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INSTITUTE OF EXPLOSIVES ENGINEERS
DECEMBER 2017

Explosives Engineering

Institute of Explosives Engineers
VOICE OF THE EXPLOSIVES INDUSTRIES

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Features

Regulars

Cover picture:
Plume of toxic fume, dust, soil and rock particulate matter in Majan limestone quarry (See page 12).

Explosives Engineering
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Opinions expressed in the Journal are those of the authors concerned. They do not necessarily represent the views of the Institute.

Institute of Explosives Engineers
VOICE OF THE EXPLOSIVES INDUSTRIES

Professional Affiliate of ECUK

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The President speaks

As we approach the festive season I find myself wondering where the last 12 months have gone! Within the Institute so much has been achieved and so many positive changes implemented. Elsewhere, there have been some remarkable acheivements by individual and company members across the globe, many of these being highlighted in the various journal articles and reports. There is a great deal to be proud of across the Explosives Sector and we are arguably poised for some significant and long-strived for successes in 2018.

Much of these successes will be born out of ongoing works such as those linked to the SSSG and education/apprenticeships. Equally, the continued success of the Early Careers Focus Group (ECFG), an influential and important element of the overarching SSSG work, should not be overlooked. Much of the SSSG work in 2017 continued to focus on qualifications and education of employees in explosives, and some recent news in regards to accreditation and qualification mechanisms will no doubt result in some changes to the way in which future courses are certificated. I am hopeful that the Institute will be able to play a leading role in this area.

I am delighted to welcome a new member of our office team, Jessica Ward has joined us to assist Vicki and Charlene with some of the administrative and day-to-day office tasks as they become increasingly involved in many of the key industry conferences and exhibitions. Equally, the scale of daily operations undertaken by the office team has never been as diverse or indeed as constant, and it seems to be growing as we move into new areas and broaden our reach.

As we look to the early part of 2018 we already have some events in the calendar including the Security Expo (SCTX18) in March where we will be exhibiting, and the all new Members' Weekend and AGM scheduled for 28th and 29th April. I look forward to welcoming you to the member weekend with your respective partners in the fabulous setting of Crewe Hall.

Finally, may I take this opportunity to wish all our readers, and their loved ones, a safe and enjoyable festive period.

Dave Welch FCMI MIExpE MIABTI
President

IExpE Conference 2018

Institute of Explosives Engineers

26th & 27th September 2018
Telford golf resort & Hotel, Great Hay Drive, Sutton Heights, Telford, TF7

New Members:

Congratulations and a warm welcome to our new Institute Members and those transferring grades

Approval date 18th August 2017
Andrew Morris
Joshua Winter
Richard Thomas
Mark Franklin

Approval date 25th August 2017
Henry Hulme

Approval date 1st September 2017
Kevin Beattie
Iain Maxted

Approved date 8th September 2017
Jonathan Sowerby
Stephane Farrell
David Graham-Battersby
Jason Hill

Approval date 15th September 2017
Elizabeth Brown

Approval date 29th September 2017
Kevin Sandison
Philip Cheetham
Gareth Wood
William Douglas
Andrew Bannister

Approval date 6th October 2017
Russell Hurst
Thomas Bradford

Approval date 13th October 2017
Paul Burns
Sam Conway
Thomas Murdock

Approval date 20th October 2017
Sophia French
Matthew Watkin
Daniel King
Thomas Gill
Robert Parkhouse
Andrew Gausden
Ammar Sabha
David Holley

Approval date 27th October 2017
Steve Holland
Anthony Wyles
Mourad Bourahla

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Past Presidents' Luncheon

The 2017 Past Presidents' Luncheon will take place on Thursday 14th December at the Caledonian Club, 9 Halkin St, Belgravia, London SW1X 7DR.
Further information: please contact Vicki Hall at vickihall@iexpe.org

Inaugural Fellows' Luncheon

The inaugural Fellows' Lunch was held in Stafford on 20th September and was attended by 13 from within the Fellows group, including one Fellow from Australia.

There are 36 Fellows and Hon Fellows within the Institute.

The grey hairs and experience of the Fellow community is an important asset to the membership body as a whole. It is therefore hoped with gatherings such as this, and that of the Past Presidents' lunches, new ideas and experiences can be discussed for the benefit of the Institute going forward.

It is planned to hold a 2019 event and other Fellows are invited and encouraged to attend.

Cranfield University academic shortlisted for award

Professor Jackie Akhavan from Cranfield University's School of Defence and Security, based at the Defence Academy of the UK, Shrivenham, was shortlisted in this year's Women in Defence UK awards. Cranfield was the only university to have staff shortlisted alongside military personnel and staff from the civil service and industry organisations. Professor Akhavan who is Professor of Explosive Chemistry and Head of the Centre for Defence Chemistry is a Fellow of the Institute and was nominated by her colleagues for being an inspiration for women to enter the defence and explosives field over a long and continuous career. Unfortunately she did not reach the final.

Registrar report

Professional Registration

Professional registration statistics as at 31st October 2017

	CEng	IEng	EngTech
QUALIFIED	31	7	3
IN PROGRESS	9	4	0

Application forms sent but not yet received back - 55

New Registrants

Our congratulations to these members on achieving professional registration:

Mike Harris IEng
Greg Sugden CEng
Andrew Maber-Jones CEng
Peter Munro-Green CEng

Society of Environmental Engineers

Members will be aware that our success in professional registration is facilitated by our relationship with the SEE. Since the new Secretary started, the turmoil we had been experiencing has abated.

PRI Assessor Training. SEE expects to run a PRI Assessor refresher training event in the autumn and I have said that we would like some slots on that event. I have also remined them that one of our Company Members, SPEX, has offered the use of its boardroom to run a PRI training event, provided that the timings are mutually agreeable. Thank you to Andy Pettitt for making this generous offer.

Continuous Professional Development

The Institute published its requirement for professional registrants to conduct a minimum of 30 hours CPD per year. This CPD can take the form of meetings, seminars and events; the single important criterion is whether the individual has learned something from the activity. As such, the Institute has decided it does not need to issue attendance certificates but will support these if requested. Council takes the view that a professional explosives engineer will not breach their own integrity by not maintaining accurate CPD records.

Auditing & Monitoring.

At the 2016 Professional Affiliates' Seminar, we were informed that the Engineering Council will impose mandatory recording of CPD from 1st January 2019 which will allow the imposition of sanctions from 1st January 2020. This does not mean that members will have to maintain their CPD records in mycareerpath, especially if they are required to keep paper records, but if selected for monitoring, we will require the report to be submitted using mycareerpath.

The SEE Council has yet to confirm the detail of how it will undertake the auditing and monitoring of professional registrants, but their concept of operations is that they will probably begin in 2018, using their own PRI assessors as the auditors (possibly seeking advice from our own assessors if they need a technical opinion) and the sample size is likely to be 5%. Sanctions, should they be necessary, would begin in 2019 but these have yet to be defined, either by the Engineering Council or the SEE.

We currently have only 75 registered users of mycareerpath and I encourage members, if they are not required to maintain CPD records in a Corporate format, to:

Figure 1. mycareerpath usage as at 29th August 2017.

a. record their own CPD on the system for which we pay an annual licence fee;
b. promote the use of mycareerpath as a benefit when they talk about membership with new or non-members;
c. demonstrate the use of mycareerpath for members if requested.

Engineering Council

Professional Affiliates' Seminar

The Institute attended the 2017 Professional Affiliates' Seminar, held at the Engineering Council offices on 26th September 2017. The objectives of the seminar were:

- To update Professional Affiliates on developments at the Engineering Council
- To discuss specific topics of interest
- To identify benefits and possible additional areas of support
- To provide an opportunity to network with other Affiliates.

Registration Fees

The Board of EngineeringUK has agreed to increase the Registration fees by approximately 3% in 2018. This increase is based on the funding requirements of both EngineeringUK and the Engineering Council.

The new fee structure is detailed in the box below:

	2018 Annual Fees			2018 Entry Fees		
Category	CEng	IEng	EngTech/ ICTTech	CEng	IEng	EngTech/ ICTTech
Full	£39.00	£33.00	£19.00	£50.70	£42.80	£17.50
Interim	£13.90	£13.90	£13.90	£10.40	£10.40	£10.40
Reduced	£17.60	£14.70	£8.40	-	-	-

The annual registration fees from Chartered Engineers, Incorporated Engineers, Engineering Technicians and ICT Technicians allow the Engineering Council and EngineeringUK to ensure quality in the profession today and investment in its future for tomorrow.

As a result, the SEE Fee Structure for 2018 for professional registrations is:

Total Fee	Route to Registration
CEng	
£150	Standard Route
£150	Individual Route
£300	Technical Report Route
IEng	
£150	Standard Route
£150	Individual Route
£250	Technical Report Route
Eng Tech	
£65	Standard Route
£65	Individual Route

NB. the total Registration administration fee is now payable in full on application.

One-off administration fee payable to Engineering Council on registration
(Note. This includes the annual subscription in the year of registration)

CEng	IEng	Eng Tech
£50.70	£42.80	£17.50

Engineering Council Annual Subscription retired/hardship rate at discretion of SEE - to note

CEng	IEng	Eng Tech
£39 (17.60)	£33 (14.70)	£19 (8.40)

Annual SEE Subscription for Joint Member registrants

CEng	IEng	EngTech
£60	£60	£60

Annual SEE handing charge for Non Joint Member registrants

CEng	IEng	Eng Tech
£50	£40	£20

In exceptional cases SEE reserves the right to increase the above fees where extra administration may be involved with the assessment process. In such cases the charges would be indicated to the candidate in advance.

Tomorrow's Engineers
Over the last year, EngineeringUK's activities to inspire a future generation of engineers have reached over half a million young people face to face, and over a million young people via the careers material we provide. The ambition over the next three years is to reach a million young people each year, something that the continuing expansion of the Tomorrow's Engineers programme looks set to deliver.

Engineering Council Guidance
The Engineering Council has issued guidance for institutions and registrants on these issues:

- Security
- Risk
- Ethics
- Whistle blowing
- Quality (tbd)
- Diversity + Inclusion (tbc)
- Public Benefit
- Codes of conduct

Interested members can download extant guidance from http://www.engc.org.uk/standards-guidance/guidance/

Special Registration Events

One of the new ways of working that we have been developing, in concert with QinetiQ, is the Special Registration Event. The idea is that we give a presentation about the Institute and professional registration to a group of employees who work with explosive substances and articles, followed by Q&A and the opportunity to complete their membership application form and also start their professional registration application at the same time. The hope is that their membership application will be approved in good time and time gap between becoming a member of the Institute and their professional registration will be reduced by running the two processes in parallel. Thanks to QinetiQ and AWE for hosting some of these events and we are looking forward to holding more this year.

Ken Cross MBE CEng MSc BSc(Hons) FIExpE
kencross@iexpe.org

Project Coordinator's report

It has been another busy period since my last entry with lots of events, forums and seminars, with plenty of bits in between.

OME Symposium

Another great OME Symposium, at which, I was proud to present an update for the Sector Skills Strategy Group (SSSG).
The presentation, which was well received, gave good insight into the group's activities over that last year, and highlighted just some of what is to come over the coming years, such as:

- Incident reports (emphasising on skills gaps)
- A suite of advice on assessing risks and hazards
- An industry recognised training passport
- Advice on good practice
- New apprenticeship schemes
- And more…

My, slightly unusual presentation, gave the audience the opportunity to interact with what was going on on the big screen, or as it did once the slight technical hitch was sorted out!

They were given this question, and were invited to share their thoughts by posting responses using their mobile phones:

'What changes, or future technologies within the energetics sector, do you think will have the biggest impact on current or future skills needs?'

The responses were very positive and varied, this is what they came up with:

Response from the OME 17 audience.

Some of the audience's answers had already been considered by the SSSG, like the changes within manufacturing which highlighted an increased trend towards autonomy within production, where skills may shift from a production worker, to the person who will have to fix or maintain the machine that now does the work of a human.

Overall the Symposium was very good, with varied and interesting presentations, and opportunities to network. We saw lots of Institute members at the event, the IExpE stand gathered lots of interest!

Vicki Hall, IExpE Office Manager, at the OME 17 Symposium

Early Careers Symposium

Moving out of Heythrop Park, and into the Oxford Belfry, the Early Careers Focus Group have put on their annual Early Careers Symposium (ECS) as well. Being supported by the Institute, this year's Symposium saw the usual line-up of quality presentations, interactive sessions, networking and teambuilding activities.
A full report is included in Industry News (see page 34).

The opening presentation: Lt Col Ted Shine highlighted details of the Fenian brotherhood to the IRA/PIRA.

Team building activities were varied, (myself on the right).

Early Careers 2017 delegates.

Before the evening dinner the entrants had further opportunity to showcase a summary of their work in the acclaimed ECS poster competition. Five hundred pounds was donated by The Explosives Engineers Education & Research Trust, and was split amongst the prize winners.

Winning posters and further details will be published in future issues of the journal.

SSSG

The SSSG continue with their aims of sustaining energetics skills within the UK and are working on a roadmap to show their 3-5-year goals. SSSG Chairman, Mark Hardman, has this to say:

'It is one year since I became Chairman of the SSSG. I would like to thank John Anderson of QinetiQ, on behalf of all members, for his time in the post. There have been many notable successes during John's tenure, but one particular example that stands out for me is the development of the Early Careers Group. This is proving to be a great success.

Already we have come a long way in the last year, but there is still more to do. We have established closer co-operation with IExpE such that the SSSG membership is managed on our behalf by the Institute; all members now benefit from Corporate Membership of the Institute and Chris Tunstall has been recruited by IExpE to become the secretary of the SSSG and working groups. We are slimming down the number of working groups to focus our efforts on skills, competencies and knowledge management. The Education & Training (E&T) and Safety Working Groups will continue to act at the core of our activities, and the Early Careers Focus Group will continue, with some additional support from the E&T Working Group.

We must focus on understanding the future needs of the sector and in support of that, how we then sustain and promote the sector as an exciting career option for our people. This will be an increasing focus for us through 2018 and beyond. I am excited by the opportunities that this brings and really look forward to working with the Institute and the other members of the SSSG over coming months and years.'

CSCS

With the withdrawal of the CSCS CRO (Construction Related Occupation) card, the Institute of Explosives Engineers has lifted this barrier that prevented the EOC Engineer from gaining access to construction sites.

You will find more details on how you can obtain a CSCS card via the Institute's website: http://iexpe.org/information-library/partners-affiliates/affiliated-organisations/cscs/

As part of my work to introduce an IExpE/CSCS card scheme, I attended the first annual CSCS Partner Card Forum during October at the Wellcome Collection in London.

The forum raised issues of card fraud, and discussed the introduction of smart technologies for future card holders.

Graham Wren, Chief Executive of CSCS, talking at the first Partner Card Forum.

HSE Conference

The first HSE 'Helping GB work well' Conference.

Another first, for the Health & Safety Executive's first 'Helping GB work well' conference held at the QEII in Westminster, where the HSE unveiled their 19 workplace sector plans and 'Go Home Healthy' campaign. Their plan covering explosives can be found at: www.hse.gov.uk/aboutus/strategiesandplans/sector-plans/explosives.htm.

The Skills & Employability Summit.

Skills & Employability Summit 2017

There were some interesting talks at this summit, and it was certainly attended by people with a passion for the Education & Training sector! Ofsted indicated a shift towards their aims for a higher standard of learning, as opposed to strong qualification results.

With the impending (or not impending!) Brexit, there will be more need for less qualified people to undertake those essential jobs, sometimes predominantly filled by foreign workers, indicating that there is a place for everybody within our society.

The general feel was that the standard education/job routes were, GCSE, A-Levels, then university, which is still seen as the 'gold standard'. But there are many more ways to get to the same place, and certainly apprenticeships were highly advocated. This ties into the good work being done within the sector to introduce the degree (level 6) OME Apprenticeship, which will lead to the creation of OME apprenticeships at other levels, i.e. intermediate (level 2), advanced (level 3), higher (level 4/5) and masters (level 7).

So, allow me to tie this into my main body of work, the SSSG, to which I would invite you to answer the same question:

What changes, or future technologies within the energetics sector, do you think will have the biggest impact on current or future skills needs?

I look forward to your response!

Chris Tunstall IExpE Project Coordinator

Further information: christunstall@iexpe.org

Institute of Explosives Engineers

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Obituary – Michael Goodwin MIExpE

Michael Goodwin was born in Lincolnshire in 1954. He was one of three children. When he was 21 he joined Hornsby and Goodwin (now H&G Explosives Services Ltd), the family firm which had been founded by his grandfather, Harold Goodwin in 1921 and in which his father worked. The firm was intimately involved in the munitions trade and had been established originally as a foundry.

Michael set about developing the business of manufacturing and supplying explosives stores. He succeeded in building the company into a leader for this product and H&G became eponymous with the term steel stores. He himself was widely and properly regarded as an expert in this field and as such was consulted by government, the police, the Institute and many others. His advice has resulted in a material increase in the safety and security of stored explosives and our debt to him is therefore a very real one.

He joined the Institute of Explosives Engineers and became a member of Council. His time on Council was unfortunately curtailed when diagnosed with pancreatic cancer. With the attitude with which we characterise him, he made light of this and he did not allow it to prevent him from enjoying himself.

Michael's home life was of great importance to him. He was devoted to his wife Pat, daughter Elvina, grandchildren, nieces and nephews – who referred to him as "naughty Uncle Michael".

Michael Goodwin
1954 – 2017

His family and his wide circle of friends were deeply saddened by his death on 24th August 2017. He was generous, humorous and a true gentleman. We are all the poorer for his passing and we remember him not only with sadness but also with the deepest respect and affection.

The Institute was represented at the service to commemorate Michael's life which was held in Scunthorpe on 8th September.

Andrew Smith MSc AIExpE

IExpE

Members' Weekend & AGM

28TH - 29TH APRIL 2018

CREWE HALL
WESTON ROAD
CHESHIRE
CW1 6UZ

We hope all IExpE Members and their partners will be able to join us for our members' weekend event to include, presentations and practical demonstrations from IExpE members involved in explosives special effects, bomb disposal and explosives detection dogs. This will be followed by a gala dinner dance to include a spectacular fireworks display organised by a member of the Institute.

Pre-paid reservations are required for this event. Please visit our website at

www.iexpe.org/Events

Where you can register information and pay through PayPal.

We look forward to sharing this wonderful weekend with you.

Advance Notice of Subscription Increase

Council have fixed the following rates of Subscription for the year ending 31st December 2018

CATEGORY	UK	ALL OTHER COUNTRIES
Company Member	£550.00	£560.00
Fellow	£139.00	£149.00
Member	£112.00	£122.00
Associate	£89.00	£99.00
Technical	£89.00	£99.00
Students*	£16.00	£17.00
Retired Members*	£56.00	£57.00
ID Card*	£10.00	£10.00

*Retired Rate available only to persons over 60 years of age on 1st Jan 2018, not in active employment and on written application
*Student rate available for a 12-month period from the date of membership, Pro rata rates do not apply to the student rate
*ID Card's issued will be valid from 1st February 2018 to 31st January 2019
Overseas Members - Remittances should be in the UK sterling
All Subscriptions Fees should be made by the 31st January, If payment's not received by the end of February a late payment charge of £35 will be incurred

If you pay for your subscription via direct debit your subscription will automatically increase
Your renewal notice will be issued with December's Journal

Analysing the role of blast design on post detonation toxic fumes generation in quarries

By **Raleke Ralus Okeke** BSc AIExpE

The potential hazards of fumes from blasting operations in quarries have long been recognised. The factors that determine which pattern to adopt during blast designs can be complicated. Some of these include the rock type being blasted, its strength and physical properties. Fragmentation requirement, vibration and air blast concerns may also have a direct influence on which pattern to select. All these factors put together will inevitably determine the hole size and depth, drilling pattern, the firing pattern to adopt and the type and quantity of explosives. When commercial explosives that include ammonium nitrate as the main ingredient detonate, significant amount of gases are liberated as detonation products. Some of these design factors may hinder the ammonium nitrate from attaining full decomposition therefore generating toxic fumes.

Introduction

Blasting is used to break up solid rock in quarries and explosives are necessary in the process. For a successful blast, an appreciable knowledge and usage of clear-cut design metrics and measurement is needed. This should also include studying the mining plans and to be well acquainted with the geology.

To attain utmost rock-breaking efficiency from any commercial explosive, having ammonium nitrate as the major ingredient, an oxygen-balanced mixture is formulated to make certain that formation of noxious gases upon detonation is minimised. Thermodynamically, the preferred end product of an ammonium nitrate based commercial explosive after full decomposition is nitrogen (AEISG, 2011). However, some factors can prevent the ammonium nitrate from fully decomposing resulting in the formation of toxic fumes. This can happen even in perfectly oxygen-balanced explosives. Depending on these various factors, the blasting process may either be ideal or non-ideal.

Under ideal conditions, upon detonation, ammonium nitrate-based explosives will produce nitrogen, water vapour (steam) and carbon dioxide devoid of oxides of nitrogen (Equation 1);

(1) $3NH_4NO_3 + CH_2 \rightarrow 3N_2 + 7H_2O + CO_2$

(Ammonium nitrate) (fuel) (nitrogen) (water vapour) (Carbon dioxide)

Apart from steam, dust and rock particulate matter, there will be no visible gases as the explosive product gases are non-coloured (Fig 1).

Conditions encountered during quarry blasting are not always ideal. Commercial explosives having ammonium nitrate as the main component produce fumes under non ideal conditions (Equation 2).

(2) $5NH_4NO_3 + CH_2 \rightarrow 4N_2 + 2NO + CO_2 + 11H_2O$

(Ammonium nitrate) (fuel) (nitrogen) (nitric acid) (Carbon dioxide) (water vapour)

Once in contact with atmospheric oxygen, the nitric oxide swiftly changes to plumes of nitrogen dioxide.

(3) $2NO + O_2 \rightarrow 2NO_2$

(nitric oxide) (oxygen) (nitrogen dioxide)

The presence of nitrogen dioxide gives post detonation fume its characteristic reddish-orange coloration and pungent odour (NIOSH, 1994). By and large, some factors such as the age and composition of the explosive, moisture content of the drill hole, velocity of detonation, charge diameter, initiation type, and most significantly explosive confinement determine the amount of non-ideal detonation products formed. Research has revealed that the level of confinement of an explosive charge and the material being blasted both have a considerable impact on production of post detonation toxic fumes (Persson and Persson, 1980).

Geology and ground conditions influence the confinement of the explosives which is a vital requirement to ensuring the explosive reaction is near ideal. The explosive may flow into fissures, voids and crevices around the drill hole hence not being able to confine properly. At this instance it forms below the critical diameter prompting an incomplete detonation leading to the generation of toxic fumes (ISEE, 2015).

Figure 1. Blasting under ideal conditions without production of oxides of nitrogen in Majan limestone quarry.

In quarry blasting, the explosives that produce fumes are normally a mixture of porous ammonium nitrate prills and fuel oil alongside other additives. These explosives may be in the form of ammonium nitrate and fuel oil (ANFO), emulsions or water gel containing ammonium nitrate. Most of the ammonium nitrate blast fume cloud is composed of dust, water vapour (H_2O), carbon dioxide(CO_2),carbon monoxide (CO), nitrogen dioxide (NO_2), nitric oxide (NO), soil, and rock particulate matter that is released by the forces exerted on the surrounding rock during the blasting operations (DEEDI, 2011).

	Blast number			
Parameter	M1	M2	M3	M4
Burden(m)	3.0	3.2	3.3	3.1
Spacing(m)	3.4	3.6	3.8	3.5
Stemming length(m)	2.5	2.7	3.0	2.8
Hole Diameter (mm)	76	89	76	89
Hole Inclination (°)	27	22	27	25
Average Hole Depth (m)	15	6	9	10.9
Number of holes	247	291	230	273
Drill Pattern	Staggered	Staggered	Staggered	Odd rows
Firing Pattern	row-by-row	row-by-row	Echelon	Echelon
Number of holes/row	11	10	10	10
Inter-hole Delays (ms)	25	25	9	25
Inter-row Delays (ms)	67	42	17	42
Decking material	crushed stone	-	-	air bag/ aggregate
Explosive Density (gcm-3)	0.82	0.82	0.85	0.82
Explosive VOD (m/sec)	3,700	3,700	3,900	3,700
Explosives Quantity(Kg)	10,000	7,050	10,096	9,875
Powder factor(kgm^{-3})	0.33	0.34	0.38	0.33
Hole condition	wet	Dry	Dry	Dry
Stemming Materials	Drill cuttings	crushed stone	crushed stone	Stemming plugs/ crushed stone

Table 1a. Blast design details for Majan Limetone Quarry.

	Blast number			
Parameter	OG1	OG2	OG3	OG4
Burden(m)	2.6	2.5	2.5	2.5
Spacing(m)	3	3	3	3
Stemming length(m)	2.2	1.7	1.6	1.6
Hole Diameter (mm)	76	76	76	76
Hole Inclination (°)	0	0	0	0
Average Hole Depth (m)	6	3	3	3
Number of holes	196	141	190	200
Drill Pattern	Rectangular	Square	square	Odd rows
Firing Pattern	Echelon	row-by-row	row-by-row	Echelon
Number of holes/row	10	12	10	10
Inter-hole Delays (ms)	109	25	25	25
Inter-row Delays (ms)	17	67	42	17
Decking material	-	-	-	-
Explosive Density (gcm-3)	0.82	0.82	0.85	0.82
Explosive VOD (m/sec)	3,700	3,700	3,900	3,700
Explosives Quantity(Kg)	5,045	1,650	2,225	2,475
Powder factor(kgm^{-3})	0.55	0.54	0.52	0.55
Hole Condition	Dry	Dry	Dry	Dry
Stemming Materials	crushed stone	crushed stone	crushed stone	Drill cuttings/ soil

Table 1b. Blast design details for Dhofar-Mining Gypsum Quarry

Research methodology

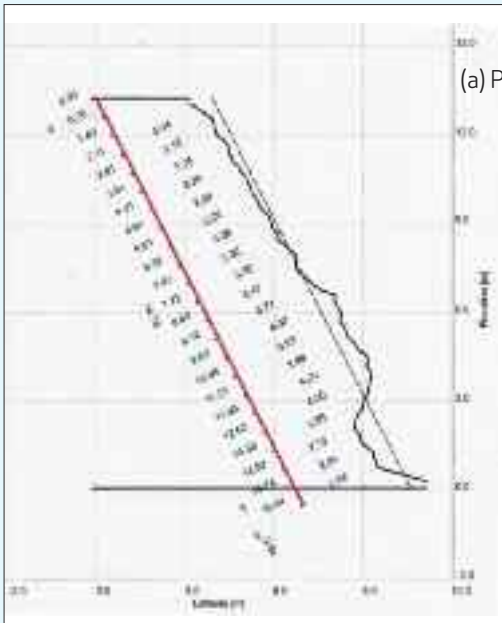
Blasting activities were conducted and closely observed in two quarries in Oman for the purpose of this study (Tables 1a, & 1b). The gypsum quarry belonging to Dhofar Mining Company is situated in Raweya near Thumrait, while the limestone quarry is sited West of Teetam, near Salalah, and belongs to Majan Mining Company. Both quarries were productive at the time of the study. Prior to developing the initial blast designs, existing geology and geologic structures were reviewed while representative rock samples were collected and analysed. Structural discontinuities and effects of weathering on existing outcrops adjoining the blast sites were appraised. For each blasting activity, a blasting specification was drawn up, taking into consideration

- a plan showing the blast location
- drilling plan indicative of proposed hole positions, diameter, depth, and inclination
- driller's log having a comprehensive view of geological anomalies (joints, cavities, and bedding planes)
- survey showing the diameter, angle of inclination, number, and spacing for each blast hole
- profile and minimum burden around each hole to determine the burden and the minimum distance between a blast hole and the face independent from any direction (Figure 2, see over page)
- diagram showing the details of explosives, detonators/cords, decks and stemming in each blast hole
- system of initiation and detailed sequencing pattern.
- plan showing the danger zone and shortfiring position.

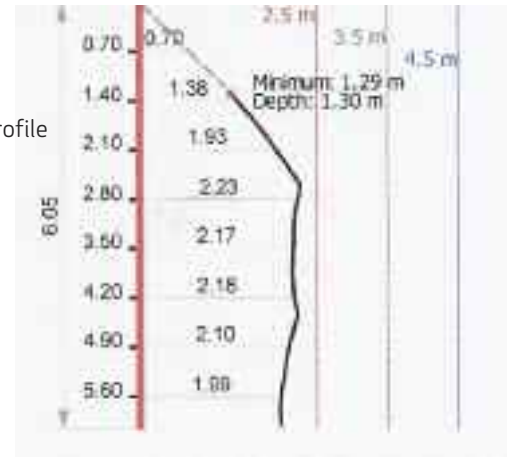
Alternate blast designs were made using 76 mm and 89 mm diameter blast holes. The holes used in the study were sometimes divided into blocks and cautiously monitored. Explosives containing a stoichiometric mix of fuel and oxidizer were carefully chosen for this study so as to minimise the production of toxic fumes based on oxygen in-balance. If there is an excess of fuel, detonation of the explosive will generate increased quantities of carbon monoxide (CO). Conversely, if there is not enough fuel, detonation of the explosive will generate increased quantities of nitrogen dioxide (NO_2) (Rowland and Mainiero, 2000). All explosives were plant mixed. Holes were either primed using emulsion cartridges or boosters and manually charged using ANFO packaged in 25kg bags and the length measured using tapes/marked stemming rods while pouring. For the purpose of this study various drilling patterns were used, the initiation timing for multiple hole blasting was varied taking into consideration different scenarios (too short, too long and normal). This enabled the observation of the effects of burden restriction, and cutoffs (ripping apart of a network of tie-ins by ground movements before it has had the chance to initiate all the holes in the firing pattern), on the production of fumes.

Geological indices of blast design

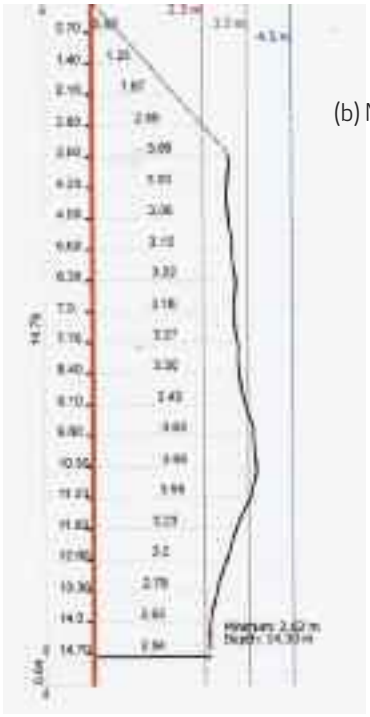
Blasting performance is influenced more by rock properties than the properties of the explosive (Bell, 1992). Modeling blast designs based on the diverse geological conditions peculiar to any quarry will help in adjusting to changing conditions encountered as mining activity progresses. The drill log provides data to the blast designer verifying the rock mass and its blastability. Ground water alteration should also be taking into consideration while gathering data.



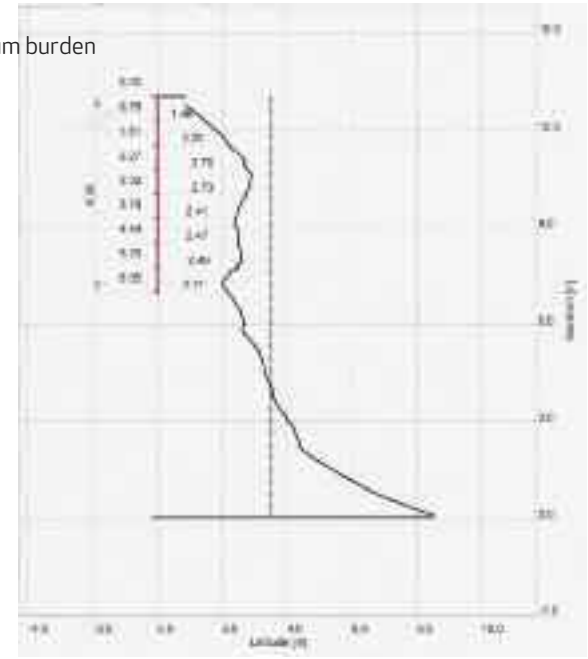
(a) Profile



(c) Profile



(b) Minimum burden



(d) Minimum burden

a & b -: hole M1-(20) at Majan Limestone Quarry
c & d -: hole OG2-(10) at Dhofar-Mining Gypsum Quarry

Figure 2. Comparison of a profile with the minimum burden diagram of the same blast hole.

Structural orientation

Generally, a rock mass is perceived to contain structural discontinuities of different types (Figure 3). Relevant data such as orientation, spacing, length, and aperture for visible joints, faults and bedding plane where possible should be accounted for. It is also important to document the type of joints, and whether or not the joints are open. Open joints could facilitate water percolation, and this will make the hole wet. As observed at the limestone quarry, conjugate joints sets were mapped in the NE. Some drill holes were noted to be wet as a result of water ingress which emanated after a low cloud ceiling during the khareef season. Wet holes undoubtedly facilitate fume formation upon explosive detonation (ISEE, 2015). Knowing the condition of individual holes will determine the design suitable for a fume free blast.

Figure 3. High wall showing structural discontinuities at Dhofa- Mining gypsum quarry in Raweya.

Quarry Location	Rock Type	Relative density(g/cm³)			Water Absorption (%)
		*OD	*SSD	Apparent	
West of Teetam, near Salalah .Oman **N 17⁰ 02' 38.3" E 053⁰ 46' 24.4"**	Limestone	2.59	2.61	2.64	0.71
Raweya, near Thumrait. Oman **N 17⁰ 30' 30.2" E 054⁰ 00' 57.1"**	Gypsum	2.32	2.33	2.34	0.39

*OD - oven dried
*SSD - saturated surface dry

Table 2. Relative density and water absorption data for rocks from studied quarries.

Figure 4. Plume of toxic fume, dust, soil and rock particulate matter in Majan limestone quarry.

The orientation of joints is also vital in quarry blast design as it tends to affect the stability of high walls. Smaller diameter blastholes are more suited to strongly jointed rocks as the decreased spacing results in fewer joints between holes. Both the strike and dip values of each visible joint should be noted, and when designing the blast, joints dipping out of the walls should be avoided to guide against wall failure and blast hole cut-offs.

From the structural orientation data in the southern pit at the gypsum quarry, joint sets daylight the quarry wall in a down-dip direction. Geological mapping located a series of minor thrust faults with dips of 20°-45° to the NW. The throws were mostly less than 1.5m. Stereographic plots from the gypsum quarry indicated that there is a possibility of wedge failure when such thrusts intersect bedding.

Rock density

The density of any rock is very much connected with its strength. By increasing the drill hole diameter, reducing the drill pattern and changing to an explosive having a stronger heave energy, adequate displacement of higher density rock can be achieved. With a good knowledge of the rock density (Table 2), the drilling pattern will be choosen to suit the design and guide against inter-hole explosive desensitisation which arises when blast holes are drilled too close together. When commercial explosives are desensitized, a non ideal scenario occurs resulting in the formation of noxious fumes (Equations 2 and 3).

Discussion

Blast hole layout and loading

Using measurement while drilling (MWD) techniques will help in determining the condition of the hole, bearing in mind that blastholes are not always perfectly cylindrical, differing internally in shape and form. This down-the-hole profiling will aid in the selection of appropriate explosive product to be placed into the holes. A different product may be required for different holes or even down the same hole if there is a noticeable strata variance.

Choosing the proper drilling pattern and placing the specific quantity of explosives which was in consonance with the blasting specification in Majan Limestone quarry, SW bench (pit 1), resulted in the optimal use of explosives with all undergoing complete detonation, (Table 1a-M2) consequently giving an ideal situation (Figure 1). However, using the same parameters on the eastern part of the pit without adjusting the blasting specification during the next blasting session, it was observed that plume of fumes was generated upon detonation.

Tables 1a-M4 and 1b-OG4 show the design parameters used in order to determine the effect of priming and charging on the production of fumes. Two blocks of four rows each (10holes/row), were used. At the Limestone quarry, the third and fourth rows were poorly primed. Figure 4, shows the plume from the studied block. Also the block containing lots of cavities was charged without caution, some holes being over charged. At the Gypsum quarry, all the holes in the first block while charging were contaminated using drill cuttings and soil. It was observed that the understudied blocks produced fumes upon detonation.

The unethical practice of indiscriminate charging of blast holes without caution by the blasting crew, consequently contaminating the explosive with drill cuttings, proved to be a contributory factor to fume formation. The blaster while loading a hole should frequently check the rise of the explosive column to prevent overloading due to the loss of blasting agents in voids and cracks. Explosive energy tends to vent through the weak zones, and when undetected voids are loaded, anticipated confinement is not achieved which in turn leads to fume formation. Hole liners could be used if it becomes apparent that the holes are wet or have cavities. Stemming provides confinement and prevents the escape of high-pressure gases from the blast hole. Insufficient stemming causes vicious fragmentation of the collar zone resulting in flyrock, airblast and fumes. The blaster should determine what type of stemming material best suits his design as no two quarries are the same. Stemming plugs or crushed stones will serve as good stemming materials.

Proper priming of blastholes is an integral part of a successful blast. Using either detonators or detonating cord, blast holes must be accurately primed by firmly embedding them in either emulsion cartridges or boosters to avoid being pulled out of place during loading. The strength of the primer should be known and sufficient enough to initiate the explosive column.

Blast timing sequence

The selection of the initiation system is one of the most important considerations in blast design. Different delay techniques are used to achieve better fragmentation, control rock movement, and to reduce ground vibration. Delays are incorporated into the blast

Figure 5. Connecting a 17ms Nonel connector to a surface trunk line at the limestone quarry.

design using detonators (electric, non-electric, electronic), cord relays or delay connectors with detonating cord (Figure 5). Generally the direction of throw and resulting fragmentation will be determined by the firing system's geometry engaged in the blast design emanating either from hole or deck initiations.

At the gypsum quarry in Raweya, for the purpose of this study, the timing sequence was altered for a block of holes to note the effect of delay pattern on toxic fume formation (Table 1b-OG1). The inter-hole delays were made to be too long. Upon initiation, due to a long delay period, the protection from the fired rows disappears thereby disallowing the adequate confinement leading to adjacent explosives product columns to become desensitized. This action hindered the complete detonation of the columns leading to fume formation. Figure 6 depicts a hole still emitting fumes about three minutes after detonation.

Table 1a-M3 summarises the blast design in Majan limestone quarry used to analyse the effect of too-short a delay. The inter-hole delays were made to be too short leading to row burdens being constrained due to not having enough time to move forward and causing formation of back breaks (Figure 7). Proper sequencing of inter-hole and inter-row delay timing is an important contributor in firing patterns for good blast results (Choudhary, 2013).

If inter-hole delays are too long, cutoffs of surface delays resulting from flyrocks may occur resulting in an incomplete detonation of the explosive charge leading to fumes being formed. If the inter-hole delay is too short, the movement of row burdens is constrained and fragmentation is poor.

Figure 6. Nitrogen dioxide fume emission from of a 76mm hole after detonation in Dhofar-Mining gypsum quarry.

Figure 7. Back break as observed after bench blasting in Majan limestone quarry.

High ground vibrations result and back-break along the new wall may be eminent, affecting the stability of the slope. Back-break occurs when the stress produced in the rock by the explosion exceeds the crushing strength of the rock. The crushing strength is typically two to five times the uniaxial compressive strength (Workman and Calder, 1992). Holes drilled behind the back-break for subsequent blasting may contain voids or cavities resulting from previous blasting. Fractures due to previous blasting should be accounted for in ensuing blast designs.

Conclusion and recommendations

The underlying causes of post detonation toxic fumes are fuel-deficiency in the explosive and or detonation reactions that do not continue to completion. Blast design no doubt plays a role in the later. In as much as a blast worked well on one side of a pit, does not necessarily entail that the same parameters will work in a different location in the pit. Complacency and assumption often lead to poor blast designs. It therefore behooves the blaster in charge to analyse a critical appraisal of the mine during the blast design so as to adjust where necessary.

Continual improvement through evaluating new technology and alternative blasting methodologies will effectively reduce the possibility of fume generation. The elimination of fume requires the concerted effort by all involved in the blasting activity. Professional expertise on the part of the blaster in charge and good work ethics from other crew members will in no small measure avert the unnecessary production of post detonation toxic fumes.

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A Prosecutor's perspective

By **Ruth Barber** LLB (Hons) AIExpE

The article addresses common misconceptions about the causes of accidents, the typical range of responses of dutyholders following an incident, and the role of the prosecutor. By identifying common misconceptions and unhelpful responses, the article aims to assist dutyholders to make better decisions in the wake of an incident.

This article is based upon a talk of the same title given at the 2017 IExpE Conference, and upon 10 years of experience working as a prosecutor specialising in high hazard environments on behalf of the Health and Safety Executive.

The opinions expressed in this article are the sole opinions of the author and do not represent the views of any organisation or any government department. This article is not legal advice, and advice should always be sought from a qualified legal professional in relation to specific problems.

You are the owner or manager of a high hazard facility and receive a call at 3am informing you that an accident has occurred at your site. You leave your home and arrive at what was formerly your premises to discover a smoking crater in the ground. What is your first response?

All high hazard sites should have in place an emergency response protocol which should advise on the steps to be taken in the aftermath of an accident. Accidents frequently occur at inconvenient moments when the person with the greatest knowledge and experience is unavailable. It is therefore extremely important that the emergency protocol can be easily located and clearly understood by someone without direct personal knowledge of the site or the likely causes of the incident.

Your actions in the immediate aftermath of an accident are critical both in relation to preserving your business as an ongoing operation, preventing the accident escalating and avoiding litigation.

The response protocol should contain:

- The details of a designated response manager
- Up to date maps of critical infrastructure
- A procedure for undertaking a rapid risk assessment of the current situation
- Procedure for logging events
- Procedure for notifying relevant authorities
- Procedure for securing/preserving evidence
- Procedure for notifying affected persons
- Procedure for data recovery
- Information on the location of other relevant information such as product inventories.

In the event of an accident staff should be able to react instinctively, and simply refer to the procedures as guidance. To ensure that staff can react instinctively regular drills should be held. A debrief at the end of each drill will ensure that the emergency response protocol remains up to date and fit for purpose. Too many companies discover the weaknesses in their emergency response protocol during the aftermath of an accident.

As the sun rises your fellow directors arrive at the site to survey the damage. The relevant parties have been notified and steps have been taken to manage the site. What do you do next?

A meeting should be organised to assess the information collected so far and plan the next steps and set up your investigation team. The person who has managed the event during the night should present his/her findings at the meeting and then be relieved by a fresh incident manager. At this stage minute by minute logging of events may no longer be necessary and the focus will shift to managing the enquiries of interested parties e.g. family members, workers, journalists, insurance assessors and health and safety inspectors.

During this initial meeting a summary of the incident to date should be prepared. A non-confidential factual summary can be used to brief interested parties. An initial list of evidence should be prepared and a plan for the collection, preservation and storage of further evidence. Photographic and video evidence of the scene is also crucial. Keep a careful record of who is doing what at the early stages of the investigation as they may be required to give evidence later. Your team should reconvene for progress meetings regularly, for example at 6, 12 and 24 hours.

An incident such as a fire or explosion will attract press interest, and journalists and members of the public are likely to quickly arrive on the scene. A person should be appointed to deal with press enquiries. This will ensure a consistent message is provided and hopefully prevent the disclosure of compromising or prejudicial information. A person should also be appointed as a worker/family liaison officer. This is especially important if injuries have occurred, but even if there are no injuries workers will be making enquiries about their future. Uninformed or anxious workers or members of the public may turn up at the site and risk hampering the investigation, or start briefing against the organisation.

At this point you may also wish to appoint lawyers. Specialist lawyers can assist with fielding queries but also bring an element of independent oversight to the investigation. They will also be able to advise on how the ongoing investigation can be structured.

How will your organisation respond to the ongoing challenges of managing a serious incident?

Many organisations that successfully manage the initial incident and its immediate aftermath, oddly flounder during the later stages. This is often the point where responsibility for managing the incident passes from direct managers at the site to senior management. Typical problems that arise at this stage are as follows:

- **Information gaps**
  Persons making decisions are not sufficiently well informed, or lack appropriate specialist knowledge.
- **Blame games**
  Some directors may be concerned at being held out as a scapegoat to protect the organisation, or consider themselves at risk of personal prosecution. They may therefore be primarily concerned with protecting themselves rather than the organisation. Alternatively, directors may seek to shift responsibility to workers or managers, thus alienating persons who might valuably help with the investigation and rehabilitating the organisation.

- **Excessive defensiveness**
  The organisation engages in a hostile manner with outside agencies and seeks first and foremost to deny all responsibility in the face of clear breaches. This approach tends to have the exact opposite effect than is intended and merely stokes suspicion and provokes a more aggressive investigation by outside agencies. Investigating authorities have a duty to act fairly and in accordance with published guidelines. If you feel that an investigating authority is not acting fairly you have a right either to lodge a complaint or make a legal challenge to their decisions.
- **Shock, denial and chaos**
  This outcome tends to afflict organisations which lack an adequate disaster recovery plan. Bizarrely some organisations fail to adequately prepare for emergencies because to do so would draw attention to potential failings. Such organisations have a perfectionist rather than a realistic worldview. When disaster strikes it hits such organisations particularly hard, and the management board can descend into a spiral of blame and acrimony. The organisation is then unable to engage with investigating authorities, and may obtain the worst possible resolution after a protracted investigation. Such organisations frequently never recover from incidents that better prepared organisations weather with relative ease.

It is helpful to have someone with first-hand knowledge of the incident present at all key post incident management meetings. External experts should be drafted in to assist as soon as possible: they provide both useful technical information and an element of independent oversight.

It is unhelpful to seek to blame individuals, especially in the early stages of an investigation. High hazard incidents are rarely the result of the actions of one individual, but rather the outcome of numerous disparate failings. Blaming individuals will seriously hamper your investigation by alienating those individuals, and will also have a chilling effect on the free flow of information from others. Show support for your workforce by offering an information amnesty and providing, where necessary, independent legal advice for workers. Prosecuting authorities take a dim view of attempts by corporate entities to offload responsibility. Unless the incident is clearly the consequence of a wholly reckless and unforeseeable act by one individual, attempting to offload corporate responsibility is unlikely to be successful.

Mitigating a disaster is usually by far the most successful strategy. Engaging promptly and proactively with investigating/prosecuting authorities is likely to speed up the investigation, saving time and money. For most organisations resolving the investigation and resuming normal operations is likely to be the priority. An ongoing investigation is expensive in terms of staff time, legal costs and ongoing negative publicity. Each organisation should take advice, but the costs of even a successful trial may well exceed the costs of an early guilty plea with good mitigation. The ultimate financial penalty imposed by the court is often the least of the financial burdens on an organisation after an accident. Organisations should also be aware that trial proceedings frequently expose commercial details of the organisation's operation which the organisation might prefer to keep confidential. Strong court mitigation after a guilty plea can also help to turn around an organisation's reputation. The organisation has far greater latitude with the content of a mitigation speech following a guilty plea, than following a conviction after trial when a Judge may also quote unfavourable witnesses when sentencing.

Early engagement with the investigation authorities may help to avoid an investigation turning into a prosecution. In the event a prosecution decision is made, carefully agreed terms for a guilty plea may assist in restricting the organisation's wider liabilities.

Why do accidents happen?

There remain persistent myths about the causes of accidents. These myths persist in part from a lack of understanding and in part because some organisations prefer to avoid addressing corporate failings.

- **Inexperience**
  Accidents are rarely caused solely by inexperienced people, as inexperienced people tend to be risk averse, and where permitted, will seek assistance with tasks with which they are unfamiliar. Accidents are usually only caused by inexperienced people when they are forced to work on tasks beyond their competence.
- **Absence of written procedures**
  The presence or absence of written procedures is rarely a cause of accidents. An absence of written procedures may be indicative of a poor safety culture, but equally indicative is a set of proforma rules not tailored to the organisation and never read. The best organisations have a set of procedures drawn up by the workers based on their own risk assessments of the workplace. Such workers will have an inherent understanding of good practice and will therefore not need to rely on constantly reading procedures.
- **Laziness**
  Laziness is rarely the cause of accidents; however, complacency is frequently a cause. Persons undertaking high risk roles for long periods become de-sensitised to the risks, and over time skimp on protective measures. Complacency can be avoided by regularly moving people undertaking high risk tasks into different roles. This management strategy has many additional benefits – staff become multi-skilled and have a better understanding of the work being undertaken by their colleagues. They can spot errors made by colleagues and cover for un-expected absences. A fresh perspective may uncover a more effective method of undertaking a task, and greater understanding of staff of the operation may lead to a more efficient team.
- **Staff absence**
  Whilst unexpected absences will put pressure on a team, there should be sufficient latency and experience within a team to cope, at least in the short term. Frequent staff absence is often a symptom of larger management and organisational problems.
- **Lack of task specific knowledge**
  Similarly to the inexperienced, the unskilled will usually resist undertaking tasks that are outside their competence, or will seek advice from other colleagues. Problems arise when workers are forced to undertake tasks outside their competence.
- **Exhaustion**
  The mental reasoning capacity of even highly skilled professionals diminishes rapidly under the effects of stress and lack of sleep. Whilst there is clearly a profit incentive to keep a business running, the cost of the consequence of poor decisions in a high-risk environment may be higher.

- **Short term profits**
  The long term cost of keeping an inefficient, or poorly maintained operating system running is likely to exceed the short term profits. Middle managers should have the freedom to shut down operations for maintenance or when they deem their staff are unable to make safe decisions, even in the face of short term losses.

- **Contractors**
  A common cause of health and safety system breakdown is an ineffective interface between contractors and employees on a site. Both organisations may independently have robust and effective health and safety arrangements, and the contractors may have been properly vetted. Problems arise because the two systems do not easily mesh and important checks may fall through the gaps: each organisation thinks the check has been undertaken by the other.

  When contractors are working closely alongside established employees, the hiring organisation should be careful to check how safety systems are working across the two organisations. It is not sufficient simply to vet a contractor before work commences; an audit shortly after work has commenced will more accurately assess how arrangements have bedded in.

- **Tick box risk assessments**
  Pro-forma risk assessments can be useful for basic tasks or as a starting point, however in themselves they are rarely sufficient for even simple tasks in high-risk environments. The danger with a tick box risk assessment is that its generic nature means that obvious, but specific risks linked to a particular task may be missed. The worker believes that once the tick list is complete the risk assessment is complete and fails to think about additional hazards. Every tick list should be clear that it is not exhaustive and require some narrative input which will force the worker to think about further potential risks.

- **Toxic culture**
  Every workplace has either a positive or negative safety culture, usually a product of explicit or implicit messages from management, or a culture cultivated by key individuals on the shop floor and not challenged by management. Workers are either encouraged to embrace safety policies or encouraged to disregard them. The difference is usually one of perception; where policies are simply imposed on workers with no input from them and no consideration of how the policies will operate in practice, the policies are likely to be shirked and disregarded. Policies are likely to be disregarded by workers where management gives the impression that the organisation regards the requirement to undertake health and safety assessments as simply an annoying and unnecessary legislative burden.

  Employees should be encouraged to undertake their own risk assessments. This process of employees analysing how their work is undertaken can also help employees provide more general feedback to employers on how their task could be made more efficient.

  Risk assessments and safety systems that have been drafted by employees undertaking the relevant tasks are more likely to be fit for purpose. Since these policies are drafted by employees and not imposed by management there is likely to be less resistance to compliance since the employees are themselves stakeholders in the process.

  In working cultures where risk taking is valued, health and safety can be viewed as a peculiar form of cowardice. In such cultures it can be helpful to focus not on the effect of incidents on the workers themselves, but the potential effect of an incident on their dependents. This also helps to promote a culture of looking after others: some workers find it more socially acceptable to look after their colleagues than to look after themselves.

- **Disconnection between safety and management systems**
  In some organisations health and safety is simply seen as a set of unnecessary and burdensome regulations. Consequently, the task of undertaking necessary risk assessments is often delegated to the least competent person who then receives little support. The assessments that are created fulfil the statutory minimum requirements but fail to identify potential problems or provide useful solutions. Some companies outsource their health and safety duties to providers of questionable quality, or fail to act upon the recommendations received from competent providers. Outsourcing health and safety assessments does not absolve the organisation from responsibility in the event of an incident.

  These approaches cause the risk assessment to be disconnected from the organisation's management systems. For health and safety measures to be useful, safety risk assessment needs to be integral to system management. Strangely, some organisations that routinely undertake, for example, financial risk assessments balk at undertaking routine safety risk assessments. The grounds for undertaking a safety risk assessment are no different than the grounds underpinning a financial risk assessment: a desire to identify potential problems to the business in advance to allow the business to take steps to prevent the problems from occurring, or mitigating their effects in the event of the worst.

Conclusion

All organisations must accept that failure on some level at some point is inevitable. Complex and high risk environments have a greater potential for catastrophic failure. A realistic approach to risk management is not to try and avoid failure but instead put in place layers of latency and checks and balances within a system. These help to prevent failure and help to prevent a minor failure becoming a catastrophe.

A sound emergency response protocol combined with regular drills should ensure that any incident is managed effectively and negative fallout is minimised.

Co-operation with the investigating authorities will usually secure the best outcome for the organisation either in terms of preventing a prosecution or by mitigating liability.

Health and safety should be integral to management systems, and a culture of taking care should be promoted within the organisation. Employees should be encouraged to take responsibility for the welfare of themselves and others and supported to report near misses. This approach is likely to have benefits not only in a reduction in accidents but will promote the development of more efficient communication and management systems within the organisation generally.

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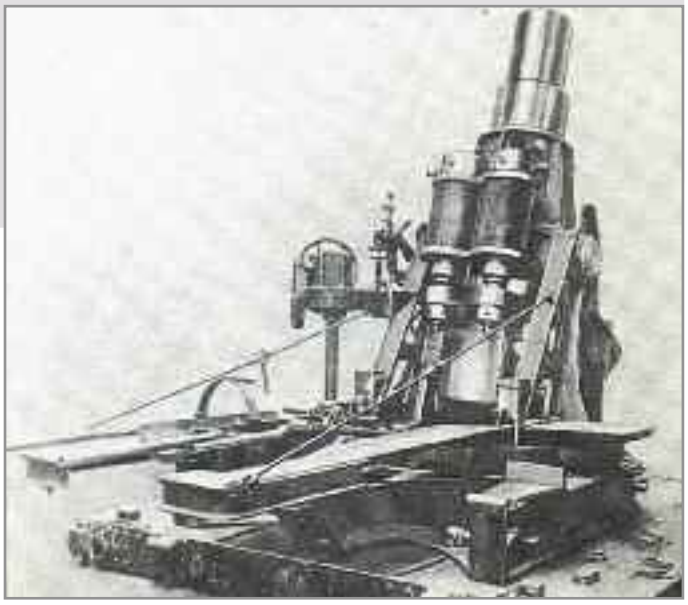
By **Ian McKay** FIExpE

When Gavrilo Princip shot the Archduke Franz Ferdinand, heir to the throne of Austria, in Sarajevo on 28th June 1914, it brought to a head matters which had been exercising the minds of the great powers for 20 years and more. It is doubtful if he anticipated the scale of the war which would result. Presently, in the first few days of August, Germany declared war on Russia, then France and Germany declared war on each other, followed by Germany declaring war on Belgium - immediately crossing her frontier - and then Great Britain joining in to aid "little Belgium". There was no obvious need for haste. The might of the allied powers, immensely supported by British jingoism and her valiant navy, would soon show the Hun what was what, and our gallant Tommies, even then embarking for France with cheery wave and song, would be home for Christmas.

By the time the first six months had passed it was shockingly and abundantly clear that being home for this, or even for next, Christmas was looking like a pious hope. The main protagonists continued to dig themselves into deeper and deeper trenches which stretched eventually from the Flanders coast near Dunkirk, something like 470 miles to the Swiss border.

Map of trench system near Beaumont (Thiepval) on 14 Oct 1916.

The last years of the 18th century had seen huge strides in improvements of guns, arms and ammunition of all types. These advances and the difference in the tactics of warfare from the fast-moving and gallant cavalry charges of the Crimea to the squalid trenches of Flanders, where a major victory was measurable in movements of a few yards, meant that there were massive changes to be assimilated by the armies on both sides.



WW1 17-inch howitzer

Eventually the multiplicity of trenches supported in the rear by guns of inordinate calibre and vast range, lead to munitions output expanding in the first six months of the War by nineteen times in Great Britain alone. Shell deliveries in the first half of 1915 were 2,278,105 and were to rise to 13,995,360 in the first half of 1916 and to 33,407,193 by the end of 1916. The enormous number of 23 million shells were fired at Verdun by the French and Germans between February and July 1916: eventually there was to be one large artillery piece for every 5¼ yards of the Flanders front.

By mid-1915, the lack of supplies of shells to maintain these prodigious feats of consumption at the front line lead to a political scandal known as the shell crisis. The British shell production was neither maintained at its highest efficiency in terms of numbers of output nor of their quality. Heads rolled. The munitions factories were thrashed into overdrive. Almost imperceptibly at first, the supply of shells and munitions improved. But the raw materials for these had to be stockpiled somewhere so that they could be sent out to the shell filling factories.

Part of a large Cordite store of WW1 date

Up to September 1915 the Ministry of Munitions of War (War Office) only had suitable magazines (a magazine is a building used for explosives storage) at Woolwich Arsenal, Purfleet and Weedon. These were just about sufficient for the supplies of home-produced cordite but were totally inadequate for dealing with propellants from overseas in addition. It was estimated that storage for twenty thousand tons would need to be found.

Initially caves and quarries were used as shell storage space but this proved to be insufficient for the huge quantities involved. A study of potential storage sites was made. Sites were selected on the basis of a number of criteria which were specified as being appropriate for a storage site for such hazardous and strategically important materials. These criteria were :

- Isolation from other buildings
- Expenditure in adaption
- Suitability from a military point of view
- Outside the area of air raid attack
- Capacity about 2,000 tons
- Suitability for traffic
- Cheap handling on site
- Distribution to (shell) filling factories (like Leeds, for example)

In October 1915 therefore it was decided that two large propellant storage depots would be built, one in Gloucestershire at Slimbridge (HM Magazine 23) and the other on the Lancashire/Yorkshire border at Salterforth, between Burnley and Skipton. In 1916, the depot at Salterforth came into use. It consisted of seven storage buildings for cordite, which is a propellant explosive used in shells. The reference to the site as His Majesty's Magazine is proof that it was for storage alone and that it was not a place in which munitions were made or filled, which would be referred to as a "factory", a "filling factory" or an "ordnance factory".

The Midland Railway main Skipton-Colne line had its junction to Barnoldswick about a mile south of Earby station. The branch was a single track line which had been opened by Midland Railway on 8th February 1871 and was closed to passengers on 27th September 1965. The company identified the 'Earby Ammunition Works Sidings' as coming off the branch line 13 chains (about 300 yards) from the Barnoldswick Junction by a single track line. Both of these are shown in the OS map extracts and sketch plan. There is contradiction in detail however between the 1931 OS map the 1923 edition. There was also access to the depot from the Leeds & Liverpool Canal.

Some of the details known about Salterforth depot are:

Magazine reference number (for administrative purposes only)	22
Location according to War Office listing	Skipton, Yorks
Consignment address	HM Magazine, Earby, Yorks., Midland Rly, Skipton to Colne line
Postal address	The Superintendent, HM Magazine, Salterforth via Colne, Lancs.
Telegraphic address	Magazine, Barnoldswick
Telephone number	Barnoldswick 41
Name of Superintendent in 1917	W.Currie
Superintendent's salary	£400 per annum

The depot appears to have finally closed in 1923, though there is no record known of it being in active use after the end of hostilities. Even by 18th June 1927 the sidings themselves had not been listed as having been removed: the date of them being lifted is not known with certainty. Part of the line of the railway itself was obliterated when the new road from Kelbrook to Barnoldswick was built. Work on this road began in 1922 but it was not opened to Kelbrook until 1934. There can still be seen in the fields some vague outlines of buildings now demolished and part of the canal wharf is also still visible a few hundred yards from the Anchor public house at Salterforth.

A railway Gunpowder Van, built in 1915 and out of service by 1922.

Did you know?

1. In 1915 there were over 43,000 persons employed in explosives factories owned by commercial enterprise (i.e., not under government control) and that this was an increase from a figure of 14.500 in 1910 and about the same in 1905. At these factories or associated with them there were 461 magazines in use in 1915. In 1915 there were 29 accidents which involved either cordite exploding or burning during production.
2. Schoolchildren were actively encouraged by the Minister of Munitions acting through the Board of Education, to collect conkers and send them to the War Office. This was not so that the conkers could be thrown at the enemy soldiers but so that they could be used to manufacturer acetone which was a critical ingredient in making cordite for shells.
3. Due to the proximity of the Salterforth cordite storage depot, the old Foulridge Methodist Chapel on County Brook Lane (OS grid ref 881433) had the unusual and curious distinction of carrying insurance against damage from Zeppelin raids, one of only a few buildings to do so.

This article was submitted to the Journal Awards Competition 2016

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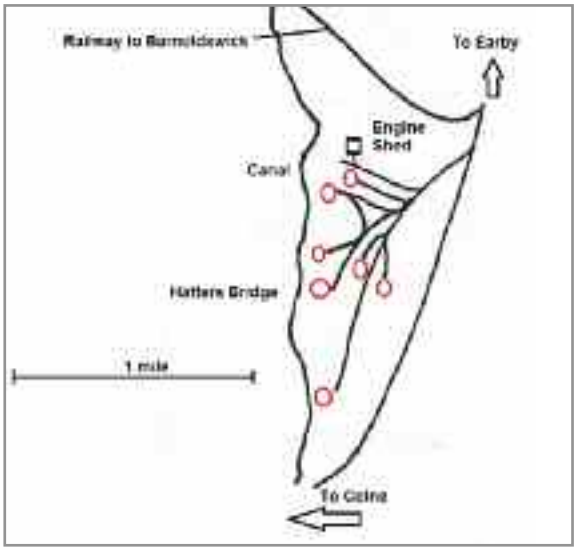
1923 OS map (part)

1931 OS map (part)



Sketch plan showing location of cordite stores

Part of modern map showing approximate boundary of site and location of Foulridge chapel

Application of blast injury research

By **Dr Spyros Masouros** CEng PhD

Explosive devices were the insurgents' weapon of choice in recent conflicts. Improvements in personal protection, evacuation logistics and medical care resulted in increasing numbers of battlefield casualties surviving with complex, multi-trauma injuries, often leading to long-term disability. The socio-economic burden of the long-term clinical sequelae of injury caused by explosions is substantial, yet largely unknown. For example, a recent study examining trauma care, rehabilitation and prosthetics estimates the total 40-year cost of the UK Afghanistan lower limb amputee cohort, some 265 individuals, at almost £300 million[1]. Improving and extending the means of preventing and managing such devastating injuries should therefore be continually sought.

One of the most significant deficits in improving protection from explosive weapons has been the dearth of clinical information of blast casualties. Central to the success of any mitigation system is the ability to protect the soldier not only from lethal injuries, but also to reduce the possibility of long-term harm. In order to achieve this aim, a fundamental requirement is to define as accurately as possible the injury profile that is likely to result in fatality and in disability in our young, highly active military population (Figure 1). In addition, scientific and engineering tools and technologies must be developed and used in order to model – computationally or experimentally – the insult and its effects on the human body, in other words replicate the appropriate injury mechanism. Defence organisations have, in the past, extrapolated injury data from the automotive industry to address blast injury. The shortcoming of this approach, however, have since been recognised and the landscape of blast injury protection is changing.

The Centre for Blast Injury Studies at Imperial College London exists to further the understanding of blast injury. Hosted by the UKs leading Department of Bioengineering, it boasts a full time membership of scientists, engineers and military medical personnel whose sole remit is to undertake the clinical and experimental analysis of blast injury, in order to influence protection and treatment. This article summarises some of the Centre's recent efforts and highlights additional work, available in the public domain, to demonstrate how these might lead to improvements in mitigation strategies.

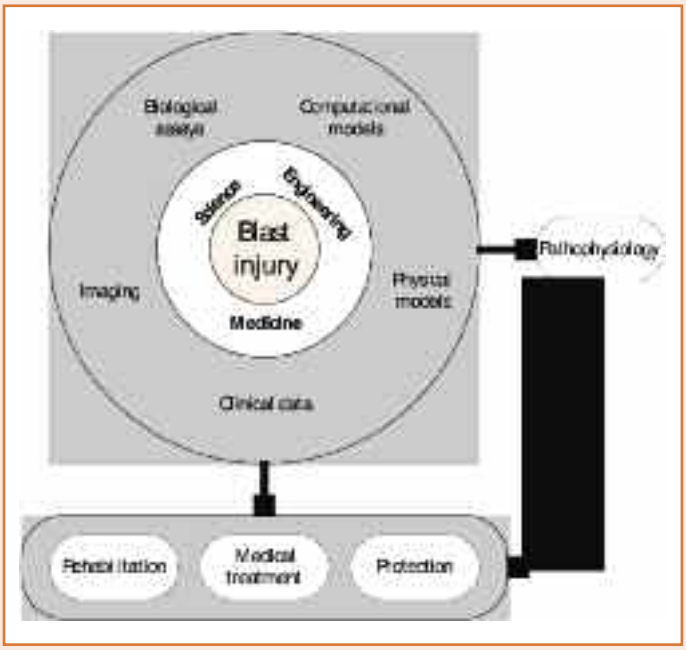


Figure 1: Research strategy for addressing blast injury.

Blast injury patterns

Analysis of prospectively collected military trauma databases, such as the UK's Joint Theatre Trauma Registry[2], combined with radiological data and clinical outcomes, has been the methodology used in recent research efforts to deconstruct complex battlefield injuries into component elements, thereby enabling injury characterisation and prognostication. The injury profile of mounted (in vehicle) and dismounted (on foot) casualties has been shown to be different[3]; specifically, a greater number of body regions were injured within the mounted group.

Dismounted

Within the dismounted group, extremity and junctional haemorrhage was the predominant cause of death. As the majority of the dismounted fatalities died of uncontrolled haemorrhage before they could be treated, improvements in medical care are unlikely to yield future survivors. With future conflicts likely seeing prolonged evacuation times compared to what was achieved in the Afghanistan conflict, increase in survivability can only result from injury prevention at the point of wounding.

Mounted

Within the mounted group, head injury (50%) and intra-cavity haemorrhage (20%) were the leading causes of death[3,4]. Lower extremity injury is the most common injury due to explosions[5]; specifically in survivors the characteristic injury that has been shown to have poor clinical outcomes has been the 'blast foot'[6]. Approximately one third of casualties with a foot and ankle injury

require amputation within three years and 75% have ongoing clinical symptoms (such as infection or osteoarthritis) at three years. Spinal injuries in survivors occur predominantly in the lumbar spine and are mostly burst and wedge compression fractures, suggesting axial and bending injury mechanisms[7]. Cervical spine injuries are not common in survivors, but are a significant cause of death in fatalities. Pelvic injuries occur at the sacrum and the pubic rami also suggesting a predominantly axial loading mechanism directly through the seat.

Blast injury mechanism and current protection

Dismounted

The dismounted blast injury pattern features devastating abdominal, pelvic, perineal, and genitourinary injuries along with proximal traumatic amputation; it also features significant contamination from high velocity fragments, soil and grit. The mechanism of dismounted injury has not been described previously in detail. Based on the injury profiles seen, our current understanding is that the main culprit, responsible for the most severe of the dismounted injuries, appears to be the blast wind carrying soil ejecta (secondary blast injury mechanism) whose energy appears sufficient to devastate the foot, shred skin, flail the lower extremity violently, and therefore cause significant disruption at the pelvic region. Protection of the groin, perineum and buttocks from soil ejecta was offered at the latter parts of the Afghanistan conflict through the introduction of 'armour' in the form of silk underwear and Kevlar lining around the groin; this was successful anecdotally in reducing contamination and soft tissue injury. Protection from traumatic amputation, pelvic fracture, and vascular injury that might be lethal, however, through personal protection equipment is yet to be attempted, and this is where the focus should now turn to.

Mounted

The mounted blast injury pattern is due to the interaction of the explosion-struck vehicle structure and the occupant. An explosion underneath a vehicle causes dynamic deformation of the vehicle's structure due to the transmitted shockwave and the soil ejecta. The shockwave hits the vehicle structure in 0.5 – 1ms followed by the soil ejecta. The resulting local accelerations cause deformation – elastic and possibly plastic – of the hull and the structures mounted on it in approximately 2 – 20 ms depending on relative location to the detonation and vehicle type. The local deformations and intrusion of the hull and its mounted structures result in transmission of load to the occupants. The injury profiles of the lower extremities and of the upper body suggest a primarily axial loading mechanism, and so the main transmission interfaces appear to be the floor, causing injuries to the lower extremities, and the seat causing injuries to the pelvis, spine, torso, and head. Data from UK casualties over the period of the recent conflict (2003-2014) suggest that these injurious mechanisms - floor and seat - are distinct, as there is no statistical correlation between occurrence of lower extremity and upper body injury, whereas there is statistical correlation between pelvic, spinal, torso and head injury. Following the local effects of blast there is a global, inertial movement of the vehicle whose extent depends on the mass of the vehicle, followed by a rebound phase whereby the vehicle returns to the ground. The return to the ground also causes axial load transmission through the vehicle structure to the occupants, however, experience with vehicle testing – albeit extrapolating from data recorded on anthropomorphic test devices (ATD) placed in the vehicles – suggests that the injuries are far more likely to occur at the initial phase due to the local effects of blast rather than the rebound phase. Injury severity depends on the posture of the occupant at the time of detonation and on the location of the occupant in the vehicle relative to the site of the explosion. In addition, there are, of course, many variables that might affect the injury profile; vehicle-hull design, foot rests, seat design, harness, and personal protection equipment such as body armour, combat boots, and helmet to name but a few. They are, however, the variables which, based on our current understanding, protection experts can optimise to influence the location and severity of injury to the occupants for a given, under-vehicle threat. It is not yet fully clear how these variables affect load transmission and body movement, therefore location and severity of individual injury.

Blast-resistant vehicle-hull design practices have been analysed from historical wars and have been largely implemented in modern military vehicle platforms in recent years. The V-shaped hull, increased ground clearance, increased total mass, and a long wheel axle base with the wheels being away from the cab have all been shown to decrease the effect of an explosive threat on the risk of occupant injury[8]. False floors, blast mats, foot rests, and blast-resistant seats are also being implemented in modern vehicle platforms in an attempt to reduce the load transmission to the occupant and therefore the risk of injury. The efficacy of such solutions, however, remains largely empirical rather than evidence-based, the main reason being that defence research often resorts to extrapolate injury criteria from automotive industry data. It is well accepted now that military blast injuries are not similar to road-traffic accidents and efforts are being undertaken internationally to remedy that. In addition, one of the main challenges in vehicle design is survivability versus mobility; the vehicle needs to be safe enough but also compact and agile enough to accomplish the mission objectives. Accurate models of human blast injury have a great role to play in future decision making of vehicle platform design.

Biomechanical blast injury research

Experimental and computational models of human injury and of mitigation technologies are necessary in order to understand the physical mechanisms involved and to allow for developing new and improved evaluation criteria, techniques, materials and designs in a cost-efficient manner. Full scale experiments (e.g. the combat boot, the vehicle, the human leg) give us an understanding of the whole 'structure' under controlled, repeatable conditions. These experiments, however, are expensive, time consuming and labour intensive, albeit invaluable. Individual-component experiments (e.g. materials testing of combat boot components, of vehicle components, of soft and skeletal human components) are well controlled and repeatable, allowing us to understand component behaviour, and therefore to build accurate computational models able to predict the behaviour of the 'structure' based on the interaction of its components. Computational models that have been validated against relevant experiments allow for multiple virtual experiments to be conducted in a cost-efficient, repeatable, well-controlled manner. They allow us to alter certain parameters related to geometry, materials, and environment inexpensively, thus enabling the examination of their effect on overall behaviour. In essence, computational models allow us to experiment with innovative designs and material combinations that could potentially result in novel and better mitigation strategies.

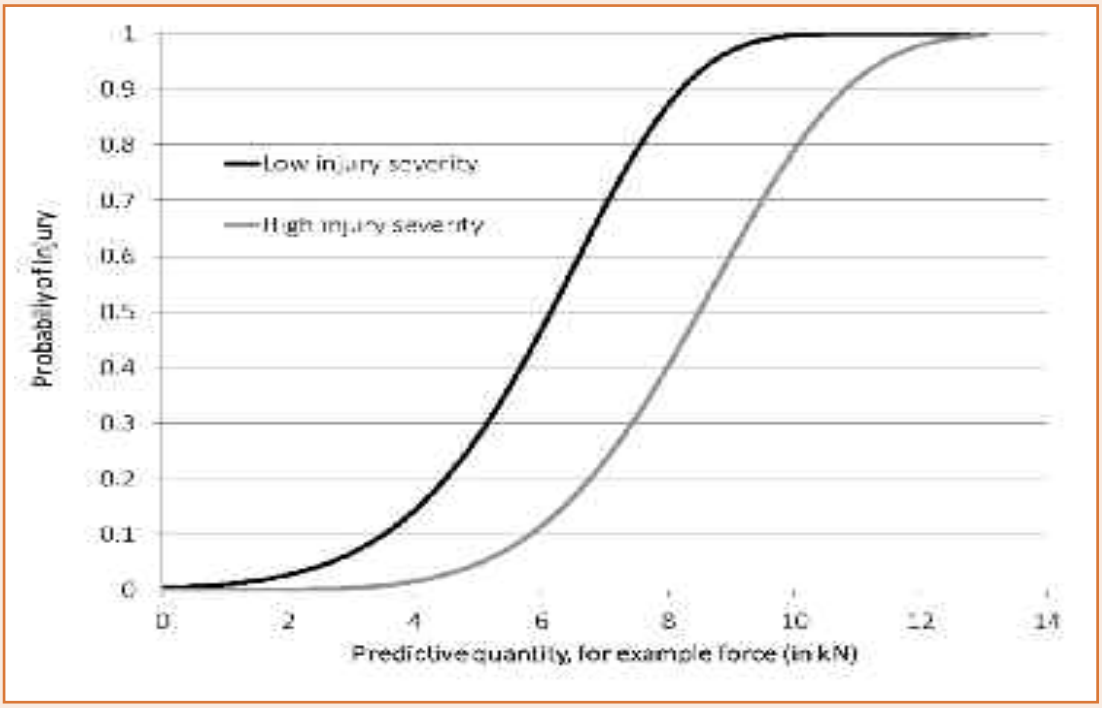


Figure 2: Exemplar injury risk curves. The y axis is the probability of injury and the x axis is the predictive quantity that can be derived from experimental measurements. For example, 6kN of force would mean a ~10% probability of a high severity injury and ~50% probability of low severity injury. The predictive quantity can then be correlated with a sensor in an anthropomorphic test device that is used in vehicle blast tests.

Prior to 2010 there was very little published work related to understanding blast injury. In 2004, the NATO standard for qualifying military vehicles against explosive devices (STANAG-4569) based injury assessment on injury criteria developed for the automotive industry. It suggested the use of the Hybrid III instrumented anthropomorphic test device (ATD) as the human surrogate, which was developed to simulate the behaviour of an average motor-vehicle passenger under frontal impact. The risk of injury of a particular body region of an occupant in a military vehicle is evaluated based on recordings of the instrumented ATD used in a blast test. For example, the risk of injury to the leg is assessed by the axial force recorded in the lower tibia load cell of the Hybrid III ATD. The risk of injury of a specific severity is developed by applying relevant loading conditions to post mortem human subjects (PMHSs) and measuring their response with instrumentation that can then be translated into respective instrumentation in the ATD (Figure 2).

It is now recognised that both the injury assessment criteria and the ATD itself have significant shortcomings when assessing blast injury as the loading rates involved and the injury mechanisms that result from automotive frontal impact are substantially different to those associated with blast injury. There is a substantial, ongoing, international effort in obtaining injury risk curves specifically

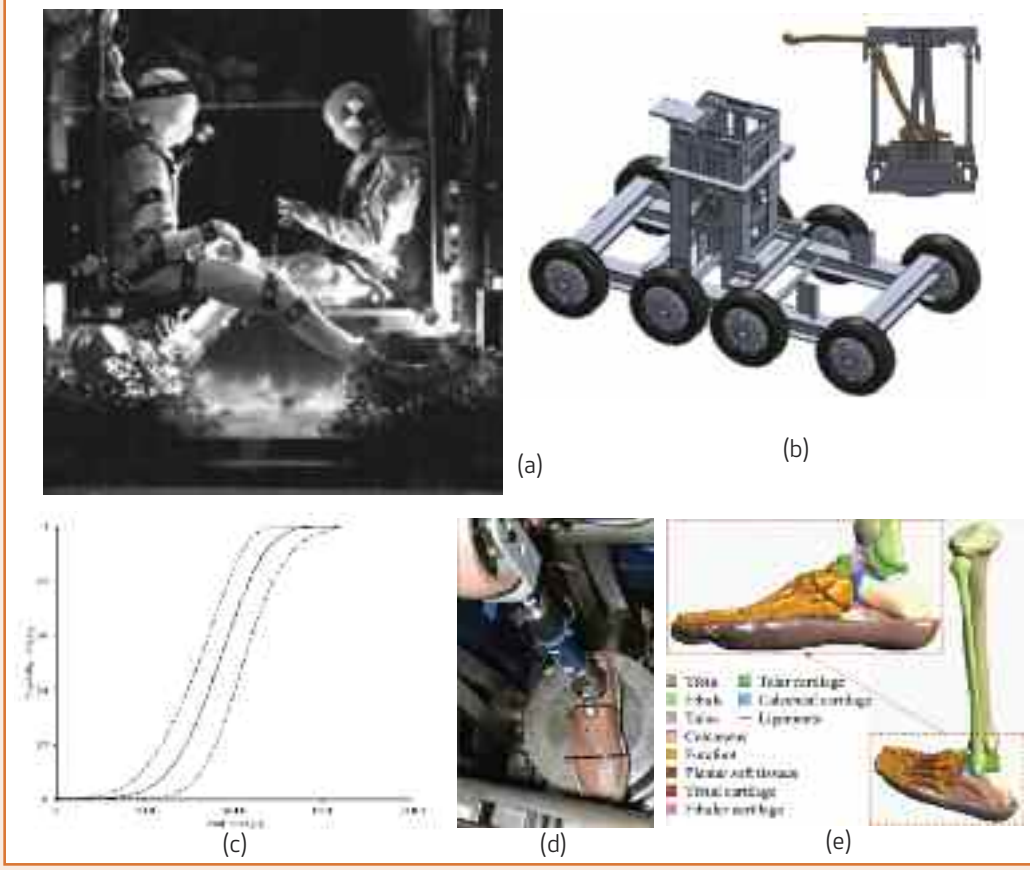


Figure 3: (a) Under-vehicle blast test rig used to compare human cadaveric (left) response with that of the Hybrid-III anthropomorphic test device (right)[12]. (b) Laboratory test rig that simulates the encroaching of the floor of the vehicle onto the legs of the occupants[11]. The insert shows a skeletal representation of a leg resting on that accelerating plate. (c) Probability of injury to the leg derived by loading human cadaveric legs at loading rates that simulate what a vehicle occupant experiences after an explosion[19]. (d) The MIL-Lx anthropomorphic test device leg has a compliant element in its tibial shaft that was tuned so as to respond similarly to a human leg under simulated under-vehicle blast loading. (e) A finite element model of the lower extremity using tissue material properties appropriate for the loading rates seen in under-vehicle blast and validated against blast-injury laboratory experiments.

for mounted blast, in recreating the injury mechanisms seen in mounted blast, and in developing an ATD whose response is validated for mounted blast[9]. This effort is expected to focus the design of protective equipment and vehicle internal – and external – modifications, but also allow for their accurate evaluation.

The lower extremity is the only body region at the time of writing for the mounted blast injury of which our understanding is somewhat mature, and so is used herein as an example of where the research and its application currently lie (Figure 3).

Experimental[10–12] and computational[13,14] models of the lower extremity under mounted blast loading have been developed, which have resulted in understanding subtleties of the injury mechanism - as well as permutations in, for example, the effect of posture on injury severity - and in risk curves[15,16] using injury severity scoring systems with appropriate resolution[16,17]. Under-vehicle blast specific ATD legs such as the MIL-Lx (Humanetics) and generation 1 of the WIAMan leg have been produced; computational representations of both ATDs have been developed too[18] that will allow an inexpensive virtual test bed for design of mitigation and evaluation of threats. Therefore, with regards to mounted blast injury of the lower extremity, we now have a significant understanding of the injury mechanism, the blast loading required to induce different severities of injury, and advanced technologies to evaluate protective strategies. This research paradigm is being implemented on other body regions, and indeed on the whole body as an entity, under mounted blast loading. This work provides the basis for designing and procuring the next generation of protective equipment and platforms, and will inform the decision-making process of future missions with regard to injury-risk taking.

Concluding remarks

The recent conflicts have, unfortunately, provided us with a wealth of clinical and incident data. We, at the Royal British Legion Centre for Blast Injury Studies at Imperial College London, have adopted a collaborative approach between clinicians, scientists and engineers to explore these data, in order to inform surgical reconstruction, improve injury outcome, and enhance mitigation technologies. This is being achieved by combining analysis of clinical information with the development of physical and computational models of blast injury. This article gave an overview of research efforts in addressing blast injury and in developing new or improving current tools and technologies for designing and assessing mitigation systems. We believe that our collaborative approach and our work in combining physical and computational modelling tools with experimentally derived data from models of blast injury, can form the basis in mitigating the injury burden suffered by the combat casualty. Our mission is simple; to improve the mitigation of injury and advance treatment, rehabilitation and recovery, thus increasing lifelong health and quality of life after blast injury.

All research output from the Centre is available in the public domain. Our annual report is published in Q1 of each year. To request a hard copy please contact cbis@imperial.ac.uk or for previous editions, please visit http://www.imperial.ac.uk/blast-injury/research/.

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Estimating explosive contamination from live-fire munitions using multi-increment sampling in Alaska

By **Dr Melissa Ladyman** PhD, **Dr Nathalie Mai** PhD and **Tracey Temple** MSc

Estimating the level of contamination on live-fire training ranges is very difficult, and usually requires characterisation of the area by soil sampling. Historically, the explosive residue from live-fire munitions has been considered minimal; however, explosives such as RDX, trinitrotoluene (TNT) and nitroguanidine (NG) are frequently detected in soils at heavily used firing and impact areas (Pennington et al., 2003). With the increasing drive to reduce or manage the environmental impact of explosives, it is becoming increasingly important to identify the risk of exposure presented by contamination from explosive activities e.g. training with live-fire, open-burning for disposal and manufacture. The Cold Regions Research and Engineering Laboratory (CRREL) have developed a method to quantify the average concentration of energetic material in residues resulting from military activities using multi-increment sampling on snow (Walsh et al., 2012). Multi-increment sampling is a systematic sampling method that can determine the average concentration of a contaminant in a defined area. Detonating munitions on fresh snow-fall makes it easy to establish a sampling area due to the dark-coloured residue, and ensures that the collected sample only contains residues from the one recently detonated munition.

With the increasing drive to reduce or manage the environmental impact of explosives, it is becoming increasingly important to identify the risk....

In February 2017, staff from the Environmental Science Group at Cranfield University were invited to participate in Multi-Increment sampling on snow in Alaska by Michael Walsh from CRREL. We joined a team from CRREL, and fellow observers from collaborating partner organisations on an explosive testing site near Anchorage. The aim of the field-work was to sample detonation residues from planned detonations, and to prepare the samples for chemical analysis. The results of the work will be published in the open forum when all analysis is completed.

Preparation of sampling areas

Alaska is an ideal location to conduct explosive residue experiments that require a clean sampling area as in the winter months frequent and heavy snowfall is common. Fifteen days of snow were recorded in February 2017, with some days recording up to 10 centimetres of snowfall. The fresh snowfall makes it possible to use the same area for explosive detonations for several sets of experiments as only the first 1-5 centimetres of snow are removed by sampling. The detonation residue tends to remain on the surface of the snow, which is packed down before detonations to ensure any larger pieces of residue do not pierce the surface. The munitions themselves are placed on platforms of ice to keep them vertical until detonation, and to prevent deep craters forming and causing cross contamination with deeper layers of snow, ice and soil. The detonations were carried out by the US Army while the research team, and guests, retreated to a safe distance. Munitions were detonated three at a time, allowing three replicate detonations to be carried out at one time.

Multi-increment sampling on snow

Setting up, and detonating the munitions took far longer than sampling the remaining residue. Once it was safe to return, the detonation areas known as plumes- defined by the dark coloured residue, were outlined with flags. The defined area (approximately 10 meter diameter) was then sampled using a multi-increment sampling method by collecting approximately 100 increments of snow evenly across the plume area. The main benefits of the multi-increment sampling method are the speed at which increments are taken, and the relatively small number of samples compared to discrete sampling across the same area. It took approximately 60 minutes to completely sample a plume, which included taking three replicate samples. The combined samples provide an average concentration of the explosive residue deposited over the plume area, with only three samples to analyse significantly minimising the cost compared to discrete sampling.

The plume- sampling area defined by the detonation residue- outlined by marker-flags. A team of two samples the plume area, while the outside control area is sampled independently.

Processing samples in the laboratory from collection bags to filtration.

In order to ensure an accurate average concentration is obtained, it is important to sample systematically across a plume area. For example, a plume was traversed from side to side by collecting a sample at set distances determined by the size of the sampling area. There may be a temptation to collect more samples from seemingly more contaminated areas, but it was crucial to make sure each increment was equal, and that sampling was even across the entire plume.

To ensure that the plume area was defined accurately, the area outside the plume was also sampled as a control. In similar experiments, these samples have been free of explosive, confirming that the plume area can be accurately defined by the edge of the dark residue. Sampling is faster when carried out in a pair, but sampling an area alone is possible.

Samples could contain up to several litres of water...

Field-laboratory sample processing

The field-laboratory in Alaska did not have the analytical equipment required to identify and quantify the explosive content of the detonation residue. However, much of the preparatory work could be carried out on-site to minimise the cost of shipping the samples to an analytical lab. An added benefit of using snow as the sampling matrix was that when thawed the water could be filtered separating the solid residue from any dissolved explosive. Samples could contain up to several litres of water, but only 1 litre was required for analysis. Some of the remaining water was passed over solid phase extraction resin and extracted into solvent to increase the concentration of explosive, ensuring that even very small concentrations of explosives were recorded. The detonated munitions contained a variety of explosive fills and would be tested for common explosives such as TNT and RDX, as well as insensitive high explosive constituents such as 2,4-Dinitroanisole (DNAN) and Nitrotriazolone (NTO).

Summary

The multi-increment method developed by Michael Walsh and the CRREL team is well documented in the literature, and has had a great impact on the research and understanding of explosively contaminated land. The opportunity to participate in residue deposition studies in Alaska was incredibly rewarding, and specifically enabled us to gain this first-hand experience. The multi-increment method is a time and cost-effective way of characterising large areas of land to understand the risk of exposure to harmful levels of explosive contamination. Although the actual sampling in snow was quite onerous; mainly adapting to the low temperatures and walking through knee high snow, it was rewarding to take part in the whole process from preparing the detonation areas, to processing the samples in the field-laboratory. Melting-out explosives residue from snow is an innovative method as it simplifies analysis of the explosive residue by providing a non-contaminated matrix that does not interfere with analytical results. Overall, being able to put the theory of the multi-increment method into practice on snow was a great opportunity, and has assisted the research that the Environmental Science Group undertake. The Environmental Science Group at Shrivenham now have valuable experience in multi-increment sampling and this has further supported the ongoing research into the fate and transport of explosives residues in the environment.

The results of the Alaska field-tests in 2017 have not yet been published, but will be communicated in the open literature later this year.

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The authors would like to thank Michael Walsh, and CRREL for inviting us to Alaska to take part in the field-work. We also thank the Explosives Engineers Educational and Research Trust for funding to enable us to undertake this field-work.

Further reference: t.temple@cranfield.ac.uk

The views expressed are those of the author:

Columnist Sidney Alford OBE MSc PhD reports on plastic explosives – a temporary solution

I have to admit defeat. Search as I may I have failed to find any individual with experience of working with the excellent imported French plastic explosive, which went into British service as PE7[1], and had experienced the rumoured tendency to go hard after prolonged storage in very inappropriately hot places. Such rumours seem to have provided the purported justification for the acceptance of Chemring's kind offer to substitute their own alternative explosive, which had previously been judged as unfit for purpose in a comparative trial when a substitute for PE4 was needed. Whoever in the MoD decides such matters clearly did not know very much about the subject when accepting Chemring's kind offer to provide their previously failed product which was duly accorded the appellation PE8.

Reports began to fall on my ears that a couple of my company's long-established products, consisting of shaped charge cases designed to be loaded with plastic explosive by the operator, were not working as well as they had been for the previous ten years or so and users enquired whether we had introduced subtle changes of design. No, we replied, the tooling is the very same and it has suffered no perceptible wear. The answer was clearly in the PE8 with which they were now being supplied.

I enquired of Chemring whether they would be kind enough to sell me a small amount – a kilo or so perhaps. The next day a clearly disconcerted junior employee rang me with the message that they would be pleased to sell me some but - his voice displayed some embarrassment - a tonne or so would be the minimal order size.

I have no idea what inducements persuaded the MoD to accept PE8 as the standard plastic explosive to be issued to users whose lives depend upon properly functioning tools. The users themselves seem not to have an effective means available for requesting that they be issued with something better and the higher ranks of the armed forces are probably too preoccupied with their diminishing personnel numbers and sparse equipment to be up to date on the subject. The Ministry of Defence seems to be too concerned with billions of pounds worth of ships and aircraft to be able to allocate a little time to the consideration of unusable sticky stuff that clings both to rubber gloves and fingers[2].

I now realise that, until the day comes when the British armed forces are issued with a plastic explosive which is suitable for precise applications, they should be made aware of a simple method for modifying the rubbish with which they are presently issued to render it usable in the field for more than simply making a loud bang. With this intention I devised a simple and safe technique for transforming a plastic explosive which shares with PE8 and with the American C4 the same awful poly-isobutylene binder (fig.1). This converts such a sticky explosive into a sufficiently user-friendly material to enable it to be easily loaded into, for example, Vulcan charge cases so that they were suitable for the disruption of a wide range of target munitions. The method lends itself readily to scaling up.

Fig.1 Plastic explosive showing adhesion to plastic loading tool.

- One hundred grams of sticky plastic explosive are placed in a glass container, such as a 250ml tumbler, and one hundred millilitres of petrol added. This dissolves the binder of the surface layer and the liberation of a fine white powder – the RDX – is immediately apparent (fig.2).

Fig.2 Disintegration and partial dissolution of explosive in petrol.

- The process may be hastened by prodding the lump of explosive with a wooden or plastic rod in order to expose continuously a fresh surface. Glass and metal should not be used in order to avoid friction between the rod and the inside of the glass.

Fig.3 Separation of RDX and plasticiser solution.

- When the entire mass has been converted to a homogeneous, mobile paste, it is poured into a filter paper in a polyethylene funnel. Note that a coffee filter is robust enough to serve the purpose well (fig.3). When there is no liquid remaining on the surface of the powdered solid, a further 25ml of petrol is poured onto the contents of the paper.

- As soon as the liquid has stopped dripping from the funnel, the paper and its contents are laid out to dry. Warming on a radiator or in the sun hastens the process.

- When most of the petrol extract has migrated out of the solid residue, this may be spread out on a flat surface and laid on a radiator or placed in the sun until dry.

This procedure yielded 60g of a slightly coherent white powder which consolidated well and did not stick to plastic loading tools. It also removed DMDNB taggant so gloves need not be worn when handling the product. Approximately 5mg were placed on a 10mm steel plate and struck repeatedly with a 150g hammer. No evidence of detonation was seen or heard.

A Vulcan was loaded with a Magnesium Cone and 37.5g of recovered RDX. The charge penetrated stacked 1cm steel plates to a depth of 22.5mm. (Had the third plate not been backed by steel this would have been significantly deeper.) This demonstrates its ability to penetrate the cases of all but the largest shells and aircraft bombs (figs.4 & 5).

Fig.4 A Vulcan Loaded with a Magnesium Cone and 37.5g of recovered RDX

Fig.5 Penetration of steel target plates

1 *vide* PE7 Rhymes with Heaven *ibid* December 2013

2 The on-line address "chemring energetics.co.uk/demolition stores" yields the curious message "It is mouldable by hand to form demolition charges of various shapes and weights without leaving any residue on the hands". Can they really have forgotten the requirement to incorporate a little taggant?

Bomb ingredients sold together on Amazon

The Parsons Green bomb. Credit: Twitter.

Amazon has been accused of aiding bomb makers as the former head of the CIA said that social media companies must take a share of the blame for the London Underground bucket bomb which was placed on the train near Parsons Green station in September The online retail giant was found to group together key components needed to create explosives under the "frequently bought together" tab. Whilst many of the ingredients are innocent on their own, together they can be used to create explosives or devices. When buying a certain chemical on Amazon the ingredients are offered to make black powder. The "customers also bought tab" also offered steel ball bearings, push button switches and battery connectors and cables. Ignition systems and remote detonators are also available on the website, the Channel 4 News investigation found which questioned why Amazon should be making bomb components available, General David Petraeus said that Google, Twitter and Facebook were failing to tackle online extremism as it emerged jihadist content gets more traffic in Britain than any other European country.

www.telegraph.co.uk/news/2017/09/19

Awards for Alford Technologies

The Construction News Awards 2017 – Business Innovation of the Year has been awarded to Alford Technologies for Explosives Demolition using Remote Methods. The judges commented that they encompassed technology transfer ideas including the invention of a unique magnetic bunch connector and the project comprised a sensitive demolition solution. They have also been awarded the British Construction Industry Awards 2017 – Health, Safety & Wellbeing Initiative of the Year for their work which will ensure the demolition industry is safer for future generations according to the judges.

Further information: Christine.Parsons@explosives.net

Roland Alford accepting the award on behalf of Alford Technologies.

Australian explosives amnesty is a big success

Explosives, gunpowder and detonators have been handed to police under an amnesty in Australia, as authorities work to remove illicit weapons from the streets. An amnesty was introduced by New South Wales in March, allowing people to turn over any commercial explosives with no questions asked to stop them falling into the hands of criminals and home-grown jihadists. More than five months into the amnesty, 146kgs of explosives, over 20kgs of gunpowder and thousands of detonators and safety fuses were surrendered. People who had explosives, including gun powder and nitroglycerine were asked not to move them as they become unpredictable with age. A national firearms amnesty has also proved a success, with 25,999 guns surrendered since June.

The Daily Telegraph, 9th September 2017.

New York bridge demolished

New York's old Kosciuszko Bridge was demolished in October after 78 years of serving the City commuters having been built to accommodate 10,000 cars a day but ending up taking 180,000 vehicles a day. After the main part of the bridge was dismantled, it was wired with 944 small 12-pound charges and the ground was piled with shock-absorbing sand ahead of the demolition according to the New York Times. The bridge will be opened finally in 2019.

Magnet'fishing hobby hooks WW2 bomb on canal

A woman using magnets to fish for underwater treasure ended up pulling an unexploded World War 2 shell from the Trevor Basin in Wrexham County in November. The location during the war had been home to a nearby munitions factory. She took the corroded mortar home and only realised what she had after posting pictures on social media. She subsequently called the police who alerted bomb disposal teams in Chester and her home and surrounding properties were evacuated.

www.bbc.co.uk/news/uk-wales

Centre of Excellence in Energetic Materials (CoEEM) website launched at the OME Symposium

Government-led initiative, the Centre of Excellence in Energetic Materials (CoEEM), announced the launch of its website at the recent Ordnance, Munitions and Explosives Symposium in Swindon.

The launch of phase one of the secure website is aimed at championing the sharing of facilities, data and other resources, with further additional functionality planned in the coming months to allow access to publications, specialist resources, CPD, education, training and more.

The site has been developed by Cranfield's Technology Enabled Business Solutions (TEBS) team and is already compliant with the General Data Protection Regulation (GDPR), which will come into force in May 2018.

The collective member data will contribute towards building a national energetics SQEP capability landscape, so CoEEM invites UK organisations and their staff who work with energetic materials to apply for membership by visiting www.coeem.org.

For more information contact enquiries@coeem.org.

Centre of Excellence in Energetic Materials

Update from HSE

In my last article (June 2017) I provided an overview of the direction of travel for the next few years for the health and safety system in Great Britain. I thought that you might like to hear what has happened since then.

Given the lead time for writing an article and to getting it published, unexpected things can crop up. At the time of writing my previous article I certainly didn't foresee a general election being called on 8 June and the consequential changes to the political environment. Nor were the impacts of the triggering of Article 50 for the UK to leave the European Union clear at that time.

As a consequence of the general election, HSE's first annual Health and Safety Conference was postponed (from June) to 18 September. Hundreds of organisations from all parts of British industry came together at the QEII Conference Centre in London to focus on the collective mission to "Help Great Britain Work Well". The conference keynote speakers were Penny Mordaunt, The Minister of State for Department for Work and Pensions and Martin Temple, HSE Chair.

Delegates heard about HSE's priorities, had the opportunity to understand HSE's role within the health and safety system and workshopped solutions to key health and safety issues. I had the pleasure to invite a number of representatives from across the explosives industry including Chris Tunstall who stood in for your President as, unfortunately, he had other prior commitments. HSE's new 'Go Home Healthy' campaign was launched and our sector plans (including that for the Explosives Sector) and cross cutting health priorities were showcased. As a reminder the Explosives sector strategy can be found at http://www.hse.gov.uk/aboutus/strategiesandplans/sector-plans/explosives.htm

Hot on the heels of the Annual Health and Safety Conference, on 25th October, the Trades Union Congress launched a campaign to mark the 40th anniversary of trade union health and safety representatives receiving the legal right, under The Safety Representatives and Safety Committees Regulations 1977, to improve health and safety in the workplace.

HSE places great importance on worker involvement and consultation, which has proved to be a key factor to improving health and safety in the workplace. A competent workforce, actively engaged by employers can make significant impact on maintaining and improving health and safety standards. Individuals directly engaged in undertaking work activities can be those best placed to develop safe working practices. To mark the 40th anniversary, a series of cases studies were produced by safety representatives, HSE Inspectors and others and have been hosted on HSE's Worker Involvement webpages (see http://www.hse.gov.uk/aboutus/safety-reps-case-study.htm)

HSE is inviting all employers (and others) to view these case studies and the material that can be found on the TUC website (https://www.tuc.org.uk/celebrating-40-years-union-safety-reps) and reflect on the valuable work undertaken by safety representatives and safety committees over the last 40 years.

In early November HSE published the latest annual ill-health and injury statistics for Great Britain. It shows that the level of injury and ill health and the associated costs (including the personal impact of being harmed at work and/or the effects on family and friends) is still largely unchanged.

Key figures for Great Britain (2016/17)

- **1.3 million** working people suffering from a work-related illness
- **2,542** mesothelioma deaths due to past asbestos exposures (2015)
- **137** workers killed at work
- **609,000** injuries occurred at work according to the Labour Force Survey
- **70,116** injuries to employees reported under RIDDOR
- **31.2 million** working days lost due to work-related illness and workplace injury
- **£14.9 billion** estimated cost of injuries and ill health from current working conditions (2015/16)

These figures should give us all cause to pause and reflect on our day to day activity. Thankfully incidents in the explosives sector are relatively rare, but as we all know if things go wrong then the results can be catastrophic – and life changing. So we cannot and must not become complacent within the industry – particularly given the challenges of an aging workforce and a decline in the core skills and competency across the sector. HSE continues to support the work of the Sector Skills Strategy Group (under the chairmanship of Mark Hardman) and associated initiatives as being one of the key workstreams to tackle the current (and future) competency gap in many areas of the industry.

Closer to home in HSE, following our fundamental review of explosives licensing, our inspectors are now issuing explosives licences in a new format, with in built flexibility for future business developments wherever this is possible and safe. Organisations should start to notice a different approach and discussions with our inspectors when applying for licences or variations to them. I would be pleased to receive feedback on how this revised approach is working in practice from your perspective. (richard.daniels@hse.gov.uk).

I fully expect 2018 to be a very busy year for the inspectorate with many challenges ahead. One of the biggest will, no doubt, continue to be BREXIT related which will impact on us all in many different ways.

Dr Richard Daniels BSc (Hons). PgDip(Physics) PgDip(Heath and Safety) PhD

HM Chief Inspector of Explosives

Early Careers Symposium 2017

Now into its third year, the Early Careers Symposium has become a well-established event in the explosive sector's calendar. This year it was hosted at the Oxford Belfry Hotel on the 13th – 14th September and with over 120 delegates was the biggest event thus far. Attendees came from across the defence sector including AWE, BAE Systems, Chemring Energetics, DE&S, Dstl, MBDA, Roxel UK, IExpE and QinetiQ.

Having retired only a fortnight before, Lt. Col. Ted Shine opened the symposium, sharing a wealth of knowledge on the Provisional IRA from his long career as an Ammunition Technical Officer. Following this, five of the delegates showcased the exciting work they were delivering early on in their careers. Before breaking for lunch, presentations related to health and safety in the explosives industry were given, covering a variety of topics from range safety to hearing loss associated with mortar systems.

The afternoon took a much more relaxed feel as the teambuilding challenges began. Balance, agility and problem solving was put to test through outdoor activities such as navigating through minefields blindfolded and code breaking against the clock. Teams became particularly competitive whilst building and launching their own rockets! Misjudging the British weather, the day concluded with an outdoor demonstration of the RAM mixer from Daniel Judd of the Falcon Project. The rain bouncing from the equipment only added to the display!

As pre-dinner drinks were served, the poster competition was underway. These further displayed the interesting and relevant work early careers personnel are involved in. Congratulations to the winner, Rhys Francis. Throughout dinner Richard Smart (Director Weapons, DE&S), Mark Hardman (MD, Roxel UK) and Dave Holley (Design Authority, Energetic Materials, BAE Systems) gave inspiring speeches, reiterating the value of retaining young people in the industry and the importance of these events to bring people together.

The next day opened with talks from Dstl on detection and analysis of explosives. Jane N from CPNI also gave a wider look into the security of national infrastructure across the UK. We were also very happy to welcome back the 11 EOD Regiment RLC, although the arrival of their Bomb Disposal vehicle probably concerned a few hotel guests. This was a great opportunity to see the equipment first-hand and have a play too!

After lunch there were further presentations on materials advances within the industry. Work by MBDA into reactive materials and by BAE Systems into PBX Additives was presented. Sara French also gave an insight into the work of the Explosive Materials and Initiation Science (ExMIS) group at AWE. Before entering the final session, Selena Wright gave an overview of one scheme particularly aimed at developing young engineers and scientists in the sector, STEM Futures. This highlighted some of the opportunities open to the younger delegates and also reiterated the value that the industry is putting on them.

The event concluded with talks on some key emerging technologies in the industry, including 3D printing of explosives and the use of GCxGC in the laboratory to enhance explosive detection. Having seen a small-scale demonstration of the RAM mixer the day before, Andy Burn presented the work BAE Systems are doing to scale-up the technology for use in industry.

11 EOD Regiment RLC showcase their equipment.

All delegates got stuck into the team building exercises.

The Early Careers delegates showing their competitive sides.

Overall the event was a huge success, showcasing to the next generation the exciting range of developments and research areas within the explosive sector. Moreover the delegates have had a great opportunity to network and build long-lasting contacts. The Early Careers Focus Group looks forward to grow this event further in 2018!

The event was hosted by the Early Careers Focus Group (ECFG), which is a sub group of the Sector Skills Strategy Group, itself a conglomerate of defence sector companies and related industries focused on sustaining explosive skills. The ECFG focuses on furthering the knowledge of explosives workers within the first ten years of their career, holding an annual symposium to build the young persons' network and arranging visits to sites of interest such as ranges and manufacturing facilities. Visits will be open to all early careers staff to expand their awareness and knowledge of the explosives sector.

For further information, or to join the mailing list to be informed regarding future events held by the ECFG, please email earlycareerssymposium@gmail.com.

Rebecca Millar CEng MIMechE TIExpE

Gunpowder plot revisited

The BBC 's recent television production "Gunpowder" takes a new look at the conspirators who attempted to blow up the House of Lords when it was known that King James 1 (James V1 of Scotland) would be in attendance on the opening session of parliament on 5th November 1605. Although it is generally remembered that Guy (Guido)Fawkes (played by Tom Cullen) was the leader, the programme instead promotes Robert Gatesby (played by Kit Harington) as the mastermind behind the plot. He was born into a Catholic family in 1572 and after his family and friends were persecuted and tortured for their faith, he wanted to return newly-Protestant England back to Catholic rule. King James 1 came to the throne after the death of Protestant Elizabeth 1 in 1603.

The plotters initially rented a house on one side of the House of Lords and tried to dig a tunnel to plant explosives under the parliament building. This proved to be too difficult and they instead rented a basement directly beneath the House of Lords. With just days to go before the plan was due to go ahead, the government received an anonymous tip-off. Catholic Guy Fawkes who had recently returned from Holland and was enlisted by the conspirators, was discovered in the cellar next to 36 barrels of gunpowder on November 4th while most of the other plotters fled. Gatesby escaped and continued with his plan to rally English Catholics but without success. He was tracked down and killed in a shoot-out on the morning of November 8th. The captured plotters were hung, drawn and quartered for high treason as was the practice at that time.

The BBC received complaints about excessive violence in the three-part series, the merging of events from different periods in history and poor sound quality. It defended the violence saying that "it was grounded in historical fact".

'Modern Guy Fawkes'

More than 130 years ago a Birmingham bomber dubbed the 'Modern Guy Fawkes' and his gang were thwarted. An audacious plot in 1883 during the 'Irish troubles' was discovered when Albert Whitehead of Birmingham was arrested and a cache of substantial bomb-making materials was found in a painter's workshop in Ledsam Street,

Chemist Robert McCreadie, who rendered the explosives safe, and below, the watch given to him by the Nobel Company on his retirement.

Ladywood, a poor and densely populated area west of the city at the time. The plan was that of the Irish Fenians and the bombs themselves were intended to blow up the Houses of Parliament in London. The bomb-making materials included carboys of acid, an unstable vat of nitroglycerine, 170lbs of explosives and a bath full of 'liquid nitro'. The lethal haul was in an extremely dangerous condition and could have exploded at any time, destroying a huge swathe of the neighbourhood. Some two hundredweight of explosive had already been shipped to London in readiness to target Parliament.

An article at the time, recently unearthed by his great grandson David McCreadie read: "The Home Office man recommended to Birmingham Police that the job of rendering the explosives safe would have to be done by an expert and told them to ask Nobel Exposives Co Ltd, at Ardreer, to send down Robert McCreadie, who had made a name for himself for his skill in handling dangerous explosives". David explained: "Nitro glycerine is usually stabilised with keiselguhr, a diatomaceous algae found in German lakes, but was later replaced with wood flour. So when the police alert came to Ardeer, and Alfred Nobel was out of the country, my great granddad was sent down with a sack of wood-flour and a wooden spoon – this would make dynamite stable and then require a detonator to explode it."

An obituary upon Robert McCreadie's death revealed what unfolded: "He went on to his knees, rolled up his sleeves above his elbows and, adding ladlefuls of earth, worked it (the wood –flour) into the mixture like a baker would kneed a huge mass of bread dough." An article from the Ardrossan and Saltcoats Herald revealed: " He worked all through on Saturday night and on Sunday morning, the new batch of dynamite was loaded into a police van and taken to a sewage farm where it was burned. Robert McCreadie was taken on a tour of the city and hailed as the 'Hero of Birmingham'.

A report at the time said: "Birmingham Watch Committee expressed their thanks to Nobel's Explosives Company and the thanks of the townspeople of Birmingham to McCreadie. After due deliberation they voted him an honorarium of 10 guineas . Nobel's intimated to the Birmingham corporation that they would only need to reimburse him his travelling expenses and were happy to put at their services an employee who undoubtedly had run serious risk in performing a public duty." McCreadie received a gold pocket watch on his retirement from Alfred Nobel himself which his great grandson David, of North Yorkshire, later inherited.

As for the Parliament plot, the accused would-be bomber Albert Whitehead and his accomplices – 20 in all – were all arrested in Birmingham, and tried in London. They escaped the fate of Guy Fawkes but were sentenced to life penal servitude in a Victorian gaol and some were believed to go insane, a sorry end to a plot that could so easily have changed British history for ever. David added; "Nobel originally developed high explosives in Scotland for peaceful reasons – mainly for coal mining - and must have felt concerned after its use in the First World War and went on to create the Nobel Peace Prize, leaving his fortune to fund this to this day."

Extract from the Sunday Mercury, October 29th 2017.

If readers have more information about this story please email the Editor at dianehall@iexpe.org

Conferences/Exhibition Diary

IExpE PAST PRESIDENTS' LUNCHEON
Caledonian Club, London, 14th December 2017
Further information: vickihall@ixpe.org

44TH ANNUAL CONFERENCE ON EXPLOSIVES AND BLASTING TECHNIQUE
San Antonio, Texas, USA, 28th to 31st January, 2018
Further information: www.isee.org

SCTX SECURITY & COUNTER TERROR EXP0
Olympia, London, 6th to 7th March 2018
Meet with over 9,5000 security professionals and connect with key decision makers across 114 different countries.
Visit IExpE on our stand
Further information: www.sctx.co.uk/explosive

IExpE MEMBERS' WEEKEND & AGM
Crewe Hall, Cheshire, 28th to 29th April 2018
Event will include presentations and practical demonstrations from IExpE members involved in explosives special effects, bomb disposal and explosives detections dogs. Gala dinner and fireworks display. The AGM will take place during the morning of Sunday 29th April 2018.
Further information: www.iexpe.org/Events

HILLHEAD 2018
Hillhead Quarry Buxton, Derbyshire, 26th to 28th June 2018
The biennial showcase for the quarrying and construction industry last year featured 476 exhibitors and an ABC-audited attendance of 18,601.
Further information: harvey.sugden@qmj.co.uk, www.hillhead.com

IExpE CONFERENCE 2018
Telford Golf Resort & Hotel, Telford, 26th to 27th September 2018
Further information: www.iexpe.org

In a Flash

Dr Andrew Barr MEng PhD AIExpE

Your age:
27

Occupation:
Engineer @SheffieldBlast

Current position:
Research Associate, Blast and Impact Dynamics, Department of Civil and Structural Engineering, The University of Sheffield

Responsibilities in job/work activities
A significant part of the group's research involves characterising the loading from high-explosive blasts, including buried events, for the development of protective systems. As part of this I investigate the behaviour of soils under extreme loadings to inform models of buried IEDs and fragment penetration in protective structures.

Why are you involved in IExpE?
As well as being the professional body most closely aligned with my work, the Institute's affiliation with The Engineering Council also provides opportunities for professional development and accreditation.

What are the benefits for you of the IExpE?
Besides professional development, the Journal is a great way to keep up to date with developments in the wider explosives industry.

What alternative career might you have followed?
I couldn't decide between engineering and architecture for a long time: it wasn't until during my dual Structural Engineering and Architecture undergraduate degree that I decided I definitely wanted to be an engineer.

Who do you most admire on the current world stage and why?
I'd have to say modern-day polymath Elon Musk – what's not to like about a guy who can be nerdy about electric cars, AI, space travel and tunnel boring all at the same time?

Who would you most like to meet from any century and why?
In terms of great dinner conversation it would be hard to beat Sir David Attenborough!

What are your favourite activities/hobbies?
I enjoy cooking (mostly for the eating that follows), and weekend jaunts into the Peak District by bike.

What is your ideal holiday?
My complexion isn't well suited to lying around on beaches, you're more likely to find me somewhere with an interesting history, great architecture and exciting food.

What is your favourite type of food?
Probably the hardest question here - you can't go wrong with Indian food. Maybe a rich lamb curry paired with a big hoppy IPA.

Explosives Engineers Educational and Research Trust

The Trust was formed in 1982 to advance the theoretical and practical education and training of persons engaged in the explosives engineering industry by the provision of training courses and the publication of technical, educational and informative material together with the financing of research and the provision of scholarships to assist with courses of study in the field of explosives engineering.

For more information and how to apply for a grant visit:
info@explosivesengineerstrust.com

IExpE Journal calls for papers

Deadline for March 2018 issue is January 31st 2018.
1500 - 3000 word articles and papers will be considered for publication and should be accompanied by digital illustrations eg. photographs, drawings and tables.
E mail the Editor: dianehall@iexpe.org

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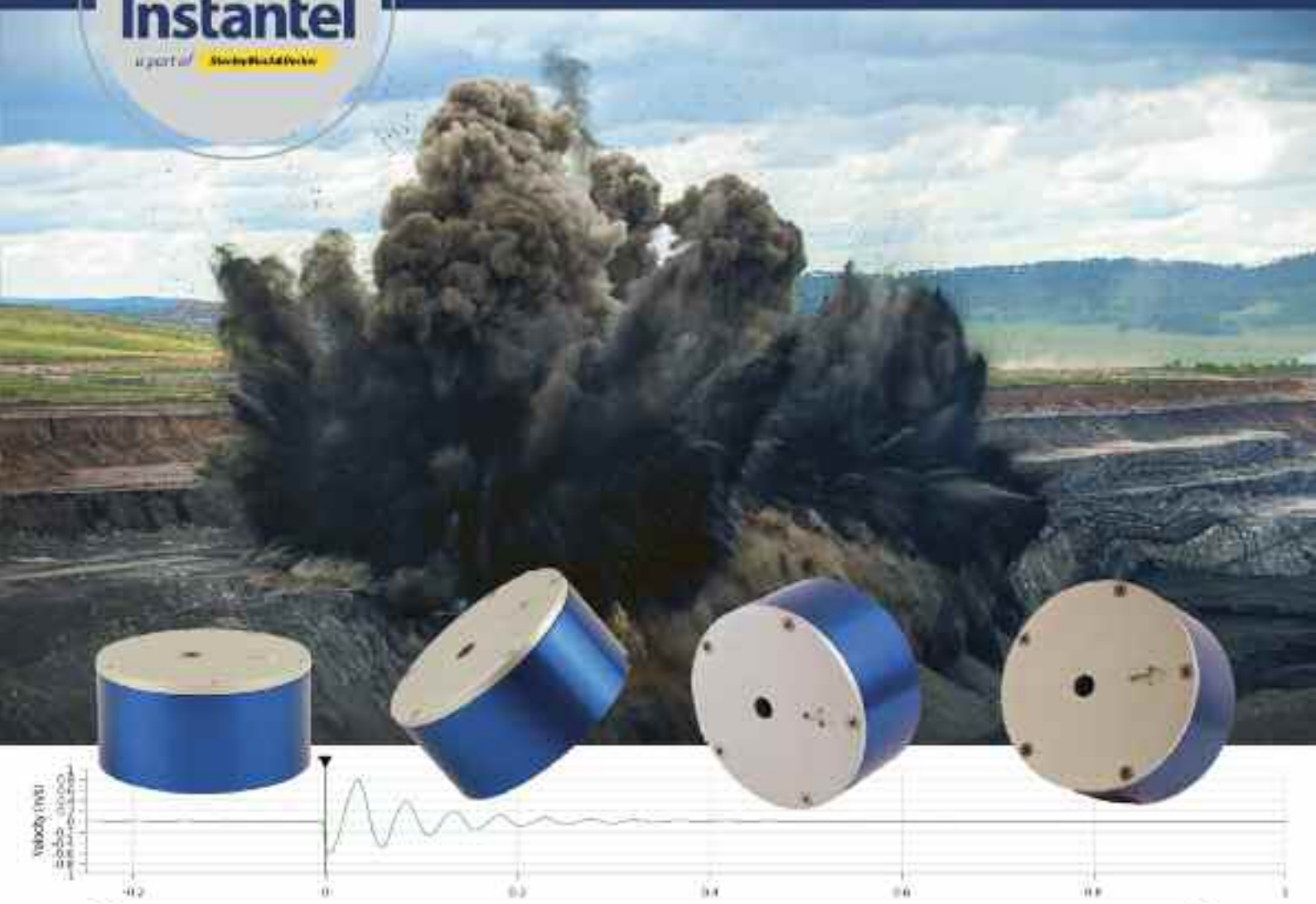

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