



# SAFEX NEWSLETTER

## No. 42, 3rd Qtr 2012



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### ***This is your Captain Speaking***

#### **Juan Andres Errazuriz (Enaex)**



Juan Andres had an illustrious academic career graduating summa cum laude as an Industrial Civil Engineer from Pontificia Universidad Católica de Chile in 1991. After being singled out as the Best Undergraduate Student in Civil Industrial Engineering by Colegio de Ingenieros de Chile A.G., he was also adjudged to be the Best Graduate Student in his field. He was the recipient of the Ismael Valdes award which is given annually by "Instituto de Ingenieros de Chile" to recognise "ethical as well as organization and managerial ability". In 1993 Juan also obtained a Diploma in Marketing and Advertising.

After completing his studies he occupied various positions such as Development Manager, Manager of Study and Development and General Manager in a number of organisations in Chile before joining Enaex S.A as its Chief Executive Officer in 2009; a position he holds to this day.

Enaex, based in Santiago, Chile, is the largest explosives manufacturing and blasting services company in Latin America. It was founded by Nobel Industries, E.I. Du Pont de Nemours and Atlas Powder Co in November, 1920 and started production at the Rio Loa plant, near Calama city and Chuquicamata mine at the end of 1923. In 1968 Du Pont became the sole owner of the Company which was then sold to the Chilean government in 1972. Austin Powder Co. and local investors bought the Company in 1987 and changed its name to Enaex in 1989. Enaex has been a public traded company since 1991 with Sigdo Koppers S.A. the major shareholder.

In the last decade Enaex has expanded the activities to other countries in Latin America such as Argentina, Peru, Colombia and Brazil. Its products which are export to almost 40 countries all over the world range from dynamites to emulsions, PETN, ammonium nitrate, cast boosters and non-electric detonators. However, the Company's focus is on blasting services. With a fleet of almost one hundred ANFO and emulsion blend trucks, both for open pit and underground operations, it employs about 1.500 people

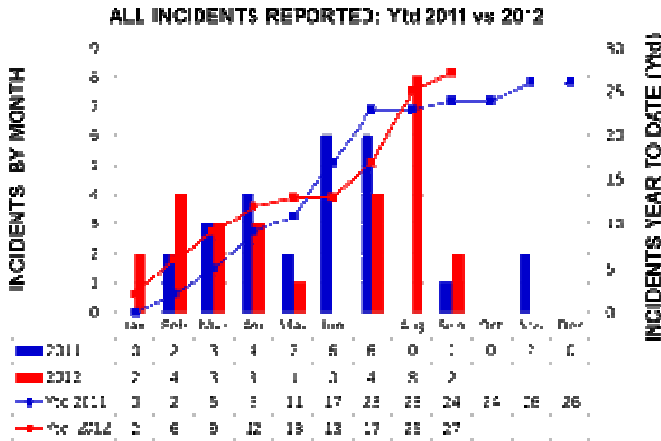
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# Incident Reporting

## Monitoring our Reporting Performance

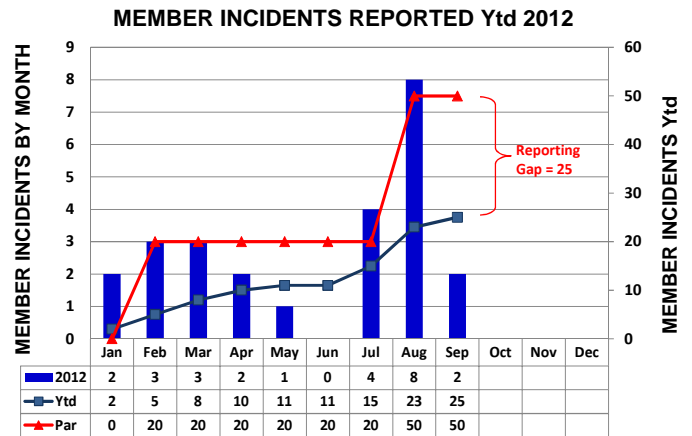
*“Every incident that is reported may prevent another from occurring. You can save a life by reporting an incident or near-event.”*

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:

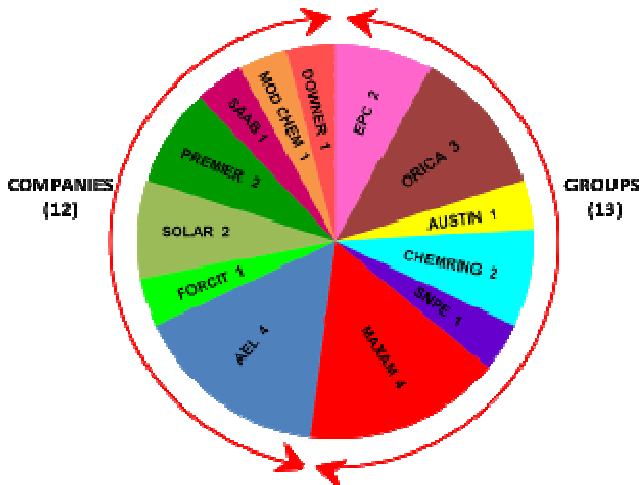


**All the incidents reported.** This chart compares this year’s sum of non-member and member incidents reported to SAFEX to the previous year’s. We have reported about the same number of incidents year to date than in the same period in 2011. As last year’s performance was lower than previous years the question remains: are we receiving all the reports we should? Every incident not reported is a lost learning opportunity. Remember, it’s never too late to report an incident.

**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. It is based on the severity of the MI’s that have been reported to date this year. The gap between the number of MI’s reported and PAR is our Reporting Gap. The Reporting Gap suggests that only ½ our MI’s are being reported.



**MEMBERS INCIDENT CONTRIBUTORS: Ytd 2012**



**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.

## 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.

### John T Hedger

#### PERSONAL

**Position:** Retired  
**Company:** Independent  
**Location:** Nice, France  
**Education:** BSc Hons, London 1970  
 PhD, London 1973  
**Affiliations:** Institute of Explosives  
 Engineers, 1996 - 2004.  
**Languages:** English



#### CAREER OUTLINE

**AECI, South Africa (1976-81):**  
 R&D Detonators; Pyrotechnics.  
**ICI Australia (1981-1989)**  
 Initiating Systems Dev. Manager  
**IES Ltd (1989-94):**  
 Detonator Product Specialist  
**Independent Consultant (1994-now):**  
 ICI & Orica

#### EXPERTISE

- Electric detonator firing characteristics & HV testing.
- Detonator safety and manufacture.
- Pyrotechnics safety and manufacture.
- Detonating cord manufacture
- Lead Azide, PETN and Pentolite manufacture
- Signal tube manufacture

#### TYPICAL ASSIGNMENTS

**1976 – 1981** R&D in electric detonator firing characteristics; development of non-electric detonator assemblies; pyrotechnic delay investigations

**1981 – 1986** Initiating Systems Development Manager.

**1986 – 1994** Non-electric detonator manufacturing support

**1996 – 2004** Principle Technical Consultant for Orica Weihai detonator factory (China)

**1996 – 2004** Technical Officer, Institute of Explosives Engineers.

**1998 – Now** Consultant to various oil exploration companies conducting audits of seismic detonator suppliers and field application of seismic explosives products.

**2004 – Now** Consultant to HONCE (Hunan Orica Nanling Civil Explosives Co. Ltd.) for non-electric detonator and pyrotechnics manufacture.

## 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 in 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 Workgroup Leaders as designated. Dr 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 will do so in alphabetical order of Leaders starting with Dr Martin Held.

### Martin Held – Good Explosives Practice



Martin Held has been the Corporate Safety, Health, Environment and Security (SHES) Director for Austin International (AI) since October 2007. He is responsible for monitoring the performance of and compliance with the SHES system in the Company and to support line management in meeting those obligations. He travels internationally to all AI sites and has been based in Cleveland, Ohio with his wife, Dagmar, and two children since 2008.

During his time with AI he was and continues to be involved in hazard studies; plant audits (License to Operate) and inspections; and incident investigations. He also organizes and conducts corporate training on Basis of Safety (BoS), Hazard Studies, Incident Investigation, Service and Operations and other topics.

Martin holds a Master's Degree in Chemistry from Dortmund University, Germany. After finishing his PhD thesis in organic electrochemistry he started work in 1992 as a lab and plant manager for Westspreng GmbH, Germany. Within the Westspreng Group, and its legal successor H&R Wasag, he held positions as Operations Manager in manufacturing of packaged and bulk emulsions, ANFO, dynamite and boosters; R&D Manager; Company Legal Advisor; project team member for emulsion plants and SHES Manager. In addition, he was Deputy Chairman of the German Explosives Standard Committee and member of FEEM working groups.

After the GEP initiative was introduced by Andy Begg at the XV SAFEX Congress (Geneva) in 2005, the Good Explosives Practice (GEP) Workgroup was established with the XVI SAFEX Congress (Madrid) in 2008. We use the term GEP to describe a method of working with explosives that illustrates:

- Explosives hazards are understood; and
- Practical measures are being taken to reduce the likelihood of initiation and the potential consequences of an ignition.

In other words, GEP is an approach to support BOS principles and ensure that those are applied.

The GEP initiative is an attempt to docu-

ment expertise that is still available in the explosives industry. The industry is witnessing the transfer of classical processes to newer technologies, the retirement of personnel with decades of specific experience and the recruitment of inexperienced personnel. As a result, the understanding of the basics necessary to avoid incidents by friction, impact, static electricity and heat as well as ways to minimize the consequences when such incidents occur are disappearing. With such a decreasing pool of basic understanding, it will become increasingly difficult to assess hazards and risks systematically. In a recent SAFEX Newsletter (No.41, 2<sup>nd</sup> Qtr. 2012) Frank Barker quoted Andy Begg who observed at the 2002 SAFEX Congress in Amster-

dam that: "All of the (inspected) facilities had safety management systems in place, yet in all cases failings in attention to basic explosives safety controls have been observed. What we are talking about is deterioration in (good) explosives practices (that) are no longer being consistently followed."

The GEP initiative is an approach to collect and document the still available knowledge in our industry. This approach will develop a database of good practices in our industry that can be accessed by any member.

The GEP Workgroup has issued two Good Practice Guides (GPG's) so far:

- GEP 01, 'Good Practices for Controlling Foreign Bodies in Explo-

sives' with Andy Begg (Individual Associate) as a major contributor

- GPG 03(1), 'Managing Electrostatic Discharges (ESD) in the Manufacture of Explosives' with Maurice Bourgeois (GD-OTS Canada), Stafford Smithies (VSA Consultants, South Africa) and Ron Zezulka (TB&S Consultants, Canada) being the primary contributors.

What plans does the GEP Workgroup have going forward?

- Maurice Bourgeois and Stafford Smithies are tireless champions of ESD management in explosives and are currently revising GPG 03 (1). We plan to publish this revision by the end of the month.
- The Technical Guide will be followed by an Operations Guide, GPG 03(2), in which we have asked Maurice Bourgeois and Ron Zezulka to take the lead.
- A draft GPG on aspects of plant design has been provided by Mervyn Traut (Expert Panel Member)
- Jon Jones (Austin International)

and Jean-Paul Reynaud (Titanobel) have contributed to a draft GPG covering disposal of explosives waste material

- Decontamination of redundant assets and equipment is being considered for a draft GPG based on contributions from Ashley Haslett (Groupe EPC), Gregor Englmayer (Austin Powder GmbH) and Rahul Guha (Solar Industries India)
- Suitable tools for explosives operations is another GPG in the making using contributions from Paul Clark (Arabian Explosives) and Luis Santiago (Austin Bacis)

The goal is to publish one GPG per year. However, given that the expertise and application of good explosives practices is declining in our industry, a larger output is desirable. I could sense huge interest in Good Practice Guides at the Istanbul Conference but we need more support to achieve our goals. There is still a lot of expertise out in field that needs to be captured and conserved. However, this requires active participa-

tion from members otherwise we will miss, and eventually lose, valuable opportunities which will leave our industry and our successors poorer.

If any reader wants to participate in and contribute to the GEP Workgroup, please contact the SAFEX Secretariat or Martin directly at [martin.held@austinpowder.com](mailto:martin.held@austinpowder.com). You may wish to participate in one of the GEP topics listed above. Alternatively, you may want to provide a draft on a different GEP topic that could be of interest to SAFEX members. We will also welcome any pictures with good or poor practices. GPG's typically contain a lot of visual information and we need lots of examples of both the "good" and "not so good" to help us in our learning.

Allow me to close with this analogy: Think of the favourite dish your grandmother used to prepare for you. She knew the list of ingredients by heart and never wrote it down. Today you can still imagine its flavour when you think of it. You will give anything to cook and eat this special dish. Sadly, the recipe is gone, as she is, - forever!

## QRA Corner

Welcome to another instalment of the SAFEX Newsletter series called the QRA Corner. Each instalment 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 focuses on the science that goes into the model used to represent the effects of a detonation.

### The Realities of QRA and QD

by

**Lon Santis (Manager, Technical Services, Institute of Makers of Explosives)**

So far, this column has introduced quantitative risk assessment (QRA) and some of the common questions about it, described the connection between testing and modelling, and discussed the necessary elements of a QRA model. This instalment delves into the realities of what QRA and quantity-distance (QD)

deliver to explosives risk managers.

First of all, QRA is really just an expansion of QD. It merely takes more factors into consideration. QD tables typically take into account factors such as the net explosive weight (NEW), the distance to the exposed site (ES), the type of explosive, the presence of barricades,

the volume of traffic, the type of ES, the relation of the person to the explosives operation and others. A valid QRA takes all these things into account, plus many other factors not suitable for incorporation into a set of human-readable tables. Broken down to its individual parts, a QRA is just a complex set of

*Table 1: The effect of variables on a QRA for long-term storage of explosive materials*

VARIABLE	UPPER LEVEL OF RISK*	LOWER LEVEL OF RISK*	RANGE OF RISK IN ORDERS OF MAGNITUDE
P <sub>e</sub>	1 per year	1 x 10 <sup>-8</sup> per year	8
Size of ES	7.0 x 10 <sup>-2</sup>	3.3 x 10 <sup>-9</sup>	7
Type of crater ejecta	2.2 x 10 <sup>-3</sup>	3.3 x 10 <sup>-9</sup>	6
Type of ES	1.1 x 10 <sup>-3</sup>	6.4 x 10 <sup>-9</sup>	5
NEW	2.5 x 10 <sup>-4</sup>	1.5 x 10 <sup>-8</sup>	4
Type of Explosive	3.4 x 10 <sup>-4</sup>	7.4 x 10 <sup>-8</sup>	4
Barricades	2.3 x 10 <sup>-5</sup>	1.5 x 10 <sup>-8</sup>	3
Number of exposures	1,000 people	1 person	3
Size of PES	1.8 x 10 <sup>-3</sup>	1.5 x 10 <sup>-5</sup>	2
Percent glass (90-1) in ES	3.0 x 10 <sup>-3</sup>	3.4 x 10 <sup>-5</sup>	2
Type of PES	2.9 x 10 <sup>-4</sup>	1.5 x 10 <sup>-5</sup>	1
Type of glass in ES	2.5 x 10 <sup>-4</sup>	5.1 x 10 <sup>-6</sup>	1

\*predicted fatalities/year to a single occupant of the ES given that an event occurs, unless otherwise noted

many tables and formulae; and the magic of personal computers make it possible to extract information from those tables and make sophisticated computations with it.

QRA is a complement to QD for explosives risk management and QD should be the first standard considered. But when the simple approach is not applicable, consider doing a QRA. If a QRA does not provide definitive guidance, more detailed modelling using finite element codes, fault-tree analyses, or subject matter experts may be required.

It can be difficult to determine when to take the next step with explosives risk management and conduct a QRA. In general, explosives risk managers should apply QRA when the limits of QD are being stretched. Typically, this involves scenarios where the probability of an event occurring (P<sub>e</sub>) is much different than the activity for which the QD standard was designed. For example, it may be inappropriate to use a QD standard designed for explosives storage for a safer activity like ammonium nitrate storage, or a riskier activity like explosives waste disposal. QD limits are also stretched when scenarios involve extremes in the variability of various parameters that affect risk. For example, QD may be less desirable than QRA

when thousands of individuals are exposed to risk or when only one individual is exposed every few days. Recognizing these extremes is the key; therefore, one must understand the levels of risk allowed by QD standards.

Table 1 above shows how QD standards allow the quantitative level of risk to vary through many orders of magnitude for different yet compliant PES-ES pairs where PES is the Potential Explosives Site. The variations were determined using the QRA tool IMESAFR V1.0 and the American Table of Distances (ATD) QD standard. Scenarios were considered that isolated and maximized the effect of each variable as much as possible and appropriate ranges from the ATD were used for distances between the PES and ES. For example, to evaluate the effect of glass, scenarios where glass was the dominant hazard were modelled. The spread in risk for QD compliant scenarios was measured as the variable changed and is shown in Table 1.

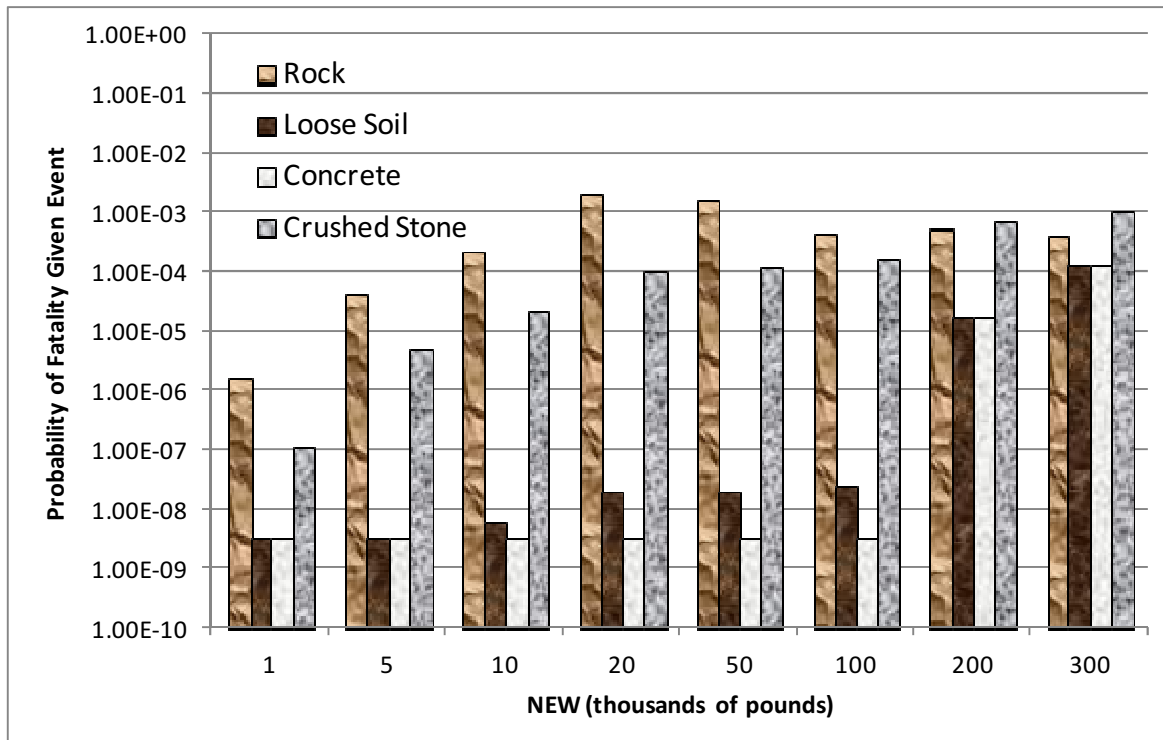
Figure 1 (on next page) shows details on how one of these variables, crater ejecta, can change the consequence factor in a QRA. The scenario modeled by IMESAFR V1.2 in Figure 1 is an open PES (explosives in cardboard boxes are sitting on the ground in the open) and

the ES is a vehicle at the unbarricaded, low-volume highway distance in the ATD for that NEW. This puts the individual relatively close to the PES in a structure that provides good protection from overpressure but little protection from debris

Risk managers can infer several things from Figure 1. Except for rock, risk increases as the NEW increases even though the distance between the PES and ES increases. This is because larger NEWs create more hazardous crater ejecta that reaches the QD arc for that NEW. Also, placing the magazine on rock or crushed stone results in higher risk at all NEWs because these materials allow more hazardous crater ejecta to reach the QD arc than loose soil or concrete for a given NEW.

Risk managers can use this kind of information to make better decisions. For example, the reward for placing the PES on a concrete pad may be significant for NEWs up to 100,000 pounds, but at 200,000 pounds and over, the risk rewards are much less. On the other hand, changes in NEW have little effect on risk from PES placed on rock. More examples of how risk managers can make informed decisions will be explored in future articles.

Figure 1: Risk as a function of crater ejecta



In a particular scenario, it is impossible for all the variables in Table 1 to coincidentally fall on either the risky or safe side and produce an overall range of risk for QD equal to the sum of the rightmost column. But even regardless of  $P_e$ , QD standards are easily capable of allowing the risk of compliant scenarios to vary through 10 to 20 orders of magnitude or more. The goal of a good QRA

should be to provide accuracy within one order of magnitude.

Risk ranging through the vast territory that QD allows makes risk managers nervous because the whole idea is to maintain a tolerable level of risk across all activities, thus providing a sustainable future for the overall endeavor. QRA is far from perfect, but blindly fol-

lowing QD and allowing risk to be on either the extreme conservative or liberal side is ill-advised for the long-term. Extreme conservatism results in inefficiency and often causes increases and shifting of risk into other areas. Extreme liberalism creates excess liability and threatens long-term sustainability. Better knowledge of QRA principles helps minimize these extremes.

## 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.

### A Review of Ammonium Nitrate solution and Emulsion Matrix Storage

by

**Prof Martin Braithwaite**

(Laboratory for Scientific Computing, Cavendish Laboratory, University of Cambridge, UK)

In large mining or explosives production operations there is frequently a need to store substantial quantities of either concentrated ammonium nitrate solution (ANS) or emulsion matrix (ANE). These materials in their normal state (concentration as per design, no contamination, no phase changes or void

inclusions) can be regarded as fairly innocuous to the extent that if there is no deviation in condition, including loss of containment for any reason, from this norm they offer no explosive or fire related hazard. The difficulties governmental regulators face is whether to accept a risk based argument [ex in an

overview, T A Kletz 1994] that significant deviations from the design intent are so unlikely as to be not credible or they take the stance that full confinement and/ or worst case scenario separation distances between units and site boundaries. Advice has been published by a number of governmental or related

authorities for the ammonium nitrate (AN) storage [WA Gov 2012, EFMA 2005]. These articles review AN properties, means of storage, separation distances, mitigative measures and recommended safe practices.

Risk management and vigilance in the manufacture and storage of potentially energetic or oxidative materials is a prerequisite for safe operation. Clearly a “belt and braces” approach limiting local hazard and also ensuring no unacceptable consequences by having bounds set by quantity distance relationships as a result of an energetic event is very desirable, though possibly over-conservative. This discussion note reviews the hazards of ANS and ANE storage, events of high consequence but very low probability, with the aim of stimulating debate rather than attempting to impose any particular design/ storage constraint.

## PHYSICAL AND CHEMICAL PROPERTIES

Pure AN is a strong oxidizing agent. Its chemistry has been extensively reviewed elsewhere [ex Shah & Roberts 1985]. Chemical reaction is very slow and predominantly endothermic at temperatures below its melting point. Solid Ammonium nitrate (ANX) and ANS cannot deflagrate, unless at pressures greater than 0.1 GPa [11]. Given sufficient shock energy or high velocity impact stimulus both AN (solid or melt) and gassed concentrated ANS can detonate though these processes are particularly difficult as critical failure diameters for detonation will be large with the exception of far more sensitive case of an molten AN.

In storing ANS, there are operational temperature bounds – not sufficiently low (fudge point) as to allow crystallization or high to result in boiling and loss of solvent or ammonia [EFMA 2005]. There are a wide range of materials that increase the reactivity of AN containing systems at elevated temperatures (normally > 120 deg C). These include:

- Transition metals and their compounds
- Halide containing species

- Reducing agents
- Acidic media
- Fuels (organic or metallic)

Examples might include copper present in piping, organic material in tank insulation or pump/ valve lubricants, confusion between nitrates and nitrites, addition of perchlorates, and loss of am-



**Figure 1:** Oppau (1921) 4500 tonnes ammonium nitrate/ ammonium sulphate initiated by dynamite



**Figure 2:** Porgera plant, Papua New Guinea



**Figure 3:** Aftermath of the Toulouse AN explosion

monia at elevated temperatures leading to more acidic conditions.

ANE is potentially more reactive than ANS due to the presence of organics (fuel, surfactant, wax etc.). Because of ANE's decreased stability the following will occur:

- Lower exothermic reaction onset temperatures

- Much reduced minimum deflagration pressures
- Reduced detonation failure diameters, still very dependent on gas void inclusions

Whereas ANS can be stored at temperatures in excess of 120 deg C to avoid crystallization, ANE with its supersaturated AN solution can remain free of significant crystallization for many weeks at ambient temperatures and only viscosity/ pumping considerations might require a modest increase in its storage temperature.

## INCIDENTS

Despite the apparent stability of ANS and ANE there have been a number of major incidents in processing units, some resulting in significant loss of life, over the last 100 years (ex Oppau 1921).

For the case of ANS, as far as this author is aware, all incidents have been caused by chemical contamination and mainly due to lack of attention to in process or in storage incompatibilities between ANS and plant materials – lagging containing organic media, use of materials other than stainless steel for storage vessels and gross overheating leading to high temperatures and acidic conditions.

ANE is nominally dense, void free, matrix and not susceptible to pressure induced ignitions. There has been at least one serious incident for ANE storage in the last 20 years as opposed to many in process, transportation and burning ground accidents. A major accident with solid AN in storage also occurred in a fertiliser plant some years later.

### Emulsion matrix - Porgera, Papua New Guinea (1995) [Moreton 2009]

Figure 2 refers. A major secondary explosion occurred when a diesel oil fire in a surrounding bund caused the explosion of matrix tank overheating in a large matrix tank, leading to exothermic reaction, explosion and detonation of some of the tank's content. It is suggested that a first explosion in a progressive cavity pump resulted in the breakage of an overhead oil line whose contents proceeded to burn in this bund .

**ANX – Toulouse, France (2001) [Fabig 2001]**

Figure 3 on the previous page refers. A major explosion occurred in a fertiliser factory in a warehouse where off-specification granular AN was stored flat, separated by partitions. It has been suggested that there was some contamination of the AN stored .

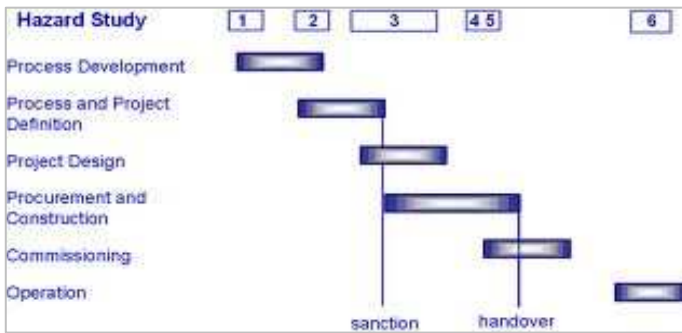
**ANS [EPA 1997]**

Two explosions of ammonium nitrate solutions that occurred during processing at ordnance plants during the Second World War were believed to be caused by the explosion of a small amount of ammonium nitrate in a blocked pipe, which then initiated the explosion of a larger quantity of solution.

**A HAZARD STUDY APPROACH TO ANS AND ANE STORAGE ISSUES**

A hazard study approach to issues concerning the safe storage of these media is taken here

*Figure 4: Hazard Study System illustrated*



**Inherent safety**

An early part of any hazard study process is to attempt to introduce inherently safe operations where practical. A series of keywords can be considered in order to identify safer processes. For example:

- *Minimize.* The size of the inventory (ANE or ANS) is an operational issue. Clearly this should be kept as small as practical.
- *Substitute.* The options for substituting a less hazardous material are minimal. On site manufacture of ANE from ANS would require the installation, and associated safety requirements, of a mini-plant or use of an MMU.
- *Moderate.* ANE should be stored at ambient temperature and ANS at a temperature above its fudge point. In neither case should temperatures be used that result in onset of chemical decomposition or loss of solvent. The use of matrix for storage and transportation, rather than sensitized emulsion, has greatly reduced these hazards as the media has been largely rendered not susceptible to shock induced detonation.
- *Simplify.* There are few obvious options here.
- *Design for containment.* In some circumstances underground storage might be considered and/ or barricades for the very unlikely event of an incident. Compartmentalization of stored material is an option provided domino effects (e.g. sympathetic detonation) can be eliminated by appropriate use of construction materials between containers

**Formal Hazard Studies II & III**

After what is essentially a data gathering exercise (**Hazard Study I**), **Hazard study II** focuses on the basic design and operation of a plant unit and attempts to identify significant hazards, their possible causes and necessary protection measures for proposed process , as per design intent .

<b>Key words for Hazard Study II</b>
External Fire
Internal Fire
Internal Explosion
Confined Explosion
Unconfined Explosion
Acute Harmful Noxious Exposure
Chronic Harmful Noxious Exposure
Pollution
Violent release of Energy
Noise
Visual Impact
Major Financial Effect

Given the design intent will be for uncontaminated storage and the absence of thermal/ impact/ shock insults and the inert nature of the stored media at these conditions one has to conclude that at this level of analysis, ignoring any deviation to normal operation, there is no significant safety issue.

**Hazard Study III** focuses on departures from the original design intent and involves a more detailed design study, requiring

<b>Keywords for Hazard Study III (Batch Process)</b>	
More of	Over -filled/heated Excessive filling/ heating High temperature/ pressure/ viscosity
Less of	Low level/ temperature/concentration/ under filled
As well as	By-products, impurities, pollution Side reactions/decomposition Generation - voids, pollutants Present – ignition, heating
Other than	Instead – start-up, shutdown, maintenance, testing, emergency Wrong material Unacceptable Impurities

Given the above possible deviations from the design intent in a level III study ANE/ANS storage might pose a hazard as a result of the following:

<b>PHENOMENON</b>	<b>CAUSATION</b>
Thermal Explosion/ Cook-off	<b>O, C</b>
Deflagration	<b>O, C</b>
Detonation	<b>O, C, S</b>
Fire	<b>O, C</b>
Phase change	<b>O, F</b>
Propagation/ domino effects from above	
<b>Causation key:</b>	<b>O</b> = Overheating <b>C</b> = Contamination <b>F</b> = Cooling <b>S</b> = Shock

The key questions for the manufacturing company and the regulator are whether contamination and / or extraneous sources of heat (insults listed below) can be eliminated from the storage units and their environment. More specifically, can these insults or deviations from design intent be eliminated by design/ operating procedures and monitoring to the extent that the departures from design intent are not credible and also that this is demonstrable to local regulators? This analysis has to include both human error and malvolent act and apply to normal storage, filling, emptying and maintenance operations.

#### Potential Insults

- Contamination – chemical/ physical/ plant/ insulation/ lubricants/ (grit, gas, corrosion)/ incompatibility/ degradation
- Temperature (high/ low) – Fire engulfment. Loss of heating, insulation etc.
- Instantaneous impact, friction, shock, electrostatic – at extreme levels
- Compression/ dieseling (gassed product)
- Malicious act

#### Mitigation

If, for some reason, ANE and ANS media in storage are regarded as a potential hazard, the consequences of an event have to be considered as well as possible mitigation considerations. The norm is to take a worst case scenario for a detonation of the storage tank contents and consider the damage that might be done as a function of distance from the event. This is achieved by analyses based on TNT equivalence or actual measurements in order to provide overpressure

circles. The TNT equivalence of non-ideal secondary explosives such as ANE when sensitized or ANS when tending to an AN melt is not well defined due to the partial reaction of these media in a non-ideal detonation event. Guidance does however exist [ex AEISG 2012].

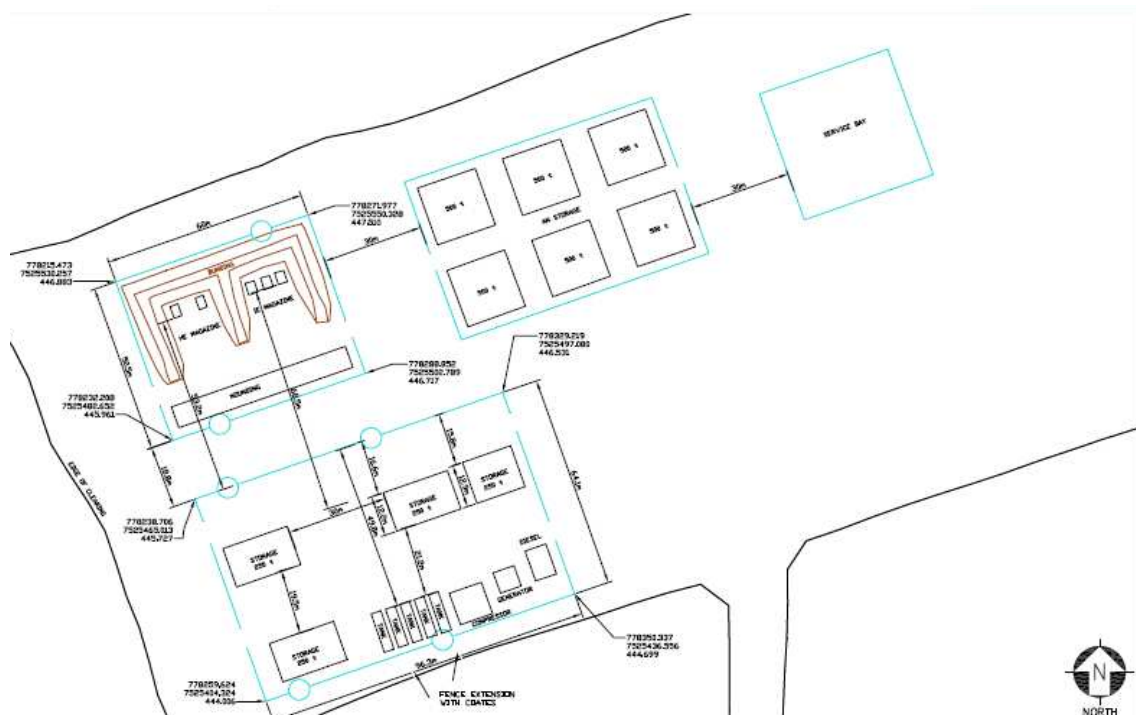
The requirement to design storage units and separation based on a quantity-distance-overpressure criterion can involve large separation distances (>100 m). Possible approaches to reduce these distances include:

- Use of barriers e.g. earth mounds
- Underground storage
- Venting (vertical)
- Compartmentalization – multiple protected storage units – no propagation between tanks
- None of these options is without some drawback, be it cost or managing an incident with an event. Any increased insulation, that offered by underground storage, may increase the likelihood of an event once any exothermic reaction has started.

#### CONCLUSIONS

In their standard storage states ANS and ANE can be regarded as not being hazardous but this is subject to there being no significant contamination or thermal insult. The major issues, without resort to substantial separation distances, will be to ensure the above deviations are not credible and convince the authorities of the veracity of any design/ operating procedures that this is the case. An alternative strategy to having large separation distances is to consider barricades or storage below ground level where this is practical and other hazards that might be introduced manageable.

**Figure 5:** Typical layout plan of an AN facility and magazines



## APPENDIX

### A. Thermal explosion (cook-off) hazards

ANS and AN have been extensively studied by a variety of calorimetries (ex Turcotte et al 2003). In the absence of any contamination, no exothermic reaction would be expected below the MPt of AN i.e. 169 deg C It should be noted that the presence of water in ANS constitutes an additional thermal sink requiring addition heat for water evaporation. ANS has to be stored at elevated temperatures, less than 169 deg C, to avoid AN crystallization.

ANE contains a supersaturated AN solution. The presence of an organic media (surfactant, oils etc) would be expected to lower the temperature for the onset of exothermic reaction – but this temperature will be well in excess (>120 deg C) of any storage temperature.

### B. Deflagration in ANE/ANS systems – ignition and minimum deflagration pressure

Pure AN or ANS does not stably deflagrate until very high pressure (> 0.1 GPa) (Sinditskii et al 2005) ANE will deflagrate, with the minimum deflagration pressure being very dependent on water concentration. For normal uncontaminated products (H<sub>2</sub>O > 10 % w/w) the pressures will be well in excess of storage pressures (Turcotte et al 2005).

### C. Shock sensitivity and detonation hazards – initiation, stable detonation

In condensed phase media containing AN, the onset of detonations normally requires the presence of voids, whose compression will lead to hot spots [Olson 2002]. Voids would normally be considered to be absent in ungassed products. In the absence of voids ANE and ANS both would require a significant shock stimulus (impact velocities > 500 m/s and initiation pressures > 1 GPa), large diameter and confinement to achieve a stable detonation. Gassed ANS detonability has been shown to increase with AN concentrations > 80 % w/w.

ANE, as a matrix, will have a large critical diameter, though this will reduce markedly at lower density. As with ANS, initiation will require high velocities or high pressures beyond the realm of normal engineering operations. Media containing molten AN, in which gas voids will inevitably be present, at temperatures in excess of 169 deg C, can be regarded as extremely hazardous in terms of propensity to explode or detonate.

### D. Deflagration to detonation transition (DDT)

Detonation is normally achieved by a shock to detonation process or a deflagration to detonation transition. By its very nature the latter requires an accelerating deflagration so considerations based on (b) and (c) both apply.

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**GLOSSARY**

AN	Ammonium Nitrate
ANE	Ammonium nitrate emulsion (base or matrix)
ANS	Aqueous Ammonium Nitrate solution
ANX	Ammonium Nitrate solid
Cook-off	Reaction runaway/ thermal explosion – heat generation in reactive media exceeds thermal losses
DDT	Deflagration to Detonation transition
Deflagration	Subsonic reactive burn
Detonation	Supersonic shock driven & self-sustaining exothermic reaction
Domino effect	Propagation from one incident to cause others
Fudge point	Temperature for onset of crystallization in solutions
Matrix (emulsion matrix)	Base emulsion, nominally free of gas voids
Minimum Deflagration Pressure	Minimum pressure for stable deflagration
SDT	Shock to detonation transition
Thermal Explosion	See Cook off

**Our Explosives Regulatory World****Good practice guidance on the carriage of blackpowder by private individuals**

Produced in Great Britain as a joint publication by the

**HSE, the Department for Transport and the Police**

This guidance contains public sector information published by the Health and Safety Executive and licensed under the United Kingdom's Open Government Licence v1.0 ([www.nationalarchives.gov.uk/doc/open-government-licence/](http://www.nationalarchives.gov.uk/doc/open-government-licence/))

The official title of this document is good practice guidance on the carriage by private individuals of black powder (gunpowder) and smokeless powders for use in small arms, small arms ammunition and model rocket motors

**GENERAL**

Private individuals are permitted to transport up to a total of 30kg of explosives for leisure/sporting activities in a private motor vehicle. In ADR<sup>1</sup> 1.1.3.1 (a), as qualified by Regulation 9 of The Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2009 (as amended), "explosives" includes black powder (gunpowder) and smokeless powders for use in small arms as well as small arms ammunition and model rocket motors.

The following recommended methods cover the safe and secure transport of explosives by road. They do not cover transport by rail, sea or by any form of public transport upon which there may

be further restrictions. It is the responsibility of the individual carrying the explosives to ensure compliance with prescribed limits. Any relevant documents must accompany the explosives throughout the journey.

**PACKAGING**

Only explosives classified for transport should be carried and they should remain in their original transport packaging whenever possible. This packaging should display appropriate hazard warning and security labels.

Where it is not possible to transport the explosives covered by this guidance in their original packaging, they should be placed in one of the following accepted containers:

- black powder flasks/horns or containers designed or adapted to throw a measured or measurable charge, having a fully closed plate or removable stopper;
- closed or stoppered tubes or phials designed to contain sufficient

powder or propellant for one shot;

- black powder twists carried in a closed container; or
- in the case of small arms ammunition and cartridges, a robust bag or purpose-made carrier designed for the purpose.

Each accepted container should be placed in outer packaging acceptable for the explosives under the provisions of ADR, such as a fibreboard box displaying the appropriate carriage and security information, and each accepted container should be packaged in such a way that the contents cannot spill or fall out.

**SECURITY**

A person involved in the carriage of dangerous goods must take all reasonable steps to ensure that unauthorised access to those goods is prevented and take appropriate steps to ensure the security of the explosives in the event of an accident or emergency.

Packages containing explosives must be covered or concealed in such a way as to prevent their identification by any casual observer or anyone not involved in the carriage. They should be kept out of view in the load carrying area (e.g. boot) with the lid or cover of any container or packaging in place. Alternatively, they can be kept in any other appropriate lockable storage area within the vehicle.

Whenever possible, a vehicle carrying explosives should not be left unattended. If the explosives are not in a locked container secured to the vehicle, the vehicle may be left unoccupied provided it is locked and within the sight of a responsible person. Vehicles carrying explosives in lockable containers secured to the vehicle may be left provided the vehicle is locked and, if fitted, its alarm and/or immobiliser set.

#### SAFETY

Packages containing explosives must be properly restrained to prevent them moving and whenever practical, they

should be located away from the external walls and doors of the vehicle.

Generally, explosives should not be carried with other dangerous goods, for example, fuel cans, gas bottles, paints, solvents etc. Explosives classified as UN Hazard Code 1.4S, may be carried like this. However, black powder, smokeless powder and rocket motors will not be classified 1.4S. Where these explosives are carried in accordance with this guidance, they will need to be adequately separated and protected from any other dangerous goods to prevent the accidental initiation of one by the other. In any event, dangerous goods carried should not be incompatible with any explosives nor with each other.

The person who possesses the explosives should ensure that all occupants of the vehicle are aware that potential sources of ignition such as smoking, naked flames or sparks are forbidden inside or close to the vehicle. Containers and the areas in the vehicle in which the explosives are to be carried should be kept clean and free from contamination, particularly by grit.

If there is an accident or other incident the person who possesses the explosives should be able to provide the following information to the emergency services:

- the type of explosives that are being carried;
- the original classification of the explosives in their transport packaging; and
- the type of hazard that the explosives are likely to present if they are not being carried in their transport packaging, for example:
  - a mass explosion hazard;
  - a projection hazard but not a mass explosion hazard;
  - a fire hazard and either a minor blast hazard or a minor projection hazard or both, but not a mass explosion hazard; or
  - the effects will be largely confined to the package and no projection of fragments of appreciable size or range is expected

<sup>1</sup>European Agreement concerning the International Carriage of Dangerous Goods by Road

## 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.

### Green emulsion plants for African mines

by

**Sashnee Moodley**

(With permission from Creamer Media's Mining Weekly at [www.miningweekly.com](http://www.miningweekly.com)  
at <http://www.miningweekly/article/green-emulsion-plants-for-african-mining-operations-2012-07-13>)

Blasting solutions company AEL Mining Services is constructing four new environment-friendly emulsion plants for mining operations in the Democratic Republic of Congo, Burkina Faso, Egypt and Tanzania.

The modular plants, which are designed to operate in demanding mining environments, are capable of producing AEL's full range of surface and underground bulk explosives products, while complying with environmental standards.

Formulations that use recycled oil from the mine can also be produced to decrease input costs and reduce environmental waste.

The new green plants will use various recycling processes, including the reclamation of effluent water for reuse and plastic and paper recycling, as well as rainwater catchment for use and solar energy to power offices, explains AEL executive in charge of Africa Stuart Wade.



“The plants ensure that operations reduce waste production. If the company is not socially responsible and does not reduce our carbon footprint, we are not doing our job. AEL policy enforces operational discipline that ensures that plants are run to be environmentally compliant or there is a risk that they will be shut down,” says Wade.

Each new plant has operational features such as pump protection against deadheading and dry-running scenarios, strainers in the suction line to prevent the ingress of foreign objects, a closed-loop hydraulic control system that guarantees product quality, and an in-plant touch-screen user interface, if specified.

The completed plant can consist of various modules, including ammonium nitrate dissolving units and power packs. The modular plant is built to fit into standard-size containers to facilitate transportation to and installation at remote sites.

The safety features of the plant comprises an independent electronic pump protection system, which monitors and controls operating pressures and temperatures on critical pumps; temperature control systems installed on the nitrate dissolving module; and emergency stops at critical locations of the plant.

The plants are convenient for African countries and deal effectively with the logistical challenges associated with transporting raw materials to these countries to manufacture explosives products.

Wade reveals that transporting raw materials to these countries can be done effectively by road and sea. Air transport is seldom used owing to various restrictions and the high cost of hiring the plane and the packaging involved.

## **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.

Shipping can be a risky means of transportation, owing to the growing number of piracy incidents around the coastlines of the African continent. High-risk areas include the east coast, around Somalia.

According to Wade, from January to December last year, there were 439 cases of piracy worldwide, which included actual, attempted and suspicious piracy activities.

He states that an efficient supply chain is critical to ensure that product supply is not stopped. Good functional support for supply chains is key to maintaining a reputation for reliability of supply over a significant period.

A shortage of competent, experienced people, particularly mining engineers, is a significant challenge for the mining industry in Africa. Local skills development is one effective way to combat this problem, says Wade.

“It is important to develop the skills of local workers, as this reduces the mining community’s dependence on expatriates. We try to train understudies who will eventually take over expatriate roles in all areas of employment. It is significant that we recently appointed a senior local manager, Ronald Joseph, as the new MD of our operations in Botswana,” he reveals.

To assist with technical skills support, AEL has established a skills development centre in Johannesburg, Gauteng, that provides formal training for employees and customers. The centre also offers commercial training, ranging from basic blasting skills to more sophisticated courses on blast design for the mining industry.

Trainers can also undertake training on site for remote operations if there are enough candidates available.

However, Wade believes that, while skills development is important, technology is also a key issue for the future. Simpler, safer and more robust products that can produce the desired results for remote operations with less sophisticated workers are also part of the future of blasting.

AEL has continued to invest significant amounts of money in research and development projects, he points out.

“The value of this investment is recognised in product and equipment enhancements that are being introduced into the blasting market. These can be used to combat the skills shortage by simplifying technology and reducing the amount of manual human input required,” Wade concludes.

The Dyno Nobel Driver Alertness Program is a Dyno Nobel health and safety initiative that may be of interests to other Safety Professionals and Newsletter readers. Helen Muller is the Senior Director, Health & Safety of Dyno Nobel Americas. She leads a team of Safety Professionals in Dyno Nobel Inc who produce a regular newsletter in which the following article recently appeared. Given the significant number of explosives transport incidents that occur throughout the world and their potential impact, SAFEX Newsletter thought this article may be of interest to our industry

We thank Helen and her colleagues for permission to reproduce their article here. More information about the Driver Alertness program and external companies who supported DNTI in its implementation can be obtained from GM DNTI [jon.beckstead@am.dynonobel.com](mailto:jon.beckstead@am.dynonobel.com)

## Implementing a Driver Alertness Program

by

**Jon Beckstead, (GM DNTI);**

**Linda Coon (RN COHN Injury Prevention & Management Specialist);**

**Helen Muller (Senior Director Health & Safety, Dyno Nobel Americas)**

Faced with an increasing number of company vehicle incidents where driver fatigue was a contributing factor that cost the company more than \$1M in damaged equipment and loss of product, it became imperative that Dyno Nobel Transportation Inc (DNTI) address fatigue.

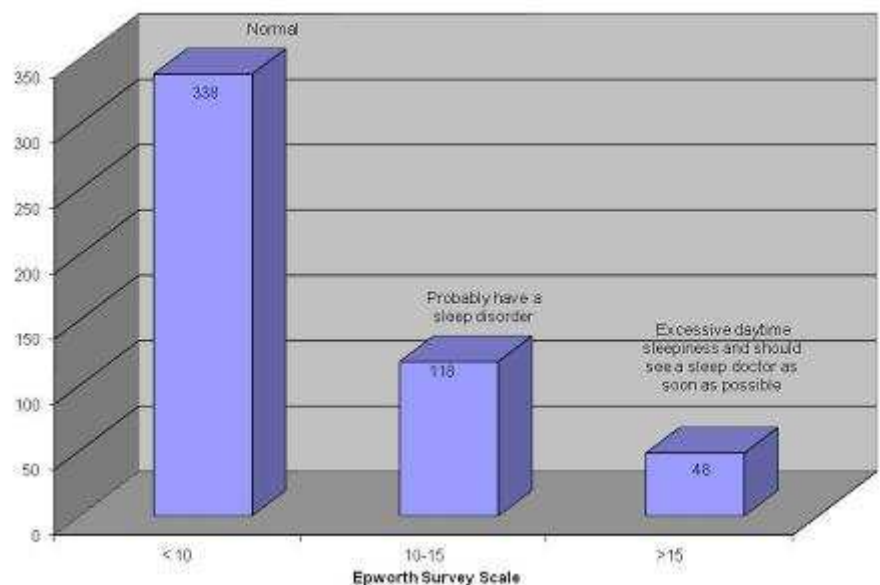
Fatigue is an issue that must be addressed in the workplace, as it has an impact on safety, productivity, health and wellness of employees. Experts estimate 1 in 5 Americans have some form of Obstructive Sleep Apnea (OSA). Shift workers and those in the transportation industry have been identified as having a higher than normal rate of OSA. At any given time Dyno Nobel Transportation Inc (DNTI) has 160 drivers on the road and clocks up some 12 million miles per year



### Fatigue Management Policy

In 2010 the Dyno Nobel North American Zero Harm Council (Senior Management HSE Committee) commissioned a cross functional team from HR, HSE, Transportation, Operations and Manufacturing to develop and implement a Fatigue Management Policy.

The Fatigue Management Policy was rolled out at the DNA HSE Conference in February 2011. The Policy included provision for on-line training from *Circadian*<sup>®</sup>, Dyno Nobel in-house training and a survey of employees using the Epworth screening tool to determine the potential for fatigue in particular sleep disorder



**Figure 1:** Results of Epworth Survey

ders. That survey indicated that 50% of respondents probably suffered from some form of sleep disorder. (See Figure 1 on the previous page)

Immediately following this survey, training on-line and in classroom was provided for all employees. DNTI made this training mandatory and measured compliance monthly. Training of all drivers and their managers was completed in less than 120days. DNTI management then worked with the Injury Prevention and Management Specialist to identify the most cost effective, least invasive testing and treatment program for Sleep Apnea.

The program chosen was *SleepWell*. This program enabled the drivers to be tested at home (or in a hotel room) and included education of family members, screening, testing and diagnosis. Treatment was then provided for those who tested positive for Obstructive Sleep Apnea (OSA).

**Beta Group**

A Beta group of 20 volunteers from the DNTI Carthage Terminal went through the program with 60% being found to have some degree of OSA. The National Department of Transport (DOT) average at the time was 28%, as published in the Federal Motor Carrier Safety Association (FMCSA) Federal Register. The response from the Beta group was overwhelmingly positive and other drivers were asking to be part of future programs

Prior to a Beta group being organized, one of the DNTI drivers was involved in a fatigue related vehicle incident and rather than the terminating the driver’s employment, which may have been the

outcome previously, the incident review board made the decision to submit this driver for screening for OSA. He was found to be high risk for severe OSA which the subsequent overnight sleep study confirmed. He began his AutoPAP treatment immediately [Editor: A continuous positive airway pressure (CPAP) system delivers pressurized air through a nasal mask, to prevent collapse of the upper airway during sleep. An AutoPAP differs from a CPAP in that an AutoPAP uses algorithms to sense subtle changes in the user’s breathing and delivers only the amount of pressure necessary to keep the airway open— cf <http://www.cpaptalk.com/wiki/index.php/CPAP>]. The change in his level of alertness and overall health was such that he now shares his story in order to make a difference in the lives of other drivers so they can avoid incidents like his and improve their health.

**Program Implementation**

The Driver Alertness program was implemented in January 2012 for the remaining DNTI and Distribution drivers and involved testing of all drivers who showed any risk to OSA during screening. As the program testing progressed drivers began to question whether the testing should be mandatory and this together with the changes made to the regulatory rule making process for OSA, resulted in DNTI developing a set of guidelines for the program going forward. The changes included:

- voluntary participation with the incentive of the costs being covered by the company
- CPAP treatment required for drivers with OSA whose Apnea severity score (AHI) during the sleep test

is > 20. Note: FMCSA made CPAP treatment mandatory for a score of >20, this was based on crash data that showed increased risk in persons over this level

- Testing material would not be filed in their driver qualification file until sleep apnea screening testing is made a regulatory requirement of driver qualification

In total 191 drivers have been screened to date with 86% showing some risk (See Figure 2). Of those at risk 75% were positive for some level of sleep apnea (See Figure 3) .

A number of family members identified their own potential for a sleep related disorder and sought treatment. In a show of support for the DNTI initiative, Senior Managers voluntarily submitted to screening and testing.

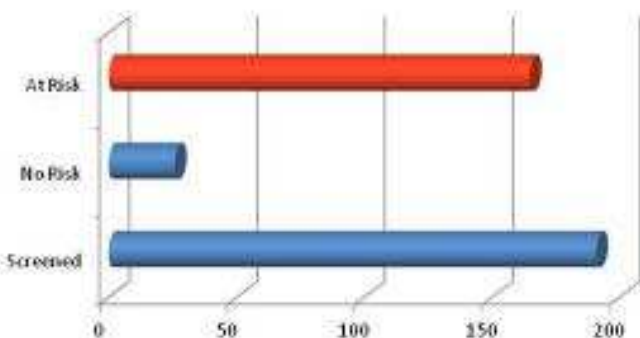
**Implementation Cost**

The Cost of implementing the Driver Alertness Program to date is less than half of the cost of one fatigue related incident without injury/fatality.

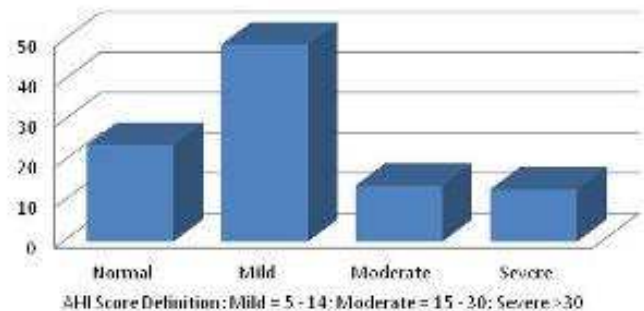
**Supporting Programs**

The Driver Alertness Program was supported by two other initiatives, implemented to address risks associated with driving: lack of driver awareness and a driver’s inability to make safe choices when driving down the highway. *Smith Systems*® and *ZIP*® (Zero incident Process) together with our Driver Alertness Program have been embraced by our drivers and resulted in the number of fatigue related incidents to date being reduced to zero.

The Smith System provides the driver with driver awareness techniques based on five keys:



**Figure 2:** Initial screening results



**Figure 3:** At-risk sleep test results

- Aim high in steering
- Get the big picture
- Keep your eyes moving
- Leave yourself an out
- Make sure they see you

ZIP® increases individual safety awareness, facilitates a cultural shift so that employees are internally rather than externally motivated to work safely.

Another important factor in the success of the Driver Alertness program is that management made a conscious decision to change their approach to driving infractions. The culture shifted from one that was punitive to one that considered the contributing factors and where these were health related every step was taken to address the issue. This does not mean infractions or violations are ignored, but rather these are handled in a more balanced and constructive manner.

### Sustaining Driver Alertness

Sustaining and ensuring programs are embedded well is critical to maintaining a safe, productive company. All existing drivers are now being monitored during their DOT physical renewal. New hires are required to complete Fatigue Management Training and submit to OSA screening and testing as part of their Orientation.

### Unexpected Benefits

There have been some unexpected benefits to both the company and the driver. Drivers with an AHI score of <20 voluntarily changed their diet, engaged in exercise and improved their sleep routines as outlined in the training. Drivers' health indicators for blood pressure, blood sugar, cholesterol have improved. Drivers are fully engaged and taking ownership for their own health and safety.

Immediate Benefits realized so far are:

- Improved sleep quality and quality of home life
- Increased energy and alertness
- Increased safety

Long Term Benefits that we are expecting for both DNTI & our Drivers include:

- Reduced risk of cardiovascular problems
- Better overall health and healthy lifestyle improvement
- Reduced risk for driving accidents
- Improved performance
- Reduced absenteeism
- Decreased health care and disability costs for both employee and DNTI
- Decreased driver turnover
- Driver engagement increased

A video of the drivers testimony can be viewed on YouTube at

<http://youtu.be/EFM1c7B2Lf8>

## Safety Snippets

### Deluge systems for ordnance works

by

**Ken Price**

Ken Price is an Individual Associate who was an explosives regulator for 30 years and retired as the CIE of Western Australia in 2001. Since then he is consulting as Riskom International Pty Ltd that recently did a simple assessment of available fire suppression and deluge systems. This was part of a Hazards and Operability Study/risk assessment at an Australian ordnance disposal facility. This article presents some of the findings and conclusions of the study.

The focus of the study was the activities conducted in the unloading bays, the dangerous goods sorting, packaging and storage rooms, the receipt/ammunition processing area and the magazine storage compound.

The ordnance considered was limited to ordnance legitimately received within the operational scope of the disposal facility. This was: small arms ammunition and ammunition components including live ammunition, cartridge cases, projectiles, cartridge primers, propellant, gunpowder (smokeless powder and black powder), fireworks (up to 75 mm diameter), distress signals (flares),

OC spray and railway track signal devices.

Before it is delivered to the facility the ordnance will have been collected by a district police officer, temporarily stored at their police station then transported to the facility. At the facility, ordnance is received, sorted, packaged and removed to temporary magazine storage. Other parties collect the ordnance from the magazines for disposal.

It was apparent during the risk analysis that the most likely place for an explosives event was the sorting room where the ordnance would be unpacked and

sorted prior to removal to another room.

A general risk analysis/HAZOP study was carried out on the operation of the facility and numerous protective features were incorporated and assessed. These included the usual fundamental concepts of quantity minimisation, separation of activities, and PPE, however in addition to these, specific consideration was given to the value or otherwise of a deluge system. This report summarises the results of some simple investigatory work done by Riskom International Pty Ltd.

The management of the facility was considering three possible options:

1. A military specification misting fire suppression system;
2. A simple water deluge system;
3. No additional protection.

Various groups and individual experts were consulted including: representatives in the USA Institute of Manufacturers of Explosives (IME), who are actively involved with the USA National Fire protection Association (NFPA); the office of the Chief Inspector of Explosives in UK; and the expert consultative group of SAFEX, which is a world-wide organisation of explosives companies.

The conclusions were:

- Deluge systems are effective to prevent the pyrotechnic material from propagating from one building or room to the next and to provide cooling for an operator.
- Detection response times of between 5 and 11 milliseconds are available; however this is still too slow to prevent flames impacting on the operator.
- There is no effective system available to protect the operator due

to the (relatively) slow response time of the water delivery, so PPE is the best option for his protection.

- Exposure to unprotected skin must be avoided, as must all synthetic (plastics) materials that may melt in a fire. Even a dust mask or cotton shirt can provide a degree of protection from skin burns in some accidents where the flash is extremely hot but only for a very short time period. (e.g. shot shell primers).
- Another recommendation for the operator is to wear total coveralls (cotton, with trouser legs outside boots), cotton gloves and a light full face helmet that prevents flames from entering the facial area.
- Some pyrotechnics when doused with water may produce superheated steam. This is more likely with larger quantities of ordnance, ordnance with metal powders or deluges with small water flows, such as misting systems. It is not likely to be a problem in this particular facility because of the lim-

ited types of materials handled.

- There are commercial systems available that will provide an effective deluge for the operations, at a reasonable cost.
- US NFPA has a few general standards applicable to deluge systems, in particular standards 13, 15 and 16<sup>1</sup>, however these are not specific for explosives and there is nothing in the NFPA explosives code on deluge systems.

The recommendation in this case was for a simple deluge system in the sorting room, based on overhead sprinklers actuated by UV/IR sensors with a reaction time between 50 and 150 milliseconds.

#### ACKNOWLEDGEMENTS

The following people provided advice and information: Piet Halliday and Henry Merrick (AELMS); Terry Bridgewater (Chemring PLC); Bob Sheridan and Phil Butt (Colleagues); Maurice Bourgeois (GD-OTS); Neil Morton, (HM CIE, UK); Lon Santis and David Boston (IME); Joe Page (Kilgore); Stephane Dath (Mecar); Ross Gourlay (SAFEX Expert Panel); Andy Begg (SAFEX Individual Associate).

<sup>1</sup> NFPA 13: Standard for the Installation of Sprinkler Systems

NFPA 15: Standard for Water Spray Fixed Systems for Fire Protection

NFPA 16: Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems

## Unplanned Explosions at Munitions Sites

by

**Eric G. Berman, Pierre Gobinet, and Pilar Reina**

(Small Arms Survey, posted 15 March 2012)

The Small Arms Survey (SAS) serves as the principal international source of public information on all aspects of small arms and armed violence, and as a resource centre for governments, policy-makers, researchers, and activists. The Survey distributes its findings through Occasional Papers, Issue Briefs, Working Papers, Special Reports, Books, and its annual flagship publication, the Small Arms Survey. The project has an international staff with expertise in security studies, political science, international public policy, law, economics, development studies, conflict resolution, sociology and criminology, and works closely with a worldwide network of researchers and partners.

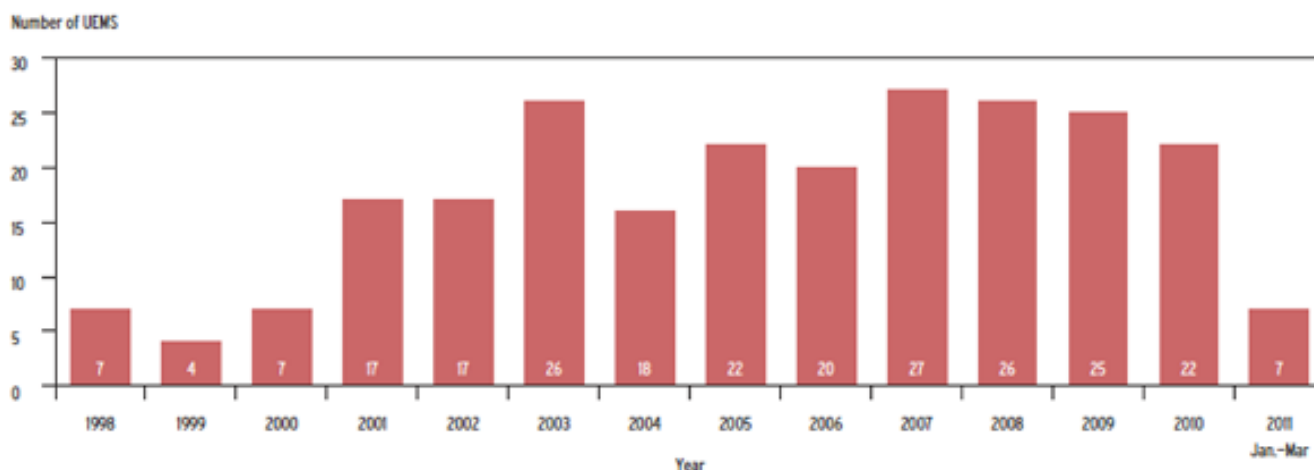
The Small Arms Survey is a project of the Graduate Institute of International and Development Studies, Geneva. For more information see [www.smallarmssurvey.org](http://www.smallarmssurvey.org) or contact SAS Researcher Benjamin King ([benjamin.king@smallarmssurvey.org](mailto:benjamin.king@smallarmssurvey.org)).

Considerable attention has been paid to the threats of small arms and light weapons proliferation and misuse, but the danger that these weapons' munitions<sup>1</sup> pose when poorly stored or mis-handled are less well known. A single

unplanned explosion at a munitions site can result in dozens of dead, hundreds of injured, and thousands of displaced people.<sup>2</sup> The damage to infrastructure can be extensive, covering many square kilometres. And the loss of economic

activity can top tens of millions of dollars and have long-term ramifications on livelihoods and the environment.<sup>3</sup>

Unplanned explosions at munitions sites (UEMS) are a global problem. Since

**Figure 1:** Number of Recorded UEMS by Year, January 1998—March 2011

Sources: Wilkinson (2011); Zahaczewsky (2011); Small Arms Survey (Forthcoming)

1998, incidents of this nature have been reported in almost a third of UN member states and on every continent except Australia and Antarctica (see Table 3 on p. 21). They have occurred regularly, with an average of less than three every two months for the ten-year period 1998–2007 (see Figure 1). According to the forthcoming Small Arms Survey UEMS database<sup>4</sup>, the rate has increased in recent years to more than one every two weeks. This database remains very much a work-in-progress. Since this page's previous update in November 2011, eleven new UEMS have been recorded for the three-month period up to 31 January 2012. Not included here is a major UEMS incident that occurred in March 2012 (after the period covered in

this update) in Brazzaville, Republic of the Congo, claiming over 200 lives, and displacing thousands. Additional research since the initial release of this page has resulted in the inclusion of 30 other incidents during the period 1998–2010, which included UEMS in five UN Member States previously not listed in our database: Azerbaijan, Dominican Republic, Luxembourg, Malaysia and New Zealand.

During 2011, the average number of explosions increased to 3.8 per month (see Table 2 on next page)—the highest rate recorded in a calendar year. It is unclear whether the problem is getting worse or reporting of incidents is improving. What is clear is that the num-

ber of explosions is not noticeably decreasing despite efforts to address their causes.<sup>5</sup>

There are numerous causes for unplanned explosions at munitions sites. Most derive from a lack of technical knowledge and uneven attention to safety standards<sup>6</sup>. Poor storage practices and poor infrastructure together cause more than half of the known explosions.<sup>7</sup> Other frequent causes include negligence during handling and during transport of ordnance. That said, for almost one-third of reported explosions no cause is recorded (see Table 1).

States exhibiting strong political will—often with international assistance—can prevent unplanned explosions or miti-

**Table 1:** Reported causes of UEMS, January 1998–March 2011

Summary of Causes				
Categorization	Causes	Number of events	% of all causes	% of known causes
1. Deterioration of the physical or chemical condition of the ammunition and explosives	Auto-Ignition of Propellant	15	6.1%	9.0%
2. Unsafe storage practices and infrastructure	Electrical Fault	7	2.9%	4.2%
	Fire <sup>a</sup>	46	18.8%	27.7%
	High Temperature	7	2.9%	4.2%
	Lightning	14	5.7%	8.4%
	Other	2	0.8%	1.2%
3. Unsafe handling and transport practices	During Demilitarization/Explosive	26	10.6%	15.7%
	Handling/Negligence	39	15.9%	23.5%
4. Poor security conditions	Security/Sabotage	10	4.1%	6.0%
5. Unknown causes	Not known	79	32.2%	
<b>Grand Total</b>		<b>245</b>	<b>100.0%</b>	<b>100.0%</b>

Sources: Wilkinson (2011); Zahaczewsky (2011); Small Arms Survey (Forthcoming)

a. Many of these fires may have originated as auto-ignitions of propellant.

gate their ramifications. Several regional organizations have developed 'best practice' guidelines regarding physical security and stockpile management (PSSM) (see, for example NATO (2010), OSCE (2008), RECSA (2005), and SEESAC (2007)<sup>8</sup>). Ad hoc coalitions of the willing, such as nine countries in South-East Europe that comprise the Regional Approach to Stockpile Reduction (RASR) Initiative, underscore the importance states attribute to PSSM.<sup>9</sup> International donors working bilaterally and through regional organizations have assisted dozens of governments to safely destroy surplus stocks of munitions and to secure remaining material in safe conditions.<sup>10</sup>

Some solutions are expensive to implement and may require external assistance, but many can be undertaken unilaterally and with modest investment. Some sites may need to be closed, and their ordnance moved to another location at great cost. New sites, incorporating quantity-distance principles and security features, may need to be constructed from scratch. Nevertheless, without necessarily striving to achieve state-of-the-art storage standards, a number of pragmatic measures can address the immediate risk of unplanned explosions. As depicted in the RASR PSSM Best Practice cards<sup>11</sup>, states can achieve positive results on their own through some inexpensive and effective first steps. These include installing proper doors and locks, using adequate fences and barriers, posting signs to warn and inform, and organizing the stockpile into stacks and aisles free of obstruction.

## DEFINITIONS

**Unplanned Explosions at Munitions Sites (UEMS)** include accidents resulting in the explosion of abandoned, damaged, improperly stored, or properly stored stockpiles of munitions and explosives. For our purposes, munitions sites comprise storage areas (including those temporarily maintained during demilitarization or explosive ordnance disposal) and processing sites, whether temporary or permanent. Ammunition manufacturing facilities (ordnance factories) are not included, but accidents during ammunition processing operations within Munitions Sites have been included where known.

**Accident** is defined as: 'an undesired event, which results in harm' (UNODA, 2011, para. 3.5, p.2). 'Harm' is defined as: 'physical injury or damage to the health of people, or damage to property or the environment' (UNODA, 2011, para. 3.120, p. 14).

**Explosion** is defined as: 'a sudden release of energy producing a blast effect with the possible projection of fragments. The term explosion encompasses fast combustion, deflagration and detonation' (UNODA, 2011, para. 3.95, p.11).

**Abandoned Explosive Ordnance (AXO)** is defined as: 'explosive ordnance that has not been used during an armed conflict, that has been left behind or dumped by a party to an armed conflict, and which is no longer under control of the party that left it behind or dumped it. Abandoned explosive ordnance may or may not have been primed, fuzed, armed or otherwise prepared for use' (UNODA, 2011, para. 3.1, p.1).

**Table 2: UEMS Incidents from 1 January 2011 to 31 January 2012 \***

### 2011

ID	MONTH	DAY	COUNTRY	FATAL	INJURED
1	January	5	Côte d'Ivoire	0	2
2		30	Venezuela	1	0
3	February	11	Romania	2	1
4		16	Tanzania	32	145
5		24	Spain	5	3
6	March	4	Libya	27	20
7		5	Cuba	0	0
8		27	Yemen	150	27
9	April	6	Russian Federation	4	4
10		11	Russian Federation	6	12
11		25	Pakistan	0	14
12		27	Albania	0	1
13		28	Albania	1	3
14	May	1	United States	0	0
15		11	United States	0	0
16		26	Yemen	28	#N/A
17		26	Russian Federation	1	12
18		26	Ukraine	2	1
19	June	2	Russian Federation	2	100
20		15	Germany	0	1
21		29	Libya	0	0
22	July	1	Luxembourg	0	2
23		4	Russian Federation	2	100
24		7	Turkmenistan	100	1'382
25		11	Cyprus	12	62
26		11	Pakistan	1	3
27		12	Russian Federation	2	2
28	August	23	Russian Federation	6	12
29	September	14	Croatia	0	0
30		19	Viet Nam	1	10
31		24	Libya	#N/A	#N/A
32		26	Sri Lanka	0	1
33		30	Bosnia and Herzegovina	#N/A	#N/A
34	October	6	Germany	0	3
35		7	Democratic Republic of the Congo	#N/A	#N/A
36		7	Democratic Republic of the Congo	#N/A	#N/A
37		8	Denmark	2	#N/A
38		17	Russian Federation	2	2
39		28	China	7	8
40	November	12	Bulgaria	0	0
41		12	Iran	36	#N/A
42		12	Azerbaijan	0	0
43		23	Lebanon	#N/A	#N/A
44	December	6	Libya	10	#N/A
45		8	Ecuador	0	23
46		17	Venezuela	#N/A	#N/A
<b>Total 2011</b>				<b>442</b>	<b>1969</b>
2012					
ID	MONTH	DAY	COUNTRY	FATAL	INJURED
1	January	2	Turkey	4	0
2		11	Bulgaria	1	1
3		17	Bulgaria	0	1
4		19	United States	0	1
<b>Total 2012</b>				<b>5</b>	<b>3</b>

\* Small arms survey (forthcoming)

**Damaged munitions** refer to the physical or chemical deterioration of ammunition and explosives. Munitions are considered improperly stored when storage does not generally follow accepted multilateral norms or guidelines, or existing national legislation and controls.

**Munitions** is used in this definition—and in common usage—to refer to weapons, ammunition, explosives and components. A number of armed forces and ammunition specialists, however, use the term munitions to refer solely to complete rounds of ammunition (cf. Ammunition) (Bevan and Wilkinson, 2008, p. xxvi).

**Ammunition:** A complete device (e.g. missile, shell, mine, demolition store, etc.) charged with explosives; propellants; pyrotechnics; initiating composition; or nuclear, biological, or chemical material for use in connection with offence, or defence, or training, or non-operational purposes, including those parts of weapons systems containing explosives (cf. Munition) (Bevan and Wilkinson, 2008, p. xix).

**Explosive Storage Area (ESA)** is defined as: 'an area used for the storage of explosives and within which authorised ammu-

nition or missile preparation, inspection and rectification operations may also be carried out' (UNODA, 2011, para. 3.108, p.12).

**Ammunition process [site]** is defined as: 'a building or area that contains or is intended to contain one or more of the following activities: maintenance, preparation, inspection, breakdown, renovation, test or repair of ammunition and explosives' (UNODA, 2011, para. 3.12, p.2).

**Table 3:** Number of Reported UEMS by region, sub-region and UN Member State 1 January 1998—31 January 2012\*

Region	Sub-region	UN Member States by sub-region	Incidence of UEMS		Distribution of events
			Number of UN Member States reporting UEMS	Number of events	
Africa	Eastern Africa	17	4	15	Mozambique (9); Tanzania (4); Kenya (1); Somalia (1)
	Middle Africa	9	3	13	Democratic Republic of the Congo (8); Republic of Congo (4); Angola (1)
	Northern Africa	7	4	10	Sudan (3); Egypt (1); Libya (4); South Sudan <sup>a</sup> (2)
	Southern Africa	5	0	0	No events recorded
	Western Africa	16	5	9	Nigeria (3); Côte d'Ivoire (2); Guinea (2); Guinea-Bissau (1); Sierra Leone (1)
Americas	Caribbean	13	2	2	Cuba (1); Dominican Republic (1)
	Central America	8	4	6	Mexico (3); El Salvador (1); Guatemala (1); Nicaragua (1)
	South America	12	8	18	Ecuador (7); Colombia (3); Brazil (2); Chile (1); Paraguay (1); Peru (1); Venezuela (2); Guyana (1)
	Northern America	2	1	11	United States (11)
Asia	Central Asia	5	4	10	Kazakhstan (6); Uzbekistan (2); Tajikistan (1); Turkmenistan (1)
	Eastern Asia	5	3	17	China <sup>b</sup> (13); North Korea (3); South Korea (1)
	Southern Asia	9	5	67	Afghanistan (20); India (20); Iran (9); Sri Lanka (11); Pakistan (7)
	South-Eastern Asia	11	7	23	Thailand (6); Cambodia (4); Philippines (4); Vietnam (5); Indonesia (2); Laos (1); Malaysia (1)
	Western Asia	17	10	41	Iraq (15); Yemen (8); Lebanon (5); Turkey (5); Georgia (2); Israel <sup>c</sup> (2); Kuwait (1); Syria (1); Azerbaijan (1); Cyprus (1)
Europe	Eastern Europe	10	6	66	Russian Federation (46); Ukraine (10); Bulgaria (6); Romania (2); Slovakia (1); Poland (1)
	Northern Europe	10	2	3	United Kingdom (2); Denmark (1)
	Southern Europe	14	8	22	Serbia (8); Albania (5); Montenegro (2); Italy (1); Slovenia (1); Bosnia & Herzegovina (2); Croatia (2); Spain (1)
	Western Europe	9	3	13	France (4); Germany (8); Luxembourg <sup>d</sup> (1)
Oceania	Australia and New Zealand	2	1	1	New Zealand (1)
	Melanesia	4	0	0	No events recorded
	Micronesia	5	0	0	No events recorded
	Polynesia	3	0	0	No events recorded
<b>Grand Total</b>	<sup>e</sup>	<b>193</b>	<b>80</b>	<b>347</b>	

\* According to United Nations Statistic Division (Revised in July 2011).

- The two incidents recorded in South Sudan involved stockpiles belonging to Khartoum government forces in Juba, in 2005 and 2007, before South Sudan became the 193rd UN Member State (on 14 July 2011) and after the signature of the Comprehensive Peace Agreement (on 9 January 2005).
- Including ten incidents recorded in Taiwan. In 1971 the UN recognized Taiwan to be a province of China.
- The two incidents in question took place in the Palestinian Territories, involving non-state stockpiles.
- The depot where the incident took place has been the Belgian Army's main munitions store since 1993.

Sources: Wilkinson (2011); Zahaczewsky (2011); Small Arms Survey UEMS database (forthcoming).

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## END NOTES

- <sup>1</sup> 'Munitions' is used in this Research Note—and in common practice—to refer to military weapons, ammunition, and equipment. A number of armed forces and ammunition specialists, however, use this term to refer solely to complete rounds of ammunition.
- <sup>2</sup> The death toll has at times been much higher: in January 2002, for example, a series of explosions at a military depot on the outskirts of Lagos, Nigeria (sub-Saharan Africa's most populated city), resulted in more than one thousand deaths, with many people drowning in nearby canals when fleeing the fires and explosions (MSIAC, 2002). See also US DoS (2010).
- <sup>3</sup> Following an explosion in Paracin, Serbia, in 2006, a main access road was reportedly blocked off for 32 hours, and an estimated 15 million Euros worth of trade was lost (Parliamentary Forum, 2008). The Serbian Army subsequently removed more than 130,000 pieces of unexploded ordnance (UXO) in an eight square kilometres (3.1 square miles) perimeter around the contaminated area (Jovanović, 2011).
- <sup>4</sup> The forthcoming UEMS database builds on the very useful listing of incidences compiled by Adrian Wilkinson and George Zahaczewsky (Wilkinson, 2011; Zahaczewsky, 2011); it will be made available on the Small Arms Survey web site later this year.
- <sup>5</sup> Private facilities are also at risk. The forthcoming UEMS database seeks to distinguish facilities that are wholly national or private enterprises from those that are state-owned but privately operated.
- <sup>6</sup> Munitions' propellant, primer, and explosive components require trained experts to conduct routine physical surveillance and chemical testing throughout the objects' life-cycle.

<sup>7</sup> Poorly managed state stockpiles also facilitate corruption due to poor record-keeping and diversion by criminals and non-state armed groups.

<sup>8</sup> See also the forthcoming United Nations Coordination Action in Small Arms (UNCASA) International Small Arms Controls Standards (ISACS) and United Nations Office for Disarmament Affairs (UNODA) International Ammunition Technical Guide (IATG) mentioned in King (2011, p.4)

<sup>9</sup> For more information on the RASR Initiative of Albania, Bosnia-Herzegovina, Bulgaria, Croatia, Macedonia, Montenegro, Romania, Serbia, and Slovenia—with the support of the US—see <http://www.rasrinitiative.org>.

<sup>10</sup> Best practices in theory often meet unexpected challenges when put into practice. See, for example, King (2011).

<sup>11</sup> See <http://www.rasrinitiative.org/resources-PSSM-identification-cards.php>

## 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](mailto: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.

### Dry powder increases sensitivity and risk

**An operator suffered facial burns and the compartment was slightly damaged when lead mononitroresorcinol (LMNR) ignited in the Fusehead Plant of one of our members. The operator was transferring dry LMNR to a storage container using a stainless steel scoop when the ignition occurred. There were also questions around the suitability of the Personal Protective Equipment in this instance: was it used and, if so, is it appropriate**

**Martin Held (Austin International) commented as follows on this incident:**

I would agree that wearing of correct PPE would have reduced the consequences. However, the first step (as mentioned) would be to prevent an ignition. My questions would be: Is a metal scoop the correct tool for this task given the possibility of metal to metal contact or would a soft tool be more appropriate? Was the metal scoop a permitted article that the operator was supposed to use? Was the operator aware and trained about the change of sensitivity when the material dries out? When we commissioned our detonating cord plant in Argentina we focussed on the change in sensitivity of wet and dry PETN. Operators moving from PETN manufacturing where they handled wet PETN to the detonating cord operation were 'surprised' by additional measures that needed to be taken with dry PETN.

We introduced what we term an internal License to Operate for detonating cord plant operators. To be "licensed" operators must demonstrate their knowledge of the Basis of Safety (BoS) of the plant by passing a written exam after their training. For the BoS training we took pictures throughout the plant to explain the BoS principles on how to avoid ignition sources and to prevent PETN dust accumulating in the wrong place. Sealing of all joints (on shelves, flanges, cameras) and plugs on bolts; less inventory and smaller portions (compared to an 80 kg batch of wet PETN when recrystallizing and filtering); humidity control; electrostatic controls; soft surfaces; soft and lightweight tools; no heavy objects that can fall; control of grit (wet mats at entrances); were some of the measures we emphasized. We explained the differences between handling wet and dry PETN and included specific questions on these issues in the exam. We also had a higher frequency of inspections during the first weeks and months of operation.

**To this the member concerned responded:** The main issue with this incident is that a production change occurred when they increased the number of batches without following the proper Change Management procedure. Secondly, metal to metal contact should not occur as the container is covered

with material. However, given that metal to metal contact is always an issue and cannot be ruled out. If there is a remote possibility that this can occur it should be engineered out, changing the design and conducting regular checks. In this way the risks as can be mitigated as best one can.

We have also introduced an initiative in case of all serious recordable injuries such as this one. The injured person (if possible), his/her immediate supervisor as well as other line managers are required to present personally the findings of the incident investigation at a meeting of the Executive Committee. It isn't intended to be a disciplinary inquiry, but the Committee asks questions to know what they experienced and learnt from the incident. It is also a way for them to acknowledge the importance of the incident and accept accountability for it. It transpired that this operator had worked with LMNR for 38 years without being involved in any incidents. While there is a visible difference between wet and dry LMNR, the operator said he really did not know that dried LMNR will react the way in which it did. As regards the PPE, it made a substantial difference as the operator sustained superficial burns to the head and face. He has fully recovered. , he is fine now with some sensitivity which is to be expected.

## More on handling incendiary powders .

The LMNR incident above reminded Martin Held (Austin International) of a similar incident. An operator was scooping delay powder from a cylindrical metal container when the powder started to burn due to metal on metal friction. As it was a slow burning powder the operator was able to leave the room and let the powder burn out. Damage was minor.

**Martin Held made the following observations when he commented on this incident:** A brass scoop had been used for decades in this operation. However, the containers in use had two different diameters which must have been as result of a change sometime in the past. The incident occurred with a container having a smaller diameter. From an ergonomic perspective it is almost impossible not to cause friction while scooping from the bottom of the container. The first proposal was to modify the shovel and shorten the shaft. However, Basis of Safety (BoS) considerations suggest it will be better to replace the material of the scoop with wood or conductive plastic to avoid metal to metal contact and potential friction in the future.

**On reading this Incident Notice, Maurice Bourgeois (GD-OTS Canada) shared their experiences with dry powder:**

- We don't use metal containers to avoid metal to metal contact as in this case. Furthermore, they are more prone to brush discharges which is why we recommend conductive plastic or rubber ones.
- The containers are slanted so a thicker layer of powder collects at the bottom and on the side of the container
- We never scrape the powder against the wall of the container. The edge of the scoop does not come in contact with the container wall.
- When there is not enough powder left to scoop without having the scoop scrape the container wall, the operator stops and re-bowls the remaining powder in a filled container if static discharge is not an issue. Alternatively he re-bowls remotely into filled containers

**Mervyn Traut (Expert Panel Member) was struck by some trends in recent incidents:** Here we have an incident involving possible impact and friction. This is one of a number of recent incidents which highlights our inability to learn from past mistakes. The following incidents illustrate this.

- IN21-10 involved pyrotechnic composition used for delay elements. Probable cause was friction between the stainless steel scoop and edges of the brass tray that ignited the composition in the tray.
- IN06-11 a frictional event took place inside the mixer in a pyrotechnic powder mixing compartment resulting in a fire
- IN12-11 reported an operator dropping a container with delay powder that spilled out of the can and started to burn when the can hit the pavement. Impact was the likely cause.
- IN26-11 involved a pyrotechnic (flare) composition with impact as the possible cause.
- IN27-10 also involved a flare composition. Here the possible cause was electrostatic discharge (ESD) or impact
- IN15-12 also involved a pyrotechnic compound. While the cause of this incident has yet to be established with certainty it could have been friction or impact
- IN 22-12 was possibly due to an impact or frictional event with a pyrotechnic compound.

The following extract from a BoS document may be pertinent: *Pyrotechnic explosives (e.g. mixtures of lead oxide and silicon) do not detonate but present a variable level of fire risk and hazard depending on the composition. They are typically sensitive to: friction, flame, spark and impact.*

## Confinement - A common cause of burning ground explosions

A burning ground explosion that was recently reported involved the destruction of waste emulsion cartridges. The investigation concluded that the most probable cause of the explosion was some stray detonator cord that landed unintentionally in the waste.

**William Spiteri (Sasol Nitro) commented as follows:** In my opinion the effect of self-confinement must not be underestimated. In our experience, whenever we have had an explosion in the burning ground, the investigation invariably determined that the explosives had been piled-up in a heap when burnt.

## And you thought cooling towers were harmless – and irrelevant

**One of our members experienced a fire when the cooling tower in their ammonium nitrate complex was being maintained. The cooling tower packing material ignited during hot work on the plant as the Permit to Work system failed to identify the extent of the hazard associated with dry packing material.**

**Martin Held (Austin International) observed as follows:** This very interesting investigation report was a trigger for me to review our BoS document on AN manufacturing. Under 'sources of fire (as an ignition source)' we carry the entry 'presence of organic/combustible materials around process areas'. As demonstrated here, the behavior of a 'controlled' combustible (being wet during operation) changes dramatically when dried out in combination with the stack-effect and the organic material (algae, moss) which then burns like cinder.

However, it also tells us to look beyond explosives and reactive intermediates or raw materials and also consider other process materials and apply the same BoS principles as for explosives. Elsewhere in this "Inbox" we saw how dried out material changed its properties resulting in a fire

## Watch those bearings - (and other power traps)

**Incendiary composition containing magnesium entered into the bearing of a mixer despite assurances from the supplier of the bearings that the bearings were fit for purpose. A fire resulted in the mixer which automatically activated the drencher system. This prevented the fire from spreading and minimized the damage.**

**Maurice Bourgeois (GD-OTS Canada) found the report very interesting.** He wrote: We had a similar experience with granulators where we had migration of tracer composition into the rotor bearings. Fortunately we caught this anomaly during a routine preventive maintenance inspection before it resulted in an accident. The bearings were properly

sealed but powder accumulated between the bearing and the shaft seal. Some time ago we also had an ignition of tracer powder in a granulator for a different reason. The granulator was not perfectly level and some powder collected in a pocket behind the rotor seal and dried there. Green powder containing solvents is less prone to initiation by friction than dry powder. Since this accumulation could not be prevented, we had to put in place a cleaning procedure between each batch.

**Martin Held (Austin International) had a question about the drenching process in this case:** As the mixture was magnesium based and contained a solvent, is there a risk when you deluge with water of:

- either the solvent (assuming it to be immiscible with water) floating on the surface of the water and continuing to burn
- or that a hot metal fire could start where water reacts with magnesium generating hydrogen? How did you find water to be suitable for these mixtures?

**We received the following response from the member concerned:** Actually, the water does not put the fire out. Magnesium will keep burning at 2,000 °C until there is nothing left – in the form we use it, it is typically consumed in 2 or 3 seconds and takes the solvent with it. All the water does is to stop the spread of the fire to other parts of the building and maybe protect some of the utilities.

## Tanker to tank transfers are not trivial

**The Explosives Inspectorate of Queensland, Australia alerted us to a large uncontrolled spill of ammonium nitrate emulsion (ANE) while it was being transferred from a road tank vehicle into a mine storage tank. The incident was attributed to a lack of vigilance on the driver's part.**

**It reminded Maurice Bourgeois (GD-OTS Canada) of a similar experience they had:** While filling No 2 oil in a tank at our power house, the truck operator went inside leaving the filling area. The tank overflowed because our boiler operator had misjudged the remaining empty volume in the tank. Hence it is important to verify beforehand the remaining tank capacity to avoid overfilling.

## 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!

## Good Explosives Practice – Is it a Lost Art?

by

**Tony Rowe (AEL Mining Services)**

When I was just a light in my daddy's eye there existed in the world a thing called "Good Explosives Practice". It is a concept so old that I once gave a talk on it. I remember that talk like it was yesterday.

I still remember yesterday. It was a time when all my teeth were my own, my

eyes worked (without benefit of the add on glassware) and I didn't walk like a limping old duck, but all that aside, exactly what is Good Explosives Practice anyway?

Well, it's a way of working safely with explosives, but it's a demanding discipline that demands a wide range of

knowledge. Unfortunately, no formalised system for recording best practice has ever existed. There is little or nothing on paper. Even my old scrolls, some dating from the time of Nebuchadnezzar are silent where Good Explosives Practice is concerned. The fragments of the early wisdom that I have managed

to unearth conjure up images of something pure and wonderful. Like an Eldorado perhaps, a legendary city this time not of gold, but of truth.

Like Eldorado, almost everyone knows something about it or has heard of it. They'd like to get there, but they don't know the way. If there was a map then, perhaps they would start the journey, but because nothing tangible, exists they fear becoming lost.

To help explain the concept of Good Explosives Practice all those years ago I attempted to conjure a picture of the Four Horsemen of the Apocalypse. These guys are of course infamous. They appear in the Bible and were named in both myth and legend as Famine, War, Plague and Death. I remember that Death rode a pale horse. Mythology and folklore are full of such characters



In other places and at other times cultures like the ancient Greeks and Romans had whole hosts of entities who controlled their daily lives. Even now, well into the twenty-first century people still make offerings to strange gods. Miners in South America and Mexico still build shrines to the various forces who they believe contribute to their personal safety and thus life and death. Around the world, people who routinely work with explosives have always turned to their individual lucky charms and personal rituals to ensure that things go well. I for instance turn to my lucky dancing frog I've named Croaker. He sits on the dashboard of my car and nods most wisely every time we hit a bump in the road. In reality though safety is best not left to luck and ritual, but rather rests in the arms of other more powerful and controllable forces. I refer of course to the Seven, not the Magnificent Seven of western movie fame, but rather the Seven Shades the undeniable overseers of every operation involving explosives. The seven, by the way even have names. The names are well known, but attract little in the way of attention which is exactly what the Seven strive for.

First there is **Careless**. Now he really is a cracker He's a dancer by profession and does a little jig each time he scores. His best friend is called **Apathy**. He doesn't know why and couldn't care less either.

My own personal favourite is **Expediency**. He always sacrifices safety to his own convenience. He's selfish and over the years has fed off the suffering of more than a few. Let's not

forget **Ignorance** either. Ignorance isn't stupid, he is simply uneducated and thus does things that a wiser person might not. There are the **Habit** Twins: Good Habits and Bad Habits, they're joined at the hip. Bad Habits is a big bruiser, strong willed and forceful. He owns both an addictive personality and a loud voice. Good Habits on the other hand is small, shy and totally lacking in confidence. He lives in the shadow of his twin so doesn't say much. He believes life is its own reward. We mustn't forget **Complacency** either, smug and overconfident little weasel that he is. Finally there is **Laziness**. He cultivates the path of least effort and spends his time encouraging what is easiest, never what is safest.

Please keep your eyes open for these guys. With the possible exception of Good Habits they are truly not your friends, however much they will try to convince you of their good intentions.



Despite the rituals, the shades and the entities, the life-blood of the explosive and mining businesses has traditionally been its reserves of experienced people. Experience though cannot be bought, it has to be earned and that takes time. Unfortunately, people grow old. They go on pension, they end up in hospitals and old age homes and ultimately of course they die. I have to ask, what was their legacy? In most cases nothing, nada, zip, zero. They took their knowledge with them. No succession planning, no download. Precious resources consigned to oblivion.

Endless downsizing and redundancy programmes have also exacted a toll on the industry while high staff turnovers continue to eat away at what little remains. The safe operation of business grows ever harder.

With most of its acolytes going or gone, Good Explosives Practice too has suffered. Its substance is so much less than it was. Soon, unless something is done, there will be only the shadows – dark leftovers, legends of what went before. Unsupported, the protection offered by the protective blanket of Good Explosives Practice weakens as its folds grows evermore threadbare. Today's managers see little use for the ancient wisdom.

I, on the other hand quietly grieve for what has been lost. I pray it's not too late.

Is it too late???

**("This is your Captain Speaking"—continued from p. 1)**

As is the case with most explosives companies in the world and given the nature of our business, Enaex's regards Safety as a real priority. This philosophy was engrained in the Company by our founders. Safety as well as quality and a concern for the environment is the responsibility of every person in the Company. We are both proud and humble of our outstanding record in this regard.

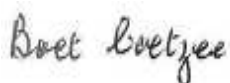
From early times we inherited the concept of the "Enaex family". It means that integrity, truth, confidence, mentoring and care are part of our culture as are passion and accountability. Values are distinctly expressed in our Code of Ethics and we believe our policy of Corporate Social Responsibility starts in house. Taking care of the business means taking care of our own people first. Blasting and explosives technology aren't formally taught in our country. So we dedicate time and effort to properly educate our employees; induction programs are an important activity of every supervisor in the company.

We not only allow but actively encourage our employees to participate in all sorts of activities that can improve our relationship with local communities, industry and professional organizations. This is one way we use to obtain our "social permit" to stay in business. Our membership of SAFEX over a decade further demonstrates our commitment to "make our industry healthier, safer, more secure and environmentally friendlier", as Claude Modoux pointed out in his last New Year's message.

Just as we strongly believe in our employees "right to know" we recognise their ability to contribute innovative ideas to improve our operations. We have a formal system for workers' suggestions that can range from simple improvements in a process to complex technological changes in products, manufacture or blasting services. The experience and knowledge of every worker, from the youngest trainee to the most experienced supervisor, are invaluable to improve working conditions and process safety. This belief has been key to Enaex's growth in our local market and international expansion. Evidence of such growth is seen in our need to hire many new employees, operators and engineers in a short period of time. Every new person is submitted to a formal in-room and on the job induction program, and simultaneously mentored by a senior supervisor.

Most of the mines in Chile are located in uninhabited areas up in the mountains, sometimes under extreme altitude or weather conditions. The focus on blasting services means that most of our labour force have to be far away from their families almost every other week. Therefore, Enaex has established programs not only to consider employee's working conditions but also to take care of their families.

Finally, we believe that safe behaviour should be at the heart of our efforts. We further believe that behavioural change does not come about by more or better procedures alone but with leadership. Here our managers perform a crucial role. Theirs is the responsibility modelling them and ensuring behaviours are aligned with our Company's values and policies .



Boet Coetsee

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