Explosives
Engineering
Professional Affiliate of the Engineering Council UK

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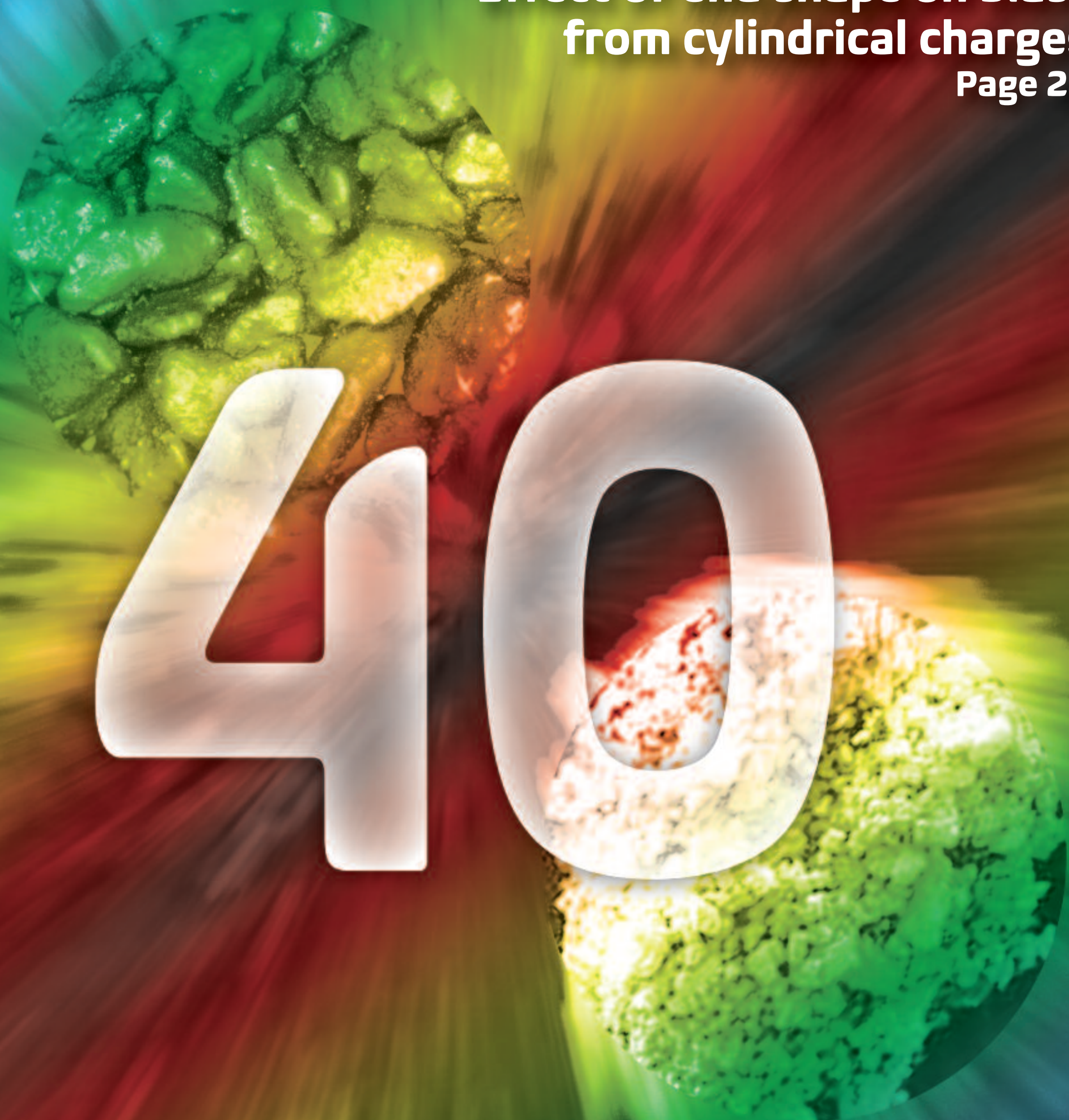


THE JOURNAL OF THE INSTITUTE OF EXPLOSIVES ENGINEERS
March 2014

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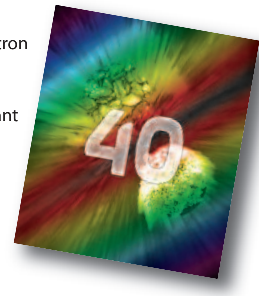


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Professional Affiliate of ECUK

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Papers, articles and letters to the Editor are welcome and should be sent to the Editor at her email address, or by post to the Institute address.

# The President speaks

I hope that when you opened this edition of the journal you noticed that it was slightly different. Our Journal Committee have updated the design, typeface and paper to mark our 40 years as an Institute and to modernise the style we launched for the 30th Anniversary. The Institute was formed in 1974 and this is included in a history of explosives in this journal. Since our formation we have come a long way and we must be very grateful to our founding fathers for setting up the Institute. We should be very proud that we are now a Professional Affiliate of the Engineering Council and those members who wish to do so can seek professional registration with the Engineering Council.

I recently represented the Institute at a professional engineering forum at the MOD site at Abbey Wood and I was approached by several graduates and apprentices who were interested in professional registration but were unsure where to start. We need to keep pushing the message to those starting off in their careers that if they are interested in professional registration then join an Institute and start recording their CPD activities.

To commemorate our forty years we held the 40th Anniversary Journal Awards competition to encourage those interested to write and submit a paper on aspects of explosives engineering. There were four categories, Fellows, Members, Associates and Non-members. We had responses in all categories and so thank you to all those who entered. The winning articles from each category are elsewhere in the journal as are details of the Awards presentation.

At the end of January we hosted a visit of our counterparts from EUExcert Sweden. The last EUExcert project ended with 8 out of 10 partner nations agreeing to adopt and adapt the UK National Occupational Standards (NOS) as the basis for certification of explosives workers. As there have been many changes in people and structures in Sweden, it was agreed that the aim of the week was to provide an introduction to the NOS and their implementation as the basis of qualifications and also as management tools. The week was a great success and we look forward to the next phase of collaboration across Europe in this area.

Members of the Institute have also been involved with the GEMS meeting. GEMS stands for Group of Experts in Mitigation Systems. It was formed in December 1999 and held its inaugural meeting at COTEC (Cranfield Ordnance Test and Evaluation Centre). The group is managed by CPNI (Centre for the Protection of National Infrastructure) and has expanded over the years to include embedded members across Government departments and agencies. Individual members are encouraged to network, communicate challenges and present their findings and questions to the wider Group. The Group meets each January in a different location; this year AWE hosted the meeting and next year DSTL will be inviting GEMS members along to one of their establishments.

In an industry as diverse as explosives, networking is very important and so I draw your attention to the Linkedin group we run. It is also very important to have the ability to find information that you need and it is not always available on the web. The Institute holds a range of documents which have now been catalogued by Dr Ian Barnes and we intend to put that list on the website so members can see what we hold. We are considering exactly which documents to retain and where they will be held. It is a sad fact of life that as establishments have closed libraries have too often been closed and their contents destroyed. If any members have documents they think would be worth keeping please let the Secretariat know and we will consider finding a home for them.

Looking forward to the AGM and after the request at last year's you will have seen that we have moved the venue to Scotland this year and we hope that those in Scotland and the North of England will take the opportunity of a shorter journey to support both functions. Details are to be found on page 7 and if you have not yet booked in, do not delay and I look forward to seeing you all in Scotland.

Finally to Council matters, first it is with sadness that I have to inform you that Peter Norton has had to resign from Council because of his other commitments and through the pages of the Journal I would like to thank him on your behalf for the work he has done as Technical Officer and for the articles he has written. As I step down from the Presidency at the AGM, the President for next year will be John Wolstenholme and the two Vice Presidents will be Mike Bolland and Paul Harris. We are looking for new members of Council and I encourage you all to vote for those you would like to see on Council. Thank you for your support over the last two years, it has been a great privilege to have been the President of such a vibrant and growing Institute.

**A J Morley** MSc BSc MIExpE

## Professional Registration update

Professional Registration statistics as at February 1st 2014:

| | CEng | IEng | EngTech |
|---|---|---|---|
| QUALIFIED | 16 | 4 | 3 |
| IN PROGRESS | 7 | 1 | 0 |

PRI Assessor training: on 27th February 2014, Col Gareth Collett and Dr Chris Owen will attend the Society of Environmental Engineers PRI Assessor training to be held at Lockheed Martin's facility in Ampthill.

**Professional Registration.** All Members and Fellows of the Institute should give serious consideration to professional registration in one of the grades available (EngTech, IEng, CEng). Professional registration is your personal quality mark that demonstrates to others in the profession and potential employers or clients that you are committed to maintaining a high quality of working, continuous professional development, and compliance with a professional code of ethics, environmental and safety standards. It is not an onerous task and those who are already registered will testify to its value in their professional lives.

To apply for professional registration call or email the Institute office: Tel +44 (0)1785 240154; Email secretariat@iexpe.org

For more information, contact Ken Cross: Tel +44 (0)7805 053791 Email: registrar@iexpe.org

**Ken Cross** MBE CEng MSc BSc(Hons) FIExpE

# EUExcert UK report

### Swedish (SWE) mobility visit 27th to 31st January 2014

The long-awaited visit of our counterparts from EUExcert SWE took place from 27th to 31st January 2014. The last EUExcert project ended with 8 out of 10 partner nations agreeing to adopt and adapt the UK National Occupational Standards (NOS) as the basis for certification of explosives workers and, as there have been many changes in people and structures in Sweden, it was agreed that the aim of the week was to provide an introduction to the NOS and their implementation as the basis of qualifications and also as management tools.

Seven members of EUExcert SWE and seven from EUExcert UK participated over the week. My thanks go to all those from EUExcert UK who put so much time and effort into providing a well-structured programme that was pitched at exactly the level our guests wanted.

### Next EUExcert project

The final sessions provided the opportunity to discuss the next EUExcert project. We outlined our position, that although we have resisted taking the leadership role for the next project in the EUExcert Programme, expecting (in concert with other EUExcert partners) that KCEM will continue to do so and in order that the programme is not seen as UK-centric, we must consider the possibility that the benefits for sustainability of skills in the UK explosives sector and mobility of UK explosives workers require EUExcert UK to form a project team to either lead or support the next phase. All members are invited to suggest options/models for setting up this team. The topic of the next project was discussed in outline and it is hoped that it will include partner participation in implementing the NOS to a certain (to be determined) level such as at least one explosives worker in one or two companies in the partner nation having qualified in a vocational qualification, with the partner nation and supporting company(ies) having created and implemented policies and processes, used the NOS to create Role Profiles and created and used supporting information systems.

The Chairman of the Board of KCEM discussed the leadership of the next project with his board in the week beginning 3rd February 2014, with the fallback option being that they should lead a virtual project team made up from the partners. At the same time, the Chairman of the EUExcert Association, Chairman of EUExcert SWE and members of EUExcert UK considered the practicalities of writing the bid for funding the project in line with the strategy that was proposed at the final meeting of the EUExcert SWE visit: to bid for funds to enable staff and learner mobility visits between UK and SWE, and other partner nations within the constraints of Erasmus+ Key Action 1 and to bid for funds for the next EUExcert project within the terms of Erasmus+ Key Action 2.

### Erasmus+

The Chairman of EUExcert UK and DOES PM (IExpE) attended the Erasmus+ briefing session in London on 10th December 2013. The UK National Agency for Erasmus+ will be a consortium led by the British Council with Ecorys UK as a key partner. In outline, Erasmus+ has some 14.7 Billion EURO to support projects over the period 2014-2020, some 75%+ of which is available for the EUExcert type of project. The Key Actions of Erasmus+ are described in full on the IExpE website. Key Action 1 of Erasmus+ is to support mobility visits for learners and staff from programme nations, of which both UK and SWE are part. Key Action 2 is to foster co-operation and innovation for good practices, which is clearly at the core of the EUExcert aims. It is important to note that all organisations will need to be registered on the European Commission's online registration facility in order to apply for funds. The Council of IExpE has agreed out of committee that they will register in their capacity as the National Node for EUExcert. Members of EUExcert UK who might wish to draw down EC funds through this scheme will also need to register.

### International Conference on Explosive Education and Certification of Skills 2014

This year's ICEECS is likely to take place on 11-12 June in Karlskoga, Sweden and the call for papers will be published soon.

### EUExcert UK Actions

1. Maintain a link to the UK National Agency for Erasmus+.
2. Members wishing to draw down Erasmus+ funds for Key Action 1 mobility visits should register with Erasmus +.
3. Prepare to support the creation of a project team to write the bid for the next EUExcert project.
4. Prepare to support the organisation of the 2014 International Conference on Explosives Education and Certification of Skills.

**K A Cross** MBE CEng MSc BSc(Hons) FIExpE
Chairman EUExcert UK

# Branch reports

### South (Central and West) Branch

Matthew Tosh presented to the branch on 10th December 2013 in Bristol. This was an informative and enjoyable presentation including some pyrotechnic demonstrations for good measure. Matthew provided an interesting insight into the chemistry and physics of pyrotechnic effects. He talked about how he has used his teaching and presenting backgrounds, along with professional firework experience, to engage audiences of all ages in the applications of science. Matthew explained why he hates bangs for the sake of bangs and some of the challenges he's encountered so far. The presentation also raised interesting reminders about why procurement managers and safety managers of explosive articles should take care when applying 'read across' from one system to another, as the smallest of changes can create significantly different explosive results. To find out more about Matthew, visit www.matthewtosh.com.

Please get in touch, through the Institute Secretariat, if you wish to attend any of the meetings or to be added to the email distribution list

**Rob Hart** CEng AIEMA MIExpE Branch Secretary


Matthew Tosh presenting to the Branch meeting.

# Development office for explosives skills

At the time of writing this update I have been fully involved with the EUExcert Swedish explosives employers mobility visit to the UK to share best practice and find out how the UK explosives sector has taken forward the use of Explosives Substances and Articles (ESA) National Occupational Standards (NOS). The trip has included visits to QinetiQ, Cranfield University, ISSEE with presentation by employers, HSQ, AVCTS, Cogent, MPQC and myself, including the use of an excellent presentation by Air Cdre Mike Quigley to the PARARI conference in Australia. This explained how the UK and DE&S are tackling the 'Sustaining WOME Sector Skills' and the SQEP issue (Suitability Qualified Experienced Personnel) and was well received.

The Sector Skills Strategy Group (SSSG) board will be reviewing the achievement and outcomes of the DOES project at their next board meeting in February 2014 and will be deciding on how they will take the project forward in the future and keep the momentum, we will keep you informed. I continue to assist the SSSG employers via the Expert Working Groups (EWG) to sign-post training opportunities and collaboration of training, as well as my other priority areas.

I have been involved in the HSE EIDAS database workshops looking at 'Trials' and 'Disposal' sub-sectors, which have been led by SSSG Expert Working Groups (EWG) members and will provide industry with a 'Lessons Learnt' database of past accidents and incidents, which will be held on the SSSG portal page.

I can report that the Explosives Apprenticeship frameworks for Level 2 and 3 are now published and available for use with early indications that some employers will start using these from April 2014 and others with their September intake.

I would like to remind members about the next Ordnance, Munitions and Explosives Symposium at Cranfield University, Shrivenham - 'Design for Safety' which will be held from 30th September to 1st October 2014 and a call for abstracts/papers is being made now.

If any IExpE member has any questions, please feel free to contact me for details.

**Allan Hinton** FinstLM MCMI MCILT AIExpE DOES Programme Manager

Email: doespm@iexpe.org or secretariat@iexpe.org
Mobile: 07866 429559 Tel: 01785 240154

## Institute Awards 2013-2014

A call for nominations for the following awards:

- **MSc Award**
- **Nobel Lecture Award**
- **Harold Swinnerton Award**
- **Rosenthal Salver Award**
- **Examination Award**
- **Journal Award**
- **Student Award**

Nominations to secretariat@iexpe.org (See page 38).

# Award Winners

## Congratulations

### to the winners in the Journal Awards Competition - 2014

As a means of celebrating the 40th anniversary of the Institute, the Editorial team created a new competition calling for original technical papers/articles for publication in the journal. The competition was publicised widely both in our journal and others and through leaflets distributed to selected universities and industries; international entries were received over an eight month period. The competition was open to all members and to non-members. The prize for each winner is a glass tankard and a cheque for £500. It had been intended to award two prizes for the Member's category but as the entries came it became apparent that only one was required.

We selected a judging panel of people who have been involved in the explosives sector for a long time and, to maintain the independence of the panel, the judges were not allowed to enter the competition. The judges were asked to grade the articles according to their quality, the technical application, explosives content, layout and interest generated by the paper.

The judges wish to commend all the entries but in particular singled out the entries from the Associate Members for the high quality and depth of the articles. The winning entries in each category are:

**Fellows – Ken Cross**
*"Best practice for Commercial Explosive Ordnance Disposal (EOD) in Great Britain"*

**Members – Holli Kimble**
*"Critical review of novel detection methods for buried explosives"*

**Associate Members - Andrew Envy**
*"A cost effective method for preliminary explosive characterisation"*

**Non Members – Tristan Worsey**
*"D10 dozer recovered from a high wall using blasting"*

The winning entries from each category are published in this journal and the remaining entries will be used in future journals at the Editor's discretion. Papers are published as entered with minor typographical changes.

It is hoped that all the prize winners will be able to attend the dinner after the AGM on 1st May to be presented with their prizes.

We are now considering whether to run another journal competition or to run one in a slightly different form. The subjects for this competition were left fairly open; should we tighten the selection of subjects, for instance? If anyone has views about this please let the Editor know.

Details of any future competition, if it is decided to run one, will be notified in the journal.

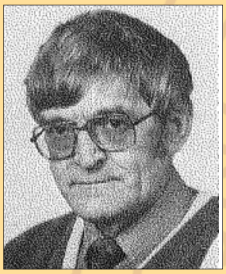
# Marking the 40th Anniversary of the Institute

**We thank the Past Presidents and Members for their contribution to the success and growth of the Institute and look forward to continued expansion and professionalism.**


1979. Bill Fowler TD FIExpE.


2012. Alan Morley MSc BSc MIExpE


2010. Ken Cross MBE CEng MSc BSc(Hons) FIExpE


1985. Fred Ogden FIExpE.


1984. R P Hughes BSc CEng AMIMinE MIExpE.


2008. Malcolm Ingry MIExpE


2006. Richard Vann MIExpE


Ken Broadhurst, MBIM FIExpE, (1987 President) congratulates Terry White, BSc CEng MIMinE FIExpE, on becoming Vice President. Terry went on to be President in 1991.


1989. Terry Digges FIExpE.


1996. Peter McGoff MIMine CEng MIExpE.


2002. Jim Hackett MIQ MIExpE.


2004. Charles Moran FiExpE


1998. Ian McKay CEng MPhil BSc DipH&S FIMM FIExpE


2000. Andy Pettit BSc MSc MIMinE FIExpE


1993. Mike Groves MIExpE.


1994. Mark Hatt MIPE FIExpE.

Note: Not all photographs of Past Presidents were available.

## Inaugural gathering of Past Presidents

A lunch will be held on 26th March at the Special Forces Club in London to reaquaint old colleagues and Presidents. Further details : membership@iexpe.org.

Please note Ken Cross is hoping to arrange a similar event for Fellows of the Institute


Picture taken at an IExpE Council Meeting in January 1985 includes the following Members: Dr Sidney Alford, Brook Foster, Nick Daniels, Mark Hatt, Fred Ogden, Jeffrey Rosenthal, Roger Hughs, Bill Fowler, Dr Gour Sen, not identified, John Butterworth, John Mackenzie, Terry White, Barry Lawe, Terry Digges.


# IExpE Merchandise

## Online ordering

Buy Institute branded items from this location including polo shirts, soft shell and fleece jackets, mugs, and ties. All items will be posted directly to you. A link is also available on the Institute's website.

http://iexpe.weebly.com

Crafty Craft | +44 7973618827

# IExpE AGM and Conference 2014

The 2014 AGM and Conference will be taking place on 1st and 2nd May 2014 at the Westerwood Hotel and Golf Resort (Cumbernauld, Nr. Glasgow, G68 0EW) with the AGM and dinner on 1st May and the Conference on 2nd May.

The theme for the 2014 Conference is "Developing Competence in Explosives Skills", with various provisional industry speakers already selected. Should you wish to be considered to present at the Conference, please contact Dave Welch or Hannah Mellish by calling: 01329 226 156 or emailing events@iexpe.org.

It is proposed that the 2014 programme will remain the same as for 2013, following a positive response, with a shorter day and an extended open forum after the symposium to allow for delegate participation. However the conference will commence slightly later this year at 09.30 to allow consideration for attendees' and presenters' travel constraints.

Thus, outline timings for the programme are below:

| | | |
|---|---|---|
| 1st May 2014 | 13:30 – 15:30 | Council Meeting |
| 1st May 2014 | 16:00 – 18:00 | AGM |
| 1st May 2014 | 19:30 – 20:00 | Drinks Reception |
| 1st May 2014 | 20:00 – 23:00 | AGM Dinner |
| 2nd May 2014 | 09:30 – 15:45 | Conference |
| 2nd May 2014 | 15:45 onwards | Open Forum/ Networking |

All Members of the Institute are entitled to attend the AGM and Conference at no cost, other than travel expense and overnight accommodation. Non-members will find the associated event costs on the AGM and Conference Booking Form, which should be completed by all attendees (including Members) and returned to events@iexpe.org or via post to Chairman for IExpE AGM and Conference, Shogun House, Fielder Drive, Fareham, PO14 1JE, at the earliest convenience. If you require a new copy of the form, please contact Dave Welch or Hannah Mellish on 01239 226 156 or events@iexpe.org. Accommodation should be booked directly through the hotel by calling: 01236 457 171, quoting "IExpE" as a reference to obtain the associated discount. As always, partners are encouraged to attend the Dinner and Conference and their attendance should be detailed on the Booking Form also.

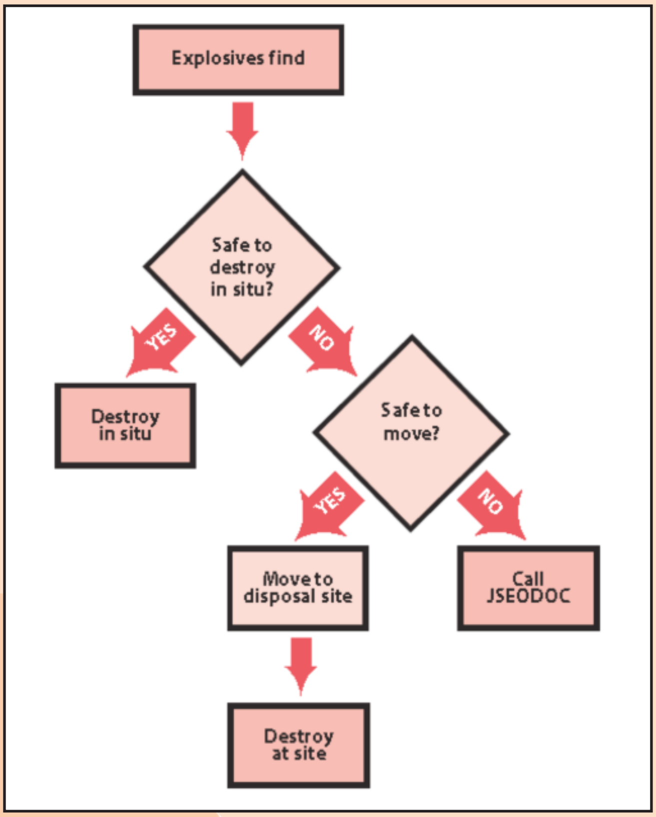
A number of sponsors have already been confirmed, however, there are packages still available due to the new restructured and tiered levels allowing for further sponsorship opportunities. All sponsorship packages are detailed in the Sponsorship Booking Form which can be obtained through Dave Welch or Hannah Mellish by calling: 01329 226 156 or emailing events@iexpe.org.

Award Winner

Category: Fellows of IExpE

# Best practice
## for Commercial Explosive Ordnance Disposal (EOD) in Great Britain

By **Ken Cross** MBE CEng MSc BSc(Hons) FIExpE
PICRITE Ltd, UK




## Abstract

*This paper outlines the background to, and development of, a new guidance document for contracting and delivering commercial EOD operations in Great Britain. It describes the changing framework for provision of EOD support from MOD-only to a blend of Defence and commercial operators. The booklet 'Guidance Notes for Commercial EOD Operations' is described as providing guidance on best working practices for dealing with potentially unexploded munitions discovered on the landmass of Great Britain or in its territorial waters. The Guidance Note is not a substitute for officially recognised training and qualifications but is intended to assist all involved in fulfilling their responsibilities for the safety of employees, contractors and service personnel, as well as the safety of people living or working in the vicinity of the EOD Operation. It is intended as a reference document for regulators, local authorities, engineering/construction contractors and commercial EOD organisations, to ensure that each understands the roles and responsibilities of the others.*

## Summary

The changing framework of EOD operations in Great Britain, especially in the latter part of the 'noughties', prompted the HSE to ask the IExpE to write a guidance note on commercial EOD operations to inform EOD contractors, their clients, the regulators and the authorities on best practice in the field. In 2009, the HSE published an article outlining the challenges that needed to be addressed. The "Guidance Notes for Commercial Explosive Ordnance Disposal Operations" is due to be published in December 2013 and this paper shows that each of the challenges is properly addressed and that the final version of the GN achieves its aims.

In short, best practice for commercial explosive ordnance disposal (EOD) in Great Britain comes down to EOD organisations being demonstrably competent across all the requisite skills at all levels of the organisation, identification of UXO and therefore the hazards and risks associated with them, compliance with regulations wherever possible and offering timely ALARP solutions to the regulators when circumstances are not covered in the regulations.

## Background

In 2009, Paul Rushton of the UK Health and Safety Executive's Explosives Inspectorate published an article in the journal of the Institute of Explosives Engineers entitled "Legal Requirements for Commercial EOD Operations". The intention of his paper was to flag up the issues that commercial EOD operators must address with respect to explosives licensing, preventing unauthorised access to explosives, and how explosives may be transported, including both the explosives to be used in disposal and the less well characterised explosives to be disposed of. The paper addressed the background to the issue, identified the key legal duties and raised some questions about how the UK might take the issues forward. In doing this it highlighted four particular challenges that UK EOD companies face in meeting their legal obligations.

The particular challenges identified were:

- Can the UXO be destroyed on-site?
- On-site licensed storage.
- Is the UXO safe to move or transport?
- Carriage to disposal site.

Having presented the paper at the IExpE AGM and published it in the journal, HSE and IExpE observed that the number of commercial EOD companies was growing to fill the gaps left as the Ministry of Defence (MOD) was pulling back from its hitherto ubiquitous presence in all disciplines of EOD across the UK due to its increasing commitments in Afghanistan and its reducing budget. It was felt that it was only right and proper to enable the burgeoning companies to have the best chance of staying on the right side of the multi-faceted regulatory requirements by providing a single guidance note that should at least ensure that the directors and employees of these companies, as well as potential clients were aware of the relevant laws and processes involved in conducting EOD in a commercial environment.

## The changing EOD framework in GB

Since before the Second World War, the MOD provided all EOD services for government and police forces across the UK. For some types of clearance, MOD was entitled to charge the recipient of the service directly, for example the EOD clearance of a scrap yard and in the 1990s it became common practice to cross-charge police authorities for the provision of pre-emptive EOD cover at major events.

The combination of changes to civil engineering standards and regulations, requiring detailed risk assessments and environmental assessments, with consequent mitigation policies and processes incorporated in the project plan, with reducing availability of MOD EOD support, provided opportunities for commercial EOD organisations to offer their services. In the maritime environment, the MOD moved away from providing regular EOD support to aggregate yards that would frequently find unexploded ordnance (UXO) in the loads brought ashore by their dredgers. This resulted in the publication in March 2010 of a Guidance Note "Dealing with munitions in marine sediments"[1].

The current MOD policy on the provision of EOD support is that "Defence provides EOD support to the civil authorities within the UK under Military Aid to the Civil Authorities principles[2]. The geographical dispersal of and response time for military EOD teams is formally agreed between the Home Office and the Ministry of Defence in a Service Level Agreement. Defence will respond at short notice where there is deemed to be a threat to life or potential for unacceptable economic damage. Outside these criteria, Defence will clear unexploded ordnance and consider requests for assisting in the clearance of other types of explosive. However, should there be a realistic expectation of encountering munitions during a commercial operation or private working, a competent commercial EOD contractor should be employed. The Metropolitan Police Service and a number of UK commercial companies maintain a range of EOD capabilities. The latter may also be engaged to support civil authorities."

It was also around this time that the MOD, along with all other government departments, began to implement austerity measures to reduce the UK's financial deficit. The austerity measures included making many service personnel redundant and, of course, that was expected to include EOD operators who would look to make use of their skills in the commercial marketplace.

This prompted the HSE's concern that such new entries to the commercial EOD space should not fall foul of the law, having worked within a highly regulated and controlled environment within the MOD that enshrined the multiple complex regulatory requirements within one or two Joint Service Publications, or as they are seen by the HSE - 'Safe Systems of Work'.

What was needed was a guide for Commercial EOD Operations that would inform newcomers to EOD provision, those organisations wishing to employ commercial EOD companies, those working within EOD companies and the authorities.

## Guidance notes for commercial explosive ordnanace disposal operations

The aims of the Guidance Notes (GN) are:

- To provide practical advice to local authorities, the emergency services, possible contracting organisations and, EOD contractors on the measures to be taken to reduce the risk to people and property when suspected munitions are discovered.
- To outline the potential risks and safety measures that need to be considered.
- To enable a contracting organisation to specify EOD Operations as a means to achieving their overall intent.
- To enable a commercial EOD company to meet the various operational and legislative requirements demanded of it in conducting EOD operations within the United Kingdom.
- To assure the regulator that commercial EOD companies working within the UK know the framework of explosives legislation within which they must operate and that implementation of commercial EOD Operations comply with that legislation and best practice.
- To outline the procedures to be followed when suspected munitions are encountered.
- To remind companies, individuals and organisation that the risks from their operations should be As Low as Reasonably Practicable[3] (ALARP).

The GN does not relieve individuals, companies or organisation from their duty to meet the legislative requirements of the Law.

It provides guidance on best working practices for dealing with potentially unexploded munitions discovered on the landmass of Great Britain or in its territorial waters. The GN is not a substitute for officially recognised training and qualifications but is intended to assist all involved in fulfilling their responsibilities for:

- The safety of employees, contractors and service personnel.
- The safety of people living or working in the vicinity of the EOD Operation.

## Meeting the challenges

**Challenge 1 - Can the UXO be destroyed on-site?**

From a risk-reduction perspective, i.e. not exposing more people and property to the hazard than is absolutely necessary, this must always be the preferred option. The simple answer to the challenge is that it will depend on the location of the site, proximity of surrounding buildings and the nature of the UXO. These then are the 'so what?' questions – what are the hazards associated with the destruction of the UXO and is the site safe and suitable for the destruction operation?

The GN provides guidance on the conduct of site surveys, UXO Risk Assessments, noise and vibration monitoring and the overall conduct of an EOD operation from planning through to remediation.

As the subject matter expert (SME), the EOD organisation is expected to be able to demonstrate competency (that combination of knowledge, experience, skills and attitude) at all levels of the organisation to undertake all the relevant processes and procedures: site survey, identification of UXO, siting of disposal area, advising and implementing mitigation, movement, storage and use of explosives, advising and implementing remediation.

Training and maintenance of competence is essential to the business and safe conduct of EOD operations. In order to operate in the UK, all EOD Operators must hold qualifications that are mapped against the National Occupational Standards for Explosive Substances and Articles (NOS for ESA), Key Role 12[45] at the level appropriate to the task in hand. It is expected that the senior EOD operator on site will be technically qualified and, in order to provide assurance to local authorities and clients of his capability to conduct dynamic risk assessments, must hold a recognised qualification in the management of an EOD or Munitions Clearance operation.

EOD can be carried out at many levels - from the neutralisation of large bombs and missiles to the destruction of grenades and sub-munitions. EOD qualifications should be appropriate to the hazard and the munitions most likely to be found. As a guide the following levels are appropriate[6]:

- EOD Level 1. Level One operators are competent to locate, identify and destroy under appropriate supervision, single items in-situ on which they have been specifically trained.
- EOD Level 2. Level Two operators are competent to locate, identify, move, transport and destroy multiple items on which they have been specifically trained.
- EOD Level 3[7]. Level Three operators are competent to conduct render-safe procedures and final disposal of any type of explosive ordnance with the exception of specialisations listed under level four.
- EOD Level 4. Level Four operators are competent to carry out specialist tasks in the following categories provided that they have the relevant training[8]:
  - Disposal of specific Guided Weapons;
  - Demilitarisation of Explosives Ordnance;
  - Chemical, Biological, Radiological and Nuclear weapons;
  - Improvised Explosive Device Disposal;
  - Disposal of weapons with specific fuel hazards;
  - Logistic disposal.

**Challenge 2 – On-site licensed storage.**
On a pre-planned EOD operation, there are two reasons why an explosives store might be required: to store the serviceable explosives required for the destruction of UXO on-site or for the temporary storage of UXO if they cannot be destroyed on the day they are found. When UXO are disposed of on the day they are found, no storage licence is required, however the potential for unforeseen delays should be considered. Delays could be due to finding a large quantity that cannot be disposed of quickly enough or due to weather conditions or availability of explosives or perhaps other factors external to the site. It is therefore sensible to have a licensed store on the site where UXO may be temporarily kept until it can be disposed of.

The GN provides an outline of the GB explosives licensing regime – HSE, Police or Local Authority, depending on the organisation's required holdings. It is incumbent on the EOD contractor to identify a suitable location on the site for an explosives store in their Method Statement and to arrange proper licensing.

**Challenge 3 - Is the UXO safe to move or transport?**
This is the most critical question in the EOD operation. As Paul Rushton noted in his original article "This is only an issue if it is unsafe to undertake the disposal on site. But it is potentially a very big one". In actual fact, there are two elements to this: is the UXO safe to move within the site, i.e. to the on-site disposal area; is the UXO safe to move to an off-site disposal area?

The emphasis in the GN on the competence of individuals at all levels in the EOD organisation, regular validation of competence and an insistence on identification of the UXO all contribute to providing the level of assurance required by the regulators. This particular issue was the most debated in all the development of the GN but an agreement was reached such that HSE Explosives Inspectorate (HSE XI) expects UXO to be destroyed in-situ whenever possible and when safe to do so; occasions when UXO are moved from the site of discovery should only be considered where the risks of on-site disposal cannot be mitigated to an acceptable level. The movement of any explosive comes with its own risks and therefore the overriding constraint is that the UXO has been assessed and is considered safe to transport, this will be largely dictated by the condition in which the UXO is found.

**Challenge 4 – Carriage to disposal site.**
The challenge was originally articulated as "Contractors cannot classify the UXO themselves, and HSE would not classify UXO without test evidence. Classification is therefore not appropriate. However HSE has the power to authorise carriage of explosives that is contrary to the prohibitions or requirements of the Carriage Regulations. Authorisations must be time limited, specify the purpose for which they are issued, and set out the conditions of carriage.

"Authorisations have most often been used to permit the carriage of unclassified fireworks from an unlicensed location to a licensed store. Before authorising such carriage, HSE needs to be convinced that the carriage is safe, i.e. that there is no risk of ignition during the transport operation. For undamaged explosives that are similar to explosives that have already been classified, this can be relatively straightforward, but for unexploded ordnance of unknown condition and unknown provenance it could be very difficult."

Annex D of the GN describes the approval process for packaging and movement of EOD arisings with the aim of providing EOD organisations the process for applying for either an annual permit to package and move EOD arisings from the site of discovery of an item of UXO to an off-site disposal area in a pre-planned EOD task, or for a one-off move of UXO in a reactive EOD scenario.

The GN requires that outer packaging must be of wooden or other non-metallic construction and must display a UN Packaging Code that shows the package can be accepted for transport. Where this is not practicable a justification as to the suitability of the proposed packaging will need to be made. Outer packaging must carry appropriate markings:

- UN Ser 0354, Articles Explosive N.O.S.
- Hazard Classification Symbol – 1.1L
- Gross Weight
- NEQ (Estimate)
- Quantity
- Name – "Unexploded Ordnance for Disposal by Open Detonation"
- Date packaged

Given the non-standard nature of the UXO, inner packaging must be safe and suitable, i.e. it must prevent the UXO from movement within the outer package and must neither add to the effects of an unexpected explosion nor the initiation of such an event e.g. by increasing the risk of electrostatic discharge. Suitable materials include, but are not limited to: anti-static bubble-wrap, corrugated card, polystyrene chips no smaller than combined outer dimensions of 5cm.

Normal ADR/CDG regulations apply with regard to approved vehicle type, placarding, training of drivers and escorts etc. UXO are not to be carried in the same vehicle as the serviceable explosives required for their destruction, hence the use of the hazard classification code 1.1L. It is recognised that this requirement adds to the logistic burden on the EOD organisation but it is imperative that the hazard of the unclassified, packaged UXO is isolated from other explosive hazards that could add to the overall hazard in the event of an unplanned explosion or fire.

1. *ISBN 978-1-906410-14-8*
2. *Joint Doctrine Publication 02 (2nd Edition) - Addendum: Operations in the UK: A Guide for Civil Responders, published February 2010*
3. *Defined by Judge Asquith in Edward v. the National Coal Board (1949) as " 'Reasonably practicable' is a narrower term than 'physically possible', and seems to me to imply that computation must be made by the owner in which the quantum of risk is placed on one scale and the sacrifice involved in the measures necessary for averting the risk (whether in time, money or trouble) is placed in the other, and that, if it be shown that there is a gross disproportion between them – the risk being insignificant in relation to the sacrifice – the defendants discharge the onus on them."*
4. *http://www.cogent-ssc.com/education_and_qualifications/NOS.php*
5. *http://www.homelandsecurityqualifications.co.uk/wp-content/uploads/2010/03/ESA-NOS-KR-12-Munition-Clearance-Search-interactive-version.pdf*
6. *CWA 15464-1, Humanitarian Mine Action - EOD Competency Standards - Part 1: General requirements*
7. *CWA 15464-5, Humanitarian Mine Action - EOD Competency Standards - Part 5: Competency for EOD level 3*
8. *CWA 15464-4, Humanitarian Mine Action - EOD Competency Standards - Part 4: Competency for EOD level 4*

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## Editorial Programme – 2014-2015

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| **June** | **Quarrying & mining**<br>**Major Majendie and the Explosives Act of 1875** |
| **September** | **Pyrotechnics, special effects and forensics** |
| **December** | **EOD/IEDD and area clearance** |
| **March** | **SOLAS (Safety of Life at Sea) equipment**<br>**Explosives used in safety equipment** |

## Award Winner

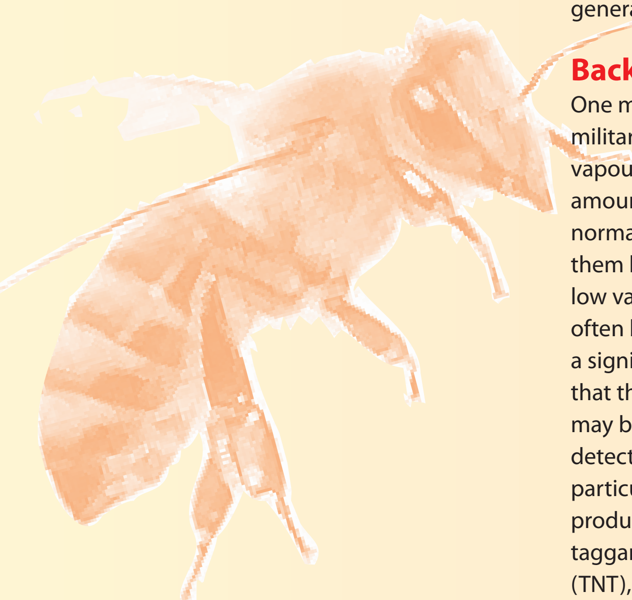
### Category: Members of IExpE

# Critical review of novel detection methods for buried explosives

By **Holli Kimble** MEng MSc MIExpE, Ministry of Defence.

## Abstract

*A critical review of different optical and olfactory methods for the detection of buried explosive devices shows that none of the novel methods examined are likely to yield a golden solution. The combination of honeybee passive sampling and bioreporting bacteria could be used to detect a range of devices containing different explosives. It is often easier to detect by-products of manufacture, decomposition products or taggants added during manufacture, and many of the novel techniques search for these chemical clues.*



## Introduction

The detection of emplaced explosives is becoming increasingly important to ensure the security of the British population, civilian and military, at home and abroad. Technology is being developed in a number of different branches to identify the threats faced in specific areas such as in airports, old minefields or the improvised explosives devices (IEDs) faced in-Theatre.

This critical review focuses on developing technologies that could be used to detect buried devices (mines and IEDs). Detection technologies will be broken into two main areas: optical methods and olfactory methods. Of particular interest are techniques that indirectly detect explosives by searching for compounds that are only found in the presence of explosives (and are generally easier to detect).

## Background

One major issue with the detection of most military explosives is that they have low vapour pressures (meaning that a low amount of gaseous emissions are released in normal atmospheric conditions), making them hard to detect outright. Despite the low vapour pressure of explosives, there are often by-products of manufacture that have a significant vapour pressure.[1] This means that the best way to detect a given explosive may be to search instead for a more easily detectable compound related only to the particular explosive (manufacture by-product, decomposition product or taggant). This is possible for trinitrotoluene (TNT), where a by-product dinitrotoluene (DNT) has a higher vapour pressure and is much easier to detect. Explosives with a low vapour pressure tend to linger for longer periods of time than high vapour pressure substances, so if an object or a surface has been in contact with the explosive, it can be detected for longer.[2]

Taggants are added to compounds to allow them to be detected and identified – they tend to be volatile and very difficult to manufacture. They are only associated with explosive compounds, making them as good, if not better, for detecting military explosives than the low vapour pressure explosive. Taggants can also be added to make explosives difficult to replicate, showing that they have been made outside a qualified laboratory. They are added during manufacture and as they are an intended additive, the detection method can be developed alongside the taggant to ensure adequate detection.[3]

Explosive compounds have a tendency to decompose over time. Often the decomposition products have higher vapour pressures than the explosive, so searching for these products is a common method of detecting the presence of an explosive.

Conventional explosives detection requires either direct contact or the ability to closely approach the target being sampled.[4] Some of the novel methods examined have the advantage that they have been developed, or have the potential, for stand-off detection, thereby reducing the risk to personnel and equipment.

## Optical methods

Luminescence-based methods of explosive detection cover a range of novel optical methods. Explosive compounds are not naturally fluorescent and in order to detect explosives using fluorescence, one can make an explosive compound fluoresce; induce a chemical reaction causing fluorescence; quench the fluorescence of other fluorophores or cause fluorescent excitation in other species.[5,6]

While explosive compounds are not inherently fluorescent, it is possible to excite them with high-energy x-rays or gamma rays. High energy X-ray fluorescence (XRF) is a technique which can be used to identify TNT, RDX, PETN, CE, C4, Comp B, black powder, smokeless powder, flash powder and ANFO.[7] Blair and Poteet also claim that the method is not affected by wind or vegetation and that it is currently possible to detect these explosives from a 2m stand-off. Nitrated explosives can be used in a redox reaction with other compounds to produce highly fluorescent species.[3] The major drawback to this method is that it is a laboratory-based experiment – the amine products of the redox reaction must be combined with a solution containing a Rubidium compound (there are numerous methods) which must then be reduced to form the fluorophore. This is impractical in the field as it requires handling of the explosive and therefore knowledge of where the devices can be found. It could be a useful identification tool, however, it is time-consuming and the chemicals involved are expensive.

Another direct luminescence method is to induce the decomposition of an explosive resulting in the formation of NO that fluoresces under UV stimulation, this fluorescence can then be measured to determine the explosive. Detection is reported to be possible in the laboratory setting,[5] but is not sensitive enough for use in the field. It is also difficult to detect RDX and PETN using this method, as they both preferentially decompose to NO2 rather than NO. At present, this technique does not have the versatility to detect buried explosives.

An indirect method of detecting the presence of explosives is a fluorescence quenching method, where the fluorescence of a fluorophore is reduced by the presence of an explosive. It has been noted that the decrease in fluorescence is proportional to the concentration of the explosive. This technique is not of practical use at this stage – there are currently requirements for solution or solid phase explosives and fluorophores, making this unsuitable for detecting buried explosives and this method is limited to the detection of nitrated explosives, so it would be necessary to know the type of explosive used in the

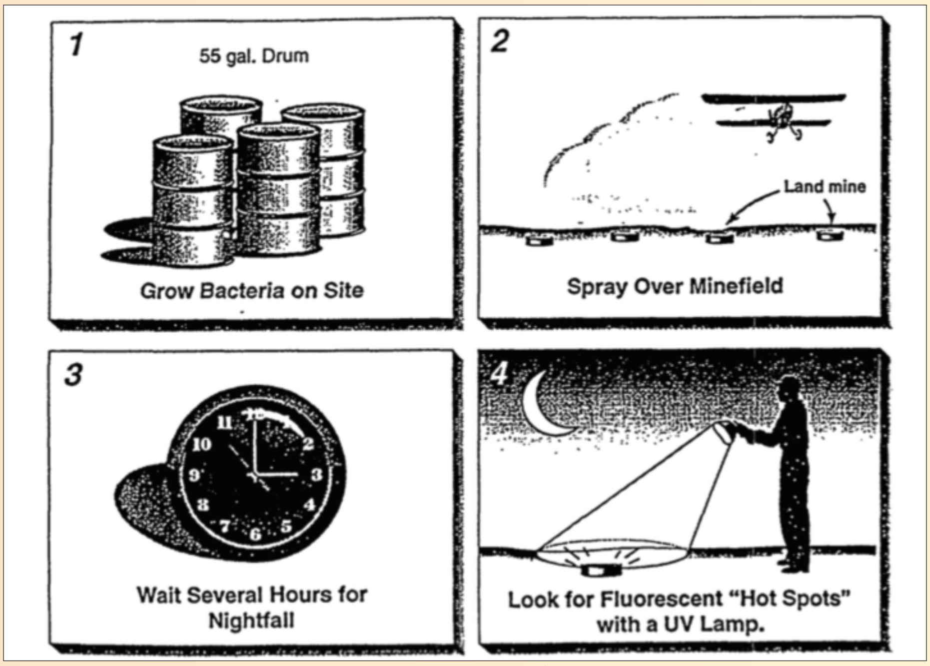


Figure 1: Procedure for explosive detection using bioreporter bacteria[6].

buried devices before attempting to detect them. Future developments could lead to a usable detection method if the quenching can occur with vapour-phase explosives. A general idea of the location for the device would be needed before this short-range technique could be used.

A crossover between optical and olfactory methods is the use of bioreporter bacteria: the genetically engineered bacteria detect cues from the presence of an explosive and translate this in a visual way (as do dogs) which humans can detect. Two different types of glowing response have been created: bioluminescence, the production of visible light by the bacterium; and fluorescence, a green glow in response to UV stimulation.[6] The mechanisms are very different and the bioluminescence is relatively weak and requires sensitive detection equipment. The fluorescence is created using a protein found in a species of jellyfish which fluoresces under UV light, the glowing response turns on and off with UV exposure, allowing the distinction between the glow of the bacteria and ambient light. As shown in Figure 1, the bacteria can be grown in large drums and then sprayed over a suspected buried explosives site, once night falls, a UV light can be used to induce regions of fluorescence which correspond to a buried device. The UV lamp can only be used at night, or the glow will not be detectable by eye, it may also be necessary to use an electronic detector to see the glow. The bacteria only fluoresce in the presence of one explosive, however, it is not inconceivable that a batch could be grown which contains several different types of bacteria suited for different explosives. Currently, it is also not possible to use genetically modified bacteria without very strict control, making it unlikely that such technology would be readily embraced.

One major implication with the use of this technology is that the rough location of numerous devices (i.e. a minefield) is known; it would not be appropriate to begin coating the entire countryside with bioreporter bacteria and then sending out an army to search the area by night. This method also has limitations in detection based on the probability of slow release of the chemicals to the surface from buried devices – this makes it useful for humanitarian de-mining, but may reduce the tempo of military operations.

The novel optical methods examined are largely at the laboratory testing stage, and the majority would be unsuitable for the detection of unknown buried explosives as they are only able to detect specific explosive compounds. Another severe limitation in their use would be the lack of stand-off detection; only the XRF and bioreporter bacteria techniques have a stand-off which may be of use. The use of electromagnetic waves in the detection of explosives avoids disturbance by environmental factors such as wind, however, detection is only possible for a bare charge at the surface as although the x-ray may penetrate to a depth, the response is not likely to be visible from a buried, cased device. The bioreporting bacteria show most promise of the optical methods examined, but the sensitivity of such bacteria would require testing to see how long it takes after burial before the bacteria can detect the explosive. In the longer term, a brighter glow or variety of colours to indicate different explosives may increase the utility of this technique.

## Olfactory methods

Sniffer dogs are certainly the best known olfactory method of explosives detection and have been used in a military setting since 1971 by the US Air Force.[2] It is still not fully understood how dogs sense the presence of explosives, and the performance of dogs against modern sensing equipment has not been fully tested. There are pros and cons to the use of dogs compared to equipment in detection, including:

**Training** – the dog requires long and expensive training to detect explosives. A human must be trained for many years to develop the technology required to detect explosives, an operator must then be trained who must take the equipment to the front line (if possible).
**Mobility** – dogs are highly mobile; specialised vehicles exist to transport the dog and handler to the required location, the dog can move on its own once it reaches the site, it can follow plumes of vapour to the source with its nose without delay. Most detection systems are not man-portable, many require samples, and others are only able to detect a single explosive without lengthy recalibration. Some detection systems are more accurately identification systems which give a negative result unless the target explosive is present; dogs can be trained to detect many explosives.
**Calibration** – machines and dogs both require recalibration. In both cases, effort must be made to ensure that the calibration samples do not become contaminated with other substances, explosive stocks are normally replaced yearly for this reason.[2]
**Reliability** – dogs are limited to working for brief durations, as they may have attention and sensitivity issues after longer shifts. Dogs are also unable to communicate the type of explosive they have detected. Detection equipment may have other reliability issues, likely to involve sensitivity.
**Sensitivity** – difficult to compare, as dogs and machinery may not be detecting the same substance, but dogs are able to detect certain explosives in the parts per trillion range in a laboratory setting[2] and detector equipment ranges from similar detection limits to a requirement for higher concentration. Dogs do not have to decide which type of explosive they are sampling for before setting out – this is a major drawback to most portable detection equipment.

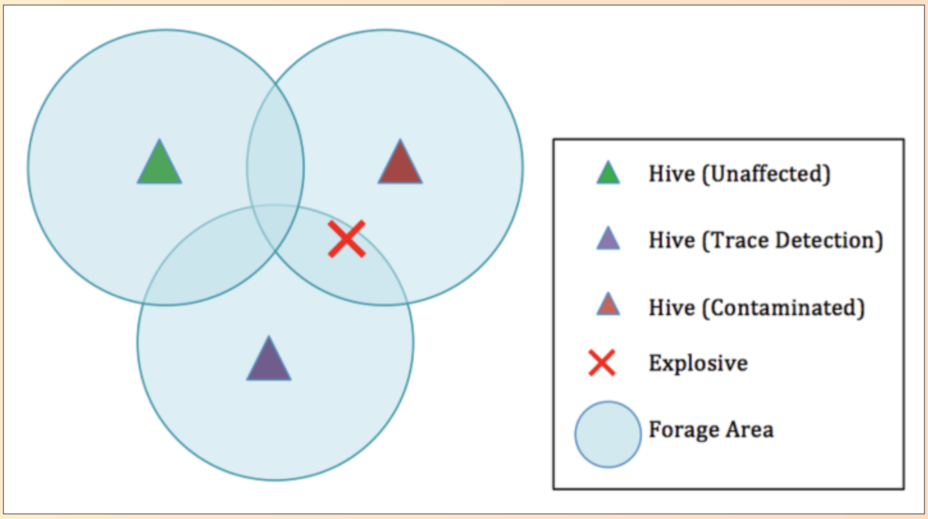



Figure 2: Detection of explosive using passive detection by honeybees.

The use of dogs is well established, but there are questions over the accuracy of canine olfactory detection. The development of electronic noses known as "sniffers" is trying to harness the power of detection in a scientific measurement device. It is held back, however, by a lack of clear understanding of exactly how a dog is able to detect the presence of an explosive – we just know that it can. Much research is going on to establish the mechanism for detection.

A downside to the use of dogs is that this valuable asset must be within the danger zone of an explosive device in order to communicate its location; this leads to a high risk to an asset that is difficult to replace.

The immediacy of feedback for canine detection is a huge advantage over the use of electronic equipment which can take minutes to process data to determine whether an explosive is in the vicinity. This makes real-time use of sensing equipment a problem, as sensing equipment for stand-off detection could potentially be flown through the area of interest, but this is not a likely solution for systems with slow processing.

Another olfactory method of detection being developed involves the training and use of honeybees. There are passive and active methods with honeybee detection.

**Passive** – based on the principle that there are 45,000 to 60,000 bees in a colony making thousands of foraging trips each day, covering around 2km[2,4] the bees come into contact with anything in that region and return to a fixed hive location. Sampling at the hive allows a snapshot to be taken of any explosives present in the vicinity of the hive. The method behind locating an explosive device relative to a number of hives is shown in Figure 2, where the closer hives become most contaminated.

**Active** – bees can be trained to search for explosives (liquid, solid, vapour, particulate). Bees could be effective in the detection of landmines[4] as 90% of landmines have TNT as the main filling, a decomposition product of which is the more easily detectable DNT. Training a bee uses similar methods to training a dog – conditional training, where bees learn to associate a particular odour with a reward. With a dog it may take many months to train, whereas bees can be trained on-site and sent out to search in the same day.

A nectar feeder is set up close to the colony and a sample of the explosive to be detected in placed within 6 inches of the reward. The bees then associate the scent of the explosive with the reward of nectar. Due to the foraging nature of bees, they will begin to search for other locations with that odour and will gather at areas where they detect that odour. Experiments performed by Sandia National Laboratories discovered that if bees from a trained hive find untrained bees from a different hive, they will teach them to associate the explosive odour with the reward and thereby recruit other bees to search for the explosives. Field trials have been performed which show that the bees prefer to visit nectar targets that have the explosive residue nearby rather than ordinary nectar. The concentration for the targets was between 0.74 and 0.8 ppb.[4]

Detection of explosives using honeybees shows promise – compared to dogs they are cheaper to train or replace, do not require a highly trained handler and are effective at detecting explosives at low concentrations. They are only sensitive to the explosive that they have been trained to detect, and it is unlikely that bees could be trained to detect numerous explosives (including taggants or by-products), so there would be limitations to their detection capability in a real-world scenario involving unknown explosives in unknown locations. Bees do not fly at night, in the rain or in cold weather,[1] they must also be taken to the area of interest. With this in mind, honeybees could not be used on their own as an effective method of detection. Another drawback to the use of bees is tracking them – it has been proposed that tiny radio transmitters could be attached to bees to report where they landed (Figure 3).[1] The utility of radio transmitters seems unrealistic, as there are thousands of bees in a colony and any one of those bees is disposable as this detection technique is based on foraging behaviour. Another limitation to this technique is similar to many others – the time taken for a buried explosive device to leak detectable traces to the surface, though the sensitivity and mobility of bees is an advantage in this case.

Although cheaper and easier to train than dogs, bees are limited to the detection of one explosive at present and it is not possible to direct them to a suspected source as it is with a dog. The passive monitoring of an area could be useful to detect changes in the chemicals present and detect explosives in an area. It is also possible that bees passing to and fro in an area would go unnoticed, whereas the trained bees may amass in an area and draw attention to themselves and this method of detection, leading to spoofing attempts.

## Conclusion

The detection of buried explosive devices is key. In order to improve on current capabilities, it may be necessary to embrace some of the novel technologies that are emerging in this sector. As can be seen from this review, none of the methods examined would be suitable on their own, but a combination of techniques may yield an improvement.

The passive detection using honeybees could be combined with specific detection using bioreporter bacteria. This combination could improve the accuracy and the efficiency of resource usage when compared to either of these techniques alone. It would allow a sweep of a wide area and would provide a more focussed region to target with the bacteria – thus reducing bacteria and manpower detection requirements.

In general, the examined optical techniques are slow, bulky and unsuitable for military use in the detection of explosives, however, as the sensing technology improves, many optical methods could be used to detect explosives at a greater stand-off, reducing the risk to personnel. These methods are also expensive, meaning that they are generally out of reach for both civilian and military applications at this point.

The olfactory techniques include the use of dogs, which are currently the best method for the detection of explosives. It is important to note that there may come a time when the benefits of using novel sensing equipment outweigh the limitations, but at this point in time, the flexibility of canine detection is superior to the expensive, bulky and (comparatively) slow equipment on offer. The instant processing, sensitivity at range and mobility of dogs are their greatest advantages, so efforts focussed on fast, lightweight stand-off detection would close the gap.

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Figure 3: Honeybees ready to be fitted with radio transmitters[8].

# Award Winner
## Category: Associate Members of IExpE

# A cost effective method
## for preliminary explosive characterisation

By **Andrew Envy** BEng AIExpE, AWE Aldermaston

## Introduction
### Explosives safety and performance testing

When an explosive formulation is being developed for whatever purpose the formulation is required to undergo a large variety of testing to establish the explosive safety and performance characteristics of that particular formulation. A performance test is required to bridge the gap between the safety and performance testing on explosive to provide approximate performance data prior to upscale in production. It is important that performance testing is carried out on new explosive formulations and even on new batches of old material manufactured to a new specification. The tests carried out for this paper are a combination of two tests, the cylinder test, and the flyer plate test, from these tests several performance properties that can be measured including velocity of detonation (VoD), brisance, detonation pressure and the JWL equation of state values.

The cylinder test, as described by Suceska 1995[1], consists of a hollow copper cylinder filled with an explosive down its entire length detonated at one end and the detonation wave runs down the cylinder forcing the copper wall outwards. The displacement or velocity of the expanding copper wall is recorded with respect to time.

The flyer plate test, as described by Suceska 1995[1], consists of a explosive material being detonated while in contact with a metal plate. The velocity of the metal plate is then recorded and the detonation pressure, $P^{CJ}$, can be calculated.

This is a report about the development of a one-shot test to determine the performance properties of an explosive at a smaller scale of production, which will highlight if the explosive being tested has the desired performance properties before a costly up scale in manufacture. The test being developed is essentially a small scale, cost effective combination of the cylinder test and flyer plate test. An array of diagnostics will be used to measure the velocity-time history of the expanding cylinder wall and of the flyer plate, positioned at the opposite end of the tube to the detonator, and the velocity of detonation of the explosive. The data recorded from these outputs can then be manipulated to give a good indication of the explosive performance properties of an explosive. This report will look at the effect that variations in the density, with respect to the percentage of the maximum theoretical density of the explosive that is achieved, and standoff between the outer diameter of the explosive cylinder and the inner diameter of the copper tube have on the results achieved by this type of test. These two tests are carried out in an attempt to understand how a small assembly or manufacturing error can affect the results during this type of test.

## Experimental methods
### Explosive formulation

The explosive composition that was used during the development of the Mini cylinder test was a HMX based explosive that will be named Composition A for the purposes of this report. The composition is made up of 90% HMX, with energetic plasticiser. This explosive has been well characterised in the past using standard cylinder tests making this the ideal explosive to use to develop these tests as this will give some indication as to whether the Mini Cylinder Test is producing comparable data.

The cylinders were filled with seven 10mm (nominal) diameter and length pressed pellets of three different densities of 98.5%, 97% and 95% (densities are given with respect to the theoretical maximum density, TMD, of the explosive composition). Following the pressing of each pellet dimensions of the pellets were measured using a micrometer. Due to availability of material only enough pellets for two shots of the 97% and 95% TMDs were pressed but it was decided that this would still provide enough data for a comparison with the 98.5% TMD pellets.

After the pressing and metrology stage of the explosive pressing were complete the pellets density was measured accurately using the Archimedes method. Table 1 shows the statistical analysis of the pellet density measurements.

| Nominal | Average | Range | Standard deviation |
|---|---|---|---|
| 95% | 95.39% | 94.57-95.95% | 0.5% |
| 97% | 97.35% | 96.57-97.75% | 0.32% |
| 98.5% | 98.44% | 98.12-98.71% | 0.12% |

Table 1. Statistical analysis of the pellet density measurements.

The pellets were then cooled and inserted into the hollow copper cylinders, seven per cylinder. Cooling of the pellets was done due to the interference fit between the pellet and the cylinder wall, the cooling shrinks the pellet and allows for insertion into the cylinder.

Figure 1 shows how a gap is introduced between the copper cylinder and the explosive pellet.

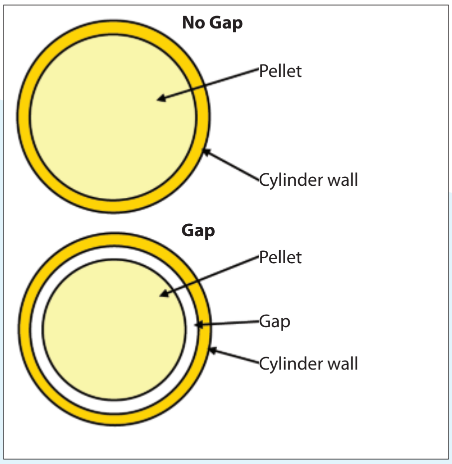



Figure 1 Image of gap between pellet and cylinder

The cylinders that were made for the gap tests had the internal diameter increased to 10.1mm and 10.2mm for 0.05mm and 0.1mm gap respectively. To ensure that there is a consistent gap between the pellets and the cylinder the pellets were inserted along with 3 equally spaced 2mm wide strips of shim.

## Experimental set up

The experimental rig was made from laser sintered rapid prototype material. This material was chosen for its high strength and low weight properties, while also being cost effective. Figure 2 shows a picture of the engineering model of the experimental rig while Figure 3 shows a picture of the experimental rig in position in the firing chamber.

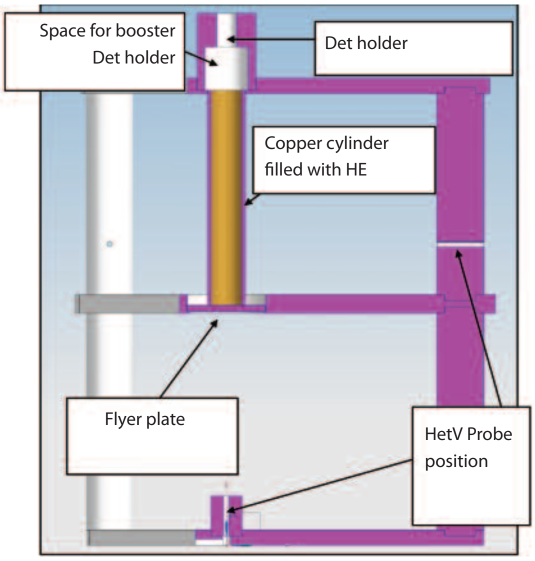



Figure 2. Engineering model of experimental rig.

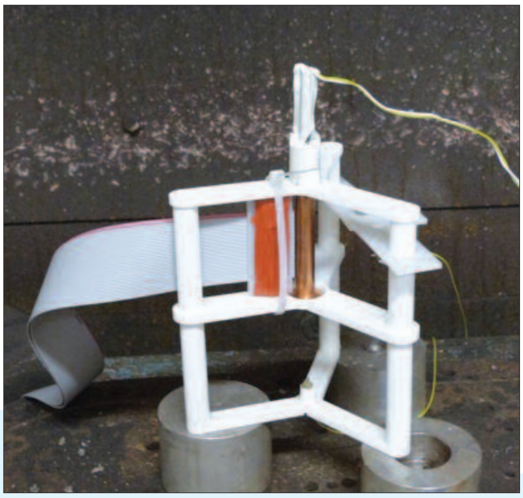


Figure 3. Photograph of experimental rig.

The prefilled copper cylinders then aligned with the laser diagnostics and the velocity of detonation probes and initiated in the firing chamber by a Number 8 detonator and tetryl booster added to the set up directly prior to firing.

Each test was designated a number from 1 to 13, Table 3 shows the number designations.

| Test Number | Test Type |
|---|---|
| 1-3 | 98.5% TMD, close wall |
| 4-6 | 98.5% TMD with 0.05mm gap |
| 7-9 | 98.5% TMD with 0.1mm gap |
| 10-11 | 97%, close wall |
| 12-13 | 95% TMD, close wall |

Table 3. Test numbers.

## Diagnostics

### Heterodyne velocimetry

The primary diagnostic that was used during these experiments was the Heterodyne Velocimetry (HetV) laser diagnostic. HetV is a laser diagnostic that directly measures the velocity of a moving reflective surface. This is achieved using a control signal along with the reflected signal from the moving target, the change in frequency from the reflected signal, due to the Doppler shift, is mixed with the control signal causing a 'beat frequency'. This beat frequency is recorded and used to determine the velocity of the moving surface, as described by Bowden 2007 [2].

For these tests the two channels of HetV were used, one channel was used to measure the radial expansion of the copper cylinder and the other was used to measure the free surface velocity of the brass flyer located at the bottom of the cylinder.

### Velocity of detonation probes

To accurately measure velocity of detonation (VoD) down the copper cylinder a line of ionisation type probes, spaced approximately 1mm from the cylinder wall, was positioned down the length of the cylinder wall. A 32 pin ribbon cable was used to perform this task, as shown in Figure 4.

By knowing that each probe was spaced 1.5mm to the next probe and the time at which the probe was impacted the results can be plotted on a position-time graph and the gradient of the line of results produced is the velocity of detonation. The velocity of

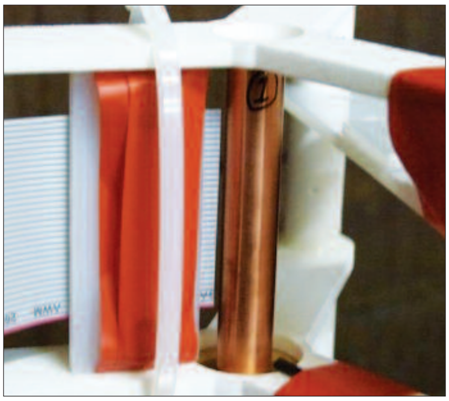


Figure 4. Velocity of Detonation probes prior to firing.

detonation of the explosive being tested is already known therefore the results gathered by the probes can be compared to the known V.o.D. giving an idea of the accuracy of the results.

## Results

### Copper wall expansion

Figure 5. Spectrogram of shot 2 radial velocity.

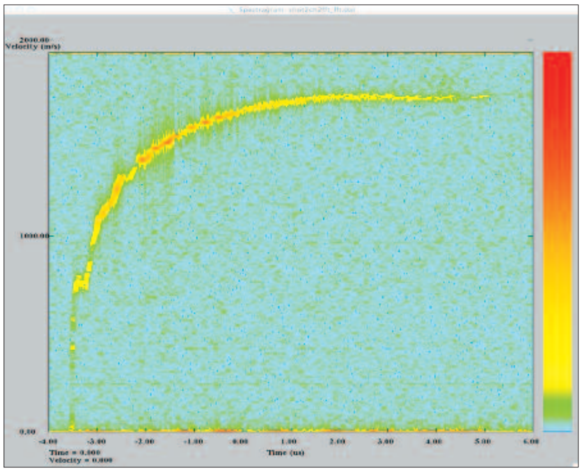


Figure 5 shows a spectrogram of velocity plotted against time for the data taken from shot 2, due to the programming constraints the axis label cannot be increased in size.

Figure 6 (over page), is a graphical representation of the spectrogram, the following are key points taken from the results.

- It can be seen that the velocity rises sharply at the initial point of movement, climbing to a velocity of approximately 700-800m/s almost instantaneously as the shock front from the detonating explosive impacts the inner wall of the cylinder.
- At this point a characteristic of the cylinder test radially expanding cylinder occurs where the velocity of the cylinder decreased sharply for a short time before rapidly increasing again. This is called pull back and occurs 5-7 times while the shock

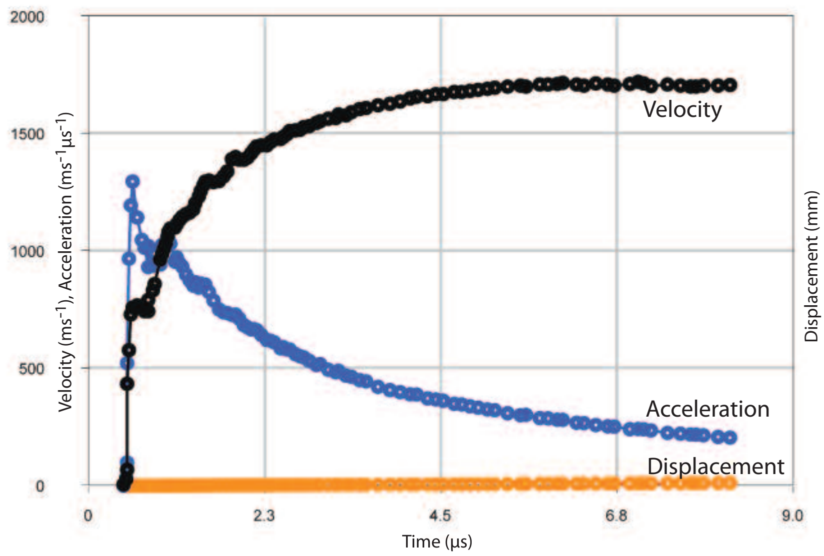



Figure 6. Digitised results for shot 2 radial velocities.

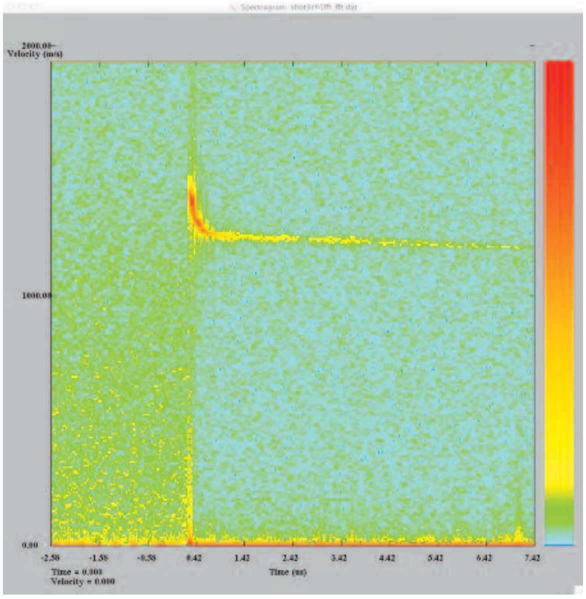


Figure 7. Spectrogram for shot 3 flyer plate velocity.

wave reverberates through the cylinder as the cylinder accelerates. This effect diminishes as the shock reflections lose their energy.

- Once the cylinder has accelerated rapidly for approximately 2μs the velocity begins to rise less steeply and plateaus to its maximum speed. The maximum velocity is dependent on a number of factors including the gurney constant of the explosive and the confinement of the explosive within the copper material.

## Gurney constant

Equation 1[3] shows the Gurney equation for a thin walled hollow cylinder filled with explosives.

$$\frac{V}{\sqrt{2E}} = \left(\frac{M}{C} + \frac{1}{2}\right)^{-\frac{1}{2}} \qquad (1)$$

Gurney equation for a cylinder.

The final peak velocity of the cylinder can be used to calculate the Gurney constant of the explosive. Table 4 shows the Gurney constants calculated from the data.

The Gurney constants show that for the high TMD, close wall tests the Gurney constant is consistent with PBX 9404, an explosive similar to that of composition A. However for the tests with gaps the Gurney constants calculate show a value higher than that even of pure HMX (2970m/s). The Gurney constant therefore cannot be used reliably calculated when there is a gap between explosive and cylinder wall.

## Flyer plate velocity

Only the peak (free surface) velocity was needed for the analysis of the flyer plate results, seen in Figure 7 at the top of the velocity spike.

| Shot ID | Thickness (mm) | Peak Free Surface Velocity (m/s) |
|---|---|---|
| 2 | 2 | 1945 |
| 3 | 5 | 1478 |
| 4 | 2 | 1927 |
| 5 | 10 | 839 |
| 6 | 2 | 1678 |
| 7 | 2 | 1784 |
| 8 | 2 | 1924 |
| 9 | 2 | 1951 |
| 10 | 2 | 1875 |
| 12 | 2 | 1784 |

Table 5. Shows the peak velocities read from the digitisation of the spectrograms.

Figure 8 is a plot of velocity and shim thickness. The value taken for the 2mm shim is the average of the values recorded for shots 2, 4, 8 and 9. The values for these shots were used because the quality of the data recorded was superior.

It has been found that the pedigree material for the shims of 5mm and 10mm thickness could not be guaranteed and it could be copper, this will affect the calculation of the detonation pressure. Below the detonation pressure is calculated for both materials.

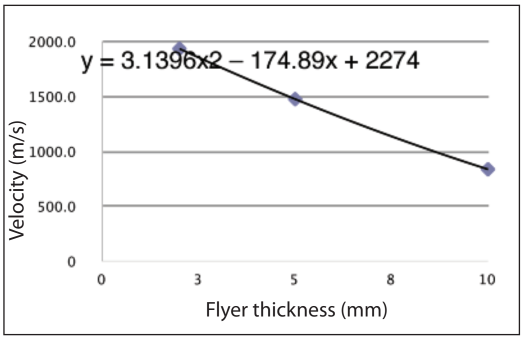



Figure 8. Free surface velocity graph thickness of shim versus velocity.

By extrapolating the polynomial curve fitted to the data back to zero it is found that the free surface velocity of the explosive is found to be approximately 2274m/s. The particle velocity is known to be half of the free surface velocity of the flyer, this can then be inputted into equation 2 below. The equation for shock hugoniot for brass is given below [4]:

$$U_s = 3.74 + 1.43u_p \qquad (2)$$

The equation for shock hugoniot for copper is given below [4]:

$$U_s = 3.91 + 1.51u_p \qquad (3)$$

The shock velocity can then be used with remainder of the known variables for equation 4[5] below is known and the detonation pressure can be calculated.

$$P_{cj} = \frac{1}{2}u_p(\rho_m U_s + \rho_0 D) \qquad (4)$$

Table 4. Gurney constants calculated from experimental data.

| | | | | | | |
|---|---|---|---|---|---|---|
| Shot | 2 | 3 | 4 | 5 | 6 | 7 |
| √2E (m/s) | 2813.47 | 2866.92 | 2911.84 | 3096.79 | 2802.29 | 3032.15 |
| Shot | 8 | 9 | 10 | 12 | 13 | PBX 9404 |
| √2E (m/s) | 2813.47 | 2866.92 | 2969.39 | 2750.58 | 2940.62 | 2900 |

Where:

| | Brass | Copper |
|---|---|---|
| $u_p$ | 1.137km/s | 1.137km/s |
| $\rho_m$ | 8.3g/cc | 8.96g/cc |
| $U_s$ | 5.34317km/s | 5.62687km/s |
| $\rho_0$ | 1.84g/cc | 1.84g/cc |
| D | 8.75km/s | 8.75km/s |
| $P_{cj}$ | 34.35GPa | 37.81GPa |

Table 6. Detonation pressure calculation.

The results recorded from these tests although not without error have proved that this method works. The literature value for the detonation pressure of this explosive is 38GPa[6] putting the detonation pressures calculated above within 10% of the actual value.

## Velocity of detonation

The data from the velocity of detonation probes were recorded using a logic analyser that detected the completion of the circuit for each probe as the copper impacted the probes. The time of arrival of each signal can then be plotted as shown below in Figure 9.

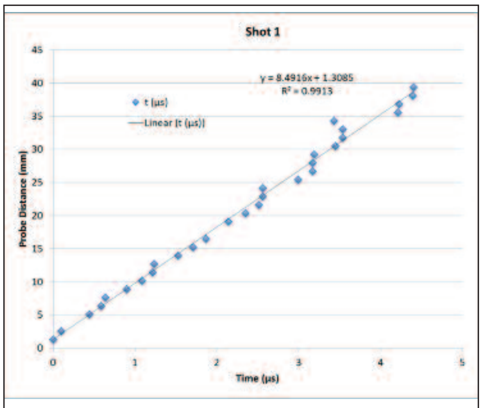



Figure 9 Velocity of detonation results for shot 1

The velocity of the advancing detonation wave as it accelerates the copper cylinder is the slope of the curve fitted to the data, as shown in Figure 9. Table 7, below, shows the values of the velocity of detonation obtained using the gradient of the curve.

| Shot | Velocity of detonation (km/s) |
|---|---|
| 1 | 8.496 |
| 3 | 8.952 |
| 9 | 8.595 |
| 10 | 9.798 |
| 11 | 9.115 |
| 12 | 7.701 |
| Known V.o.D. | ~8.7-8.8 |

Table 7. Velocity of detonation results for all tests.

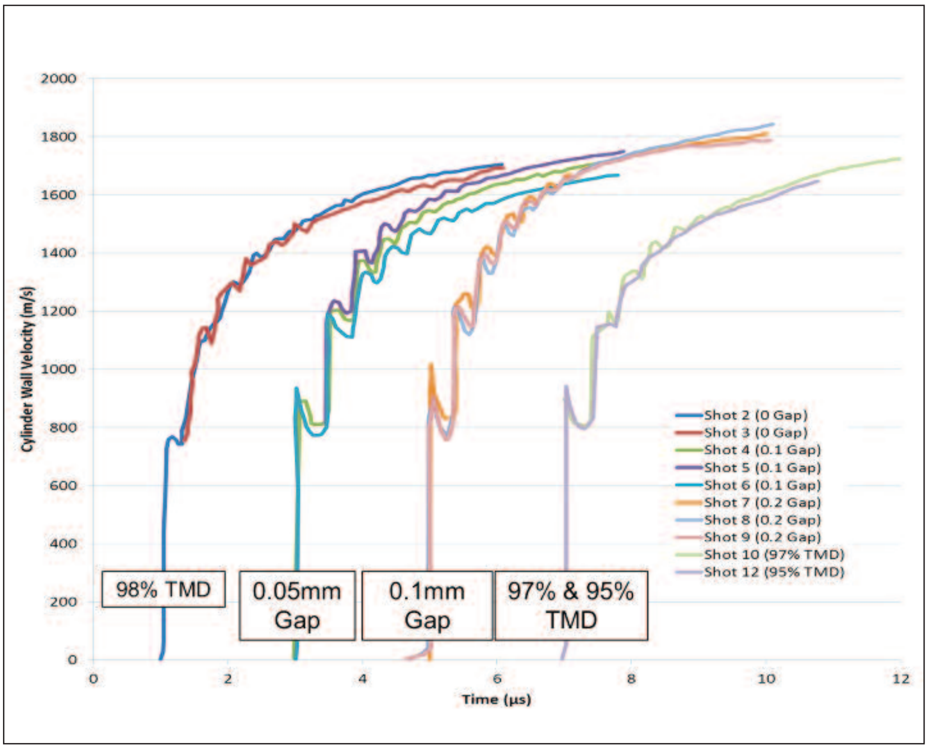



Figure 10. Variable time visualisation of the radial velocities for all shots.

## Discussion

### Radial expansion

In order to compare the early expansion time of the different types of test the digitised cylinder expansion data is plotted on Figure 10 with separated time bases.

The first thing that can be seen from the results that have been recorded is that the data from these tests are very consistent and reproducible. All of the results from each test show a sharp instantaneous rise to the first 'pull back' with a consistent number of 'pull backs' of diminishing strength before the copper wall velocity levels to a constant velocity of between approximately 1650 and 1850m/s. With the exception of the 0.05mm gap shots the traces from each of the different types of shot almost overlay each other showing very good reproducibility. The results for shot 2 show that there were weaker reverberations between this shot and that of the gap type tests. Although there does seem to be some enhancement of the reverberation for the gap shots the most likely reason for apparent lack of 'pull back' is lack of resolution due a small misalignment of the laser during set up. The effects of small density variations in the explosives observed by these tests are small. The rise to similar peak velocities with the traces for the lower densities being shown on the same time base show very little notable difference. The significance of this result is that this means that the explosives for this type of test do not need to be pressed to as high a TMD as possible using higher temperatures and isostatic pressure techniques reducing cost and time constraints.

Shots 7-9 are the results of the intended 0.1mm gap test. The main differences between the 0.1mm gap shots and no gap shots are:

1. The already discussed stronger reverberations, especially on the first three 'pull backs'. The velocity of the initial rise in velocity prior to 'pull back' is also higher for the 0.1mm gap shots.

2. The cylinder wall appears to level off at a higher velocity for the gap tests. This happens for all three of the gap tests and seems to be higher than the no gap tests by approximately 50-75m/s.

There are two reasons why the cylinder wall velocity has increased for the gap tests. The first theory involves the gurney constant equation for explosively driven cylinders, Equation 1. The cylinder wall thickness was reduced as the outer diameter of the cylinder will have remained the same for all tests while the inner diameter was increased to allow for the gap. This decrease in wall thickness would increase the velocity of the cylinder wall according to the Gurney equation.

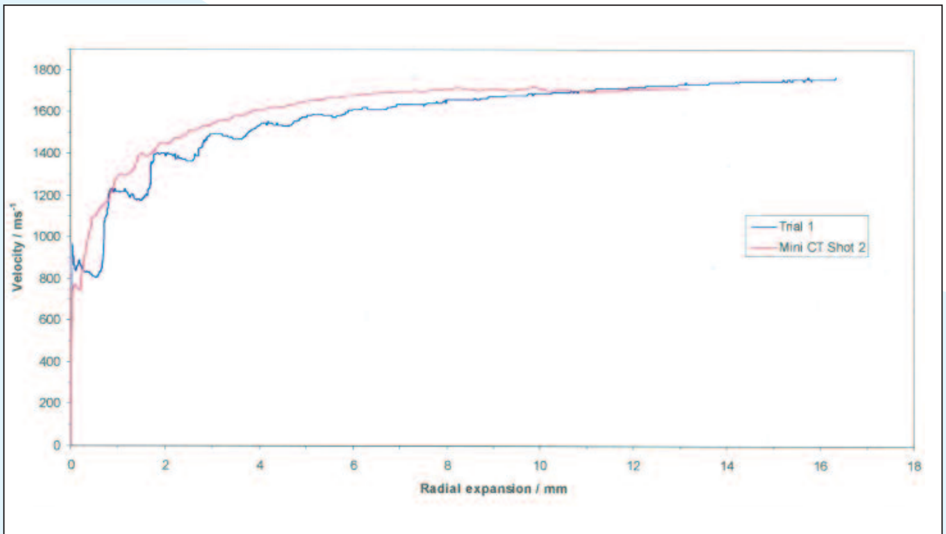
The second theory is that as the air gap between the explosive and cylinder wall allows the detonation wave to straighten radially decreasing the vertical component of the velocity and therefore increasing the radial velocity.

## Comparison with standard cylinder test results

An important test as to whether it truly gives a rough reflection of the standard cylinder test is to directly compare the radial expansion history recorded by the mini cylinder with that of the standard cylinder test for the same material. Figure 11 shows the radial expansion history from shot 2 of the mini cylinder tests plotted on the data from a standard cylinder test for the same material. The data provided for Figure 11 was taken following a private communication with Dr Ferguson, the data was presented at A.P.S. Conference in 2013 by Ferguson et al [7,8].

The graph shows radial velocity on the y axis and displacement of the cylinder along the x axis. As can be seen there is good comparison between the two results, the two don't completely overlay but there are reasons for the discrepancies seen. These are in the main part due to the thicker wall of the copper in the standard cylinder test as the material properties of the copper have a more prominent affect on the results. A higher peak velocity is observed from the standard cylinder test. The most likely reason for the higher velocity is that the thinner copper wall will break up earlier than the thicker standard cylinder test wall allowing the pressure to escape from the cylinder earlier than the standard cylinder test. The release of the pressure at an earlier point means that the copper is being driven harder for longer in the standard cylinder test.

Figure 11 Comparison of mini cylinder test with standard cylinder test radial velocities[6].




## Velocity of detonation

The results from the V.o.D. probes were not completely accurate but the method for obtaining the V.o.D. used on these tests is sound and with some refinement in the method in future tests better data will be recorded.

## Considerations for future work

The tests carried out for this paper are a good start for the 'A Cost Effective Method for Preliminary Explosive Characterisation'. The methods used in the tests are sound but could be improved on in the following ways:

- The method used for measuring the velocity of detonation of the explosive material needs to be improved upon.

- The explosive rig needs to be reengineered to aid in the positioning and alignment of the HetV diagnostic, a lot of time was spent carrying out this operation and at times still provided less than perfect results.

## Conclusions

This work has shown:

- That scaling down or miniaturising the cylinder test can be used as a 'A Cost Effective Method for Preliminary Explosive Characterisation'. The data produced has proved to be repeatable and in good agreement with the results seen on standard cylinder tests. Although the results are not 100% accurate the mini cylinder test could be used as a screening test as a comparison to previous data recorded for previous batches of the same explosive material or to directly compare with other explosive materials.
- The effects of a gap and of lower densities were studied and compared with data for no gap at a maximum velocity. It was found that for the differences in density that the explosive material was pressed to be negligible meaning that the method of pressing can be relaxed reducing the costs. The gap produced interesting data that warrants more research to be carried out, the increased ringing of the cylinder during expansion and the higher velocity are two effects of note.
- The loss of control over some of the test components lead to some inaccuracies in the results. These included the material choice of the flyer shim.

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# Award Winner

## Category: Non Members of IExpE

# D10 dozer recovered from a high wall using blasting

By **Tristan Worsey** BSc MSc MISEE, Newmont Mining Corporation, Nevada, USA


## Abstract

*A dozer operator at a surface gold mine accidentally drove a D10 off the side of a high wall. The blade of the dozer caught on the lip of a catch bench 18.3 m (60 ft), down, stopping its descent. The operator scrambled to safety in fear that the dozer would not hold. Engineering and management looked at multiple dozer recovery options, with safety the overriding consideration. The initial plan was to rent a crane to lift the dozer out. However, Caterpillar would not sanction tying off on the tool bar. This meant that personnel would have to remove the tool bar on the high wall, which was deemed unsafe. For work to be done at the dozer level an access bench was necessary. Mechanical excavation was initially attempted, but only had success several feet down before the rock was no longer digable. The only option other than abandoning the dozer was blasting the access bench down to the elevation of the dozer blade.*

*The drill and blast team had discussed blasting solutions and came up with a sound approach that was presented when mechanical excavation failed. Normal mine production blasts use 200 mm (7 7/8th in.) holes drilled 7.0 m (23 ft) and loaded with 2.1 m (7 ft) of powder, with 30 to 40% hole utilization and a PF of 0.2 Kg/tonne (0.4 lbs\ton). Down the hole detcord and surface delays are used and blasts can be violent. The problem was three fold: damaging the dozer with flying rock, knocking the dozer down the high wall, and vibrations causing cascading material to bury and damage the dozer. Fortunately the ground was mostly waste rock, which meant there were few constraints on blasting. The plan involved increasing both powder factor and hole utilization to send more of the energy into breaking the rock and casting it away from the dozer whilst eliminating flyrock and minimizing ground vibrations. Blasts as near as 24 m (80 ft) away from the dozer were designed using one of the highest powder factors ever used at the mine of 0.4 kg/tonne (0.8lbs/ton) or 0.9 kg/m3 (1.6lbs/yd3) and a 63% hole utilization using the timing precision of electronic detonators with the process, philosophy and designs described in detail in the paper. The process was documented using video, seismograph and laser profiling movement monitoring.*

*The D10 dozer was successfully extracted with none of the windows damaged and no damage from the blasting. It was back in operation at the mine after a thorough inspection and maintenance.*


Figure 1. The day after the dozer drove off the high wall.

## Introduction

A dozer operator during night shift drove a D10 dozer up a berm and off the edge of the high wall. The dozer fell down the high wall 18.3 m (60 ft) before the front blade dug into a catch bench. The dozer operator high tailed it out of the dozer and climbed to safety after the dozer came to a stop on the catch bench. The high wall the dozer drove off was at a 65 degree angle but the dozer sat on the catch bench at a 40 degree angle. Figure 1 shows a photograph of the dozer caught on the catch bench.

At first hooking onto the dozer's tool bar and dragging it out was suggested, but this was deemed unsafe and damaging to the dozer. Bringing in a crane to lift the dozer was also suggested but in order to access a sufficient tie off point the tool bar would have to be removed. It was deemed unsafe for personnel to do any work on the dozer in the middle of the high wall. The decision was made to excavate down to the bench elevation in order for personnel to be able to work on the dozer from the safety of bench elevation.

At first they tried to free dig the material but it soon turned too hard to dig. The blast tech team knew that blasting would be an option if we changed our normal blast design. When excavation was no longer possible the idea of specialized blasting was casted out and management took the bait.

## Methodology

The whole idea of the design was to put as much of the explosive energy into breaking and casting the rock as possible to reduce the amount of vibrations escaping the blast pattern. Explosive energy likes to take the path of least resistant. The less contained a blast is the more energy goes into breaking and casting the rock in the direction of the free face than goes into the material behind the blast. The bigger the bench height to burden ratio is the more tensile stress is exerted onto the rock. Rock tends to break best under tensile stress. This is like trying to break a tall skinny pencil in half and a short fat pencil in half. The tall skinny pencil is a lot easier to break. The plan was to increase the powder factor by decreasing burden and spacing and increasing face height. This in theory would increase movement of the material, increase fragmentation, and decrease ground vibrations.

## Design

The bench elevation that the dozer drove off was on the 1750 m (5740 ft) elevation. The front dozer blade caught on the 1731 m (5680 ft) catch bench below. This meant the blast would have to fragment 18.3 m (60 ft) of material to be excavated to create a pad to work on the dozer. Two types of blasting were designed for creating the pad, one being for the initial drop and the other for removing the material closest to the dozer.

Since we had to drop down 18.3 m (60 ft), the drop cut was made by shooting two levels. The first level was drilled to 1736 m (5697 ft) and the second was drilled to the 1730 m (5677 ft). This was because we used normal production design for the drop because it was far enough away to not be as concerned with moving or hurting the dozer. This helped out the speed of the mining cycle.

Signature hole analysis was done on a 12.2 m (40 ft) bench using normal production practice of down hole cord and on a 18.3 m (60 ft) bench using a down hole electronic detonator. An explosives supplier was used to analyze the signature hole data and they came up with 33 ms hole to hole and 62 ms row to row for the 12.2 m (40 ft) bench and 25 ms hole to hole and 53 ms row to row for the 18.3 m (60 ft) bench. These situations simulated well at 30.5 m (100 ft) and 61.0 m (200 ft) locations from the blast hole.

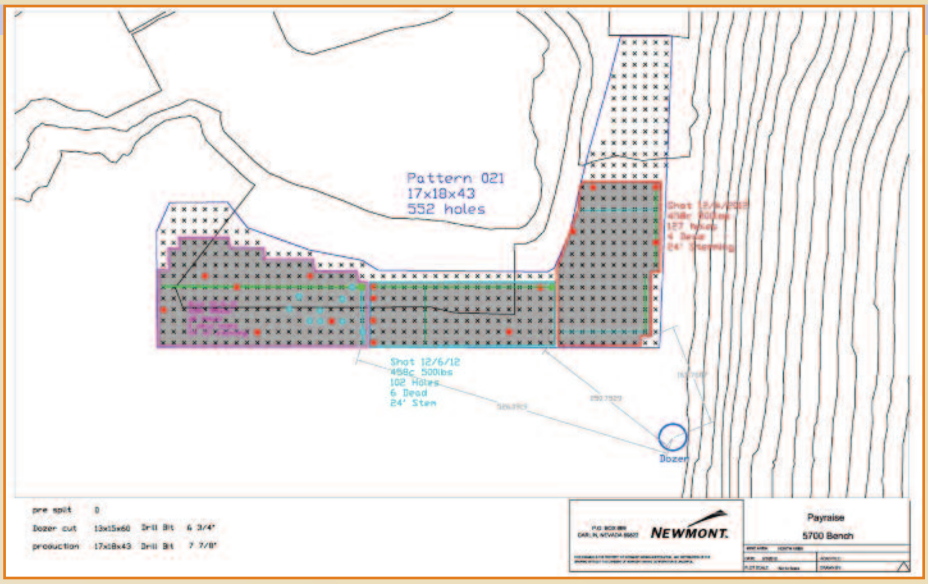


Figure 2. 5700 bench shot map.

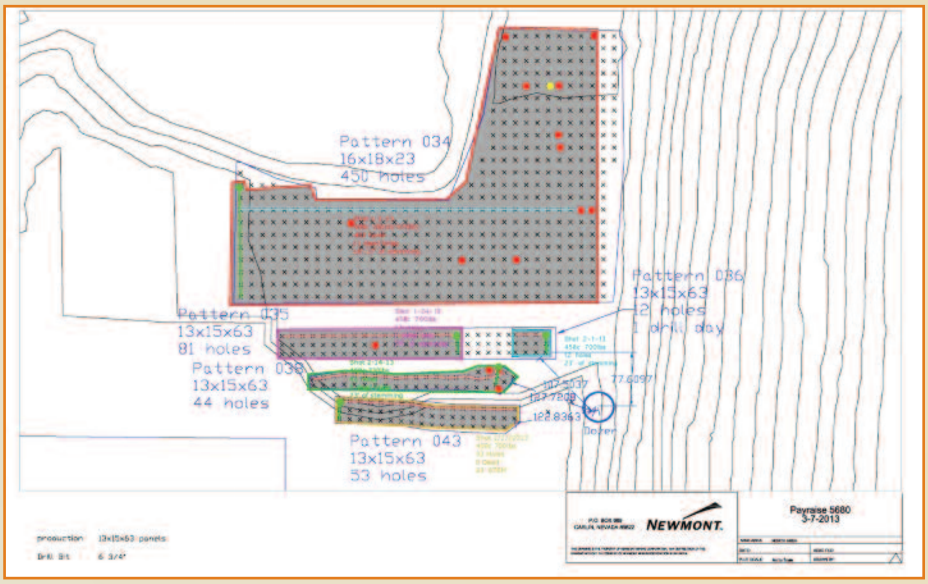


Figure 3. 5680 shot map.

Normal production patterns used at the mine site are 4.9 x 5.5 x 7.0 m (16 x 18 x 23 ft) (Burden x Spacing x Depth) in ore and 5.5 x 5.5 x 13.4 m (18 x 18 x 44 ft) in overburden. The average powder factor on site is around 0.2 kg of explosives per tonne of material (0.4 lbs/ton). The decision was made to double the powder factor to 0.4 kg/tonne (0.8 lbs/ton) for the special panel shots by decreasing the burden and spacing to 4 x 4.6 m (13 x 15 ft) and increasing depth to 19.2 m (63 ft). The weight of explosives was limited in the 19.2 m (63 ft) face by using a 171 mm (6.75 in.) hole instead of normal 200 mm (7.875 in.) hole. A buffered blend with a density of 1.15 g/cc was used due to reactive ground potential. Unfortunately getting nice crushed stone wasn't an option for stemming so drill cuttings were used for stemming the holes. The quality of the drill cuttings for stemming was decent due to

Table 1. Pattern designs.

| Shot type | Burden (ft) | spacing (ft) | hole depth (ft) | Hole diameter (in) | bench height (ft) | PF lbs/ton (ft) | PF lbs/cyd | Stemming | lbs/hole | Blend (% emulsion) |
|---|---|---|---|---|---|---|---|---|---|---|
| 40 ft drop | 17 | 18 | 43 | 7.875 | 40 | 0.54 | 1.10 | 24 | 500 | 15 |
| 20 ft drop | 16 | 18 | 23 | 7.875 | 20 | 0.34 | 0.84 | 16 | 180 | 15 |
| 60 ft panel | 13 | 15 | 63 | 6.75 | 60 | 0.8 | 1.62 | 23 | 700 | 15 |
| Metric | (m) | (m) | (m) | (mm) | (m) | Kg/tonne | Kg/m^3 | (m) | Kg/hole | % |
| 40 ft drop | 5.2 | 5.5 | 13.1 | 200 | 12.2 | 0.27 | 0.61 | 7.3 | 227 | 15 |
| 20 ft drop | 4.9 | 5.5 | 7.0 | 200 | 6 | 0.17 | 0.43 | 4.9 | 82 | 15 |
| 60 ft panel | 4 | 4.6 | 19.2 | 171 | 18.3 | 0.4 | 0.90 | 7.0 | 318 | 15 |

the damp conditions of winter and stemming ejection was minimal.

The panel shots were limited to three rows to minimize constipation of the shot. After three rows, relief caused by the row timing and material moving, starts to decrease. This causes an increase in vibrations going back into the wall. The pattern designs of the drop cuts and panel shots are shown in Table 1. Figures 2 and 3 show a plane view of the pattern designs.

## Results

Unfortunately there are no regulations on the maximum vibrations for a D10 dozer sitting on the edge of a high wall. The engineers had no starting place besides trial and error. Since the material with the dozer didn't fail due to weather conditions changing, it was assumed that the dozer could take quite a bit more than the regulation for structures of 50.8 mm/s (2 in/s). Table 2 shows the distances away from the blast of the seismographs and seismograph data. Notice that the last three blasts had significantly more ground vibrations. This was due to the proximity of the blasts. From data collected vs. what was estimated, vibrations near the dozer were significantly reduced by using signature hole data and increasing powder factor by decreasing burden and spacing and increasing hole length. Now in a perfect world the hole diameter would have been drastically reduced. This would have decreased weight per hole to be less than production and still doubled the powder factor. With this operation going lower than 171 mm (6.75 in.) diameter this was not an option.

The first blast went well. Laser profile scans were taken before and after the blast and showed minimal movement. Figure 4 shows a picture of the blast. Notice the dozer in the lower right hand corner. The dozer was 50.6 m (166 ft) away from the blast. We did not decide to bring the next pattern back from the crest edge because the scans didn't show any movement in the material between the dozer and the blast. The blast had 127, 13.1 m (43 ft) holes, and 227 kg (500 lbs) of explosives per hole. The seismograph reading next to the dozer had a peak reading of 53.848 mm/s (2.120 in/s) at 26.9 Hz with the lowest frequency of 21.3 Hz at 46.736 mm/s (1.840 in/s). It was noted that normal blasting practices did send quite a bit of material down the high wall. If this design was shot by the dozer it would have covered the dozer with material and potentially dislodged the dozer. See Figure 2 for the location of the blast on 4-12-2012. It is the blast bordered in red.

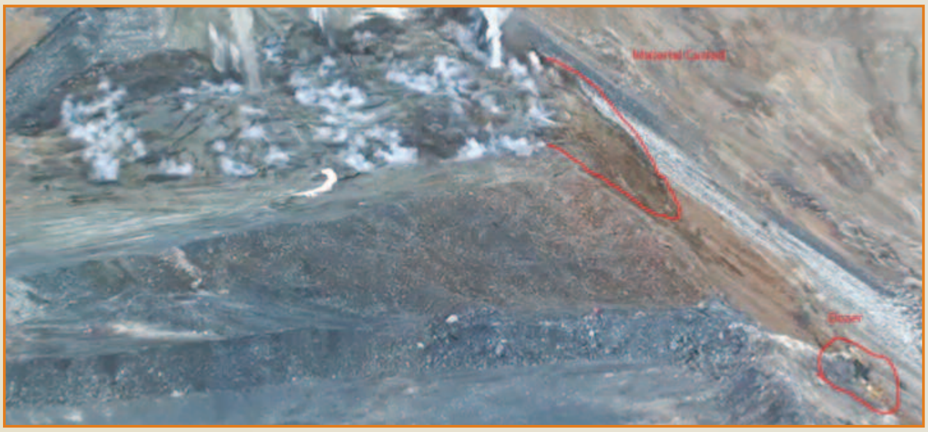

Figure 4. First dozer shot.

Figure 5. Second dozer shot.

Figure 6. Third dozer shot.

The next two blasts were on the same bench as the first with the same design and timing. These blasts are outlined in pink (5-12-2013) and teal (6-12-2012) in Figure 2. The second shot had 161 holes (8 dead) and was 161 m (529 ft) away from the dozer. This shot had a peak particle velocity of 5.334 mm/s (0.210 in/s) at 9.3 Hz with the lowest frequency being 8.9 Hz at 4.572 mm/s (0.180 in/s). Little to no movement was reported from the scans for the material around the dozer and the dozer itself. In Figure 5 the blast shows a little stemming ejection. This is very common when using detcord down the hole as an initiator. The stemming ejection causes quite a bit of fly material that is unwanted once we get closer to the dozer. The third shot had 102 holes (6 dead) and was 77m (251 ft) away from the dozer. This shot had a PPV of 34.544 mm/s (1.360 in/s) at 17.0 Hz with the lowest frequency being 10.2 Hz at 34.544 mm/s (1.360 in/s). The scans reported little to no movement of the dozer from before the blast. In Figure 6 the blast shows a little more violent stemming ejection.

Table 2. Seismograph distance from blast and data.

| Blast | Seis distance(ft) | Seis distance(m) | PPV (ips) | PPV (mm/s) | Frequency (Hz) | Calculated PPV (ips) (k factor of 1140) | Calculated PPV (mm/s) |
|---|---|---|---|---|---|---|---|
| 1st (12-4-12) | 157 | 48 | 2.12 | 53.85 | 26.9 | 47.23 | 1199.64 |
| 2nd(12-5-12) | 493 | 150 | 0.21 | 5.33 | 9.3 | 7.57 | 192.28 |
| 3rd(12-6-12) | 220 | 67 | 1.36 | 35.54 | 17 | 27.53 | 699.26 |
| 4th(1-2-13) | 153 | 47 | 1.52 | 38.61 | 22.2 | 22.14 | 562.36 |
| 5th(1-24-13) | 170 | 52 | 1.88 | 47.75 | 13.4 | 58.95 | 1483.23 |
| 6th(2-1-13) | 72 | 22 | ips>5 | mm/s>127 | N/A | 233.05 | 5919.47 |
| 7th(2-14-13) | 92 | 28 | N/A | N/A | N/A | 157.44 | 3998.98 |
| 8th(2-27-13) | 84 | 26 | 8.8 | 223.52 | 28.4 | 182.11 | 4625.59 |

Figure 7. Fourth dozer shot.

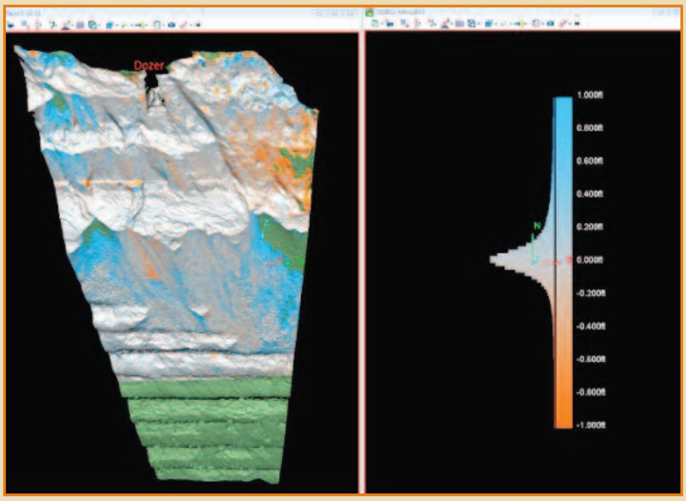


Figure 8. Before and after scan of the first panel shot.

Blast number four next to the dozer was a 6m (20ft) drop pattern to get the 1737 m (5700 ft) down to the 1731 m (5680 ft) elevation to fully free face the panel shot. Since this shot had less than half the explosives per hole than the 12 m (40 ft) drop it was decided to shoot all 402 holes (11 dead) in one shot. This is the blast shot on 2-1-13 outlined in red in Figure 3. The closest hole to the dozer was 48 m (158 ft) and gave a seismic reading of 38.608 mm/s (1.520 in/s) max at 22.2 Hz and the lowest frequency 13.0 Hz at 32.512 mm/s (1.280 in/s). The dozer scans did not show any significant movement near or around the dozer. This blast (2-1-13) is outlined in red in Figure 3. This blast had less ground vibrations than the first shot that was similar in distance but this shot had less than half the kgs per delay. This blast had a lot of stemming ejection and was also quite violent as can be seen in Figure 7. Quite a bit of material was cascaded down the side of the high wall and there was some fly material that could have hit the dozer if it had been closer. There was a little bit of snow that fell down the high wall in front of the dozer but no actual material fell.

Shot number five next to the dozer was the first panel shot. There was a failure in the wall that split the pattern up into two shots. In Figure 3 there is a gap in-between the pink and teal shots that was the area that failed. The pink pattern (24-1-13) was the panel shot we shot first. The blast had 53, 19 m (63 ft) holes, and 318 kg (700 lbs) of explosives per hole. The closest hole to the dozer was 67 m (219 ft). This shot gave a PPV of 47.752 mm/s (1.880 in/s) at 13.4 Hz, which was the lowest frequency. The before and after dozer scans came back negative for significant movement. Figure 8 shows a picture of what the before and after scans looked like. All of the scans looked very similar except for one so only two scans will be shown in the paper. In the scan anything that is in blue is up to 0.3 m (1 ft) of material gain, grey is zero movement, and orange is up to 0.3 m (1 ft) of lost material. The green color means it went out of the range of -0.3 m (-1 ft) to 0.3 m (1 ft). The scan shows that the material near the dozer was basically unaffected. The material that is right next to the free face shows a little bit of loss but it was right in front of the blast and it was expected to see a little bit of movement in front of the blast. One thing to note from this scan is that the material next to where the blast was located is unaffected. This means that this is a safe distance (43m/140 ft) from the high wall to put the blast once we get to patterns directly behind the dozer. Figure 9 shows a photograph of the blast. This blast had the least amount of fly material and only one stemming ejection that was from a hole plugging during stemming.

Shot number six was the second panel shot next to the dozer. The blast had 12, 19 m (63 ft) holes (0 dead), and 318 kg (700 lbs) of explosives per hole. The teal pattern (1-2-13) in Figure 3 shows shot number six. This pattern was only 33 m (108 ft) away from the dozer and had more burden than designed due to the failure. This pattern also had some short holes in the middle of the pattern. This shot gave a PPV greater than 127 mm/s (5 in/s). Unfortunately the seismograph was set to a max of 127 mm/s (5 in/s) so data was not received. The scan showed little to no movement on and around the dozer. This was a good sign that the dozer was pretty well set in the catch

Figure 10. Dozer scan of the sixth shot.

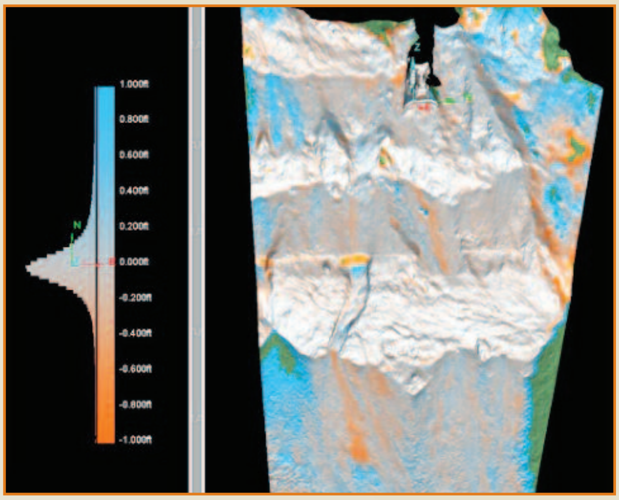


Figure 9. Fifth dozer shot.

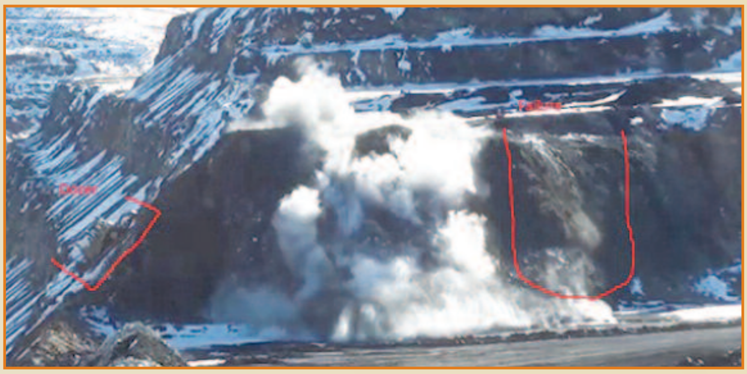
Figure 11. Sixth dozer shot.


Figure 12. Eighth dozer shot.

bench and as long as the material in the catch bench didn't get casted the dozer would be fine. One thing from this blast that was noticed was the material in-between the dozer and the blast did show a little bit of movement, as seen in Figure 10 below. It was then decided to pull the rest of the panels 15 m (50 ft) back. Figure 11 shows a photo of the shot. This shot had no fly material and no stemming ejection.

Shots 7 (14-2-13) and 8 (27-2-13) were similar in design to the first panel shot and can be seen in Figure 3 in green and yellow respectively. Shot 7 was 39 m (128 ft) away from the dozer. This blast was done while the blasting engineers were at the 2012 ISEE conference and the seismograph monitors were improperly set up and a valid reading was not obtained. The video was also missed, but the before and after dozer scans showed little to no movement of the dozer and the surrounding material. This shot was slightly north behind the dozer. Shot 8 was the last dozer shot needed for equipment space to retrieve the dozer and was slightly south behind the dozer. This shot had 53, 19 m (63 ft) holes (0 dead), and 318 kg (700 lbs) of explosives. This shot gave a PPV of 223.52 mm/s (8.80 in/s) at 28.4 Hz with the lowest frequency of 4.7 Hz at 152.4 mm/s (6.00 in/s). The scans showed little to no movement of the dozer or the material around it. Figure12 shows a photograph of the eighth dozer blast. This shot had some stemming ejection that was caused by using drill cuttings and holes plugging.

After the eighth shot the bench was down to the dozer blade elevation and there was enough room for equipment to operate. The 15 m (50 ft) buffer zone ended up being easy to dig. This was due to the shock wave from the blast creating micro fractures in the rock. This was expected, but wasn't expected to work as well as it did. Figure 13 shows the dozer after final excavation of the buffer zone. The removal of the dozer was done by strapping onto the tool bar with the shovel and digging the material out from under it with a backhoe then dragging it to more stable ground. The dozer had no blast damage and all of the glass was intact. Once the fluids were changed this dozer was out in the pit again working.

## Conclusion

The dozer rescue using blasting to excavate the bench to the level of the dozer was a success. Although vibrations were significantly more at the dozer with the panel shots than the drop cuts, using regular production blasting design would have caused even more vibrations in the same location and would have cast material onto the dozer and disturbed the catch bench material that the dozer was sitting on, resulting in dozer loss. Using the technique of increasing the powder factor by decreasing burden and spacing and increasing face height, while casting the rock away from the dozer, did significantly reduce the impact of blasting near the dozer.

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Figure 13. Dozer after final excavation.

# A history of explosives:

## as they relate to the UK

By **Ian McKay** CEng MPhil BSc Dip H&S FIMM FIExpE

*Berthold Schwartz.*

**1 ©**
Gunpowder appears to have been discovered by the Chinese during the first century AD.

**668**
"Greek fire" - a form of napalm? - used in battle.

**13 ©**
Gunpowder introduced into Europe by Berthold Schwartz.

**1242**
Roger Bacon knows a formulation for gunpowder and conceals it in cypher to protect it.

**1346**
Cannon used at Battle of Crecy.

*Roger Bacon.*

*W G Armstrong.*

*Ascanio Sobrero.*

**1846**
First synthesis of nitroglycerine by Ascanio Sobrero in a laboratory in Turin.

**1859**
W G Armstrong perfects the world's first successful breech-loading system of field artillery that fired elongated, fused projectiles through a polygroove rifled steel barrel.

**1860**
Gunpowder and Fireworks Act covers making and keeping.

**1861**
Gunpowder and Fireworks (Amendment) Act covers carriage.

**1865**
Nobel devises the first reliable detonator.

**1865**
January 21st - first use of explosives in oil well shooting by Roberts in Pennsylvania.

**1866**
First oil well perforating charge, a "torpedo" used in USA.

**1867**
Dynamite invented by Nobel. Produced in UK at Ardeer from 1871.

**1867**
Ammonium nitrate added to dynamite by Swedish chemists Ohlsson and Norrbein.

**1860s**
A series of serious explosions, killing many, mainly in the Midlands munitions trade, raise public concerns about the explosives industry in UK.

*Vivian Dering Majendie.*

**1869**
Nitroglyerine Act covers importation.

**1874**
Vivian Dering Majendie, a Major in the Royal Artillery, commissioned to make investigations and to write a Report to the Secretary of State which addressed the Necessity for the Amendment of the Law relating to Gunpowder and other Explosives with suggestions for a new Act.

**1875**
The Explosives Act passed . This Act was modelled by Crown colonies and dependencies around the globe. It covered manufacturing, keeping, selling, carrying and importing Gunpowder, Nitro-Glycerine, and other explosive substances but not use. It came into force on 1 January 1876. Majendie is appointed the first HM Inspector, later Chief Inspector, of Explosives.

**1878**
Alexander Redgrave appointed as first HM Chief Inspector of Factories.

*Alexander Redgrave.*

**1888**
The first testing gallery in the UK for explosive testing for safety in flammable atmospheres in coal mines constructed at Hebburn by the North of England Institute of Mining and Mechanical Engineers and used 1888 - 1896. Explosives safety in flammable atmospheres achieved.

**1951**
Fireworks Act comes into force. This is an Act to confer powers of seizure where dangerous fireworks are found, and powers to determine or amend licences or certificates for explosives factories where fireworks are made.

**1956**
First version of the UN "Orange Book" - the Recommendations on the Transport of Dangerous Goods. This sets up the system for codifying dangerous goods and is the cornerstone of much succeding explosives and hazardous materials legislation.

**1972**
European Communities Act.

**1972**
Lord Robens delivers his report to Parliament in July. This Report was demanded as it was found that about 1000 persons died each year and half a million were hurt at work in the UK, with 23 milion working days lost annually. It says that "there is too much law .... it is badly structured....". (and) unintelligible." the existing legislation was "haphazard" and "a mass of intricate detail". A radical overhaul is proposed. There was to be a consolidated Act covering health and safety.

**1974**
Institute of Explosives Engineers holds its inaugural meeting in Birmingham on 22 May at which fifty persons attend and formally establish the Institute.

**1974**
Health and Safety at Work etc. Act drafted and enacted. The Explosives Inspectorate, long part of the Home Office is transferred to become part of newly formed Health and Safety Executive and ceases formally to exist as a separate entity after 31 December 1974.


*Example of a Hazard diamond.*

**1970s**
ANFO, slurries and emulsion explosives developed.. These can be made to be non self-sensitised and not cap sensitive. Along with a range of improvements in detonator design and with the introduction of advanced and reliable initation methods by shock tube, these represent a significant potential increase in safety in transport, handling and use.

**1975**
Health and Safety Executive formally established.

**1985**
The Royal Ordnance factories in the UK are sold off to become Royal Ordnance plc on January 2, ending the State control of munitions of war which was begun in 1640.

**1986**
Single European Act amends Treaty of Rome. The Community now empowered to set minimum standards for health and safety of workers. Numbers of Directives ensue, dealing with lifting, work equipment, manual handling, display screens, etc.

**1986**
NCVQ (National Council for Vocational Qualifications) first introduced NVQs, some of which apply to the explosives sector.

*Guy Fawkes.*

**1415** Battle of Agincourt on 25 October. This is a major victory against the French in the Hundred Years War. Following this, Henry V established the Board of Ordnance to supply guns and ammunition to the Navy. In the fullness of time the Ordnance Board would become the Defence Ordnance Safety Group.

**1605** Guy Fawkes (1570 - 1606) intends to use about 36 barrels of gunpowder to blow up the House of Parliament in London on 5 November. Betrayed, the attempt fails and Fawkes and others are tortured and executed.

**1630 and onwards** Gunpowder recorded as being used in, respectively, the Endon copper mines in Staffordshire (1630), in the Mendips (1683)and in Cornwall (1689).

**1640** Gunpowder production begins at Waltham Abbey.

**1641** The first UK staute relating to explosives is passed on 3 August. This is An Act for the free bringing in of Gunpowder and Salt-petre from Foreign Parts, and for the free making of Gunpowder in this Realm.

**1772** The Gunpowder Act bans edge runner mills. This is the first statute aimed at controlling conditions in explosives manufacture.

**1800** Fulminates discovered.

**1802** The Health and Morals of Apprentices Act is the first statute aimed specifically at control of working conditions. It becomes law on 22 June.

**1804** The first fatality in coal mining known to be due to shotfiring fumes, recorded by Desgrange.

**1807** Fulminate of mercury used in the first percussion cap for use by the armed forces.

**1831** Bickford develops a safety fuse.

**1833** Enacted, "An Act to Regulate the Labour of Children and Young Persons in Mills and Factories of the United Kingdom" – the first of a series of Factory Acts. Fundamentally and crucially, this is the first Act under which the appointment of Inspectors of Factories could be made in order that the provisions of the Act could be enforced.

**1833** Alfred Nobel born 23 October.

**1845** Nitrocellulose discovered and developed as an explosive.

*Coal mines explosives test gallery.*

*Alfred Nobel.*

*William Bickford.*

**1896** Alfred Nobel died 10th December.

**1898** Sir Vivian Majendie dies 24 April.

**1911** The Coal Mines Act uses the phrases "so far as possible" and "so far as practicable" in relation to safety provisions.

**1914 to 1918** World War I. The failure of the Battle of Aubers Ridge on May 9, 1915 was attributed by Sir John French the British C-in-C, to a lack of shells. This was "The Shell Scandal," reported by the Times, as "The want of an unlimited supply of high explosives was a fatal bar to our success". Shortage of cordite, made from acetone, most of which came from abroad, was now acute. Schoolchildren exhorted to collect horse chestnuts to be used by War Office to ferment into acetone. "Every chestnut is of use to the country". In 1917 there were produced 183,000 tonnes of shells in the UK. By the end of the war, the British army alone had fired 170 million shells, most of which hit France or Belgium.

**1930s** Reliable delay detonators developed, primarily in Germany and UK.

*WW I.*

**1935** Massive explosion of ammonium nitrate and other ammonium salts takes place on 21 October in Oppau, Germany. Something approaching 5000 tonnes of material explodes, killing over 500 persons. Workmen were using dynamite to loosen the material which had caked in a silo.

*One of the first 10 ton bombs, photographed in 2009.*

**1937** O in C No. 30 to the 1875 Act Classes Acetylene as an explosive and prohibits it under certain conditions.

*Oppau.*

**1939 to 1945** World War II. Many explosives devices developed and improved - typical of wartime. The Munroe effect (first described in 1792) used in the Bazooka and, later, in countless oil well perforating charges. By 1943/1944, the peak annual UK output had reached 20,023 naval guns, 10.2 million rounds of large diameter ammunition, 233,206 mines and depth-charges, 7039 torpedoes, 3,046,000,000 rounds of small diameter ammunition, and 21,584,000 grenades in addition to 300 thousand tons of explosives. About 5 million persons, over 16 % of the workforce, were employed in production of munitions of war.

**1945** United Nations organisation founded after World War II to replace the rather discredited League of Nations. Its stated aims were to stop wars between countries, and to provide a platform for dialogue. It contains multiple subsidiary organisations to carry out its missions. There are 193 Member States including every internationally recognised sovereign state in the world excepting the Vatican City.

*UN logo.*

**1992** Management of Health and Safety at Work Regulations incorporate the provisions of the framework Directive 89/391, when required employers to control risk, into UK law.

**1994** Heather Slater of HSE Buxton Laboratories (later HSL) becomes the 1000th Member of the Institute when she joins on 16 November.

**2000** The Standards Setting Body (SSB) for Explosives, Munitions and Search Occupations was established to develop National Occupational Standards and National Vocational Qualifications for those involved in munitions clearance and search activities.

**2005** Many of the remaining requirements of the 1875 Explosives Act are swept away by the Manufacture and Storage of Explosives Regulations (MSER).

**2008** The Institute is formally recognised as a Professional Affiliate of the Engineering Council on 24 July.

**2011** Allan Hinton appointed as the Development Office for Explosives Skills Programme (DOES) Manager with the responsibilities to support the Sector Skills Strategy Group (SSSG) in sustaining UK skills in Explosives Substances and Articles (ESA).

**2012** The Institute ceases to be a trading association and is registered as a Limited Company. The Certificate of Incorporation is dated 11 January.

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# Effect of end shape on blast from cylindrical charges

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Project Supervisors: Dr N. Davies, Dr C. Knock, Cranfield University

## Introduction

The concept of "TNT Equivalence" is used extensively throughout the explosives industry to compare the specific output characteristics of an energetic material to that of TNT. It is a fundamental parameter used in evaluating the damaging effect of a particular charge on buildings, structures and personnel and forms the basis for several government regulatory criteria including the storage and transportation of explosives.

However, the data used in the determination of TNT Equivalence is based mainly on experimental results from detonation of spherical charges, despite that most military charges are more nearly cylindrical. A number of studies have shown that the near-field blast effects from plane-ended cylindrical charges[1] exhibit quite different characteristics from those of spherical charges of similar mass [4; 6; 7; 8; 9; 11; 14]. Free-air detonation of cylindrical charges results in a complex blast field comprising of primary, secondary and bridge shock waves [5] which is "obviously far from spherical" [10]. A number of fundamental studies have investigated the blast field generated from the detonation of plane-ended cylindrical high explosive charges [3; 6; 10; 12; 14; 15]. These have illustrated that Mach interaction of the blast waves produced from the sides and ends of the charge produces bridge waves off the corners, and that secondary or reflected waves are generated from the ends of the bridge wave due to reflection of the primary waves (see Figure 1). This results in a multiple shock phenomenon which is evident in blast gauge histories in the near field (see Figure 2).

As the blast wave propagates away from the charge, the reflected waves tend to overtake the primary and bridge waves such that, after some distance, the blast wave resembles that produced by a spherical charge and is said to be 'healed'. This is because the velocity of the shock wave is related to the local ambient temperature, pressure and density of the medium. Hence, the reflected waves travel more quickly through the pre-shocked air.

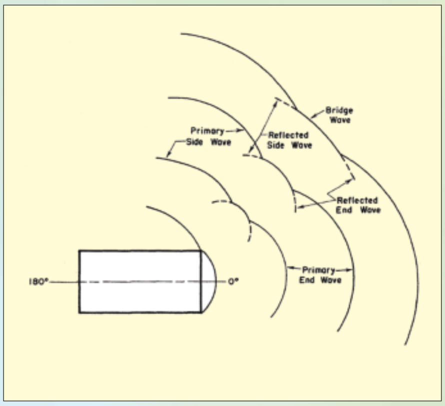



Figure 1: Schematic of the Blast Field around a Cylindrical Charge [14].

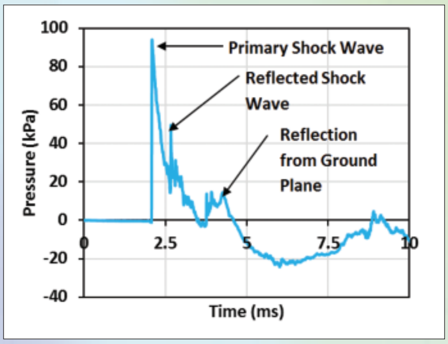



Figure 2: Near Field P-T Gauge History from a Cylindrical Charge.

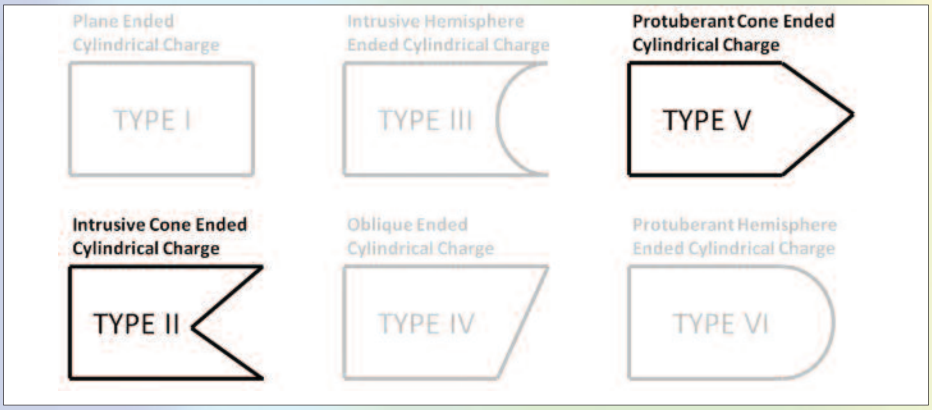
A variety of factors may necessitate that the end geometry of an explosive charge deviates from that of a simple plane ended cylinder. The incorporation of a cavity in the end of an explosive charge (hollow charge) in order to increase axial blast effectiveness was noted as early as 1792 [13]. Later studies, documented by Bawn [2], used Schlieren imagery to examine the shock wave system around cylindrical charges with varying end geometries, confirming that "minor changes in the shape of the end have a seemingly disproportionate effect on the properties of the end effect". Research by Wisotski and Snyer [14] examined blast from plane and hemispherical ended charges, also concluding that "it is interesting to note how unquestionably the slope of the pressure-distance curve changes with only minor changes to the end contour of the cylinder".

Still, despite these early findings and the potential significance to current quantity-distance based safety standards and low collateral warhead development, little recent research has been directed specifically at comparatively assessing the effect of changes in end geometry of cylindrical charges on the resulting blast field generated.

## Scope

A programme of work was undertaken to investigate the near-field blast effects produced from detonation of six cylindrical 400g PE4 charges of Length/Diameter (L/D)≈2 with varying end profiles (see Figure 3). A combination of hydrocode modelling and experimental firings were conducted to provide Pressure-Time data at distances of 1m to 3m from the end of the charge and at angles varying from 0° to 90° from the central axis. In addition, High Speed Video (HSV) of experimental firings was employed to augment modelling results and enable visualisation of the shock wave system produced.

Figure 3. Cylindrical Charge Geometries.



Only the findings from the Intrusive and Protuberant Cone Ended charges (Type II and Type V) are discussed here.

## Experimental

A series of experiments were conducted to investigate the blast field produced from a total of 18 charges with 6 different end geometries. Trials were conducted at the Explosive Research and Demonstration Area (ERDA) of the Defence College of Management and Technology (DCMT), Shrivenham, UK, December 2011.

### Charge design

Geometry for the explosive charges was determined using Computer-Aided-Design software based on a target charge mass of 400g and L/D of 2. The charges were prepared by hand pressing of PE4, using a purpose designed moulding system, into a light cardboard tube casing with a 3mm SX2 booster. An L2 Electrical Detonator was inserted into the end of the charge and located centrally by a low density pinewood Detonator Support. Figure 4 illustrates a cross-section of a fully assembled charge.

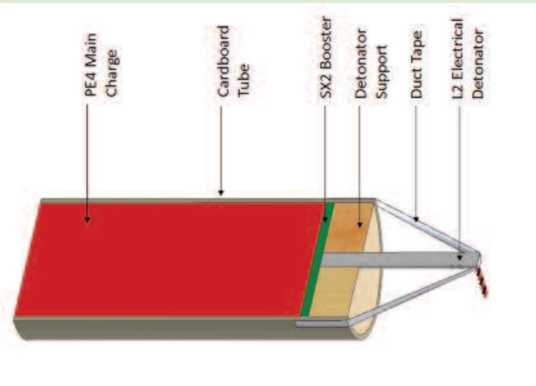



Figure 4. Cross-Section of a Fully Assembled Charge.

### Experimental setup

To capture the near field blast waves generated, an array of blast gauges were positioned around the charge. HSV (High Speed Video)was also used to provide a visual indication of the shape of the blast field. Figure 5 shows the general arrangement of the HSV, blast gauges and charge at the ERDA range.

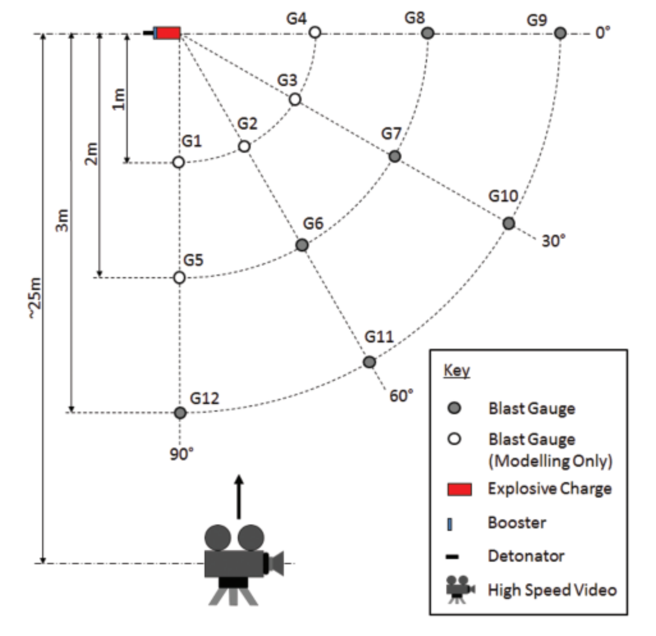



Figure 5. ERDA General arrangement of HSV, blast gauges and explosive charge.

Each charge was mounted on a steel post with an ionisation probe attached to the charge casing to provide a trigger pulse for the data acquisition systems (see Figure 6). Blast gauges were mounted within circular baffle plates to ensure that only the side-on pressure component of the blast wave was measured. Each gauge/baffle assembly was

Figure 6. Mounted explosive charge and blast gauges.

mounted atop a steel post, at a height of 2m from the ground to prevent interference from reflected waves.

## Computer modelling

Hydrocode modelling of each charge type was conducted using ANSYS Autodyn. For comparison purposes, further modelling was later conducted by MSC Software using MSC Dytran and found to correlate well with the Autodyn results.

Where possible, models were simplified using 2D axial symmetry. An Euler solver was used to model the explosive charge and surrounding air medium. The main charge explosive was represented by C4, but the detonator and booster charges were not modelled. The Euler domain was graded to give a cell size of 1mm in proximity to the charge, increasing to 3.5mm at the extremities. Flow-out boundary conditions were applied to all off-axis edges of the Euler domain and a gauge array, similar to that used in the experimental firings, was added around the charge including five additional gauges (see Figure 5). All simulations were solved to a time of 10ms.

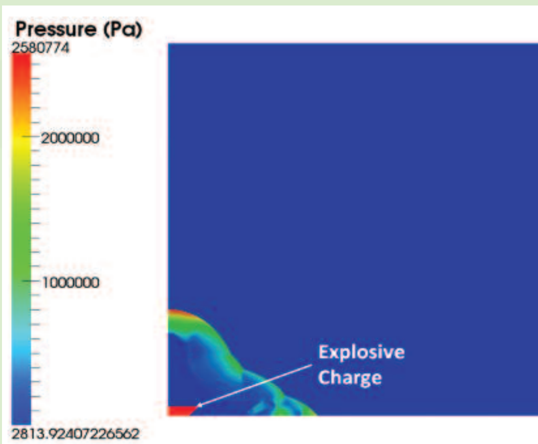
## Results

Experimental and modelling P-T gauge history data was collated and plotted. A preliminary analysis was conducted to determine the key characteristics of the blast wave recorded at each gauge, namely Time of Arrival, Peak Overpressure and Positive Impulse. Positive Impulse was calculated by integration of the pressure trace, from the arrival of the shock front to the time at which the curve crossed the x-axis.

HSV from the trial was found to be unreliable. Problems with triggering of the camera prevented capture of the initial firings and later efforts were hampered by inclement weather. Overall the quality of the HSV data that was gathered was poor, predominately due to difficulties associated with providing sufficient natural light to the camera.

Pressure contour plots were created from the simulation results, at various intervals, to provide a visualisation of the development of the shock wave system around each charge. Figure 7 illustrates the shock wave system predicted from MSC Dytran simulations around the Intrusive Cone Ended Charge (Type II) after 0.32µs.

Figure 7. MSC Dytran Pressure Contour Plot for Intrusive Cone Ended Charge at 0.32µs.



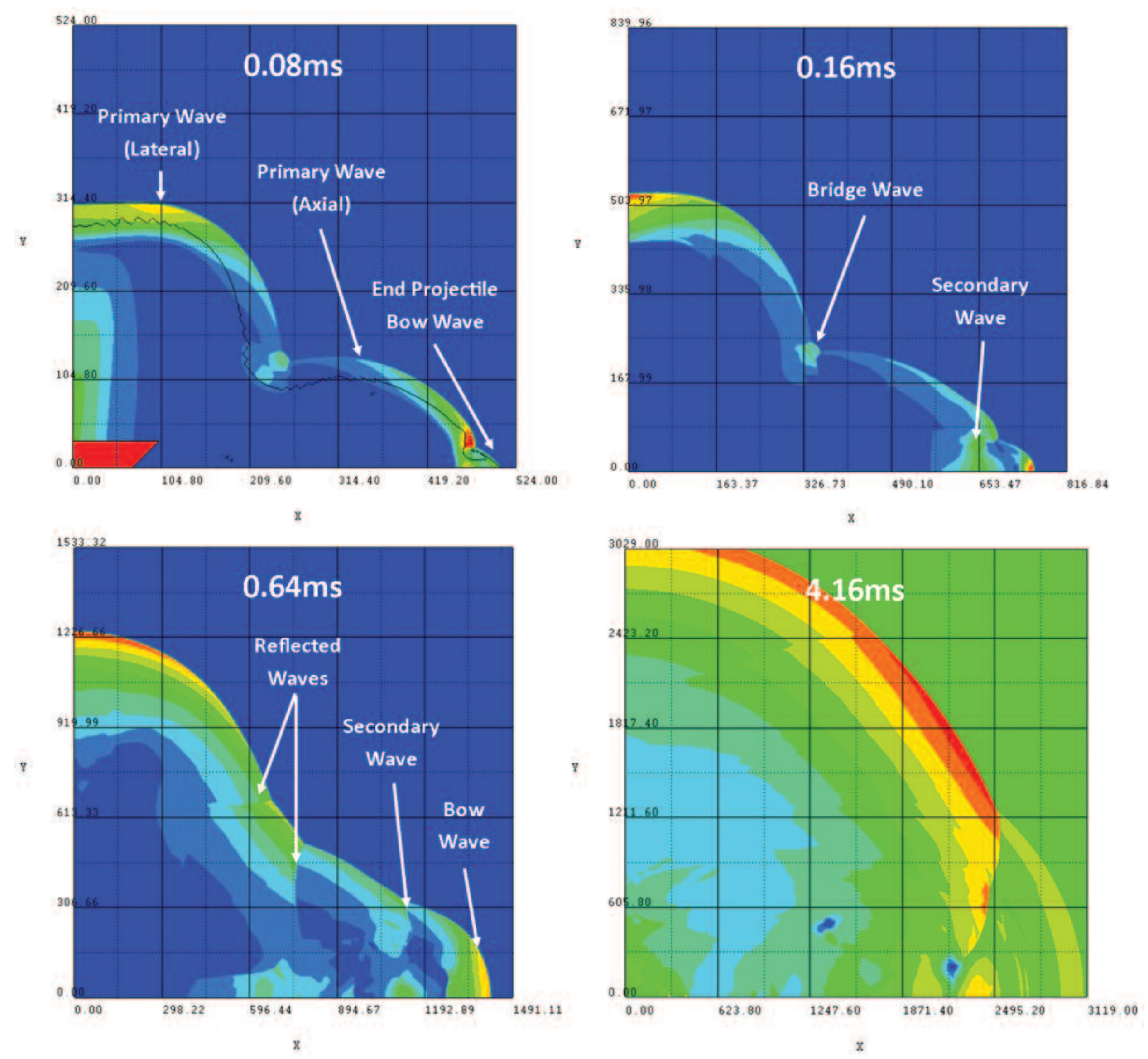
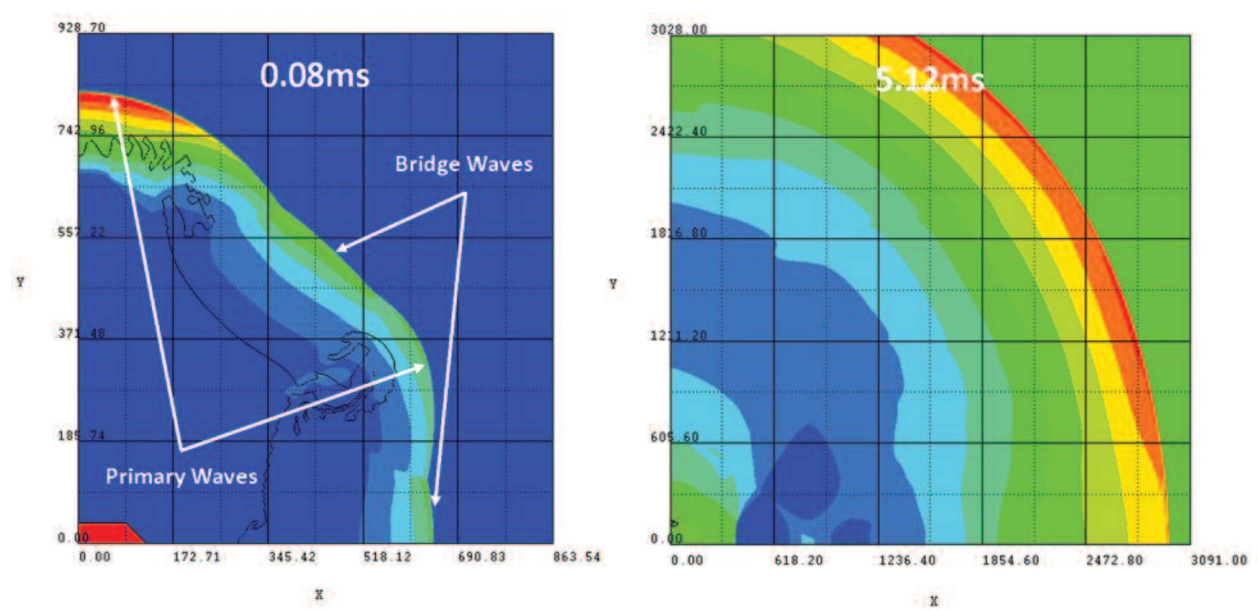



Figure 8. Development of shock wave system around Intrusive cone ended charge (Type II).

Figure 9. Development of shock wave system around protuberant cone ended charge (Type V).



## Analysis and discussion

### Shock wave system

Since the quality of the experimental HSV data was found to be poor, analysis of the shock wave system around each charge is based primarily on the review of modelling results.

Figure 8 illustrates the predicted development of the shock wave system around the Intrusive Cone Ended Charge. Shortly after initiation, primary blast waves are produced from the end and curved surfaces of the charge. A projectile-like disturbance is evident, emerging from the axial primary wave, with an associated bow shock wave.

Sometime later, a bridge wave can be seen developing at the intersection between the two primary waves, similar to that for plane ended charges. The axial bow shock wave becomes more pronounced and a secondary shock wave can be seen travelling behind. This may be as a result of Mach interaction between the axial primary shock wave and bow wave although, since no additional bridge wave is apparent, it is likely that it is simply a continuation of the primary axial wave which has been overtaken by the bow shock.

As the shock system continues to propagate, reflected waves form from the triple point. Along the axis, three regions of high pressure are apparent, corresponding to the bow, secondary and reflected shock waves.

Eventually the lateral primary and bridge wave 'heal' to form a smooth, almost spherical shock front. The axial primary and bow wave also become superimposed at the shock front to form a single disturbance, as noted by Bailey and Murray [1].

For the Protuberant Cone Ended Charge (Type V), the shock wave system produced is found to be more complex than that from a plane ended cylindrical charge (see Figure 9). In accordance with the findings of Bawn [2] and Bailey and Murray [1], modelling results show that primary waves are generated from the plane surfaces of the charge and that these are connected by a bridge wave which forms at the intersection. Also evident, is that an additional bridge wave forms along the axis of the charge, due to Mach interaction of the primary waves generated from opposing surfaces of the conical end. As the blast wave propagates the separate identities of the primary and bridge waves become less pronounced until eventually the blast wave 'heals' and the shock front resembles that from a spherical charge.

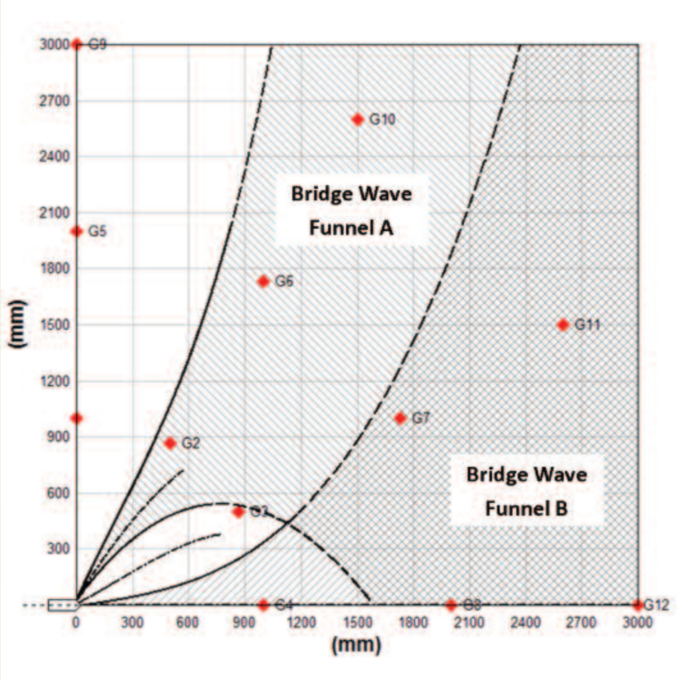



Figure 10. Intrusive Cone Ended Charge Shock Wave Funnel Plot.

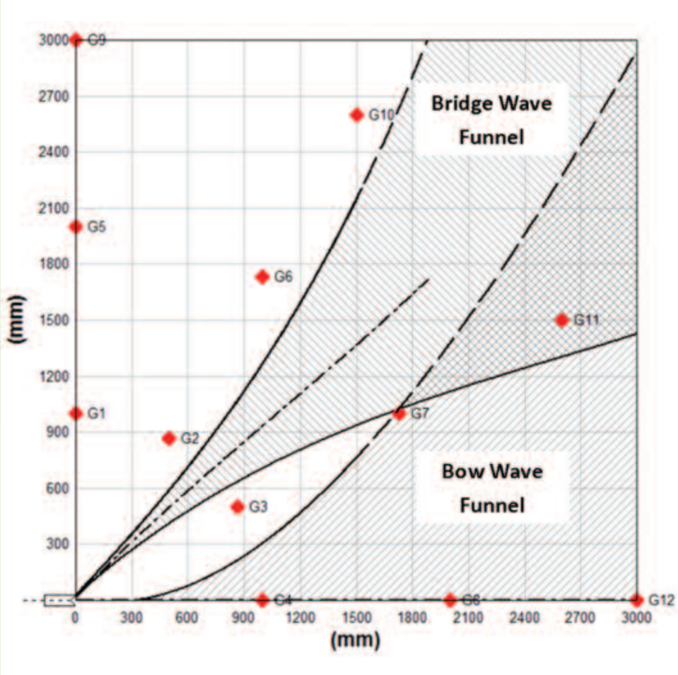



Figure 11. Protuberant Cone Ended Charge Shock Wave Funnel Plot.

Similar to those presented by Bawn [2], the predicted shock wave systems around each charge can be summarised as shock wave funnel diagrams; produced by tracing the locus of the intersection of the bow/bridge waves with the primary shock waves[2], based on the hydrocode modelling results (see Figure 10 and Figure 11).

Since, as stated, a reflected wave is generated at the point of intersection of the primary and bridge wave and it is this phenomenon which is responsible for a double peak in the blast wave, the general form of the predicted shock wave funnel was verified by comparison with the experimental P-T gauge data.

For example, for the intrusive cone ended charge, Gauges 5 and 9 are located outside of the bridge and bow wave funnels, in the 90° direction. As expected, the experimental data for these gauges shows only a single peak. Gauges 6 and 10 also lie outside, but are in close proximity to, the upper bounding surface of the bridge wave funnel. The experimental results show that a double peak occurs at Gauge 6 but not at Gauge 10. This is because, as indicated on the shock funnel plot by the transition from a solid to broken line, prior to reaching Gauge 10 the primary lateral and bridge wave shock fronts merge, meaning that no reflected shock wave is generated. Gauge 7 lies just below the lower boundary of the bridge wave funnel, within the path of the merged primary axial and bridge wave, and does exhibit a double peak response. Whereas Gauge 11 is exposed to only the merged primary lateral and bridge shock waves and shows only a single peak. The form of the P-T curve for the axial gauges is more complex, with both Gauges 8 and 12 showing multiple peaks corresponding to the passage of a bow, secondary and reflected shock wave, as discussed previously.

## Positive impulse

A quantitative examination of the experimental and modelling P-T data for each charge was undertaken. For the following reasons, the analysis was confined to the positive impulse of the blast wave only:

Firstly, the positive impulse "is generally a more useful indicator of blast damage potential" [10]. It is a function of both the overpressure and the positive phase duration and thus better characterises the blast wave than peak overpressure alone, particularly when multiple peaks are observed;

Secondly, whilst consistency of the experimental data for the key blast parameters was generally good, giving relative standard deviations[3] of below 10%. Modelling results for first and second peak overpressure were found to give errors averaging 20% and 50%, respectively, and could therefore not be used to reliably support the analysis. However, correlation of both time of arrival and positive impulse was much improved, being generally below 10%.

Figure 12 and Figure 13 illustrate the experimental and modelling positive impulse data for the intrusive and protuberant cone ended charges relative to the plane ended charge.

## Intrusive cone ended charge (Type II)

### Experimental

At 2m from the charge, experimental results for the intrusive cone ended charge show a noticeable reduction in positive impulse along the charge axis (approximately 18%). This decrease in axial impulse is perhaps somewhat surprising, considering that hollow charges are often used to increase

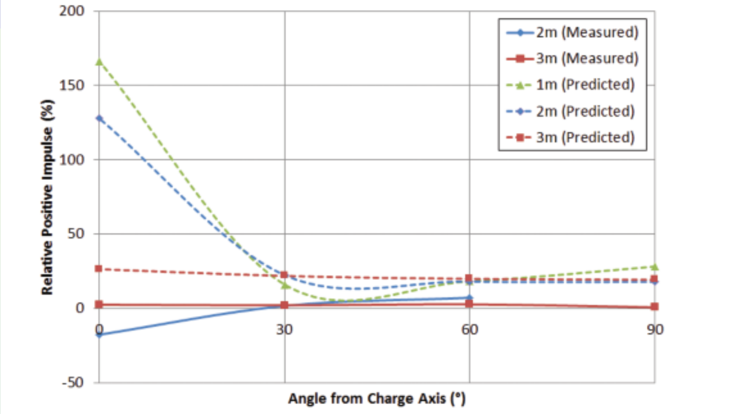



Figure 12. Relative positive impulse for intrusive cone ended charge.

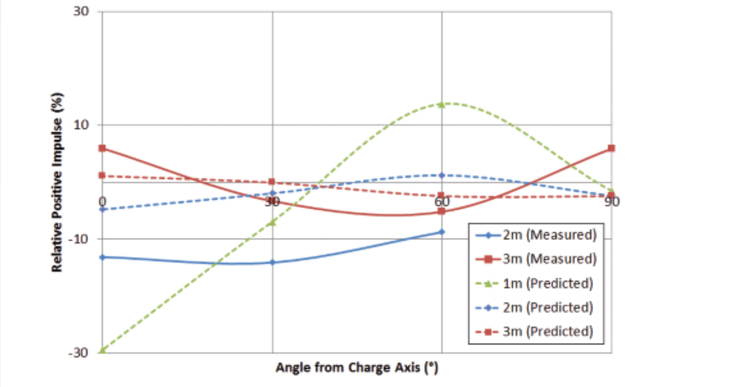



Figure 13. Relative positive impulse for protuberant cone ended charge.

axial effect. However, previous analysis of the predicted shock wave system illustrates that along the axis the blast wave comprises of a series of multiple shocks. Inspection of the P-T data collected shows that, despite the peak overpressure remaining similar to that of the plane ended charge, each of the individual shocks is of relatively short duration and hence the positive impulse of the wave is reduced.

In the 30° and 60° directions, small increases over the plane ended charge are found (1.8% and 7.2%, respectively). In the 30° direction this may be attributed to the fact that Gauge 7 was located just below the lower boundary of the bridge wave funnel, whereas for the plane ended charge it was contained within it. As such, the P-T trace for the intrusive cone ended charge shows a double shock phenomenon which increases the positive phase duration and, hence, the positive impulse of the blast wave.

At 3m, the axial positive impulse appears to have recovered, then showing a 2.6% increase over the plane ended charge. This may be due to the 'feeding-in' of energy from higher pressure regions of the blast wave, as proposed by Wisotski and Snyer [14], or due to an increase in the positive phase duration, owing to the secondary and reflected waves receding from the primary shock front. However, at all angles a general increase of between 0.7% and 2.8 is found.

### Modelling

At 1m from the charge, modelling results show greatly enhanced positive impulse along the axis (166% in comparison to the plane ended charge). However, what is particularly interesting is that in the 30° to 90° directions, positive impulse is also found to have increased by 16.1%, 18.3% and 28.2%, respectively. In fact, it was consistently the greatest of all cylindrical charge types investigated.

Contrary to the experimental data, at 2m, modelling results continue to show significantly increased positive impulse along the axis (128% greater than for the plane ended charge). It is thought that the lack of correlation with trial results can be attributed to the complex axial shock wave system which exists and accumulation of errors in the prediction of peak overpressure for the bow, secondary and reflected shockwave components. In the 30° to 90° directions, results also appear to overestimate the positive impulse showing increases of 22.5%, 18.2% and 17.9% respectively, when compared to the experimental data; albeit by a lesser extent. It is most likely that this is due to energy fed in from the high impulse, axial region of the blast wave. With this in mind, it is considered that the predictions for positive impulse at 1m may also be exaggerated.
At 3m, results show that the axial impulse has decayed somewhat, then only giving a 26.4% improvement over the plane ended charge. However, at greater angles similar

increases as at 2m are observed. Comparison with experimental data does illustrate that the model continues to overestimate the magnitude of the positive impulse at all angles; although, there is general agreement that an increase in blast effectiveness occurs at all angles.

## Protuberant cone ended charge (Type V)

### Experimental

At 2m, experimental results show an increasing, approximately linear relationship between the magnitude of the positive impulse and angular displacement from the charge axis. At all angles between 0° and 60°, the positive impulse is reduced compared to the plane ended charge, with the greatest reductions occurring in the 0° and 30° directions (13% and 14%, respectively). The presented area theory [10; 14] may explain the reductions in impulse compared to the plane ended charge, and 'feeding-in' of energy could account for greater positive impulse in the 60° direction. At 3m, positive impulse along the axis appears to have recovered; showing an increase of 6% at both 0° and 90°, whilst remaining suppressed in the 30° and 60° directions by 3% and 5%, respectively. In fact, in the 60° direction the positive impulse was found to be the lowest of all six charge types investigated.

### Modelling

At 1m, modelling results for the protuberant cone ended charge show a 30% reduction in axial positive impulse, compared to the plane ended charge. At 30° the impulse remains marginally reduced (7%), but at 60° an increase of 14% is observed. In the perpendicular direction, positive impulse is almost identical to the plane ended charge. At 2m, axial, 30° and 90° positive impulse is reduced, in comparison to the plane ended charge, by 5%, 2% and 3%, respectively; whilst in the 60° direction an increase of 1% is found. Correlation of the modelling and experimental data was reasonable with errors across all angles not exceeding 10%. However, the increase in positive impulse noted in the 60° direction is not observed in the experimental results, and in the other directions the model tends generally to predict lower attenuation of the blast effect. At 3m, the axial positive impulse has recovered to give a 1% increase over the plane ended charge but remains identical in the 30° direction. At greater angles a reduction of 2% is apparent. Comparison with the experimental results does reveal some discrepancies in the predicted trend, despite that absolute errors in the positive impulse predictions remain within 10%. Whilst the axial increase, and 30° and 60° decreases in positive impulse are observed in the experimental results, in all cases the model tends to marginally underestimate the magnitude of these effects. However, the relative increase in perpendicular positive impulse is not captured at all by the model.

## Conclusion

The effect of varying end shape on the blast produced from 400g cylindrical charges of PE4, with L/D=2, has been investigated using a combination of experimental and hydrocode modelling methods. The results have clearly supported the findings of previous authors, showing that relatively minor changes to the end shape of the charge can have a significant effect on both the shock wave system produced and the positive impulse of the blast wave at varying angles around the charge.

The presence of an intrusive conical end profile produces an axial projectile effect which results in a complex shockwave system consisting of a bow, secondary and reflected shock wave. In other directions the components of the blast wave are similar to that from a plane ended cylindrical charge. At small scaled distances, significantly enhanced positive impulse is generated along the axis. This phenomenon is well documented and is used commonly in a variety of applications (breeching charges, rock blasting, etc.) to increase near-field axial effect. What is most interesting is that, whilst this axial increase tends to decay quite quickly, both experimental and modelling results agree that a general increase in the blast effectiveness of the charge, at all other angles and stand-off distances, is achieved by incorporation of the conical cavity.

A protuberant cone ended charge generates primary waves which propagate in a perpendicular direction from the surfaces of the cylinder and conical profile, and are connected by a bridge wave. However, in common with the findings of previous authors, a further bridge wave is formed along the charge axis due to Mach interaction of the primary waves produced from the opposing surfaces of the conical end.

A protuberant cone ended charge generates a definite near-field attenuating effect along and in proximity to the axis at small scaled distances, without materially affecting blast effects in the perpendicular direction. At greater distances, the axial and perpendicular impulse shows small enhancements, but at the intermediate angles the impulse remains suppressed in comparison to a plane ended charge of similar dimensions.

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1 A plane-ended cylindrical charge is a solid explosive bounded by two parallel planes and such a surface having a circle as its directrix.

2 At the point where the intersection of the primary and bow/bridge waves was no longer clear, the boundary has been extended by use of a polynomial extrapolation, as indicated by the transition from a solid to broken line.

3 Relative Standard Deviation (%) = (Standard Deviation / Mean) x 100

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# Tech Spec

**Bruce Cochrane** MPhil MIExpE

## Exploders

It is a New Year and a new, but somewhat less aesthetically pleasing, face peers out from the header on the Tech Spec page. On behalf of everyone who has enjoyed his column, I would like to thank Pete Norton for the splendid work he has done over the last three years. I know Pete well from our former careers as Ammunition Technicians in the Royal Logistic Corps (RLC) and this is not the first time that I have found myself gazing upon the absurdly high standards he has set and wondering how I am ever to approach them, let alone meet them.

Back in the June 2012 Journal, Pete wrote a fascinating piece on the various types of detonators[1] and this article follows on from that by looking at the means of initiating electric detonators. Here I am referring to low voltage detonators of the type that, I suspect, most of us are familiar with, and not the high voltage varieties such as Electric Bridgewire, Exploding Foil or Slapper detonators. As Pete noted, Henry Julius Smith patented the electric detonator in 1868 and they were in use by the 1880s[2]. In the Saar mining region, between 1907 and 1909, it was found that the cost per electrical shot was higher than those using igniferous means, but the overall blasting costs per ton of coal extracted were considerably lower.[3]

Despite the benefits of electrical initiation, the British army was slow to adopt it. No mention was made of it in the demolitions section of the Manual of Field Engineering, published in 1911.[4] This all changed during the First World War. Writing in The Seven Pillars of Wisdom, TE Lawrence 'of Arabia' discussed using electric detonators in sabotage attacks on the Hejaz railway, beginning in 1915.[5] Describing the exploder he used, Lawrence said:

"The exploder was in a formidable locked white box, very heavy. We split it open, found a ratchet handle, and pushed it down without harming the ship. The wire was a heavy rubber insulated cable. We cut it in half, fastened the ends to screw terminals on the box and transmitted shocks to one another convincingly. It worked."[6]

Not knowing that special electric detonators were needed, he initially tried to insert his firing leads into the open end of a plain detonator and was puzzled by its apparent failure to explode.[7]

One of my greatest disappointments on joining the explosives fraternity was discovering that the initiation of electric detonators was no longer achieved by plunging an imposing T shaped handle into the bowels of a great wooden box. I should say that, at that point, most of my explosives knowledge had been gleaned from cartoons.

When I took over as Troop Warrant Officer at Northolt Troop, 11 EOD Regiment RLC. I was most gratified to find in the Troop museum an exploder of the sort that Lawrence of Arabia and Wiley Coyote had used, complete with an impressive T handle plunger.

Alongside it was a twist handle exploder, and next to that sat an Exploder Dynamo Condenser. Along with the Shrike Exploder on the EOD van, these provided a pretty good representative sample of the types of exploder available and offered a potted history of exploder development.

The role of the exploder (or blasting machine, as they are called in some sectors of industry and in some overseas countries) is to provide sufficient current over a distance to initiate one or more detonators or other electrical initiator.

Exploders must be portable enough to be carried to remote locations, robust enough to survive the journey and the conditions encountered, and safe.

They can be divided into two groups, according to their method of operation. These are dynamo types (also referred to as generator or magneto types) and condenser types (also known as capacitor types). The difference between the two is that a dynamo exploder creates an electric charge and releases it immediately, while a condenser exploder stores an electric charge in a capacitor before discharging into the firing circuit.

## Dynamo exploders

Dynamo types are the oldest and do not require any form of stored energy, such as batteries. They work by converting mechanical energy into electrical energy.[8] The operator either twists a handle or depresses a rack bar – that T handle plunger of my cartoon based ambitions - which in turn operates a dynamo comprising copper brushes and a commutator.

Most are designed so that the contacts to the firing circuit close at the end of the stroke. This is to ensure that current is released when the electric energy generated is at its peak.[9] However, some simple generators do not have this feature, comprising simply a generator and a rotating handle.[10]

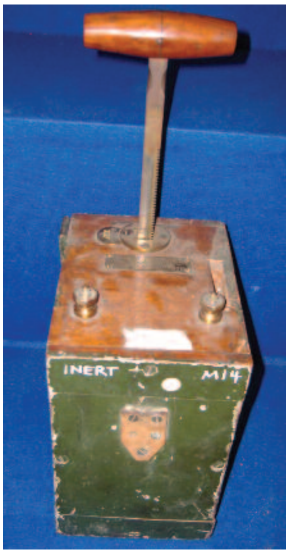
Rack bar machines could typically fire between 20 and 200 detonators in series, while a twist handle machine might be expected to fire up to 20 in a series.[11] The output of a machine depends on its condition, which deteriorates over time, and the effort expended by the firer. Because most exploders are designed to only fire at the end of the stroke, it is important to vigorously operate the handle through its full range of movement in order to reliably fire the series.

The rack bar exploder illustrated is a British Exploder Dynamo Mk V, made in 1918. It is housed in a sturdy wooden box, measuring 13 x 8 x 6 inches which was usually painted white. The top is fitted with two brass output terminals for the firing leads. It was probably one of these machines that Lawrence was referring to and it is entirely typical of early dynamo exploders. To operate it, the rack was fully withdrawn, the leads were connected to the terminal, then the handle was smoothly and swiftly pushed down, which operated the dynamo and, when the end of the stroke was reached, closed the contacts and released the charge.[12] What could be simpler or more satisfying?

The standard military exploder of the Second World War was the Exploder Dynamo Mk 7 which was also a rack bar machine. This continued in British service well into the 1950s alongside more modern condenser types. The Mk 7 was a more compact version of the Mk V and was capable of firing 42 shots in series over a cable length of 880 yards[13] and through a resistance of 150 ohms.[14]

Twist handle machines are smaller and lighter than their rack bar counterparts, although they operate along the same principles. The example pictured is a Drake,


Exploder Dynamo Condensor Mk II, 1950s.




Exploder Dynamo Mk V, 1918.

ICI Drake Dynamo Exploder, 1960s.

made by ICI. This was a capable of firing six shots in series.[15]

The dynamo has given – and still gives - reliable service the world over, especially in places where batteries and/or recharging facilities are not available. I worked with Greek army EOD teams in 2011 and was surprised to see them using a 1950s vintage twist handle dynamo exploder to fire their recently purchased and cutting edge EOD weapons. It worked perfectly. However, in most applications, the generator has been replaced by condenser machines, thus consigning the satisfying twist or plunge to history and the tender care of Warner Brothers.

## Condenser exploders

In condenser exploders, a charge is stored in one or more capacitors and then released by the operator pressing a button or carrying out some other action. There are two groups of condenser machines: those with batteries and those with a manually operated dynamo. In some cases the low voltage energy provided by the batteries or dynamo is converted to high voltage by a converter or transformer, before being passed to the capacitors. In others, the batteries or generator charge the capacitors directly. In most cases, when the capacitors are fully charged a lamp illuminates. [16]

The Exploder Dynamo Condenser was the standard British military exploder from the 1940s to the 1970s. It is typical of a condenser machine in which the capacitors were charged by the manual operation of a dynamo and is similar in concept to commercial machines such as the Beethoven exploder, which is still available.

The exploder illustrated is the Mk II version. It is housed in a moulded synthetic resin case and has a plastic window on top which covered a neon lamp. The exploder was fitted with two output terminals at one end and a firing button and safety switch flap at the other.

Inside there is a generator which supplies alternating current to an auto-transformer, an 0.5 microfarad condenser and two metal rectifiers which are arranged in a voltage-doubler circuit and convert the AC current to DC. This then charges a 6 microfarad capacitor to between 1100 and 1500 volts.

The neon lamp is connected between taps on the auto-transformer and limits the voltage to which the capacitor can be charged. It also indicates when the capacitor is fully charged.

To operate the exploder, the firing leads are connected to the output terminals. The safety switch flap is moved to expose the dynamo armature spindle. This also removes a resistor shunt across the capacitor. The dynamo handle is crewed onto the spindle and briskly rotated clockwise to produce AC current, which is converted to DC and passed to the capacitor. The neon lamp flashes continuously when the capacitor is fully charged.

With the dynamo handle left in position, the firing button is pressed. This switches the capacitor connections from the charging circuit to the output terminals. Current is released into the external circuit and the series is fired.

If the handle is removed before the firing button is pressed, the capacitor is connected to a resistor and is fully discharged.[17]

An example of an old, but very simple, battery powered machine is the Femco Multi Shot Condenser Exploder. In this, the operator inserts and holds down a key, which causes the batteries to charge the capacitor. A lamp indicates when they are fully charged. When the operator removes the key, the capacitors discharge into the external firing circuit.[18]

More typical of a modern battery powered exploder is the Exploder, DC, Electronic Handheld. This is more familiar to soldiers and engineers the world over as the Shrike exploder and has found widespread military and civilian applications.

I started this article with a thanks and I should like to end with some as well. I am indebted to Harry Lewis and Dave Parkes at EODTIC, and to Malcolm Holden at the Defence Explosives Munitions and Search School for supplying much of the technical information which informed this piece.

I hope to look at commercial explosives in my next few pieces, so if you work in the explosives industry, please do not be too surprised if I contact you, begging for information. Alternatively, if you have ideas or information on a subject that could benefit from the Tech Spec treatment, please do not hesitate to contact me through the Institute or via email at *btcochrane@hotmail.com*.

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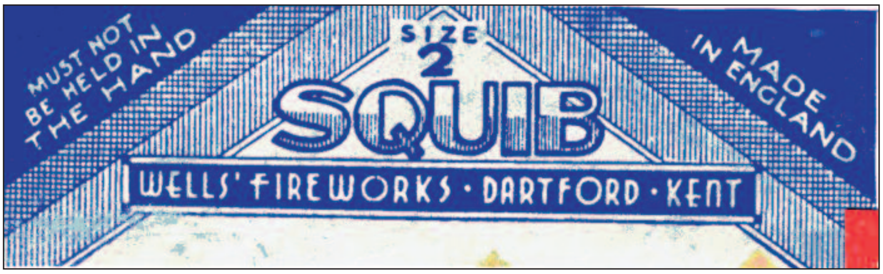
# The Bennett file

**Our columnist John Bennett reflects on the fireworks references in our language**


Having previously confessed in these pages to the guilty secrets of a mis-spent youth, I am about to open wider the door to the cupboard in which the skeletons are kept. Yes, I searched the streets after Guy Fawkes' Night to try to find those delightfully smelly remnants – mostly rockets and aeroplanes but, if on adjacent fields and allotments, fireworks not normally prone to leaving the ground. Now, of course, I know that, far from being alone in this activity, there were fellow aficionados all over the country hiding in shadowy corners ready to leap out when the coast was clear to secure another artefact for the collection. It is a practice of which I am, now, rather proud since it resulted in a collection of labels still extant. Should I say others are envious that certain items (albeit possibly dirty) are in my collection (and those of other seekers after unconsidered trifles) and not in theirs?

No, that can be admitted and few reading this publication and none reading *Fireworks* will turn a hair. But what of using your children as an excuse for such searches in difficult to locate corners? I can remember the rockets from our own Guy Fawkes' party which landed in the industrial estate compound behind our house and which would have, otherwise, been difficult to retrieve: 'I am sorry; my daughter likes to have the rockets that we fired. Would you just let us in to…?' It worked every time. 'Of course she can come in; now where exactly was it?

Given that, while perfectly acceptable, firework hunting is not a normal activity among the uninitiated, such methods were useful to get back fireworks which landed in other gardens – in fact I often had knocks on the door when another find was made by a diligent child working on 'our' behalf. Well trained children (and my daughter was happy to retrieve fireworks and indeed eagerly awaited the following day's excursions) are a god-send. You can walk along whistling while exhibiting a smile which tells all who pass by – 'I do like to indulge my children – don't you?' and another rocket is secured.

While fireworks are not universally loved (it's a funny world) many use expressions which have them as their theme. I wonder how many who describe a disappointing outcome as a 'damp squib' really know what a squib is. While readers will doubt this, it is many years since that particular firework was available in this country, or indeed anywhere. There is even disagreement on how they should be fired. Our squibs were used like stickless rockets: they would act like a saucisson, a firework which worms its way round the garden before (unlike a saucisson) emitting what was always known as a 'report'. The curious thing is that I never saw a squib with instructions on it. Others inserted them in the ground so that the effect was one of a gerbe emitting a finale bang.

Ron Lancaster recalled, in an early edition of *Fireworks* the use of squibs in Huddersfield: 'Squibs were sold when I was a boy in Huddersfield for removing soot in the tops of ovens in old cast iron kitchen ranges. The soot collected over the top of the oven and there was a little door where you could insert a flue brush or a squib. It was a hand rolled tube funnel and wired with a gunpowder charcoal mix and had a grain bounce at the bottom.' Few would know that now.

If we get ejected we 'get a rocket'. Yes, it could be an allusion to a space craft but the expression has been around for a long time – long before space travel was an everyday topic. An old car which emits explosive noises as it jumps along is called 'an old banger'. A good looking lady is a 'firecracker'; a bouncing object is like a 'jumping jack'. Literary references to Roman candles are many and we are delighted to have a 'cracker' of a party.

Fireworks are used in advertising – in anything that presages an exciting event. They give meaning to important scenes – are used as a background to a love scene. While the lovers kiss at the end of a film, shells fill the background.

While no longer acceptable subject matter for comic stories and children's magazines, exploding shells and cakes illustrate literature for the young. While Beano would no longer tell the story of our hero's use of fireworks, books for children – like *Firework Maker's Daughter* – are still in vogue. I well remember cartoon strips where fireworks were used to foil a burglary or do all manner of good deeds, while misbehaviour with them was also a topic. Now it is all a bit more responsible.

But, like it or not, fireworks are part of life – acceptable in the main. And thoroughly enjoyable!

*John Bennett is editor of Fireworks, a magazine for enthusiasts and the trade. It is obtainable, by credit card on the website www.fireworks-mag.org or, by post, from Fireworks, PO Box 40, Bexhill TN40 1GX Telephone: 01424 733050;
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£10 annual subscription payable to Fireworks Magazine.*

## The views expressed are those of the author:

**Our columnist Sidney Alford MSc PhD reflects on mercenary matters and the dearth of competent people**

### On trying to be an expert

Readers may recall my comments on the Prosecution's case in which my services as an Expert Witness for the Defence had been requested[1] and in which the seriousness of the evidence was indicated by a remarkable weight of about 2.7kgs of printed paper which, rumour had it, had generated a bill of about £3,000,000. More recently I was contacted by another firm of Instructing Solicitors about another case and, after hearing the bones of the allegations, and feeling that another injustice might be hovering, I agreed to cast an eye over the Prosecution evidence. This weighed in at just under 8.7kgs, corresponding proportionally to a hypothetical rumour of £9,666,666. After a couple of days of perusal, I was asked what fees I would charge for my services.

In April of last year I had read[2] of the government's intention to save money (and get tough on susceptible alleged criminals?) by denying a defendant the right to choose their own lawyer but, instead, to be allocated a representative, thereby contributing to a cut of £220,000,000 from the billion pound annual budget for criminal legal aid and, incidentally but more sinisterly, no doubt augmenting the conviction rate. On 6th January of this year courts fell silent around the country as barristers, for the first time ever, stayed away and demonstrated publicly their profound disapproval.

Being somewhat out of touch with such mercenary matters, and wondering what might constitute a reasonable charge for my services, I corresponded on the subject with Dr Chris Pamplin, Editor of the *UK Register of Expert Witnesses*, who kindly gave permission for the reproduction of data from a table from its Expert Witness Survey 2013 which presented average charging rates for report writing and court appearances according to speciality. This listed a series of professions and the average hourly rates for the writing of reports by his responders. These ranged from experts in medicine (£207), accountancy (£193)[3], building (£157), surveying (£152), engineering (£145) and science (£134).

I then corresponded with the Legal Services Commission, which classified me as an "Explosives Expert", and informed me that I could charge for no more than twenty two hours of preparation - apparently regardless of the weight of prosecution evidence - at £90 an hour, giving a total of £1,980. Thus my efforts were rated at only 47% of those of an accountant, 57% of those of a builder and 67% of those of a "scientist".

They presumably considered an "explosives expert" to be any one of the thousands of people who have been taught the correct way to label boxes of safety fuse, to blow up unwanted munitions *in situ* or to pour ammonium nitrate slurries from a tanker down a shot-hole. They paid no heed to the fact that this case related to the alleged preparation and properties of home made explosives (HMEs), and devices incorporating them -- subjects in which the acquisition of practical experience is forbidden in most places in which chemistry may be otherwise lawfully practiced and conventional explosives lawfully handled or used. This means that "home made" explosives are almost exclusively the domain of criminals and of the DSTL (Defence Science & Technology Laboratory) Forensics Laboratory which, it so happens, provides the Experts who compile the Prosecution's evidence. Thus the evidence is heavily loaded with allusions to "explosives" even when one characteristic of the compositions involved is to emit hot gas very fast but, for example, as a rocket fuel, definitely not to explode. It may be that DSTL's care for its employees' welfare is such that they are permitted very little practical acquaintance with the actual behaviour of these naughty, naughty substances.

One most regrettable aspect of such prosecutions is that, from the original Explosives Act of 1875 onwards, the use of the word "explosive" was extended from gunpowder and dynamite to include "*every other substance ... used ... to produce ... a pyrotechnic effect*", but which no genuine expert would dream of describing in real life as an explosive. Consequently, without any malicious intent, any device capable of fizzing until it goes pop is likely to be described as an IED (Improvised explosive Device) – a term properly applied to bombs – and introduced into Prosecution statements related to pyrotechnic compositions in contexts quite unrelated to harmful intent.[4]

In the recent case I accepted the request to act an Expert Witness for the Defence not for the paltry payment but in the hope of seeing justice done. Suffice it to note that, when I had driven three quarters of the way to the Crown Court with the intention of disabusing the Prosecuting Council of certain misunderstandings from the dock, a message informed me that the Prosecution had dropped all related charges. The duty of an Expert Witness is to the Court, not the Defendant, but I saw no reason to quarrel with their Expert's eventual wise judgement. They and the police would still have found that the case was a nice little earner.

In his Reflections[5], marking his retirement as HSE Chief Inspector of Explosives, Neil Morton commented that, "*When I first encountered HSE in 1977, it was a new organisation, bringing together inspectors from different backgrounds, with an Explosives Inspectorate staffed by people with significant hands-on explosives experience*". As he left, however, "*the Explosives Inspectorate can no longer rely solely on recruiting experienced people from the explosives sector*".

If the HSE finds it difficult to recruit informed experts then so will lawyers. Moreover, there may well be a dearth of competent people willing to argue for the Defence: those who have the expertise tend, inevitably, to feel loyalty to the military or civil services whence they acquired their expertise.

And what does it take to be an "expert"? Why, keeping outwardly calm when confronted by such legal statements[6] as "*The following explosives, together with smokeless powder, do not require an explosives certificate*" and "*Explosive articles which ... are intended to be used for the propulsion of model rockets*".[7]

1 *vide* JIExpE, December, 2011
2 The Law Society Gazette, 8th April 2013
3 A year earlier accountants had headed the list at £220 an hour: bankers were, alas, not listed.
4 See ref. 1
5 *vide* JIExpE, September, 2013
6 Control of Explosives Regulations 1991 (as amended)
7 In reality, smokeless powders, if treated like high explosives, usually behave like high explosives and rocket motors, believe it or not, are designed not to explode.

# Industry News

## Camborne School of Mines celebrates 125 year anniversary

A centre of mining excellence which has pioneered the very best in industry-led teaching, research and technological advances has been celebrating a truly special landmark. 2013 marked the 125th anniversary of the Camborne School of Mines (CSM) one of the world's foremost mining and minerals engineering institutions, with events throughout the year.

To celebrate, CSM organised a series of events to help share the passion, enthusiasm and excellence that has become the hallmark over the years. These included a distinctive Live Wall, an interactive forum designed to showcase the highlights, milestones and achievements since its inception in 1888. The Live Wall features memories and anecdotes from alumni based across the globe, interesting facts and figures about the industry and its relevance and importance to today's society, and fascinating insights into the history of CSM. It brings together contributions from the CSM community, with regular updates and additions.

Professor Frances Wall, Head of CSM, said: "We are all very excited about celebrating this landmark occasion with the most important part of our history: our staff, students, alumni, collaborators and supporters. CSM has grown from fairly humble beginnings to now be regarded, quite rightly, as one of the best mulitdisciplinary mining schools anywhere in the world. Our achievements over the past 125 years are a source of pride, inspiration and motivation for everyone who is part of the CSM community, past and present. We are sure that the celebrations highlighted just what we have achieved together so far, and also our plans for the future."

Camborne School of Mines has developed an enviable reputation of producing pioneering research, focusing on the key challenges of resource sustainability, environmental production and mine health and safety.

CSM is recognised as having had a global impact on the mining and minerals industry, by training graduates who are now leading the sector in new and exciting ways. It has also built close relationships with local, national and international business, and these collaborations have helped to promote advances in sustainable mining, geological exploration and renewable energy.

2013 was the 20th anniversary of CSM's association with the University of Exeter. It is now located in purpose-built facilities on the Penryn Campus. Anyone associated with CSM who would like to share any videos of their work, or messages for the celebrations can upload them to YouTube using the hashtag #CSM125.

*Further information:www.exeter.ac.uk*

## Educational charity seeks one hundred 12-14 year olds for engineering experience

The independent educational charity The Smallpeice Trust has launched a new course timetable for 2014 and is seeking hundreds of 12 to 17 year old students to sample their engineering taster courses. Any student can apply to attend a wide range of subsidised residential courses which take place at universities nationwide. These are designed for students with an interest in or natural flair for Science, Maths, Design or Technology with a view to encouraging them to consider a career in engineering.

The Smallpeice Trust will be running an Engineering Experience course at the University of Nottingham from 14th to 16th April 2014. The course offers one hundred students aged 12 to 14 (Years 8 and 9) an opportunity to explore the subject of engineering through a series of real-life challenges. Competing in teams, students will also work on design-and-build projects with young role model engineers from companies such as Babcock, Jaguar Land Rover, Rolls-Royce and the Royal Navy, who will guide them through every stage of product development, from initial concepts to final testing.

Throughout the process, students will be confronted with real-life issues including the need to work within a budget to make the project commercially viable. All Smallpeice courses are linked to the National Curriculum and are designed to improve core skills such as team building, financial management, communication and problem solving.

*Further information: www.smallpeicetrust.org.uk*

smallpeice

## "Major Miner"

### Professor Gour Sen's book in new edition

*Engineers Australia* have published a new and enlarged edition of Professor Sen's book "Major Miner" in an e-book format at a cost of A$20 per copy.

(See review *Explosives Engineering* March 2013).

*Further information: gour.sen@gmail.com*

## The Institute of Explosives Engineers Awards 2013-2014

A timely reminder to you all to think about those you have come into contact with in the explosive-related world. Here is the opportunity for those individuals to be recognised by their peers and receive one of the following awards, which will be presented at the annual AGM and Conference held in Glasgow 1st to 2nd May.

# Conman hired soldiers in bomb detector scam

The government accepted thousands of pounds from a fraudster to assist a global trade in fake bomb detectors despite a Whitehall-wide warning that such devices were "no better than guessing" and could be deadly.

The Kent businessman Gary Bolton paid the government to enlist serving soldiers and a British ambassador in what turned out to be the fraudulent sale of bomb detectors based on novelty golf ball finders. Bolton, 48, was sentenced to seven years in jail last year for fraud after claims that use of his handheld devices cost lives and resulted in wrongful convictions.

The ability of UK firms to hire top diplomats to arrange introductions for as little as £250 a time, and serving soldiers to act as salesmen for £109 a day plus VAT, without checks on the authenticity of products, is revealed in Whitehall documents about Bolton's dealings with the UK government released to the Guardian under the Freedom of Information Act. The government accepted more than £5,000 in payments from the fraudster to supply uniformed Royal Engineers to promote the bogus kit at international trade fairs in the Middle East and Europe, and to secure the backing of Giles Paxman, the brother of the BBC presenter Jeremy Paxman and then UK ambassador to Mexico, who set up sales meetings for Bolton's firm with senior Mexican officials engaged in the country's bloody drugs war. The British embassy in Manila also helped, and Whitehall trade bodies took money to support Global Technical at least 13 times from 2003 to 2009 as Bolton made up to £3m a year. Sentencing Bolton last year, an Old Bailey judge said the scam "materially increased the risk of personal injury and death".

One of the devices sold by the fraudster Gary Bolton. Photograph: PA

The government's role has caused diplomatic embarrassment and as recently as late last year British embassies were instructed to warn host governments that "these systems are not effective … have either no working parts or no power source" and to "exercise extreme caution if these devices are in use to protect life".

The devices are known to have been sold in Thailand, Mexico, Lebanon, the Philippines and several African countries. In 2001 a warning was circulated across government by a senior Home Office scientist who tested an early version of Bolton's bomb detector. Tim Sheldon, of the Defence Science and Technology Laboratory, said the results were circulated to about 1,000 officials.

His warning concluded: "Although the idea of security forces forking out thousands of pounds for a useless lump of plastic seems incredible or even funny, a surprising number of people have been taken in. If they are relying on such devices to detect terrorist bombs, the implications are deadly serious."

The government has denied any knowledge that the equipment was useless and, despite its own trials, has argued it could not have known it was backing a scam. "It is right that in some circumstances UK Trade & Investment will seek reimbursement for promotional and advisory services," a government spokesman said. "When UKTI becomes aware that a company has acted fraudulently it will withdraw its support and refer matters to the appropriate authorities. UKTI has an important job to do in supporting British business across the world and is aiming to help 50,000 businesses next year. UKTI cannot undertake a test or assessment of all products and services for every business it supports."

Giles Paxman, who is now retired, said there had been no reason "to suspect that [Bolton's] activities were in any way untoward", but questioned whether the government had the right procedures to alert embassies about dubious products. "I am sure that I would have very careful not to provide any specific endorsement of Mr Bolton's products," he said.

Campaigners against the trade have called for officials to be held responsible for their support for Bolton's equipment. Human rights activists in Thailand have identified two bombings that killed four people after the device was used to check suspicious vehicles. In Mexico where an estimated 1,000 of the devices were sold, campaigners say they have resulted in convictions of innocent people.

In 2009, Bolton paid UKTI's Mexico branch to arrange for Paxman to send introductory letters on his behalf to officials in states fighting drug cartels. Diplomats set up sales meetings, offered to take officials out for lunch as part of Bolton's sales drive, and suggested using the imprimatur of the embassy for a public relations drive for Bolton's equipment.

At arms fairs in Kuwait and Bahrain, corporals in the Royal Engineers were hired by Bolton to promote the GT200 device, as well as at security and weapons shows in Europe. Bolton paid the Royal Engineers Export Support Team and UKTI £5,631.93, the trade minister Lord Green has admitted.

*Further information: The Guardian, 26th January 2014,*

*www.theguardian.com/politics.2014*

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**Nobel Lecturer Award:** member or non member who is recognised to have done exemplary work in the field of explosives.

**Harold Swinnerton Award:** member or non member who has done the most for services to the industry.

**Rosenthal Silver Salver Award:** member who has committed an outstanding service to the Institute.

**Examination Award:** for the best student in the Entrance Examination.

**Journal award:** For the best article in the calendar year published in *Explosives Engineering*.

**Appreciation awards:** In recognition of support of the Institute or Branch.

Further details are available on the website.

I would really appreciate a flurry of nomination. There are well-deserving people out there that should be congratulated for a job well done. Please email the secretariat with your nominations at secretariat@iexpe.org and Vicki will forward those for our consideration.'

**Fiona Smith** AIExpE, IExpE Awards Committee

# Conferences
## Exhibition Diary

### GAS, VAPOUR AND DUST EXPLOSION HAZARDS
**Faculty of Engineering, University of Leeds, 24th to 28th March 2014**
Protection, mitigation and prediction.
Further information: www.engineering.leeds.ac.uk,
Email: cpd@engineering.leeds.ac.uk

### COUNTER TERROR EXPO 2014
**Olympia, London, 29th to 30th April 2014**
The premier international event for the entire security sector, Government, military, law enforcement, emergency services, private sector and security services.
Further information: www.counterterrorexpo.com
email: counterterrorexpo@clarionevents.com

### IExpE AGM AND CONFERENCE 2014
**Westerwood Hotel and Golf Resort, Cumbernauld, Nr.Glasgow, 1st to 2nd May 2014**
The theme of the conference is "Developing competence in explosives skills".
Further information: email:events@iexpe.org
*See details on page 7.*

### XVIII SAFEX CONGRESS
**Warsaw Marriott Hotel, Warsaw, Poland, 19th to 24th May, 2014**
Further information: secretariat@safex-international.org

### INTERNATIONAL CONFERENCE ON EXPLOSIVE EDUCATION AND CERTIFICATION OF SKILLS 2014
**Karlskoga, Sweden, 11th to 12th June 2014**
Further information: www.euexcert.org

### HILLHEAD 2014
**Lafarge Tarmac's Hillhead Quarry, near Buxton, 24th to 26th June 2014**
www.hillhead.com

### ORDNANCE MUNITIONS AND EXPLOSIVES SYMPOSIUM
**Defence Academy of the United Kingdom, Shrivenham, 30th September to 1st October, 2014**
On behalf of the Sector Skills Strategy Group (SSSSG) of the explosives Industry and Cranfield Defence and Security, the theme will be "Design for safety of ordnance, munitions and explosives and their associated facilities". There will be four strands to this theme: equipment, facilities, people and policy.
Further information: www.symposiaatshrivenham.com
*See details on page 7.*

# In a flash: Ben Hoge

BA (Criminal Justice) I.A.A.I CFI CFEI MIExpE

Your age: 51

**Occupation:**
I am employed by ProNet Group, Inc., a leading forensic engineering firm.

**Current position:**
I am the lead Fire and Explosion Investigator for the firm's United States Western Region.

**Responsibilities in job/work activities:**
I determine the origin, cause and responsibility of fires and explosions. I advise and participate in the collection of forensic evidence at fire and explosion scenes, and provide expert testimony regarding fire investigation and explosion analysis.

**Why are you involved in IExpE?**
The Institute of Explosive Engineers allows me to associate with many explosives professionals from diverse backgrounds and disciplines. In my former public safety fire career, I was assigned to the department's arson bomb squad for 18 of my 24 years' service. Prior to retiring as the Chief Investigator and Bomb Squad Commander, I was certified as a bomb technician for 17 years performing basic and advanced techniques in improvised explosive device defeat while specializing in explosives safety, explosives disposal and explosives storage operations. My current position, when called for, allows me to consult and provide an array of explosive related analysis.

**What are the benefits for you of the IExpE?**
The ability to participate and network with numerous explosives professionals in a manner that provides education about all explosives disciplines while being updated about current explosives technological trends. I am proud to be a Member of an organization which does a superb job of communicating the needs and benefits for the safe and professional use of explosives in today's modern society.

**What are your main goals in the next 10 years?**
I am not a scientist, but as a former explosives handling practitioner, my goal is to continue to read and study applied research that documents the physics of explosive properties, or, a term I personally like to describe as "The speed of energy". As Members, we are all involved in the business of using explosives energy to accomplish work in some form, and currently my job entails examining explosion scenes to determine what happened. Understanding explosives energy and the speed at which it functions is critical for both our analysis of how to use explosives for good purpose in addition to evaluating that energy when something goes wrong.

**What alternative career might you have followed?**
My friends know I am a cowboy at heart. I grew up in the western state of Nevada. Given the opportunity, I would have majored in agriculture instead of criminal justice and probably developed a large cow ranch operation.

**Who do you most admire on the current world stage and why?**
Christine Lagarde, Managing Director of the International Monetary Fund (IMF). She took the helm of an international organization in 2011 amid a crisis with vision and strong leadership acumen. I am always an admirer of those who believe in themselves and ultimately triumph in the face of adversity as they make the best leaders.

**Who would you most like to meet from any century and why?**
Raffaello Sanzio da Urbino, also known as Raphael. He was an artist and painter during the Renaissance. I studied his works in college. My favorite work of his is The School of Athens, a fresco. He lived during an enlightening time, and although he is known primarily for his sketches and paintings, his work in architecture and engineering was extraordinary for that era.

**What are your favourite activities/hobbies?**
Spending time with my family, western horsemanship trail riding, camping in the mountains and leather craft, which is my personal form of art expression.

**What is your ideal holiday?**
My wife finally convinced me to take a 10 day cruise to the Caribbean for our 20th wedding anniversary 4 years ago. I have come to enjoy the cruise vacations as there are so many different destinations to choose from and the food is just incredible.

**What is your favourite type of food?**
Enjoying a great cut of beef at a good Steak House.

## IExpE Journal calls for papers

Deadline for June 2014 issue is April 30th.
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: editor@iexpe.org