the oxidiserevaluated are shown in Table 2.

Table 2: Silicon to oxidiser ratios on mass balance

Oxidiser	Ratio Si:Oxidiser	Si Theoretical (g)	Oxidiser Theoretical (g)	Si actual (g)	Oxidiser Actual (g)
SP ($NaClO_4$)	1:0.50	1.5	3.2761	$1.5069^{\pm 0.0009}$	$3.2665^{\pm 0.0012}$
$LiClO_4$	1:0.50	1.5	2.8487	$1.5016^{\pm 0.0010}$	$2.8423^{\pm 0.0009}$
$Ba(ClO_4)_2$	1:0.25	1.5	4.4970	$1.5022^{\pm 0.0014}$	$4.4893^{\pm 0.0010}$
PETN	1:0.16	1.5	2.8139	$1.5011^{\pm 0.0008}$	$2.8132^{\pm 0.0014}$
NT	1:1.00	1.5	6.9617	$1.5016^{\pm 0.0011}$	$6.9581^{\pm 0.0013}$
HNS	1:0.16	1.5	4.0164	$1.5004^{\pm 0.0012}$	$4.0079^{\pm 0.0014}$

3.0 Results

3.1 Ageing characteristics of nano-porous silicon-based explosive formulations

The relative reactivity of the tests conducted was calculated using equation 1, and the datais given in Tables 3 through 6. Relative reactivity results of the ageing evaluation of nano-porous silicon-based explosive formulations are shown in Tables 5 (NT used as oxidiser) and 6 (SP used as oxidiser).

Table 3: Noise / time results of nano-porous silicon-based explosive formulations (NT oxidizer)

	T1		T2		T3		T4	
Days	Time s	Noise dB	Time s	Noise dB	Time s	Noise dB	Time s	Noise dB
0	4.71	62.26	3.65	74.10	5.19	84.00	4.6	76.23
5	4.25	60.00	2.61	73.10	2.47	76.70	4.15	71.50
24	6.92	61.00	5.03	65.10	4.35	78.55	4.61	67.55
31	5.24	57.00	4.47	71.60	3.47	73.30	3.63	65.70
45	4.55	59.40	3.76	68.20	2.84	74.35	4.31	66.76
75	5.28	49.80	4.03	63.90	5.08	72.65	4.42	62.63
380	6.35	49.80	3.98	50.17	6.05	55.38	6.67	72.01

Table 4: Noise / time results of nano-porous silicon-based explosive formulations (SP oxidiser)

	N1		N2		N3		N4	
Days	Time s	Noise dB	Time s	Noise dB	Time s	Noise dB	Time s	Noise dB
0	18.47	75.70	12.06	108.23	15.76	106.90	7.46	76.33
5	28.07	70.50	5.28	106.20	19.21	104.10	4.76	74.60
24	42.15	67.00	8.05	102.30	35.00	76.20	5.37	66.26
31	45.00	65.20	12.47	97.60	-	-	4.00	65.10
45	51.44	67.80	11.25	75.20	-	-	6.48	68.15
75	-	-	10.85	60.90	-	-	5.28	63.40
380	-	-	-	-	-	-	7.92	68.26

Table 5: R_r results of nano-porous silicon-based explosive formulations – NT

NT formulations from Table 1								
	T1	STD.dev.	T2	STD.dev.	T3	STD.dev.	T4	STD.dev.
Days	R_r $X10^{17}$	R_r $X10^{17}$	R_r $X10^{17}$	R_r $X10^{17}$	R_r $X10^{17}$	R_r $X10^{17}$	R_r $X10^{17}$	R_r $X10^{17}$
0	1.86	0.56	13.70	2.61	33.70	11.62	14.44	1.52
5	1.42	0.58	16.70	3.95	28.50	4.74	8.41	1.69
24	1.03	0.11	2.72	0.56	20.60	1.62	4.30	0.27
31	0.69	0.08	7.92	1.07	12.90	1.70	4.13	1.40
45	1.20	0.33	5.79	0.55	18.20	5.75	4.08	0.36
75	0.18	0.01	2.82	0.20	8.06	1.78	2.10	1.05
380	0.15	0.02	0.25	0.08	0.45	0.16	5.62	1.84

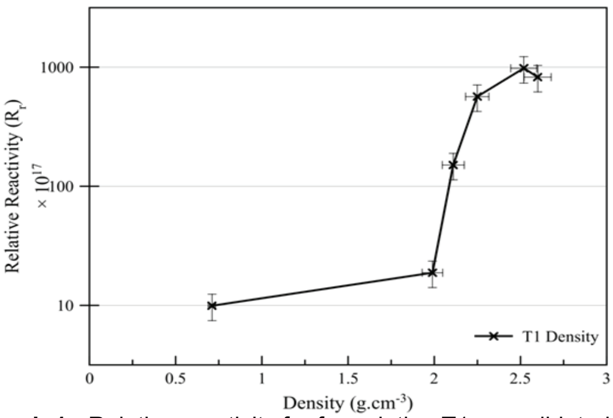
Table 6: Rr results of nano-porous silicon-based explosive formulations - SP

SP formulations from Table 1								
	N1	STD.dev.	N2	STD.dev.	N3	STD.dev.	N4	STD.dev.
Days	R_r X10^{17}	R_r X10^{17}	R_r X10^{17}	R_r X10^{17}	R_r X10^{17}	R_r X10^{17}	R_r X10^{17}	R_r X10^{17}
0	3.35	0.59	183.00	59.80	124.00	36.20	9.00	0.98
5	1.08	0.12	346.00	25.98	77.80	11.20	11.20	2.80
24	0.43	0.05	156.00	28.78	1.89	0.29	3.04	0.47
31	0.31	0.08	62.90	11.52	NR	NR	3.42	0.27
45	0.40	0.05	5.14	0.39	NR	NR	3.34	0.28
75	NR	NR	0.65	0.13	NR	NR	1.29	0.14
380	NR	NR	NR	NR	NR	NR	2.77	0.38

NR denotes no reaction

3.2 Effect of density on the relative reactivity of nano-porous silicon-based explosive formulations

The effect of density on nano-porous silicon-based explosive formulations is shown in graph 1.



Graph 1: Relative reactivity for formulation T1 consolidated at different densities

3.3 Reactivity determination ofnano-porous silicon-based explosive compositions

The relative reactivity results of nano-porous silicon-based explosive formulations, prepared to be stoichiometrically balanced, are given in Table 7.

Table 7: Relative reactivity results obtained for Si/oxidiser mixtures

	Si:$NaClO_4$	Si:$LiClO_4$	Si:$Ba(ClO_4)_2$	Si:PETN	Si:NT	Si:HNS
	R_r x10^{19}	R_r x10^{19}	R_r x10^{18}	R_r x10^{17}	R_r x10^{18}	R_r x10^{16}
Average	2.57	2.29	7.44	2.30	1.99	4.06
Min	1.79	0.01	1.48	1.56	1.32	2.38
Max	3.06	6.85	13.40	3.86	3.15	6.88
Standard deviation	0.37	2.29	4.83	0.70	0.55	1.44

4.0 Discussions

The different formulations evaluated show discriminating results with respect to noise and time. The level of oxidation of the nano-porous silicon has an effect on the reactivity of the nano-porous silicon-based explosive formulations evaluated. Beckman noted, as early as 1995, that porous silicon films underwent pronounced 'ageing' when stored in ambient air for a prolonged period of time (Canham, 1997) [7]. The speed and the extent to which the oxidation of the silicon occurs depends upon many factors such as intensity of light, level of humidity and level of highly oxidising airborne species [8]. Previous studies have shown that the magnitude of influence on the reactivity of the Si / oxidiser mixtures is not only a function of the level of oxidation of the nano-porous Si, but also by the type of oxidiser used. The difference in noise and time to reaction can primarily be ascribed to ageing of the formulations.

Formulations T1 to T4 and N1 to N4 were used to understand the change in reactivity over time. The relative reactivity results (Tables 5 and 6) indicate a distinct difference in reactivity when T1 is compared to T2, T3 and T4. Difference in reactivity was also noted whenN1 is compared to N2, N3 and N4. Nano-porous silicon-based explosives formulations, where SP was used as the oxidiser, show a rapid decline in reactivity (Table 6). Formulations N3 (no binder) did not react after 24 days. Binders were used in an attempt to extend the shelf life of formulations N1 and N2. The results obtained do not show a significant increase in the shelf life of these formulations (Table 6). Formulation N 4 showed a significant decline in reactivity over 380 days but not a complete deprivation of reactivity after 380 days.

Nano-porous silicon-based explosives formulations where NT was used as the oxidiser, show a rapid decline in reactivity (Table 5). Binders were used in an attempt to extend the shelf life of formulations T1 and T2 (Table 5). Formulation T 4 showed a significant decline in reactivity after 75 days. The reactivity then steadily increased again over the remainder of the 380 days.

The oxidation behaviour, of explosive formulation T3 showed a slower decrease in reactivity than formulation N3. The reactivity behaviour of formulations T4 and N4 can be ascribed to the addition of 75% nitriminotetrazole. Tables 5 and 6 show a rapid decrease in relative reactivity for the formulations prepared with SP and a slower decrease in relative reactivity for the formulations prepared with NT.

Increasing the density of the nano-porous silicon explosive formulation (T1), resulted in an increase in the reactivity of the formulation. This increase in reactivity is seen from a density of 2.2 g.cm-3. The increase in reactivity is achieved through both a decrease in the reaction time and an increase in the noise level of the reaction obtained from the test (graph 1).

Using inorganic oxidisers to sensitise nano-porous silicon yields a higher Rr compared to organic (high energetic material) oxidisers. The repeatability and accuracy of nano-porous silicon formulations prepared using organic oxidisers showed to be better compared to formulations prepared with inorganic oxidisers.

5.0 Conclusions

From the study conducted the following can be concluded:

i. The oxidiser used in manufacturing nano-porous silicon-based explosive formulations influences the relative reactivity of the formulation,

ii. The shelf lifeof nano-porous silicon - based explosive formulations is influenced by the type of oxidiser used as well as the binder systems incorporated in to the explosive formulation,

iii. Increasing the density of a nano-porous silicon-based explosive formulation results in a significant increase in the relative reactivity of the formulation,

iv. The relative reactivity methodology can be used to compare different explosive formulations from thermal and noise measurements,

v. The relative reactivity methodology can be used to compare different explosive characteristics from thermal and noise measurements.

6.0 Future activities

Continuous development of the relative reactive methodology to include thermal and noise measurements studies related to particle size, influence of additives and other explosives characteristics.

7.0 Acknowledgement

The author thanks AEL Intelligent Blasting for their continuous financial support and for providing the test facilities.

8.0 References

[1] Sailor, Micheal. Computer chips found to possess explosive properties useful for chemical analysis and nanoscale sensors.
http://ucsnews.ucsd.edu/newsrel/science/mcporous.htm

[2] Subramanian, Shanthi.,Tiegs, Terry., and Limaye, Santosh. Nano-porous Silicon Based Energetic Materials. New Jearsy :Vesta Sciences, 2009.

[3] Loni, A and others. Compositional variations of porous silicon layers prior to and during ion-beam analysis.Journal of applied physics. Vol. 5 1994: 76.

[4] Loni, A. Initiators Using Porous Silicon: Phase 1 Report. Intrinsiq Materials, 2011.

[5] Szendrei, T. Prediction of the Blast Noise Levels from Ash Dump 5. Dynamic Physics Consultants cc, 2010.

[6] Bezuidenhout, H.C. & Mukhopadhyay, S. 2013. Thermal sensitivity of nano-porous silicon based explosive formulations. Proceedings of the 44th International Annual Conference of ICT, Karlsruhe, Germany, 25–28 June.

[7] Canham, L T., Properties of porous Silicon: Storage of porous silicon. London : The institution of Electrical Engineers, 1997

[8] Loni, A. Initiators Using Porous Silicon: Phase 1 Report. Intrinsiq Materials, 2011.

EXPLOSIVE INDUCED DEMOLITION OF 150m HIGH STACK

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ABSTRACT

Demolition is conventionally carried out either manually or mechanically using large hydraulic equipment such as hammers, cranes, excavators or bulldozers and elevated work platforms. Newer conventional demolition methods use rotational hydraulic shears and silenced rock-breakers attached to excavators to cut or break through wood, steel and concrete. However, larger buildings require the use of explosives and knowledge of dynamic numerical modelling techniques to design and implement the building demolition effectively, safely and with due compliance to the environmental standards. This paper discusses demolition of a 150 m high stack using dynamical modelling techniques and explosives. This paper shows a close match between actual demolition results of the stack over time and predicted demolition results by dynamic modelling software. The explosive induced demolition of stack met all environmental standards in terms of vibration, noise and dust as stipulated by Korean regulator.

Keywords: Demolition, Dynamic numerical modelling techniques, Blast, Stack

1.0 INTRODUCTION

The demolition of large and complex civil structures requires the use of explosives and knowledge of dynamic numerical modelling techniques to design and implement the demolition effectively, efficiently and safely. Explosive demolition has time, cost and environmental advantages (noise, vibration and dust) over mechanical demolition. Explosive demolition is a method inducing time dependent structure collapse by gradually removing major structural frameworks using explosives weakening structural stiffness distribution over time. This paper explains a felling of a 150 m high stack explosive demolition in a power plant in South Korea. The stack was 150 m high, 11.2 m bottom diameter, 6.9 m top diameter, made of shear wall and firebrick.

2.0 NUMERICAL TECHNIQUES USED IN SIMULATION

The developed software is a derivative of the Finite element method and discrete element method with capability to perform linear, nonlinear, static and dynamic analysis that follows the behaviour of structures through separation, collision and collapse.

2.1 Characteristics of modeller

The pre-processor provides demolition engineers with comprehensive and intuitive style-based modelling interface that allows user to quickly and easily create 3-D solid element structural models for non linear static and dynamic analysis structures.

2.2 Characteristics of solver

The solver automatically calculates

- Yielding of Reinforcement: automatically calculates material strain from elastic to plastic deformation.
- Plastic Hinge Formation: automatically places plastic hinges.
- Buckling and Post-buckling: automatically calculates elastic and plastic bending under compressive loads.
- Crack Propagation: automatically calculates the location and propagation of cracks.
- Membrane Action & P-Delta Effect(P-Δ): automatically calculates the dynamic force and displacement caused by Membrane Action and the P-Delta Effect.
- Separation of Elements: automatically separates elements based on nonlinear material properties.
- Collision and Collapse: automatically calculates the collision and collapse of separated elements.

There are two solver options available depending on the type of analysis being performed and time to solve:

- **Exact Solver:** optimal in static and dynamic analysis with a relatively large time step (0.01 or 0.001 sec).
- **Iterative Solver:** optimal in cases where the time step used is very small, like in penetration or blast analysis problems (recommended time step is less than 0.0001 sec). This results in a significant reduction in RAM required to process the problem.

2.3 Characteristics of Post Processor/Viewer

The software allows to view frame by frame results as the solver runs and perform a number of post-processing tasks in order to analyze the results and export presentation and report materials.

3.0 DEMOLITION PLAN

3.1 Site details

The structural details of the stack are tabulated in Table -1

Height	150m
Bottom diameter(External)	Around 11.2m
Top diameter(External)	Around 6.9m
Structure	Shear wall + Firebrick

Variables that could influence the results include sample mass, silicon (Si) to oxidiser ratio and the rate of temperature change. These variables were controlled by:

- keeping the rate of temperature change as constant as possible,
- predetermining the Si to oxidiser ratio and keeping this ratio constant, and
- determining the influence of sample mass on the magnitude of the noise reading.

The optimum sample mass,which showed the least effect on the noise reading, was determined. A sample mass of between 0.030 gram (g) and 0.040 g was used for the samples that were tested.

The stack comprised a shear wall and firebrick. It was separated by 2 rooms with a 25m high shear wall inside it. There were many structures within the 150 m of the stack as can be seen in Figure 1.The shape of the stack and the direction of felling by applying single point toppling is also shown in Figure 1.

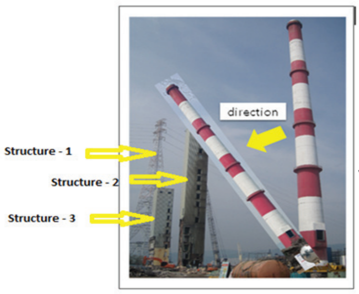

Figure 1 - Photograph of the Stack with surrounding structure

4.0 DEMOLITION SIMULATION

4.1 Simulation model

The structure was modelled using the pre-processor. The thickness of bottom wall was 700mm and the thickness of top wall was 250mm. The diameter of the circular column was 12 m and was made up by #8 (D 25mm) with rebar spacing as 270 mm and is shown in Figure 2.

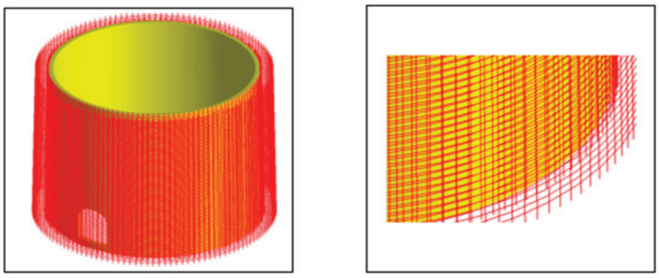

Figure 2 - Rebar spacing in Structure

Figure 3 shows the simulation model and the material properties of the structure is shown in Table – 2.

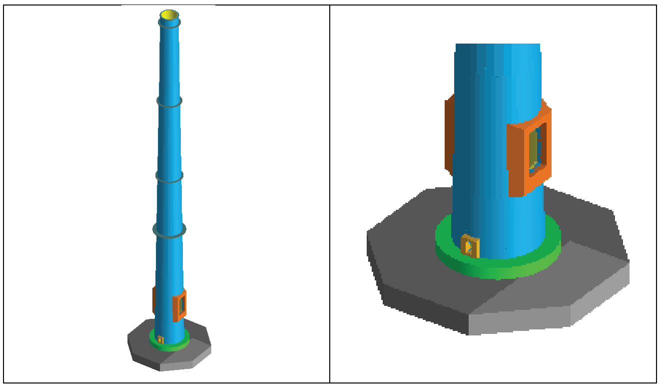

Figure 3 - Simulation model of the Stack

Table 2: Material properties of the structure

Material	Young's modulus (MPa)	Compressive strength (MPa)	Tensile Strength (MPa)	Tensile yield stress (MPa)	Ultimate Strength (MPa)
Concrete	26,200	24	0.2	-	-
Steel	200,000	-	-	360	504

4.2 Pre-weakening

Cylindrical shell structure is needed to select explosion spots and pre-weakening spots considering shape, angle and height of openings in order to weaken structural stiffness, induce smoothly felling collapse as planned, and prevent kick-back until moment of rotation begins after explosion. Figure 4 shows explosion spots and pre-weakening spots.

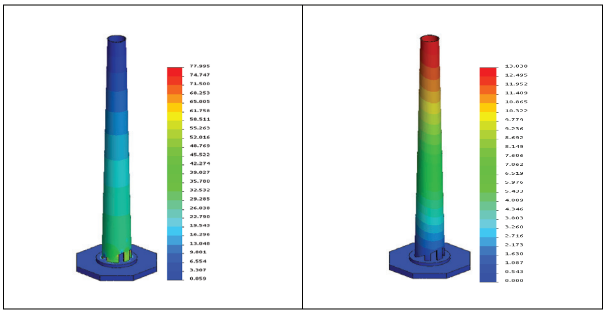

Figure 5 - Stress / Displacement distribution before / after pre-weakening

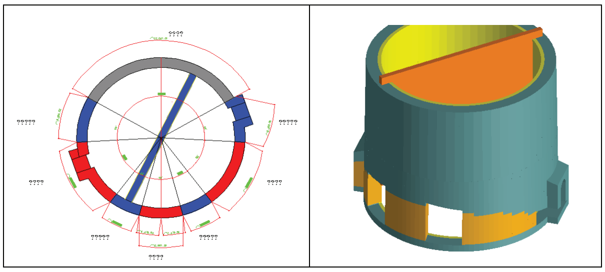

Figure 4 - Explosion spots and pre-weakening spots

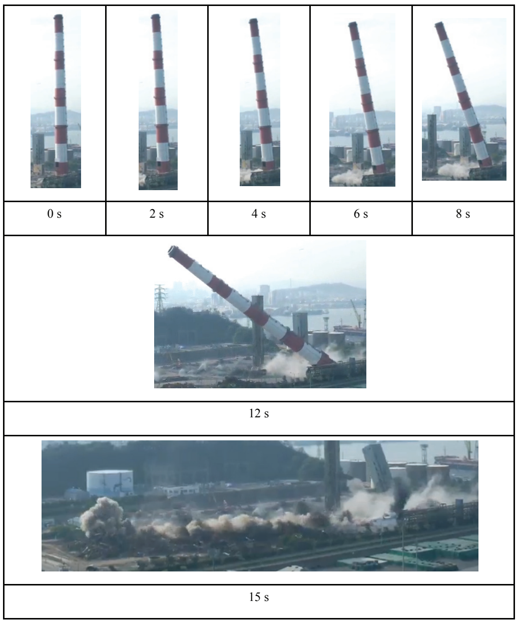

Figure 6 - Actual demolition result over time

4.3 Structure safety analysis

Whilst weakening structure collapse can happen because of structure instability. Since it can make huge loss of lives it is accomplished to analyze standing safety on structure weight and wind-load after applying pre-weakening to check structure safety before commencing pre-weakening. Figure 5 shows stress distribution after pre weakening.

5.0 DEMOLITION RESULTS

The actual demolition results over time is shown in Figure 6 and results obtained from numerical simulation over time is shown in Figure 7.

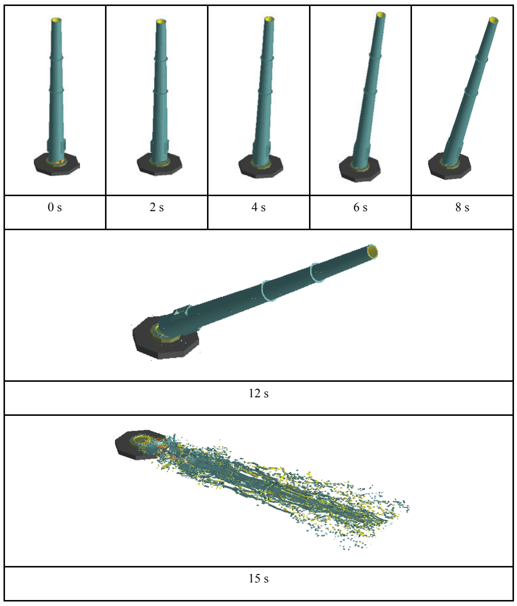

Figure 7 - Numerical Simulation results over time

6.0 ENVIRONMENTAL HEALTH & SAFETY

Environment has always been the most important consideration for demolition and following generic precautions were taken to ensure environmental compliance during demolition.

- The demolition process in accordance with the requirements and satisfaction of all relevant authorities (Local Authorities, Ministries responsible for public infrastructure, labour and health among others).
- Existing natural drains and watercourses on or in the vicinity of the site was covered.
- All demolition work was carried out in day hours between 10.00 am to 4 pm. Rescheduling of several noisy operations was planned concurrently to avoid continuous noise disturbance.

- The minimum protection practiced during demolition structure wise, height wise and horizontal wise is shown in Table 3.
- The regulator set the threshold in terms of noise and vibration as follows, which was complied with:

Sl. No.	Threshold set by Regulator	Actual Observation
1	PPV at demolition site as 0.10 mm/s	0.08 mm/s
2	Air Overpressure at demolition site as 110 dBA	105.6 dBA

Dust mitigating measures undertaken during demolition is enumerated below:

i) Appropriate safety measures such as hoardings and geo textile screens were installed on site.

ii) Demolition was scheduled investigating the meteorological data in advance during periods of low winds to decrease dust emissions.

iii) Water spraying of the site was carried out to reduce dust nuisance.

iv) Demolition materials and stockpiles was covered or sprinkled.

Table 3: Type of Minimum protection required during demolition

Horizontal distance from inside of the sidewalk to the structure	Height* to Horizontal distance ratio	Type of minimum protection required
Less than 3m	6:1 or more	Type A
	4:1 to 6:1	Type B
	3:1 to 4:1	Type C
	2:1 to 3:1	Type D
	Up to 2:1	Type E
Over 3 m to less than 4.5 m	10:1 or more	Type A
	6:1 to 10:1	Type B
	4:1 to 6:1	Type C
	3:1 to 4:1	Type D
	Up to 3:1	Type E
Over 4.5 m to less than 7.5 m	15:1 or more	Type A
	10:1 to 15:1	Type B
	6:1 to 10:1	Type C
	4:1 to 6:1	Type D
	Up to 4:1	Type E
Over 7.5 m to less than 12 m	15:1 or more	Type B
	10:1 to 15:1	Type C
	6:1 to 10:1	Type D
	Up to 6:1	Type E
12 m or more	10:1 or more	Type D
	Up to 10:1	Type E

Type A: Total blockade of the road
Type B: Temporary diversion over the entire length of the footpath adjacent to the structure
Type C : A sidewalk shed for the entire length
Type D : A fence of tightly seated 25 mm planks, minimum height 2.5m
Type E: A railing at least 1.5m high with mid rail and cross bracing
*Height of the building or portion thereof to be demolished.

v) Misty water spray was created near the demolition sites by mechanical means to reduce the airborne dusting from demolition work.

vi) Adequate care was taken to comply the regulatory requirements of height to horizontal distance ratio as tabulated in Table 3.

Demolition wastes such as concrete and bricks were sent for reprocessing at stone crushing plants. Building components (doors, windows) and wood were sent for recycling as far as possible. All recyclable wastes, including iron bars, metals and plastics were properly collected for eventual recycling.

7.0 REFERENCE

1. Youngchul Kang, 1995, Explosive demolition for high rise structure, Institute of International Information Technology
2. Seunggon Kim, Hun Park, Hyungsik Yang, 2002, Effect of normal weight on fragmentation of explosive demolition for Concrete column, Journal of Korea Society of explosives and blasting Engineering, pp. 97-109
3. Kimiro Meguro and Hatem Tagel-Din, 2001 Applied Element Simulation of RC Structures under Cyclic Loading, ASCE, Vol. 127, Issue 11, pp. 1295-1305
4. Hyon-Soo Kim, Hoon Park, Seung-Kon Kim, Yeon-Gyu Lee and Sang-Ho Cho, 2001, Collapse Simulations of High-Rise RC Building Using ELS Software and Application of Explosive Demolition Methods to Transition Process Analysis from Local Damage to Progressive Collapse ", Korea Society for Explosives and Blasting Engineering
5. Okamura H. and Maekawa K, 1991, Nonlinear analysis constitutive models of reinforced concrete, Gihodo Co. Ltd., Tokyo
6. Hoon Park, Chul-Gi Suk, Seung-Kon Kim, 2009, Collapse Modeling of model RC Structure Using Applied Element Method, Tunnel and Underground Space Journal of Korean Society for Rock Mechanics, Vol. 19, No. 1
7. Code of Practice for Demolition of Buildings, 2004, Building Department, The Government of Hong Kong
8. Hoon Coi, Hyungjoong Joo, Hyojin Kim, Soonjong Yoon, 2008, Pre-weakening area setting and Structural Safety Simulation for Explosive Demolition, Korean society of Steel Construction
9. Hoon Park, Chul-Gi Suk and Seung-Kon Kim, 2008, Numerical Study on the Structural Behavior Accorded by Pre-weakening Before Demolishing a Cylindrical Structure, Korea Society for Explosives and Blasting Engineering
10. Park, H., S.O. Jang, H.K. Park, N.H. Kim and C.G. Suk, 2008, A study on explosive demolition of the cylindrical silo structure, 3'rd International Conference on Explosives and Blasting, Busan
11. Hoon Park, Chul-Gi Suk, 2009, Execution Case Study on the Explosive Demolition of a Large-Section RC Special Structure", Journal of Korean Society for Rock Mechanics, Tunnel & Underground Space, Vol. 19, No. 5.

Electronic Detonators – Need of the hour for the Indian blasting industry




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ABSTRACT

Rock excavation is a major operation in mining and civil construction projects and blasting play a significant role in efficient opencast mining operations. There have been constant technological developments towards safer, faster, economic and more efficient blasting systems. Further, globally increased competitiveness has necessitated to carry out blasting in such a way that the desired degree of fragmentation is achieved with minimum undesired side effects such as ground vibration, air blast/noise, flyrock. Therefore, the ultimate objective of the blasting engineer is to ensure that the blasts are carried out in an eco-friendly manner. From safety fuse system to shock tube initiation system, commercial basting helped to improve safety and productivity of the blasting, however each system has some limitation in terms of accuracy of delay, safety requirement as well as complexity required in terms blast requirement. Electronic detonators have come long way since their invention in late 90s. They have helped Blasting Engineers in solving environmental problems, better control on fragmentation, Blasting multi layer rock together, controlling throw & back break etc. Electronic Detonators have been introduced in the Indian market in last 10 years mainly for Vibration controls. Of late the Indian mining industry is now gearing up to realise the other technological benefits of Electronic detonators. The paper deals with the review of use of electronic detonators and various advantages and sustained growth prospects in Indian Mining and construction industry. This paper also presents a case study of a coal mine where a controlled blasting was conducted at a shovel bench near a village hutments. The case study was aimed at improvement of safety by reducing ground vibration intensity and flyrock as the blasting is taking place very near to a village habitats. Another objective of the study was to quantify the improvement blasting productivity by enumerating the blast performance parameters like fragmentation, back break and improvements in downline operations. An attempt has been made to increase blast frequency by constructive interference technique with signature hole analysis by using Electronic Detonators and the advantages have been quantified. Keeping in view of the edge of Electronic Detonators over Pyrotechnic Detonators it is high time for Indian blasting industry to abreast with the new initiation technology not only to solve safety issues but also to make a quantum jump in blasting productivity.

Keywords: Electronic detonator, pyrotechnic detonator, controlled blasting, signature blasting.

1.0 INTRODUCTION

In India the annual production of all Minerals is around 1000 Million tons and corresponding overburden removal is around 4200 Million tons. Extraction of rock metal is around 800 Million tons per annum. In order to extract such a huge quantity of minerals and rock material by blasting, explosive consumption is in the range of 0.9-1 million tons and detonators consumption is about 1000 million. The efficiency of explosive utilization and blast performance is the function of method of initiation and amount of delay. This implies the importance of explosive initiating systems. It is always prudent to plan the blasts in such a way, so that one hole fires at a time. This reduces maximum charge / delay, helps in creating more free faces (for other holes to be fired), yields smaller & uniform fragments, significantly controls back break, controls noise & ground vibrations to a large extent. Firing many holes at a time, can cause unsafe situations like flyrock, back break, excessive vibration levels & air blast levels and also result in oversize fragments. Therefore, the explosive is initiated with a delay time factor which is expressed in milli-seconds per meter (ms/m). The delay time depends primarily on blast objectives, sonic velocity, spacing of holes in the same row & between rows, number of rows, hole depth etc. The optimum delay time in ms/m varies from 4 – 12 ms /m for the holes in the same row and 9 -30 ms/m across rows. A rock having higher sonic velocity needs shorter delay time and having lower sonic velocity needs larger delay time. The delay time requirement for the holes in the same row is 8-10 ms/m and in between the rows it is 12-18 ms/m. This requires accurate delays (1ms) and field programmable delays (1-10000ms) for getting better blast results.

All delay detonators manufactured in factories are pyro-technique delays and they are all called fixed interval delays. A slow burning chemical element is inserted into detonators for providing delay time. The delay time varies based on delay element length & delay composition. The accuracy of pyro-technique delays is a function of internal process efficiency of an organization as well the method of making delays. Generally, it is observed, that delay scatter is found in the pyrotechnique detonators and the scatter may increase over the life of delay detonator. Scatter in delays results in more or less delay time between consequent firing of holes, than planned one. Few instances were reported from field, where second row holes fired before first row holes due to scatter/ accuracy issues. This limits the blast size significantly when we need to do blasts in constrained conditions. The shortcomings of pyro technique delay detonators are listed below:

a) Limited delay intervals – 17, 25, 42, 65,105 ms
b) Delays are less accurate and scatter is in the range of 30-40%.
c) Blasting single hole at a time cannot be ensured due to delay scatter
d) Reproducibility & consistency is an issue
e) Scatter likely to increase over the life

In view of the above disadvantages with the pyrotechnique detonators, there is a global paradigm shift towards more accurate and variable delay detonators.

2.0 Review on Electronic Delay initiation

In Electronic Detonator (ED), the delay is achieved electronically; a computer chip is used to control delay timing. The longitudinal cross section of all types detonators showing the construction details are given in Figure 1. An integrated circuit chip and a capacitor internal to each detonator control the initiation time. ED were developed from an idea originated in the 1990s. The time to time technological developments of ED are explained in the following sections.

i) Daisy Chain Communication -4 wire system:
The system is having Dual voltage system. Information of delay is stored inside the detonator. The detonators can be Pre-programmed, Semi programmed or Fully programmed.

ii) Bus wire communication (two wire system):
Two wire ED are fully programmable. There can many variants in which delay timing can be assigned to each detonator or the position in the shot can be assigned to the detonator. In the former case information can be stored inside the detonator or inside the equipment controlling the delay while in the later case it is stored inside the control equipment. Most of the system adopts dual voltage system for better safety as shown in Figure 2.

iii) Wireless ED:Wireless ED are also available in some countries. This does not need any bus /harness wire for connecting holes. The ED along with boosters are lowered inside the hole and EDs are programmed wire lessely.

An electronic detonator has a number of advantages, e.g. higher precision, improved blasting result owing to a wide range of delays, reduction of airblast/ground vibration, and safe use in extraneous electric environments, and the possibility of limiting the amount of detonators per shot. It has some disadvantages too, e.g. higher cost per detonator and the need for intensive training for users.

EDs were introduced in Indian mining almost 10 years back. The product was mainly used for controlling environmental issues viz. Vibration & Airblast. With rapid urbanisation, increase in mechanisation & production requirement, controlling vibration & Airblast becoming most challenging. With tighter norms of vibration limits as posed by statutory bodies, EDs are helping mining companies to carry out blasting activity in more environmental friendly way. Indian mining companies are making attempts made to harness the other benefits associated with use of EDs. Benefits by use of EDs are summarized below:

i) Control of ground vibrations
ii) Better Fragmentation
iii) Better control over Muck pile shape
iv) Wall & Back-break control
v) Increase in blast size
vi) Opportunity to increase pattern
vii) Blasting multilayer rock formation etc

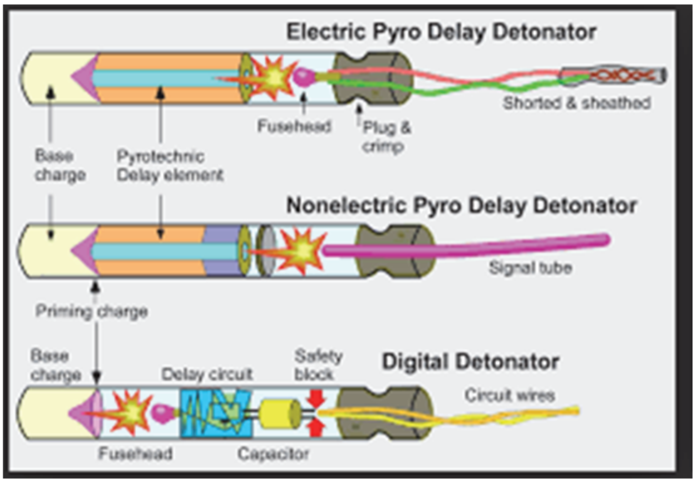


Figure 1 - Longitudinal cross section of all types delay detonators showing construction details (after Lalwani and Menon, 2016)

Some of the major benefits are described below in detail:

2.1 Ground vibrations

A study by Sharma and Rai (2016) examines the structural response to blast-induced ground vibration by underlining the importance, from an environmental point of view, of minimizing vibrations induced in urban dwellings by blasting. The maximum response of a house to blast-induced ground vibration occurs whenever the frequency of the ground vibration matches the natural resonant frequency of the house: if there is little or no energy at the resonant frequency of the structure, the structural response to the vibration will be negligible. In a case study, Mishra et al (2017) states the advantage of using electronic delay in limestone mines near sensitive structures with controlled blast design using signature hole analysis technique.

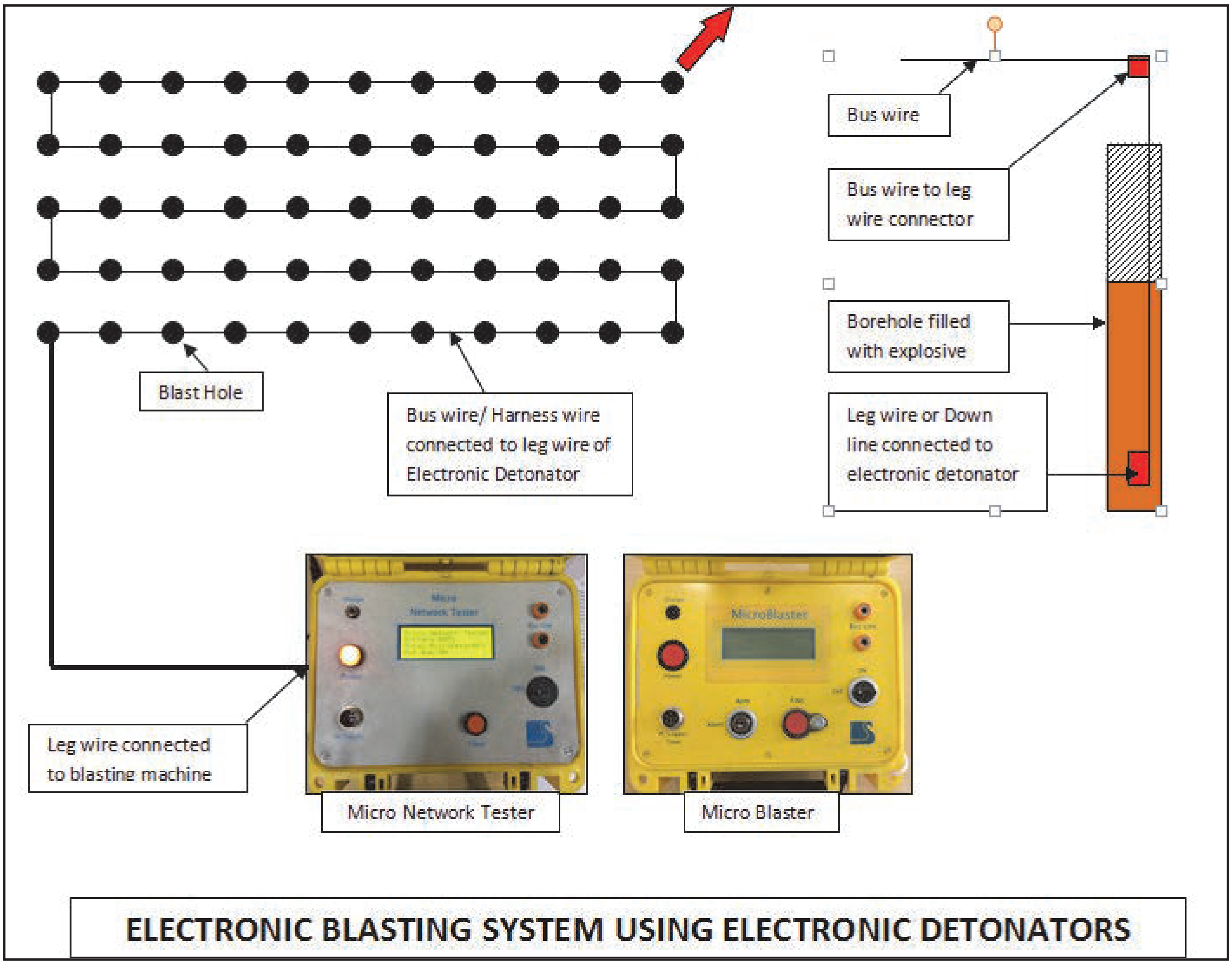


Figure 2 - Blasting machine with dual voltage system for better safety (after Lalwani and Menon, 2016)

Some experimental blasts carried out by Wetherelt (2007) and Bleuzen et al (2005) for a comparative study of ppv and perimeter control in tunnels by using both non electric detonators and electronic detonators, reveal a substantial control on both ppv and profile of tunnels.

By choosing delay times (Δt) that create "destructive interference" at frequencies that are favored by local geology, the vibration that excites structural elements could be reduced. The process of destructive interference and constructive interference of particle velocity are shown in Figure 3. In this method, accurate delay times are crucial to effective vibration control. Electronic detonators have less than 1 ms scatter. In this light, researchers have started to find both limitations and new potential in this new technique of controlling blast vibration. The computer analysis determines the application of delay timing between holes, between rows and between decks which would produce the most favorable blast-induced vibrations for buildings and urban dwellings. The studies conducted by Decon & Duniam (1997) and Bartley & Trousselle (1998) have shown reduction in PPV by use ED in comparison with Pyrotechnic Detonators (PD). The data were compared of the above studies are shown in Figure 4. Few studies have evaluated the increase in frequency by use of ED. A summary of some of these studies are tabulated in Table 1. The higher frequency is obtained by ED are very helpful aspect in managing vibration limits. As the structures are more prone to damage in low frequency range as compared to higher frequency range.

The study by Sharma (2009) examines the structural response to blast-induced ground vibration. He underlines the importance, from an environmental point of view, of minimizing vibrations induced in urban dwellings by blasting. The maximum response of a building to blast-induced ground vibration occurs whenever the frequency of the ground vibration matches the natural resonant frequency of the structure: if there is little or no energy at the resonant frequency of the structure, the structural response to the vibration will be negligible.

A reduction of the ppv is noticeable when ED are used: this trend is shown in Figure 4, where scaled distances are plotted against peak particle velocities; data refer to 18 blasts that were fired during testing on site, 9 of them with PD and the rest with ED.

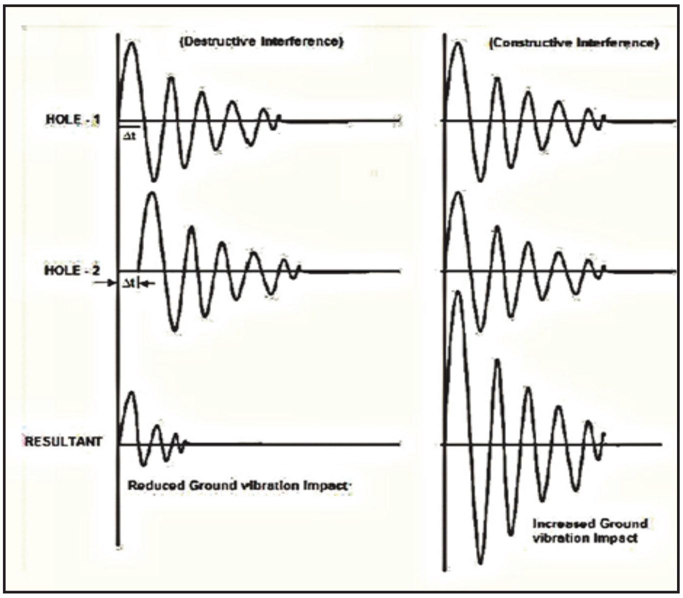


Figure 3 - Process of destructive interference and constructive interference of particle velocity.

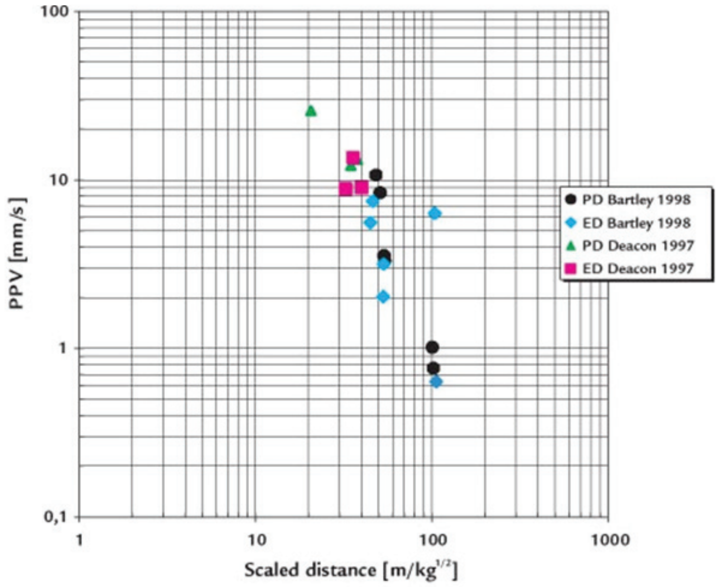


Figure 4 - PPV data from Deacon et al.(1997) and Bartley et al.(1998) have been processed to obtain comparison between ED and PD

Authors:		ppv Min			ppv Max		
		ED	PD	%	ED	PD	%
Deacon C., Duniam P., Jones M., 1997		8.85mm/s	12.18mm/s	-27	13.54mm/s	25.8mm/s	-47
Bartley D.A., Trousselle R., 1998	Rad.	0.25mm/s	0.51mm/s	-51	5.21mm/s	5.72mm/s	-9
	Vert.	0.25mm/s	0.38mm/s	-34	4.06mm/s	3.94mm/s	3
	Tran.	0.64mm/s	0.76mm/s	-16	7.49mm/s	10.7mm/s	-30
Bartley D.A., Winfield B., McClure R., Trousselle R., 2000	Rad	4.57mm/s	3.3mm/s	38	8.89mm/s	5.84mm/s	52
	Vert.	2.54mm/s	3.3mm/s	-23	6.1mm/s	4.57mm/s	33
	Tran.	2.79mm/s	5.08mm/s	-45	14.2mm/s	7.11mm/s	100
R., Chantry R., 2003		3.0mm/s	3.8mm/s	-21	5.0mm/s	9.8mm/s	-49
McFerren W., Moodley P., 2004		0.13mm/s	0.8mm/s	-84	24.3mm/s	152.0mm/s	-84

Table-1 Comparison between different ppv values, using ED and PD firing systems separately.

The study by Bartley et al. (1998) refers to the employment of a 60 kg/hole charge per delay (cpd); the events were monitored at a distance varying from 400 m to 822 m. Deacon et al. (1997) refer to another case, in which the cpd were in the 20-46 kg/hole range using PD, and in the 16-20 kg/hole range using ED ; the events were monitored at a distance of 140 to 180 m (using PD), and from 130 to 160 m (using ED). During mining operations in a South African quarry (quartzite and sandstone) McFerren et al. (2004) adopted ED and PD (shock tube). The cpd was 230 kg and the powder factor was 0.42 kg/m3. The ppv monitored by Chavez et al. (2003) are the results of the blast with the comparison of ED vs. PD, with inter hole delays of 12 ms in a French limestone quarry. In the same paper, the reductions of ppv generated by ED in another quarry are reported; 40 to 55 % with respect to the ppv obtained by PD. Few authors evaluate the frequency increase when EDs are employed. In particular, by using the relation F = 1000/delay to get the dominant frequency, the expected value of the frequency can be calculated (Deacon, 1997; Chavez, 2003). The increase of frequency values was observed by adopting ED instead of PD (shown in Table 2).

Also, the airblast levels were recorded by Baka Abu (2002) and McFerren et al. (2004) during mining operations. The first author obtained these results: the airblast levels were reduced from 127 dB to 108 dB (-15 %) using ED instead PD. McFerren et al. (2004), during blasts initiated with ED instead of PD, observed a reduction of 3 %.

Authors	ED	PD	%
Bartley D.A., Trousselle R. 1998	26÷64 Hz	20÷47 Hz	30÷36 %
Carter R.A., 2002	26÷39 Hz	8÷20 Hz	>95 %
Bartley D.A., Winfield B., McClure R., Trousselle R., 2000	13÷63 Hz	19÷55 Hz	-31÷15 %
McFerren W., Moodley P., 2004	30÷71 Hz	26÷57 Hz	15÷25 %

Table - 2 Comparison between different ppv values, using ED and PD firing systems separately.

2.2 Control of Fragmentation

No formal information is available on primary reason by various customers for use of ED over PD or other systems. However improvement in Fragmentation seems to be second biggest reason for increase in use of ED. Better fragmentation also impacts the downstream operations of mining. Grobler (2003) refers to the results obtained in surface mining, particularly on the log-linear plot of muck pile; ED produced a reduction in the upper size and the fines. In contrast, the grain size distributions related to ED, evaluated by König et al. (1994) and Havermann et al. (1995), are systematically higher compared to PD. The study by Bartley (2001) of the post-blast muck pile excavation indicated a 25% reduction in dig time using ED. Moreover, the crushing operations show a reduction of electric power consumption (kWh/t) of about 6 - 10 % if EDs are employed. When EDs are employed, fragmentation improved and the block size distribution is upgraded (in comparison with PD) as follows:

- maximum block size: reduction of 24 %.
- mean size: reduction of 25 %.
- minimum size: reduction of 10 %.

Tose and Baltus (2002) compared the fragmentation results from the use of electronic detonators and shock tube initiating systems under similar mining conditions. Rai and Imperial (2005) reported reduction of mean fragment size from 0.55-0.59 m (with PD) to 0.43-0.45 m by use of Electronic detonator in hard rock formation. Another comparison between ED and PD is the rock fragmentation degree obtained from the blast (Table 3).

2.3 Control of Muck pile shape

Muck pile requirements for Dragline, Shovels & Wheel loaders are different. With ED's accurate timing, it's possible to speed up and slow down certain parts of the shot to change the muckpile profile. A basic rule is that a hole that detonates a long time after the hole next to it will tend to move into the gap where the last hole was. It's possible to change the height of the pile and where the pile sits by changing the timing between the holes.

Authors	Max Size		%	Mean Size		%	Min Size		%
	ED	PD	%	ED	PD	%	ED	PD	%
HAvermann T. et al., 1995	1500mm	1800mm	-17%	255mm	410mm	-38%	60mm	100mm	-40%
Deacon C.,Duniam P., Jones M., 1997	680mm	900mm	-24%	125mm	200mm	-37%	20mm	50mm	-60%
Bartley D.A., Trousselle R., 1998	1115mm	1485mm	-25%	236mm	291mm	-19%	13mm	21mm	-38%
Konig R., Petzold J., 1998	1100mm	1500mm	-27%	250mm	400mm	-37%	75mm	100mm	-25
Petzold J., Hammelmann, 2000	812.8mm Passing			406.4mm Passing			202.3mm Passing		
	78.30 %	63.20%	19%	34.90%	24.10%	45%	9.40%	4.8%	96%
Bartley D.A. et al., 2000							203mm Passing		
				214mm	320mm	-33%	76.70%	55.90%	-37%
Mckinstry R., Floyd Bartley D., 2002	90% Passing			50% Passing			10% Passing		
	3.98*	7.07*	-44%	2.87*	2.92*	-2%	1.44*	0.99*	45%
Grobler H.P.,2003	90% Passing			50% Passing			10% Passing		
	500mm	750mm	-33%	70mm	70mm	0%	10mm	3mm	233%
McFerren W., Moodley P., 2004	53mm sieve aperture			13.2mm sieve aperture			2mm sieve aperture		
	10%	17%	-41%	50%	75%	-33%	90%	95%	-5%

Table - 3 Rock fragmentation as a result of blasting with electronic delay versus Nonel delay

2.4 Miscellaneous Advantages

The overarching goal for drill and blast is to use the energy from the bulk product to fragment the rock. In most mines, the bulk product cost is more than all other drill and blast costs combined. ED when used to their potential will achieve more with the rock using the same energy. Depending on the mine's situation, this can deliver increased productivity or assist to reduce costs by blasting the rock better so it digs faster and the mine produces more for the same cost. With accurate timings of ED it is possible to reduce back break & control wall damage. Idling of mining machinery during the time of blast as well as wear & tear of mining equipment due to shifting away the blast face can be reduced with increasing the size of blast without increasing the vibration limits. Some of the Indian mine has reported increase in blast size by 40-50% in critical area. Also it is possible with ED to blast multiple coal seam or seam having steep gradient along with intermittent burden, in metal mines ore & waste can be blasted together, with very low dilution.

3.0 FIELD APPLICATION OF ELECTRONIC INITIATORS - A CASE STUDY:

Although the electronic delay initiation is an established technology abroad, not much quantitative studies have been conducted in India. So far it has been opted as a safety requirements rather than a productivity booster. Therefore, CSIR-CIMFR undertook a study to quantify the benefits of electronic initiation system in one of the major coal mines of Western Coalfields Limited (WCL).

3.1 Details of the mine

Ghughus Opencast Coal Mine is situated at about 50 km from nearest town Chandrapur of Maharashtra. The area is bounded by 20o 01' 05" to 20o 04' 10" N & Longitudes 79 o 03' 09" to 79 o 05' 00" E and falling in Survey of India Topo Sheet No. 55 P/4. The annual production capacity is 1.90 MT anf the total mining lease area is 1020 ha. The nearest village is situated within 1 km from the boundary of mine. The mining is done by mechanized method of Shovel – dumper and dragline system of with horizontal slicing method. Rock excavation is by drilling and blasting by using Cartridged Emulsion explosive. The bird eye view of the mine and the OB benches where the trial blast conducted are given in Figure 5 and Figure 6 respectively. The working depth of mine varying from 90m to 140 m below ground level. Water table is in the range of 3-13 m bgl.

3.2 Geology of the mine

The geological formation encountered in the Ghugus OC can be divided into mainly three categories. The top layer is soil with varying thickness of 3-20m and next layer is yellow, brown, red, yellowish white ferruginous sandstone, occasionally grey sandy shale/shale of Kamthis series with varying thikhness of 6-100m. Most of the OB benches of this mine exists in this layae. Next to this layer is Grey white medium to grey sandstone of Barakar series with varying thickness of 12-140m.

Figure 5 - Bird eye view of Ghugus Opencast mine

Figure 6 - Test blast preparations with electronic delay at OB bench

The overburden bench consists of sandstone with medium hard strength and the compressive strength measured by Schmidt Rebound Hammer was in the range of 60-75 MPa. There exists a composite seam, which is about 21 m to 26 m thickness including all dirt bands and parting in the present area occurs in 4 sections and the parting between Composite Sections varies from 3.54 m to 7.06 m. All sections of the Composite Seam are virgin. The general strike of the coal seam is north-south in the major part of the area with minor swing in central part of the area as determined from the floor contour plan of Composite-D Section. In the sub crop zone near boreholes CMWMG-17 & 28 the strike becomes northwest-southeast. The dip of the strata ranges from 4° to 7.5° (gradient 1 in 7.5 to 1 in 14.0) and dipping towards west and southwest direction.

3.3 Test Blasts at OB bench

Four test blasts were conducted with electronic delay initiation system and five blasts were conducted with Nonel shocktube initiation system at different OB benches having similar rock mass and depth from surface with an objective to compare blast performance and results of two different initiation systems. Electronic detonators of Gulf Oil Corporation Limited (GOCL) with a trade name 'e-det' were for electronic initiation. The specifications and features of this electronic initiation system are:

- *Product name: GOCL make e-det*
- *Length of leg wire with detonator: Any length can be provided (down the hole)*
- *Length of Harness wire: Any length can be provided (between holes)*
- *Contents of Tool kit : Programmer Tester – For testing functionality before use and programming delay time; Field circuit Tester – For testing the circuit continuity and reading the delay time given for each det in the circuit; e-Exploder - For firing the circuit after charging / stemming, withdrawal of men & machinery to safe distances is over.*
- *Key attributes of e-det include:*

  (a) They are designed to be accurate to the extent of 1ms scatter or 0.02% of delay time used

  (b) The delay time can be chosen from 1 m -10000 ms as per blast conditions like excess crest burden, excess toe burden, excess spacing, rock structure, rock type etc.

  (c) They delays are safer to handle and use as they can be detonated only with an e-exploder, which in turn generates digital signal specific to a manufacturer. They can't be fired with any other device whatsoever. Thus they are less theft prone too.

  (d) They are designed to be safe from extraneous currents/charges like static charges, electro-magnetic waves, radio waves etc.,

  (e) Millions of detonators can be made with similar accuracy and with consistency.

  (f) Can be checked for functionality, before use, without firing.

  (g) An electronic chip is being provided inside the electronic detonator for providing delay time, these detonators have longer shelf life without sacrificing on delay time accuracy.

Field circuit tester with electronic delay detonators and leg wires used for charging are shown in Figure 7. The blasthole diameter was 150mm and the bench height and hole depth was varying from 9 to 11m. Maximum number of rows were 7-10 in each round. The average specific charge used was 0.5 kg/m3 in all the rounds. The other blast design parameters are given in Table 4. The blast parameters like fragmentation, throw and peak particle velocity of vibration were monitored for blast performance evaluation. The blast vibrations were monitored by blasting seismographs and fragmentation size distribution analysis was carried out by image analysis software called Wipfrag of Wipware Inc., Canada.

4.0 BLAST PERFORMANCE ASSESSMENT

In order to quantify the benefits due to use of electronic delay, a comprehensive study was carried out by conducting a detailed investigation on the blast rounds with Nonel delay and electronic delay. Blast performance evaluation was carried out by conducting post-blast analysis and measuring blast induced ground vibrations and air overpressure, fragmentation, flyrock and backbreak for both types of initiation systems. The blast data analysis and the comparative results of two different explosives are explained below in detail.

Blast No.	Initiation Type	No. of holes	Avg. Burden x Spacing	No. of cartridges per hole (m)	Avg. Total Charge / hole	Total Charge/ round (kg)
1	Electronic Initiation system	80	6.0 x 8.0	18	237.5	19000.0
2	Electronic Initiation system	96	6.0 x 8.0	19	237.5	22800.0
3	Electronic Initiation system	110	6.0 x 8.0	18	240.6	26468.8
4	Electronic Initiation system	70	6.0 x 8.0	17	240.6	16843.8
5	Nonel Initiation system	120	6.0 x 8.0	19	234.4	28125.0
6	Nonel Initiation system	135	6.0 x 8.0	20	234.4	31640.6
7	Nonel Initiation system	155	6.0 x 8.0	18	234.4	36328.1
8	Nonel Initiation system	115	6.0 x 8.0	20	240.6	27671.9
9	Nonel Initiation system	140	6.0 x 8.0	19	234.375	32812.5

Table - 4 Blast design parameter used for test blasts at Ghugus OC

Figure 7 - Field circuit tester with electronic detonators and leg wires

4.1 Blast induced Vibrations

The ground vibrations for all the test blasts were recorded with seismographs fixed near site office building. The dominant excitation frequency data for both the initiations is given in Table 5. Attenuation model for ground vibration levels with Nonel initiation and electronic delay initiation is shown in Figure 8. The models clearly indicate that the intensity is vibrations is higher with Nonel initiation and electronic delay initiation in comparison with the electronic delay initiation. The vibration intensity due to electronic delay initiation is reduce by 44-57 % in comparison to the vibration induced due to Nonel initiation.

Another important result observed in regression analysis is there is less scatter in the attenuation data due to electronic delay initiation than Nonel initiation and hence the correlation coefficient is more for electronic delay initiation than Nonel initiation i.e. 0.95 and 0.78 respectively. This might be due to scatter in the rated delay due to Nonel initiation.

The delay between subsequent holes is set in such a way that there would be constructive interference of particle velocity, which was shown in Figure 3. The time lag, Δt was calculated based on the graph from signature hole event data. The constructive interference could be generated successfully, as it was evident from the frequency increase in ED initiation blasts. But in some of the blast rounds it could be achieved partially because of the reasons that the particle wave pattern of that site might not be matching with the signature hole pattern.

4.2 BLAST vibration frequency

Dominant excitation frequency for both the initiations was recorded by seismographs at two different sites. The frequency levels for both PD and ED initiations at two different sites are plotted and shown in Figure 9. The data collected for 8 blasts clearly indicate that at same locations the frequency levels are increased with ED initiation in comparison to PD initiation. The frequency recorded with PD at site office and village is of the range of 6-9.5 Hz and 6-7.5 Hz respectively. Similarly the frequency recorded with ED at site office and village is of the range of 9-12.5 Hz and 9.8-13 Hz respectively. The increase of frequency at site office is in the range of 29-89% except for one event (for 5th blast), where the increase was nominal i.e. only 5%. Similarly there is an increase in the frequency recorded at village, which is in the range of 60-92%.

Another important result observed in frequency analysis is that the jump in frequency facilitated increase in the threshold peak particle velocity as per the statutory limits of DGMS, India (Anon, 1997). This in turm benifitted in increase of maximum charge per delay as well as charge per hole. The increase of dominant frequencies with both types of initiation are within the range of resonance frequencies of structures.

4.3 Backbreak

The back break for all the test blasts were surveyed. The pictures showing back break distances with Nonel initiation and electronic delay initiation are shown in Figure 10. The average back break was 1.4 m with Nonel blasts while it was <0.3m with electronic delay blasts. The back break observations show that it is almost 5 times more for Nonel delay blasts in comparison to electronic delay blasts.

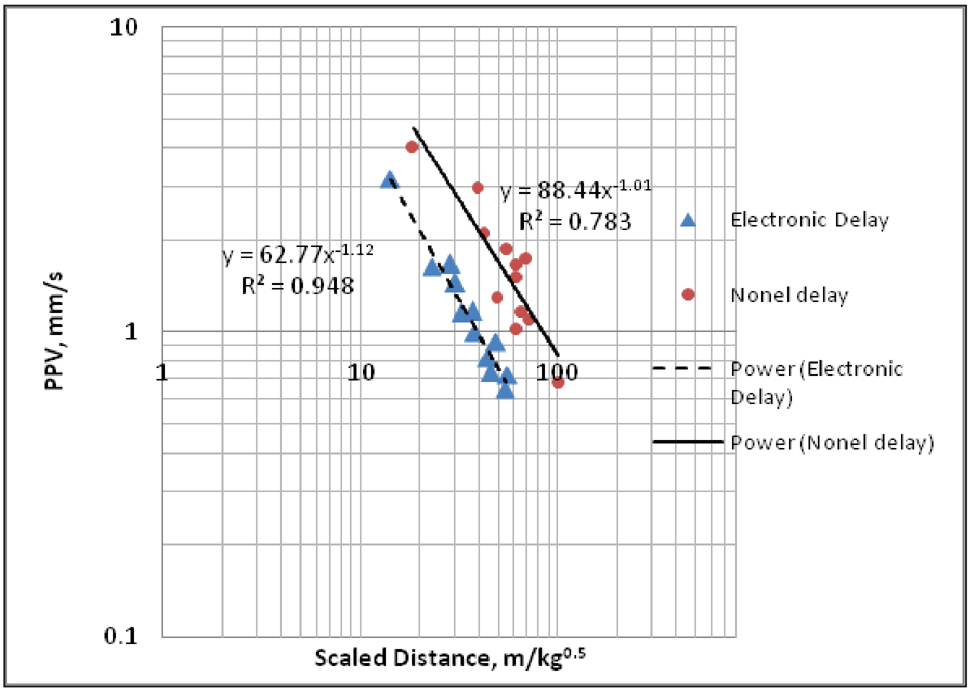
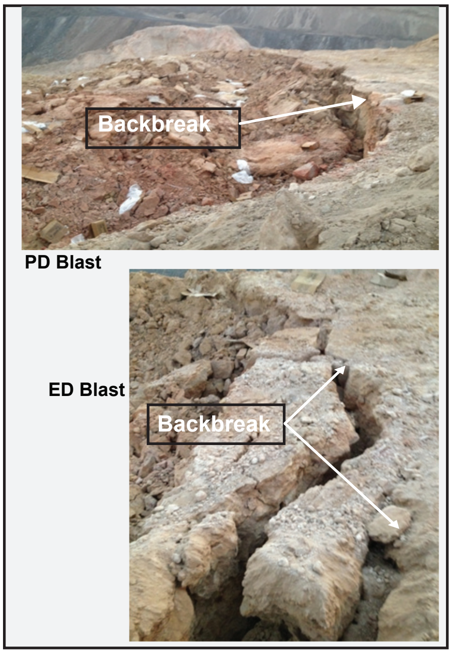


Figure 8 - Peak particle velocity attenuation models with Nonel initiation and electronic delay initiation systems

Figure 10 - Extent of back break levels with PD and ED blasts.



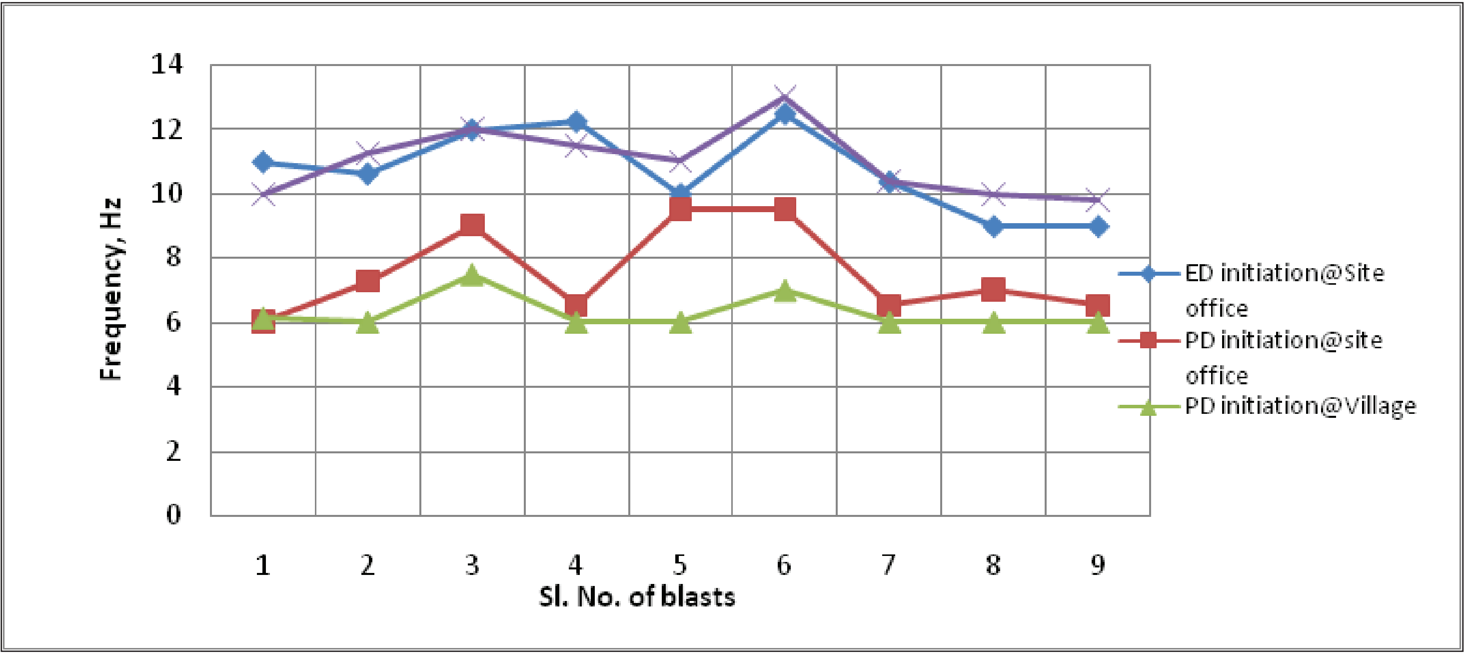


Figure 9 - Frequency levels for both PD and ED initiations at two different sites

4.4 Flyrock

The flyrock projectiles were within 30m electronic delay blasts and that was about 50-70m with Nonel delay blasts. It was also observed that the flyrock from Nonel delay blasts were elected from back side rows of the bench. This could be due to mismatch of the delay time and the prevailing confinement at the back side rows. Therefore, it is also clear from the study that flyrock control is also possible with use of electronic delay initiation.

4.5 Blast Fragmentation

Images of fragmentation were captured with high resolution camera and analysed with Wipfrag software to determine mean fragment size. Two sample pictures taken from the muckpile of blasts with both Nonel delay blasts and electronic delay blasts and shown in Figure 11. Fragment size distribution of muckpiles of test blasts with Nonel delay blasts and electronic delay blasts are shown in Figure 12. The histogram of fragment size distribution with Maximum, minimum and mean sizes of both the initiations are shown in 13.

The 50% passing size (k-50) is considered as the average fragmentation size for all the practical purposes of fragment size analysis vis-a-vis blast optimisation and assessment of performance of unit mining operations. The average fragment size measured by the digital image analysis for blasts with nonel delay blasts and electronic delay blasts was 0.53 m and 0.27 m respectively. It is very clear that the avarage fragment size generated with electronic delay blasts is smaller than that of nonel delay blasts and the reduction in the fragment size is aabout 50%. The fragmentation analysis results for both types of initiations are summarised in Table 5.

Maximum size (m)		Mean size		Minimum size		K-50 size	
PD	ED	PD	ED	PD	ED	PD	ED
2.154	1.66.8	0.562	0.45	0.005	0.005	0.54	0.27

Table - 5 Summary of fragmentation analysis results for both Nonel delay blasts and electronic delay blasts

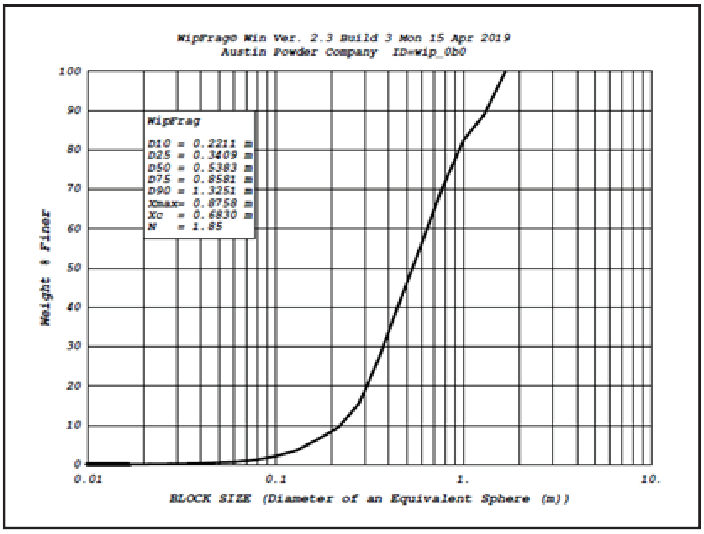
PD Blast **ED Blast**

Figure 11 - Representative image of fragmentation due to PD and ED blasts.

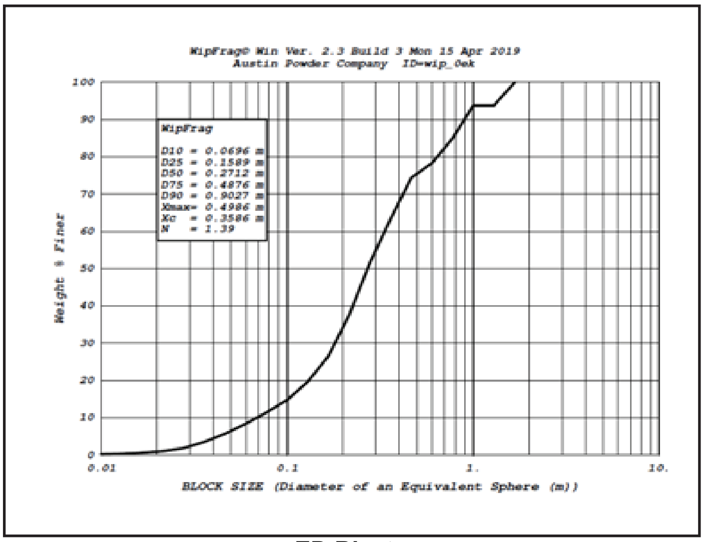
4.6 Shovel Loading Performance

The Shovel Loading Performance study was for both PD blasts and ED blasts. The shovel loading cycle time observed was 36 s/m3 and 21 s/m3 for PD blasts and ED respectively. There was considerable improvement of 42% in shovel loading cycle time with use of ED in place of PD.

Figure 12 - Fragment size distribution of muckpiles of test blasts with PD and ED blasts.

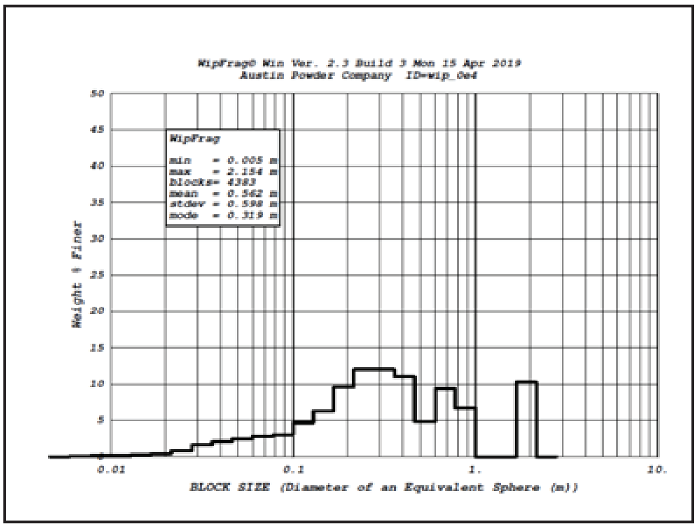


PD Blast

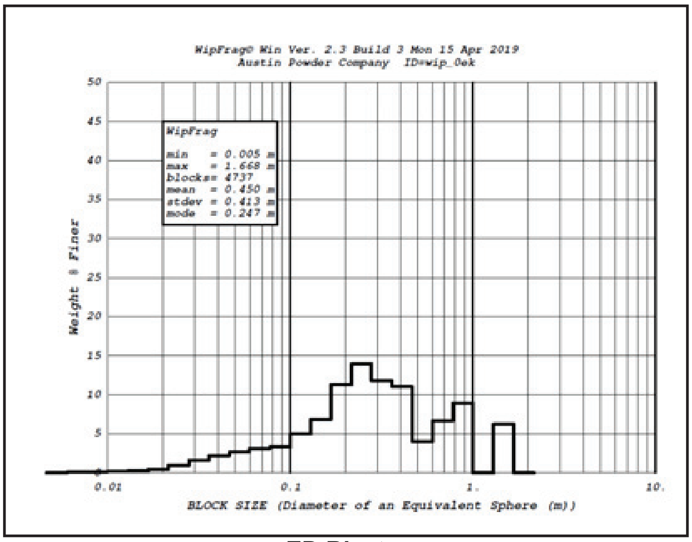


ED Blast

Figure 13 - Histogram of fragment size distribution with Maximum, minimum and mean sizes with PD and ED blasts.



PD Blast



ED Blast

5.0 CONCLUSIONS

The study illustrates substantial advantages in controlling of side effects as well as improvements in blast performance and productivity in sandstone benches of a coal mine. The use of electronic delay detonators with proper blast design and implementation can provide best technical solutions for controlled blasting. The results of comparative case study shows that the employment of electronic delay detonators is advantageous in terms of vibration and airblast reduction, increased frequencies, control of overbreak, which allows greater profile accuracy. The study also resulted in improved fragmentation, diggability which is going to help in overall cost saving. It goes without saying that the advantages of electronic delay initiation can be gained, only when blasts are conducted proper design and implementation. As discussed, the electronic detonators provide more accurate timing than the conventional pyrotechnic detonators.

The following conclusions can be drawn with use of electronic detonators in place of pyrotechnic detonators:

- Field programmable unlimited intervals of delay.
- More efficient application of explosive energy.
- Improved muck size uniformity.
- Increase in excavation productivity.
- Improved control of blast-induced vibrations.
- Improved performance of blasting subsystem like loading, transportation and crushing, if any.
- Cost saving in excavation operations.
- Improved public acceptance of blasting near sensitive and critical zones.

Keeping in view of the edge of Electronic Detonators over Pyrotechnic Detonators, the study concludes that it is high time for Indian mines to switch over to a new initiation technology for not only to address safety issues but also to improve blasting productivity.

6.0 AKNOWLEDGEMENTS

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7.0 REFERENCES

1. Anon, 1997. DGMS, India, S&T circular number 7 on Criteria for safe vibration limits on structures, pp. 1-8.
2. Baka Abu J., 2002, The Implementation of the Smartdet Universal System at Damang Gold Mine, Ghana., Marcus Evans conference, New Paradigm Shift in Drilling and Blasting, Johannesburg, South Africa.
3. Bartley D. A., Trousselle R. Daveytronic, 1998, Digital Detonator Testing in a vibration sensitive environment". ISEE. pp. 247-261.
4. Bartley D. A. 2001, Field Applications and Quantification of Electronic Detonator Technology. ISEE. pp. 1- 19.
5. Bartley D. A., Winfield B., McClure R. 2000, Trousselle R."Electronic detonator technology: field application and safety approach. Explosives & Blasting Technique", EFEE, Munich pp. 149-158.
6. Bartley, D. A., Trousselle, R., 1998, Electronic digital detonator testing in a vibration sensitive environment. In: ANN. Conf. On explosives and blasting technique, 24. New Orleans, Louisiana, USA ISEE,. p. 247-261.
7. Bleuzen Y., Monath F., Quaresma M., João M. 2005, Tunnel blasting in a sensitive environment using electronic detonators". The Journal of Explosives Engineering (Sep/Oct). pp. 6-14.
8. Carter, R. A. 2002, Plugging in to digital detonation: electronic sequencing and initiation systems can improve blasting performance and reduce neighbor complaints. Rock Products, p. 28-30, May.
9. Chavez, R., Chantry, R. 2003, Actual benefits from new technologies related to constant timing with electronic detonators and uniform energy control. World Conference On Explosives And Blasting (EFEE), 2. Prague, , p. 303-311.
10. Deacon C., Duniam, P., Jones, M. 1997, Improved blast control through the use of programmable delay detonators. Int. Conf. On Explosives & Blasting Technique (ISEE), 23. International Society of Explosives Engineers, p. 55-68.
11. Grobler, H. P. 2003, Using electronic detonators to improve all-round blasting performance. International Journal for Blasting and Fragmentation, v. 7, n. 1, p. 1-12.
12. Havermann, T., Vogt, W., Plaumann, G., König, R., Thomas, K., 1995, Digitale Haufwerkanalyse von elektronisch gezündeten Sprengungen im Steinbruch Groß-Bieberau der Odenwälder Hartstein-Industrie GmbH (OHI). Nobel Hefte, n.1, p. 1-9.
13. König, R. 1994, Three modern firing methods are on choice. Nobel Hefte, n. 1, p. 1-12.
14. Konig, S., 1994, Specificity of coenzyme binding in thiamin diphosphate-dependent enzymes. Crystal structures of yeast transketolase in complex with analogs of thiamin diphosphate. 269(14):10879-82.
15. König, R., Petzold, J. 1998, Diez años de experiencia con el sistema electrónico de iniciacion 'DYNATRONIC'. Rocas y Minerales, p. 60-66, nov.
16. Lalwani M., and Menon, S., 2016, Electronic delay detonators-benefits and growth prospects in India, International conference on Recent Advances in Rock Engineering (RARE 2016), Bangalore, pp.424-428.
17. Mcferren, W., Moodley, P. , 2004, Electronic detonator success: an african story, 30thISEE Int. Conf. on Explosives & Blasting Technique. International Society of Explosives Engineers, p. 1-12.
18. McKinstry, R., Floyd, J., Bartley, D., 2002, Electronic detonator performance evaluation. The Journal of Explosives Engineering, May/Jun., p. 12-22.
19. Mishra, A.K., Nigam, Y.K., and Singh, D.R., 2017, Controlled Blasting in a Limestone Mine using Electronic Detonators: A Case Study, Journal Geological Society Of India, Vol.89, January, pp.87-90.
20. Rai, P. F.L. Imperial, 2005, Mesh area vis-à-vis blast performance in a limestone quarry: a case study. Fragblast Int. J. Blasting Fragm. UK 9(4), pp.219–232.
21. Petzold J., Hammelmann, F., 2000, The second generation of electronic blasting systems. Int. Conf. on Explosives & Blasting Technique, EFEE, p. 159-164.
22. Sharma, P. D., 2009, Electronic detonators: Results in substantial techno-economic benefits for large mining operations. Mining Engineers' Journal, India (February). pp. 50-60.
23. Sharma, S.K., P Rai, (2016), Assessment of Blasting Performance Using Electronic Vis-à-Vis Shock Tube Detonators in Strong Garnet Biotite Sillimanite Gneiss Formations, Journal of The Institution of Engineers (India): Series D, April 2016, Vol. 97, Issue 1, pp. 87–97.
24. Tose, S. J., Baltus, C., 2002, Comparison of the fragmentation results from the use of electronic detonators and shock tube initiating systems under similar mining conditions. Fragblast 7 Rock Fragmentation by Blasting, Beijing,p. 50-53.
25. Wetherelt, A., 2007, A comparative study of ppv analysis of tunnel rounds using both non electric and programmable electronic detonation. 33rdISEE Int. Conf. on Explosives & Blasting Technique, International Society of Explosives Engineers, p. 10.

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The idea of "Visfotak" as a Scientific Society took birth in 1998, on the eve of the National Seminar on Explosives Safety and Technology *(Visfotak - 98),* when for the first time the three major constituents of the industry, viz, the Government Regulatory Bodies, the Manufacturers, and the Users respectively, were formally brought together on one platform to deliberate on common Concerns and Issues. Arising from the deliberations, a proposal to establish a Scientific Society exclusively dealing with the Safety & Technological aspects of the Explosives industry was unanimously endorsed.

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(b) To assist the Government of India through its appointed departments and officials in recommending, formulating policies pertaining to explosives manufacture, handling and usage.
(c) To hold seminars, workshops, conferences to promote interaction between the three constituents, viz. the Government regulatory bodies, the manufacturers of explosives and the users of Explosives, in the interest of the growth and health of the explosives industry.
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Prof. Ajoy K. Ghose, a doyen of the Mining Engineering Academia of India, passed away on 13th March, 2019. Prof. Ghose was amongst the leading lights during the founding of 'Visfotak', and later, extremely supportive in every manner he could as an inspirational member of the Editorial Advisory Board of this Journal. As a token of our gratitude with a deep sense of loss, we reproduce below his 'Message' that he sent for the inaugural edition of the Journal !!

Editor

Prof. Ajoy K. Ghose
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Indian School of Mines, Dhanbad

Foreign Member, Academy of Mining Sciences (Russia)
Hony. Life Member, Polish Association of Mining Engineers
Vice President, International Organizing Committee of World Mining Congree
Editor, Jouranl of Mines, Metals & Fuels
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MESSAGE

I am delighted that Visfotak, India's very own Explosives Safety and Technology Society, is launching a News Journal for networking amongst its members and all those involved in the explosives industry. I am confident that this will help in disseminating information besides understanding the trials and tribulations of the explosives industry. The role of Visfotak, as a scientific society, in providing the roadmap for future for this core sector will, I hope, be highlighted.

Ever since the time of Berthold the Black, use of explosives in the industry has made rapid strides, providing a key tool for all excavation systems. From the serendipitous discovery of dynamite by Alfred Nobel, the explosives industry has made major advances in developing explosive, compositions of improved safety, and the cascade of innovations in bulk explosives, has contributed to improved economy in operations in the minerals sector. The developments in explosive accessories, have been equally phenomenal. I have no doubt, that the newsletter will be able to encapsulate for its discerning readers, the trajectory of new developments and educate them in the safe usage of explosives.

I hope that this Newsletter will have a wide readership, simulating and encouraging explosives users, manufacturers, academics and scientists to join in the adventure of development for making explosives safe and cost-effective. I wish the Newsletter all success – good luck and godspeed!

Prof. Ajoy K. Ghose

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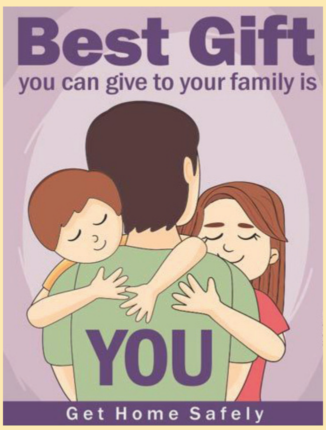

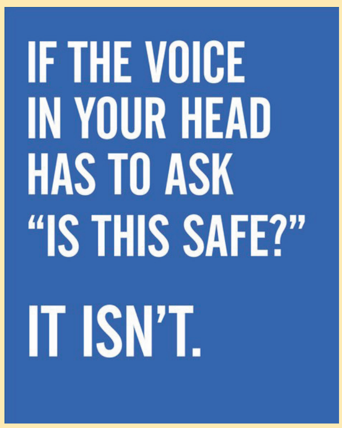

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ENTRANCE FEE ☐ Rs. 50/-

MEMBERSHIP FEE FOR FIVE YEARS ☐ Rs. 200/-

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Membership of Professional Bodies, Awards, Recognitions ______________________

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Mode of Payment : Payments towards Membership fee may please be made by Cheque in favour of 'Visfotak' drawn on any Bank. Add Rs. 30/- for Outstation Cheques or send a Demand Draft payable on any bank in NAGPUR.

DD / Cheque No. _________________ Date __________________ For Rs. / US $ ___________________

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Please forward the above application along with Cheque / Demand Draft to the following address :

Dr. N.R. Thote, Assistant Professor
(Hony. Secretary, Student Chapter
Explosives Safety & Technology Society (Visfotak)
Department of Mining Engineering
Visveswaraya National Institute of Technology, Nagpur - 440 011

Place : _______________ Date : _______________ Signature ___________________________

***Please enclose a detailed BIO-DATA and a recent passport size PHOTOGRAPH.**

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Outokumpu invents for human safety in mines

Fire or explosion in the mine area can create many severe life threatening circumstances & rescuing employees from underground mine can be very difficult. The mine is demanding environment for any material, but stainless steel has advantages, which no other material can beat. This was also the reasons why HEAT-IT Oy from Rovaniemi, Finland selected Outokumpu's high-chromium ferritic stainless steel grade 4622 as the building material for RESPETRA rescue chamber.

The RESPETRA rescue chamber is a stainless steel cabin used in underground mines and construction sites. It provides shield and protection for miners for example in case of fire for as long as for four days. HEAT-IT makes two different size chambers. The smaller cabin is for eight persons and the larger one is available for 14 persons. The rescue chamber operates independently and contains full equipment for persons, such as seats, tables, beds, toilet and washing facilities. Oxygen masks are not needed inside the chamber.

Outokumpu's stainless steel is already in use for rescue chambers in mines in Kittilä and Kemi, Finland, as well as in underground construction sites in Oulu and Helsinki capital area.

Natural choice for the Rescue chamber

Outokumpu 4622 is high-chromium ferritic stainless steel developed recently in Outokumpu Tornio Research Centre and it contains 21% chromium. This is improved grade from high- chromium ferritics currently available in the market offering and it was designed based on customer needs.

Outokumpu 4622 has high corrosion resistance and it is competitive alternative to common austenitic grades, such as 1.4301 (304) and 1.4307 (304L). Its performance is even superior in certain environments. It has good chloride resistance, even including resistance of stress corrosion cracking. One of the benefits is the good weldability and machinability. Also high r-value and limiting drawing ratio makes this grade ideal for deep drawing applications.

Outokumpu 4622 is a natural choice for a rescue chamber, because it is a perfect fit for the demanding environment in the mine. Stainless steel is practically maintenance free, which leads to low life cycle cost.Besides good weldability, corrosion and heat resistance 4622 has lower cost than stainless steel grades with nickel.

Low life cycle cost

Stainless steel surface doesn’t require any coating. As the wall of the chamber are not painted, the air in the rescue chamber stays fresh. Outokumpu 4622 is technically very suitable for the rescue chamber due to its good combination of strength and toughness and can thus handle pressure relief well. The walls of the rescue chamber are curved to provide protection against pressure and gases.

Development based on customer needs

The Outokumpu 4622 is one of the new additions to the Outokumpu's portfolio and the RESPETRA rescue chamber is just one example where this high-chromium grade could be used.

The Outokumpu 4622 is Outokumpu's first high-chromium grade. The grade offers tangible benefits to Outokumpu customers for example in corrosion resistance, strength and formability. It is competitive alternative in terms of alloying.

Outokumpu 4622 can be used in a broad range of applications from home appliances, to exhaust systems, process equipment and cladding panels. Outokumpu 4622 steel grade is a standard ferritic stainless steel by its technical properties. The new ferritic steel grade fulfills already ASTM UNS S44330 requirements.

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Tata Steel ensures efficient mining by adopting innovative technologies to minimise environmental impact and help conserve precious raw materials. Iron ore fines generated during mining and processing are made productive by converting into pellets, which are used as blast furnace feeds, replacing iron ore lumps and leading to energy savings. Clean Coal Technology reduces ash content from 15% to 8%; reduces carbon consumption and cuts down CO_2 emissions. Tata Steel was also the first to use Stamp Charge Coke Making Technology for steelmaking with lower-grade coal.
Noamundi Iron Mine of Tata Steel has been adjudged as the 5 Star rated mine in the country by the Ministry of Mines, Government of India
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