SAFEX INTERNATIONAL
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This is your Captain Speaking

Rene Blouin (GD-OTS Canada)

René Blouin is the Vice President and Chief Operating Officer of **General Dynamics Ordnance Tactical Systems (GD-OTS) Canada Inc.,** formerly SNC Technologies Inc.**,** which is a subsidiary of General Dynamics Corporation. The Company specializes in the manufacturing of large, medium, and small calibre ammunition as well as products and services related to military and para-military activities .

René holds a Master Degree in Mechanical Engineering and started his career in a company that specialized in flight simulators. In 1985 he joined GD-OTS Canada and moved through different roles in Engineering, Programs, Manufacturing, Procurement, Quality and R&D. He occupied leadership positions in executive management and has for many years been responsible for driving the strategic plans of the Company .

GD-OTS Canada has provided ordnance to Canada's National Defense and many foreign armies since 1941. It operates the following facilities located in the province of Quebec with a total work force of 1,200 employees:

- Repentigny, the headquarters (near Montreal), for loading, assembling and packing all calibre ammunition
- St-Augustin-de-Desmaures (near Quebec city) focuses on metal forming (brass cartridge cases and projectiles
- Valleyfield looks after the development and manufacture of energetic materials and extruded propellants
- Nicolet is a Government-owned site that the Company operates for proofing, testing and evaluating ordnance

The Company is committed to protect the Health & Safety of all employees and our environment. We are committed to meet or exceed all applicable Environmental, Health & Safety laws, regulations, company policies and customer requirements while producing high quality products. Our primary concern is safety in the use of our products, hence safety of our customers and safety in manufacturing. Everyone in the company must be committed to safety and quality from top-down and commitment is not only measured in words but also in deeds. The Company has invested a lot in employee safety awareness and training with the STOP™ program by which employees become trained observers of dangerous conditions, behaviour or actions. They are required to intervene by correcting or notifying or having a safety talk with the person who's actions or behaviour can have dire consequences.

A prerequisite to employee commitment is participation. I feel that employees that participate in making the workplace safer and more efficient will share management's commitment to safety. Hence, we have monthly employee-management safety committee meetings. An employee group collects improvement suggestions and gives feedback whether or not their suggestion has been accepted or rejected together with the reasons for doing so. Management presents safety statistics and feedback regularly during monthly safety meetings and top management briefs all employees on safety performance and improvements for the previous year at the yearly kick-off meeting.

We have a robust system with simple and clear procedures to manage and follow all activities related to health and safety. Accidents and near misses are thoroughly investigated; production is stopped until the root causes are found and corrective measures are implemented. This applies not only to the area where the accident happened but also to other areas with similar conditions.

Another important contributing factor to safety performance is a quality culture. One of our motto's is ''Always on Target''. That means ordnance has to function 100% at the target all the time. Our employees are fully aware that our soldiers' lives depend on it. This culture carries over to the shop floor. A poorly assembled ordnance part can have detrimental effects on subsequent steps in the process. The Quality value impacts on all we do: equipment design, risk analysis, housekeeping, documentation, etc. Hence it makes for a safer work environment.

GD-OTS Canada has had an excellent record for many years but we can't rely on past achievements. It has to maintain its efforts in training and employee safety awareness, in continuous safety improvements of its equipment and processes and in good housekeeping. It is an ongoing battle and a long haul.

Meet the new SAFEX Chairman

In the last edition of the SAFEX Newsletter we said goodbye to Claude Modoux as Chairman of SAFEX International. Claude will be staying on as Governor but decided to hand over the baton (or is it the gavel!) to John Rathbun. In electing John as the new SAFEX Chairman, the Board of Governors recognized his passion and commitment to SAFEX. On behalf of our readers we wish John a very fruitful term as Chairman and pledge our support in whatever way we can help to advance the cause of our Association. With John at the helm and with the backing of the SAFEX Board of Governors, there is no doubt SAFEX is in capable hands.

John brings new insights to his role and we invited him to share some of his thoughts and aspirations with our readers.

John Rathbun (Austin International)

John studied mining engineering at the South Dakota School of Mines and Technology. Upon graduation in 1984, he started work as a section foreman underground in West Virginia for the Consolidation Coal Company. In 1986, John joined the Austin Powder Company as a Technical Representative based at the corporation's main manufacturing site, Red Diamond, in McArthur, Ohio. Since this time, John has been involved within many facets of the company and has enjoyed being a part of Austin's growth for the past 28 years.

Since 2001, John has been based in Cleveland, Ohio, leading Austin's international business. Given that much of Austin's international growth has been through acquisitions, a fundamental focus for Austin has been towards creating a common culture and language among these companies based around safety being the first priority. With the help of many, Austin's operations today are more aware of the processes, the role of each worker, the sensitivities of the products that we work with and how we all need to continually strive to ensure our operations are safe. Austin has historically been a strong supporter of the tenets of SAFEX and as a Chairman, John will continue in this tradition.

In addition to the work with SAFEX since 2003, John has been active as a member of the Industrial Advisory Board for the mining program at the South Dakota School of Mines.

When not working or with his family, John can be found in the outdoors either hunting grouse with his pointer Roxy or fly fishing in a nearby stream.

It is an honor to be elected Chairman of SAFEX and I am truly thankful for the opportunity to attempt to give back to an industry that has given so much to me. I believe the mission of SAFEX is an "industry critical" one and I am also greatly appreciative that those leaders of the various explosives companies 60 years ago recognized this and created SAFEX International.

I also believe that the mission of SAFEX is a very human one with the fundamental task of saving lives and preventing the disruption of families. If one member learns of a mistake, an oversight, an improvement…then to share it with the other member companies helps everyone avoid the same mistake or oversight. In doing so, the logic follows, we reduce the number of events and impacts to our employees, our neighbors, our companies and our industry.

One of my intentions as Chairman of SAFEX is to raise participation by industry in the organization. A recent trend that we have seen is that the largest companies in our industry are reporting incidents less as well as reducing the numbers of attendees to the congresses. It has been a regular discussion point during Governor meetings – "how can we improve the participation of our member companies? How can we improve the participation of the largest companies in our industry to reverse the trend and share more rather than less? "

An interesting dynamic is taking place within SAFEX at this time and that was apparent recently at the Warsaw Congress. There were record numbers of attendees this year with participation from many smaller companies and from far away countries. This is the good news for the industry, that the workshops that were offered became over- subscribed and the congress halls were full of attendees.

The recruiting efforts of the past years have paid dividends in expanding around the world the membership. New member companies are found today in countries that the founding Governors couldn't have conceived of and yet there is still more to do in this area. However, the opposite is happening when the historically dominant companies of our industry are examined. The numbers of attending delegates from this group was very low and this is a flashing yellow light for all of us.

We need for our various member companies to share their wealth of knowledge when it comes to safety and to use SAFEX as a repository of corporate memory and a forum to discuss. Given the recent trends of executives being held accountable on a brutally quarterly basis for their financial progress, this challenges the systems and people within the various organizations in unintended ways. For example, it takes years, perhaps decades, to properly develop the balanced managers that our industry dictates. Managers who have the knowledge and ability to make the best judgment on how to run a facility properly and professionally. The ones who can articulate how the specific systems work and how we are protected while they operate. These facts need to be nurtured and protected within our own organizations as well as within the industry. However, we have been seeing many very seasoned and knowledgeable practitioners leaving companies and ultimately industry due to the short-term financial demands that exist today. SAFEX has a role to play here as a keeper of acquired knowledge and this should be supported by all with the desire to share with all. This may be more important today than it has ever been.

I would also like to recognize at this time the excellent Board of Governors that SAFEX enjoys today. We have a passionate group of Governors from practically every continent with a range of experiences and backgrounds. With their continued guidance, I am sure that the coming years we will see many new ways for members to interact within SAFEX….whether it is via the website, probing the database, participating in a workshop, learning on-line, deep-diving into a Master Class, etc. The organization today is full of energy and on solid financial shape due to the blessings of strong past leadership. We have the opportunity to build on this further between now and the next Congress in 2017.

Therefore, over the course of the coming years, please do not be surprised if you receive a request to increase your participation in SAFEX. Whether it is a Governor reaching out for an expert from your company, a request to increase incident reporting or a call to see what more can SAFEX do to protect us all. At this point in time, SAFEX needs to see members stepping up and supporting its' role in industry.

G.S. Biasutti in the Conclusion of his book "History of Accidents in the Explosives Industry" notes:

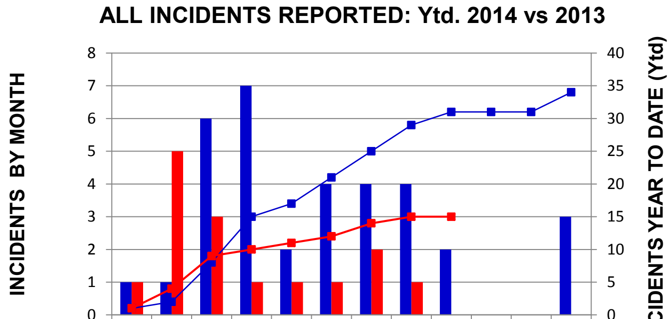
"The moral of this book is not that explosives are dangerous, but that all accidents can be avoided by preventing their occurrence. This presupposes that the persons who are responsible for the design, construction or operation of the plant must have the knowledge of the potential hazards and the way to prevent them. They must also have the power, the ability and the authority to enforce the rules by demanding discipline and sense of responsibility from everyone concerned."

Incident Reporting

Monitoring our Reporting Performance

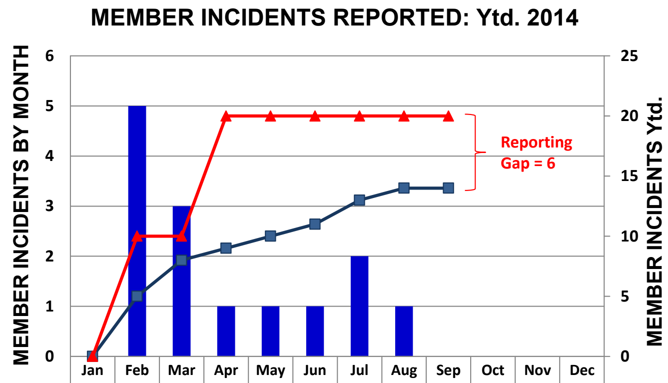
"Every incident that is reported may prevent another from occurring. You can save a life by reporting an incident - including a near-event."

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



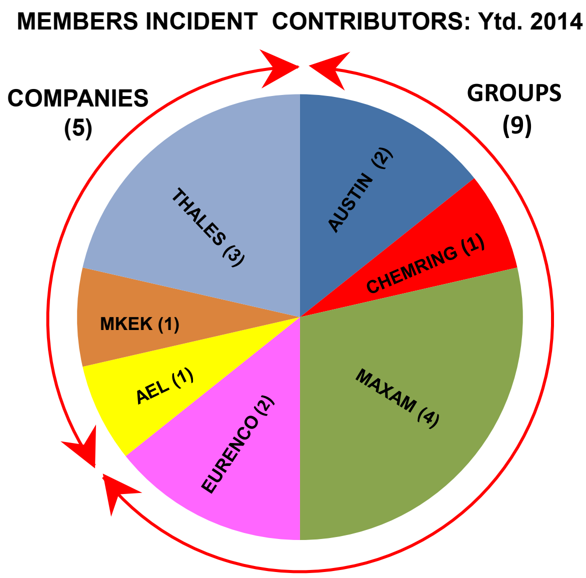
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2013	1	1	6	7	2	4	4	4	2	0	0	3
2014	1	5	3	1	1	1	2	1	0			
Ytd 2013	1	2	8	15	17	21	25	29	31	31	31	34
Ytd 2014	1	4	9	10	11	12	14	15	15			

All the incidents reported. This chart compares the sum of non-member and member incidents reported to SAFEX every month this year compared to the previous year. We have only reported half the incidents this year than in in the same period last year and the gap is widening. Are we having fewer incidents or are we not reporting the incidents we are having? Every incident not reported is a lost learning opportunity. Remember, it's never too late to report an incident.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2014	0	5	3	1	1	1	2	1	0			
Ytd	0	5	8	9	10	11	13	14	14			
Par	0	10	10	20	20	20	20	20	20			

Member incidents reported. Because they give us the best learning opportunities, we track member incidents (MI's) separately in the chart on the right. PAR is an estimate of how many MI's are occurring based on the severity of the MI's that have been reported this year. The gap between the number of MI's reported and PAR is our Reporting Gap. The Reporting Gap suggests that only 70% of our MI's are being reported.



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 Group Members have reported about twice the number of incidents Company Members reported.

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.

Gérard Chaloyard

PERSONAL

Position: Proprietor
Company: GC Tec
Location: Vonges - France
Education: MSc (1974)
Blasting license (1982)
Affiliations: AFP - GTPS - A3P -
Until 2008: FEEM, AFNOR, CEN Working Groups
Until 2007: GEMO
SAFEX
Languages: French, English.

CAREER OUTLINE

Gunpowder National Factory (1975-1980)
Production Manager

SNPE (1980-1995)
R&D Manager

Nobel Explosifs (1995-2008):
Production and R&D Manager)
Explosives Technology Expert.
Plant Manager (Vonges)

GC Tec (2008-Present):
Consultant

EXPERTISE

- Production - military smokeless gun powders (simple & double base) and military high explosives.
- Research & Development and Production - black powders, ANFO, cast boosters, watergels, slurries, emulsions, explosives for metal cladding, different devices for blasting applications (pre-splitting, post splitting, hot furnaces)
- Design, development and use of the MEMUs,
- Test center management for pyrotechnical and UN safety tests
- Technology transfers - civil explosives (under license) in foreign countries,
- Compliance testing and documentation preparation for submission to European Notified Bodies
- Hazard identification and risk assessments in manufacture and use - black powder, high and civil explosives
- Accident investigations (Black Powders, civil explosives, precursors...),
- Operating procedures (mining and blasting) - quarries, mines, underground applications

RECENT PATENTS & PUBLICATIONS

- EP Patent - 2000-01-05 Cartridged energetic emulsion explosives
- FR & BE Patents - 2002-07-02 : Explosion trap for bulk explosives pumping circuit
- International Occupational Safety and Health Information Center (CIS)- ILO-CIS Bulletin 2002/02 CIS 02-886 - Hot mass blasting - Safety techniques and development of a pyrotechnic system
- Most recent publication : **A3P - "Septièmes Journées Scientifiques Paul Vieille"** November 21, 2012, *The ammonium nitrate and 150 years of its use in the civil explosives : dynamites, nitrated explosives, ANFO, watergels and slurries, emulsions and their blends*.

TYPICAL ASSIGNMENTS

- Assignments cover all the areas listed in "EXPERTISE" above
- Pyrotechnical test center development, for all the class 1 tests, new UN test series 8
- Evaluation and characterization of some precursors like TAN, hot solutions, emulsion matrix, SP for UN classification.

Meet our New Governors

At the recent Ordinary General Meeting of members held during the XVIII SAFEX Congress in Warsaw, the following new Governors were elected:

- Dr Noel Hsu (Orica USA Inc)
- Edmundo Jimenez (Enaex Servicios)
- Dawie Mynhardt (BME South Africa)

We will be introducing the new Governors to our readers in forthcoming Newsletters and start with Dr Noel Hsu.

Noel Hsu (Orica USA Inc.)

Noel Hsu is a newly appointed member of the Board of Governors and is the Vice President of Global Regulatory Affairs with Orica Ltd. Orica, with over 14,000 employees worldwide is the world's largest provider of commercial explosives to the mining and infrastructure markets and a leading supplier of underground mining and tunnelling technology.

Noel is very active in SAFEX: He leads the SAFEX Workgroups on Ammonium Nitrate and Explosives Security as well as the Steering Team on SAFEX e-learning initiatives. He is an active member in the UN Explosives Working Group, the International Group of Experts on the Hazards of Unstable Substances (IGUS) and the Institute of Makers of Explosives (USA).

With over 25 years with Orica and its predecessor company ICI, Noel has worked in R&D and manufacturing covering technologies in nitroglycerine, airbag propellants, TGAN, bulk and packaged explosives as well as explosives delivery systems. Over the last few years Noel has been in the regulatory affairs role for Orica and interacts with the global competent authorities.

He graduated from MIT with a Bachelors and Masters in Chemical Engineering and has a PhD in Chemical Engineering from the University of Toronto. He has furthered his formal education through courses in Transition to General Management (Columbia University) and Strategic Management for Regulatory and Enforcement Agencies (Harvard Kennedy School of Government).

Together with his wife Janice, Noel enjoys going to the movies and exploring Colorado's great outdoors. He is an avid cyclist and also dabbles in the art of photography.

QRA Corner

Welcome to another instalment of the SAFEX Newsletter series called the QRA Corner. Each column will examine a particular aspect of state-of-the-art applications, large-scale testing, and algorithms associated with Quantitative Risk Analysis (QRA) models. Your authors will rotate between Lon Santis, who runs his own consulting business, Explosives Risk Managers LLC; John Tatom, Vice President at APT Research, Inc and Manager of their Explosives Safety and Testing Group; and Mike Swisdak, creator of the US Department of Defense' ESKIMORE large scale test program and currently a senior scientist at APT Research. This instalment discuses the importance of the debris produced by an explosion and whether traditional QD approaches cater for it satisfactorily.

Evaluating Debris Hazards

by

John Tatom (Vice President, Explosives Safety and Testing, APT Research, Inc)

Most Quantity-Distance (QD) systems are based, directly or indirectly, on some form of cube-root scaling. This means that in order to keep the same pressure level, the required distance increases proportional to the cube-root of the charge weight. In general, this produces consistent results for pressure (and impulse) considerations, but what about the debris produced from an explosion? The answer is quite different: certainly the quantity of explosives and the distance to the "target" affect the results, but the cube-root scaling does not apply, and there are many other factors to consider. When studying the problem, it becomes clear that a "cookie cutter" solution may not be available.

Quantitative Risk Assessment (QRA) models, as has been discussed in this article series, must consider these additional factors, and can use the test results to generate more realistic debris density predictions (also discussed previously). But is this just an academic exercise? How safe are people from debris hazards when they are far enough away, according to QD? Let us consider a series of tests to examine this issue, rather than discussing it hypothetically.

If we look at several different tests with approximately the same explosives quantity, we can look at QD and debris patterns to make a general comparison, and also consider how differences in the test parameters affect the debris results. Since we have several tests at approximately 1000 kg, each with comprehensive debris catalogs, let's look at QD and debris at that charge weight. The tests are from the US DoD's Project ESKMIORE series: ISO-3, ISO-4, and SciPan 4. We'll use the American Table of Distances (ATD) to determine the QD arcs.

ISO-3 had 1054 kg of munitions inside a 20' ISO container on the ground (not on a truck, like ISO-1 and ISO-2), with no barricades involved. Using IMESAFR 2.0 with an ISO-3 debris scatter plot as a background image, we can look at QD and the debris pattern. Figure 1 shows this, looking at only the debris from the ISO container (no primary fragments from the munitions), with both regular Inhabited Building Distance (IBD) and the barricaded value (IBD [B]) shown. In this figure, the different colors merely represent the different debris recovery quadrants. IBD in this case is 329m. The dashed red circle represents the Risk-Based Evaluation Distance (RBED), which is an indication of the distance beyond which IMESAFR predicts negligible risk, regardless of angle. In this case, the RBED is 478m.

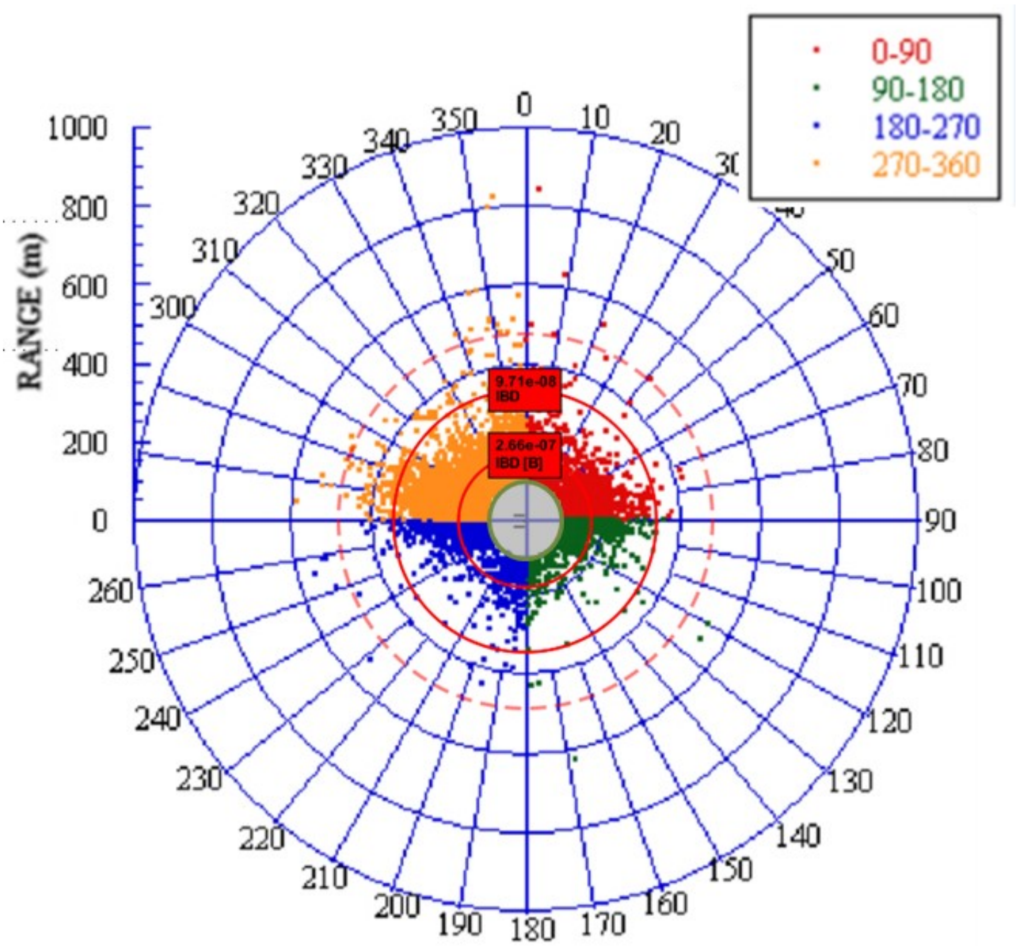
Note: the numerical values in the red label boxes represents the highest risk that IMESAFR calculates at the IBD arcs. These values depend on the input assumptions and are not the focus of this article.

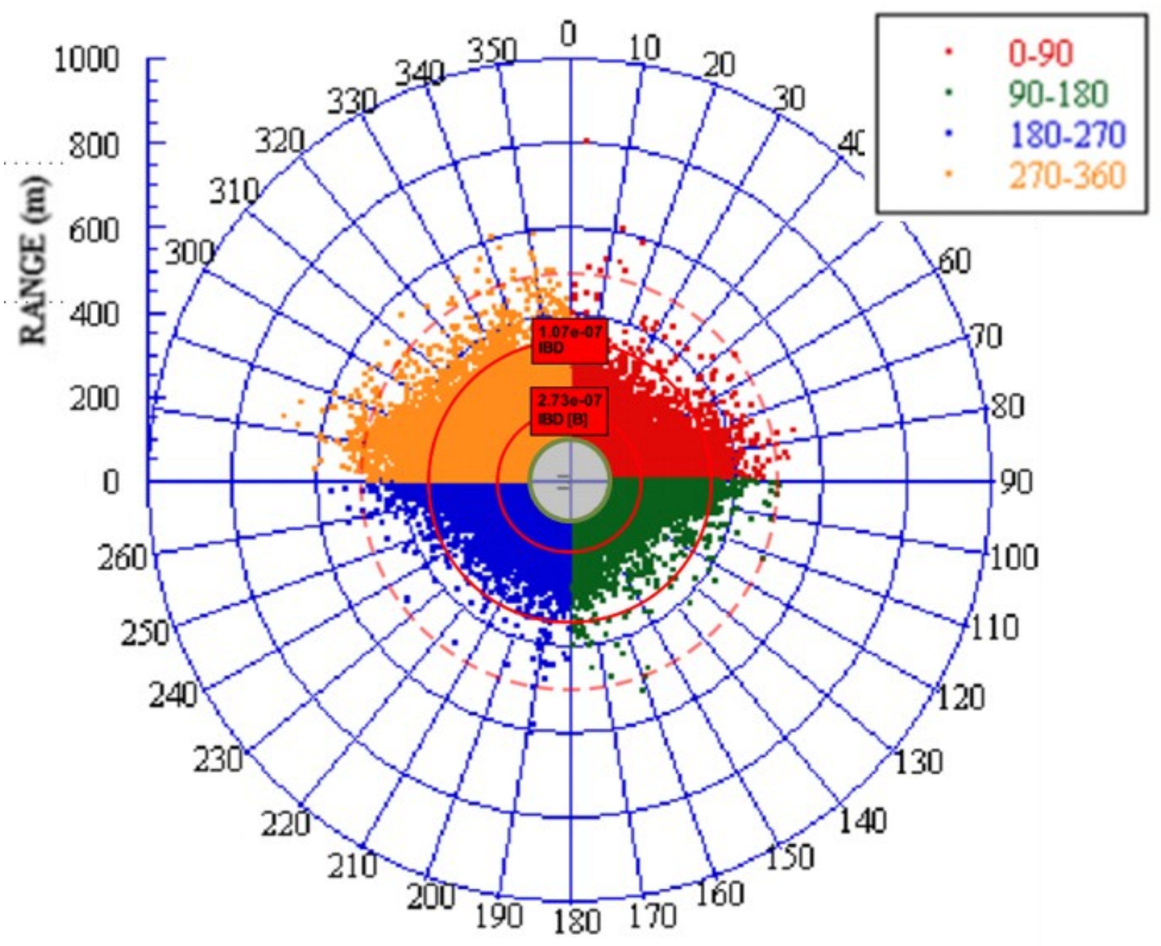
Looking at Figure 1, we see that some debris goes beyond IBD – some well beyond it, to 800m or so. This should disprove the misconception that QD is a "force field" that prevents debris from escaping. But perhaps there isn't that much debris beyond QD, depending on what angle you look at. It's unclear if there is a cruciform pattern to the debris, because the relatively strong wind at the test seems to have skewed everything to the "northwest" in this plot.

Figure 2 on the next page again shows the ISO-3 test results, but this time plotting only the primary fragments from the munitions, versus the same IBD arcs. Note that the introduction of primary fragments has increased the the RBED (again shown as the dashed red circle) to 493m, though IBD is still 329m.

Now we see quite a lot of debris beyond IBD, especially in the 270-360° quadrant. Also, although there does not seem to be a pronounced cruciform pattern to the debris, there does seem to be a "long axis" for the debris, along the 270-90° line.

Figure 1. (below): ***ISO-3 (ISO container debris only) Debris Scatter Plot with QD Arcs***



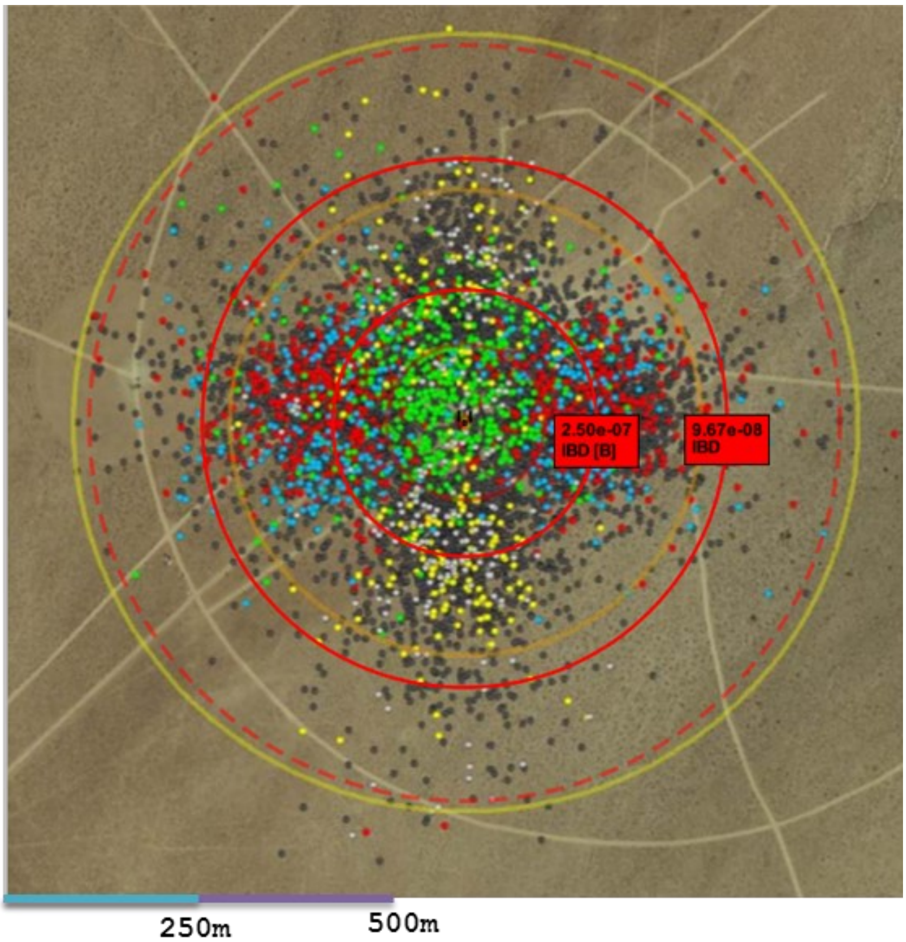


<u>Figure 2</u> (above): ISO-3 (primary fragments only) Debris Scatter Plot with QD Arcs

But normally typical commercial explosives will not have this primary fragment concern, at least not to this degree, so let's consider another test.

ISO-4 had 1000 kg of bulk explosives (no primary fragments) inside a 20' ISO container on the ground, with no barricades involved. There was only a slight wind to the "northwest" in this test. Using IMESAFR 2.0 with an ISO-4 debris scatter plot as a background image, we can plot the same QD arcs again, as shown in Figure 3. Now the RBED is 478m.

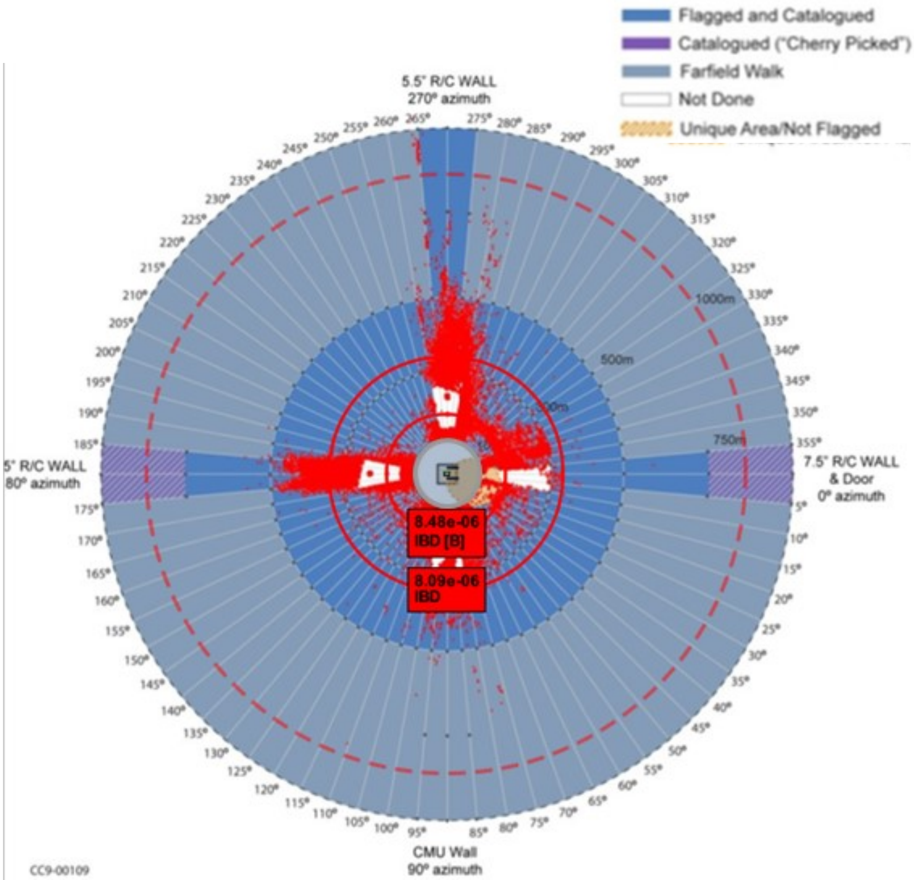
In this plot, the color of the point represents the origin of the debris (in terms of what part of the ISO container), when known, as described in a previous article. The solid rings without labels are 100m (red), 300m (orange), and 500m (yellow). As with ISO-3, debris is found well outside the IBD arc (329m). Without a significant wind, a cruciform pattern is evident in this scatter plot, but it not particularly pronounced.



<u>Figure 3</u>. (above): ***ISO-4 Debris Scatter Plot with QD Arcs***

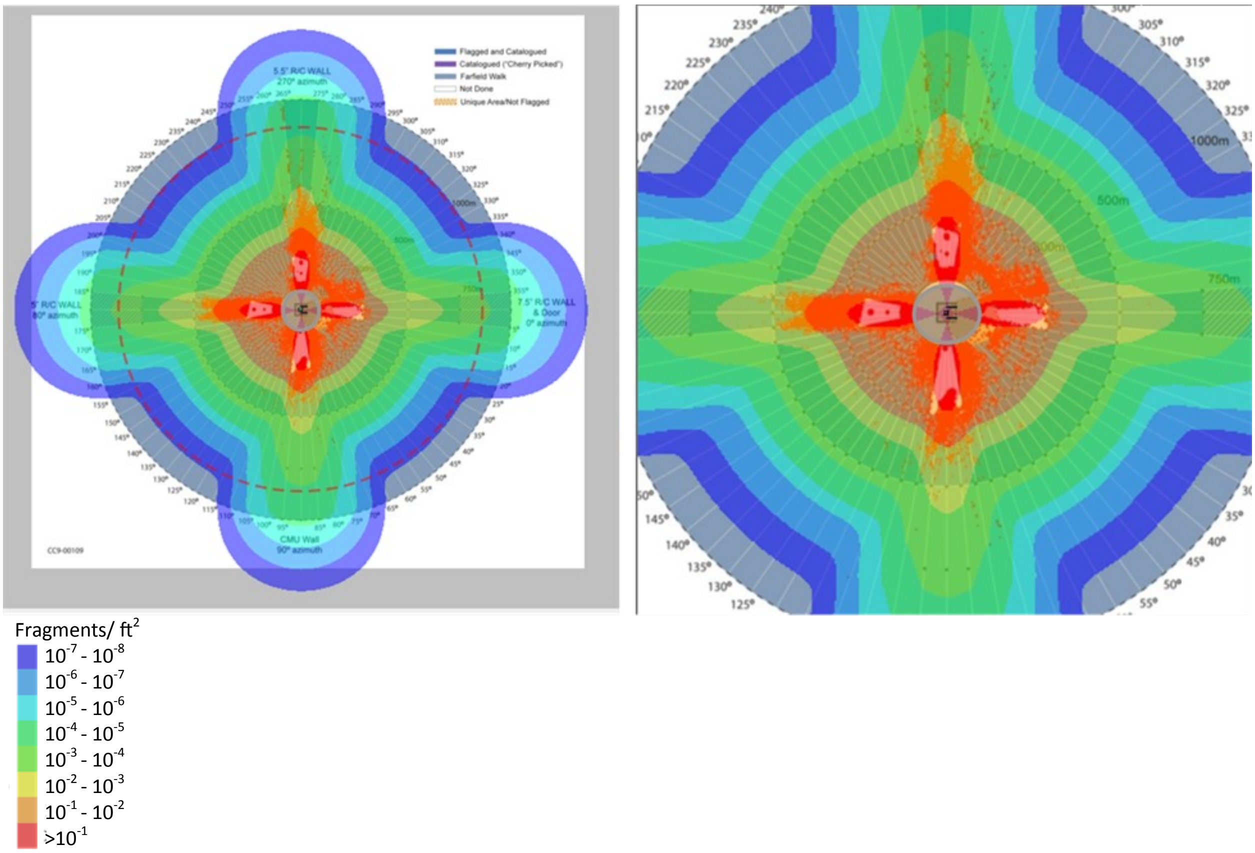
Changing from an ISO container to an aboveground concrete structure (with no earth-cover), but staying at 1000 kg, we can now view the same sort of plot for SciPan 4. Figure 4 shows the concrete debris beyond IBD (still 329m), and has a distinct cruciform pattern. In this case, it is not just a question of a few pieces here or there exceeding IBD – there are thousands of pieces beyond 329m along each of the wall normals. Because of the anticipated increase in debris hazard, IMESAFR has generated a much larger RBED (866m).

It is evident at this point that there is some debris hazard beyond IBD. The question then becomes how this can be addressed (or how well this can be addressed) by a QRA model. Using the ISURF downrange debris prediction model, as described in a previous article, and a presumption of Gaussian cross-range debris density decay, IMESAFR 2.0 produces the debris density prediction shown in Figure 5 (overlaid on the same scatter plot, without the QD arcs). An overview is shown on the left, and a zoom-in on the high density areas is shown on the right.



<u>Figure 4</u> (above): ***SciPan 4 Debris Scatter Plot with QD Arcs***

<u>Figure 5</u> (below): ***QRA Debris Density Model vs SciPan 4 Debris Scatter Plot***



As the scatter plot and the debris density contours indicate, the debris hazard is different at various angles for a given distance. If a siting standard provides only a single distance for a certain NEW (i.e., a QD arc), there is no easy way to establish that distance without resorting to a very conservative approach that works for all angles. And how does one account for the debris variations observed between different types of structures? Would there be a different distance for each type of structure? Whereas these complexities are hard to address with QD, they are inherent to a QRA model.

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.

We're delighted to be able to publish another contribution from Canadian Explosives Research Laboratory (CanmetCERL) in this edition of the Newsletter and thank Richard Turcotte and his colleagues for supporting our efforts in this way.

Safety Testing of a 3" (76 mm) Rotary Gear Pump with Unsensitised Bulk Emulsions

by

R. Turcotte, C. Badeen, C. Iyogun, and L. McCauley (CanmetCERL, Ottawa, ON, Canada)

1. Introduction

Despite their insensitivity to accidental initiation under normal operating conditions, water-based commercial explosives and precursors such as ammonium nitrate (AN)-based emulsions have still been involved in a significant number of accidental explosions and history demonstrates that pumping emulsions either for manufacture or handling operations can be a hazardous process.

In response to several pumping accidents [1], many pump test results have been generated since the 1980s by various explosive manufacturers. In Canada, some of these results were shared among selected stakeholders. This led to the development of pumping guidelines that were endorsed by both the explosives industry and the Canadian government [2]. Similar guidelines were also issued by the Institute of Makers of Explosives in the United States [3]. However, no safety test results on rotary gear pumps could be found in the open literature. Therefore, the program described herein set out to determine if an explosion could be caused while pumping unsensitised emulsions (UN3375) with a typical gear pump used in the explosive industry.

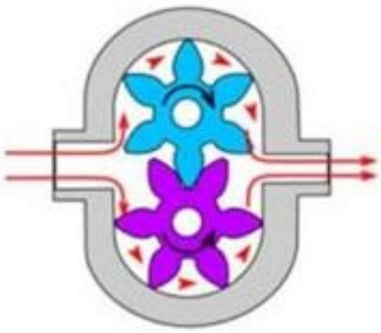


__Figure 1__*: Schematics of Gear Pump*

Gear pumps contain, within their housing, a pair of equally sized, fixed displacement gears (Figure 1), one or both of which may be driven. The gears are covered with an elastomer which prevents metal-metal contact and improves the seal. Such gear pumps are very commonly used for the pumping of bulk emulsion products (UN 3375) for transfer and down-hole applications. In these operations, hazardous high temperature conditions may result from possible no-flow situations where the pump is running dry or is deadheaded.

In the experiments reported herein, various dry-running and deadheading tests were performed with a rotation speed 20 % higher than recommended by the pump manufacturer and with an electric drive capable of delivering 3 to 4 times more power than that used in actual explosives applications. Several repeats of each test configuration were carried out in order to provide some degree of confidence in the results. A total of 44 tests were completed with three different formulations of unsensitised bulk emulsion.

Due to the significant efforts required, Natural Resources Canada (CanmetCERL), Orica Ltd., and Dyno Nobel agreed to undertake this project jointly. All experiments were performed at the Dyno Nobel test site near North Bay, Ontario, Canada. This site offers good protection of operators against projectiles as it is located in a depression having high rock faces on three sides.

2. Experimental

A test rig was designed and built specifically for this project. It consisted of a 3" (76 mm) rotary gear pump, a 30 kW (40-hp) electric motor driven by a variable frequency drive (VFD), a hopper, pneumatically actuated or automated valves, and 1.5" (38 mm) stainless steel pipes used to make a closed loop covered with 2" (50 mm) hot water jacket pipe and 1" (25 mm) insulation. The resulting test rig is shown in the photographs of Fig. 2. The piping connecting the outlet of the pump to the hopper has been angled vertically in this fashion to simulate some pressure head caused by a somewhat long discharge hose or a vertical tank arrangement.

Before each experiment, 50 kg of emulsion was introduced in the hopper and the valves were positioned so as to prime the pump and piping by briefly recirculating the emulsion. Once bubbles were no longer observed in the hopper, the pump was stopped. The valve positions were then adjusted so as to produce the desired test configuration. The pump was then restarted and quickly ramped to the RPM required for the particular experiment.

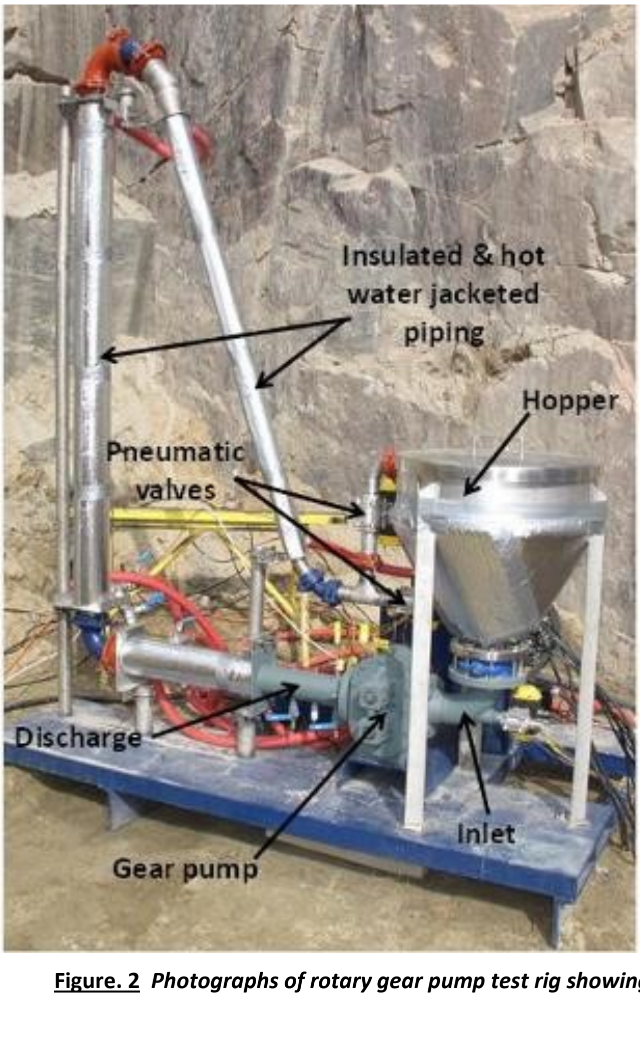
2.1 Emulsion products and test configurations

In order to simplify the logistics of the tests, it was decided that unsensitised bulk emulsions available on site at the Dyno Nobel North Bay facility would be used for these tests. Throughout the test program, three different "live" emulsion products were used:

- Titan 1000: A surface AN bulk emulsion formula
- Dyno RUP: An underground AN/CN emulsion formula with less water than the surface formula
- Dyno RU: An underground AN/SN emulsion formula also with less water than the surface formula (less prone to break down than the other two)

The test program consisted of four test configurations: Dry-running with blocked suction (DRBS), dry-running with open suction (DROS), deadheading with blocked suction (DHBS), and deadheading with open suction (DHOS). For all dry-running tests, at least three repeats were to be carried out. For deadhead tests, it was felt that nine repeats would be necessary to provide sufficient degree of confidence.

All tests were kept running until the temperatures and the discharge pressure had stabilized and were either falling or



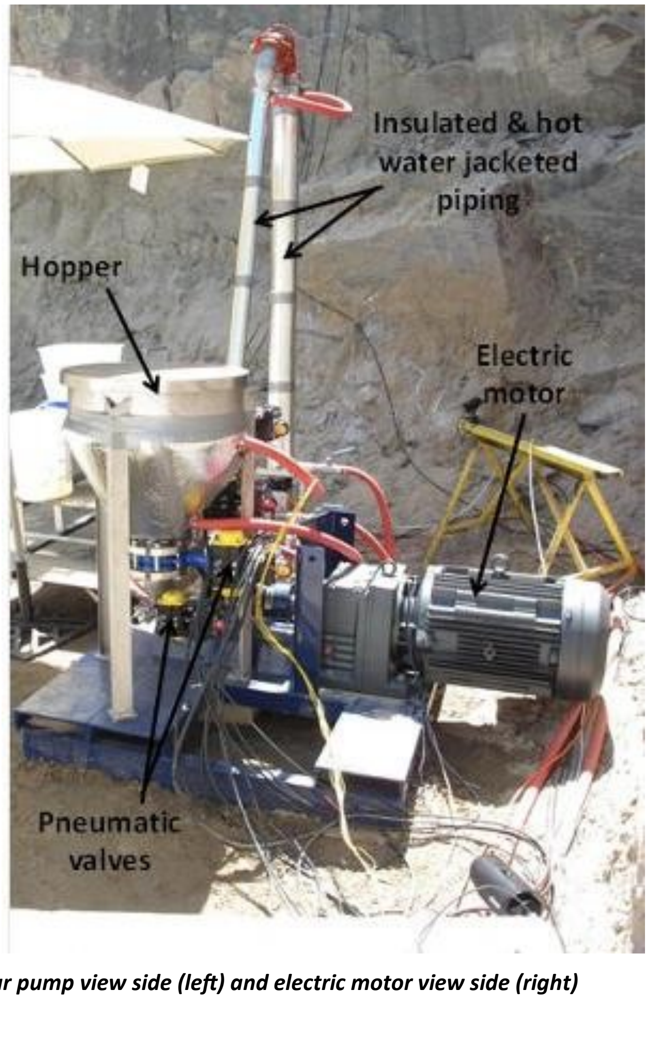


Figure. 2 ***Photographs of rotary gear pump test rig showing gear pump view side (left) and electric motor view side (right)***

Table 1: ***Summary of testing configurations and conditions***

Test Configuration	No of tests	Emulsion product	RPM
DHBS	10	Dyno RUP	360
DHOS	1	Titan 1000	360
DHOS	6	Dyno RUP	360
DHOS	5	Dyno RU	360
DHOS	1	Dyno RUP	240
DHOS	1	Dyno RU	300
DRBS	1	Titan 1000	360
DRBS	4	Dyno RUP	360
DRBS	1	Dyno RUP	240
DRBS	1	Dyno RUP	300
DROS	5	Dyno RUP	360

not increasing for at least 15 minutes. As seen from Table 1, extra tests at 240 and 300 RPM were also performed to gain information on the dependence of the heating rates on RPM.

2.2 *Instrumentation*

Standard K-type thermocouples (3 mm or 1/8" sheathed - ungrounded) from Omega Engineering were used to measure temperature at various locations. Except for T1 which was bolted to the top surface of the pump, all thermocouples were mounted through the pump body or inlet and discharge pipe using 3 mm (1/8") compression fittings. These thermocouples were located as follows:

T2: Through the pump side plate with tip close to top gear
T3: Through the pump side plate with tip close to bottom gear
T4: Through top of pump body with tip close to top gear
T5: Through pump discharge, angled so that its tip was close to the contact point of the gears
T6: Through the discharge pipe 2.5 cm (1") from the pump discharge
T7: Through pump inlet (added at a later stage)

The pressure transducers (pump inlet and discharge) were 0-7 MPa (1000 psig) full-scale voltage transducers (Omega PX309 series). They were mounted on steel nipples filled with a thick layer of low heat conductivity grease to insulate the transducer from the high temperature emulsion. The motor load was obtained directly from the VFD module, which was equipped with a 0-10 V signal output that scaled at 5.0 kW V^{-1}. An infrared (IR) camera (FLIR Model SC325) was also used to capture the surface temperature distribution of the pump. The sensor for the rotation speed measurements was an inductive proximity sensor (Omron Model E2E2-X3D1) which picked up the signal from a custom made shaft collar attached to the pump drive shaft.

The data were acquired using an Omega DAQ3005 data acquisition system with an Omega OMB-PDQ30 expansion module. A DasyLAB-based (Measurement Computing) program was written to control the DAQ and acquire the various signals. To provide protection against strong signal pick-up from the pump electric motor, signal conditioners were added to each sensor line (Seneca Model Z109REG2).

The DAQ, computer, power supplies, line conditioners and all other instrumentation for monitoring the pumps were built into a large protective metal box which was installed behind a heavy concrete block barrier, relatively close to the pump site. Power was supplied from a 100 kW electric generator which was situated in a protected area. The generator supplied power to a double-conversion Uninterruptible Power Supply (UPS) to which all the other electrical power supply connections to the pump, computers, and other equipment were made.

The experiments were controlled from a remote building situated at a safe distance. Communication with the DAQ computer was achieved by “Ethernet Radio” (Banner Model DXER9). Ethernet radio signals were boosted using 10dB gain antennas. In the remote building, a laptop computer was used to monitor the signals, and to remotely control the DAQ computer at the pump site (in the protective box).

Finally, there were four video cameras positioned at strategic locations. These cameras were hard-wired to a recording system located in the remote building, thereby giving live images and audio of events taking place while a test was ongoing.

3. Results

3.1 Deadhead Testing with Blocked Suction (DHBS)

This configuration simulated simultaneous blockages in the pump’s inlet and outlet. All attempts to start the pump in this configuration using the recommended gear/side plate clearance (0.2 mm or 0.008") and new gears resulted in either tripping off the VFD overload protection or breaking the drive shaft. It was therefore concluded that it would be impossible to start the pump in this configuration unless the gears would be aged and somewhat used up to allow sufficient emulsion slip. In order to simulate this, it was decided to increase the clearance between the gears and the side plates by stacking gaskets between the side plates and the pump body. Several different additional experiments were performed in order to define the minimum clearance that would allow the pump to be deadheaded. It was found that it had to be increased to about 3 mm (0.120"; total for both gear sides).

Using gear end clearances that varied from 2.8 to 3.6 mm (0.110-142"), 10 additional DHBS experiments were completed. The results were characterised by high initial heating rate (up to 127 °C min^{-1} or 229 °F min^{-1}), then slowing down with

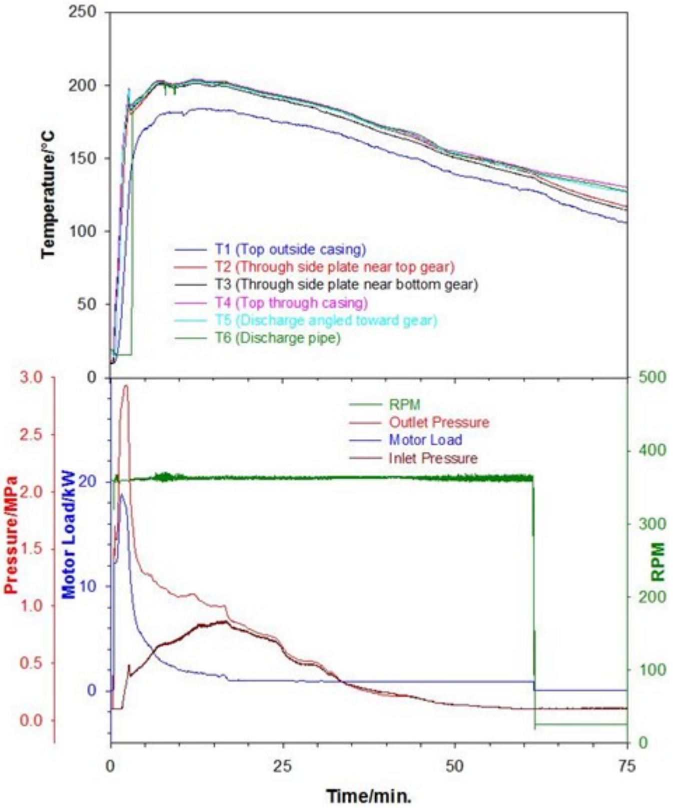


Figure 3: *Acquired signal from typical DHBS run*

Figure 4: *Typical gear damage after a DHBS run*

the temperature stabilising typically around 200 °C (392 °F) and then decreasing (Figure 3). All thermocouples followed each other quite closely, except T1 at the outside surface. In general, T6 remained at ambient temperature for the first few minutes and then quickly caught up with all the other thermocouples. In most cases this seemed to coincide with the point at which significant pressure was observed in the inlet. This might indicate early breakdown of the emulsion so that viscosity was reduced and more product slippage occurred as well as less viscous product was pushed into the discharge. The discharge pressure peaked for about the first 5 minutes with no obvious trend in amplitude: maximum discharged pressures varied from 1.9 to 6.3 MPa (260-900 psig) in the different tests. After this first spike it decreased and equilibrated with the inlet pressure and they both continued decreasing as gears were being damaged. The behaviour of the motor load followed that of the discharge pressure very closely. In this case, the maximum motor load varied between 17 and 30 kW (23 and 40 hp) from one experiment to another.

Internal damage to the pump and product degradation with each test were all similar: the elastomer coating on the gears was mostly destroyed (see Figure 4) and the emulsion product inside the pump chamber and within the pump inlet and discharge was broken into 2 phases.

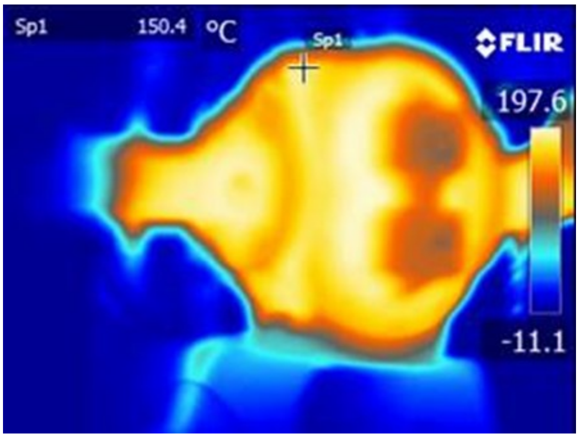


Figure 5: *IR camera image at 30 min mark in a DHBS experiment (pump inlet on the right)*

A still infrared camera image, taken 30 minutes into a DHBS experiment (Figure 5) provides quick visual indication that temperatures were symmetrically distributed in the pump (top and bottom gears) and that the thermocouples were located in the hottest areas in the pump. For the DHBS experiments, the temperature field in the discharge pipe indicates that hot product did not travel further than the location of the pressure transducer.

3.2 Deadhead Testing with Open Suction (DHOS)

This configuration simulated a blockage in the pump's outlet. Similarly to the DHBS experiments, increased side plate clearances had to be used (2.8 to 3.4 mm or 0.110 to 0.134") for the DHOS tests.

In general, the tests at 360 RPM were also characterised by high initial heating rates (up to 140 °C min^{-1} or 252 °F min^{-1}) slowing down until a stable temperature plateau was reached for time periods up to two hours. The temperature of this plateau ranged from 140 to 180°C (284-356 °F). As for the DHBS experiments, the discharge pressure and motor power had initial spikes (2.6-5.3 MPa (360-750 psig) and 20 -30 kW (27-40 hp), respectively) that decreased to much lower values within the first few minutes. In general, the signals in the DHOS experiments with Titan 1000 and RUP were much noisier than for the DHBS tests. Large fluctuations

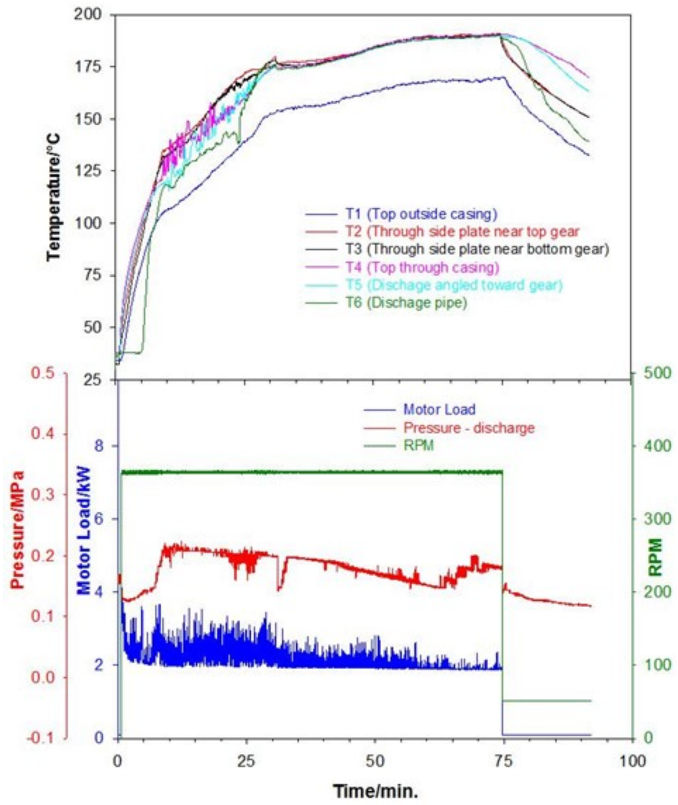


Figure 6: ***Acquired signal from typical DRBS run***

were observed on several signals and these seemed to be correlated with the observation of puffs of steam emitted from the hopper on the video cameras.

Similarly to the DHBS experiments, no explosions or even signs of sustained combustion were observed. With Titan 1000 and Dyno RUP, the emulsion was systematically broken down and heavy gear damage was observed after the experiments. In the experiments with the Dyno RU emulsion, much quieter signals were obtained. The emulsion did not break down but was heavily refined and was observed to be much thicker after the experiments. Also, little gear damage could be observed in these cases.

The experiments performed at 240 and 300 RPM produced similar results but with slower initial heating rate (32 and 60 °C min^{-1} or 58 and 108 °F min^{-1}, respectively).

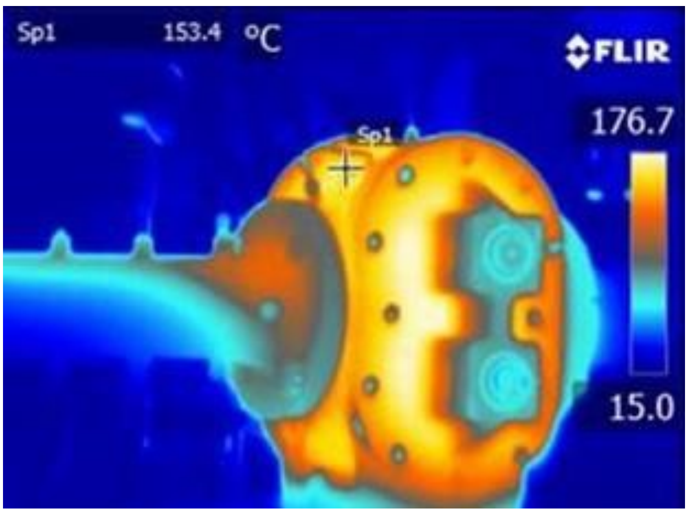


Figure 7: ***IR camera image at 30 min mark in a DRBS experiment (pump inlet on the right)***

3.3 Dry-run Testing with Blocked Suction (DRBS)

This configuration simulated a blockage in the pump's inlet. All dry-run tests were carried out with the recommended 0.2 mm (0.008") side plate/gear clearance.

Compared with the deadheading experiments, much more gradual initial temperature increases were observed. Typically an initial increase to about 125°C (257°F) was observed in the first 10 to 25 minutes. This was followed by much more gradual increase up to a plateau in the 170-215°C range (338 -419°F) (typical example in Figure 6). Also, it was observed that T6, in the pump discharge, remained low until the temperature at the other thermocouple locations reached about 125-130°C (257-266°F), which is the temperature at which the emulsion is expected to start boiling.

The discharge pressure showed an initial spike of relatively low amplitude (maximum 1.4 MPa or 190 psig). The motor load exhibited a similar behaviour with an initial fast spike up to 18 kW (24 hp). After these initial very short spikes, both signals reduced to much lower values (0.2 to 0.3 MPa (15-30 psig) and 0.3 to 6 kW (0.4-8 hp), respectively).

The IR image of Figure. 7 shows two key points. Firstly, the discharge pipe is significantly cooler than the body of the pump, especially at the early stages of the test. This is consistent with the observations from T6, whose temperature did not rise initially until it came in contact with either hot products or vapours from boiling emulsion. Secondly, there is a noticeable temperature gradient in the discharge pipe with the upper surface of the discharge pipe being hotter than the lower surface at the same horizontal distance from the pump section.

Two other DRBS tests were conducted at 300 and 240 RPM, respectively. The difference in these tests compared to those at 360 RPM is mostly the maximum temperature obtained in these tests. Although it seemed there was not a large decrease when the motor speed was reduced from 360 to 300 RPM (200 to 190°C or 392 to 374°F), there was a more significant temperature drop when the motor speed was further reduced to 240 RPM (190 to 170 °C or 374 to 338°F).

3.4 *Dry-run Testing with Open Suction (DROS)*

This configuration simulated an empty hopper or missing emulsion supply. These results of DROS tests were characterised by relatively low initial heating rates (1.4 to 5.1 °C min^{-1} or 2.5 to 9.2 °F min^{-1}) up to a temperature plateau at about 125-150°C (257-302°F). In two of the tests, the temperature started increasing again after some time until reaching the 250-275°C (482-527°F) range. In this range spikes in T2 to 285 and 320°C (545 and 608°F) were observed for several seconds. It is believed that these were local combustive events (either emulsion or elastomer burning locally) since large amounts of smoke and possibly steam were observed on the video images of the hopper at the same time. Afterward, the temperature returned to the 125-150°C (257-302° F) plateau value until the tests were stopped.

The initial short spike in discharge pressure was even more modest than for the DRBS tests (0.3-0.7 MPa or 30-85 psig). The initial spike in motor load varied from 2.6 to 7.4 kW (3.5 to 9.9 hp) but it quickly dropped to less than 2 kW (2.7 hp) for the rest of the test.

In these experiments, the gears remained intact for test durations up to 2.8 hours. The gears were however blackened, charred and swollen after tests lasting 3.4 to 4.7 hours. IR images of these tests show that the body of the pump remained significantly cooler than the side plates. They also show that the surface of the discharge pipe remained close to ambient temperature for most of the experiment duration.

4. Discussion

The key result of the study was that, of the 44 tests performed with live bulk emulsion, there were zero pump explosions. Not even a definite sign of sustained combustion could be observed.

For the four testing configurations described above, each test was continued until the temperatures and the outlet pressure had stabilised, or were not increasing anymore for at least 15 minutes. Tests typically ran for 1 to 4 hours. Overall, there was significant variability in the measured data, not only between different tests (e.g. dry-run vs deadhead) but also between repeats of the same test. For this reason the summaries in Section 3, above, should be considered as generalisations.

It was found that, under dry-running conditions, sustained temperatures of up to 220°C are possible and some high temperature spikes (close to 300°C or 572°F) were observed at specific locations inside the pump. These temperature spikes are thought to be due to local burning of emulsion and, possibly, of pump gear elastomer. Partly burnt emulsion and badly damaged gear elastomer with burn marks were observed in the post test examinations. After each test none or a very small residue of broken down, dried out and burnt emulsion remained in the pump. In five tests for each dry-run configuration (360 RPM) no explosive events were observed.

Under deadheading conditions, it was found that, even with the high power of the electric motor, the pump could not be started with new gears installed according to the manufacturer's recommendations. Only if gear elastomer wear was simulated (allowing slippage of product) by increasing clearance between the gears and the side plates, it was found that the pump could then be started in deadhead configurations. In this case, maximum temperatures recorded were in a range of 140-220°C (284-428°F) with moderate to significant breakdown of the product and delamination of the gear elastomer. In ten repeats of each deadhead configuration (360 RPM) no explosive events were observed.

For practical reasons, three different products had to be used in these tests. Some were strongly affected by the pump mechanical action which generated heat causing emulsion to break down at different stages of the tests, while some would significantly increase in viscosity without breaking down. It is believed that this might have influenced the test results to some degree.

5. Conclusion

This program set out to determine if an explosion could be caused while pumping unsensitised emulsions (UN3375) with a typical gear pump used in the explosive industry, under more severe conditions than would be expected in a typical real life scenario. Since it was not possible to cause an explosion in any of the repeats of these tests it is concluded that this type of pump, in this particular configuration and under the specific conditions of the tests, is inherently safe with unsensitised bulk emulsion products. This conclusion may not apply to different applications or to other types of pumps used in conjunction with emulsions. It is therefore recommended that, in the future, other explosive process equipment such as pumps and emulsifiers be characterised with the same degree of detail.

Acknowledgement

The work reported in this article results from a joint project between Natural Resources Canada (CanmetCERL), Orica Ltd., and Dyno Nobel. The active participation of all partners at all levels of the project is greatly acknowledged.

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Our Explosives Regulatory World

The Taroom Ammonium Nitrate Accident

by

Geoff Downs (Chief Inspector of Explosives, Department of Natural Resources and Mines, Queensland, Australia)

We are very grateful to Geoff Downs for his willingness to contribute to this Feature of our Newsletter. Through Geoff's kind offices, SAFEX regularly receives safety alerts and other valuable information from the Queensland Inspectorate for which we are very grateful. SAFEX regards all explosives regulators as important collaborators in its endeavours and is therefore privileged to publish this contribution from the Queensland Inspectorate.

In Australia, about 2.5 million tonnes of technical grade ammonium nitrate are transported by road each year. This ranges from short distances to others of considerably long distances. Even though the Taroom ammonium nitrate accident is quoted in lists of ammonium nitrate incidents, I have not seen a paper or article other than the one I wrote for the Queensland Emergency Services Journal called Emergency Volume 1 Number 3 December/January 1994/1995. It is important that any lessons learned are shared. As a regulator, our role includes the promotion and sharing of information in addition to the provision of advice and information, collecting, analysing and publishing statistics, and promoting and supporting education and training.

The reference for this paper is the information from the papers for the Coronial inquiry held in 1973 and the Coroners findings in 1974 regarding the death of three men at the incident that occurred on a stretch of road near Taroom in Queensland, Australia. Imperial units have been quoted as SI metric system was not in place in Australia at the time the investigation was undertaken.

At approximately 6:40 pm on 30 August 1972 on a desolate section of the Taroom-Bauhinia Road about 62 miles north-north-west of Taroom, three men believed to be watching the fire in a semi-trailer load of ammonium nitrate when it exploded and they, the vehicle driver and two brothers from a local property, were killed instantly. The vehicle driver was aged 25 years, and the two brothers, who were bystanders from a nearby grazing property called Stonecroft, were aged 20 years and 18 years. Their injuries were too shocking to describe.

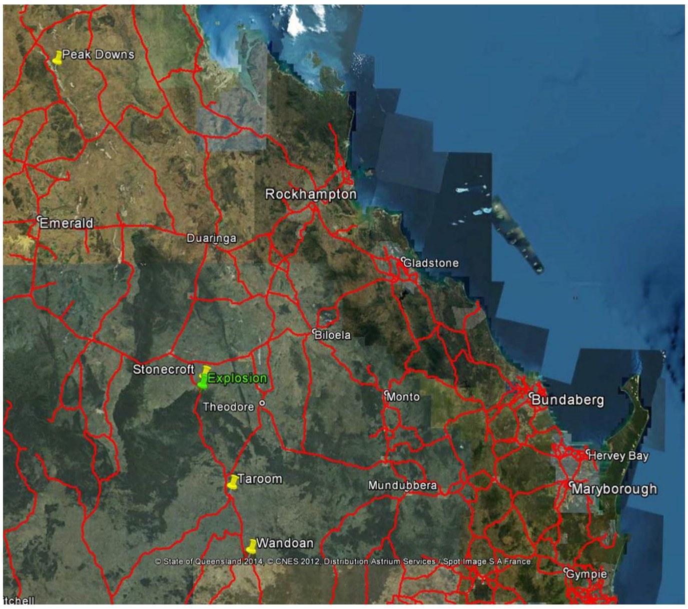
The semi-trailer was carrying a load of 18.5 tons (20.4 short tons) of prilled grade ammonium nitrate in 80 pound polythene bags. There were 510 bags. The load was being transported from Botany in Sydney, New South Wales to the Peak Downs coal mine in Central Queensland. The ammonium nitrate was loaded in the early afternoon on 28 August. Two semi-trailers were loaded with the ammonium nitrate and these vehicles operated in convoy to reach their destination at Peak Downs. The two semi-trailers were operated by two brothers. The distance from Sydney to Peak Downs is about 1100 miles with the Sydney to Taroom section being about 700 miles and the Taroom to Peak Downs being about 400 miles

The prime mover was an International Transtar powered by a 250 HP Cummins diesel. It was 20 feet 4 inches long and was driven on 10 wheels, the front wheels and two sets of duals at the rear. From the descriptions given, the prime mover had two 45 gallon fuel tanks one on each side of the unit just below the doors. The cabin was made of aluminium and fibreglass. The prime mover did not have any fire extinguisher attached.

The trailer was 35 feet long, 8 feet wide and was constructed of a metal frame and a timber floor. The overlap of the trailer onto the prime mover was 7 feet 6 inches. It was carried on 8 wheels, two sets of duals. There was a 60 gallon auxiliary fuel tank also referred to as a belly tank containing diesel fuel on the trailer situated on the driver's side (right hand side drive in Australia) of the unit between the two sets of wheels and just under the edge of the trailer. There was a tool box on the other side of the trailer in the opposite position. The tank was connected to the other tanks. The tank was not vented to atmosphere. This was not usual. This tank was made from 14 gauge steel which is quite thick for a fuel tank. The trailer did not have any fire extinguishers fitted.

The prime mover was reported to have had a history of electrical problems. During its last trip on 15 August 1972, the wires leading into the starter had fused. There was plenty of smoke but no fire. The wires were taped up. The truck was not used again until the trip to Sydney for the load of ammonium nitrate. The prime mover had recently had a new fibreglass and aluminium body fitted and the truck dealership who did that work had also agreed to rewire the prime mover. While in Sydney before the journey, the trailer springs were reset.

The convoy reached Wandoan at about 10:00 am on Wednesday 30 August and refuelled. While refuelling at Wandoan, the driver told the service station operator that he had a new cabin fitted to the truck and that the electrical wiring was faulty. The driver also told the service station proprietor that he could only start the motor by crossing the two loose ignition wires and pointing to the wiring burnt out in the instrument panel of the vehicle. All the vehicle fuel tanks including the auxiliary tank were filled, the amount being 150 gallons of diesel. The two vehicles headed north to Taroom where they had a break.



<u>Figure 1</u>: *Map of explosion area and Map of journey*

They left Taroom at about 3:00 pm and headed north on the Taroom-Bauhinia Road. Since this was a gravel road, they stopped about every 20 miles to check the loading and the tyres. The other brother was the lead in the convoy. They stopped about 5 miles from where the explosion occurred and then he went in front and had gone on another 20 miles to wait for his brother to catch up. He arrived at the next stop about 19 miles from the explosion site at about 5:55 pm and waited there until about 7:00 pm. He then drove back to investigate, saw a fire in the distance which flared up and died down. He eventually came across the hole in the road which was the blast crater and the accident scene.

A fire is believed to have started in the prime mover between 5:30 pm and 6:00 pm. The cause of the fire is believed to from the electrical fault in the prime mover cabin based upon the recent history of the electrical fault. The driver was not a smoker. Another reason to believe that the fire started in the prime mover was the trailer was not unhitched from the prime mover. If the fire was in the trailer, there would have been sufficient time to uncouple the trailer and drive off.

The fire initially must have been small because the driver had sufficient time to remove his personal belongings, jack, ropes and tools from boxes attached to the prime mover and also his brief case from the cabin floor. He also had sufficient time to crawl under the trailer and remove the four spare wheels and tyres. This also supports the theory that the fire started in the prime mover cabin. There were not any fire extinguishers on the vehicle and hence the small initial fire could not be extinguished by an extinguisher or by any other means. The driver was not a smoker and ammunition or firearms were not kept in the cabin.

At some stage between 5:30 pm and 6:30 pm, the two young men from the neighbouring property Stonecroft must have noticed the fire. The homestead was about 1 mile away from the fire. They left food prepared on the table and went to the fire on their motorbikes. This was possibly to investigate a suspected bushfire or alternatively to lend some assistance. They parked their motorbikes about 60 yards away from the semi-trailer. The reason is not known why the motorcycles were parked so far away from the semi-trailer but it could have been due to the intensity of the fire.

If the fire started in the prime mover, the fire would have burnt like a giant cigarette spreading from the prime mover into the trailer from the front and burning down towards the rear of the trailer where the dual bogie axle wheels and auxiliary fuel tank which was full of diesel . The floor of the trailer was made from timber which would have been hardwood.

Even though the description given for the prime mover was fitted with two 45 gallon fuel tanks and the trailer had a 60 gallon unvented auxiliary fuel tank mounted between the axles, the total fuel carrying capacity of the vehicle combination had been quoted as 210 gallons maximum and the total quantity of diesel fuel in the prime mover and trailer combination and it was estimated that there was about 190 gallons of diesel fuel in the vehicle combination at the location near Stonecroft station. The auxiliary fuel tank was full of diesel since the vehicle refuelled at Wandoan, about 100 miles away. The fuel consumption of the truck was in the order of six miles to the gallon.

The slope of the road where the semi-trailer was at rest was 16 per cent. Ammonium nitrate melted and ran down the road. The stream was approximately 363 feet long by an average 3 feet wide and varied in depth from 1 inch to 3 inches and was estimated to contain about 7 tons.

After burning for between 30 minutes and 1 hour, the load detonated at about 6:40 pm. A watch recovered at the scene had stopped and showed the time at approx. 6:40 pm. A brother of the two bystanders from Stonecroft station who lived 25 miles away heard a noise similar to an explosion at about 6:40 pm. It was rumoured that people in Theodore heard the explosion.

The three men at the scene were found about 25 to 30 yards away from the truck. Evidence suggests that they were standing quite close to the vehicle at the time of the explosion. Body parts were found on the broken guide post about 74 feet away. They were killed instantly by missiles and the force of the explosion. The truck was completely demolished with parts of it being scattered at least 600 yards and other debris scattered for 1 ¼ miles. The engine block was thrown 25 yards, the bullbar 500 yards, the differential housing 240 yards and the turntable 320 yards. All the immediate area seemed as if an explosion had occurred and there were fires all around the area. There were little fires in the timber and grass up to four or five hundred yards around the scene which were started by the blast.

The spare tyres were all punctured from flying debris, yet the motorbikes which were 50 metres away from the blast, were still standing on their stands with no damage.

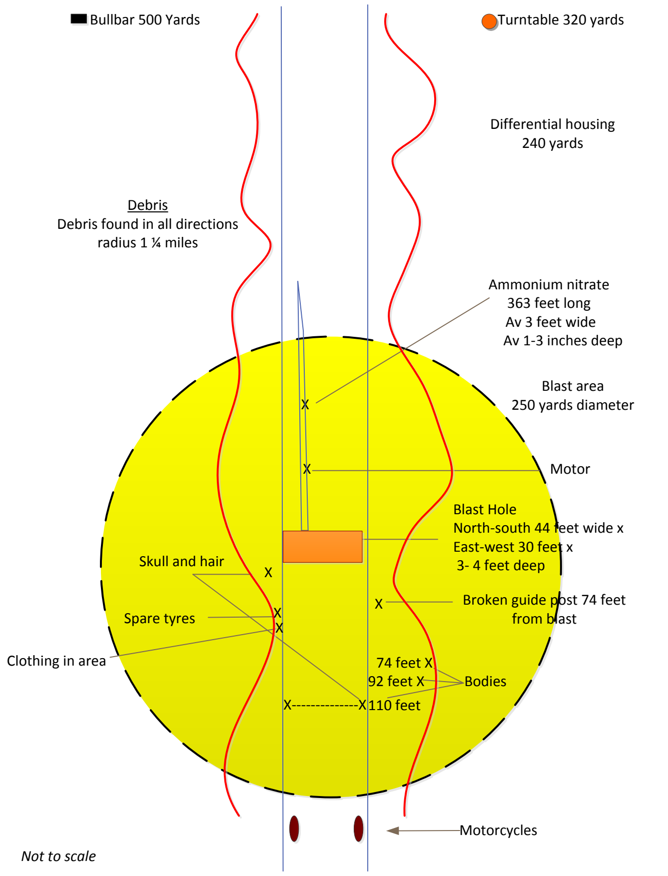


Figure 2 – Replication of sketch of site

The following items had been removed from the vehicle and placed about 70 feet south, back towards Taroom and presumably up-wind of the crater

- Brief case containing log book, trip sheets, etc.,
- Small steel box containing spanners
- Personal clothing and portions of a suitcase, the clothes being scattered about
- Four spare wheels and tyres which may have been placed near the other three had been blasted away and deflated

The leaves in the rear spring were bent, the metal had been tempered, softened and changed its shape. The change of shape was not from the explosion but from heat and supporting that the rear- end of the trailer been on fire before the explosion.

A replication of a sketch of the site is given in Figure 2.

Evidence was provided at the Coronial by an Inspector of Police, a mining engineer and a technical manager from the explosives company and an Inspector of Explosives from the Government Chemical Laboratory, Department of Health (who was the Regulator at that time). These witnesses explained how the explosion could have occurred. The ammonium nitrate was in a molten state. This was clearly shown by the trail of molten ammonium nitrate downhill (which did not explode). At its melting point, ammonium nitrate becomes highly dangerous because it becomes sensitised to shock and can be detonated by shock or missiles. The ammonium nitrate in the pool contained 1% of carbon black (an organic). The carbon black came from the burning tyres.

Even though carbon black was identified in the trail of ammonium nitrate, ash from the burnt timber of the trailer was not discussed even though it was considered that the burning timber floor of the trailer had collapsed onto the tyres and auxiliary fuel tank.

While the exact cause of the detonation is not known, some witnesses believed that the detonation of the ammonium nitrate came from the rupturing of the auxiliary fuel tank between the dual bogie axles in the trailer. The tank was sturdy (14 gauge metal), full of distillate and a pressure vessel (a non vented design tank). The tank was calculated to fail at a pressure of 165 psig (11 atmospheres pressure). The intense heat would have produced huge pressure build up in the tank causing it to fail in these conditions and in doing so detonating the ammonium nitrate. This theory seems credible and it is reasonable to assume that the fire took between 30 and 60 minutes to spread from the prime mover to the end of the trailer.

At the inquest, it was stated that two incidents in the USA a few years earlier resulted in ammonium nitrate detonating under similar circumstances.

Details provided at the inquest are as follows.

> *"Further for consideration I quote from a comprehensive investigation carried out in the U.S.A by the U.S. Bureau of Mines in co-operation with the U.S. Manufacturing Chemists Association as the result of the explosion of ammonium nitrate in polythene bags in a freight car in 1960, and this explosion occurred in conjunction with intensive fire following the derailment of 23 freight cars of a train near Traskwood Arkansas. It is reported in the U.S. Bureau Reports, Report of Investigation 6773 on page 60.*
>
> *The Bureau reported that the detonation of ammonium nitrate as a result of fire cannot be ruled out entirely, but that direct deflagration leading to detonation would appear to be possible, if at all, only in a pile of large dimensions with ignition at the bottom or centre of the pile.*
>
> *Investigations carried out by the United States Bureau of Mines have shown that ammonium nitrate heated to near its melting point is sensitive to in initiation to shock from missiles. There have been two incidents in the United States which have been attributed to this cause. Since this accident, there has been another accident in the United States again attributed in this case to a propane tank on a front end loader exploding in a fire and the missile impinged on molten ammonium nitrate, and caused an explosion of a couple of tons."*

Other evidence provided on the Traskwood Arkansas incident and other matters are as follows.

"Following an explosion in late 1960 near Traskwood, Arkansas, USA, of a burning rail wagon carrying ammonium nitrate which was involved in a large train derailment, an investigation lasting three years by the United States Bureau of Mines into the conditions under which ammonium nitrate may explode when subjected to intense fire exposure. It was established that at temperatures just below its melting point ammonium nitrate becomes very sensitive to detonation by shock.

The Traskwood detonation was most probably caused by missiles from a previous explosion in two tank cars being projected into the burning freight car where molten ammonium nitrate was present. These other tank cars contained burning gasoline and fuming nitric acid.

Summaries of the work carried out by the USBM are given in their Reports of Investigations Nos RI 6746 and 6773.

As it was considered projectiles from the ruptured fuel tank impinging on the molten ammonium nitrate could have initiated this explosion, a letter was sent to Dr R van Dolah, Research Director, Safety Research Centre, United States Bureau of Mines, describing the incident and asking for an opinion on our theory to the ruptured auxiliary fuel tank.

The following is taken from Dr van Dolah's reply –

'It is always difficult to establish the cause of such incidents but I think perhaps your theory of initiation by missiles from the bursting fuel tank may be the most probable cause. Besides Traskwood, to which you refer, and a truck incident at Marshall's Creek, we have only one incident that bears any relationship. The Marshall's Creek truck incident involved ammonium nitrate-fuel oil. The other incident to which I have alluded is one that occurred in a fertilizer mixing plant in which a 50 ton pile of ammonium nitrate detonated as a result of relatively long-time fire exposure. Investigation, however, showed that there had been a large drum of parathion very near to the pile of ammonium nitrate. We know that parathion is extremely heat-sensitive and has led to explosion in the past by itself. We postulated that the most probable cause in that case was that the drum of parathion exploded and the missiles initiated the hot perhaps burning – pile of ammonium nitrate.'

In view of this evidence, it is considered probable that the cause of the detonation was the rupturing of the auxiliary fuel tank and the projection of some part of it into molten ammonium nitrate."

The Coroner made no findings on the exact cause of the explosion of the load of "nitropril" (ammonium nitrate). He made findings that there was a massive explosion and that the injuries of the deceased were consistent with injuries received as a result of the explosion.

The Coroner's observations, comments and recommendations for consideration were:

- The evidence suggests that "nitropril" (ammonium nitrate) is considered to be safe for transport by normal road transport in its present form
- The evidence suggests that an explosion of great magnitude did take place on this occasion
- The evidence does not conclusively find the exact cause of the explosion but the technical witnesses, while differing slightly in their opinions, basically agreed on the probable cause
- As ammonium nitrate in the form of "nitropril" is being commonly transported in large quantities by road transport around the country it is most desirable that steps be taken to prevent any possible repetition of a similar explosion and especially in confines of population and buildings where the consequences could be most harmful and damaging.)
- As the evidence does point to fire being at least a contributory cause of this explosion the suggestions put forward by the witness, Bardwell, and adopted by the witness, Cherry should be considered by those for public safety to ensure that a similar explosion does not occur
- Those suggestions were two-fold, namely:-
  - that fire extinguishers should be carried in prime-movers which normally engage in the haulage of "nitropril". These fire extinguishers would be used to extinguish any "primary" fire in the prime-mover, semi-trailer or loading, and
  - that no auxiliary fuel tanks be permitted to be fitted underneath the bodies of semi-trailers which normally carry "nitropril'.

Extract from SAFEX Good Practice Guide (GPG) on "*Storage of Solid Technical Grade Ammonium Nitrate*" (SAFEX GPG02Rev2.01, p 19):

"Fires involving ammonium nitrate (AN) should never be fought. If the fire involves AN, the facility (area) must be evacuated".

Improving Explosives Competence

All explosives manufacturers recognise the importance of training and developing people who work in and are responsible for explosives operations. SAFEX recently responded to a perceived need to develop leaders of explosives operations by embarking on the development of the *SAFEXplosives Management Course* in an e-learning format. We are not alone in trying to support SAFEX members in their quest for improved workplace competence. SAFEX is willing to partner with anyone or use any technology that can contribute to the competence of people working with explosives and thereby make our workplaces safer.

In this Newsletter feature we propose to present a series of articles that explain the UK's National Occupational Standards (NOS) in Explosive Substances and Articles (ESA). In the coming editions of the Newsletter, each article will examine a different aspect of the ESA standards and explain how they can be used for a range of purposes.

Assessing people against the Explosive Substances and Articles National Occupational Standards (ESA NOS)

by

Denise Clarke (Managing Director, Homelands Security Qualifications)

Homeland Security Qualifications (HSQ) is a British-based awarding body that specializes in the award of explosives-related qualifications. Denise has spent the last twenty years specializing in the specification and measurement of competence, working in a wide range of industries. Working with the industry, she has developed UK National Occupational Standards in Munition Clearance and Search and in Explosive Substances and Articles, creating qualifications and supporting assessment materials. HSQ now has five qualifications assessment centres, delivering a range of bespoke, industry-recognized and nationally regulated competence-based qualifications. Please visit www.homelandsecurityqualifications.co.uk for more information.

There is an enormous body of work that has been written on the subject of competence-based assessment. It is not the intention to debate the ins and outs of this in general here but rather, to talk about the UK explosives industry's experiences in assessing people against the ESA NOS and to share any good practice and ideas for the benefit of readers of this article. That said, it may be worth looking briefly at a definition of what is meant by 'competence-based assessment'. Wolf (1995) defines it as:

> *… a form of assessment that is derived from the specification of a set of outcomes; that so clearly states both the outcomes – general and specific – that assessors, students and interested third parties can all make reasonably objective judgments with respect to student achievement or non-achievement of these outcomes; and that certifies student progress on the basis of demonstrated achievement of these outcomes. Assessments are not tied to time served in formal educational settings.*

I have already described the structure and coverage of the ESA NOS in previous articles in this column so let's take that as read. This article will stick to the point of reporting to you how organizations assess their people against the ESA NOS and to share with you their experiences and extracts of any useful documentation that might make your lives easier too.

Assessment and accreditation

Organizations might want to accredit their people with qualifications that are based on the ESA NOS or they may just wish to use the standards to amplify their own internal performance management processes. Either way, best practice in assessment and the quality of evidence still apply.

We are no doubt all familiar with the principles and processes of written examinations but assessment of workplace competence and knowledge can take different forms. The most common form of assessment in the UK for explosives-related vocational qualifications is the compilation of a portfolio of evidence. This requires candidates to assemble different kinds of evidence (a better test of competence then producing purely one kind) and organizing them into a portfolio which is mapped against the components of the ESA NOS. This includes work products (ie the outputs that candidates produce through doing their jobs such as reports, calculations, correspondence etc), observation reports (where an assessor has watched the candidate carrying out a task), witness testimonies (provided by a reliable person who has watched the candidate carrying out a task) and written evidence of the assessor's questions asked and the responses to these.

Written examinations may also provide evidence of someone's knowledge which supports their competence. These might be "old fashioned" written examination papers or printouts of a touchscreen test (such as the UK driving theory test). Or there might be other forms of written tests such as short answer tests, multiple choice papers and quizzes, etc. However, these may only attest to someone's knowledge – their ability to translate this knowledge into workplace competence will still need to be assessed.

Requirements of evidence

Whatever form the evidence takes, it must adhere to the same requirements i.e. it must be:

Sufficient:	cover all the requirements of the standard;
Valid:	provide genuine evidence of achievement;
Authentic:	be the candidate's own work;
Current:	give a current picture of competence/ knowledge;
Reliable:	give consistently reproducible results

In achieving these requirements, we are likely to achieve validity and reliability – which are the key requirements of effective assessment.

How are the ESA NOS being used in assessment?

To put this article together, we interviewed a number of people who are involved in using the ESA NOS for assessment purposes. These include those who have taken the strategic decision to use the ESA NOS for assessment purposes; those who assess people against the standards; those who assess and/or verify people against the standards for the purposes of qualifications and those who are candidates and/or those who assess themselves. We are very grateful that they have all kindly agreed to share their observations and experiences. As each organization has its own needs and priorities, the uses of the NOS vary slightly which therefore affect the approach to assessment.

"A significant driver to the implementation of the ESA NOS is the Defence Safety & Environmental Authority's (DSEA) requirement, which has been referred to in annual assurance reports, for organizations to be able to demonstrate objectively the competence of their staff. But we're not just doing it because the regulator says so, the ESA NOS are a helpful tool for managing explosives skills, training needs, personal development etc" explains Mike Quigley of Defence Equipment and Support (DE&S) of the Ministry of Defence (MoD).

They are used in three ways:

- post skills profiles and personal profiles are both recorded on the Human Resource Management System (HRMS). These profiles reference both the relevant ESA NOS and the MoD's core and functional competences. Line managers are able to use these to assess individuals' competence against the requirement for the post. This is especially useful for those staff who are still growing into their role;
- some of the MoD's explosives-related courses have been mapped to the ESA NOS. In addition, "shareshops" take place of a regular basis to train and update staff on a range of topics, for example, where new initiatives or policy changes are introduced or when lessons learned need to be shared with others. "It would be a simple step to say that such and such a shareshop contributes to a particular ESA NOS" suggested Chris Child of the MoD;
- the MoD issues Letters of Technical Delegation (LOTDs) to those Explosives Safety Advisers who are deemed to be competent. This system references the ESA NOS and assesses competence against selected parts of them. In future, the LOTDs will be time-limited and a panel review process will determine whether individuals have maintained the required degree of technical competence.

Lars-Erik Pettersson of Life Time Engineering (LTE) (Sweden) explained that by necessity, the legislation and regulations governing the manufacture and use of explosives must be non-specific as these are extremely varied. However, what does this mean for an organization in its day to day use of explosives? LTE was very pleased to discover the ESA NOS because "they provide well-structured guidelines that are easy to follow and understand" as Lars-Erik Pettersson put it. He went on to say that "We were all enthusiastic about implementing the standards in the company although, at the time, we didn't know how to do it." Subsequently, LTE has used the ESA NOS within its recruitment and training processes.

LTE is aware that, as a result of delivering qualifications based on the ESA NOS, should an accident occur, it will be able to demonstrate to safety inspectors the extensive precautions that the company has taken with regard to educating its staff. Consequently, LTE has taken the decision to deliver qualifications that are based on the ESA NOS and the final achievement will be certificated by Homeland Security Qualifications (HSQ).

The Atomic Weapons Establishment (AWE) is currently using the ESA NOS as part of its system to measure the competence of its workforce when working with explosives and to provide a standardised approach to:

- RD&D;
- trials & testing;
- manufacture;
- assembly/disassembly;
- storage/transportation;
- disposal.

The AWE is currently using the standards as a metric against which staff can be deemed to be "SQEP" (suitably qualified, experienced people) to work with explosives so that the AWE can demonstrate that it is in ontrol of its explosives operations. Job roles have been mapped to the NOS and to explosive processes which helps to identify any gaps in competences. So, the AWE can synchronize best practice across the company and provide evidence of competence to its stakeholders.

The qualification that Deflog VQ Trust is delivering to British Army Ammunition Technicians at the Defence Explosives Munitions School Training Regiment (DEMS Trg Regt) is based on the ESA NOS. The business driver was to implement explosives-related qualifications and the Explosives

Apprenticeship across the Royal Logistic Corps and the Ammunition trade where no relevant civilian-recognized qualifications existed before.

The sensitivity of assessment

One of the issues in conducting performance appraisals is the potential for sensitivity and potential subjectivity of judging performance, so, has the use of the ESA NOS removed or reduced this? The AWE points out that the assessor still has to apply his/her own qualified opinion of the evidence that has been presented (in a way that is similar to the CPD requirements used in any professional registration activity).

As Shaun Dooley of the AWE points out, “The use of the ESA NOS removes the 'mystery' of what competence 'looks like' (the phrase is often heard that someone ‘doesn't know what they are looking for but they know it when the see it’). The use of the ESA NOS helps assessors to 'see' what they are looking for.”

To be assessed against an ESA NOS means that everyone is subject to the same requirements. “Working toward the ESA NOS aligns everyone to achieving the same standards”, as Dave Nelson of Deflog explained – a point with which Lars-Erik Pettersson agreed “The candidates taking the qualifications are pleased to be judged against the objective standard provided by the ESA NOS and they understand the need to be assessed in detail against all the components of the standards.”

Whilst many people have experience of assessing people in general terms (e.g. for performance appraisal purposes), few have experience of assessing people against such specific technical standards as the ESA NOS. Historically, people have been inclined to be judgmental, but “this structured approach [means] greater objectivity … your judgment is a lot more finite because the detail is in the standards and this makes it easier”, as Ken Cross (of Picrite and a qualifications assessor and internal verifier) put it. This approach certainly helps to remove the sensitivity of the appraisal process.

Methods of assessment

For those organizations interviewed that are delivering HSQ’s competence-based qualifications (i.e. LTE and Deflog VQ Trust), candidates must assemble a portfolio of evidence that attests to their competence. However, even though the MoD and the AWE are not delivering qualifications, they are also using the portfolio method.

The Weapons Operating Centre in DE&S is working toward a system whereby explosives personnel will assemble a portfolio of evidence of their competence (as defined by their role profiles). When these staff are assessed as competent, the evidence can be used to attest to their "SQEPness" and can be used to support the formal delegation of authority for equipment safety and the provision of technical/safety advice.

When the AWE first started assessing workers against the ESA NOS, it found that the process involved too much paperwork – a point that the MoD also sees as a risk as both Andrew Brigden and Chris Child point out: “We are working on the production of a standard portfolio format. When this is rolled out, it will be supported by appropriate training for assessors and the managers who make assessment decisions. Rollout is planned for completion later this year”.

The AWE has simplified the recording system and developed a logbook for each role being assessed which is mapped to the ESA NOS. Individuals are now able to assess themselves prior to their supervisor signing them off when they reach full competence. Acting as a verifier (i.e. a moderator) and having carried out periodic observations of the individual during the year, the line manager confirms the assessment through the appraisal process. Future plans include the development of a summary document that captures the key skills and expertise of each individual (as recorded in the logbook) so that the AWE will have a “snapshot” of all staff’s explosives competence and any related caveats. Since the work has already been done to map explosives processes to the ESA NOS, this greatly facilitates the plan for the business to know what everyone can do in terms of common, portable skills.

The AWE encourages staff to maintain their own physical evidence folder where all records can be collated. Staff can record work in terms of tasks per day or week and then record observations or testimonies as they occur. Line managers are encouraged to visit their staff on regular occasions and write an account of the visit and this can be used to their advantage at subsequent quarterly or annual performance reviews.

Deflog VQ Trust takes a slightly different approach in that it uses an electronic portfolio. Learners gather their evidence of competence and upload it into the portfolio (historically, assessors used to do this but now, learners are encouraged to take responsibility for their own learning). The learners carry out seven months’ training at the military training school before returning to their units in the field where they consolidate the knowledge that they have gained on the course by putting it into practice in an operational environment, gathering evidence of their knowledge and competence from both training and operational tasks. In this way, learners’ development is kept under constant review and their knowledge and competence is assessed throughout the duration of the Apprenticeship (just over a year).

For learners, the use of a wide variety of evidence (work products, assessor questioning and observation etc) provides for a choice of assessment methods that may better meet their preferred learning styles. For Deflog VQ Trust, some kinds of assessment are more effective and cost-effective than others. For example, the use of electronic recordings of question and answer sessions (audio and video) has cut down greatly on the time needed to type them up and link them with learners’ portfolios. Even hard copy assessment records are now scanned and stored electronically.

Lars-Erik Pettersson of LTE is working toward a UK L4 qualification in Explosives Safety Management. To ensure that he has the required knowledge, this is evidenced through the completion of an assignment and the application of the knowledge is tested through competent performance in the workplace. For LTE's staff member who is undertaking a qualification in Test & Evaluation, work is arranged so that the candidate can show his competent performance by being observed during a visit by the assessor.

What are the key characteristics and requirements of effective assessment?

Everyone agreed unanimously that one of the critical factors in achieving effective assessment is the competence of assessors and internal verifiers as these are the people who will be making judgments about people's competence. So, not only is their explosives technical competence important but also their competence in assessment. As Jon Baker (AWE) pointed out, "It is fundamentally important that assessors should be occupationally competent. If not, how would they know when to probe an individual when they suspect that they are not fully competent?" Similarly, any doubts about the validity of evidence need to be probed by someone who is technically competent to do so.

Equally important is the point that assessment cannot be undertaken in a vacuum: the context of the individual needs to be taken into account. "You need to know who you are working with to be able to assess them properly', said Jon Baker. He continued: "You need to understand their characteristics and how long they have been working in a particular area and therefore, their training needs." "The person doing the assessment must have the right levels of SQEPness" agreed Andrew Brigden and Chris Child "then, the assessment will have value." Another who agreed with this point is Ken Cross who pointed out that "It is important to understand the work on which the learner is being assessed and having experience of making judgments about people."

Dave Nelson of Deflog went one step further: "If you haven't got competent assessors to assess learners at the right level, you shouldn't be doing the job … we expect assessors to be several steps ahead of learners…"

The AWE uses internally focused training. Although this does not deliver formal qualifications, the AWE appoints both assessors and internal verifiers following training, the latter having a standardization role. To ensure that rigour is maintained in assessment, ten subject matter experts have been selected and trained to OCR Level 3 in Assessing Competence. (OCR is a UK awarding body that offers nationally accredited qualifications in assessment.) Those nominated were selected with care as the AWE recognizes that the role is pivotal to ensuring that the explosives workforce is assessed to a standard that is robust, auditable and common to all. As those nominated are not the line managers of the individuals being assessed, this assures a degree of independence of assessment. The assessors:

- are competent in the area of assessment;
- manage and lead the assessment of explosives competence in their area;
- ideally, are members of the Institute of Explosives Engineers;
- maintain the high standards set and report directly to the Facility Manager on a regular basis with regard to competence of the workforce in their area.

"It's learner-led – getting them involved in understanding the process is critical" as Dave Nelson of Deflog put it. "Assessment should be well planned and will fail if it not – not just because of a lack of "buy in" from learners and their managers, but even because of simple, practical problems such as clashes of dates and a lack of availability of the learner when an assessment might take place" he added. This points to the need for good communication between those involved in the assessment process and line managers whose cooperation is needed for assessment to take place at the right time in the right place.

It sounds obvious but a further characteristic of effective assessment is the need for access to learners, evidence and assessors. This can be problematic for learners who have been posted to remote or inaccessible parts of the world and it is important that learners have access to learning materials and the advice of their assessors when they need it. Deflog is creating a "Virtual Learning Environment" (VLE) which will facilitate this (provided that the learner has access to the internet or a mobile telephone). This development will widen the lines of communication and harness the benefits of social media and thus helps to ensure that the delivery of the Apprenticeship is designed around the best way to obtain evidence.

A simple but important point, as Ken Cross pointed out, is that users of the ESA NOS and qualifications candidates must all have access to the detail of the standards and be involved actively in the planning process. Then, they can assess themselves against the NOS and identify their own development needs prior to any kind of formal assessment.

What benefits have resulted from assessing people against the ESA NOS?

Those we talked to in creating this article found that a range of benefits resulted from assessing people against the ESA NOS.

For the AWE, conducting interviews against the ESA NOS has allowed managers to focus on asking the right questions of the candidate or trainee with less likelihood of missing important elements. However, it has found that the greatest benefit has resulted from using the ESA NOS as part of the performance appraisal process. For example, during "process walk-downs" where the standards are used as an aid to check for individuals' adherence to procedures. The use of a "SQEP" checklist has given the walk-down more focus; as a result, there is clearer evidence to back up managers' judgments.

Rather than identifying weaknesses, the AWE has found that the use of the ESA NOS has helped in writing lesson plans so that staff can deliver and/or receive training in a structured way, irrespective of who is the trainer. Also, in the example of trials and tests (ESA NOS 3.14 *Carry out trials of explosive substances and/or articles*), the AWE realized that dealing with contingency planning had been well considered up to the point of physical intervention of dealing with the event. However, maintaining competence in areas that happen very seldom is something that is not easy to plan and train for. The AWE is therefore developing a Firing Officer Course with such occasions in mind.

Overall, the AWE has found the most obvious benefit of using the ESA NOS is the clarity that is achieved across company boundaries such as between departments where competence is very similar but the work process or outputs may be quite different. Departments have learned from each other through the standardization brought about by the assessment process.

For Deflog VQ Trust, the creation of the Explosives Apprenticeship framework has opened up opportunities to learners who previously did not have a civilian-recognized qualification available to them.

The MoD has found that managers can sometimes be unaware of the significance of someone's background (and sometimes, the individuals themselves are unaware of the relevance of the work they did in their previous jobs). Equally, there is often a lack of understanding of the skills and expertise held by the military by civilian personnel and vice versa. "The portfolio is a mechanism to cross this divide" agreed Andrew Brigden and Chris Child.

"The ESA NOS are becoming much more relevant now" said Andrew Brigden. "The DOSG (Defence Ordnance Safety Group) workforce is younger than it was three years ago and people are looking at how qualifications will help their employability. They are looking for a means to record their experience " he added. Chris Child pointed out that the interest in the ESA NOS is not just limited to new joiners as well-established people also want to get on board now.

What challenges have arisen in assessing people against the ESA NOS?

Ken Cross points out that the first challenge to be met in introducing users to the ESA NOS is helping them overcome the "shock of capture" of being required to work to a standard or qualification. This is because the decision to do so has often been imposed on the individual concerned and it might be a very long time since that person was last assessed formally for a qualification. This points to the need to give users of the standards a positive experience from the outset in order to allay their fears and concerns. This can be done by ensuring that everyone is properly briefed as to what to expect, explaining that their assessor will be working with them to help them and emphasizing that they can work at their own pace in their own place of work. In doing this, as Ken says, "You give them that little bit of control back." This is a two-edged sword as he went on to observe that "assessing people against the ESA NOS … makes you as an assessor realize your development needs."

He also found that one of the initial hurdles to be overcome is getting people to understand the evidence that is needed that would attest to their competence. Until they understand this, people are inclined to present evidence that does not meet the requirements. For example, one qualification candidate offered evidence of developing a process that was similar – but not the same – as the one that he was operating. Also, it had been written by someone else so it was not the candidate's own work.

Organizations in the UK are accustomed to the concept and practice of workplace assessment but this is a new idea in other countries. LTE found that some development work was needed at the beginning of the process. For example, because LTE has an integrated management system, the manual needed to be rewritten to accommodate the use of the ESA NOS. It is also the intention that, in the future, the ESA NOS will be available on this system to all staff. In the beginning, the concept of workplace assessment and portfolio-building was new - and therefore, a challenge - but because of the confidence they had in their assessor's (Ken Cross) expertise (both explosives and in assessment), LTE soon grasped what was needed and saw the benefits quickly. With the benefit of hindsight, what would LTE have done differently? "We would ask for more guidance on what constitutes valid evidence" said Lars-Erik "and we would have sought to plan the assessment process right through to the end right at the beginning. ... this would have made it easier to embed the ESA NOS into our processes so we would have met our assessor for more detailed planning before embarking on the process."

In some organizations, one hears that the evidence collection process and demonstrating competence is time-consuming. However, the AWE had already deployed supervision, so this system does not represent extra work for those involved in explosives activities. "We are more aware of competence through objective based assessment", Jon Baker said – and this obvious benefit outweighs the perceptions of extra work. Dave Nelson agreed with this point: "Whilst effective assessment for a qualification cannot be done overnight, it shouldn't be a major additional burden as this proves that they can do their jobs. You know what people can do when they've been assessed".

One of the remaining challenges for the AWE is the confusion amongst staff members about the relation between ESA NOS and qualifications. Some do not see the benefit of developing a comprehensive record of their competence without the advantage of the attainment of a formal qualification. Others have questioned whether the concept of measuring individuals' competence in this way is a trend that will go away, whereas in fact it is a development that is here to stay.

When Deflog's learners are carrying out operational tasks (this could be anywhere in the world), they are reliant on witnesses (usually, their line manager and/or Unit Commanders) to provide witness statements that can be used as proof of competence. This raises the question as to how so many people can be briefed to ensure that the testimonies meet the requirements of the task. This is achieved in two ways: first, Regimental Career and Manning Officers are briefed on such developments and requirements at their annual conferences and second, Deflog VQ Trust prepares templates that, if completed correctly, will meet the requirements of the task and the relevant ESA NOS.

Whilst learners need to be fully involved in the assessment process, they also need to be realistic and the assessor's expertise and judgment is fundamental to successful assessment. For example, a learner may feel that he (or she) will be ready to be assessed on several units at the next assessment. However, the assessor may feel that this would be unrealistic within the timescale.

Bi-annual standardization meetings amongst assessors and internal verifiers help to ensure that all involved in assessing learners maintain the same rigorous standards of assessment. A recent development within Deflog is that, in future, assessors will not just assess – they will be involved actively in helping learners meet the required standards. This might involve them giving demonstrations, supervising practice sessions and further coaching before learners are re-assessed.

How do the ESA NOS link to other processes, procedures, standards and documents?

Shaun Dooley of the AWE feels that the ESA NOS have helped to develop other parts of the business such as Work Instructions (WIs) and training and development plans. For example, the WI or process instructions tell operators *what* to do but not necessarily *how well* to do it. For example, a WI might require them to set up for an explosive test, but it is the ESA NOS that describe the performance of the individual in terms of expected outcomes. As a result, work instructions are being mapped to the ESA NOS and reference to the latter is made in the SQEP documentation. This has closed the loop between adherence to procedures, training and the assessment of the competence of the individuals operating the process.

The AWE has integrated the ESA NOS across its HR processes in that is has:

- standardized explosives role profiles right across the AWE;
- placed the ESA NOS on its intranet so that staff can add to and view their role profiles;
- enabled a record of each role holder's competence to be maintained electronically;
- created logbooks for each explosives worker to record their experiences, achievements and competences;
- mapped training courses to the ESA NOS;
- used the ESA NOS for appraisal purposes.

Future plans include:

- the use of the ESA NOS to help write job advertisements;
- developing the coaching skills of managers now that on the job training is used to greater effect to deliver developmental improvements against individuals' identified development needs;
- enhancing the management training of supervisors;
- using the ESA NOS to create a comprehensive career management framework and 'audit' of company-wide explosives strengths and capabilities as defined by the assessment summaries;
- the rationalization of related processes (e.g. whilst managers decide whether or not their staff are competent as measured against the ESA NOS, there is a separate process to decide who is competent and qualified to become a Trials Conducting Officer).

Like the AWE, the MoD has also identified where the use of the ESA NOS could be used to rationalize processes that are currently operated separately as Chris Child explains: "The process used at stakeholder meetings to demonstrate "SQEP-ness" should be part of the same process as issuing LOTDs but, at present, it isn't. The plan is that, in future, individuals will be assessed against the requirements specified in the LOTD. Those needing development will need to develop an action plan to address gaps and shortfalls."

Andrew Brigden and Chris Child both agreed that it would be useful to have a standard way of recording the evidence so that it could be used for different purposes – for example, for issuing LOTDs, proving "SQEPness", for CPD purposes and professional registration in fact for all HR purposes. It could also count toward the achievement of qualifications and support applications for membership of professional institutes.

LTE is establishing and documenting the use of the ESA NOS in its processes so that it will link to the OHASS 18000 and ISO 9001 standards (the former will be a mandatory requirement for Swedish companies within the next two years). For his UK L4 qualification in Explosives Safety Management, Lars-Erik Pettersson of LTE has the task of writing a new explosives safety policy. The business driver to the need for the policy has come about because the company is applying for ISO accreditation and needs to integrate all its safety policies into one. The policy will also form a valuable piece of evidence for ESA NOS 2.5 *Review an organization's safety management system for explosives* and 2.8 *Analyse and identify aggregated hazards and risks for explosives.*

The challenge for DE&S (MoD) is to devise a competence management framework that is comprehensive yet flexible and user friendly so that project teams (which are increasingly going to be managed on a matrix basis) can make informed resourcing decisions, for example, in the redeployment of weapons project technical personnel between teams, so that best use is made of individuals' skills, strengths, experience and expertise. The ESA NOS form part of the answer to this challenge, but such a framework also needs to capture other competence requirements including proficiency in project management, safety, quality and environmental matters. "A lot of our work is technical project management" said Mike Quigley "and our delivery project teams need a range of competences including those described by the ESA NOS." He added: “We also need a supporting HR management information system that allows data to be drawn off and used to give an organization-wide picture of skills, strengths, development needs and any limitations.”

Conclusion

We hope that readers will find the ideas and lessons learned by our interviewees helpful in developing and proving the explosives competence of their employees and colleagues. It is clear that assessing people against the ESA NOS can make this process easier and more objective. As Shaun Dooley put it, “the use of the ESA NOS has been a tool for continuous improvement processes…. things are different … [and the use of the ESA NOS] provides the underpinning knowledge and understanding that can be applied in diverse work environments.” As Mike Quigley summed up: "This is an exciting time ... our weapons project teams need a flexible, professional workforce and the ESA NOS are an important element of the solution.”

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Mr Dave Nelson, Quality Manager, Deflog VQ Trust

Mr Lars-Erik Pettersen, owner and Chairman of the Board, LifeTime Engineering (LTE) Sweden

Air Cdre Mike Quigley, Weapons Head of Engineering, DE&S (Defence Equipment and Support), MoD

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Note to readers: The ESA standards are available free of charge and can be downloaded from: www.homelandsecurityqualifications.co.uk/documents

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.

Flame-resistant Clothing: A Vital Consideration for Energetic Operation

by

Jackson Shaver (Director of Pyrotechnic Processes, Special Devices Inc /Daicel)

Jackson has a PhD and has been associated with Special Devices Inc (SDI) since 2000. SDI is a member company of SAFEX International with operations in North America, Europe and Asia. The company specialises in precision engineered energetic devices including gas generants, ignition compositions and propellants. While Jackson focuses on the manufacture of pyrotechnic and explosive ordnance he is passionate about Occupational Hygiene. Prior to joining SDI he worked in fields such as mining / chemical refinement; automotive safety products; thermal treatment of hazardous materials as well as Aerospace and Defense products. With expertise in Process Safety Management for energetic operations, Occupational Hygiene, HAZCAT / First Response and Six Sigma, Jackson is well placed to “Ponder the Profession”.

U.S. Occupational Safety and Health Administration (OSHA) investigators recently conducted an examination of a fatal explosion at a company that manufactured gun powder. The employer placed employees in close proximity to the gun powder manufacturing process and did not provide proper flame-resistant (FR) clothing or a change room to don and doff work clothing covered with oxidizer and gunpowder. Case studies released by the United States Chemical Safety and Hazard Investigation Board (CSB) involving energetic materials also note the employers failed to apply the proper use of flame-resistant clothing as a protective measure. In one example, the employees assigned to process highly combustible metals (zirconium, titanium) were provided 100% cotton clothing, but not flame-resistant clothing for the operation. In another example, employees dismantling firework assemblies were not provided personal protective equipment in addition to the noted absence of other process safety considerations as shown in Figure 1 below (Reference 2).

"Flame-resistant (FR) clothing can significantly reduce burn injury resulting from flash fire exposure. This occurs first by minimizing or avoiding clothing ignition, and second by creating a thermal barrier, which reduces the exposure energy reaching the victim's skin. Consequently, over the past decade, there has been increased emphasis by OSHA, ASTM and NFPA standards organizations on the use of FR clothing by workers exposed to flash fire hazards." (Reference 4)

Figure 1: ***Employees dismantling fireworks without the necessary personal protective equipment (Photo: Figure 5, CSB Report No. 2011-06-I-HI, Jan 2013 at www.csb.gov)***

Figure 2: ***Photograph illustrating a flash fire (Photography by*** www.workingperson.com)

In each incident, the investigating agency recommendations for corrective action focused on establishing process safety controls which included FR clothing. When it comes to FR clothing, employers and users should be aware of the limitations and effectiveness of FR clothing and the terms applied to the selection process. FR clothing is intended to resist ignition, prevent flame spread and self-extinguish when the ignition source is removed. Ultimately, the end user should be confident the FR clothing retains the flame resistant properties for the stated service life of the garment. FR clothing protection should not wash out, fall off, or wear out.

Some researchers made the following observation:

Terms and classification systems most frequently applied to flame-resistant clothing are Hazard Risk Category and Arc Thermal Performance Value. The Hazard Risk Category (HRC) levels range from 1 to 4 and are associated with the National Fire Protection Association. The HRC level is based on job tasks (see NFPA 70E Standard for Electrical Safety in the Workplace). The HRC chart can be used to determine the necessary arc rating of a garment worn when performing certain tasks. In some work situations, multiple layers of clothing may be needed to achieve the recommended rating. The Arc Thermal Performance Value (ATPV) is the arc incident energy required to cause the onset of a second-degree burn. Fabrics with a high ATPV value provide more protection. ATPV values were developed by ASTM International.

Table 1***: Table showing typical Protective Clothing Systems (Flame Resistant Work Wear Table, Bigbill.com)***

Hazard Risk Category	Clothing Description (Number of clothing layers given in parentheses)	Total Fabric Weight (oz/yd2))	Minimum Arc Thermal Performance Value (cal/cm2))
0	Untreated Cotton (1)	4.5 – 7	N/A
1	FR Shirt and FR Pant (1)	4.5 – 8	4
2	Cotton Underwear + FR Shirt and FR Pants	9 – 12	8
3	Cotton Underwear + FR Shirt and FR Pants + FR Coverall (3)	16 – 20	25
4	Cotton Underwear + FR Shirt and FR Pants + Double Layer Switching Coat and Pants (4)	24 – 30	40

One online industry newsletter suggested that once the Hazard Risk Category level and Arc Thermal Performance Value rating are known that it is easy to select the correct flame-resistant clothing. Perhaps for some applications, the FR clothing selection process is not particularly complex. There may be regulatory or industry association guidance similar to the US OSHA directive for employees working at or supervising pyrotechnic mixing, pressing and loading operations. However, the flame-resistant clothing selection process may often require a very high level of sophistication to determine the appropriate FR clothing for the task.

The Confederation of British Industry released a guidance document for the selection of personal protective equipment for explosive operations in January 2014 that provides guidance for FR clothing. The NFPA 2113 standard for the selection and maintenance of FR clothing provides guidelines when flame-resistant clothing must be used by employees exposed to potential flash fire hazards. Chapter 4 of the NFPA 2113 standard provides guidance for FR clothing selection. Manufacturers should also be consulted regarding the intended application and use to provide guidance and product limitations that may impact the selection process. Laboratory testing of FR clothing may also be necessary to validate the performance expectations.

FR clothing is not normally intended to provide an effective chemical resistance barrier and when chemical exposure is present, effective barriers should be considered in the hazard assessment. FR clothing may also be adversely affected by the work conditions. Chemical compounds are known to degrade some fabrics or compromise the flame retardant properties. Flame-resistant cotton which is frequently used in static-sensitive environments can be compromised by some solvents, alkalis and acids. The laundering process should be examined to ensure the manufacturer's guidelines are followed and the effectiveness of the FR clothing is not compromised by the detergents, starches, softeners or deposits of insoluble mineral salts on the fabric.

Employers have the obligation to provide controls to prevent injury from harmful energy sources. When the hazard assessment is completed for tasks that require FR clothing, the team should examine FR clothing options and match the HRC and APTV requirements with the FR clothing selected. FR clothing can prevent a worker's clothing from burning or melting and making injuries caused by the initial flame source even worse. FR clothing can provide workers protection from heat energy sources and should be given strong consideration for operations involving energetic materials.

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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.

It is with regret that SAFEX is unable to provide an article for this Feature. We urge any readers who are able and willing to contribute appropriate material for this Feature to contact the Secretariat.

Under Lock & Key

SAFEX's purpose is to eliminate harm to people, property and the environment from unplanned explosives events. It does so by helping members share relevant experiences and information that will prevent the recurrence of such events or incidents. We have traditionally focused on incidents in the development, manufacture and distribution of explosives. However, there is an increasing awareness of the harm events involving the illegitimate use of explosives can cause. The SAFEX Board has long realised the importance of sharing information about how better to secure our products and broadened the SAFEX domain to "health, safety, security and the environment (HSSE)". Explosives security is about preventing conventional explosives or precursors from falling into unauthorised hands. In this vein SAFEX Newsletter wants to encourage readers to contribute articles that will increase awareness to help our industry counter those intent on causing harm through the unauthorised use of explosives.

The Improvised Threat

by

Sally Sterling (Desk Officer JIEDAC)

Introduction

The **Improvised Explosive Device** (IED) is used by insurgents, terrorists and criminals around the world, due to its ease of manufacture, relatively low cost and potentially devastating effect on people and property.

The previous article, by the UK Ministry of Defence (UK MOD) Joint Improvised Explosive Device Analysis Centre (JIEDAC), published in SAFEX Newsletter No. 49, assessed the history, evolution and associated technologies of the IED threat which have led to the IED becoming a significant weapon of choice for terrorists, criminal organisations and individuals worldwide over the past century.

This article will describe the typical construction of an IED noting in particular the use of Commercial Grade Explosives (CGE), to inform SAFEX readers of their use in order to prevent further catastrophic events.

Construction of an IED

As stated in the previous article an IED is "a device placed or fabricated in an improvised manner incorporating destructive, lethal, noxious, pyrotechnic or incendiary chemicals and designed to destroy, incapacitate, harass or distract." (*Ref 1*)

IEDs are a global threat; where victims include not just security forces but civilian men, women and children. In the 12 months prior to July 2014, more than 27,000 IED incidents were recorded across the world, resulting in over of 56,000 casualties either killed or injured. (*Ref 2*)

IEDs by their nature have constantly adapted and evolved dependant on availability of resources, and action by global Counter-IED (CIED) measures. A primary example of this is the main charge explosive which can consist of a wide mixture of explosives from Military Grade Explosives (MGE) to Home Made Explosives (HME), created using agricultural fertilisers, to CGE procured through various means.

The development and proliferation of IEDs has been aided through the use of the internet. It has allowed individuals to share knowledge and plan terrorist acts. This has led to a rise in the capabilities of home grown terrorists, such as the Boston Marathon bombings of April 2013, when 2 pressure cooker IEDs detonated within seconds of each other near the finishing line. The bombing was carried out by two individuals aged only 26 and 19 who were able to construct the IEDs and the HME content from Al-Qaeda manuals proliferated via the internet. They used household and commercially available products to create the IEDs, including a mixture of ball bearings, nails and additional shrapnel for maximum destructive power. The result from their bombing left three people dead, including an 8 year old boy and 264 people injured, including several who had limbs amputated. (*Ref 3*)

The typical construction of an IED is composed of a trigger mechanism (switch), an explosive main charge, an initiator, detonating cord which is commonly used and a power source. Typically, the variations for each component part are:

Figure 1*: The manipulator arm of a remote controlled wheelbarrow Robotic device cautiously reaches for an Improvised Explosive Device that has been under a vehicle during exercise* *(Ref 4)* © Crown Copyright 2014 Imagery

A. Switch

The trigger mechanism will act as a switch in order to close the circuit within the IED and begin the explosive chain. The switch will normally be chosen depending on the target that the user wishes to attack and the amount of control they want to have over the device. This may include having an arming switch before a firing switch. There are many types of trigger mechanisms, these include:

- **Command wire** – Command wire devices will enable the perpetrator to initiate the device by manually closing the circuit of an IED and start the detonation train. The IED will be emplaced with a long length of wire from the initiator to the firing point; this can be up to a few thousand metres. The command wire will often be camouflaged or buried in order to avoid detection.
- **Victim operated** – Victim operated devices are the most indiscriminate. The device will be activated by an individual whether or not they are the intended target. This type of device allows the emplacer to maintain an unlimited distance between themselves and the IED, but it removes precision. Victim operated devices are most commonly pressure plates (sometimes created from saw blades or other conductive material suspended between a wooden set up, which when compressed closes the electrical circuit and starts the detonation chain). Improvised trip wire devices have been used along with other more complex systems.
- **Suicide bomber** – Suicide bombers maintain the principle of direct control over the detonator. They will look to disguise the device on their person or in a vehicle, intending to take their own life as part of the attack. Through maintaining such close proximity to the device, the bomber minimises the opportunities for any countermeasures intended to stop the device detonating and taking lives.
- **Radio controlled** – Radio controlled IEDs tend to be the most sophisticated type of initiation. They cover a spectrum from simple radio circuits to cell phones that require a certain input from the bomber to arm and detonate the device at a time of their choosing. Radio controlled devices allow the bomber to maintain distance from the IED to avoid being identified, yet enables them to be more precise in their attack.
- **Time lapse** – Time lapse IEDs are emplaced with a timing device that will initiate a detonation after a set period of time. The timing devices most often seen are electrical or mechanical in nature; however chemical delays have occasionally been seen. Time lapse devices allow the bomber to be at some distance from the device before it detonates, minimising their chances of being caught. Figure 1 shows a training device that imitates a time lapse under-vehicle devices, which are magnetically attached to the vehicle and were used extensively in Northern Ireland.
- **Combined devices** - Combined devices may have a combination of trigger mechanisms to aid their ability to kill their intended target. For example a radio controlled device may be used to initiate a victim operated device

B. Main charge explosives

Main charge explosives vary according to the availability of explosive material, the target and the financial restrictions on acquisition of materials. The main charge will often be disguised within innocuous objects, such as pressure cookers, palm oil canisters or propane gas canisters, that might add to the destructive effect by providing fragmentation. Main charges can be constructed from Military Grade Explosives, Commercial Grade Explosives, or Home Made Explosives.

- **Military grade explosives (MGE)** within areas of conflict may be relatively accessible through theft from explosives stores, as explosives remnants of war, or illegal arms deals. Often groups may lack the expertise or equipment to use the munitions in their intended manner and, as such, will use them in IEDs.

Figure 3 *The Grand Hotel in Brighton a few hours after the PIRA bomb attack on October 12 1984*. *(Ref 7)*

- **Commercial grade explosives (CGE)** are often acquired by groups illicitly through theft, illegitimate front companies or illegal trading. Examples of CGE procurement by terrorist groups include:
  - The Madrid bombings of March 2004. Four packed commuter trains were rocked by 10 IED explosions. The devices were initiated by cell phones, injuring over 1800 people and killing 191. The main charge was reported to be CGE, manufactured for use in mining. It transpired that the explosives had been obtained from a retired miner who still had access to blasting equipment. (*Ref 5*)
  - The bombing of the Grand Hotel in Brighton (see Figure 3) In October 1984. The Provisional Irish Republican Army (PIRA), a Northern Irish terrorist group, attempted to assassinate the UK Prime Minister Margaret Thatcher at the political party conference, through the use of an IED. The IED main charge was Frangex, a commercial gelignite designed for mining, which was procured illicitly in spite of security service efforts. The device was placed behind a bath panel with a long delay trigger, set to detonate three and a half weeks after emplacement. This allowed the bomber, Patrick Magee, to escape and avoid detection. When the device detonated, the midsection of the hotel crashed into the basement. The Prime Minister was outside the blast radius and was uninjured, however 5 individuals were killed and 34 injured; some seriously. (*Ref 6*)
- **Home Made Explosives (HME)** are often used where CGE and MGE are unavailable, however they may also be chosen to avoid law enforcement detection methods. The content of HME varies, as with other components of IEDs, according to the availability of materials and the associated cost. In order to produce HME, chemicals that have legitimate commercial uses are combined and processed in order to create an explosive capable of detonating. Within Afghanistan, the predominant main charge has changed over the past few years due to action by security forces, government and industry. Ammonium nitrate (AN) fertilisers were predominantly used, however this changed when the Government banned AN fertilisers and the insurgency moved to potassium chlorate, which equally has legitimate uses within the textiles and match making industry. (*Ref 8*) A good example of HME use outside of a conflict zone is the 1995 bombing of a federal building in the US City of Oklahoma where two individuals built a vehicle borne IED, using ammonium nitrate fertiliser, nitromethane and illicitly acquired CGE. The IED, hidden inside a rental truck, was detonated outside the building, killing 168 people including 19 children and injuring over 800. (*Ref 9)*

C. Initiator

Initiators are a critical part of an explosive device as without the initiator the device is unable to detonate. Commercial & Military electric blasting caps are most commonly seen in IED construction however non-electric blasting caps and improvised blasting caps have been used. Commercial blasting caps have been procured through mining activities whether it is through theft or illegal sales.

D. Detonating cord

Detonating cord is a key element recovered in IEDs worldwide. Detonating cord is typically used for linking main charges however it has also been used within IEDs as a booster to detonate blasting agents such as ammonium nitrate fuel oil (ANFO) mixtures. Although improvised detonating cord has been seen in IEDs, it is a very difficult item to produce so bombers will tend to use commercial detonating cord which is very often seen in IEDs globally.

E. Power Source

Most IEDs use an electric initiation system and so require a power source to initiate the detonator. This will normally be in the form of a commercially available battery. The resistance within the circuit will dictate the size of the battery, in the case of command wire IEDs, it is the length of wire that will dictate the resistance and thus tend to require a larger battery in order to deliver the amperage required to overcome the resistance. Batteries will range from the type used in portable electronic devices, to groups of vehicle batteries.

The Future of IEDs

IEDs will remain a threat in the future, adapting and evolving to exploit new technologies that challenge and defeat countermeasures. The primary evolution will be switches, exploiting new and more complex methods, aided by the proliferation of knowledge online and an increasingly technological society. It is likely that the bomber will continue to utilise commercially available products in IEDs such as cell phones and remote control devices.

Whilst developments are expected in switches and methods of employment it is not anticipated that explosive material used within IEDs will change without action. Bombers will continue to use CGE, MGE and HME where available. However, if action is taken by industry and governments to reduce access to material it will be more difficult for bombers to make IEDs. This combined with greater control of precursor elements will lead to a greater chance of bombers being caught and stopped before they are able to strike.

Conclusion

IEDs provide a threat world wide; often aided by online proliferation of knowledge and technology. The key elements for Counter IED forces are switches, initiators, the detonating cord and the main charge, which may include elements of CGE. Commercial explosive products are made with the intention of legitimate use, whether for demolition, mining or construction purposes. However, as some of the examples have illustrated, they have been diverted for illicit uses. Through combined efforts by governments and industry working in partnership, it is hoped that improved control over these elements can eliminate or diminish the access to those who intend to cause harm and kill through the use of IEDs. The next article will look at what has been done by global Counter-IED forces to date to combat the threat presented by IEDs.

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Dyno Nobel plant receives prestigious security award

by

Jessie Mahon (Corporate HSE Analyst, IPL)

On June 13, 2014, the Coast Guard awarded the Rear Admiral Richard E. Bennis Award to the Dyno Nobel Donora plant. The award is a bi-annual award that serves to recognize organizations that demonstrate outstanding achievements and contributions related to implementation of the Maritime Transportation Security Act and other maritime security best practices in safeguarding our nation's maritime transportation system. The Donora plant is situated along the banks of the Monongahela River and receives and ships products along the river under the jurisdiction of the US Coast Guard Port of Pittsburgh.

The Rear Admiral Richard E. Bennis award honours an outstanding Coast Guard leader who embodied the USCG Core Values and demonstrated an exceptional commitment to the security of the United States and the marine transportation system. The award seeks to increase public awareness and stress the importance of protecting the marine transportation system. The intent is to recognize and encourage organizations that establish and foster a comprehensive culture of security throughout their workforce.

Applicants were evaluated through criteria including: emergency and security planning; physical plant security; personnel training; communication and interaction with local authorities, responders and the general public; and a demonstration of their commitment to a proactive approach to facility security.

There were four recipients of the Rear Admiral Bennis Award in 2014 and are as follows:

Port Authority: Port Authority of New York/New Jersey
Facility, Large: Distrigas of Massachusetts, LLC
Facility, Small: **Dyno-Nobel Inc. – Donora, PA. Facility**
Company, Large: APL Co. PTE LTD (APL)

The personnel of the Dyno Nobel Donora plant are proud to receive this award in recognition of their efforts to ensure the facility continues to operate in a safe and secure manner to the benefit of the employees of Dyno Nobel and the surrounding community. Dyno Nobel thanks the US Coast Guard for their continued excellence in monitoring and protecting America's maritime transportation system.

(Editor: SAFEX is proud of Dyno Nobel's achievement in this important area of SAFEX's domain and congratulates the Donora plant on behalf if its members.)

Extract from SAFEX Good Practice Guide (GPG) on "*Storage of Solid Technical Grade Ammonium Nitrate*" (SAFEX GPG02Rev2.01, p 50):

Appendix C: Security Plans

Security plans may be required by the regulatory authority. If not, developing a plan based on vulnerability and threat in the area of operation should be undertaken. The suggestions below might be implemented based on your risk assessment.

The appropriate level of security can vary significantly from facility to facility. It depends on the number of employees, the level of pedestrian and vehicular traffic into and out of the facility, the attractiveness of the facility as a target for various threats, the proximity of the facility to populated areas, and many other factors.

The principal objectives of a security plan are:

- To provide secure storage for TGAN
- To enable theft to be detected quickly and the authorities to be advised.
- To identify and report security related incidents
- Prevent deliberate contamination
- Control access to product

The security plan will have four main elements:

1. Security risk assessment;
2. Personnel management;
3. Site security; and
4. Procedures.

Key points for each of the security plan elements are then outlined in the GPG. If you wish to obtain an electronic copy of this Good Practice Guide, kindly contact the SAFEX Secretariat at secretariat@safex-international.org .

Inbox @ SAFEX-International.org

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

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

Migration of explosives - not a trivial problem

An operator was lowering an empty cut powder buggy to the ground, when multiple flashes or sparks were observed coming from the housing of an air driven chain hoist. After dismantling the hoist, propellant grains were found imbedded in the grease inside the chain drive mechanism.

Maurice Bourgeois (Expert Panel) noted: This case illustrates the risks of explosives migration into process equipment. In my previous company we had a similar problem with a granulator which was not perfectly level. Consequently, the cleaning frequency where the wet powder accumulated had to be increased. In another case powder migrated into planetary mixer bearings. After investigating the sealing of the bearings, we couldn't really improve the current set-up so increased the inspection frequency. I guess the first step is to try to determine where and how the migration takes place. The following questions come to mind: if the hoist is a chain hoist and propellant grains migrate in the links, how does it happen; are the grains propelled onto the chain during the dumping operation; does the chain come in contact with the propellant stack during the transfer operation; can the migration be prevented by shielding or chain basket; would a cable hoist reduce risk of migration.

If migration cannot be prevented, the next step should be to look at the inspection frequency as well as the areas to be inspected (explosive collection area)?

Do operators know "older" type explosives

In another incident three operators were badly burnt and a wall and door of the building damaged when an explosion occurred during the pressing of rocket propellant.

Mervyn Traut (Expert Panel) commented: One cannot help wondering whether people involved with "older" types of explosives such as this propellant have the basic knowledge and skills with respect to handling the these explosives safely. We will have to wait for the investigation to be completed to answer questions such as: Was a foreign object responsible for this incident? Was there a standard procedure for handling press stoppages? Why were 3 operators required to investigate?

Dynamite destruction by open burning

There were no injuries but the burning cage was destroyed when old dynamite cartridges exploded during destruction by burning on a burning ground.

Maurice Bourgeois (Expert Panel) weighed in with the following observations: Proper preparation of the explosive or explosive article is the name of the game when it comes to burning explosives especially when there is presence of exudation. In my former job we used to submerge waste primer caps (bulk) in water to prevent accidental detonation during transport to the burning ground. After we had an accident due to some live caps that remained at the bottom of the burning pan after incineration, we decided to use diesel fuel instead of water which made much more sense to ensure complete combustion of the primer caps.

In the case at hand, if the envelope of the dynamite stick does not burn fast enough to prevent the contained explosive from reaching its critical temperature, detonation can occur. Cutting the envelope open is obviously too risky. Perhaps (if the envelop is cardboard) submerging the sticks in diesel for an extended period to soak the cardboard could help the envelope to burn more rapidly. The compatibility of diesel with NG should be confirmed (I am not a chemist). Particular care should be taken especially with explosive articles.

Gerard Chaloyard (Expert Panel) had this to say: This incident reminds us again that the risk of violent reaction must be taken into account whenever we destroy explosives by burning. This activity must be systematically performed at a safety distance and watched permanently from a secure control station.

Paulo Siqueira (Expert Panel) was grateful for the information on this incident and wrote: Fortunately there were no injuries whatsoever. NG always has a high potential for explosion and following safety procedures and explosives good practices as this member did is the best way to control the risks.

Let's talk deluge systems

An initiation of single base propellant occurred during the drying of water wet propellant. The activity was carried out remotely from a control room and the building involved was fitted with an ultra-high speed fire detection and suppression system that activated when the propellant initiated. The fire system activated the building alarm and an emergency response team extinguished the fire that was not fully controlled by the automatic fire system

Maurice Bourgeois (Expert Panel) found this incident very interesting : As in an earlier incident it also illustrates migration of explosives to areas that can generate sufficient energy to ignite the explosive. Where I worked previously we had incident in which wet igniter composition that is relatively insensitive migrated into a cavity under the screen of a granulator. After prolonged exposure to air, the migrated powder dried and became highly sensitive to friction. We had two ignitions before discovering the root cause. In this case the member has probably identified where the explosive dust if any can migrate close to friction generating mechanisms. If such migration cannot be prevented, a cleaning procedure which identifies the problem areas and cleaning frequency should be implemented. Also just as in the granulator case I described above, consideration to in-process by-products such as dust, crystal formation due to condensation and their sensitivity as well as in-process characteristic changes such as wet-dry explosives should not be overlooked as possible ignition sources.

Finally, the deluge system did not prevent propagation which may indicate that it should be reviewed. The first consideration should be the detection itself. A possibility could be that the UV detector was blinded by an object or polycarbonate shield. UV detectors become less effective with age especially for periphery sight and the sight angle reduces with time. For example, a new UV detector can see in a range of let's say 120 degrees. After 5 years the vision range can be reduced to 80 degrees. (These figures are illustrative only so please don't quote me on them). It is important to test UV detectors regularly. Also, check for blind spots by using a portable UV emitting source. The next thing to check is reaction time. Usually the electronics of UV detectors designed for pyrotechnics have a very rapid response time (milliseconds or less). For speed, water supply is an important issue and here it depends on whether the system is "wet" or "dry". With the "dry" type system reaction time is slower because the legs or branches of the system must fill with water first before it can flood the explosive through the deluge head. By that time it is too late. "Wet" systems are faster. In such systems the deluge heads are equipped with ejectable caps fixed to the deluge head to prevent projection against neighbouring objects or explosives.

Also deluge head positioning is important. The height, angle and position above the explosive will determine the amount of water that will wet and submerge the explosive. If the head is mounted higher, the cone of water is wider but also less dense. On the other hand, if the head is too close, it can propel the explosive outside the hopper or container without proper wetting.

It's about nuts and bolts - and other things

An explosion occurred in the powder feeder of a shock tube extrusion line. It communicated back to the expense magazine which detonated a few seconds later. Regrettably, the operator was fatally injured.

The report of this incident recommended preventative measures which prompted Maurice Bourgeois (Expert Panel) to think about how bolts and screws can be treated to prevent ingress of explosives: In my previous employment I went through a similar ordeal. A mechanic working for me sustained a major injury when a bolt shot through his hand while he was unscrewing it because the threads were contaminated with explosives. We gave instructions to every employee (operators and trades personnel) to consider bolts and screws in explosive contaminated areas as loaded guns. They were urged not to expose any body part to the potential trajectory of the bolt (i.e. along its axis) when threads rupture due to an explosion caused by thread contamination. Also we put in place a program to seal bolt heads with silicone caulking to prevent contaminated wash water from migrating into the threads where explosives can collect. Finally we instructed all trades personnel to use penetrating oil and let it set before unscrewing potentially contaminated screws or bolts.

I don't know if the member in this instance implemented corrective measures to address the potential causes of the accident such as wetting areas where explosives can collect to reduce their sensitivity with, for example, alcohol. If possible, the removal of large quantities of explosives, or at least isolating the same, and cleaning communicating chutes may prevent propagation. When disassembly of equipment is required, the documented cleaning instructions should have: pictures of the different parts of the equipment; identify the risks involved in disassembling these parts; and the precautions to be taken.

Dudley Moore (1935 - 2002) on motor car safety:

"The best car safety device is a rear-view mirror with a cop in it."

Snippets

Will you be at the EFEE Conference next year?

The European Federation of Explosives Engineers, EFEE, invites you to its next World Conference on Explosives and Blasting in Lyon 26th – 28th April 2015.

Since 2000 EFEE has arranged seven World Conferences with great success and it is fully convinced that its 8th Conference at the Lyon Convention Centre in France will be the same and attract delegates from all over the World. Lyon is the third largest city in France and one of the oldest. Located at the confluence of the Rhône and Saône rivers, Lyon is influenced by the Mediterranean and the Continental Europe climates. As an UNESCO World Heritage Site, Lyon has 2,000 years of history imprinted on its cobblestone streets. Lyon is a popular area for travellers, with its dynamic university, first-class shopping, antique markets, vibrant theatre and music festivals, and a range of interesting museums, The city has a distinctly sophisticated air with adventurous gourmets who indulge in their wildest gastronomic fantasies. During the Conference a programme for participants and spouses has been arranged, including sightseeing around Lyon

For more details visit http://efee2015.com/

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, recently retired from AEL Mining Services, 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!

Basis of Safety (Part 4) – Heat

by

Tony Rowe (Retired from AEL Mining Services)

You may recall that in the previous edition of the Newsletter Tony told us about an ancient Latin manuscript entitled ***FUNDAMENTUM SALUTIS - MALLEUM NIQUITIEA, MALA CONSUETUDINE*** which being translated means "The Fundamentals or Basis of Safety – Hammer of Wickedness and Bad Practice". It consists of several sections as outlined in the Contents page:

PRAELOCUTIO (Prologue)

CAUSA:

I. CONLISIO (Impact)
II. ATTRITION (Friction)
III. INCENDIUM (Heat)
IV. SCINTILLA ELECTROCUTUM
V. CHEMICA INSTIBILITATEM

In this edition we continue the study of the FUNDAMENTUM SALUTIS ("The Fundamentals of Safety"). In the last issue we explored the opening or introductory element. It was entitled "PRAELOCUTIO". This time we open the book at Chapter Three, INCENDIUM, which can be translated as HEAT

Readers new to "**THE FUNDAMENTUM"** and to the wealth of information it contains may find themselves keen to learn a little more about its early history. Fresh information in this regard has recently come to light. During 2009, a substantial fragment of a copper scroll was discovered by researchers excavating the refuge caves of Wadi Muhrabi in the Q'um region of what was once ancient Palestine. Wadi Muhrabi is of course known for its links to the ancient city of Carthage and the city's charismatic founder Elissa. As the reader would of course have guessed, the text was written using a cryptic Nabatean form of Aramaic.

Translated, the scroll fragment provides an illuminating glimpse into a little known, but well-established area of science far ahead of its time. It also provides a window for historians to gain insight into the socio-political outline of one of the most poorly documented, but scientifically prolific periods in history.

The translation into English provided below was furnished by an internationally respected Professor of Antiquities from the University of Ashkeloor :

"Unfortunately the recent decline in our joint fortunes has created a real danger of the knowledge being lost forever. It has thus been requested by the Grand Mufti, Shophet and advisor to the Emperor and Vizier to the twelve princes that a central library be created where the sum of this knowledge may be stored forever. It was also declared that as much of the information as possible be published in order that the nation as a whole may profit. In addition a great scroll of the energetics shall be created so that its knowledge may be available to future generations. The scroll shall contain all that has been learned around the safe manufacture of the energetic materials.

The great scroll shall henceforth be known as:

F*N*A*EN*U* *ALUT* - M****** *******A MA** CO**UE***INE**

** characters missing or illegible*

As it was spoken, let it be so. By the command of Antiochus, Lion of Palestine, Slayer of the Hosts of Kush and ruler of the 15 tribes, the Great Library was created. It was built and dedicated to the Bithdren, goddesses of safety and wisdom."

The next 2 lines are illegible. The fragment continues:

"If we are to hold our own, attitudes within the little that still survives must alter very considerably. Solomon was right when he wrote "Get wisdom, gain understanding li....."

("**THE FUNDAMENTUM"** *was one of the few documents known to have survived the library's destruction by fire in the first century AD)*

One of the first headings we encounter in Chapter 3 translates best to the modern English word for temperature. Here is what it has to say:

TEMPERATURE

The term "temperature" is simply a scientific label or qualification intended to reflect our primary sensations of hot and cold.

Changes in temperature have great effects on our personal comfort as well as on the properties of substances such as water that we use every day. "**THE FUNDAMENTUM"** explains that we, as human beings, tend to interpret temperature not only based on the contrast between hot and cold, but may also unconsciously incorporate not only our environment, but often our emotional state into the assessment.

As we well know, anything that depends on our personal interpretation of the world is always subjective. Subjectivity is the bogeyman under the bed of science, the great curse that renders all such contaminated data as unreliable. It must never be countenanced.

In the absence of a means (other than our own somewhat fallible senses) for reliably determining temperature, our alchemists, necromancers and sorcerers were left pulling at their beards. Besides causing pain, dry skin, hair loss with the almost inevitable ugly rash, it was found wanting. The wise ones were bereft and it must be said, somewhat sore and itchy too. Some even developed a form of galloping Fredruff, Dan's somewhat dyslexic brother.

It was clear to everyone that an accurate, robust and reproducible means for determining temperature was desperately required. Such a device would hopefully be more accurate than ourselves and, if properly constructed, would correlate well with each other – or at least a lot better than people do.

This need was finally met when Grand Master Abu Dhabi invented the linseed oil thermetricator. The Grand Master himself remains one of history's great enigmas. A solitary man who besides being known to affect "V" necked underpants and to walk with a bit of a trot, little else is known. Linseed oil by the way is a natural, slow drying oil pressed from flax seeds. The thermetricator consisted of an open-ended glass tube with a bulb or reservoir for the oil positioned at its lower end. The oil level rose when heated and fell when cooled.

Flax oil, somewhat coincidentally, was once considered a sovereign remedy for dry skin, skin rashes and hair loss. It was also used in paints, glues and gums as well as a topical application when oiling flat faced wooden clubs. It was once highly recommended for use on the hand rubbed stocks and tillers of crossbows and other fine weapons.

Thermetricators were deemed as valuable instruments and were henceforth employed in the Assyrian city of Babylon's extensive greenhouse complexes. King Hammuratti II decreed they be installed and used to indicate the correct temperatures for the cultivation of the different fruit bearing plants and trees the King insisted be grown in the hanging gardens. Whilst possessed of no definite scale, thermetricators were known to be mounted against wooden backboards carved at the appropriate points with representations of fruits such as apricots, dates, guavas, peaches, pomegranates and grapes. Gardeners could move between the cultivars and regulate and maintain the temperatures more precisely. Hammuratti got his fruit and occasionally some nuts too!

HEAT

Just as “All roads lead to Rome,” all initiations of explosives, whether accidental or deliberate, require the judicious application of heat in one form or another.

In general though, energetic materials don’t like being heated. Uncontrolled heating is even worse. Energetics subjected to uncontrolled heating many may suddenly undergo a frightening change in character, switching from benign old Dr. Jackal to terrifying Mr. Hide in, but a moment, your best friend one moment, your sworn enemy the next. This is not good. So it is with many of the energetics, Like a certain well-known breakfast cereal, when energetics get too hot and all the snap, crackle and pop abruptly stops. It’s all bang, blast and shrapnel thereafter. When this happens it is very bad indeed.

In the early days, the Grand Sorcerer, Calvados of Chirm, developed his theory of “explosion temperature”. As part of his research program he simply caused samples of explosives to be heated until they exploded. The slaves tasked with watching the hourglasses whilst simultaneously holding the samples over the fires failed to appreciate their contribution. It wasn’t long before they withdrew their support (ancient guvspeak for ran away and hid). Slave labour coalitions were quickly formed and a common approach presented. Soon, no group, whatever their socio-economic background, would continue with the work. Threats of a life sentence in the pistrinum or a few years down the salt mines of Samarkia also failed to improve matters.

For Calvados it was a serious setback, but his results were rarely reproducible anyway. What Calvados had failed to understand was that many factors beyond that of merely achieving some predetermined time/temperature curve were involved. The rate of heating, the size of the sample, thermal losses both within the sample and by the equipment itself, the frequency and accuracy of the temperature profiles to name, but a few. The fundamentals controlling the thermal decomposition process were clearly not yet understood.

“**THE FUNDAMENTUM”** goes on to explain that INCENDIUM or HEAT - as it is called today - is simply a “catch-all expression” for fire, flame and high temperatures, whatever the source. It tells us that heat is a complicated area for study as it encompasses not only the heat generated by sunlight, by grass and brushfires, oil heaters, electric heaters, vehicle or hot air, exhausts, steam pipes, but even the sparks from a cutting disk or sander. The list is long and includes open flames from matches, candles, cigarette lighters, welding sets, (whether gas or electric) and gas flames. It encompasses soldering irons and even glass light bulbs. Heat can be radiated, carried by convection currents or conducted directly. It can be found in a discarded, but still smouldering cigarette end and within a whole range of exothermic (heat generating) chemical reactions, including the dilution of concentrated acids or even failures to effectively neutralise acid-based reactions such as the nitrations of cellulose or the mythical pentaerythritol.

It is said that long, long ago, at a factory, deep in the bushlands of far-off Nibiru, a wet slurry made from the constituents of black powder was slowly stirring in a Naughtymixer. Legend says the slurry was called “Paste.” It is said that the lower bearing at the base of the great vertical screw grew so hot that eventually the water was driven off and the resulting dry mass began to deflagrate. As these things go, the result was not so terrible. No casualties, but a spectacular display of the alchemists art and a building left all, but roofless. The storytellers tell that the onlookers gave a rousing chorus of “Let the Sun Shine In.”

We know too that heat is liberated whenever an electrical current flows through a resistance. Consider water baths, oil baths, hot plates, electric elements and even microwave ovens. All are intended to supply heat, but heat can also result from faulty electrical wiring, an ill positioned magnifying lens or even a concave mirror. Heat is generated by drilling, hammering, hacksawing, filing, grinding and by electrical sparks (which can also generate air shock). Adiabatic compression is particular one to watch especially where emulsion explosives are concerned.

All these things and perhaps hundreds more, represent potentially hazardous sources of heat. One group of energetics though demands a special mention. These are the pyrotechnics, mixtures of finely divided fuels and oxidisers that, when ignited, produce huge amounts of heat per unit mass. Mixtures of metal fuels and metal oxides known collectively as “Thermites” and their unquenchable offspring, the gasless delay compositions, may be even more liberal in this regard. Because only a small proportion of their reaction products are gaseous, what is liberated is not mechanical energy, but heat – lots and lots of it. Loose, poorly pressed or fast burning compositions can present a real hazard with temperatures in excess of 3000 degrees centigrade being achieved in just a few milliseconds. With many flash and/or igniter compositions, once ignited the reaction will run its course whilst the human mind and body is busy contemplating the choices of fight or flight, but in reality there is no running away. Pyrotechnics can also promote the spread of fire. They do so by spraying hot metallic slags or still actively burning fragments over a wide area.

“**THE FUNDAMENTUM**” points out that heat is a far more complicated subject for the layman and its nature is often “heatedly” disputed. Some alchemists maintain heat to be the motion of particles within the body being heated whilst others describe it as a fluid filling the body’s pores. What are often referred to as "heated arguments" further the progress of science best when they produce light (illumination) and not so much heat.

Some sorcerers have claimed heat to be a form of energy, but a few public executions and some floggings have, for the most part, silenced such heresies. For now, measurements remain relative and no quantity of heat has yet been defined.

Authors note: In the nineteenth century, however, the importance of understanding heat made assigning it a unit essential. Fahrenheit was the first person to prove that liquids boiled at fixed temperatures. He was delighted with his discovery. Later on the Calorie and the BThU were established and universally accepted. (A calorie is the amount of heat required to warm 1gm of water through 1^0 Centigrade. A BritishThermal Unit (BThU) is the amount of heat required to warm 1lb of water through I ^{0} Fahrenheit)

FIRE

Flame (from the latin "Flamma") is the bright and visible part of a fire. Flames are often blue at the bottom, yellow in the middle and red at the tip. We can see the colours and if we get close enough, even feel the heat. Alchemists call it pyrolysis. The sorcerers claim it is the work of demons. The alchemists reason that it occurs as the fuel turns to gas before going on to react with the oxygen in the air. The reacting gases then become progressively both (thermo) luminescent and then incandescent in turn.

The sorcerers tell us that flames are inspired by the fire demon Bar-Bea whose breath is so hot that it consumes flesh and blackens bone. Many believe that Bar-Bea formed the root of the ancient expression "**BRAAIVLEIS**" meaning to cook meat over flames.

Much valuable information in regard to fires and heat and energetic materials has been collected, collated and accumulated by the small number of specialised departments dealing with energetic materials. These groups have traditionally operated within the umbrella of the Society of Alchemists, Necromancers & Sorcerers or **SANS**.

To help us remember about fire and flames, **"THE FUDAMENTUM"** has helpfully provided us with an earworm or simple verse. It goes like this:

Roses are red,
Violets are red,
Daffodils and daises are red,
Flippin' Flying Fishnets!
THE WHOLE GARDEN'S ON FIRE!"

THE FUNDAMENTUM" teaches that when a fire begins, at first the flames may appear hesitant, even shy. Newborn flames are terribly nervous. Only scarcely alive, they risk being snuffed out in an instant. You see, in its early stages, a fire is intensely vulnerable. This is why in its initial manifestations it tries so desperately to avoid being noticed. The first flames are small, rather choosing to flicker away quietly on the very edges of vision. Too much fuel and they seem to die, but fed slowly and with care, they will increase, quickly growing big and strong. As they grow their character changes. No longer shy or timid, they now begin to demand an audience. Their great performance has begun. The fire starts to sizzle, hiss and crackle as the orchestra of conflagration tunes up for the grand show. Soon the flames begin to roar, screaming out their demands for sustenance. They have evolved to become the rampaging mob. Ravenous and chaotic, they rage out of control, consuming everything they can find.

Authors note: Some polymers, notably the polyacetal's are remarkably easy to ignite. Worse they burn with a clear blue flame that is almost invisible in natural daylight. The air above a fire involving polyacetals seems to dance and flow, the air shimmering in an extravaganza of sinuous and silent motion. Soon they then begin to drip molten fire on everything beneath. Such a fire spreads very quickly indeed! By the way, Chuck Norris can set ants on fire with a magnifying glass - at night!

"THE FUNDAMENTUM" tells it with much less fuss and confirms that burning takes place in stages:

1. It starts with an appropriate fuel, the presence of oxygen and a source of ignition. Easy-peasy so far.
2. As the initial fire grows, it generates more heat. This leads to the further thermal decomposition of the immediate fuel source. More fuel turns into combustible gases and reacts with atmospheric oxygen generating even more heat. Smoke and gases are emitted. The fire grows. A vicious circle has begun.
3. Eventually the heat becomes so intense that everything combustible in the immediate vicinity reaches a temperature in excess of its own ignition temperature.
4. The next step is called flashover. Suddenly and almost without warning everything combustible explodes into flame.
5. Finally what has become a fully developed fire now becomes the ignition source for other combustibles much further away. The fire spreads. If not extinguished the process will continue until all the available fuel is consumed.
6. Now with all combustible material actively burning and contributing to the fire, heat, smoke and gas generation all increase hugely. The fire is now officially out of control.

The relevance of all this to energetic materials in general and the basis of safety in particular is simple enough. You see, when energetic materials are heated sufficiently they may begin to react. This is undesirable as if not detected and instantly addressed ignition, detonation or explosion are likely to follow, none of which are good outcomes. The hotter energetics become and the closer to their ignition temperatures that they get, the less the amount of additional energy required from any alternative source for ignition to take place. This is why hot explosives are so hazardous. Some of them don't even have to get particularly close to their actual ignition temperatures, but simply have get hot enough for a runaway (exothermic) reaction to start. In such materials once runaway temperatures are reached, the reaction is self-sustaining.

Set out below is a table of ignition temperatures sourced from "**THE FUNDAMENTUM**" itself. The temperatures provided are estimates, unverified by modern science. No account has been taken of pressures or the oxygen concentrations in those reactions where oxygen plays a role, nor was time to ignition ever a consideration. For these reasons no credibility should be attached to them. Students of energetic materials should carry out their own comprehensive literature searches before embarking on any work involving any of the single molecule energetics listed below:

What follows comes with an admonition NOT to take the data supplied too literally and to actively seek out further technical information in a process (which must include obtaining counsel from knowledgeable persons skilled in the art) before proceeding further. It is vital that all persons engaged in managing or carrying out of such work possess the fullest and most up to date information available.

Black Powder	approx 337 ^{o} C
Cyclotetramethylenetetranitramine (HMX)	approx 291 ^{o} C
Cyclotrimethylenetrinitramine (RDX)	approx 213 ^{o} C
Diazodinitrophenol (DDNP)	approx 190^o C
Lead azide	approx 318 ^{o} C
Lead styphnate	approx 260 ^{o} C
Mercury fulminate	approx 165 ^{o} C
Pentaerythritoltetranitrate (PETN)	approx 205 ^{o} C
Paper	approx 500 ^{o} C
Nitrocellulose (NC)	approx 185 ^{o} C
Silver azide	approx 273 ^{o} C
Trinitrotoluene (TNT)	approx 418 ^{o} C
Tetrazene	approx 140 ^{o} C
Wood	approx. 250 ^{o} C

The ignition temperatures listed above are provided only as a guide. For instance, the presence of adulterants can change an ignition temperature either up or down. Remember the cardinal rule "**EXPLOSIVES ARE NOT YOUR FRIEND.**" As an example, "**THE FUNDAMENTUM**" speaks of a nitrocellulose based pyrotechnic possessing an ignition temperature of a mere 137 ^{o} C.

So what can we do? The first thing of course is fire prevention. So, observe the no-smoking rules.

- Understand that smoking and naked flames are forbidden within 30 meters of a vehicle carrying explosives.
- Always control all fire initiators such as matches and lighters.
- Explain that good housekeeping is vital. Good housekeeping creates a clean and tidy environment, one that is (a) much safer; and (b) more pleasant to work in.
- Electric ovens, often used for drying, remain an ongoing hazard. Always provide comprehensive operating instructions and in-depth training around the use of all electrically operated ovens and heating elements.
- When using ovens at temperatures set above 35^o Centigrade, always wear appropriate heat resistant gloves when removing heated trays or containers as a hot tray can quickly become a dropped tray!
- It may seem obvious, but never handle hot energetics (explosives or pyrotechnics).
- Don't leave energetic materials in operating ovens either overnight or over weekends.
- Ensure that the ovens used have dual thermostats and are fitted with runaway trip mechanisms.
- Never place energetic materials on the floor of an electric oven as the heating elements may lie directly beneath.
- Ensure that all electrical motors, switchgear, lighting and other electrically powered devices meet the minimum standards for the category and class of energetic materials being processed.
- Store volatile and flammable solvents appropriately in well ventilated, purpose built storage areas and restrict the volumes permitted at any point of use.
- The storage, transport and use of high risk, spontaneously igniteable substances (pyrophorics) should be rigorously controlled. Only fully trained personnel, aware of all the hazards and signed off, should be allowed access and then only under direct supervision.
- Store oxidisers and fuels separately in storage areas well apart from one another.
- Oily rags, cotton waste and paper towels must be stored in closed metal bins in a safe place outside the house or building. Such bins must be emptied daily.
- Never place any energetic material into a microwave oven.

"THE FUNDAMENTUM" has also provided this note around the use of fire extinguishers:

The Use of Fire Extinguishers

- **In the explosives industry you are not required to fight a fire. EVER**!
- **If you have the slightest doubt about your ability to control the situation <u>do not fight the fire</u>**.

To assist the student in his or her endeavors "**THE FUNDAMENTUM"** has also provided the thermal outputs produced by a few day to day items.

A candle flame for instance burns at about 800 – 1000 ^{o}C and a wood fire at around 1050 ^{0} C. An oxy-acetylene torch flame is much hotter at around 3300 ^{o}C. Even a smouldering cigarette can achieve up to 800 ^{0} C. An electric stove element generates around 600 ^{0} C whilst the external glass surface of an electric light bulb can reach 300 ^{0} C. Electrical arcing can result in nearly 4000 ^{0} C.

Yet another source of heat can be created during the dilution of concentrated or strong acids. Strong acids can react violently with water. It is an exothermic reaction liberating so much heat that the water can physically boil. A steam explosion then results, splashing water and any still undiluted strong acid over a wide area. "**THE FUNDAMENTUM**" points out that it is best not to be splashed with strong acid.

Finally, here are some Do's

- ◊ Always use common sense and good professional judgment.
- ◊ When in doubt, seek help and advice.
- ◊ Obtain an Open Flame Permit when planning work such as welding or grinding.
- ◊ Ensure that any chemicals which are used or stored together are compatible.
- ◊ Dispose of all oily or contaminated rags or cloths appropriately.
- ◊ Read labels on bottles before using the contents
- ◊ Dilute acids only by adding acid to water whist stirring
- ◊ Observe and comply with all warning signs.
- ◊ Keep chemical containers closed when not in use.
- ◊ Keep all chemicals in their original labelled containers.
- ◊ Read the MSDS of all materials you plan to use.
- ◊ Follow all manufacturers' recommendations and requirements.
- ◊ Use only appropriate and properly wired electrical devices and equipment.
- ◊ Implement good housekeeping measures - accidents are more likely in areas with poor housekeeping.
- ◊ Eliminate all potential tripping hazards in the work area.
- ◊ Have established procedures for the closing down of operations during emergencies or power outages.
- ◊ If an electrical device emits an unusual odor, turn it off and unplug it immediately. Do not use the device until it is repaired.
- ◊ Wear safety glasses whenever explosives are present.
- ◊ Ensure that all spills are cleaned immediately and safely.
- ◊ Wear closed toe shoes.

I'm out of space……… going to call NASA right away!

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