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

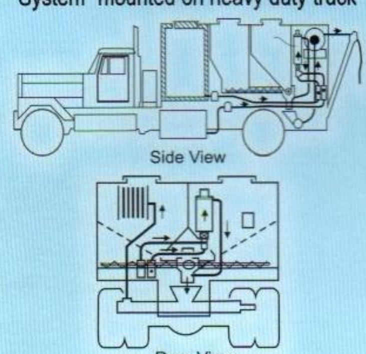
1985

IRECO US Patent Number 4,526,633, July 2, 1985

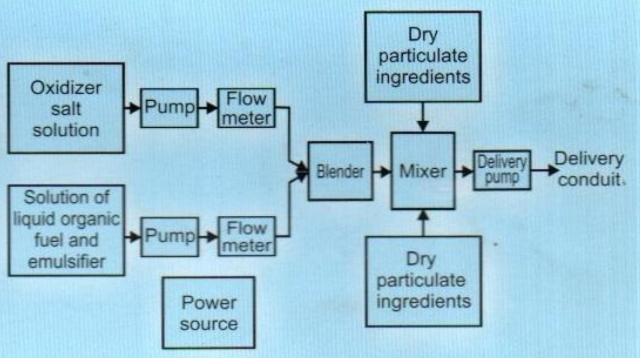
(Formulation and Delivery System for Emulsion Blasting)

Embodiment of the Invention

Schematic view of "Mixing and Delivery System" mounted on heavy duty truck



Equipment and Flow Diagram



2016

A Modern "Mixing and Delivery Bulk Truck Unit"

Raw Materials : (carried in bins) :

- Ammonium Nitrate Prill;
- Diesel Fuel;
- Emulsion;
- Water;
- Gassing Chemicals.

Products :

ANFO	Auger discharge
Heavy ANFO	Auger discharge
Gassed Heavy ANFO	Auger discharge
Gassed Emulsion	Down hole pump
Solid Sensitised Emulsion	Down hole pump

(Source : Dyno Nobel Technical Information)

Cover Feature : Review of the State of Bulk Explosives Technology in India

The illustration provides an interesting global paradigm of the growth of 'Bulk Explosives Technology', in that ANFO, since its advent in the 1950s & quickly gaining predominant share of the global market during the 1960s /1970s, has virtually traversed a full circle and regained its pre-dominant status vide its new avatar of water-proof 'ANFO-Emulsion Blends (Heavy ANFO)', affording a wide range of blends of various sensitivity and energy density, suitably modulated at site to match specific requirements.

MISSION STATEMENT

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

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Providing Niche Services In

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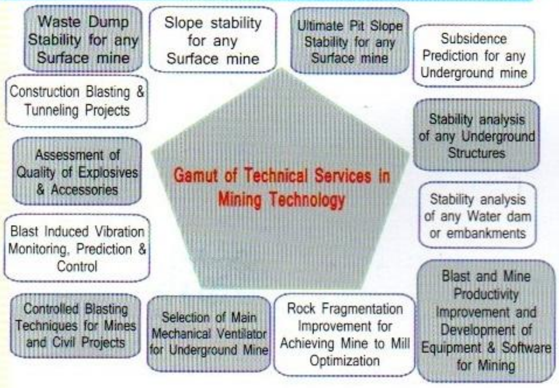
Details of Consultancy Services from aegis of ICEx



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Editorial...

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

New technologies bring with them new regulatory challenges; and if not met at the cusp, then there are serious consequences of 'Opportunity Cost (OC)' to the economy. Ironically though, the old order changeth not - 'the more things change the more they stay the same' - and we tend to stick with old concepts ?.

Just such an enigma was the subject of the 'Cover Feature' in the previous edition of the Journal, dealt in the back drop of an anachronistic NG era dispensation of statutory tests criteria and methods being applied for 'Technical Specifications' of Ammonium Nitrate based Explosives (ANEs). The standards prescribed by the Bureau of Indian Standard Institution (BIS), vide IS 15447 (Part 2), revised as late as 2008, grossly fail to take due cognizance of the fundamental disconnect between the detonation characteristics of the two classes of explosives, i.e., the near Ideal characteristics of the long phased-out NG explosives vis-à-vis the Non-Ideal characteristics of modern ANEs, respectively. As for the consequential implications of OC, the CIL Tender Document for requirement of explosives for the period 2015-2017, valued around Rs. 4000 crores, where the 'Technical Specifications' are based on IS 15447, is a worthy example in point for assessment ?.

We live in the brave new age of 'Information Technology (IT)' with its accompanying endowment of new resources for innovative technology supporting solutions to improve existing processes over a broad range of efficiencies and differentiation at the same time. The organizational infrastructure of a modern economic enterprise has also duly evolved, by providing for a new strategic management domain, headed by a 'Chief Information / Technology Officer', that constantly addresses the conundrum of 'What Is ? and 'What Could be ?, by scouting for useful technologies and applying technology to improve existing processes.

Whereas, if seen in the perspective of the explosives industry and its major constituents in India, not withstanding very impressive growth of explosives demand over the years, the scenario appears bereft of a 'Technology Vision' ?. In this context, it's appropriate to quote here from the book - "India 2020 : A vision for the New Millennium" by Dr. APJ Kalam :-

"About two decades after independence, despite our numerous achievements, doubts emerged about our ability to handle our system on our own".

"Faced with this unusual combination of growing dependency with a few bold successes, a unique institution called the 'Technology Information, Forecasting and Assessment Council (TIAFAC)' was born in 1988. Its major task was to look ahead at the technologies emerging worldwide, and pick those technology trajectories which were relevant for India and should be promoted. In this task, TIFAC networked various stake holders : the government, industries, users, scientific and technological institutions, financial institution and intellectuals "

This quotation clearly begs an obvious question : whether the benefits from TIFAC were ever availed or networked for the development of the explosives industry ?. The answer is an emphatic 'NO' ! The only official platform which could have net worked with TIAFAC, would have been the 'Explosives Development Council (EDC)' mandated for any scheduled industry under the Industrial Act ,1951; whereas, unfortunately, the Council has been functional only sporadically, in short tenures ; and for the past ten years or so up until now, has remained moribund !.

Surely, and undeniably so, the explosives industry as one of the core sectors of the economy - deserves better !. This important aspect, inter-alia, also comprise the thematic burden of the 'Cover Feature' in this edition of the Journal.

Best wishes for 2018 !.

Ardaman Singh

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COVER FEATURE

"Review of the State of Bulk Explosives Technology in India"

1.0 PROLOGUE :

1.1 The previous 10th edition of the Journal (2016), vide its 'cover feature', dealt with the urgent necessity for developing a separate 'Standardized Protocol of Test Criteria and Methods for Technical Specifications of Ammonium Nitrate based Explosives (ANEs)', in order to replace the present protocol fixated in the NG era.

1.2 Whereas, this feature is a logical follow-up review of the current state of the ANEs technology in India, in particular of the Bulk Systems, viz, Mobile Production and Delivery Units (MDUs) which constitute a major share of the market, around 65 %, in the country.

In this context, significantly, the implication of 'Opportunity Cost (OC)' to the economy is deserving of a much closer attention than given hitherto - measured in terms of the cost of a particular technology / operating system(s) in use vis-a-vis the differential cost / value dividends available from the next best alternative(s), forgone by default or not chosen for want of requisite resources conforming with the best global practices.

1.3 Historically, the explosives industry has been driven by two fundamental imperatives : firstly of the industry's innate linkage with the national objectives for sustainable development of country's economy, and secondly, addressing the intrinsic concerns for 'public security and safety'. Consequently, the industry, over time, has emerged as a truly creative industry, through individual skills and innovations, bringing about evolutionary, and many a time revolutionary shifts in technology and safety paradigm of the industry, thereby lending substantial economic and safety dividends.

1.4 ANEs comprise unique technological advances across board, viz , production, application/ performance / productivity and safety.

Most notably, the free flowing rheology of ANE formulations duly led to a paradigm shift towards bulk mixing / production and delivery from a mobile platform, and servicing requirements directly down the blast hole at a blasting site.

The modern range of ANEs formulations are predominantly ANFO centric; from 100% ANFO in dry conditions to blends of ANFO with Emulsion in various proportions, appropriately designed at site to match specific field requirements. An illustration of the versatile range of Bulk Explosives Delivery Technologies, developed for both surface and underground operations, respectively, is provided in Annexure - I.

1.5 What is as significant is the fact that simultaneously, there have been many path - breaking technological developments in the domain of 'Explosives Initiating Systems and related Blasting Services'. The important developments are briefly highlighted in Box - 1.

New Initiating Systems and Blasting Services **Box - 1**

➢ *Electronic Sequential Blasting Machines (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 (1970s).*

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 a 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) - (1980s).*

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 the risk of blast hole cutoffs and misfires.

The EDDs 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.- (1990s).*

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

➢ *Computer modeling and simulation of blast design -(1972).*

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.

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

1.6 Commensurately, with the advent of (MDUs), the traditional explosives manufacturing dispensation has also undergone a sea change in that the manufacturing facilities are increasingly and exclusively devoted to production of 'explosives initiating systems' only.

1.7 As a result, in the modern context , the role of an explosives manufacturer has evolved to one of 'Blasting Services Provider'. Accordingly, the modern explosives business paradigm has moved from the traditional commodity /product protocol, to a consumer driven protocol comprising a set of marketable 'Products Systems and Services (PSS)', supported with supply of requisite range of initiating explosives accessories .

1.8 The new business paradigm is a self-learning innovative process of continual improvement to deliver Quality that Customer Wants (QCW). The leading edge companies / enterprises, whether they sell to individual customer or businesses - have duly upgraded their economic offerings to the next differential economic value by staging 'experience economy' through 'Virtual visualization' of PSS and Performance : According to a recent report of IBS World, on the USA market, by 2016 : "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". A QCW business model is illustrated in figure 1 below :-

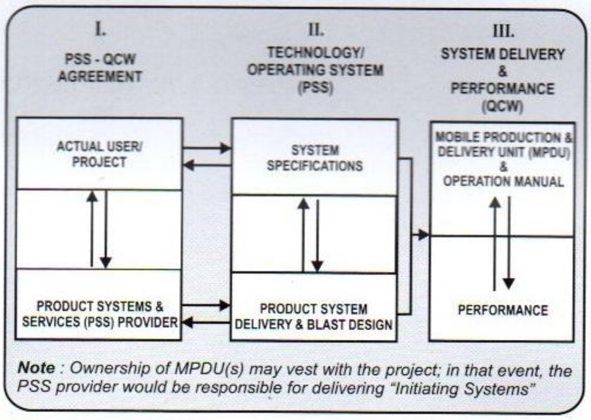


Figure 1 - QCW Business Model (Ref. 6th edition of the Journal)

2.0 DISCUSSIONS : EXPLOSIVES MARKET PROFILE

2.1 A Case Study - 1983 :

A study titled 'Indian Explosives Industry - Whither ?', was presented at a Seminar on 'Safety in Industrial Explosives', held under the aegis of the Department of Explosives, Government of India, at Nagpur in 1983. Important excerpts from the paper are shown in Annexure II. However, a few salient aspects that were discussed at the seminar are briefly highlighted below for ready reference :-

i) Global Scene :

ANFO had already replaced Nitro-Compound explosives to the extent of 70% share of the explosives market in the USA by 1970 and in due course, by the early 1980s, in conjunction with the development of water- compatible ANEs, viz, Slurry and Emulsion blasting agents, together constituted well over 80 % of the demand in the USA and Canada, 90 % in Australia, and 60% in South Africa, respectively.

Bulk ANEs, which are relatively very simple and safe to produce, easily replicatable, duly gave rise to the concept of establishing 'Satellite Plants' close to or at the explosives consuming centers, and the requirements duly serviced by 'Mobile Units', dispensing bulk formulations directly at the blasting site. Economy of scale became relatively less important if not irrelevant, because annual consumption levels as low as 500t, became commercially viable.

ii) Indian Scene :

Symptomatic of a short supple economy that existed in the country, there were serious imbalances in the context of the global developments. A comparison of the then profile of the explosives market vis-à-vis a hypothetical market profile if the explosives technology in India had conformed with the global developments by that time (see Table in Annexure II), revealed an 'Opportunity Cost' to the country's economy, in the order of more than Rs 20 crores at that point in time, which if translated at present value would be humongous at around Re 2000 crores ? Such were the consequences from an asymmetrical growth profile of the explosives industry in India vis-à-vis the global trend?.

The study duly suggested a strategy for developing an optimum matrix of product systems and services compatible with global trends.

2.2 Current Status (2016 - 17) :

The relevant set of statistical data is presented below for reference.

2.2.1 Demand Matrix :

❖ Production of ANEs

Product	Quantity (t)
Packaged	4,07,065
Bulk (slurry, emulsion including blends)	8,03,666
ANFO	68000
Total	**1278731**
(Source : Annual Report of Chief Controller of Explosives, Government of India (2016-17)	

- Estimate of AN production in the country and the consumption of AN in the form of AN Melt, Crystalline / granulated AN, etc., by the explosives industry.

i) Indigenous:			
Production (t)		**Consumption (t)**	
RCF	1,00,750	Packaged ANEs	2,64,592
GNFC	1,59,973	Bulk ANEs	5,46,493
Deepak Fertilizers	3,57,667	**Total**	**8,11,085**
Smart Chem.	16,870		
Total	**6,35,260**		
Less : Exports	22,267		
Total	**6,12,993**		
ii) Imports (uncoated AN prills only) :	**3,11,796**		
Total availability	**9,24,789**		

- ANFO consumption (Consuming Industry- wise) :

i) Mining	**ANFO (t)**
Coal	9,000
Limestone	25,500
Metal Mines	3,500
ii) Projects and Construction	30,000
Total	**68,000**

The consumption of ANFO has in fact come down after the notification declaring AN as an explosives and brought under the Explosives Act. However, at the face of it, looking at the capacity for AN production in India, there is absolutely no viable justification for such a low level of availability of explosive grade, low density porous AN prills from indigenous sources.

2.3 The State of the Bulk Explosives Technology (2016-17) :

2.3.1 Technology matrix : relative demand / share of various bulk ANEs :

Bulk Explosive	Quantity (t) / Relative market share (%)
ANFO -	60,000 / 7
Sluury -	16,000 / 2
Emulsion (Straight)	560,000 / 70
Emulsion Matrix - AN blends with AN	160,000 / 20
Heavy ANFO (Emulsion - ANFO Blends)	9000 / 1 (recently introduced)

2.3.2 No. of licensed premises for Site Mixed Explosives (SMEs):

There are 128 licensed premises, serviced by 40 manufacturers, and operating around 670 Mobile Truck Units, with an aggregate licensed capacity of around 13,00,000t (See Annexure II).

The break down of the number of the operating mobile truck units in relative percentage, in terms of various bulk explosives system(s) is as follow :-

Technology	%age share
Slurry	1-2%
Sensitized Emulsions	70%
Doped Emulsions (20% AN and 80 % Emulsion Matrix)	20%
Heavy ANFO (40-50 % ANFO)	< 10%

As earlier stated, ANFO-Emulsion blends, viz, Heavy ANFO, by overcoming the singular deficiency of poor water resistance of AN, has globally emerged the most popular bulk explosives system, affording a wide range of sensitivity and energy density, modulated at site to match specific field requirements. See figure 2.

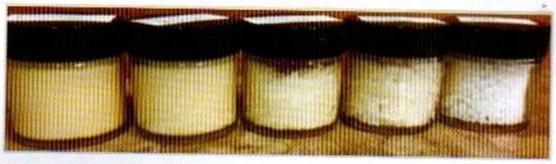


Figure 2 - From left to right : Emulsion, Emulsion ANFO blends - 70/30 Blend, 50/50 Blend, 30/70 blend and ANFO

Whereas, as confirmed by the data provided above, the Indian scenario is unfortunately way behind the global curve !

3.0 A ROAD MAP ADDRESSING THE 'DISCONNECT' WITH THE GLOBAL TREND :

3.1 Global Bench Mark:

The development of the explosives market in the USA is deemed an appropriate 'Bench Mark' for India for the following compelling factors :-

- Both the countries have similar 'continental size' endowments of natural resources, and identical 'Techno-Economic Profile' of the commercial explosives market. See Table 1.

Table 1 - Explosives Consumption Profile in USA and India 2009-2010 *(Ref. 6th edition of the Journal).*

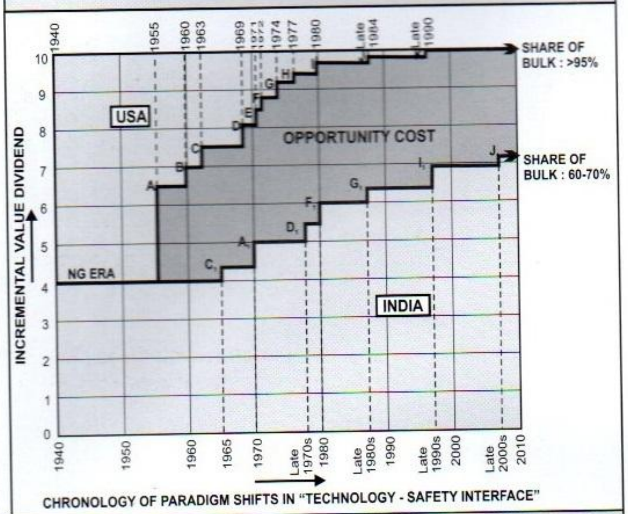
2009-2010	Consu-mption	Coal	Quar-rying	Metal Mining	Const-ruction	Misc.	Total
USA	Expl.(t)	1590000	209000	176,000	235000	60000	2270000
	(%)	70	9.2	7.8	10.4	2.6	100
INDIA	Expl.(t)	480000	20000	90000	100000	10000	700000
	(%)	68	2.8	13.6	14.2	1.4	100

- As importantly, the other remarkable facet of the technological paradigm in the USA, driven by a free, competitive market environment, is that new emerging technologies are quickly assimilated and scaled up to commercial level in short order of less than five years; whereas, India has consistently failed to keep pace with the global trend as, illustrated in figure 3 below.

Technology Profile

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.



Technology Profile

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 Early2000s.

Figure 3 - Incremental 'Added Value' Dividends *(Ref. 6th edition of the Journal).*

It shows that India is lagging behind the global development curve by 4 basic points on a scale of 0-10 points with regard to incremental added-value dividends from emerging technologies, and consequentially the substantial 'Opportunity Cost' to the economy?

3.2 Way Forward : Stewardship of the Explosives-Environment Paradigm.

3.2.1 *Macro-management : Establishing a Nodal agency for Stewardship*

The Industrial (D&R) Act 1951, provides for the establishment and constitution of 'Development Council', for any scheduled industry or group of scheduled industries, and the functions that may be assigned to the Councils are detailed in the Second Scheduler of the Act (See Annexure II).

Unfortunately, the explosives industry hasn't had the benefit of a permanently tenured 'Explosives Development Council'; and excepting for a very brief period during the 1960s/1970s, the council has remained moribund for a long period of time up until now.

Clearly therefore, without much delay, the Explosives Development Council (EDC) should be quickly revived and reconstituted with a permanent tenure and importantly, mandated under the statute to serve as the Nodal Agency for developing, inter alia, an institutionalized frame work for 'Technology Information / Forecasting and Assessment' of emerging technologies, with appropriate incentives for the industry to adapt emerging Technologies / Products and Services, within an assigned time frame.

Concurrently with the above, the Safety Regulatory / Licensing Regime under the Department of Explosives, needs to have a robust underpinnings of 'Research and Development', responsive to emerging technologies and be collaboratively engaged with EDC in order to promote adaptation of such technologies that afford maximum value dividends, viz, Quality, Performance, Health and Safety of workers and of course, 'Public Safety' at large.

3.2.2 *Micro - management : 'Work Culture' / 'How we do things?'*

- The modern age of Information Technology (IT) :

"In a recent survey of CEO's conducted by PwC, 80% of CEOs believe innovation will drive efficiencies and lead to competitive advantage Close to 70 percent of CEOs are investing in IT to reduce costs and become more efficient, while 54 percent are also funneling funds towards growth initiatives . This sentiment is not limited to any particular industry sector. such as high-tech. It applies to enterprises of all sizes in all industry sectors".

Consequently, the organizational infrastructure / frame work has also duly evolved, by providing for a new strategic management domain headed by a 'Chief Information / Technology Officer', addressing the conundrum of 'What Is ? and 'What Could Have Been ?', by constantly and purposefully searching for 'Technology Supporting Solution Identification' and application thereof, in order to improve existing processes.

- 'Value- Cost' management frame work :

To quote from Peter F. Drucker's "Management Challenges of the 21 st century" : *"Traditional cost accounting focuses on what it costs to do something; whereas, activity based costing also records the cost of not doing".*

It is therefore, important to constantly differentiate 'Value' from 'Cost' of an activity. See Box - 2 *(Ref. 5th edition of the Journal).*

The above frame work implicitly enjoins evaluation of every activity from the stand point of maximizing value, relevant to processes and functions within an activity as well as in relation to other activities ; and there from to evolve an optimal production process map.

For example, Optimization of rock fragmentation by 'Drilling and Blasting' which constitutes only around 15% of the total operating cost, would directly influence the down-stream activities of a project comprising the major share (80-90%) of the operating cost. Therefore, optimization of the cost-value characteristic of 'Drilling and Blasting' would duly enable establishing the 'Most Economic Cost-Value Characteristic', of a project, as the operational 'Bench Mark'.

- Research & Development :

The centrality of "Operational Research & Engineering Services" is clearly envisioned in the scheme of things enunciated above. Unfortunately, this all important management resource is often conspicuous by its absence in most of the mining and construction projects in India. This important aspect needs to be urgently addressed.

VALUE CHAIN FRAMEWORK

Box - 2

1. PROJECT
(Purpose - Raison d'etre)

2. VALUE CHAIN PROFILING

2.1. primary activities (activities relating with production)	**2.2 support activities** (activities that are necessary for effectiveness and efficiency of the primary activities)
• in-bound logistics • operations • out bound logistics • marketing & sales • services	• infrastructure • human resource management • technology development • procurement • operations research & engineering services

3. **VALUE ANALYSIS and ENGINEERING**
A structured thought process of "WHAT, HOW and WHY", by which the various activities are analysed to evaluate options for maximizing value and minimizing cost.

4. **PRODUCTION PROCESS MAP (PPM) AND VALUE LINKAGES**
4.1 Project Vs. Primary Activities : to ascertain how much and at what stage value is added for the project.
4.2 Identify "KEY" primary activity.
4.3 Sequential value linkages between activities.

5. **IMPLEMENTATION STRATEGY**

MARGIN

This review is the latest in the series of deliberations in the past through the medium of this journal, dealing with the various contemporary 'issues of concern' relating to the state of technology and safety of explosives in India, the significant ones are indicated below; the full texts can be can be accessed @ www.visfotak.org.

- 2nd Edition (2007) : Cover Feature titled 'Energy Audit of Commercial Explosives'
- 4th Edition (2009) : Cover Feature titled - 'Explosives and Environment'
- 5th Edition (2010) : Cover Feature titled 'Value Chain Analysis of Open Pit Mining'
- 6th Edition (2011) : Cover Feature titled 'Emerging Dividends from 'Technology-Safety Interface' of Modern Industrial Explosives : Why India has lagged behind the Global Trend'

All the above editions, the earliest as far back as 2007, have one common thread weaving through them, viz, pleading for a statutorily institutionalized 'Nodal Agency' for the stewardship of the "Explosives Environment Paradigm" in India, with representation from all the major constituents of the industry, duly mandated to develop an operating frame work for 'Technology Information, Forecasting and Assessment' of emerging technologies, with appropriate incentives for the industry to adapt best technologies / products ans services , within an assigned time frame .

Editor .....

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Annexure - I

An Illustration of Modern Bulk Explosives Technologies / Systems

(Source : Technical Information - Dyno Nobel)

TTT Bulk Truck Unit

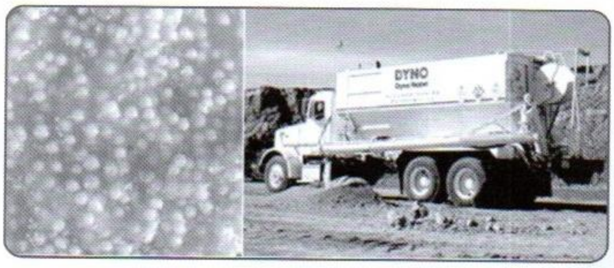
The 17.1 tonne TTT is a Mobile Processing Unit (MPU) designed to provide a complete range of bulk explosive products direct to the blasthole.

The truck is designed to incorporate large product bins to maximise the carrying capacity and thereby minimise turnaround times. Discharge rates are optimised for 150mm diameter and greater blastholes.

Product	Discharge Method
ANFO	Auger discharge
Heavy ANFO	Auger discharge
Gassed Heavy ANFO	Auger discharge
Gassed Emulsion	Down hole pump
Solid Sensitised Emulsion	Down hole pump

Sensitized Bulk Emulsion

Booster sensitive, high performance, economical, repumpable bulk emulsion explosive specifically formulated to provide superior blasting performance in nearly all open pit applications, blended with up to 45 ANFO for direct pumping to the bottom of water-filled boreholes or as the emulsion explosive component for augerable Heavy ANFO blends. Refer to the data table for the physical properties and loading methods for some typical emulsion/ANFO explosive blends.

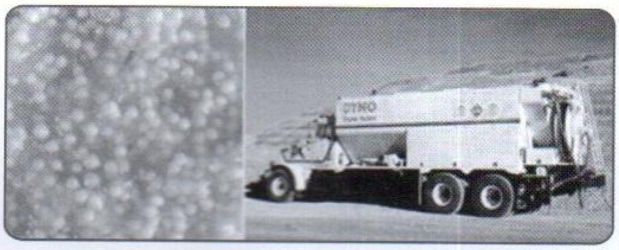


Percent Emulsion		100	70	50	40	30
Density	(g/cc)Avg.	1.25	1.29	1.30	1.25	1.15
Energy	(cal/g)	680	740	780	800	820
	(cal/cc)	850	955	1,015	1,000	945
Relative Weight Strength		0.77	0.84	0.89	0.91	0.93
Relative Bulk Strength		1.17	1.32	1.41	1.39	1.31
Velocity	(m/sec)	5,800	5,600	5,400	5,000	4,700
	(ft/sec)	19,000	18,500	17,700	16,400	15,300
Detonation Pressure (Kbars)		105	101	95	78	64
Gas Volume·(moles/kg)		45.0	44.8	44.4	44.2	44.0
Water Resistance		Excellent	Excellent	Good	Fair	Poor
Minimum Diameter (mm)		90	115	150	125	125
	(inches)	3.5	4.5	6	5	5
Loading Method		Pump	Pump	Auger	Auger	Auger

Unsensitized Gassable Bulk Emulsion Matrix

An unsensitized bulk emulsion matrix specifically formulated to be sensitized during loading at the borehole using chemical gassing technology. Booster sensitive emulsion explosive can be used alone in 65 mm (2-1/2 in) and larger boreholes or in larger boreholes when used in an emulsion/ANFO blend. Chemical gassing can vary the density from 1.10 and 1.30 glee.

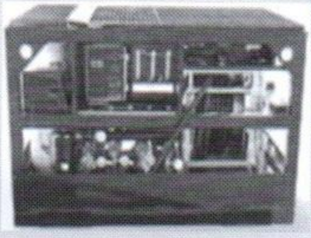
Site Mixed System



The SMS Bulk Delivery Truck is a self-contained, mobile bulk emulsion manufacturing facility which produces SMS Bulk Emulsion explosives and then delivers it to the bottom of the borehole. Only non-explosive ingredients are used !.

DynoMiner Uphole on a Triple 4CE carrier
Emulsion capacity : 1,360 kg (3,000 lb)
Loading rate: 56 kg/min (125 lbs/min)

DynoMiner Uphole as a removable cassette
Emulsion capacity : 4,500 kg (11,000 lb)
Loading rate : 56 kg/min (125 lbs/min)



DynoMiner Advance - Stoper
For long horizontal or vertical downholes
Emulsion capacity : up to 4,400 kg (10,000 lb)
Loading rate : 90 kg/min (200 lbs/min)

DynoMiner Advance - Drifter
For short horizontal holes
Emulsion capacity : 636 kg (1,400 lb)
Loading rate : 90kg/min (200 lbs/min)

DynoMiner Shaft
Emulsion Capacity : 1,725 kg (3,800 lb)
Loading rate : 27 to 40 kg/min (60 to 90 lbs/min)

Annexure - II

Licensed Premises for Site Mixed Bulk Explosives Systems (2016-17)

Part - I : No. of Licensed Premises by Manufacturers of Explosives

Sr. No.	Manufacturer	No. of Licensed Premises
1.	Indian Explosives Ltd.	17
2.	Solar Explosives Ltd.	15
3.	Gulf Oil Corporation	14
4.	Indian Oil Corpn.(IBP Division)	12
5.	Keltech Energies Ltd.	8
6.	Nav Bharat Explosives P Ltd.	3
7.	Nav Bharat Fuses P.Ltd.	5
8.	Ideal Expl. Ltd.	6
9.	Premier Expl. Ltd.	5
10.	Blast tech. India P. Ltd.	4
11.	Special Blast Ltd.	3
12.	Shree Cement Ltd.	2
13.	Sua Explosives P. Ltd.	2
14.	Bharat Explosives Ltd	2
15.	Singareni Collieries Ltd.	2
16.	Renegenesis India P. Ltd.	2
17.	AKS Explo. Chem P. Ltd	2
18.	Orient Explosives P. Ltd.	2
19.	AMA Ind. P. Ltd.	1
20.	Aravali Explo P Ltd	1
21.	Black Diamond P. Ltd	1
22.	Emul Tech P. Ltd	1
23.	Gajraj	1
24.	Chemicals	1
25.	Grasim India Ltd.	1
26.	Kesoram Cement	1
27.	Orissa Explo. P . Ltd.	1
28.	Shri Vihnu Explo P. Ltd.	1
29.	Sesan Powders Ltd.	1
30.	Zuari Cement Ltd.	1
31.	Bharathi Cement Ltd.	1
32.	Rungta Mines Ltd.	1
33.	Prasad Explo. P. Ltd.	1
34.	Rajasthan Explosives and Chemicals Ltd.	1
35.	Salvo Explo ChemP.Ltd.	1
36.	Shri Krishna Expl. P Ltd.	1
37.	Vetrivel Expl. P Ltd.	1
38.	Benami Cement Ltd.	1
39.	Techno Blast India P Ltd.	1
40.	Tamilnadu Explosives Ltd. / NALCO :	1
	Grand Total	**128**
	Total Licensed Capacity Approx.	**13,00,000 t**

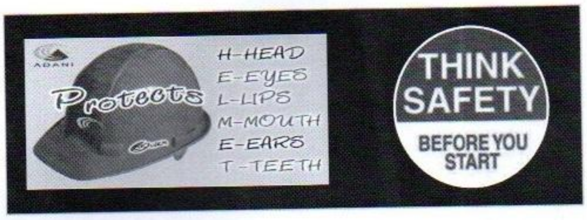
(Source - Annual Reports of Department of Explosives , Govt. of India)

Part - II : No. of Bulk Mixing and Delivery Truck Units, categorized byEnd - User

Sr. No.	End User	No. of BMD Units
1.	Coal India Ltd.	507.
2.	Singareni Collieries Ltd.	97
3.	NMDC (Bailadila and Donimali (Iron Ore Mining)	20
4.	TISCO (Coal and Iron ore)	8
5.	Hindustan Zinc Ltd. (Zinc mining)	6
6.	Malajkand Copper Ltd. (copper mining)	5
7.	Neyvali Lignite Corpn. (Lignite mining)	6
8.	Reliance and JP Industries (Coal)	10
9.	Cement & Others	10
	Total	**669**

The Truck Units comprise a mix of 7t, 10t and 13t carrying capacities.

(Source - Market information)



Case Study - 1983

(Selected excerpts from the paper "Indian Explosives Industry - Whither", authored by the Editor in 1983 for presentation at the Seminar on "Safety in Industrial Explosive", held under the aegis of the Department of Explosives, Govt. of India, at Nagpur).

Abstract

Symptomatic of a short supply economy, the explosive industry in India has been treading a thin edge in terms of demand and supply for well over a decade. Though the Government hall sanctioned adequate capacity which at present stands at well over 3,00,000 t, whereas the demand for explosives by the end of the Sixth Plan period is expected to grow to a level of 122000 t pa, the situation is by no means entirely satisfactory. Unfortunately, the Government has tackled the problem in the gross quantitative terms alone. There exist serious imbalances, which threaten to aggravate the already tenuous demand and supply equation.

The author has analysed the Indian scene in the context of the global trend, and has suggested a strategy for correcting the imbalances and developing a cost effective, technologically optimum, and market oriented matrix for the Indian Explosives industry.

1.0 Introduction :

The role of explosives in the economic development of a country is self-evident. The per-capita consumption of explosive in the USA is around 5000g whilst that in India is around 120g. The growth in industrial production in the last decade and that in explosive consumption during the same period has been as follows:

Year	Index of Industrial Production (1970-100)	Explosives Demand (t)
1970-71	100	33650
1971-72	106	35700
1972-73	115	34450
1973-74	107	41650
1974-75	107	47900
1975-76	122	52200
1976-77	141	59500
1977-78	151	57500
1978-79	156	61600
1979-80	148	7000
Average growth rate (compound) (%pa)	5	9

Thus, there is a strong relationship between the industrial growth and explosives consumption. However, in it context of explosives consuming industries, we need to go behind the veneer and look at tile constituents it the micro-level on the basis of compatibility, appropriateness of systems and cost-benefit characteristics.

The last decade has been interspersed with periods of shortages in supply of explosives; and consequently, the Government has taken determined steps, over the past five years so, to build up adequate capacity much so that at the present moment of well over 300000 t is covered by Industrial licenses, Letters of Intent, md Registration with the Directorate General of Technical Development, whereas the demand for explosives currently is around 90-95,000 t pa, Even so the situation is by no means as rosy as it may appear. In actual fact. the requisite accretion in capacity in a desired mix has not taken place. There exist serious imbalances, both technological and logistical.

2.0 The Global Scene:

If we see the development of explosives in the global context, more specifically in the Western world, we find that explosives have constantly evolved and closely matched the needs of the consuming industries, the most important of them being the mining industry, by dint of a deliberate evolutionary process. As new mining methods evolved, so the explosives systems to match them.

Bigger and better designed machines, greater degree of automation and improved mining methods, have paid off in higher productivity in recent years; and commensurately, the development of and preference for Bulk Explosives Systems (BES) to match the emerging trend of productivity growth has taken place. The significant features of the global scene are:-

1) BES constitute well over 80% of the entire explosives consumption in the USA, similar proportion in Canada, 90% in Australia, 60% in South Africa and 40% in the UK.

2) Prilled Ammonium Nitrate in the form of ANFO is by far the most widely used and predominant explosive system constituting around 75% of the explosives consumed in the USA, and almost similar pattern exists in the other countries. Slurries make up the balance of BES.

3) Bulk explosives being basically 'system biased' have given rise to concept of satellite plants located very close to or at the consuming centres. Economy of scale is relatively less important, if not irrelevant, for BES because systems catering to consumption levels as low as 500 t pa to as large as 15000 t pa are viable.

4) NG based explosives in packaged form are used only for underground coal mining, and specialized applications. They have been almost completely replaced by BES in underground metalliferous mining.

3.0 The Indian Scene:

In India, the explosives industry has been relatively hide-bound, The users industries have to make do with what is available. The reasons are partly historical, partly the inability to relate global trends to Indian - scene, and partly the outcome of a short supply economy that exists in India.

As mentioned earlier, the capacity planning has been done in gross quantitative terms alone without ensuring appropriate explosives mix in a "Time Technology Logistic" frame work vis-a-vis the needs of the consuming industries.

The licensed capacity mix is as follows :

Type	NG (t)	Slurry (t)	Other including ANFO (t)	Total (t)
Established Manufacturers / Ind. Licenses issued	62500	55000	12000	129500
Letters of Intent / Registration with DGTD	60000	10800	6800	174800
Small scale Sector,	-	8000	-	8000
	122500	171000	18800	312300

It will be seen that the licensing philosophy has no resemblance with the global trend. On the one hand, ANFO duesnot feature significantly in the scheme of things, and on the other, capacity for slurry is primarily "Fixed Plant - Packaged Explosives Based".

4.0 Prilled AN:

The obvious question that comes to mind is why prilled AN hasn't attained its due place in the Indian scene. With a strong ammonia / chemical fertilizer base that exists in the country, there is no reason why it shouldn't have taken off in a big way. The *opportunity was perhaps missed in 1973 in the wake of the* explosion at Gomia when the Government decided to import NG. based explosives from Poland for surface applications. If only Prilled AN had been imported and a seeding program launched, not only valuable foreign exchange would have been saved but it would have given philip to the indigenous manufacture of prilled AN. Given a captive source of ammonia and Nitric Acid which is available in a fertilizer complex, the investment for a 30 t pa prilled AN unit is about Rs. $2^1/_2$ Crores whereas the capital investment for a similar capacity NG unit is many times more, around Rs. 30 crores.

5.0 Slurried Blasting Agent:

Another global development of note is the emergence of slurried blasting agents; and here again as emphasized earlier, the trend in India is quite the opposite of the global trend. Slurry explosives were developed primarily for reasons of safety to replace Nitroglycerine, and as more powerful. Water compatible cousins of ANFO. Slurries are basically bulk explosives like ANFO. Cartridging was never an essential feature of the scheme of slurry development. in India, excepting for a modest effort by Indo-Burmah Petroleum to develop bulk slurry systems, we don't see any significant development consistent with the global scene. On the contrary, we see a modern concept being marketed in a traditional package to the detriment of the consumers interest A Cartridge slurry is about 15% less effective in performance and about 2070 more expensive than the bulk system. This fact assumes significant dimensions when one perceives that about 60% of the Capacity licensed/covered by letters of intent, etc., is in slurry explosive alone. There is therefore, a need to build a system-bias in the licensing procedure so that only those offering appropriate systems are allowed, Further, since slurries are system-biased. it enables optimum cost effectiveness if the facilities are located close to the markets. Therefore, the logistic / Locational aspect of the slurry capacity becomes very significant. As a corollary, economy of scale is not relevant for bulk slurry unlike the manufacture of NG based explosives.

The following pattern of usage should be developed in Indiâ consistent with global trends:

Nitroglycerine based explosives; (Packaged System)

- Underground coal miming, special applications like underwater blasting, seismic shootings, etc.
  - Slurry Blasting Agents:
  - Packaged System
- Underground coal mining.
  - Bulk systems
- All medium to large open-cast mining complexes, as well as under ground metalliferous mining wherever feasible. There are at least 16 identifiable consuming complexes! markets where bulk slurry systems can be viable. -
  - Prilled AN as ANFO: (Bulk systems)
- All surface blasting and underground metalliferous mining including tunneling, with appropriate systems catering to small, medium and large scale operations respectively.

On the above basis, a techno-economic comparison between the desirable mix versus the prevailing trends by, say 1984~85, as an example is shown below :-

Type	Desirable Basis			Prevailing Basis		
	Mining (t)	Non-Mining (t)	Total (t)	Mining (t)	Non-Mining (t)	Total (t)
NG Explosives	20800	5400	26200	31500	7500	39000
Slurry – Bulk	29100	29100	-	2000	-	2000
Cartridges	20500	*500*	21000	61600	1900	63500
ANFO	36600	8500	45100	9000	5000	14000
Misc.	-	600	600	2900	600	3500
Total	**107000**	**15000**	**122000**	**107000**	**15000**	**122000**
Estimated Cost based on current price Rs. (Crores)	**81**	**13**	**94**	**98**	**16**	**114**

Note: The above demand for explosives in 1984-85 is based on budgeted targets as per the sixth Five Year Plan.

The above comparison throws up some interesting inferences concerning capacity rationalization. The advantages of Bulk Systems in terms of safety in manufacture, storage, transport and use are self evident The resultant savings to the consuming industries are significant.

6.0 Conclusion :

The capacity planning and implementation needs to be rationalized in consonance with global trends. Prilled AN must emerge the leader explosives system, and provide the edifice for the explosives industry to grow. Slurries, to be cost effective, should complement ANFO and together service the bulk of the market.

7.0 Discussions :

1. Mr. Santosh Kumar, MSMC Nagpur :

   In your projection for 1984-85, you have given the following figures -

Slurry	Desirable Basis	Prevailing Basis
Bulk	29100	2000
Cartridged	21000	63500
ANFO	45100	14000

Q. In order to enable Prilled AN to emerge as the leader explosive system in 84-85, what would be the evel of investment for prilled AN unit and savings vis-a-vis NG unit?

Ans. Manufacture of prilled AN should preferably be a part of a fertilizer complex to be economical. Given a captive source of Ammonia and Nitric Acid the investment needed for setting up prilling facilities for 30t pd unit is approximately Rs. $2^1/_2$ crores, whereas the cost of setting up NG explosives unit of similar capacity will be manifold, about Rs. 30 crores as mentioned in the paper.

2. Mr. Vardarajan IDL Chemicals Ltd.

Q. a) Could the author indicate the locations of markets in India where Bulk Systems would be viable. What is the minimum economic size of the market for Bulk System.

b) Conditions of roads and bridges in India is not strong enough to take large bulk carriers, wouldn't it be a serious constraint for developing viable Bulk Systems?

c) Where should facilities for AN production best be located?

Ans: a) As I have already indicated in my paper, there are atleast 17 identifiable markets in India where bulk systems can be viable. In my view, even as small a market as 500 t pa can be economically serviced by a bulk system.

b) It is true that the conditions of Roads and Bridges in India are not entirely satisfactory, but one has to learn to live with it. One way of overcoming it is to locate bulk facilities within the leasehold of a mining complex where roads are generally good and designed for the movement of large capacity dumpers.

c) As I said earlier, the proper place for setting up facilities for AN would be a Fertilizer Complex.

3, Mr. H. N. Srlharl, Indian Explosives Ltd.

Q. While the 'out-of-step' trend in ANFO in Indian mines is fairly well recognized, don't you think it is the mining trends which are out of step?

Ans : I don't agree with this statement. I shall give an example, Those of you who have visited the facilities for manufacture of Prilled AN at FCI Sindri, would have seen that the quality of prills as they come from the prilling tower is excellent, but at the warehouse, a bag of prills gets hard, The reason is simple. The prills are not treated by an anti-setting agent and dried properly before bagging. Thus, the entire investment on prilling is really wasted. I am sure if FCI had ensured proper treatment of prills for proper flow and storage characteristics, the demand would have picked up and they would have been by now be perhaps manufacturing around 20,000 t of prilled AN per annum.

4. Mr. C.N. Chandrasekhar, Tamil Nadu Explosives Ltd. Madras:

Q. Can you kindly enlighten us as to what are your findings in regard to LEARNING CURVES - in USA and in India for educating users. This has very much to do with utility pattern in 84-85.

Ans : Let me firstly clarify that what I have projected for 84-85 is only to illustrate a perspective for the explosives industry in India if it had conformed with the global trends. There is a learning process in every activity; but I also believe and it is true for explosive industry that markets are created by developing appropriate matching systems. A customer will always welcome a cost-effective system. In the USA no sooner was it found that AN in combination with Fuel oil was an explosives mixture, its usage as commercial blasting agent caught on like fire, and it emerged as a leader explosive system with in 5 years of it inception. The trend in India would have been no different if the mushroom growth of AN producers, from CAN fertilizer / AN liquor, is . taken as a pointer in India.

STRATEGIC ROAD MAP FOR IMPROVING BLAST PERFORMANCE IN INDIAN COAL MINES

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ABSTRACT

Coal is the mainstay of Indian energy supplies and Government of India has set a target of 1.5 billion metric ton by 2020 to meet the coal demand of country indigenously. The manifold increase in demand for coal puts a huge pressure on augmenting blast productivity from opencast mines as well as from underground mines. The projected demand of commercial explosives for Indian coal industry will increase by more than two times to touch whopping figure of 8,00,000 metric ton(approx.) to achieve the targeted production. Presently, commercial explosives are primarily procured by majority of coal production companies as commodity instead of treating it as a technical product. The progressive decline in utilization and availability of Heavy Earth Moving Machineries working in Indian surface coal mine is mainly due to poor blast productivity. In order to achieve blast optimisation for a given geo-mining condition, knowledge of target rock and the explosives characteristics are very important and selection of explosives demands a technical insight to have bench specific and mine specific differential products in terms of energy release instead of existing practices of using blanket product. The use of ANFO for dry holes, Heavy ANFO for hard and watery benches and blended emulsions with variable energy mix to meet the varied geo mining condition may prove to be a harbinger for practicing blasting engineers for achieving optimal explosives energy utilisation in rock fragmentation by minimizing the environmental nuisances. For underground coal mines, there is need to innovate, design and manufacture low critical diameter permitted explosives with high air gap sensitivity to increase pull per blast. Design and development of low cost, handy and indigenous tool will add techno economic values in improving the overall blast performance. The replacement of age old powder factor by quantitative, instrument driven scientific mechanism needs to be introduced. The implementation of simulation methods and numerical modelling techniques will improve the blast productivity and mine productivity significantly. The present paper discusses strategic road map, which may be practiced to improve the blast performance in Indian coal mines. There is need to formulate and support quality research in Indian Coal Mining Industry so that necessary technical guidelines can be evolved after successful implementation of the research outcomes for gainful application as there exists ample technical scope of improvement in blast performance, mine productivity and economics.

Keywords - blast performance; mine productivity; explosives

I.0 Introduction

India is currently among the top three fastest growing economies of the world. As a natural corollary India's energy needs too are fast expanding with its increased industrialization and capacity addition in Power generation. In India coal is the critical input for major infrastructure industries like Power, Steel and Cement etc. and is pivotal for "India's Growth" as it is most important fossil fuel for its energy security. Chikkatur et al [1] observed that coal accounts for about 70% of total electricity generation in India and is likely to remain a key source for at least the next 30-40 years. Coal shall remain India's most important energy sources till 2031-32 and possibly beyond [6]. Coal is a crucial and enduring element in a modern, balanced energy portfolio, providing a bridge to the future as an important low cost and secure energy solution to sustainability challenges. The manifold increase in demand for coal puts a huge pressure on augmenting production from opencast mines as well as underground mines. The increase in production within a short period of time demands for heavy blasting in overburden and coal benches of opencast mines as well as increasing the pull per blast from working faces in underground mines.

Under the present "Mine to Mill Concept" blasting subsystem is the key to the success for all post blast sub systems utilization viz. loading, hauling and transportation. Drilling and blasting are the two important unit operations in the production cycle of a mine. A strong link exists between the two and other unit operation like loading, transportation and crushing. Consequently, the overall mining cost is directly or indirectly influenced by drilling and blasting. It is important to optimise the drilling and blasting operations techno economically so that the combined excavation cost and overall mining cost is minimum. This paper deals with the strategic road map for improving the blast productivity in Indian mines so that mine productivity and profitability get improved to minimize the overall cost of excavation per cubic meter. The various strategic initiative is discussed below.

2.0 Selection of Explosives

Presently, commercial explosives are procured in India as a commodity. Irrespective of variations in local site condition, varied geo mining condition at mines, the procurement decision is driven commercially to procure a blanket product for all mines to decrease the cost of explosives and accessories. The powder factor is accorded top priority in selection of explosives in Indian coal mines rather than total cost of excavation comprising of various subsystems viz. drilling cost, explosives cost, accessory cost, loading cost, hauling cost & transportation cost. The process of improving blast performance starts from selection of proper explosives for a rock, designing of blast and to ensure fragmentation for minimizing cost of loading and transportation. The two key characteristics governing the explosives selection for Indian coal mines is velocity of detonation (VOD) and density, which is commonly used as 3500-4500 m/s and 1.05-1.25 g/cc. However, apart from VOD and density, sensitivity of explosive vis-à-vis diameter of blast hole or cartridge diameter also plays pivotal role in performance of any explosive As blast performance is a direct function of explosive performance, due emphasis is required to be given on all the primary factors[9]. It is a very open band to facilitate manufacturing of blanket product rather than site specific and customized product. In order to select site specific explosives, rock impedance can be ascertained using geo physical methods and matching explosives impedance product can be used in the mine. It is possible to run multiple traverses in advance in accordance to the production planning to map the rock mass layers and estimate the layer wise VOD for obtaining effective blast performance results. One of the case study highlighting such exercise is shown in Figure 1 & 2 carried at one of the mines of Coal India Limited, which evidently demonstrate the determination of layer wise VOD. This methodology can help in choosing effective decking mechanism also so that explosive does not get charged at the interfacing layers.

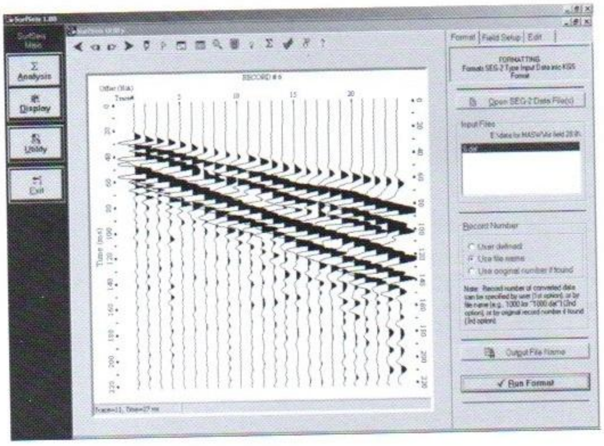


Figure 1 - Geophysical technique to estimate the rock impedance

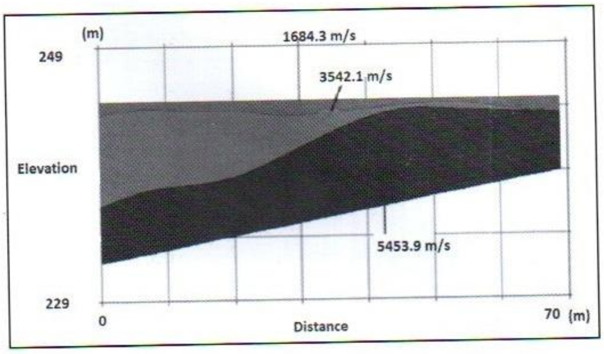


Figure 2 - Estimating of layer wise velocity of detonation

It may be generalized that selection of explosives should be carried out scientifically so that overall cost of excavation is minimum.

3.0 Development of Scientific Criterion for Explosive Performance Evaluation

In the present global context, blasting operation at a mine plays a pivotal role in overall economics of any open-cast mine. The criteria for a 'good blast' can be varied depending upon the results desired (i.e. good heave, loose muck, muck profile angle, ease of digging, uniform fragmentation, or normal fragment size distribution or any combination thereof). Optimizing blasting practice therefore may also affect equipment selection such as drills, shovels, dozers etc. Despite its pivotal role in controlling the overall economics of the operation, the expected blasting performance at our mines is presently judged almost exclusively on the basis of prescribed Powder Factor (i.e. kg of explosives per cu.m of rock) without considering the specific energy consumed by loading equipment (Dragline or Shovel) for any known volume of blasted muck as well as the productive yield considering the length of drilling. The explosives performance evaluation should not only be dependent upon results obtained by carrying out random sampling but should encompass drilling, explosives and loading cost. Use of handy, user friendly and quantitative methodology for evolving criterion for explosives performance was tried in one of the coal mine as depicted in Figure 3(a) & (b), where blast results are investigated on the basis of combined cost of excavation per cubic meter using Artificial Intelligence techniques. The user does not require to undertake any cumbersome mathematical treatments but gets the post blast results readily by tool as shown in Figure 3(a) & (b).

It may be generalized that there is need to replace the age old practice of normative powder factor used in coal mines for explosives and blast performance by scientific yardsticks. The proposed methodology increased the cost of drilling and blasting sub system by 18 % in case study mine but reduced the overall cost of excavation by 4.8%. The reduction in overall cost of excavation affected the profitability and productivity of the mines significantly.

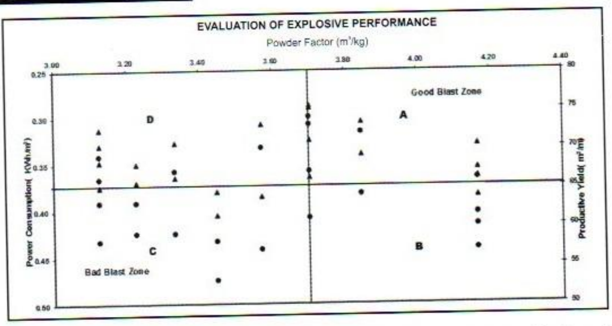


Figure 3(a) - Scientific methodology of determining explosives/ blast performance

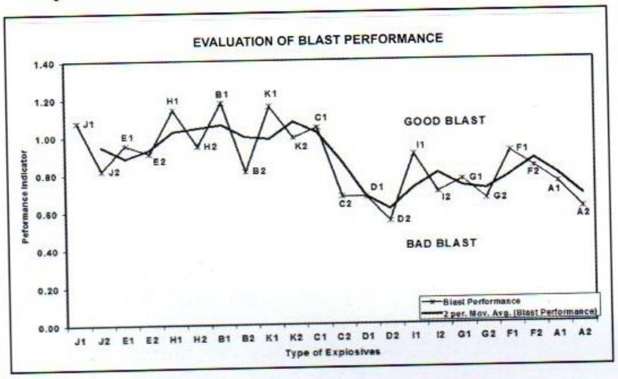


Figure 3(b) - Scientific methodology of determining explosives/ blast performance

4.0 Determination of Explosive Energy by Underwater Testing Facility

When a mine purchases explosives, they are actually purchasing the energy that these explosives release into the rock mass. The only direct way to determine the explosive energy for a given explosive product is to conduct underwater energy testing facility. There is no Underwater testing facility in India and there is urgent need to develop such facility for determining the total energy of explosives. Since the 1970s, the underwater detonation test increasingly has been applied for determination of the strength of explosives, especially those that are not cap-sensitive. The test is of particular importance because it enables the determination of strength of explosives that cannot detonate completely when a charge mass in less than 10g (that means that they could not be tested by existing practice by ballistic mortar or lead block test). By Underwater testing, the strength of an explosive is determined on the basis of measurable forms of energy released by underwater detonation Shock wave energy and Bubble energy. The method is based on the detonation of an explosive charge by means of a detonator or via a booster at a defined depth under the water surface, and on recording the Shock wave-time profile and Bubble-pulse period at a given distance from the explosive charge. From shock wave-time profile, the Shock wave Energy is calculated, whereas from bubble-pulse period the Bubble Energy is calculated. The sum of the shock wave energy and bubble energy gives the Total Energy of the explosives.

Various geological condition require specific types of energy to maximize the results. There should be in-house facility of underwater testing for commercial explosives in India which can develop scientific formulation to enable maximization of either gas or shock energy as per the geological conditions. It is possible to test and evaluate any explosive product or specific formulation and determine the energy partition or ratio of shock to gas energy output for any specific commercial product or potential new formulation. The use of commercial detonation codes viz. IDeX, Cheetah, TigerWin, Vixen-I, TDS, BKW gives theoretical estimate of energy release during ideal detonation and cannot be considered for non-ideal detonation. In real life, all our blasts are falling in the category of non-ideal detonation and require for establishment of an underwater facility in our country, which may be used for estimating the energy of commercial explosives.

5.0 Online Fragmentation Assessment Tool for Assessing Blast Performance

With the advent of new technologies, it is possible to assess the blast performance by using online fragmentation analysis system. The online system provides an economical alternative to manual sampling, screening and objective quantitative measures than the subjective qualitative estimates. Online fragmentation system is an automated image processing system designed to operate continuously to measure or monitor the fragment sizes as well as oversized boulders for monitoring and controlling the process. The technical decisions, blasting costs, operational efficiency and productivity, equipment performance are all related to optimum rock fragmentation. Profitability can be improved by optimizing the fragmentation of overburden and coal to maximize the blast performance. Figure 4 shows the various online fragmentation system which can be used for surface, underground and conveyor belt configurations.

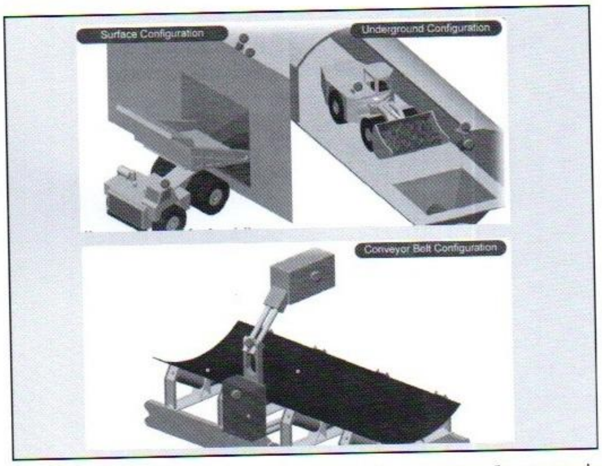


Figure 4 - Various online fragmentation system for assessing blast performance

6.0 Minimizing Scattering in the Detonator

It is technically desirable to use precise detonators with accurate delay timings to achieve desired blast results in terms of improved fragmentation, lower level of vibration and air overpressure. Precise surface and down-the-hole delay timing affects explosives energy utilisation and precise timing would help enable to achieve desired blast results. Scattering in initiation systems is presently a common phenomenon in Indian manufacturers which affects the blast performance significantly. Delay timing is primarily, provided using delay element made up of pyrotechnic composition placed between the ignition system and the primer charge. Initiation system made with pyrotechnic delay compositions has inherent scattering in their delay timings. Scattering is the biggest problem which affects the effective explosive charge per delay responsible for blast induced vibration generation. Figure 5 shows nos. of deck detonated vs. detonation time due to scattering, affecting the blast fragmentation and increasing the ground vibration. Use of electronic detonator should be increased to minimize the scattering so that enhanced fragmentation may be obtained with reduced vibration.

Fig.5. Nos. of deck detonated vs. detonation time due to scattering.

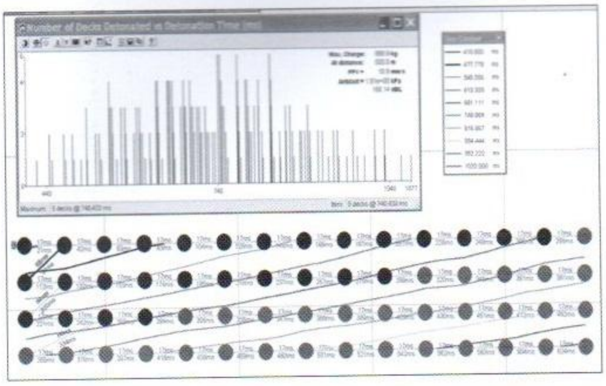


Figure 5 - Nos. of deck detonated vs. detonation time due to scattering

7.0 Improving the Pull and Coal Availability in Underground Mine at the Faces

The availability of coal at the working face is a big constraint for improving the face production and productivity. Presently, Blasting-off-Solid is resorted for coal winning using 32 mm P-5 permitted cartridges in underground development and depillaring district using 40 mm drill holes. Maximum charge per hole allowed for P_5 explosives are 1000 g and 565 g in degree-I and higher gassy mines respectively. Due to restriction on explosive quantity per hole, the coal availability at the face after blasting is ranging between 12-18 tonne per round of blast in a development district which should be increased by promoting research in formulation of permitted explosives. Suitable drilling and blasting parameters is to be evolved for improving the pull and coal availability at the development and depillaring district so that productivity of the loading machine viz. Side discharge loaders or Load- Haul-Dump can be maximized. There is a technical need to decrease the critical diameter of permitted explosives so that length of the explosive column inside the hole can be increased significantly for better energy release and release rate from the explosive cartridges by maintaining the regulatory limits. There is a need to develop an indigenous light weight drilling machine so that it can be operated under hand held condition and drillers in India can use it effectively and efficiently.

8.0 Use of Numerical Techniques in Blasting

With the rapid development of computing power, interactive computer graphics and topological data structure, numerical models derived from sound mechanical principles indicate a promising approach to untangle the blasting problem. Various kinds of computer code dealing with the blasting have rapidly sprung up like mushrooms, for example, discrete element analysis by Preece [7] and Donze et al [2], dynamic lattice network model by Song and Kim [8], discontinuous deformation analysis by Mortazavi and Katsabanis [5], finite element model by Thorne et al [10] and others. Numerical method has a prospect to do both wave analysis and fracture analysis for the whole blasting process. Hallquist [3] mentioned that LS-DYNA provided a new approach to model the detonation process and the stress wave propagation which uses transient dynamic finite elements capable of simulating complex real problems. Stress wave propagations by blast can be reproduced using LS-DYNA as narrated by Liu et al [4].

During modelling of blasting process, the detonation pressure of the explosive applies forces on the constructed numerical elements in each time step. The accelerations of elements are updated according to Newton's second law. Boundary condition explained above is applied on the boundary elements. The velocities and displacements of the elements are calculated according to kinematics condition. The current time is compared with the prescribed time for each time increment and process terminates once the current time is larger than the prescribed by Liu et al [4].

By using suitable pre-processors, 2D or 3D numerical models can be constructed and dynamic loading can be applied resembling the blasting process to simulate the various blast scenarios. After solving the various blast scenarios, post processors can be used to investigate the results leading to time and cost advantages. A typical diagram of a numerical modelling used to predict the blast induced impact of surface blasting of Lajkura opencast mine on the underground structures of Orient Mine No. 2 using ANSYS-ANSA-LS_DYNA is shown in Figure 6.

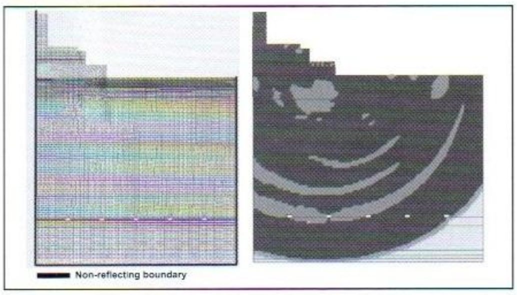


Figure 6 - Numerical model for simulating the impact of surface blasting on underground workings

9.0 Application of Artificial Neural Network (ANN) in Blasting

Conventional predictors derived from Statistical Modeling are based on only maximum charge per delay, distance between blast face and monitoring point and attenuation factor. These predictors do not take into account other unknown influencing vital parameters like site specific rock mass geo technical properties. Another drawback of the predictors is that they are not setup to give any predictions of the frequency of wave attenuation. By adopting ANN technique, PPV and frequency level can be predicted prior to the blast. The blast design can be modified accordingly so that blast nuisances can be minimized to a greater extent. Considering the complexity of the relationship among the inputs and outputs, the results obtained by ANN are highly encouraging and satisfactory. ANN can learn new patterns that are not previously available in the training dataset. ANN can also update knowledge over time as long as more training data sets are presented, and can process information in parallel way. Therefore, the technique results in a greater degree of accuracy than other analysis techniques. Hence, the technique proves to be economical and easier in comparison to tedious expensive experimental work. The statistical methods using the linear method where as ANN use the non linear method of estimation. A typical diagram of ANN used for evolving a vibration predictor equation is shown in Figure 7 for estimating the peak particle velocity (PPV) for known distance and explosive charge per delay.

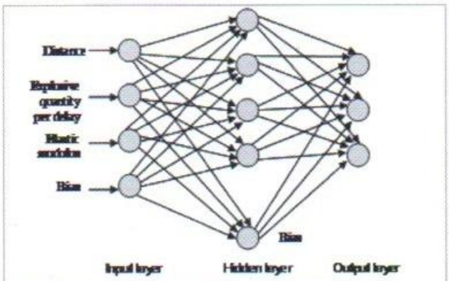


Figure 7 - A typical diagram of ANN used for evolving vibration predictor equation.

10. Promoting Research on Fracture Mechanics to Understand the Fragmentation Process

Accurate measurements of dynamic fracture parameters are pre-requisite for understanding fracture mechanism and also useful for rock fragmentation in blast engineering applications. Fracture initiation toughness, fracture energy, fracture propagation toughness and fracture velocity are key dynamic fracture parameters. The energy balance in blasting can be better understood by understanding the dynamic properties of rock under blast loading. The Split Hopkinson Bar Technique (SHPB) can be applied to investigate fracture mechanism of rock and coal. The SHPB tool can even provide vital information on energy partitioning requirements or ration of shock to gas energy output for any specific commercial product or potential new formulation. Figure 8 shows the SHPB facility for determining the dynamic properties of rock mass. Figure 9 shows that rock has developed significant crack after 190 μs of application of dynamic loading and after 299 μs the rock sample can't withstand any dynamic load as significant cracking has take place. After the formation of blast induced cracks the gas pressure will lead to opening and extension of new crack and movement of rock mass.

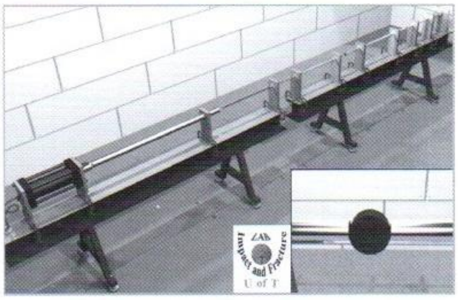


Figure 8 - SHPB testing facility for determination of dynamic properties of rock samples.

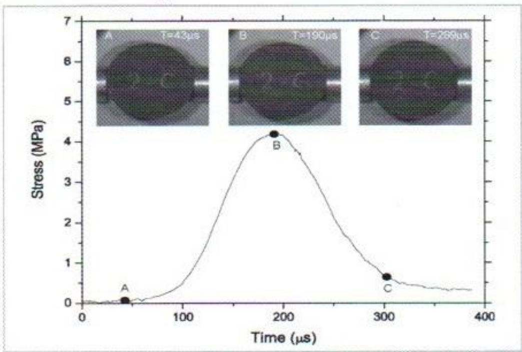


Figure 9 - Impact of dynamic load on rock specimen over time domain.

11.0 Monitoring-while-drilling Tool for Rock Mass Characterization from Blastability Point of View

In order to achieve blast optimisation for a given geo-mining condition, the explosives characteristics and knowledge of target rock are very important. The later implies rock mass characterisation which can be accomplished effectively during drilling operation by monitoring and capturing the parameters viz. rotary torque, rotary speed, penetration rate and pull down force so that rock mass can be well characterised during the drilling operation and charging of blast hole can be carried out using suitable explosives. Knowledge of rock mass characteristics will provide suitable guidelines to blast designers to correlate rock mass characteristics with known and well characterized explosives properties. Till date, there is no indigenous tool available to characterise the rock mass as drilling progresses and there is a need for a thorough study and concentrated research. It is indeed necessary to develop an indigenous tool and technical capacity for mines of Coal India to accomplish rock mass characterization as drilling progresses so that suitable explosives of impedance matching to the rock impedance can be gainfully used. It would provide substantial cost savings in achieving this functionality relative to buying imported off-the-shelf systems as well as delivering systems that are customized to Coal India's specific needs.

The logical first step towards optimizing the overall mining process starts at the production bench-level by

- Understanding/Characterizing rock mass properties
- Implementing drilling and blasting parameters that accounts for variability in rock strength & structure to optimize fragmentation size with respect to loading equipment deployed at the bench with due regard to better post blast performance.
- Drilling and blasting parameters are the key parameters which can optimize all the downstream subsystems affecting overall mine productivity and techno-economics of the mine.

12.0 Alteration of Frequency from Low to High by Media Modification

The mining activities are being spread towards the habitats in view of the conservation of minerals. This is raising more risks of structural damage to the structures and properties due to blast induced ground vibration. The scientists, academics, planners are making good effort to contain the ground vibration within the threshold values by reducing the maximum charge per delay, as this is the most common method to control the vibration level.

The statutory bodies, world over, have decided various threshold values of peak particle velocity based on various ranges of predominant frequency of vibration for different types of structures. The reason is to contain the amplitude of vibration which reflects the strain. Higher level of frequency permits more ground vibration and hence large explosives charge parameters. On the contrary, lower vibration level is permitted for low frequency range, permitting smaller charge parameters.

The low frequency vibration, <8 Hz, is the major cause of structural damage. Improving the vibration frequency should help in achieving larger blast rounds and hence higher productivity. But enough studies have not been carried out to control the frequency level. As a result, no effort other than vibration modulation is being tried as a control measure. It would be beneficial for the mining community to develop some innovative technique by which low range of frequencies can be either converted or moderated to higher level enabling to use larger charge parameters and hence, better productivity, without endangering the safety of the structures. No acceptable method has yet been developed towards this objective.

13.0 Use of HANFO and MMU in Indian Mines

Globally, all dry holes are blasted with ANFO but in India, its properties are not viewed because of non-availability of Bulk ANFO explosives for coal sector. Use of HANFO (Heavy Ammonium Nitrate Fuel Oil) and MMU (Mobile Manufacturing Units) improves the blast performance and overall blast economics. The density and strength of over burden strata are not hard in most of Indian coal mines. The density is in the range of 2200 and 2400 kg/m^3 and P-wave velocity is in between 2000 and 3000 m/s. The compressive and tensile strength are below 400 kg/cm^2 and 150 kg/ cm^2 respectively. Therefore, there is a need to promote the use of HANFO for Indian coal mining industry. As more than 90 % of the explosives consumption is in form of bulk explosive, there is an important requirement to upgrade our Bulk mixing and delivery unit(BMDs) as MMUs. The whole gamut of the science and art in MMU manufacturing in India must be in conformity with modern developments in global market so that a well characterized and site specific explosive product may be delivered by PLC driven and belly fit MMUs.

14.0 Understanding the Energy Balance of the Explosives

Energy released by an explosive, can be grouped into gaseous energy and shock energy, working on the surrounding strata resulting in fragmenting the medium through various breakage mechanisms. Some of these mechanisms are responsible for - (a) fracturing energy, that ultimately is responsible for creating new surfaces in the rock fragments, (b) energy transferred as shock waves into the rock mass propagating as seismic waves or ground vibrations beyond the fragmentation zone, and (c) energy to displace the fragmented material and form the muck pile, that appears as kinetic energy. This energy partitioning is related to the characteristics of explosives and the strata, and to some extent to the blast geometry. The energy balance of the blast may thus be expressed as:

$$EE = EF + ES + EK + ENM$$

where,
EE is the Explosive Energy,
EF is the Fragmentation Energy,
ES is the Seismic Energy,
EK is the Kinetic Energy, and
ENM is the Energy forms not exactly Measurable.

There is a need to determine the energy balance of the industrial explosives so that energy can be used gainfully.

15.0 Use of Blast Instrumentation

As blast instrumentation is a key to increase the mine productivity and mine economics, every mine should use scientific tools for face profiling, VOD determination (confined as well unconfined), fragmentation assessment and prediction, vibration monitoring and management, signature hole analysis etc so that scientific tools can be gainfully used to increase blast productivity, mine productivity and mine economics.

17.0 Conclusion

Considering the size and growth potential of Indian coal sector, it is important to support and promote design and development of indigenous tool in blast instrumentation to achieve optimum blast performance. There is need to promote quality research to evolve technical guidelines in many areas which will minimise the ill effects of blasting in form of controlling vibration, fly rock, air overpressure, frequency of blast induced wave and possible damages to structures. The numerical modeling in blasting will result into time and cost advantages as compared to carrying out the field experimentations. ANN tool can help in evolving the vibration predictor equation more accurately, effectively and reliably. The heavy ANFO and low density emulsion will render techno economic solution to varied geo-mining condition in India. The knowledge of energy balance will help in improving the blast productivity.

GUIDANCE DOCUMENT REGARDING ACCEPTORS UNDER ATF REGULATIONS AT 27 CFR 555.220

(Developed by the Institute of Makers of Explosives, USA).

IME
institute of makers of explosives
The safety and security institute of the commercial explosives industry since 1913

Abstract

To aid in the process of understanding what qualifies as an "acceptor" in 27 CFR 555.220 (Table of Separation Distances of Ammonium Nitrate and Blasting Agents from High Explosives and Blasting Agents), IME has developed the fo llowing framework in consultation with the Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF).

Included as AN acceptors in Table 27 CFR 555.220	DONORS in table 555.220	Excluded as an acceptor / not included in Table 555.220
• Solid AN in prill, flake, and granule form • AN Solutions greater than 93% • Unsensitized ANEs Watergels and Emulsions (Un3375) • (*Note Blasting agents can be an acceptor for 555.220 as well, but are not addressed in this document.*)	• BA/ANFO • HE	• AN Solutions less than 93%

The information provided is not intended to cover all hazards, safe practices or technical challenges associated with the manufacturing of ammonium nitrate (AN); the manufacturing, storage or use of explosives or blasting agents containing AN; or the transportation of AN and AN-containing products. For additional information, please consult other sources including the appropriate references, standards, and regulations cited at the end of this document.

1.0 Ammonium Nitrate Solids and Solution

1.1 AN Solids:

The most common form of solid AN is that of prill. AN can, however, be manufactured as granules or as flake. The behavior of AN prill as an acceptor is well documented. AN is considered a 5.1 Oxidizer per DOT test procedures.

1.1.1 Chemical Properties of AN

AN has a molecular form ula written as NH4NO3. It is described as a nitrate salt of ammonia andnitric acid. AN is a chemically bonded compound consisting of three (3) nonmetal elements: nitrogen (N), hydrogen (H) and oxygen (O) forming two molecules (ammonium and nitrate) that create a compound having an atomic weight of approximately 80. Table 1 shows the element breakdown of AN. AN prill products normally contain internal and external trace chemicals to increase the friability, hardness and mechanical stability of the prill. Typical formulas for AN prill are 99.8% AN or more with small quantities of additives. The maximum quantity of combustible material allowed in AN is 0.2%.

Table 1 - Elemental Breakdown of Ammonium Nitrate

Element	Atomic Wt.	# Atoms	Atomic Wt. in AN	Percent AN
Nitrogen	14	2	28	35%
Hydrogen	1	4	4	5%
Oxygen	16	3	48	60%

Prills are typically solid, white, spherical-like particles which can be porous or non-porous (used in agriculture). An image of the prills is shown in Figure 1 & 2. Porosity can be either high density typically 0.90 to 1.00 g/cc or low density typically 0.74 to 0.88 g/cc. Both densities are used in explosive products.

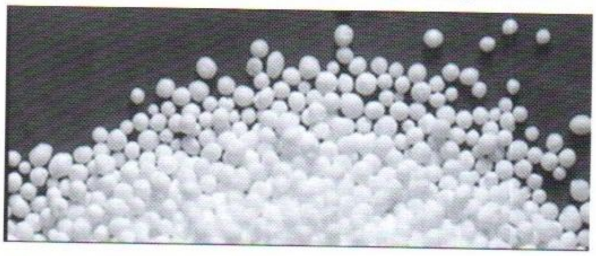


Figure 1 - Photograph of AN prills

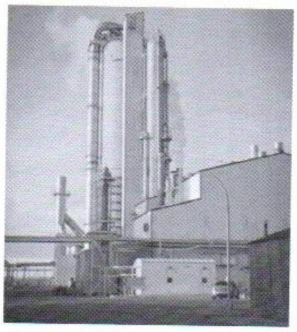
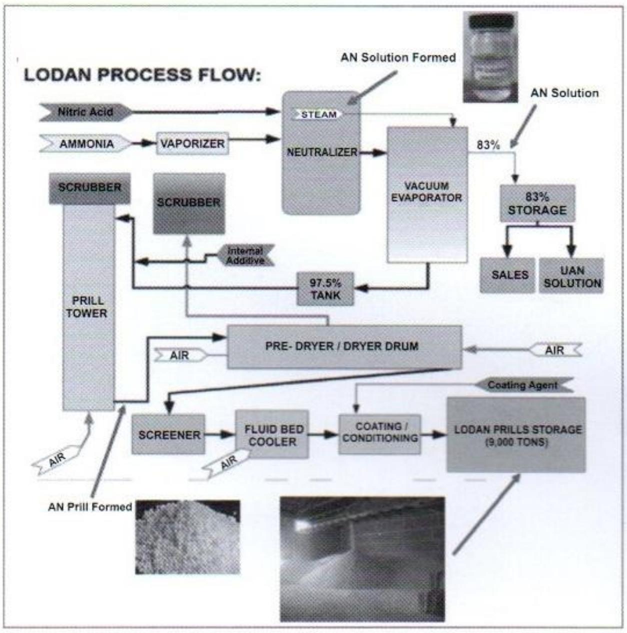


Figure 2 - Image showing the AN Prill Tower

1.2 AN Prill Manufacturing Process

A typical flow diagram for the manufacture of AN prill is shown in the schematic below.



The process begins with nitric acid and ammonia as the raw materials. Typically 50-70% nitric acid is pumped into a batch neutralizer or continuous neutralizer along with the appropriate amount of vaporized ammonia wherein the acid is reacted with the ammonia to form ammonium nitrate in water (ANSOL). The resulting solution, generally in the 75-90% AN range, can be fed to storage or to an evaporator (heat exchanger) to reduce the water content to around 3% before the solution is sprayed into prill towers (See Figure 2). An upward movement of air in the tower causes the droplets to solidify into prills during their fall in the tower. From the tower the prills are dried, screened, cooled and coated. This finished prill product is transferred by conveyors into storage buildings in preparation for shipment to customers.

1.3 AN Granules and Flakes

The predominant form of solid AN used in the explosives industry is AN prill. For completeness, the two other forms granules and flakes are briefly described.

AN granules are formed by "graining" high strength ANSOL (~94-98% AN) in agitation tanks to form granules or grains of AN. These are typically pure AN, but additives can be introduced if particular properties are needed for a specific application(s).

Flaked AN is less common but can also be formed from high strength ANSOL forming a flake as oppose to granules or prills.

In composition, flakes and granules are almost identical to prill.

1.4 AN Solution (ANSOL)

AN solutions coming out of the manufacturing process (shown in the schematic above) are typically in the 75-90% strength range. These solutions are maintained at temperatures above their crystallization point so that they can be handled, pumped and used to make AN emulsions. Rail and truck transport of ANSOL are the typical methods of shipment. Rail shipments of ANSOL typically requires the ANSOL to be reheated at the destination to re-dissolve the AN due to temperature losses during transport that causes part of the AN to crystalize.

The principal use of solution is for the manufacture of AN emulsions (ANE).

There has been no recorded instance of a storage vessel of AN solution behaving as an acceptor. Research papers show that high concentrations can be detonated but only with aeration and not in a quiescent state.

Research papers can be provided.

2.0 Ammonium Nitrate Emulsions and Watergels (ANE)

ANEs are a relatively new type of substance and are denoted by UN3375. The substances are unsensitized emulsions and gels which are classified as Division 5.1 according to the UN Model Regulations.

The composition of ANEs must fit within the UN description as shown below.

2.1 Composition of UN3375:

UN3375 is defined in the UN Model Regulations through Special Provision 309:

This entry applies to non sensitized emulsions, suspensions and gels consisting primarily of a mixture of ammonium nitrate and fuel, intended to produce a Type E blasting explosive only after further processing prior to use.

The mixture for emulsions typically has the following composition: 60-85% ammonium nitrate; 5-30% water; 2-8% fuel; 0.5-4% emulsifier agent; 0-10% soluble flame suppressants and trace additives. Other inorganic salts may replace part of the ammonium nitrate

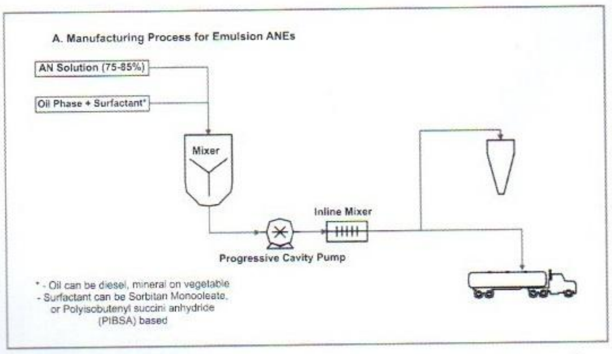
The mixture for suspensions and gels typically has the following composition: 60-85% ammonium nitrate, 0-5% sodium or potassium perchlorate, 0-17% hexamine nitrate or monomethylamine nitrate, 5-30% water, 2-15% fuel, 0.5-4% thickening agent, 0-10% soluble flame suppressants, and trace additives. Other inorganic salts may replace part of the ammonium nitrate.

In the US, both emulsions and watergels1 are transported in bulk.

There is a well-defined testing regime for UN3375 Test Series 8, although one of the tests has shown to be unsuitable for AN emulsions (the Koenen Test, 8(c)).

There has been no recorded instance of an ANE being initiated by shock alone. The only recorded instance of ANE acting as an acceptor is one in which an ANE storage tank (Porgera, PNG) was involved in a prolonged fire following a plant explosion. A bulk truck was on fire after the first explosion, and the fire impinged on the storage tanks, which were also breached. The explosion of the truck and ANE tanks occurred approximately 1h:15min after the plant explosion.

A. Manufacturing Process for Emulsion ANEs



❖ Process Description:

A schematic of the emulsion manufacturing process is shown above.

The AN solution, typically (75-85%) is pumped into a mixing vessel together with the organic phase, which consists of the oil to be used as fuel, and the surfactant, which is used to stabilize the emulsion. The most common mixing vessel is a tank with a motor driven impeller. The shear action of the impeller disperses the AN solution phase in the organic (oil) phase. The surfactant prevents the AN droplets from coalescing. The emulsion is water-in-oil, i.e., the AN droplets are finely dispersed in the continuous phase which is the oil.

The resulting coarse emulsion is then pumped through in-line mixers, which further refines the emulsion to the desired viscosity, which is indicative of the droplet size. Smaller droplet sizes result in higher viscosities. The unsensitized product has the consistency of mayonnaise and is not free flowing. Emulsions with three different viscosities are shown in Figure 3.

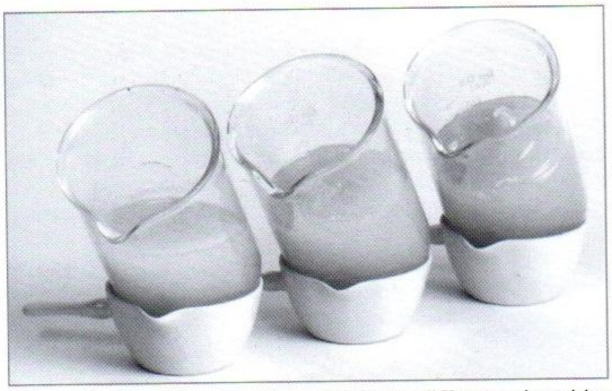


Figure 3. Emulsion samples with three different viscosities (lower to higher L to R)

The emulsion as viewed under a microscope is shown in Figure 4 below:

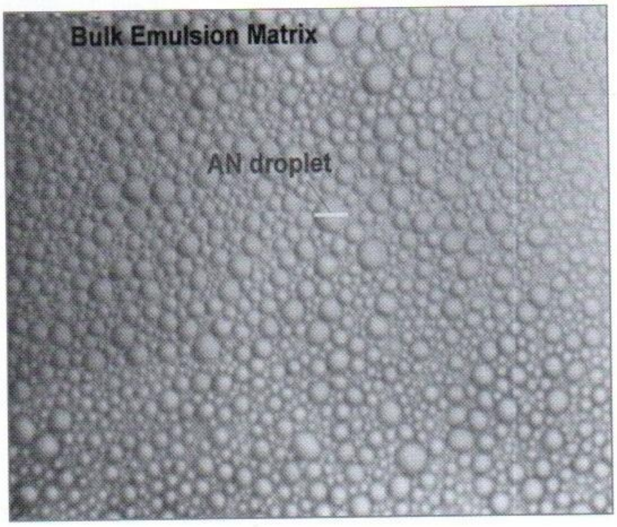


Figure 4 - Emulsion as viewed under an optical microscope.

Depending on the type of oil used, the emulsion can have different colors. In some instances, a dye may also be added. Examples of emulsion products are shown in Appendix A.

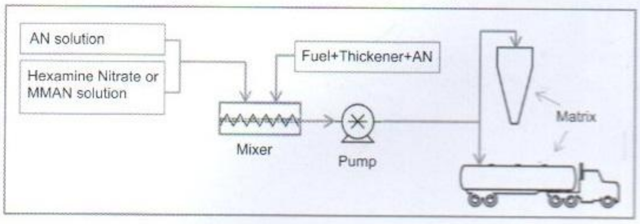
The emulsion is sensitized by voids, which can either be gaseous such as nitrogen gas, or enclosed voids such as glass or plastic microballoons. The generation of nitrogen gas into the emulsion typically takes place as the emulsion is being pumped into the bore-hole. The gassing agent commonly used is sodium nitrite, and this is metered and mixed with the emulsion as it goes into the bore-hole. If the emulsion is to be sensitized by microballoons, these are mixed in at the plant, in most instances. The microballoons can also be added while the emulsion is pumped into the bore-hole, but this is not common practice the bulk density of the microballoons is very low and a large volume container is required to transport them.

Depending on the application, the emulsion may be 'doped' with AN prill. The AN bulk products cover the range of ANFO, straight emulsion, and blends of the two products.

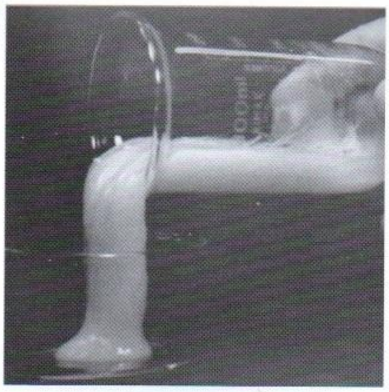
B. Manufacture of Watergels

A watergel is a viscous gelatinous aqueous solution. It consists of oxidizing salts, nitrate salts of organic amines and fuels dissolved or dispersed in a continuous liquid phase. In contrast to an emulsion which has two liquid phases, watergels generally have a liquid and a solid phase. A relatively large amount of oxidizer surrounds a relatively small amount of fuel. The continuous liquid phase of the watergel is usually thickened by guar gum or other long chain organic polymers.

❖ Manufacturing Process for gels:



Process Description:



A schematic of the watergel manufacturing process is shown above.

The Ammonium nitrate solution and hexamine nitrate solution or monomethylamine nitrate solution are pumped into a mixer and blended together with dry AN, a thickener and liquid fuel. The most commonly used mixer is a ribbon blender.

The rheology of a typical pourable watergel is shown in the adjoining image.

Examples of watergels are shown in Appendix B.

Most common final watergel products are blends of the watergelmatrix and AN or ANFO. Th ese are manufactured at a fixed plant or in a mobile bulk truck. Fixed plants manufacture blends for packaged products, however, the most common method of making blends is in mobile bulk trucks on the blast site. This product is directly loaded into boreholes. The final product can be sensitized with solid microspheres, chemical gassing or by the introduction of porous AN prill.

For bulk products, the watergel matrix is transported in bulk tankers to a mine site or quarry where it is offloaded into a silo or a mobile bulk truck. On a mobile bulk truck, a calibrated amount of watergel matrix and AN or ANFO is blended together in a mixing auger. The blended mixture is discharged from the auger into a borehole. If the holes contain water, the ratio of the watergel matrix is increased and the product is pumped. The final product is then delivered through the hose to the bottom of the hole.

Usually, pumped p roduct is chemically gassed for desired density and crosslinked to increase the water resistance of the product. A gassing additive and crosslinking agent can be added at the pump or at the end of the hose. In some cases, a straight watergel matrix is chemically gassed, crosslinked and pumped into a borehole.

Appendix A : Images of AN Emulsions

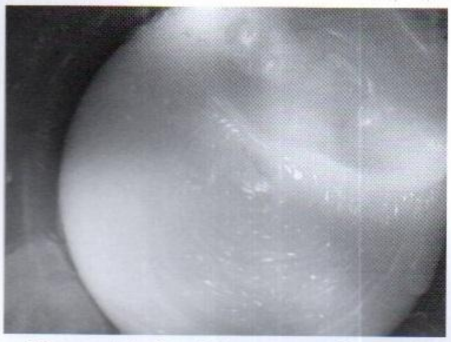


Figure A1 - Emulsion as manufactured

Figure A2 - Emulsion as manufactured

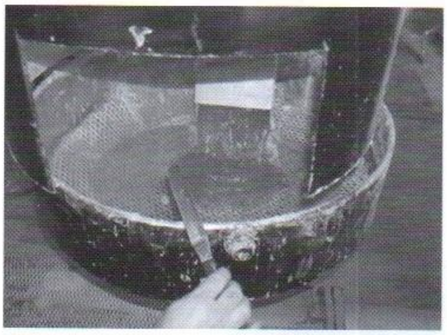


Figure A3. Emulsion with pink coloration

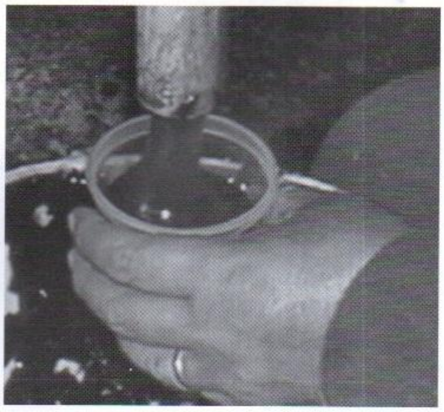


Figure A4. Emulsion made with recycled oil

SUPPLEMENT - 2

Appendix B: Images of Watergels

Figure B1 - Watergel matrix Type "a"

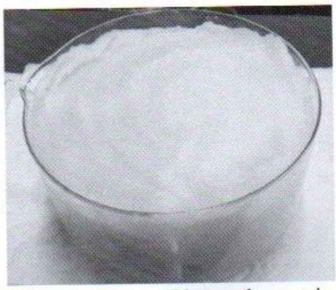
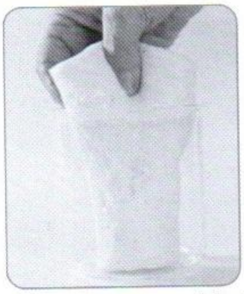


Figure B2 - Watergel matrix Type "b"



Cross-linking process which gels and increases water resistance

Figure B3 - Watergel final product cross-linked

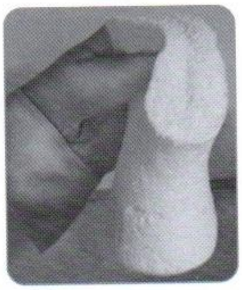


Figure B4 - Watergel final product 70/30 blend

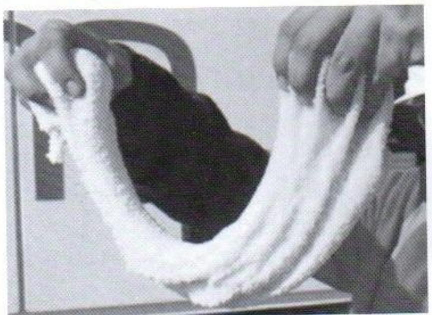


Figure B5 - Final watergel product 70/30 (gel:prill) blend

Appendix C : Images of Emulsion and Watergel Loading in the Field

Final product is manufactured at the borehole on mobile bulk truck. Watergel Matrix and ANFO are blended in a truck auger, chemically gassed to reduce density and crosslinked as pumped into the borehole

Figure C1 - Final Product (Left) and Truck loading a hole with a Watergel/ANFO blend

Figure C2 - Final Product being loaded into a Borehole from a Truck

Appendix D : AN solution

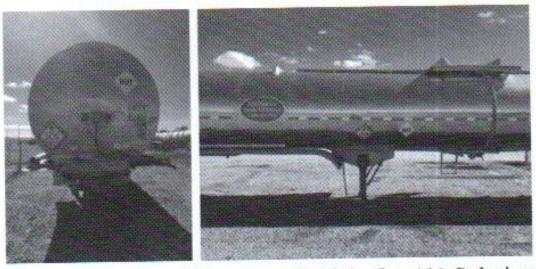


Figure D1 - Road Transport Vehicle for AN Solution (Shipped as Un2426)

Figure D2 - Truck carrying 85% AN solution (Un2426)

References:

- ATF Regulations, 27 CFR Part 555
- IME Safety Library Publication No. 2, The American Table of Distances (2011)
- IME Safety Library Publication No. 30, Safe Handling of Solid Ammonium Nitrate (2017) UN Model Regulations on the Transport of Dangerous Goods

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ELECTRONIC BLAST INITIATION SYSTEMS (EBIS) GUIDELINE

(Developed by the Institute of Makers of Explosives, USA, for "General User Information for Mining, Quarrying and Construction Applications")

IME
institute of makers of explosives
The safety and security institute of the commercial explosives industry since 1913

Preface

The Institute of Makers of Explosives (IME) developed a guideline to provide users of Electronic Blast Initiation Systems (EBIS) with a "plain language" source of information to clarify the technology associated with electronic detonators. The Guideline describes basic design features of EBISs, provides general use and handling recommendations, identifies possible risks associated with EBISs, and stresses the need for field awareness of the critical features and designs of the various systems available to ensure their safe use and correct application.

There are several blasting environments to which all detonator systems may be exposed that can influence their functionality and performance. The Guideline is designed to also heighten the awareness of these environments and the need for all blasters and users of any detonator system to be familiar with these environmental concerns to ensure that the systems are used safely and reliably. That said, the paper focuses particularly on environments affecting EBISs.

IME has developed a series of Safety Library Publications (SLPs), including, SLP 4 Warnings and Instructions (2016), and SLP 17 Safety in the Transportation, Storage, Handling and Use of Explosive Materials (2011), that incorporate recommendations and best practices for the use of any electronic initiation system. Users should ALWAYS consult these resources prior to using any electronic initiation system in order to develop an understanding of the best practices for the safe application of electronic detonators. In addition to consulting IME SLP 4 and SLP 17 (which provide general guidelines and recommendations), users should ALWAYS consult the manufacturer's user manuals specific to the system they will use / are using to ensure a complete understanding of that system's design capabilities and limitations.

The information in the Guideline is designed to provide users, regulators, and those handling and storing electronic detonators basic information and fundamental knowledge of the technology. A thorough understanding of the technology is key to conducting proper risk assessments and to ensuring the safe and practical use, handling and transportation of these types of systems.

*The information provided is **not intended** to cover all hazards potentially associated with the use of EBISs. EBIS users should review and understand this Guideline and, as noted throughout the document, should always consult and follow the instructions and recommendations provided by the manufacturer of the particular EBIS being used.*

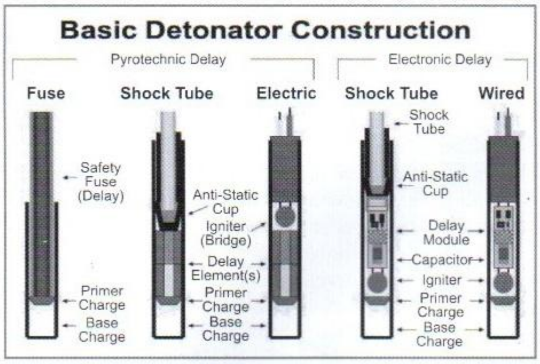
Background

Electronic Detonators: NOT Electric and NOT Nonelectric

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

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

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



For the foreseeable future, existing electric detonator regulations may continue to be mistakenly applied (or misapplied) to electronic detonator technologies.

To recognize the actual risks associated with EBISs, a basic understanding of the physical construction of the system components, starting with the detonator, is essential. Users should then develop a full understanding of all the test equipment, programming units and firing devices to fully appreciate the risks unique to electronic systems and to ensure the safe application of the technology.

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

The physical construction of an electronic detonator is the primary reason that electronic detonators should not be confused with electric or nonelectric detonator technologies. As seen in Figure 1, the electronic detonator wire leads do not attach directly to a match head or bridge wire, unlike electric detonators.

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

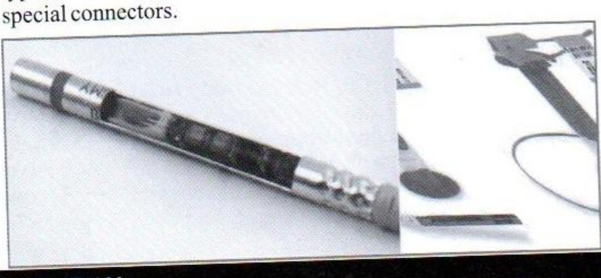
In addition to a physical separation from the bridge wire, electronic detonators generally have several other components as part of the design that further increases the level of protection from extraneous electrical energy sources and the risk of premature initiation.

Some of these protection devices include:

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

In addition to an electronic detonator's design and construction, EBISs have other built-in features that provide a further level of safety and security that may not be found in other systems. EBISs incorporate a logic component in the detonator design in the form of a microchip technology or an ASIC (Application Specific Integrated Circuit) that provides not only a "logic" protection from premature initiation, but also provides a level of timing control and security from unauthorized use. Generally, the built-in logic circuits will allow operators to limit and control who can use the system though passcode protection.

Most will also require a "physical *key"* to gain access to firing circuits, which increases the level of security by limiting the use of equipment and detonators to ON LV authorized and fully trained blasters. The photos below show a cut-away of a typical electronic detonator as well as the full assembly with special connectors.



Environmental Influences

Electronic initiation systems and their associated equipment and components have been in use for many years and have seen a wide variety of field application challenges common with the introduction of any type of new technology. Many of these challenges or issues can be attributed to a lack of user familiarity with system capabilities and/or incomplete understanding of the system design limitations with respect to the environments in which they were designed to work.

Radio Frequency Energy

Lack of understanding of electronic initiation systems, along with some misguided warnings, including warnings from some mining/construction equipment manufacturers, has resulted in confusion and safety concerns for users who mistakenly believe that electronic detonators may prematurely initiate if exposed to RF energy sources.

Although RF energy may interfere with the communication of these systems, extensive testing by the manufacturers and independent laboratories have verified that electronic initiation systems will "fail to a safe" mode even if exposed to RF levels that exceed levels typically experienced in mining, quarrying, and construction applications.

To help clarify risks associated with RF energy sources and detonator technologies, IME has developed a suggested warning for equipment manufacturers, i.e., that **electric detonators** are clearly at risk of premature initiation from RF energy sources, and users should recognize and apply safe distances outlined in SLP 20, *Safety Guide for the Prevention of Radio Frequency Radiation Hazards in the Use of Commercial Electric Detonators (Blasting Caps).* It is important to note that SLP 20 does **NOT apply to electronic detonator technologies.**

The need for the above clarification is illustrated by a confusing warning message recently encountered on some mobile equipment. The equipment manufacturer's warning recommends that operators turn off communication devices when using both electric *and* electronic detonators, or to observe safe operating distances for vehicles with communication systems. The distances referenced are taken from SLP 20 which, as noted above, applies only to electric detonators.

EBISs provide not only a high level of immunity from premature detonation due to their design and construction (as discussed above), but also provide a high level of resistance to potential interference sources. However, not .2!! electronic systems use the same construction and design concepts to provide this protection. Users should read and understand all aspects of the system they use and follow the manufacturer's recommendations.

Electro Magnetic Pulse (EMP)

An electromagnetic pulse (EMP), also sometimes called a transient electromagnetic disturbance, is a short burst of electromagnetic energy. EMP origination may be a natural or man-made occurrence and can occur as a radiated, electric or magnetic field or a conducted electric current, depending on the source. Electromagnetic fields can be generated from several sources including, natural atmospheric conditions such as thunderstorms, large solar storm (geomagnetic) events, and chemical or nuclear explosions. A powerful EMP event such as a lightning strike can damage physical objects.

EMP interference is generally disruptive or damaging to electronic equipment at higher energy levels. The management of EMP effects is an important branch of electromagnetic compatibility engineering. EMP has been identified as a source of damage and risk to the performance and reliability of electronic detonators. Today's electronic detonators and initiation system equipment and technologies generally have built-in protection from this type of extraneous energy, but users should always consult the manufacturer of the product they are using to ensure that the product will meet the types of demands encountered in some blasting environments. Close boreholes, metallic orebodies and certain types of explosives products can enhance the production of EMP, which can damage an adjacent detonator's circuitry or the firing equipment, potentially causing misfires. In rare cases, blasters have experienced short duration electrical shock when the EMP travels back through the firing line to the firing equipment.

EBIS manufacturers have studied EMP and have successfully reproduced the phenomena in controlled experiments. The voltages could be relatively high (+/- several kilovolts depending on the source) but very short in duration. No known fatalities or serious injury has ever been reported due to a known EMP from a blasting event. That said, basic precautions should be taken to avoid electrical shock and prevent misfires and equipment damage. These precautions may include; proper grounding of the equipment, avoiding standing in water, keeping clothing, gloves and hands dry, and the use of EMP protected detonators.

To weigh the risk of EMP, users should be familiar with the conditions that might produce it. The causes and characteristics of EMP are varied and complex. A thorough explanation is beyond the scope of this Guideline. A typical environment will consist of positive (+) and negative (-) charges in the atmosphere with both being equal (+/-). When a blast is detonated and especially when the blast is particularly violent, excitation of the gas particles and debris in the atmosphere may alter the (+/-) state and generate an electromagnetic field.

A short duration EMP event would take place in a somewhat similar form as a lightning strike. This EMP is seeking a ground source. The detonator wiring could become a conduit, and if the EMP is strong enough it may damage the circuits and shut down the remaining detonators before they fire.

This would be more common, for example, in underground development headings, tunnels and shafts where the holes are often closely spaced and/or un-stemmed. EMP has also been known to occur in surface operations, e.g., in un-stemmed pre-split holes or where oversized boulders are blasted with unconfined or minimally confined explosive charges. Even in stemmed holes, if conditions are conducive to EMP, blast holes can produce EMP which may then result in very violent results and/or unpredictable events.

While underground applications seem to be the most affected, EBISs have been used very successfully underground for many years in large and small scale bench, stoping or raise round blasting. They can be used safely in the previously described conditions if the risks are understood and adequate precautions are taken.

Some detonator manufacturers have implemented built-in protections from EMP. Before using any EBIS, one should assess the risks of EMP, design the blast accordingly, and select a detonator type with adequate protections. Consult the detonator manufacturer for specific recommendations.

Dynamic and Static Pressure Resistance

Pyrotechnic initiation systems have been in use for centuries beginning with early forms of black powder fuse technologies to today's chemical or pyrotechnic delay found in electric and nonelectric detonators. These technologies rely on mixtures of fuels and oxidizers consolidated in steel, lead, or other material sleeves to provide the timing required for blast initiation control and sequencing. These technologies have been developed over the years to not only provide a high degree of timing control and precision, but also to withstand the dynamic pressures associated with blasting environments.

As noted above, electronic detonators utilize microchip technology and logic to provide timing and firing control. These technologies have also been developed to provide a high level of reliability, but users should always consult the manufacturer for specific recommendations on the level and type of dynamic pressure and or shock that should be allowed for and protected against.

On-Bench Field Testing and Programming Equipment

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

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

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

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

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

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

Electronic Blasting Machines

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

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

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

Typical Electronic Blasting Machine

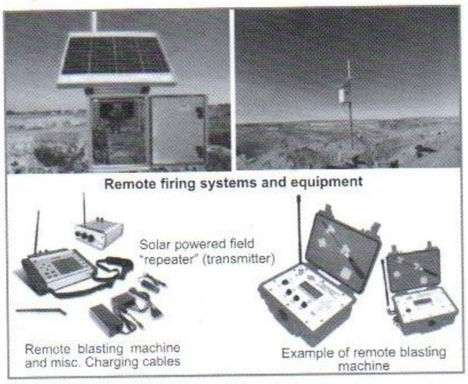
Many systems will require both password protected firmware and/or software interfaces for the user as well as a physical key or manual device to ensure no accidental firing can occur. As mentioned above, each system is specific to a manufacturer's design and users must understand and follow all protocols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

Remote Firing Devices and Systems

Today's EBISs offer users a full range of product features and solutions in terms of size of shots, programming times available, testing features and methodology of programming and firing. One such feature includes the ability to incorporate remote firing equipment into the user's blasting protocol. As with other initiation systems, electronic blasting machines are available that allow a wireless interface between the "bench" and the preferred/safest location of the "Blaster-In-Charge" (BIC).

These systems have been designed with the highest level of communication reliability possible to ensure the same full scale testing, programming and firing of blasts. Users, however, must always ensure they are fully trained and understand the capabilities and limitations of these systems. Distance limitations, weather conditions, line of site requirements, RF interference, etc., can all playa factor in communication reliability and users should ALWAYS test and verify the system prior to use. As with any blasting machine use, the blast area must be cleared prior to connection. Remote firing devices can add additional challenges when clearing an area, therefore remote communication systems should be tested and verified prior to connecting to any blast circuit.

The following photos show a few examples of remote firing equipment used to ensure that the highest level of safety is achieved and that appropriate, safe distances are established for all personnel.

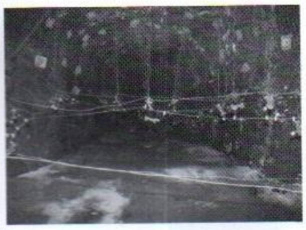


Remote firing systems and equipment

Underground Electronic Initiation Systems (UEIS)

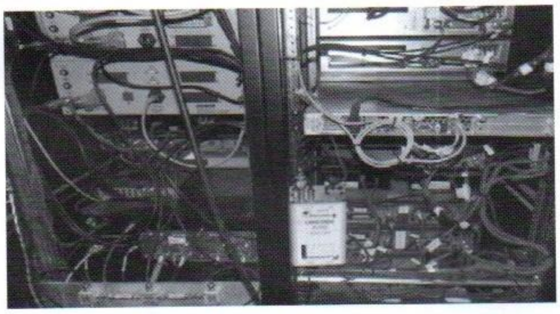
Several developments have taken place over recent years with EBISs in underground use. Many underground mining operations have embraced UEISs for the safety and productivity benefits they provide. Generally, electronic detonators have built-in immunities to RF energy, static and stray currents and electromagnetic interference which exceed those found in the types of conventional electric detonators that are often used underground. The design flexibility that is inherent in an electronic system provides additional advantages. Nevertheless, the operator must always follow the manufacturer's instructions for the specific system being used.


Fully tied in underground electronic stope blast


Underground miner programming electronic detonator

Several EBIS manufacturers have developed systems specifically for underground applications. Loading, programming, tie-in, testing and firing procedures differ significantly from typical surface operations. Extensive theoretical and hands-on training is essential for the successful implementation of any UEIS.

One of the major driving forces of UEIS development is the need to fire blasts remotely from the surface, thus removing miners from the potential hazards of noise and concussion, rock fall, dust and fumes, and lost communication and isolation.


Leaky Feeder Panel for Underground Blast

Two-way communication for the UEIS is essential in underground works. In addition to the standard central firing line, various methodologies have been developed for remote firing. This includes but is not limited to: Leaky Feeder, Wi-Fi, Fiber Optic Lines, PSTN (public switched telephone network), RS-485 and SHDSL (symmetrical high-speed digital subscriber line) modems.

Furthermore, sophisticated IT network systems can be set up, enabling the operator to store and share information as well as to monitor and manage multiple blasts independently or simultaneously on multiple levels at great distances from a single dedicated firing station. With a wide variety of mine specific requirements and communication systems already in place, a customized solution is often necessary.

SCIENTIFIC / TECHNICAL PAPERS

TUNNEL BLAST DAMAGE CONTROL BY ALTERING BLAST DESIGN PARAMETERS IN HIMALAYAN ROCKS

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ABSTRACT

Blast induced overbreak is a severe side effect in tunneling projects, which are excavated by drilling and blasting methods. The construction projects have to pay huge price for the excessive overbreak quantities through their nose. The over break also leads to increase the duration of project which has got huge indirect cost implication as the back filling by concrete is very costly and time consuming. Therefore, practice of proper controlled blasting techniques play a vital role in economic construction as well as timely completion of project. However, the general controlled blasting techniques need to be tuned to the site specific application to get maximum results in control of overbreak. CSIR-CIMFR carried out extensive investigation on control of overbreak and increase of pull in Himalayan rock formation for tunnels National Road Highway projects. One such project in Chenani Nashri Tunnelway Limited (CNTL) at Udhampur-Srinagar Highway project, which is one of the longest roadway tunnels in India with 9.0 km (5.59 miles) length. The project consists of main tunnel and escape tunnel with 13m (42.45 feet) diameter and 6m (19.68 feet) diameter respectively.

The effect of various parameters like rock, explosive and blast design were thoroughly investigated with regards to extent of overbreak. Studies were conducted on various governing parameters like blast design of contour holes, delay numbering and sequence, joint orientation/foliation, blast design of production holes, stemming practice and drilling angle of contour holes for the assessment of their effect on blast induced over break.

It was found that the foliation of joints with respect to tunnel axis, predominantly influence the extent of overbreak. It is generally considered that the blast design of contour holes play a significant role in control of overbreak. But from several trail blasts it was noticed that blast design of cut holes and penultimate row of contour holes play equal role as contour holes. It was also found that the overbreak is inversely proportional to the area of cross section of tunnels for given geo-tunneling conditions.

Application of in-hole delay blasting technique in cut holes and smooth blast design of penultimate back holes reduced the overbreak from 0.5m to 0.1m, which is upto 90% reduction in both main tunnel and escape tunnel. It was observed that effective practice in-hole delay technique and smooth blasting, in contrast to conventional blasting, resulted in saving of 21-39 % of overall cycle time of tunneling. The reduced cycle time resulted in substantial bearing on the economics of the project. The In-hole delay blast reduced the peak particle velocity of vibration by 45-50%, which is directional proportional to the rock mass damage in the sides and roof of the tunnel.

1.0 INTRODUCTION

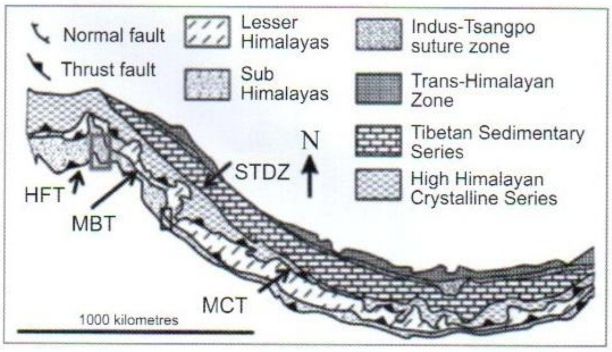
Drilling and blasting is the most acceptable method for excavation of rock, in-spite of destructive in nature. This is because of low capital investment and possesses the characteristics of high progress rate for underground excavation works (Hallvard Holen, 2002). The drilling and blasting method has got inherent disadvantages of damage and overbreak. Though, overbreak enhances total cost of tunneling to a level of 15% or even more of the scheduled cost of construction, construction manual guidelines allows a magnitude of 1520 cm overbreak in crown and 1015 cm overbreak along sidewalls to avoid confrontation for payment between contractor and client and at the same time facilitate drilling along periphery row for subsequent rounds (Korea Highway Corporation, 2000, Cunningham and Goetzsche, 1990). Overbreak either occurs immediately after blasting or with duration of time *i.e.*, either dynamic or quasi-static type. The quasi-static type of overbreak is caused with lapse of time of excavation and is generally caused by re-distribution of stresses and loosening or weakening of filling material between two blocky rock masses. This type of over-excavation is the result of interaction between improper sequence of excavation, excavation profile or shape and/or inadequate application of support with respect to in situ stresses or poor assessment of rock mass quality. Uniaxial Compressive Strength, Joint Plane Spacing, Joint Plane Orientation, Joint Plane Aperture and filling material between joints) contribute towards controlling damage or overbreak in in situ peripheral rockmass, an effective blast design with proper charge parameters and initiation sequence should be implemented to minimize the impact of detonation pressure on uncontrollable parameters in magnifying the magnitude of overbreak (Harries, 1978, Liu and Katsabanis, 1993, Scoble et al., 1996, Lewandowski et al., 1996, Dunn and Cocker, 1995 and Hallvard Holen, 2002). The blast induced overbreak is measured radially and is expressed in metre. The overbreak and the underbreak are often measured volumetrically in m^3 of in situ rock mass over or under-broken. These may be expressed in per cent of the designed volume. However, in most of the projects in India, the permissible limit of overbreak has been defined in terms of width and height of tunnel. The Swiss Society of Engineers and Architects defines the permissible overbreak limit as 0.07A, where A is the tunnel area or 0.4 m whichever is less (Innaurato et al., 1998). Irrigation Department of Maharashtra, India decided no payment for additional excavation beyond 0.1 m of the designed contour of a tunnel (Irrigation Dept., Govt. of Maharshtra, 1998).

The paper, here, discusses and analyzes the extent of overbreak for two tunnels excavated in National highway road tunnels of Himalayan formations. These two tunnels include Main tunnel with dimensions of 14m width and 6.75m height and Escape tunnel with 5.8m width and 6.15m height. In these two sites excavated profile and magnitude of overbreak was determined with the help of laser profiler. The influencing parameters on overbreak and controlling measures are discussed in detail in the following sections.

2.0 DESCRIPTION OF THE SITE

The new Highway link project between Udhampur and Srinagar is one of the recent, most important Indian projects planned for the connection of the Kashmir valley with the whole Indian transportation network. The Government of India has entrusted the National Highways Authority of India (NHAI) with the responsibility of the "Rehabilitation, Strengthening and four Laning of Chenani to Nashri Section of NH-1A (new alignment) including 9000 m long tunnel (2 lanes) with parallel escape tunnel. In particular, the most important structure along the Project layout is the Chenani Nashri Tunnel at the section between Udhampur and Banihal. This is a single-bore tunnel for bidirectional traffic, with a parallel escape tunnel. These two tunnels include Main tunnel (14m wide and 6.75m high) and Escape tunnel (5.8m wide and 6.15m high). This project is located in the DODA district of Jammu & Kashmir state.

The project area lies in the Western Himalayan region in a sector of Himalayan collisional belt known as sub-Himalayas. This tectonic domain is bounded toward south by the Himalayan Frontal Thrust or Main Frontal Thrust (HFT or MFT) and the Main Boundary Thrust (MBT) to the north. (Figure 1.). These main thrusts as well as most of the belts and units of this NW region of Himalaya orogen show a regional strike of NW-SE to WNW-ESE with moderate to steep dips either towards north or the south. Within the regional geology context, the project Chenani-Nashri Tunnel will cross the rocks belonging to the Murree formation (Oligocene - Miocene). These lower tertiary sedimentary rocks consist of molasse sediments, representing the filling of foreland basin (foothills of the Himalayan Range), an area where the sedimentary record of material eroded from the mountain belt is preserved. The rock mass characterization was done by both Geological Strength Index (GSI) and Rock Mass Rating (RMR).



Legend: MCT: Main Central Thrust; STDZ: South Tibetan Detachment Zone; MBT. Main Boundary Thrust; HFT=MFT: Main Frontal Thrust.

Figure 1. Himalayan orogenic belt showing potential Himalayan source rocks for the sediments of the foredeep.

3.0 TRIAL BLASTS WITH CONTROLLED BLASTING

Test blasts were conducted to assess and control the overbreak at both Escape tunnel and Main tunnel of South portal and Escape tunnel of North portal of CNTL. The main objectives of test blasts were to minimise the overbreak/underbreak by smooth blasting application and to get maximum pull per round. Initially, two blasts were conducted with the existing blast design parameters and ground vibrations were monitored for the purpose of comparison with modified design. The excavated profile and magnitude of overbreak were determined with the help of a laser profiler. The average specific charge and specific drilling in Escape tunnel was 2.0 kg/m^3 and 3.0 m/m^3, respectively whereas the average specific charge and specific drilling in the main tunnel were 1.2 kg/m^3 and 2.5 m/m^3 respectively. Peak particle velocity, measured at a distance of 50m, was 8.86 mm/s and 7.08 mm/s for Escape tunnel and Main tunnel respectively. Blast details and the results with the existing are given in the Table1. Tunnel Profile with undercut and overbreak with prevailing blast pattern are shown in Figure 2.

Table 1 - Details of trial blasts and results with prevailing blast pattern for roadway tunnels

Trial Blast	No. 1	No. 2
Location	South Portal, Escape Tunnel at Chainage 173.0m	South Portal, Main Tunnel at Chainage 81m
Rock condition: GSI	50	45
Rock condition: RMR	61	47
Rock condition: Rock strength, MPa	75	27.5
Blast design modifications	Prevailing pattern	Alternate contour holes charged
Total Expl. charge, kg	216	220
Depth of blast round, m	3.0	2.5
Specific charge, kg/m^3	2.3	1.4
Specific drilling, m/m^3	2.46	2.40
Avg. Pull, m	2.5-2.75	2-2.2
Overbreak	Upto 0.2m (0.3 at crown due to *in-situ* block dislodgement)	0.3-0.5m
Underbreak	0.2-0.3m	Nil
Half Cast Factor (%)	25-30	25-30
Peak particle velocity at 50m distance, mm/d	8.86	7.08
Cycle time of tunnel excavation, hours	20.75	18.5

Figure 2 - Tunnel Profile with undercut and overbreak with prevailing blast pattern

Keeping the above observations in view, the following changes were made in the existing blast practice if the tunnels:

1. Contour holes were charged with mild charge concentration (combination of cartridge and detonating fuse) by leaving dummy holes regularly.
2. Explosive charge for the holes adjacent to contour holes was reduced by 0.5 kg as they cause damage and overbreak of side walls and roof.
3. Explosive charge in baby cut holes was reduced by 0.39-0.5 kg while in the cut holes the charge was increased by 0.39-0.5kg to get more pull per round.
4. All the rib holes/side holes were charged with 0.39kg+200gm PETN
5. Explosive charge was reduced by 0.39kg for the last but one crown holes as they also causeoverbreak of overt rock.

After the initial test blasts, the following observations were made on the existing blast pattern and practice:

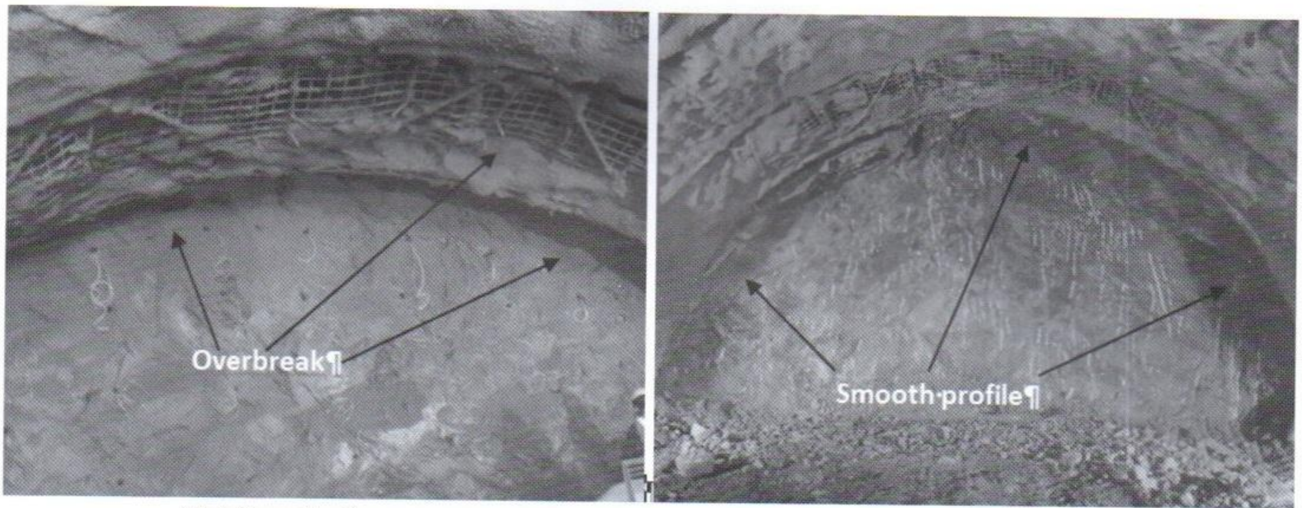
1. Half cast marks (half barrels) were rarely visible even in good rock mass conditions.
2. The rule of smooth blasting i.e. Spacing/Burden ≤ 0.8 was not followed for contour holes.
3. The contour holes in weak rocks required charging of alternate holes by leaving dummy holes in between.
4. The specific charge used for main tunnel (> kg/m^3) and Escape tunnel (> 1.5 kg/m^3) was on the higher side, which might have also caused overbreak.
5. The charge for penultimate contour row (last but one crown holes) was not controlled which might also induce rock mass damage. The charge should be less than 0.75 times the charge of its previous delay.
6. Charging for contour holeshas to be site-specific to properly control overbreak. Blast holes were charged uniformly without regard to weak and strong rocks, mainly for contour holes.
7. Bottom corner holes and bottom holes/ lifters were often undercharged which resulted in underbreak in both the tunnels.
8. The explosive with 80% strength was invariably used for all the blast holes. It was suggested to use the explosive with 60% strength for the contour holes of both the tunnels.
9. Four relief holes were absolutely for the success of the burn cut pattern.
10. Vibration monitoring was suggested to assess the performance of blast.

Based on the results and analysis of the existing practice, a total of six blasts were conducted with modified blast pattern in order to control overbreak. The tunnel blast pattern at both Escape and main tunnels was partially modified by reducing the explosive charge in contour holes with an objective of getting smooth blast results. The results of the partially modified patterns and the existing pattern on overbreak are shown in Figure-3.

The following blast results were observed with the above changes at Main tunnel blast round:

i) Overbreak was reduced substantially and smooth profile was visible at the overt and ribs.
ii) The average overbreak on LHS of the face was 0.3m and 0.2m on RHS of the face.
iii) Peak particle velocity at 50m distance from blast face was 2.5 mm/s.
iv) The initial shotcreting took just 15 minutes, which otherwise used to take about 30+ minutes.
v) The average pull per round was 2.4m, which was 96% of hole depth.

The design modifications for every blast for control of overbreak are mentioned in Table2. Details of blast performance improvement with modified controlled blast pattern are mentioned in Table3.Profile with undercut and overbreak with modified controlled blast pattern are shown in Figure 4.



(Existing pattern) (Partially Modified pattern)

Figure 3 - Overbreak due to existing blast pattern and the partially modified pattern

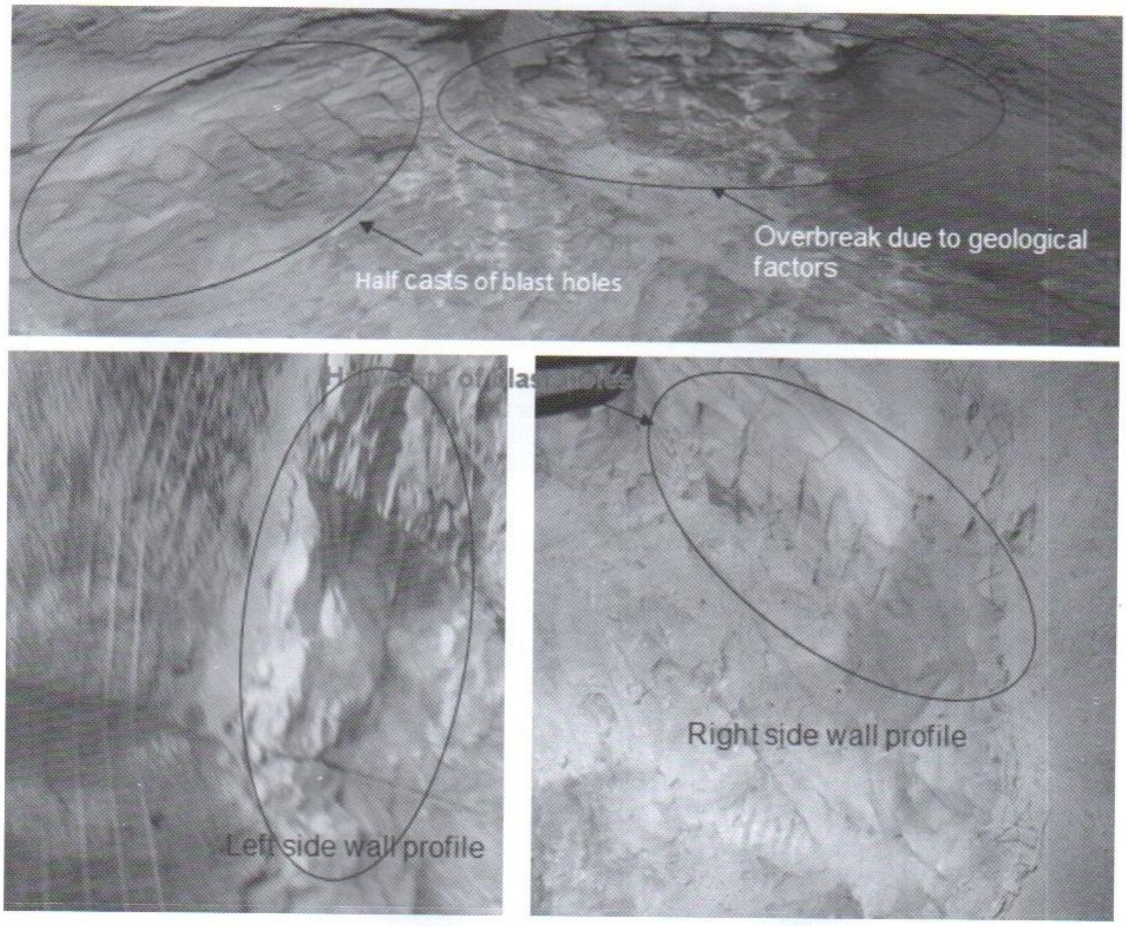


Figure 4 - Profile with visible half casts with modified controlled blast pattern of Blast 4

Table 2 - Details of trial blasts and results with modified controlled blast pattern in roadway tunnels

Location	Trial Blast No				
	3	4	5	6	7
	South Portal, Main Tunnel, Chainage 82.7m	**South Portal, Escape Tunnel, Chainage 175.8m**	**South Portal, Escape Tunnel, Chainage 179m**	**South Portal, Escape Tunnel, Chainage 182m**	**South Portal, Main Tunnel, Chainage 82.7m**
Rock Type/condition	GSI=50; RMR=61; Rock strength: 75MPa	GSI=45; RMR=58; Rock strength: 75MPa	GSI=45; RMR=54; Rock strength: 84MPa	GSI=45; RMR=54; Rock strength: 84MPa	GSI=45; RMR=47; Rock strength: 27.5MPa
Blast design modifications	Alternate contour holes charged with 200gm decoupled explosive	All contour holes charged with (500+80) gm decoupled explosive	All contour holes charged with (500+80) gmdecoupled explosive & Rib holes with 1kg	All contour holes charged with decoupled explosive & Rib holes with 1kg; used in-hole delay cut method with one reliever.	Alternate contour holes charged with 200gm decoupled explosive
Total explosive charge, kg	175	164	180	190	216
Depth of blast round, m	2.5m	3.0	3.0	3.0	2.5
Specific charge, kg/m³	1.2	1.6	1.7	1.8	1.2
Specific drilling, m/m³	2.46	2.46	2.46	2.46	2.46
Avg. Pull, m	2.3	3.0	3.0	2.8	2.5
Overbreak	Upto 0.2m	Upto 0.2m (0.3 at crown due to in-situ block dislodgement)	Upto 0.1m (0.3 at crown due to in-situ block dislodgement)	Upto 0.1m (0.3 at crown due to in-situ block dislodgement)	Nil
Underbreak	Nil		Nil	Nil	Nil
Half Cast Factor, %	25-30	50-60	60	75-80	25-30
Peak particle velocity at 50m distance, mm/s	3.94	3.81	5.06	2.25	3.56
Cycle time of tunnel excavation, hours	12.75	15.5	15.25	15.6	14.25

Table 3 - Details of blasts performance with modified patternsin the road tunneling project

Blast result	**Blast 3**	**Blast 4**	**Blast 5**	**Blast 6**	**Blast 7**
Specific charge, %	Nil	20	20	10	Nil
Specific drilling, %	2	25	18	18	2
Pull, %	Nil	27	27	27	8
Reduction in overbreak, %	40	70	80	90	90
Half Cast Factor, %	85	90	92	95	82
Peak particle velocity at constant distance, %	44.4	57	43	75	5
Cycle time of blasting round, %	39	22	23	21	36

4.0 DISCUSSIONS ON OVERBREAK CONTROL

The orientation of joints with respect to tunnel axis predominantly influenced the extent of overbreak. Therefore, varying explosive charge concentration towards the joint inclination and across the joint orientation would result in better control of overbreak, rather than uniform charging. It is generally considered that the blast design of contour holes plays a significant role in control of overbreak. It was observed that design of cut holes as well as helper holes is equally important to control overbreak. Care also be taken in the charge design of contour holes. It was also found that the overbreak is inversely proportional to the area of cross section of tunnels for given geo-tunneling conditions.

Application of in-hole delay blasting technique in cut holes smooth blast design of penultimate back holes reduced the overbreak by 40-90% in both main tunnel and escape tunnel. It was observed that good smooth blasting, in contrast to conventional blasting, resulted in saving of 21-39 % of overall cycle time of tunneling. The reduced cycle time resulted in substantial bearing on the economics of the project. The In-hole delay blast reduced the peak particle velocity of vibration by 45-50%, which is directional proportional to the rock mass damage in the sides and roof of the tunnel.

5.0 CONCLUSIONS

The study clearly indicates that application of site specific smooth blast pattern is very important to provide smooth tunnel profile which is essential for the ongoing NATM method. The smooth blasting has got tremendous bearing on performance of all the subsequent tunneling operations like scaling/dressing, chiseling, shotcreting/supporting and mucking. It was observed that effective practice in-hole delay technique and smooth blasting, in contrast to conventional blasting, resulted in saving of 21-39 % of overall cycle time of tunneling. The reduced cycle time resulted in substantial bearing on the economics of the project. The In-hole delay blast reduced the peak particle velocity of vibration by 45-50%, which is directional proportional to the rock mass damage in the sides and roof of the tunnel. Therefore, it very clear from the studies that the site specific smooth blast design judicious charge distribution with respect to joint inclination is the effective method of controlling overbreak. The new controlled blasting practices fulfilled the objectives of minimum overbreak and maximum pull/progress for the prestigious CNTL project of national importance.

6.0 ACKNOWLEDGMENTS

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SCIENTIFIC / TECHNICAL PAPERS

NUMERICAL MODELLING TECHNIQUE FOR DEMOLITION OF STRUCTURES A CASE STUDY AT SEOUL, SOUTH KOREA

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ABSTRACT

The use of numerical techniques in demolition is gaining popularity due to its distinct advantages over conventional method of mechanical demolition by providing an accurate analysis of the proposed demolition plan, indicating the possibility of any mishap or hazard during demolition, studying the seismic analysis of the propagation of seismic waves created by structural debris to the neighboring structures and post demolition comparative analysis of the actual demolition results with predicted demolition results. Numerical techniques has marked advantages in terms of time, cost and safety over the conventional mechanical demolition. As South Korea is one of the world leader in implementing demolition using numerical techniques, a South Korean case study has been discussed. This paper shows the close match between actual and predicted demolition results in terms of breakage pattern, sequence of breakage and debris distribution in muck pile. The peak particle velocity and noise threshold as set up by the Korean regulator was also met effectively suggesting success of numerical techniques for carrying out demolition in any country.

Keywords: Blast, structure, debris, Numerical techniques, demolition

1.0 INTRODUCTION

As per standard design procedure in vogue in South Korea, the expected life of majority of civil structures is planned as 35-40 years and controlled demolition gets necessitated at the end of the service life of any structure. Presently, the regulatory bodies at South Korea enforces the owner of structures considered for demolition to submit detailed demolition plan along with estimated environmental nuisances in from of Peak particle velocity(PPV) and noise at strategic locations. As demolition is a big industry in South Korea, numerical techniques code is becoming popular providing a high degree of confidence to the regulators and building owners. The explosives induced demolition has time, cost and safety advantages over mechanical demolition but involves damage threat also from flying fragments ejected by concrete or masonry structures if executed without proper planning and by unskilled professionals. The capability to predict the spatial distribution of debris of any structure as a function of parameterized blast loads by numerical techniques is an effective engineering tool and is gaining popularity in South Korea. This papers discusses the demolition of an extensive five storey building having height of 35.32 m by using 39.625 kg of explosives and 800 detonators. The computational spatial distribution presented good agreement with the actual demolition, closely matched breakage patterns, initial fragmentation, debris distributions produced by simulated results. To achieve a successful demolition the following factors must be taken into consideration

- **Effect on Adjacent Structures:** Falling debris should not impact the neighboring structures
- **Flying Debris:** Flying debris should be minimized to avoid damage to people or property
- **Size of Debris:** The size of debris pieces should be manageable to facilitate its removal
- **Seismic Vibration:** The vibrations due to the impact of the debris with the ground should not exceed allowable limits as set by the any regulator

2.0 NUMERICAL TECHNIQUE USED IN DEMOLITION

The numerical analysis code was used in predicting the continuum and discrete behaviors of structures. The modeling method adopts the concept of discrete cracking allowing it to automatically track structural collapse behavior passing through all stages of loading: elastic, crack initiation and propagation in tension-weak materials, reinforcement, yield, element separation, element contact and collision, as well as collision with the ground and adjacent structures. The developed code is a high ended structural analysis software combining the features of Finite element method and Discrete element method based simulation. The program has its own solver capabilities for the generation of PC-based structural analysis and is capable of automatic tracking and propagation of cracks, separation of elements, element collision, and collapse of structures under extreme loads including blast induced load.

2.1 Underlying Principles of Software Code

The structure is divided virtually and modeled as an assemblage of relatively small elements. The elements are then connected through a set of normal and shear springs located at contact points distributed along the element faces. Normal and shear springs are responsible for the transfer of normal and shear stresses from one element to the next. The hierarchical steps in demolition code is enumerated below

2.1.1 Element generation and formulation

Each object is divided into a series of elements connected and forming a mesh. The elements are connected by a series of non-linear springs representing the material behavior. There are three types of springs used in code.

- **Matrix Springs**: Matrix springs connect two elements together representing the main material properties of the object
- **Reinforcing Bar Springs**: Reinforcement springs are used to implicitly represent additional reinforcement bars running through the object without adding additional elements to the analysis
- **Contact Springs**: Contact Springs are generated when two elements collide with each other or the ground. When this occurs three springs are generated (Shear Y, Shear X and Normal)

2.1.2 Automatic element separation

When the average strain value at the element face reaches the separation strain, all springs at this face are removed and elements are no longer connected until a collision occurs, at which point they collide together as rigid bodies. Separation strain represents the strain at which adjacent elements are totally separated at the connecting face. This parameter is not available in the elastic material model. For concrete, all springs between the adjacent faces including reinforcement bar springs are cut. If the elements meet again, they will behave as two different rigid bodies that have now contacted each other. For steel, the bars are cut if the stress point reaches ultimate stresses or if the concrete reaches the separation strain.

2.1.3 Automatic element contact/collision

Contact or collision is detected without any user intervention. Elements are able to separate, contact and/or make contact with other elements. The developed code uses three contact methods include Corner-to-Face, Edge-to-Edge, and Corner-to-Ground.

3.0 DESCRIPTION OF STRUCTURE OF DEMOLITION

This paper deals with demolition of an old frozen garage having an extensive ground area of 12400 m^2. Originally, demolition was planned by owner using conventional techniques i.e. using mechanical equipment. However, after analyzing the structural stability of structure, it was observed that structure is incapable of withstanding weight of mechanical equipment proposed to be deployed during demolition. Accordingly, blast induced plan was the only technical option left for demolition of the structure. The height of the structure was 35.32m and had five storeys. The structure was built by Rahmen Construction, Seoul in 1971 for storage of frozen fishes. The size of main column was 700mmX 700mm. The floor height was 6.4 m. The height of roof from floor in each level was 6.4 m against the standard height of 3m and posed a technical challenge during demolition. The minimum stand-off distance was 12m.

4.0 DETAILS OF DEMOLITION

4.1 Surroundings

The structure was situated in a thickly populated area. The distances of various structures from surrounding is enumerated below.

- Fish market building was located 110meter away to the east
- Busy Metro station was located 227meter away to the east
- Fruit and vegetable market was located 55meter away to the south
- Railroad was located 87meter away to the south
- A construction site was located 35meter away to the west
- 2 motorways were located 24meters and 106meters away to the north respectively

The typical photograph of the surroundings, structure and scaled numerical model is shown in Figure 1(a) and Figure 1(b) respectively.

Figure 1(a) - Typical Photograph of the Surroundings near demolition site (shown in red box)

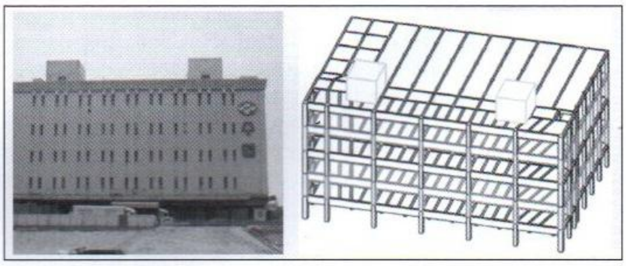


Figure 1(b) - Photograph of the structure and its scaled numerical model

4.2 Demolition plan

Based on the static structural analysis, all standard method of demolition was applied numerically and explosion plan as shown in Figure 2 was technical finalized as optimal with regard to cost, safety and time. As the closest structure was only 12 m away from the structure, it was suggested by running the demolition code that tilting of the structure will be the best technical choice over various standard method of demolition. Accordingly, non-permitted small diameter cartridge was planned for being used in 1^{st} and 3^{rd} floor on the basis of simulated sequence of optimal breakage. Based on the software output, explosion height was decided as 2.1m with four shot holes on the 1^{st} floor at height of 1.5m and four holes on the 3^{rd} floor at the height of 1.8 m. The chipping off the outer columns on the 3^{rd} floor was also suggested by the structural stability code to pre weaken the extensive structure.

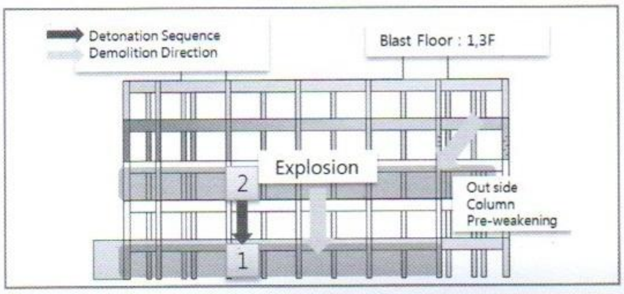


Figure 2 - Diagram showing the Explosion plan to demolish the Structure

5.0 DETAILS OF EXPLOSIVE INDUCED DEMOLITION

5.1 Pre-weakening

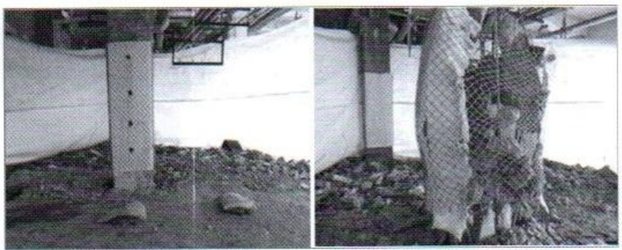
Pre-weakening means removing non-shear wall to induce smooth collapse, breaking some part of shear wall to make opening spots and weakening rebar's tension force by cutting some part of columns. Usually to maximize pre-weakening, it is prudent to increase the number of explosion spots without compromising the static structural stability of the structure. As the structure under demolition was a frozen garage, there were less non-shear walls inside the structures. Primarily, the shear walls were only in form of stairs and elevator walls. Accordingly, stairs were chipped and other shear walls were removed up to 3m from the ground level, which is little higher than explosion spot. Figure 3 shows the pre weakening of the stairs and elevator wall as per the suggestion of the numerical modelling software.

5.2 Test Explosion

Considering the charge amount for column's rebar and concrete, the program suggested to use two holes in 1^{st} column for test explosion by charging the drilled holes using 104.2g in upper hole and 83.3g in lower hole. Depending on the results obtained during test explosion, 83.3g was chosen as optimum charge amount so that optimal breakage is ensured. Figure 4 shows the results of test explosion.

(a) Pre-weakening stairs (b) Pre-weakening elevator walls

Figure 3 - Photograph showing the Pre-weakening of stairs and elevator walls



(a) Before test explosion (b) After test explosion

Figure 4 - Photograph showing results of Test explosion

6.0 DEMOLITION RESULT AND ENVIRONMENTAL EVALUATION

6.1 Actual Demolition Result

The actual demolition results with time has been shown in Figure 5 and estimated demolition results over various time period has been shown in Figure 6

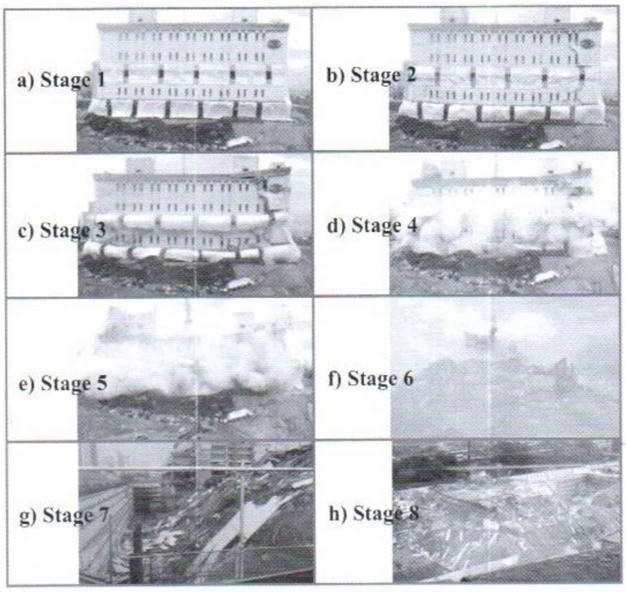


Figure 5 - Actual results of demolition recorded during stages of demolition

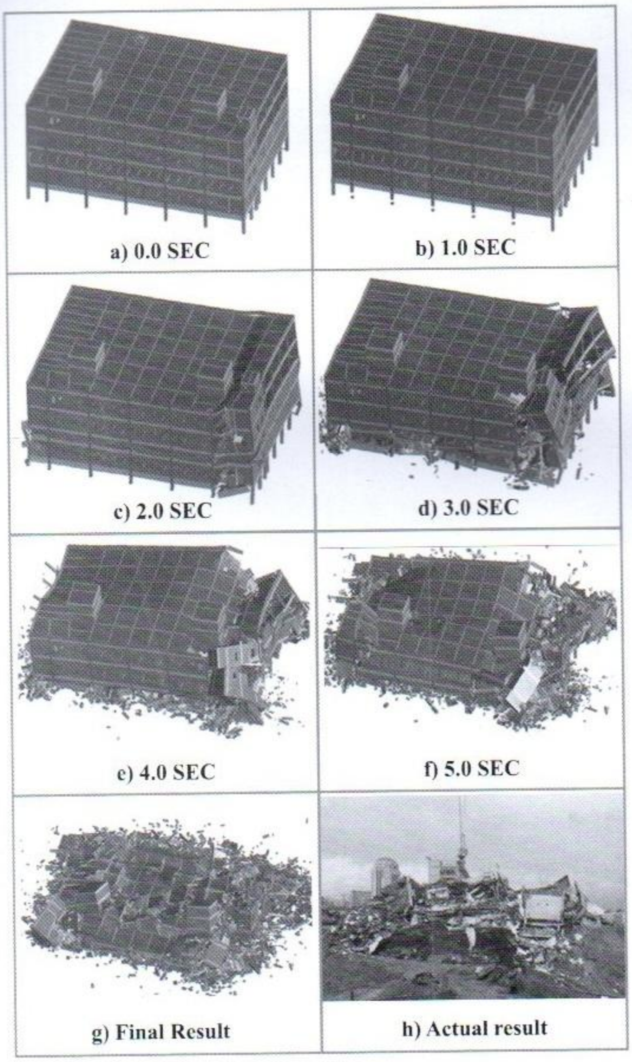


Figure 6 - Estimated results of demolition recorded over time

6.2 Environmental Evaluation

Explosive induced demolition causes noise, vibration, dust. Accordingly, timing of demolition was decided by regulators in such a way that impact of dust and ground vibration is minimum. The blasting was done at 1.20 PM (local time) and dust settled down in less than 4 minutes. The regulator had fixed different threshold value of PPV and noise in respect of few sensitive places as shown in Table 1 and the data recorded during demolition ensured that PPV and noise thresholds were met effectively. The "N/T" symbol stands for "Not triggered" stating that PPV was below the threshold limit of the seismograph.

Table 1 - Evaluation for noise and vibration

Site	Seismograph Serial No.	Results Obtained				
		X (cm/sec)	Y (cm/sec)	Z (cm/sec)	PVS (cm/sec)	MIC dB(A)
1) Motorway	11029	N/T	N/T	N/T	N/T	N/T
2) Demolition site	14014	0.029	0.035	0.119	0.120	105.6
3) F&V Market	2445	N/T	N/T	N/T	N/T	N/T
4) Railroad wall	3229	N/T	N/T	N/T	N/T	N/T
5) Fish Market	2485	N/T	N/T	N/T	N/T	N/T
6) Station 1	3264	0.013	0.018	0.010	0.018	71.6
7) Station 2	13470	N/T	N/T	N/T	N/T	N/T
8) Station 3	12118	N/T	N/T	N/T	N/T	N/T
9) Station 4	11035	N/T	N/T	N/T	N/T	N/T
10) Railroad	3503	0.051	0.025	0.032	0.051	74.2

Table 2 - Vibration Record as monitored by Seismograph

Site	Threshold set by Regulator	Actual Result	Remark
1) Motorway	0.010 cm/s	N/T	The recorded PPV was too less and Seismograph did not trigger
3) F&V Market	0.010 cm/s	N/T	The recorded PPV was too less and Seismograph did not trigger
4) Railroad wall	0.010 cm/s	N/T	The recorded PPV was too less and Seismograph did not trigger
7) Station 2	0.010 cm/s	N/T	The recorded PPV was too less and Seismograph did not trigger
8) Station 3	0.010 cm/s	N/T	The recorded PPV was too less and Seismograph did not trigger
9) Station 4	0.010 cm/s	N/T	The recorded PPV was too less and Seismograph did not trigger
5) Fish Market	0.010 cm/s	N/T	The recorded PPV was too less and Seismograph did not trigger
2)Demolition site	1.0 cm/s	0.120cm/s	The recorded PPV was 12% of the limit
6) Station 1	0.3 cm/s	0.018 cm/s	The recorded PPV was 6 % of the limit
10) Railroad	0.3 cm/s	0.051 cm/s	The recorded PPV was 17 % of the limit

Table 3 - Noise Record as monitored by Seismograph

Site	Threshold set by Regulator	Actual Result	Remark
1) Motorway	75 dB(A)	< 75 dB(A)	The recorded noise level was less than the threshold value
3) F&V Market	75 dB(A)	< 75 dB(A)	The recorded noise level was less than the threshold value
4)Railroad wall	75 dB(A)	< 75 dB(A)	The recorded noise level was less than the threshold value
7) Station 2	75 dB(A)	< 75 dB(A)	The recorded noise level was less than the threshold value
8) Station 3	75 dB(A)	< 75 dB(A)	The recorded noise level was less than the threshold value
9) Station 4	75 dB(A)	< 75 dB(A)	The recorded noise level was less than the threshold value
5) Fish Market	75 dB(A)	< 75 dB(A)	The recorded noise level was less than the threshold value
2)Demolition site	75 dB(A)	105.6dB(A)	The recorded noise was higher than the threshold but less than 110 dB(A) as per ILO norm
6) Station 1	75 dB(A)	< 75 dB(A)	The recorded noise level was less than the threshold value
10) Railroad	75 dB(A)	< 75 dB(A)	The recorded noise level was less than the threshold value

7.0 CONCLUSIONS

Explosives induced demolition has time, cost and safety advantages over mechanical demolition. Numerical techniques and simulation in demolition can prove to be a harbinger in estimating the optimal demolition plan, sequence of initiation, debris distribution, muck pile profile and safety distances during executing demolition of any structures. It may be concluded that optimal demolition plan may only be arrived by running all the variants in design of experiments(DOE). Numerical techniques in demolition can help in controlling the induced peak particle velocity, noise level and flying fragments also.

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SCIENTIFIC / TECHNICAL PAPERS

FLYROCK : FRENCH EXPERIENCE

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Editor

ABSTRACT

The work of the EFEE's Environment Committee has shown in the last few months that it is still very difficult to obtain feedback about incidents or accidents occurring during blasting operations. In France, this information should however be declared in a database managed by the State (www.aria.developpement-durable.gouv.fr), which regroups technological accident feedback.

Although everyone agrees that this feedback is fundamental for preventing probable future incidents and therefore for risk management, the incidents and their causes are still badly indexed. However, civil society, elected officials and especially residents, increasingly demand that these incidents be accounted for by public authorities, companies, and sometimes request information directly via the press or television. Unfortunately, when such situations occur, the company has a duty to provide a pragmatic response and to manage information and communication. We have noticed that the way in which these points are carried out influences the way operations are resumed and their conditions, therefore the financial costs.

We have decided to share our research office experience in incident management pertaining torocks being projected beyond site roads and quarries in France.

1.0 FLYROCK CASES IN FRANCE

Indeed, France still has some rare cases of flyrock beyond the safety zone of planned blasting area.

A number of factors particular to France could be at the root of this observation:

- It is possible that our country is one of the few that declares such cases to the responsible authority, and in which investigations are carried out!
- All types of rocks can be found in France, in all possible states of weathering
- The majority of French quarries are of a small to average size, spread over the whole territory and often close to housing. In the last few years, the development of road networks and residential housing on the outskirts of cities and villages has contributed to the arrival of residents less than 300 m from blasting operations.

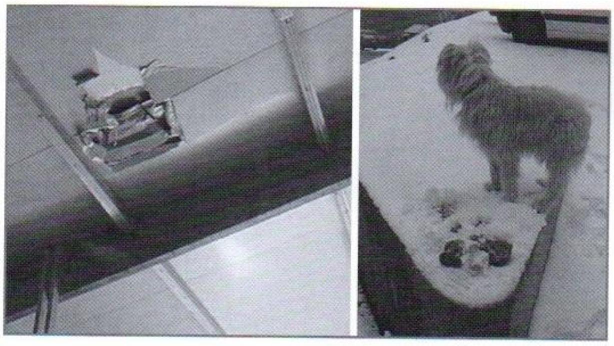
In the case of an incident involving pieces of rock being ejected from a quarry or building site, the French Administration generally orders all or part of blasting operations, and therefore production, to stop as a protective measure. Before allowing blasting activities to be resumed, the authorities require that the operator submit proposals on how to improve blasting operations and blasting control processes. Depending on the requests from the local residents mainly affected, this notably requires that the operator is able to guarantee a high level of safety for the duration of future operations.

In this case, as in the examples below which occurred over the last ten years, we become involved by way of an emergency intervention at the request of the operator, after confirmation by the relevant state department. This also implies that our expertise is paid for by the operator, unless the case comes under a judicial framework.

Example 1: Secondary school in the vicinity of a quarry with blocks landing in the playground approximately 300 m in front of the blast

In these situations, our work consists of:

- Making an independent study,
- to draw up a sound diagnosis and justify each of the points included,
- and to make proposals for the resumption of operations in the very short term,
- and for the continuation of the operating site in the long term.



Example 2: Damage to a factory roof and blocks landing approximately 200 m in front of the blast

Our experience firstly strengthened by analysing flyrock cases reported as part of the quality process for a civil explosives producer who was periodically involved in explosives implementation and blasting. This experience then developed with operators' specific requests. As time passed, we were able to study flyrock cases closely in a variety of blasting contexts, with variable levels of gravity and multiple causes.

2.0 PARAMETERS OF FLYROCK CONTROL

Flyrock, or 'wild flyrock' if we refer to the terminology used by Little & Blair (2010, "Mechanistic Monte Carlo Models for Analysis of Flyrock Risk". Sandrichian (Pub.) Rock Fragmentation by Blasting.), corresponds to the propulsion of a rock fragment of varying size over a large distance from the blast, more precisely exceeding the acceptable distance or 'exclusion zone limits' that have been determined or estimated by the blaster.

This propulsion depends on the explosive energy used, the geometry of the confining rock mass and the explosive charges as well as the way the rock mass controls the explosive detonation. The detonation timing of the different explosive charges used in the blast is also an important factor in the occurrence of flyrock in as far as it is likely to modify the way the explosive charges function and to affect the geometry of the faces developed during the blast dynamics.

Of all the parameters that make it possible to control flyrock, explosive energy and the use of delays are the most controllable. On the other hand, even if the height of the benches is generally an easily controlled parameter, it is not the same case for rock thickness around (confining) explosive charges. These varying thicknesses depend on the structure of the massif and on the orientation of the faces within this discontinued volume, on the blasting plan being adapted to these conditions, and also, on the accuracy of the drilling already carried out.

Controlling these variations mainly depends on the level of equipment used to check the burdens for every blast. But even the best type of equipment does not stop variations in the use of the system from one operator to another: for example, from which bench thickness (more or less) does an operator decide to change the explosive loading?

Initial blasting condition audits make it possible for us to quantify the explosive energy used and the variability of the geometric confinement of the charges.

Flyrock risk is therefore linked to controlling these different parameters throughout the entire operation.

3.0 THE RIGHT REFLEXES IN THE EVENT OF INCIDENTS RELATED TO FLYROCK

The process of carrying out an investigation must begin promptly after the incident, in particular so as to record the impacts, if they are numerous, and information pertaining to the projected blocks in detail (figure 3). This fundamental step should be carried out rigorously, but this task is often made difficult because the operator has the internal and exterior roadways cleaned up quickly, (which can be understood) without necessarily locating the impacts or preserving the blocks. In the last few years, the wider application of electronic photographs has become a good ally when recording information, but this alone cannot suffice. In the best cases, it had become an established routine to take a video of the blasting systematically: if the video frame covers the whole blasting zone, the number of hypotheses regarding the mechanisms of the cause of the flyrock can be reduced considerably.

All this information is very important as it allows the flyrock to be mapped, to link the blocks to a particular area of the rock mass, and to propose the most probable reasons for the incident.

The purpose of the on-site investigation is therefore to record:

1) the position of the projected rocks the blocks
2) the characteristics of
3) the blasted rock mass
4) the actual positions of the blast holes
5) the actual charges
6) the succession of drilling-blasting operations and the materials used.

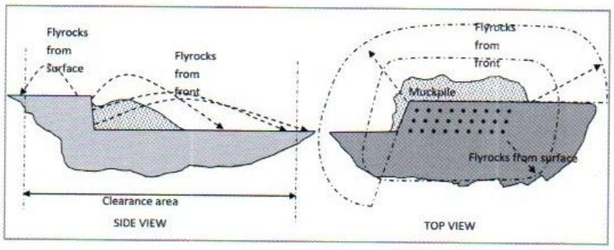


Figure 3: Zones affected by flyrock resulting from blasting

This information completes the more general data:

- Theoretical and implemented blasting designs
- Planned drilling and blasting equipment
- Procedures for drilling-blasting and evaluation
- Timing scheme
- Previous blasting designs baked up by measurements of their impact (vibration and overpressure/flyrock)
- Residents and their activities

The blaster is the person incriminated immediately following the incident. In these situations he is responsible for the whole blasting operation, since in France, even if he is not the designer, he is responsible for the final adaptation of the blasting design in order to respect internal procedures (set up, loading and priming and safety clearances).

His presence, time and expertise is required after the incident and he must collate all the technical evidence (state of the faces, drilling report, details of the loading and priming, detail of the explosives used, a possible 2D or 3D survey, evaluations of the drilling deviation, bench thicknesses, misfire handling procedure).

All of the assembled data is then analyzed in order to draw up a list of the possible to probable causes of the flyrock that exceeded the expected safety zone (diagram 4).

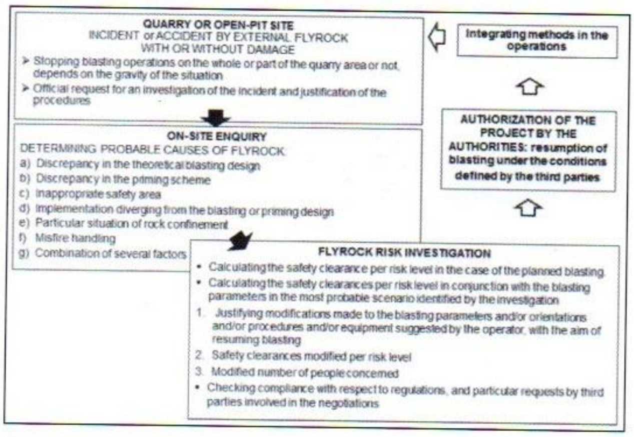


Diagram 4: analysis process of an accidental flyrock incident and conditions of blasting resumption.

4.0 JUSTIFYING THE RESUMPTION OF BLASTING "UNDER ACCEPTABLE CONDITIONS"

Considering the urgency to provide a quantified flyrock risk report to the authorities and to be able to resume quarrying operations promptly, there is a great temptation to set up flyrock calculation and checking tools for every blast.

But the computational tools of isolated blasting operations, even very sophisticated ones, do not take into account the variation in the functioning of explosives, blasting geometries or charge confinement, there being so many different parameters which are the source of flyrock risks during operations.

In addition, day-to-day blasting calculations do not make it possible to anticipate future risks. This situation cannot satisfy the residents or the authorities, neither can it help the blasting organization to diminish their risk over the long term or to control costs.

Therefore, we have fine-tuned statistical studies resulting in calculating the definition of safety clearances depending on the initial flyrock area (originating from surface or the face).

5.0 IMPACT PROBABILITIES

Our studies use a method of calculation that takes into account the parameters and the associated variations: it was described in several international publications (see A. Blanchier, Quantification of the Levels of Risks of Flyrock, Proc. ofISEE Conference 2013)

By using the blasting parameters and data specific to the operation, the model makes it possible to determine successively:

- the distance of maximum flyrock for each hole depending on the level of probability;
- the probability that a person be impacted by flyrock from this hole;
- the annual probability of impact.

6.0 RISK AND ACCEPTABILITY

In classic risk analyses, the probability of an accident occurring and the effects of this accident on people are analyzed separately. These effects decrease in relation to the distance from the accident area.

In the case of accidental flyrock, the triggering factor is the blasting, meaning that this incident is not random. In addition, the effects of flyrock do not decrease with distance: a 200- gram projectile can be fatal at 20 m, as it can at 1,000 m.

Consequently, the approach to risk is noticeably different from those of other hazards: the effect of flyrock does not change markedly according to the distance; it is only the probability that changes.

In fact, the risk of fatality, being the product of the probability of an accident per the fatal probability in a defined danger zone, knowing that an accident has occurred, corresponds in our case to the probability of impacting a person at a given place, presuming that each impact is fatal.

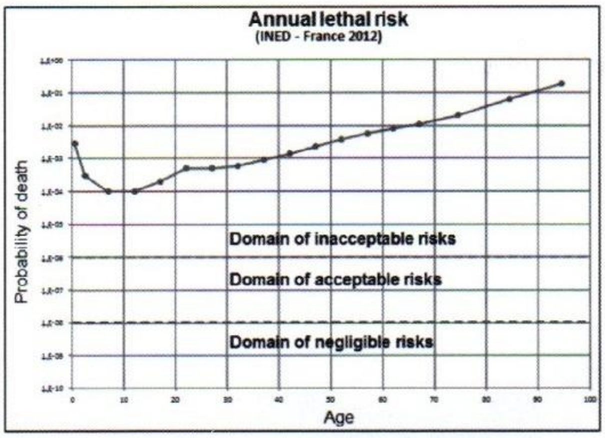
These risks are compared to the risk of annual 'natural' mortality. In the case of France, the probability of death is given in Graph 5. The values are similar to those from other European countries.

The lowest annual risk of death (between 5 and 14 years of age according to French statistics) is in the region of 10^{-4}. Added-on risks that increase the probability of death by less than 1 are considered as being unacceptable. Levels of negligible risk can also be defined.

In this way, the NATO rulings integrated in the main into different European regulations accept a maximal risk of 10^{-6} for the external environment. These limits are reinforced for areas with a high-density population for which the maximal risk of 10^{-8} is generally accepted.

Flyrock leading to significant effects on people only leads to minor damage on infrastructures:

The main risks are indeed risks of glazing breakage or damage to roofs or unsteady partitions.

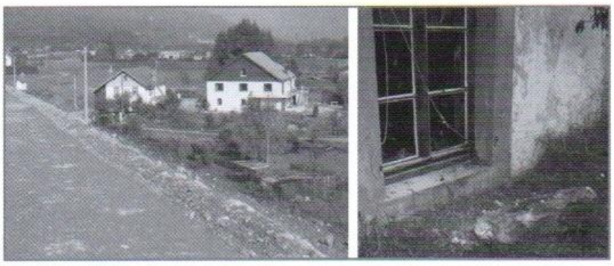


Graph 5: Probability of death in France - INED 2012

7.0 UTILIZATION OF IDENTIFIED FLYROCK CAUSES UNDER CONDITIONS OF BLASTING RESUMPTION

Initially, our calculations were carried out in studies of incidents to compare the risks originating from the theoretical blasting design and those affiliated to the real blasting designs, which were reconstituted after investigation. We run a simulation of the situations under consideration based on gathered evidence: the data entered into the calculations is information from real blasting operations and it is understood that the logical continuation of the analysis consists of proposing adapted modifications to the procedures of these operations and/or to the blasting parameters, depending on the causes of the incident, with a quantified justification of their effectiveness.

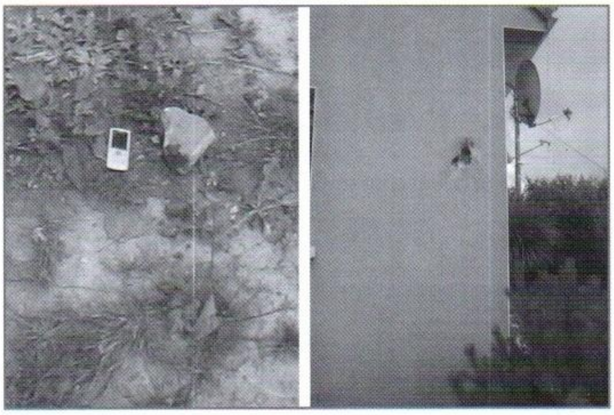
Proposals of conditions to resume blasting are all the more relevant, as the information retrieved on site is precise and thorough: the operator therefore may find it beneficial to cooperate as soon as the data-gathering begins, in order to then find an acceptable solution for the operations or the site.



Example 5: Houses bordering a site road and blocks projected onto the frontage approximately 200 m from the blast

Any person having experienced an incident linked to blasting outside the operating site involving the intervention of a third party, apart from official representatives of the State, can testify to the complexity added to "crisis recovery". Indeed, different actors become involved in the bounds of comprehensible safety requirements, but these are disconnected from the regulations and technical rules specific to our field.

It is at this time that the independent design office that we are and the statistical method chosen, have their full use in establishing a climate of confidence, in justifying the technical blasting choices and in supporting the resumption of blasting operations, if this is requested.



Example 6: Blocks landing in a field and another impact on a dwelling more than 430 m from the blast

8.0 ANTICIPATION OF THE RISKS FOR EFFECTIVE PREVENTION

In the last ten years in France, we have seen methods for evaluating risk in industrial activities as a whole become generalized and harmonized, and this has led to flyrock risk studies becoming formalized in the initial stages of a project using explosives.

Our flyrock investigations inevitably begin by examining the actual or planned blasting conditions. This includes not only drilling equipment, the choice of explosives, priming and geometrical parameters, but also methods for evaluating these parameters and the teams' working methods.

Diagram 7 describes the process of a flyrock risk study in blasting operations in the case of extraction which is in progress or planned. It results in checking compliance with the legal blasting requirements established in the local context. It is not only the people concerned and their activities which are taken into account, but also the nearby facilities and infrastructures depending on their respective strategic importance.

These studies, undertaken in the early stages of the works when the operating schedule is being organized, when procedures are being drawn up, when the choice of equipment and the last negotiations with local public bodies and project supervisors are being discussed, reduce the risks and contribute to a better cohesion between all the stakeholders during the operational working phase.

At this stage, choices to be made often concern the orientation of the faces which would be advantageous to risk management when considering external activity, adapting the height of the benches, programming the closure of a road during the blasting phase, or more simply deciding on a higher top stemming after having checked that the charge does not lead to a blasting dysfunction.

Once the highest risk levels have been reduced during the operations, the blasting manager can focus on the residual hazards, such as the modification of confinement around the charges (through a variation in the quality of the rock or in its structure, for example), a change of explosives or initiation system, or an operator or a type of equipment.

When modifications call the calculation hypotheses into question, prompt, complementary investigation is necessary.

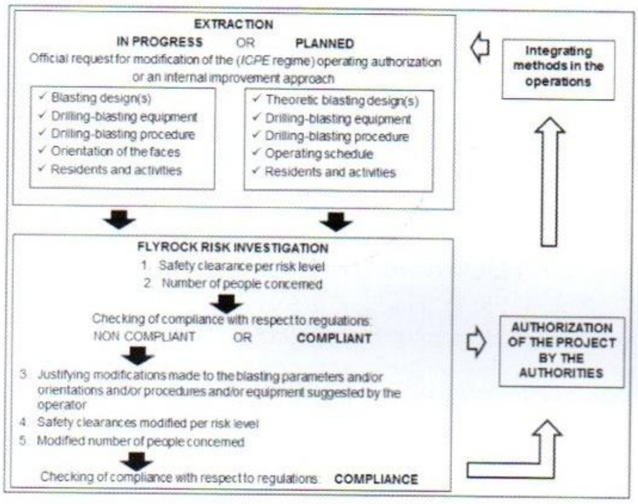


Diagram 7: Process of flyrock risk study and blasting conformity study with respect to regulations pertaining to environmental risks.

9.0 CONCLUSION

Without the experience of detailed analysis of the origins of flyrock beyond the safety zone, the work relating to the prevention and justification of controlling the risks would have been much more difficult to promote in critical blasting situations.

Declaring an incident such as flyrock, analyzing the causes of the incident and justifying a new organization, are industrial processes that are commonly used in other sectors.

Thanks to accident prevention practices in the pyrotechnical sector, there is a very small number of accidents in our profession, in the opinion of our parent ministries themselves. Flyrock does not occur frequently, however, each time it does take place, it can have significant consequences and occur over a large distance. Consequently, it has a strong impact on the perception of explosives use.

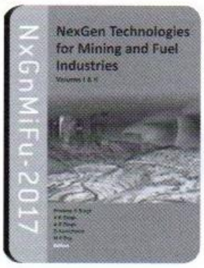
With risk level computational tools now being available, no one can be satisfied with studying these cases without working on a daily basis towards their prevention.

Over and above dealing with a specific incident, preventing flyrock risk requires that this aspect of the environmental impact of blasting be explicitly integrated into blaster and blasting designers training, as well as into regular meetings on work safety organized in accordance with labour legislation.

All technical elements that make it possible to improve the control of blasting parameters and confinement can contribute to reducing flyrock frequency.

However, our experience enables us to assert that an increase in blasting technicality (e.g. carrying out 3D surveys of the faces coupled with measuring drilling deviations, or putting in place electronic priming that are easier to implement and presenting results on a more regular basis) does not solely guarantee an absence of flyrock, neither does it alter its range of projection. It is necessary to identify situations at risk in the early stages and to work in anticipation of eliminating occurrences at a critical range.

TECHNOLOGY ABSTRACTS



Selected Abstracts from the Proceedings of the NexGen Technologies for Mining and Fuel Industries, Vol. I on 15-17, February 2017, New Delhi, India

Digitization in Excavation Process of Iron Ore: A Case Study

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Abstract

*Excavation process in mining industry basically consists of drilling, blasting, loading and hauling. These activities are supported by short and long term planning and scheduling based on the quality of ore and as per the requirements of customer. Surveillance of excavation process in mining industry is a major challenge which results in loss of production, productivity, safety and deviation in quality standards. GPS based system is the only feature available but it is too costly and its maintenance has always been an issue as spares availability and replacement takes long time. The paper highlights an advanced in house developed technology for continuous monitoring of excavation process. The main purpose of the study is to develop a cost effective and standardized monitoring system suitable for Joda East Iron mine. The idea behind this project is use of vehicle tracking system in mining industry. With this concept, the position, location, speed, cycle time, speed violation, operating hours, idle hours, breakdown hours etc. can be monitored. But for a mining industry, the problem lies in tracking the position of vehicles as per the excavation plan. Compliance to feed schedule as per the excavation plan is important in order to conserve minerals for sustenance and adaptability. Excavation plan was first geo-referenced and then it was integrated with the system software which is based on the Google mapping process. For integration, the excavation blocks were converted into 10*10*10 block model. It was then scheduled in XACT software for scheduling the material plan as per quantity and quality. These blocks when scheduled were further converted into kmz file. Further to add on this system drilling plan is also integrated. In the drill machine this feature has been installed, any deviation in the excavation plan would result in pop-up symbol and same will be communicated through message or audio visual signals. This feature has resulted in exact scheduling of waste and ore feed able in plant and thus helping in mineral conservation and adding value through cost effectiveness. The project has led to increase in tonnage and aerial excavation compliance. The cost of installation and maintenance is very cheap. It has resulted in productivity improvement of HEMMs. A significant improvement has been achieved in relative utilization percentage. A net savings of approximately Rs. 5 crore. per annum has been achieved.*

Some Technological Requirements of the Opencast mines of India in Near Future

Avtar K. Raina and R. Trivedi
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Abstract

Benching is an important aspect in opencast mining. India, with the emphasis on achieving one billion ton coal target is set to have an enhanced focus on opencast mines. Such mines have two major issues that have direct fore-bearing on the sustenance of the productivity. These are fragmentation and slope stability. Stability of benches and overburden dumps is an ever growing concern in such mines since the slopes have to be stable during and after the excavation. The slope domain involves a detailed analysis of their stability, continuous monitoring with best possible equipment and instrumentation and simulation techniques. The second aspect in such mines is fragmentation as it determines the downstream costs or system performance. Optimization of mine-mill fragmentation system is going to be one of the core issues, and since determination of blast fragment size is fundamental to this, it will require quite a few technical advancements. This will be in addition to an onsite mechanism for blast design and evaluation. The near future will provide lot of challenges for the scientists and technologists in the arena of opencast coal mining. The solutions that will be required will have to be developed on budget and on time to match the demand. This paper pokes into the details of such requirements on the above two aspects.

Optimization of Dragline Working Parameters for Enhancement of Cut Advance rate, while Ensuring the Safety and Economics of the Mining Operation : Case study

Tapas Kumar Nag, Manish Kumar and Ajit Kumar Choudhary
NCL, Jayant, Singrauli

Abstract

Burgeoning coal demand of the nation has been associated with the corresponding increase in the size and depth of the opencast mines. The deeper coal deposits have necessitated the handling of large volume of OB, resulting in formation of huge waste dumps. A dump slope failure could, besides being disastrous to life and machinery, affect the mine economics remarkably. In view of the constraints to acquire large tracts of land for open cast mining, high and stable dump slopes has become a matter of concern for smooth production and better economics of a mine.

Due to operational advantage of dragline, in simultaneous excavation and back-filling, draglineis preferred in the flatter coal deposit of large opencast mines of Northern coalfields limitedSingrauli. Draglines in NCL, are deployed to expose the bottom most coal seam (Turra seam), which is a thicker seam and have a higher calorific value.

Steeper dump slope angle in the dragline working, favor the economics of mine operation. However the slope must be flatter in order to make it safe and more secure against sliding. The point of concern, while planning for dragline working is to derive a common line between safety and economics of mining operation working of draglines at Jayant OCP of NCL, was found to be associated with higher dumps and lower rate of cut advance. Reduced rate of dragline cut advance have a consequent effect of reduced percentage of bottom seam (Turra) coal extraction, thus affecting the overall quality of coal dispatch of the project and space constraint for transport dump, thereby, affecting the operational efficiency of the mine.

The paper deals in optimization of dragline working parameters so as to find a satisfactory compromise between the conflicting requirements of flatter slopes and optimum re-handling of overburden by dragline while ensuring the increase in rate of cut advance, so as to create substantial space for transport dump and also increase the percentage of bottom seam coal (higher grade coal), in the overall coal production of the mine.

Evaluation of Quality of Explosive Products of Different Manufacturers at SCCL

Sanjay Kumar Roy and Rajeev Ranjan Singh
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Abstract

Breaking of coal and rock in most of the opencast mines in India are presently done using explosives and accessories. Most of the public sector undertaking companies producing coal like SCCL purchase explosive products from different manufacturers on lowest quotation basis. Quality of 328 sample of explosives and accessories supplied to SCCL by different manufacturers for use in opencast mines were evaluated for different parameters to check their conformity to desired values as specified in purchase order. Analysis of test results revealed that about 58% of samples failed to meet the requirement of at least one quality parameter. All samples of nonels and cord relays containing pyrotechnic delay elements failed to meet the requirement of delay timing parameter which can lead to out of sequence firing of shot holes. Moreover, some of the explosives and accessories samples failed to exhibit satisfactory firing characteristics which may result in misfire of shot holes.

Safety Management Plan for use of Bulk Explosives in Opencast Mines

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Abstract

The burgeoning rise in coal and other mineral production in India had not only laid emphasis on developing huge infrastructure facilities to handle with the engagement of large capacity excavation, transportation and material handling systems in our mines. This has also given rise to the large scale use of huge quantities of explosives and blasting accessories in excavations all over. The rise in explosive use is also simultaneous with the growing emphasis on eco-friendly blast design, optimum blast design and safe blasting operation. The safety in our blasting operations are largely due to the effective regulations in place, coordinated effort of the regulator with mine management and explosive manufacturers and all other stakeholders. India could achieve best safety records in blasting owing to several steps adopted in mines and support facilities. An attempt has been made to highlight various aspects of safe use of explosives (including bulk SME) and also development of a safety management system for opencast mines.

Energy Factor: Blast Fragmentation

P.V.S. Sarma, A.D. Sao and N. Vidyasagar, *IDL Explosives Limited*

Abstract

Opencast mining industry in India today uses over 650000 MT explosives per year, to extract minerals like coal, limestone, bauxite, iron ores, lead and zinc ores, copper ore, embedded in earth's crust. To extract minerals embedded in rocks, mining industry needs to break and move waste rock to the extent of 3–12 times the mineral produced. The operational safety, productivity of Heavy earth moving machinery and mining costs are largely governed by fragment size generated. Thus Blast fragmentation becomes an important, relevant, and not -ignorable aspect of mining. As the industry encounters rocks of different breaking strength's (5–300 Mpa), the industry need explosives of different energy values so that quantity of explosive usage remain less. To differentiate types of explosives, energy content of explosives, expressed in kilo calories per kg, comes into play. The rock strength in Indian coal mines vary from 5 MPA–60 MPA, in Iron ore mines from 50–300 MPA, In Granite from 120–300 MPA. Indian coal mining industry is using an energy factor of 200–250 Kcals/cum, Indian Metal mining sector is using energy factor of 550–600 Kcals/cum, whereas Indian quarrying industry uses energy factor of 800–900 Kcals/gm. Today, in the absence of data on energy content of an explosive, the mining and quarrying industry is using a term called charge factor (CF- Kgs/cum) for deciding charges required to break rocks to desired fragmentation. When we know energy of explosives (Kcals/kg), we can use energy factor (EF - Kcals/cum) for deciding the charges. The energy factor can be derived as CFX Product energy i.e., Kgs/Cum X Energy/Kg = Energy/Cum. Clear understanding and appreciation of Energy factor, is the biggest enabling factor in blast design. In this experience, author's combined experience as a developer, manufacturer and service provider is narrated.

Optimization of Blast Design Parameters for Reducing the Social and Economic Impacts during Operation in Large Opencast Mine : Case Study

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Abstract

India has reached the forefront of world coal scene, largely due to rapid increase in contribution from opencast coal mines. The share of dragline operated opencast mine is also more than 45% of total coal production by opencast mining in India. But India with a very large density of population, is in a very disadvantageous position in acquiring large tracts of land for opencast coal mining with the concurrent problem of depletion of forest area, resettlement and rehabilitation of people affected by opencast mining projects.

Jayant OCP of NCL, exists in close proximity (about 500 to 600 m) of Medhauli village of Singrauli district (MP), and complaints related to blasting vibrations, from the state administration is a point of important concern. At the same time, deployment of large draglines and large capacity shovels at Jayant requires, deep hole blasting with high explosive consumptions. In such circumstances, reduction of surface ground vibration in the area of dip side dwellings of the mine, while ensuring the efficiency of mining operation by proper fragmentation of overburden, has become a challenging task for the blasting team of the project.

The study for reduction of ground vibration, involved experimental blasts in dragline and large capacity shovel benches, using electronic detonators, on account of its advantages in providing precision delay and maximizing the utilization of explosive energy. Blast design parameters, including programming of electronic detonators, were varied for different blasts of dragline and shovel benches, during the study, to find out the resultant profile of ground vibrations at strategic locations in the Medhauli village. 'Stemming retention' observed in the deep hole blasting, even for a few milliseconds, has demonstrated better utilization of explosives energy, resulting in finer fragmentation and better heaving action (loose muck piles).

The paper deals in optimization of blast design parameters, while using electronic detonators for deep hole blasting, for minimizing the surface ground vibration around the dip side dwellings, with a view to mitigate the social and economic impact of mining operation.

Blast Design and Fragmentation Control using Next-Gen Technological Tool-electronic Detonators

P.V.S. Sarma and A.D. Sao, *IDL Explosives Limited*

Abstract

Rock blasting need in India is growing, particularly in coal industry and rock metal generation industry. The annual demand for coal and rock metal is going to be 1000 and 1200 million tons respectively in next 5–6 years. The stripping ratios in in many new large coal mines is going to be large say 1:6 and the operating depths going to be +200 Meters. All the above factors indicate, rock blasting need is growing in India. It can also be seen from growing demand for explosives, more particularly bulk explosives. Thus the importance of Blast design principles for fragmentation control, such as energy distribution (in the blast block and blast hole), energy confinement, energy release is more pertinent.

In the opencast mines and rock quarries, the most important requirement is to get defined fragment sizes with less boulder count and with good control on breakage line. Another key issue is, to lessen the number of blast events per year. The negative issues, needing control are containing fly-rock to 10–15 meters distance (from blast block), containing ground vibrations (PPV and frequency) to lay down standards, controlling throw to defined levels. Blast design principles play a key role in fragmentation control and control of negative issues. Today, the blast design engineer is seriously constrained by the limited range of delay times and less accurate delay times. Usage of next-gen initiating technology-electronic detonators increases the scope and control for a blasting engineer. The real time blast results (like fragmentation and breakage line control), observed in open cast mines of India, while designing blasts using electronic detonators, is being shared in this Paper.

Rapid Advance using Underground Bulk Emulsion

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Abstract

Rapid development is key to any mine's performance. Optimizing drill and blast parameters is important to accelerate the development rate of a mine. The parameter that is central to drill and blast practices is explosives. Selecting the correct explosive gives the mine leverage in achieving desired outcomes. Underground bulk emulsion is one such advancement in the explosives technology.

Over the past decade, underground bulk emulsion has established itself as a highly preferred alternative to packaged emulsion/ANFO in the global hard rock mining fraternity in terms of safety, rapid advance benefit, inventory control and mechanization of blasting process. 100% coupling and excellent water resistance differentiates this product from the rest of the explosives range used in development blasting.

Powerbulk™, the trade name of Orica's underground emulsion product, is an water in oil non explosive emulsion matrix developed for development and down hole applications in hard rock underground mining. It is opaque grease like substance loaded into blast holes using specialized delivery system named the Maxiloaders™. Maxiloader™ is an intrinsically safe delivery system developed by Orica. The pump is designed to externally sensitize the non-explosive emulsion matrix using appropriate gasser solutions. The ability to add gasser solution externally allows for use of different product densities for different blasting application. This provides certain flexibility in blast designs.

With such marked benefits, the product was introduced for the first time in Indian Mining at Sindesar Khurd Mine, Hindustan Zinc Limited in 2014 followed by Rampura Aguha Mine in 2016. Powerbulk™ drive was used in conjunction with Exel™, Orica's Non-electric initiating systems. The designs for development rounds were developed using ShotPlus-T™, Orica's proprietary blast design software. Both the mines are geologically very different. The two primary performance measures agreed between HZL and Orica were a) advance per round b) charging time.

A combination of customized drill and blast patterns, designed using ShotPlus Powerbulk™ Drive and Exel™-T, along with delivered faster advance rate. An improvement of 10% in advance per blast round and a reduction in charging time of 67% were observed with implementation of underground bulk emulsion. The corresponding consolidated cost benefit for the mine with the introduction of this technology is estimated at around INR 130 Mn (A$ 2.5 Mn).

Fracture and Fragmentation of Rock from a Mining Perspective: A Review

B. Mohanty
Lassonde Institute of Mining, University of Toronto, Toronto, CANADA M5S 1A4

Abstract

R This paper analyzes rock fracture under dynamic loads and resulting fracture and fragmentation behaviour in the light of rapid advances made in associated technologies in mining and excavation operations. The dynamic loads under consideration would be due to impact and explosive loads; the former applicable to drilling and crushing and the latter to explosive loading for blasting of rock. The essential difference between these two types of loads is described, and the methods to achieve these conditions in both laboratory-scale and small-scale tests are outlined. Some key parameters in describing the response of rock to such loads are shown to be 'dynamic' strength and the resulting fracture patterns. The measurement of these parameters under these varying load rates (i.e. 'strain-rate') in selected rocks under controlled laboratory conditions is described, and their dependence on prevailing strain-rate analyzed.

The two experimental techniques employed for quantifying the behaviour of target rock under these conditions are the Split-Hopkinson Pressure Bar (SHPB) technique, and small-scale singlehole blasting tests under varying explosive loads and borehole coupling conditions. The results of small-scale experiments involving both medium strain-rate (i.e. drilling and crushing) and high strain-rate (i.e. blasting) are described. Quantification of resulting fracture and fragmentation characteristics for a range of load characteristics (e.g. impact velocity, explosive load, and borehole coupling conditions) under both types of loading is detailed for selected rock types. The current predictive approaches employing advanced numerical codes for fragmentation and size distribution are outlined. It is shown that until the fundamental fracture properties of the target rocks under prevailing load rates have been taken into account, the best that can be achieved to date for prediction of blast results will remain largely qualitative.

Studies on Properties of Unwrapped Explosive to Improve Blasting Performances: A Case Study

B.M.P. Pingua[1], **N.K. Bhagat**[1] **and R.R. Singh**[2]
[1]*Rock Excavation Engineering Division, CSIR-CIMFR, Dhanbad, India* [2]*Explosion and Explosives Section, CSIR-CIMFR, Dhanbad, India*

Abstract

Site Mixed Emulsion and ANFO explosives are extensively used in excavation projects. These are unwrapped explosives and directly loaded into the blast holes for blasting the rock. The use of site mixed emulsions is increasing day by day because of its excellent water resistant properties. Whereas, ANFO cannot be used in watery hole conditions due to hygroscopic nature of ammonium nitrate. It is only preferred for dry hole blasting. Jhamarkotra is a fully mechanized rock phosphate mine. It is the biggest and high grade phosphorite deposit mine located about 30 km from Udaipur City of Rajasthan. The site mixed emulsion and ANFO explosives are being used for excavation work in Jhamarkotra mines. The total consumption of explosive in this mine is approx. 3200–3400 ton per annum. The hole diameters of the blast holes were 110 mm and 160 mm and their depth varies from 11 to 13 m. Most of the blast holes were watery up to 2 to 3 m. Watery holes required good quality of emulsion explosives to achieve optimum blasting results. Similarly, good qualities of ammonium nitrate prill have its own importance in producing better quality of ANFO to release higher energy during detonation. Explosive parameters like density, viscosity, VOD, water content in premix and water resistant properties of site mixed emulsion were studied. The detonation velocity of emulsion explosive measured in unconfined conditions which vary from 4400 to 4600 m/s. The velocity of detonation of site mixed emulsion explosive reduces and found in between 3500 to 3600 m/s in hydrostatic pressure head. Explosive properties like density, VOD, Porosity and Oil absorption and retention capacities of Ammonium Nitrate Prills were studied for ANFO explosive. This study may help the opencast projects to select the good quality of site mixed emulsion and ANFO explosive for toe clearance, fragmentation improvement and reduction in blast failures as well as secondary breakage

Fragmentation and Muck Profile Control at Big Opencast Mine with Minimum Vibration Level

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[2]*Moher and Moher Amlohri Extn. Opencast Mine, Sasan Power Limited, Singrauli, India*

Abstract

The paper deals with a systematic blasting study conducted at one of the largest coal mine of India and subsequently to determine optimal blast design parameters for deep Dragline benches (45 to 60 m) and shovel benches (15 to 20 m) for better fragmentation and suitable muck profile with minimum vibration level. When the blasting of a rock is performed, interactions occur between rock mass properties, explosives properties, blasting geometry and the detonation timings. A more optimised use of resources requires a better understanding of these interactions. Extensive field studies have shown that blast fragmentation and suitable muck profile influences the performance of downstream processes in a mine, and as a consequence, the profit of the whole operation can be greatly improved through optimised fragmentation. Blasting parameters have to be adjusted according to the desired fragmentation level especially and muck pile profile on the mines to ensure optimal use of loading equipment. In view of the above a study was conducted at Moher and Moher Amlorhi Extn. Opencast Project of Sasan Power Limited in India who has committed to produce electricity at the rate of hole VOD of different explosives was determined and placement of boosters was standardized. The signature blasts were conducted to optimize the delay interval between the holes in a row and between the rows. The optimized burden and spacing were decided for dragline and shovel benches considering the available drill machine of 311 mm and 259 mm respectively. Rock fragmentation analyses were carried out for each blast using photo-analysis system. The blasts resulted with excellent uniform fragmentation. The efficiency of loading equipment was enhanced significantly. ` 1.19 per unit. Thirty nine blasts were conducted with varying blast design and charging pattern at Dragline and shovel benches of the mine. In-the

Plasma Blasting Technique (Blasting without Explosives)

S.P. Singh, *WCL, Nagpur, India*

Abstract

This paper highlights the role of Plasma blasting Technique which includes low energy cost, high productivity, long equipment life and lower mining cost. This method is reliable and efficient and the simple operation this technology can be used in opencast for soft and hard rock blasting, blasting of coal, and secondary blasting for big boulders without generation of fly rocks. The method can be also used for blasting in hot strata where charging and blasting of explosive pose serious safety hazards.

The Benefits of using Electronic Detonators in both Opencast and Underground Mines

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Abstract

The development of programmable electronic delay detonators started in the early 90's, with rapid improvements to the detonator's reliability and programmable features during the mid to late 2000's. The product offering expanded to include pre-programmed, semi-programmable and fully programmable electronic detonators, with more capable control equipment which offer several methods to initiate the detonators from a point of safety.

The Mining Industry has had exposure to electronic blasting systems since the early 90's, with the adoption rate being different between sectors in the industry. The cost of electronic detonators, compared to those of non-electric detonators, presents the most significant obstacle for Mine Managers to adopt this technology. In addition to this, the real benefits of using electronic detonators have also not been quantified and documented properly over the years.

The use of non-electric detonators have always been restrained by its reliance on:

- *limited number of delay periods*
- *limited burning front*
- *risk of overlap due to scatter and delay accuracy.*

These "shortcomings" place some constraints on the blast design and implementation, which might result in multiple misfires under certain conditions. When a blast is initiated using non-electric detonators, one will not necessarily know if there has been any misfires until the blasted material is being loaded.

Electronic detonators offer a series of benefits to the end user, of which safety is the most important benefit. The concern around safety is addressed by several of these benefits, of which the most understated benefit is the availability of information, when using electronic detonators. This paper will serve to update the Mining Industry regarding the array of benefits when using electronic detonators, with the objective to show how the user can offset the cost of using electronic detonators against the benefits gained from using electronic detonators appropriately.

Identification of Extent of Blast-induced Crack Development using Ground Penetrating radar (GPR)

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[2]*Department of Mining Engineering, Indian Institute of Technology, Kharagpur, India*

Abstract

Uncontrolled drilling and blasting technology used for excavation of underground openings damages the surrounding rockmass due to generation and widening of cracks. Stability of underground excavation for these cases is one of the burning issues in Indian mining industry. Assessment of the extent of these crack networks is difficult and often neglected. One of the most common techniques for assessing the blast induced damage is ground vibrations measurement and its analysis for possible prediction of damage extent (Dey, 2007, Yang et.al 1993). Most of these vibration based predictors are developed from the measurement of actual damage extent using some geo-physical tools, namely, P-wave velocity (Tezuka, 1995), seismic imaging (Dey, 2011), bore hole pressure monitoring (Brent and Smith, 1996), electrical resistivity (Grady and Kipp, 1993), GPR (Adams et.al, 1993) etc. Ground Penetrating Radar (GPR) is a geo-physical tool, which use the Electro-magnetic (EM) pulse for characterizing the medium. This instrument essentially contains a transmitter and one/more receivers to generate the EM pulse and receive the same after reflection/refraction from the medium(s). Thus, it is felt that GPR technique can be used to detect the invisible cracks inside the rockmass.In this paper, a review of the GPR technology and its use for determination of the extent of blast-induced crack along the roof and wall of the blast site is discussed. Field study is carried out in an underground manganese mine in Central Indiaextended up to a depth of 300 m and operates on the =cut and fill' method of mining. Wedge cut blasting is carried out in the horizontal drifts of the mine using suitable blast design. A 1.6 GHz antenna was chosen in order to demonstrate clear reflection from the walls and roof. The signals sent from the ground penetrating radar transmitter gets reflected back from any type of interference between materials in the target area, with different dielectric properties and is received by the receiver part of the =trans-receiver' antenna and displayed in the Data Acquisition Unit (DAU) leading to the determination of the position of the cracks. The data acquired is processed using RADAN 6.6 software. A prediction model has been developed on propagation of the radar waves through the different layers (i.e. the cracks and alignment of joints) of the mine walls and roof. The 4 strata layer has been considered and the angle of incidence was found to have insignificant effects on the solution (Loulizi, 2001) the model is developed assuming normal incidence.The corresponding joint sets are seen in the radargram as =projections'. It is found that the cracks that have been interpreted as the black and white patches. The black and white contrasts accounts for the drastic change in the dielectric constants of the surrounding medium (i.e. Rock mass) and the air filled cracks. The cracks seem to orient in a pattern in this case. Processing of the GPR signal data provides image of cracked zone profiling and indication of the presence of joints which is also helpful for the blasting engineersfor proper placement of explosives to achieve optimum pull. The paper also discussed the use of GPR for crack profiling and estimation of threshold level of vibration for damage zone.

The Chemical Factors of Explosives used in the Mines, Quarries and Tunnels in Slovakia

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Abstract

Rocks engineers designs to perform blasting of rock with utilization of detonation energy in underground and surface mining. Different kinds of gelatine, emulsion and granular safety explosives are being used in mineral extraction industries and tunnels excavation at present in Slovakia. Above mentioned groups of explosives are commonly initiated by using electric or Non-Electric (NONEL) system. In our country, the electronic initiation system is used for blasting in only few places. The explosives and detonators are utilized by short-range and large extension blasting works as well. The application of explosive products mentioned above includes dangerous components that are effecting on the health of workers and blasting surround too. The harmful influences of explosives are demonstrable at site of blasting works performance and in stage of explosives production. It is possible to specify Hazardous Chemical Factors (HCHF) from the structural elements of explosives and detonators. Alike is possible to define the certain risk degree for each explosive hazardous substance in the both explosive and detonator, that entail health threat and safety work hazard. By analysis of the all chemical factors in selected types of explosives and detonators, risk of dangerous substance for case of handling with products have been evaluated. Listing of hazard chemical factors has been composed on the basis of complete tests of some selected blasting agents. Optimum operating conditions for handling with blasting agents products have also been simultaneously appointed from the maximum permissible exposure limits point of view. Toxicological influences of particular dangerous chemical factors in term of their effecting at the humane organism were also evaluated. From above said reasons the new type of plastic emulsion explosive were tested in operating mine condition.

Tapping of Electrical Energy from Ground Vibrations caused due to Blasting : An Innovation

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Abstract

Generation of electrical energy has become a basic aspect in power system, because of increasing demands from citizenry in electrical distribution system. Power may be generated in different ways. Numerous developments took place in power generation technology for the generation of electricity, but those are all dependent on conventional sources. In the present research, generation of electrical energy using piezo sensors was done by tapping electrical voltage from undesirable ground vibrations generated from blasts in mines.

Blasting operations in mines and quarries always result in ground vibrations, which are of major environmental concern. Studies were carried out in three different limestone mines and two different sandstone formations of coal mines, situated in Southern India, to assess and analyze the seismic energy resulting from the blast induced ground vibrations. In total, 116 blast vibration events in limestone formation and 94 blast vibration events in sandstone formation were studied from various blasts. It was observed that there is a potential for tapping of electrical energy from the ground vibrations generated due to blasts carried out in mines and quarries, using piezo sensors. Piezo generator circuits were developed and used in addition to the seismographs at different distances, from short to long range, in all mining locations, to tap the ground vibrations. Electrical voltage was tapped from the blast induced ground vibrations during studies, which later was used for running low powered VLSI systems as ambient power source. Also, it was noticed that the obtained electrical potential is in direct proportion to the input vibration intensity.

The range of voltage tapped from ground vibrations is up to 4531.42 mV in limestone and 4277.51 mV in sandstone formations. Further, the amount of voltage acquired was used to obtain the intensity of blast vibrations. A very good correlation between seismic energy (obtained from ground vibrations using signal processing analysis) and electrical energy (obtained from piezo generator developed) was observed during the studies. Results also indicated that the working of piezo sensor in tapping ground vibrations is as accurate as conventional ground vibration monitors.

RECENT PATENTS

RECENT PATENTS OF INTEREST (2017)

United States Patent Application
Phillips; Edward H. ; et al.
20170130452
May 11, 2017

Explosive Blast Energy Dissipating And Carrying Building Structure

Abstract

A structural assembly for use in building applications is disclosed. The assembly has spaced inner and outer face sheets, as well as one or more intermediate panels positioned between the inner and outer face sheets. The assembly provides an enhanced ability to dissipate blast or projectile impact forces and to carry the forces throughout the assembly, thus maintaining sufficient structural integrity in the building to enable the occupants to evacuate, to enable contents to be evacuated, and to enable reuse of the building itself.

Inventors : **Phillips; Edward H.**; *(Glen Haven, CO)* ; **Phillips; Tiffany**; *(Estes Park, CO)*
Assignee : **TNP Holdings LLC,** Estes Park, CO, US

United States Patent Application
KLUNKER; Jurgen ; et al.
20160052835
February 25, 2016

Systems for Delivering Explosives and Methods Related Thereto

Abstract

Systems for delivering ***explosives*** *with variable densities are disclosed herein. Methods of delivering* ***explosives*** *with variable densities and methods of varying the energy of* ***explosives*** *in a blasthole are disclosed herein.*

Inventors: **Halander; John B.**; *(Salt Lake City, UT)* ; **Kome; Cornelis L.**; *(Salt Lake City, UT)* ; **Nelson; Casey L.**; *(Murray, UT)* ; **Bruner; Jon**; *(Draper, UT)*
Assignee : **Dyno Nobel Inc.**, Salt Lake City, UT, US

United States Patent Application
N V; Srinivaso Rao ; et al.
20160153752
June 2, 2016

Detonator

Abstract

In the present invention; a new detonator was developed which can be used with safety fuse, electrical fuse head or non-electric shock tube. It can be instantaneous or with delay. These detonators are made without any lead salts and sensitive primary ***explosives****. These detonators are safe to handle. These detonators function exactly like conventional detonators. The application of these detonators is also same as that of conventional detonators. The safety in handling is very high when compared to conventional detonators*

Inventors : **Lorenzo; James M.**; *(Mars, PA)* ; **Pyles; Robert A.**; *(Bethel Park, PA)*
Assignee : .

United States Patent Application **20160146587**
ZANK; Johann; et al. **May 26, 2016**

Explosive Composition Manufacturing and Delivery Platform, and Blasting Method

Abstract

A mobile manufacturing and delivery platform that is adapted to provide in a blasthole an explosive composition comprising a liquid energetic material and sensitizing voids, the sensitizing voids being present in the liquid energetic material with a non-random distribution. The platform comprises a storage tank for the liquid energetic material; at least two delivery lines for conveying respective streams of the liquid energetic material from the storage tank; a void delivery system for producing sensitizing voids in at least one of the streams of liquid energetic material; a mixer for mixing the streams of liquid energetic material to produce the explosive composition; and a blasthole loading hose. The mixer may be provided at the end of the loading hose. A blasting method employs the platform to manufacture and deliver the explosive composition into a blasthole, which composition is subsequently detonated.

Summary of the Invention

[0109] In accordance with a first embodiment of the invention there is provided an explosive composition comprising a liquid energetic material and sensitizing voids, wherein the sensitizing voids are present in the liquid energetic material with a non-random distribution, and wherein the liquid energetic material comprises (a) regions in which the sensitizing voids are sufficiently concentrated to render those regions detonable and (b) regions in which the sensitizing voids are not so concentrated, wherein the explosive composition does not contain ammonium nitrate prill.

[0110] The explosive composition of the present invention is defined with reference to its internal structure. The liquid energetic material comprising (a) regions in which the sensitizing voids are sufficiently concentrated to render those regions detonable and (b) regions in which the sensitizing voids are not so concentrated, rendering different detonation characteristics. Thus, a charge made up (entirely) of liquid energetic material in which the sensitizing voids are sufficiently concentrated to render the liquid energetic material detonable will have different detonation characteristics when compared with a charge made up (entirely) of liquid energetic material in which the sensitizing voids are not so concentrated. The (regions of) liquid energetic material having lower concentration of sensitizing voids (i.e. those regions "in which the sensitizing voids are not so concentrated" may be per se detonable but with reduced detonation sensitivity when compared with (those regions of) liquid energetic material including higher concentration of sensitizing voids. Alternatively, (the regions of) liquid energetic material having lower concentration of sensitizing voids may be per se non-detonable.

[0111] Herein differences in detonation sensitivity relate to the intrinsic sensitivity of the individual regions, and also concentration of the sensitizing voids present within the regions, of liquid energetic material. It is generally accepted that the sensitivity of an energetic material to shock wave initiation is governed by the presence of the sensitizing voids. Shock-induced void collapse due to application of a shock wave is a typical mechanism for hot spot formation and subsequent detonation initiation in energetic materials. The generation of the shock induced hotspots, or regions of localized energy release, are crucial processes in shock initiation of energetic materials. The effectiveness of the shock initiation further depends on the amplitude and duration of the shock wave.

Inventors : **ZANK; Johann**; *(Valentine, AU)* ; **RAYSON; Mark Stuart**; *(Tuggerawong, AU)* ; **SUJANSKY; Vladimir**; *(East Burwood, AU)* ; **WALTER; James**; *(Cottesloe, AU)* ; **KIRBY; Ian John**; *(Ayr, GB)* ; **COOPER; John**; *(Ayr, GB)*
Assignee : .

United States Patent Application **20160265883**
Lorenzo; James M. ; et al. **September 15, 2016**

Energy Absorber for High Performance Blast Barrier System

Abstract

The present invention provides an energy absorber for a blast barrier system comprising a substantially tubular member extending longitudinally along an axis from a first end portion to a second end portion, each of the first end portion and the second end portion having a substantially similar geometric, profile, wherein the energy absorber collapses under a predetermined load when compressed by a residual blast force. The energy absorber of the present invention may help minimize damage to people and structures by further dissipating force from a blast in a blast barrier system.

Inventors : **Lorenzo; James M.**; *(Mars, PA)* ; **Pyles; Robert A.**; *(Bethel Park, PA)*
Assignee : .

SPECIAL REPORT

IME
institute of makers of explosives
The safety and security institute of the commercial explosives industry since 1913

ISSUE BRIEFS (2017)

We are presenting below a selected set of 'Issue Briefs' that were prepared by IME during 2017, to assist the Legislators and the Regulators in formulating policies and standards with regard to Safety and Security of commerce and use of explosive products in the USA. This forms a part of the continuing serial on IME Issue Briefs, started with the 10th edition of the Journal.

Editor

1.0 Ammonium Nitrate Detonability Question

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

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

Discussion: AN is a stable, noncombustible chemical compound. The chemical structure of TGAN and FGAN is the same, NH□NO□. The only difference is the density of the finished prill. TGAN is less dense than FGAN.

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

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

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

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

2.0 Fumes from Blasting

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

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

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

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

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

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

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

3.0 Strengthen OSHA Regulations Covering Ammonium Nitrate (AN)

Issue: After more than 45 years, should the regulations covering manufacture and storage of AN under OSHA rules found at 29 CFR

1910.109(i) be updated?

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

Since 1971, the manufacture and storage of AN has been regulated under OSHA rules found at 29 CFR 1910.109(i) that specifically address the unique properties of this material. There has been no known accidental detonation of AN where a facility has been compliant with this OSHA standard. In addition, AN is subject to a number of other ATF, EPA, DHS, and DOT safety and security regulations. The insensitivity of AN renders the material highly unlikely to mass-detonate during manufacturing, storage, and transportation. DOT acknowledges AN's insensitivity, classifying it as a Division 5.1 oxidizer and listing it as a "Table 2" not "Table 1" material. The "technical" grade of AN (TGAN) used in the explosives industry has the same chemical composition as the "fertilizer" grade of AN (FGAN) used in agriculture, only the density of the prill is different. AN, in either form, is not self-reactive and does not pose a threat of an accidental release of energy or fumes unless subjected to substantial and sustained heat (e.g., fire) or shock from high explosives.

Discussion: EPA considered expanding the Risk Management Program to cover AN, eventually deciding against it. Currently, OSHA is considering whether AN should be regulated under the extensive Process Safety Management (PSM) requirements. In multiple prior rulemakings, however, OSHA determined that AN does not pose the type of threat that PSM requirements are intended to address.

While these governmental bodies conducted their reviews of AN, IME, the safety and security arm of the commercial explosives industry, developed and published Safety Library Publication Number 30 (SLP-30) describing the best practices used by the explosives industry to safely manage AN. SLP-30, Safe Handling of Solid Ammonium Nitrate, can be found under publications at www.ime.org.

Recommendations: SLP-30 captures all relevant federal regulations and industry best practices in one document. IME continues to believe that existing regulations, if followed, are protective of workers and the public, with two major exceptions. OSHA's 29 CFR 1910.109(i) regulations should be updated: (1) to require noncombustible materials for bins and structures used to store AN; and, (2) to train emergency responders to evacuate at risk populations when fire has engaged the AN, not to attempt to fight such fires. The current regulations, as evidenced by a 45-year safety record of no accidental detonations, have proven effective for decades. By updating the regulations IME hopes to keep workers and the public safe for the next 45 years.

4.0 Permissible Explosives Approvals

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

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

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

The only way to evaluate these critical safety-related properties is to conduct elaborate tests. The government has not conducted these tests for over 19 years, the equipment is in disrepair, and the corporate knowledge needed to conduct the tests is slipping away into retirement. The government laboratory where permissible testing was conducted for 80 years has decided to abandon not just permissibility testing, but all explosives-related research.

Discussion: This situation must be corrected:

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

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

5.0 Taggants in Explosives

Issue: Should taggants be mandated in commercial explosives?

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

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

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

IME has worked closely with both the ATF and NAS to ensure that industry data was available to complete the study.

The NAS report, completed and issued in March 1998, concluded:

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

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

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

IME's position is consistent with these findings:

- Less than 1 percent of the bombings in the United States involve commercially manufactured high explosives.
- Identification taggants can dangerously increase friction sensitivity when added to the manufacture of high explosives, and their benefit to law enforcement is disputed as taggants may complicate the investigation and prosecution of bombings.
- Countries which have faced real terrorism problems, such as Israel, Ireland, Germany, Japan, and Great Britain, have not adopted a taggant program and do not intend to do so.
- The substantial costs associated with placing taggants in commercially manufactured high explosives are not justified by the minimal benefits.

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

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

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

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

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

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

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

Recommendation: We support the safe use of drones and we do not want to limit this new innovative technology. However, as Congress considers legislation for a long-term authorization of the FAA Act, we want to preserve the gains achieved under P.L. 114-190, to direct FAA to use DHS' definition of "critical infrastructure" rather than use scarce resources to invent another competing definition, and to ensure that there are appropriate penalties for those who violated restricted airspace above critical infrastructure with UAS overflights.

SPECIAL REPORT

Safex International

'Safex Incidents Notices' : October, 2016 to October, 2017

Summary

Activity			No. of Incidents
*	Manufacturing :	Fixed Plant	
		HE	4
		Explosive Accessories	5
			9
	Mobile Manufacturing Unit (MMU)		-
*	Handling :	Within Plant Area	-
		Outside Plant Area	-
			-
*	Storage :		-
*	Transportation	Vans	-
		MMU	-
			-
*	Waste / unused explosives disposal, etc.		1
		TOTAL	10

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

- Editor

1

1) **INCIDENT TITLE :** 13 October 2016-Lead Azide Explosion

2) **INCIDENT OUTLINE**

a) **What material was involved :** After the installation of a new motor to rotate the granulator stirrer at the lead azide production area, several tests were being made to set the right working conditions (rotating velocity).

b) **What happened**: The plant supervisor, the maintenance manager and two operators were doing some tests to set the right working parameters for the motor that had been replaced recently. After the tests with water were finished, the plant supervisor and the maintenance manager, in the presence of one plant operator, decided to perform tests with lead azide. Following standard operating procedure, 6 small containers of lead azide were poured onto the feeder (around 4kg). In the standard operating procedure, the different steps of the process are performed remotely from the control room. During the tests the maintenance manager, the plant supervisor and one of the operators entered the granulation room. Following the instructions of those within the granulator room the operator in the control room increased the speed of the granulator. Around two minutes later an explosion took place. At the time of the explosion, the maintenance manager was at the entrance of the room and only the plant supervisor was inside, approaching the granulator for visual inspection.

c) **Why did it happen theory** : Based on the information that the investigation team gathered and analyzed, the most probable direct cause was associated with the higher mechanical energy applied in the granulation process. Several other factors were also contributing to the accident.

- ❖ Quality problems with the lead azide granulation led the team to focus the attention on the agitator of the granulator;
- ❖ A new motor was purchased, more powerful than the original one. As a result, once the new motor was running, more mechanical energy was introduced into the process.
- ❖ The new motor/installation was tested with water and accepted to be ready to operate. The plant supervisor, the maintenance manager and one of the operators then decided to proceed with the tests, now with lead azide.
- ❖ The team involved in the tests with lead azide entered the granulation room several times during the tests to check how the agitator was working.
- ❖ Some safety tools were poorly implemented such as work permits, management of change and task observations.
- ❖ An internal audit had been recently carried out but the action plan to address the findings was still in preparation,

Following the chain of events, it can be considered that the most probable causes were:

- ❖ Quality problems weren't treated previously with a proper problem solving analysis system and no multidisciplinary team was gathered.
- ❖ No proper management of change process was applied when the new motor was purchased and installed.
- ❖ Deficiencies in work permit system allowed a lack of proper risk assessment during the installation of the new motor and during the tests.
- ❖ Lack of a proper risk perception would lead to failure in taking the necessary safety precautions and in following the defined safety rules.
- ❖ Insufficient safety culture and awareness of the hazards involved in the activity have been demonstrated.

d) **What was the impact** : 1 Fatality and 1 serious injury.
The plant has been partially destroyed, although the physical barriers of the building contained the explosion, as expected per design(See Photo).

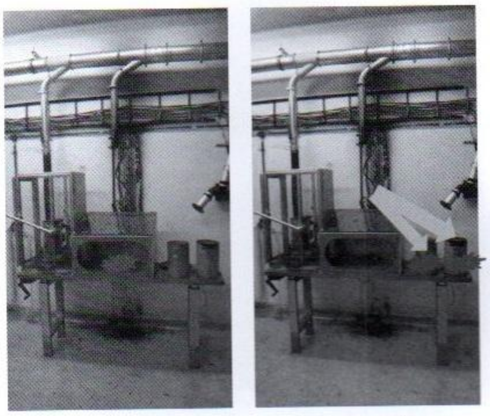
3) **COMMENT**

a) **Value of incident** : -

b) **Observations :** None

2

1) **INCIDENT TITLE :** 24 November 2016: Delay Powder Initiation
2) **INCIDENT OUTLINE**
   a) **What material was involved :** 12 kg of delay powder were initiated and burnt.
   b) **What happened**: Settled dust in a working box was initiated when the operator was manipulating with a brass pestle on the table.



Initiation of delay powder in working box, transmission into 2 containers

The flash/flame was propagated into the exhaust dust flexible antistatic hose). The hose burnt completely within 30 seconds and hot particles from the hose initiated the delay powder in two containers (8 + 4 kg) outside the box.

   c) **Why did it happen theory** : IThe likely cause of the ignition was an impact/friction event between the pestle and the settled dust. This had happened in the past with the event being contained inside the working box. To be able to adjust the height of the workbench to the operator, a fixed steel duct had been replaced by a flexible ESD hose which is antistatic but not fire resistant. The hose caught fire and hot particles ignited the delay powder in the containers outside the box which were considered to be at 'a safe distance'. There were also no lids on the containers.
   d) **What was the impact** : No injuries. Some material damage from fire.
3) **COMMENT**
   a) **Value of incident** : All consequences of a change (exchange of fire resistant steel pipe vs a combustible ESD hose) have to be risk assessed (what can happen around?). Old operations (heavy weight pestle, cleaning of settled dust) should be reviewed regularly. BOS standards to be reviewed regularly (cans without lid).
   b) **Observations :** None

3

1) **INCIDENT TITLE :** 30 November 2016: Lead Styphnate Explosion
2) **INCIDENT OUTLINE**
   a) **What material was involved :** 2kg of lead styphnate primary explosives.
   b) **What happened**: An ignition occurred during the sieving of lead styphnate material in building DD6. As a result of the ignition most of the equipment in the cell was damaged due to the detonation of approximately 2kg of material.
   c) **Why did it happen theory** : Investigation has concluded that the ignition occurred due to a friction/impact event at the sieve pot. It was identified that the securing ring, used to hold the lab sieve in place, was not sufficiently tightened. This allowed material to collect in an area where the material ignited due to the friction generated by the loose parts of the sieve assembly. The root cause of the incident has been attributed to poor design of the sieving equipment.
   d) **What was the impact** : Building DD6 has been designed to remotely manufacture primary explosive compositions therefore there were no injuries as a result of the ignition. Significant damage occurred to the equipment within the manufacturing cell and because of this the cell has been out of use until all equipment is replaced. As a result of the incident the sievingprocess has been completely re designed.
3) **COMMENT**
   a) **Value of incident :** -
   b) **Observations :** -

4

1) **INCIDENT TITLE :** 16 February 2017: Smouldering Explosives Contaminated Waste
2) **INCIDENT OUTLINE**
   a) **What material was involved :** RDX/TNT contaminated waste
   b) **What happened**: An operator smelt something burning before observing smoke emanating from the floor of a wooden contaminated waste box. The box was immediately hosed down with water and the waste buckets of RDX/TNT removed.
   c) **Why did it happen theory** : Under investigation
   d) **What was the impact** : There were no injuries or damage sustained.
3) **COMMENT**
   a) **Value of incident** : This incident highlights that increased risks associated with handling explosives wastes.
   b) **Observations : None**

Figure 1: Wooden Contaminated Waste Box

Figure 2: Base of wooden box (Note: the paper items had been removed from the box during clean-up and replaced for this picture)

5

1) **INCIDENT TITLE :** 22 February 2017-Ignition Mixture Deflagration
2) **INCIDENT OUTLINE**
   a) **What material was involved :** 10 kg of ignition mixture
   b) **What happened**: At 08:47 am an incident in the ignition mixture department occurred, involving 2 x 5 kg of ignition mixture, which partly deflagrated within and below 1(of 2 installed) sieving machine(s).
   c) **Why did it happen theory** :Under investigation.
   d) **What was the impact** : No injuries to personnel, only damage to the building and the two sieving machines. The pressure door, resistance wall and barricade did effectively contain all effects of the deflagration, i.e. neighbouring production areas were not impacted.
3) **COMMENT**
   a) **Value of incident** : Though the reason for the ignition is yet unknown, the mitigating controls regarding operator safety (remote operation) and physical damage were adequate. This is also valid as the permitted inventory levels in the sieving machines/room were strictly followed.
   b) **Observations : None**

6

1) **INCIDENT TITLE :** 2 March 2017-Nitro ester Explosion
2) **INCIDENT OUTLINE**
   a) **What material was involved :** Small quantity of nitro esters (suspected)
   b) **What happened**: A small explosion occurred during the renovation of the floor of the tunnel used to transport dynamite from the Tellex mixer building. Three worker were removing a portion of the floor using a jackhammer when the small explosion took place.
   c) **Why did it happen theory** : The actual cause is still under investigation, but it is suspected that an unspecified amount of nitro esters remained trapped in the concrete even after decontamination of the area.
   d) **What was the impact** : One worker was thrown and killed after a fall and two others were injured .Little damage to the tunnel.
3) **COMMENT**
   a) **Value of incident** : -
   b) **Observations :** None

7

1) INCIDENT TITLE : 7 May 2017:**Detonator Press Explosion**
2) INCIDENT OUTLINE
   a) **What material was involved :** Under investigation
   b) **What happened**: Detonator Press Room, during the routine cleaning process. The area of the explosion was the PETN charging station.
   c) **Why did it happen theory** : Under investigation
   d) **What was the impact** : One fatality
3) COMMENT
   a) **Value of incident** : -
   b) **Observations :** -

8

1) INCIDENT TITLE : 19 June 2017: HMX Incident
2) INCIDENT OUTLINE
   a) **What material was involved :** HV-5 at Process
   b) **What happened**: After finishing the batch of HMX, the operator opened a valve to pass away the material from the reactor. A small amount of wet explosive clogged the drain. The operator took a metal tool and tried to open the clog. This action caused a small explosion
   c) **Why did it happen theory** : It was found that the metal tool was a hollow section tool, and a few grams of dry explosive were hidden in it (from previous process), and caused the explosion
   d) **What was the impact** : The operator moderately wounded from shock wave, heat and fragments that burst out from the upper entrance of the reactor. He is being treated at Hospital. The burst caused some damage to equipment. No environmental issues were encountered.
3) COMMENT
   a) **Value of incident** : -
   b) **Observations :**

9

1) INCIDENT TITLE : 21 August 2017: Smokeless Powder Deflagration
2) INCIDENT OUTLINE
   a) **What material was involved :** NG based propellant-Smokeless powder
   b) **What happened**: A deflagration of the NG based, smokeless powder occurred during the pressing process. The accident occurred during testing of new equipment for pressing and cutting of tube propellants. The equipment was supplied as a turnkey operation by TS Plzen.
   c) **Why did it happen theory** : Intensive investigations are in progress in cooperation with the Police of CZE, fire brigade and supervisory authorities to ascertain the main issues that could have caused the deflagration.
   d) **What was the impact** : Three workers were injured by flame and deafened from the acoustic shock, one of them lost 3 fingers on the left-hand due to the accident. The equipment was moderately damaged, but can be repaired.
3) COMMENT
   a) **Value of incident** : -
   b) **Observations :** None

10

1) INCIDENT TITLE : 6 October 2017 : Atomized aluminium powder deflagration
2) INCIDENT OUTLINE
   a) **What material was involved :** Atomized aluminium powder
   b) **What happened**: Deflagration of aluminium powder in suspension inside the feeding hopper of the aluminised ANFO production workshop, during its filling. At this time there was no explosive production. To anticipate the next manufacturing to come on next Monday, the operator decided to proceed with the filling of the hopper of aluminium.
   Having positioned the big-bag of aluminium, the operator (located in a separate room) started the vertical screw allowing the transfer of the aluminium from the feeding hopper to the metering tank, and then started the bottom screw of the feeding hopper. After about ten seconds he heard a noise generated by the explosion of the aluminium inside the feeding hopper.
   c) **Why did it happen theory** : This incident is still under investigation. The very first analysis of the causes leads to the creation of a potentially explosive atmosphere by suspension of aluminium during the filling, associated with an unexpected source of energy. Maintenance operations performed during the week before the incident had required the emptying of the augers. For this reason the feeding hopper was less filled with regard to the usual operating cycles. This situation certainly favoured the creation of a potentially explosive atmosphere(dust cloud). Concerning the accidental source of energy, several hypothesis are under investigation: electric failure, foreign body, mechanical heating etc
   d) **What was the impact** : No injuries to personnel.
   Hopper slightly damaged. Lid of the hopper deformed and a Plexiglass porthole at the level of the intake auger broken (fragments thrown inside the room).
3) COMMENT
   a) **Value of incident** : -
   b) **Observations :** None

ABOUT THE SOCIETY

Visfotak

Explosives Safety & Technology Society

Secretariate Address :

Maimoon Chambers
Gandhibagh, Nagpur - 440 032

E-mail : visfotak@yahoo.com

Website : www.visfotak.org

** Note - Vacancy created by the passing away of Sri Limsay, is being filled soon.

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.

Governance :

The activities of the Society are overseen by a Governing Council, comprising of eminent professionals and technocrats, including nominees from the two major Regulatory Bodies ,viz, the Office of the Chief Controllers of Explosives, and the Directorate General of Mines Safety, respectively.

Institutional Association :

- **'Institute Associate Member' of Safex International . e.f 30 May, 2008**
  (Safex International is a global organization founded by the manufacturers of explosives and pyrotechnics , currently having 110 members in as many as 46 countries. For more vdetails on Safex , visit www.safex-international.org)
- **'Liaison Member ' of the Institute of Makers of Explosives (IME) , e.f. Oct 29 , 2014**
  (IME is the safety and security institute of the commercial explosives industry in USA since 1923. For more details on IME , visit www.ime.org)

Membership of the Society :

The membership application form is enclosed. The application form can also be accessed and down loaded from the society's web-site .

Student Chapter:

This is an initiative launched by the society to promote the mission of the society amongst the students and academics who are , directly or indirectly associated with the science and technology of explosives. The application form for membership of the student chapter is enclosed ; it can also be accessed and downloaded from the society's web-site .

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 of its individual members.

News & Events

Homage

Mr. Kumar H. Limsay, Hony. Secretary of the Society, passed away on Dec. 3, 2017. He served Visfotak with distinction. The Governing Council extends heartfelt condolences to his bereaved family. RIP - Kumar !

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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Discount Offer : In case, advertisement is booked for four issues of the Journal at a time for one of the above categories, the concessional rates charged will be equal to three issues.

Payment is to be made through cheque / draft in the name of **"Visfotak", payable at Nagpur.**

SHARE YOUR ACHIEVEMENTS

Visfotak welcomes you to share highlights of your achievements and activities with other professionals through this journal.

Please send it to us through e-mail at : visfotak@yahoo.com

or write to

Secretary General

Visfotak : Explosives Safety and Technology Society, Maimoon Chambers, Gandhi Bagh, Nagpur - 440 032, India

Tear along this line

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 ☐
Entrance Fee Rs. 2,000/- (US $ 200)
Membership Fee Rs. 3,000/- (US $ 300)

INSTITUTIONAL MEMBER ☐
Entrance Fee Rs. 2,000/- (US $ 200)
Membership Fee Rs. 3,000/- (US $ 300)

INDIVIDUAL MEMBER ☐
Entrance Fee Rs. 1,000/- (US $ 100)
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 ______________

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

admas

Tear along this line

Visfotak **EXPLOSIVES SAFETY & TECHNOLOGY SOCIETY**

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

MEMBERSHIP APPLICATION FORM FOR STUDENT

(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).

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

ENTRANCE FEE ☐ Rs. 50/-

MEMBERSHIP FEE FOR FIVE YEARS ☐ Rs. 200/-

Name of Corporate Body / Institution* ______________________

Represented by (Head - Other) ______________________

*NAME IN FULL ______________________

(First Name) (Middle Name) (Surname)

Date of Birth ______________________

Name of Institution ______________________

City __________ Pin Code __________ Country __________ E-mail __________

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

Educational Qualification ______________________

Academic Course being persued : ______________________

Membership of Professional Bodies, Awards, Recognitions ______________________

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Membership of Professional Bodies, Awards, Recognitions ______________________

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Areas of Interest ______________________

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.**

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

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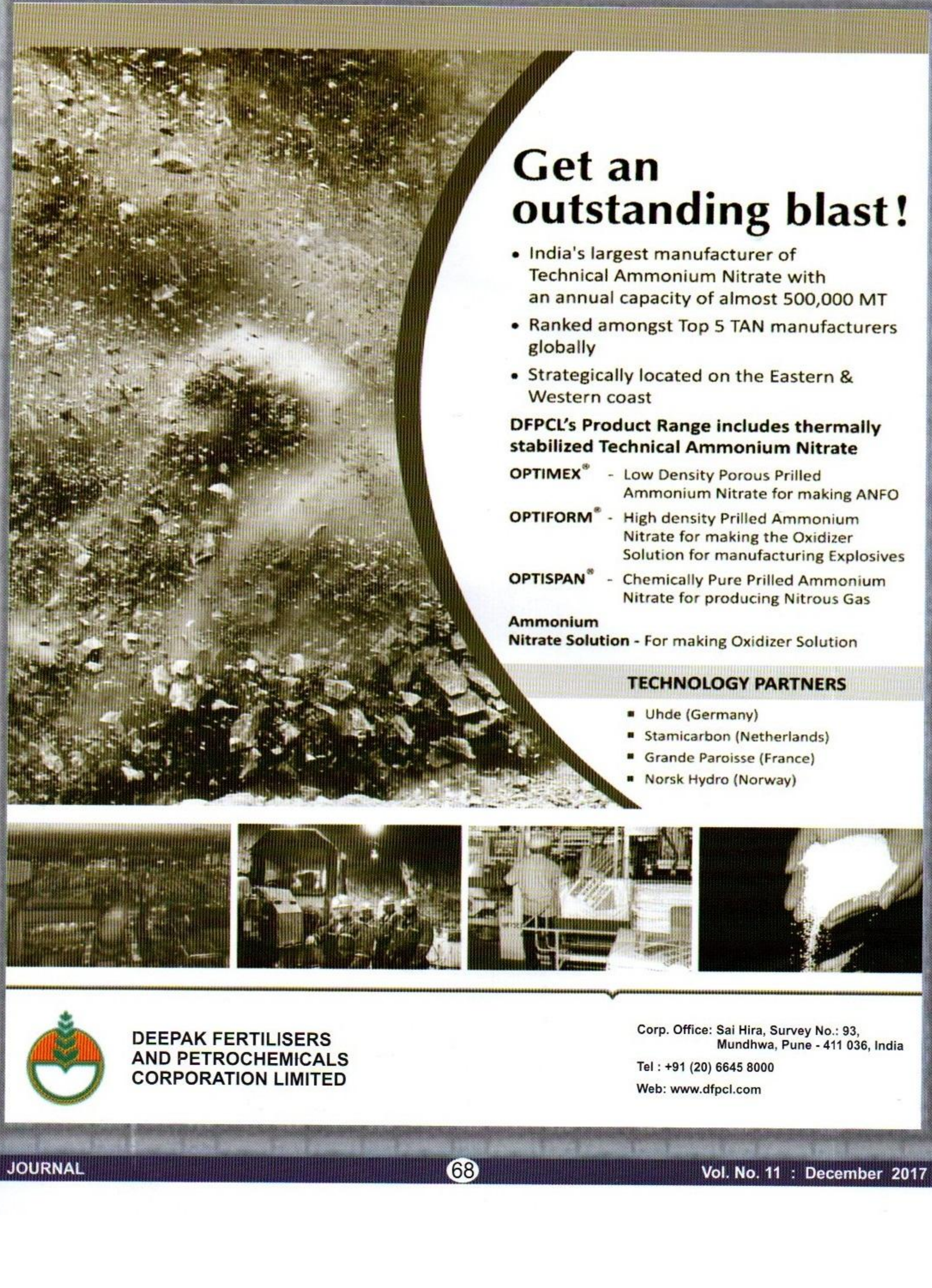
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OPTIMEX® - Low Density Porous Prilled Ammonium Nitrate for making ANFO
OPTIFORM® - High density Prilled Ammonium Nitrate for making the Oxidizer Solution for manufacturing Explosives
OPTISPAN® - Chemically Pure Prilled Ammonium Nitrate for producing Nitrous Gas
Ammonium Nitrate Solution - For making Oxidizer Solution
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