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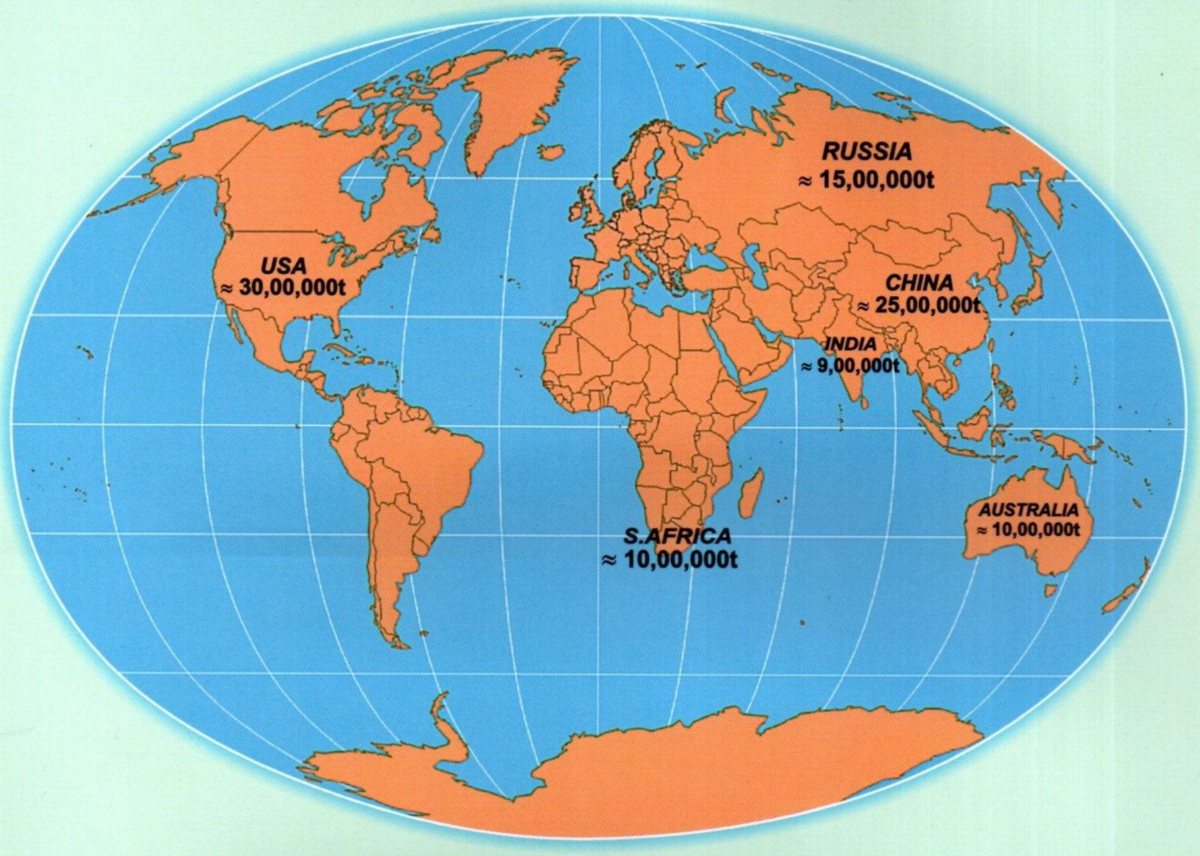
JOURNAL OF THE EXPLOSIVES SAFETY AND TECHNOLOGY SOCIETY (VISFOTAK) INDIA, DEALING WITH SAFETY AND TECHNOLOGICAL ASPECTS OF THE EXPLOSIVES INDUSTRY



GLOBAL EXPLOSIVES CONSUMPTION - 2012 (EST.) : 10-11 MILLIONS TONNES

India ranks amongst the major producers of industrial explosives in the world, with an impressive growth trajectory from a small demand base of 2500t in 1950 to the current level of 900,000t and burgeoning @8% annually. Nevertheless, the progression on the technology curve has been tardy and persistently asymmetrical with the global trend by a long margin ?

Cover Feature : Emerging Dividends from "Technology - Safety Interface" of Modern Industrial Explosives : Why India has lagged behind the global trend ?

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."

Editorial...

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

A new explosive technology is potentially differentiated by its unique technology-safety interface; and it hadn't been more stark than the transition from NG based explosives to the new genre of simple and safer AN based blasting agents which are amenable to bulk production and delivery directly into blast holes from a mobile platform, thereby yielding unparalleled dividends in terms of efficiency and productivity with absolute public safety at large.

Correspondingly, an erstwhile rigid, commodity- product focused marketing paradigm has entirely given way to an open-ended dispensation of marketable set of Product Systems & Services(PSS) which are customer specific, designed to jointly fulfill the Quality Customer Wants (QCW)
.

Though India presently ranks amongst the major producers of industrial explosives in the world; nevertheless, the progression on the global technology curve has been tardy and asymmetrical , and the explosives market is yet to fully converge and match up with global developments ?

These are the issues of concern which are dealt in the 'Cover Feature' by appraising the Indian paradigm keeping the USA market as the 'Bench Mark'.

What ever developments have come about are not due to any policy frame-work, but entirely by virtue of the remarkable impact of the new genre of blasting agents on the explosives market. An outstanding example is the idea of establishing small scale units close to the points of consumption, made feasible by the simplicity of slurry formulations; and soon enough during the 1980s, SSI Slurry units quickly mushroomed leading to over capacity and intense price competition in the market place. These SSI units further lent strong impetus to the growth of Mobile Bulk Systems which currently make up close to 70% share of the market.

However, whilst the growth of Bulk Systems has been impressive, it's yet to reach its full potential. The mobile bulk units currently deployed are mostly designed to dispense one kind of formulation. In other words, the bulk operations are more or less homogeneous; indeed, basically commoditized and differentiated only on the basis of relative prices on offer: a far cry from the modern user specific, 'PSS-QCW' business protocol.

The balance 30% of the explosives market comprise 'packaged explosives' and clearly anachronistic in the context of the global trend?. Close to 1000t of explosives are handled and transported by road every day across the length and breadth of the country, through a large net work of storage magazines, explosives dealers and retailers. From the stand point of 'Public Safety', this segment of the explosives market must transit soon enough to bulk systems, through appropriate legislative and administrative instruments.

Ardaman Singh

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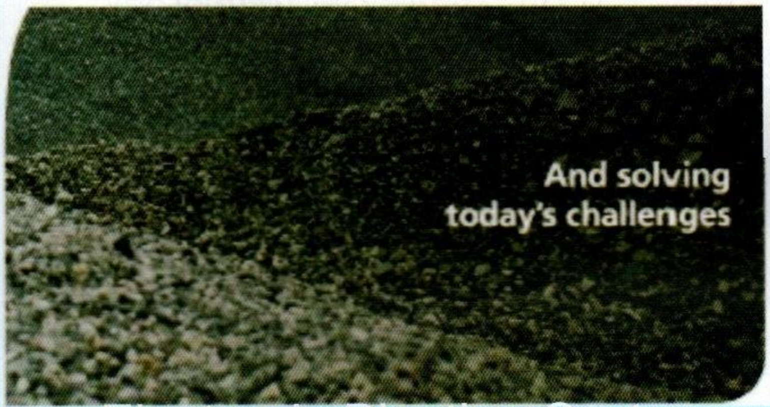

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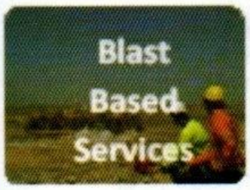

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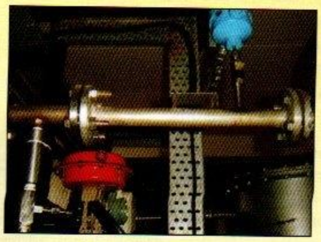

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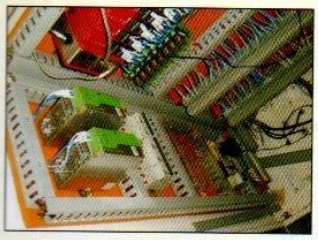

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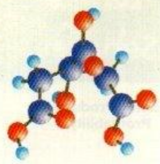

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COVER FEATURE & SUPPLEMENTS

COVER FEATURE

EMERGING DIVIDENDS FROM 'TECHNOLOGY - SAFETY INTERFACE' OF MODERN INDUSTRIAL EXPLOSIVES : WHY INDIA HAS LAGGED BEHIND THE GLOBAL TREND?

1.0 HISTORICAL LEGACY:

1.1 Ancient India was well versed in the science and art of pyrotechnics. There exists enough historical evidence to suggest that India was the original home of gunpowder used in fire arms; references of 'Agneya-Astra' and 'Cannons' are found in the epics of 'Ramayana' and Mahabharta.

1.2 Be that as it may, from the middle of the 18th century, India lost its pre-eminence, paradoxically coinciding with the industrial revolution in Europe ; and perversely enough, it was also the beginning of 'De-Industrialization' of India under the British colonial rule. India's share of world income steadily collapsed from 22.6 % in 1700 to as low as 3.5% in 1950. What ever industrial development that did come about , was created only to sub serve the growth of industries in the UK.

For example, in the context of Nobel's invention of 'Dynamite', it manifested in India for the first time in the form of the Indian Explosives Act,1884, which was enacted only to facilitate import of Dynamites from the UK; whereas, the first indigenous high explosives manufacturing facility in India was established after India gained independence in 1947.

1.3 Free India inherited a weak and disorganized industrial infrastructure, entirely dependant upon foreign sources for technologies. . The mineral/mining base was very small , and so the explosives market, see Table-1.

1.4 Under these circumstances, India perhaps justifiably, opted for a strong, centrally administered and controlled economy model for industrial development, avowedly for rapid economic development and alleviating the poverty in the country. Whereas, in retrospect, it is fair to state that whilst the country did economically advance, the rigid industrial licensing regimen, which was overtly skewed in favor of public enterprises, singularly failed to promote a competitive economy so crucial for fostering an innovative entrepreneurial industrial culture in the country.

Some relevant extracts from *"India 2020 A Vision for the New Millennium", by Dr. A P J Abdul Kalam with Y S Rajan* are illuminating in this regard:-

"About two decades after independence, despite our numerous achievements, doubts emerged about our ability to handle our system on our own. Many of our vital socio-economic sectors began to have a greater dependence on foreign sources for innovation or technology. Self-reliance and commitment to science and technology were the declared policies, but often crucial economic and industrial decisions were based on technology imports or licensed production, both in the private sector and public sectors.

Faced with this unusual combination of growing dependency, a unique institution called the Technology Information, Forecasting and Assessment Council (TIFAC) was born in 1988. Its major task was to look ahead at the technologies emerging world wide, and pick those technology trajectories which were relevant for India and should be promoted.

TIFAC duly prepared during 1993-1996, a Technology Vision - 2020, with the following objectives, for consideration in the Ninth Five Year plan (1997-2002):-

- provide direction for national initiatives in science and technology (ST) ;
- provide a strong basis for policy framework for investment for R&D in the public and private sector;
- the development of an integrated S&T policy both at the state and national levels".

Table 1 - Minerals and Mining, 1951

Mineral Output/ Explosives Consumption	Coal	Iron ore	Lime stone	Lead/Zinc	Copper	Other minerals	Total
ROM (million tonnes)	25	4	3	0.01	0.40	2.0	34.41
Mineral Value (Rs. million)	506	235					741
Explosive Consumption (t)	1500	1000					2500

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

Even though major economic reforms were initiated in the 1990s, and the industrial sectors once closed to the private sector were opened up, the basic structural imbalances have persisted; relatively inefficient public enterprises still account for 20% of the GDP; and the R&D activities are mostly confined to government institutions and research centers. The asymmetry with global developments remains entrenched in the economy which is also reflected by the abysmally low investment in industrial R&D in the country, a paltry sum of $3 per capita (PPP basis) in 2010, compared to $128 in China, and $1350 in the USA.

1.5 Though India is currently amongst the major producers of industrial explosives in the world, with a very impressive growth trajectory, from a small base of 2500t in 1950, to the current size of 900,000 t, and burgeoning @ 8% annually, it is also a reality that the market has persistently trailed behind on the global technology curve by a long margin.

2.0 EVOLUTIONARY PARADIGM OF EXPLOSIVES "TECHNOLOGY - SAFETY INTERFACE":

A new explosive technology is potentially differentiated by its unique 'Technology-Safety Interface' with regard to a troika of three value propositions, viz, Complexity of Manufacture and Use; Scope of Application/ Performance; and importantly, Public Safety.

A chronology of developments in explosives and blasting technologies, since the 1940s, coinciding with the emergence of free India (Annexure-I), highlights a series of revolutionary paradigm shifts in the "Technology - Safety Interface, beginning with the advent of porous prilled ANFO in the 1950s, which have collectively yielded enormous dividends across the entire value spectrum from production to application.

A qualitative assessment of incremental 'added value' dividends, progressively at every shift, on a scale of 0-10, is illustrated in Figure 1.

The incremental profile representative of growth in India is also shown, which is indicative of an entrenched asymmetrical paradigm and consequentially, very high 'Opportunity Costs' to the country's economy, which is the cost of a particular system in use, measured in terms of the value of the next best alternative which is forgone or not chosen?.

2.1 Clearly, there are lessons to be learnt?

3.0 USA AS THE BENCHMARK:

Almost the entire array of new technologies in the 20th century have originated in the USA, and this fact is particularly relevant for India which has similar 'Continental Size' endowments of natural resources, and identical "Techno Economics" profile of explosives demand. See Table 2.

Therefore, the developments in the USA would serve as excellent "Bench Marks" for India.

3.1 A revolutionary paradigm shift in the "Technology - Safety Interface" of industrial explosives occurred in the early 1950s with the advent of porous prilled ANFO and, in its wake, a new genre of modern blasting agents which have for ever, altered the landscape of the explosive industry.

3.2 The remarkably simple and safe 'Do it Yourself' ANFO quickly became the most widely used explosive for surface mining in the USA (propelled by the large spare capacity for nitrogen gas built during WWII and duly converted for ammonia and ammonium nitrate based fertilizer production after the war) and by early 1970's, ANFO held 75% of the explosives market. Indeed, ANFO would have taken over the entire commercial explosives market, barring the permissible class of explosives for underground coalmining, but for the singular deficiency of being hygroscopic and thereby, readily becoming de-sensitized in contact with water.

3.3 As a logical sequel, in due time, came the Cook-Farnam's slurry concept in 1956, which led to the development of water resistant fuel-sensitized AN based Water Gel Slurry Blasting Agents (SBAs), using "saturated aqueous oxidizer (primarily AN solution) in a continuous gel phase for dispersion of both excess solid oxidizer and a sensitizing 'fuel', into a slurry mixture, and chemically cross-linked in order to provide a body to blanket off or retard diffusion of water into and out of the final product."

The safety and efficiency of SBAs was apparent and it effectively replaced around 50% of NG based permissible explosives in underground coal mining, with in a decade of its first approval in 1970.

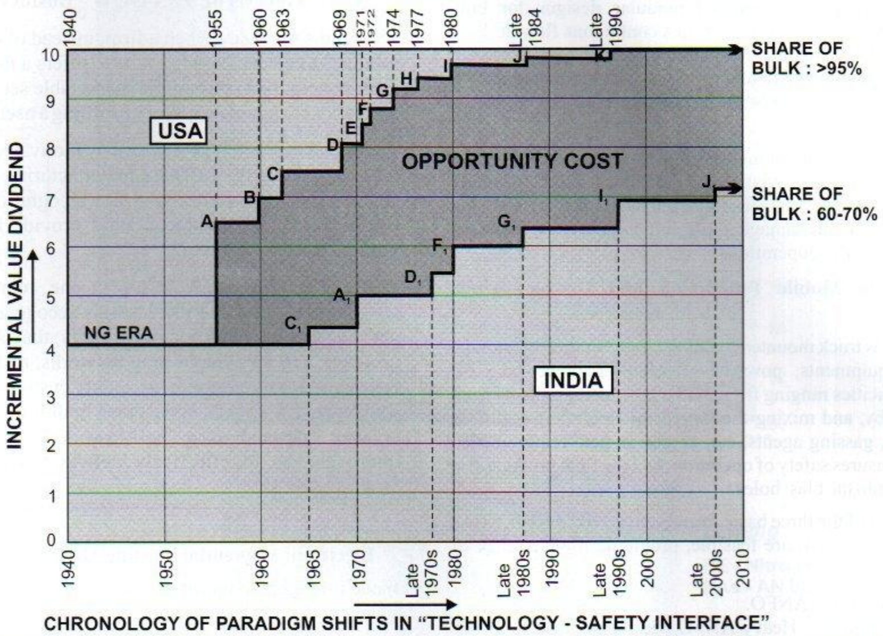
3.4 It was only inevitable that the concept of aqueous AN solution was followed up to its logical conclusion a few years later with an invention in 1969, of a 'Water Proof' Avatar of ANFO in the form of energetic "Aqueous AN solution - in -Fuel Oil" Emulsions, over a wide range of energy densities - from a high of 100 cal /cc to a low of 20cal/cc, on one platform.

Emulsion explosives have proven to be extremely versatile for application across the whole range of blasting requirements, eventually leading to complete phasing out of 'Dynamites' from the explosives market.

4.0 EMERGING DIVIDENDS:

The modern genre of blasting agents, viz, ANFO, Slurries and Emulsions, represents advances in the most important categories of industrial explosives, viz, economy, safety, performance, speed of manufacture and bore hole loading, as follows:

4.1 Simplicity and Inherent Safety of Manufacture and Use.



USA

A - Prilled ANFO : Dawn of Bulk Systems,1955.
B - TNT/ Aluminised Slurries by Cook and Farnam,1960.
C - Non-Aluminised, Fuel Sensitized Slurries, Ireco, 1963.
- Plant-Mixed and Site Pumped Slurry System, Ireco, 1963
D - Emulsion Explosives, 1969
- Methyle Amine Nitrate slurries, DuPont. 1969.
E - Emulsion - ANFO Blends, 1971.
F - On-Site Slurry Mixing and Delivery Unit, Ireco, 1972.
G - Shock Tube Non-Electric Detonators, 1974
H - Computer Modeling of Blast Design, 1977
I - Bulk Emulsion Matrix- AN prills. Blends, 1980
J - Electronic Delay Detonators, Late 1980s.
K - Digital Age of "Virtual Product Delivery and Blasting";
- Laser profiling of benches; GPS hole spotting and automated Drilling and other blast related services, Late1990s.

INDIA

A_1 - AN prills introduced, FCI. 1970 (small quarries)
C_1 - Fuel sensitized slurries,1965 (packaged)
D_1 - Emulsions, Late1970s (packaged)
F_1 - On-Site Slurry Bulk System, Ireco Technology, 1980.
G_1 - Shock Tube Non-Electric Detonators introduced, Late1980s.
I_1 - Bulk Emulsion Matrix – AN prills Blends, Late 1990s.
J_1 - Electronic Delay Detonators introduced Early 2000s.

Figure 1 - Incremental 'Added Value' Dividends.

Table 2 - Explosives Consumption Profile in the USA and India - 2009

Country	Consumption	Coal	Quarrying	Metal Mining	Construction	Misc.	Total
USA	Expl. (t)	1590,000	209,000	176,000	235,000	60,000	2,270,000
	(%)	70	9.2	7.8	10.4	2.6	100
INDIA	Expl. (t)	480,000	20,000	90,000	100,000	10,000	700,000
	(%)	68	2.8	13.6	14.2	1.4	100

4.2 **The unique Rheology of these formulations**, viz, the flow characteristics of solid and fluid ingredients under applied stresses or strains, has enabled modular designs for bulk production processes and systems in a continuous flow at high speeds, easily adaptable for automation and digital control systems for optimization of processes with complete safety, including capability to modify formulations 'on-line' to match specific requirements.

Further, unlike the traditional batch processes, the 'In-Process' volume of active formulation can be minimized and fully contained, thereby, significantly reducing the extent and severity of collateral damage to life and properties, in the event of an accident during operations.

4.3 **Transition to Mobile Production and Delivery Units (MPDUs).**

Typically, a MPDU is truck mounted modular configuration of storage and processing equipments, powered through a power-take off mechanism, of capacities ranging from 5-15, carrying ingredients from a base plant close by, and mixing the ingredients including additives such as sensitizers, gassing agents, etc, at site, as per requirements, with The design ensures safety of operation; and the final product(s) is dispensed directly into the blast holes.

A number of variants of the three basic formulations, viz, ANFO, SBAs and Emulsions, respectively, are feasible, providing a wide range of options for best results :-

- **Dry conditions** : 100% ANFO.
- **Mild Wet conditions** : Heavy ANFO ; Emulsion Matrix mixed with AN Prills.
- **Very wet conditions** : 100% Emulsion Explosive or Slurry Blasting Agents.

The MPDUs, first introduced with ANFO in the 1950s, currently serve over 95% of the explosives market in the USA with the following path breaking, dividends :-

Firstly, *from the stand point of public safety, by eliminating in one stroke, all the risks and hazards associated with handling, storage and transportation of packaged explosive products from fixed plant sites to various distant destinations by road or otherwise;*

Secondly, *and as significantly, the explosive business is for ever unshackled and transformed into an open ended, consumer driven, business model which provides a set of marketable options of 'Product Systems & Services (PSS) tailored to provide Quality solutions that the Customer Wants (QCW). See Box.; And*

Thirdly, *the new market dispensation duly led to the development of new blast related 'Value Adding' technologies and systems to further augment the scope of Bulk System, as follows :-*

- **Computer Modeling and Simulation of Blast Design.**

First introduced by Lang & Favreau in 1972, the application of computer aided blast design and simulation services is an integral component of modern blasting technology. This aspect was dealt in greater details in the previous issue of this Journal, as a 'Cover Feature' 'Value Analysis of Open Pit Mining'.

Box

Genesis of 'PSS-QCW ' Business Model

PSSs put simply, are when a firm, instead of traditional focus on products as saleable commodities, offers a mix of both products and services, that is to say, "a marketable set of product systems and services capable of jointly fulfilling a user's needs".

The initial move to PSS was largely motivated by the need on the part of traditionally oriented manufacturing firms to cope with changing market forces and the recognition that services in combination with products could provide higher profits than products alone.

While PSSs may not result in the reduction of material consumption, they are increasingly recognized as an important part of a firm's environmental strategy; that is to say, a system of products, services, supporting networks, and infrastructure that is designed to be competitive, satisfy customers' needs, and have a lower environmental impact than traditional business models. It is also defined as a "self-learning" system of 'continual' improvements to effectively deliver Quality that Consumer Wants (QCW).

- **Electronic Sequential Blasting Machine- 1973.**

It made it feasible to undertake large blasts with precision and safety, enabling a quantum leap in productivity.

- **'Shock Tube' - Non - Electric Delay Detonators.**

A unique non-electric initiating system with traditional pyrotechnic delay detonators, making it possible to set off an explosive charge at any predetermined point in the blast hole for best results, without the deleterious effect of compression and desensitization of explosive charge which is normally caused by detonating cord initiation system

- **Programmable Electronic Delay Detonators (EDDs).**

The development of EDDs n the 1980s effectively over came the deficiencies inherent in the traditional pyrotechnic delay compositions / initiating systems , that is, the limitation of a small range of sequential delay timings, further constrained by unpredictable variations in the burning time of delay compositions; consequent risk of blast hole cut-offs and misfires.

The EDD's are programmable at-site, making it feasible to precisely program and assign delay time to each blast hole over a wide range with total accuracy, supported by fool-proof circuit testing system thereby completely eliminating cut-offs, and hazards from stray current, etc. Though EEDs are relatively more expensive, but the substantial gains achievable through incremental benefits of greater productivity and safety down stream, far outweigh the additional cost.

- **Laser Profiling of Benches; PLC Operated Automated Drills; GPS Hole Spotting, etc.**

These are supportive precision technologies developed and dovetailed with Bulk Systems.

5.0 LEADING 'BENCH MARKS' FOR INDIA:

The growth profile of the explosives market in the USA and India, respectively, since the 1940s vis-à-vis the chronology of new technologies and developments as they emerged is illustrated in Figure 2.

COVER FEATURE

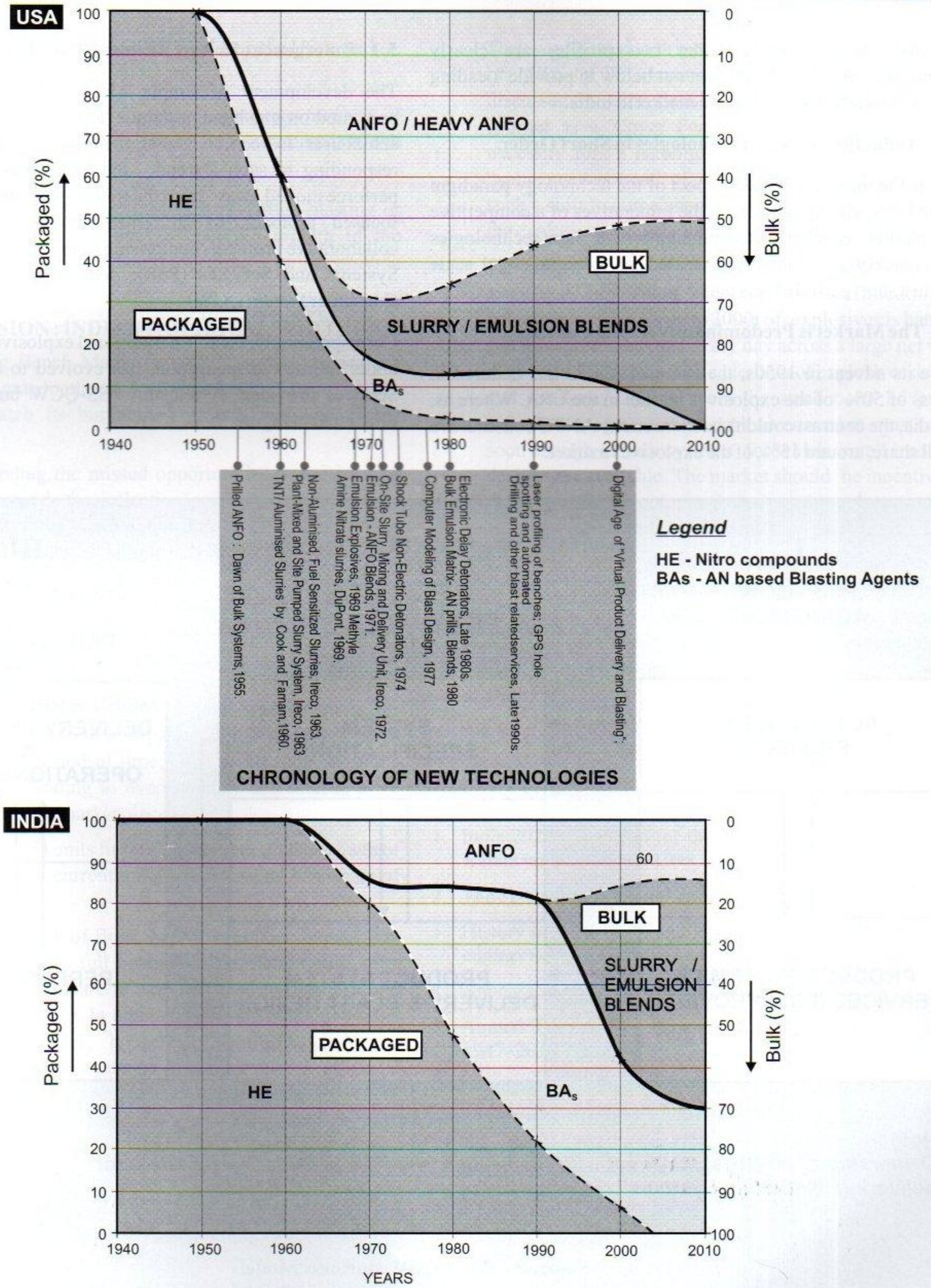


Figure 2 - Profile of Explosives Market in the USA and India : 1940 - 2010

COVER FEATURE

The asymmetries between the two profiles are clearly discernible, which are briefly set out below to provide 'Leading Bench Marks' for the explosives market in India.

5.1 Induction of New Technologies in Short Order.

This is the most remarkable aspect of the technology paradigm in the USA, clearly driven by the imperatives of a competitive free market economic environment where new technologies are quickly assimilated and scaled up to commercial scale within a short period of less than 5 years.

5.2 The Market is Predominantly ANFO Centric.

Since its advent in 1950s, the share of ANFO has endured in excess of 50% of the explosives market in the USA. Where as, in India, the contrast couldn't be more stark; ANFO constitutes a small share, around 15%, of the explosives market.

5.3 Emergence of a New Business Paradigm.

The development of simple AN based bulk formulations, presented on one hand, a unique 'Do it Yourself' option to the actual user to become its own manufacturer; and on the other, responding to such a trend, the explosives business duly perforce moved away from the traditional commodity/product focused protocol, to an 'Open-Ended', consumer driven, collaborative protocol comprising a marketable set of Product Systems and Services (PSS), dedicated to Quality that Consumer Wants (QCW).

Correspondingly, the role a traditional explosives manufacturer, under the new dispensation, has evolved to one of 'Blasting Services Provider'. A relevant PSS-QCW business model is illustrated in Figure 3.

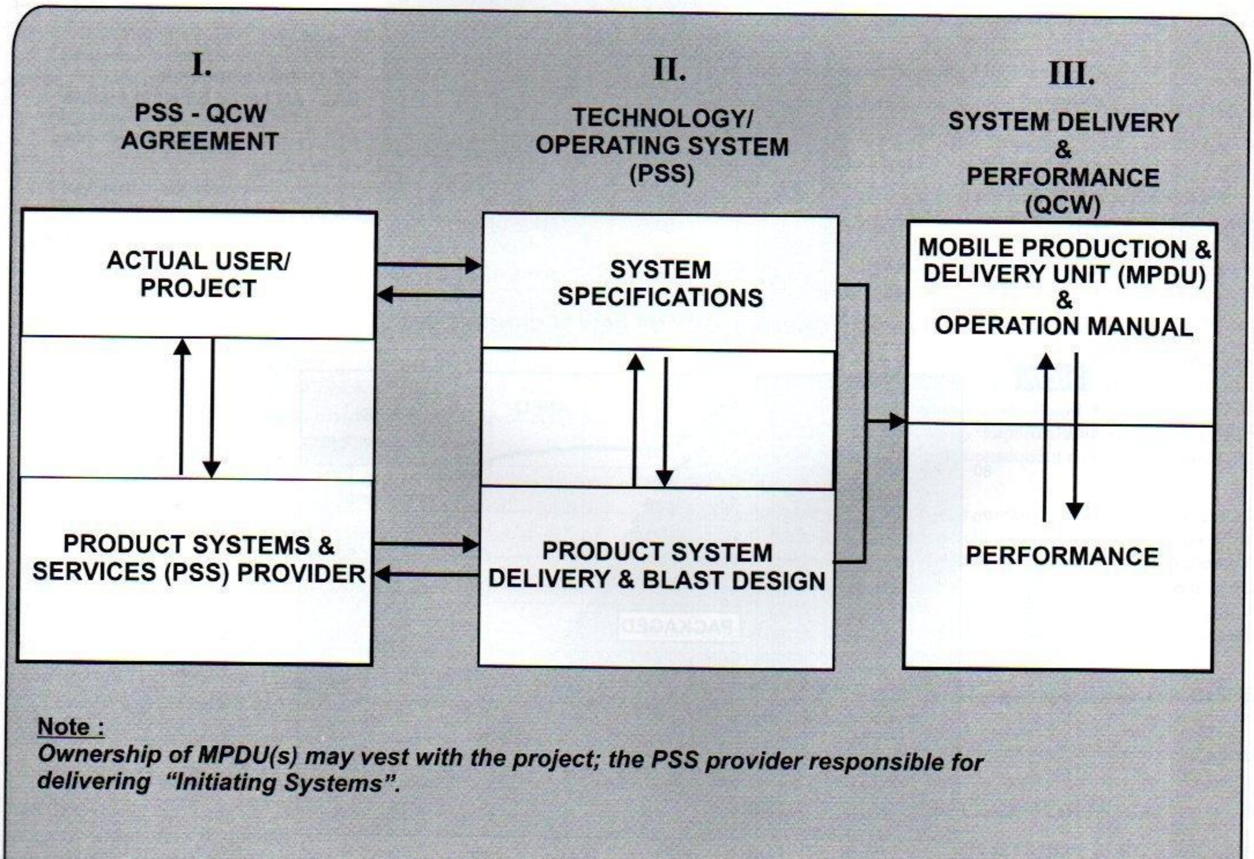


Figure 3 - PSS - QCW Business Model

COVER FEATURE

According to a recent report of IBS World, on the USA market, by 2016 :

"The explosives industry is forecast to generate revenue of roughly $2.3 billion, which represents a five year annual growth average of 2.9%."

"Growth in value adding services such as virtual blasting or product delivery, will continue to underpin growth in the industry, especially in mature market sectors, as well as provide a means for differentiation".

6.0 CONCLUSION : INDIAN PARADIGM , WHITHER?:

6.1 The leading Bench Marks delineated above, set out the future road map for the explosive market in India in order to quickly match its burgeoning growth with the global trends.

6.2 Notwithstanding the missed opportunities in the past, as earlier discussed, the inflection point in the technology paradigm perforce came about during the 1980s, by the remarkable impact of simple AN based slurry blasting formulations on the explosives market in India which gave rise to an innovative idea of small scale industrial (SSI) units for slurry explosives, easy to manufacture and replicate, close to the points of consumption. The investment limit on Plant and Equipment of Rs.10-15 lacs permitted for SSI units at that time was adequate for establishing 3000-5000t capacity units, and very soon within a short period of time, close to 30 such SSI units were created, leading to over capacity and intense price competition in the market place.

Indeed, these SSI units further lent impetus to the growth of MBPDUs which currently make up close to 70% share of the market.

6.3 Whilst the growth of Bulk Systems has been impressive, it's yet to reach its full potential. The mobile bulk units currently deployed are mostly designed to dispense one kind of formulation. In other words, the bulk operations are homogeneous, basically commoditized and differentiated only on the basis of their relative prices : a far cry from the user specific 'PSS-QCW 'Model illustrated in Figure 3, which is the gold standard for modern bulk operations .

6.4 Clearly, therefore, the market needs to be scaled up on the technology curve. In this regard, the role of the consuming mineral industry constituting over 80% of the market, and predominantly made up of large public enterprises, notably amongst them Coal India Ltd, which is the largest consumer, is extremely critical. They would need to drive and steer the market on the path of "PSS-QCW" business model. This aspect was discussed in some details in the previous issue of the Journal as a 'Cover Feature' emphasizing, 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".

6.5 The balance 30% of the explosives market comprise 'packaged explosives' servicing the construction and irrigation sectors. Close to 3000t of explosives is handled and transported by road every day across a large net work of storage magazines with a plethora of explosives dealers and retailers Clearly, from the stand point of 'public safety', this segment of the explosives market must transit soon enough to bulk systems for which small modular designs are available. The market should be incentivized to adopt and indigenize such designs through appropriate legislative and administrative instruments.

6.6 Ideally, therefore , complementing the transition to bulk systems, the traditional explosives manufacturing activity should and be only concerned with 'Initiating Systems', and with the development of programmable electronic detonators , the prospect of complete 'public safety' is eminently within reach.

- Editor

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Annexure - I

CHRONOLOGY OF EXPLOSIVES AND BLASTING TECHNOLOGY (1940 - 2010)

(Source : The 'World of Explosives : Society of Explosives Engineers, Inc'; 'The Science of Industrial Explosives by Melvin A. Cook'; and IBIS World reports).

Alfred Nobel
The Father of Explosives

1930s /1940's

- Packaged Dynamite perfected ;
  Non-NG,high AN, cap sensitive types developed;
- Self propelled open pit rock drills introduced. Use of tungsten carbide bits began in mining in Sweden.
- Short interval millisecond delay electric blasting caps introduced.
- Fertiliser GradeAN (FGAN) explosion at Texas City, Brest , and Black Sea.
- U.S. production of ammonium nitrate (AN) for fertilizer totally converter to prilling method.

1950s.

- Down hole drill introduced using high-pressure portable air compressors.
- First use of ANFO by U.S. Steel Corp. 1956.
- Dr. Mel Cook introduces TNT and Aluminized Slurry Explosive to mining.
- First Bulk Vehicles blow mixed ANFO down-the-hole at Iron Ore Co. of Canada.
- High-speed photography for blast analysis introduced.
- Prilled AN Fuel Oil mixture begins to replace dynamite.
- Bulk trucks and loaders developed.

1960's.

- Tunnel boring machines begin to seriously impact the use of explosives in large tunnel jobs.
- Non-aluminised fuel sensiotised slurry, IRECO.
- On-site Mixing and loading units for slurry explosives, IRECO.
- Plant Mixed, Site-Pumped Slurry System, Hercules.
- Shock Tube non-electric delay detonators introduced in Sweden.
- Emulsion explosives introduced.
- Methyle Amine Nitrate Slurries, Du Pont.

1970s.

- Large rotary drills with drag bits and roller cone bits come into use.
- Emulsion ANFO blends introduced.
- Lang & Favreau introduce Computer Modeling of Blast Design.
- Electronic sequential blasting introduced.
  (Largest pre-production blast round - 4 million pounds of explosives - at Old Reliable Mine in Arizona)
- Hydraulic powered drifter drills come into use.
- First electronic recording seismographs developed by Dallas Instruments.
- Shock tube-type non-electric delay detonators introduced in U.S.
- First commercial use of glass "bubbles."

1980s.

- Bulk Blends introduced.
- Laser profiling for blast design and analysis, developed in Britain, introduced in the United States.
- Electronic delay detonators (EDD's) introduced.

1990's.

- Use of automated drilling, GPS hole spotting and PLC operated drills for surface mining. "

2000 and beyond .

- Digital age of 'Virtual' Bulk Product Delivery and Blast Design'.


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बिरला गोल्ड सीमेन्ट सभी प्रकार के निर्माण एवं जलवायु के लिए अनुकूल है। घर बनाना हो
या फिर कोई बहुमंज़िला इमारत या कोई कारखाना, बाँध या पुल, बिरला गोल्ड सीमेन्ट
की गुणवत्ता सभी निर्माणों के लिए श्रेष्ठ है।
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(A State Government Undertaking)
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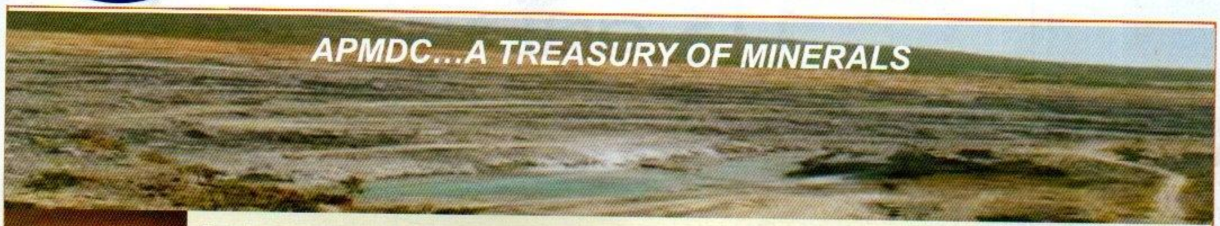
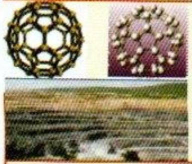


APMDC...A TREASURY OF MINERALS

Barytes deposit at Mangampet in Kadapa District is the World's single largest deposit having about 74 million tonnes of reserves. Main uses of Barytes is in the field of Oil Well drilling and in Barium Chemical Industry etc. APMDC causes export of 1.00 Million tonnes per annum apart from catering the domestic requirement of about 3.00 lakhs MTs. M/s.ONGC and Oil India are prime customers in Oil and Gas segment on domestic front.



Fullerene is expected to be present in the Overburden (Black Shale) at Mangampet Barytes Project, Kadapa District. This is a strategic Mineral used by Department of Atomic Energy and also in Nano-Technology. The value of Fullerene is about 10 times more than the value of Gold.

Black Galaxy Granite at Cheemakurthy in Prakasham District is produced for Domestic & International needs and is used for Decorative purpose.

Laterite is mined by open cast mine method at Maredumilli R.F, East-Godavari District. It is One of the mineral used for manufacture of Cement.

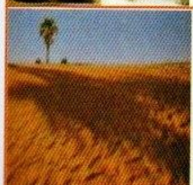
Iron Ore is available in Prakasham, Kurnool, Anantapur and Khammam Districts. Raw material for Iron and Steel industry.

Limestone is mined in Guntur and Adilabad Districts and also available in Mahaboob Nagar District. Raw material for Cement industry.

Manganese Ore is available in Vijaya-nagaram District. Raw material for Steel Industry for making Ferro alloys.

Ball Clay is mined at Dwaraka Tirumala in West-Godavari District. Raw material for Ceramic Tiles, Insulators and Refractory.

Quartz & Feldspar is available in Mahaboob Nagar, Medak and Nalgonda Districts. Raw material for Ceramics and Glass Industries.



Beach Sand is available in Srikakulam, Vijayanagaram, Visakhapatnam, East & West-Godavari and Krishna Districts. Beach Sand contains Illmenite, Rutile, Zircon, Monazite, Garnet, Sillimanite, Leucoxene and mainly used for manufacture of Titanium pigments, which is used in paint industry.

Bauxite is available in Visakhapatnam and East-Godavari Districts. Raw material for manu-facture of Alumina & Aluminum.

The Corporation entered into JVC for exploitation of **Coal** in neighboring states of Orissa and Madhya Pradesh for supply to the power generation units. The main JV Partner is M/s. SCCL and M/s. OMC.

Calcite mineral is available in Visha-khapatnam District. It is used in paper and paint industry.

COVER FEATURE & SUPPLEMENTS

SUPPLEMENT

TRANSITION FROM NG BASED EXPLOSIVES TO EMULSIONS : PARADIGM SHIFT IN TECHNOLOGY AND SAFETY OF PRODUCTION AND DELIVERY

RAHUL GUHA
Sr. General Manager (Technical)
Solar Industries India Limited (earlier known as Solar Explosives Ltd.)

The first use of explosives for commercial purposes dates back to the seventeenth century when Blackpowder was used in mineral mining, tin mining & in civil engineering for construction of tunnel. Even today Blackpowder still finds use in quarrying activities where the shattering effect in the use of high explosives is not desirable.

The true potential of explosives for mining and quarrying began with the development of nitroglycerine based explosives in the nineteenth century and the advent of detonators. This created a more efficient method of using chemical energy both in breaking rock and for lift and heave in trenching or cratering to move earth. These dynamites were mainstay of commercial explosives until the 1950's at which time explosives based on ammonium nitrate began to develop. This led to the development of slurry and emulsion explosives and these are now displacing nitroglycerine based explosives in the commercial sector.

TECHNOLOGICAL AND SAFETY DIVIDENDS:

Different types of explosives require different ignition energies, see Appendix I. Primary explosives exhibit instantaneous transfer of energy from the time of ignition to mass decomposition; whereas the time could very from microseconds to minutes in the case of NG based explosive, and as long as 15-30 minutes with Emulsions. This shows that Emulsions do have a large factor of safety, but it should not be taken as a guarantee for safety and should be treated at par with NG explosives as far as safety of operation is concerned.

The chart presented in Appendix II gives the trend of production of various types of explosives in India and shows the decline of NG explosives production before being banned in 2004. The trend is similar in Europe & USA the only difference being that production of NG based explosives still continues in these countries. Currently NG based products represent approximately 15% of the European market but this is steadily declining as some plants have shut down due to some fatal accidents.

A comparative study presented below, between manufacture and handling of NG based explosives and emulsion explosives would throw up the tremendous advantage gained from this shift.

A) Manufacture : (Flow chart in Appendix III & IV)

i) A glance at the comparative manufacturing processes will reveal that in case of NG explosives, a much bigger infrastructure is required to produce, first nitroglycerine and then the finished product incorporating NG. In case of Emulsion explosives,the manufacturing process is quite compact and can be produced in a limited area.

   Correspondingly the capital cost for an Emulsion plant is much less than that for NG explosives plant of comparable capacity.

ii) Hazardous acids like Nitric acid, Sulphuric acid are required to be stored in bulk for making mixed acid which is used in the manufacture of nitroglycerine. The only bulk storage of any chemical used in Emulsion manufacture is Ammonium Nitrate melt of around 80% concentration. This chemical is less hazardous as compared to the acids required for making NG.

iii) Mixing of NG explosives has to be a batch process and generally it is between 500 kg to 750kg per batch. This constituted a serious hazard as the consequences of 500 kg of NG explosives exploding are disastrous. There have been recorded incidents of the devastation created by a batch NG explosives, exploding. In case of Emulsion explosives while mixing can be carried out as a 500kg batch, the option to have continuous mixing is there. In such a case the quantity in a continuous mix, which is again non-explosive, can be as low as 5kg/minute to a maximum of around 20kg/minute. Hence the hazard during emulsification in a continuous process is much less as the matrix is considered to be non explosive till it is sensitised by chemical gassing or by introduction of physical voids like glass microballoons or perlites.

B) Inprocess Quality Control and Testing.

In process quality control in case of nitroglycerine based explosives is really not necessary nor is it possible. Whereas it is possible and done in case of emulsion explosives, to ensure quality.

It is the testing of finished product which is mandatory in case of NG explosives and involves the following three different types of tests in order to ensure quality and safety: i) Heat test for thermal stability ii) Exudation test & iii) Liquefaction test. Hence, release of explosives for despatch is time consuming and could take as long as 7 days in case of some products.

Release of Emulsion explosives for despatch usually happens after 24 hrs .as no statutory testing is involved.

C) Physiological Concerns.

Overexposure to Ethylene Glycol Dinitrate (EGDN) or nitroglycerine beyond acceptable levels can create health hazards. These explosives may be absorbed into the body by ingestion, inhalation or through skin contact. Absorption of sufficient quantities may cause vasodilation, increased heart rate and reduced blood pressure. Overexposure may be followed by nausea, with consequent fatigue. In view of these health concerns there had to be regular monitoring and controlling EGDN and NG in the work place to achieve minimum exposure levels.

Predetonation (in processing buildings &storage magazines) and post detonation toxic fumes (in mines) with NG based explosives were a major concern.

Such health concerns are non existent in the manufacture, storage and usage of Emulsion explosives .

D) Safety during Manufacture.

Since NG explosives are highly sensitive to impact and friction, all care had to be taken to guard against conditions which would aggravate the situation in respect of impact and friction sensitivity (Appendix V). While safety systems were in place during the manufacture of nitroglycerine, no mechanised safety systems could be put in place to take care of any untoward incident during further processing of NG into finished explosives.

In the case of Emulsion explosives, it not that serious incidents have not taken place but the hazards in manufacture are well recognised and are known to be mainly due to a) decomposition by excessive heating b) pumping during manufacture. Sufficient knowledge is available nowadays to guard against any untoward incident and various trip systems are being put in place to safeguard the process of manufacture.

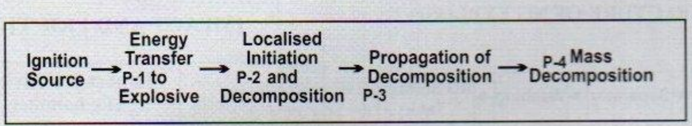
SUMMARY

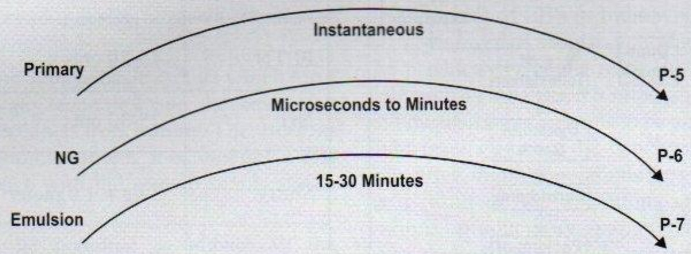
To summarize it can be said that changeover from NG based explosives to Emulsion explosives has benefited both the mining and explosives industry in respect of concerns on health and safety. Added to this is the prohibitive manufacturing cost of NG based explosives which would be uneconomical in the current market scenario.

The views presented in the paper are his personal thoughts and not necessarily those of Solar Industries India Ltd.

APPENDIX I

IGNITION CHARACTERISTICS OF EXPLOSIVES

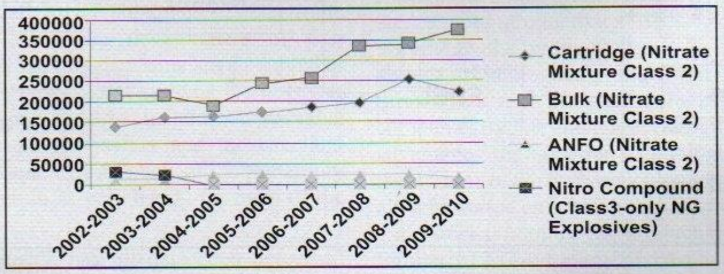




APPENDIX II

EXPLOSIVES PRODUCTION

S. N.	Product	Yearly Production of Explosives in India in Tonnes							
		2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	2007 2008	2008-2009	2009-2010
1.	Cartridge (Nitrate Mixture Class 2)	140386	163962	165024	175011	187955	200028	254807	225613
2.	Bulk (Nitrate Mixture Class 2)	215645	217120	190924	245137	258429	334740	343018	374524
3.	ANFO (Nitrate Mixture Class 2)	14051	14315	26094	26585	22146	24165	26310	15301
4.	Nitro Compound (Class 3-only NG Explosives)	30450	23306	0	0	0	0	0	0

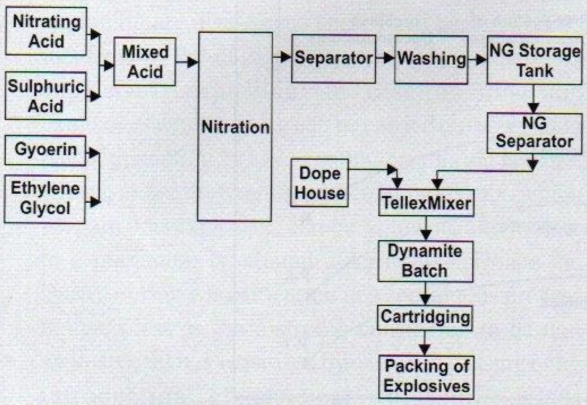


Note : Information presented above are from the annual report of PESO

SUPPLEMENT

APPENDIX III

FLOW CHART FOR MANUFACTURE OF NG EXPLOSIVES



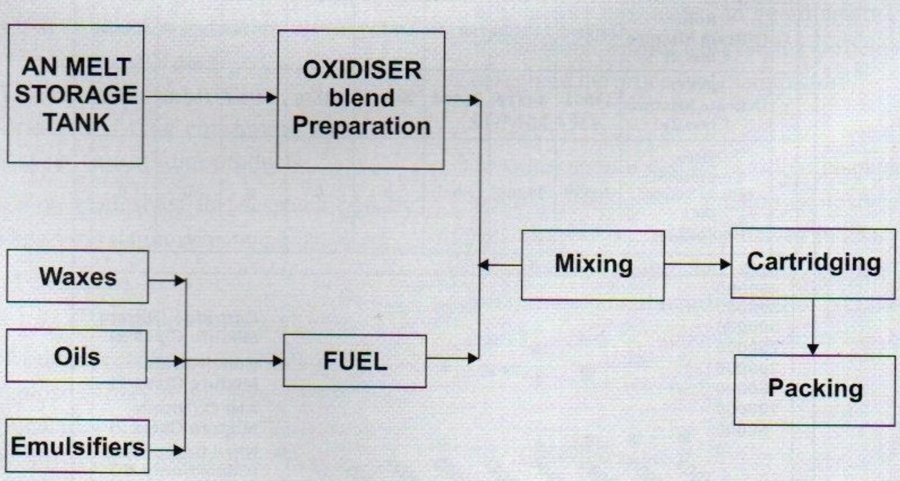
APPENDIX IV

IMPACT AND FRICTION SENSITIVITY

Explosive	Impact Sensitivity ½ kg hammer	Friction Sensitivity 1 kg torpedo
Lead Azide	10-15 cms	¼ kg 10-15 cms
PETN	15-20 cms	50-60
NG	25-30 cms	70-80
Slurry	5 kg > 1.0 meter	2 kg > 1.0 meter
Emulsions	5 kg > 1.0 meter	2 kg > 1.0 meter

APPENDIX V

FLOW CHART FOR MANUFACTURE OF EMULSION EXPLOSIVES



ELECTRONIC BLASTING SYSTEMS : INITIATING THE FUTURE OF MINING IN INDIA

VIVEK MISRA
Technical Services Manager, Orica Mining Services, India

In recent years, the growth story of India has attracted attention at almost every platform world over.

Power, steel and cement sectors are the basic sectors which form the backbone of growth of any economy and the basic raw material for all of these sectors comes from mining. Therefore, in order to sustain the rapid economic growth, it is imperative that the mining industry keeps pace with the growth trends across various value chains.

Drilling and Blasting has the potential to impact all the downstream activities in a big way. And, at the heart of the blasting lie the initiation systems. The Indian mining industry has witnessed the successful use of all types of initiating systems, e.g. safety fuse, detonating cord, electric and non-electric detonators for initiating explosives and explosive primers. Over the past two decades, safety standards and product reliability have started playing an increasingly important role in governing the choice of explosives and initiating systems. This has helped non electric systems to capture the major share of the initiating systems' market.

It has long been understood by the Blasting Engineers that different blast delay timings can drastically change blast results. Conventional delay sequence of blasts is achieved using pyrotechnic delay elements, which have an inherent aberration in their accuracy.

The dynamics of explosives and rock interaction are such that the critical processes occur within milliseconds of blast hole detonation. The use of highly accurate initiation systems can harness these effects to give improved blast outcomes. Typical results include improved throw, better fragmentation, reduced vibration, wall control, dilution control, segregation of ore from waste and higher dig rates. All these represent enormous value to mine operators. This has led to development of Electronic Blasting Systems (EBS). Since the development of first generation of electronic systems, these systems have evolved in big way and, now, there are customized systems for open-cut mines, underground mines and tunnels. In addition to value propositions as above, the inherent safety and the excellent Inventory Management because of on-bench programmability feature these detonators come in as very handy for most of the users.

EBS, in Indian Mining Industry, has till date been perceived primarily as a tool to reduce blast induced vibrations in environmentally sensitive areas. This view has crippled the development of EBS in India whereas in other countries EBS is mainly viewed as a tool to optimize the blasting results to improve the productivity of the mine. In order to understand the value delivered by the EBS, it is imperative to have better mine planning and measurement systems to be able to benchmark and assess the final results against the benchmarks set. In developed mining industries, mining operations are systematic and well planned and as a result all the operations are continuously monitored on various productivity parameters by the use of different measurement tools such as survey controls, Total Dispatch System, bore hole track, Photogrammetry etc. One of the Indian examples which has realized different values delivered using EBS is Rampura Agucha Mine (RAM) of Hindustan Zinc Limited (HZL). The main reason for the success of EBS in RAM has been good mine planning, availability of measurement tools, the management's understanding of value drivers and the careful selection of EBS system instead of just buying Electronic detonators.

International mining companies use 'Mine to Mill' concept to understand the performance of the systems. In other words, they concentrate at the total cost of production rather than the cost of individual sub-operations. EBS can increase the cost of drilling and blasting but at the same time can act as a catalyst, when supported with proper hardware and softwares, to reduce overall production costs. Correct bench-marking allows one to see the total value delivered by the system, despite an expensive product. The consumption of Millions of EBS detonators per annum in US and Australia supports the importance of "Value approach" followed by Giant Mining companies as against "Cost approach".

Of late, Indian mining giants are struggling to meet their productions targets and one of the most important reasons, apart from reasons well known i.e. forest clearances, land acquisitions etc, is poor productivity. EBS can play a significant role in improving the productivity of existing mines. EBS can also deliver technologically high end blasting solutions such as Stratablasts and Through-seam blasts, which can help these companies, reduce their target deficits largely. Having understood advantages the superior technological knowhow can bring to them, some of the forward looking Indian mining companies have already started embracing the latest technological developments. Tata Steel is aiming for productivity improvement with EBS. Similarly EMTA, Lafarge and Ambuja Cements are among others who are really keen to leverage the latest technology to improve the efficiency and safety in their respective mines.

SCIENTIFIC / TECHNICAL PAPER

HAZARDOUS CONTAMINANTS OF AMMONIUM NITRATE

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ABSTRACT

The contents of this report may be based on work in progress or may contain speculative comments by the authors. Readers are cautioned to rely on their own judgment in assessing the correctness of the contents. CERL does not warrant the quality, accuracy or completeness of the contents and is not responsible for any errors or omissions, or any technical inaccuracies. CERL disclaims liability for any injury, damage, or other loss resulting from any use of or reliance on the report or its contents.

1.0 INTRODUCTION

It is well known that ammonium nitrate (AN) is incompatible with a number of materials. Although AN is essentially stable and safe for handling purposes up to its melting point at 169°C, and only decomposes slowly below 200°C, it can be rendered much less stable if mixed with incompatible materials. Thermodynamically speaking, AN is metastable: it would prefer to decompose to lower-energy products with the release of heat, but there is an activation barrier preventing it from doing so (Figure 1). Unfortunately, a number of accidents over the years provide ample evidence that contaminants help AN overcome the barrier and accelerate its thermal decomposition.

Generally speaking, the main mechanism by which contaminants create problems with AN is to reduce its thermal stability, resulting in unplanned thermal runaway and sometimes transition to detonation. This is not always the case however. Figure 2 shows crystals of tetrammine copper (II) nitrate that had formed via the interaction of AN with copper in an electrical junction box in an explosives plant. This copper compound is explosive and rather sensitive to initiation.

We have a long-standing interest in AN compatibility at the Canadian Explosives Research Laboratory (CERL), going back several decades. For example, following the explosion in Walden, Ontario, in 1998, which involved the detonation of a truckload of blasting explosives following a fire, we produced an internal review of the relevant literature in 2000. In 2009, as part of our joint hazards program with Orica Mining Services, we updated the 2000 review, this time with an emphasis on AN contaminants.

The purpose of this short article is to provide a summary of our recent review. While much of the information may be familiar to the industry, we hope that it will serve as a useful reminder as to why compatibility of AN with other materials is an important safety consideration for the explosives industry.

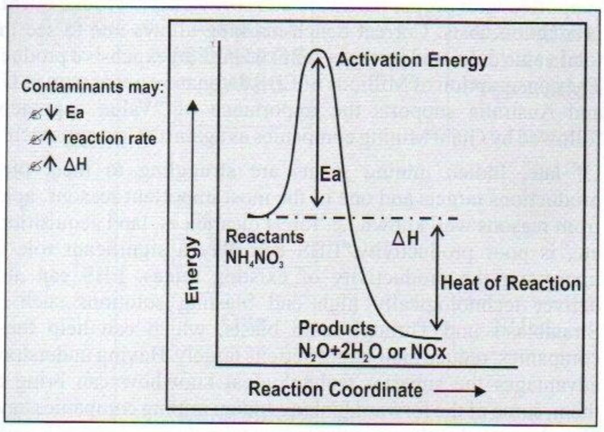

Figure 1 - Contaminants can render AN less stable by reducing the barrier to reaction, providing alternative reaction mechanisms, or increasing the amount of heat generated.

Figure 2 - Crystals of tetrammine copper (II) nitrate formed by the interaction of AN with copper in an electrical box in an explosives plant.

SCIENTIFIC / TECHNICAL PAPER

2.0 SCOPE OF REVIEW

The review focused on open-source literature from 2000 2009, using common search engines (primarily Scopus, Science Direct and WorldWideScience). References prior to 2000 were taken from our internal database at CERL and include both open and unpublished sources. A total of 98 relevant items was found, with 36 after 2000. Brief notes were produced for each of the 98 items. These notes and detailed citations are available to readers, on request.

3.0 COMPARING LIKE WITH LIKE

There are many ways to measure thermal stability and we use several techniques to do so at CERL. However, it is important to understand when a particular technique is appropriate and when it is not, especially when attempting to compare results obtained using different techniques. Ammonium nitrate presents a particular challenge for thermal analysis, as there are competing endothermic (heat absorbing) and exothermic (heat liberating) reaction channels for AN decomposition (Figure 3). The relative importance of the different reaction channels depends on the temperature and the conditions of the test. The endothermic vaporization step (Path 1 in Figure 3) is generally favoured at lower temperatures and so is very important for scenarios where the material is being heated up, as in many potential accident scenarios. Figure 4 shows differential scanning calorimetry traces for AN in an open vessel and in a sealed glass ampoule. In both cases, three endothermic phase transitions are seen as the temperature increases, the third being the melting point at 169°C. Above the melting point, however, the two traces are completely different. In the open vessel (red line), the endothermic vaporization step dominates: the sample absorbs heat and vaporizes; no exothermic reaction is seen. Based on this trace alone, one might deduce that AN presents no hazard for thermal runaway.

However, in the sealed ampoule (green line), the endothermic vaporization is largely suppressed as pressure builds up and the exothermic pathways in Figure 3 dominate as the temperature rises, resulting in an obvious heat output. For this reason, at CERL we almost always study the effects of contaminants on AN using well-sealed sample containers.

Typically speaking, when looking at thermal stability, the key parameter from a safety perspective is the temperature at which the first signs of thermal runaway are observed. It should be understood that the measured onset temperature depends also on the sensitivity of the technique and the amount of material used. In general, large-scale techniques with very low heat losses will produce the lowest onset temperatures that are also the closest to the behaviour expected at full industrial scales. For example, the Adiabatic Dewar Calorimetry technique that we have used at CERL is very sensitive and gives results that are directly applicable to large scales. However, with sample sizes of 100 g and above, the work cannot be done without blast protection of some kind and runaway reactions can require a complete re-build of the instrument! At CERL we generally prefer to use Accelerating Rate Calorimetry (ARC) for AN compatibility work (Figure 5). ARC is not quite as sensitive as the Adiabatic Dewar Calorimetry but, as it uses samples of around 1 g, the work can be done in a standard laboratory environment. In an earlier SAFEX newsletter, we described how ARC is both very practical and provides results that can be readily applied to large scales.

4.0 WELL-ESTABLISHED HAZARDOUS CONTAMINANTS

What follows is a compilation of fairly well-established hazardous contaminants from the literature, as confirmed by our survey. The compilation is by no means exhaustive, but should provide a reminder of the wide range of materials that are incompatible with AN.

4.1 Fuels, Carbonaceous Materials

Given that AN is an oxidizer and in light of the very wide range of fuels that can be used to produce ANFO-like explosives, it is not surprising that AN is known to be incompatible with a wide range of fuels, e.g., acetone, aniline, carbon disulfide, ethanol, ethylene glycol, waxes, oils and stearates. Reactions with 'Bag paper' have been observed as low as 140°C and with cellulose starch at 100°C. Mixing AN with fuels is generally not a good idea, particularly under confinement at high temperatures.

4.2 Metals and Metallic Compounds

AN is highly incompatible with some metals, metal ions and compounds containing metals. These may react directly with AN, catalyze its decomposition, or simply increase the rate of reaction due to heat accumulation. Examples include:

- Lead, copper, nickel, zinc react violently with AN below its melting point
- Violent reactions have been observed with molten aluminum
- The catalytic effect of metallic chromium and chromium ions on AN decomposition has been highlighted on several occasions in the literature[7-]

4.3 Acids

AN melts are acidic due to the high volatility of NH_3 relative to HNO_3 (open systems containing molten AN or concentrated AN solutions tend to acidify with time). Acid catalyses AN decomposition, the rate increasing with increasing free acid content. For example, 5% nitric acid at 200°C accelerates decomposition by orders of magnitude. The same effect is seen to a varying degree with other acids.

The incompatibility of AN with certain sulphide-containing ores, such as pyrite and pyrrhotite provides a good example of its acid-catalysed decomposition. There have been a number of

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1. $NH_4NO_3 \leftrightarrow NH_{3(g,\ell)} + HNO_{3(g,\ell)}$ endotherm (dissociation/vaporisation)
2. $NH_4NO_3 \rightarrow N_2O + 2H_2O$ exotherm (major reaction)
3. $NH_4NO_3 \rightarrow \frac{3}{4}N_2 + \frac{1}{2}NO_2 + 2H_2O$ exotherm
4. $NH_4NO_3 \rightarrow N_2 + 2H_2O + \frac{1}{2}O_2$ exotherm
5. $8NH_4NO_3 \rightarrow 5N_2 + 4NO + 2NO_2 + 16H_2O$ exotherm
6. $NH_4NO_3 \rightarrow \frac{1}{2}N_2 + NO + 2H_2O$ exotherm

Figure 3 - Multiple decomposition pathways for AN. The endothermic dissociation is favoured at low temperatures. The exothermic pathways are more favoured at higher temperatures.

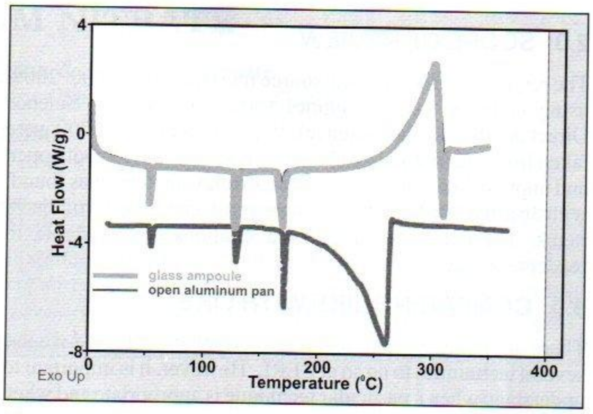

Figure 4 - Differential Scanning Calorimetry traces for 0.5 mg of AN in open (red line) and sealed (green line) sample containers.

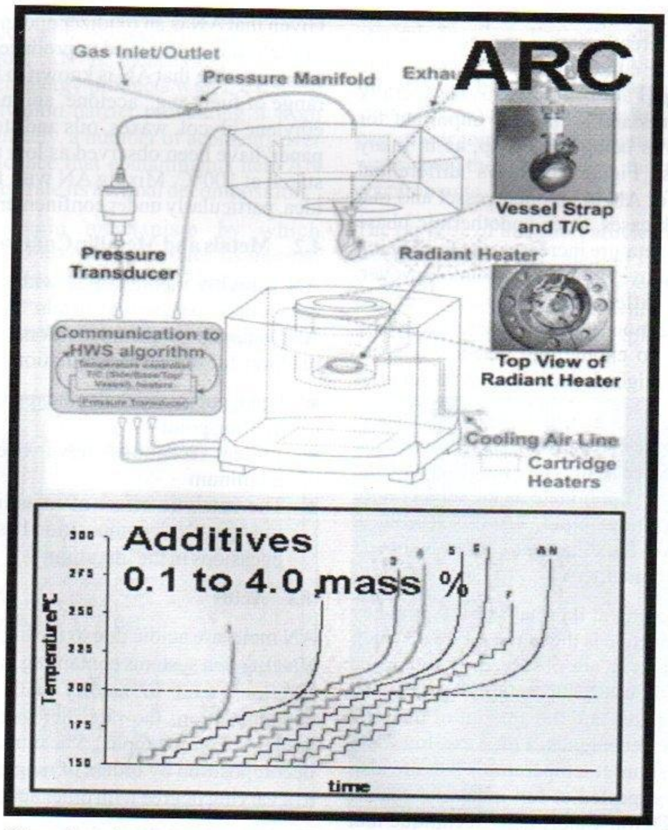

Figure 5 - Use of Accelerating Rate Calorimetry to evaluate the compatibility of AN with various contaminants. Top a schematic of the ARC technique. Bottom examples of ARC experiments with different AN additives. With additives #1 and #2 runaway reaction begins at lower temperatures than for pure AN, whereas other additives actually delay the onset of thermal runaway

unexpected deflagrations and detonations around the world, when AN-based blasting explosives have been left in contact with acidic sulphide ores. The time to runaway reaction depends on many factors and the chemistry is complex, although the situation is particularly problematic with partially weathered ores, as these tend to be most acidic.

4.4 Chlorides

Potassium, sodium, ammonium, calcium (and other) chlorides present a very serious incompatibility with hot AN or AN solution. Chlorides significantly decrease the stability of AN through a catalytic effect. The effect has been known since at least the 1920s. The catalysing effect increases proportionally with the concentration of (nitric) acid and is synergistic: the total effect of chloride and acid is greater than the individual catalytic effects.

5.0 EXAMPLES FROM THE RECENT LITERATURE

Literature emerging after the accident in Grande Paroisse (Toulouse, France) plant in September 2001, identified sodium dichloroisocyanuric acid (SDIC or 1,3-dichloro-1,3,5-triazine-2,4-dione-6-oxide, see Figure 6) as being extraordinarily incompatible with AN. Adding as little as 0.5% of SDIC to AN lowers its onset temperature for thermal decomposition by ~100°C. By 2006, SDIC and its trichloro analogue were being cited as being incompatible with ammonium salts (i.e., AN) and combustible materials.[5] The di/tribromo analogues are suggested to behave similarly. In retrospect, the interaction between SDIC and AN is not surprising as SDIC, a swimming pool disinfectant, is a chlorine donor and AN is known to be incompatible with chlorides.

Apart from SDIC and its analogues, no new materials have been identified as being significantly incompatible with AN since 2000. AN compatibility is still an important issue, however, and research work has continued in the area to refine our understanding of the matter. For example, there have been two studies that addressed the effects of chlorides on AN stability. Even at levels of 0.1%, chloride salts have a significant effect. Two studies used DSC to investigate the effect of a fairly wide range of contaminants.[26]

CONCLUSIONS

We hope that this short article has provided a useful reminder of the broad range of materials that are incompatible with AN. In an industrial setting, it can be difficult to ensure that incompatible materials are not brought into contact with each other. For example, as part of this work, an inventory of chemical products at an Orica AN manufacturing facility identified over 300 chemical products on site. In some cases, it might not be known whether two materials are incompatible ahead of time, particularly if commercial products such as cleaners or lubricants are used, where the actual chemical composition is not declared. Material Safety Data Sheets are useful, but not always complete, so precautionary testing is sometimes advisable. Similarly, newly developed potential additives for AN require testing for compatibility before being put into production. At CERL, we are asked to test several materials a year for compatibility with AN. The work has been going on for over a decade and there is no sign that the supply of new materials for testing will dry up soon. We plan to do some additional work on the well-known incompatibility of AN with sodium nitrite in the near future, for example.

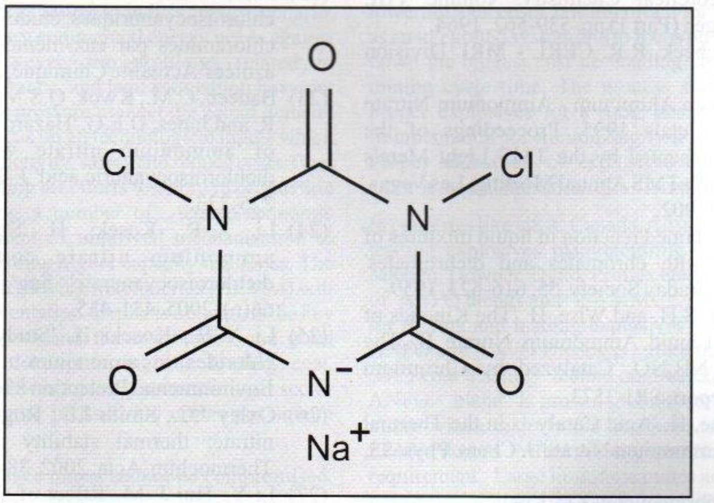

Figure 6 - Sodium dichloroisocyanuric acid or 1,3-dichloro-1,3,5-triazine-2,4-dione-6-oxide. More conveniently known as SDIC.

We would be most interested in hearing from any readers about cases that they might have come across during the course of their operations, where incompatibilities of materials with AN have arisen. We are very aware that not all compatibility work is done as part of an academic study that is destined for publication and would like to hear of any unusual interactions, however they were observed.

ACKNOWLEDGMENTS

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SCIENTIFIC / TECHNICAL PAPER

A CRITICAL ANALYSIS OF APPLICATION OF ANFO AND ANFO BLENDS IN OPENCAST COAL MINE BLASTING IN INDIA

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ABSTRACT

The overall mining cost is directly as well as indirectly influenced by drilling and blasting. It is important to optimize the drilling and blasting operations so that the the overall mining cost is minimum. Loading cost and hauling costs are typically 4 to 5 times of the explosives cost and for large machines idle time is pretty expensive making ideal fragmentation very important. In India, more than 95% of the bulk explosives used for opencast coal mines blasting are emulsions/slurries which need to be reviewed critically so that techno economically suitable explosives can be selected for a given geo mining condition. In dry holes, charging with Ammonium Nitrate Fuel Oil (ANFO) results into a direct savings of 25-30 % of explosive charge quantity per hole just by the virtue of its bulk density. Medium hard rocks require more of gas volume, better confinement of gases and its effective release through an ideal detonation process. Partitioned energy (shock energy and heave energy) requirement of various rocks and the partitioned energy produced by various explosives should be matched for a proper explosive selection process. Globally, all dry holes are blasted with ANFO but in India, its properties have not been viewed because of non-availability of bulk ANFO for coal sector. Use of Heavy ANFO (HANFO) improves the blast performance and overall blast economics. Bulk trucks for HANFO loading are designed to blend components prior to loading of emulsion or ANFO alone or as blends, in varying proportions to meet diverse strata requirements of energy partitioning in a block or in a blast hole so that energy distribution and blast performance across the blast hole is maximized.

1.0 INTRODUCTION

Coal is the most dominant energy source in India's energy scenario. It meets around 52% of primary commercial energy needs against 29% the world over. However, the problems related to environmental and forest clearance, and land acquisition have put Indian coal companies under pressure to meet the actual demand for coal. . It is important to focus on all technological inputs which can enhance production, productivity, safety and reduce costs. Coal producing companies are putting all efforts to improve production and productivity by adopting a number of techno-economic measures. There is requirement of improved mechanization to speed up the production by putting higher capacity machines. The efficiency of all Heavy Earth Moving Machineries (HEMM) will depend on the quality of fragmentation. Explosive energy is the key input required for blasting coal and the overburden and good fragmentation is important for optimizing the loading cost. Presently, the industrial explosives and accessories in coal sector have touched a whopping figure of Rs. 2000 crores per annum (approx).

Blasting in the context of surface mines cannot be compromised. This is perhaps the key to the success of all post blast sub systems utilization viz. loading, hauling and transportation. The explosives cost is so visible and so easily measured, that the explosives element is usually one of the first areas to get cut in a cost cutting exercise which is exactly the opposite of what should be done in lowering total costs. It is important for the industry to view blasting as an integrated system and to focus on a good blast which can bring down the biggest cost i.e. loading cost by 10-15% with reduced mining cycle time. The process should start from selection of proper explosives for a rock, designing of blast and to ensure fragmentation for minimizing cost of loading and transportation. Proper utilization of explosives enhances safety and reduces environmental nuisances like vibrations, airblast and flyrock.

In countries like USA, Canada, Australia, Indonesia etc. most of the leading explosives manufacturing companies like Orica, AEL, Maxam, Downer, Dyno, Primex etc. manufactures the entire range of ANFO blends and use MMUs (Mobile Manufacturing Units) for mixing and loading explosives in the blasthole. The share of ANFO and ANFO Blends is more than 80 % share in opencast (OC) coal blasting. Techno commercial advantage of ANFO and ANFO blend is proven globally as well as in Indian limestone mines which majorly (90 % share) are using ANFO made from PPAN (Porous Prilled Ammonium Nitrate) for their OC blasting requirement. Large limestone mines and some iron ore mines have even gone in further for owning their own ANFO BMD Trucks.

In India more than 95% of the bulk explosives used for OC coal mines blasting is Straight Emulsions which needs to be reviewed for deciding the future course of blasting. It is observed that rocks require less shock energy and more gas energy compared to the shock and gas energy delivered by Bulk Emulsion explosives for optimum fragmentation of shale, sandstone and limestone.

2.0 ANFO AS A BLASTING AGENT

ANFO (ammonium nitrate/fuel oil) is a widely used bulk industrial explosive mixture. ANFO under most conditions is cap-insensitive, and so it is classified as a blasting agent and not a high explosive; it decomposes through detonation rather than deflagration with a moderate velocity of about 3,200 m/s in 5-inch diameter, unconfined, at ambient temperature going up to 4750 m/s in larger dia holes(310 mm) under confinement. It is a tertiary explosive consisting of distinct fuel and oxidizer phases and requires confinement for efficient detonation and brisance. Because it is a cap-insensitive, it requires a primer, also known as a booster to ensure continuation of the detonation wave train.

3.0 WHY ANFO COULD NOT PENETRATE THE INDIAN OC COAL BLASTING?

ANFO did not penetrate the Indian coal mining sector till date mainly due to:

- *Limited availability of good quality porous explosive grade prills till 2011*
  Deepak Fertilizers and Petro chemicals Limited (DFPCL) has recently commissioned its new TAN plant with a 3, 00,000 tonnes annual capacity with Technology from Uhde and Grand Pariosse to reach a total capacity of nearly 5,00,000 tonnes, becoming the fifth largest producer in the world.
- *Availability of an effective ANFO Mixing and Delivery Unit*
  Globally the ANFO / Blended ANFO BMD systems are considered the safest and most effective Bulk mixing and loading systems to meet the requirement of large opencast coal mines. High charging rate ranging from 150 kg/min for ANFO systems to 600 kg/min for blends are in use. Licensing hurdles have been overcome and in the last two years a number of limestone mines in India have got their ANFO BMDs and they are being used successfully with an overall techno-commercial advantage of 15-20%.
- *Limitation of ANFO for application in watery holes*
  ANFO is not suitable for blasting in watery holes, however technology has been developed for blending emulsions with ANFO to successfully encounter dynamic and static water in blast holes. Globally dewatered holes can be loaded with WRANFO (Water resistant ANFO), especially developed for such applications.
- *Commoditization of Bulk explosive product*
  After late 90's the explosive procurement process is based on the landed cost of explosives mainly. It has led to development of low cost emulsion explosives but has led to poor blasting, misfires, hard toes with reduction/deduction on account of powder factor in many mines.

4.0 EXPLOSIVES ENERGY REQUIREMENT FOR OPTIMUM FRAGMENTATION OF OVERBURDEN

Explosive energy is delivered to the rock in two main forms- Shock energy and Heave Energy. Shock energy is characterized by properties such as velocity of detonation, density and weight strength. Heave energy comes mainly from volume of the gases, its confinement and effective detonation. Rocks also require a particular amount and proportion of the above energies for optimum fragmentation with maximum safety and minimum environmental impact. The excess/shortage of either form of energy than required will lead to sub optimal blast performance. Optimum fragmentation necessarily minimizes the total cost of drilling, blasting, loading and hauling and should never be compromised. Proper methods are required to be developed to quantify the advantages of fragmentation towards reduction in loading and hauling costs and to view the explosives cost in total.

It is calculated that the shock wave accounts for up to 20% of the total energy released by a typical commercial high explosive. An explosive like ANFO will generate compressive shock waves with instantaneous pressures of 27,000 kg/cm^2 for ANFO which far exceed the dynamic compressive strength of rock (sandstone 2250 to 2500 kg/cm^2, basalt 2,800 to 3,276 kg/cm^2 and quartzite 2,569 to 6,411 kg/cm^2) (Persson et al, 1993). Gas energy can account for up to 60% of the energy of the explosive, the remainder being lost as heat etc. Generally, explosives with a lower velocity of detonation (VOD) tend to convert to gas over a longer time period than explosives with a high rate of reaction. Heave energy or the gas pressure energy mainly depends on the percentage of Ammonium Nitrate in the explosives, stoichiometric ratio with the fuel, effectiveness of the detonation process, etc.

In fact, the contribution by explosives to productivity and cost savings extends far beyond the explosives cost, which needs to be quantified for actual evaluation of blasting. They can be as enumerated below:

- Bucket fill factor of loading unit and the fill factor of hauling units is substantially better.
- Loading units are subjected to less shock loading and wear and tear when excavating well blasted ground.
- Loading unit cycle times are optimized in that less time is spent on digging through a poorly blasted face
- Power consumption is reduced under good digging conditions
- Truck bodies are subjected to less impact from loading poorly blasted material
- There is less possibility of spillage in the loading areas on the haul road
- Truck leave the shovel both optimally loaded and with the load distributed evenly in the truck body.

5.0 EXPLOSIVE SELECTION CRITERIA (EXISTING)

In India, explosives properties are still not well defined and selected by properties such as velocity of detonation, density and theoretical thermo-chemical energy calculated as per the

Differential thermal analysis values of a standard composition. Explosives Impedance which is a product of VOD and density is also considered a yardstick for selection of explosives to match with the rock impedance.

ANFO with a density of 0.75 -0.8 g/cc and a VOD of 4000 m/s still scores with a 15 % better powder factor in a limestone mines than emulsion explosives with a VOD of 4500 m/s and density of 1.15 g/cc. Inspite of having 60 % extra on impedance, performance of emulsion explosives is weaker in medium hard rocks such as limestone. Same will hold good for other medium hard rocks such as sandstone and shale. This clearly shows the requirement of a broader perspective for consideration of explosive properties for effective blast design.

6.0 SUGGESTED EXPLOSIVE SELECTION CRITERIA

Explosives technology has demonstrated a clear cut differentiation in the capability and partitioned energy release from ANFO or Emulsion explosives. ANFO is now recognized as a powerful explosive with distinct capabilities. It is successfully used as ANFO or ANFO blends to meet diverse strata requirements of energy partitioning in a block or in a blast hole.

While emulsions are high VOD, high water resistance explosives, ANFO is a power house for gas energy producing uniform coarser fragmentation with good displacement of the rock mass. ANFO with a relatively low VOD produces high volume of gases and provides sufficient confinement for longer time which helps the gases to play their role more effectively

Three important parameters needed to understand the work capability of an Ammonium Nitrate based explosive are:

1. Detonation Energy
2. Shock wave and Bubble pulse energy from underwater detonation tests.
3. Expansion work performed at Volume expansion ratio V/Vo=10, 15 and 20.
   (V/Vo= Ratio of the volume of the gases after detonation/original volume)

Detonation Energy is primarily responsible for crack generation in the rock mass by the compressive and tensile stress waves. Shock wave and bubble energy from underwater tests give a fair idea of the partitioned energy capability but since water does not simulate a rock in terms of resistance or confinement, energy parameters cannot be used in absolute terms (Cooper et al, 1996).

The effective volume expansion ratio for rock fragmentation is in the region of 10 to 20, the lower value for the hard rock and the higher for weaker rocks. In that range the rock breaks loose and the remaining expansion work is through expansion in the air. ANFO typically has a V/Vo ratio 15 to 20 % higher than an emulsion product because of its higher oxidizer content and longer confinement.

In a bench blasting all this expansion energy cannot be used. As the rock starts to break cracks open up and the detonation products propagate and escape through them. Typically this happens when the pressure is of the order of 1000 bar and when the detonation products have expanded to 10-20 times the initial volume (Cook, 1974). If the temperature is high and the crack generation process is fast more energy is wasted as thermal energy through the already developed cracks cannot is a single word. Please replace "can not" with cannot everywhere in the text.

7.0 WHAT IS CONTRIBUTING TO THE EXTRA POWER OF ANFO/ BLENDS

Globally explosive manufacturers are supplying ANFO blends to the site in the desired proportion in a MMU (Mobile Manufacturing unit). . Leading global explosive manufacturers offers a large range of ANFO blends to its customers. A study of the properties of some common ANFO Blends is shown in Figure 1.

- ANFO is globally considered to be the safest and most consistent explosive product for OC blasting.
- ANFO is having a bulk density 0f 0.75-0.80 g/cc as against 1.2g/cc of a standard emulsion product resulting into better column built up/savings on explosive quantity in a blast hole. In dry holes, charging with ANFO results into direct savings of 25-30 % of explosive charge quantity per hole per virtue of its bulk density.
- ANFO delivers thermo-chemical energy of 3.75 MJ/kg @ 1 atm and 25 deg C as against 2.65 MJ/Kg for a straight emulsion.
- ANFO has 94 % oxidizer content as against 71 % in a standard emulsion product. It produces much more gases and heave energy required for displacement of the fractured mass. ANFO produces 0.973 m^3/kg of gas as against 0.70 m^3/kg for an aluminized slurry and 0.78m^3/kg for explosives like PETN (ISEE, 1998).
- With ANFO blasting because of lower VOD cracks take longer time to expand. Gases are confined for a longer duration and the available gas energy because of the volume expansion is much higher and faster to result into better fragmentation.
- ANFO made from PPAN provides stable hotspots in terms of pores. PPAN has the oil absorption capacity of minimum 8 % with an additional 12-14% pores introduced in the crystal lattice acting as hotspots only.
- An Emulsion: ANFO mixture of 45:55 offers highest available bulk Explosion energy of about 4.6 MJ/litre against 3.3 MJ/litre of straight emulsion and 3.1 MJ/litre of ANFO and makes the best combination to minimize cost of blasting and to expand the drilling pattern .

- Effectiveness of detonation for ANFO will largely depend on the quality of Ammonium Nitrate prill and the BMD system hardware. ANFO efficiency increases with an increase in the porosity of the prill and homogeneity of mixing of AN and fuel oil.

8.0 SUCCESS STORY OF BLASTING BY HANFO (ANFO PLUS EMULSION BLENDS)

ANFO blends are mainly developed to improve the water resistance, increase the bulk energy and to reduce the mining costs. Globally all the major companies like Orica, DYNO, Downer, AEL, Maxam etc have now switched to offering the entire range of ANFO: Emulsion blends to have a perfect match with the energy requirement of a particular rock. Addition of Emulsion increases the water resistance and the density of the explosives. Emulsion occupies the space between the spherical AN prills to increase the density. The mixture still provides solid state stable voids of PPAN used in ANFO as hot spots.

Most of the blends are manufactured in an emulsion to ANFO ratio of 20:80 to 80:20. Emulsion ratio of 60 % and more is used in watery holes and is required to be pumped. All pumped emulsions are required to be sensitized by chemical gassing or by glass microballoons.

Emulsion ANFO blends up to 55 % emulsion are augered into the boreholes and are considered the best for optimum performance. No chemical gassing is required for such blending and the products are extremely safe and consistent as well.

HANFO increases the density of ANFO, increases the energy in borehole and provides water resistance to the borehole. Bulk trucks for loading of the HANFO are designed to blend components prior to loading of emulsion or ANFO alone or a combination of two, in varying proportions. The typical properties of ANFO and Emulsion: ANFO blends are given in Table 1.

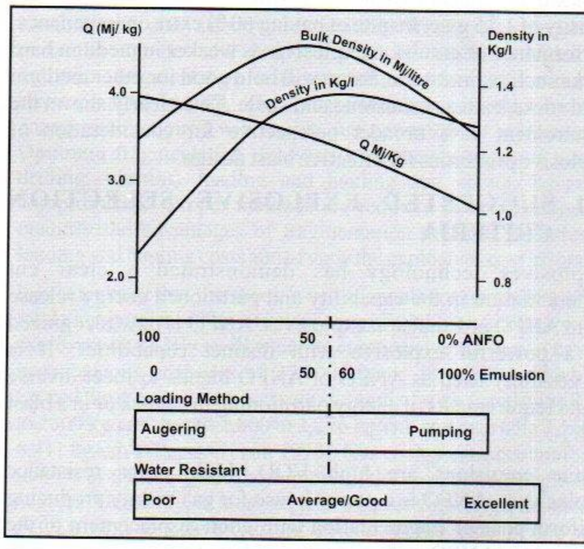


Figure 1 - Density, explosion energy Q and Bulk Strength of ANFO/Emulsion Mixes as a function of emulsion content
In this figure, please replace kg by kg

Table 1 - Properties of ANFO and Emulsion blend.

Product Name	Ratio Emulsion: ANFO	Density[1]	Water Resistance[2]	Q Thermo Chemical Energy (MJ/kg) @ 1 atm and 25 deg C	A Available Energy [3] (MJ/Kg) @ 1000 atm	RAWS Available Relative Weight Strength @ 1000 atm	RABS Available Relative Bulk Strength @ 1000 atm	Borehole Pressure (K atm)	VOD m/s
ANFO		0.80	0	3.75	2.03	1.00	1.00	20	4451
Heavy ANFO	20:80	1.05	0	3.55	2.19	1.08	1.38	33	5000
	25:75	1.13	1	3.50	2.25	1.11	1.52	37	5152
	30:70	1.20	2	3.45	2.30	1.13	1.66	42	5305
	35:65	1.25	3	3.40	2.32	1.14	1.74	46	5396
	40:60	1.30	4	3.35	2.36	1.16	1.85	50	5518
	45:55	1.35	5	3.30	2.38	1.17	1.93	54	5610
	50:50	1.30	5	3.25	2.30	1.13	1.79	49	5457
	55:45	1.30	5	3.20	2.27	1.12	1.77	48	5396
Pumped Blend	60:40	1.30	5	3.15	2.24	1.10	1.75	47	5335
	65:35	1.30	5	3.10	2.21	1.09	1.73	47	5274
	70:30	1.30	5	3.05	2.17	1.07	1.69	46	5213
	75:25	1.30	5	3.00	2.14	1.05	1.67	46	5152
	80:20	1.30	5	2.95	2.11	1.04	1.65	45	5091

1. Density may vary from this value due to AN prill density/ or percent fines.
2. Water resistance Scale 0 to 5
   - 0 Equals No water resistance.
   - 1 & 2 equal water resistance sufficient for dewatered boreholes when loaded and hot.
   - 3 & 4 equal water resistance sufficient for dewatered boreholes.
   - 5 equals excellent water resistance.
3. Thermo-chemical energy calculated at final explosion product expansion pressure of 1000 atm
   - Most rock types fragment at pressures greater than 1000atm.

9.0 LIMITATIONS OF BULK EMULSION EXPLOSIVES

1. Bulk emulsion explosives use gas bubbles for sensitisation and the stability of gas bubble depends on the viscosity of the emulsion, strength of emulsification and the hydrostatic pressure due to the depth of borehole. It often leads to a phenomenon called "Dead pressing" in deep holes where the emulsion density goes above the critical density of 1.3 leading to blast failure. For effective blasting in deeper holes, solid state voids in form of PPAN improves the blast performance significantly.
2. At times bulk emulsion flows into the cracks and fissures more easily leading to higher charge concentration and lower column built up.
3. Decking with bulk emulsion explosives leads to significant contamination near the deck and reduces its performance.
4. Final density of the emulsion inside the blasthole is not known and only estimated based on the cup density measured after gassing and before charging the blast hole. The deviation from the optimum density of emulsion reduces the VOD of explosives.
5. It is difficult to distribute energies across the blast hole with plant mixed bulk emulsions.

10.0 IMPORTANCE OF VARIOUS PROPERTIES OF POROUS PRILLED AMMONIUM NITRATE FOR MAKING AN EFFECTIVE ANFO EXPLOSIVE

1. Porosity

Tremendous industrial importance of ANFO stemmed from the physical character of these prills, which had an available porosity of 0.07 cc per gm & an unavailable porosity of about twice this amount (Cook, 1974). So, explosive grade PAN is essentially porous & possesses available air-voids around 7% & non-available air-voids around double the available-voids. So, porous, low-density PAN normally possesses around 20% (available + non-available) voids to offer hotspots for an ideal detonation process.

Hot Spot theory of Detonation

The compression pulse generated during detonation compresses the air bubbles in the explosive, resulting in extremely high temperatures or "hot-spots". These "hot-spots" would appear to sustain and enhance the detonation propagation.

Sudden compression causes small local areas, like voids and gas bubbles, to heat up faster to a much higher temperature than the material around the bubble. Thus we see that in hot-spot initiation, we depend on heating small local area very rapidly to cause a faster decomposition, higher energetic & self-sustaining reaction. In "Hot Spot" theory, the gas pockets develop into "hot spots" when the detonation shock front passes through them. By virtue of the high temperature attained in the pockets (>1200 K) these hot spots act as starting points from which the chemical reaction proceeds into the explosives medium. Hot spots can be created by chemical gassing in explosives, imparting porosity by using PPAN in an ANFO explosive or by using glass microballoons.

Electron Microscope images to show the porous structure of the prill

Figures 2 shows images & structures of Porous Prilled-AN & FGAN. It may be noted that these are extensive voids, pores & capillaries in porous prilled AN. The image of the FGAN shows that it is mainly non-porous, with minimal voids or pores.

2. Thermal Stability of the Prill

Ammonium Nitrate undergoes a phase change from orthorhombic phase II to orthorhombic phase III when the temperature falls below a transition temperature of 32.2 deg C or vice versa. Similar phase change occurs at -16 deg C, 84.2 deg C and 125.2 deg C. Prills are made thermally stable so that it can withstand the phase change during the transition temperature changes.

3. Moisture Content

The moisture is always kept below 0.3% to make it stable. Low moisture keeps the prill form stable and free flowing with better detonation characteristics.

4. Shape and Size of the Prill

Smaller and spherical uniform prills offer more fuel- oxidizer contact area and enhance the blasting performance. Spherical prills improve the flowing characteristics through mechanical augers and pumps. A stable prill with an average size of 1.5mm-1.8mm is considered to be excellent for making ANFO.

5. Coating of the Prill

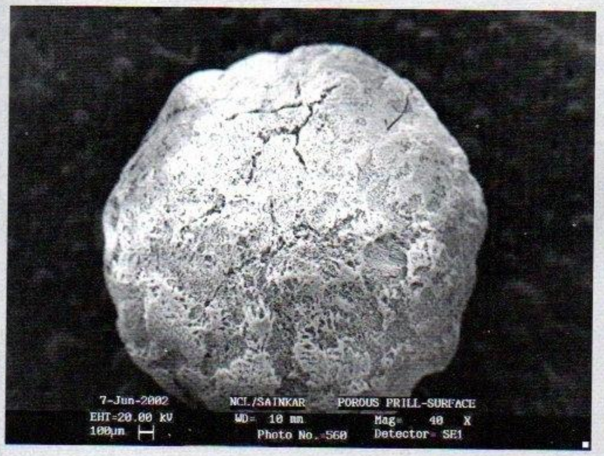
Prills are suitably coated with organic/inorganic coatings for imparting anti caking properties for better flowability and dispersability.

6. Technology to Manufacture PPAN

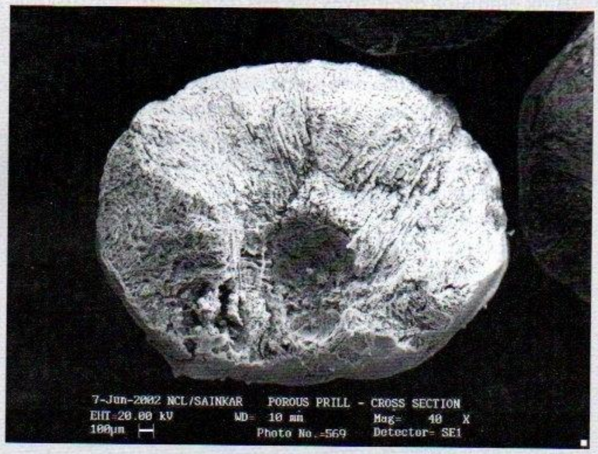
PPAN is manufactured by a properietory technology vested with a few global players

The AN prills are manufactured in a specially designed prilling tower 40-60 m high. Ammonium Nitrate melt is conditioned with a crystal habit modifier, polorising agent and suitable additives and sprayed in a prilling tower. Droplets of ammonium nitrate melt falls in counter current to a cold stream of air and are partially crystallised.

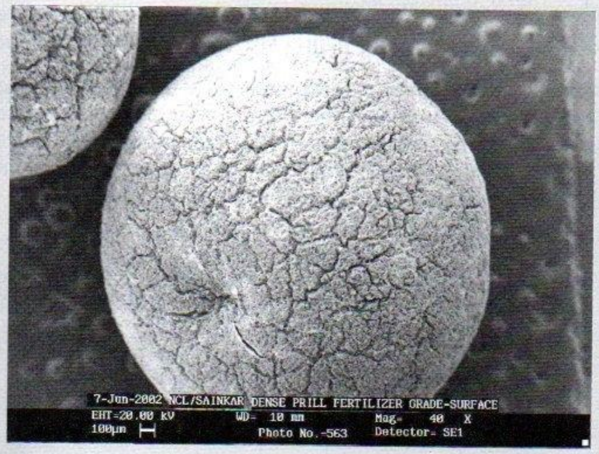
At the bottom of the prilling tower, the AN prills are sent to the pre- dryer and dryer drum. In the dryer, the product is dried by conditioned air, flowing in the first part in co-current and in the second part in counter-current with the product. Controlled



PPAN-Surface Features of low density, porous, prill.



PPAN-cross-Section showing internal pores, capillaries, locked-in voids



HDAN Surface Features showing cracks.

HDAN Cross section; showing minimal pores, capillaries or voids.

Figure 2 - Images & Structures of Porous Prilled AN & FGAN

evaporation of water in the dryer combined with crystallisation of saturated Ammonium Nitrate solution allows creating an evenly distributed porosity within the particles.

From the outlet of the dryer, the product is conveyed to the screen where undersized and oversized particles are separated. Both undersized and oversized prills are recycled to the AN Solution Tank where they are dissolved and returned to the Prilling section.

On-size product coming from the screen is sent to the Fluidized Bed Cooler to be cooled and thermally stabilized below the IV-III transition point, it is subsequently coated with an anti caking agent to avoid that end product picks up moisture in the storage. A schematic process layout of manufacturing of PPAN is shown in Figure 3.

11.0 HARDWARE REQUIRED FOR MIXING AND LOADING OF ANFO AND ANFO BLENDS

In India most of the Bulk Explosive Trucks are used for loading plant mixed emulsions in the blast holes. Some trucks in NCL have the facility to load doped emulsions where they can use 15-20% of AN prills for blending. In last two years large limestone mines in India have fabricated their own ANFO BMD trucks for using Bulk ANFO in their mines. India has developed capability for fabricating ANFO BMD trucks of global standards.

India still lacks the hardware of global standards for ANFO blends. Globally companies like Treadcorp are now offering Unibody trucks with four bins for flexible product mix which can be augered at a rate of 600 kg/min. These trucks come with a optional quad capability (an attachment to the truck for pumping the explosives into the borehole through a hose). Similar hardware can be fabricated indigenously for use in our coal mines. A typical photograph of QUAD capability and Unibody MMU is shown in Figures 4 & 5 respectively.

The details of all parts of MMU are enumerated below:

1. Discharge auger approx. 4m long, mounted on bearing turntable with movement controlled from in cabin, fitted with optional reducing chute.
2. Inclined auger.
3. Process fuel tank with dished ends for added strength.
4. Ammonium Nitrate bin with rounded corners for appearance and added strength.
5. Optional one piece sliding lid for ammonium nitrate bin.
6. Optional aluminium checker plate deck to cover complete unit.
7. Emulsion tank complete with dished ends and rolled side for added strength.

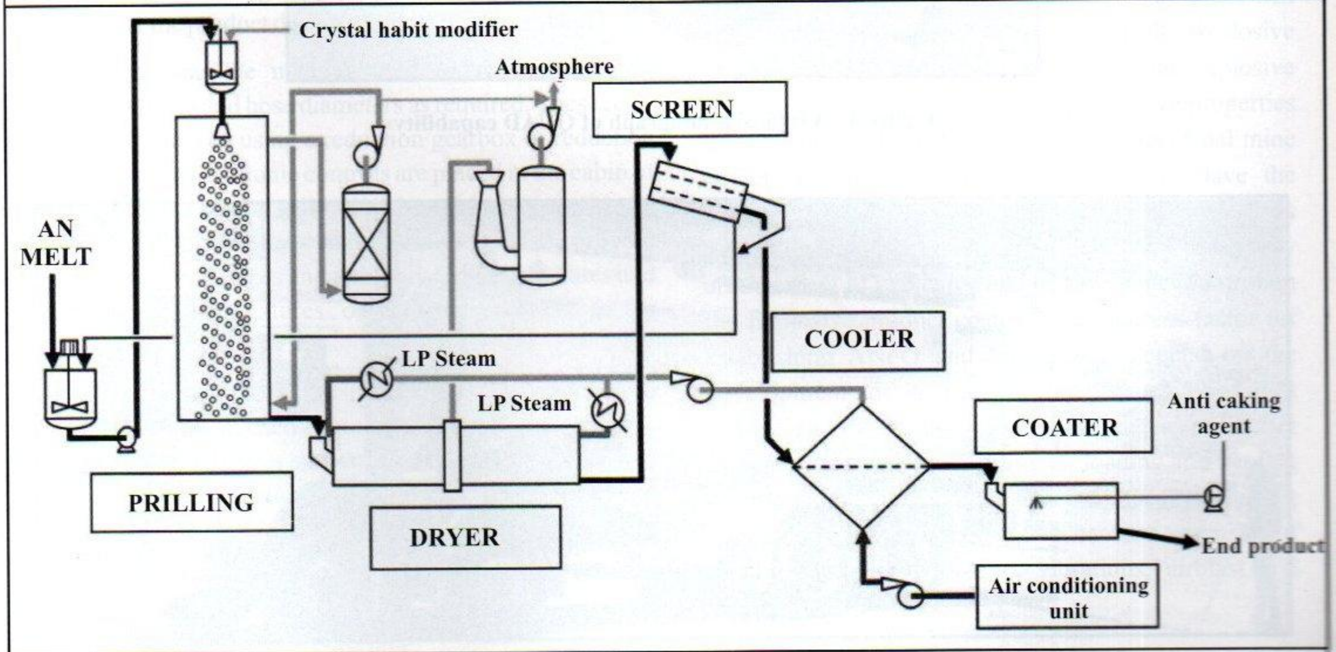


Figure 3 - Schematic Process Layout of manufacturing of Porous Prilled Ammonium Nitrate.

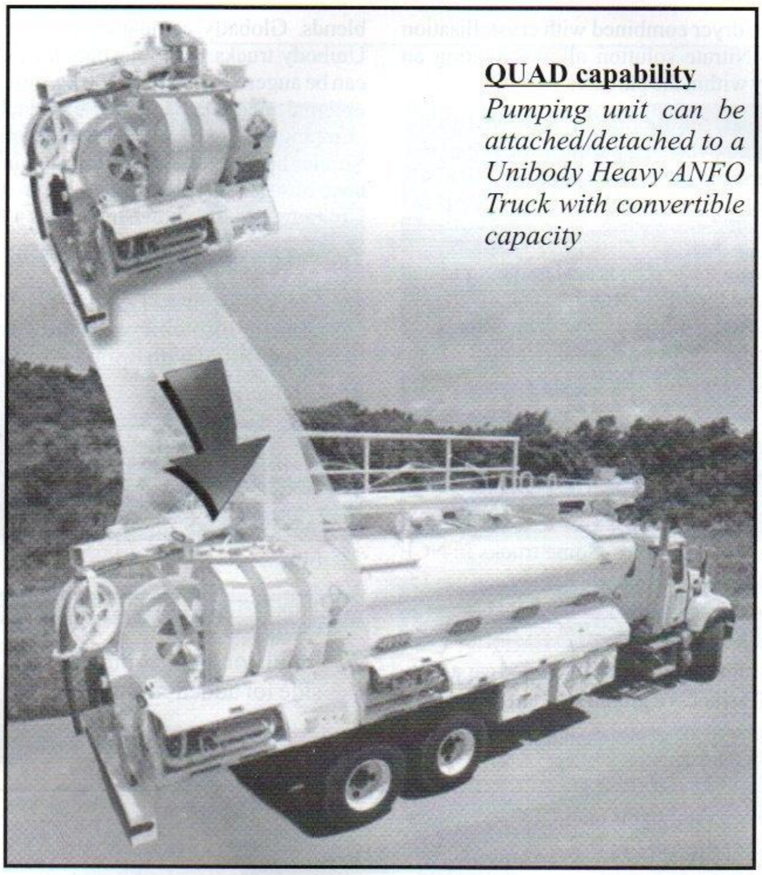


Figure 4 - A typical photograph of QUAD capability

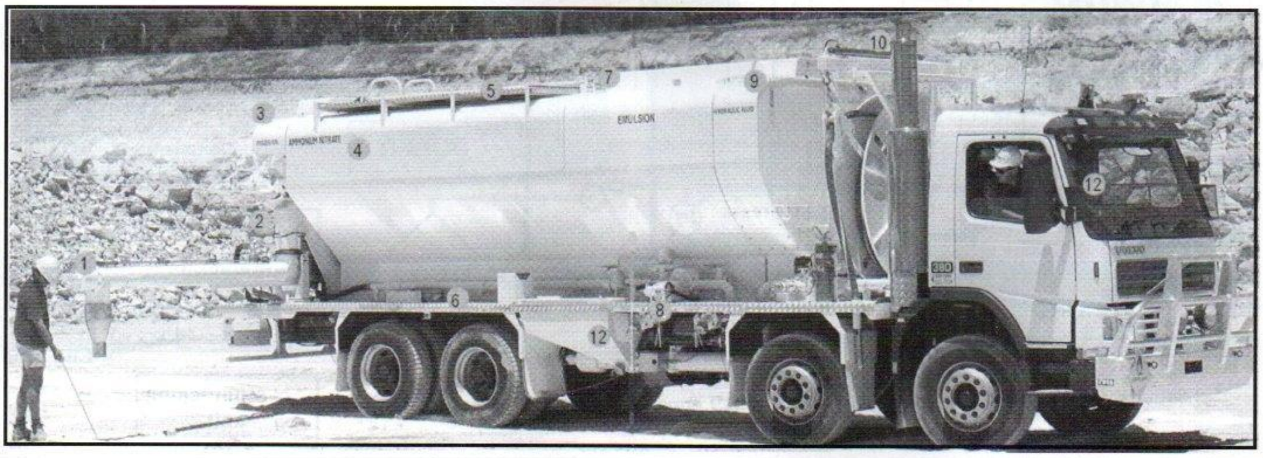


Figure 5 - Multiple Mix / Pump Unit (Mobile Manufacturing Unit)

8. Emulsion filler points located at working height and angled to relieve hose stress.
9. Hydraulic oil tank in same shape as emulsion tank.
10. Large capacity hose reeler fitted with in cabin controls which enable auto retract during the pumping operation.
11. In cabin controls which enable the unit to be operated by a single person.

Down-hole mono pump system complete with level indicators to enable full in cabin operation.

12.0 MULTIPLE MIX / PUMP UNITS

These units have the ability to manufacture ANFO and Heavy ANFO to auger or pump a blended product into blast holes. Bins are again generally permanently fixed to the chassis. These units consist of an Ammonium Nitrate storage bin, Emulsion storage tank, fuel oil tank, water tank, hose reel and optional product additions tanks. Product is discharged using either an overhead discharge auger or side mounted auger, or pumped to a wet blast hole using a loading hose. Emulsion is generally added to the ANFO in the discharge auger. A helical rotor pump is used to transfer the product during wet hole loading process.

Hose reels can be manufactured to suit the various discharge rates and hose diameters as required. These reels are usually driven using a reduction gearbox or reduction chain system. Electronic controls are placed in the cabin of the unit. These controls allow batch and total amounts to be displayed. Specialised controllers can also provide ingredient percentages and individual ingredient rates and allow different mixtures of various products to be produced.

These controls allow batch and total amounts to be displayed. Specialised controllers can also provide ingredient percentages and individual ingredient rates and allow different mixtures of various products to be produced.

In-cabin controls allow the unit to be operated by a single person. Controls can also allow for automatic retraction of the loading hose from the blast hole.

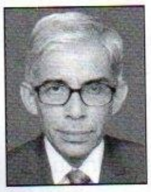
Total bin capacity ranges from 4 - 20 tonnes, however weight restrictions of the cab chassis is the final limiting factor to the size of the unit. The auger discharge rate varies from 50-1000kg per minute, while pumpable rates range from 40 - 450kg per minute. Our multiple mixing units can accurately blend many ingredients (in all or part) to produce a variety of augered or pumped products related to the explosives industry requirements.

13.0 CONCLUSION

Considering the requirement of optimum fragmentation for large opencast mines and for minimizing the total cost of mining, it is important to implement the global blasting practice in India too. The first step to this direction may be the use of Bulk ANFO explosive in dry holes of OC coal mines which can result into huge direct savings of explosives quantity per hole and then graduating to manufacturing of ANFO Blends and mixing and loading with Mobile Manufacturing units.. Introduction of ANFO and blends to Indian mines will reduce the dependence on a single Bulk Explosive product. ANFO should be viewed as an explosive product with distinct and different explosive properties as compared to Bulk Emulsion Explosives. Coal mine operators may insist for Bulk Trucks to have the flexibility of explosives products for various geotechnical requirements, alternative supply arrangement of explosive and to have better control on the Explosive product cost. Critical success factor for establishing ANFO and blends will depend on the development of a reliable mechanism for blast evaluation to quantify the advantages of better fragmentation and muck piling on loading and hauling operations and the negative impact of undesired blasting effects such as secondary blasting, hard toe, extension of mining cycle time, misfire, vibrations, airblast and flyrock.

ASSESSMENT OF BLAST PERFORMANCE WITH PRILLED ANFO AND EMULSION EXPLOSIVE AT MAIHAR CEMENT LIMESTONE MINE





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ABSTRACT

Blast performance assessment with prilled ANFO and emulsion explosive was carried out at a limestone mine of Maihar Cement, Madhya Pradesh. Test blasts conducted at the limestone mine with both types of explosives. Blast data was generated on velocity of detonation, fragmentation, backbreak and ground vibrations. Vibration intensity of test blasts with ANFO was 45-50% less than that of blasts with emulsion explosive. The mean fragment size and backbreak were reduced by 72% and 79% respectively with ANFO in comparison to emulsion explosive. There was also considerable improvement of 6% in shovel loading cycle time. Although impedance matching was good with emulsion explosive compared to ANFO, the blast performance with ANFO was far better than with emulsion explosive. The blast results clearly indicate that the selection of proper explosives with high heave energy result in improving the blast fragmentation, reducing the backbreak and vibration intensity. The study reveals that the heave energy factor plays a vital role than the impedance matching of the shock energy for fragmentation of soft rock like limestone. The study also indicate that explosives with high heave energy like ANFO are more suitable in soft and medium hard rocks than the explosives with high shock energy. The paper stresses the need for selection of blasting agents like ANFO for better blast fragmentation and productivity in soft rock formations like limestone rock.

1.0 INTRODUCTION

The productivity in open cast mines depends heavily on the degree of fragmentation. Various unit operations like drilling, blasting, loading and transportation are influenced by fragmentation and jointly contribute to the overall productivity. It is often observed that practising engineers indiscriminately use explosive charges to improve fragmentation with scant regard to rock formations and explosive properties. This may not be in the best interest of the overall mine productivity. It calls for a study on proper selection of explosive for various rock properties. The best matching for optimum shock wave transmission to the rock occurs when the detonation impedance of explosive is equal to the impedance of the rock material (Atchison, 1964). Impedance is the product of compressional wave velocity and density of the material. Impedance calculation requires the determination of in-situ P-wave velocity (Vp) and density of rock mass. However, impedance matching ensures the shock energy requirement of an explosive but not the heave energy. The heave energy component plays a key role in fracturing and fragmentation of relatively soft rock like sandstone and limestone. Therefore, a comprehensive study was conducted at a limestone mine to quantify the advantages of prilled ANFO. The results of the study are enumerated in terms of improvements in parameters like better fragmentation, specific charge, specific drilling and improved cycle time of loading and transportation. This paper deals with the importance of the heave energy component of explosives in fragmentation and blast optimisation.

2.0 EXPLOSIVE SELECTION FOR PIPRAHAT LIMESTONE MINE

Pradhan (2001) have extensively dealt an overview related to different types of explosives suitable for surface mines in Indian mining scenario. Pradhan et al (2009) also explained alteration of site mixed slurry explosive for blast performance improvement. A wide variety of explosives of different strength and water resistance are available for the purpose of blasting. For a given blasthole water condition, any one among ANFO, emulsion, versions of these explosives can be selected to produce the required blast result. The correct design, of course, is the one which gives the desired blast results at the lowest cost. One of the first factors to consider when selecting an explosive is the blasthole water conditions. If blastholes are predominantly, wet emulsion explosive is selected. On the other hand, if the holes are dry, prilled ANFO is used. The next most important factor is the cost, given a blast design requiring a certain bulk strength explosive. ANFO stands fair from the point of the cost.

Prilled ANFO was the main explosive employed in dry holes while various percentage of ANFO/emulsion blends were used in dewatered and wet holes. The advantages with ANFO are its safety and consistency for application to opencast blasting operations. ANFO has a bulk density of 0.75-0.80 g/cc as against 1.2g/cc of a standard emulsion product resulting into better column built-up and saving on explosive quantity in a blast hole. Owning to its high bulk density, charging with ANFO results into direct saving of 25-30% of explosive charge quantity per hole in dry holes. ANFO gives 3.75 MJ/kg of thermo-chemical energy as against 2.65 MJ/kg for the emulsion. ANFO has 94 % oxidizer content as against 71 % in a standard emulsion product producing much more gases and heave energy required for displacement of the fractured mass. ANFO produces 0.973 m^3/kg of gas as against 0.70 m^3/kg for an aluminized slurry and 0.78m^3/kg for explosives like PETN (ISEE Handbook, 1998). ANFO released shock waves require longer duration of rock interaction, because of lower VOD, which result in gaseous energy confinement for a longer duration. This enhances the available gas energy because of the volume expansion is much higher and faster to result into better fragmentation. ANFO provides stable hotspots in terms of pores with oil absorption capacity of minimum 8 % with additional 12-14% pores. Effectiveness of detonation for ANFO will largely depend on the quality of ammonium nitrate prill. ANFO efficiency increases with the increase in porosity of the prill and homogeneity of mixing of AN and fuel oil.

3.0 FIELD EXPERIMENTATION AT PIPRAHAT LIMESTONE MINE

3.1 Mine Details

Piprahat Limestone Mines, is a captive mine of Maihar Cement Plant and Maihar Cement Plant Unit-II, belonging to M/s Century Textiles and Industries Ltd. The mining lease area is located at Piprahat village of Maihar Tehsil, under Satna District of Madhya Pradesh. Maihar town is well connected by rail and road, situated on Bombay- Howrah via Allahabad railway line and on Nagpur-Varanasi NH No. 7. The Piprahat limestone mines is included in Survey of India Topo sheet no. 63D /16 and lies between the following co-ordinates Latitude - 24° 8 ' 40 " to 24° 7 ' 36 " North Longitude - 80° 46 ' 19 " to 80° 45 ' 55 " East. A bird-eye view of the mine is shown in Figure 1. The occurrence of cement grade limestone is in 663.0 hectares. The mining lease is stratigraphically controlled and it is associated with Rohtas limestone formation of Lower Vindhyan super group. Rocks of this formation comprise limestone, shale and dolomite with occurrence of interstitial clay. These rocks are structurally undisturbed. The setup of the limestone and inter bedded shale has more of less uniform and show gentle dips 10° to 15° due north. A complete sequence of the rock belonging to Vindhiyan super group is exposed in Maihar Bhadanpur-Dhanwahi (Kuteshwar) area. Litho-stratigraphic succession of this region. The major portion of this deposit is made up of main lithic units of limestone and shale which occur in central and western blocks of the mining lease area. The Eastern block is made up of predominantly shale and limestone, which are lying as laminated sedimentary deposit. The limestone deposit is light to dark grey coloured, thinly bedded with intercoalation of shales of different colours such as white (due to decomposition), pink and slaty grey and fine grained. The hardness varies from 3.5 to 4 and specific gravity is 2.5. Stone is laminated and breaks along the planes of lamination. The compressive strength of intact rock is 15-20 MPa. The intact rock properties of various benches are given in Table-1.

Table 1 - Intact rock properties of various benches of the mine

Site	Rock density, kg/m^3	P-wave velocity, m/s
Bench-I	2500	2100
Bench-II	2500	2150
Bench-III	2500	2215

3.2 Test Blasts At Piprahat Limestone Mine

Five test blasts were conducted with emulsion explosive in partially wet holes and another five blasts with ANFO in dry holes. The two different types of explosives used at the test site are shown in Figure 2 and 3. The prilled AN was mixed with 5% diesel manually at the magazine and loaded into the blast holes with emulsion as 20% primer charge. The density of emulsion and ANFO is 1200 kg/m^3 and 800 kg/m^3 respectively. The initiating system used was Nonel shock tubes to reduce ground vibrations and air overpressure. The blasthole diameter was 110mm and the bench height and hole depth was 6m. Maximum number of rows was 3 in each round. The average specific charge used was 0.16 kg/m^3 all the rounds. The other blast design parameters are given in Table 2. The blast parameters like fragmentation, throw and peak particle velocity of vibration were monitored for blast performance evaluation. The vibration monitoring was and engineering seismographs and fragmentation size distribution analysis was carried out by image analysis software called Wipfrag software.

4.0 BLAST RESULTS

Blast performance evaluation was carried out by measuring velocity of detonation, blast fragmentation, flyrock, backbreak and ground vibrations. It was observed during the experimentation that AN and fuel oil are mixed manually as there is no mechanical mixture available to the user. This manual mixing cannot make an effective ANFO, which leads to inferior VOD. This results in poor blast as the ANFO efficiency increases with increase in porosity of the prill and homogeneity of mixing of AN and fuel oil. This problem will also be solved if the manufacturer supplies the AN as a technology rather than

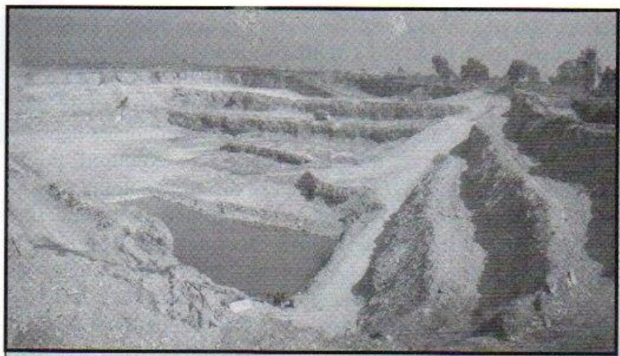

Figure 1 - View of Piprahat limestone mine where trial blasts were conducted.

Figure 2 - Picture showing the emulsion explosive used at the test site.

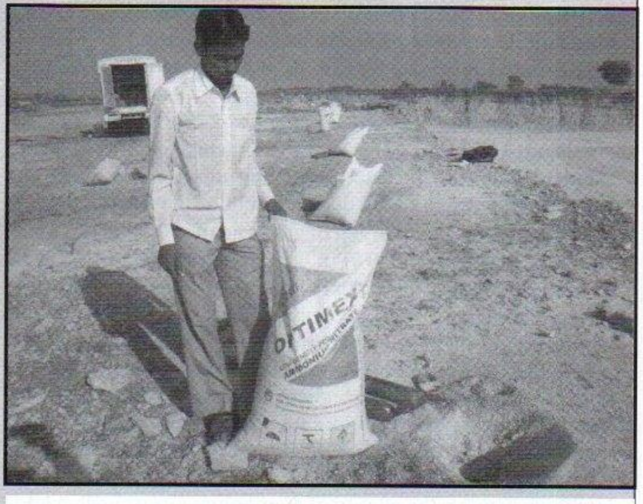

Figure 3 - Picture showing the prilled ANFO explosive used at test site.

Table 2 - Blast design parameter used for test blasts at Piprahat limestone mine

Blast No.	Date	Explosive Type	No. of holes	Avg. Burden x Spacing (m x m)	Avg. Stemming (m)	Avg. Charge / hole (kg)	Total Charge/ round (kg)
1	14/12/11	Emulsion	26	4.0 x 6.0	3.00	23	598
2	15/12/11	ANFO	18	4.0 x 6.0	2.5	23	414
3	15/12/11	Emulsion	24	4.0 x 6.0	3.00	23	552
4	16/12/11	ANFO	23	4.0 x 6.0	2.5	23	529
5	16/12/11	Emulsion	23	4.0 x 6.0	3.00	23	529
6	16/12/11	ANFO	17	4.0 x 6.0	2.5	23	391
7	16/12/11	Emulsion	23	4.0 x 6.0	3.00	23	529
8	16/12/11	Emulsion	17	4.0 x 6.0	3.00	23	391
9	17/12/11	ANFO	15	4.0 x 6.0	2.5	23	345
10	17/12/11	ANFO	20	4.0 x 6.0	2.5	23	460

a commodity. The blast data analysis and the comparative results of two different explosives are explained in detail below.

4.1 Velocity of Detonation

Velocity of detonation (VOD) was monitored by Handitrap of MREL Inc., Canada. The VOD monitoring set up is shown in Figure 4. The VOD of emulsion and ANFO explosive determined was 3916 m/s and 3485 m/s, respectively, which was shown in Figure 5 and Figure 6.

4.2 Blast Fragmentation:

Images of fragmentation were captured with high resolution camera and analysed with Wipfrag software to determine mean fragment size, which is considered as the representative fragment size of each blast round. At least 10 representative pictures were captured from each blast round and same procedure is repeated for all the trial blasts. Two sample pictures taken from the muckpile of blasts with both emulsion and ANFO and shown in Figure 7 and 8. Fragment size distribution of muckpiles of test blasts with emulsion and ANFO are shown in Figure 9 and Figure 10 respectively. The mean fragment size measured by the digital image analysis for blasts with emulsion and ANFO was 0.18m and 0.05 m respectively. It is very clear that the mean fragment size generated with ANFO is smaller than with emulsion explosive and the reduction in the fragment size is 72%.

4.3 Shovel Loading Performance

The Shovel Loading Performance study was conducted on the blast fragmentation of both emulsion and ANFO resulted muckpiles. The shovel loading cycle time observed was 142.5 s and 134.3s respectively for emulsion and ANFO explosives respectively. There was considerable improvement of 6% in shovel loading cycle time with use of ANFO in place of emulsion.

4.4 Blast Vibrations

The ground vibrations for all the test blasts were recorded with seismograph.. Attenuation model for ground vibration levels with emulsion and ANFO is shown in Figure 11. The models show that the intensity is vibrations is higher with emulsion explosive in comparison with ANFO. The use of ANFO also reduced the vibration intensity by 45-50% in comparison to the vibration induced by emulsion explosive.

4.5 Backbreak

The back break for all the test blast were measured by surveying. The back break levels with emulsion and ANFO is shown in Figure 12. The average back break was 0.55m for ANFO and 2.65 for emulsion explosives. The back break observations show that there is reduction of back break by 79% with ANFO explosive.

4.6 Flyrock

The flyrock projectiles were hardly crossed 15m from the blasting bench in both the type of explosives which be due to the use of Nonel initiation system. Therefore, comparison of flyrock distance was not possible, though theoretically ANFO generates more flyrock as it is a coupled charge with high gaseous energy content.

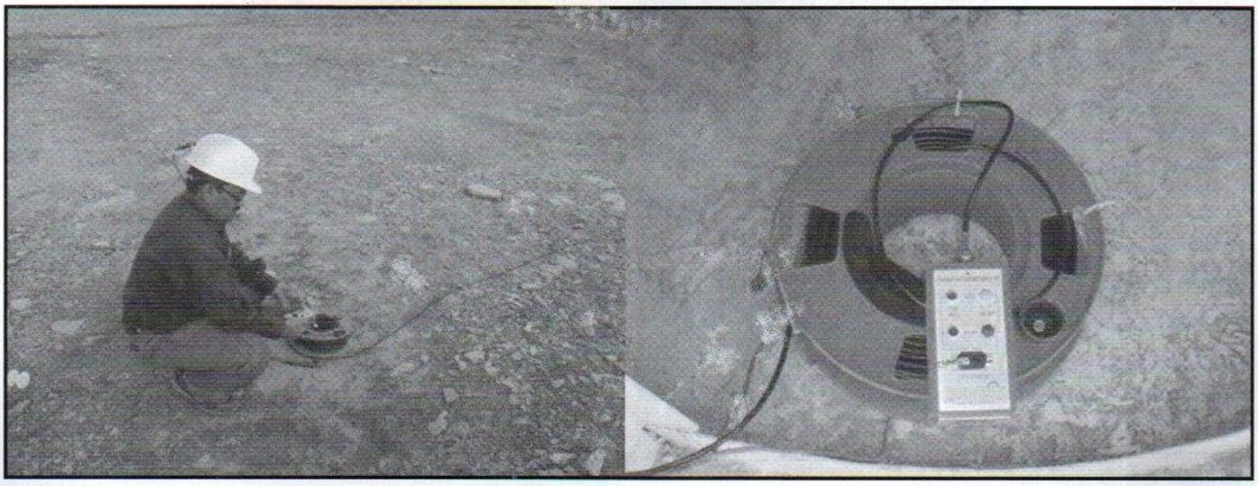

Figure 4 - Instrumentaion (MREL's Handitrap) used for monitoring of velocity of detonation of explosive at test site

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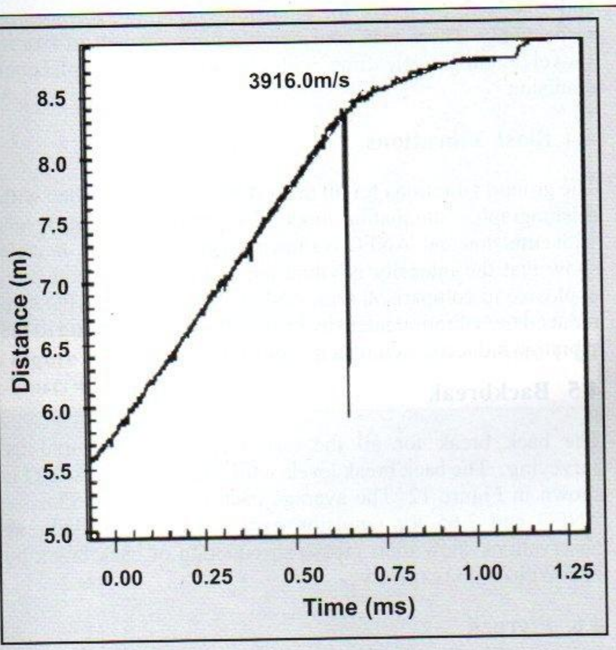

Figure 5 - VOD record with emulsion explosive

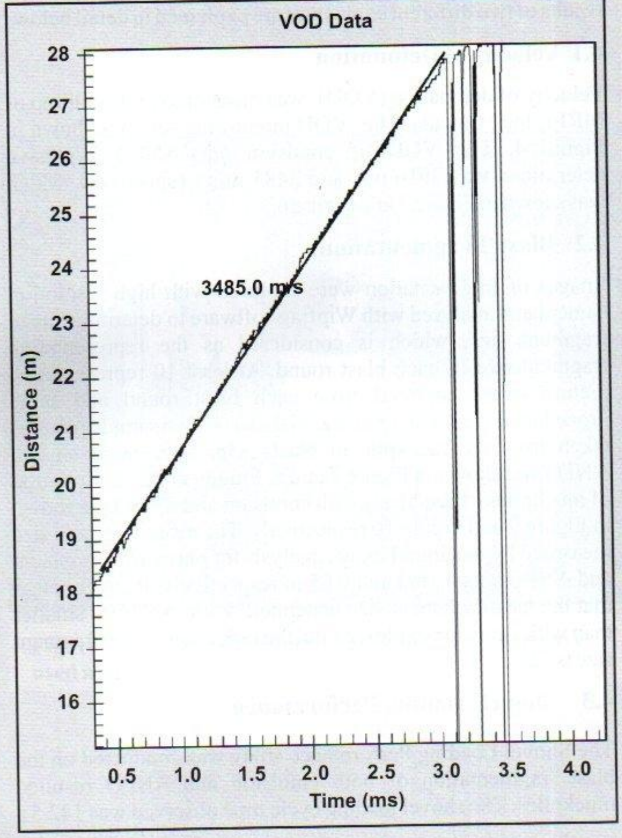

Figure 6 - VOD record with ANFO explosive

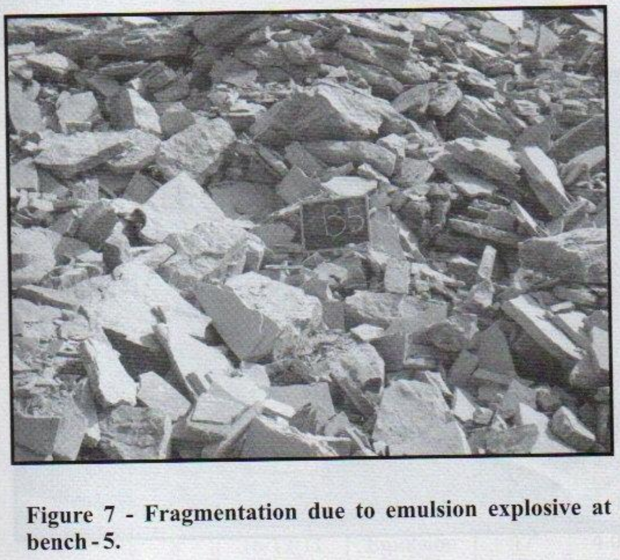

Figure 7 - Fragmentation due to emulsion explosive at bench - 5.

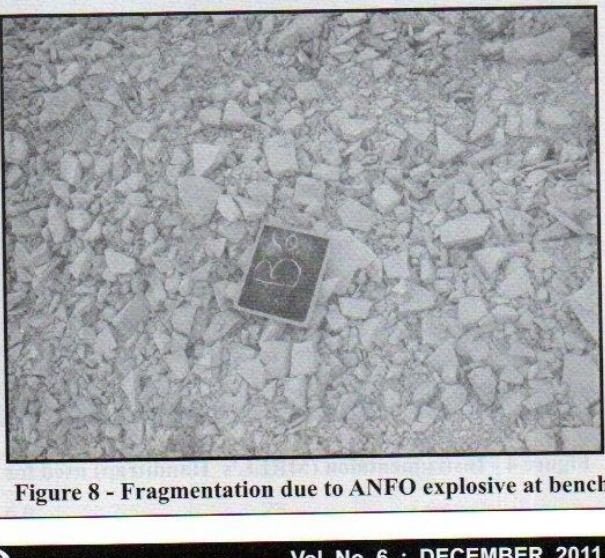

Figure 8 - Fragmentation due to ANFO explosive at bench-6.

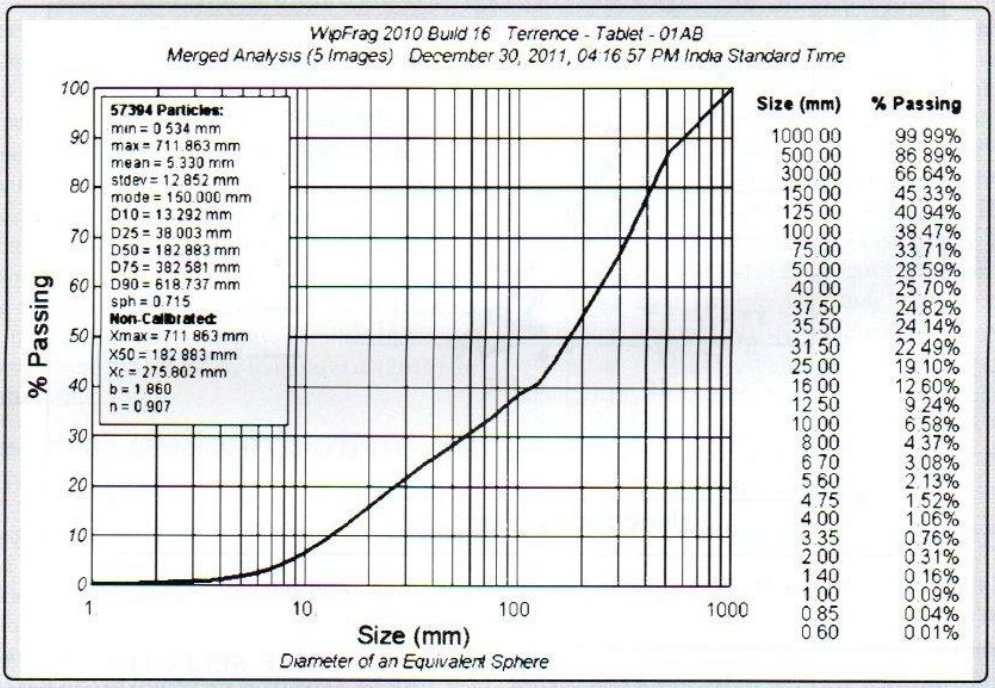

Figure 9 - Fragment size distribution of muckpiles of test blasts with emulsion explosive

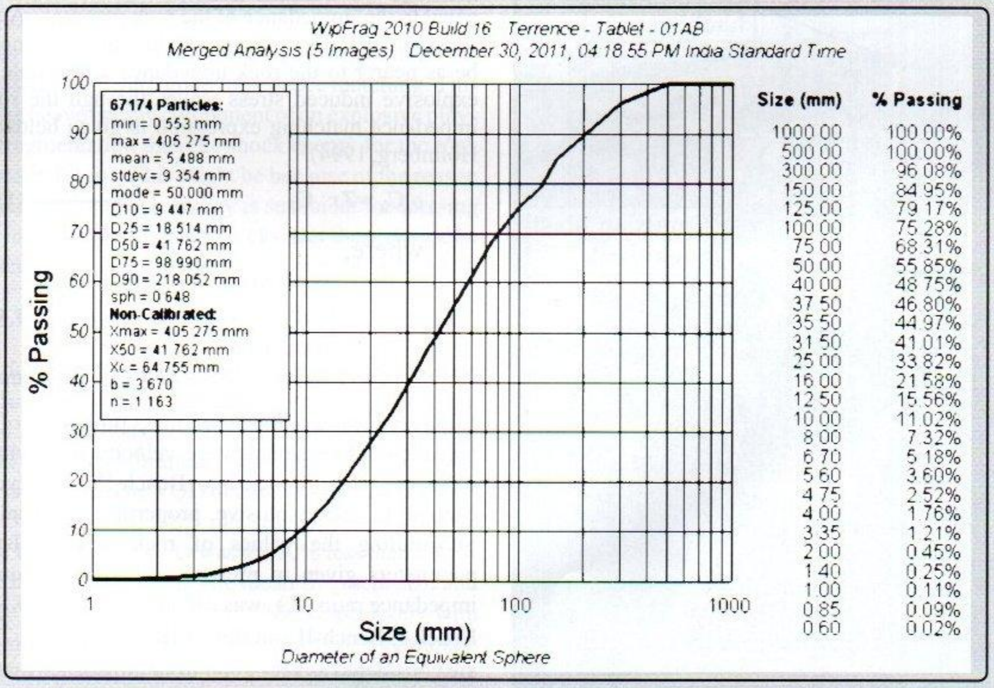

Figure 10 - Fragment size distribution of muckpiles of test blasts with ANFO explosive

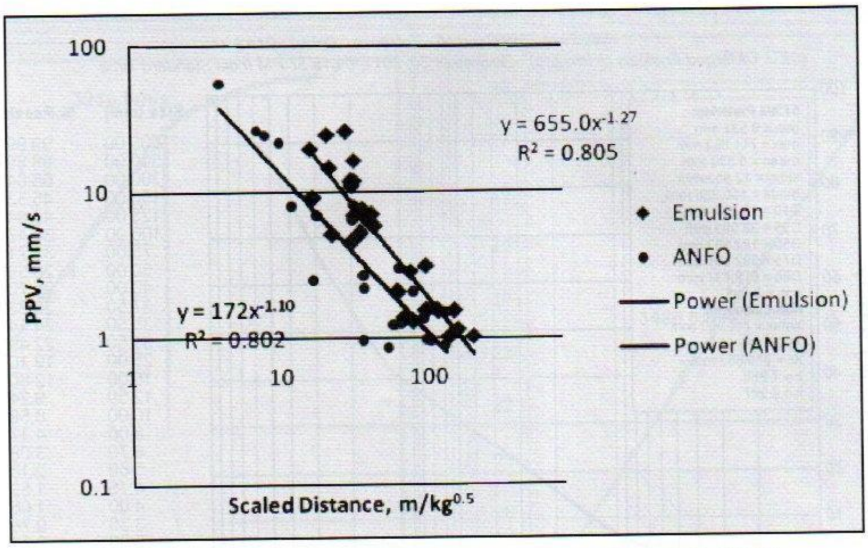

Figure 11 - Vibration attenuation models with emulsion and ANFO

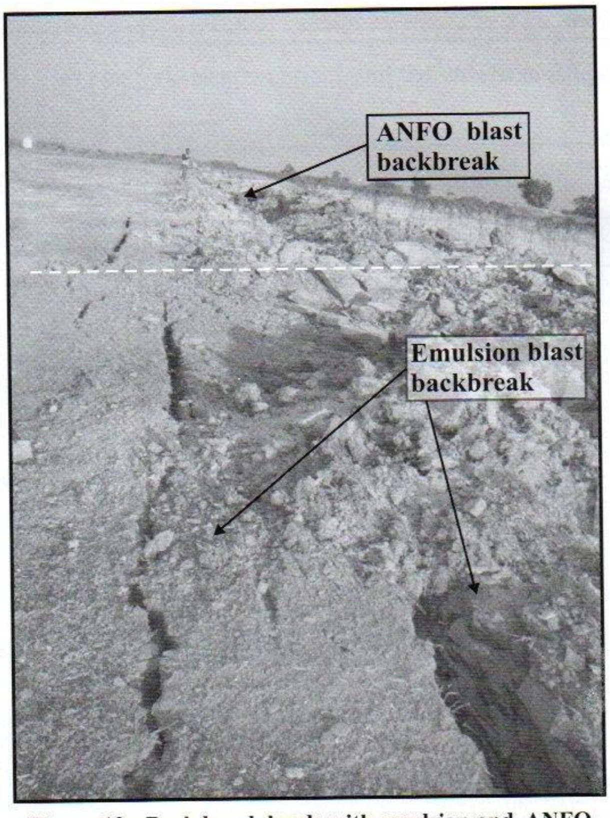

Figure 12 - Back break levels with emulsion and ANFO

5.0 EXPLOSIVE SELECTION BY IMPEDANCE MATCHING OF SHOCK ENERGY

The best matching for optimum shock wave transmission to the rock occurs when the detonation impedance of explosive is equal to the impedance of the rock material. According to the theory of impedance matching, the explosive impedance should be as nearer to the rock impedance as possible to couple the explosive induced stress waves through the rock mass. The impedance matching expression is given below (Persson and Holmberg, 1994).

$$\rho_e C_d = Zr\ \rho_r C_p \qquad \text{----------- (1)}$$

where,

ρ_e = explosive density,
C_d = VOD of explosive,
ρ_r = rock density,
C_p = P-wave velocity and Z_r = impedance ratio

It is very clear from the rock mass properties of the limestone that the compressional wave velocity is varying from 2100-2215 m/s from Bench-I to Bench-III, however there is no change in the explosive properties, especially the VOD. Substituting the values of rock and emulsion explosive parameters given in previous sections, in equation (1), the impedance ratio (Z_r) was calculated as 0.90, 0.87 and 0.85 for Bench-I, Bench-II and Bench-III, respectively. These Z_r values are considered as very good from impedance matching point of view (Persson and Holmberg, 1994). Similarly, substituting the values of rock and ANFO explosive parameters given in previous sections, in equation (1), the impedance ratio (Z_r) was calculated as 0.53, 0.52 and 0.50 for Bench-I, Bench-II and Bench-III, respectively. These Z_r values are considered very poor from impedance matching point of view. But the blast performance with ANFO is very good compared to emulsion explosive, irrespective of its poor impedance ratios. This indicates that the explosive selection on the basis of impedance matching of shock energy is not appropriate. This result suggests going for the explosive selection by considering heave energy rather than shock energy. Similar studies of explosive selection were carried out by Ramulu *et al* (2011) for sandstone bench blasting.

6.0 EXPLOSIVE SELECTION BASED ON HEAVE ENERGY

As the rock mass to be blasted is limestone which is not so hard, a low brisance explosive such as ANFO was proposed for blasting. In spite of the poor Zr values, ANFO was proposed to use for limestone benches and the blast performance was monitored. The blast performance evaluation done by fragmentation analysis and vibration monitoring for both the explosives indicate reduction of fragment size is 72%. Use of ANFO explosive also reduced the vibration intensity by 45-50% in comparison to the vibration induced by emulsion explosive. The sieve analysis showed that the ANFO with poor impedance matching resulted in better fragmentation than the emulsion explosives with very good impedance matching. This indicates that the heave energy component of an explosive plays a vital role in fragmentation than the shock energy for the rock formations like sand stone. This might be because of the reason that a meager amount of shock energy is sufficient for forming crack network in soft to medium hard rocks. But there should be enough heave energy to extend the cracks for fragmentation.

7.0 CONCLUSIONS

Test blasts conducted at Piprahat limestone mine with two types of explosives for comparison of blast performance. Blast data was generated on velocity of detonation, fragmentation, backbreak and ground vibrations and analysed for blast performance assessment. The VOD of emulsion and ANFO was determined as 3916 m/s and 3485 m/s respectively. Vibration intensity of test blasts with ANFO was 45-50% less than that of blasts with emulsion explosive. The mean fragment size and backbreak were reduced by 72% and 79% respectively with ANFO in comparison to emulsion explosive. Although impedance matching was good with emulsion explosive with ANFO, the blast performance was far better than with emulsion explosive. This study clearly indicated that the selection of proper explosives with high heave energy result in improving the blast fragmentation, reducing the backbreak and vibration intensity. The study reveals that the heave energy factor plays a vital role than the impedance matching of the shock energy for fragmentation of soft rock like limestone. The study also indicate that explosives with high heave energy like ANFO are more suitable in soft and medium hard rocks than the explosives with high shock energy. The study strongly recommends a mechanical mixture of AN and fuel oil rather than manual mixing as ANFO efficiency increases with increase in homogeneity of mixing. In order to get the full advantage of ANFO for better fragmentation and productivity, the ANFO user requires a material and mixing technology rather than just commodity from the supplier.

ACKNOWLEDGMENTS

The authors thankful to the management of Piprahat OCP mine, for their help and co-operation during the field experiments. They are also grateful to the Scientist-in-Charge of CIMFR Regional Centre-I, Nagpur, Dr. A.K.Soni and project assistant Mr. S. Chette for their cooperation and help during the studies. The views expressed in the paper are those of the authors and not necessarily of the organizations they represent.

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ELECTRONIC DETONATOR SUCCESS : AN AFRICAN STORY

by

William McFerren & Pragasen Moodley. DetNet Solutions

ABSTRACT

African, especially South African, surface mining operations have shown a significant rate of adoption of Electronic Detonators (ED's) over the last few years. Proven benefits of converting to ED's from pyrotechnic initiation systems have aided this market conversion. These benefits are experienced throughout the mining operation.

ENVIRONMENTAL IMPACT CONTROL

(i) Location:

Coedmore Quarry (Quartzite and sand) blasting within 100m (328ft) of a built up neighbourhood

(ii) Results:

The following parameters were analysed and then compared for shock tube vs. electronic blast results:

- Peak Particle Velocity & Frequency
- Airblast
- Number of "no triggers", i.e the number of blasts that did not trigger the seismographs.
- The PPV, Frequency and airblast levels were plotted against the scaled distance $= \frac{\text{Distance from Blast}}{\sqrt{\text{Mass of explosives per delay}}}$, in order to provide a more accurate comparison

Measurement	Shock Tube	Eds	%Change
% below 10 mm/s	79%	91%	+15%
Ave PPV (mm/s)	8.80	4.24	- 52%
% of triggers	16%	29%	+ 81%

Airblast - lower with ED's	(3% on average)	
Av.Frequency - (Hz)	25	30
Scaled distance at 30Hz frequency	11m.	30

The average scaled distance for shock tube blasts was lower than that for ED initiated blasts, as the mass of explosives per delay was higher. This would be due to the limited choice of delay using shock tube as opposed to the flexibility allowed by electronic initiation systems. This, in conjunction with the precision gained from ED's, allowed single hole firing during the blasts using ED's.

IMPROVED MINING EFFICIENCIES

(i) Location:

Damang Mine, an open pit gold operation; Production 17 Million tonnes annually and annual gold output of 322000 ounces.

(ii) Results:

There were visual differences between adjacent Shock Tube and ED blasts in terms of improved Fragmentation; resulting in increases in loader productivity of 11% in Phyllite, 21% in Sandstone and 22% in Dolerite. A further benefit was a 10% increase in crusher throughput. These benefits can be attributed to improvements in the fragmentation distribution.

Other benefits, which were either not quantified or the results were not available, were a reduction in secondary breaking at the crusher, shorter loading and hauling cycle times due to better floor conditions, minimised wear and tear of the crusher cone as well as reduced operating costs of the load and haul fleet

The mine also benefited from improved control over the environmental effects of blasting. This was seen in a 50 % reduction in Peak Particle Velocities, and airblast levels were reduced from 127dB to 108dB (15%) (Baka Abu, 2002).

INCREASED CAST BENEFIT

(i) Location:

New Clydesdale Colliery

The overburden bench heights range between 22m to 38m with 200mm diameter holes drilled to the top of the underlying coal seam. The initiation system that was used prior to ED's was "down-the-hole" shock tube with

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detonating cord on surface. The delays between rows ranged from 0ms to 375ms and all holes within rows were fired instantaneously, hence a "line blasting" method. A pre-split was fired before the main blast.

(ii) Results:

- The 1st ED blast mimicked the benchmarked shock tube blasts. By only replacing shock tube with ED's the cast benefit increased to 51%.
- In the 2nd ED blast, a delay of 9ms between holes within a row was introduced whilst the rest of the blast parameters remained unchanged. This resulted in a further increase to 54.7% cast benefit.
- In the 3rd ED blast, the inter row delays were changed. The 3rd row was initiated 25ms faster than originally designed. The cast gain increased even further to 60.5%
- The 4th ED blast replicated the 3rd with very similar results.

IMPROVED FRAGMENTATION

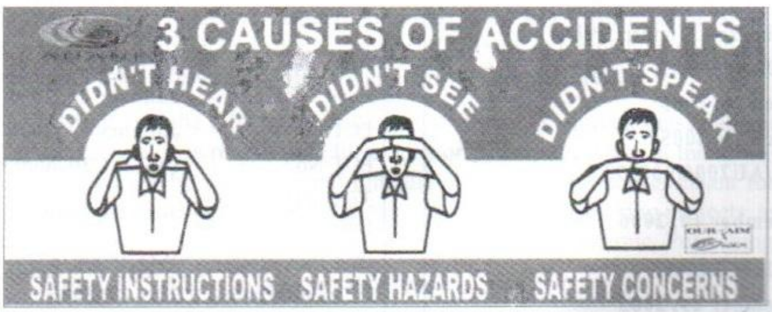
(i) Location

Peak Quarry : The rock is highly folded and bedding planes vary in intervals of 50cm to 150cm apart.

(ii) Results

An increase in demand for crusher dust or fines (6.75mm), was met through Blasting with EDD's with greater cost efficiency rather than more costly alteration in the crushing plant; the mean fragmentation size of the run of mine material at the in-pit crusher dropped by 50% from 53mm to 26.5 mm.

- Blast fines increased from 13% to 33%
- Oversize reduced to less than 0.2%
- 11% increase in truck fill factors - from 27 to 30 tonnes
- A 25% increase in diggability, resulting in the removal of one dump truck
- A 10% reduction in the primary crusher setting with no impact on throughput
- Frequency and cost of liner changes in the primary crusher decreased by 50%
- A 25% reduction in the secondary crusher setting with no change in throughput (Bedser, 2000)



RECENT PATENTS OF INTEREST

United States Patent	8,066,425
Boer , et al.	November 29, 2011

Homogenisation valve

Abstract

The invention relates to an improved homogenisation valve, and more particularly, but not exclusively, to a homogenisation valve for use in homogenising emulsion explosives. The homogenisation device comprises a body having a flow passage therethrough, opposing first and second homogenisation members located in the flow passage; the homogenisation members having opposing homogenisation surfaces that form a flow restriction of the flow passage therebetween. At least one of the homogenisation surfaces has a flow resistance being suitable to cause at least part of the flow passing through the flow restriction to be diverged in a non-linear path across the homogenisation surface.

Inventors:	**Boer; Willem George** (Johannesburg, **ZA**), **Sanders; Graham Innes** (Fourways, **ZA**)
Assignee:	**Chemical Services Limited** (Bryanston, **ZA**)
Appl. No.:	**11/998,993**
Filed:	**December 3, 2007**

United States Patent	8,069,789
Hummel , et al.	December 6, 2011

Connector for electronic detonators

Abstract

Fire, arm, and disarm signals are typically transmitted to electronic detonators via signal transmission lines. Traditionally, such signal transmission lines include wires wherein one end of each wire is soldered directly to printed circuit boards and/or other signal processing components retained within the shell of a detonator. Other `modular` blasting apparatuses of the prior art provide means to connect signal transmission lines to detonators in the field. Signal transmission line/detonator contacts are susceptible to disruption, particularly when the signal transmission lines are subject to inadvertent tugging or tensile forces at the blast site. The present application discloses an electrical connector that enables secure connection between a signal transmission line and any detonator adapted to receive and optionally process electrical signals from the signal transmission line. Specifically, the electrical connector can be affixed to the signal input end of a detonator, and includes at least one bridge element to provide electrical contact between a signal transmission line, and internal electrical component(s) of the detonator.

Inventors:	**Hummel; Dirk** (Hennef, **DE**), **Boos; Thomas** (Niederkassel, **DE**)
Assignee:	**Orica Explosives Technology Pty Ltd** (Melbourne, Victoria, **AU**)
Appl. No.:	**10/598,906**
Filed:	**March 16, 2005**
PCT Filed:	**March 16, 2005**
PCT No.:	**PCT/AU2005/000373**
371(c)(1),(2),(4) Date:	**September 14, 2006**
PCT Pub. No.:	**WO2005/090895**
PCT Pub. Date:	**September 29, 2005**

United States Patent	7,938,920
Waldock , et al.	May 10, 2011

Explosive composition, method of making an explosive composition, and method of using an explosive compos

Abstract

An explosive composition is provided that is comprised of a Heavy ANFO and grain hulls. In one embodiment, the grain hulls are comprised of rice hulls. The grain hulls serve both as an inert bulking additive that reduces the density of the composition and as a sensitizer that reduces the energy needed to reliably detonate the composition. Also provided is a method for manufacturing an explosive composition comprised of Heavy ANFO and grain hulls, such as rice hulls. Additionally, a method of using an explosive comprised of ANFO and grain hulls in a mining operation is disclosed.

Inventors:	**Waldock; Kevin H.** (Singleton, **AU**), **Kulish; Christopher J.** (Denver, CO)
Appl. No.:	**11/163,380**
Filed:	**October 17, 2005**

United States Patent	7,929,270
Hummel , et al.	April 19, 2011

Wireless detonator assemblies, and corresponding networks

Abstract

Wireless detonator assemblies (51-59) in use, form a cross-communicating network of wireless "detonator assemblies, such that communication of each wireless detonator assembly (57-59) with an associated blasting machine (50) can occur either directly, or via relay of signals (61-69) between other wireless detonator assemblies (51-56) in the network. Wireless detonator assemblies (51-59) can disseminate information (such as status information, identity information, firing codes, delay times and environmental conditions) among all of the wireless detonator assemblies in the network, while compensating for signal transmission relay delays at nodes in the network, thereby enabling the wireless detonator assemblies to detonate the explosive charges in accordance with the delay times. Various wireless detonator assemblies and corresponding blasting apparatus are disclosed and claimed. Methods of blasting using the wireless detonator assemblies and blasting apparatus are also disclosed and claimed.

Inventors:	**Hummel; Dirk** (Hennef, **DE**), **McCann; Michael John** (Chadds Ford, PA)
Assignee:	**Orica Explosives Technology Pty Ltd** (Victoria, **AU**)
Appl. No.:	**11/795,793**
Filed:	**January 24, 2006**
PCT Filed:	**January 24, 2006**
PCT No.:	**PCT/AU2006/000085**
371(c)(1),(2),(4) Date:	**June 03, 2008**
PCT Pub. No.:	**WO2006/076777**
PCT Pub. Date:	**July 27, 2006**

BOOK REVIEW

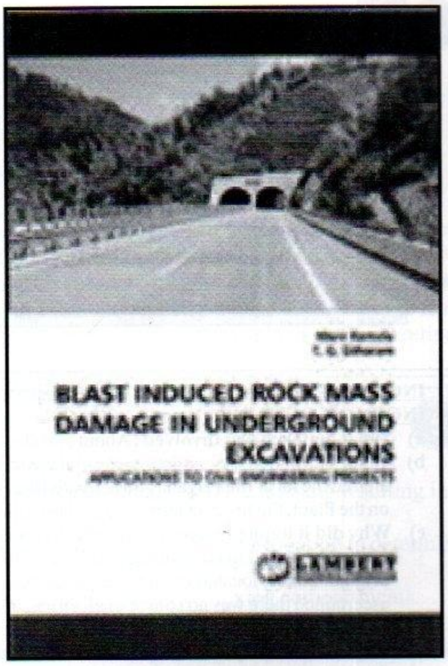
"BLAST INDUCED ROCK MASS DAMAGE IN UNDERGROUND EXCAVATIONS APPLICATIONS TO CIVIL ENGINEERING PROJECTS"

By

Dr. More Ramulu & Prof. T.G.Sitharam

Reviewed by

Dr. N.R.Thote, Dept. of Mining Engineering, VNIT, Nagpur



This book is one of the rare books on Blast Induced Rock Mass Damage in Underground Excavations It is very important for both Mining and Civil engineers to acquaint with state of the art tunnelling technology with regards to rock mass damage. This book presents case studies on rock damage assessment due to blasting, and the experiments performed at the tunnel construction sites and measured values were compared with theories proposed by other researchers. Although tunnelling by tunnel boring machines are becoming popular for longer tunnelling works, drilling and blasting is still the most common and economic technique of rock excavation. Although there have been significant developments in blasting, application of this technology for rock excavation induces damage to the remaining rock mass. The rock mass damage problem will increase manifold if the blast loading is applied repeatedly as compared to single episode blast rounds. The damage can easily extend a few meters into the rock mass and the deteriorated rock mass can give rise to serious support design problems in tunnels and caverns. This book deals with the quantification of blast damage as a function of rock mass quality (Q), which can be used for assessment of damage levels, in case of repeated exposures of vibrations. A correlation between damage and shear wave velocity was also established. The book also illustrates the effect of joint orientations on blast damage to enhance the safety and stability of underground excavations. The authors bring out the lacunas in using Holmberg-Persson model for near-field damage assessment which used a simple charge weight scaling law and dynamic stresses and strains. The authors propose a new dynamic damage model in this book, for assessment of damage due to blasting forces. The new model facilitates the assessment of near-field damage by substituting dynamic tensile failure criteria and charge-weight scaling law in Homberg-Persson model. The authors correlated damage with Rock Mass Quality (Q), the most popular parameter for rock mass characterisation in tunnels. Rock Mass Quality (Q) based criteria was established to assess damage due to far-field sub-critical repeated vibrations and found the reduction in critical PPV. The book also illustrates the field validation of the models at railway and hydel projects. The book explains how to redesign the support system to optimise its strength and to improve safety and stability of underground excavations.

The purpose of this book is to reveal the effect of repeated blast vibrations on rock mass damage and the importance of restricting subcritical vibration, which is responsible for extension of damage zone; at the same time the objectives and contents contribute to improved safety in mining and tunnelling works. The book is meant for professionals who are involved with blasting engineering and support design in mining and civil engineering projects, as well as for mining and civil Engineering students. The book is published by LAP- Lambert Academic Publishing, Germany (www.lap-publishing.com) with ISBN 978-3-8433-9318-8.

SPECIAL REPORT

SAFEX INTERNATIONAL
'Safex Incidents Notices' : October 2010 - September 2011

Summary

Activity			No. of Incidents
* Manufacturing :	Fixed Plant	9	
	Mobile Manufacturing Unit (MMU)	-	
		9	9
* Handling :	Within Plant Area	1	
	Outside Plant Area	-	
		1	1
* Storage :			
* Transportation	Vans	1	
	MMU	2	
		3	3
* Waste / unused explosives disposal, etc.		4	4
		TOTAL	**17**

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

- Editor

1

1) **INCIDENT TITLE :** 17 Jan 2011: Italy Fire in waste detonators preparation building.

2) **INCIDENT OUTLINE**

a) **What material was involved :** About 500 electric detonators

b) **What happened:** A guard noticed smoke coming from a waste preparation building and heard a sequence of 5 to 6 small explosions. He alerted the local fire brigade and activated the Seveso External Emergency Plan. After receiving the go-ahead from the responsible person on the Plant, the fire brigade proceeded to extinguish the fire from a safe distance.

c) **Why did it happen theory** : The affected building is used to prepare waste detonators for destruction. In this operation the operator cuts off the wires and makes packages of 120-150 detonators. At the time there were approximately 500 electric detonators, packaged in the original boxes, located on top of a pallet. No other material, explosive or non-explosives, was present in the building. As far as can be ascertained there was no source of electrical or thermal ignition inside the building. Furthermore, the building was closed and nobody was working inside it at the time. Despite a careful examination of the scene, the cause of the fire could not be determined.

d) **What was the impact** : The paperboard packages, the wires of the detonators, the pallet and parts of the building itself burnt. Some of the detonators present exploded while others were scattered on the floor. The walls of the building were blackened and the door and windows destroyed. There were no injuries.

3) **COMMENT**

a) **Value of incident** : As no possible cause was established, the incident is primarily of statistical value. It again demonstrates the potential for unplanned incidents in handling explosives waste.

b) **Observations :** We will be interested in any theories members may have about possible causes.

2

1) **INCIDENT TITLE :** 2 Feb 2011: Ireland Underground cartridged emulsion explosion

2) **INCIDENT OUTLINE**

a) **What material was involved :** An estimated 50 kg of cartridge emulsion material and detonators

b) **What happened** : There was an explosion with emulsion cartridges underground during shift change-over.

c) **Why did it happen theory** : The reasons for the explosion are unknown.

d) **What was the impact** : 1 fatality and 1 serious injury.

3) **COMMENT**

a) **Value of incident** : There is little to be learnt from this incident As it stands. However, any unplanned initiation of explosives is of concern to members. IIE who reported this incident are waiting for the results of the mine investigation which will clarify the learning points.

b) **Observations :** None.

SPECIAL REPORT

3

1) **INCIDENT TITLE :** 1 Mar 2011: South Africa Explosion in cartridged emulsion plant.
2) **INCIDENT OUTLINE**
   a) **What material was involved :** Unknown quantity of Megamite Super, a high energy cap sensitive cartridged emulsion explosive
   b) **What happened :** All that is known at this stage is that an explosion occurred in the cartridged emulsion plant
   c) **Why did it happen theory :** BME cannot commence the investigation as the authorities served it with a Prohibition Notice preventing any access to the scene pending the finalisation of their investigation.
   d) **What was the impact :** Three workers were killed and six others injured in the explosion.
3) **COMMENT**
   a) **Value of incident :** At this stage this incident is of statistical importance but it has significant value potential. The BME investigation process will be led by an independent and internationally recognized incident investigation organisation.
   b) **Observations :** On behalf of all its members, SAFEX extend its sincerest condolences to the family and friends of the deceased as well as the Management and staff of BME.

4

1) **INCIDENT TITLE :** 21 Mar 2011: USA Pentolite booster fire
2) **INCIDENT OUTLINE**
   a) **What material was involved :** Unknown quantity of pentolite used in the manufacture of boosters
   b) **What happened :** An operator noticed smoke from one of the boosters that had come out of the cooler. He immediately evacuated the plant as trained to do. The fire spread to the entire building.
   c) **Why did it happen theory :** The cause of the fire is unknown and is under investigation.
   d) **What was the impact :** There were no injuries to anyone on the site but the building was destroyed.
3) **COMMENT**
   a) **Value of incident :** Until we receive more information about this incident it is primarily of statistical importance. There will be additional lessons forthcoming from the way the recovery is handled (see Comment below)
   b) **Observations :** With the evacuation of the site 3 kettles in another building containing pentolite melt were abandoned and their contents solidified as a result. Orica is requesting information from SAFEX members who have had to recover from similar situations. If remelting is the preferred option, please let us have your recommended procedures and precautions for safely dealing with this situation.

5

1) **INCIDENT TITLE :** 7 Apr 2011: South Africa Fire during pyrotechnic powder mixing.
2) **INCIDENT OUTLINE**
   a) **What material was involved :** Unknown quantity of pyrotechnic delay composition powder.
   b) **What happened :** A frictional event took place inside the mixer between the mixer blade and the housing resulting in a mass fire which spread to an adjoining compartment.
   c) **Why did it happen theory :** The material being mixed was contaminated with foreign bodies. Investigation to determine the source of the contamination is continuing.
   d) **What was the impact :** No injuries occurred. There was serious damage to the structure of two mixing compartments.
3) **COMMENT**
   a) **Value of incident :** Highlights the sensitivity of explosives and incendiary mixtures to friction caused by the presence of foreign material such as grit.
   b) **Observations :** It will be interesting to see from the investigation if the spread of the fire to adjoining compartments could be prevented. It is good to see that whatever personal protective measures were employed worked in this case.

6

1) **INCIDENT TITLE :** 3 Apr 2011: Saudi Arabia ANFO truck fire.
2) **INCIDENT OUTLINE**
   a) **What material was involved:** 7,500 Kg of ANFO (packed in 25 kg bags), 260 kg cartridge emulsion and 5,000 m detonating cord (12 g) in a 40 ft. container.
   b) **What happened :** On the way to the customer site a tyre fire occurred which spread to the truck..
   c) **Why did it happen theory :** Heating of the brake pads caused jamming of the brake disk resulting in a tyre fire.
   d) **What was the impact:** The civil defence organisation who responded to the emergency evacuated the area and allowed the truck with the containers of explosives to burn out. The driver and the policeman who accompanied him were not injured.
3) **COMMENT**
   a) **Value of incident :** This incident is primarily of statistical value. However, it also underlines the importance of avoiding tyre fires which can spread to the rest of the load.
   b) **Observations:** Some of our Associate Members are doing work on tyre fires and we need to access this information. It may be an issue the SAFEX explosives Transport Workgroup can pick up.

SPECIAL REPORT

7

1) **INCIDENT TITLE :** 13 Dec 2010: Argentina Fire in RDX plant.

2) **INCIDENT OUTLINE**

a) **What material was involved :** Unknown amount of nitric acid and hexamine

b) **What happened** : After charging the reactor with nitric acid in a typical nitration process, the addition of hexamine commenced. Shortly thereafter the operator noticed a flame through the opening where the hexamine was being added. He stopped adding hexamine and manually drowned the contents of the reactor. A carbon dioxide fire extinguisher coupled to the reactor was activated and the fire extinguished.

c) **Why did it happen theory** : After the incident the operator realized the agitator was still running at low speed. It had not been switched to high speed prior to the addition of hexamine as specified in operating procedures. The hexamine ignited as it was not properly incorporated into the nitric acid. Too little agitation causes the hexamine to float on top of the liquid phase. The reaction creates hot spots on the surface which leads to an ignition.

d) **What was the impact** : There were no injuries or damage.

3) **COMMENT**

a) **Value of incident** : This incident illustrates the ease with which things can go wrong due to operator error. The plant is looking at making the process inherently safer by incorporating appropriate trips.

b) **Observations :** It is gratifying to see that despite his error the operator was able to apply the appropriate emergency responses.

8

1) **INCIDENT TITLE :** 18 Mar 2011: Spain Forklift rollover

2) **INCIDENT OUTLINE**

a) **What material was involved :** Empty reels.

b) **What happened** : While transporting empty reels, a forklift hit a bump in the road causing an empty reel to fall off. The driver stopped and hurriedly got off the vehicle to retrieve the reel. The forklift started moving downhill due to a slope in the road. The operator then tried to get onto the forklift through the left door in order to stop it. But before he could do that, and with half of his body inside the cockpit, the front left wheel collided with an obstacle and that caused the forklift to roll over onto its right side. Fortunately, the direction of the rollover prevented the operator from being trapped under it. Instead, he found himself lying on top of the left side of the vehicle with only a slight blow to his forehead from the steering wheel.

c) **Why did it happen theory** : The actual cause was non-compliance with the approved procedures for driving forklifts. He overreacted when he saw the reel fall off and did not engage the hand brake.

d) **What was the impact** : The driver suffered a slight injury to his forehead and there was minor damage to the forklift.

3) **COMMENT**

a) **Value of incident** : This incident is of statistical value and a reminder of how unstable forklift trucks are. Reacting spontaneously and in a hurry to a situation can result in overlooking the risks involved.

b) **Observations :** A number of forklift truck incidents in explosives plants have been reported over the years highlighting the risk associated with them.

9

1) **INCIDENT TITLE :** 4 Apr 2011: France Explosion on waste burning ground.

2) **INCIDENT OUTLINE**

a) **What material was involved :** A significant quantity of waste material comprising pyrotechnical compositions, about 250 kg of emulsion cartridges and contaminated metal drums.

b) **What happened** : About 10 min after lighting the fire on the burning ground there was an explosion.

c) **Why did it happen theory** : 1. Confinement due to the quantity of material being burned and the way the waste was laid out for burning - the material was left in a pile.
2. Metallic drum burst for an unexplained reason. Some metallic splinters from the drum could initiate the emulsion due to the shock wave.

d) **What was the impact** : There were no injuries and damage was limited.

3) **COMMENT**

a) **Value of incident** : In addition to its statistical value, this incident again drives home the hazards associated with a burning ground operation. The Investigation Report will highlight specific learning points including the sorting of waste, reduction of quantity of waste to be destroyed at a time and laying out of the waste to be burnt.

b) **Observations :** EPC France's honesty in this report is appreciated.

10

1) **INCIDENT TITLE:** 20 Apr 2011: Czech Republic Dynamite explosion in Drais mixer

2) **INCIDENT OUTLINE**

a) **What material was involved:** Unknown amount of dynamite known as Perunit E

b) **What happened**: An explosion occurred in the Drais mixer and liquid nitro ester weighing rooms..

c) **Why did it happen theory**: The cause of the explosion has not been established and is under investigation.

d) **What was the impact**: 4 workers are still missing and 9 people were injured by debris and flying glass. Two buildings were destroyed. Production of dynamite was temporarily suspended.

3) **COMMENT**

a) **Value of incident**: In the absence of any additional information, at this stage this incident is primarily of statistical value. There are bound to be important learning points once the investigation is concluded.

b) **Observations:** SAFEX expresses its sincerest condolences to the family and friends of our missing colleagues as well as to the management and staff of Explosia. We wish them a safe recovery from this tragic incident.

11

1) **INCIDENT TITLE :** 8 Jun 2011: South Africa Explosives truck collision with stationary vehicle

2) **INCIDENT OUTLINE**

a) **What material was involved :** 13,4t Anfex (ANFO for underground use) and 600kg packaged explosives.

b) **What happened :** The incident happened pre-dawn and in the rain. The driver was temporarily blinded by the headlights of an on-coming vehicle. He slowed down but was unfortunately too late to see a truck with platinum ore parked on the same side of the road and collided with it.

c) **Why did it happen theory :** Poor visibility. The poor condition of the road also forced the explosives truck to the left where the ore truck was parked. The parked truck was unattended without visible lights. Its red warning triangle was dirty and positioned 5m from the parked truck instead of the required 50m.

d) **What was the impact :** No injuries. Serious damage to the explosives truck as the box body was almost ripped off. Minor damage to the ore truck. 900kg of Anfex and 50kg of packaged explosive had to be destroyed.

3) **COMMENT**

a) **Value of incident :** with poor visibility drivers must exercise extra caution. The data logger indicated that the driver had adhered to procedures.

b) **Observations :** None.

12

1) **INCIDENT TITLE :** 6 Apr 2011: Indonesia Shocktube snap-and-shoot.

2) **INCIDENT OUTLINE**

a) **What material was involved :** About 2 500m of Suretube Green shock tube coated with an HMX and aluminium layer on the inside

b) **What happened :** Shocktube Assembly Plant, Subang, Indonesia

c) **Why did it happen theory :** combination of oil applied to brake pads and an untidy shocktube reel caused the tubing to come off the reel and become entangled. Oil was applied to the brake pads in an attempt to increase the length of coils.

d) **What was the impact :** Production delays and 2 500m of wasted tubing. There were no injuries or damage.

3) **COMMENT**

a) **Value of incident :** In addition to its statistical value this incident illustrates the consequences of implementing changes without going through a formal modification proposal process.

b) **Observations :** None

13

1) **INCIDENT TITLE :** 17 May 2010: Russia Non-electric detonator crimping explosion

2) **INCIDENT OUTLINE**

a) **What material was involved :** 12 detonators and a coil of shocktubing

b) **What happened :** A manually activated pneumatic crimping tool is used to crimp a detonator onto a coil of shocktube in the final stage of manufacturing a shocktube assembly. An operator inserted a detonator into the tool and activated the switch. The detonator cap fired as it came out of the crimping tool and initiated extra detonators which the operator held in her left hand.

c) **Why did it happen theory :** Incomplete insertion of the detonator into the crimping tool resulted in pressure being applied to the detonator's primary charge which initiated it. The impact was aggravated by the extra 11 detonators the operator held in her hand during crimping. This was in violation of safety procedures.

d) **What was the impact :** The operator lost her left hand and a technician suffered multiple shrapnel injuries. The damage to the property was minor. Psychological impact on the operators at the adjacent work stations resulted in aproductivity loss of about 30% over 2 months

3) **COMMENT**

a) **Value of incident :** In addition to its statistical value this incident highlights some mechanical design issues; the importance of adhering to operating procedures; and the impact of an unplanned initiation of a single or small number of detonators.

b) **Observations :** SAFEX has reported similar incidents previously. This emphasizes the importance of applying the lessons from incidents if we are going to prevent their recurrence. ISKRA has attempted to quantify the commercial consequences of this incident which is interesting

SPECIAL REPORT

14

1) **INCIDENT TITLE :** 2 Jul 2011: Spain Blackpowder initiation during disposal of pyrotechnics
2) **INCIDENT OUTLINE**
   a) **What material was involved :** An estimated 50kg blackpowder used in pyrotechnics.
   b) **What happened** : An accident took place during the dismantling of pyrotechnics which had been brought into the factory for incineration. The initiation occurred during the handling prior to any burning operation.
   c) **Why did it happen theory**: The most likely cause is thought to be friction during dismantling. An investigation is being conducted to determine the details and basic causes of the accident.
   d) **What was the impact** : An operator was killed and another severely burned.
3) **COMMENT**
   a) **Value of incident** : This incident is a further illustration of the risks associated with the disposal of waste explosives. We neglect this aspect of our operations at our peril.
   b) **Observations :** SAFEX conveys its condolences to the family, friends and colleagues of the deceased on behalf of its members.

15

1) **INCIDENT TITLE :** 12 Aug 2011: India: ASA powder explosion
2) **INCIDENT OUTLINE**
   a) **What material was involved :** Approximately 2.7 kg of an ASA mixture consisting of lead azide/lead styphnate/aluminium powder.
   b) **What happened** : The ASA mixture is dried, sieved and filled into bottles by way of remote and automatic operations. Each antistatic bottle is normally filled with approximately 900 g of ASA mixture. The operator enters the premises only to collect the three bottles, transfer them manually into a wooden carrying box and carry them to the designated magazine for storage. An inadvertent explosion took place when the operator went inside the room to fetch the ASA filled bottles.
   c) **Why did it happen theory** : One of the bottles with ASA initiated during collection handling leading to sympathetic detonation of the other two bottles. No process abnormalities were noted. Probable reasons for occurrence of the explosion are:
   a) Mechanical impact / friction.
   b) Static electricity - inadequate dissipation thereof
   d) **What was the impact** : The operator was fatally injured. The roof and soft walls of the building were severely damaged as was the equipment in the drying chamber.
3) **COMMENT**
   a) **Value of incident** : In addition to its statistical value, this incident highlights the extreme sensitivity of such primary explosives mixtures. More learning points will undoubtedly surface in the IR.
   b) **Observations :** None

16

1) **INCIDENT TITLE :** 28 Jun 2011: South Africa MMU collision with car
2) **INCIDENT OUTLINE**
   a) **What material was involved :** Mobile Manufacturing Unit (MMU) R53 transporting about 3 t of Emulsion S100Eco
   b) **What happened** : The MMU was approaching a 4-Way stop street at a major intersection of two open roads. Approximately 200 meters from the stop street a private vehicle, which was travelling in the opposite direction, collided head-on with the MMU in the MMU's lane.
   c) **Why did it happen theory** : It is suspected that the private vehicle tried to overtake a vehicle in front of it and landed in the path of the MMU. Darkness, poor road conditions and no visible lane markings were contributory factors
   d) **What was the impact** : Slight damage to MMU and but severe damage to the private vehicle. Two people in the private vehicle were killed and one was hospitalized.
3) **COMMENT**
   a) **Value of incident** : Besides its statistical value this incident highlights the necessity for extra vigilance by drivers when light is poor. Vehicles also need to be very visible in the dark
   b) **Observations :** None

17

1) **INCIDENT TITLE :** 2 Feb 2011: Czech Republic Delay composition ignition
2) **INCIDENT OUTLINE**
   a) **What material was involved :** 15 kg of delay composition
   b) **What happened** : The operator was carrying a can of delay composition from the magazine towards a waiting trolley. He slipped and while stumbling he threw the can with the delay composition to the front away from himself. When the can hit the pavement, the delay powder spilled out of the can and started to burn.
   c) **Why did it happen theory** : Lack of attention by the operator when going out of the magazine. Contributory factors were a slightly sloping and very smooth doorstep of the magazine that was wet from the snow left by the patterned soles of the operator's shoes.
   d) **What was the impact** : The operator was not injured. Insignificant material damage and no environmental impact occurred.
3) **COMMENT**
   a) **Value of incident** : Besides its statistical value, the incident illustrates the importance of extra vigilance by operators in adverse weather conditions.
   b) **Observations:** As he fell this experienced operator threw the can away from him where it can do little harm. This action is also interesting.

Visfotak

Explosives Safety & Technology Society

Secretariate

Address :
Maimoon Chambers
Gandhibagh, Nagpur - 440 032

E-mail : visfotak@yahoo.com

Website : www.visfotak.org

History

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.

Consequently, the Explosives Safety & Technology Society (Visfotak) was registered vide Certificate No. 410 / 99 (Nagpur) dated June 17th, 1999.

Objectives

(a) To promote and develop modern concepts relating to safety and technology in manufacture, handling, and usage of explosives.

(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.

(d) to collaborate with academic and research institutions in promoting the objectives mentioned above.

(e) To promote and strengthen affiliation with other world bodies / societies dealing with explosives safety and technology for exchange of information.

(f) To institute awards, fellowships and scholarships for the excellence in the field of explosives.

The Society has been accepted as an ***Institute Associate Member*** of SAFEX INTERNATIONAL at a General Meeting of SAFEX members on 30 May 2008 with the privileges and obligations that pertain to the membership.

SAFEX INTERNATIONAL is a non profit global organisation founded by the manufactures of explosives and pyrotechnics; currently having 110 members in as many as 46 countries. Visfotak is committed to discharge its obligations as a member by sharing information with SAFEX on all accidents with industrial explosive in India. Visfotak urges all the explosives manufactures and users to cooperate by reporting all accidents to the Society.

Membership

The membership application form which is enclosed, may be filled and sent to the Secretary General at the Secretariat along with the membership fee by a crossed account payee Cheque (add. Rs. 30/- for outstation cheques) or Demand Draft in favour of **Visfotak, payable at Nagpur**.

Student Chapter : This is a new initiative launched by the Society to promote the mission of the Society amongst the students/academics who are associated, directly or indirectly, with the science and technology of explosives.

The membership application form which is enclosed may be filled and sent to 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 along with the membership fee by a crossed account payee Cheque (add. Rs. 30/- for outstation cheques) or Demand Draft in favour of **Visfotak, payable at Nagpur.**

Visfotak being a Scientific Society, shall totally refrain from partisan activities of any manner or kind and shall not entertain tasks which are biased with commercial interest to its individual members.

THE SOCIETY

Dr. More Ramulu, an esteemed member of the Editorial Board, has been awarded the prestigious National Geosciences Award 2010, for Mining Technology

Dr. More Ramulu, receiving National Geoscience Award-2010 from Hon'ble Speaker of Loksabha in presence of Hon'ble Minister of Mines (I/C), at Vigyan Bhavan, New Delhi.

INVITATION TO MEMBERSHIP

In its quest for interaction towards improved Safety & Technology in Explosives, Visfotak cordially invites concerned people to enrol as members.

Membership Categories comprise :

CORPORATE OR INSTITUTIONAL

Entrance Fee	***Membership for 5 years***
Rs. 2000/-	*Rs. 3000/-*
US $ 200	*US $300 - For Foreign Nationals*

INDIVIDUAL

Entrance Fee	***Membership for 5 years***
Rs. 1000/-	*Rs. 1000/-*
US $ 100	*US $300 - For Foreign Nationals*

STUDENT

Entrance Fee	***Membership for 5 years***
Rs. 50/-	*Rs. 200/-*

Application forms are enclosed with this journal for necessary action.

- Secretary General, Visfotak

ORDER FORM

For Advertisement in Visfotak

To,
Secretary General
Explosives Safety and Technology Society (Visfotak)
Maimoon Chambers, Gandhi Bagh, Nagpur - 440 032

1. Name & Address of the Organisation.
2. Advertisement enclosed : Hard copy / Soft copy / Both
3. Advertisements for each issue of Visfotak Journal are solicited with the Tariff as follows :

Full Page (170 mm x 258 mm)		
Colour	Outer back cover	Rs. 50,000/-
	Inside front cover	Rs. 40,000/-
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Payment is to be made through cheque / draft in the name of **"Visfotak", payable at Nagpur.**

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Visfotak EXPLOSIVES SAFETY & TECHNOLOGY SOCIETY

REGISTERED UNDER SOCIETIES REGISTRATION ACT MAHARASHTRA NO. 410 / 99 NAGPUR (INDIA)

MEMBERSHIP APPLICATION FORM

(Registered members will be given a Certificate and they would be entitled to participate in all the events conducted by the Society, and receive the publications of the Society free of cost).

Category of Membership : (Please tick ✓) MEMBERSHIP FEE FOR FIVE YEARS ONLY

CORPORATE MEMBER ☐	INSTITUTIONAL MEMBER ☐	INDIVIDUAL MEMBER ☐
Entrance Fee Rs. 2,000/- (US $ 200)	Entrance Fee Rs. 2,000/- (US $ 200)	Entrance Fee Rs. 1,000/- (US $ 100)
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Name of Corporate Body / Institution ______________________

Represented by (Head - Other) * ______________________

* NAME IN FULL ______________________
(First Name) (Middle Name) (Surname)

Date of Birth ____________ Designation / Current Status ____________

Mailing Address ______________________

City ________ Pin Code ________ Country ________ E-mail ________

Telephone (Office) ________ (Home) ________ (Mobile) ________ (Fax) ________

Qualifications Educational ____________ Professional ____________

Year of passing ____________ Institute / University ____________

Nature of Industry (Explosives, Mining, Hydel Power, Cement, Highways, Irrigation, Academic / Research / Technical Services, Defence, Statutory Bodies, Other) (Please specify) ____________

____

Membership of Professional Bodies, Awards, Recognitions ____________

____

____

Professional Experience ______________________

____

Areas of Specialization ______________________

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 $ ____________

Drawn on ____________ Bank ____________

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

The Secretary General, Visfotak - Explosives Safety & Technology Society
Maimoon Chambers, Gandhibagh, Nagpur - 440 032 (India)
Tel. : 2768631 / 32 ▪ Fax : 0712 - 2768034 ▪ E-mail : visfotak@yahoo.com

Place : ____________ Date : ____________ Signature ____________

*** Please enclose a detailed BIO-DATA and a recent passport size PHOTOGRAPH.**
For Corporate and Institutional Members enclose Bio-data of the Head or Representative

Please send your detailed address, telephones / mobile numbers, fax and e-mail ID

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Membership Fee Rs. 3,000/- (US $ 300)	Membership Fee Rs. 3,000/- (US $ 300)	Membership Fee Rs. 1,000/- (US $ 100)

Name of Corporate Body / Institution ____________________

Represented by (Head - Other) * ____________________

* NAME IN FULL ____________________

(First Name) (Middle Name) (Surname)

Date of Birth __________ Designation / Current Status __________

Mailing Address ____________________

City __________ Pin Code __________ Country __________ E-mail __________

Telephone (Office) __________ (Home) __________ (Mobile) __________ (Fax) __________

Qualifications Educational __________ Professional __________

Year of passing __________ Institute / University __________

Nature of Industry (Explosives, Mining, Hydel Power, Cement, Highways, Irrigation, Academic / Research / Technical Services, Defence, Statutory Bodies, Other) (Please specify) __________

Membership of Professional Bodies, Awards, Recognitions __________

Professional Experience __________

Areas of Specialization __________

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Tel. : 2768631 / 32 ▪ Fax : 0712 - 2768034 ▪ E-mail : visfotak@yahoo.com

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Place : __________ Date : __________ Signature __________

*** Please enclose a detailed BIO-DATA and a recent passport size PHOTOGRAPH.**
For Corporate and Institutional Members enclose Bio-data of the Head or Representative

Please send your detailed address, telephones / mobile numbers, fax and e-mail ID

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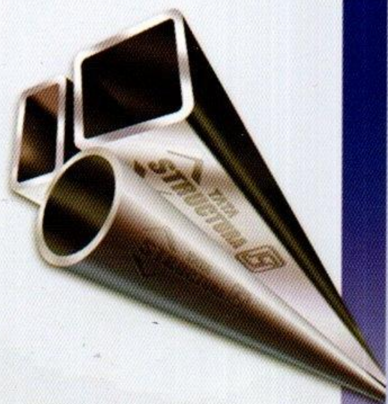
TATA
STRUCTURA
STEEL HOLLOW SECTIONS
THE SHAPE OF THINGS TO COME

The 5Cs of Tata Structura

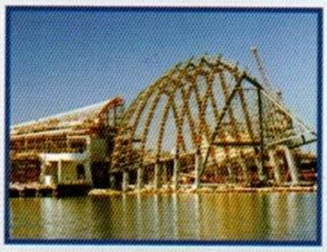


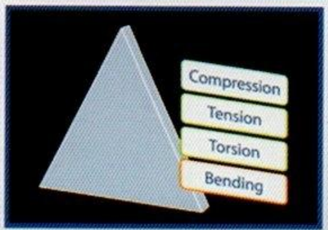
Cost Effective

Savings in material consumption, cutting, welding, transportation, painting and maintenance costs

Corrosion Fighter

Internal corrosion cannot occur as water is excluded and oxygen not is replenished





Concentric Strength

Increased compressive strength
Increased tensile capacity
Improved strength under torsion
Full strength even while bending

Convenience of Fabrication

Flat surface of closed structurals enables easy and quick fabrication with cleaner, streamlined look

Creativity

Design flexibility
Superior aesthetics

THE SHAPE OF THINGS TO COME

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