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## About this Newsletter

This is the last Newsletter before the triennial SAFEX Congress in May 2008. As can be expected the Congress features prominently in this issue. We have endeavoured not to repeat what we covered in our previous Newsletter. Instead we emphasize the content of the Open and Closed Days' plenary sessions. In our *Meet the Governors* feature we are happy to introduce Karl Maslo. As incident reporting remains one of the principal concerns of SAFEX, we track this in *Our Incident Reporting Performance* which appears next. This is followed by the *2008 Congress Preparation* feature to which we alluded earlier. *From CERL's Research Notes* is a popular feature and in this edition their work on minimum burning pressures of emulsion explosives is the focus. The minimum burning pressure of an explosive is a key safety parameter and can be used to define a basis of safety. The new feature *Our Regulatory World* discusses how explosives are classified for transport. The Newsletter concludes with *Safety Snippets* in which we feature a Safety Alert published by Australia's NSW Department of Primary Industries. We hope you enjoy this edition of our Newsletter.

## Meet the Governors

### Karl Maslo



Karl was born in New York, USA but grew up in Germany and Peru. Because of his father's long involvement as Managing Director of EXSA, he has had a lifelong connection with the explosives business. Therefore, it was no surprise when he went to Germany to study chemical engineering at the Karlsruhe Fridericiana University graduating in 1988 with a master degree in commercial explosives at the Fraunhofer-Institut.

After graduating he worked for some years in a welding company that specialized in special welding products, a competitor to EXSA's welding products line. Karl was responsible for merging his welding company with EXSA in 1996. As part of the merger he accepted the appointment in EXSA as Assistant General Manager reporting directly to his father. In 1999 he was promoted to General Manager and took charge of both EXSA divisions: Welding and Explosives. During his time at EXSA Karl managed to open new export markets. He also diversified the Company's core business converting it into a full supplier of blasting products and services based mainly on its own technology and patents. Safety

was something with which Karl grew up; it is in his blood so to speak. To him there is no question safety comes first in all aspects of business. So when joining SAFEX he had a very clear notion of what "safety" meant and the importance of its contribution to society especially with regard to explosives. It does not surprise us, therefore, that he has served as a SAFEX Governor for a number of years.

Karl lives in a Lima suburb. In his free time he likes travelling around the country with friends and family in his 4 x 4 SUV. "It gives me great satisfaction to discover the beautiful scenery and landscapes of Peruvian mountains, jungle and desert" Karl says. "But during the summer I love doing the things I have done since childhood like fishing and scuba diving." SAFEX is fortunate to have an entrepreneur like Karl on the Board. He understands the South American business environment as well as the issues smaller explosives manufacturers face. His mastery of three languages is also an outstanding feature of Karl Maslo.

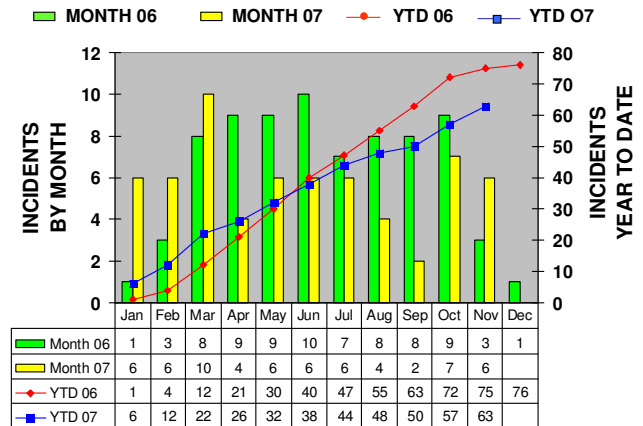
# Incident Reporting

## Monitoring our Reporting Performance

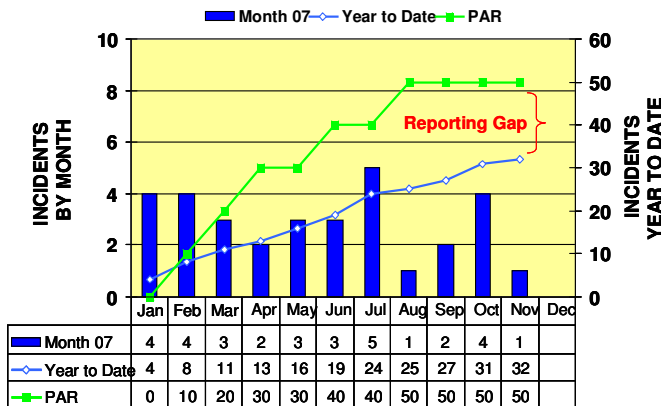
Incident Reporting is one of SAFEX's key services. It is a service for which we depend on each and every member. If members do not report their incidents we will not know about them. It goes further than merely reporting an incident, of course. For us to learn from an incident it must be properly investigated, the learning points extracted and the information shared with other members. However, it all starts with the reporting of incidents and that is why we track the number of incidents reported using the following charts:

**All the incidents reported.** This chart shows the sum of non-member and member incidents of which we were notified every month this year and compares it to the previous year. Compared to last year, 2008 started slowly but reporting did pick up in March. The slow start is understandable if no incidents from which anyone could learn occurred. However, if such incidents are occurring and we are not reporting them, we are missing learning opportunities for which our industry will pay a price.

**ALL INCIDENTS REPORTED : 2007 v 2006**



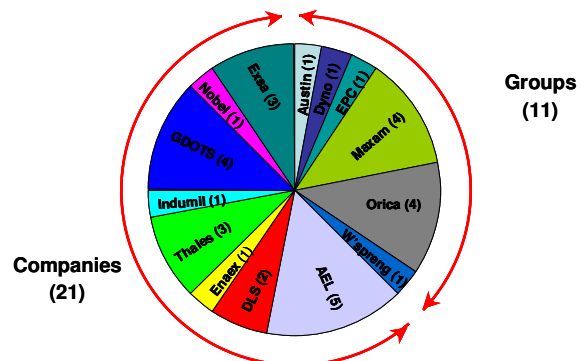
**MEMBER INCIDENTS REPORTED: 2007**



**Member incidents reported.** We track separately the number of incidents of which members notify us. In these incidents members identify learning points when they investigate each incident. An important indicator in this chart is the gap between the number of incidents we receive and those we believe are occurring but go unreported. According to this chart we are only notified of 2 out of 3 explosives incidents our members are experiencing. It means we are losing out on 33% of the possible lessons we can learn.

**Contributors of member incidents.** Because we get most value from member incidents, this chart identifies those members who have taken the trouble to report their incidents. It shows the number of incidents each member has reported and the total number of reports received. The chart distinguishes between Groups and Companies merely to indicate the performance of the two membership categories. Each category has about the same number of operating units. The previous increase we saw in the number of company members that report incidents has been maintained up to the end of November.

**CONTRIBUTORS: MEMBER INCIDENTS - YTD NOV 2007**



## ***XVI Congress in 2008, Madrid***

### **Hotel reservations – Can I still register after 31 March 2008?**

In its agreement with the Novotel, SAFEX was guaranteed room accommodation for its delegates provided delegates make their reservations before 31 March 2008. What must delegates do who have not made their reservation before 31 March? Does it mean they cannot register for the Congress? No, they can and should still register. All it means is they

have to take a chance with the hotel accommodation that is available. Obviously the sooner you make your reservation the better your chances are of getting accommodation. Remember, in order to make use of the special rate SAFEX delegates have been given use the reservation form we sent all Contact Persons. If you don't have a copy please contact

the Secretariat at [secretariat@safex-international.org](mailto:secretariat@safex-international.org)

Please remember there are two hotel options for the Congress: the Sofitel and the Novotel at Campo de las Naciones, Madrid. While the Congress will take place in the Novotel, the Sofitel is right next to it and equally convenient.

### **Schengen Visas to visit Spain**

Spain requires visitors from certain countries to have a valid Schengen Visa to enter the country. MAXAM, one of our Group members, is based in Spain and

will be the local host for our Congress. The Company is ready to issue a letter of invitation to any delegate who may require it. Please contact the Secretariat at

[secretariat@safex-international.org](mailto:secretariat@safex-international.org) for information about obtaining a letter of invitation if you require a visa.

### **Training Session still has vacancies**

“We recognize how important the topic of the Training Session is to members; we can, therefore, still accommodate participants who wish to attend”. This is the message from Andy Begg who is organizing this Session which deals with *Risk Management for the Explosives Environment*. Andy reminds us that the Training takes

place over two days - on Tuesday and Wednesday, 26 and 27 May. He goes on to say: “It is free of charge and will be offered by some top class instructors lined up specially for this event in a well-structured programme that participants will find meaningful.” This is an opportunity not to be missed and while there is still

room we urge interested delegates to register for the Training Session soon. Remember participants in the Training Session who stay on for the Congress are not part of the normal limit of two delegates for Company Members or ten for Group Members.

### **The Open Day is packed with stimulating papers**

This is the view of Frank Barker, Convener of the Open Day Session on Thursday, 29 May. Frank has managed to obtain papers from a number of visiting speakers who are prominent in their field. They are ably supported by representatives of member companies that have done interesting work in the themes selected for the Open Day. Each of the four themes will be the subject of a dedicated plenary Session. Each Session, which will be chaired by a SAFEX Governor,

will comprise four papers. There will be adequate time for questions, discussion and summary of the papers presented about that theme at the end of each Session. “We will be encouraging questions and input from delegates so that they can take as much learning from the Congress back with them,” says Frank. Then with a twinkle in the eye he goes on to say: “Yes, the Open Day will be stimulating but we will be working hard. The Day starts at 08:15 am in the morning and will go through to

6:00 pm that evening. This is not to test delegates' endurance but rather to maximize the benefit for members and visitors who will be participating in this first Open Day at a SAFEX Congress.”

Let's see what papers Frank is proposing for the four themes: Ammonium nitrate (AN) safety and the environment; Training – the people side; Process safety – the plant side; and Health, Safety and the Environment (HS&E) outside the factory

## **AN safety and the environment**

Prof Martin Braithwaite from Imperial College in London will give an overview of AN Hazards. Against this backdrop Dr Phil Lightfoot from the Canadian Explosives Research Laboratory (CERL) will discuss some of the work they do regarding the hazard properties of AN. He will introduce the new Canadian Regulations on the Control of Explosives Precursor Chemicals that were published on 19 March.. Vincent van den Hoogenband from TNO in the Netherlands will review the detonation characteristics of AN products using some large scale tests their laboratory have conducted. Pat Cosgrove from Irish Industrial Explosives, one of our members, will wrap up the Session with a Case Study on AN storage in the context of the SEVESO III requirements.

### **Training – the people side**

The people side of safety is also receiving high-class attention in the Open Day by way of the plenary Session on Training. The Competence Centre for Energetic Materials (KCEM) from Scandinavia is the driving force behind the EUExcert initiative. This is a programme looking at establishing criteria for certifying explosives workers in Europe. Erik Nilsson from the KCEM will set the context for this initiative in his paper. It will be followed by prof

Jackie Akhavan from Cranfield University in the UK who will discuss the content of the programme in her paper which looks at developments in training for the explosive sector in the UK. Dr Dallas Wilkinson from Orica EMEA, one of our Group members, will outline their experience with the Core Critical Procedure training which Orica has used with much success. The Session will be wrapped up by an old friend, Chris Ronay, who will review the IMESAFR risk analysis programme in which the Institute of Makers of Explosives (IME) is training people from our industry world wide.

### **Process safety – the plant side**

The third plenary Session of the Open Day is dedicated to Process Safety which looks at the plant side of safety. Frank has succeeded in attracting some top class speakers from outside and within the SAFEX community to address this theme. Tom Watts from Tread Corporation brings his company's experience to bear in a paper that reviews the design and execution of progressive cavity pump protection for a Mine Manufacturing Unit (MMU). Frank Barker himself will then outline some very interesting work that his company, Orica USA Inc has done in implementing a periodic hazard study process. At this point Neil Morton, the UK Chief Inspector of Explosives and

another good friend of SAFEX, will review safety performance indicators that he believes is crucial in the explosives industry. A member of our Expert Panel, Mervyn Traut, wraps up the Session by capturing aspects of plant design for improved health, safety and environmental (HS&E) performance based on lessons learnt from 20 years of land remediation of explosives and chemical plants.

### **HS&E outside the factory**

In the final Session of the Open Day we will be looking at HS&E from an “outside the factory” perspective. Dr Hans Karlstrom of Kimit AB, a member company, will be sharing the work they did on fire testing AN matrix in aluminium and stainless steel tanks such as one would typically find on truck trailers. Eric Nygaard of Yara International, another member company, continues the theme by outlining his company's work on large scale detonation testing of AN. We are then fortunate enough to have Odd Arne Grovo from the department of Civil Protection and Emergency Planning in Norway discuss the testing of explosives magazines in which he will be showing videos of the tests they did. Ben Barrett, another Expert Panel member, will then conclude the Session and the Open Day with a paper on developments in the transport classification of AN and explosives.

## **Topical incidents featured in the Closed Day**

The Closed Day on Friday, 30 May focuses on the review of incidents members had since the last Congress. Thanks to the commitment of those members we are also fortunate to offer papers on some of the recent incidents in our industry; incidents that have stimulated a lot of interest among

members. These include: the emulsion incidents Premier Explochem (India) and Quin Investments (Australia) have had; the lead azide detonation at CMMPM (Mexico); and the explosion of an AN transporter that caught fire in Mexico. While these incidents are the ones that

attracted attention there are other valuable incidents which will be covered in depth during the three plenary Sessions that make up the Closed Day. Each Session which is convened by a SAFEX Governor will be dedicated to one of the following themes.

- Ammonium nitrate and emulsion incidents (Stephen Connolly);
- Incidents with initiating systems (Jose Ayensa); and
- Incidents highlighting the safe transport of explosives (David Gleason).

The plenary Sessions are structured to allow at the end of each Session discussion of the incidents that were presented. By encouraging as much participation as is necessary, the Session Chair will urge delegates to identify good practices based on their experience and the lessons from each of the incidents. In this way delegates will be equipped with practical learning they can immediately apply back in the work place.

Besides the recent high profile incidents mentioned above, delegates at the Closed Day can expect in-depth reviews of incidents in each of the three

themes. In the *AN and Emulsion Session* delegates will receive a well-developed analysis of Orica's packaged emulsion incident in Lorena, Brazil. Austin International will highlight their learning experiences from an emulsion pump incident in Costa Rica. After the Premier Explochem and Quin incidents, that will be part of this Session, Parchin Chemical Industries (PCI) will conclude the Session with a review of AN Incidents.

African Explosives Ltd (AEL) will start the *Initiating Systems Session* with a detonator priming incident. This will be followed by a paper on the inadvertent initiation of ZPP which Special Devices Inc. had in the manufacture of airbag initiators. After the CMMPM incident with lead azide, which we have already mentioned, Visfotak will present a paper on a detonating fuse incident in India. Austin International will

conclude the Session by discussing the fusehead incident it had in the Czech Republic.

The *Safe Transport of Explosives Session* will comprise a review by Austin Powder of transport incidents throughout the world. MAXAM will present the learning points from transport incidents it had as a Group. Austin Powder will discuss an incident in which a contaminated truck trailer was involved. Then African Explosives Ltd (AEL) extract the extensive learning from an incident involving an explosive truck on a public highway. The explosion of the AN transporter in Mexico which we mentioned at the beginning will also feature in this Session.

Truly a Closed Day packed with relevant incidents from which delegates will be able to extract good practices.

## From CERL's Research Notes

### Minimum Burning Pressures of Emulsion Explosives

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#### Introduction

With the scale of modern mining operations, large volumes of emulsion explosives have to be manufactured and transported. The potential damage from an accidental initiation of such large quantities of emulsions is considerable and the corresponding manufacture and handling systems must offer a very

high degree of reliability. Despite their relative insensitivity to accidental initiation under normal operating conditions, emulsions have still been involved in a significant number of accidental explosions and history demonstrates that pumping emulsions is the most hazardous process.

While several quantitative tests have been developed to investigate thermal runaway hazards, very few tests have been put forward to quantify hazards originating from localized thermal ignitions in commercial emulsions. The closest test used on a regular basis is the Internal Ignition/DDT test in the UN TDG Orange Book [1], in which a black powder charge is

used both to ignite and pressurize a confined sample. However, this test provides no quantitative information and involves the potential detonation of 2.5 kg of explosive in a steel pipe, with all the attendant safety concerns. It is known that, following local ignition in water-based explosives, there is a minimum pressure required for combustion to propagate. The latter is usually referred to as the 'Minimum Burning Pressure' (MBP). The MBP is a very important and useful safety parameter as, if an explosive is maintained below its MBP, accidental ignition and propagation should not be possible.

Within the commercial explosives industry, the concept of MBP can be used to estimate safe operating pressures for pumping and mixing equipment. The technique to determine the MBP was pioneered for watergel explosives at Canadian Industries Ltd. in the 1970's and is a modification of the classic strand-burner technique used to measure the effect of pressure on the burn rates of propellants [2]. In simple terms, measurement of the MBP of an explosive involves igniting a sample in a pressurized vessel by means of a heated wire. Tests are repeated at increasing initial pressures until sustained combustion of the sample is observed.

Over the last several years, we have designed and built a pressurized vessel test at CERL to measure the MBP of emulsion (and other) explosives. Although the idea is straightforward, a number of factors can affect the ignition and steady propagation of a burning front in emulsions. It would be fair to say that this task has proved to be rather more

difficult and complicated than we initially anticipated. On the plus side, it has meant that we have had the opportunity to do some interesting science! We are now in a position where routine measurements are possible and are generating a lot of useful information. Much of the more recent work has been done in partnership with Orica Mining Services.

The purpose of the present article is to give a brief overview of the development of our MBP test at CERL and to demonstrate how the test can be useful in determining the basis of safety for operations involving commercial explosives.

## Making Emulsions

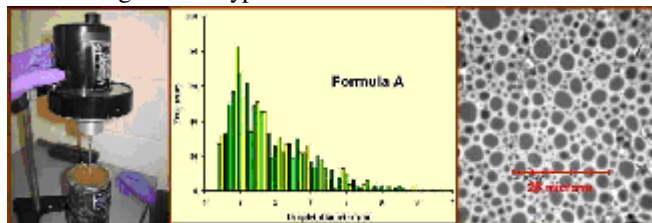
A big hurdle to a scientific study of the parameters that affect the ignition characteristics and minimum burning pressures of emulsion explosives is the fact

that it is usually not possible to purchase a range of explosives where one component, such as the water content, has been systematically varied. The nature of commercial emulsion formulations is such that if one variable is changed, others are also changed to re-optimize the overall formulation. As a result, it was necessary to set up a small-scale emulsion manufacturing facility at CERL. The set-up consists of a Hobart mixer with a jacketed bowl (Figure 1a). The temperature of the bowl is controlled by a heated oil circulation bath. The whole set-up can be rolled into one of our blast chambers for mixing. Typical batch sizes are 2-3 kg. The resulting products are characterized in terms of their viscosity, droplet size distribution and water content (Figure 1b). We can now make a wide range of emulsions routinely.

Figure 1a: Small-scale emulsion manufacturing facility



Figure 1b: Typical emulsion characterization



## Development of the Technique

In principle, MBP measurements are simple to carry out: put some explosive in a vessel, pressurize and ignite with a hot wire. If the emulsion burns, we are above the MBP, if it doesn't, we are not. In fact, there are a number of tricks to obtaining meaningful results. We have spent several years at CERL working out these details and would be happy to share them with other organizations.

First of all, the ignition source must be capable of delivering enough energy into the explosive to reach stable combustion. We began, like other groups, by using a small, tightly wound coil of resistance wire imbedded in the emulsion as the ignition source. There are a number of problems with this, not the least of which is the fact that it is difficult to get good contact between the inside of the coil and the explosive. The geometry is also very difficult to model. The size and shape of the sample has also been identified as an important factor. In early experiments, the sample was held in a tapered ceramic crucible and when the burning front radiating out from the coil reached the crucible wall it was quenched, leaving unburned sample. In consequence, it proved to be difficult to determine if the sample had achieved sustained combustion. As a result of these factors, we now use a straight wire running through a cylindrical sample as an ignition source: contact with the sample is good, the cylindrical geometry helps with modelling work and the distance from the wire to the wall of the sample container is constant, so it is clear if the sample fully burned.

Figure 2 shows the current

experimental set-up. More details can be found in References 3 and 4. Emulsion samples are loaded into 25-mm diameter PVC cell; typically, around 60 g of emulsion is used. A straight Ni/Cr wire is imbedded in the explosive. The cell is suspended in a 4-L high-pressure vessel, which is closed and pressurized to desired initial pressure with argon. A constant current is then passed through the wire. Pressure, current and voltage across the hot wire are acquired.

Figure 2a: Overview of 4-L vessel used for measurements



Figure 2b: Detail of sample container

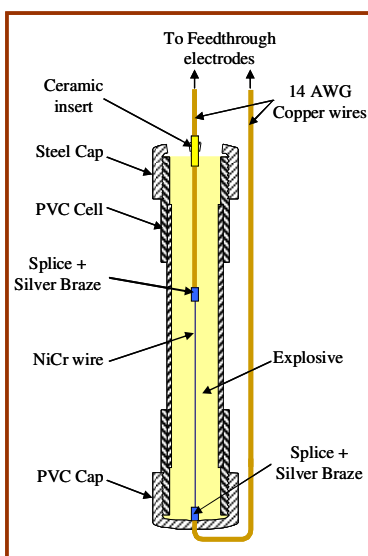
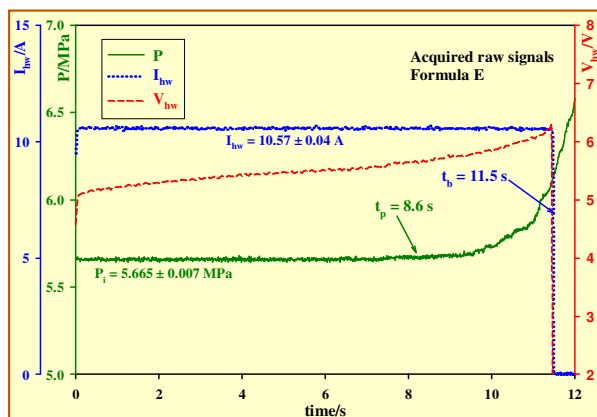


Figure 3 (next page) shows the raw experimental data collected from a typical experiment designed to investigate ignition characteristics. In this case, a constant current of 10.57 A is passed through the wire for 11.5 s, at which point the emulsion is already ignited and the wire burns out. The pressure starts to rise at 8.6 s. As the resistance of the wire is carefully calibrated as a function of temperature, it can be used as both an ignition source and a temperature probe. The voltage across the wire increases steadily with time, despite the constant current, indicating that the resistance and hence temperature is increasing. Figure 4 (next page) shows the temperature information derived from the raw data in Figure 3. Over the first few seconds, the temperature rises rapidly at first, but then begins to level off, in the manner that would be expected if the wire were in an inert medium. However, at 2.9 s, the temperature begins to deviate upwards from the inert curve, indicating that heat is being generated by the emulsion and fed back into the wire, a sign that self-heating is beginning. The change over from the wire heating the sample to the sample heating the wire is clearly seen in the temperature derivative curve.

As the temperature of the hot wire is known at all times and the ignition geometry is well defined, it is possible to estimate the cumulative amount of energy deposited into the emulsion at the point of self-heating. This is of course an important safety parameter. Initial results indicate that the energy required to ignite an emulsion can be very high close to the MBP (100 – 400 J cm<sup>-2</sup>). Importantly, we have demonstrated that careful control of the ignition system is required to measure realistic MBP values,

Figure 3. Typical raw data from a MBP experiment: pressure in green; hot-wire voltage in red; hot-wire current in blue.



as it is quite easy to underestimate the MBP by using an ignition source that is not properly designed. Currently, we use an ignition current of 10.5 A, which seems close to optimal, based on many detailed measurements.

In earlier work, we were very careful to try to maintain the pressure in the MBP vessel constant. In order to do this, we used a venting mechanism with a computer-controlled feedback loop. If the pressure rose, the vent was opened to release some gas. In addition to increasing the complexity of the experimental setup significantly, the venting mechanism has a more significant downside: releasing pressure effectively released energy and cooled the sample. As a result, the combustion of some samples was quenched and the MBP was overestimated. We now no longer vent samples during experiments to maintain a stable pressure, although we do, of course, employ a pressure relief mechanism for safety purposes. One potential problem with not venting during the experiment is that the pressure rise caused by the burning emulsion could cause the burning to self-accelerate (as burning rates for explosives typically increase with pressure), thereby introducing an error in the measurement of the

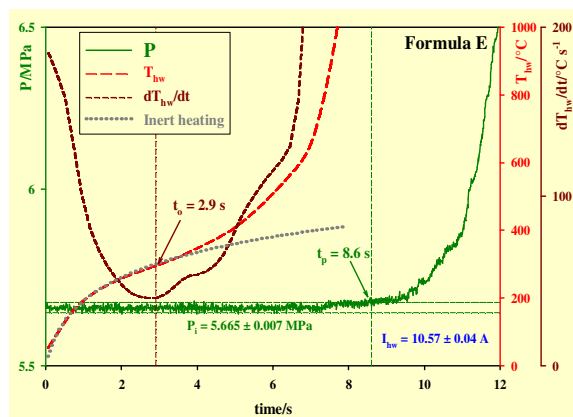
MBP. We have carried out experiments in a much larger pressure vessel (19 L vs. 4 L) to minimise any pressure rise. The results were identical in the two systems, indicating that self-pressurisation is not an issue for our MBP measurements.

## Typical MBP Measurements

After the work described very briefly in the previous section, we now believe that our current MBP apparatus works well, generates conservative MBP values and can be used for routine measurements. Now that the exacting requirements for proper ignition and other experimental details have been worked out, it is not necessary to instrument the tests as heavily, or carry out such involved data reduction, if only the MBP is sought. The methodology for finding the MBP can be summarized as follows:

1. Guess initial test pressure as the expected MBP.
2. Pressurize the vessel and ignite the sample using a current of 10.5 A. Do not vent the combustion products while combustion is taking place.
3. If sample burns completely

Figure 4. Typical data from a MBP experiment. Pressure in green; temperature in red; time derivative of temperature in brown



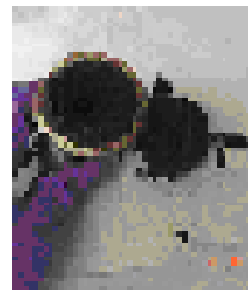
(Figure 5), the experiment is deemed to be a 'go'. Reduce the pressure for the next experiment.

Otherwise, the experiment is deemed to be a 'no-go'. Increase the pressure for the next experiment. Repeat Steps 2 – 4 while gradually decreasing the pressure increments (or decrements) until the MBP has been determined to the desired degree of precision.

Figure 5. End results of MBP experiments.



Incomplete combustion, hole burnt by hot wire in centre of sample.



Bottom: complete combustion.

Table 1 shows the measured characteristics of five generic emulsions produced for MBP work. Formula E was used to provide the examples in Figures 3 and 4. The MBP values quoted in the table are approximate and are intended to be indicative only. However, from these and other measurements to date, we can conclude that water content is a major factor controlling MBP. The higher the water content the higher the MBP, all other parameters being equal. The use of chemical sensitizers (in this case sodium perchlorate) can lower the MBP dramatically. It is of note that earlier work with sub-optimal ignition sources produced much higher MBP values for high-water-content, bulk emulsions.

## Conclusions

We believe that the minimum burning pressure (MBP) of a water-based explosive (emulsion or and watergel) is one of its most important hazard characteristics. If a material cannot undergo self-sustained burning, an ignition that does not heat up the whole mass will not lead to runaway reaction and detonation. Maintaining pressures well below the MBP can be a basis of safety for operations involving emulsion explosives. In Canada, we are beginning to incorporate MBP considerations into the licensing process for explosives operations.

MBP values are key safety

## References

- [1] Recommendations on the Transport of Dangerous Goods – Tests and Criteria, Fourth Revised Edition, United Nations, New York and Geneva 2003 ST/SG/AC.10/11/Rev.4.
- [2] S. K. Chan and J. Kirchnerova, Ignition and Combustion Characteristics of Water-gel Explosives, Minutes of the 18th Explosives Safety Seminar, Department of Defence Explosives Safety Board, Virginia, USA, 1978; Volume I, pp. 193-208.
- [3] R. Turcotte, P.D. Lightfoot, C.M. Badeen, M. Vachon, D.E.G. Jones, and S.K. Chan, A Pressurized Vessel Test to Measure the Minimum Burning Pressure of Water-Based Explosives, Propellants Explosives Pyrotechnics 2005, 30, 118.
- [4] R. Turcotte, S. Goldthorp, C.M. Badeen, and S.K. Chan, 'Behaviour of Emulsions Explosives in Hot-wire Ignition Experiments', Proceedings of the 9th International GTPS Seminar in conjunction with the 34th International Pyrotechnics Seminar (Europyro 2007), Beaune, France; I: 349 (2007).

Table 1. Representative emulsions and MBP measurements

Formula	Water Content /mass %	Density /g cm <sup>-3</sup>	$\eta^1$ /kCpS	D <sub>mean</sub> <sup>2</sup> / $\mu$ m	MBP /MPa
A (AN/SN)	8.7 ± 0.1	1.39 ± 0.01	85	1.50 ± 0.78	1.0
B (AN/SP)	10.3 ± 0.1	1.40 ± 0.00	101	1.71 ± 0.90	0.5
C (AN/SN/Al)	8.3 ± 0.1	1.42 ± 0.02	71	1.85 ± 1.14	1.0
E (all AN)	17.2 ± 0.1	1.32 ± 0.01	96	1.78 ± 0.88	4.9

<sup>1</sup> Brookfield viscosity (spindle 7, speed 20) at 70-80°C;

<sup>2</sup> Mean diameter.

parameters for all operations that involve handling emulsions. For example, it is to be expected that many packaged products will be subjected to pressures close to or above their MBP during the manufacturing process. On the other hand, it might be possible to design processes such that bulk products with high water contents are never handled at pressures close to their MBP values. One area where we believe that MBP measurements can contribute significantly to explosives safety is for underground bulk products. Many underground applications require pumping pressures of several hundred MPa in order to fill upholes and, as a result, may be being handled at pressures close to or exceeding their MBP values.

Clearly, one long-term goal should be an ability to relate formulation to MBP values, or at least to have a good understanding of how formulation changes and other parameters such as temperature

might affect the MBP of a product and hence the basis of safety for a given operation. We have just begun a systematic test program to look at the effect of formulation variables on MBP values. We anticipate that we will be able to share the results with the explosives community in the next year or two.

We now have a method by which realistic MBP measurements can be carried out routinely and fairly efficiently. The method is repeatable, data reduction is limited and the results are easily interpreted. The method uses only about 60 g of sample, an important safety consideration. We would be happy to share our experiences with MBP measurements with other organizations and invite collaboration. A long-term goal we have is to establish a relatively simple MBP methodology that could be adopted by laboratories around the world.

## The Explosives Regulatory World

This feature by Ben Barrett, an Expert Panel member, was introduced for the first time in our last Newsletter. Ben is an independent consultant specializing in regulation of explosives. DG Advisor, Ben's consultancy, is dedicated to participation in the development and modification of international dangerous goods regulations and helping clients comply with US and international regulations.

### How are Explosives Classified for Transportation?

Explosives are classified for transportation according to the Manual of Tests & Criteria developed by the United Nations (UN). Unlike storage or manufacturing, transportation across state (country) borders results in a need for harmonization between national regulations. Global harmonization thus provides the impetus for international cooperation on classification and regulation. This work is prosecuted within the framework of the UN.

The UN Manual of Tests & Criteria, currently in its 4<sup>th</sup> revised

edition, is maintained by the UN Sub-Committee of Experts on the Transport of Dangerous Goods. The Sub-Committee consists of voting members from government and non-voting members from industry. Within the Sub-Committee, a subset of government and industry experts on explosives participates in an Explosives Working Group on behalf of the Sub-Committee, and it is this working group which crafts changes to the explosives classification system, for approval by the Sub-Committee.

At the outset let's define the

terminology and conventions used in the classification of explosives. Explosives are assigned to Class 1 of dangerous goods. Goods of Class 1 are, in turn, assigned to one of six divisions, depending on the type of hazard they present, and to one of thirteen compatibility groups which identify the kinds of explosive substances and articles that are deemed to be compatible. When an explosive is classified as belonging to Division 1.4S, for example, "1" refers to the class, "4" to the division and "S" the compatibility group. We would be interested in the following Divisions:

**Table 1: Outline of Divisions and their Definitions**

DIVISION	DEFINITION
1.1	Substances and articles which have a mass explosion hazard (a mass explosion is one which affects almost the entire load virtually instantaneously)
1.2	Substances and articles which have a projection hazard but not a mass explosion hazard
1.3	Substances and articles which have a fire hazard and either a minor blast hazard or a minor projection hazard or both, but not a mass explosion hazard. This division comprises substances and articles: (i) which give rise to considerable radiant heat; or (ii) which burn one after another, producing minor blast or projection effects or both;
1.4	Substances and articles which present no significant hazard This division comprises substances and articles which present only a small hazard in the event of ignition or initiation during transport. The effects are largely confined to the package and no projection of fragments of appreciable size or range is to be expected. An external fire shall not cause virtually instantaneous explosion of almost the entire contents of the package
1.5	Very insensitive substances which have a mass explosion hazard This division comprises substances which have a mass explosion hazard but are so insensitive that there is very little probability of initiation or of transition from burning to detonation under normal conditions of transport
1.6	Extremely insensitive articles which do not have a mass explosion hazard This division comprises articles which contain only extremely insensitive detonating substances and which demonstrate a negligible probability of accidental initiation or propagation

There are eight test series for possible use in this classification, some of which are specific to certain types of explosives:

**Table 2: Outline of Test Series and their Application**

TEST SERIES	PURPOSE
1	to determine if a substance has explosive properties
2	to determine if a substance is too insensitive for inclusion in Class 1
3	to determine if a substance is thermally stable and not too dangerous to transport in the form in which it was tested.
4	to determine if an article, packaged article or packaged substance is too dangerous for transport
5	to determine if a substance may be assigned to Division 1.5 (blasting agents)
6	to assign a substance or article to Division 1.1, 1.2, 1.3 or 1.4 or exclude it from Class 1
7	to determine if an article may be assigned to Division 1.6
8	to determine if an ammonium nitrate emulsion (ANE), suspension or gel intermediate for blasting explosives, is insensitive enough for inclusion in Division 5.1, and to evaluate the suitability for transport in tanks.

Test Series 1-4 determine provisional acceptance of a product into Class 1. Test Series 5-7 determine the classification division, or may result in exclusion in Class 1. Test Series 8 determines whether a blasting agent is too unstable for transport, a Division 1.5 blasting agent, or relatively insensitive to shock and heat resulting in assignment as a Division 5.1 oxidizer. Although 33 tests are available for classification, many of these are ruled out for a specific product because they are not applicable or may be waived by the competent authority as unnecessary.

Perhaps a word about compatibility group S may be appropriate at this point. Substances and articles are in Compatibility Group S if they are so packaged or designed that any hazardous effects arising from accidental functioning are confined within the package unless the package has been degraded by fire, in which case all blast or projection effects are limited to the extent that they do not significantly hinder fire-fighting or other emergency response efforts in the immediate vicinity of the package

The flowchart in Figure 1 shows

how Test Series 5 to 7 are used to assign a product to Divisions 1.1 through 1.6, and how 1.4S explosives are separated from other Division 1.4 products.

#### **Example of Test Selection and Resulting Classification**

The application of these concepts can be illustrated by way of the following example for qualifying a small arms primer. Being an article, Test Series 1 through 3 were skipped. Series 4 tests were conducted including thermal stability and twelve-meter drop tests. The primers did not exhibit ignition or thermal runaway when subjected to 75°C for 48 hours, and no ignition occurred in the drop test.

Test Series 6 was next applied using the 6(a) Single Package and 6(c) Bonfire tests. The Single Package test consisted of a single case of 5,000 primers placed on a witness plate and covered with sand to a minimum of 0.5m in all directions. One primer was ignited using an electric wire. Up to 22 primers ignited. The test was conducted three times with similar results. Since there was no mass explosion, the product was determined to not be Division 1.1.

Test 6(c) was conducted by

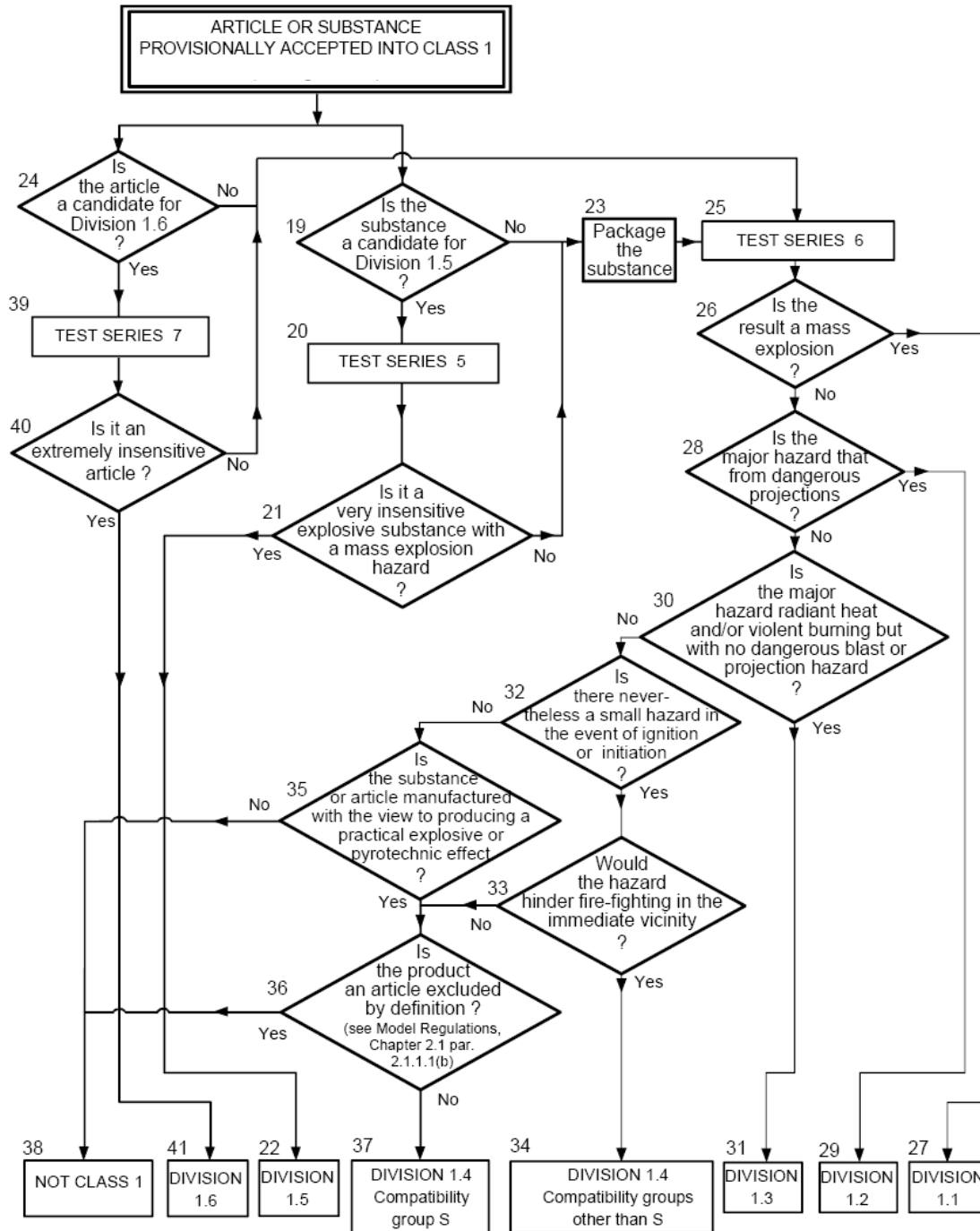
placing 0.15m<sup>3</sup> of primer cases, about 30 cases or 150,000 primers, on a steel stand above 20 gallons of diesel fuel. Witness stands were placed around the product at a distance of 4m. No mass explosion occurred, ruling out a classification of Division 1.1. None of the witness screens were perforated and no projectile exceeded 20 Joules of energy, thus ruling out Division 1.2. No fire ball extended beyond the witness stands, no fiery projection was thrown more than 15m, and the heat flux did not exceed the maximum limit, which ruled out a 1.3 classification. Division 1.4S was achieved because:

- No fireball extended more than 1m from the flames
- No fiery projection was thrown more than 5m
- No indentation in the witness screens exceeded 4mm
- No metallic projection exceed 8 Joules
- thermal flux requirements were met

If any of these 5 criteria had not been met, then the primers would have been assigned to Division 1.4 to a compatibility group other than S.

Thus four tests were conducted on a common product to assure its classification as a Division 1.4S explosive.

Figure 1: Flowchart illustrating the assignment of a product to Divisions 1.1 through 1.6



## Safety snippets

Several members of the SAFEX community (members, Expert Panel members and collaborators) brought this Safety Alert to our attention and thought it may be of interest to members. It is published by the NSW (Australia) Department of Primary Industries and we are grateful to it for permission to include it in this Newsletter.

### Lightning strikes stationary truck

#### Incident

A large rear dump truck (RDT) was struck by lightning while stationary and unattended. No employees or personnel were injured.

#### Circumstances

Three tyres were blown off the truck between 2 to 5 minutes after the lightning strike. Two tyres exploded (position 1 and 3 tyres) on the driver's side of the truck, sending debris several hundred metres from the vehicle and causing extensive damage to the truck and other equipment.

One complete wheel base (weighing 1.6 tonnes) was thrown about 100 metres from the truck. A solid wheel flange (weighing 250kg) was thrown to the top of the stockpile about 275 metres from the truck.

The air blast and shock wave caused damage to the operator's cabin, other equipment and buildings up to 230 metres from the truck. The tyres were ejected and finished between 50 to 60 metres from the truck.

#### Damage to the truck

1. The truck operator's rear cabin window was blown into the cabin and all other windows were blown outwards from the cabin. The driver's door was blown open.
2. The final drive was extensively damaged. The rear outer position 3 wheel base exploded off the final drive breaking 57 one-inch grade 10.9 bolts in

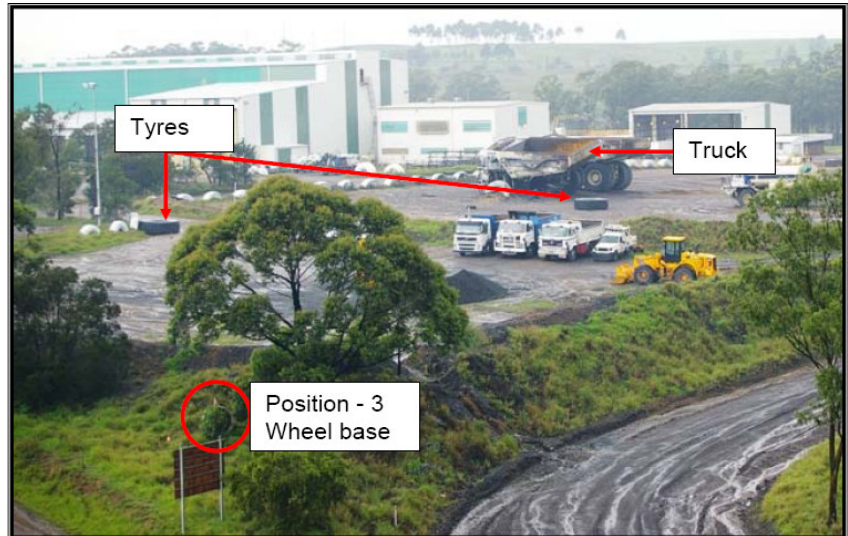


Figure 1: Parking area



Figure 2: Close-up of the truck

3. Position 1 tyre (new tyre) had one complete side wall blown out.
4. Position 3 tyre had the side wall blown out for three-quarters of the circumference.
5. Position 4 tyre was inspected with no visual damage. This tyre was scrapped due to oil

- contamination inside the tyre.
6. The engine sump was cracked and damaged. The oil cooler was damaged.
  7. The front position 1 wheel strut mounting was distorted, and the front wheel hub was bent.
  8. Fuel tank mountings were significantly damaged.
  9. The three wheel bases were damaged and scrapped.

#### Other damage

The operator's cabin windscreen of a water truck parked 20 metres from the RDT was blown out. A window of a car parked in the employee car park was broken. Some washery office windows were broken by the shock wave, and damage was caused to some sheeting on the outside of the elevator building. Some bath house windows were broken. Five windows in the main office were also broken.

#### Immediate action taken

The site Tyre Fire Procedure was put into place:

1. Area barricaded as a no-go zone.
2. Incident reported to the NSW DPI Mine Safety inspectorate.
3. No-go zone in place for minimum of 24 hours then to be reassessed.

#### Investigation

Position 1 tyre (driver's side front) showed evidence of earthing through this tyre, and it's believed the lightning earthed through No 1 and No 3 position tyres.

#### Further action:

1. All tyres have been sent to the manufacturer for further inspection.
- 2.. Review the risk assessment of the mine's response when thunder storms are approaching and if equipment is struck by lightning.
3. Attempt to determine the energy released by the exploding tyres and the lightning strike.

#### Recommendations

All mines should be aware of potential risks associated with mobile plant in electrical storms. Consideration should be given to the following:-

1. Distance and time of exclusion zone from a suspect heating tyre.
2. Park-up procedures and locations around buildings.
3. Develop a Lightning Management Plan.
4. Review existing emergency procedures.
5. Review *AS 1768 – 2007 Lightning protection*.
6. Review NSW Department of Primary Industries Safety Alert SA04-01.



Figure 3: Tyre side wall from position number 1

**SAFEX International** thanks the following for their contributions to this Newsletter:

- **Karl Maslo**, Governor of SAFEX
- **Dr Phil Lightfoot**, Manager, Canadian Explosives Research Laboratory
- **Ben Barrett**, member of the SAFEX Expert Panel
- **NSW (Australia) Department of Primary Industries**

*Boet Coetzee*

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