SAFEX NEWSLETTER No. 43 4th QTR 2012

SEASON'S GREETINGS

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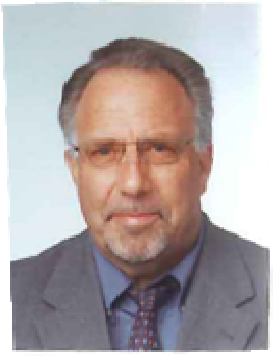


As I write this message there is a metre of snow outside with temperatures some 4 degrees Celsius below freezing. It is hard to imagine that in some other part of the world people are sweltering in temperatures of 30 to 40 degrees Celsius. The only snow they will see will be in pictures on the Christmas cards they receive. Yes, it is Christmas time and the end of another year is upon us. It never ceases to amaze me that despite differences in climate or location many people will be approaching this time of the year in the same spirit which has special significance for those who celebrate Christmas. Besides Christmas though, for many people it also marks the end of the calendar year and the beginning of a New Year. For them it will be a time of reflection on the past year and a sense of expectation about what 2013 may bring.

Some say celebrating this festive season is nothing other than a habit. While many of us will disagree, it made me think about habits. We're creatures of habit that often struggle with breaking habits. How does the saying go, "Habits die hard?" But habits are not always bad. People have recognised this over the ages. It was Aristotle who suggested, "We are what we repeatedly do. Excellence, then, is not an act but a habit".

Habits become ingrained through repeated actions. Nobody knows this better than SAFEX members. We recognise that habits can be a positive or destructive force. Consequently a large portion of our corporate lives is spent encouraging employees to develop the good and eliminate the bad habits. We have come to realise that our subconscious mind — call it the habitual mind if you wish — is very important. I read somewhere that it is over one million times more powerful than the conscious mind. As the writer puts it, we spend a substantial amount of our lifetime on "autopilot," playing out the mental programs that govern our behaviour. Has it happened that while driving your car you were deep in thought? In the meantime your subconscious mind is attending to the turns and bends in the road, watching other traffic on the road and taking all the necessary actions. Suddenly, you're aware of having travelled some distance without any recollection of it. It is then we realise how vast and powerful the subconscious mind is. It truly runs our lives — whether we realise it or not!

It happens in the routine operations in our manufacturing plants as well. Try as we must to have our operators concentrate (use their "conscious" minds) all the time, we cannot guarantee it will happen. We will probably never know how many times the "autopilots" of our operators may have let them down in the incidents we experience. Did the incidents happen because of bad habits - poorly programmed "autopilots"? Our battle, personally and in the workplace, is to make sure bad habits (behaviours that corrupt our "autopilots") don't take root.

Is it difficult? You bet it is! Just ask anyone who has an annoying mannerism and tries to get rid of it. The point is: Habits — good, bad, or neutral — are difficult to break; they die hard. We know what we must do but it isn't easy to replace destructive habits with successful habits. The key lies in understanding we have the power to choose and the power to change.

So as you reflect on some habits you need to replace and undertake to do so in the year to come, I extend to you, your relatives and families, our best wishes for a joyful and festive holiday season. May 2013 be free of harmful incidents as well as a blessed and happy new year for us all.

Claude Modoux
Chairman, SAFEX International

This is your Captain Speaking

Ian Hansen (CSBP Ltd)

Ian Hansen is the CEO - Chemicals with Wesfarmers Chemicals, Energy & Fertilisers (WesCEF), a role he has held since July 2010. Prior to this, Ian was Managing Director of the Chemicals and Fertilisers division (CSBP Limited) from October 2007 until it merged with the Wesfarmers Energy division in July 2010.

Ian has worked within Wesfarmers for more than 25 years during which time he has held a wide range of operational and commercial management roles.

He is a director of a number of Wesfarmers Group subsidiaries and joint ventures, is a board member of the Plastics and Chemicals Industries Association and the Australian Institute of Management in Western Australia and a past president of the Kwinana Industries Council.

He holds a Bachelor of Science with a double major in chemistry from the University of Western Australia and is a graduate of the INSEAD Advanced Management Program.

WesCEF is one of eight divisions of Wesfarmers, which is one of Australia's largest publicly listed companies and has more than 200,000 employees in Australia and New Zealand. WesCEF brings together a diverse set of chemicals, gas and fertilisers businesses with an equally diverse set of safety challenges.

AS CEO of the Chemicals business within WesCEF, I am ultimately responsible for the sustainable operation of our chemicals facilities and the safe stewardship and transport of all our products. Of paramount importance to me is the businesses' responsibility for the health, safety and well-being of our employees and the communities in which we operate.

Chemicals businesses within WesCEF include:

- The manufacture and supply of ammonia, nitric acid, ammonium nitrate and industrial chemicals to the Western Australian resource and industrial sectors through CSBP.
- Queensland Nitrates, a 50 per cent joint venture between CSBP and Dyno Nobel Asia Pacific which manufactures and supplies ammonium nitrate to the mining sector in the Bowen Basin coal fields in Queensland.
- Australian Gold Reagents, which is CSBP's 75 per cent joint venture with Coogee Chemicals, and manufactures and supplies sodium cyanide to the Western Australian and international gold mining sector.
- Australian Vinyls, Australia's leading manufacturer and supplier of polyvinyl chloride resin to the Australian industrial sector.
- ModWood, a subsidiary of Australian Vinyls which is a leading manufacturer of wood-plastic composite decking and screening products. ModWood products are manufactured from recycled milk bottles and reclaimed pine saw dust.

While we have made significant safety improvements in our Chemicals businesses over the last decade our safety performance in recent years has plateaued, which is of great concern to me, and our operational and business leaders.

The WesCEF board (of which I am a member) identified the need to do more to reduce risk and ensure the safety of our people, and through the hard work of our Health, Safety and Environment team we have recently introduced a new approach to safety to ensure safe behaviour becomes more engrained in our workplace culture.

We have given our new approach to safety the identity: *Safe Person, Safe Process, Safe Place*. Using this new approach our Health and Safety team, along with our business leaders will work to make health and safety more accessible and meaningful at every level of our workforce.

CSBP is major manufacturer and supplier of chemicals, fertilisers and related services to the mining, minerals processing, industrial and agricultural sectors. We operate a 530,000 tonnes per annum explosives grade ammonium nitrate (EGAN) production facility, as well as ammonia, nitric acid, sodium cyanide and fertiliser production facilities at our major industrial complex located in Kwinana, Western Australia.

By the very nature of the work we do, a variety of elements play a part in building our overall health and safety culture. This ranges from the design and maintenance of every piece of plant and equipment, to the competency and behaviour of every employee and contractor, through to the numerous regulations under which we operate.

Safe Person, Safe Process, Safe Place succinctly conveys our commitment to safe operations, and the safety behaviours and culture that we all need to continually be improving upon to support it. While we have only just introduced *Safe Person, Safe Process, Safe Place* this year, the approach is by no means about creating more systems or starting our safety journey as a business again.

Instead it unifies all of our previous safety endeavours, clearly articulates our expectations around safety behaviours to our employees and contractors, and converts our sometimes passive safety communications into a direct call to action.

Safe Person, Safe Process, Safe Place calls on every single person within our businesses to meet their individual responsibilities in being a safe person, using a safe process, and creating a safe place.

While the integration of *Safe Person, Safe Process, Safe Place* into our Chemicals businesses' culture is an exercise that will take a few years, I believe its potential to deliver significant returns to our people around improved safety behaviour is well worth the hard work.

QRA Corner

Welcome to another instalment of the SAFEX Newsletter series called the QRA Corner. Each column will examine a particular aspect of state-of-the-art applications, large-scale testing, and algorithms associated with Quantitative Risk Analysis (QRA) models. Your authors will rotate between Lon Santis, Manager of Technical Services of the Institute of Makers of Explosives; John Tatom, Manager, Explosives Safety Group at APT Research, Inc; and Mike Swisdak, creator of the US Department of Defense' ESKIMORE large scale test program and currently a senior scientist at APT Research. Our previous instalments comprised a series of questions and answers that often come up when the issue of QRA is first raised and the issue of large scale testing to enhance the algorithms used. This instalment provides details of one of the test series supporting the algorithm.

SciPan—A Test Series to Determine the Response of Reinforced Concrete and Masonry Structures to Blast Loading

by

Michael Swisdak (Senior Scientist, APT Research, Inc)

Accurate quantitative risk assessment (QRA) models depend on debris hazard prediction methods that are validated against full scale tests. When the effects of gravity are important, tests conducted at a reduced scale do not provide reliable data. The SciPan test program, which was planned as testing at full scale, was designed to help fill these data needs.

The SciPan program derives its name from an abbreviation for the Department of Defense Explosives Safety Board (DDESB) Science Panel and is in no way affiliated with the city/island of Saipan in the Northern Marianas Islands. The SciPan test series has been structured to examine the break-up and debris generation of reinforced concrete and masonry structures exposed to internal detonations of varying sizes. In addition, where feasible, various types of target structures have been exposed to the air overpressure produced by these detonations in order to ascertain their behavior under blast loading.

The Potential Explosion Site (PES) dimensions and building materials were chosen to represent those of typical operating buildings. The building designs included a floor slab and foundation as well as reinforced concrete and masonry walls and a reinforced concrete roof. The PES was designed for normal dead plus live loads (in other words, the PES was not a hardened structure). Figure 1 on the next page shows the nominal PES configuration for a 1000 kg detonation, which corresponds to the fourth test in the series, SciPan 4.

As depicted in Figure 1, three different PES wall cross-sections were included in each test:

- 14 centimeter (cm) thick reinforced concrete (R/C) with a grid of no. 15 (Metric) rebar spaced at 40 cm center-to-center (40 cm centers)

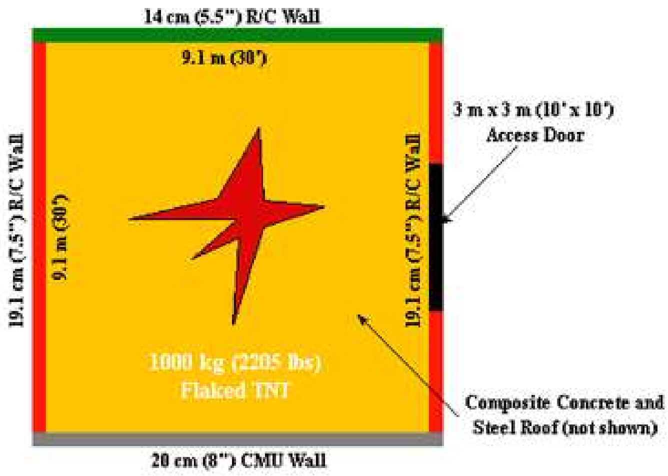


Figure 1: *SciPan 4 PES Nominal Configuration*

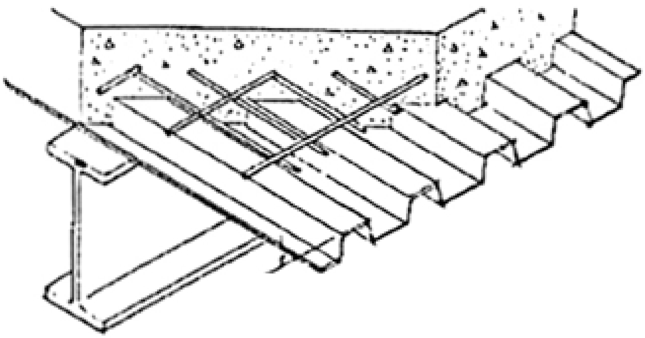


Figure 2: *Composite Roof Cross-section*

- 19.1 cm R/C, and with a grid of no. 15 rebar @ 40 cm centers
- Fully-grouted, reinforced 20 cm Concrete Masonry Units (CMU) with a grid of no. 15 rebar vertical @ 40 cm centers and No. 15 rebar horizontal @ 80 cm centers

In each test, the roof was a composite section, as shown notionally in Figure 2; it had a corrugated metal deck with an R/C fill, and a grid of no. 10 rebar @ 40 cm centers. The average thickness of the R/C was about 11 cm. The roof was supported with steel beams spanning the length of the structure. Similar to the roof, the floor slab on each test was 10 cm thick R/C with No. 10 rebar @ 40 cm centers each way.

Table 1 provides a brief summary of the tests that have been conducted thus far during the SciPan test program.

Table 1: *SciPan Program Summary*

Test	Date	NEQ** (kg)	Loading Density*** (kg/m^3)	PES Volume (m^3)	PES Dimensions	Exposed Site (ES) Description
SciPan 1	4/19/2003	12,249	11.74	1,043.9	14.6 m x 14.6 m x 4.9 m	(1) 139.7 mm Tilt-up RC Wall/Wood Roof (2) 190.5 mm Tilt-up RC Wall/Wood Roof
SciPan 2*	7/9/2003	2,270	NA	NA	N/A	(1) 139.7 mm Tilt-up RC Wall/Wood Roof (2) 190.5 mm Tilt-up RC Wall/Wood Roof
SciPan 3	4/6/2005	27,218	106.79	254.9	9.1 m x 9.1 m x 3.0 m	(1) 203 mm Unreinforced CMU/Wood Roof (2) 203 mm Double Wythe Brick Wall/Wood Roof (3) Concertainer Barricade****
SciPan 4	8/27/2008	1,000	3.92	254.9	9.1 m x 9.1 m x 3.0 m	(1) Concertainer Barricade****
SciPan 5	6/8/2011	2,991	11.74	254.9	9.1 m x 9.1 m x 3.0 m	(1) Concertainer Barricade****

* No PES
**Flaked TNT used as explosive on each test
***Explosive Weight/Structure Volume

****The concertainer barricade design provides a cellular structure using a welded mesh framework with a geotextile lining. It can be filled with local material such as sand or soil.

Figure 3: *SciPan 4 PES*

Figure 3 shows three views of the SciPan 4 PES. The photo on the left shows the intersection of the 20 cm CMU wall with the 19.1 cm wall with the opening into the structure. The center photo shows the 14 cm wall and the concertainer -type barricade. The photo on the right shows the intersection of the 19.1 cm R/C wall with the 14 cm R/C wall.

The SciPan test series has produced several kinds of unique information. This information has significantly contributed to the science of both explosive-safety quantity-distance (ESQD) and QRA. These data sets include, but are not limited to, the following:

- Effect of concertainer-type barricades on debris density,
- Mass distributions (debris sizes) for R/C of various thicknesses as a function of loading density,
- Quantification of both the range and angular dependence for the debris density from R/C and masonry structures (quantification of the cruciform debris pattern),
- Initial velocities, launch angles, and uncertainty for the debris produced by explosions inside R/C and masonry structures, and
- Better estimates of the range at which the density of hazardous fragments falls below a value of 1 hazardous fragment per 55.7 m^2 (1 per x 600 ft^2) for R/C structures.

Several of these observations are scheduled to be the topics of future columns. As an introduction, however, this article provides a summary of one of these results—the effect of concertainer-type barricades on debris density.

As indicated in Table 1, (previous page) the effects of concertainer-type barricades on debris density were examined on three of the SciPan events. Figure 4 shows the measured debris density (number of debris strikes per square meter) as a function of range for both the barricaded and unbarricaded direction for the SciPan 3 event. As can be seen in this figure, the barricade has the effect of reducing the total number of debris strikes out to a range of about 700 meters from ground zero. Figure 5 shows the remains of the barricade after the detonation. The portion of the barricade that was located directly in front of the opening in the 19.1 cm wall was completely obliterated, while the rest of the barricade remained standing, albeit after sustaining massive damage.

This article has provided an introduction to the SciPan testing program which was designed to provide much-needed information in two areas:

- Secondary or donor (PES) debris generation and density versus distance, and
- Target building (ES) response to blast loading.

Future articles will provide summaries of two other programs: SPIDER and ISO Container testing. Other articles will describe and discuss additional aspects of the data that have been generated.

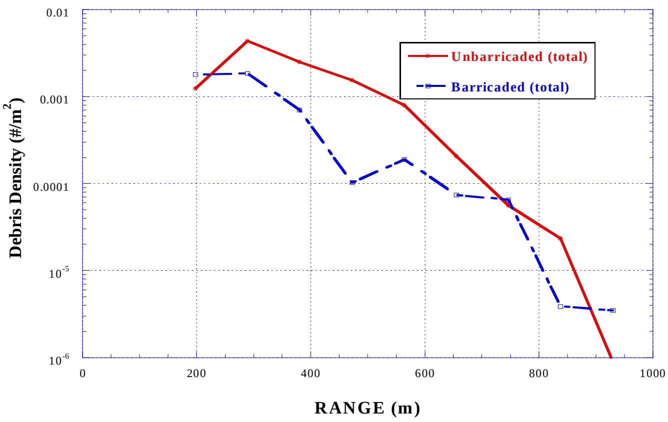


Figure 4: *Barricade Effect on Debris Density*

Figure 5: *Barricade Remains—Post Detonation*

IMESAFR V2.0 Training Session Scheduled for ISEE Conference

Readers of SAFEX Newsletter are well acquainted with IMESAFR. It is a probabilistic risk assessment tool used to calculate risk to personnel from explosives facilities. This software not only calculates QD based on American Table of Distances (ATD) and other Quantity Distance regulations, it can determine a level of safety based upon risk. In addition to explosives quantity and distance, IMESAFR uses the donor structure and activity, the structure of the exposed sites, the number and duration of exposed personnel, and other factors to determine a level of risk. In conjunction with ATP Research, the IME has just launched an upgraded version of IMESAFR called IMESAFR v2.0

The first North American IMESAFR v2.0 training course will be held from 7 to 9 February, 2013 at the Sheraton Fort Worth Hotel & Spa just prior to the 39th Annual Conference on Explosives & Blasting Technique. This is just down the street from the ISEE Conference venue. The new version of IMESAFR has some significant upgrades; including a completely new interface. Some main points of interest are:

- QD Analysis Capability
- Metric Capability
- GIS/Mapping Interface

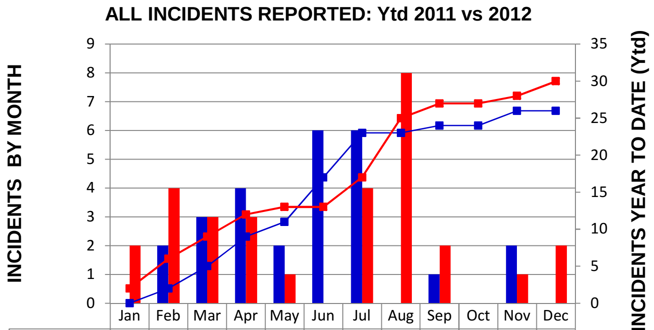
The new interface of the tool allows users to import maps or drawings of their site to assist with visualizing facility layouts and results. Because the new version is drastically different from earlier versions, previously trained students will be required to be retrained. However, there is an option to attend an abbreviated version of this class (2-days vs. 3-days). The price to attend the 3 days is $1,500. Previously trained users can attend just the last two days of training for $1,000. For more information or to register, call +1 256.327.4016 or email abedwell@apt-research.com .

Incident Reporting

Monitoring our Reporting Performance

"Every incident that is reported may prevent another from occurring. You can save a life by reporting an incident - including a near-event."

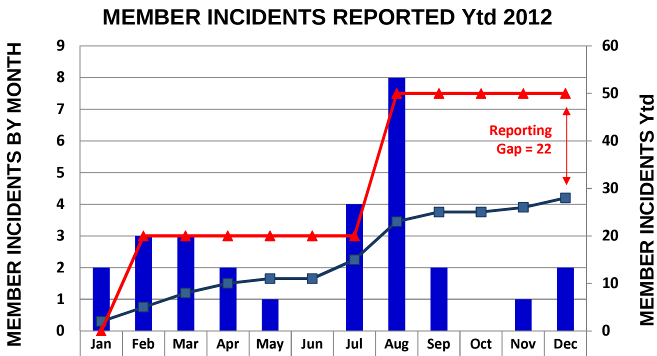
SAFEX learns from its members' experiences through the incident reports we receive. By applying these lessons we can prevent similar incidents recurring. That is why we track our incident reporting performance as follows:



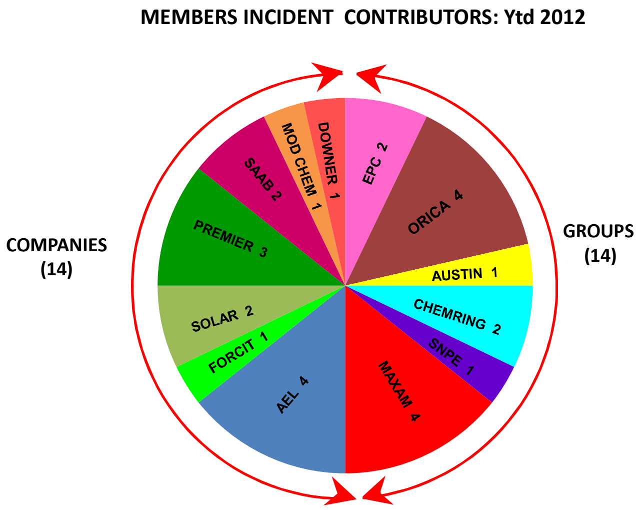
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2011	0	2	3	4	2	6	6	0	1	0	2	0
2012	2	4	3	3	1	0	4	8	2	0	1	2
Ytd 2011	0	2	5	9	11	17	23	23	24	24	26	26
Ytd 2012	2	6	9	12	13	13	17	25	27	27	28	30

All the incidents reported. This chart compares the sum of non-member and member incidents reported to SAFEX every month this year to the previous year. We have reported 15% more incidents this year than in in the same period 2011. This does not necessarily indicate we had more incidents than last year. It could be that members have been more diligent in reporting their incidents. In that case we are most grateful and want to encourage members to continue this improved reporting performance.

Member incidents reported. Because they give us the best learning opportunities, we track member incidents (MI's) separately in the chart on the right. PAR is an estimate of how many MI's are occurring based on the severity of the MI's that have been reported this year. The gap between the number of MI's reported and PAR is our Reporting Gap. The Reporting Gap suggests that only a little more than ½ our MI's are being reported.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2012	2	3	3	2	1	0	4	8	2	0	1	2
Ytd	2	5	8	10	11	11	15	23	25	25	26	28
Par	0	20	20	20	20	20	20	50	50	50	50	50



Contributors of member incidents. This chart identifies those members who reported incidents. It shows the number of incidents each of these members reported relative to the total number of MI's received. The chart distinguishes between Groups and Companies merely to indicate the performance of the two membership categories. There are about twice as many operating units in the Groups than single Companies. So far this year each category has reported about the same number of incidents.

"Every incident not reported is a lost learning opportunity. Remember, it's never too late to report an incident."

Know the Expert Panel

The **Expert Panel** comprises individuals who were nominated by members and approved by the Board. Such an individual must be associated with the explosives industry and possess expertise in specific fields. He must also be willing to make his expertise available to SAFEX members on a commercial basis which is agreed between the expert and the member. SAFEX does not get involved in the detailed arrangements but merely "connects" the Expert and the Member with the need.

To access the services of a SAFEX Expert, a client Member accurately defines the need it wishes the Expert to address. This requirement is captured in a Brief which is e-mailed or faxed to the Secretary General. The Member will be notified of the details of Experts that specialize in the fields of expertise designated by the client Member. It is then up to the Member to select an Expert and enter into an agreement directly with him.

Horst Marz

PERSONAL

Position: Consultant
Company: Marzcad
Location: Otterburn Park, Canada
Education: Dipl.Ing. HTL Germany
Languages: English, German

CAREER OUTLINE
(Explosives related)

AE&CI: (1971-1974)
Design Engineer
CIL, ICI Explosives, Orica: (1975- 1999)
Design Engineer,
Principal Engineer,
Engineering Manager
Marzcad: (2000- Present)
Consultant to Orica and AEL

EXPERTISE

- Design of safe machinery and equipment for manufacturing of explosives and initiation systems.
- Design of safe pumping systems.
- Sound knowledge of progressive cavity and piston pumps.
- Design of safe Packed and Bulk Emulsion Plants

TYPICAL ASSIGNMENTS

- Originator of "Thermofuse" deadhead protection for progressive cavity pumps
- Inventor of inherently safe progressive cavity pump US patent # 5779460
- Co-author of ICI pump code
- Designer of safe modular Emulsion Plants especially suited for deployment in developing countries with a strong emphasis on build in inherent safety in preference to using extensive instrumentation.

Meet our Workgroups and their Leaders

The SAFEX Workgroups are an integral part of SAFEX's service offering. One can describe them as the engine room of SAFEX's efforts to identify good explosives practices. They focus on specific areas where members have common health, safety or environmental (HS&E) concerns. In the Workgroups members pool experiences and resources to produce an outcome that reflects their collective knowledge for that area of concern. Typical outcomes include a standard, guideline or good practice that promotes ongoing safe operation in the area concerned. The Board of Governors has established the following Workgroups with the designated Workgroup Leaders. Piet Halliday is the Governor responsible for overseeing the performance of the Workgroups:

Good Explosives Practice (GEP) (Dr Martin Held – Austin International)
Explosives Traceability - Track and Trace (Dr Noel Hsu – Orica Mining Services)
Safe Technical Grade Ammonium Nitrate (TGAN) Storage (Dr Noel Hsu – Orica Mining Services)
Explosives Transport (Henry Merrick – AEL Mining Services)
Explosives Emulsion Manufacture (Dawie Mynhardt – BME South Africa)
Explosives Remediation/Decontamination (Mervyn Traut – Expert Panel Member)

Given the importance of the Workgroups, SAFEX Newsletter will be introducing our Workgroups and their Leaders to you in future editions. We are doing so in alphabetical order and Dr Noel Hsu is next on the list.

Noel Hsu – Technical grade ammonium nitrate (TGAN) and Explosives Traceability

Noel Hsu, is the leader of the SAFEX TGAN and Explosives Traceability Workgroups. His current role in Orica is Vice President for Global Regulatory Affairs and North American Government Affairs. He graduated from the Massachusetts Institute of Technology with a Bachelors and Masters in Chemical Engineering and has a PhD in Chemical Engineering from the University of Toronto. Noel furthered his education on Transition to General Management (Columbia University) and Strategic Management for Regulatory and Enforcement Agencies (Harvard Kennedy School of Government). With close to 25 years with Orica and its predecessor company ICI, Noel has worked in R&D and manufacturing covering technologies in nitroglycerine, airbag propellants, TGAN, bulk and packaged explosives, and explosives delivery systems. External activities include membership in the UN Explosives Working Group; co-chair of the European Union Task Force on enhancing the security of explosives; and membership in industry safety groups.

SAFEX TGAN WORKGROUP

I have the honour and privilege to introduce the SAFEX TGAN Workgroup. Several companies have participated in the Workgroup and generously contributed to its activities by making their experts available to share their knowledge, expertise, and best practices. The members of the core group that now meets annually are:

Richard Bilman
Clark Bonner
John Brulia
Don Cranney
Martin Held
Steve Hessel
Ian Lake
Erik Nygaard
Carlos Orlandi
Andre Cunha
Bill Evans
Piet Halliday
Paul Harrison
Alan Pikor
Greg Spoor
Donald Thomas
Larry Wilson

Accomplishments

The most significant achievement of the TGAN Workgroup has been the preparation and publication of a SAFEX Good Practice Guide (GPG) on the storage of solid technical grade ammonium nitrate. Within the explosives industry the predominant chemical used for manufacturing bulk and packaged explosives is ammonium nitrate. It is used in the form of both solid prills and solutions to manufacture emulsions and slurries or gels.

The accident in Toulouse in 2001 was traced back to contaminated AN. The increased focus on the storage of TGAN due to its illegal use in improvised explosive devices has led to the tightening of regulations on this product around the world. Discussions with global manufacturers of TGAN prill, many of whom are also explosives manufacturers and SAFEX members, led to the view that an industry good practice Guide was required for the storage of technical grade ammonium nitrate (TGAN).

This Guide is written for the storage of TGAN prills only. The scope of this SAFEX GPG covers TGAN prill storage at manufacturing, distributor, storage and end-user sites, and also addresses TGAN prill that is out of specification.

The SAFEX GPG is a comprehensive document that covers the following areas:

- safety management systems
- regulatory requirements
- site design, construction and management
- siting and layout of TGAN storage, and
- operation of stores.

For the siting and layout of TGAN, the methodology advocated is a risk-based methodology for the site. This is common practice in most of the industry. Owners and operators of TGAN storage sites are encouraged to continually manage the safety and security aspects through control measures that are aimed at reducing the likelihood of any incident.

It is not uncommon for TGAN and explosives to be stored on the same site. If the storage site also contains explosives, i.e. Class 1 substances, the Guide no longer applies since this 'mixed' storage is covered under the local Explosives Regulations and a recommendation is made to that effect.

The objective of this GPG is to provide guidance to organisations that store TGAN to further minimise the unlikely potential for an accident by applying prudent risk management principles and practices.

If you are interested in this Guide please contact the SAFEX Secretary General. Should you be interested to participate in the Workgroup or provide information that will be suitable for this Guide, please contact Noel Hsu at noel.hsu@orica.com.

Future plans:

The next annual meeting is planned for February 13, 2013 in Fort Worth after the ISEE Conference ends. Among the topics to be discussed will be any new information on AN testing that may impact the content of the SAFEX GPG; the transport of AN in containers, which is increasingly becoming a common mode of transport; modifications to the UN tests and Model Regulations; and a risk tool, IMESAFR, that has been developed for the explosives industry.

SAFEX EXPLOSIVES TRACEABILITY WORKGROUP (TRACK AND TRACE)

I also chair a Workgroup that is evaluating the trends in explosives product traceability. This group met to review the traceability initiative that is being implemented in the European Union to determine what learnings can be extracted from this initiative. Traceability is relatively new in the explosives industry with a handful of countries such as China and Brasil requiring explosives articles be labelled for traceability. The European Union is the single largest bloc that has taken this step and by doing so have set a global standard. The SAFEX Workgroup agreed that a global standard should be developed based on the guidelines in the European Commission Directive.

Future Plans:

The future meeting of this Workgroup will be focussed on developing this global standard

Putting Science to Work

In this Newsletter Feature we try to publish articles with a technical bias that illustrate how our industry is putting science to work in the interests of explosives health and safety. We want to recognise those who are involved in research and development as well as encourage them to continue improving our understanding of the behaviour of explosives. While explosives have been around for millennia there are still big gaps in our understanding of how and why they sometimes behave the way they do. As long as those gaps exist we are vulnerable. This Feature is also a forum for explosives scientists to advance scientific theories on why certain incidents occurred. This can further enhance our learning from those incidents. SAFEX wants to put science to work in order to prevent the harmful effects of explosives incidents.

Energetic Materials Research and Teaching Activities at the University of Pardubice, Czech Republic

by

Dr Jiri Pachmann

(Institute of Energetic Materials, Faculty of Chemical Technology, University of Pardubice)

Univerzita Pardubice Fakulta chemicko-technologická

UNIVERSITY OF PARDUBICE CZECH REPUBLIC Institute of Energetic Materials

Introduction

Education in the field of explosives is important in assuring continuous training of new staff for both industrial as well as governmental organizations. Explosives research enhances understanding of energetic materials in general and enables the development of safer, more specific and cost efficient explosives. In the Czech Republic both education and research are carried out at the Institute of Energetic Materials (IEM), traditionally part of Faculty of Chemical Technology in the University of Pardubice.

The education in the field of science and technology of explosives was started in Czechoslovakia in 1920 at Prague Institute of Chemical-Technological Engineering (now VSCHT Prague). In 1953 it was transferred to the present Faculty of Chemical Technology, in Pardubice. Today the department is known as the Institute of Energetic Materials. Its facilities have always been unique in the territory of the former Czechoslovakia. The numbers of students who so far have graduated are: 361 in MSc-level studies, over 450 from two four-semester non-degree courses (technology and blasting techniques) and 75 at PhD-level.

The specialist course, Theory and Technology of Explosive, covers a multidisciplinary field and includes the following areas:

- Chemical technology including the chemistry and technology of individual energetic materials and special analytical chemistry expertise.
- Technology of explosives covering aspects of military and industrial explosives, propellants, primers, pyrotechnics and initiators, as well as the processing and disposal of waste military explosives.
- Physics of explosion covering the theories of explosion and detonation, safety of blasting and the basics of construction of weapon systems.
- Safety engineering, which deals with the application of risk analysis and safety of chemical technologies.

IEM also provides non-degree courses for individuals employed at facilities dealing with explosives (retraining and additional participant qualifications). These four semester courses last 400 hours; they are organized as three-day workshops each month. Two types of courses are taught: Theory and Technology of Explosives and Rock Disintegration by Explosion. IEM is also involved in research activities in the following areas: safety engineering (loss prevention in the process industries), explosives technology, study of initiation of condensed energetic materials, explosion physics and development of techniques and methods for evaluation and testing of energetic materials properties.

NTREM

The seminar New Trends in Research of Energetic Materials (NTREM) [1] is an annual meeting of individuals working in the field of teaching, research, development, processing, analysing and application of all types of energetic materials (EM) in academic as well as industrial sectors. The seminar is intended as a meeting point of students and junior researchers with scientists well established in the field. In order to attract many young participants there is no registration fee and the entire financial burden is underwritten by our sponsors. The intention of this meeting is to provide pleasant and welcoming atmosphere where exchange of professional experiences goes along with building of strong personal relations among young specialists working in the field of EM.

EuEXCERT, EuEXNET, ESSEEM

IEM was the national representative of Czech Republic in EuEXCERT program [2] which aims to establish a stable, firm foundation and framework for vocational education of people in the European explosives sector. The outcome of this project revealed the importance of such activity and IEM took part in the continuing project – EuEXNET. This project aims to develop a systematic approach, at European level, for bridging the gap between the demand of education and training for workers in the European explosives sector and the supply of training. A further project ESSEEM [2] (European Shotfirer Standard Education for Enhanced Mobility) aimed at harmonisation and enhancement of the education and training of shotfirers in Europe followed.

OZM RESEARCH LTD.

OZM Research [3] is a successful spin-off company established at the IEM, University of Pardubice in 1997. It was founded by two of the younger assistant professors and from the early days it focused on the development of testing instruments for characterization of explosives. Good relations of the IEM with army, police and industry including explosives manufacturers provided excellent feedback and enabled the newly founded company to target particular issues in various specialist applications (stability of nuclear plant waste, stability of gun powders and rocket propellants, reactivity of substances in the reactor of aniline production, stability of plastic explosives, etc.). Development and production is always aimed at custom build devices not available on the market and at the same time needed by the explosives community. Current col-

***Figure 1**: NTREM 15th Symposium*

laboration between OZM and IEM is carried out through a joint laboratory to the benefit of both involved parties.

The company core business consists of testing instruments, technologies and expert services for energetic materials (explosives, propellants, pyrotechnics, ammunition). These are described at the company web site (www.ozm.cz): two examples are briefly mentioned here of the instruments developed – EDS (ESD 200A) , Figure 2 and new type of strand burner (Stojan vessel SV2), Figure 3.

Electrostatic spark ignition is one of the most frequent and the least characterized causes of accidental explosions of energetic materials. To have reliable data on electric spark sensitiveness of energetic materials is thus a critical property in R&D, manufacture, processing, loading or demilitarization of energetic media. The small scale electrostatic (electric) spark sensitivity tester ESD 2008A is designed for precise determination of the minimum amount of energy of an electric spark that will cause initiation of the tested sample of energetic materials.

The test is based on discharging bank of capacitors in a spark gap containing tested sample. The amount of energy necessary for initiation of the sample is then taken as the measure of sensitivity. Various methods of measurements and results evaluation exist and must be carefully selected based on the nature of tested sample.

Determination of the burning rate as a function of pressure has been traditionally carried out using Crawford bomb (strand burner) or small-scale rocket motors. These conventional methods are based on measurement of burning time of standardized solid propellant grains at constant or semi constant pressures. About

Oscillating mode	Damping mode
short discharge duration (ns - ms)	long discharge duration (ms - ms)
high currents in discharge (100 - 1000 A)	Low currents of the discharge (< 5 A)
Noticeable mechanical effect of discharge rather than heat effect	Noticeable heating effect of discharge
typically used for • high explosives	typically used for • pyrotechnic mixtures • propellants • primary explosives

10 individual measurements are necessary to determine the burning rate in whole pressure range for both methods. The Stojan Vessel is a simple and safe instrument based on a more advanced mathematical procedure for calculation of ballistic properties and only one shot alone is sufficient to obtain the same data. The special shape of the sample (or strand) used in standard strand burner tests is not required as part of the real rocket motor (cylindrical or tubular) is used directly. Significant reduction of time needed for the analysis, increased safety and reduced running cost have provided significant benefits

IEM CAPABILITIES

The technological complex of the University of Pardubice is located outside of the main campus as it contains the only academic facility in Czech Republic enabling testing of explosives. Along with the capability for unconfined testing it also possesses state of the art detonation chambers for testing in an enclosed environment. The majority of detonation parameters of synthesized samples may therefore be easily tested right on the campus site. Activities include:

***Figure 2**: EDS (ESD 2008A) – Electric spark ignition sensitivity test (top). Detail of the spark gap at the time of discharge (bottom)*

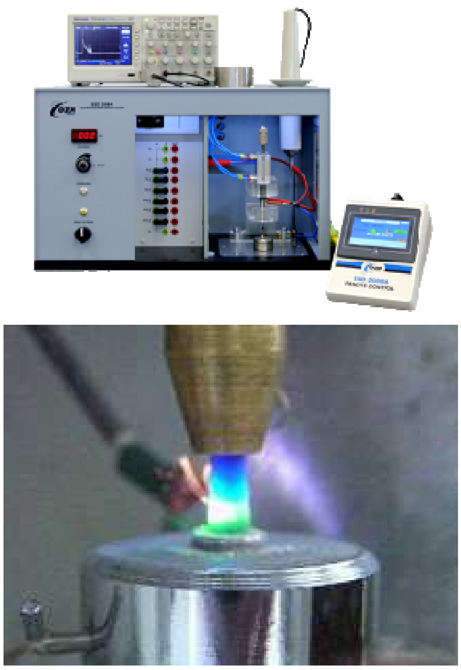
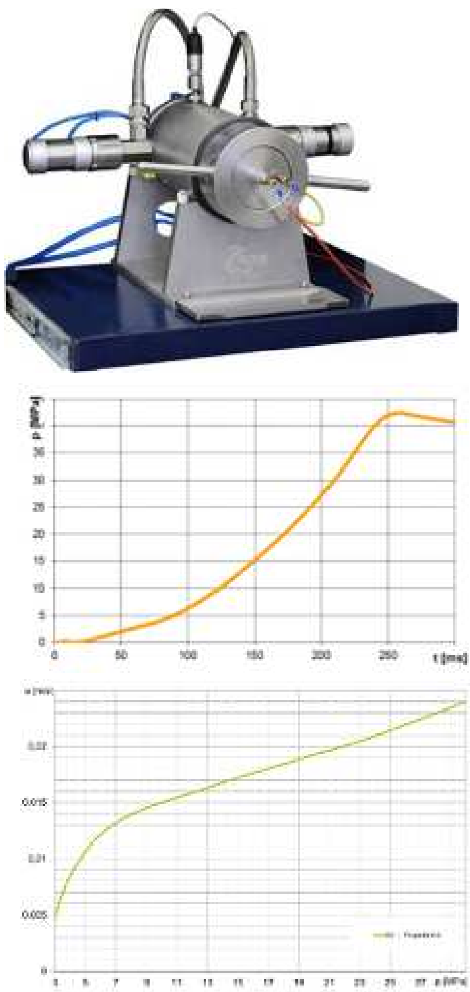


***Figure 3 (below)**: Stojan vessel (top) and example plots of typical raw record pressure (MPa) vs. time (centre) and the resulting burning rate ($m.s^{-1}$) vs. pressure dependency (bottom) obtained from just one shot.*



a. Synthesis and formulation preparation

The main activity of IEM is focused at synthesis and characterization of new explosives. The search for new individual compounds with higher energy is accompanied by the preparation and characterization of formulations containing substances in more usable form. In recent years research has been aimed at highly energetic nitramines and their usefulness in preparation of powerful plastic explosives. Significant effort has also been put into a search for environmentally responsible replacement for lead containing primary explosives.

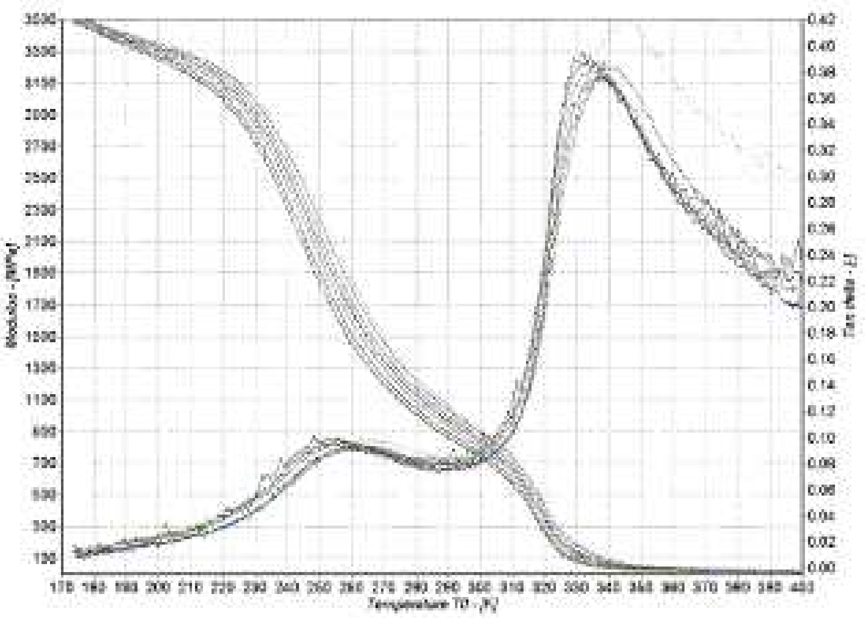
b. Thermal characterization

IEM is traditionally strong in the synthesis of explosives. Individual compounds as well as formulations prepared in the laboratories are first tested using traditional chemical analysis (spectroscopy, chromatography, etc.) followed by thermal stability tests as shown in Table 1. Usually we start the testing with DTA. An advantage of our approach in testing the thermal stability using DTA before going to standard DSC is the ability of our devices e.g. DTA Ex-550 [3] to withstand explosion of quantities up to 20 mg of primary or up to 50 mg of secondary explosives.

***Table 1**: Thermal Analysis tests used In IEM with corresponding STANAG number*

Traditional Thermal Analysis	DTA,DSC,TGA	STANAG 4515
EGA (evolved gas analysis)	VST	STANAG 4556
	Decomposition	
DMA (dynamic mechanical analysis)		STANAG 4540
ARC (acceleration rate calorimetry)		
Cook Off	Small Scale Slow	
	Small Scale Fast	

***Figure 4**: Typical result of dynamic mechanical analysis thermogram of double base rocket propellant in temperature range from -100 to +130°C at different frequencies showing the change from hard brittle material at low temperatures to a very viscous one at high temperatures.*



Its simple and robust construction provides safe and cheap method for the first brief characterization of the thermal behaviour of the sample. Further thermal characterization of our samples is done in accordance with standards (STANAG, MIL, ASTM, COS or others). The typical thermo-analytical techniques such as DTA, DSC or TGA are accompanied with ones less common in the field of explosives including ARC and DMA. Typical thermogram obtained with the last mentioned technique is presented on Figure 4. This record shows two transition regions corresponding to changes of mechanical properties of double base rocket propellant .

After thermal stability tests, samples are always tested for sensitivity to determine correct handling procedures. The usual methods include determination of sensitivity to:

- Impact (BAM) [STANAG 4489]
- Friction (BAM) [STANAG 4487]
- Electrostatic discharge [STANAG 4490]

The initiation of the primary explosive TATP by electrostatic discharge is demonstrated in Figure 5 on the next page. The explosive is initiated in plastic collar holding it on the electrode. The photograph clearly shows rupture of the collar and propagation of the shock wave from the detonation of the explosive.

Processing safety tests are carried out in accordance with standards as well, in some cases however we use different methodologies for data evaluation, such as Probit analysis, to decrease the number of necessary tests and increase the information value of the results obtained.

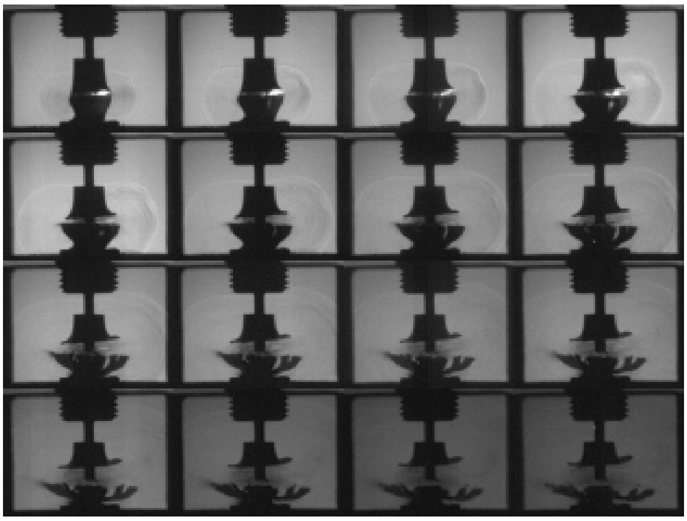


***Figure 5**: Initiation of sample of TATP by electrostatic discharge at IEM (spark gap photographed by ultra high speed framing camera, Specialized Imaging)*

***Table 2**: Standard detonation characterization tests*

Detonation velocity	continuous	Electrical/ optical
	averaged	
Detonation Pressure		
Shockwave characterization	in air	Confined/ unconfined
	in solids	Manganin gauges
DDT		
GAP tests	Water gap	
	PMMA barrier	
Ballistic Mortar		
Brisance	Hess, Kast	
Plate Dent Test		
Minimum Ignition Energy	Dust dispersions	EN 13821
Combustion calorimetry		ČSN EN ISO 1716

c. Detonation tests

The testing chambers/ sites include:

- detonation chamber KV-2 (max 2kg TNT equivalent, fragments)
- open pit test site (max. 1kg TNT equivalent, not fragmenting applications)

The detonation chamber KV-2 (Figure 6, bottom left) is a hydraulically operated steel vessel with internal volume around 2 m^3, weighting around 10 tons. It is capable of containing detonation of up to 2 kg of TNT equivalent with diagnostic equipment next to it. A wide variety of experimental measurements that would be difficult to set up outside are carried out here. The open space test site (Figure 6, right) is used for less complicated routine tests not requiring sensitive diagnostics in close vicinity of the explosion. The open test site is also used for experiments such as measurement of free field blast waves that cannot be carried out in a confined space. Standard testing used at IEM is listed in Table 2.

In addition, some less frequent tests/applications include:

- explosive forming of metals
- fragmentation tests (small and medium scale)

CASE STUDIES (based on recent publications)

a. Forensic and Thermal

Improvised explosives have been studied at IEM over 20 years at the request of the ministry of interior. The main reason for the continuing interest is rather unpredictable nature of such explosives. Standard industrial explosives must be products of certain constant quality. This is not the case with improvised or home-made explosives. Our interest is therefore focused at understanding how reaction conditions affect resulting products and their properties. Out of the many improvised explosives we have looked at TATP (3,3,6,6,9,9-hexamethyl-1,2,4,5,7,8-hexoxonane, triacetone triperoxide) is by far the most well-known example. The reaction conditions used in preparation of this primary explosive significantly affect the resulting product. This creates a quite dangerous situation

***Figure 6**: Detonation chamber (left), test polygon with blast wave sensors being set up (right)*

for the law enforcers as they encounter product of varying properties (stability, sensitivity) despite the fact that it is identified as TATP.

At IEM we studied the influence of reaction conditions used for TATP preparation [5] on its chemical and thermal stability, friction sensitivity and on the composition of product. It was found that different types of acids used as catalysts in preparation of TATP significantly affect the thermal stability and the composition of the product. Sulphuric acid gives a product that begins to decompose as low as 50°C at heating rate 5°C/min while hydrochloric acid yields product relatively stable up to 140 deg C i.e. in its molten state (Figure 7)

The spontaneous transformation [6] of TATP to DADP (diacetone diperoxide) was another rather surprising property of TATP we discovered. The temperature and the type and amount of catalyst proved to play important role. In practice this means that forensic samples stored for too long may change and a second analysis after some time may provide completely different results.

An analytical method for determination of residual anions (originating from the acid used during TATP synthesis) in the resulting TATP crystals was recently developed at IEM. Knowing the type of acid used for TATP production can help in identifying those involved in it preparing it and hence provides an invaluable lead to criminal investigators [7].

Our recent research is aimed at studying the possibilities of decreasing the sensitivity of improvised primary explosives to friction [8]. Figure 8 shows decrease of friction sensitivity of TATP by adding oil or water. It clearly demonstrates that water desensitizes TATP to the same extent as oil. Figure 9 further shows that when 20% or more of oil is added the probability of initiation does not significantly change in the entire probability range. The results can be useful for anybody handling improvised explosives at work (primarily for EODs, criminal investigators or forensic analysts). Our activities are not focused on TATP alone but include several other improvised explosives - primarily hexamethylene triperoxide diamine (HMTD), methyl nitrate (MeN) and erythritol tetranitrate (ETN).

Figure 7 ***(below):*** *DTA thermograms of TATP prepared using inorganic acids as catalyst (heating rate 5°C min^{-1}, 30 mg samples and static air atmosphere)*

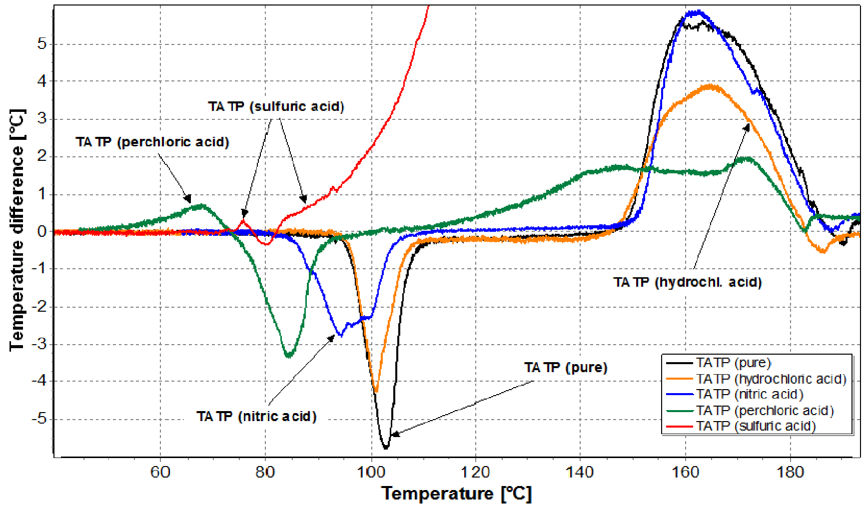


Figure 8 ***(below)****: The influence of addition of water or oil to pure TATP on its friction sensitivity determined as a F_{50} (Dinol - DDNP, MF - mercury fulminate and LA - lead azide are used as a reference)*

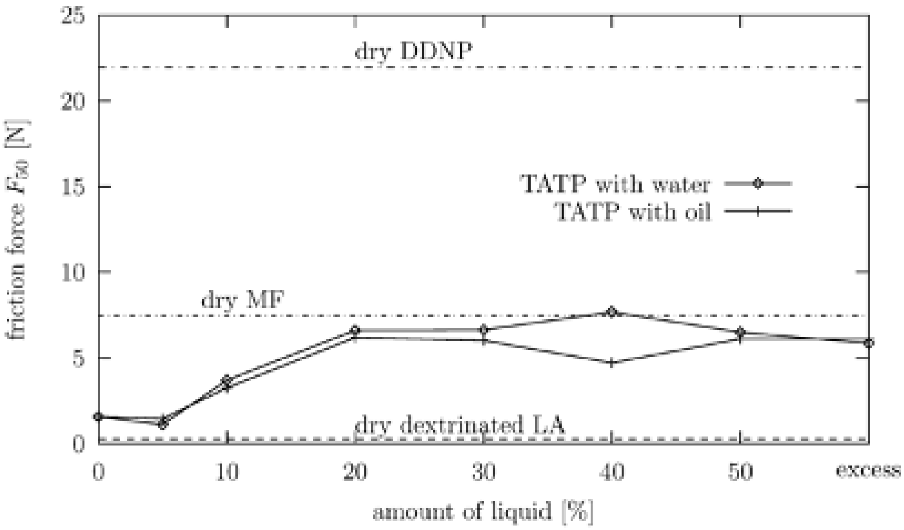
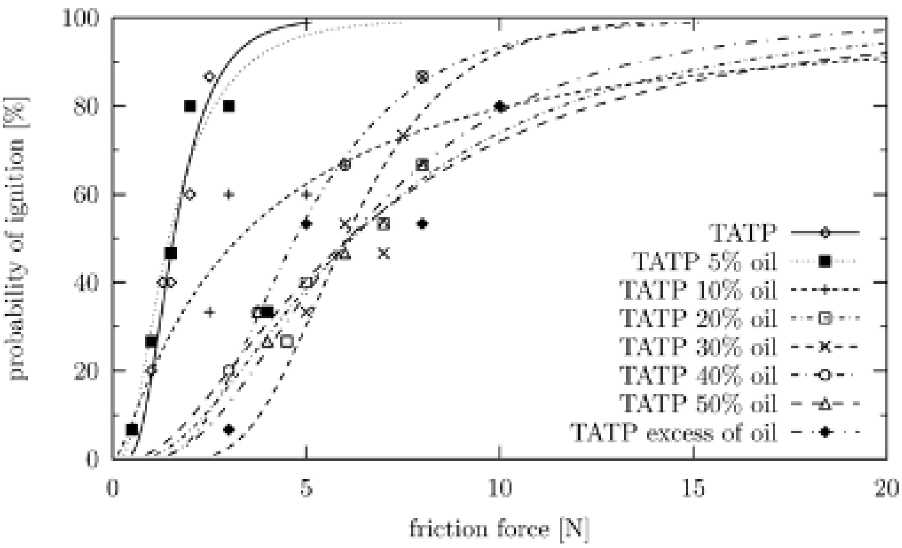


Figure 9 ***(below)****: The influence of addition of oil to pure TATP on its friction sensitivity determined by Probit analysis*



b. Probit analysis

The sensitivity of explosives to various initiating events is important in two aspects – safety and reliability. The safety point of view addresses the need to know the limits where probability of initiation is low to negligible. On the other hand explosives must detonate after initiation and the level above which they reliably do so is equally important. The sensitivity changes gradually from 0 to 100% of probability of initiation with increasing initiation energy (Figure 10). The dependence of the initiation probability on impulse energy has sigmoidal behaviour. In standard sensitivity tests only one point on this curve is sought, usually the 50% initiation probability level. The most common method for its determination is the up-and-down method (staircase, Bruceton staircase) [9,10]. The whole sensitivity curve can be obtained by conducting large number of trials at all levels or more effectively by probit analysis. The usage of Probit analysis and the improvement of the precision of the results in comparison with the up-and-down method, are demonstrated on the example of determination of sensitivity of DDNP to friction [11]. The main benefit of Probit analysis in comparison with the standard up-and-down method is obtaining of the whole sensitivity curve from similar number of trials [10] as used in the up-and-down method. Furthermore the result of this kind of analysis can be easily improved by performing an additional series of trials as demonstrated in Figures 11 and 12.

The curve in Figure 10 is usually asymmetric (see e.g. experimental results in [12-14]) and it is similar to a cumulative distribution function of a log-normal probability distribution. It is therefore suitable to use the probit analysis [15, 16] to calculate the sensitivity curve.

***Figure 10* (below)**: *General form of the sensitivity curve for an explosive*

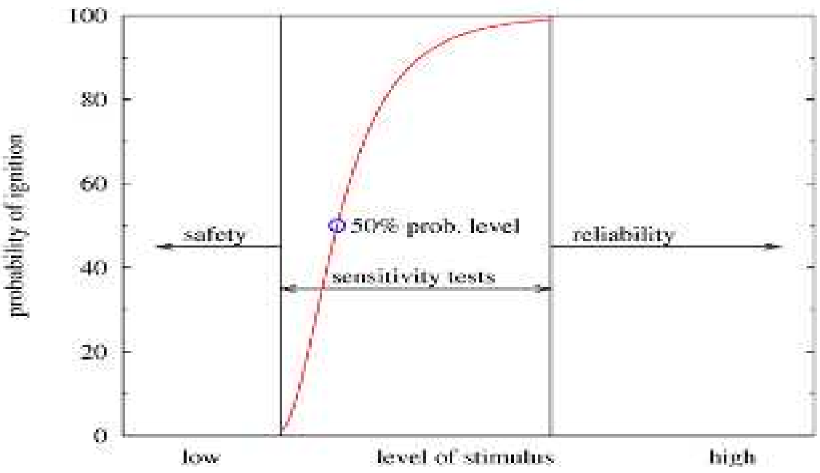


***Figure 11* (below)**: *The friction sensitivity of DDNP. The curve was obtained from four points; each point corresponds to 10-12 trials at one level of a friction force.*

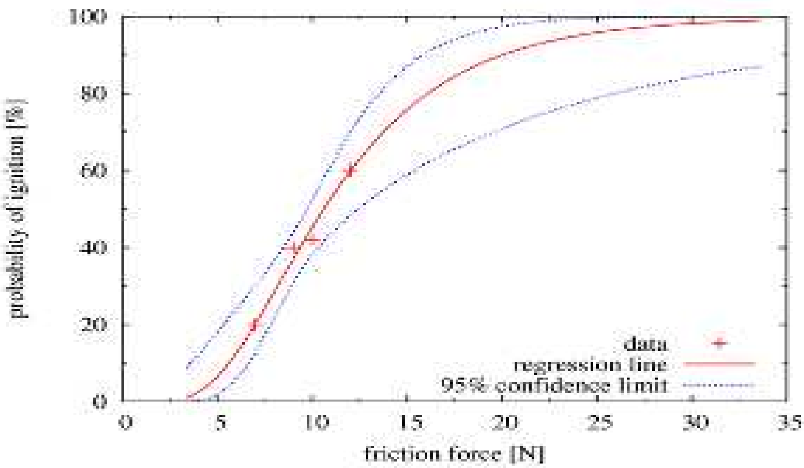
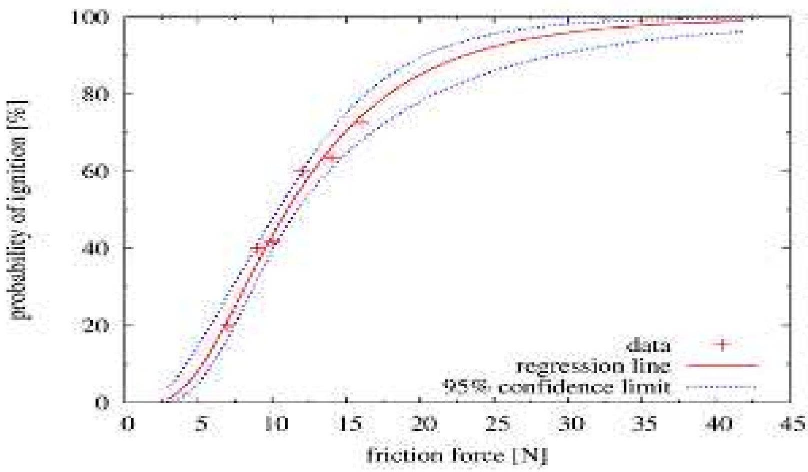


***Figure 12* (below)**: *The friction sensitivity of DDNP. The curve was obtained from six points; each point corresponds to 10-12 trials at one level of a friction force.*



The procedure to determine data for probit analysis starts with selection of few levels of explored stimulus and determination of probabilities of ignition on each level. Usually five levels of the stimulus and fifteen trials at each level are used. The probabilities are then expressed as probits and plotted against the levels in logarithmic form. Linear regression is performed and the regression line represents the probability vs. stimulus level dependency that can be transformed back into the original coordinates. The whole sensitivity curve can be obtained using this procedure at 4 to 6 levels. Typical results are displayed in figures 11 and 12.

FUTURE DEVELOPMENTS

IEM will maintain and develop both research and educational activities in future. Education is being transformed at present time to provide all courses in English as an alternative to already running ones in Czech. Further cooperation with other educational institutions in Europe will be extended and existing ties strengthened. The basic research into reactivity of energetic materials will be accompanied by applied research with its focus directed at the needs of industry including both manufacturers and consumers. IEM will further participate in activities against improper use of explosives and provide the scientific feedback to government agencies. The studies of preparation and characterization of new explosive individuals and formulations will address the need for higher performance, higher manipulation safety and environmental aspects. The major activities for near future include:

- *chemistry aimed at new materials, or older materials in new compositions, particularly – high performance energetic materials including high performance plastic explosives, insensitive energetic materials and energetic compositions for safety inflators*
- *detection and methodologies for training explosive detecting dogs*
- *development of optical methods for measurement of detonation properties*
- *improve the testing capabilities (introducing high speed framing camera into everyday testing, building and fine-tuning laser interferometer, collaborating on feasibility study and prototype development of minimum deflagration pressure facility)*

Safety engineering will address simulation of gaseous mixtures explosions in closed and ventilated cases as well as modeling of scenarios of accidental releases of chemicals including the consequences and modeling of accidental escapes of natural gas and crude oil and their possible consequences. Moreover, we will attempt to help our students and partners in industry adopt modern safety concepts and approaches. We advocate a modern approach to the analysis of incident causes, support application of safety management elements, based on risk analysis, and aim to learn and teach meaning of sound safety culture as a base of everyday safety.

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Our Explosives Regulatory World

The Explosives Sector in the 21st Century

by

Neil Morton (HM Chief Inspector of Explosives, Great Britain)

This article is based on the Keynote address given to the Institute of Explosives Engineers' Annual Conference, Hayling Island, 17 April 2012. It is published here with the kind permission of Diane Hall, Editor of "Explosives Engineering" which is the Journal of the Institute of Explosives Engineers (IExpE). The IExpE is a corporate Associate Member of SAFEX International.

INTRODUCTION

In 2009 the Health and Safety Executive (HSE) published a document called "The Health and Safety of Great Britain – Be Part of the Solution" [1]. This sought to involve businesses, workers and other stakeholders in taking forward the effective management of occupational health and safety – getting these groups to recognise that they had key responsibilities for good health and safety.

As part of its roll-out of this approach, HSE worked with stakeholders to develop a series of sector strategies, which translated the 2009 document into the context of targeted employment sectors and which set out specific aims and objectives to tackle the issues (i.e. the key risk factors) of each sector.

During 2010 HSE's Explosives Inspectorate (ExI) produced an "Issues paper" which, based on the information and intelligence available to ExI, described the challenges and risks facing the explosives sector. For this purpose the "sector" was described as those businesses which manufacture explosives, or which store explosives in large (more than 2 tonnes) quantities. Many of the issues described will, no doubt, be relevant to others who store in small quantities or who use explosives but those businesses were covered by other sector strategies, e.g. mining, construction, entertainment etc.

The "Issues Paper" was shared with, and agreed by, the Explosives Industry Forum – a stakeholder liaison group within Great Britain (GB), chaired by HSE and which includes representatives of the main British explosives industry associations and the Institute of Explosives Engineers. A copy of the paper[2] is available on the Explosives Industry Forum community web-site.

A strategy was then developed to address the issues, identifying those activities which ExI would discharge or lead and those where the sector would need to take on a greater role. This strategy formed the basis of the ExI plans of work for 2011/12 and 2012/13 and will continue to set the agenda for several years to come.

This article expands on a presentation given as the Keynote address of the annual conference of the Institute of Explosives Engineers in April 2012 and subsequently published in the Institute's journal, "Explosives Engineering". It is reproduced here with the kind permission of the the Institute of Explosives Engineers. This article presents a summary of progress made so far in delivering the Sector Strategy, as well as highlighting some of the remaining challenges.

THE WAY WE WERE

Not so many years ago, and certainly within the professional experience of many of us, the British explosives sector looked quite different to the industry we have today. Many manufacturing processes involved significant manual intervention by operators, under close supervision. The workforce was relatively large: sites employing 2,000 to 3,000 people were scattered around the Country. Between the workforce and management, there was significant experience of handling a wide range of explosives and although some of this experience had been bitter, occasionally involving serious accidents, even this was retained in the corporate memory and often influenced subsequent behaviours in a positive way.

RECENT DEVELOPMENTS

Over the last twenty or so years, there have been many changes in the explosives sector: new products and materials have been brought to the market and new manufacturing processes have been introduced, e.g. the manufacture of ammonium nitrate-based emulsions which can then be transported to the user site as non-explosive and sensitised as they are pumped into the shot-hole. Whilst these sorts of product have been often described as lower risk, we should recognise that this is achieved by reducing the likelihood of a mass explosion involving such products, rather than significantly reducing the explosion hazard itself.

Over the same period of time we have seen fireworks with mass explosion hazard, propellants containing high explosives constituents and propellants incorporated into pyrotechnic compositions. At a time when levels of experience and competence have been declining throughout the sector, we have increasingly seen the blurring of the traditional concepts of primary and secondary explosives, or of high and low explosives, meaning that technical knowledge is at a premium when hazards need to be assessed in an actual industrial activity.

Whilst the explosives sector in the 21st Century has less human intervention in manufacture, and hence fewer people at immediate risk from process hazards, the losses of experienced, knowledgeable staff over the last twenty years may well be seen as contributing to the accidents occurring now. As a regulator, we are seeing hazardous situations and accident causations today where the solutions were well known many years ago. There is an emerging belief that the sector's loss of competent staff has led to the repetition of old mistakes. There seems to be a corporate or sector amnesia about accident causation, made worse in a shrinking industry, by the apparent reluctance of some businesses to share information about good practice in managing safety and about those accidents or near misses which do occur.

A similar concern arises from some of our experiences with explosives site licence applications. It sometimes appears that businesses simply regurgitate explosives quantities and separation distances from published tables without really understanding the "basis of safety", e.g. in the configuration to be used in the process, how the explosives will behave in the event of initiation and how (or indeed whether) the structure and orientation of the building will mitigate the consequences.

THE VISION

As someone who has either worked in or regulated the explosives sector for most of my 35 year career, my personal vision for the future is to see an explosives sector which:

- is safe and sustainable;
- uses and shares good practice;
- continues to make a key contribution to our society;
- employs competent, knowledgeable, professionals; and
- is influential in relevant European & World-wide developments.

THE REGULATORY FRAMEWORK

The UK Government's position on the regulation of major hazards industries, which includes the explosives sector described in this paper, was set out clearly in a Ministerial Statement, "Good health & safety, good for everyone" [3], published in 2011. This confirmed that, "Hazardous industries … are essential to our everyday life but have the potential to cause large numbers of deaths or injuries from a single event as well as potentially catastrophic long term impacts on society, the environment or the economy …. The Government believes the regulation of these industries to be soundly based and in accordance with international best practice and does not plan to reduce the current level of oversight. However there will be a continuing programme of modernisation of regulatory approaches. ….. HSE will build on and expand its joint working initiatives with industry to promote better health and safety and pass on good practice".

Within this context, the challenges to all of us are:

- to ensure the sector operates safely with its smaller workforce (and hence smaller group of competent people);
- to share good practice and lessons learned in managing safety;
- to ensure legislation is relevant, future-proof and easy to understand;
- to ensure that regulatory activities are transparent, consistent and targeted and that regulatory burdens are proportionate to risk; and
- to maintain a successful key economic sector

HSE has begun to tackle these challenges through the development of the Explosives Sector Strategy, in 2010/11, and its delivery from April 2011 onwards. Progress so far, and next steps, will be described below. At the same time, IExpE has been developing a strategy for its own future activities, and it's clear to both HSE and the Institute's officers that there is real scope to link these strategies and make them complimentary.

The Explosives Sector Strategy has six aims, which can be summarised as follows.

1. A **robust regulatory framework** implemented through statutory "permissions", inspections, investigations and enforcement
2. Organisations demonstrating **strong and effective leadership** to set the right culture and ensure their major hazards are properly controlled
3. Major hazard duty-holders **managing asset integrity risks**, from both ageing facilities and new-build assets
4. Duty holders able to **provide assurance** to themselves and others that major hazard risks are under control
5. Duty holders who are **competent to manage** their major hazards and a regulator able to meet its responsibilities
6. Industry and other stakeholders **playing a greater role** in driving forward improvements in major hazards control

The first Strategic Aim is one of the most pressing challenges for all of us: to rationalise and simplify the legislative package which applies to explosives in GB. HSE has established an Explosives Legislative Review (ELR) which is looking at the complete suite of explosives legislation for which HSE is responsible. There are currently twenty separate pieces of legislation, from Acts to Regulations to Orders. We aim to produce a single comprehensive set of regulations for true explosives and to split off the controls which currently regulate acetylene.

The target date for delivery is 2014 and the intention is also for an update of the current guidance and Approved Code of Practice to be in place by that deadline. Industry and IExpE have already provided much expertise, knowledge and experience to the ELR regulation working groups previously established; we will certainly be looking for a continuation of such input as we review the guidance on good practice.

In spite of the very challenging programme of work and tight deadlines, ELR has already achieved some early successes through the support of businesses, Institute members and other stakeholders: in October 2011 the Classification and Labelling of Explosives Regulations (CLER) were revoked and largely replaced by an industry code of practice [4], which means that GB now relies solely upon ADR to regulate the transport of explosives by road. This has produced immediate savings for those who import explosives into GB from other ADR signatory states, but without reducing standards of safety. A further early success for ELR was the urgently-needed amendment to the Identification and Traceability of Explosives Regulations (implementing the EU Track and Trace Directive) to give industry more time to comply.

In addition to updating the regulations and guidance, HSE is also working to improve the quality and efficiency of its "permissioning processes" (e.g. licensing, classification etc.) and to enhance the transparency of its inspection activity. On the latter, we are steadily introducing internal instructions, "Delivery Guides", which summarise for inspectors what they should regard as good practice and what is unacceptable. These documents also link to HSE's enforcement decision-making guidance[5] and should drive even greater consistency between inspectors. Whilst these guides are internal documents, the intention is to make all of them publicly available on the HSE web-site's "Freedom of Information" (FoI) pages[6] in due course.

The second Strategic Aim is targeted at ensuring that explosives businesses have strong and effective leadership, which sets the right culture and ensures that major hazards are properly controlled. The widely-accepted principles of good process safety leadership[7] have been published and Explosives Inspectors are now assessing the take-up of these principles during site inspections. There is a real opportunity for the industry associations and I.Exp.E to influence businesses in this aim, by fostering a culture of effective safety management amongst their members and by supporting those who work in the sector.

The third Strategic Aim recognises that many of the facilities still used within the sector date back to the 1930s and are being used well beyond their original design life. Given the often critical function of building structures in mitigating explosion effects, it is essential that businesses understand the basis of safety within their operations and can maintain the effectiveness of protection measures which rely on building integrity.

Equally, where new facilities are being built, these are often within very constrained sites: it is often not an option to push licence separation distances out beyond their current envelope and so structural engineering techniques are increasingly being used to justify the "unitisation" of hazards and enable the new facilities to be squeezed into existing sites. In these cases, the new structures are even more critical to overall safety than when traditional, aggregated quantity/distance approaches are used and HSE has worked with industry to produce new guidance on making, and assessing, what are termed "structural justifications" [8].

Strategic Aim four seeks the development and use by businesses of meaningful safety performance indicators to provide the assurance that their risk control systems are appropriate, are in place and will work when required. HSE has previously published HSG 254 [9], a piece of guidance on the development of process safety performance indicators, whilst an example specific to the explosives sector was published[10] following research carried out on our behalf by the Health and Safety Laboratory. An industry-led group was also established during 2011 to share experience and good practice in the development of performance indicators relevant to explosives businesses.

It is our view that the development and use of performance indicators is a prerequisite for the effective management of major hazards, and particularly so for sites which are subject to the Control of Major Accident Hazards (COMAH) Regulations. Explosives Inspectors are now actively assessing the take-up of such measures as part of their routine COMAH site inspections.

The fifth Strategic Aim will certainly not be news to those who have been around the industry for any length of time. It follows the widespread concern in recent years at the loss of competent staff from across the sector. The aim is to ensure that organisations and their workforces are competent to manage the major hazards they create – and that the regulator has staff who are competent to regulate. Within GB, a great deal is being done, prompted and supported by I.Exp.E, to improve the management of competence. National Occupational Standards (NOS) are in place for many safety-critical roles with the explosives industry and training is being developed and delivered, to match the needs of businesses. Within HSE we have also recognised the value of the NOS and have incorporated the principles of the safety management NOS within our own competence framework for explosives inspectors.

Whilst we don't see the role of Explosives Inspectors as routinely assessing the competence of specific individuals, we do expect every business to have a competence management system proportionate to their needs. Inspectors are currently assessing such systems against expected standards and a Delivery Guide[11] has been published to assist this work specifically in relation to COMAH sites. An equivalent Delivery Guide for non-COMAH sites is under consideration.

Strategic Aim six underpins most of what has gone before. It was one of the key aspects of the 2009 Strategy "Be Part of the Solution". Under this aim, the sector itself will take greater ownership of safety; it will not wait for HSE to determine priorities or develop standards but will voluntarily share knowledge and good practice. Discussions are already under way with senior managers within the sector, with a view to establishing a group to take forward this aspect of the Strategy. I also see the expert working groups, recently established under the Sector Skills Strategy Group, as being a significant force for the sharing of knowledge and good practice.

This article has described some of the safety challenges facing the explosives sector in the 21st Century and set out the strategy, agreed between HSE's Explosives Inspectorate and industry representatives, to address those challenges. Good progress has been made in the initial delivery against that strategy but more remains to be done. I firmly believe that success can be achieved and that the explosives sector has a strong and safe future, but this will rely on more and better co-operation and collaboration between all stakeholders in the sector, whether they be regulators or regulated, business leaders or workers, or bodies such as SAFEX or the Institute of Explosives Engineers, which set out to improve knowledge, competence and standards of professionalism throughout the industry.

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Global trends in classifying and regulating explosives – and ANE (UN3375)

by

Ken Price (Riskom International Pty Ltd)

Ken Price is an Individual Associate who was an explosives regulator for 30 years and retired as the CIE of Western Australia in 2001..

Two big issues appear to be developing in the world of explosives:

- A loss of technical competence at senior decision making levels (replacement of Chief Inspectors of Explosives who had technical competence, with generalist administrators); and
- A greater reliance on the United Nations Manual of Tests and Criteria for classifying explosives and legitimate explosives precursors (ammonium nitrate emulsions, suspensions and gels).

In the olden days (perhaps only as long ago as 10 years) jurisdictions that historically were part of the British Empire had a position typically titled Chief Inspector of Explosives. The person in this position had a high level of technical competence in the field of explosives safety and his role was to administer the explosives safety legislation on behalf of the public. The Chief Inspector's position was a reflection of the highly technical and changing world of explosives and his role was to interpret the legislation and make decisions that would allow industry to develop while assuring public and worker safety. Similar positions have existed in many other countries.

Over the years, legislation, in the guise of being "performance based", has largely replaced the legislation based on the original 1875 UK Explosives Act. And in parallel with this many technically competent Chief Inspectors have been replaced by an administrator, usually someone with no technical competence.

In a typical situation, industry may develop something different, which they confirm with the inspectorate that they are legally on shaky ground; perhaps the regulations didn't contemplate this. To make the situation legal, previously it was necessary to convince the Chief Inspector that all was safe and a decision could be made. Now, the inspectorate must prove to their administrative chiefs that the new position is safe, and often this can be extremely difficult to do.

Typically now, there will be some sort of legislative position with the legal authority to make administrative decisions, however the occupant will not have the technical competence to understand the nuances of the issue of concern.

This is usually done in the guise of "transparency" or to avoid the possibility of corruption of the decision making process. To put it bluntly, politicians no longer trust their civil servants.

One of the consequences of this change has been a reliance on the exact wording of the legislation. Without technical competence, the administrator of the legislation is in no position to give exemptions or approvals to deviate from the written word. If in doubt, the response will be: "comply with the regulations/Code of Practice". This is creating significant problems within the industry.

The United Nations Manual of Tests and Criteria

In the environment of explosives development, transport and testing, the above changes are diabolical for industry as they are placed squarely on the horns of a dilemma.

The Manual of Tests and Criteria specifically states:

1.1.2 It should be noted that the Manual of Tests and Criteria is not a concise formulation of testing procedures that will unerringly lead to a proper classification of products. It therefore assumes competence on the part of the testing authority and leaves responsibility for classification with them.

The Manual has been drafted (primarily by testing laboratories) with this in mind, and those testing laboratories have competently made variations to the tests and cooperated with each other with round-robin tests to validate their testing activities.

Increasingly however, explosives are being developed outside the mainstream traditional sources of explosives and we increasingly see South Africa, Australia, Malaysia, and others needing test results on emulsions without access to European Notified Bodies or North American laboratories. This need for widespread testing facilities is further compounded by the requirement in the IMDG Code for any Ammonium Nitrate Emulsion transported in tanks to be subjected to Test Series 8. (This requirement is hidden away in Special Tank Provision TP32, which effectively requires any emulsion transported in tanks to perform satisfactorily in the 8 (d) (Vented Pipe) test.)

When these "outlying regions" try to perform the tests they find the exact materials prescribed in the Manual are difficult or impossible to obtain. At this point, a simple "follow what is written in the Manual" is not much help. And it is made worse by the prohibition on transport of emulsions by air or without specific Competent Authority approval of the packaging for surface modes.

There is some light at the end of the tunnel.

At the recent meeting of the United Nations Committee of Experts on Transport of Dangerous Goods, in Geneva in July 2012, numerous changes were made to the United Nations Model Regulations for the Transport of Dangerous Goods and the Manual of Tests and Criteria.

In brief, the United Nations Subcommittee of Experts agreed the following:

- The pentolite boosters used in Test Series 8 may be simple cast boosters, not pressed as prescribed;
- The steel tubing used in the 8 (b) test need not be cold drawn, and the dimensions have been more closely aligned with commercially available pipe or tubing;
- The PMMA (Perspex) rod used for the gap in the 8 (b) test need not be cast – it may be the more commonly available extruded rod;
- The steel witness plate needs only be mild steel;
- IBCs were recognised as valid transport containers for Ammonium Nitrate Emulsion, Suspension or Gel (UN3375) without the need for Competent Authority approval.

In conjunction with these decisions, the United Nations Subcommittee of Experts also agreed to a gradual revision of the Manual of Tests and Criteria. This is likely to be a fairly protracted affair over at least 4 years. The initial focus will be on obvious errors in the text and then an examination of identified areas in need of revision.

At the last International Conference of Chief Inspectors of Explosives in Berlin, held in conjunction with the IGUS EPP meeting in May 2012 the industry delegates agreed to work with regional administrators to assist with the review.

IME agreed to coordinate the review of Test Series 6 and AEISG (Australia) agreed to coordinate work on Test Series 8. South Africa and USA industry groups also offered support where needed.

This will be a long slow process, but hopefully it will produce a Manual that is either clearly more flexible or clearly prescriptive in a form that the entire explosives world can follow.

Workplace Proficiency

All explosives manufacturers recognise the importance of training and developing people who work in and are responsible for explosives operations. SAFEX recently responded to a perceived need to develop leaders of explosives operations at all levels by embarking on the development of the *SAFEXplosives Management Course* in e-learning format. We are not alone in trying to support SAFEX members in their quest for improved workplace proficiency. One of the specialist organisations with which we collaborate is *EUExcert*. *EUExcert* is a project that plans to establish a firm, stable framework for vocational education of people in the explosives sector. SAFEX is willing to partner with anyone or use any technology that can contribute to the explosives specific aspects of people development and make our workplaces safer. We all share one objective and that is to reduce the number of accidents in the explosives industry. This Newsletter feature enables members and readers to contribute relevant articles with this objective in mind. SAFEX will not promote or endorse any commercially available training product or service but will publish relevant contributions in order to keep its members informed of developments in the field.

Explosives Qualifications Accredited

By

Denise Clarke (Managing Director, Homelands Security Qualifications)

In the 4th Quarter, 2011 SAFEX Newsletter, Denise was co-author of an article introducing explosives occupational standards. The company she represents is Homeland Security Qualifications (HSQ) which provides awarding body services to the explosives industry in the UK and abroad. Readers may be interested in the developments outlined in her contribution.

Homeland Security Qualifications (HSQ) began in 2006 as a company dedicated to supporting the continuing development of competence standards and qualifications for the explosives industry. By 2008, it was clear that the unique structure and needs of the United Kingdom's explosives industry did not suit conventional awarding bodies. We have therefore set out to provide awarding body services to the explosives industry – both at home and abroad. HSQ is now able to offer nationally accredited qualifications through its partnering arrangements with the Institute of Commercial Management, although HSQ is not yet itself accredited by the Office of the Qualifications and Examinations Regulator (Ofqual).

Through our partnership with the Institute of Commercial Management, HSQ has recently gained national accreditations for three more explosives-related qualifications:

- L2 Certificate in Explosives Storage (Ofqual ref: 600/6826/7)
- L2 Certificate in Explosives Maintenance (Ofqual ref: 600/6776/7)
- L2 Diploma in Explosives Storage and Maintenance (Ofqual ref: 600/6828/0)

These qualifications are designed to accredit the technical competence of those who work in explosives storage facilities, those who maintain explosives and those whose responsibilities combine both. The L2 Diploma will be used to underpin the Apprenticeship in Explosives Storage and Maintenance which is currently under development.

To view the details of the qualifications on The Register of Regulated Qualifications, please go to: http://register.ofqual.gov.uk/

For more information about HSQ and how to deliver these qualifications, please visit: http://www.homelandsecurityqualifiations.co.uk

Over the coming months, HSQ plans to offer more nationally accredited qualifications relating to competence in working with explosives. The company also offers industry-recognized qualifications based on the National Occupational Standards in Explosive Substances and Articles and is able to offer an accreditation service for in-organization training and competence development measures.

The 6th ICEECS is Calling for Papers

The EUExcert Association and KCEM are pleased to invite readers to participate in the 6th International Conference on Explosive Education and Certification of Skills (ICEECS), to be held at Nottingham Belfry Hotel, in Nottingham, United Kingdom, on 2nd and 3rd of May 2013. The registration fee for the two days is EUR 350 for Conference delegates and EUR 250 for speakers. Registration forms will be available on the conference website www.kcem.se or www.euexcert.org .

The overall objectives of the Conference are to contribute to the harmonization of training and qualification of personnel in the explosives sector for the development of a transferable certificate of Explosive Competences, through the discussion and sharing of knowledge, as well as experiences on the training and procedure of accreditation of individual competencies. The conference addresses all people occupied and active in the sector of explosives (explosives, propellants and pyrotechnics).

Authors have 30 minutes including 5 minutes for questions to present their papers orally. Opportunities to make poster presentation will be provided if requested. Papers and posters will be reviewed on the basis of an Abstract of not more than two pages (maximum 800 words Times New Roman), with optional figures and tables together with exact title, author(s) name and affiliation. Interested authors are invited to submit their Abstracts in English to Mr. Erik Nilsson at erik.nilsson@kcem.se by 15 February 2013.

Explosives Eco-talk

The impact explosives and explosives manufacture has on the Environment fall squarely in the SAFEX domain. We are committed to publish the experiences members of the SAFEX community (Members, Associates and Expert Panel) have in minimising explosives' environmental impact. While most of our explosives incidents concern the safety and health impact, we are eager to learn about the environmental side of our activities. By way of this Feature we want to encourage readers to let us have contributions which create awareness of this facet of our operations as well as assist our industry to behave with environmental sensitivity and responsibility.

"Greener" Detonators using Nickel Hydrazine Nitrate (NHN)

by

Srinivasa Rao (Production Director, Premier Explosives Ltd, India)

INTRODUCTION

Historically detonators used mercury fulminates as the primary explosives. Being ultra sensitive to friction and impact, it was replaced with a combination of lead azide (LA) and lead styphnate (LS) along with a small quantity of aluminium powder. This is commonly known as ASA.

ASA had been a common primary explosive since its advent some 70 years ago. Though safer than mercury fulminate, ASA is quite sensitive to friction, impact, static electricity, etc. Our observation is that most of the untoward incidents in the detonator production process occur during handling, drying and manipulation of lead azide, lead styphnate or ASA. There have been efforts all over the world to develop a safer molecule or a mix to replace LA, LS or their combination.

A primary explosive needs to be sensitive enough to initiate a detonator but at the same time it should also be safe enough during manufacture. These are conflicting requirements making it difficult to find an alternative. The primary explosive charge in a detonator is initiated by the flash from the squib or fuse head, then starts deflagrating before evolving in a reliable detonation that sets off the base charge of the detonator. Nickel hydrazine nitrate (NHN) has been identified as a suitable replacement for LA and LS as well as ASA in detonators.

PROPERTIES OF NHN:

NHN is a bright purple coloured and free flowing powder having the following properties:

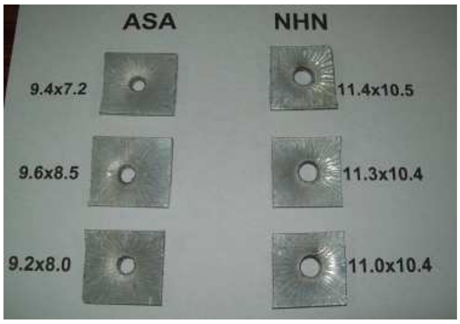
Molecular Formula	$N_i H_{12} N_8 O_6$
Formula weight	278.69
Colour	Purple violet
Crystal density (g/cm^3)	2.1
Nickel content (%)	21.16
Hydrazine content (%)	34.46
Nitrate content (%)	44.47
Nitrogen content in co-ordination sphere (%)	30.25
FTIR peaks, (cm $^{-1}$)	3238, 1630 (NH_2); 1356, 1321 ($-NO_3$)
Moisture content (at 333K for 10 min) (%)	0.34
Average mol wt of combustion products	27.35
Percent condensable Ni (l)	18
Oxygen-fuel ratio	0.8571

***Photograph 1* (below)**: *Appearance of HNH synthesised at Premier Explosives*

***Table 1* (below)**: *Comparison of VOD's of primary explosives*

Compound	VOD m/sec	Density g/ml
LA	4630	3.0
LS	4900	2.6
DDNP	6600	1.5
NHN	7000	1.7
DDNP = Diazodinitrophenol		

***Photograph 2* (below)**: *Comparison of Al witness plate tests*



With a decomposition temperature of over 2000 °C, it is a stable compound. The NHN synthesised at Premier Explosives has a polycrystalline structure and is almost spherical in shape (see Photograph 1). It is free flowing and amenable to the dosing and consolidation required during the manufacture of detonators. In in-house testing at the laboratory of Premier Explosives, NHN was found to be less sensitive than ASA in friction sensitivity with 50g torpedo released at 80° angle as shown below:

- NHN: 50% Ignition height = 40 - 45 cm
- ASA: 50% Ignition height = 15 cm

DETONATOR PERFRORMANCE—NHN v ASA

Being relatively insensitive to impact and friction, NHN has lower capacity to move from deflagration to detonation. A longer column is, therefore, required to achieve full detonation. However, under optimum conditions it has a higher VOD compared to other primary explosives. VOD of various primary explosives are compared in Table 1. The NHN detonators give a very reliable initiation of base charge and give equivalent or better dent in 3mm aluminium witness plate than that of ASA as Photograph 2 illustrates.

Various products manufactured by Premier with NHN have been successfully qualified by Departmental Testing Lab of Petroleum and Explosive Safety Organisation (PESO). Their effectiveness has been further upheld in actual use on the mines. After various tests, Premier's NHN-based detonators have been included in the list of Authorised Explosives by PESO.

Premier is now regularly manufacturing all types of NHN based detonators on a commercial scale. They are not only free of lead chemicals but safer too .

Pondering the Profession

This column is devoted to our 'Safety Professionals' in recognition of the important role they play in the explosive industry's health, safety and environment efforts. It is intended to be a forum in which we can talk about the Profession. Our aim is that this column will be read by all but that the Safety Professionals in our industry will make it their own.

SAFEX has a high regard for the role of the Safety Professional in our industry and wants to enhance their effectiveness and standing. We therefore urge Safety Professionals to let us have their contributions for this column. Unfortunately, we have not received any contributions for this edition of the Newsletter. However, we hope to feature it again in the next Newsletter.

Safety Snippets

Separation distances between solid ammonium nitrate stores and off-site occupied buildings – an Australian perspective

by

Peter Drygala (Chief Advisor Explosives and Dangerous Goods, Western Australia)

Dr Peter Drygala works as an explosives and dangerous goods advisor and regulator for the Dangerous Goods Safety Branch of the Western Australian Department of Mines and Petroleum. The views in this paper are those of the author and not necessarily those of the department. The author wishes to thank the department for supporting this work

INTRODUCTION

The use of ammonium nitrate (AN) in Australia's mining industry has doubled over the last 10 years. Australia now uses in excess of 2 million tonnes of AN per year, usage is rising continually. In parallel, the production capacity of Australia's existing ammonium nitrate plants is expanding.

In Western Australia new AN stores with up to 20,000 tonnes have recently been commissioned in the Pilbara mining centres of Port Hedland and Karratha to service the iron ore mines. Encroachment by residential and accommodation developments have been proposed. Similar situations occur in the other two big mining states of Australia – Queensland and New South Wales.

Local Government, industry and the community need urgent guidance on the land use compatibility of new AN stores with residential and commercial developments. Comprehensive guidance with an unassailable rationale is needed to avoid expensive and lengthy litigations to settle disputes between competing parties.

This paper aims to provide the necessary comprehensive guidance. It is a timely contribution not just for Australia, but for other countries with communities that aspire to a similar high level of public safety.

The conclusions on safety distances in this paper aligns the safety distances for solid AN with the generic risk criteria for land use around hazardous industries contained in the NSW Department of Planning advisory paper titled "Risk Criteria for Land Use Safety Planning" (HIPAP4)[1].

The conclusions would not have been possible without comparing these generic risk criteria with the likelihood frequency for accidental explosions published in the in the SAFEX International *Good Practice Guide: Storage of Solid Technical Grade Ammonium Nitrate* (SAFEX Code) [2].

RECENT INCREASES IN SEPARATION DISTANCES TO AMMONIUM NITRATE STORES IN AUSTRALIA

Over the last 15 to 20 years Australia has seen a significant shift in the thinking on the size of safety/separation distances: the distances between AN stores possessing an explosion risk (UN 1942 and UN 2067) and off-site occupied buildings.

The 1995 edition of the Australian Standard AS 4326 – "*The storage and handling of oxidising agents*" required a separation distance of only 8 metres from any type of off-site buildings for any storage exceeding 50 tonnes.

The standards committee responsible for the 2008 edition of AS 4326 could not agree on any separation distances and simply referred the reader to the relevant State or Territory regulations. None of these regulations offer any useful guidance. The legislation is general and performance-based containing duties to isolate dangerous goods installations from people and property by means of distance or barrier "as far as reasonably practicable".

However, some useful guidance is found in the Western Australian Code of Practice (2012/ second edition) regarding "*The safe storage of solid ammonium nitrate*" (WA Code) [3], the Queensland Government *Information Bulletin No. 53* [4] and in the SAFEX Code [2].

These publications feature quantity/

distance tables and agree on recommended minimum distances to off-site "protected works" based on a 7 kPa overpressure calculated using D = 17.8 $Q^{1/3}$ (where D is the distance in meters and Q is the TNT equivalence in kg).

For instance, Table 4.1 in the WA Code shows the "recommended minimum separation distance" between the maximum allowable stack of 500 tonne to off-site protected works to be 890 metres. This assumes adequate inter-stack distances so that stacks do not explode sympathetically.

Hence over the 17 years between editions of AS 4326, there has been an increase in separation distances from 8 to 890 metres for off-site occupied buildings.

The TNT equivalence for accidental AN explosions vary widely with circumstances and depends on the bulk density, the mode of initiation of the explosion, the configuration of the stack and even the type of material. It is therefore necessary to choose an average value. A TNT equivalence value of 25% has been used throughout this paper in line with the WA Code.

REASONS FOR THE INCREASED SEPARATION DISTANCES

The reasons for the increased distances are not obvious, but an examination of the underlying factors is revealing. There are three important factors driving the debate over safety distances and these are explained below. They are in addition to the expansion of the use of AN and the clash of incompatible land use between AN stores and other land use developments.

The legislative requirement for a hazard analysis

The first decade of the century saw the introduction of performance-based dangerous goods regulations in Australia based on the national standard "Storage and Handling of Workplace Dangerous Goods" [NOHSC: 1015 (2001)] [5].

The new regulations contain a mandatory duty for industry to perform a hazard analysis for any significant dangerous goods installations. As a result safety professionals tried to determine the likelihood and consequence of chemical hazards including the explosion hazards emanating from ammonium nitrate of Division 5.1.

It is this hazard-analysis approach that has determined the larger separation distances – the old separation distances were based largely on guess work.

The Toulouse explosion

The distances have also been affected by the disastrous Toulouse explosion on 21 September 2001.

Government Regulators were shocked by the high consequences of the explosion of fertilizer grade AN at the Toulouse AZF fertilizer plant: 29 fatalities included 8 member of the public and some 2,400 people living in the surrounding suburbs were injured [6].

The lesson from that calamity was that society should not rely exclusively on likelihood reduction measures since safety management systems are subject to failure. Companies can find it difficult to impose sufficient operational discipline on their employees, either because of the absence of procedures or because procedures are flawed or not followed depending on the quality of the safety culture in the organisation.

The better solution is to reduce the consequence of the explosion through increased separation distances. These increased distances must not be unnecessarily large since the competition for available land can be fierce and a compromise between absolute safety and practicality needs to be struck to do justice to all community interests.

Inter-stack distances

Finally, there can be no proper consequence or hazard analysis of accidental explosions without an understanding of the inter-stack distances required to prevent sympathetic explosions.

If inter-stack distances are insufficient, then separation distances to off-site protected works need to be based on the total amount of AN stored in a building, instead of just the amount in a single stack.

The total storage quantity in a building is often 5,000 tonnes, while the quantity in the largest stack is typically 500 tonnes, the maximum amount permitted in a single stack in Australia.

Recent years have seen definitive experimental studies estimating the inter-stack distances for stacks/piles of AN that will prevent sympathetic detonation. These can now be used with confidence to determine how to avoid a sympathetic detonation. In this respect the landmark study by Erik Nygaard of Yara International ASA on the "*Storage of technical (porous) ammonium nitrate*" should be consulted [7].

As a result, simple rules governing inter-stack distances can now be applied to practical situations and their size depends on the bulk density of the AN as well as the way the stacks are configured and whether they are IBCs or bulk.

The current Australian Standard, AS 4326 (2008) is deficient in this regard, since it allows an inter-stack distance for IBCs, without regard to the bulk density or stack configuration, of 3 metres. It has now been demonstrated that the inter-stack distance should be at least 9 metres for the type of low density (porous) technical grade AN commonly used in Australia with bulk densities in the range of 0.75 g/cc to 0.85 g/cc.

See Table 1 on next page. which is based on the work by Erik Nygaard [7]. Inter-stack distances were derived from small-scale gap tests performed between ANFO and AN to determine the critical initiation pressure to produce sympathetic detonation, followed by computer simulations.

ESTIMATION OF THE LIKELIHOOD OF AN EXPLOSION DURING STORAGE FROM THE SAFEX CODE

The history of accidental AN explosions shows that the storage of AN is relatively safe, certainly safer than the operations of transport or manufacture.

There have been very few accidental explosions during storage following early explosions and major disasters such as the Oppau explosion on 21 September 1921 and the ship explosions at Texas City in 1947. With the benefit of hindsight, these early explosions occurred due to a profound ignorance of

Table 1: *Inter-stack distances*

Type of storage	Stacking configuration	Separation between stacks in metres
IBCs	Normal configuration where each successive layer is set back half an IBC diameter from the layer below	Low density – 16 Medium density – 9 High density - 1
IBCs	Pyramidal configuration where each successive layer is set back one and a half IBC diameters from the layer below	Low density – 9 Medium density – 7 High density - 1
Where: • Low density AN: less than 0.75 g/cc; • Medium density AN: equal to or greater than 0.75 g/cc, but less than or equal to 0.85 g/cc; • High density AN: greater than 0.85 g/cc;		

the chemistry and hazards of AN. The causation of these disasters seems no longer relevant to modern storage practices.

To understand the likelihood of AN explosion, it is relevant to look at the history of storage explosions since 1950.

The safety literature contains three storage explosions since 1950:

1. Cherokee Nitrogen company in Oklahoma on 17 January 1973 [8];
2. Toulouse AZF plant explosion on 21 September 2001 [6];
3. Farmer's barn explosion in St Romain en Jarez (a village in France) on 2 Oct 2003 [9];

The SAFEX Code lists the following estimates of the likelihood of an accidental explosion (from historical data) in chances in a million per year as follows:

1. IBCs without the presence of wooden pallets – 55;
2. IBCs with wooden pallets – 80;
3. Bulk storage – 70;

These estimates have been used as the basis for the development of a risk assessment policy in this paper.

RECOMMENDED RISK CRITERIA FROM HIPAP4

The assessment of risk necessitates the establishment of criteria against which judgements can be made as to the compatibility of various land uses. The adoption of formal criteria assists in providing a consistent and transparent approach in the decision-making process of deciding the suitability of various land uses in the vicinity of the AN store.

There are two dimensions of risk which should be considered separately, individual and societal. On the one hand, the individual's concern about their own life or safety is mostly independent of whether the risk is from an isolated incident or a large scale disaster. Society's risk perception, however, is mostly influenced by multiple-fatalities disasters.

This discussion will look exclusively at the individual fatality and injury risk, but the Regulator and the industry need to keep in mind that the placement of high population developments of any kind warrants an additional consideration of societal risk.

1. Hospitals, schools, child-care facilities, old age housing – 0.5
2. Residential, hotels, motels, tourist resorts – 1
3. Commercial developments including retail centres, offices and entertainment centres – 5
4. Sporting complexes and active open space – 10
5. Industrial – 50

HIPAP4 uses the following individual fatality risk criteria for the various land uses as a risk in a million per year:

In setting these criteria, HIPAP4 has taken some account of the variations in the duration of exposure to the risk at any particular point by any one individual. Likewise people's vulnerability to the hazard and their ability to evacuate was also a factor.

The one in a million criterion assumes that residents will be at their place of residence and exposed to the risk for 24 hours a day, continuously day after day for the whole year. In practice this is not the case and this criterion is conservative.

On the other hand, land uses such as commercial, retail or open space do not involve continuous occupancy. Individual occupancy is intermittent and people tend to be more mobile and therefore a higher level of risk may be tolerated. It is possible that societal risk considerations may out way individual fatality risk considerations for very high population developments.

HIPAP4 provides additional injury risk criteria for explosion overpressure for residential and sensitive use areas as follows:

> *"Incident explosion overpressure at residential and sensitive use areas should not exceed 7 kPa at frequencies of more than 50 chances in a million per year."*

Finally HIPAP4 also contains a recommended explosion overpressure maximum of 14 kPa at a frequency of more than 50 chances in a million per year to protect off-side property damage to buildings.

HIPAP 4 not only represents the only comprehensive government source of risk criteria for explosions in Australia, but appears to fit well with community expectations.

The 7 kPa value to protect against injury for residential developments is likely to be the most acceptable maximum overpressure value when compared to any others listed in Table 2 on the next page, which is copied from HIPAP4.

***Table 2**: Effects of Explosion Overpressure*

Explosion over-pressure	Effect
3.5 kPa (0.5 psi)	• 90% glass breakage • No fatality and very low probability of injury
7 kPa (1 psi)	• Damage to internal partitions and joinery but can be repaired • Probability of injury is 10%. No fatality
14 kPa (2 psi)	• House uninhabitable and badly cracked
21 kPa (3 psi)	• Reinforced structures distort • Storage tanks fail • 20% chance of fatality to a person in a building
35 kPa (5 psi)	• House uninhabitable • Wagons and plant items overturned • Threshold of eardrum damage • 50% chance of fatality for a person in a building and 15% chance of fatality for a person in the open
70 kPa (10 psi)	• Threshold of lung damage • 100% chance of fatality for a person in a building or in the open • Complete demolition of houses

RISK ASSESSMENT POLICY FOR AMMONIUM NITRATE STORES

When applying the above HIPAP4 risk criteria, and comparing them with the likelihood of an accidental explosion taken from the SAFEX Code, it is possible to arrive at rules or risk assessment policies capable of guiding the regulator, industry and other stakeholders

The Regulator should incorporate four columns of quantity/distance tables of "recommended safety distances" into an approved, non-mandatory code of practice on the safe storage of solid AN. One column for each of the following four types of land uses, which are further discussed below under separate headings:

1. Residential developments;
2. Commercial developments;
3. Industrial developments and "sporting complexes and active open spaces" and
4. Vulnerable facilities.

This legislative approach gives the Regulator the ability to enforce the distances in a suitably flexible way to satisfy competing interests.

The enforcing legislation needs to be performance-based and enable the approval of non-mandatory codes of practice by the Minister. This is the usual arrangement in Australian OH&S and dangerous goods legislation.

Recommended minimum distances for residential developments (7 kPa)

The likelihood values for the accidental explosion risk of 55, 80 and 70 chances in a million for IBCs and bulk AN storages respectively are sufficiently high to justify the application of the 7 kPa criterion for injury risk at residential and sensitive use developments since it is "*more than 50 chances in a million per year*".

What happens if a particular proposal does not conform to the 7 kPa distances and overpressures at the off-site residential development exceed 7 kPa?

Four options are available to satisfy the 7kPa injury criterion:

1. Increase the separation distance so that the 7 kPa distance is conforming.
2. Apply additional risk controls to the AN store (additional to the standard requirements in the WA Code) and reduce the likelihood of an accidental explosion well below a risk of 50 in a million. Industry will be able to suggest a number of solutions including:
   a. the installation of superior fire fighting systems, such as a sprinkler system,
   b. the installation of CCTV or nitrous oxide detection meters to give an early detection of smoke/flame or nitrous oxide;
   c. Improvements in the emergency response arrangements;
   d. The exclusion of vehicles from the AN building to avoid a potential source of fire and contamination;
   e. Improvements in preserving the purity and consistency of the AN;
3. Reducing the consequence of the explosion by achieving the safety distances through a reduction of the maximum stack size.
4. A mixture of some or all of the above options.

Option 2 is likely to be favoured by dangerous goods operators, since it will allow for a maximum stack size of 500 tonnes and therefore maximise the available storage space and allow the most cost-effective use for the AN store.

However, option 2 relies on the quality/reliability of the control measure. It also relies on a good safety management system and on the quality of the organisational safety culture. That safety culture depends on good leadership and may be subject to change over time.

Option 3 is the more effective and certain way to ensure public safety. It does not depend on the preservation of the safety management system as long as the stack size is properly controlled.

The particular HIPAP4 injury criterion permits exceeding the 7 kPa overpressure subject to lowering the likelihood frequency below 50 chances in a million. Nevertheless, regardless of such likelihood reduction measures, the maximum overpressure for residential developments should never exceed 14 kPa.

A 14 kPa overpressure is already associated with a 1%

chance of fatality due to partial collapse of some buildings [10]. Therefore the individual fatality risk for residential developments would be 0.01 x 55 x 10^{-6} = 0.55 x 10^{-6} in the case of an IBC store without wooden pallets. This value still complies with the widely accepted risk criterion for individual fatality risk of one in a million, but any larger overpressure than 14 kPa will not comply, because of the associated rise in fatality risk.

Using the formula D = 10.4 $Q^{1/3}$ for a 14 kPa overpressure [4] one calculates a distance D = 520 m (instead of 890 m for 7 kPa) assuming a stack of 500 tonnes and 25% TNT equivalence. This illustrates the degree of flexibility in safety distances that is potentially open to the Regulator without demanding a reduction in stack size.

Recommended minimum distances for commercial developments (14 kPa)

Any code of practice in regard to AN safety distances needs to distinguish between the safety distances to residential developments on one hand and to commercial developments on the other hand. The reason for this is that the HIPAP4 injury criterion of 7 kPa only applies to residential developments and the individual fatality risk for commercial land uses is higher.

It is proposed that the code of practice needs to include a column for the 14 kPa safety distances to "commercial developments including retail centres, offices and entertainment centres". These have an individual fatality risk of 5 in a million.

Again there needs to be flexibility in the application of the 14 kPa safety distances. It is suggested that the upper overpressure limit for this type of land use be 21 kPa. This overpressure is associated with a 20% fatality risk and the individual fatality risk for commercial developments would be 0.20 x 55 x 10^{-6} = 11 x 10^{-6} in the case of an IBC store with no wooden pallets. This exceeds the criterion of 5 in a million and would therefore require significant additional likelihood reduction measures.

Recommended minimum distances for industrial developments, sporting complexes and active open spaces (21 kPa)

The code of practice should also include the 21 kPa safety distances for "industrial developments". In this case there seems to be a little flexibility for higher overpressures as long as the individual fatality risk criterion of 50 in a million per year is adhered to.

It is difficult to set safety distances for "sporting complexes and active open spaces" because of the transient nature that an individual user of the open space is exposed to the risk. As a guide one should use the 21 kPa distances.

At first glance the fatality risk of 11 in a million appears to correlate with the HIPAP4 risk criterion of 10 in a million for "sporting complexes and active open spaces" (for an IBC store without wooden pallets). However, the actual fatality risk of any individual user of open spaces would always be much less than one in a million per year because of the transient exposure. It seems that only a societal risk assessment can arrive at a meaningful decision for sports stadia and other open-air venues where the exposed population is very high.

Recommended minimum distances for vulnerable facilities (5 kPa)

There is a need to cater for the most sensitive land uses. Any code of practice should distinguish between "vulnerable facilities" such as hospitals, schools, child-care facilities, old age housing and high density multi-storey residential apartments on one hand and ordinary single family suburban dwellings on the other hand.

It is suggested that these "vulnerable facilities" be given greater protection at the larger 5 kPa distances. Non-conforming distances need to be rectified by the reduction of the biggest stack size without allowing flexibility by the reduction in likelihood. The problem with relying on a likelihood reduction alone is that the estimation of likelihood is fraught with uncertainty, while a reduction in consequence gives certainty in regard to avoiding the worst injury and damage to people and property.

One could also use a 3.5 kPa overpressure advocated in the SAFEX Code, but this appears overly conservative in view of the very low likelihood of an explosion. Such large safety distances are not advocated in the Queensland Government information bulletin [4].

The 5 kPa distances are used in Australia for separating class 1 explosives from off-site occupied buildings (see AS 2187.1). They give protections from fatalities and allow a low chance of injury. It seems a suitable choice for vulnerable facilities given the lower likelihood of an explosion with AN when compared to class 1 explosives.

SUMMARY OF RECOMMENDED RISK ASSESSMENT POLICIES

In summary this paper recommends any code of practice should contain four columns of "recommended safety distances" for the following off-site land uses (calculated using a TNT equivalence of 25%):

1. Vulnerable facilities such as hospitals, schools, child-care facilities, old age housing 5 kPa – D= 22.2 $Q^{1/3}$ [3]
2. Residential developments including hotels, motels and tourist resorts 7 kPa – D = 17.8 $Q^{1/3}$ [2, 3,4]
3. Commercial developments including retail centres, offices and entertainment centres 14 kPa – D = 10.4 $Q^{1/3}$ [2,4]
4. Sporting complexes and active open space and industrial areas 21 kPa – D = 7.8 $Q^{1/3}$ [2]

It is recommended that the Regulator, industry and other stakeholders should apply the following rules when negotiating the best outcome over non-conformances with the above "recommended safety distances" to off-site land uses:

1. Strict adoption of inter-stack distances to prevent sympathetic detonations;
2. Compliance with the HIPAP4 criteria for individual

fatality risk and injury risk;

3. Additional likelihood reduction measures (beyond those recommended as standard by the WA Code or the SAFEX Code) must be put in place to exceed any of the designated safety distances;
4. There is little ability to tolerate non-conforming distances for “vulnerable facilities” and conformance will need to be achieved through distance or stack reduction of the maximum stack size;
5. The higher the population density of the development the greater the need to keep to the designated separation distances and the more effective the additional likelihood reduction measures have to be to tolerate non-conformances;
6. For high population densities an additional assessment of societal risk may be necessary

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2013 IGUS-EPP Meeting and International Conference of CIE’s Announced

Delegates at the 2012 IGUS-EPP Meeting and 12th International CIE Conference during field trip to BAM facilities, Horstwalde, Germany

The IGUS Explosives, Propellants, and Pyrotechnics Working Group and the 13th International Conference of Chief Inspectors of Explosives have announced their 2013 meeting schedule. They will meet in Oviedo, Spain from 7 - 13 April 2013. The meetings will be hosted by:

- LOM, the Spanish testing authority
- Spain's Chief Inspector of Explosives
- MAXAM

The meetings will include technical discussions, a field trip to the Museum of Mining and Industry in El Entrego and an open forum conference with many of the world's chief inspectors of explosives. **SAFEX members** and other interested **industry members** are invited to attend. Those interested in attending can contact the SAFEX Secretariat for the following information:

- Preliminary notification
- Call for papers and registration form
- Accommodation and transportation details

EFEE 7th World Conference on Explosives and Blasting Call for Papers

The European Federation of Explosives Engineers (EFEE) has called for Papers for their 7th World Conference which will be held at the Hotel Cosmos in the Prospekt Mira district of Moscow, Russia. The Conference purposes to bring together people from the explosives and blasting techniques disciplines. It should provide delegates with a forum to share the latest developments and technical practices combined with an opportunity to network with peers throughout the world'

Members and non-members of EFEE are invited to submit abstracts for papers to be presented at the Conference. Authors must be prepared to present their papers which must not be of a commercial or advertising nature in person. Authors are invited to submit an abstract in English and/or Russian by 31 January 2013. The abstract should summarise the proposed paper and highlight its major points in 200 - 400 words. The online submission form must be completed to express an interest in submitting an abstract. Paper formatting and presentation guidelines will then be sent to authors.

The cost of the conference will be RUR 24 400 (about EUR 610) per delegate for registrations before 31 May 2013. Thereafter it will cost RUR 26 800 (about EUR 670) for a delegated to register.

Inbox @ SAFEX-International.org

From time to time we receive e-mails from members of the SAFEX community on a variety of issues. It is important we share such experiences and insights and if necessary debate them. Our quarterly Newsletter may just be the forum for doing so.

We therefore invite ALL readers to drop us a line at secretariat@safex-international.org if they want to raise an explosives health, safety or environmental issue or comment on any of the opinions received from our correspondents.

Understand the chemistry of our process reactions

An operator noted that after manufacture a batch of NHN was becoming hotter and moved it to an empty building before summoning supervision. Two managers inspected the batch and moved outside the building to confer on what they should do when the batch deflagrated. The two managers received minor injuries.

Maurice Bourgeois (GD-OTS) commented as follows on this Incident Notice: This incident shows how important it is to properly identify the risks when things go wrong. This was a real close call because the deflagration could have happened anytime in the presence of the employees who would have been seriously injured if not killed. The Basis of Safety should beforehand:

- Identify the risk of an exothermic reaction; and
- Suggest an emergency procedure e.g. drown the reacting material and evacuate the building promptly.

Is the risk of exothermic reaction of NHN a documented reaction? If not, I guess now it should be. I think it would be worthwhile that SAFEX members share their knowledge of such reactions with the explosives they handle or manufacture so SAFEX would have a data base of common reactions and preventive measures. For example, Pentolite when heated above a certain temperature transits into an exothermic reaction. Hence the melter should have a cooling system of some kind (e.g. hot water melt system which can be controlled to cool down the molten Pentolite mix.)

Tony's Tale-piece

A tailpiece is something that appears at the end of a publication. I guess it is derived from the tail of an animal which is (normally) fixed to "the end" of it. However, we refer to this feature as a "Tale-piece". It is not a spelling mistake but a different tale. This "tale" is about telling stories. While it appears at the end of our Newsletter, it is also meant to tell a story hence the play on words. Let me tell you what "Tony's Tale-piece" is about.

Tony Rowe from AEL Mining Services has kindly agreed to provide a regular feature based on truths he has discovered over many years in his work with explosives. He has a unique style of writing (perhaps "telling stories" may be a better way to describe it) which we hope gets a well-known message across in a new way. This Feature is there to remind readers of some explosive(s) truths in a different way!

Playing with Fire

by

Tony Rowe (AEL Mining Services)

Today is a good day. It is warm and the sun is shining. From my chair which I have cunningly positioned to be close to the window I can see the upper half of the world outside. There's a decrepit old tree out there. Amidst the tangle of its spreading canopy, I have spotted some movement. There! Clambering about amongst the dusty leaves I can see not one, but two, grey coloured and frowsy looking birds. Long tailed, they seemed to be adapted for climbing rather than flying. They remind me somehow of parrots, but there are no bright colours and neither bird has a hooked beak. They are handsome too, though in an austere sort of way. Beady black eyes have now found mine and are staring knowingly back. It is disconcerting. There is intelligence there. It just occurred to me that while I was watching them, they were also watching me. Suddenly in a flurry of wings, they both flew away. They were clumsy flyers though, possessing all the grace of a couple of pot-plucked chickens.

I think they were Louries, Go-Away birds, so named because of their distinctive call when disturbed. They apparently eat fruit and flowers. If that is indeed true then whatever do they eat during the South African Highveld winter when there is no such food about? No flowers. No fruit.

I began to speculate. For instance I've never seen a Lourie eating road kill or swooping down recklessly at passers by. No half eaten kittens in trees or even the odd, freshly pecked Jack Russell. I

suppose we should be grateful? Another mystery then? The world is filled with them. Hey, I was wondering the other day just how stuff ignites. Box of matches and a piece of paper. Strike the match and voila the paper, she is on fire. Oh look so are the curtains. Quick get a hose!

Is ignition really that simple?

Intrepid old me decided to have a look. On my desk lies a square shaped, plastic, "towery" thing. It is filled almost to the top with differently coloured squares of paper. Too small for the loo, they were clearly meant for ignition trials so I took one. Perfect .

Strike! With a hissing sound the match ignited, burning steadily with a bright yellow flame. I pass that flame quickly across my square of paper. I'm holding

my breath and….Nothing. It didn't light. I repeat the exercise. Nothing….. Again…. Still nothing. The match burns my fingers.

I am learning though.

I strike another match. I grab a fresh paper square. It's a pale green one this time. I hold the flame to a one corner of the paper. It immediately begins to blacken and curl. It is burning.

What have I learned? I've learned that ignition isn't just about temperature, there is a time component too.

I decide to wet a corner of the same square. I use a special mixture of stale old coffee especially left on my desk over this very weekend for the purpose. I strike yet another match and apply it to the coffee-dipped corner. I hold it there and the paper stubbornly refuses to light. I don't understand. Cold flame? Pass finger over flame. AAARRRRHHHHH!!! No! Hot flame. Apply cold water and seek medical help.

Has the ignition temperature of paper changed? I place the paper on my radiator where it soon dries out. It lights easily enough when dry. The coffee is doing something. There is a definite effect there. Aha! The coffee is absorbing the heat. It is trying to change face, I mean phase. Solid to liquid, liquid to gas. Coffee at office temperatures is already a liquid and if heated sufficiently will eventually become a gas, in this case steam, which will be driven off. To do this it needs heat and lots of it. Since the boiling point of water is far lower than the ignition temperature of the paper, the paper cannot ignite while the water is present. I keep the match flame on the wetted corner for much, much longer this time. The coffee progressively disappears. Eventually I am rewarded. The paper ignites and burns.

When we set things on fire we carry out quite complex deductive processes quite instinctively, without conscious thought. For instance we usually apply the flame to a corner of the paper. It lights easily. But, if we take a book (use an old one and not the Wife's latest Jodi Picoult novel) and clamp its pages together, the book doesn't light when we apply the match flame. Applying the flame to one corner doesn't help much either. Why? It is still paper, isn't it?

Now think about making a coal fire. Few people that I know would try to light any of the various lumps of coal directly with the match. Most of us would make a heap of stuff, paper, lots of wood and then coal on the top. Posh people use firelighters. They work too. The method though is the same, we light the easy stuff first, the paper or the firelighter. That in turn lights either the wood or the coal. That, like the book, is because its thermal mass is just too great for the amount of heat available.

I don't wish to delve too deeply though. I'm not that bright and will expose how little I really know. No, my aim is simply to provoke, to tease a little and get the reader to explore his or her world a little further. We are discussing some of the complex processes that manufacturers of explosive products have learned to fear. This article provides only the merest of glimpses into the strange world of interface problems, but for the technically minded, they remain as ever, the stuff of nightmares.

The answer though is always the same. Ignition is a function of time and temperature. You just have to get it hot enough for long enough.

Stay safe and remember "Explosives are never your friend."

You know it makes sense.

SAFEX thanks all Newsletter readers for their support and encouragement during 2012. We wish you all an incident-free Festive Season and a safe and successful 2013.

Boet Coetzee

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