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CONTENTS

SAFEX CONGRESS XX
SALZBURG 2020

From the Secretary General's Desk

Already 3 months into the new year and the first Newsletter of 2019!

It has been a busy 3 months for SAFEX with a Board of Governors meeting at the end of January and the CIE/IGUS Conference in Namibia in March. The latter was very successful and well attended. Several issues around testing of emulsions for the UN Series 8 and the classification of ammonium nitrate were discussed.

Arrangements for the 2020 Congress is well in hand and notifications will be sent during the course of this year. The final call for papers was met with a very good response and the call for abstracts and papers will be issued in the next few months.

Police Band at CIE/IGUS Conference

The use SAFEX eLearning Portal has grown significantly and you can read all about it in this Newsletter.

Tony Rowe informed us that this will be his last article as Tony's Tale Piece. SAFEX thanks Tony for many years of interesting insights into the explosives industry. We also call upon members to come forward and fill this slot with a series of articles on the History of Explosives!

A series on incident recall kicks off with the explosion at Sierra Chemicals .Andy Begg delivered this talk at the Congress in Istanbul .There is a lot of good learning in this report and we call on all members to come forward with "old" incidents for future publication- history tends to repeat itself and this vicious circle can only be broken by learning from the past.

SAFEX also welcomes Dr Mark Taylor from Chemring as a new Governor replacing Terry Bridgewater who retired after many years' service. We wish Terry many happy years of retirement!

Introducing Dr Mark Taylor-Chemring

Mark Taylor started his career as a specialist in Safety Culture and Human Error and has worked internationally across industry sectors including Maritime, Oil and Gas, Chemical and Pharmaceuticals, Atomic Weapons and Defence. He was the Technical Operations Director for Ryder Marsh, a boutique specialist consultancy, and later an Associated Director for WSP responsible for the development of behavioural services. Becoming one of the global leading practitioners in the field, during his time as a consultant he has worked on several major client projects, including the Public Inquiry into Ladbroke Grove Disaster and the 2012 Olympics. He later left consultancy taking his first senior HSSE position within BG Group, an Oil and Gas company, where he spent several years as Vice President. During this time his focused moved towards the understanding and prevention of Major Accident Hazards. Mark later joined Centrica Pl, a FTSE 100 company, as the HSSE Director of Distributed Energy and Power responsible for the businesses across the globe. After a short, but successful period with Centrica, Mark joined the Executive Committee of Chemring Group Plc in May 2018 as the Group Director of HSSE.

Mark holds several degrees in Industrial Psychology including a doctorate degree on research into Safety Culture and its influence on individual risk taking He also holds several professional memberships and is Chartered Occupational Psychologist, Chartered Scientist, Registered Member of the Institute of Human Factor and Ergonomics and a Specialist Member of the International Institute of Risk and Safety Management. He held board membership of Tripod Foundation, a non for profit organisation founded by Shell to promote barrier based thinking to reduce incidents. In his spare time Mark is highly involved in charitable causes.

AN Solution Manufacture :Product and Safety Issues for Emulsion Plant Consumers by Ron Peddie, Peddie Engineering

Discussion about ANS (Ammonium Nitrate Solution) at the last SAFEX congress in Helsinki showed that many people were unaware of some of the production issues in making (ANS) which could affect Emulsion manufacture.

I wrote this note to discuss some of these issues.

If you find this note of interest, I would suggest a visit to your friendly ANS supply plant to gain more insight!

Description of Ammonium Nitrate Solution manufacture

Ammonium Nitrate is the main raw material for all bulk explosives manufacture. It is a chemical produced in huge quantities.

Using Ammonium Nitrate Solution to make emulsions can be a very efficient process. There is no solids handling, dissolving, waste water, waste bags etc. when using ANS.

ANS is about the fourth or fifth top chemical by tonnage produced in the world.

The neutralisation of Nitric Acid with Ammonia is one of the fastest known reactions, an instantaneous and highly exothermic reaction

It is an acid - base reaction - neutralisation-amazing some senior managers listen to it called a neutraliser hundreds of times and only understand what it means after years!

This note is not about the reaction methods, though that is a fascinating subject (1) –except for my wife who is very bored with it.

I want to discuss the properties of the ANS product especially for those who make emulsions and how these are realised on the neutralisation chemical plants.

Strength (concentration)

ANS is used in emulsion manufacture at about 76% strength.

The strength of solution produced inside the chemical plants depends on the inlet acid strength and temperature and handling of the internal condensate produced by the plants.

Modern plants can produce high strengths 94 – 96%. This strength is reduced before transport as ANS solution.

The limit on ANS strength for transport is 92%, sometimes lower.

When deciding on a transport limit remember the neutralisation plant can provide very pure water for dilution and this could be transported with the ANS.This could avoid the need for separate water supply to an onsite emulsion plant at the same time ensuring water quality.

This would only apply if you were negotiating a dedicated supply. Lower strength ANS also can be transported much longer distances without fudging.

So, the supply strength can be optimised on customers' needs and transport and handling costs.

pH

ANS pH is very important for the chemistry of emulsions.

For the neutraliser operator's pH shows the completion of the reaction. pH can swing very easily on a neutraliser from very low to high,

So, vigilance is needed on the plant by the operator to keep it in specification

ANS pH is the outcome of the ratio of NH_3 and HNO_3 in the neutraliser. There is no cost for the producing plant to adjust pH, but this can be an expensive and time-consuming exercise for an emulsion plant. So, an emulsion plant should try to get ANS as close as possible to the final requirement.

Transport regulations mandate pH typically 5 – 7 at 10% dilution. However, there is little danger at pH levels slightly below these levels, so the regulation specification is just rule based.

Low pH is often mentioned as a danger source, but this is in manufacture at very extremely low pH - say less than 1 and at high concentrations and temperatures.

A 'real' high pH of ANS is not physically possible, however it is possible to get a high pH reading. Above the neutral point NH_3 is not held and will come off as a gas. Neutral pH is about 5.4 – 5.6 (depends on dilution). If you can smell ammonia the ANS is above neutral. So, tankers arriving with ammonia smell or ammonia coming offANS tanks shows over ammoniation. The reading for ANS will show above the neutral point, but over time ammonia will release and the pH will drift back to neutral pH.

For emulsion manufacture below neutral, about 4.5 pH at 10% dilution, is ideal – means less need to adjust the pH down on site for the manufacture of emulsions. There is no advantage in adding NH_3 above the neutral point – it will just flash off as gas.

A problem with high pH's is they must be adjusted with strong acids, nitric or sulphuric These acids are hazardous to handle.

Temperature

The initial manufactured temperature of ANS is much higher than needed for emulsions typically more than 150ºC. This must be reduced by cooling and dilution to manufacture emulsions.

There is a potential danger if you cool high temperature ANS with water jackets in an emulsion plant, as there is always the potential to generate steam and overpressure equipment. You also must consider if boiling is a danger. If this is not considered, a design could even be illegal under pressure vessel code.

Higher temperatures of ANS allow tankers to travel long distance and still be unloaded easily.

So, the best temperature to transport and distribute ANS is again a matter for discussion, the producing plants will always have to cool and dilute.

Contamination

ANS should be water clear when above the solidification point and pure white when cooled and solidifying.

There is a very high mass rate of production in an ANS plant, so gross contamination is unlikely and difficult simply because of the volume of product being made. The raw material ammonia and nitric acid are very pure with few avenues for contamination.

Red solution is the most frequent problem. Turning solution red is quite easy if steel or stainless steel is corroding in the neutralisation plant. A human eye detects iron contamination with incredible sensitivity. Sometimes below the level of detection by analysis. So, a1 ppm level of iron looks red, at 5ppm level looks bright red and 20 ppm looks like a sludge.

Thereis no evidence that iron at these levels cause problems in emulsion manufacture, but it is very obvious and appears unusable.

Role in emulsions manufacture trouble shooting

I think ANS is very often an unlikely candidate for emulsion manufacturing problems. However, I am biased as I have always been on the receiving end of complaints. Blaming ANS can seem to be another effortless way out, as it requires someone else than the emulsion manufacturing plant to make changes.

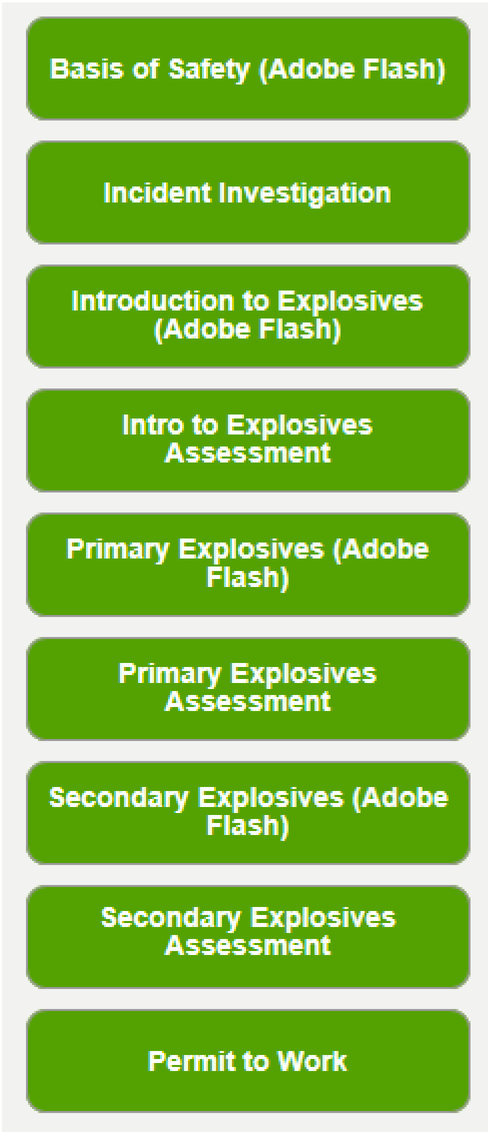
I can say that in over 40 years I have not seen an emulsion manufacturing problem traced conclusively to an ANS problem.

References

(1)UNIDO and TWA, Fertilizer Manual, Dordrecht : Kluwer Academic publishers, 1998, p. Chapter 8.

SAFEX eLearning

The SAFEX eLearning project has grown from a humble start 7 years ago to a formidable learning platform utilised by some of the biggest companies in the industry.



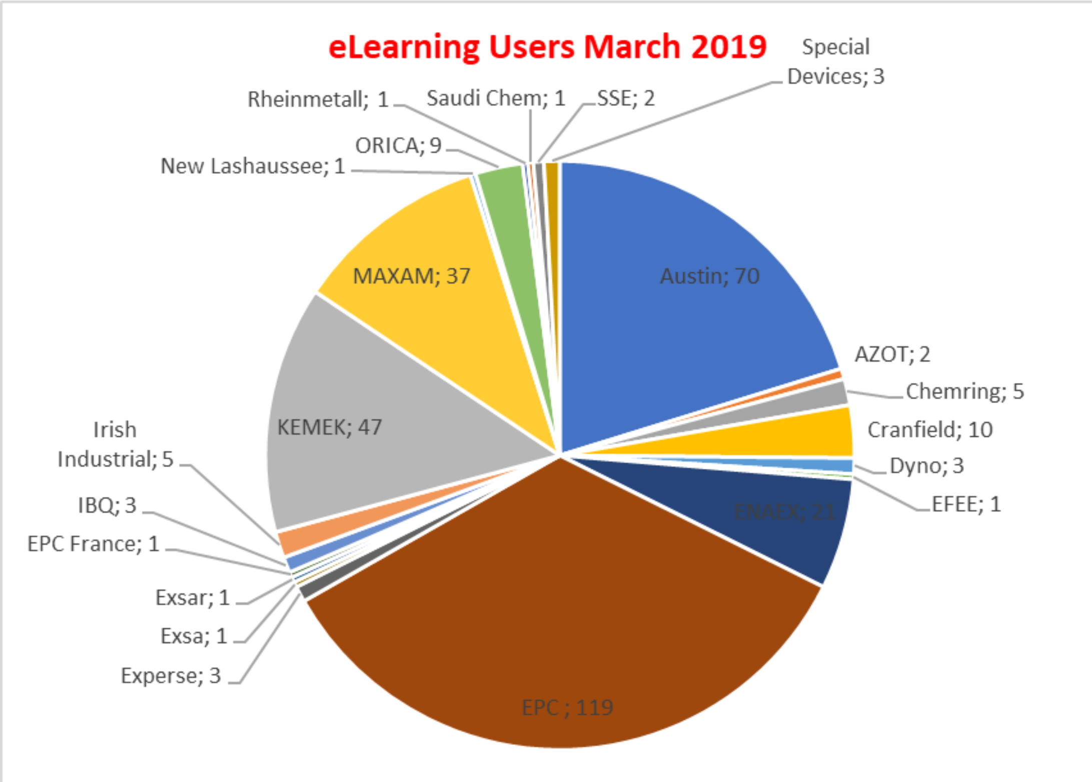
The modules above are available in English with:

Basis of Safety also in Spanish and Portuguese
Incident Investigation also in Spanish

The translations of the various eLearning modules continue to make progress. The French translations for BOS and Incident Investigation and the Russian translation for BOS are under final review and will be launched soon.

An emulsion safety package as an independent module, that can also be used for internal individual or group training purposes as a download version is in its final preparation steps and will be available within the next few months.

The usage of the eLearning Portal has increased to 350 individual users over the last 12 months.



The question to ask is: **"Why is your Company not using this fantastic training opportunity?**

The modules were developed to train individuals and through that assist in creating a much safer workplace. The cost of these modules is included in the annual subscription; thus, the only investment is willingness to use the modules and create the space and time for training.

I urge you to use this opportunity to strive to the objective of **Zero Harm** in your company.

Please contact me ,Piet Halliday ,at secretariat@safex-international.org and I will register and set you and your company up to do the training in your own time.

Incident Recall: Cast Booster Plant Incident
By
Andy Begg

Investigation Report into an incident on 7th January 1998 on the cast booster plant by
The US Chemical Safety and Hazard Investigation Board (CSB)
Presented at the XVII SAFEX Congress in Istanbul-2011

1.Introduction

On January 7, 1998, two explosions in rapid succession destroyed the Sierra Chemical Company (Sierra) Kean Canyon plant near Mustang, Nevada, killing four workers and injuring six others. Because of the loss of life and extensive damage, the CSB sent a team to investigate the explosion in an attempt to understand the causes of this incident.

The investigation focused on identifying the most probable initiating event of the incident and the equipment, management systems, manufacturing process, and human performance failures that led to the incident.

The Kean Canyon plant manufactured explosive boosters for the mining industry. The boosters manufactured at the Kean Canyon plant consisted of a base mix and a second explosive mix, called Pentolite, both of which were poured into cardboard cylinders. The primary explosives used in the base mix were TNT (2, 4, 6-trinitrotoluene), PETN (pentaerythritol tetranitrate), and Comp-B, a mixture of TNT and RDX (hexahydro-1, 3, 5-trinitro-1, 3, 5-triazine). The Pentolite is a mix of TNT and PETN.

2. Investigative Process

The CSB investigation team conducted an on-site investigation from January 10, 1998, to February 6, 1998. The scope of the investigation team's responsibility was to examine and analyze the circumstances of the explosion, to learn what happened, and to attempt to determine the cause of the explosion. The team evaluated the process design and safety management systems to determine their adequacy in controlling the cause of this explosion. The ultimate objective of this investigation was to develop recommendations to help prevent similar incidents.

The team used the following investigation methodology, adapted to address overlapping roles and responsibilities of other agencies investigating this incident. Facts were compiled by examining evidence at the incident site, conducting interviews, and reviewing documentation.

To minimize duplication of effort, the team used the information collected by other agencies to the maximum extent practical.

Events and causal-factors charting were used to establish the sequence of events chronologically and show the related conditions.

Because there were no survivors from Booster Room 2, the building where the four workers were killed, hypothetical event sequences were developed to test the feasibility of specific initiating events.

An analysis of initiating events was used to evaluate their likelihood. Change analysis was used to identify changes in operations on the day of the incident and differences between operations in Booster Room 1 and Booster Room 2 that could provide an explanation as to why an explosion might occur in Booster Room 2. Barrier analysis was used to identify those missing physical, administrative, and management controls that contributed to the explosion.

3. Plant facilities

Sierra's explosives facilities are located approximately seven miles east of the company headquarters in Sparks, Nevada. The plant is located in Kean Canyon, north of Interstate 80. Sierra also leases land in Kean Canyon to the Frehner Construction Company, which operates an adjacent gravel pit south of the plant. There was one primary access road to the explosive's facility, which was controlled by a locked gate. All of the magazines and buildings at the Sierra facility had either key or combination locks.

These buildings typically were locked, except when workers required access during the workday.

The Kean Canyon plant produced a variety of materials for the mining industry. The melt/pour manufacturing operation produced explosive boosters, which are used with blasting caps to initiate detonations of blasting agents or other less sensitive high explosives. Explosive raw materials and finished boosters were stored in magazines built into a hillside in the western side of the canyon.

The plant's facilities were built on a series of terraces as shown in Figure 1. The highest terrace was a storage yard for equipment and materials. The next terrace contained storage tanks for process water and soda ash. Booster production, flux mixing, and soda ash repackaging operations were located in the production building on the third terrace down, approximately ten feet below the previous terrace. A chemistry lab, an employee break room, and a parking area were located on the fourth terrace, which was 18 feet lower than the previous terrace. The PETN building and magazine were located on the fifth terrace, approximately five feet below the previous one, or about 23 feet below Booster Room 2.

Figure 1

3.1 The production buildings

The production buildings housing the booster manufacturing, flux, and soda ash operations were constructed over several years as add-ons to an expanding operation.

The explosives manufacturing buildings were constructed of fully grouted, reinforced, 8-inch concrete block. They had asphalt and tar roofs supported by wooden trusses. A pre-fabricated metal building warehoused paper products and finished flux.

Figure 2 shows the various buildings and rooms used in the melt/pour, flux, and soda ash operations. Booster Room 2 was built before 1974 and was refurbished for the melt/pour operation in 1996. For convenience, north is shown to be at the top of Figure 2, perpendicular to the back wall of the production buildings. True north is 44 degrees clockwise.

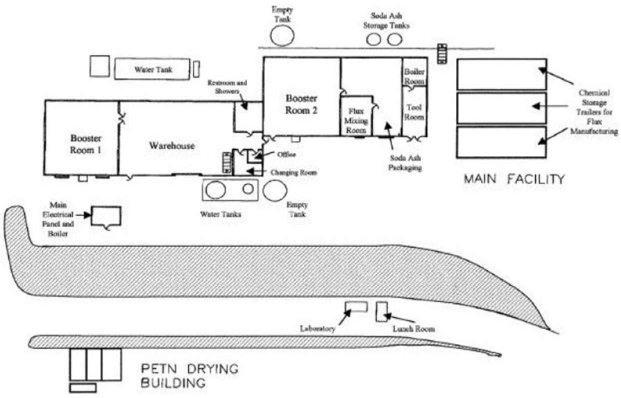


Figure 2

3.1.1 Booster Room 2

Booster Room 2, shown in Figure 3, was approximately 40 feet wide by 40 feet long and had been put into operation about four months prior to the explosions. A platform along the north wall of Booster Room 2 had an 8-inch, reinforced, poured-concrete floor supported by steel I-beam. Workers placed materials in the centre of the platform between two independent melt/pour production lines.

Figure 3

Booster Room 2 contained six mixing pots on or beside the four-foot high platform along the north wall. These pots were numbered 1 to 6 from east to west. Pots 1, 2, and 3 were placed in a mirror image of pots 6, 5, and 4, respectively. Pots 1 and 6 had not yet been placed in service.

Pots 2 and 5 were used to make the base mix consisting of TNT, Comp-B, and PETN.

Pots 3 and 4 were smaller, were used to make Pentolite from PETN and TNT, and were mounted in an I-beam support structure located directly in front of the raised platform. All mixing pots were equipped with gauges that indicated steam jacket temperatures and explosive mixture temperatures to aid operators in controlling the process. Each pot had an exhaust line to carry any dust or vapor from the pots outside through a series of particulate filters. The mixing pots in Booster Room 2 and the location of explosives between the pots are shown in Figure 4.

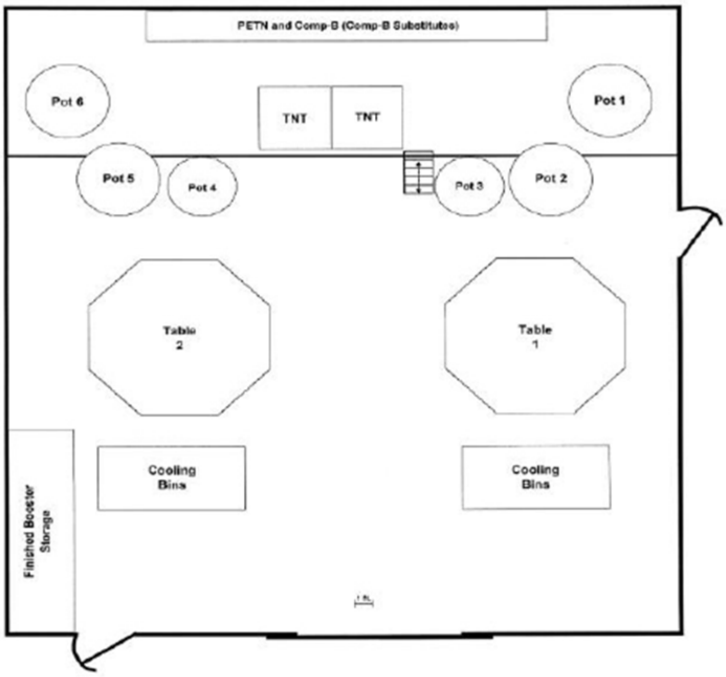


Figure 4

Pots 1, 2, 5, and 6 were acquired as excess equipment from the Department of Defense.

A two-horsepower motor, coupled through a 38:1 gear reducer, drove stainless-steel mechanical mixing blades. The blades on the large pots were attached to a central shaft and curved upward along the inside surface of the pot in an elliptical fashion. The pots were stainless steel with a carbon steel steam jacket. Two “breaker bars” extended down into the mixing pot to help agitate and break up chunks of material that might be present. Steam provided heat to the pots through the steam jacket and the two breaker bars, and through a jacket on the explosives draw-off line on the bottom of the vessel.

Pots 3 and 4 were purchased from an industrial food-processing supplier. The pots were similar to the other four pots, except they were smaller and constructed of lighter-gaugestainless steel. Stainless-steel stirrers provided agitation. The stirrers had two mixing blades extending parallel to the pot wall from the bottom of a central shaft in the shape of an anchor. Steam heated the water jackets and draw-off lines.

3.1.2. Booster Room 1

Booster Rooms 1 and 2 were similar in design and size. Booster Room 1 contained three melting and four mixing pots. Three of the mixing pots were used in the melt/pour operation. Workers used the fourth pot to maintain a liquid supply of Comp-B, one of the ingredients in the melt/pour operation. The three melting pots were used to maintain a supply of liquid TNT. The room also contained a small portable magazine in the northwest corner of the room that was used for PETN storage.

3.1.3. PETN Building and Magazine

PETN is shipped wet to reduce its sensitivity. The PETN building, where the water was removed from the PETN, was constructed of fully grouted, reinforced, 8-inch concrete block. The reinforced-concrete roof had a skylight over the drying room. The building consisted of three rooms (see Figure 2). One room was a weather room to permit the offloading of material during inclement weather. The second room, called the drip room, was where wet PETN was transferred to canvas bags and spun in a centrifuge to remove water. The last room, called the drying room, was where workers placed dewatered bags of PETN on racks to dry. Adjacent to the PETN building, and connected to it via heating ductwork, was the PETN magazine. The magazine was a skid-mounted steel structure also used for storing the PETN while it was drying. The PETN building and magazine were normally locked.

4. Plant personnel

There were four classifications of personnel who worked in the melt/pour operation at Sierra's Kean Canyon facility: outside workers, melt/pour operators (operators), boxers, and supervisors. The outside workers were paid an hourly rate and worked normal shift hours. Operators and boxers were paid on production, based on the number and type of boosters produced or boxed. Although operators worked nominal shift hours, operators could, and often did, extend their hours by coming in early and/or leaving late to increase their production. The supervisor was salaried. Outside workers were responsible for the PETN drying process and for handling raw materials and finished goods. They would stock the booster rooms once each day to ensure that the rooms had enough raw materials for all shifts of the next day's operation. They added TNT to the melting pots in Booster Room 1 to maintain a constant supply of liquid TNT. They were also responsible for loading and unloading shipments of materials to and from the explosives magazine. When sufficient rejected (unusable) boosters accumulated, the outside workers would break up the rejected boosters to recover the explosives for reprocessing.

Boxers packed finished boosters into boxes for storage. They assisted outside workers in moving materials into and out of the booster rooms. The duties of the operators varied, depending on the room, the shift, and the experience of the individual. Nominally, an operator was responsible for start-up of the mixing pots, preparing two mixes, pouring the mixes into the booster cylinders and placing finished boosters into the cooling bins. Operators on the day shift in Booster Room 1 worked in teams of two. The first operator would prepare the mixes and pour the base mix. The second operator would set up the table to prepare for the pour and then pour the Pentolite. The more senior operator generally was responsible for preparing the mixes. In Booster Room 2 and during the Booster Room 1 second shift, the operator worked by himself on one line. In Booster Room 2, the lines were totally independent. In Booster Room 1, the lines shared certain pots.

The supervisor spoke Spanish and English and had over 20 years' experience with the company. He oversaw production and was responsible for establishing production runs, monitoring work practices, safety and quality, shipping and receiving materials, and clean up. The supervisor conducted safety meetings with an emphasis on housekeeping, washing before eating, and never taking contaminated clothing home. Because most workers spoke only Spanish; the supervisor was the principal translator and communications link between management and employees at the plant.

5. Analysis of the incident

On January 7, 1998, two explosions occurred at the Sierra Kean Canyon facility and resulted in four fatalities, six injuries, and catastrophic damage to the site. The first explosion occurred at 7:54:03 a.m., and was followed by a second, larger explosion 3.5 seconds later, as recorded by the Seismology Laboratory at the University of Nevada, Reno. The interval between explosions was estimated by the laboratory to be accurate to ± 0.2 seconds. The CSB investigation team determined that the first explosion occurred in Booster Room 2, the second in the PETN building.

The explosions involved a number of explosive materials, including PETN, Comp-B, TNT, and other explosives purchased through the Department of Defense demilitarization program, such as A-3 and LX-14, used in place of Comp-B. Management estimates of the explosive materials present in the operating facilities at the time of the incident are presented below. The total quantities of each explosive ingredient is based on management's estimate of inventory differences following the explosion, compared to the December 31, 1997, inventory, and reconciled to account for shipments made and received. There were 47,000 pounds of unaccounted-for explosives estimated to have been destroyed by the explosions and subsequent fire.

Location TNT (lbs.) Comp-B (lbs.) PETN (lbs.) Total (lbs.) *

- Booster Room 1** 14,000 2,000 4,000 20,000
- Booster Room 2 9,000 2,000 1,000 12,000
- PETN Building and Magazine 15,000 15,000

*Based on company's estimate and includes the explosive quantities in finished
boosters.

**No detonation occurred in this room.

5.1. Sequence of events

At 3:00 p.m. on January 6, an operator for the west side of Booster Room 2 left work early, leaving 50 to 100 pounds of melted explosive base mix in pot 5. He mentioned this to the other operator in the room, who later checked and saw the explosives in pot 5.
Explosives manufacturing operations began the next morning, January 7, shortly after 6:00 a.m. in Booster Room 1. Two teams of two workers each had finished mixing operations for the first batch of the day and were beginning to pour. A fifth worker was also working in Booster Room 1, packing the finished boosters from the previous day. The operator for the west side of Booster Room 2 arrived at work, and at about 7:30 a.m. visited Booster Room 1 to greet his fellow workers who were pouring boosters. He talked briefly with a Booster Room 1 operator about a pouring pitcher he had returned to that worker's locker in the change room, and then left at about 7:35 a.m. The supervisor arrived at approximately 7:40 to 7:45 a.m., stopped in Booster Room 1 for about 5 minutes, then rode to the nearby gravel pit in a backhoe with another worker.
Besides the operator assigned to the west side of Booster Room 2, there were three other workers in or near Booster Room 2. The suspected locations of the four workers are consistent with the locations of human remains found during the investigation. Worker locations at the time of the incident are shown in Figure 5.

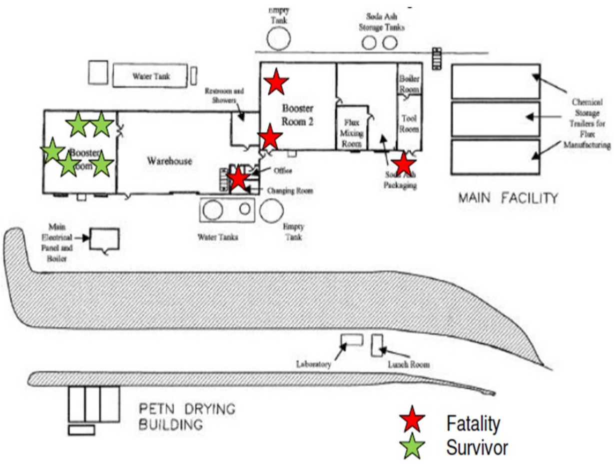


Figure 5

When the first explosion occurred, a worker in Booster Room 1 saw a huge fireball engulf a truck, which was parked immediately outside the building. The Booster Room 1 worker was thrown against the west wall, as the ceiling and east wall of the room collapsed on top of him and four other workers. Seconds later, a second, louder explosion occurred. After the explosions, the north, west, and south walls of Booster Room 1 were still standing; however, the rest of the site, including Booster Room 2, was essentially levelled. The site of the PETN building and adjacent magazine was now a 40-by 60-foot crater,

5.2. Sequence of explosions

Before the investigation team could determine the cause of the explosions, it was necessary to first determine which building exploded first. The Seismological Laboratory
at the University of Nevada, Reno, reported that their network of sensors recorded two explosions on January 7. Analysis of this seismic data pinpointed the time between the
explosions (3.5 seconds) and the sequence of explosions. The seismologists reported that "air waves unambiguously demonstrate that the northern of the two explosions occurred first." Because Booster Room 2 was located north of the PETN building, these findings confirmed the investigation team's determination that the first explosion took place in Booster Room 2. Moreover, seismic data indicated that the second explosion was stronger than the first. Because PETN has a higher energy content per pound than the explosives that were stored in Booster Room 2, and the PETN building contained more explosives than did Booster Room 2, these findings were also consistent with the investigation team's conclusion that Booster Room 2 exploded first, followed by the PETN building.

5.3. Melt/Pour Operations in Booster Room 2

Two separate production lines were located in Booster Room 2. There was no TN melting pots. All of the TNT used in the process was added to the mixing pots in a flake form. Since beginning operation on September 18, 1997, only four of the six pots in Booster Room 2 had been used. Each production line used one large base-mix pot and one smaller Pentolite-mix pot.
A new steam system put into service in Booster Room 2 provided high-capacity, low-pressure (less than 15 psig) steam heat to the mixing pots. The system was capable of quickly heating and melting the materials. Only a day shift schedule was worked in Booster Room 2. At the beginning of the day, all of the PETN, flake TNT, and Comp-B type materials needed for making boosters were already on the platform near the mixing pots, having been staged during the previous afternoon. The shift in Booster Room 2 normally started between 7:00 and 7:30 a.m. Unlike Booster Room 1, where there were two operators per process line; Booster Room 2 had only one operator per process line. Based on a composite of interviews with operators, the normal initial stepsfor starting up melt/pour operations in Booster Room 2 included:

- Check the pots for material.
- Open the steam supply and condensate return valves to the base-mix and Pentolite pots.
- Turn on the mixing motors.
- Break up chunks of Comp-B, if necessary.

The investigation team noted that some of the operators interviewed said that they did not check for material left in the pots. Operators reported that at the end of the shift, the base-mix and Pentolite mixing pots were normally left empty.

5.4. Melt/Pour Operations in Booster Room 1

Booster Room 1 had been in operation for over twenty years. It contained three TNT melting pots and four mixing pots. Two of the mixing pots were used for base mix. One of the mixing pots was used for Pentolite, which was used to finish the boosters. The last mixing pot was called the "Comp-B pot" because it was used to melt the materials that were commonly referred to as Comp-B. This additional pot was used because of the slow heat-up rate of the hot-water system in Booster Room 1.

Unlike Booster Room 2, in which employees worked only one shift, Booster Room 1 had a second shift that started at about 3:00 p.m. Working the second shift in Booster Room 1 resulted in operators using different steps to begin melt/pour operations. For example, since operations were already in progress from the day shift, there was no need to inspect the contents of mixers prior to beginning production. In Booster Room 1, the base-mix and Pentolite-mixing pots were normally left empty at the end of the second shift.

The investigation team determined that the use of different operating steps in Booster Room 1 and Booster Room 2 was significant. Operators trained during the second shift in Booster Room 1, but who were later assigned to work in Booster Room 2, probablydid not use a work routine that included looking into mixing pots prior to beginning melt/pour operations.

6. Analysis of credible initiating scenarios and process safety management

Several credible incident scenarios were identified and considered by the investigation team. While the investigation of this incident determined one of these scenarios to be the most probable, an absolute determination of which scenario actually caused the incident is not the most important issue. Each of the credible scenarios demonstrated the existence of serious safety system failures at the Kean Canyon plant. While one of these scenarios were found to be the most probable by the investigation team, the other scenarios could have easily resulted in a disaster on another occasion. Examination of each credible scenario provides a more complete understanding of the safety problems at the Kean Canyon plant. (An alternative scenario that attributes the initial explosion to an act of sabotage was presented to the CSB for its consideration. The CSB's analysis of and response to this alternative scenario is to be found in the full report.)

6.1. Most probable scenario

Solidified Material in Pots at Start of Day Shift

The night before the explosion, an operator in Booster Room 2 left 50 to 100 pounds of explosives in base-mix pot 5. This was verified by another operator on the parallel production line who looked into pot 5. This other operator indicated that the depth of explosive material left in pot 5 was about four inches, which matched the weight of explosives that he estimated. At the end of each day, operators were instructed to leave a steam line valve to each pot partially opened to keep the boiler cycling, to prevent freezing of condensate in the lines. This amount of steam would be insufficient, however, to maintain any quantity of explosive mix above its melting point if outside temperatures were below freezing. OSHA investigators reported that the temperature during the night before the explosion dropped to between 20- and 25-degrees Fahrenheit. Without agitation, the different explosives and binders of the mix tend to stratify due to their different densities. This stratification would increase the sensitivity of portions of the explosive material left in the pot. Turning on an agitator immersed two inches into a solidified mass of stratified explosives presents a high risk of explosion from the impact. An overcurrent protection device on the electrical mix motors in Booster Room 2 would stop the motor if the blade was unable to break up the explosives, but not before the start-up torque was applied to the explosives. Due to the solidified material in the explosives draw -off line on the bottom of the pot, it would be impossible for the explosives to simply break free of the pot without causing friction with the interior of the pot and shearing a portion of the explosives in the draw-off line. The day before the explosion, the operator who had left explosives in his pot offered the remaining material to the operator on the other production line in Booster Room 2. Because the operator who was leaving did not reach a firm agreement on whether the second operator would use the residual explosives, it is possible that no steam valves were left open that afternoon because leaving the valves open would make the remaining base mix too runny to pour. The operator who left early may have mistakenly thought that his remaining base mix would be used that afternoon and mixer motor. The investigation team concluded that and, thus, he failed to look in the pot the next morning before turning on the steam this was the most likely scenario.

The worker mixing in Booster Room 2 on the day of the explosion had learned to perform the basic melt/pour operation in Booster Room 1 while working on the second shift. The second shift workers in Booster Room 1 had a different starting process than the day-shift workers. Because mixing pots would already be in operation when they came to work, they did not need to turn on the mixing pot motors. This fact affected operator training. The on-the-job training was based on what operators needed to know to perform their work. Even if a trainer explained the need to check a pot before turning the mixing motor on, there was seldom an operational need to turn the mixing motor on.

It is doubtful that workers who learned the melt/pour operation on the second shift would have developed a work habit of checking a mixing pot before turning on the mixer motor.

The operator who left the material in his pot had been working in Booster Room 2 for eight weeks prior to the incident. His normal practice was to leave both of his mixing pots empty. Because he was the only person working his production line, he would normally know whether his pot was empty when he started work the next day. Some of the operators who worked in Booster Room 2 indicated that they did not need to look into the mixing pots in the morning because the pots were left empty at night. Leaving material in the mixing pot overnight was a change to normal operation, but it was an acceptable practice at the Kean Canyon facility to alter the usual process without discussion or management approval. Several months before the incident, when material had been left overnight in the Comp-B mixing pot in Booster Room 1, management made it clear that this was an unacceptable practice because it delayed the operation of the day-shift workers. Facility management did not consider this to be a safety issue.

Since the pots in Booster Room 2 heated material much faster than the pots in Booster Room 1 did, it is possible that the operator on the day of the incident thought that leaving material in the pot would not be hazardous. Metallurgical analysis of mixer parts found after the incident provided further evidence supporting the CSB's conclusion that explosive material was left in pot 5. This analysis showed that damage to the hub of the mixing blade was consistent with it having been in contact with explosives at the time of detonation.

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6.2. Other credible scenarios

6.2.1. Dry Mixing of PETN in the Pentolite Mixing Pot

One significant difference in the operations of the two booster rooms was that in Booster Room 2, PETN was added to the Pentolite pot without first adding TNT. This was done to reduce residual moisture from the PETN. The supervisor indicated that Booster Room 2 was given the PETN with the higher moisture content because the mixers in that room had a higher heating capacity. The practice of adding the PETN to the heated pot, without TNT as a solvent and lubricant, created conditions that were ideal for generating static electricity or high friction in the pot. Operators did not know that of the four explosives used in the process, PETN was most susceptible to electrostatic discharge, impact, and friction. Because supervisors at the facility did not observe the start-up processes in Booster Room 2, and because there was no written procedure for operations in this room, there was no wayfor supervisors to be aware that operators were mixing PETN without first adding TNT.

6.2.2. Chunks of Explosive Material

Operators routinely broke up chunks of explosive raw material by using a hammer. Use of any type of hammer to break chunks of explosives could cause a detonation. Workers described sometimes using a plastic mallet or a bronze hammer to break up the chunks of explosive raw material in a box, which was placed on other boxes or on the floor. Several workers indicated that they had used a steel, or carpenter's hammer to break up the material. Another practice was to knock the pieces together over the pot-feedopening. Workers described pouring some of the contents into a second empty box and then breaking up the contents with a hammer. Use of a carpenter's hammer or a bronze mallet to break apart large chunks created a serious potential for detonation due to impact or impingement of the material. It was also possible that there were foreign objects in the raw material that could have sparked or resulted in impingement of the explosives when struck with a steel carpenter's hammer. Even if a bronze, non-sparking hammer was used, an explosion could still be generated due to the impact of the tool. Moreover, LX-14 had recently been introduced into the booster-making process, and it had larger and harder chunks that required greater force to break apart. An additional problem faced by the workers in Booster Room 1 was the slow heat-up rate of the hot water system, which delayed the pouring operation. In the initial steps of filling the base mix pot, some liquid TNT was added, followed by Comp-B. To compensate for the slow heat rate, the operators broke up any large chunks in the Comp-B, LX-14, or other materials before they added the material to the base-mix and the Comp-B pots. The workers indicated that there had been a recent increase in the size and hardness of the chunks of the Comp-B or LX-14 materials they were receiving. Even though the mixers heated faster in Booster Room 2, the operators there would still break the larger chunks of Comp-B materials before they added it to the base mix pots. Another detonation hazard involved the possibility of large chunks of explosive material being impacted between the mixing blade and the pot walls or breaker bars. The inner wall of the large base-mix pots in Booster Room 2 were made of 3/8-inch stainless steel. As a result, these mixing pots were more rigid than the approximately 1/8-inch mixer wall thickness of stainless-steel pots used in Booster Room 1. This structural rigidity increased the potential for friction, shearing, and impact.

6.2.3. Foreign Objects in Mixers

Workers reported hearing scraping noises in the mixers in Booster Room 1 caused by foreign objects. Adding reclaimed explosives containing metal foreign objects created a high potential for detonation due to friction or sparking of the foreign objects. If the material left in the base mix pot in Booster Room 2 had partially melted before adding more Comp-B materials to the pot, it is possible that foreign objects in the material may have scraped along the inside of the pot, causing friction, which ignited the mix. Operators in Booster Room 1 indicated that it was common to find foreign objects in the Comp- B pot and the base-mix pots. Most of the foreign material originated in the Comp-B. The operators used the metal handle of a plastic bucket to help retrieve the foreign objects. Included in the operators' descriptions of foreign material found in the pots were nuts, bolts, screws, a conical-shaped piece of copper, and aluminium posts from booster-mould trays. These foreign objects were responsible on earlier occasions for causing damage to the inner shell of the large Comp-B pot in Booster Room 1.

Operators in Booster Room 2 also found foreign materials in the base mix, but these items tended to end up in the boosters rather than remaining in the pots. This was because the draw-off lines and valves were larger in the new Booster Room 2 facility.

7. Unsafe work practices and use of substitute materials.

Interviews with workers revealed the use of many unsafe work practices involving explosive materials. The investigation team also found problems with the substitution of different raw materials in the manufacturing process.

7.1. Unplugging Draw-off Lines with Metal Tools

The investigation team found that operators regularly used metal tools to unplug mixing pot draw-off lines in Booster Room 1. Several explosives manufacturing incidents during melt/pour operations at other companies have been caused by using metal tools to chip or forcefully break apart clogs in draw-off valves.

In Booster Room 1, draw-off lines and valves, especially on the Comp-B pot and the large base-mix mixing pot, clogged frequently. Two tools generally were used to clean out the clogged valves. The first tool was the wire handle of a plastic bucket. The loop in the end of the handle was used to help augur the material from the valve. The second tool was a 0.5-inch-diameter steel rod, with a looped handle. The working end of the rod was honed to a sharp point, which helped to break up the clogged material. The plant manager found this tool in Booster Room 1 on more than one occasion.

When the manager found the rod in the booster room, he stated that he told operators not to use the tool, and the rod was taken to the tool room. Operators reported, however, that this tool was routinely kept in Booster Room 1 and was also used to push unmelted TNT on the surface down into the liquefied TNT in the melting pots.

BR 2 had a different design of valve that did not require use of the metal tools so this was not considered to be the cause of the explosion.

7.2 Breaking down rejected boosters

Metal hammers were sometimes used to break apart rejected boosters. The outside workers broke down the boosters in the northwest corner of Booster Room 1, by the PETN magazine. Use of hammers created a serious potential for an impact or impingement ignition. Use of a steel hammer added the potential for sparking. Workers broke down rejected boosters when approximately 300 had accumulated. This occurred about every two or three months. The breakdown process involved placing the rejected booster on a block of wood on the floor and striking the booster with a hammer. A plastic hammer, a bronze hammer, and a steel carpenter hammer were all reported to have been used, depending on what was available.

Another hazard involved cleaning up the scrap pieces of the boosters using synthetic bristle brooms, plastic dustpans, and plastic buckets. This created electrostatic charges in the waste material. An electrostatic discharge potentially could detonate the material.

7.3. Using different explosive materials

The potential safety hazards of using LX-14 or other substitute Comp-B materials was not subjected to a management of change review before it was introduced into the pots.

The problem with LX-14 came to the attention of operators and management only when he material did not melt. Management was not informed that any problems existed with the size and consistency of the chunks.

8. Building spacing and construction

Buildings at Sierra were not located at safe distances from each other in order to prevent the propagation of an explosion from one building to another. Based on the explosive quantities contained in the buildings, the lack of effective barricading, and published safe intra plant distances (IME, 1996), Booster Room 2 should have been located at least 490 feet from Booster Room 1, rather than the actual separation distance of about 80 feet.

Additionally, Booster Room 2 and Booster Room 1 should have been located at least 245 feet from the PETN building, rather than the actual separation distances of about 220 feet and 185 feet, respectively. Moreover, if Sierra considered both booster rooms to be a single explosive facility for hazard analysis purposes, the recommended separation distance from the PETN building should have been increased to at least 295 feet. The flux operation and other chemical activities that were unrelated to the manufacture of explosives were located in rooms adjacent to the Booster Rooms. This resulted in one additional fatality and destruction of the chemical facilities from the explosion in Booster Room 2. The OSHA PSM standard requires explosives manufacturers to analyze the siting of their facilities.

A skylight had been installed over the drying room at the east side of the PETN building. The skylight could be breached by overpressure from an explosion in Booster Room 2. The skylight also made it easier for falling, hot debris from Booster Room 2 to penetrate the PETN building and detonate the explosive material. This could happen even if recommended barricaded intra plant distances had been used. The probability of hot debris falling through the roof of the PETN building would decrease, however, if the buildings were separated by the recommended distances. Terracing, which acted as a barricade, could protect only against high-velocity ballistic fragments that were projected horizontally. Terraces could not protect against falling debris. Building construction was also inadequate. Booster Room 2, like Booster Room 1 and the PETN building, had walls constructed of fully grouted, reinforced, 8-inch by 8-inch by 16-inch concrete blocks. The PETN building had a concrete roof that provided a degree of protection from external events.

9. Process Hazard Analysis

The OSHA PSM standard requires that explosives manufacturers perform a process hazard analysis (PHA) of their operations. Conducting an effective PHA requires that the PHA team includes personnel who have experience with the process and equipment that is being analyzed. No one from the Kean Canyon plant was involved in conducting the PHA of this facility.

The PHA team included Sierra's president, the vice-president for explosives, a process safety management specialist, and the compliance/engineering manager. This team performed PHA's of the booster-manufacturing process in Booster Room 1, and of the on-site transportation and storage facilities, completed on December 20, 1993, and May 17, 1994, respectively. A PHA was not performed on Booster Room 2. Management believed that a PHA for Booster Room 2 was not necessary because of the similarity of the operation with that in BR1. Operators were not aware of the existence of any PHA's.

When interviewed, some of the participants in the PHA did not recognize hazards listed in the study. For example, even though the PHA states that static electricity can potentially cause a detonation, one participant interviewed said that static electricity was not a hazard. Sierra managers were aware of some recent safety -related incidents in the explosives manufacturing industry. They had not systematically incorporated lessons learned from incidents at other companies into the PHA program, however. For example, clogged draw -off valves were routinely cleared at the Kean Canyon plant by using a half-inch-diameter metal rod. Management understood the hazards associated with this activity and had copies of a report describing how this practice had caused a detonation at another site.

All of the operators interviewed by the investigation team, however, considered the practice of using a metal rod to clear clogged valves a normal, routine operatingpractice.

The human factors analysis portion of the PHA did not include specific analysis of the effect of performance errors by booster room operators. The explosives and chemicals in co-located operations, hazards of those materials, process-safety information, and facility siting also was not covered.

The PHA of Booster Room 1 stated that workers should perform a visual inspection of raw materials to prevent placing scrap metal into the mixing pots. Operators and the plant supervisor reported that, in practice, raw materials were rarely inspected before pouring the material into the pot. The only documented inspection was a visual inspection of the contents of one box, done without removing the contents, which occurred occasionally when a new shipment arrived.

Operators normally did not find scrap metal until it came out of the draw-off valve into their pouring pitcher, or it was found in the bottom of the pot after the pot was empty.

The PHA also did not consider safe distance requirements in the siting of buildings and explosive materials. Lack of safe distance allowed the explosion in Booster Room 2 to destroy the flux room. As a result, a flux room worker died and unrelated chemical facilities were destroyed.

10. Training

10.1 Worker Training

Sierra's almost total reliance on the use of on-the-job training created a situation in which hazards were poorly understood and controlled. The melt/pour-training program relied on oral communication and physical demonstration to communicate the senior operator's expectations for job performance. Training effectiveness was dependent on the work habits, skills, experience, and memory of the operator doing the training. There were incentives to complete the training quickly. The trainer could lose salary if conducting training reduced the number of boosters the trainer produced. Moreover, without management-provided written procedures, checklists, standards, or performance criteria, the content of the training and the determination of what constituted acceptable performance was left to the discretion of the trainer.

Unless properly structured, implemented, and evaluated, on-the-job training can result in important information being omitted. Failure to communicate important information can result in the use of inconsistent work practices among employees. The on-the-job training program at the Kean Canyon plant made no provision for introducing new information from industry-wide experience.

Workers generally understood the need to work safely with explosive materials, however, they lacked the detailed information needed to do that. Workers in both booster rooms used work practices long recognized to cause detonations in melt/pour operations in military facilities. The workers were not aware of the hazards of these unsafe practices.

10.2. Manager and Supervisor Training

The investigation team found serious deficiencies in line managers' and the supervisor's technical understanding of the reasons why work precautions were necessary when working with explosive materials. Managers primarily relied on their personal work experience in addressing plant safety.

Management believed that, short of using a blasting cap, it was almost impossible to detonate the explosive materials used or produced at the Kean Canyon plant. This was the case even though the PHA of Booster Room 1 and Sierra's own product literature identified numerous potential hazards that could lead to explosions.

Managers emphasized housekeeping as their primary safety concern. They did not adequately implement control measures identified in the PHA of Booster Room 1 into work practices. Management did not prepare a PHA for Booster Room 2.

11. Language Barriers

Spanish was the only language understood by the majority of the operating staff at the Kean Canyon plant. The generic OSHA training program used at the facility included a few Spanish language videotapes, but Material Safety Data Sheets (MSDS's) for the chemicals used on-site were not written in Spanish. The production supervisor and three of the production workers spoke and read both English and Spanish. When safety training was provided for the workers, it was conducted in English and translated into Spanish by one of the employees who spoke both languages. This was normally the production supervisor. Tests were written in English, and the supervisor translated the questions and the workers' answers. The translation process allowed opportunities for changes in meaning based upon the quality of the translation. There were no policies or procedures at the facility written in Spanish that could be referenced during training or during subsequent operation.

12. Employee participation in process safety management

Absence of employee participation in process safety activities was a major cause of the lack of understanding of hazards by the workers. The employee participation program at the Kean Canyon plant made no provision for employees to be involved in thedevelopment of safety programs and policies. According to the workers, no operators helped develop any of the programs. Workers were not aware that an employee participation program existed. Based on interviews with workers, their safety activities were generally limited to preventing fires, using dust masks, and clothing control. While employees were told to report problems, the issues they raised were considered by the supervisor to be production issues even though they could also have safety hazardimplications.

13. Management of change

There was no evidence that process changes were systematically evaluated using a management of change procedure. Many changes in the design, staffing, and the operation of Booster Room 2 had taken place since it was constructed. Some of these changes were implicated in the credible scenarios determined by the investigation team. Process changes included:

- leaving explosive material in pots;
- the varying composition of the Comp-B and substitute materials;
- single-operator versus two-operator operation;
- changes in heat transfer rates;
- changes in pot size and rigidity; and
- use of damp PETN

14. Incident investigation programme

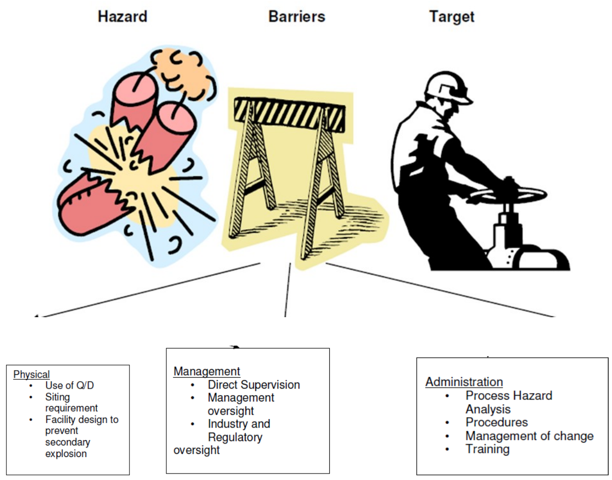
Sierra had an incident investigation program, but workers were unaware of it, and no investigations had been conducted. The program did not have criteria for identifying and investigating near-misses. In addition, lessons learned from incident investigations conducted at other explosives plants had not been communicated to Sierra personnel. This allowed unsafe practices to go uncorrected. The failure to systematically incorporate lessons learned from incidents at other sites and to conduct investigations of internal incidents and near-misses, perpetuated a lack of understanding of the hazards of the explosives manufacturing.

15. Safety audits

Management had no planned program of oversight to determine that safety management programs were effectively implemented or that safe work practices were followed. When supervisors and managers performed walkthrough inspections, they did not verify the knowledge and performance of the workers against documented standards.
Managers and workers indicated that managers visited the facility often. During these visits, if managers saw something that appeared to be unsafe, they brought it to the attention of the worker or the supervisor. These management walkthroughs, however, were not intended to verify specific elements of safety programs or the effectiveness of PSM activities.

16. Barrier Analysis

Barrier analysis is used to identify administrative, management, and physical barriersthat could prevent, control, or reduce energy flows such as explosions to targets such as people or objects. This barrier analysis was concerned with those barriers that could have prevented or mitigated the impact of explosions but that either failed or were missing.



16.1. Hazard Barriers Target

16.1.1. Administrative Barriers

One principle for administratively dealing with explosives hazards is to minimize risk by exposing the minimum number of people to the least quantity of hazardous material for as short a time as feasible. No personnel or explosives limits were established for production areas at the Kean Canyon plant. Thus, the storing of large quantities of Administration:

- Process Hazard
- Analysis
- Procedures
- Management of change
- Training
- Physical
- Use of Q/D
- Siting requirement

- Facility design to prevent secondary explosion
- Management
- Direct Supervision
- Management oversight
- Industry and Regulatory oversight

explosives in the production areas was common practice. Because workers were not taking finished boosters to storage magazines as they were produced, there was more explosive material in the booster rooms than necessary.
Safety systems under the PSM program were not effectively implemented. Although a PHA had been developed, it did not address operation of a mixer with solid materials, hammering chunks of explosive materials or boosters, or addition of PETN to the mixing pot without TNT to dissolve it. The PHA's recommended actions for controlling static electricity, hot pot, scrap metal, and pour valve problems were not implemented. No Kean Canyon plant personnel were involved in conducting the PHA. Other than informal safety reminders and observing the testing of boosters, workers had no formal training regarding explosives safety. There were no written procedures provided to the workers.

16.2. Management Barriers

The supervisor who was primarily responsible for worker safety had no formal explosives safety training. There was no supervision of operations when the plant manager was not at work. There was no systematic verification that safety management systems were implemented and that safe work practices were being followed.
Neither industry nor regulatory agencies have established training guidelines to ensure that owners and explosives workers understand fundamental explosives safety and manufacturing principles and practices.

16.3 Physical Barriers

The skylight in the roof of the PETN building may have permitted falling debris to more easily penetrate the building and cause the second explosion. Thus, the design of the PETN building did not prevent propagation from the explosion in Booster Room 2.

17. Change analysis

Change analysis is one of the tools used to help identify the cause of incidents. In change analysis, one question is considered: What was different about the operation on the day of the incident? If Sierra manufactured boosters for more than 20 years without serious incident, what changed to permit this explosion to occur?
Change Analysis:

- 13 changes identified
- Each considered for relevance in the credible scenarios
- Used to support the probable scenario.

18. Root and Contributing causes analysis

Underlying root causes found at various management levels permitted the explosion at Sierra to occur. Addressing root causes has a greater effect on improving safety. The root causes as well as contributing cause of this incident are shown below.

18.1. Root causes

- Hazard study was inadequate
- Training programmes inadequate
- OI's inadequate or not available
- Insufficient safety distances
- No systematic auditing/inspection programme
- Employee participation programme inadequate.

18.2. Contributing cause

Oversight by regulatory organisations inadequate.
The goal of the CSB recommendations is to communicate and institutionalize lessons learned. Accordingly, the recommendations are organized by responsible agencies, organizations, or groups.

19. Recommendations

19.1 Sierra and other explosives manufacturers

- Process Safety Management (PSM) requires both careful planning andimplementation.
- Prevention of explosions, as well as prevention of propagation of explosions, requires a clear understanding of explosives safety principles and safe practices.
- Recommendations in this section have been prepared based on the conditions found at Sierra's Kean Canyon plant.

Explosives manufacturers should evaluate the effectiveness of their explosives safety programs using the following recommendations (numbered for identification) to ensure that:

1. Process hazard analyses include examination of quantity-distance requirements, building design, human factors, incident reports, and lessons learned from explosives manufacturers.
2. Written operating procedures are specific to the process being controlled and address all phases of the operation
3. Procedures, chemical hazards, and process safety information are communicated in the language(s) understood by personnel involved in manufacturing or handling of explosives.

4. Explosives training and certification programs for workers and line managers provide and require demonstration of a basic understanding of explosives safety principles and job specific knowledge.
5. Process changes, such as the construction or modification of buildings, or changes in explosive ingredients, equipment, or procedures are analyzed and PSM elements are updated to address these changes.
6. Pre-startup safety reviews are performed to verify operational readiness when changes are made.
7. All elements of OSHA's Process Safety Management Standard are verified by performing periodic assessments and audits of safety programs.
8. The employee participation program effectively includes workers and resolves their safety issues.
9. Explosives safety programs provide an understanding of the hazards and control of detonation sources. These include:
   - foreign objects in raw materials;
   - use of substitute raw materials;
   - specific handling requirements for raw materials;
   - impact by tools or equipment;
   - impingement;
   - friction;
   - sparking; and s
   - static discharge.
10. The following issues are addressed in plant design or modification:
   - Operations in explosives manufacturing plants are separated by adequate intra plant distances to reduce the risk of propagation
   - Unrelated chemical or industrial operations or facilities are separated from explosives facilities using quantity-distance guidelines.
   - Facilities are designed to reduce secondary fragmentation that could result in the propagation of explosions.

19.2. Institute of Makers of Explosives (IME)

1. Develop and disseminate process and safety training guidelines for personnel involved in the manufacture of explosives that include methods for the demonstration and maintenance of proficiency.
2. Distribute the CSB report on the incident at Sierra to IME member companies.
3. Develop safety guidelines for the screening of reclaimed explosive materials.

19.3. Nevada Occupational Safety and Health Enforcement Section

Increase the frequency of safety inspections of explosives manufacturing facilities due totheir potential for catastrophic incidents.

19.4. Department of Defence

1. Develop a program to ensure that reclaimed, demilitarized explosives sold by the Department of Defence are free of foreign materials that can present hazards during subsequent manufacturing of explosives.
2. Provide access to explosives incident reports and lessons learned information to managers and workers involved in explosives manufacturing, associations such as IME, government agencies, and safety researchers.

20. Melt/pour incidents elsewhere.

The following explosions have occurred in melt/pour operations at other sites. These accounts indicate the degree of hazard associated with melt/pour operations and the types of initiating events that must be controlled. The source of this data is the U.S. Army and the IME:

- 7/24/16 Clogged draw-off pipe was being cleared with brass rod, which impinged heated Amatol (60/90) against steel pipe, causing detonation. 1 Fatality 3 Injuries Trent, Great Britain
- 11/04/18 Foreign material was present in the melt pot due to lack of screening of fresh TNT or reworked Amatol. Approximately 1,200 lbs. of TNT was added to the pot from boxes without screening or examination. About 200 lbs. of scrap Amatol was added directly. 64 Fatalities 100 Injuries Perth Amboy, New Jersey
- 12/12/41 Sublimed TNT crystals in ventilator duct due to high TNT vapor (0.87 mg/m³) caused the explosion. Sublimed TNT crystals are sensitive to friction, impact, or static spark. 13 Fatalities 53 Injuries Burlington, Iowa
- 3/4/42 Draw-off valves slamming shut were suspected in detonation of TNT (60-40 Amatol). Also, the exhaust ventilation system was clogged by sublimation. The TNT vapor level was 0.80 mg/m³. 22 Fatalities 84 Injuries Burlington, Iowa
- 3/24/45 A hot-water hose with brass nozzle was being forced into a clogged draw-off pipe on a TNT melt unit. Impact or friction caused the explosion. 2 Fatalities Joliet, Illinois
- 5/26/45 The agitator impacted a screen in a mixing pot or the valve diaphragm failed, resulting in metal-to-metal contact in TNT melt operation. 9 Fatalities 6 Injuries Grand Island, Nebraska
- 10/01/51 Excess Comp-B detonated when warheads struck each other or fell to ground. Metal-to-

metal contact of items coated with Comp-B caused the detonation. 5 Fatalities Hawthorne, Nevada

- 2/20/59 Friction between a steel spatula and concrete floor contaminated with DNT sublimated crystals caused a detonation. 1 Injury Dottikon, Switzerland
- 7/6/61 Prolonged heating of 60 lbs. of molten Pentolite (55% PETN/45% TNT) led to detonation after seven hours. (Rotary valve was involved in explosion.) Property damage Seneca, Illinois
- 10/8/63 Cyclotol (70% RDX/30%TNT) detonation caused by impingement of explosives with spark-proof hammer and screwdriver while cleaning draw-off lines and valves. 2 Fatalities Milan, Tennessee
- 8/16/68 Detonation of cyclotol melt operation probably caused by adding "riser scrap," which is explosive solidified in the risers used to fill projectiles and grenades, that normally is introduced into the melt pot when the molten explosive could bathe the scrap and soften it for re-melting. If riser scrap added prematurely, impact of the agitator-could provide source of detonation. Evidence of detonation inside the melt pots was found. 6 Fatalities 4 Injuries Shreveport, Louisiana
- 7/25/79 Decomposition of PETN during melting released oxides of nitrogen. Heat was removed but the reaction continued until detonation. Property damage East Camden, Arizona
- 8/18/89 A clogged draw-off line had been removed from a pot. Pentolite in the line detonated when struck by a non sparking screwdriver with a rawhide mallet 2 Fatalities Joplin, Missouri

By the Chemical Safety and Hazard Investigation Board**.**
Paul L. Hill, Jr.
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Member

UN Decisions and the Explosives Industry

By: David W. Boston, UN Consultant, Institute of Makers of Explosives

Summary. This paper reviews the changes in the UN Model Regulations, the Globally Harmonized System of Classification and Labelling, and the Manual of Tests and Criteria as they pertain to the explosives industry. IME participates in the fora related to these instruments. The key changes adopted during the recently completed 2017/2018 biennium include the creation of additional entries for electronic detonators, revision to an entry for ammonium nitrate, and a new test for AN emulsions, water gels and suspensions.

Introduction. Within the United Nations, there are two bodies whose work significantly influences national and international regulations worldwide. These are the Sub-Committee of Experts on the Transport of Dangerous Goods (TDG) and the Sub-Committee of Experts on the Classification and Labelling of Chemicals (GHS). The former develops model regulations related to the transport of dangerous goods including classification, packaging, marking, labeling, placarding, shipping papers, and other transport related activities. The latter develops recommendations for classification and provision of hazard information in the form of labels and safety data sheets for all work activities including transportation (deferring to the TDG), manufacturing, storage, distribution, use, and so forth.

A sub-group within the TDG is its working group on explosives that provides technical support related to the classification and testing of explosives under both the TDG and GHS systems. Due the specialized nature of issues related to explosives that arise at the TDG, they are assigned usually to the EWG that meets separately from, but concurrently with, the TDG. The EWG also consults with the GHS on issues related to physical hazards of explosives. The outcome of this work is reported back to the relevant sub-committee at which time a decision is taken whether to adopt or reject a proposal or to request additional information be developed before the proposal is considered further.

The two sub-committees work on a biennial basis and that work results in amendments to the following documents:

Recommendations on the Transport of Dangerous Goods, Model Regulations (TDG, ST/SG/AC.10/1) – related to transportation of dangerous goods, this manual addresses subjects such as classification, security, packaging, and hazard communication.

[1] Referred to as EWG (explosives working group) throughout this paper

[2] Referred to as "Model Regulations" throughout this paper

The document serves as the basis of national and international regulations on the transport of dangerous goods.

Referre

- Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria (TDG/GHS, ST/SG/AC.10/11) – this document provides logic for classification of dangerous goods under the TDG and GHS systems. The document also provides tests and criteria to support those classifications.

Referre

- Globally Harmonized System of Classification and Labelling of Chemicals (GHS, ST/SG/AC.10/30) – Deferring to the TDG system where applicable, this document provides classification criteria for chemicals in all sectors including transport, manufacturing, storage, distribution, and use. The document also globally harmonizes communication elements used in hazard communication including labels and safety data sheets.

IME's participation.

Various groups participate in the work of these subcommittees including member states (also known as "experts"), observer nations, UN specialized agencies, other international bodies, and non-governmental organizations (NGOs). All groups are allowed to present proposals, comment on proposals and participate in various working groups; however, only the "experts" have the right to vote on proposals.

The Institute of Makers of Explosives (IME) participates as an NGO on both the TDG and GHS sub-committees. IME's participation is led by its UN Consultant and, presently, two subject matter advisers, Dr. Noel Hsu (IME member company Orica USA, Inc.) and Dr. Jackson Shaver (IME member company Special Devices, Inc.). IME is an active participant in the work of the EWG as well, with IME's UN Consultant serving as the working group's secretary.

2017/2018 Recap.

The following presents a summary of work addressing explosives and related matters completed in the 2017/2018 biennium. It should be noted that the work of the two sub-committees extends well beyond the subject of explosives; however, this paper only addresses those proposals addressing explosives.

1. **Electronic detonators** – Based on a proposal from the NGO Australian Explosives Industry & Safety Group (AEISG), the TDG sub-committee, on the recommendation of the EWG, adopted three new entries to distinguish between electronic and electric detonators To accomplish this, the TDG:

    - Added 3 new entries into the Dangerous Goods List (DGL) of Chapter 3.2 of the Model Regulations. Once published in the 21st Revision of the Model Regulations (expected in mid-2019), these entries will appear in the DGL as shown in Table 1.

UN No.	Name and description	Class or division	Subsidiary hazard	UN packing group	Special provisions	Limited and excepted quantities		Packagings and IBCs		Portable tanks and bulk containers	
(1)	(2)	(3)	(4)	(5)	(6)	(7a)	(7b)	(8)	(9)	(10)	(11)
0511	DETONATORS, ELECTRONIC programmable for blasting†	1.1B				0	E0	P131			
0512	DETONATORS, ELECTRONIC programmable for blasting†	1.4B				0	E0	P131			
0513	DETONATORS, ELECTRONIC programmable for blasting†	1.4S			347	0	E0	P131			

[3]Referred to as "MTC" throughout this paper
[4]Referred to as "GHS Purple Book" throughout this paper

- Added UN 0512 and 0513 to the indicative list of high consequence dangerous goods found in Table 1.4.1 of Chapter 1.4 (Security Provisions) of the Model Regulations. Since all Division 1.1 explosives are included in the list, it was not necessary to add UN 0511 to the list.

- Modified the definition of “Detonators” found in Appendix B of the Model Regulations to include a reference to electronic detonators. Beginning with the 21st Revision, the definition will appear as follows:

  Detonators

  Articles consisting of a small metal or plastics tube containing explosives such as lead azide, PETN or combinations of explosives. They are designed to start a detonation train. They may be constructed to detonate instantaneously, or may contain a delay element. The term includes:

  DETONATORS FOR AMMUNITION and

  DETONATORS for blasting, ELECTRIC, NON-ELECTRIC, and ELECTRONIC programmable.

  Detonating relays without flexible detonating cord are included.

- Added a new definition to Appendix B to describe electronic detonators. That definition will read as follows:

  DETONATORS, ELECTRONIC programmable for blasting

  Detonators with enhanced safety and security features, utilizing electronic components to transmit a firing signal with validated commands and secure communications. Detonators of this type cannot be initiated by other means.

2.UN 0222 Ammonium nitrate – Based on a proposal from IME, the TDG subcommittee amended Special Provision (SP) 370 of Chapter 3.3 of the Model Regulations to clarify to what types of ammonium nitrate (AN) the 1.1D entry UN 0222 applies. The revised SP will read:

370 This entry only applies to ammonium nitrate that meets one of the following criteria:

- *Ammonium nitrate with more than 0.2% combustible substances, including any organic substance calculated as carbon, to the exclusion of any added substance; ~~and~~or*

- *Ammonium nitrate with not more than 0.2% combustible substances, including any organic substance calculated as carbon, to the exclusion of any added substance, that gives a positive result when tested in accordance with Test Series 2 (see Manual of Tests and Criteria, Part I). See also UN 1942.*

This entry shall not be used for ammonium nitrate for which a proper shipping name already exists in the Dangerous Goods List of Chapter 3.2 including ammonium nitrate mixed with fuel oil (ANFO) or any of the commercial grades of ammonium nitrate.

3.New test for UN 3375 – Extensive research was carried out by IME’s member company Orica on the Koenen Test, which demonstrated that for certain ANEs this test generates false positives. Based on a proposal from IME and Canada, the TDG subcommittee added a new test to Test Series 8 to evaluate ANEs suspected of yielding false positives in the 8(c) Koenen test due to high water content and/or the presence of low volatility oils. The new test, designated “8(e) Canmet/CERL Minimum Burning Pressure (MBP) Test”, will only be used to evaluate those ANEs that fail the 8(c) test and meet criteria of reaction time and water content. Several amendments to the MTC and the GHS Purple Book were required to add the 8(e) test:

Amended the last sentence of SP 309 of Chapter 3.3 of the Model Regulations to read as follows:

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[5] SP 370 only applies to UN 0222

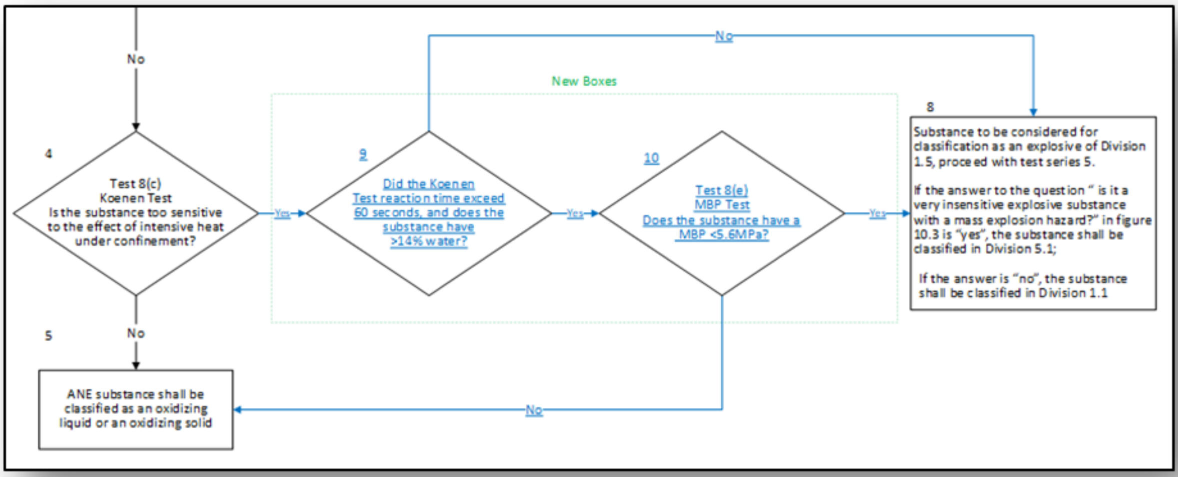
[6] Throughout this paper, *blue underscore* = new text, *~~red strikethrough~~* = deleted text, *black text* = unchanged text

[7] Ammonium nitrate emulsion or suspension or gel, intermediate for blasting explosives

Substances shall ~~satisfactorily pass Tests 8(a), (b) and (c)~~ satisfy the criteria for classification as an ANE of Test Series 8 of the Manual of Tests and Criteria, Part I, Section 18 and be approved by the competent authority.

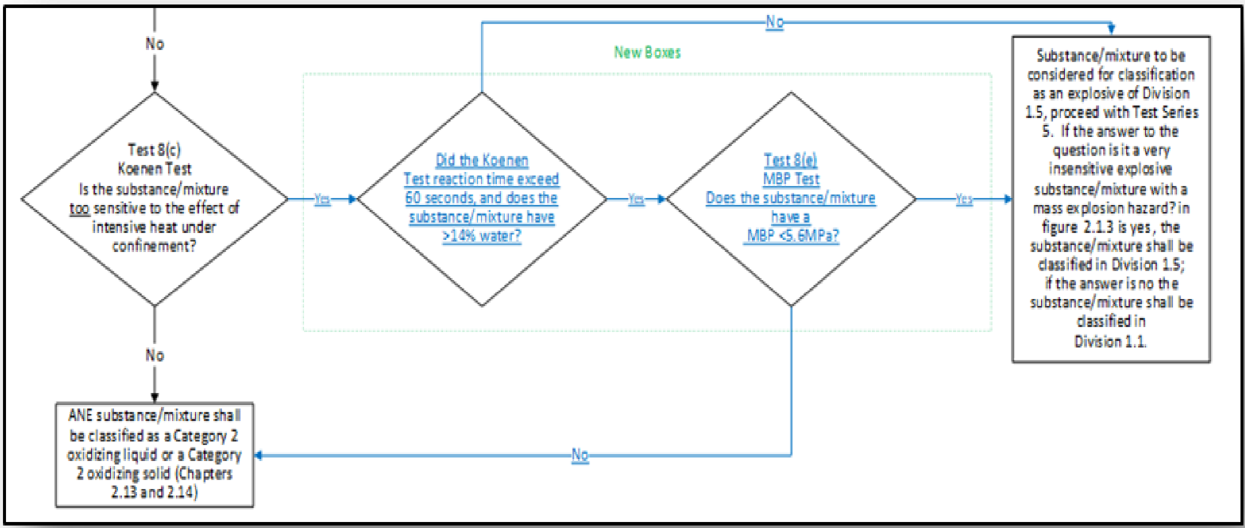
- Inserted the 8(e) MBP test into the ANE classification flowchart in Figure 10.4 of the MTC (see Figure 1).

Figure 1: New boxes added to MTC Figure 10.4



- Inserted the 8(e) MBP test into the ANE classification flowchart in Figure 2.1.4 of the GHS Purple Book (see Figure 2).

Figure 2: New boxes added to GHS Purple Book Figure 2.1.4



- Amended MTC Section 18.1 to add appropriate references to the 8(e) test:

The assessment whether a candidate for "ammonium nitrate emulsion or suspension or gel, intermediate for blasting explosives (ANE) is insensitive enough for inclusion in Division 5.1 is answered by series 8 tests and any such candidate for inclusion in Division 5.1 should pass each of the three types of tests comprising the series 8(a), 8(b), and 8(c), or if the substance failed the 8(c) and the substance had a time to reaction in 8(c) longer than 60 seconds and a water content greater than 14%, the series 8 (a), 8(b), and 8(e). The ~~three~~ test types are:

Type 8 (a): a test to determine the thermal stability

Type 8 (b): a shock test to determine sensitivity to intense shock

Type 8 (c): a test to determine the effect of heating under confinement

Type 8 (e): a test to determine the effect of pressure on combustion

- Added the 8(e) test to the list of Series 8 tests in MTC Section 18.2:

Test Code	Name of Test	Section
8(a)	Thermal Stability Test for ANE[a]	18.4
8(b)	ANE Gap Test[a]	18.5
8(c)	Koenen Test[a]	18.6
8(d)	Vented Pipe Tests[b]	18.7
8(e)	CanmetCERL Minimum Burning Pressure (MBP) Test[a]	18.8

- Amended MTC Section 18.6.1.4 to indicate when the 8(e) test can be used if a false positive is suspected in the 8(c) test:

The result is considered "+" ~~and the substance should not be classified in Division 5.1~~ if three negative (-) results cannot be achieved within a ~~minimum~~maximum of five tests. In such a case, the ANE candidate may either be assigned to the class of explosives or, if the time to reaction exceeds 60 seconds and the substance has greater than 14% water, it can be subjected to Test 8 (e) (as described in 18.8) to determine whether it may be classified in Division 5.1.

- Added the new 8(e) test procedure as section 18.8. Too lengthy to be reproduced here, the procedure may be found in the 54th Session EWG Report, UN/SCETDG/54/INF.50, Annex 3, Amendment 5 (begins on page 15), available at: http://www.unece.org/fileadmin/DAM/trans/doc/2018/dgac10c3/UN-SCETDG-54-INF50e.docx

4.New test and data to evaluate nitrocellulose – Based on proposals from the NGO European Chemical Industry Council (CEFIC), the TDG adopted new tests and data for evaluating the stability of nitrocellulose:

- Added two special provisions to Chapter 3.3 indicating when tests should and should not be applied:
- *393 The nitrocellulose shall meet the criteria of the Bergmann-Junk test or methyl violet paper test in the Manual of Tests and Criteria Appendix 10. Tests of type 3 (c) need not be applied*
- *394 The nitrocellulose shall meet the criteria of the Bergmann-Junk test or methyl violet paper test in the Manual of Tests and Criteria Appendix 10.*

- Added SP number 393 to column 6 of the DGL for entries UN 0340, 0341, 0342 and 0343.
- Added SP number 394 to column 6 of the DGL for entries UN 2555, 2556, 2557 and 3380.
- Added Appendix 10 (Stability Tests for Nitrocellulose Mixtures) to the MTC. Appendix 10 provides test method for determining nitrocellulose stability. Too lengthy to reproduce here, the complete text of this new appendix may be found in the consolidated list of draft amendments adopted during the 51st – 53rd sessions, ST/SG/AC.10/C.3/2018/65, beginning on page 57, available at: http://www.unece.org/fileadmin/DAM/trans/doc/2018/dgac10c3/ST-SG-AC.10-C.3-2018-65e.docx
- Reworded Section 51.4.5.1 of the MTC to read, "A compilation for the test results and classification data for more than 200 industrial nitrocellulose products is given in Appendix 11."
- Added Appendix 11 (Compilation of classification results on industrial nitrocellulose for the purposes of supply and use according to GHS chapter 2.17, which can be used for the classification of Industrial NC products) to the MTC. Too lengthy to reproduce here, the complete text of this new appendix may be found in the consolidated list of adopted texts, ST/SG/AC.10/C.3/2018/64, beginning on page 2, available at: http://www.unece.org/fileadmin/DAM/trans/doc/2018/dgac10c3/ST-SG-AC.10-C.3-2018-64e.docx

5.Use of the MTC in the context of the GHS – over the past two biennia (2015 – 2018), the EWG was engaged in a review of the MTC with the intent to broaden the applicability of the document from solely transport-related to applicability for all sectors within the GHS system. The goal of the review was to remove references to "transport" except where essential, make the document applicable to both TDG and GHS purposes, and not affect current transport classifications. The review was completed at the end of the 2017/2018 biennium and will result in the publication of a 7th revision of the MTC. As this work continued through the last meeting of the biennium (TDG 54th session), and last minute corrections and amendments were made during that session, a clean version of all the amendments is currently pending. Readers are encouraged to look for Addenda 2 (ST/SG/AC.10/46/Add.2) to the TDG/GHS Committee report (ST/SG/AC.10/46) that, once published, will be available at: http://www.unece.org/trans/main/dgdb/dgcomm/ac10rep.html

6.Review of GHS Chapter 2.1 – also over the past two biennia, the EWG has been engaged with a GHS informal correspondence group (ICG) to review Chapter 2.1 (Explosives) of the GHS Purple Book. The mandate of this review was to review the technical criteria for assignment of explosives within the GHS to make that classification system appropriate to all sectors covered by the GHS without consequential changes to the current classification system in transport. By the end of the biennium, a 2-category classification system for GHS purposes was proposed and generally agreed by the EWG and ICG with Category 1 being those explosives that, for whatever reason, have not been assigned a transport classification and Category 2, those explosives that have been assigned a transport classification. Category 2 would be further divided into three subcategories: 2A (high hazard), 2B (medium hazard) and 2C (low hazard). In general, criteria have been tentatively agreed; however, this work will continue into the 2019/2020 biennium.

7.Others – The previous sections of this paper discuss major additions and amendments to the Model Regulations, the MTC, and the GHS resulting from the work of the EWG. Other amendments were also considered and adopted during the 2017/2018 biennium:

- Added Division 1.6 to the indicative list of high consequence dangerous goods found in Table 1.4.1 of Chapter 1.4 (Security Provision) of the Model Regulations.
- Amended the outdated reference to "ISO 12097" in section 2.1.3.6.4(b) of the Model Regulations to read "314451-2 using a heating rate of 80 K/min". Section 2.1.3.6 deals with exclusion from Class 1 and section 2.1.3.6.4 provides the criteria for such an exclusion.
- In the Spanish edition of the Model Regulations, amended the description for "Charges, shaped, flexible, linear" (UN 0237 and UN 0288) to read "CARGAS MOLDEADAS LINEALES FLEXIBLES".
- Removed an unnecessary reference to para. 2.1.1.1(c) contained in Section 2.1.3.3.1 of the Model Regulations:
- *If the substance is manufactured with a view to producing a practical explosive or pyrotechnic effect ~~(2.1.1.1 (c))~~, it is unnecessary to conduct Test Series 1 and 2.*

- Amended Section 16.5.1.4(c) of the MTC to better define what criteria should be used in determining what means of initiation to use when performing the 6(b) test on non-intentional explosive substances:

Substances not intended for use as explosives, but provisionally accepted into Class 1, should be tested using whichever initiation system ~~gave a "+" result~~ gave evidence of a mass explosion in a type 6 (a) test.

2019/2020 Biennium. The following summarizes those items that have been included on the EWG work program for the current biennium:

1. **Review of test series 6.** The mandate of this review is to remove over specifications, redundancies, impractical specifications (due to limited or no availability of test materials), and to otherwise provide improvements to the test series drawing upon decades of experience performing the tests and assessing test results.

2. **Improvement of test series 8.** Work will continue with a goal to improving the 8(c) Koenen Test used for classifying ANEs into UN 3375 (Division 5.1) and seeking practical improvements or alternatives to the 8(d) Vented Pipe Test used for evaluating the suitability of ANEs for containment in tanks as oxidizing substances (i.e., UN 3375).

3. **Review of tests in parts I, II and III of the Manual of Tests and Criteria.** Nothing specific has yet been identified for this item.

4. **UN standard detonator.** The current standard detonators, described in Appendix 1 of the MTC are no longer commercially available. Additionally, there are two versions (European and USA) of the detonator. The goal of this review is to develop a single specification that will meet the use requirements for a standard detonator and that will be readily available to those performing sensitivity tests on explosives.

5. **Review of packing instructions for explosives.** Nothing specific has yet been identified for this item.

6. **Application of security provisions to explosives N.O.S.** Nothing specific has yet been identified for this item.

7. **Test N.1 for readily combustible solids.** Nothing specific has yet been identified for this item.

8. **Review of Chapter 2.1 of the GHS Purple Book.** The work will continue to refine the GHS classifications generally agreed during the last biennium and to develop appropriate label and SDS specifications. Once that is complete, a rewrite of the chapter will be undertaken. Presently, the goal for completion is the end of the 2019/2020 biennium. This project will be led by the ICG chair (Sweden) with input, as needed from the EWG.

9. **Energetic samples.** Nothing specific has yet been identified for this item.

10. **Issues related to the definition of explosives.** Nothing specific has yet been identified for this item.

11. **Review of packaging and transport requirements for ANEs.** Nothing specific has yet been identified for this item.

UN Website. Details of the work of the TDG and GHS sub-committees can be followed by reviewing the information available at UN's Dangerous Goods website. There, one will find information regarding meetings and meeting documents (agendas, report, working papers, and informal papers),

The website is available here: http://www.unece.org/trans/danger/danger.html

About the Author. Active with IME since 1985, David Boston has served as IME's UN Safety Consultant since 1995. He has been an IME board member since 1992, has served as chairman of IME's Transportation & Distribution Committee, Safety & Health Committee, UN Committee, GHS Subcommittee, and several other working subcommittees.

During his tenure as IME UN Safety Consultant, David has served as head of delegation on both the United Nations Sub-Committee of Experts on the Transportation of Dangerous Goods (TDG) and Sub-

Committee of Experts on the Globally Harmonized System of Classification and Labelling of Chemicals (GHS). He also serves as secretary of the TDG's Working Group on Explosives. Among other things, David was instrumental in IME's recognition by the TDG and GHS as a Non-Governmental Observer (NGO), the TDG's inclusion of a harmonized identification marking standard in that Sub-Committee's Model Regulations, and the TDG's acceptance of a non-explosive classification for ammonium nitrate, suspension, and gels.

David holds a BA in Business Administration and has worked in the explosives regulatory compliance field for more than 40 years. He founded (1993) and is president of Owen Compliance Services, Inc., the regulatory compliance division of IME member company Owen Oil Tools LP.

Born and raised in the Dallas/Fort Worth, Texas area, David still lives in the North Texas area with Patty, his high school sweetheart and wife of over 40 years. He enjoys landscape and wildlife photography in his spare time.

BEYOND BEHAVIOUR BASED SAFETY: A NEUROSCIENCE PERSPECTIVE

Presented by The University of South Africa (UNISA)

BEYOND BEHAVIOUR BASED SAFETY: A NEUROSCIENCE PERSPECTIVE

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Jenny Venter is registered as an Industrial psychologist and lectures on psychological adjustment and wellness in the work context at the department of Industrial and Organisational Psychology at the University of South Africa. She has 10 years' consulting experience in various areas including HR information technology, organisation development and coaching. She is currently completing her PhD, with a focus on applied neurosciences.

Introduction

The management and reduction of workplace injuries is of constant concern to industry and government stakeholders, not only due to the social and moral imperatives but also the associated economic burden, with accidents, incidents and fatalities costing economies around the globe billions each year. Existing risk management strategies (specifically Behaviour Based Safety or BBS models) rely on overt behavioural observation to draw conclusions about the employee's attitudes to safety. These include the successful Antecedent-Behaviour- Consequence (ABC) and Skills-Rules-Knowledge (SRK) models and safety practices such as the Job-Safety-Analysis (JSA) procedure (Elliot et al. 2015). However, despite the achievements of BBS strategies, these models fail to provide meaningful explanations for breakdowns in safe working behaviour.

The argument in this article is that an applied Neuroscience approach to safety management can contribute to the enhancement of safety in the explosives industry and any hazardous work environments. The rationale for the argument is that Neurosciences provide us with an integrated, holistic approach whereby the brain, mind and body are not viewed separately but as an integrated whole (Arden, 2019). It provides us with important information about the mutual influence of these systems on safety, for example a thorough understanding of the motivation behind behaviour and decision making and the role of wellness factors such as perception awareness, self-awareness and control, collaboration, adaptability, innovation, lifestyle, fatigue -, drug and alcohol awareness and the management thereof.

The effect of human factors such as inattention, financial stressors, social stressors, frustration, fatigue, complacency and other social factors, and their influence on safety performance and physical safety has always been recognised in safety management systems. Many programs to manage human factors has been introduced as part of safety management programs, such as programs to improve attention, programs to improve fatigue management, programs to assist people to deal more effective with stress, bullying and harassment, mental health programs and suicide prevention programs. Although the benefits of some of these programmes are undeniable, they focus on conscious risk management strategies, which neglect subconscious mental and emotional responses that can contribute to unsafe practices. Neuroscientific research estimates that up to 95% of human's everyday actions are subconscious (Clemson, 2009). In response to this, Sylvestre (2017) has advocated a new approach to safety management and systems where more attention is given to influencing the subconscious processes that drive 'the autopilot mode' of employees. A holistic, integrated framework, based on neuroscientific principles to enhance worker well-being will most likely increase safety performance and reduce workplace incidents and accidents in the explosives industry.

The neuroscience of safety

The human brain and its interaction with behaviour is extremely complex. There are many variables involved that influence the physical, psychological and emotional well-being of human beings in different settings. It is also impossible to study a human's behaviour and well-being within a specific setting (e.g. at work) while ignoring tension and stress attributed to other factors/ settings (e.g. at home) and vice versa. All aspects are intrinsically linked, and therefore inevitably influence each other.

Considering the above, it may appear as an insurmountable task to identify and hence to measure wellbeing itself and to correlate that with workplace safety. However, revolutionary research in the field of Neuroscience is peeling back the layers of mystery to uncover exciting possibilities. It is providing an evidence-based platform that enables a greater understanding into what drives human behaviour, consciously and unconsciously, how behaviour is shaped and most importantly, how it can be influenced.

The soft human issues that once seemed so fluffy and intangible are becoming hard issues, with physical neurobiological systems clarifying our understanding of safety behaviour.

Research done over the past decade in neuroscience and resilience has indicated that emotional and psychological wellbeing and the ability to deal with stressors in the workplace depend to a large extent on a person's level of resilience. It is this link that provides an opportunity to determine factors and measures of resilience that impact on wellness and hence on safety at an individual, team and organisational level.

Rossouw and Rossouw (2017) developed a resilience model with specific domains which correspond with markers in the brain that are related to the satisfaction of basic human needs, namely, the need for attachment or belonging, the need for control, the need to increase pleasure or to avoid pain and the need for self-esteem enhancement or maintenance. Fundamental to well-being and essential for the satisfaction of these needs, is the need for psychological safety. Psychological safety describes a climate of interpersonal trust and mutual respect such that people feel free to innovate, voice opinions and ask judgement free questions. It promotes proactive and productive discussions that prevent incidents and accidents. When such safety is present, the brain can access a myriad if resources that is required for safety behaviour. When such safety is compromised, the quality of the communication between various structures in the brain is compromised and the brain's access to resources are restricted.

Beyond the well-known operational and environmental risks, teams often develop subtle interpersonal risks that provoke anxiety and erode self-confidence, esteem and motivation when their experience of safety is violated by the culture of the team or organization. Individuals develop perceptions and beliefs about how others will respond if they chose to speak up, ask questions, seek feedback, report a mistake, propose a new idea or identify as injured, unwell, fatigued or ill-experienced. Thus, fear of rejection, embarrassment or punishment not only compromises psychological safety, but also inhibits learning, productivity, health and physical safety, even at an organizational level (Henson & Rossouw, 2013; Rossouw, 2017).

Resilience

Considering the extent to and the way in which the abovementioned needs, especially the need for safety (Rossouw, 2014), is satisfied, lead to the differentiation between two systems of resilience, namely 'survival' resilience and 'thriving' resilience. "Survival" resilience refers to behaviour motivated by avoidance (reactivity), whereas "thriving" resilience is behaviour that is motivated by proactively approaching adversity (Elliot, 2008; Rossouw & Rossouw, 2017). From this perspective, resilience is regarded as "the capacity to maintain whole brain activation and requires higher-order, solution-focused neural networks" (Rossouw & Rossouw, 2018, p.34), a capacity we coin as brain fitness. On a more operational level, it is the capacity to manage, negotiate and to adapt to significant sources of stress, trauma or change. This capacity to bounce back in the face of adversity is thus facilitated by resources within the individual and resources from the environment (Rossouw, 2018; Windle, Bennet & Noyes, 2011).

Rossouw and Rossouw (2017) identified 6 domains of resilience, namely Vision, Composure, Reasoning, Tenacity, Collaboration and Health. Each of these domains of resilience were linked to neural pathways that can be developed. It is the cultivation of all these domains that is required for a healthy stress response. However, further research, done by one of the authors (Potgieter) has indicated that high-risk work environments (e.g. mining, explosives) present even further challenges to worker welfare and therefore the domain of 'Health' was extended by including fatigue and substance use (which are known to directly impact brain health) as quantifiable domains of resilience. Therefore, the following domains may serve as a resilience framework for enhancing brain fitness and hence safety performance in the explosives industry:

- **Perception Awareness** refers to the ability to evaluate our own cognitive processes and the filters through which we view the world. It requires a positive self-concept, a proclivity to set goals as a pathway to meaning and a belief in self-worth. Developing perception awareness facilitates critical thinking, the awareness and understanding of others, improved judgement & decision-making and a greater risk awareness.
- **Self-Awareness and – Control.** Self-awareness and control implies having the composure to identify, interpret and manage emotions, in order to respond in an appropriate manner. Developing self-awareness and control facilitates positive thinking, emotional intelligence, relationship management and self-management in the workplace.

- **Collaboration and support.** Healthy relationships are critical for generating value in complex and changing environments where adaptation, innovation and high levels of engagement are of essence. Collaboration fosters supportive networks that allows individuals to thrive. Benefits of developing collaborative skills facilitates communication and trust, conflict resolution, high performance teams and safety cultures.
- **Adaptability** is all about engaging in 'approach' as opposed to 'avoidance' patterns of behaviour, and to persevere irrespective of adversity. It requires embracing mistakes or perceived failure as opportunities for learning and growth. Developing adaptability facilitates 'can do' attitudes', optimism and tenacity, complex problem solving and managing through change.
- **Innovation** involves adopting resourcefulness to achieve common goals despite obstacles or challenges. Developing innovativeness facilitates critical thinking, growth mindsets and a solution focused approach to problems.
- **Physical Wellbeing – Healthy Lifestyle.** Physical wellbeing plays an integral role in job satisfaction, productivity and safety performance. A healthy lifestyle entails the habits that directly enhance physical, mental and emotional wellbeing. Developing healthy lifestyles facilitates safety behaviour and performance, productivity and endurance, proactive cultures and cognitive flexibility.
- **Physical Wellbeing – Fatigue Awareness & Management** entails the identification of the influence of fatigue on productivity, health and safety performance and the provision of strategies to manage fatigue such as obtaining quality sleep. Developing fatigue awareness and management facilitates safety behaviours and performance, physical and mental health, efficiency, productivity and the development of fatigue management strategies, especially with regard to shift workers.
- **Physical Wellbeing – Drug & Alcohol Awareness & Management.** Drugs and alcohol change the brain in terms of both form and function. Substance use or abuse has the potential to negatively influence physical, mental and emotional health along with all aspects of performance. Developing drug and alcohol awareness facilitates personal responsibility and accountability, support networks, risk awareness and safety performance**.**

Let us consider the case of the well-known 2018 truck explosion in China. The blasting company delegated their responsibilities to the SSL mine project department of a construction company, who did not have a permit to transport, store, and blast or perform cleaning services. An operator of the SSL mine project department threw the detonators in the bucket containing the emulsion explosives as they were moving it underground. The detonators were initiated and the explosion followed.

What do we make of this? Safety regulations, processes and technology exists. The blasting company knew these regulations and the SSL mine project department of the construction company knew that they did not have a permit to engage in these activities.

Human failure fundamentally involves a series of poor quality decisions. There were numerous points of bad decision making in this event, from management to the operators. The elements discussed above have links to neural pathways that work together to improve the quality of decision making around safety. It gives us access to the unconscious processes that drive the quality of decision-making. It capacitates us to measure these elements, identify focused brain-based interventions to develop these elements and track its progress over time. In this way, we address the drivers of safety behaviour instead of reactively waiting for the behaviour to happen.

Measuring resilience

With the clear link between the functioning of the brain, wellness, resilience and safety, robust surveys are needed that are economically viable, non-intrusive and logistically feasible. Such surveys could provide the opportunity to determine the current safety risk for an organization; to clarify the human capital investment needed for the development of resilience; to develop and implement holistic, integrated, but focused and tailor-made interventions; and to calculate the ROI (Return of Investment) of proactive workplace interventions needed to enhance safety on an individual, team and organizational level. Furthermore, the use and recording of these measures could also assist in establishing a new benchmark for safety performance and in fueling cross-pollination of best practices across industries.

Conclusion

In today's fast-paced environment with consistent change and uncertainty, jobs are evolving to accommodate technology, artificial intelligence and diversity, along with excessive competition and demands for compliance. The traditional way of life at the managerial and operational levels are challenged. This has resulted in many employees experiencing increased levels of stress, anxiety and depression. In turn, management is inundated with the social and economic burdens of absenteeism, decreased productivity, poor safety performance as well as the socio-economic challenges in the communities where they operate. The impact of current working environments on safety performance is compounded by environments characterized by high risks due to the nature of the business such as the explosives industry.

Recent developments in Neuroscience have provided us with a new, holistic and integrated framework on the enhancement of safety in the workplace. It uncovers the impact of well-being on organizational safety performance by pointing to the links between the brain, psychological safety and wellness and highlights the importance of enhancing resilience as a requirement for working in high-risk environments. Enhancing wellness through the development of resilience could lead to employees that are fit to advance despite adversity.

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THE LAST POST

By

Tony Rowe

Sadly, for me at least, this will be my last article. It was not an easy decision to make as writing for the SAFEX magazine has been both a rare privilege and a lot of fun. However, all things, even wonderful things must, sooner or later, come to an end. Shakespeare once wrote “There are tides in the affairs of men, which taken at the flood lead on to fortune.” My tide though has long since ebbed. Nowaday’s it’s all sand and shallows and even my few remaining rock pools dried out months ago.

I have grown old, which given my life’s choices, may in itself be an achievement. These days though, my hands shake, my eyes grow dim and so many bits and pieces have fallen off, that I’m now less than half the person I used to be. I have become as ephemeral as dandruff. My skin has become translucent and I bruise so easily, worse still, I drool. My wife has taken to calling me Hooch, not because I drink, but rather in memory of the slobbering dog in a Tom Hanks movie of yesteryear called “Turner and Hooch.”

There is another problem. I remain an anachronism and as a consequence, what I have to say is becoming increasingly less relevant. I make no apologies, I was simply born a long time ago. I grew up in a world of no TV, no computers, no internet, no online shopping and no cellphones. In my day, cars had solid rubber tyres and wicks in the headlamps. Car drivers wore goggles.

We lived in caves and hunted mammoths. Apart from the bathroom, our cave was heated by coal fires, indeed there was a fireplace in every room. The “living room,” as we called it, was equipped with a huge coal-fired range made from cast-iron. The oven door had brass handles and brass hinges that were kept mirror bright and the whole thing had to be blackleaded once a week.

A wooden clothes drying rack was fixed to the ceiling above the fireplace. This could be raised and lowered by means of a rope and pulley system. Cooking was done in the kitchen on a coal gas stove. For ironing we used a coal gas clothes iron. It had a hose instead of a cable and you lit it with a match.

During ironing it made a peculiar hissing sound while producing mysterious blue flames from somewhere deep within.

I suppose I was a reclusive and sensitive child and there were always plenty of frogs to kiss. My playgrounds included a host of bombed and empty houses, beaches strewn with “dragon’s teeth’’ (tank traps) plus a number of disused air raid shelters and concrete pillboxes.

Most homes had gas, electricity and water. Outside the street lighting came from tall, cast-iron lampposts fuelled once again by coal-gas. Each lamppost had its own clockwork timer to switch on the gas and a permanent pilot light to ignite it.

A local meeting place for lovers and ne’er-do-wells was known simply as “Five Lamps.” There was a circle of 5 double-headed gas lampposts at the site plus a First World War Memorial that I suppose made it distinctive. Apart from swinging on the lampposts, there was not much to do in the evenings. So, street urchins that we were, we got up to mischief.

I learned my letters and multiplication tables by rote: thirty-six children, the whole class standing up and reciting as one the various arithmetical tables, religious verses or the alphabet.

Back in those days we used to get free school milk. It came in kiddy-sized glass bottles - one third of a pint each - and you had to drink it, like it or not. Along with the calcium powder (creta) added to flour it helped prevent rickets, a disease of the bones. At secondary school I was taught to write in a progressive new script called "Italic" which probably explains my now almost illegible, spidery scrawl. The project was later abandoned. Thousands of children were thus spared similar suffering.

So you see, just like poor old Hooch, my place is in the past.

Within my lifetime, the face of blasting has also changed. The age of electronic detonators and autonomous mining is now upon us, but all I can write about is capped fuse, ignitercord, cheesasticks (fuse-igniters) and large chunks of smoldering ceiling board. In my day we didn't have the economic pressures created by a diminishing marketplace, our suppliers met our stringent specifications and the challenges from competitors were addressable. Neither can I comment upon the emerging host of technical and quality problems that seem to defy resolution, but I do know a little about the other, age old, complication.

What we in the industry produce not only goes bang - party balloons can do that - but our products possess an inherent ability to cause damage to structures and harm to personnel that is not apparent to the casual observer. Who would believe that a single detonator has, at its immediate disposal, some 5000 Joules of usable energy? Astonished? That is enough to a remove a large portion of someone's hand in a single blast of raw power that is over almost before it begins. For the unfortunate victim, the longer term effects, however, have only just begun. Trauma is not fun. The words are clearly spelled differently T.R.A.U.M.A. has six letters whilst F.U.N has only three. Amputation by the way is forever. We are not crabs although we can catch them (pediculosis pubis) and although death and taxes are both inevitable, I want to die in bed while holding tightly onto my money - with both of my hands.

I had hoped to leave behind some sort of legacy. Some wise words perhaps, something stirring, even inspiring. "We'll fight them on the beaches. We'll fight them on the landing grounds," that sort of thing. I can see it now, my articles being reverently unfolded and read out on SKY News or The Discovery Channel.

That won't happen though. My writing and technical skills are simply insufficient. The best I can offer are the few cheesy paragraphs set out below. Printed out, the pages can also be used to line the bottom of bird cages everywhere. In such applications please be so kind as to place the printing face-up so that the avian occupant of the cage may benefit.

Today, almost everyone has the right to decide what level of risk they want in their life. Sadly, you can't tell just by looking at something quite how dangerous it might one day prove to be. Think about stonefish and cone shells or even the tiny blue-ringed octopus. Then there are cars, chemicals, drought, water, too much water, firearms; even gravity can be a killer.

The workplaces of explosives industry are, however, different. Within their admittedly stark interiors we constantly strive to reduce risk. All in all it's a pretty safe place to be and the one I fell in love with. Don't tell the wife though. On second thoughts, she probably knows anyway.

The words you are about to read may or may not be my own. I may have read them somewhere, heard someone else speaking them or copied them from some long lost document. Some may have even been published before in earlier SAFEX articles
In any event, few of them are uniquely mine. They belong instead to the industry. There are not so many, but knowing and following them may not only save your own skin one day, but perhaps that of somebody else.

I therefore unhesitatingly commend the paragraphs set out below to all practitioners of the explosives arts.

A GERIATRICS GUIDE

- Please report all accidental initiations however small. This is not to get people into trouble, but so that proper corrective actions may be taken. Minor incidents are the heralds of major ones. In this regard they provide advance warnings of possibly unsuspected hazards and deviations. In the absence of such information, opportunities for rectification may be missed. In such cases the consequences are unlikely to be good. This is bad. Forewarned is forearmed.

- Unforeseen initiations of explosives are usually associated with some form of energy input. Heat, fire, sparks; friction, impact, excessive pressure etc. are all typical examples. Some explosives require much lower energy inputs to cause them to pop than others. Lead styphnate for instance will require very little whilst an emulsion explosive will need quite a lot. In all cases though the more energy you put in, the more likely the chance of an explosion. Nothing though is certain. A common sense approach works best. To keep the probability of initiation low, treat all explosives as gently as possible and strive to avoid all other unwanted energy inputs. Easy-peasy.

- Have you ever dropped a glass onto a hard floor? Usually the glass breaks when it strikes, but amazingly sometimes it doesn't. Explosives follow a similar trend, but in reverse. Usually they don't go off. Probably just as well. **BNAG** (where nothing happened) might sometimes be preferred to **BANG**, (where something did) although survival can lead to a false sense of security. Can you as the reader remember your own reaction the first time you dropped something that could potentially bite and the relief afterwards when nothing happened? Generally though, such moments, encourage further careless behavior. Within a manufacturing environment where a person may be handling thousands of explosive or explosive related items per shift, such incidents are not uncommon. As a result, natural wariness is quickly replaced with a false confidence which, when given the smallest degree of nurturing, can grow spectacularly. How do you convince a person who handles perhaps thousands of such items per annum and has personally witnessed and perhaps even perpetrated such events themselves, that such behaviors carry a high level of risk? Their own experience - sometimes decades long - tells them something different. They are at the sharp end. You sonny boy, all dressed up in your nice white labcoat, are just blowing smoke.

- Let us for a moment consider the phenomenon we call impact. Common sense tells us that a glancing blow is more likely to occur than direct impact. In a glancing blow, the colliding surfaces strike one another at an angle. Two components are involved, impact and friction. Glancing blows are thus extremely complex events often combining the physics of mechanical energy transfer with pseudo-adiabatic compression and frictional hot-spots. Glancing blows, are especially to be avoided, but besides direct "hammer" type blows, a mechanism for direct, "head on" impact does exist. It is so commonplace. We call it gravity. Think about it, the simple act of dropping something is usually quickly followed by an impact event, but it's not the fall that does the damage, it's the sudden stop at the end.

- Such incidents aside, even the mildest of people can resort to violence when things don't work perfectly. Consider how many times you personally have hit the TV or the radio when the picture or the sound isn't just so. Have you ever smacked the computer screen or bashed that helpless little mouse onto the top of the desk and what about the telephone? Who hasn't walloped the receiver back down in a hissy-fit of barely suppressed rage? Impact though doesn't only result from dropping things. Any collision between surfaces constitutes an impact event and impact events, however small, result a local increase in both pressure and temperature, this is why striking one hard object against another in the presence of explosives is sometimes all it takes for an initiation to occur.

- What I am trying to say is to avoid becoming complacent. Just because nothing has ever happened does not mean that it never will. No matter what you believe, no energetic material, mixture of energetic materials or products containing one or more energetic materials is ever your friend. Energetic materials are neither benign nor affectionate. In fact they have no feelings at all. They're products of chemistry, not biology.

- Chemical stability does not imply safety.

- Nitrocellulose can decompose over time. I can illustrate this issue with a real experience. Some years ago I was called to an old factory complex. The new owners had discovered a small stores building that was filled with large cardboard drums containing industrial grade nitrocellulose which, according to the labeling was originally stored wet under isopropyl alcohol. The trouble was that time and the hot African sun had caused all the alcohol to evaporate away. The nitrocellulose wasn't wet anymore and while it was a relatively cold day in July, some of the drums felt disconcertingly warm to the touch. When the drums were opened, somewhat carefully I might add, the nitrocellulose inside had turned a yellowish-brown. The matter was immediately dealt with and a serious fire – or worse – was probably averted.

- The absence of warnings within published information, source material or indeed any of the available local literature does not mean that any new product, material or substance is safe. Do not take liberties with or carry out experiments until basic safety tests (impact, friction, flame, spark, confinement etc.) involving the product, material or substance have been painstakingly carried out and completed. Even then apply trust exceedingly sparingly as personal injury resulting from the unforeseen initiation of energetic materials must almost universally be seen as human failure, perhaps yours.

- A one in a million chance sounds like pretty good odds, but it can go wrong the first time, the third time or the nine hundred and ninety nine thousand, nine hundred and ninety ninth time. None of us are immortal. We all break and burn. Remember too that it is hard to put flesh back onto bone and that "black and crispy" does not reflect the ideal human condition. Neither, by the way, does it make for particularly tasty bacon.

- We all make mistakes and sooner or later everyone does the wrong thing. We are human, but understand that just because you got away with a spot of malpractice this time does not mean that you will do so again. Learn from your mistakes and don't repeat them.

- Treat all chemicals as potentially poisonous. Avoid breathing in chemical fumes, vapours, mists, dusts or gases. Take care too that poisonous substances are not accidently swallowed. The effects of ingested or absorbed poisons may not become apparent for years. Always wash hands thoroughly before eating, drinking or smoking. Skin is precious, but especially vulnerable to chemical attack. Many chemicals can gain access to the body through the mechanism of skin absorption.

- Learn **HOW** and **WHERE** to acquire reliable and trustworthy information. Your local doctor, hairdresser, chaplain, shop assistant or social worker are unlikely to be able to supply accurate technical information such as the velocity of detonation (VOD) of mannitol hexanitrate, its melting point or whether it is soluble in acetone. For the record, the VOD of mannitol hexanitrate is, at a density of 1,5, around 7000 m/s. It melts at 112 - 113 degrees Centigrade and is soluble in acetone. How do I know? I looked it up in a reliable source document years ago and came across the information again yesterday when burning old and unwanted personal documentation.

- Make it your business to know the characteristics of all the products you are working with. Learn and understand their individual sensitivities to heat, flame, friction, impact, and electrostatic spark and always stay well within safe working parameters. If they are toxic, carcinogenic or allergenic take all necessary precautions.

- Understand the limitations of your personal protective equipment (PPE). If you don't know, go and find out.

- Lead is both a killer and a mutagen. The water soluble salts of lead such as lead acetate and lead nitrate present unique and serious hazards from skin absorption and ingestion.

- It may surprise you to learn that PETN is more impact sensitive than lead azide.

- Be alert to what are called unsafe conditions. Things rarely go as expected. The reality is that things go wrong all the time. This can be especially important whenever new operations or tasks are being attempted, it may happen that despite all the risk assessments and comprehensive written work instructions that have been penned, on the day, activities may not go quite as planned or anticipated. Should this occur, do not continue blindly on with the original plan, rather stop and reconsider (perhaps in conference with others) all possible safe options.

- The need to finish or complete an operation, experiment, exercise or process can sometimes become overwhelming. Pressure, even self-imposed pressure can lead to mistakes. Mistakes can have consequences.

- When things go wrong, people are like sheep. Some will panic, a few will make loud noises whilst others will try to run away. Few will do anything remotely useful. So, when undertaking training sessions or demonstrations involving "live" energetic materials be sure to inform your audience of escape routes, location of telephones, fire extinguishers, eye-wash bottles, first aid facilities and emergency sirens (if available). Get them to write the emergency number - in ink - on their hand or provide printed stickers bearing the information. Perhaps such information should also be sewn on or attached to the PPE provided to visitors

- Never place yourself or others into a situation where the unforeseen initiation of an energetic material (whether it be a pyrotechnic or detonable explosive) can result in the death or injury of either yourself or other persons.

- When initiated most pyrotechnics tend to produce huge quantities of heat. They kill and maim by fireball, radiated heat and molten slag.

- Loose pyrotechnics may burn much faster than their pressed counterparts. They may too be more sensitive to certain forms of initiation than standard testing regimes suggest. For instance, where especially finely divided mixtures are concerned, spreading a thin layer onto a smooth, but thick glass surface and tapping the layer gently with the teeth of a junior hacksaw blade may produce the odd surprise. Take all precautions when conducting such tests. Minimum quantities, an appropriate and licensed facility, appropriate PPE etc.

- Never, under any circumstances allow explosives and their initiators to be transported together either within the same load compartment of a vehicle or plastic carrier of the type used underground.

- Be aware that not all detonators explode immediately upon initiation. Delay detonators may have built in delays of up to 30 seconds, perhaps even longer. I'm so out of date. Electronic detonators, by the way, don't even get hot. Once the fire command is received and accepted they just count down steadily and detonate reliably.

There, my story is done. My pen has run dry and there's no more paper. Thank you for your support over the years. It has meant so much. It made an old man very happy.

Stay safe and live long.
Tony Rowe.

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 June Newsletter is 10 June 2019 , I look forward to your support .

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