*While **SAFEX International** selects the authors of articles in this Newsletter with care, the views expressed are those of the authors and do not necessarily represent the official position of **SAFEX International**. Furthermore, the authors and **SAFEX International** cannot accept any liability for consequences arising (whether directly or indirectly) from the use of any advice given or opinions expressed in this Newsletter*

SAFEX INTERNATIONAL
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CONTENTS

SAFEX CONGRESS XX

SALZBURG 2020

25 till 29 May 2020

From The Secretary General's Desk

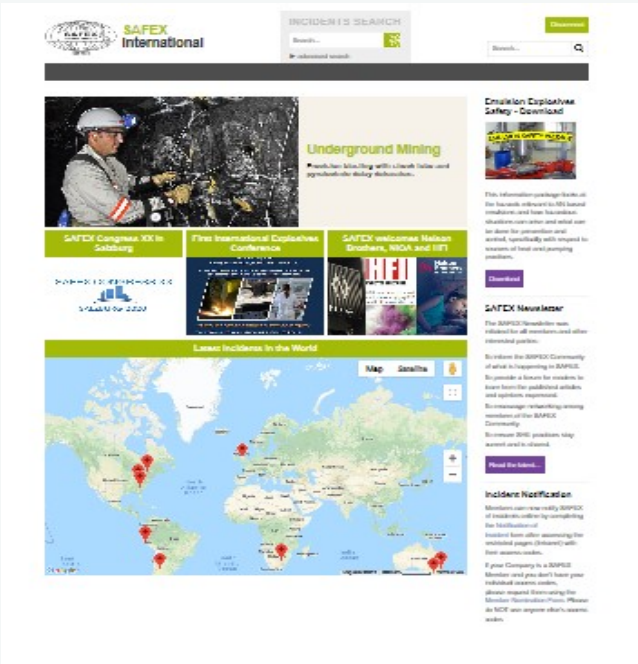
"Establishing this Association is a humanitarian task, a moral and social mission and no effort undertaken for this purpose can be considered too great".

Founders of SAFEX International, 1954

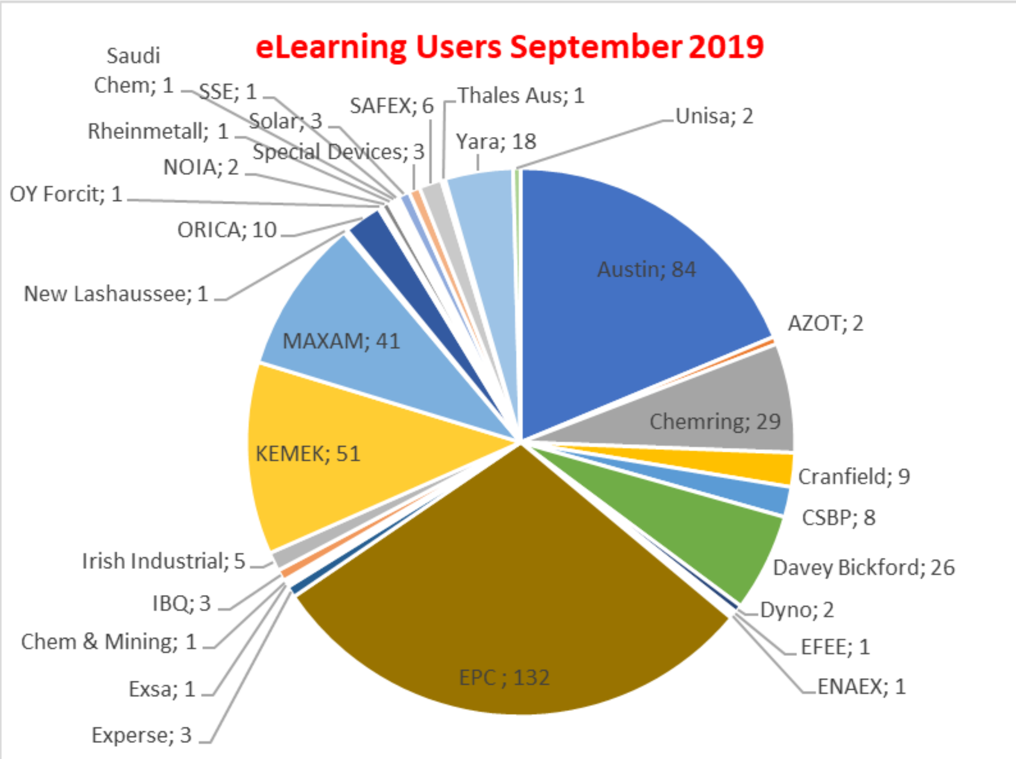
The mission statement of the nine founding member companies of SAFEX International is still the foundation of our organisation. SAFEX has since grown to 58 Member Companies and 8 Group members giving a total of 238 members.

During the early years the Incident Database was initiated, which today contains a library of thousands of incidents going back to the 19th century.

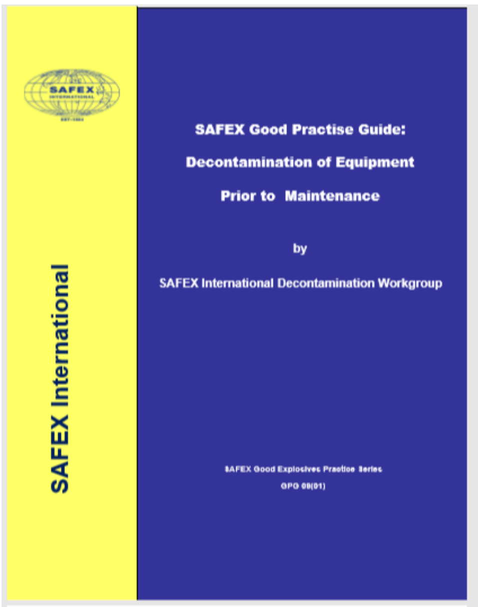
This database is now resident on the SAFEX Website which was started more than 15 years ago. On 1 October we will see the launch of the upgraded website, which will be more user friendly and will have a modern search function. All the other information pertaining to SAFEX activities over many years will still be available for use by members.



Another successful initiative SAFEX embarked on was the establishment of internet-based training. This had the objective of assisting Member Companies in training relevant personnel in a wide variety of safety and system related issues. The eLearning Portal has become so successful that it has outgrown its current software base. SAFEX recently signed a contract with Cranfield University to upgrade the Portal to accommodate future growth and requirements with ease .The target date to complete the upgrade is the end of the first quarter of 2020 .At this time French and Russian translations of the Basis of Safety Module will be included. Below is a graph of the current usage of the ePortal (Total Users:449):



The latest Good Practice Guide on Decontamination of Plant Equipment is now available on the Website for download and use.



Arrangements for the SAFEX 2020 Congress are well in hand and documents for registration and hotel bookings will be sent to members during the next few months. the proposed program as in the past, presents a full week starting with 2 days of training on:

“The application of explosive BOS in specific tasks and manufacturing”

One day of Work Groups are planned on:

Decontamination -Noel Hsu
Emulsions-Martin Held
Explosives Transport-Noel Hsu
Remediation- Mervyn Traut

The Plenary sessions will as traditionally be taking place over a 2day period.
Noel Hsu will be responsible for the Day 1:

Behavioral issues determining the Safety Culture
Manufacturing technologies and impact on safe operations
Emergency response

The Day 2 session will be organized by Martin Held:

Focusing on Incident Reporting
Learning from Plant Design and Management of Change

Please diarize these dates and distribute the programme to interested members. SAFEX looks forward to hosting you at this very important event in Salzburg.

DATE	ACTIVITY	CONCURRENT ACTIVITY
Sunday, 24 May	Registration - Training	
Monday, 25 May	Registration - Training Training Session	
Tuesday, 26 May	Training Session Registration – Workgroups	
Wednesday,27 May	Registration - Workgroups Workgroup Sessions Registration - Congress Welcome Reception	FEEM AGM
Thursday, 28 May	Registration - Congress Plenary Sessions – First Day Chairman’s Programme Board Meeting	Spouses’ Programme
Friday, 29 May	Plenary Sessions – Second Day General Assembly of Members Gala Dinner	Spouses’ Programme
Saturday, 30 May	Congress Excursion	

In this issue of the Newsletter we continue with the Incident Recall articles and this time relook at the first recorded pump explosion with water based explosives and reflect on the learnings for application in today’s world.
We also continue the SMS series with an article on Personal Protective Equipment– one of the safety pillars to ensure safe and injury free operations on our plants and business areas on the customer sites.

Finally I call again on all members to please share your learnings and SHE systems via articles in the Newsletters :

‘By three methods we may learn wisdom: First, by reflection, which is noblest; Second, by imitation, which is easiest; and third by experience, which is the bitterest.’ –Confucius

Thermal and Mechanical Hazards of NC and NC/NG Mixtures

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1. Introduction

At high nitration levels, nitrocellulose (NC) has been used extensively as a principal ingredient in a wide variety of energetic materials, particularly in propellants where it is often used in combination with nitroglycerine (NG). Although there is a wealth of data available in the scientific literature on the hazards properties and on the kinetics of NC thermal decomposition, unexpected ignitions of such propellants are still not uncommon in the corresponding manufacturing processes.

Historically, many different techniques have been used to study the thermal decomposition of NC. These have produced a wide range of kinetic and thermal parameters applicable in different temperature ranges, thus revealing the complexity of NC thermal decomposition and the resulting formation of a large number of product species. Much of the available data has been reviewed by Brill and Congwer [1] in an attempt to extract kinetic information applicable to different temperature ranges.

In order to evaluate NC process hazards, it is common to use a decomposition temperature of the order of 170-190 °C, which is most often quoted in the thermal analysis literature [2, 3] and in Safety Data Sheets (SDS) [4]. These decomposition temperatures are generally obtained with very small-scale thermal analysis techniques such as Differential Scanning Calorimetry (DSC), Thermogravimetry (TGA), and Differential Thermal Analysis (DTA) for which the samples (mg quantity) lose their heat to the instrument having a very large heat capacity. In comparison, when an adiabatic technique such as Accelerating Rate Calorimetry (ARC) is used with larger samples (gram quantities), the onset temperature is significantly lower and varies between 100 and 115 °C depending on the ambient pressure (0.1 to 14 MPa) [5, 6]. This has more serious implications for pressing operations with propellant grains.

The basic concepts regarding the NC and NG decomposition mechanisms have been both recently reviewed, and their decomposition is autocatalytic (AC) in nature [7]. When held at a given isothermal temperature, the initial decomposition of the chemical begins to generate an auto catalyst as a reaction product. As time proceeds, the concentration of the latter will slowly increase for some induction time period until it reaches a certain threshold; then the self-heating reaction starts. If the heat dissipation rate is not fast enough, a run-away reaction will ensue. This behaviour has been studied empirically in two different regimes. The fast regime (1 to 15 s) was investigated by Shteinberg [8] who used an in-house “flash-block” device to force small pellets of pressed NC against a heated block maintained at constant temperature in the range 212-242 °C. In this case, the measurements provided an induction time to ignition as a function of isothermal temperature. The slow regime (1 to 10 days) was studied by Kotoyori [9] using an in-house isothermal storage test in closed cells (0.4 g samples). Induction times for self-heating (so-called AC induction times) were measured in the temperature interval of 73-91 °C. These data have important implications for the storage of NC under relatively isothermal conditions. In the present work, the ARC technique was used in an attempt to partially bridge the gap between these two regimes for NC and to produce equivalent data for one NC/NG system without stabilizer.

In one of the most recent reviews of accidental ignitions of energetic materials [10], mechanical causes such as tapping, hitting, scraping and rough handling were found to account for over 50% of all accidents. Therefore, impact and friction are still regarded as the most important source of accidents in this industry. NG and dry NC are both known to be very sensitive to impact [11, 12] (even more than PETN), but relatively insensitive to friction [12, 13].Therefore, while it is imperative to eliminate the possibility of energetic impacts in the corresponding manufacturing processes, friction can be tolerated to some extent but appropriate hazard quantification data should be used to evaluate this latter case.

In the present work, well calibrated and instrumented friction (ABL type) and impact (BAM type) apparatus were used to quantify the sensitivity of NC and a double-base propellant (NC/NG mixture with stabilizer). The method of probit analysis [14] was used to obtain probabilities of ignition as a function of friction and impact mechanical dose parameters.

2. Experimental

2.1 Materials

Grade C NC (with 13.15 ± 0.05% Nitrogen by mass) was manufactured by Synthesia. The material, which was 25% water-wet, was dried in desiccator until constant mass was obtained and was kept in desiccator for the complete study.

The NC/NG sample was prepared by GD-OTS-V as a 65/35 mixture. The grade C NC was first wetted with alcohol/acetone. The necessary mass of NG was desensitized by dilution with acetone and added to the wetted NC. This mixture was then stirred regularly until a homogeneous granular paste was obtained. The latter was transferred onto a stainless-steel plate and left to evaporate at room temperature for at least 48 hours. It was then peeled off, broken into small pieces, and delivered to Canmet CERL where it was further dried at room temperature, under vacuum until constant mass was obtained. It was then stored in sealed anti-static containers. This NC/NG sample contained no stabilizer(s).

A double-base propellant sample was also provided by GD-OTS-V for the sensitivity tests and isothermal ARC test. This sample contained approximately 55% NC (grade C) and 35% NGin addition to a stabilizer. The sample was dried in a desiccator under vacuum (room temperature) until constant mass. It was then sealed in anti-static vials for storage until testing.

2.2 Thermal Stability

The isothermal ARC technique [15] with an ARC 2000 calorimeter originally manufactured by A.D. Little was used to investigate safe storage “times” under isothermal conditions and the kinetics of thermal decomposition under such conditions. For NC, 0.5 g samples were introduced into approximately 10 mL thin-wall spherical titanium vessels. In the case of the NC/NG mixture and the double-base propellant, samples weighing only 0.2 g were introduced in a 1 mL thin-wall cylindrical titanium vessel. The sample weight was reduced for safety reasons and the use of a thin-walled smaller vessel was intended to keep a similar thermal inertia (so-called phi factor [16]) as for the NC samples.

All the sample vessels used were coupled to the closed gas manifold of the calorimeter, quickly heated up (at 5 °C min^{-1}) to the chosen isothermal temperature, and maintained at this temperature (± 0.5°C) until an exotherm was detected by the apparatus. Exotherms were defined as any detected self-heating rate above 0.02 °C min^{-1}.In this case, the isothermal sequence was interrupted and the temperature of the calorimeter tracked that of the sample until the self-heating rate reached a threshold value of 0.5 °C min^{-1}, at which point all heaters were stopped and cooling air was injected into the calorimeter to avoid rupture of the vessels following possibly violent runaway reactions.

For each experiment, the time from first arrival to the isothermal temperature to the first departure from isothermal temperature, indicating the start of the run-away exotherm, was evaluated as the delay time to self-heating (or AC induction time).

2.3 Friction Sensitivity

An in-house sliding block friction apparatus, based on the ABL friction machine test design [13], was used to quantify the sensitivity to friction. This apparatus has been described in detail elsewhere [17, 18] and a schematic diagram of it is reproduced in Fig. 1.

It is instrumented with a pressure transducer to measure the normal (vertical) load and, therefore, the apparent contact pressure “P_a” between the shoe and the plate, a position detector to measure the total length of the slide “L”, and a velocity transducer to measure the average friction velocity “v” for every test. Furthermore, the average apparent contact area “A_a” and the contact length “l” (length of contact area parallel to the velocity) have been carefully calibrated as a function of the normal load.

In the present measurements, the dose parameter $P_a\ l\ v^2$ [18] was used; several series of tests were performed at different values of the dose parameter by varying the vertical load and the average friction velocity, which is controlled by the pendulum drop-angle.

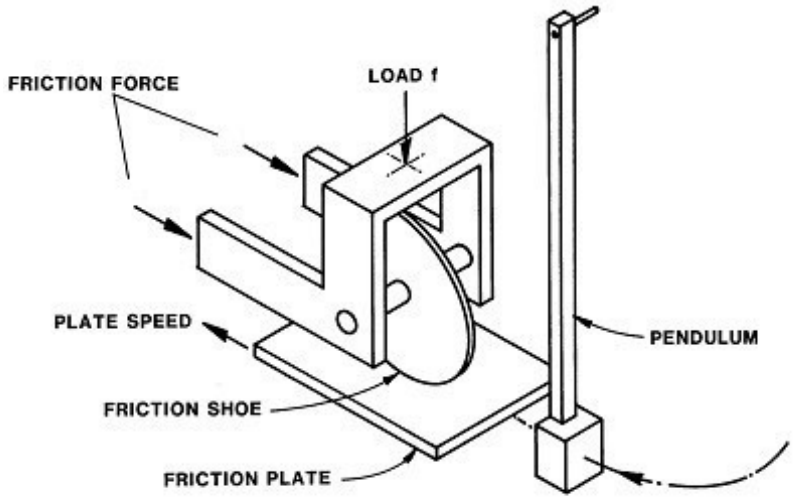


Fig. 1 Schematic diagram of sliding block friction apparatus

At each $P_a\ l\ v^2$ value, a series of 12 tests was performed. Before each test, the sample was spread as a thin deposit on the friction plate. Reactions from the samples were inferred on the basis of NO_x and CO gas analyzers, using a reaction index essentially proportional to the extent of reaction. By plotting the average reaction index as a function of average dose parameter, a threshold reaction index that discriminates local decomposition from combustive type reactions could be deduced [18]. All tests producing a reaction index above this threshold were considered "positive" when building the corresponding probit curve expressing the probability of ignition as a function of average dose parameter. Further details about how the reaction index was obtained are provided in Section 3.2.

The apparatus is computer interfaced so that all data can be readily analyzed on-line as the tests are performed.

2.4 Impact Sensitivity

Impact probit curves were measured by performing 12 tests per series of drop-tests using a standard BAM Fall Hammer apparatus [13] equipped with a 5 kg drop-weight and instrumented with a force ring transducer to measure the impact pressure history for each event (Figure 2). Compared to friction, positive reactions were easily detected by the operator himself as a light flash or an audible report, while the force records obtained from the transducer were acquired using a storage oscilloscope with MHz capability.

For various applications, different hazard analysts may prefer expressing the probability of ignition as a function of various probit parameters such as E/t (J s^{-1}), or E/A (J m^{-2}) or $P_{max} = F_{max}/A$ (GPa). Here, "E" is the potential energy of the drop-weight, "t" is the impact duration (about 100 ms for steel/steel impact, measured by the force transducer), "A"is the impact area (usually taken as the area of the steel roller bearings sandwiching the sample) and "F_{max}" is the maximum impact force measured by the transducer.

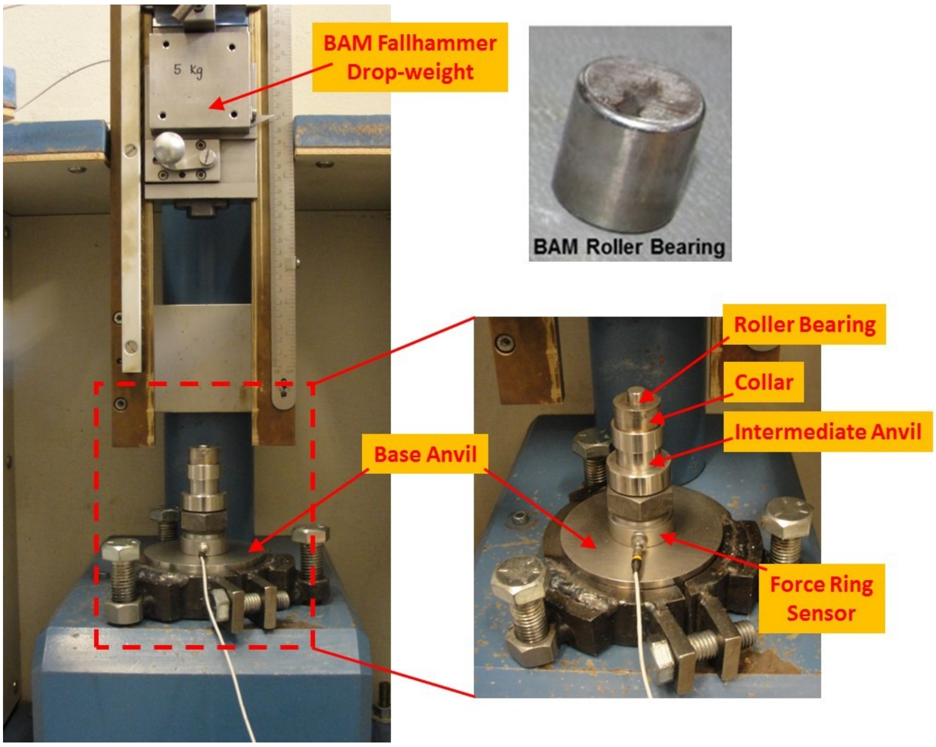


Fig. 2 BAM Fall Hammer apparatus with target assembly instrumented with a ring force sensor.

3. Results

3.1 Thermal stability

For NC, 14 ARC isothermal experiments were performed in the 80-125°C temperature range with duplicates at 100 and 115°C to check reproducibility. For the NC/NG 65/35 mixture, 15 experiments were completed in the 65-115 °C temperature range with duplicates at 70 and 75°C. In each case, higher temperatures could have been attempted to further close the gap between the Shteinberg and Kotoyori data sets. However, it was evaluated that, for induction times lower than 0.5 to 1.0 hour, the time required to reach the isothermal temperature was becoming non-negligible, which could introduce bias in the data (Fig. 3).

For NC, AC induction times from 0.9 to 53.5 hours were measured for isothermal temperatures varying from 125 to 80 °C. For the NC/NG mixture, it varied from 0.5 to 152.2 hours when the isothermal temperature was decreased from 115 to 65 °C. For comparison, an additional isothermal ARC run was conducted on the double-base propellant (containing a stabilizer) at 100
°C, and no self-heating could be detected for a period of up to 19 days (456 hours).

For the purpose of evaluating useful storage times as well as in-process runaway hazards, the three data sets from Shteinberg, Kotoyori, and CanmetCERL have been plotted in an Arrhenius plot of ln (τ) – vs – T^{-1} in Fig. 4.

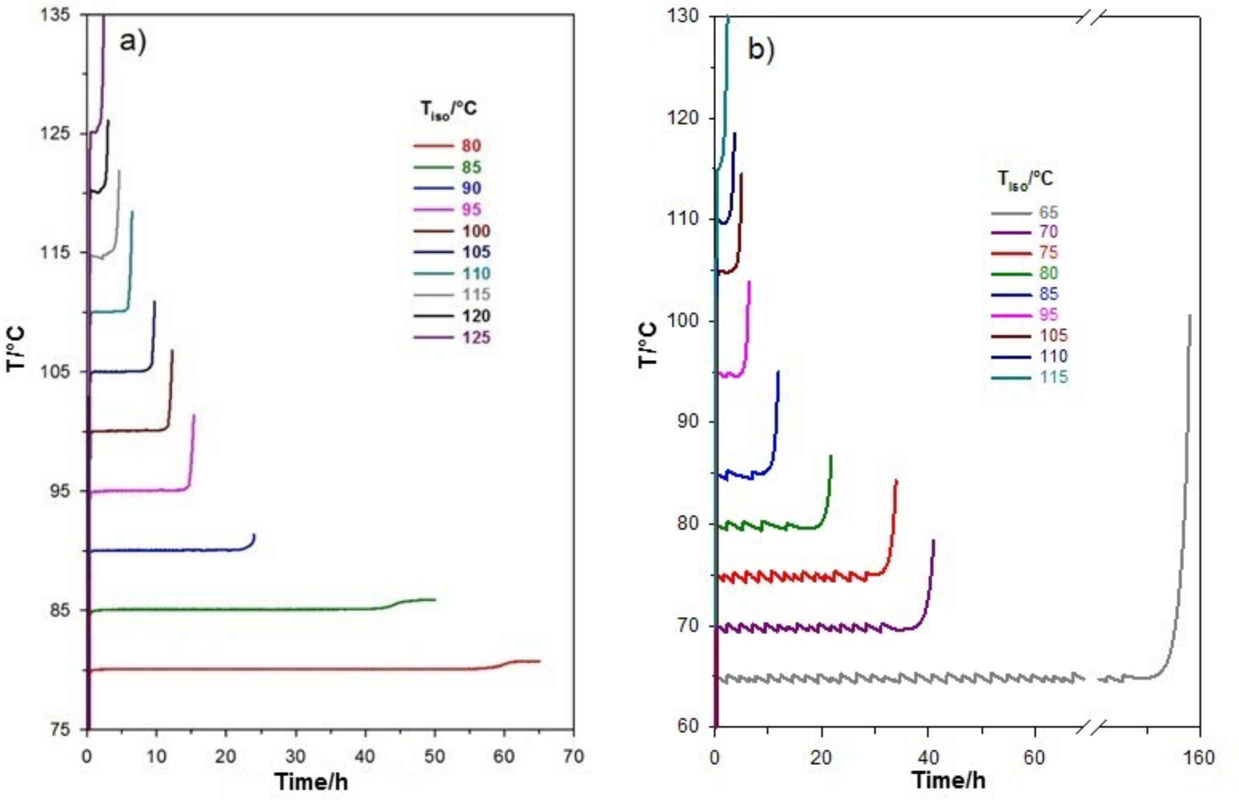


Fig. 3 Temperature-time records for ARC isothermal tests a) on NC (Grade C) and b) on NC/NG (65/35) both in ambient air.

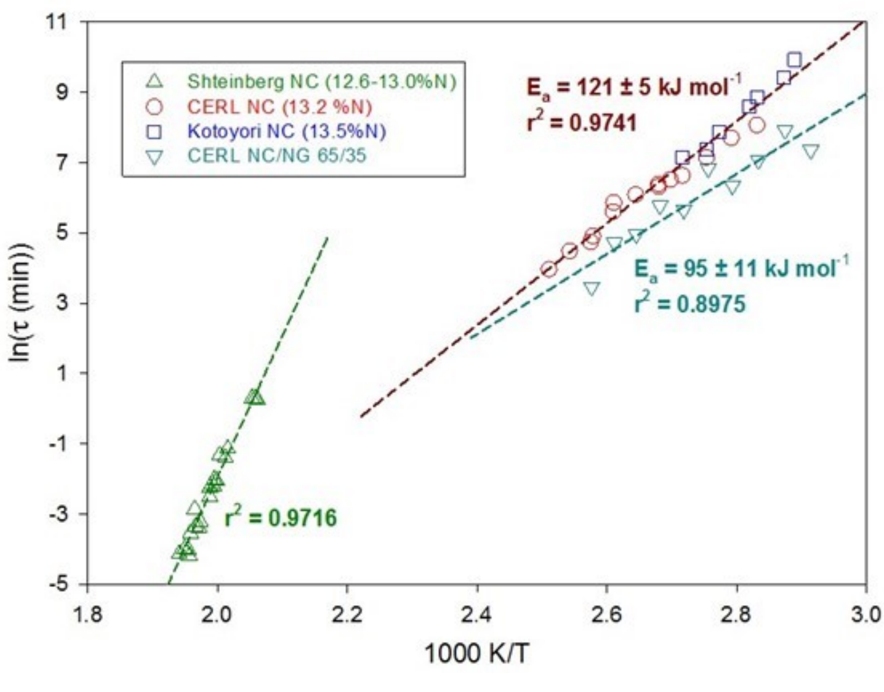


Fig. 4 Arrhenius plots for NC and NC/NG (65/35) from isothermal data in ambient air

It can be first observed that the CanmetCERL isothermal ARC data are quite consistent with Kotoyori's in-house isothermal test data, even if different NC grades were used (Grade C and Grade B, respectively). The two data sets exhibit a fairly linear behaviour as seen from the linear correlation coefficient of 0.9741. The slope of this line provides an apparent activation energy of E_a = 121 ± 5 kJ mol^{-1}, which allows one to extrapolate the data in the temperature range approximately from 50 to 140 °C.

On the other hand, Shteinberg's data set appears to be relatively inconsistent with the other two. While the behaviour also appears to be linear in this Arrhenius plot representation, the slope of the corresponding line is much steeper and does not reflect the same physical process. This is probably related to the fact that the measured induction times reflect the times to ignition in a higher temperature range, compared to the AC induction times (times to self-heating) for the other two data sets.

It is also observed that, NC/NG data points for this mixture exhibit much more scatter than NC ARC data and this may reflect some lack of uniformity in NG content throughout the sample (Fig.4). Nonetheless, the behaviour is also consistent with a straight line ($r^2 \approx 0.9$) with a slightly lower activation energy of 95 ± 11 kJ mol^{-1}. This can also be used to extrapolate the data in the same temperature range as for the NC data, with less confidence, however.

3.2 Friction Sensitivity

The measured behaviour of the average NO_x and CO reaction index <R> (volume of gas per mm of friction slide) as a function of the average friction dose parameter <D=P l v^2> is shown in Fig. 5 for both NC (Grade C) and the double-base propellant.

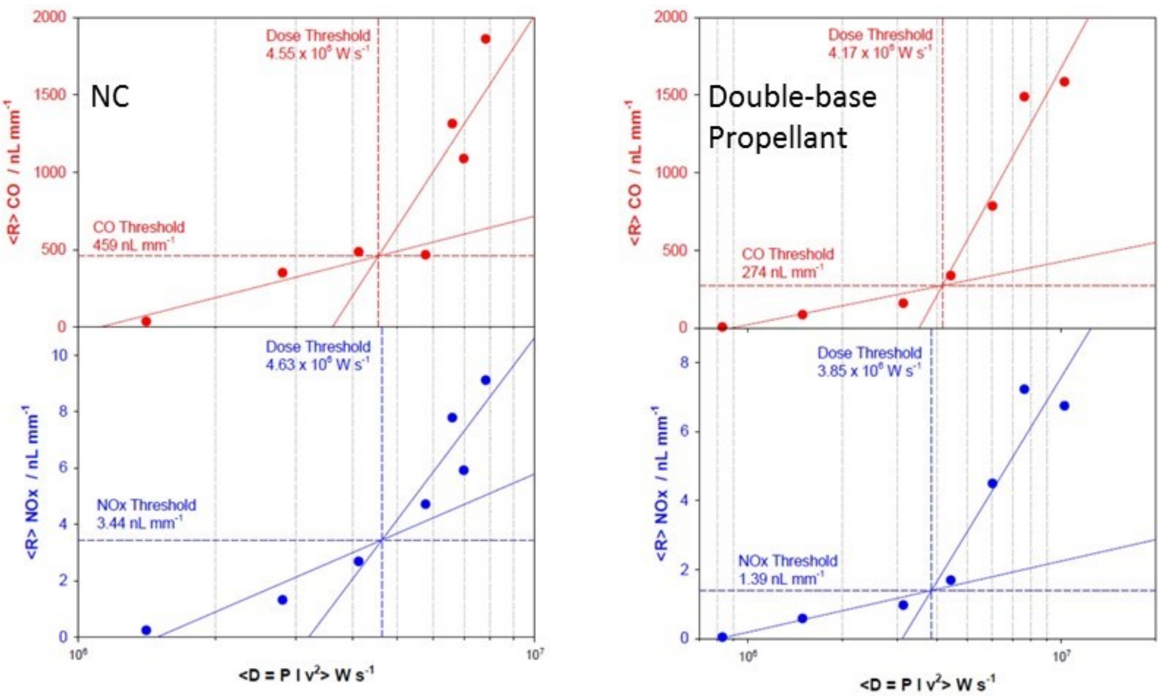


Fig. 5 Evolution of average reaction index for NC (left) and double-base propellant (right)

Two reaction regimes can be clearly identified for both CO and NO_x in Fig. 5. In each case, the inflexion point between the two regimes has been determined by the intersection of the two linear regressions for the two regimes. The threshold dose corresponding to the crossing points are in relatively good agreement for the two gases ($\langle D \rangle = 4.6 \pm 0.1 \times 10^6 W\ s^{-1}$ for NC and $\langle D \rangle = 4.0 \pm 0.2 \times 10^6 W\ s^{-1}$ for the propellant). The corresponding threshold reaction indexes for NC decomposition gases were 459 nL mm^{-1} for CO and 3.44 nL mm^{-1} for NO_x. Compared to NC, the double-base propellant had lower gas thresholds of CO and NO_x (CO = 274 nL mm^{-1} and NO_x = 1.39 nL mm^{-1}), which correspond to the onset of combustion reactions having some potential to propagate.

As shown in Fig. 6, the corresponding friction probit curves were obtained by combining the data for both gases. The CO data points were obtained by assigning as positive all events for which the threshold reaction index was met (i.e., at least 459 nL mm^{-1} for NC and at least 274 nL mm^{-1} for propellant). Similarly, all the NO_x datapoints were obtained by assigning as positive all events for which the reaction index was at least equal to the measured threshold. The error bars represent limits, assuming a 13th event could have been either positive or negative in each series.

A statistically based method was used to perform the linear regression for the probit curves [14].In this method, since the lowest dose data point only consists of an upper bound, the probability of ignition (so-called "I_P value") corresponding to this data point was varied, within the specified bounds, so as to minimize the sum of the residuals for all other data points.

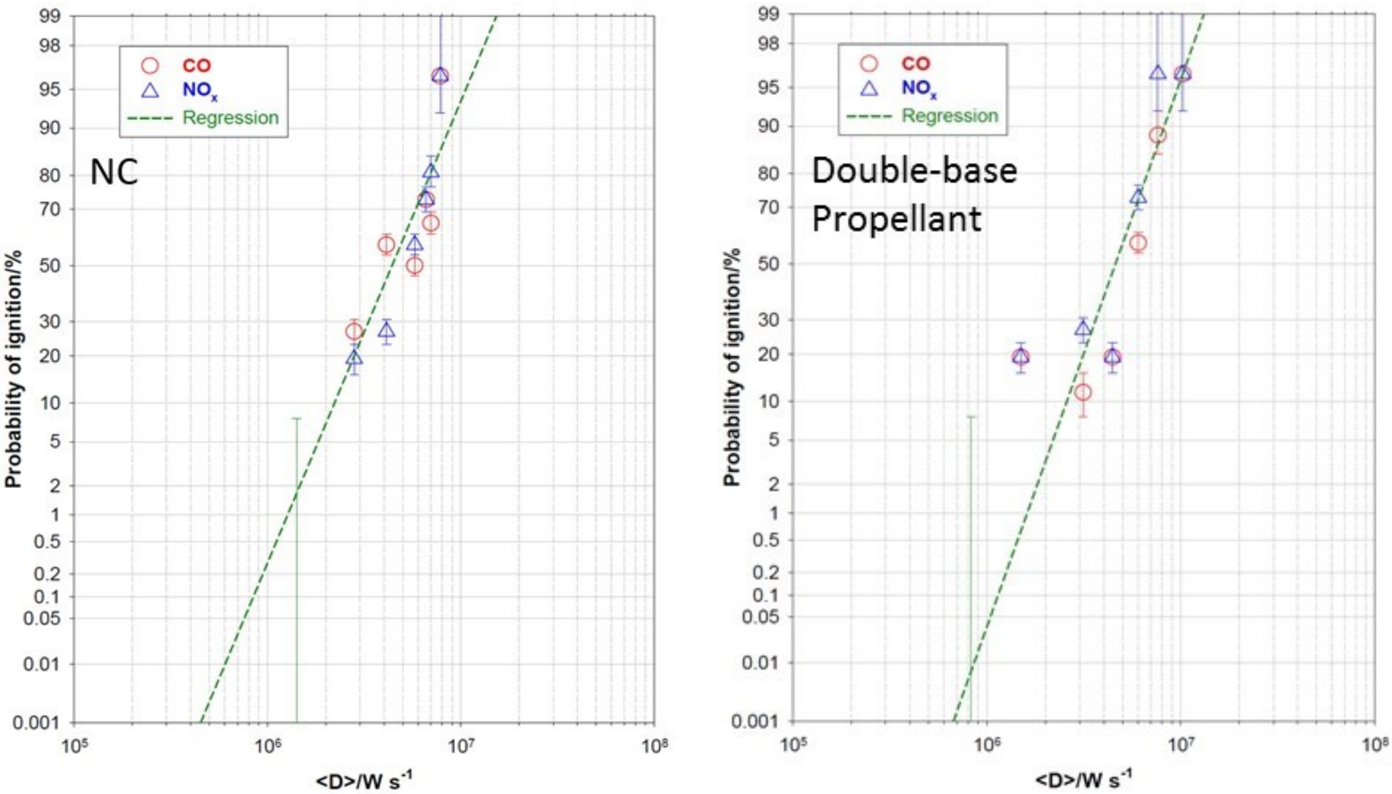
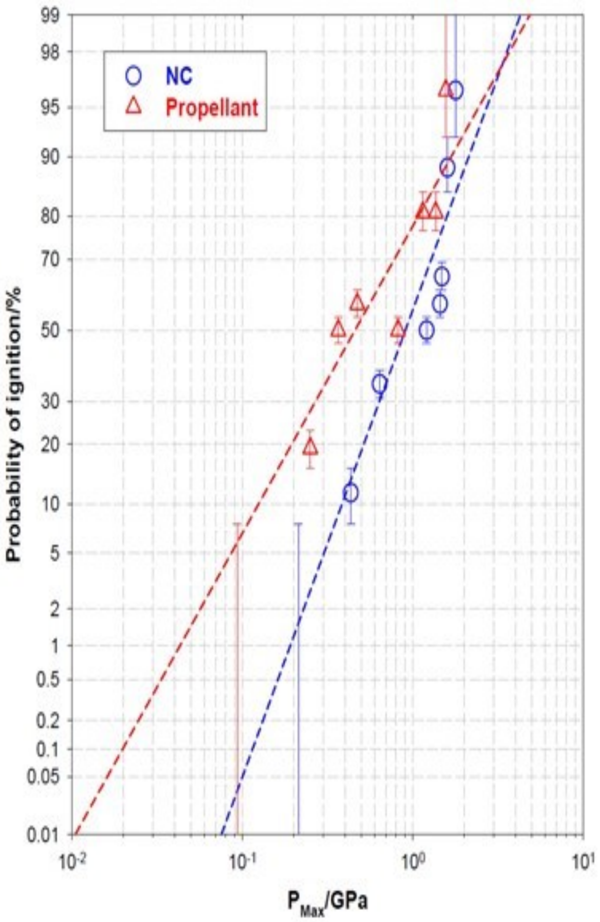


Fig. 6 Friction probit curves for NC (left) and double-base propellant (right)

3.3 Impact sensitivity

As mentioned above, an impact test was considered positive if an explosion (e.g. light flash, audible report) was observed by the operator. Based on this approach, the I_p values were calculated with error bars representing limits, again assuming a 13th event could have been either positive or negative in each series.

The probit curves for NC and propellant using both the maximum impact pressure and the impact energy density as dose parameters are both shown in Fig. 7, respectively. As for the case of friction, a statistically based method was developed to perform the linear regression for the probit curves. The I_p values corresponding to the lowest dose data points (0 positive events out of 12 trials) were varied within the limits, so as to minimize the sum of the residuals for all other data points.



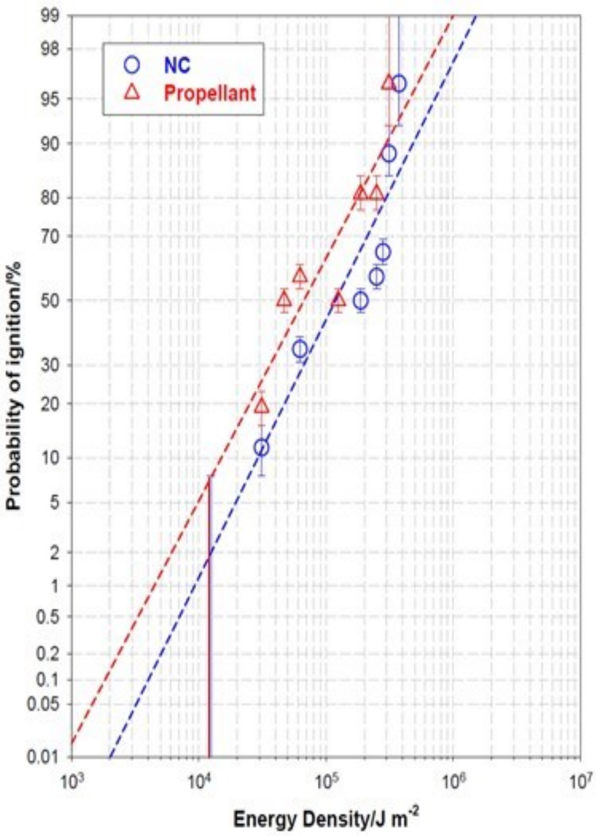


Fig. 7 Impact probit curves for NC and double-base propellant as a function of maximum pressure (left) and energy density (right)

4. Conclusions

The thermal stability data presented above can be used to evaluate the AC induction time for both NC and an NC/NG mixture in the temperature range from approximately 50 to 140 °C. This range covers induction times of a few minutes up to a few weeks and is therefore applicable to both in-process thermal hazards and short-term storage hazards.

Methodologies to obtain friction and impact probit data for the quantification of process hazards were recently developed and applied to explosives and pyrotechnics [17, 18]. In the present work, these methodologies were shown to also apply to NC and NC-based propellants.
The results from the present friction work suggest that pure NC and a NC/NG double-base propellant have quite comparable sensitivity to friction, and this may be due to the presence of a binder that can lower the friction coefficient in the case of the propellant. The impact sensitivity data suggest that the double-base propellant is significantly more sensitive than pure NC. These trends should be confirmed by future work. It is planned to generate similar data for a wider range of propellants and intermediate products in order to provide data applicable to the range of products normally processed in industrial facilities. A typical example of the use of such probit curves to quantify process hazards can be found in ref. [17].

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Incident Recall

By

Andy Begg

The following incident is from the SAFEX Incident Database. I have added some additional notes (bold italic) on the background to the technology and the impact on the parent company – ICI Explosives. Unfortunately we do not have access to the full report for photographs but in view of the quantity of explosives involved - in excess of 7000lbs – it is not difficult to imagine the scene of destruction. Although an old incident the messages it contains are as valid today as they were on that day in 1976.

CIL, McMasterville, Quebec,

January 7, 1976

Summary of Beloeil Explosion Investigation Report

On October 1, 1975, at 7:48 p.m. an explosion took place in building NI-1 at Beloeil Works in which cap sensitive EGMN - ethylene glycol mononitrate - slurries were being manufactured. Seven operators in the building were killed by the explosion, and 19 people in adjacent buildings were injured. One QC assistant walking some distance outside the mound was killed by a small fragment which hit the back of his head.

Background to EGMN slurries (watergels)

In the early 1970's senior management in several explosives companies were becoming increasing concerned regarding the safety of nitro glycerine (NG) and NG based explosives. Incidents were not uncommon and would often result in multiple fatalities However, the numbers of personnel exposed to a single event were reduced by the plant design philosophy of separating the full process into individual single process buildings. The major explosives companies led by Dupont were making active plans to replace NG products and processes with inherently safer options. Dupont had Tovex – a monomethylamine nitrate (MMAN) based watergel. MMA was a by-product from one of their processes and it could be nitrated easily to make the MMAN in solution and this solution made a very effective sensitizer for watergels. ICI and many other companies were marketing paint fine (PF) aluminium sensitized watergels but these were not as effective as Tovex as a dynamite replacement. CIL – part of ICI Explosives – was under significant competitive pressure from Tovex in Canada and they pursued the development of watergels based on ethylene glycol mononitrate – EGMN (made using similar nitration technology to NG). This was made by nitration of ethylene oxide. The EGMN gave a competitive advantage over the PF aluminium watergels and their development was very aggressive within CIL – other members of ICI also doing an evaluation of EGMN. Watergel operations were often designed with mixing, cartridging and packaging in one large building on the basis that the products and processes were very safe, and explosion was very unlikely.

The incident investigation.

Following the explosion, an investigating committee was formed to establish the cause of the explosion and to make recommendations to prevent recurrence of a similar accident.

The committee carried out the following tasks:

- interviewing of witnesses,
- study of the sequence of known and probable events preceding the explosion,
- study of repair and maintenance files on the building,
- analysis of ingredients used, and products manufactured just prior to the explosion,
- study of production records, tables and reports of the plant operation preceding the explosion,
- study of equipment, controls, usage and behaviour of equipment in the building, examination of debris, examination of damage to surroundings, study of atmospheric conditions at the time of the explosion, and
- study of safety measures and programs, working conditions and training methods.

Evidence

The committee interviewed 19 witnesses; in addition, a sub-committee interviewed 20 other witnesses. Over 400 items of debris of the explosion were photographed, collected, identified and charted.

The process involved the batch mixing of EGMN liquor with ammonium nitrate, thickeners, crosslinking agent and other non-explosive ingredients depending on the specific composition. The building housed 2 production lines each with one mixer one hopper and a KP cartridging machine fed by a Moyno progressive cavity pump (PCP). On the basis of evidence from the witnesses and from a complete debris analysis, it was possible to establish that a total of 7230 lb. of explosive exploded, viz: the contents of two mixers (3600 lb. POWERMEX-500), the contents of two hoppers (1500 lb. POWERMEX), the contents of two buggies filled with ammonium nitrate (880 lb.), the contents of two volumetric EGMN liquor tanks (1080 lb.) and small quantities of POWERMEX-500 in hoses, KP cartridging machines, loose cartridges and boxes (170 lb.). A truck loaded with 2100 lb. POWERMEX-500, which was situated at the loading ramp of the building, did not detonate (an indication of the lesser hazards of slurries; NG products on the truck would certainly have detonated).

Analyses indicated that all ingredients examined met the required standards

All ingredient percentages were found to be on-specification and sensitivity tests done indicate that this material had a sensitivity similar to that obtained with other cap sensitive slurries, including regular POWERMEX -500.

All possible, likely or unlikely sources of the explosion were examined by a technical subcommittee consisting of five explosives experts, aided part time by a number of additional specialist experts. Many sources could be eliminated quite easily such as: (a) heavy objects, such as film reel holders or boxes ,dropping on a layer of explosive on the floor; (b) fire; (c) electrical failure; (d) malicious damage; (e) suicide; (f) stray rifle bullet; (g) explosion in an AN grinder which was being used in the building; (h) explosion in the EGMN liquor tanks or pumps; (i) a dust explosion or (j) an explosion under the ground floor, either from the catch tank or from residual explosive from a previous operation.

Several witnesses testified that they saw lightning strike down in the NI-1 region just prior to the explosion. On close examination, most of these witness accounts proved to be descriptions not of lightning but of a reflection of the explosion flash against the low-hanging clouds. Also, although there was some lightning in the region, there were no accounts of any thunder, indicating clearly that thunderstorms were far away, in fact too far even for the NG plant to be closed down. Finally, even though there was no lightning protection on or near NI-1, it is unlikely that building NI-1 would be struck because the close-by tall chimney of the powerhouse was a much more likely target. Nevertheless, because of two witnesses who are adamant about a lightning bolt striking, this possibility cannot be ruled out and is ranked as a possible cause of a detonation in one of the two mixers.

This analysis left as the only likely sources the mixers, hoppers, pumps and cartridging machines. For each of these a scenario was constructed of the likely sequence of events; this was then compared with the available evidence from testimonies and debris. In this manner, one source could be identified as giving the best overall match with the available evidence.

Some of the more important items of evidence are given below. The report mentions that the analyses and reasons for eliminating or emphasizing a piece of equipment or item of evidence are, of necessity, incomplete and can therefore, in many instances, be criticized or replaced by different arguments. However, the overall analysis fits best with all the evidence available.

Mixers:

All evidence from witnesses and debris indicates that both mixers were full and that both agitators were off. Heavy missile marks are evident along the whole length of the shaft from mixer no. 2, including those sections of the shaft where the ribbon rings were attached before the event.

The rings themselves were not marked by missiles. The shaft from mixer no. 1 was only slightly marked, by burns. The end ribbon rings had broken loose from both shafts by the force of the detonation and were ejected great distances. This evidence indicates that a detonation took place in mixer no. 2 before the shaft was hit by missiles, in other words, these missiles did not cause the detonation in mixer no. 2. Mixer no. 2 probably detonated before mixer no. 1, ejecting debris towards mixer no. 1 and thus causing it to detonate; mixer no. 1 in turn ejected debris back towards mixer no. 2, thereby spraying its shaft. A corresponding conclusion is that hopper no. 2 and the attached J-8 pump detonated before hopper no. 1 and the attached J-10 pump did.

The various possible causes of initiation in a mixer were considered to be:

- steam left on or failed on,
- operation of a discharge port,
- lightning,
- thermal decomposition in a packing gland,
- dust explosion in a duct ejecting missiles into a mixer, and

- a foreign object between ribbon and well.

Based on evidence and analysis, only the first two or three of these were considered as possible mechanisms.

Hoppers:

Both hoppers were completely shattered. No evidence was found for initiation in a hopper.

The possible causes considered were:

- adiabatic compression caused by a mix being dumped,
- friction by scraping of dried-out slurry, and
- friction of hopper wheels on the floor.

All three are considered unlikely in view of the low sensitivity of the product. However, it is considered possible that the scraping of dried out product, in an empty hopper, combined with this product falling into an overheated pump, must be considered a possible mechanism (see below).

Moyno Pumps:

Shafts and tie rods from both pumps were thrown 120 - 300 ft. and in directions consistent with their original location relative to the main exploding mass. Of particular interest are the rotor parts; each rotor was broken up into 4 pieces and those of the J-8 pump were all found near the center of the explosion, whereas those of the J-10 pump'were thrown great distances. All J-8 parts were consistently less damaged than the corresponding J-10 parts; this can be explained by the smaller quantity of explosive in the hopper above J-8 (300 lb.) as compared to that in the hopper above the J-10 pump (1200 lb.); but another possible explanation is that the detonation in the J-8 pump was low order ***(now considered to be very speculative).*** (Recently, the rear, i.e. drive-end, knuckle of the J-8 pump was found; the damage indicates that a detonation arrived into the knuckle from the forward end of the pump, and then moved upwards into the hopper; this information came too late to be included in the report). Also, the predominant direction of the pump and hopper components is towards the East, i.e. the direction from hopper no. 2 to hopper no. 1, indicating a general direction of all detonation waves.

The possible causes of detonation in the pump were considered to be:

- friction in a universal joint, either at the ball/knuckle interface, or at an interface between the locating pin and knuckle or ball;
- friction in the gland (which was packed with asbestos based material);
- electrical resistance heating caused by a faulty electrical circuit;
- friction or thermal decomposition in the drive motor housing; overheating and
- pressurization by dead-head pumping;
- mechanical breakdown;
- overheating by dry pumping;
- friction caused by foreign bodies

friction between auger and hopper.

Of these, the first two are considered the main suspects. The ball/socket (or universal) joint is the area where the largest frictional forces are concentrated, where metal-to-metal contact can take place, where dried-out material may concentrate, and where there is sufficient containment to localize temperature/pressure build-up and to prevent pressure relief. Heating of explosive in this area would be most pronounced after long, sustained operation of the pump and this happened to be the case for two days prior to the explosion; the whole operation went so well that the pump, especially the manufacturing J-8, was operating almost continuously.

KP Machines:

Three possible causes on the KP machines were considered:

- thermal initiation of explosive on a hot surface of the heat sealer casing;
- thermal initiation of explosive in the filler tube caused by impinging of hot sealer air; and

friction/impact initiation at the clipper tie assembly.

Evidence from witnesses indicated that the KP-3 machine was probably running at the time of the explosion and that the KP-4 machine was not. This was borne out by evidence of damage to the internal components of the KP machines that were found. Neither of the two filling tubes was found, supporting the assumption that both were filled with explosive and the contents of both detonated. The support posts were damaged by forces indicating that the corresponding hoppers detonated before the KP machines did, viz: a large sideways force as well as debris marks from the hopper and a smaller downward force on the top plates from the hose entering the KP machines. The fragments of the top plates of both KP machines could be assigned by chemical analysis, and these gave the most conclusive evidence, viz: that the detonations entered into and did not originate from the KP machines. This evidence consisted of the direction and location of identical, deep pit marks from the feed-through couplings on the top surface of the top plates, and marks made by the nuts of the support posts indicating that identical tilting force couples had been applied to the top plates by the explosion. The retainer rings for the feed-through tube couplings were forced radially outwards and clearly showed signs of having been forced upwards viz: from the general bending and from the imprint of lugs and bolts.

Conclusions

The major conclusions reached by the committee were:

a. The most probable source of the explosion was the J-8 Moyno pump and the second most probable source was mixer no. 2 (these two pieces of equipment were installed on the NI-2 side). The J-10 Moyno pump is a less probable source and mixer no. 1 and the two cartridging machines are very unlikely sources.

b. The committee recognizes that the cap-sensitive POWERMEX-500 involved in the explosion is an intrinsically safer explosive than explosives based on nitro glycerine. Basing itself on this fact, CIL had applied standards which were less rigorous than those necessary for the manufacture of NG based explosives, with regard to number of personnel and quantity of explosives in each building, tool control, equipment selection, testing and personnel training.

c. While some relaxation of NG standards might be justified on the basis of a quantitative assessment of the lesser hazards of slurries, the committee considered that the hazard evaluation carried out by CIL prior to the explosion, though extensive, had probably not been sufficiently quantitative to justify relaxing of some standards.

Recommendations

The report makes 14 major recommendations. In addition, there are a large number of additional detailed recommendations, suggestions for implementation of the recommendations, and a number of proposed studies on which future decisions might be based. The major recommendations are that:

1. The manufacture of cap sensitive slurries be revised so that concepts, techniques, handling and supply of raw materials, tool control and employee attitudes conform more to NG standards.

2. The Research and Technical Department make a quantitative assessment of the differences in hazards of slurries and NG products. Any decision to relax NG standards must be based on this assessment and receive written approval from the R&T Department.

3. A greater effort be made to minimize the number of employees exposed to explosives manufacturing operations.

4. Improvements be made so as to increase the safety of slurry pumping equipment.

5. All metal (structure and equipment) is to be thoroughly grounded and bonded in accordance with the Electrical Code.

6. The proper authority in the Provincial Government be requested to provide special sections in the Electrical Code to cover the manufacture and storage of explosives.

7. The quantity of explosive in explosives manufacturing buildings be minimized.

8. Grinding and preparation of explosives ingredients be carried out in buildings other than those for explosives manufacture.

9. Drop testing of cartridges and cases, as well as any other potentially hazardous type of testing, never to be done inside an explosives manufacturing building.

10. Start-up of new plants, processes and machines, should not be undertaken until a hazards and operability analysis study has been completed and all recommendations which are considered essential by this study have been implemented. Start-up should be formally approved by an appropriate authority.

11. A formal written training program be prepared showing all newly assigned personnel their responsibilities, how they are to do their job and the possible hazards associated with it.

12. A joint union-management committee be formed to discuss safety matters.

13. The implications of the detonation of AN and EGMN liquor on licensed quantities be examined.

14. Periodic inspections be made by Provincial inspectors, in accordance with Quebec law, to ensure that the appropriate regulations are followed in explosive manufacturing operations.

<u>Impact of this incident on ICI Explosives</u>

Following the incident described here the use of the standard knuckle-joint PC pump was basically banned in ICI and peristaltic pumps used for a period for the EGMN slurries. Subsequently the pump safety system was developed and after detailed assessment PC pumps were once again used but only if fitted with the various safety devices/systems still in place today for slurries and emulsion explosives. The period also saw the use of vertically mounted flexi-shaft PC pumps which had no immersed coupling. The successful development and commercialisation of emulsion explosives made the EGMN slurries obsolete and their production ceased.

Subsequently in 1988 there was an explosion in a research facility in CIL McMasterville when a high-pressure piston pump on an emulsion pilot plant exploded killing four scientists and injuring one other person.

One of the actions from this second incident was the detailed study of the hazards in pumping emulsions and the development of a full Pump Management System (PMS) that was mandatory in all ICI Explosives operations. This PMS is still valid today and is consistent with the recently issued SAFEX emulsion and pumping training systems. The study also demonstrated that compression of a void containing a volatile gas phase adjacent to an emulsion can lead to the initiation of a deflagration in the emulsion.

These incidents were also the drivers for CIL/ICI/Orica, and finalized with CERL, for the development of the Min Burning Pressure Test that is now in the UN Manual of Tests and Criteria for non-sensitised emulsions and water gels.

In parallel with pump safety development ICI Explosives and some other manufacturers designed emulsion plants to take advantage of the new technology to;

I. ***Reduce inventory in mixing operations using small continuous mixers***

II. ***Cartridging and packaging operations in separate buildings so reducing personnel exposure in the event of a single explosion***

Use cooling conveyor systems with multiple speed conveyors to ensure there was a detonation trap between linked cartridging and packing buildings.
Basically, we have gone full circle and moved back to NG style philosophy for plant design.

Elimination of an incident, SMARTROC C50

by

Josef Ruska, SSTVP Slovakia

The Sliding of a drilling machine SMARTROC C50 from a quarry bench due to collapse of a wall.

On 21st June, 2016 at 4.09 p.m. I was informed by a production foreman that an incident occurred in Vcelare Quarry – i. e. the sliding of a drilling machine from the bench IV (northern part of the western quarry wall, at workplace P7). At that time, I did not have information about the operator's health condition.

Based on information received, I issued the following instructions:

I authorized the production foreman (Mr František Máté, as a deputy person responsible to solve exceptional situations) to ensure the following precautions until my arrival:
- to check the operator's health condition and to call the Emergency Medical Services
- to ban entry to the area where the incident happened
- I instructed the dispatch to contact and inform the Country Coordinator, Quarries Manager, Safety Manager and the Mining Authorities about the incident

At 4.25 p.m. dispatch called and informed me that the drilling machine operator hadn't been injured.

The Emergency Medical Service arrived to the workplace at 4.30 p.m. and checked the operator's health condition. The Service left at 4.50 p.m.
Then I contacted the maintenance manager to try to ensure a heavyweight crane with the necessary lifting capacity.

Upon my arrival at the quarry 4.42 p.m. I contacted the ambulance staff to get more detailed information about the operator health condition.

After that I shut down the production and I authorized the production foreman to call the "emergency team" and I also contacted the maintenance foreman to get back on to the workplace.

Then I went to the place of the incident. At the same time the head of maintenance informed that a crane with 80 ton capacity was on the way from Kosice to Vcelare quarry.

Facts:
A bench had collapsed in the northern part of the quarry, approximately 6000 t of rock slid down the from the edge of the bench (on the same place where drilling operations were carried out according to a drilling passport nr 086/16) .

Picture # 1 – Drilling machine after the slide

Picture # 2 – View on the drilling machine from the bench V.

The drilling machine was approximately 5 meters below the level of the bench IV, on an inclined position, it leans on a rock and seems to be on a stabilized position.

The rock massive seemed to have stabilized, further sliding or rock material was not observed.

Finally a crane arrived on the site of the incident and we started to prepare to pull up the drilling machine. We contacted a company named ISOP Zvolen to obtain required information regarding the machine's anchoring system.

The first attempt to pull the drilling machine failed and were finished at 7.50 pm as the crane's capacities were not sufficient for this task. Subsequently, the Felbermayr crane was transferred from Vcelare quarry.

I then contacted several other companies who would be able to provide us with a large crane but since there was no cranes available on that day we ceased the works.

On 21st of June 2016 we had a meeting with the Žeriavy Košice crane company and an inspection of the incident site was carried out. A new solution was proposed – the company would provide two cranes, but since there was only a 70 ton and a 40 ton crane available, the outcome of the solution was uncertain.

At 12.30 p.m. the Žeriavy Košice informed me that the 70 ton crane will be available only after 7.00 p.m. so I consulted with our internal team and we decided to refuse this solution.

Then we contacted the Felbermayr again and asked them, whether they could provide us with two cranes, 70 tons and 100 tons.

Picture # 3 – Fixing of the drilling machine to the

Then the following things happened: The Felbermayr stated that they could only provide the cranes next week, approximately on Wednesday. The Žeriavy Košice stated that they will try to ensure a second crane until Friday, but there is a high probability that they will be able to provide the crane only next week. They have a 120 ton crane in Czech Republic but the transport to Slovakia would be complicated.

At 5.00 p.m. I consulted the problem with a company called Česmad, they proposed to use two tow cars in combination with one crane. We agreed on a visit to the site on the 23rd of June, 2016 at 12.00 p.m.

23.06.2016 Thursday

9.30 a.m. we started to secure the drilling machine. We used tandem ropes which were anchored to the drilling rod, the drilling rod was inserted into a drill hole approximately 20 meters from the edge of the bench. The rescue of the drilling machine was supervised by a person who's responsible in solving exceptional situations in a quarry according to Mining Act.

10.30 a. m. – We visited the site of the incident with Česmad company. It was stated that under the current state it was not possible to pull the drilling machine up by using two quarry truck, as the edge of the bench would damage the ropes and cause a breakage of the ropes.

11.20 a.m. – I agreed on a procedure with a production foreman – to make a road behind the drilling machine by using a hydraulic crusher. The works would start on Friday morning and we would continue throughout the weekend (until the road with necessary parameter would be done)

2.30 p.m. – I made an agreement with the Česmad that they would be pulling the drilling machine. The provisional date – on June 27th 2016 (Monday), but I had to wait for them to confirm the date.

2.50 p.m. – The Česmad confirmed the date and promised to provide us with 2 trucks. I Also confirmed the date with ISOP company to guarantee the presence of their technician.

24.06.2016 Friday

6.00 a.m. Briefing of the employees about the procedures, a supervisor was designated.

6.25 a.m. An excavator with hydraulic crusher has been transferred to the incident site.

7.00 a.m. We started with creating the road behind the drilling machine.

Picture # 4 – forming of road cut

25.06.2016 Saturday

6.25 a.m. – Creating the road continues.

7.30 a.m. – Transport of the rocks by dumpers.

9.00 a.m. – Checking the progress of the work, a road with a width of 3.4 m , length of 8-9 m, depth of 0.9 meters has been made. The edge of the road is 3.5 m from the anchoring point of the drilling machine.

4.50 p.m. Checking the progress of the work. A road with a width of 3.4m, length of 8-9 m and depth of approximately 1,4 meters has been made. The edge of the road is 3.5m from the anchoring point of the drilling machine.

Picture # 5 - Road cut of depth 1,4 m

Picture # 6 – cleaning of drilling machine surrounding area

5.20 p.m. We designated the spot for placing the securing ropes. The channel was 2m in northerly direction from the edge and had the dimensions of 6.0 x 0.4 x 2.5m.

5.40 We had to relocate the securing ropes due to widening of the road in northerly direction – it was agreed with the maintenance manager. The works were carried out on 26th of June, 2016, at 8.00 a.m.

26.06.2016 Sunday

6.25 a.m. – We created a channel for ropes and continued the work with hydraulic crusher to make a road. 8.00 a.m. – We place the ropes to the channel 8.26 a.m. – We relocated the safety ropes.

8.30 a.m. – We Deepened the road by using the hydraulic crusher. 12.00 p.m. – The external company, who works in heights, arrived and we agreed on the following steps. Clearing away the rocks from around the drilling machine and ropes.

3.18 p.m. – We relocated the protective sheets. 3.30 p.m. – We continued with the works for the road.

4.00 p.m. We made an agreement on a date, when will the drilling machine be pulled out, using two tow car from Česmad, the date was set to 27th of June, 2016 at 8.00 a.m.

Picture # 7 – Finished road cut

Picture # 8 - Check of surrounding area

27.06.2016 Monday

6.30 a.m. - We cleaned the road from rocks.

6.55. a.m. – Checking the progress of the works. A road with the width of 4.5m, length of 8-9m and depth of approximately 2.8m had been made. The edge of the road was 0,76 meters from the anchoring point of the drilling machine.

7.00 a.m. - We removed the protective sheets.

8.00 a.m. – The two tow cars arrived to the site of the incident.

Picture # 9 – Arrival of special tow vehicles

Picture # 10 – Ensuring the vehicles by loaded dumpers

8.10. a.m. – Two dumpers arrived on the site of the incident.

8.20. a.m. – we started with the preparations of pulling the drilling machine out, securing the tow cars with dumpers.

8.30 a.m. – 10.45 a.m. – We pulled the drilling machine out.

Picture # 11 - Order to start the saving

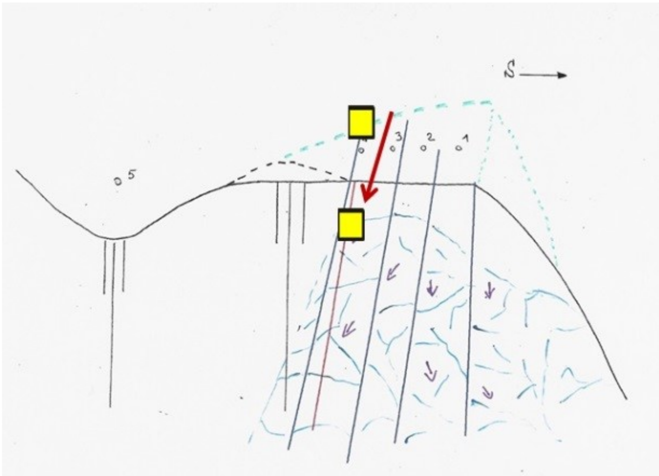
Picture # 12 – saved drilling machine on the bench

10.55. a.m. We made some preliminary checks to the drilling machine and after that put it into safe distance to hand it over to the ISOP technicians.

11.00 a.m. The works were finished.

The process was managed and supervised by Mr Jozef Ruska (a person who is responsible of solving exceptional situations) and by Mr Kraćunovský, Mr Belák, Mr Máté (deputy persons for solving exceptional situations). The works were carried out from 21st of June (4.08 p.m.) 2016 to 27th of June, 2016 (11.00 a.m.).

During the incident and the process of rescuing the drilling machine no personal injuries or damages to the property occurred.



Picture # 13 – Incident description

Picture # 14 – Drilling machine after the slide

SMS series

Personal Protective Equipment – PPE

By

Andy Begg

PPE is equipment that will directly protect the user against health or safety risks at work. It can include but is not limited to items such as safety helmets and hard hats, gloves, eye protection, hearing protection, inhalation protection, high-visibility clothing, safety footwear and safety harnesses. Inside explosives operations buildings the most common PPE is likely to be safety glasses and conductive shoes.

PPE should be used as a last resort in terms of ensuring workplace safety and health. For example when crimping detonators there must be several higher levels of safety protection to avoid accidental initiation and controls to contain initiation effects in place – then safety glasses are added as the “final” control or mitigation against harm.

Note – safety harnesses and associated fall prevention and fall arrest equipment will not be covered in this topic.

PPE Standard

PPE will be supplied that is:

- properly assessed before use to make sure it is fit for purpose;
- maintained, stored and disposed properly;
- provided with instructions on how to use it safely
- used correctly by employees

Detailed requirements for PPE

Assessing suitable PPE

General

To make sure the right type of PPE is chosen, consider the different hazards in the workplace and identify the PPE that will provide adequate protection against them; this may be different for each job.

Ask suppliers for advice on the types of PPE available and their suitability for different tasks. Review SAFEX documents including incident reports for examples of where PPE has failed and where it has performed well in fire and explosion situations.

Consider the following when assessing suitability:

- Does the PPE protect the wearer from the risks and take account of the operation undertaken and local conditions? For example a faceshield designed to protect against acid splash may not protect against high velocity metal fragments from an exploding detonator or when using an angle grinder to cut steel.
- Where potentially corrosive liquids are being handled check the compatibility of the PPE materials with the actual chemicals involved in the different steps of the process
- Does using PPE increase the overall level of risk or add new risks, e.g. by making communication more difficult, by reducing manipulative skills, causing discomfort due to overheating, hearing protection making it more difficult for operators to hear alarms etc?
- Can it be adjusted to fit the wearer correctly?
- What are the needs of the job and the demands it places on the wearer? For example, the length of time the PPE needs to be worn, the physical effort required to do the job or the requirements for visibility and communication.

If someone wears more than one item of PPE, are they compatible? For example does using a respirator make it difficult to fit eye protection properly?

Explosives hazards

When assessing which PPE should be provided in explosives operations it is vital to ensure that the actual hazard is well understood. The hazard could be shrapnel from the item being worked with e.g. a detonator or a missile or part of a workstation projected by a blast. Potential exposure to heat could be from a short duration very high temperature flash fire or from a longer duration lower temperature deflagration – the PPE requirements may be different. It is very important to understand how the hazardous material will behave under real worst case plant situations. PPE tested and approved for 1 detonator may not be suitable if the real work situation involves the operator being exposed to 5 or 10 detonators. Similarly 5kg of a pyrotechnic will behave very differently to 5gm. These hazards and effectiveness of PPE must be known.

Always keep in mind that before determining the use of PPE we should ask whether the workplace hazards can be eliminated or reduced by, for example, low inventory of material handling or better design of workstation. PPE must always to be regarded as the last line of protection, not the first.

Due to the specific hazards associated with explosives handling it may be necessary to conduct special tests in-house or at an external testing laboratory to confirm that the recommended or chosen PPE is in fact suitable for the situation. For example will the safety glasses protect the wearer from the shrapnel from a high strength detonator at a distance of 0.5m, 0.75m or 1m**?** It must never be assumed that PPE will be fit for purpose simply because it was recommended by a supplier or "has always been used".

Selection and use

When selecting PPE:

- Choose good quality products which are CE, MSHA or equivalent marked or approved by local authorities.
- Choose equipment that suits the wearer – consider the size, fit and weight; you may need to consider the health of the wearer, e.g. if equipment is very heavy, or wearers have pre-existing health issues; standard PPE may not be suitable.
- In new situations let users help choose it; they will be more likely to use it.

Using and distributing PPE to employees:

- instruct and train people how to use it;
- tell them why it is needed, when to use it and what its limitations are. Videos that demonstrate the effectiveness of the PPE in worst case conditions can be very helpful.
- never allow exemptions even for those jobs that 'only take a few minutes'
- if something changes on the job, check the PPE is still appropriate
- when transferring an employee from one area to another, ensure that he or she receives PPE and training according to the hazards in the new workplace.
- control the shelf life and replace PPE as required
- PPE is for individual personal use only.

The hazards and types of PPE

Eyes

Hazards: Chemical or metal splash, dust, projectiles, gas and vapour, radiation

Options: Safety spectacles, goggles, face-shields, visors.

Note: Make sure the eye protection has the right combination of impact/dust/splash/molten metal eye protection for the task and fits the user properly.

Head

Hazards: Impact from falling or flying objects; risk of head bumping; hair entanglement.

Options: A range of helmets, hard hats and bump caps

Note: A site-wide requirement for a hard hat may be easy to monitor but in some situations the hat can become a source of hazard if it should slip from the wearer's head and impact on explosives. The requirement should be workplace risk based.

Breathing

Hazards: Dust, vapour, gas, oxygen-deficient atmospheres.

Options: Disposable filtering face-piece or respirator, half- or full-face respirators, air fed helmets, breathing apparatus.

Note:
1.The right type of respirator filter must be used as each is effective for only a limited range of substances. Where there is a shortage of oxygen or any danger of losing consciousness due to exposure to high levels of harmful fumes, only use breathing apparatus – never use a filtering cartridge. Filters only have a limited life; when replacing them or any other part, check with the manufacturer's guidance and ensure the correct replacement part is used.
2.When not in use, breathing protection apparatus must be stored in a clean area

Typical exposures that may require respirators include: handling TNT/PETN at cast booster production; preparation of pyrotechnic compositions; sieving; cleaning plants; stemming the boreholes on a dusty bench; emergency response; etc.

Protecting the body

Hazards: Temperature extremes, adverse weather, chemical or metal splash, spray from pressure leaks or spray guns, impact or penetration, contaminated dust,

Options: Conventional or disposable overalls, boiler suits, specialist protective clothing, e.g. leather aprons, fire resisting coveralls, high-visibility clothing.

Note: The choice of materials includes flame-retardant, anti-static, chain mail, chemically impermeable, and high-visibility. Care must be taken for not to use synthetic winter clothing in areas where static sensitive explosives are handled.

Hands and arms

Hazards: abrasion, temperature extremes, cuts and punctures, impact, chemicals, electric shock, skin infection, disease or contamination.

Options: Gloves, gauntlets, mitts, wrist-cuffs, long-sleeved shirts, armlets.

Note: Avoid gloves when operating machines such as bench drills where the gloves could get caught.

Barrier creams are unreliable and are no substitute for proper PPE. Wearing gloves for long periods can make the skin hot and sweaty, leading to skin problems; using separate cotton inner gloves can help prevent this. Be aware that some people may be allergic to materials used in gloves, e.g. latex.

Typical exposure where gloves will be necessary include: handling delay compositions that contain lead in the formulation; handling of wet PETN; pouring TNT on melter, etc. Contaminated gloves must be properly disposed as hazardous waste.

Feet and legs

Hazards: Wet, electrostatic build-up, slipping, cuts and punctures, falling objects, metal and chemical splash, abrasion.

Options: Safety boots and shoes with protective toe caps and penetration-resistant mid-sole, gaiters, leggings, spats.

Note: Footwear can have a variety of sole patterns and materials to help prevent slips in different conditions, including oil or chemical-resistant soles. It can also be anti-static, electrically conductive or thermally insulating. It is important that the appropriate footwear is selected for the risks identified.

Others

As more of our activities are becoming carried out on mines and quarries we also need to consider the following

Hazards: Skin exposure to high levels of sunlight – especially at higher altitudes.

Options: UV blocking creams, face, arm and leg clothing

Hazard: Insect or reptile bites

Options: Insect repellent cream, clothing

Damaged, defective or dirty PPE must be removed from the workplace and replaced.

Training

Make sure anyone using PPE is aware of why it is needed, when to use, repair or replace it, how to report it if there is a fault and its limitations.
Train and instruct people how to use PPE properly and make sure they are doing this. Include managers and supervisors in the training, they may not need to use the equipment personally, but they do need to ensure their staff are using it correctly.

It is important that users wear PPE all the time they are exposed to the risk. Never allow exemptions for those jobs which take 'just a few minutes'.

Check regularly that PPE is being used and investigate incidents where it is not. Safety signs can be useful reminders to wear PPE, make sure that staff understand these signs, what they mean and where they can get equipment, e.g. for visitors or contractors. Safety signs should be clearly visible to advise people before entering the plant.

Maintenance of PPE

There should be systems and procedures to ensure:

- equipment is well looked after and properly stored when it is not being used, e.g. in a dry, clean cupboard, or for smaller items in a box or case;
- equipment is kept clean and in good repair – follow the manufacturer's maintenance schedule (including recommended replacement periods and shelf lives);
- simple maintenance can be carried out by the trained wearer, but more intricate repairs should only be done by specialists;
- replacement parts match the original, e.g. respirator filters;
- you identify who is responsible for maintenance and how to do it;
- employees make proper use of PPE and report its loss or destruction or any fault in it.

Make sure suitable replacement PPE is always readily available. It may be useful to have a supply of disposable PPE, e.g. for visitors who need protective clothing.

Checklist for the auditor.

- Is there a formal system for the management of PPE?
- Do operating instructions include PPE requirements specific for that activity?
- Is there a formal system for sourcing PPE?
- Is PPE required to be tested under likely worst case conditions?
- Is there a formal system for training in PPE and are there records of PPE training?
- Is there a system to routinely inspect PPE?
- Is there a system for auditing the issue and use of PPE?

Field guide for the auditor

- Are there clear requirements specified for PPE on entering the facility? Good signage?
- Were you provided with the relevant PPE?
- Are operators wearing the correct PPE according to requirements?
- Do operators know why the PPE is required? Were they trained in its use?
- Is the PPE in good condition? Safety glasses clear lenses, dust masks good fit and clean?
- Are cabinets or other places provided for the safe and clean storage of PPE when not in use?
- Is hearing protection required in noisy areas?

A Review of the American Table of Distances
by

S. Kevin McNeill

BACKGROUND

EARLY EXPLOSIVES REGULATIONS

The earliest accounts of explosives regulations date back to 1719 when Great Britain passed an act that regulated the location of explosive storage. However, explosives regulation, in the form that we know it today, was significantly shaped following a major explosion[2] in 1864 that led to the Explosives Act of 1875[3] in Great Britain. The Explosives Act of 1875 regulated the manufacturing, storage, sale, transportation, and importation of explosives. This act established specific explosive quantity-distance [4](QD) regulations for different buildings and groups of people; however, the QD regulations were arbitrary and had no foundation in science.

DEVELOPMENT OF EXPLOSIVES REGULATIONS IN THE UNITED STATES

The regulation of explosives in the United States (U.S.) began almost 30 years after the British Explosives Act of 1875. Massachusetts implemented the first regulation in 1904[5]. It merely adopted the QD tables in the Explosives Act of 1875. A few years later, the Association of Manufacturers of Powder and High Explosives committee was established to evaluate public safety with respect to commercial explosive storage facilities in the U.S. This association studied 117 accidental explosions that occurred between 1864 and 1914 with the goal of formulating regulations based on explosion consequences (building damage), rather than the arbitrary rules in the Explosives Act of 1875. The association distributed the first edition of the American Table of Distances (ATD) in 1914. Ralph Assheton later published the results of the study in a book titled "History of Explosions on Which the American Table of Distances was Based"[6]. IME released the ATD in their Safety Library Publication No. 2[7] (SLP 2), where it is still available today. The Bureau of Alcohol, Tobacco, Firearms, and Explosives (ATF) based the current explosive storage regulations on IME's SLP 2 and is referred to by the ATF as the Table of Distances (TOD)[8].

CONCERNS WITH THE AMERICAN TABLE OF DISTANCES

ATF uses the Table of Distances as a consequence model. Consequences are the undesirable outcomes of accident scenarios. The first step in any consequence model is to define the consequence endpoint.

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[1]Chief, Explosives R&D Division, National Center for Explosives Training and Research, Bureau of Alcohol, Tobacco, Firearms, and Explosives, USA, shonn.mcneill@atf.gov
[2]On October 1, 1864, two gunpowder magazines, situated on the southern bank of the Thames, between Woolwich and Erith, Great Britain, exploded killing 10 and wounding 7.
[3]Original, as enacted, can be found at http://www.legislation.gov.uk/ukpga/Vict/38-39/17/contents/enacted.
[4]Quantity-distance (QD) criteria is a general term that encompasses all regulations that defined the safe distance based on the quantity of explosive like the American Table of Distances.
[5]Licenses and Municipal Regulations of Police, Sections 87-121, An Act to Authorize the Fire Marshal's Department of the District Police to Make Regulations Relative to Explosives and Inflammable Fluids.
[6]Assheton, Ralph, "History of Explosions on Which the American Table of Distances was Based", Charles Story Press Co., Wilmington, Delaware, 1930.
[7]Institute of Maker of Explosives, "The American Table of Distances – SLP 2", IME, Washington, DC, 2017.
[8]Implemented as part of Title XI, Regulation of Explosives (Title 18, United States Code, Chapter 40 (84 Stat. 952)) of the Organized Crime Control Act of 1970 (84 Stat. 922).

The endpoint can vary depending on the event. For ATF, the endpoint is public harm (injury or fatality) in the event an explosive storage magazine explodes. When a magazine explodes, the physical effects are thermal, overpressure, fragmentation, building collapse, and secondary debris, see Figure 1. Any of these effects can result in injuries or fatalities to the public. Unfortunately, the ATD, never defined the consequence to be public harm; instead the ATD establishes an area of extreme structural damage[9]. This is a fundamental flaw in the ATD, because there is no way to relate building damage to public injuries or fatalities.

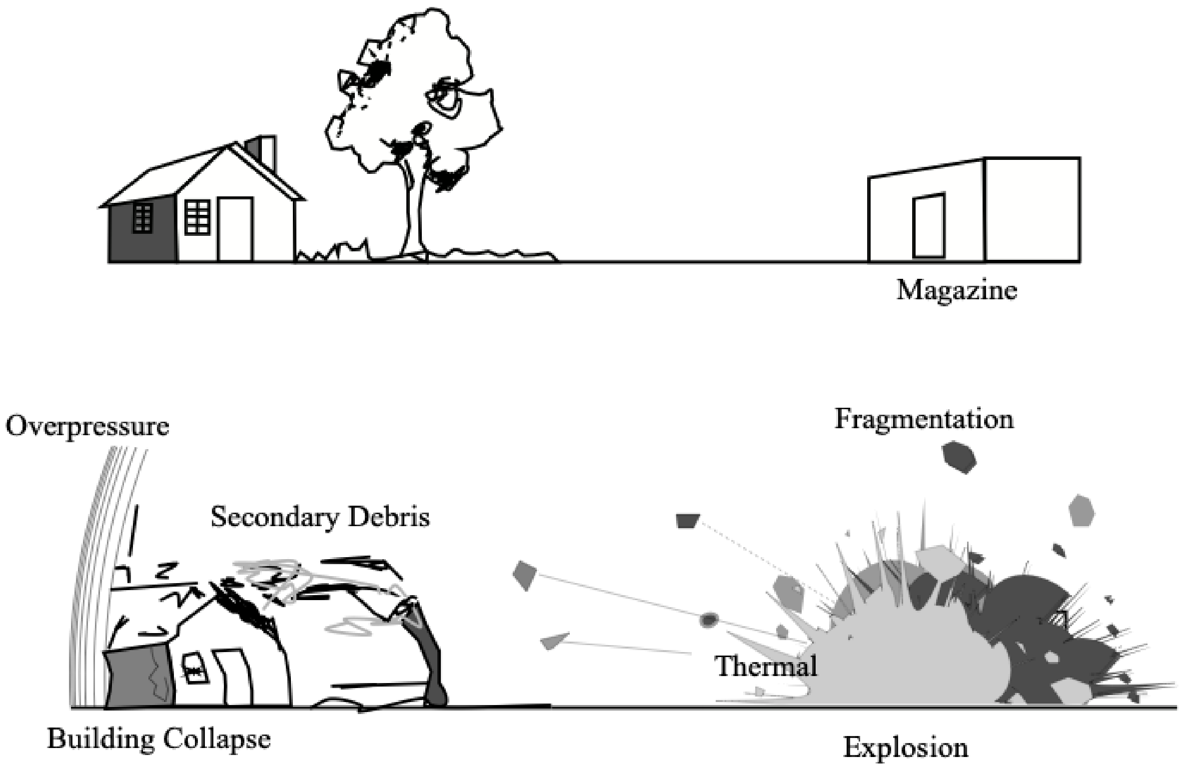

Figure 1. Diagram showing the overpressure, thermal, fragmentation, building collapse, and secondary debris hazards of an explosion.

IME collected the accident data on extreme structural damage during the original work to develop the ATD. During the accident review process, IME also gathered data on the maximum fragmentation and glass breakage distances. However, as can be seen in Figure 2, these additional hazards (fragmentation and glass[10,11] breakage) were not considered in the development of the ATD. Figure 2(b) shows the "safe" curves for the ATD (safe-zone is located to the right of the curves.) However, as can be seen in Figure 3(c) and 3(d), both fragmentation and glass breakage occur at distances considered safe by the ATD. Equating public safety with extreme building damage and ignoring fragmentation and glass breakage is a public safety concern.

[9] See page 18, Assheton, Ralph, "History of Explosions on Which the American Table of Distances was Based", Charles Story Press Co., Wilmington, Delaware, 1930.

[10] Most victims of the Oklahoma City Bombing who were not in the federal building sustained injuries from flying glass and other debris.

[11] S. Mallonee, S. Shariat, G. Stennies, R. Waxweiler, D. Hogan, and F. Jordan, "Physical injuries and fatalities resulting from the Oklahoma City bombing.," JAMA, vol. 276, no. 5, pp. 382–7, Aug. 1996.

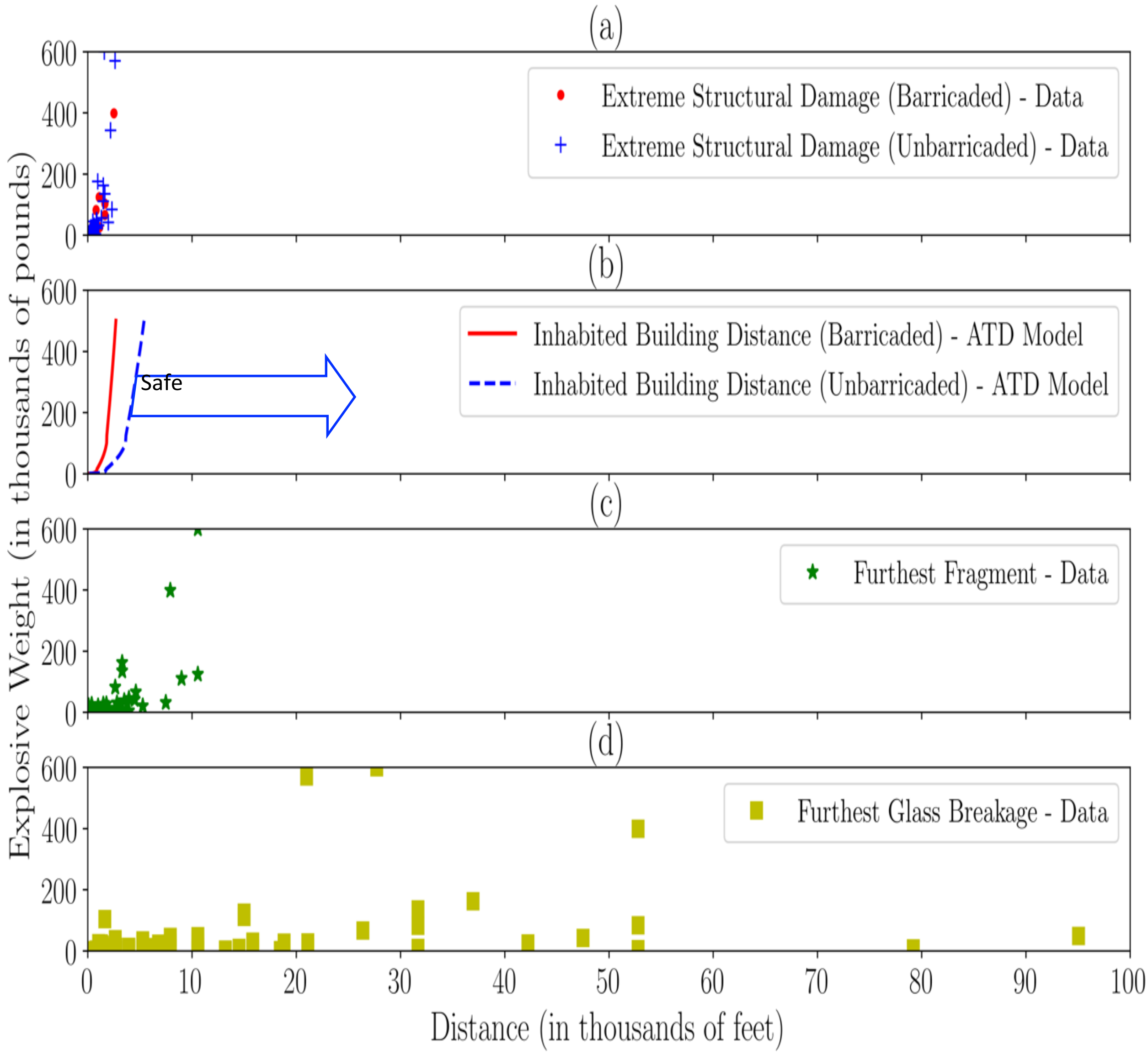

Figure 3.

(a) A plot of the data used to develop the ATD model based on extreme structural damage.

(b) A plot of the ATD models for barricaded and unbarricaded structures. The area to the right of the curves "should" be safe.

(c) A plot of the furthest fragments thrown showing these fragments traveled much further than the ATD models.

(d) A plot of the furthest glass breakage that also extends well beyond the ATD model. These four plots have been scaled to the same distance to allow a comparison.

Another issue with the ATD is the age (1864-1914) of the accident data it is based upon. The ATD has not kept pace with the explosives industry over the last 100 years. The most significant change was an adjustment to the unbarricaded inhabited building distance[12]. There is now an abrupt jump from the unbarricaded inhabited building distance [13](IBD) curve up to the barricaded IBD curve at a distance of 2,000 feet, see Figure 4. Interestingly, this change makes the unbarricaded IBD less conservative and therefore, possibly less safe to the public. There are two other areas where the original accident data collected no longer matches current industry

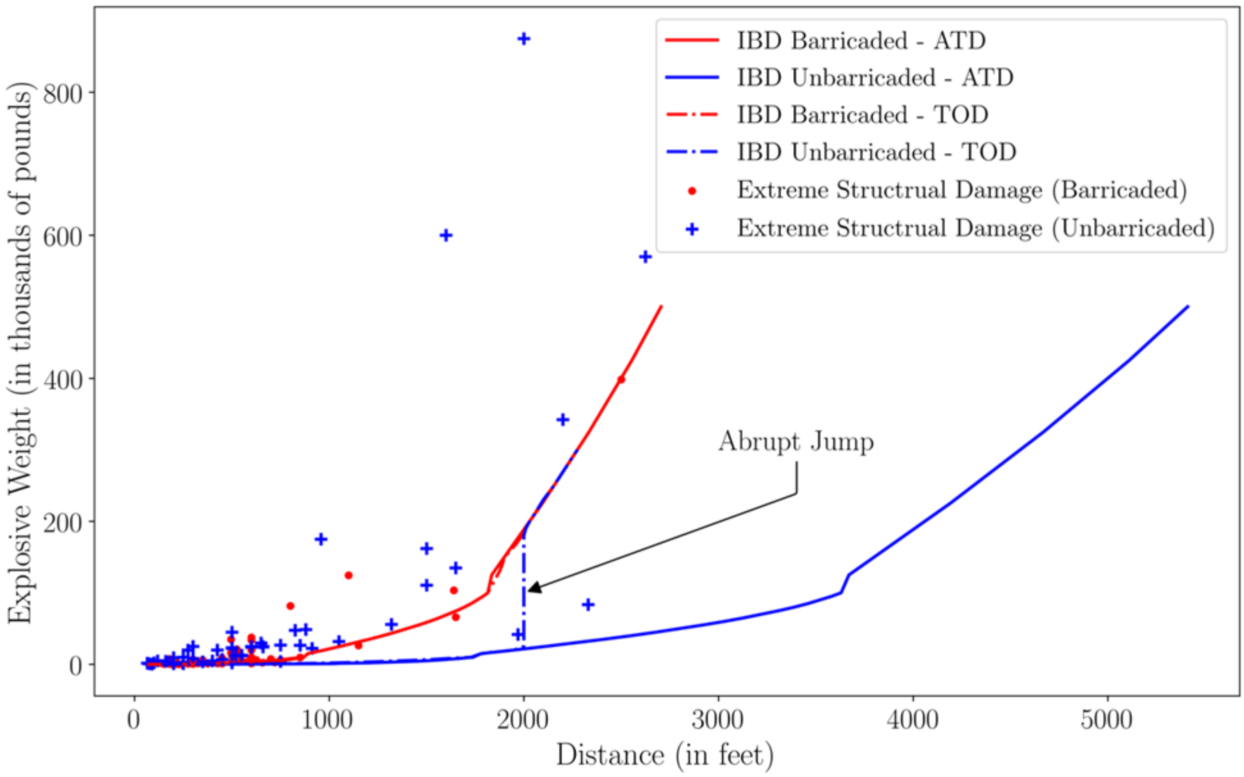

Figure 4. A plot of the inhabited building distance (IBD) of the 1914 American Table of Distances (ATD) and the modern ATF Table of Distances. Note the change in the ATD that occurs at a distance of 2,000 feet for the IBD unbarricaded. This is the only significant change that has occurred in the original ATD in the last century.

practices. These are the explosive products used and how blasting operation procedures are conducted. When you consider the commercial explosives used in the years between 1864 and

[12]The unbarricaded inhabited building distance (IBD) is defined as the "safe" distance an explosive magazine can be from a building occupied by the public which does not have a barricade positioned between the explosive magazine and the inhabited building. Because the building is unbarricade the "safe" distance is further away compared to the barricaded IBD.
[13]The barricaded inhabited building distance is defined as the "safe" distance an explosive magazine can be from a building occupied by the public which has a barricade positioned between the explosive magazine and the inhabited building. Because there is a barricade the "safe" distance is closer compared to the unbarricaded IBD.

1914, the predominant explosives consumed were black powder[14] and nitroglycerin[15]based explosives, see Figure 5. This is in contrast to the blasting materials used today.

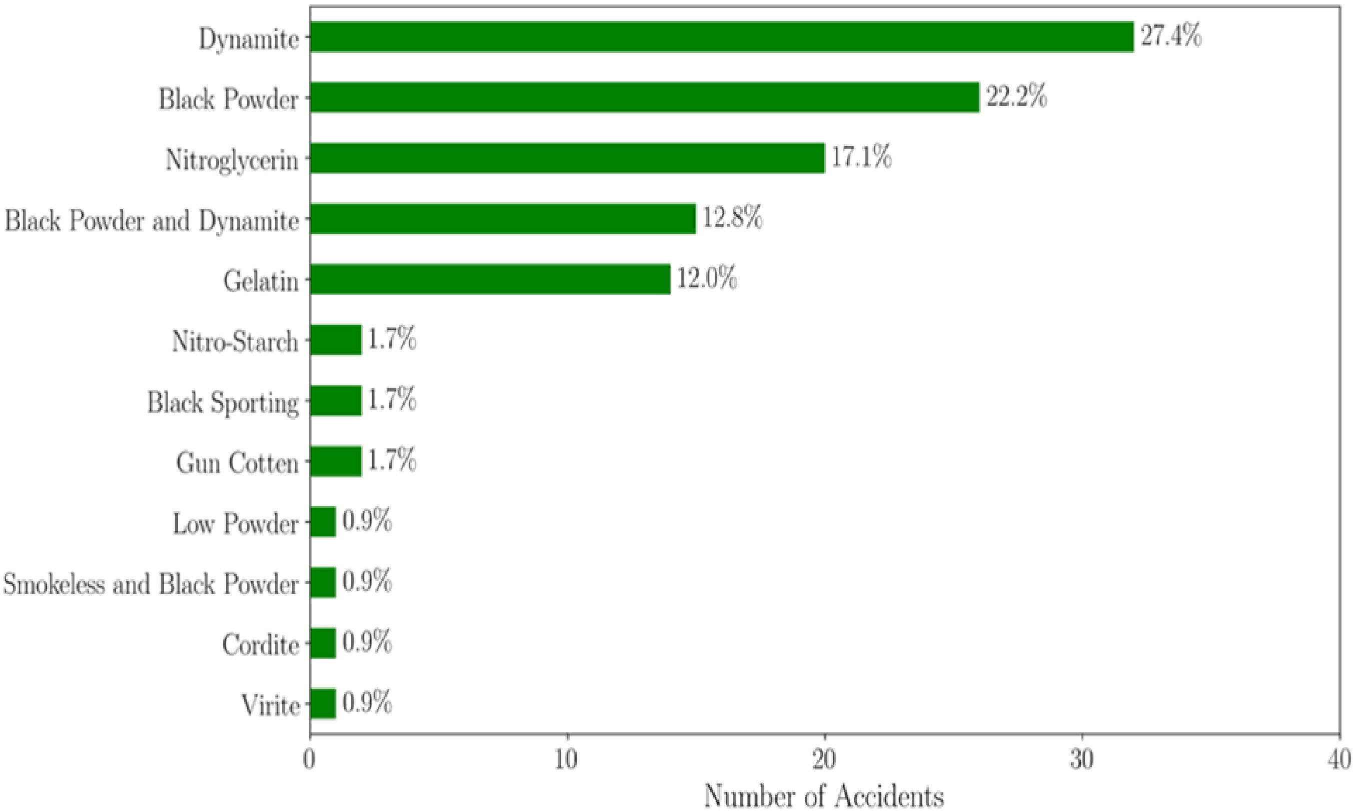

Figure 5. Plot showing the percentage of each type of explosive used in the 117 accidents studied in the development of the American Table of Distances. The majority of explosives, 91.5%, used between 1864 and 1914, were either sensitive black powder or nitroglycerin based.

As of 2016, the blasting materials consumed in the U.S. explosives industry are primarily blasting agents[16] and oxidizers[17], see Figure 6. Therefore, the explosives used in the development of the ATD are completely unrepresentative of the explosives used today.

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[14]Mixture of sulfur (S), charcoal (C), and potassium nitrate (saltpeter, KNO_3). Sensitive to spark, flame and friction.
[15]Explosives contain nitroglycerin ($C_3H_5(NO_3)_3$) as the main explosive ingredient. Typical examples include dynamite and gelatin. Nitroglycerin is unstable and sensitive to impact or friction.
[16]Blasting-agents are very-insensitive explosives. They 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.
[17]Oxidizer is a material that may, generally by yielding oxygen, cause or enhance the combustion of other materials. (Not classified as an explosive)

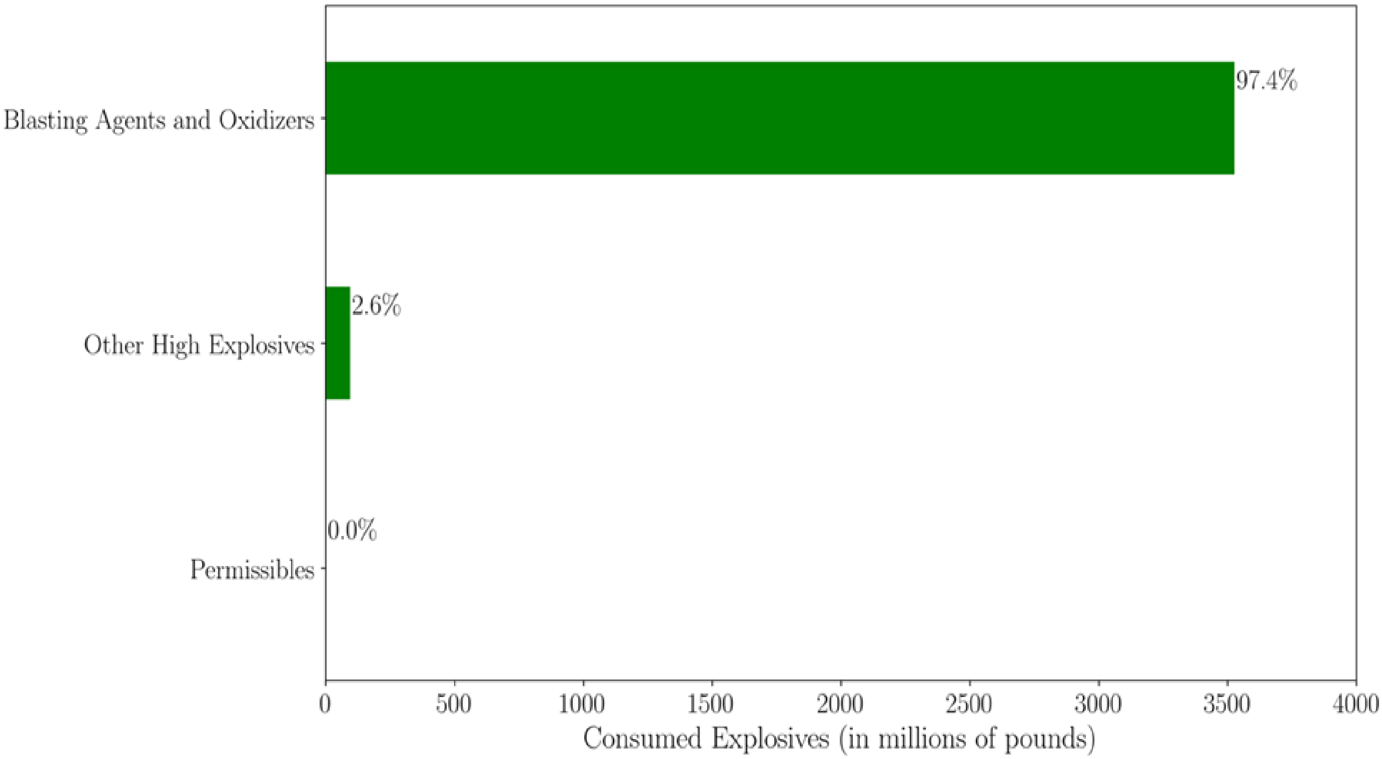

Figure 6. Plot of the U.S. Geological Survey Annual Explosives Report for 2016. Nearly all, 97.4%, of the explosives used in the U.S. in 2016 are blasting agents (very insensitive explosive) or oxidizers (not an explosive). A small percentage, 2.6%, are high explosives.

These less sensitive modern explosives, as compared to black powder or nitroglycerin, result in fewer accidents in manufacturing, storage, and use.

Lastly, the explosives industry safety practices have changed significantly over the last century. In the explosives industry between 1901 and 1910 there were 111 accidental explosions[18] and between 1994 and 2004[19] there were four[20] accidental explosions. The significant change in the number of accidents is the result of safer products and safer industry operations. Figure 7(a), is a photograph from the turn of the 20th Century showing a blaster pouring black powder with an open flame on his hat. In contrast, Figure 7(b) is a modern blaster loading a cast booster into a blast hole.

CONCLUSION

In summary, the ATD are based on extreme building damage not on public safety. As a result, the distances specified by the ATD allow for an unknown risk to the public at the distances specified by the ATD. Fragmentation and glass breakage hazards extend well beyond the range of the ATD adding additional unknown risk to the public. Lastly, the ATD was based on explosives and operations that do not represent the safer explosives and work practices of the

[18] Mainiero, R. J., & Verakis, H. C. (2010). A Century of Bureau of Mines / NIOSH Explosives Research. Society for Mining and Exploration, 1–10.
[19] The latest accident data that IME has records on is 2004. IME is currently in the process of updating these data.
[20] Chrostowski, J., & Haber, J. (2018). IMESAFR P(e) Peer Review. Torrance, CA.

(a) (b)

Figure 7. (a) Photograph of a turn of the 20th-century blaster preparing a black powder cartridge with an open flame on his hat and (b) modern blaster lowering a cast booster into a blast hole.

explosives industry today. Both the flaws and the obsolescence in the ATD need to be addressed with public safety as the primary objective.

As a tentative first step, ATF accepts variances [21] for explosive storage siting using quantitative-risk-assessment [22] (QRA). In contrast to the ATD, the QRA models used for explosive magazine siting consider public safety (not building damage) and account for changes in explosives and operations. However, adding a future-proof QRA regulatory framework to ATD is costly and would require a significant increase in resources to support the necessary research, testing, and operations.

In conclusion, public safety is ATF's most important responsibility. The Bureau's explosives enforcement mission is unique, in that an accident in the explosives industry may result in catastrophic public injuries and/or fatalities. Therefore, it is incumbent upon the Bureau to continuously improve public safety as the explosive industries we regulate change and adapt.

[21] Title 27 CFR §555.22 allows federal explosive licensees (FEL) to submit alternate methods or procedures as long as the Director finds 1) good cause, 2) consistent with and substantially equivalent to the prescribed method, 3) and the alternate method is not contrary to any provision or law, does not increase the cost to the government, or hinder effective administration. Currently ATF has accepted 11 QRA variances from FELs with 4 pending approval.

[22] Quantitative risk assessment is the systematic analysis of the risks of a hazardous situation, evaluating the significance of those risks, and providing information for use in decision making on safety issues.

UN SaferGuard Update

Presented by

Hans Wallin

UN SaferGuard
Securing ammunition, protecting lives

Quarterly Update – Spring 2019

UN SaferGuard Technical Review Board & Strategic Coordination Group

1. Ammunition Management Advisory Team

In January 2019, the Ammunition Management Advisory Team (AMAT) was jointly launched by the Geneva International Centre for Humanitarian Demining (GICHD) and the United Nations Office for Disarmament Affairs (UNODA).

AMAT provides sustainable technical support to interested States in the safe and secure management of ammunition in accordance with the International Ammunition Technical Guidelines (IATG).

Establishing AMAT is a concrete activity in realizing the "Saving lives" pillar of the Secretary-General's agenda for disarmament, *Securing Our Common Future*, specifically action 22 on securing excessive and poorly maintained stockpiles.

AMAT is anchored at the GICHD and guided by the AMAT Advisory Council (AC) composed of donors, States engaged in improving ammunition management, relevant international and regional organisations, and implementing partners.

The first AC meeting was held in Geneva in March 2019. Priority themes of discussion included the AC's composition and Terms of Reference, as well as AMAT's strategy, work plan and modus operandi.

More information at www.amat.org

2. IATG support guides

To promote the effective, safe and secure management of ammunition stockpiles and to make the IATG more accessible, the UN SaferGuard Programme published three practical IATG support guides. The hope is that these guides will support the broadest selection of users in utilizing the IATG".

Critical Path Guide to the International Ammunition Technical Guidelines

The **Critical Path Guide** clarifies how the measures within the IATG are to be interpreted and applied in practice and explains technical concepts and processes in a simple, clear, and concise manner. It supports users in navigating the principles, methodology and technical content of the IATG.

A Guide to Developing National Standards for Ammunition Management

The **Guide to Developing National Standards for Ammunition Management** aims to assist State authorities in the development of national standards for ammunition management based on IATG and in implementing those standards across State institutions. It outlines the key considerations and processes involved in the development of national standards and provides advice for the development of an organizational framework necessary for an effective, coordinated and sustainable national ammunition.

Utilizing the International Ammunition Technical Guidelines in Conflict-Affected and Low-Capacity Environments

The **Utilizing the International Ammunition Technical Guidelines in Conflict-Affected and Low-Capacity Environments** guide offers practical information on how basic ammunition stockpile safety and security can be improved and risks reduced in ammunition storage and processing facilities in conflict-affected and low-capacity environments. It extracts essential elements from the IATG to this end. This guide was developed by the United Nations Institute for Disarmament Research (UNIDIR), a key research partner of the UN SaferGuard Programme.

3. Informal Meeting of the UN SaferGuard Technical Review Board

UNODA will host an informal UN SaferGuard Technical Review Board (TRB) meeting from 9-12 July 2019 at the United Nations Headquarters in New York.

This informal meeting will allow TRB members to hold the required in-depth technical discussions on the 2020 IATG update and the improvement of the IATG implementation support toolkit.

Results of the informal meeting will be discussed at the next formal TRB and Strategic Coordination Group meeting in November 2019.

4. UN SaferGuard Ammunition Management Expert Validation Process

With a view to both populate the UN SaferGuard roster of experts and promote harmonized international assistance in the area of ammunition management, solidly founded in the IATG, the UN established the UN SaferGuard Ammunition Management Expert Validation Process.

The next UN SaferGuard validation exercise will be convened from 26-30 August 2019 in Austria. 16 ammunition technical experts from national authorities, United Nations entities, and non-governmental organizations have been selected and are currently taking part in an e-learning programme on the IATG prior to the in-person validation exercise in August.

Two previous validation exercises, held in Switzerland and Austria in 2017 and 2018, respectively, allowed for the development and further refinement of the impartial, standardized validation methodology, firmly based in the IATG. The validation is conducted through roundtable discussions, individual technical exercises, group role play-exercises, substantive questions and answers, and presentations.

With the generous financial support of Germany and Switzerland, UNODA and AMAT are now undertaking the regional roll-out of the UN SaferGuard validation process with a view to validate ammunition expertise and competence across regions to build a cadre of UN SaferGuard-validated experts to engage locally and/or regionally in IATG-related assistance.

In the course of 2019 and 2020, UN SaferGuard will carry out four regional validation exercises in Europe, Africa, Latin America and the Caribbean, and in the Middle East and North Africa.

Safe and Secure Ammunition Management through the UN SaferGuard Programme

Presented by

Hans Wallin

UNODA United Nations Office for Disarmament Affairs

FACT SHEET

SAFE AND SECURE AMMUNITION MANAGEMENT THROUGH THE UN SAFERGUARD PROGRAMME

In more than 100 countries, over the past five decades, poorly-managed ammunition stockpiles have resulted in explosions, often bringing about humanitarian disasters.[1] Thousands of people have been killed, injured and displaced, and the livelihoods of entire communities have been disrupted.

In addition to the humanitarian and socio-economic consequences, unsecured or poorly managed ammunition stockpiles fuel insecurity. Massive diversion of ammunition to illicit markets has been a catalyst for armed conflict, organized crime and terrorism. Moreover, diverted ammunition is increasingly used to assemble improvised explosive devices (IEDs).

Taken together, these consequences demonstrate the very serious safety and security challenges posed by inadequately-managed stockpiles.

In response to these concerns, the Security Council recommended that stockpile security and the management of arms and ammunition be promoted "as an urgent priority (S/RES/1952 (2010))." The General Assembly requested the United Nations to develop guidelines for adequate ammunition management to ensure that the United Nations consistently delivers high-quality advice and support (A/RES/63/61). In response, the **International Ammunition Technical Guidelines (IATG)** were developed in 2011 and the UN **Saf*er*Guard Programme** was established as the corresponding knowledge management platform.

Devastation from a 2012 ammunition depot explosion in Brazzaville, Congo. 200 people were killed, 2000 injured. Photo: Erwan Morand.

The UN Saf*er*Guard Programme, managed by the UN Office for Disarmament Affairs (UNODA), oversees the dissemination of the IATG: practical, modular guidance on the safe and secure management of ammunition for the benefit of all interested stakeholders.

International Ammunition Technical Guidelines

The UN Saf*er*Guard Programme serves as the custodian for the IATG – ensuring their highest technical quality through regular updates. The **IATG are publicly available** to assist national authorities – including armed forces, police officers and border control officials – as well as

[1] See: Small Arms Survey: Unplanned explosions at Munitions Sites.

July 2019

industry, private security companies and operational non-governmental organizations to enhance the safety and security of ammunition stockpiles. The aim of the IATG is a reduction of the dual risks of unplanned explosions and illicit diversion.

The IATG are voluntary, practical guidelines for use by interested States and other relevant stakeholders to inform the development of national standing operating procedures.

The IATG consist of 12 volumes that provide practical guidance for 'a whole-of-life' approach to ammunition management. These volumes are subdivided into 45 individual modules. Users of the IATG can opt for applying the guidelines' **basic**, **intermediate**, or **advanced** levels, making the IATG relevant for all situations by taking into account the diversity in capacities and resources available. These increasingly thorough steps are called *risk reduction process levels* (RRPLs).

The IATG are updated, at a minimum, every five years to reflect evolving ammunition stockpile management norms and practices, and to incorporate changes due to changing international regulations and requirements. The IATG are available in multiple languages. The latest version of each guideline can be found at www.un.org/disarmament/ammunition. The next version will be published in 2020.

IATG implementation support toolkit and guides

Key IATG implementation support tools – ranging from a risk reduction checklist to an explosive-limit license generator – are available for immediate use by ammunition experts to improve ammunition safety at www.un.org/disarmament/un-saferguard.

To assist authorities in utilizing the IATG and in developing national standards and procedures, the UN Saf*er*Guard Programme has also published three practical IATG support guides – "Critical Path Guide to the International Ammunition Technical Guidelines", "A Guide to Developing National Standards for Ammunition Management" and "Utilizing the International Ammunition Technical Guidelines in Conflict-Affected and Low-Capacity Environments"..

Assistance

In line with the Secretary-General's Agenda for Disarmament, specifically action 22 on securing excessive and poorly maintained stockpiles,[2] the Ammunition Management Advisory Team (AMAT)[3] was established to provide technical expert assistance to interested States in accordance with the IATG, including under the UN Saf*er*Guard Quick-Response Mechanism. AMAT seeks to enhance State and regional action on safe and secure management of ammunition and to facilitate effective and sustainable international cooperation and assistance.

www.un.org/disarmament/ammunition
conventionalarms-unoda@un.org

[2] See www.un.org/disarmament/sg-agenda.

[3] See www.amat.org.

July 2019

International Explosives Conference 2020

30 June-2 July 2020

Victory Services Club, Marble Arch, London, UK

An international conference on the fundamental science of explosives and other energetic materials for the research community

"Future Developments in Explosives and other Energetics"

The UK's Centre of Excellence in Energetic Materials (CoEEM), in conjunction with the Sector Skills Strategy Group (SSSG) and Cranfield University, is hosting the inaugural International Explosives Conference (IEC-2020).

Confirmed keynote speakers:

Dr Yogi Gupta – Washington State University

Dr Jesse Sabatini – US Army Futures Command

Dr William Proud – Imperial College London

Presentations, Interactive sessions, Three Minute Thesis, Posters...

Conference Themes:

- Energetic Materials and Characterisations
- Manufacturing and Processing
- Responses to Stimuli
- Advances in Experimental Techniques & Diagnostics
- Theory, Modelling and Simulation

ARTICLES FOR NEWSLETTER

This is a reminder that through the Newsletters we share knowledge in the areas of Safety, Health, Environment and Security pertaining to the Explosives Industry. SAFEX thus call on all members to submit articles on these subjects within their own companies and countries.

The deadline for articles for the December Newsletter is 10 December 2019 ,I look forward to your support .

SAFEX BOARD OF GOVERNORS

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Thierry Rousse (Groupe EPC)
Adolfo Sanchez (EXSA)
Noel Hsu (Orica)
Mark Taylor (Chemring)

UPCOMING EVENTS:

IME's 2019 Annual Meeting Lake Tahoe, USA: 8-10 October 2019

NIXT Conference #74 ,RDM, South Africa : 17 October 2019

ISEE 46th Annual Conference on Explosives and Blasting Technique, Denver Colorado : 26-29 January

SAFEX International Congress #20, Salzburg, Vienna : 25-26 May 2020

International Explosives Conference ,30 June – 2 July 2020 Location: Victory Services Club, London,UK

SAFEX thanks all the authors and contributors as well as the editing team for their for their valuable support.