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

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From the Desk of the SG

COVID-19 is still ruling our lives and businesses, but the vaccinations appear to have curbed the worst of the advance and most countries are easing down on their lockdown measures and international travel is opening up. With this as background, the Board of Governors has decided that arrangements for **the SAFEX XX Congress** is to go ahead for **4-8 April in Salzburg, Austria**. Below is the proposed programme:

DATE	ACTIVITY	CONCURRENT ACTIVITY
Sunday, 3 April	Registration - Training	
Monday, 4 April	Registration - Training Training Session	
Tuesday, 5 April	Training Session Registration – Workgroups	
Wednesday,6 April	Registration - Workgroups Workgroup Sessions Registration - Congress Welcome Reception	
Thursday,7 April	Registration - Congress Plenary Sessions – Open Day Ordinary General Meeting	Spouses' Programme
Friday, 8 April	Plenary Sessions – Closed Day Gala Dinner	Spouses' Programme
Saturday, 9 April	Congress Excursion	

The formal programme and registration documents for the Congress and Hotel Reservations will be issued by 30 October. My thanks go to the presenters, trainers, and Work Group Leaders who under very difficult circumstances maintained the momentum to yet again present a high quality and full week of activities. The Board of Governors look forward to your participation and attendance.

The SAFEX Webinar 1 was met with great enthusiasm and was an astounding success. As a result, the SAFEX Webinar 2 will be held on 27 October 2022 with an attendance of more than 200 members from around the globe! I wish to take this opportunity to thank the presenters and organisers for their invaluable support. Austin Powder has agreed to run the IT platform for the second time, without the support of their management and IT team the webinar would not have been as successful!

Several New Initiatives were stated by the Board and virtual meetings have commenced to develop GPG's on Primaries, PETN, Shock Tube and Explosives Transport. Some of these Work Groups will have sessions at the 2022 Congress.

The eLearning Portal is undergoing translations into French, Portuguese, Spanish and Russian- these will become available during 2022. An animated learning session on the Sierra Incident is under development and will be revealed to members at the Congress.

In this Newsletter we touch on a wide range of topics which we hope you will find useful in your quest to operate your company to the highest safety standard possibly. Safety incidents not only impacts on business, members life's, but also on the whole industry!!

Use the Newsletters, the eLearning Portal, the SAFEX Website and the Expert Panel to assist you to gain the knowledge and insight to make our industry the safest in the world.

A guide to the use of Relevant Good Practice (RGP) for explosive demolition of structures by J Wolstenholme Part 2 of 2

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Introduction

Explosive demolition has safety benefits in reducing risks from conventional health and safety hazards by undertaking a single demolition event under controlled conditions. The technique provides a predicted collapse mechanism to induce a progressive collapse where the structure cannot support the applied loadings and fails under gravity.

This is the second part of a two-part paper presenting the author's opinion on what Relevant Good Practice (RGP) for undertaking explosive demolition of structures (including those on nuclear sites) looks like. It identifies those aspects of client and project team activities, preparation and planning, contractual arrangements, technical design and justification, safety management systems (SMS) and supervision that experience has identified as being required to undertake a project safely. **The safety of a project does not just rely on a competent contractor but also requires an engaged and adequately resourced intelligent client with a competent project team.**

Part 1 introduced the concept of Relevant Good Practice (RGP), the UK regulatory environment and the expectations on the client's and project team's safety management systems SMS.

Part 2 identifies how effective implementation of that RGP in the management of the contracting process, the development of proportionate method statements and the operation of those SMS bring together the technical and people-based aspect of a project to ensure that it can be delivered safely.

These papers have been condensed to meet publication requirements.

Disclaimer

The content in this paper represents the opinion of the author and is a product of professional research. It does not represent the position or opinions of the Office of Nuclear Regulation (ONR).

Tendering and Award of Contract

Having developed their competence as an intelligent customer the client will need to appoint their demolition contractor. Employing a robust pre-qualification, tendering and contracting process will enable an effective exchange of information that should identify an appropriate contractor who can work effectively with the client's project team. It should also minimise so far as is reasonably practical (SFARIP) risks to the project, those working on the project and those elsewhere who could be affected should any of the hazards associated with the project be realised.

Failing to establish an open and robust process can result in uncertainties in management arrangements, commercial certainty, and technical requirements, as well as program pressures that may reflect in the tender price or influence human behaviour when undertaking the works. For example a failure to follow adequate tendering procedures might result in a contractor exhibiting "perverse behaviours" such as inappropriate acceleration of the works or taking unnecessary risks in order to deliver contractual expectations that could have been revisited and revised as part of an effective tendering process.

Prequalification processes should be established to identify suitably qualified experienced contractors (SQEP) who have previously safely undertaken explosive demolition work of the same scale, hazard, complexity and technical content.

The prequalification and tendering processes should be organised so that the client's project team, acting as the intelligent customer, is provided with sufficient information to assess:

- The adequacy of the tenderers' SMS including arrangements for:
  - ensuring compliance with the Construction Design and Management Regulations (CDM2015);
  - staff competence including how the tenderer would expect to deliver the competence requirements of BS5607:2017[1] and BS6187:2011[2];
  - their arrangements for Temporary Works in accordance with BS5975:2019[3].
  - ensuring that engineered design solutions are robust and are subject to design review

[1] BS 5607:2017 Code of practice for the safe use of explosives in the construction industry
[2] BS 6187:2011 Code of practice for full and partial demolition
[3] BS 5975:2019 Code of practice for temporary works procedures and the permissible stress design of falsework

and assurance;
- supervising the works;
- subcontracting and assessing the competence of any subcontractors.

♦ The tenders' financial stability and ability to sufficiently resource the project to safely undertake the works. The tenders' accounts should be subject to a proportionate due diligence process covering a range of areas including cash flow, liquidity, asset and debt levels. This benefits all parties in assuring commercial stability particularly for large projects with long contractual periods that may require guarantees, performance bonds and complex financing. Similarly, this improves the clients' confidence in the eventual total project cost.

The tendering process should follow recognised industry practices. Appropriate forms of contract for demolition projects should be selected. For example the Institution of Civil Engineers' (ICE) 'New Engineering Contract' (NEC) forms or the National Federation of Demolition Contractors' (NFDC) 'Form of Direct Contract' or the client may choose to use their own standard form. Whichever form of contract is selected, it should reflect the "balance of risk" between the client and contractor. This is particularly relevant for NEC forms of contract where there are six different payment options available and contractual clauses can be modified by the use of "Z" Clauses.

The prequalification and tender documentation should be clear in what constitutes the formal tender suite and what documents are for information only. There should be opportunities for tenderers to assess the structure by site visits and meetings. Any technical queries could potentially be of critical safety importance to both the tender process and the ultimate success of the project. Where they can, technical queries should be clarified and the outcome should be recorded by the project team with provision for managing and controlling any uncertainty or unforeseen element.

Assessment of the tender returns should include detailed consideration of:

- Compliance with the requirements of the tender document, including any specified limits, restrictions and conditions.
- Adequacy and quality of the demolition blowdown design including the substantiation of the tenderers collapse philosophy with the justification of the claims and evidence in their outline engineered design.
- Residual risks arising from the proposal and the adequacy of the tenderer's risk register in identifying, collating and managing that information,
- The safety record of the tenderer including evidence of trends and improvements resulting from incidents, investigations and near misses.
- Training records for relevant personnel and CVs, including any membership of relevant professional bodies (e.g. Institution of Civil Engineers (ICE), Institution of Structural Engineers (IStructE), Institute of Explosives Engineers (IExpE) and Institute of Demolition Engineers (IDE),) possession of relevant vocational qualifications as well as evidence of Continued Professional Development (CPD) through, for example, attendance at relevant training courses.
- Clarification should be sought from the tenderer of the basis of any assumptions made or any omissions of facts, hazards or risks that have been identified by the project team as part of the project planning and tendering process.
- Any alternative methodology or technology to that envisaged by the project team. Alternative techniques should not be precluded and may offer benefits and opportunities from advances in technology, methodology and safety. However, they should be subject to rigorous engineering assessment based on the evidence of the technical aspects, safety claims, arguments and evidence when compared against current Relevant Good Practice (RGP). This assessment should confirm that the alternative technique can be carried out safely without increased risk and that the potential for unintended consequences or different hazards has been considered. The project team may choose to retain a competent third-party consultant to provide an independent assessment of any alternative methodologies.
- Whether a robust engineering justification of safety has been provided for all proposed techniques before proceeding to other issues such as quality, programme and cost.

The client should seek clarification on any gaps in the information supplied by the tenderers before coming to a final judgement on which tenderer to appoint as the contractor. The client should also independently obtain references from tenderers previous clients to substantiate their claims and evidence.

The outcomes of the tendering process should include

- clarity on who owns and is responsible for the risks identified in and from the tender submission; and
- demonstrable assurance that the works can be undertaken safely.

In making their appointment decision, the client should have confidence that the preferred tenderer can produce an engineered design that is robust, technically underpinned, conservative, fault tolerant and safe to undertake. The project team should have sufficient competence to be confident that the chosen design is robust to engineering scrutiny and challenge by both the project team and external third parties. Commercial considerations should not disproportionately influence the final decision.

The client should document the evidence they have used to inform their decision-making process to provide an audit trail for record purposes and future review.

CDM2015 : Construction Phase Plan (CPP) and Method Statements

Depending on the contractual arrangements, the Principal Contractor may be the explosive demolition contractor. Whatever the arrangements, the expectations of the "contractor" would be as below.

The principal contractor should comply with the requirements of CDM2015 by producing the Construction Phase Plan (CPP) and this should be supported by detailed method statements. On nuclear licensed sites the CPP would be included in the licensee's safety case.

The aim of the CPP is to demonstrate that the activity will be the safely managed, that good engineering practice will be followed, that appropriate safety principles have been applied, that the project, so far as is reasonably practicable, is safe to undertake and that residual risks are as low as is reasonably practicable. The CPP and associated method statements should be understandable to those who will undertake the demolition blowdown works and those with direct responsibility for safety. The CPP should be developed in parallel with the Building Information Modelling (BIM)[4] model or an equivalent Virtual Reality (VR) process appropriate for the project scale.

The Principal Contractor's CPP and method statement should cover a range of topics appropriate to the project and should be based on or take account of relevant guidance relevant such as BS5607:2017, BS6187:2011 and BS5975:2019 as well as UK or other national regulator produced guidance and industry and professional bodies' publications.

The CPP and method statements would generally be expected to include:

- A **general description** of the site and scope of works to be undertaken, including any limits or conditions on the site as well as a description of offsite features that may be affected by the demolition blowdown works. These should input into a detailed risk assessment for all activities on the site including any effects that may affect areas outside the exclusion zone boundary and that could affect public safety or the environment.

- Verified **clearance certificates** or the equivalent from the client or licensee, that demonstrates that hazardous materials such as asbestos, ionising radiation, polychlorinated biphenyls (PCBs) and other chemical or biological contamination has been removed so far as is reasonably practical. This clearance process should reflect an awareness of the potential for concealed contamination or trapped liquids, solids or gases in valves, pipework and features that are difficult to decontaminate or investigate.

- The **collapse philosophy** for the explosive demolition which should be clearly defined and articulated. This may be illustrated within the BIM model or VR equivalent or on a series of drawings, illustrating the collapse mechanism at different time delay intervals. This will also inform the design of the protection works including the use of shielding bunds and the size of the exclusion zone.
- The contractor's structural engineer should provide the project team with the **temporary works design** required for any **pre-weakening**. This should include structural calculations and detailed drawings showing the type, details, location and setting out of all the pre-weakening works and the direction of fall of the structure. This design should justify the collapse philosophy and should reflect an understanding and working knowledge of the different types of structure, their layout, provision of load paths, joints and connections, tying and bracing, material characteristics, degradation mechanisms and historical properties in both the permanent and temporary load cases. There should be a statement of how the design is to be implemented that follows the guidance in BS5975:2019.

[4] https://ukbimframework.org/

- The design may require structural alterations to existing structural members, for example, where part of a flange has to be removed, where kicking plates are required or where members need local reinforcing. The structural engineer's design should justify the adequacy of these structural alterations and assess any subsequent consequences on the collapse philosophy. The structural engineer should also confirm that the pre-weakening design has been through a demonstrable robust process of **challenge and peer review** and that the structure will remain stable pending blowdown. This process should be appropriate to the project size and complexity and should follow relevant guidance such as BS 5975:2019 and Part 3.4 Vol 1 of the Design Manual for Roads and Bridges[5]. It is recognised that these are usually undertaken as "CAT 3" independent checks. Some structures, particularly those on nuclear licensed sites, are robust and highly resistant to progressive collapse due to the provision of substantial foundations, heavily reinforced robust RC concrete sections, moment resisting steel frames and other construction forms.

Masonry Chimney Widnes

- The requirements for **3rd party review in Europe** will be specific to individual countries and the project team should identify those details and implications at the earliest practical stage in the planning process. For example, in Germany, the 3rd party peer review process follows the principles undertaken for a new or refurbished structure. This is usually undertaken by the Federal Association of Testing Engineers for Structural Engineering eV (BVPI)[6]. A chartered design review engineer, usually working on behalf of the local building control authority will check the structural analysis, the working drawings and the chosen method. The client and project team will have to allow for this process as they develop their overall programme and project costings.

- Nevertheless, the structural engineer should be able to demonstrate an **understanding of risks arising out of**:

◆ Missing, inadequate, uncertain, unrecorded or out of date structural information, together with the risks from unauthorised changes or modifications carried out during the structure's construction and life cycle.

◆ degradation from recognised corrosion mechanisms that may affect the properties and behaviour of structural members.

◆ the ways that certain structures were constructed e.g. thin-shelled cooling Widness, water towers, bridges and arches. Some forms of construction will have required temporary works and elements of those works could remain as part of the built structure. Those details may not have been recorded as part of the permanent work record.

◆ uncontrolled transfers of loads into parts of the structure that do not comply with the original design philosophy and calculations. This can cause redistribution of loads giving overstressing, rotations or collapse of structural members leading to structures falling or rotating in the wrong direction, partially failing or collapsing onto their foundations in "a sit down". Similarly, structural framing containing splices, joints, connections, stiffeners, tying members or compound sections that may unexpectedly either attract loading, become overstressed or fail when they become part of the temporary load paths should be identified and considered because they can adversely affect the collapse mechanism.

◆ Having incomplete cutting in separating service pipes, cables or ducts that are fixed or supported on connecting structural elements. A single uncut armoured electric cable between two elements can provide enough restraint over a few milliseconds, to adversely influence the predicted collapse mechanism.

◆ failure of retained or pre-weakened sections of the structure that contribute to the development of the collapse mechanism. For example, assumptions made on the presence and extent of continuity of lapped reinforcement in reinforced concrete sections should be supported by robust evidence.

◆ the contractor's need to alter the existing

[5] https://www.standardsforhighways.co.uk/dmrb/
[6] https://www.bvpi.de/bvpi/de/verband/ueber-bvpi.php

structure to enable installation of explosive charges. The removal of member sections and cutting holes in webs or flanges to allow access needs to be recognised by the structural engineer and any requirement for strengthening should be included in the design.

- ♦ a failure to implement rigorous monitoring and supervision of any pre-weakening activities.
- ♦ the differences in the Codes of Practice and Standards used in the original design and construction, together with the recognised shortfalls or conservatism in the methods of structural analysis be that empirical or software based. There can be significant risks if modern design codes are used to model or analyse older structures where it would be more applicable to use the original design code and undertake a gap analysis against modern codes. A list of commonly used codes of practice, standards and guidance applicable to the demolition industry is available in the parent technical paper.

- The structural engineer should also be able to demonstrate that structures have been **investigated** to identify the means of construction and any consequential risks those means might present. The investigation process should consider what features and materials could be present in the structure that are not immediately obvious. Risks can arise from the presence of non-structural elements or features that would not be immediately recognised as having an influence on the structural behaviour during a blow down. For example mechanical plant and services or ventilation ducts and shutes, cable trays and cables etc.
- The structural engineer should also identify and record the arrangements for **cooperating** with the project's personnel. Depending on the contractual arrangements, these could cover a range of BS5975:2019 roles including a Temporary Works Designer (TWD), Coordinator (TWC), Principal Designer (PD) and the Designated Individual (DI).
- There should be clear and **demonstrable links** to the work undertaken by the contractor's structural engineer in the demolition design and the contractor should provide and confirm details of how the structural engineers' design has been checked. In some cases, depending on project scale or complexity, this may be by retaining a competent independent third-party organisation. Alternatively, the client may choose to appoint that **independent third party consultant** for their own assurance. On a nuclear licensed site this would be in the form of an Independent Structural Assessment (ISA) together with an Independent Nuclear Safety Assessment (INSA) of the overall project. The check and any resultant changes should be recorded along with a discussion of how those changes have been assessed, approved and taken account of in the final design.
- The design should describe how the contractor intends to **undertake the pre-weakening works** on the structure. The details should be clearly stated on approved drawings showing the latest revisions. These drawings should be subject to robust **change management** procedures and should be regularly updated to record the date and scope of the completed work.
- All structural cut points or openings should be clearly marked prior to cutting or breaking out. When cuts or openings are made, they should be inspected to confirm that they are in accordance with the method statement and clearly identified as agreed along with the details of who was responsible for making it. It is good practice to **record pre weakening works** such as the cut positions or openings before and after they have been made. This can be done using physical markings and records, digitally dated photographs or other suitable techniques. This visual evidence supports details recorded on drawings, sketches and schedules and allows ongoing assessments to be made of the stability of a pre-weakened structure. The client and contractor should agree the proposed technique to be used for recording this detail. Depending on the project scale and complexity, consideration should be given to recording and visualising the information within a BIM model or equivalent depending on the project scale.

- The contractor's **explosive demolition design** should describe the :
  - ♦ chosen demolition technique;
  - ♦ approach to any pre-weakening not detailed above
  - ♦ the specification and quantity of all the explosives to be used;
  - ♦ drilling patterns to be used for charge placement in concrete or masonry or
  - ♦ the location, orientation, and fixing methods of different types of charges for example cutting and kicking charges on steelwork,
  - ♦ approach to securing explosives in place e.g. stemming of holes

- ♦ type of initiation system for example nonelectric, electric or electronic
- ♦ time delay sequence and backup systems;
- ♦ protection of the initiation system from damage due to shrapnel fly
- ♦ provision and design of primary and secondary protection
- ♦ provision of any visual indicators to confirm that specific sections of the works have been successfully initiated,
- ♦ arrangements for the delivery and return of explosives to an offsite store or storage of explosives on site,
- ♦ arrangements for security on site and accountability of explosives "in use" or being prepared on site,

- If the design requires cutting charges to be used then full details of the requirements for their specification, placement and initiation should be included. The explosive contractor's design should demonstrate a clear understanding of issues around their use, such as the potential for liner or secondary fragment fly, and describe how the initiation system and timing requirements between cutting and kicking charges will be managed.

Linear Cutting Charge on Steel Section

- The design should explicitly consider the **protection** requirements against the effects of debris fly, fragments, vermin attack or any other circumstances that may result in a misfire or a hangfire and where such a risk exists it should detail the preventative and mitigatory measures that will be employed. The design should also describe how:
  - ♦ any flying debris will be retained to ensure safety; and
  - ♦ what protection methods will be used to provide effective containment around the structural members to minimise both the transmission of fly and protect the initiation system.

Column Protection Wrapping

- Recognised methods used for primary and secondary protection include chain link fencing and geotextile, geotextile screens, rubber matting or belting, sandbags, steel plates and water drums or similar.
- The design should include estimates of the levels of **vibration and air overpressure** that may affect neighbouring structures. These can be verified by the retention of competent independent consultants. Estimates can be calibrated from results obtained during test blasts to produce regression lines and be considered iteratively as the design progresses during the works.
- The method statement should provide details of reducing and controlling air overpressure, ground vibration and **dust** that cannot be eliminated in the engineered design. They should address the potential adverse effects on people, infrastructure, plant and equipment sensitive to damage or degradation due to dust ingestion or vibration. Examples are dust filters to hospital ventilation systems, vulnerable or sensitive buildings or infrastructure, dust settling on roads, drainage systems and surface water courses. Similarly, details should be provided for proposed control measures such as protection, water suppression from hoses, Intermediate Bulk Containment (IBC's) or other appropriate methods, and the clean-up of surrounding areas after the demolition. The design of the exclusion zone should allow

for these environmental effects.

- **Environmental monitoring** usually involves subcontracting to a competent specialist environmental testing contractor and the use of remote or automated monitoring stations. Any hazards and risks arising from how the environmental monitoring equipment operates should be considered and incorporated into the relevant risk assessments and method statements. Remote monitoring for asbestos or other dusts provides public confidence that any previous decontamination works have been adequately undertaken.
- **Test blast** results should confirm deterministically if the proposed explosive design will generate a structural collapse. The contractor should detail any proposals for undertaking test blasts in their demolition design. These proposals should include including drawings and photographs, confirm the suitability of the proposed explosives and the reasons for this as well as the predicted failure mechanism of the structural element and the adequacy of the protection design. Reports should be produced following test blasts and provided to the project team. These reports should consider whether the test blast achieved its intentions and how the demolition design will be modified to take account of the results of the test blast. The report should also include results from environmental monitoring of vibration, air overpressure and witness materials, to give an indication of the expectations for

Cooling Tower Test Blast Location

- the main blowdown. Any changes to the demolition design should be subjected to a formal change control process before demolition designs and associated method statements are modified. Where test blasts are precluded on the structure to be demolished or similar structures, alternative options such as using a mock-up or similarly constructed and loaded structural element should be considered. However, such test blast results generally require a cautious approach to decision making to be followed when assessing how the results of tests might influence the demolition design for the main structure.
- The extent, establishment and control of the **exclusion zone** are key elements of the demolition design and the associated method statements. The contractor should provide details of how the exclusion zone has been determined as well as how it would be expected to be established and controlled as part of the demolition design. The determination should consider the type of structure and the collapse mechanism, charge weights and placement, primary and secondary blast protection, and environmental considerations. This is important if public attendance is anticipated because dust and fly can travel over distances and present significant risks. Effective design of the exclusion zone should take account of the available space and any natural features such as roads, rivers or residential areas which act as boundaries. Guidance can be found in the HSE guidance document Construction Information Sheet No. 45[7], BS6187:2011, BS5607:2017 and NFDC publication Demolition exclusion zones DRG 110:2014[8].
- The design of the exclusion zone should also consider the residual risks to sensitive infrastructure, buildings, other structures or facilities and populations (including spectators) outside the exclusion zone. Similarly, arrangements for adapting to changing **weather conditions** such as thunderstorms, high winds or changes in cloud level and density.
- Arrangements and identification of who is responsible for the **post blowdown clean up**

Preliminary Setting out of Openings in Masonry Chimney

The project team should assess the contractor's demolition design and associated method statement to ensure it provides a clear, coherent, conservative, fault tolerant design and safe method of work. The project team should take into consideration the results of the independent 3rd party organisation (or

[7]Establishing exclusion zones when using explosives in demolition https://www.hse.gov.uk/pUbns/cis45.pdf
[8]https://demolition-nfdc.com/download/exclusion-zones/

ISA / INSA review on a nuclear licensed site). The client should then make the decision as to whether to permit the start of the works.

Safety management system (SMS)

The contractor should provide the project team with details of the arrangements and procedures that will be in place for undertaking the management, supervision, auditing and record keeping for the works. This would be expected to include holding daily toolbox talks to specify the works to be undertaken that day, arrangements for monitoring, supervising and inspecting those works as they proceed and identifying and recording responsibilities for signing the works off as complete and in accordance with the method statement.

The arrangements should include a written and photographic record of the finished works, suitably identified, labelled and referenced. These records can provide an audit trail to provide assurance that the works have been carried out as per the method statement with no unauthorised deviation or changes. This process of record-keeping should be undertaken for the structural pre-weakening, initiation and backup system and protections works.

This process of recording should be audited at an appropriate frequency to suit the scale, complexity, risks and consequences of failure for the works. These audits should be undertaken not only by the contractor but also the project team, the client, and if appropriate, independently by a separate body within the client's or Licensee's organisation or an independent 3rd party acting on behalf of the client or Licensee. HSE's guidance document HSG159 Managing contractors: A guide for employers[9] provides a useful framework for managing the work of contractors in a high hazard environment and can be used to supplement the arrangements expected by CDM2015. Similarly ONR guidance document TAG 76 Construction Assurance NS TAST GD 076 (Rev 4)[10] provides additional guidance for nuclear licensed sites.

Wall Drilling to RC Walls

Collecting, maintaining and reviewing a record of the finished works also allows the contractor and the project team to identify any changes to the structure that might have occurred as a consequence of the temporary works, any pre-weakening activity or unauthorised changes. The contractor's safety management system should identify how the risks associated with any changes to the structure will be assessed and what techniques they would expect to employ to inspect any suspected changes in detail.

Key elements of the project's safety management system will also include the approaches to be taken to:

- emergency planning
- change control processes
- supervision
- liaison with stakeholders and the public

The contractor should detail proposals for dealing with foreseeable emergencies that may arise on site during the works. Proposals should include a communications plan for liaison with the client and the project team as well as all the emergency services. The client and project team should have arrangements for communicating with external stakeholders where that would not be part of the contractor's role and responsibility. The plan should be clear in the roles and responsibilities of all parties and include the actions required under the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 2013 (RIDDOR) [11].

There should be a process to assess and control any proposed changes to the demolition design and agreed method statements that may arise. The changes should be categorised according to their safety significance and given the appropriate level of engineering assessment and scrutiny, which may include additional independent third-party checks. The decision as to whether to accept the proposed changes should be made at the appropriate level of competence, responsibility and authority within the project team. The evidence and justification of the change should be fully detailed and provide an auditable trail of the review and decision-making process.

The project team should have arrangements for the adequate supervision of the contractor's work. Supervision should include physical site inspections, review and planning meetings, safety audits and program meetings. Site inspections and meetings should be attended by the contractor, the project team and the client and have agreed minutes to record results and any matters arising that need to be actioned. There should be a clear procedure for showing how any is-

[9] https://www.hse.gov.uk/pubns/books/hsg159.htm
[10] http://www.onr.org.uk/operational/tech_asst_guides/ns-tast-gd-076.pdf
[11] https://www.hse.gov.uk/riddor/

sues have been resolved, including what decision-making process is to be followed. This approach provides an audit trail of how and when information and decisions have been shared with other appropriate contract parties.

The client may choose to have a permanent presence on site and this is accepted practice on UK nuclear licensed sites.

Arrangements for supervision should identify roles and responsibilities in the client, project team and contractors and describe the chain of command, the methods of communication, and mechanisms for liaison with third parties. The extent of the arrangements should reflect the complexity of the project and the extent of the hazards and risks it involves.

Security of explosives

The contractor may choose to store explosives on site or more usually have them delivered on a daily basis as charging requires. The requirements for the secure and safe storage of explosives, including the permissions required and the prevention of access by "Prohibited Persons" are provided in the Explosives Regulations 2014 (ER 2014) with additional guidance available in the HSE publications L151, and L150 and relevant subsector guidance. On a nuclear licenced site such arrangements will require the involvement of the Civil Nuclear Constabulary (CNC) and the Office of Nuclear Regulation (ONR). Away from nuclear licensed sites regular contact with the relevant police force's explosives liaison officers will be key to ensuring the arrangements for security are proportionate and effective.

The explosives must be subject to appropriate security arrangements after being charged into the structure and security provisions should continue if the demolition is either delayed or only partly successful and unexploded charges are left in the structure or debris. Arrangements for appropriate stock control and for checking the quantity and locations of explosives charged into the structure should be robust and monitored on a daily basis.

Blowdown Day

The contractor and the project team should have well established and rehearsed arrangements in place for managing the day of the blowdown well before the event. These should include the arrangements in place for establishing and maintaining the exclusion zone, timings and cooperation with the project team on site as well as external stakeholders such as local and highway authorities, the emergency services, the public and any other stakeholders appropriate to the project circumstances. There is an expectation that these arrangements will have included adequate levels of public information and consultation. A checklist of required actions and go/no-go criteria can be beneficial in ensuring that no issue or procedure has been overlooked prior to blowdown. Relevant parts of this checklist should be shared with the appropriate project members and third parties on the day. For example, the sentries providing the exclusion zone will require details of the blowdown timings, contact numbers and a guide on what actions to take in the event of any contingency being invoked.

Contingencies and associated actions should be considered and developed as soon as the blast design has been finalised. The contractor should detail proposals for dealing with any contingencies. For example, what needs to be done in cases of full or partial stand-up, misfires, hangfires, unauthorised intrusions into the exclusion zone, 3rd party stoppages of the work and any other external occurrences that could impact on the blowdown. Provision should be made for example for maintaining the exclusion zone for extended periods and the availability of onsite and offsite plant required to address the identified contingencies should be prearranged. Confirmation that these arrangements are in place should be included in the relevant checklists.

The contractor's shotfirer has to be confident that all the safety management arrangements, particularly establishing and securing the exclusion zone, are adequate and have been confirmed as such on the day of the blowdown. Only at that stage should the shotfirer decide whether it is safe to proceed and whether or not to fire the shot.

The safety management arrangements should identify full details and timings of the sequence of events before and after the blowdown and when the exclusion zone can be removed. The explosive demolition contractor's shotfirer should be the person making the decision to call "all clear". This should follow a physical inspection of the collapsed structure to ensure that full detonation has occurred, that there are no stand-ups or structural sections left in an unstable condition and that no explosives and detonators are knowingly unfired.

The contractor and any employees clearing and processing the demolition waste should be provided with explosive awareness training and should have procedures in place to follow if unfired explosives or detonators are identified during the clearance operation.

CONCLUSIONS

Explosive blowdown of structures is an appropriate technique if it is carried out safely. The demolition design should provide a justifiable and engineered solution that meets expectations of Relevant Good Practice (RGP). Those expectations are reflected in the assessment of a safe, robust and fault tolerant design and the implementation of a safety management system that ensures the method statement is implemented correctly. They should draw on the application of the UK codes, standards, industry guidance and where appropriate nuclear ONR Safety Assessment Principles (SAPS) and Technical Assessment guides (TAGS).

Explosive blowdown requires competent people within the client or licensee's management team, the project team and contractors if an adequate engineered design and a safe system of work that reduces the risks so far as is reasonably practicable are to be developed and implemented .

The client or licensee should demonstrate an intelligent customer capability, ensuring that they have employed competent people, processes and procedures with a robust challenge function and change control process to deliver a safe blow down. The client or licensee should also be a learning organisation that seeks to obtain information and experience from others who have undertaken similar works.

There should be detailed planning and the provision of all reasonably obtainable information to both the project team and tenderers if they are to adequately develop the engineered demolition design and identify risk reduction opportunities. There should be in compliance with the requirements of CDM 2015.

The client should select a suitably qualified and experienced contractor that is financially stable and has sufficient resources to undertake the works safely. There should be a contractual process that appropriately apportions the risk balance between client and contractor together with a suitable payment process.

A competent explosives contractor should develop a justifiable engineered design including any temporary works, which is robust against scrutiny, challenge and review. Similarly, a robust system of site supervision should be implemented to make sure the works are undertaken in accordance the contractor's agreed method statement.

An adequate safety management system is required to introduce proportionate controls to the safe undertaking and supervision of the works.

A change management system should be implemented to assess any change from or modification of the agree method statement and records of the decision-making process in approving any such change should be made and kept.

Thorough, well planned and practiced command and control arrangements should be exercised in preparation for the blow down. These arrangements should include provision for contingencies, emergencies and incident mitigation.

Acknowledgement

The author is grateful for the assistance of Martyn Sime BSc (Hons), PGDIP, MRSC (CCHEM), FIExpE for his assistance in compiling this article.

"First published in Explosives Engineering September and December 2020 editions. Published here with the kind permission of the author and publisher".

What do we learn from incidents?

by

Andy Begg

My immediate response to this question is "Nothing". But - - - read on.

Like a few of my contemporaries and peers in the industry I have been around for a while and seen many explosives plants and operations throughout the world. I have many very fond and happy memories of the times I have spent visiting the plants and talking with the people who design, operate or are responsible for them.

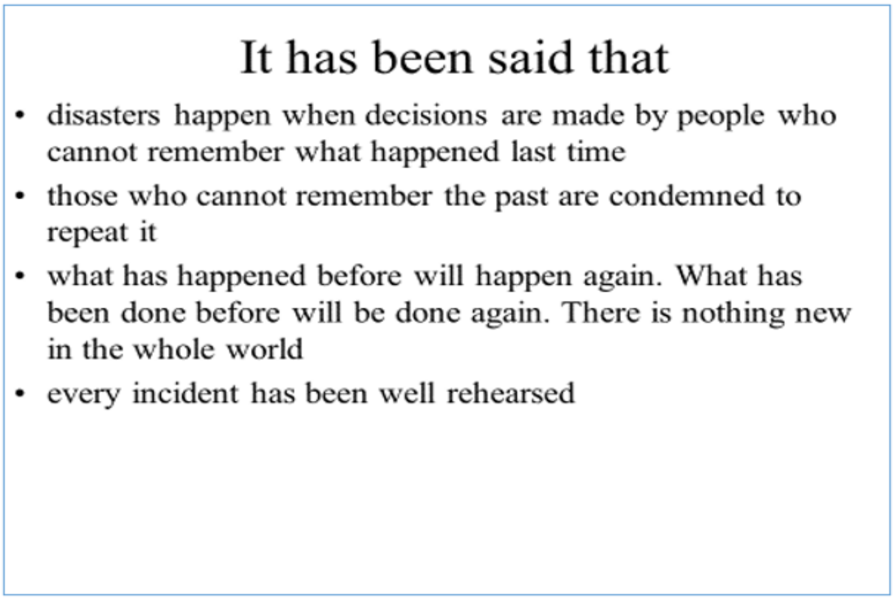
However, our plant visits have too often been as a result of an incident as members of the investigation team and some bring back memories that we would prefer not to dwell on. Inspecting the remains of a building where 9 people lost their lives the previous day and finding body parts – I would prefer to forget but never will. The "lessons" from that incident and many others - I will never forget. In my early career as a research chemist I was encouraged to read old technical and incident reports and to talk with older much more experienced colleagues about their experiences. So when I visit plants today I frequently observe conditions or situations that cause a connection in my brain and I get a mental message "You have seen this before and it was not good then and it is still not good." So I am recalling an incident, an audit or perhaps something I have read or been told many years ago. I advise the plant personnel of course and normally there would be a corrective action taken and the issue "fixed". Sadly, when I visit another plant or perhaps even the same plant a year or two later I often see the same issue. My contemporaries report the same. We read a newly reported incident notification and think "Here we go again."

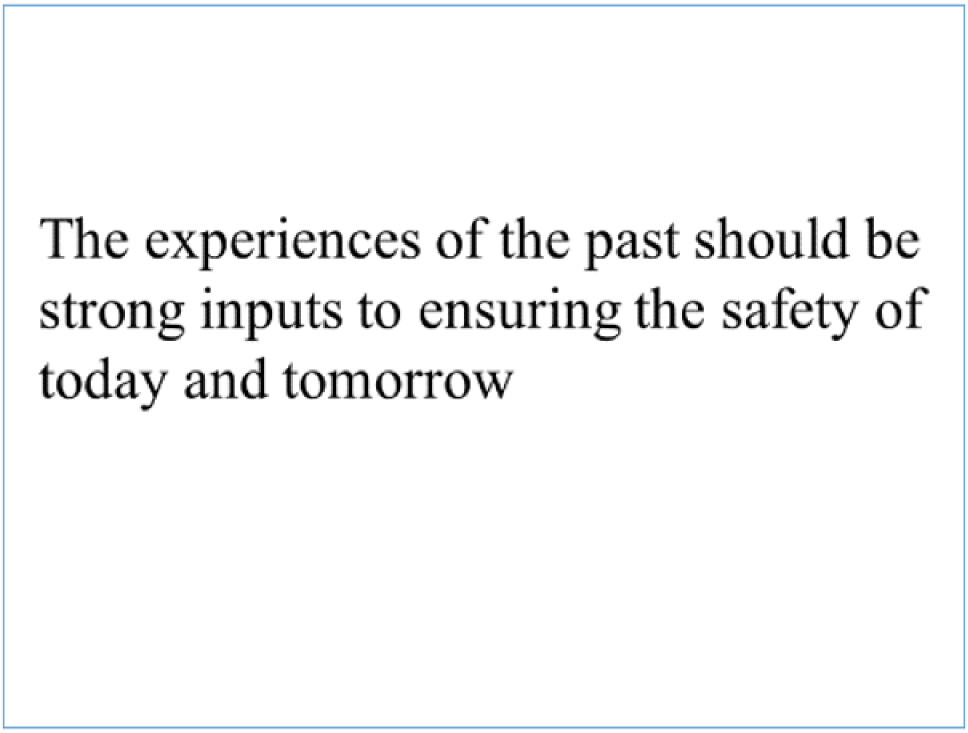
It is very frustrating for us "old guys" and we often say to ourselves "Why do we bother. We visit, we inspect, we analyse, we train, we discuss issues, we write articles – but it seems we are wasting our time. Why don't we learn, remember and apply safety lessons?"

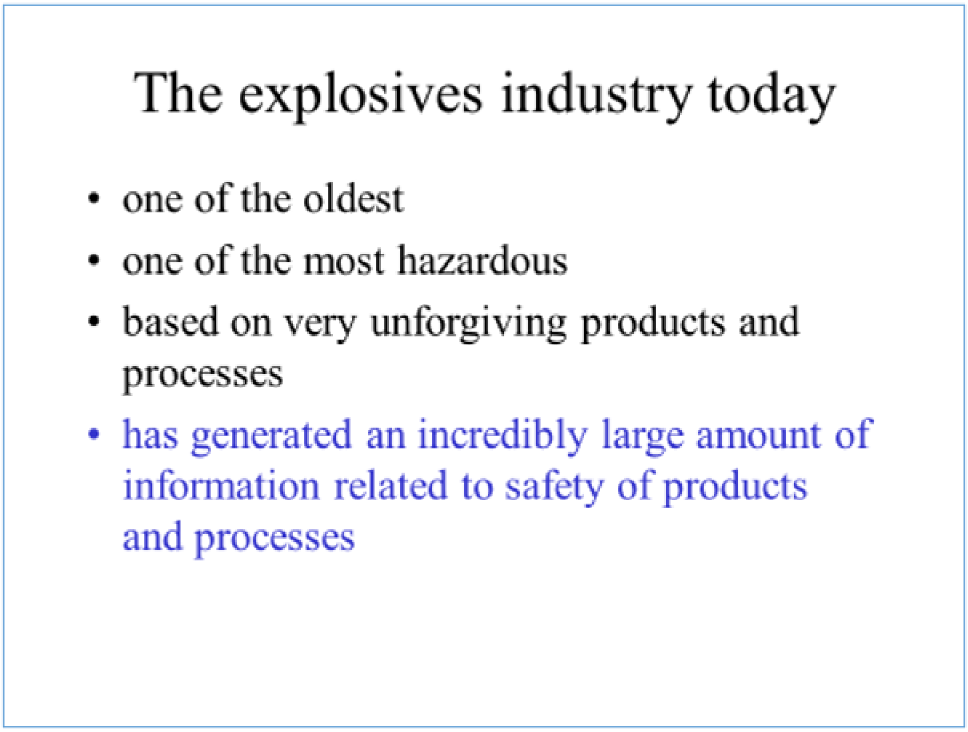
Why don't many people who have responsibility for the safety of other people and plants know what the hazards are and how they should be avoided and make sure that this happens?? Is there no memory in the company to ensure that basic safety information is available, known and acted upon by personnel? How often do you read a new incident notification and say "Didn't the same incident happen a couple of years ago in xxx plant?" Burning ground incidents, pump explosions, failure to decontaminate – the list goes on. Hence my answer at the start of this article.

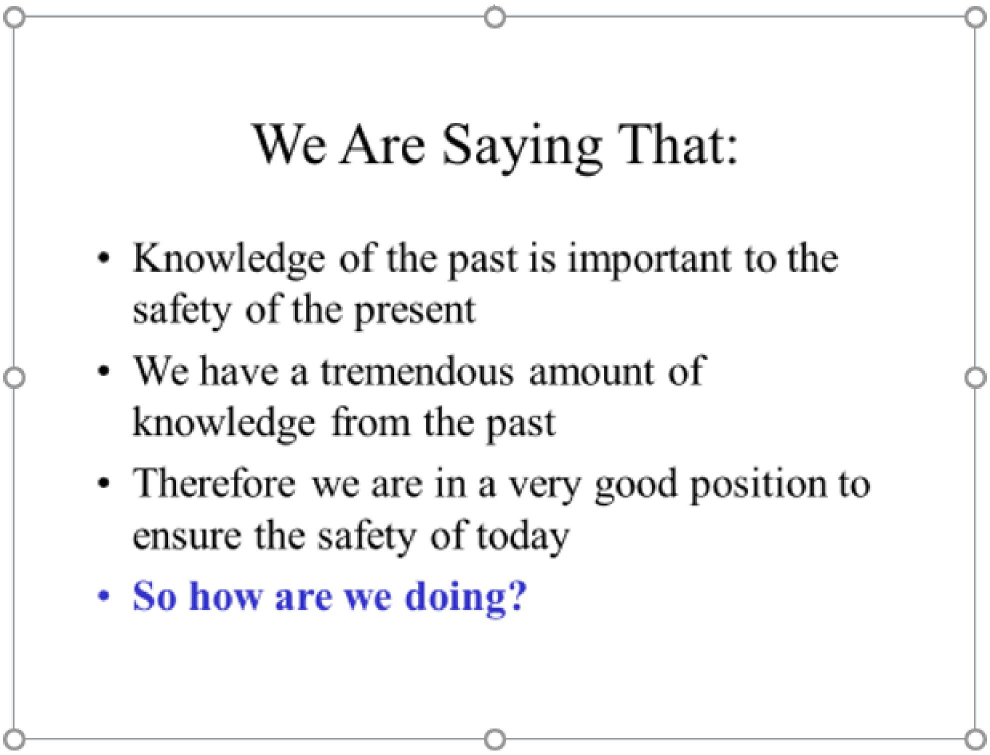
To be fair there will be readers who, when reading a current incident report, will not have seen such an incident before and for them it will be new knowledge. So someone does learn from a current incident even if it has happened before the reader's time and therefore there is still tremendous value in the reporting of repeat incidents. However, collectively we already knew of this but somehow have failed to instil that knowledge in the memories of those who need to know.

These thoughts are not new to me and my peers. About 20 years ago I presented a paper on Corporate Memory to FEEM and present some extracts here. So, here we go with thoughts from the past. I will be re-using some of the original slides from that presentation.




The experiences of the past should be strong inputs to ensuring the safety of today and tomorrow

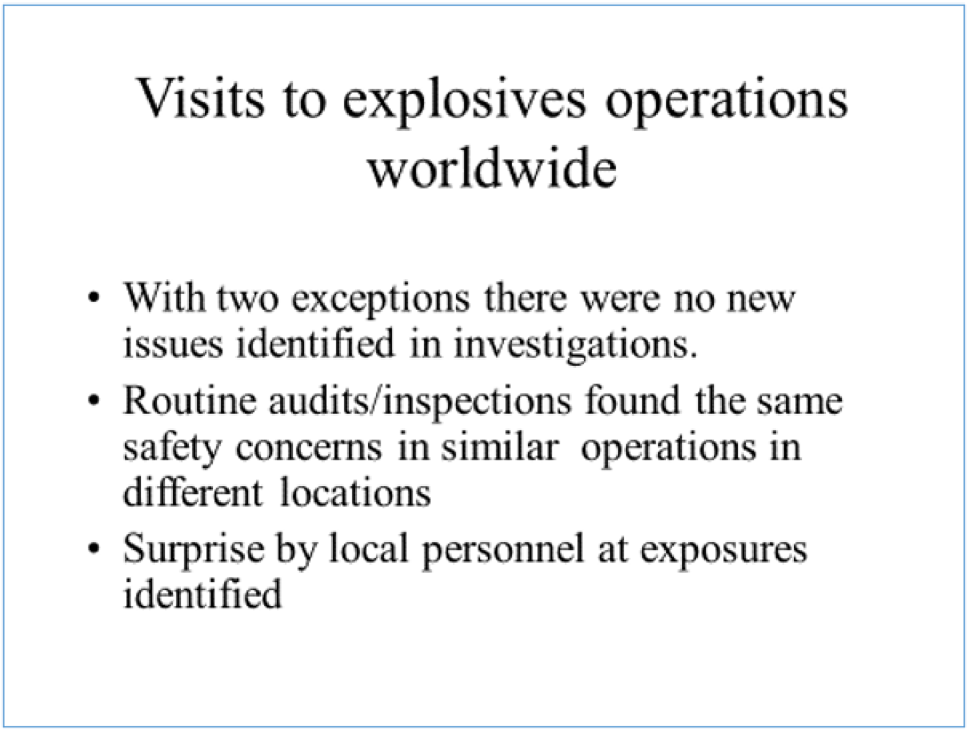

The explosives industry today
• one of the oldest
• one of the most hazardous
• based on very unforgiving products and processes
• has generated an incredibly large amount of information related to safety of products and processes



So how do you think we are doing?

I have to say we could do better. Look at the repeating of incidents, the repeating of findings on plant audit and inspections.

From 20 years ago I commented :



The only change I would make to this for today is to remove the first bullet point – to my knowledge we have not identified any “new” hazards /issues. However, if any reader does know of a new hazard that has been identified please let me know – always ready to learn!

And I continued:

Specific observations

- Key personnel not aware of specific hazards
- Key personnel not aware of previous similar incidents
- Basic explosives equipment not maintained to original specification
- Design specifications for key plant items not available
- Reliance on a few experienced personnel

The situation today appears to be no different. Our Corporate Memory continues to fail. We see this at plant level and at company level.

When we do have a repeat incident it is very easy to say the Corporate Memory has failed and move on. However, Corporate Memory is not some sophisticated computer system or App on a mobile phone.

What is Corporate Memory?

- It is the **ability** an organisation has to assess, store, access and utilise knowledge
- This knowledge may be stored in file, database, library or an individual’s memory
- The storage may be internal or external to the organisation
- It is driven and effected by people

Corporate Memory is about people. When we say it has failed, the reality is that some of us have failed – individually and collectively.

One of the advisors to the Piper Alpha disaster in the North Sea – if you are not aware of this incident I suggest you do a web search for it as it makes for salutary reading – stated:

Safety is not an intellectual exercise - - - it is a matter of life and death and it is the sum of our contributions to safety management that determines whether the people we work with live or die.

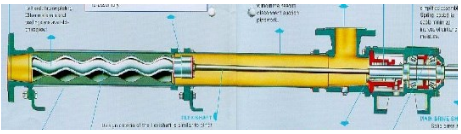
I believe this is an example of Corporate Memory in action.

How do we do better ???

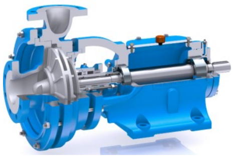
About pumping emulsions, did you know that…… ?

Emulsion (explosive) pumps are classified as **Safety Critical Equipment** because there is a potential for an explosion from high temperature/heat and friction with unacceptable consequences.

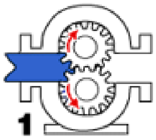
What type of pumps are commonly used?



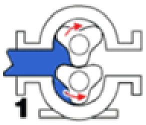
Progressive Cavity Pump



Centrifugal Pump



Gear pump



Lobe Pump

Diaphragm Pump

How can the main hazards occur? The answers are:

Dry Running à No Flow = Heat

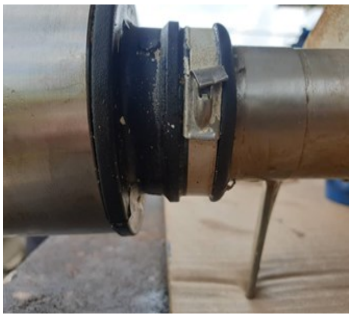
Dead Heading à No Flow = Heat

Foreign object à Friction + Impact = Heat

Unusual Noise à Friction + Impact = Heat

However, it is sometimes overlooked that heat from friction and foreign material can also occur in PC pump joints that are worn out and where the ingression of emulsion (then posing foreign material inside the joint) can create a reactive mixture when exposed to friction and heat generation inside the joint. This can happen for various reasons such as

- Too much clearance of the pin in the hole of the coupling rod
- Holding bands of the boot have become loose or haven't been tightened properly (during maintenance or new pump)
- Damage to boot from excessive force or foreign body allowing ingress of emulsion
- Pump inspection does not require to check the joints and/or replace parts after a regular schedule
- Unawareness/lack of competence
- Joint damage from improper pump alignment
- Too high product viscosity causing the pump to run at its limit



Damaged boot

Too much clearance

Excessive wear

Emulsion/grease mix inside Joint

It is important to mention that these occurrences can happen despite having a maintenance plan implemented – when not considering the described details and with lack of awareness/competence

Key aspects:

Pumps are selected according to their application and only one **RESPONSIBLE PERSON** such as the Location or Plant Manager has the responsibility to ensure that all critical pumps are:

- Only used in **approved applications**
- **Properly maintained and operated** in a safe manner by a **trained operator**
- **Approved and properly maintained**
- Maintained by trained and competent mechanics performing **required routine inspections** with **special attention to joints and alignment** according to the Critical Pump Management System

Do you know the Six Steps to Pump Safety?

1. Right Pump, Installed Correctly

2. Trained Pump Operator Ensures Flow

3. Correct Pump Safety Devices and properly located

4. Proof Test the Pump Protection

5. Follow MOC/Maintenance Procedures

6. Know and Practice Your Emergency Procedures

Pump safely every day, every time!

"Keep in your head"

Thoughts on the future of Ammonium Nitrate by

Ron Peddie

The origin of this note is a presentation I was asked to make to a fertiliser conference. They wanted me to talk about the future of the Ammonium Nitrate industry. While I would be far more interested in the future of lottery numbers, I gave it a go.

So, what I will go through is the trends for the medium term say the next 20 years, just to take a general look at things that are happening with Ammonium Nitrate in the medium term. These are things we can see starting to happen but have not yet taken the leading role in its market development.

Topics discussed

- AN use and possible substitution market trends
- Some technology
- Some safety and regulatory stuff

AN use in the future

After incidents like Beirut, there is always discussion about whether AN can be substituted. AN owes its dominant position due to its unique blend of cost, efficacy, and safety.

In terms of cost, its basic raw materials cost only about 2 times the price of natural gas and it is easy to manufacture and store on a vast scale – there is nothing that comes close to that.

For Fertiliser use it has the ability to release two forms of nitrate immediately and not lose any NH3 to atmosphere. It is the only way to fertilise from short growing seasons. So, I can't see this being substituted unless there was a desire for the world to starve

In explosives there is concern over the greenhouse gas emissions when AN is used – there is no doubt this is a problem. There is some small degree of investigation over the use of hydrogen peroxide as a clean alternative – but obviously, there are safety considerations in handling millions and millions of tons of hydrogen peroxide. The green economy depends on materials from the mining industry like cobalt and copper so if these initiatives take place there will be a need for large scale mining and therefore for AN. We should remember AN is a remarkable chemical which has done immense good for the world

Changes in production methods due to greenhouse gas

The AN and nitric acid processes

The AN process itself is a clean process if engineered to modern standards - so I have never heard of a green AN process.

Due to some excellent engineering effort over the last decade, that problem has been solved by catalytic abatement and the nitric process itself will be the same as it was - and will be a clean process for greenhouse gas emissions.

Its associated process- Nitric acid- used to have a problem with N2O NOx? To cover all gases emissions. N2O is a very potent greenhouse gas coming at over 300 times more greenhouse effect than CO2. Although N20 looks like it should be one of the NOX gases it is not. It is closer to nitrogen and is colourless and non-reactive. It has to be said most of the engineers working on nitric acid plants did not even realise it was there till about 15 years ago – it was treated as nitrogen and caused no problems. A surprise was when it was calculated it came in as about 10 – 15% of the CO2 equivalent emissions of most advanced economies – because of the huge multiplier. You don't need to worry about N2O in blasting – it needs a catalyst.

I stuck in a couple of quiz questions to check how many of the SAFEX members recall their high school chemistry

Quiz question: What is the Nitric acid synthesis process called?

The raw material for both these processes is Ammonia and there is much more activity in this area. Traditionally made from hydrocarbon (almost any hydrocarbon – natural gas coal or Naphtha) the process of manufacture by hydrocarbon does produce a lot of CO2 so alternatives have been sought.

The technology being applied on projects right now is an old one- hydrolysis of water by electricity to produce hydrogen which can then be combined with nitrogen from air separation to produce NH3. This process is not new – it has been available for over 100 years but has not been economic. The only new thing here is that the electricity used for the electrolysis is green made from renewable resources.

There is a search for more efficient methods than hydrolysis and these are popping up in the research papers

Quiz question: What is the Ammonia synthesis process called?

The effect of this may be to move NH3 production to areas with vast untapped renewable energy. So, we see vast 40 million tonnes per year plants planned for the deserts of western Australia = where will the water come from in a desert?. Whether the AN plants follow is a moot point but more likely I think that the Ammonia will just be shipped to plants, which are already in optimal locations.

Safety and regulation in the future

After the tragedy in Beirut there have been calls for further regulation of AN. My take on this is just to stick to the fundamentals on fire and security and the industry needs to stick to the belief we do know how to handle and use AN safely. When asked about what lessons there were from Beirut for a technical perspective, I said nothing really, we knew it all before. There will be new initiatives like the one in January from the left field, we got a proposal for an organisation not previously involved- UN institution for disarmament research. I think some of our SAFEX colleagues will have better knowledge of the actual machinations of these processes than me.

We do seem to be building a trust deficit whereas where people would previously have said OK to our detailed technical risk assessments, they are now lifting their eyebrows.

When contemplating a discussion in a tribunal - a few lines from Robert Burns came to mind

O wad some Pow'r the giftie gie us

To see oursels as ithers see us!

In an inferior English pronunciation

Oh, would some Power give us the gift

To see ourselves as others see us

In other words, we need to listen closely to people's concerns about the industry

What happens next

- Basic manufacturing technology of AN and Nitric acid unchanged
- Ammonia will move to areas with high levels of renewable energy
- AN manufacture may move, or ammonia be shipped
- AN regulation will be tightened, and rogue operations eliminated
- There will be some work required to stop overzealous regulation

Quiz answers:

Nitric acid process Ostwald process Leipzig 1902

Ammonia process Haber Bosch process Oppau 1913

Asset Integrity

by

Dan Reinke, PE, CSP

CHG Group, Inc.

A Marsh insurance review of major accidents in the hydrocarbon industry from 1974 through 2019 found a recent increase in the number and cost of large property damage events in the onshore oil and gas sector[1]. Mechanical integrity failures accounted for 60% of losses, with a recent increase that is attributed to aging assets. I'm sure many of us have found the same thing when investigating incidents in energetic manufacturing operations. Failure to consistently and properly maintain production equipment can lead to energetic events, especially when working with sensitive materials. While every manufacturing operation performs preventive maintenance on their equipment, how can we assure that these practices are adequate, especially if good practices are only understood by long-time maintenance personnel?

The Role of Asset Integrity

Part of increasing the safety of manufacturing operations entails utilizing remote automation and controls, separating people from hazardous environments. As operations become more and more complex, they can be harder to maintain. In addition, as equipment ages it can be more prone to failures caused by inadequate maintenance. Also contributing to challenges in Asset Integrity are the retirement of seasoned maintenance professionals, pressures to "do more with less" and increased turnover of newer maintenance employees who may not seek to spend their entire career at one company.

Preventing accidents in energetic manufacturing operations thus requires having a strong Asset Integrity management program. The specific needs of each operation varies based on the materials and processes involved, since with some products and processes it may be acceptable to take a "run to failure" approach while others require strong systems to prevent unplanned breakdowns. General advice on what constitutes a best practice in Asset Integrity systems can be found in two books published by the Chemical Center for Process Safety, specifically *Guidelines for Asset Integrity Management* (2016) and *Guidelines for Mechanical Integrity Systems* (2006).

Asset Integrity Program Elements

While the needs of each business will vary, there are several criteria that make up a good Asset Integrity program. These include:

- Responsibility and Accountability
- Equipment Selection
- Inspections, Testing and Preventive Maintenance (ITPM)
- Competency and Training
- Quality Assurance
- Deficiency Management
- Performance Management and Assurance

Key to the success of an Asset Integrity program is to have appropriate ownership and involvement by many functional groups. Design, process and facility engineers will often be best equipped to identify the components of each asset, applicable codes and standards, replacement part specifications and operational parameters. Leaving this task to maintenance personnel is often inefficient and can lead to missed ITPM requirements. Safety personnel often organize and maintain the records from hazard analyses and incident investigations that can help identify safety critical components and maintenance activities, including frequencies. Training and human resource personnel can help establish competency programs and ongoing training needs to ensure personnel conducting ITPM work are appropriately qualified. Third-party specialists and original equipment manufacturer representatives may be needed to maintain specific equipment. Strengthening an existing maintenance program requires significant internal resources so cannot be effectively accomplished without strong leadership.

Good Asset Integrity programs begin with identifying and documenting the equipment and systems involved, ensuring the equipment meets program requirements, and understanding the failure modes and consequences to identify what IPTM activities are most critical. Examples of equipment and systems that should be included in energetics manufacturing ITPM programs include:

- Fire protection and deluge systems
- Shielding and barriers
- Explosion/deflagration and overpressure relief systems
- HVAC and humidity control systems
- Grounding and bonding systems, including grounding testing equipment
- CCTV systems
- Data loggers
- Emergency power systems
- Lightning detection and lightning protection systems
- Safety interlocks
- Process controls and monitoring systems/HMI screens
- Process flow, pressure and temperature monitoring systems
- Process heating and cooling
- Release detection and secondary containment systems
- Solvent vapor detection systems
- Alarms and emergency shutdown systems

Development of specific ITPM procedures for each asset can be complex, especially for the custom-built machinery and systems that are often found in our industry. Company and industry experience, codes and standards, manufacturing manuals and good engineering practices are all sources of information to be reviewed when developing ITPM procedures and frequencies. In the US, that often means referring to Recognized and Generally Accepted Good Engineering Practices (RAGAGEP) contained in NFPA, ANSI and API codes as well as industry resources such as SAFEX Good Explosive Practices.

Well written ITPMs allow different personnel to conduct their work consistently and get the same results. Tooling, equipment and replacement parts should be clearly specified. Good ITPM procedures can contain photos or videos and embed or have links to guidance materials. Many Asset Integrity software management systems accommodate use of tablets to aid maintenance personnel in conducting ITPM tasks and documenting results.

Competency programs are essential to ensure the personnel assigned to ITPM tasks conduct them appropriately. Effective competency programs ensure maintenance personnel are trained in and observe an ITPM task before working under direct supervision to demonstrate their competency. For high hazard operations, training and demonstration work may be first conducted on non-production equipment and are tested using inert materials. Periodic formal competency verification checks should be conducted to ensure personnel follow procedures as written rather than developing short cuts.

Quality Assurance programs are required to ensure testing equipment and replacement parts meet the required specifications. As part of this there must be clear acceptance criteria for these materials. The Quality Assurance program must also review and manage any changes to equipment and procedures, including the basis for each change.

There may be times when equipment cannot be kept within process specifications or when certain devices do not function properly. If these deviations do not impact safety or the product, there may be situations where alternative safeguards are used to allow continued operations. To allow operating with deficiencies in safeguards there needs to be a formal deficiency management and authorization procedure.

Lastly, a good Asset Integrity program needs to be managed using appropriate Key Performance Indicators (KPIs) and an assurance program to verify ITPM procedures are conducted appropriately and any deficiencies properly addressed. Asset Integrity KPIs can address:

- Asset condition and performance against specification.
- Condition monitoring
- Inspection status
- Critical backlog
- AI-related Near-Miss/unplanned downtime/ reactive maintenance reporting
- Competency of personnel
- Status and effectiveness of process safety barriers
- Compliance with AI procedures
- Reliability and review of Asset Integrity data

Summary

As equipment and systems become more complicated, as older equipment wears out and as our experienced maintenance personnel retire, having a strong Asset Integrity program is key to preventing energetic incidents in our manufacturing operations.

The views and opinions expressed are my own and do not necessarily represent the views and opinions of CHG Group, Inc. or Chemring Group.

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Psychological Safety - Making Your Team and Organization Safer

by

Lance Tinney, SVP Human Resources – Dyno Nobel Americas

The focus of workplace safety is generally centered around "physical safety" or the traditional disciplines of occupational health and safety. This is understandable as we strive day-in, day-out in manufacturing plants, mining operations, quarries, construction projects and mobile equipment to deliver safe production. However, taking steps to create a psychologically safe organization, will go a long way towards building a physically safe organization (an organization strong in the traditional elements of occupational health and safety). Whether it be the 2003 NASA Space Shuttle Columbia incident where seven astronauts were killed, or failures that led to the Volkswagen group's "dieselgate" scandal, or the fall of the Nokia telecom company, where the absence of psychological safety was seen as a cultural root cause that had a direct and identifiable impact in creating a workplace that allowed these events to occur. Common in these incidents was a workplace or team climate characterized by fear and discomfort that prevented people from speaking up.

So, what do we mean by psychologically safety? *"Psychological safety is broadly defined as a climate in which people are comfortable expressing and being themselves. More specifically, when people have psychological safety at work, they feel comfortable sharing concerns and mistakes without fear of embarrassment or retribution."* [1]

Back in the 1990's when, as a doctoral student and in the process of clarifying her research interests for her eventual dissertation, Amy Edmondson joined a group studying medical errors in several hospitals. Doctor, nurse and administrative teams were all part of the research which collected data on error rates and measures of team effectiveness. The research team unexpectedly found that the better teams were making more mistakes, not fewer, than the less effective teams. Edmondson found that the better teams had a climate of openness that made it easier to report and discuss errors. The better teams didn't make more mistakes, they reported more. People in the better teams talked openly about the risks of errors, often trying to find new ways to catch and prevent them - everyone from the lowest ranking employee to the highest, felt empowered to speak up. Edmondson later labeled this workplace climate difference "psychological safety". These initial research findings set her off on a path of proving through many studies in different companies, hospitals and government agencies that psychological safety is a reliable predictor of learning behavior, performance, and incident rates.

When people don't feel comfortable in speaking up with their concerns or questions, the physical safety of employees, customers and the community is put at risk; a culture of silence is a dangerous culture. A workplace where employees don't feel safe or comfortable to take interpersonal risks such as raising concerns, sharing mistakes, and asking questions … is an unsafe workplace. A lack of psychological safety can create an illusion of success that can eventually turn into serious safety incidents and the earlier information is shared on concerns and errors, the earlier impacts can be managed thereby avoiding a more serious incident. Such is the value of open sharing of near-miss events and seeing them as learning opportunities; you are being provided an opportunity to prevent a more serious event sometime in the future. Taking this a step further, a safety management system that values near-miss and hazard reporting but not psychological safety, is leveraging just a small amount of its potential learning and improvement and creating space for more serious incidents to occur. In a psychologically safe workplace, small failures are seen as the currency of learning and improvement.

What are we likely to see in a workplace where psychological safety is present?

- Leaders who welcome bad news. Leaders who welcome only good news create fear that blocks them from hearing the truth. When someone comes with bad news in a psychologically safe workplace, leaders ask themselves how they can make this a positive experience – how they can help, support or guide the next steps.
- Leaders acknowledging their own fallibility, not meaning that they are deficient or incompetent, but showing that they are human. In acknowledging this, a leader is saying "I might miss something here. I need you to tell me if I do."
- Limits of current knowledge are admitted – the answers to some questions or solutions to some problems may not yet be known. More information may be needed.
- Participation is invited and input from all team members is expected. A thoughtful leader will proactively invite input from others through good questions, showing that he or she is genuinely interested in what others have to contribute. Leaders of psychologically safe teams are generally seen as approachable and accessible.
- Team members respond positively to the input from others. People feel listened to. People believe they can (and must) be forthcoming at work.
- Failure is destigmatized. Failures, other than those caused through willful negligence, are celebrated as learning opportunities – in this way, failure is reframed.
- Boundaries are established which define clear violations or consequential behaviors.
- The purpose of the work being done is emphasized – identifying what is at stake, why it matters that the work is done well.
- Interactions are characterized by healthy levels of candor and openness – mutual respect is not determined by having the same opinion.

Some readers will think and ask, "well how is a leader supposed to hold people accountable if we celebrate errors?" Firstly, fear as a motivator, is ineffective in holding people accountable (in a normal day to day organizational context) – through fear, what might be achieved is a belief that accountability exists when it is totally absent. Creating a psychologically safe workplace is not about lowering performance standards. Researchers around the world continue to find that psychological safety promotes high performance (including safety performance) in a wide range of work environments and industries. Figure 1 below, shows that psychological safety and performance standards are two separate, equally important elements both of which impact team and organizational performance in interdependent ways. There doesn't have to be a "trade-off" between psychological safety and high standards.

	Low Standards	High Standards
High Psychological Safety	*Comfort Zone*	*Learning & High Performance Zone*
Low Psychological Safety	*Apathy Zone*	*Anxiety Zone*

Figure 1: *How psychological safety relates to performance standards. Edmondson 2019.*

In the apathy zone, people will show up to work but they aren't truly engaged – their hearts and minds are somewhere else and discretionary effort is missing. In the comfort zone, an employee is not challenged by their work and learning is compromised. Probably the most concerning quadrant as it relates to workplace safety is the anxiety zone where psychological safety is low; where employees are anxious about speaking up. In such workplaces, managers have potentially confused setting high standards with good management but trying to set high standards in a low psychological safety environment will present problems. When both standards and psychological safety are high, this enables learning and performance to coexist. In this zone, people collaborate, learn from each other, and get quality work done. Therefore, one of the most effective ways to hold people accountable in the workplace is through the promotion of high standards in a psychologically safe environment.

Leaders of teams, departments and companies play an important role in shaping psychological safety and you could be excused from thinking that this is all about leadership. It isn't - everyone contributes to building a culture and leaders set the standard however, everyone can make a contribution in creating psychological safety in a workplace. The following actions are ones that any employee can take - these are ways in which everyone can be a safety leader, irrespective of job title:

- Ask a good question. An open question (not one that can be answered with a simple "yes" or "no") that is fueled with curiosity or a desire to give someone else a voice. Questions create a space for answers and an opportunity for someone else to contribute.
- Active listening – sometimes described as "listening to understand" (rather than listening to respond). Responding with interest, building on the ideas of others, and giving feedback – seeing feedback as the gift it is. This doesn't mean that you have to agree with what is being said, just appreciating the effort someone else put in to share his/her idea.
- Reframing the challenge that the team is facing. The Stockdale Paradox is worthy of mention here – it calls on us to identify the brutal facts of a situation while having a sureness of success. The Stockdale Paradox was referenced in the book Good to Great by Jim Collins and reflects how Admiral James Stockdale survived seven and a half years as a prisoner of war in Vietnam.
- *"You must never confuse faith that you will prevail in the end—which you can never afford to lose—with the discipline to confront the most brutal facts of your current reality, whatever they might be." Admiral James Stockdale.*
- Being prepared to be vulnerable and say things like "I don't know", "I need help", "I made a mistake". This, for many people, will involve taking a risk however, they are the sort of comments that lead to responses like "what are your concerns?", "how can we help? As the level of psychological safety builds in a team or organization, the fewer risks people will consider themselves needing to take; speaking up and asking questions will just be seen as a characteristic of the way the team operates.

Psychological safety has been studied predominantly in medical centers and technology organizations around the world for many years, but it has only been recently that its relevance and value are being realized in broader workplace applications. The same principles and lessons learned in these research environments can be applied to explosives industry workplaces and teams to achieve similar success experienced through safety culture transformation, team effectiveness, and improved organizational safety performance. Although leaders play a critical role in establishing and maintaining safety standards along with determining safety culture strength, each and every employee can play a part in creating psychological safety irrespective of job title; you don't have to be a boss to be a leader. Incident databases are full of events where contributing factors or root causes detail an absence of psychological safety – where someone was concerned but didn't speak up, where leaders didn't want to hear bad news, and where the question on the minds of a few people wasn't asked. Let's bring greater awareness to the topic of psychological safety in our teams and organizations – let's work at building it and in doing so, we will be making our teams, organizations, industry, and communities safer.

References:

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Changes to burning ground operation and design after a burning ground explosion of PETN waste

by

Antonio Mendez, Martin Held

Introduction: Austin Star Detonator had observed an explosion at the explosive burning ground on November 6, 2020 at its facilities in Matamoros/Mexico. The incident had been reported to SAFEX (IN 20-06).

After the incident investigation, changes to the burning process and layout to the burning ground have been made. These changes are described in this article together with a review of the contributing factors to this incident.

Brief Incident Description (the incident is described in more detail in the incident note that can be found in the SAFEX data-base for further reference):

An operator placed 2.5 kg dry PETN fines (out of spec material) in two of four available burning bays (5kg total) for destruction. A few minutes after remote ignition two detonations were heard and felt by the personnel on site.

Original burning ground design:

The burning ground had been in use for more than 15 years. Basic construction included 4 burning bays built with cinder block. 6 feet of earth/dirt between the walls separated the bays from one another. A cement covered earth berm barricaded the rear of the bays, which faced the nearest production building located approximately 150 meters away. Burning bays were used to destroy explosive and pyrotechnic waste along with explosive contaminated trash material.

The ductwork of the exhaust system was a serial installation and connected all 4 bays.

The dry PETN fines were spread out evenly by the operator inside a metal tray located in the center of each bay and remotely initiated.

Contributing Factors to the incident: From the incident investigation, the following operational, product and design factors were analyzed to redesign the explosive burning process:

- **Task Condition- Generation of PETN Fines**

Resulting from a supply change, the dry PETN fines became a new waste stream, and a method to handle and dispose of it was generated. Rather than following an existing procedure that described mixing wetted PETN fines with sawdust and diesel for burning, a new procedure was created.

- **Absent/Failed Defense – Work Instruction/Procedures**

An operating procedure was generated for the new waste stream. The procedure was drafted without including important details such as establishing a schedule to collect the fines on a regular basis, and clearly define a maximum amount of explosive to be burnt in one cycle. The absence of details led the operator and others to create their own routine where dry PETN fines were collected on a weekly basis. Records of production and waste generation illustrate that on average 4 kg of dry PETN fines were collected weekly.

- **Absent/Failed Defense - Internal control/Supervision & Verification**

A further deficiency found in the burning area is the lack of a verification process, supervision and adequate staffing for the new task.

- **Condition -burning pattern**

As described in the procedure, the operator pours the dry PETN fines from an aluminum container in an "S" pattern onto a metal tray (which was more of a trough with high side walls). Variances in pouring such as total quantity, and consistency/ uniformity of the pour are likely to have played a role in the incident.

Recognizing the nature of PETN and having rows of wide mounds poured in the manner described, it is likely that the burn began as a deflagration and went into detonation once reaching a point where the mound itself created its own confinement.

- **Condition- Metal troughs for burning in poor Condition**

Each bay contained a metal trough-like structure that would provide a base for the waste contents to be incinerated. These troughs over time have warped and deformed from daily burns. Replacement had been made after an irregular pattern, but not a defined (maintenance) schedule.

Warped sections were approximated between ½" to 1" deep at some points and varied in shape and width. It is likely that these sections contributed to confinement of the explosive material.

Design changes to the burning ground and operation:

As a result of the Nov 2020 incident and the learnings from the detailed investigation, a new design incorporating an open concept was implemented. Constructed was completed in February 2021.

1.Restricted Access to Burning Grounds. CCTV cameras were installed for security and safety

2.Metal roofs and doors were replaced by roll away tarps to eliminate possibility for confinement.

3.Exhaust and ductwork which was shared between the 4 bays was eliminated. A smokestack remained installed on 1 of the 4 bays for air quality checks as required by local regulation. Cement covered earth berm to serve as a barricade.

4.Cinder Block construction on the exterior. Walls to the front of the bays added for additional protection from heat.

5.Thermo-block construction on the interior of each bay. Metal trough structures were replaced by more shallow trays with metal grate lid to allow air flow and contain fly ash. Bays are only used for contaminated material/trash. No explosive or pyrotechnic waste is burned inside of bays any longer .

6.An open burning concept for explosive and pyrotechnic waste is now performed in open metal troughs. Troughs are shallow and narrow and allow a defined and constant filling level of the amount of waste set to be burnt. Remote ignition via leg wires and electric ignitor initiates the burn.

Management of Near Miss Events

Paulo Siqueira

This article intends to raise our level of awareness in managing the near miss events that happen in explosives manufacturing activities. The practice to report and investigate near miss events is not new and all those with some years of experience in explosives manufacturing sites already know it and have stories to tell. However, as the incidents repeat from time to time, it is always useful to recall the attention to its importance and to involve the new generations in keeping the system alive as it does not matter whether we are old or young, our objective is the same: to protect people, plants and the environment.

On an ordinary Tuesday afternoon, the production on a bulk emulsion plant was running well and smoothly. The operator was monitoring the process occasionally peeking into the hopper to check the pump feeding. The second operator was on his lunch break when the MMU arrived to load as there was a blasting service to attend in the mine. The plant operator positioned the truck under the silo and began loading. A few minutes later the operator rushed when he saw smoke coming out of the hopper and noticed that the thermal fuse in the transfer pump had blown and the emulsion was spreading upon the floor while the pump was still running. The operator promptly stopped the production. The maintenance mechanic was called, made a quick inspection on the equipment and replaced the fuse by a new one. As there were no injuries whatsoever and no major consequences the area was cleaned and the production was restarted.

What is a near miss event about?

When something like this happens, with no harm and no further problem, some workers tend to be complacent about the situation and move on without giving it enough attention to a such a potentially dangerous occurrence.

It's very different from when someone gets hurt at work and even more if it is a lost time injury for which there are procedures to report, investigate and impact on safety statistics. In fact, some organizations put more effort in treating incidents than near miss events.

However, in both cases, whether an injury incident or an event that does not result in personal injury but may result in property damage or the potential for serious consequences are worthy of recording and must receive equal attention by the safety management system of the organization.

The OSHA and National Safety Council Alliance define near miss as an “unplanned event that did not result in injury, illness, or damage – but had the potential to do so”. Some companies have a slightly different definition and here it will not be the place to discuss these aspects since the most important is to keep focus on the benefits of the system as they can precede events in which a major loss or injury could occur. Such events are also known and familiarly called as unusual occurrences, dangerous occurrence, close call, narrow escape, near miss or near event as in SAFEX incident database.

What we should keep in mind is that when we talk about injury incidents, we look for the past, for something that has already happened. On the other hand reporting and analysing near events we aim at what could have happened, to influence the future, to take the opportunity to prevent repetition and further outcomes.

Why is important to report and investigate?

Reporting near miss events is particularly necessary in the explosives business where a deviation from good explosives practices may result in catastrophic consequences. Therefore, when an undesirable event happens and does not result in more serious consequences, it is an opportunity not to be missed to record, learn lessons and prevent future incidents.

Smoke was noticed coming from an MMU while pumping explosives down holes in preparation for blasting. Closer inspection revealed the explosives pump was overheating and product was starting to become contaminated with rubber from components of the pump (Safex Incident Database, record nº 18683).

What could have caused the pump to overheat? Feed tank empty? Lack of flow due to line obstruction? Valve closed? Pump failure? Probably one of these elements may have contributed to the incident. But when investigating events like in this example we will find within the underlying causes the weaknesses in the management system, e.g., wrong design, poor maintenance, unaddressed modifications, outdated operating procedures, lack of risk assessment, failure in auditing and implementing actions raised form investigations, absence of protective devices, etc. So this is the big chance to fix the problem at its root.

In the SAFEX incident database there are more than 200 registered near events and companies that have the system already implemented for some time should have even more records. The analysis of such information indicates similar cases that occurred in different places and this allows us to group them into categories that enable a more comprehensive management of the problem.
These are the highest incidence categories, but they are not the only ones:

Near Event (suggested categories)	
Environment	Abnormal atmospheric emission Abnormal effluent discharge Chemical spill or leak
Production & Storage	Chemical reaction / Decompositon / Contamination Faulty tool / machinery / equipment Foreign Body Process fire Process Ignition / Deflagration / Detonation Disposal of hazardous waste
Distribution	Loading / Offloading vehicles Vehicle fire Vehicle crash, colision
Blasting services	Blasting related incidents Flyrock Product related incident
General	Non process fire Security incidents / Theft / Malicious act Slip, Trip and Fall
Other events	

A slip, a trip and a fall can be a simple fright, but without attention to the conditions that caused this it may result in a broken ankle next time and therefore should be properly treated. However, in the explosives business, other apparently insignificant events may result in extremely serious consequences to the plant, multiple injuries or fatalities, environmental pollution, corporate damage, customer service disruption and business liability.

A foreign body detected in raw materials or in the working place perhaps as grit falling over a dry PETN container increase the sensitivity and the risk of ignition by friction during the production of detonators or det cord. Loose nuts and bolts may fall into TNT melter kettles or leave pieces of equipment loose. Once the hazardous condition is discovered it shall be promptly com-

Crack in wall at PETN container is a source of grit (Credit: SAFEX)

Metal date stamp left on lid of pentolite kettle (Credit: SAFEX)

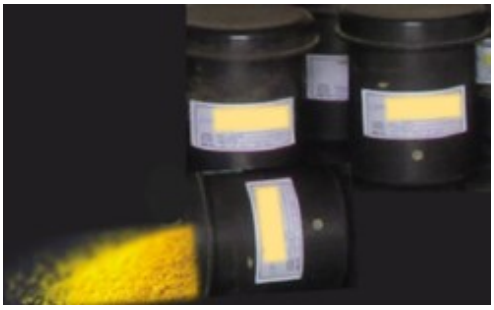
⇒ *A large piece of equipment (hopper) worked loose and dropped into a PETN slurry vessel while it was in operation. It was later discovered that the hopper assembly had an insecure mounting design. No injuries and no equipment damage (Record nº 20575).*

⇒ *Strange and loud noises were heard in the turbo mixer used for mixing watergel explosive. A foreign metal object together with a damaged paddle arm was discovered in the body of the mixer (Record nº 19377).*

⇒ *Not following procedure, operatives removed the mesh to add recycled emulsion into the hopper of the pump. As a result, foreign objects got into the process. The pump was stopped when unusual noises were heard. Fortunately, there was no ignition (Record nº 20499).*

⇒ Below are some more real cases of near events extracted from SAFEX Incident Database that can illustrate the suggested categories.

⇒ *The feed device containing 10 g of lead azide fell three times from its inclined support without any apparent reason. The azide spilled out without reacting (Faulty machinery. Record nº 16539).*



⇒ *An explosives vehicle was parked on a decline 15 metres from a magazine entrance when the vehicle ran uncontrolled down the decline and into the direction on an explosives magazine. There were no explosives on board the vehicle, but the magazine door was damaged (Vehicle collision. Record nº 18679).*

⇒ *After loading emulsion into a transport vehicle, foaming was noted from the hatch after the vehicle was driven a short distance. Water was added to the tank, and the vehicle parked in a safe location. Sodium nitrite contamination suspected (Chemical reaction. Record nº 20601).*

⇒ *A near-event occurred when a crimping tool crimped a second time onto the detonator of a shock tube assembly as it was being removed from the tool. There were no injuries or damage. A basic PLC program had not been updated (Faulty machinery. Record nº 19937).*

⇒ *A piece of metal (part of band clamp from the joint of the shaft of a PC pump) was found in the mandrel of a KP machine. This followed the use of excessive force to clear a blockage in the pump. There was no ignition (Foreign body. Record nª 20576).*

⇒ *A cab fire broke out in a MMU whilst parked under a silo with 20 tons of explosives. The operative quickly moved the vehicle and extinguished the fire. The fire was possibly started by an oil leak contacting a hot part of the engine (Vehicle fire. Record nº 20529).*

Porgera Mine Explosion - Papua New Guinea – August 2nd, 1994: fire on the bulk truck, around and underneath the bulk emulsion tanks led to the explosion. 11 Fatalities.

How to report & manage near miss events?

Many organizations already have the system in place, but the main challenge is to keep the system simple, user friendly, without requiring a lot of time to report, to manage improvement actions and to generate indicators. Otherwise, this will not motivate people to participate willingly. As in the incident investigation the basic information required is to know: Where and When did it happen? Why or How did it happen? What are the causes and consequences? What has been done to solve the problem?

People at all levels shall be encouraged to report but an important detail to be obeyed is to keep the people who report informed about what was done from the report they produced. People like to have feedback and that motivates them to keep contributing.

How to classify the severity?

Establishing a severity criterion can be useful to prioritize the treatment of occurrences. A severity matrix can be developed from the event categories listed above. For example, the table below can be used as a reference for your company to establish its own criteria.

Near Events - Severity Matrix

Categories	Severity 1	Severity 2	Severity 3
Chemical spill or leak	Small leakage (less than 5 liters) of chemical, which is quickly and easily controlled, without presenting risk to people, equipment or the environment.	Accidental chemical escape from any building, process plant, equipment, storage tank, loading-offloading trucks, drum or other container, in volume greater than 5 liters and less than 50 liters. The leak has caused or has potential to cause injury to workers and damage to the environment. All the leaked product was contained within the plant boundaries.	Accidental chemical escape from any building, process plant, equipment, storage tank, loading-offloading trucks, drum or other container in a volume greater than 50 liters. The leak has caused or has potential to cause injury to persons and major land contamination. Some of the leaked product may have exceeded the plant limits.
Fire in Process	Fire or decomposition in any building and which has caused minimal disruption of activities. Damages were limited to the place where it occurred with no potential to propagate to other places.	Fire in any building or plant that has caused suspension of activities at the place where it occurred, for more than one shift, but less than 24 hours.	Fire in any building or plant that has caused suspension of activities at the place where it occurred, for more than 24 hours. Fire was caused by ignition of materials in process; final products or waste disposal.
Foreign Body	All cases in which a foreign body found does not represent the potential to cause fire, explosion or interruption to the process.	Any foreign body located in raw materials and which which has not yet been fed in the process equipment (reactor, mixer, blender, auger, pump, etc). The object was detected during visual inspection and retained before crossing a final barrier.	Any foreign body that has crossed all previous barriers installed to retain it; reached the process equipment (reactor, mixer, blender, auger, pump, etc) and that by pure chance did not cause fire or explosion.

(to be completed with all other category/scenarios of events)

What is the benefit?

What is the benefit of preventing injuries, explosions, fires and loss of containment?
It is not necessary to say what are the benefits of preventing injuries, explosions, fires, environmental damage, because doing all this is our first responsibility and gives us license to operate our plants.

But let's go back to the fictional scenario at the top of this article and see what it would be the outcome of that dangerous occurrence if the near event system were implemented and alive.

On that ordinary Tuesday at the bulk emulsion plant, after seeing smoke coming out of the hopper and the emulsion spreading upon the floor, the operator quickly pressed the emergency button, stopped production and called his supervisor. Although there were no injuries or more serious consequences the near event was recorded, analysed and the investigation revealed the key weaknesses:

- *The high temperature trip and alarm to shut the pump down malfunctioned.*
- *There is no no-flow switch and no low level control on feeding tank.*
- *Lack in the maintenance program for regular inspections and tests to ensure the reliability of safety systems*
- *Pumping operations was not monitored at all times by the plant operator.*

It is not easy to predict what could happen if this dangerous occurrence were to be repeated but it is certain that no one would want to see it. In this way, the actions taken allowed the plant to restart production with a higher safety standard and probably preventing a pump explosion in the future

How to keep the system alive?

In a newsletter published by ICI the question "How can we keep alive the memory of incidents that have happened on the plant when staff change every few years?" Trevor Kletz – Technical Safety Advisor answered: "One method which has been used successfully on at least one plant in the Division is the plant black book. On this plant there is a folder containing reports of every serious incident and near miss that has occurred on the plant, together with reports of incidents in similar plants in other companies. This is compulsory reading for all managers and engineers when they first join the plant, and the old hands dip into it from time to time to refresh their memory."

Perhaps this could be a suggestion for your company. A book that started being written some time ago and will continue to be written until the plant is decommissioned and with the contribution of everyone who worked on it.

Also sharing learnings from near events will help protect people and prevent losses in the SAFEX community.

EFFECT OF MAGAZINE GEOMETRY AND LOADING DENSITY ON BLAST LOADS FROM EARTH-COVERED MAGAZINES

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ABSTRACT

Explosive safety assessments of earth-covered magazines (ECMs) need reliable methods of predicting the blast load on an acceptor ECM in the event of an explosion at an adjacent potential explosive site (PES). Such methods are currently available in the community through the Blast Effects Calculator (BEC) tool released by the Department of Defense Explosive Safety Board (DDESB). BEC provides pressure and impulse as a function of scaled standoff in the three cardinal directions from the PES: front, side, and rear.

In a recent study for the Canadian Directorate of Architectural and Engineering Services (DAES), BakerRisk and ACTA evaluated the applicability of the BEC curves for pressure and impulse from an ECM to the specific geometry of the Canadian long-span ECM (CLSECM) which is one of flat-roofed reinforced concrete construction. This was done by isolating experimental data from flat-roofed tests alone and comparing to the BEC curves. We further evaluated the effect of variations in loading density (ratio of charge weight to magazine volume) by looking at data from a series of tests in which different loading densities were tested in the same geometry.

The results indicate that the geometry of the ECM (flat-roofed vs. arched) is not a significant factor in determining blast loads, that in fact the same curves are applicable as well to one as to the other. The data does show a correlation between loading density and blast, but it is relatively minor in magnitude. Additional research would be needed to quantify this relationship, including a more refined look at the database accumulated in support of BEC.

BACKGROUND

Earth-covered magazines (ECMs) are frequently used to safely store large quantities of ammunition and high explosives, primarily by military agencies. A typical design, as illustrated in Figure 1 and Figure 2, consists of an enclosed concrete structure (in this case, a rectangular one), with a hardened door to provide access to the interior. A headwall (facing the viewer) acts as a means of retaining the soil cover that is provided above and around the magazine, and also supports the door. Another common configuration of ECM uses a semi-circular arch structure instead of the rectangular one, with the arch being of concrete or steel fabrication. Typically, ECMs are constructed in arrays in which a particular spacing is provided from side to side and from one row to the next, as shown in Figure 3. The spacing is critical in order to insure that, should one magazine experience an accidental explosion,

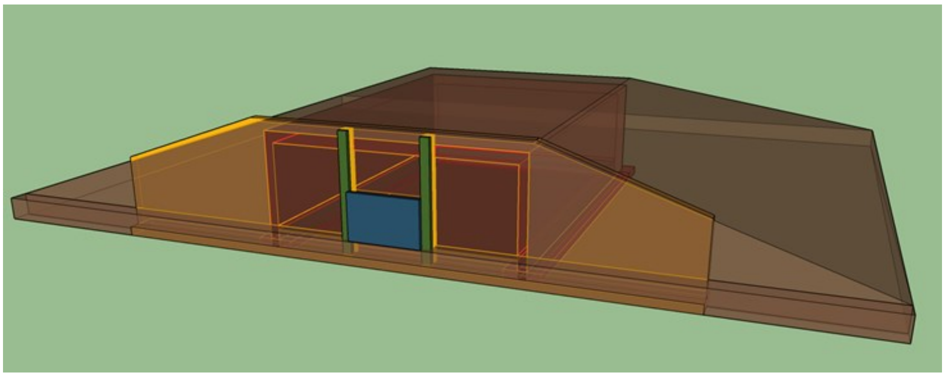

Figure 1: Schematic view of earth-covered magazine design

Figure 2: Typical ECM as constructed.

Figure 3: Typical array of ECMs.

ECM design requires a reliable definition of the blast loads on an adjacent magazine from the accidental detonation of any of its immediate neighbors. Simple blast models (e.g., that of Kingery-Bulmash, [1]) are for bare charges and do not account for any effects from the donor magazine on the airblast. To make such predictions in a time-critical design environment requires that engineering models be available to practicing engineers, otherwise the use of high-fidelity computational fluid dynamics (CFD) models for each calculation would be prohibitively costly. The model must predict loading in three different directions from the donor magazine (front, i.e., through the headwall; side, i.e., through the soil berm on the side of the structure; and rear, i.e., through the soil berm on the rear of the structure). Each loading direction can provide a load on a particular component of an acceptor magazine, as illustrated in Figure 4; more such combinations are possible than are illustrated in the figure. The loads would be a function not only of charge weight in the donor magazine, but also of the distance to the component being analyzed or designed. Additionally, they could be related to the construction of the ECM, the amount of earth overburden, or the loading density within the donor ECM.

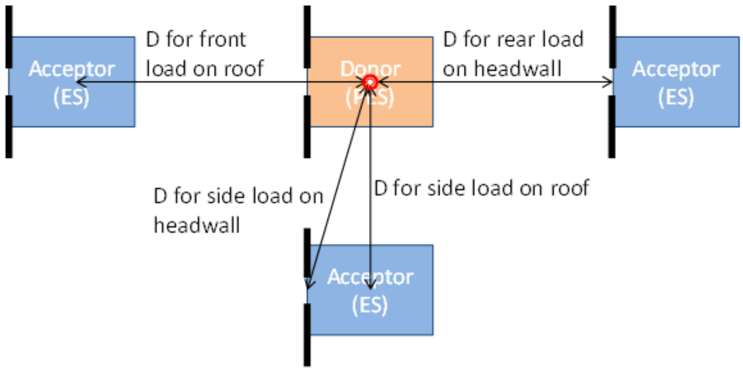

Figure 4: Examples of definition of distances for blast load computations.

EXISTING METHODOLOGIES

At the current time, two models exist in the community for predicting blast loads from ECMs, and as it turns out, they are intimately related. First, the Blast Effects Calculator (BEC) v. 7.0 was released nearly two years ago by the Department of Defense Explosives Safety Board (DDESB) [4]. While this tool is not authorized for use in design, it can be used for research purposes. BEC has been formulated in a spreadsheet for ease of use. The user selects an ECM for the donor, and then selects the load direction (front, side, or rear). The documentation provides a series of plots showing the source data (all of it experimental) and the best-fitting curves that represent that data. An example (the one for front loads) is presented in Figure 5. We note that the body of data on which the curves are based is quite extensive, comprising over a hundred individual data points.

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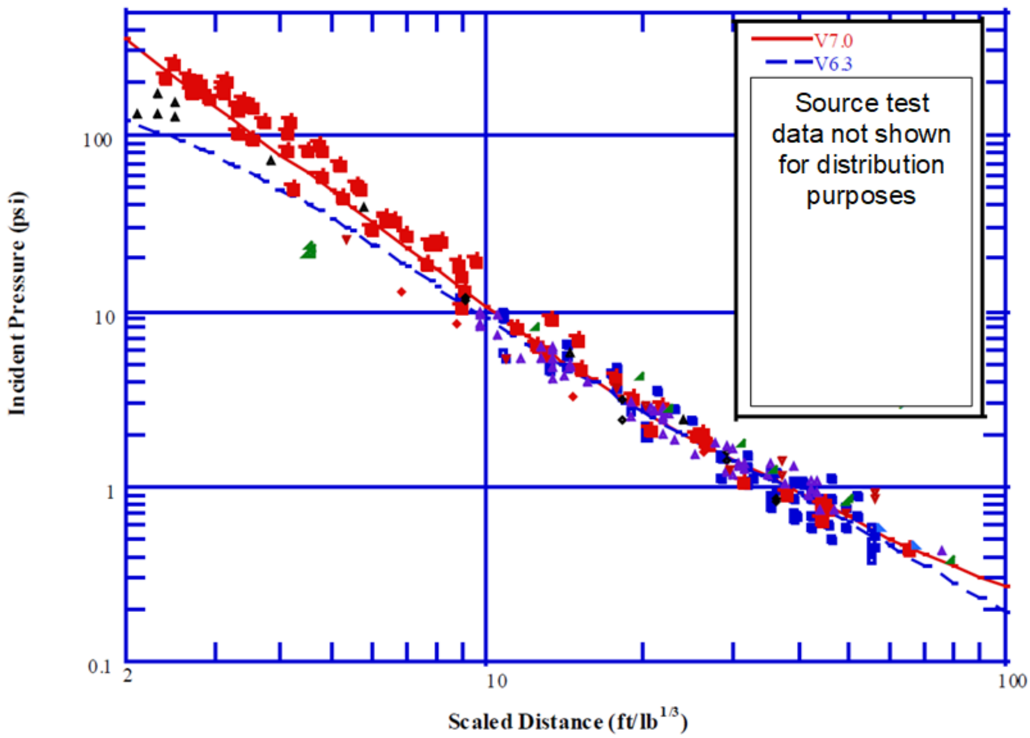
The other model is found in AASTP-4 published by NATO [5]. The manual provides the mathematical formulation of the model, so even though no spreadsheet tool is provided, the equations can be easily implemented by a user. One may note that both models were developed by the same person, but in two very different mathematical formulations. The AASTP-4 model is the simpler, in that a sixth order polynomial is used to represent each of the pressure or impulse vs. scaled standoff curves, with the abscissa being the scaled standoff. In the BEC model, a high-order polynomial curve represents not pressure or impulse, but an equivalent charge weight; this charge weight is then intended to be input to a standard blast model such as that of Kingery and Bulmash [1] which in turn produces pressure and impulse.



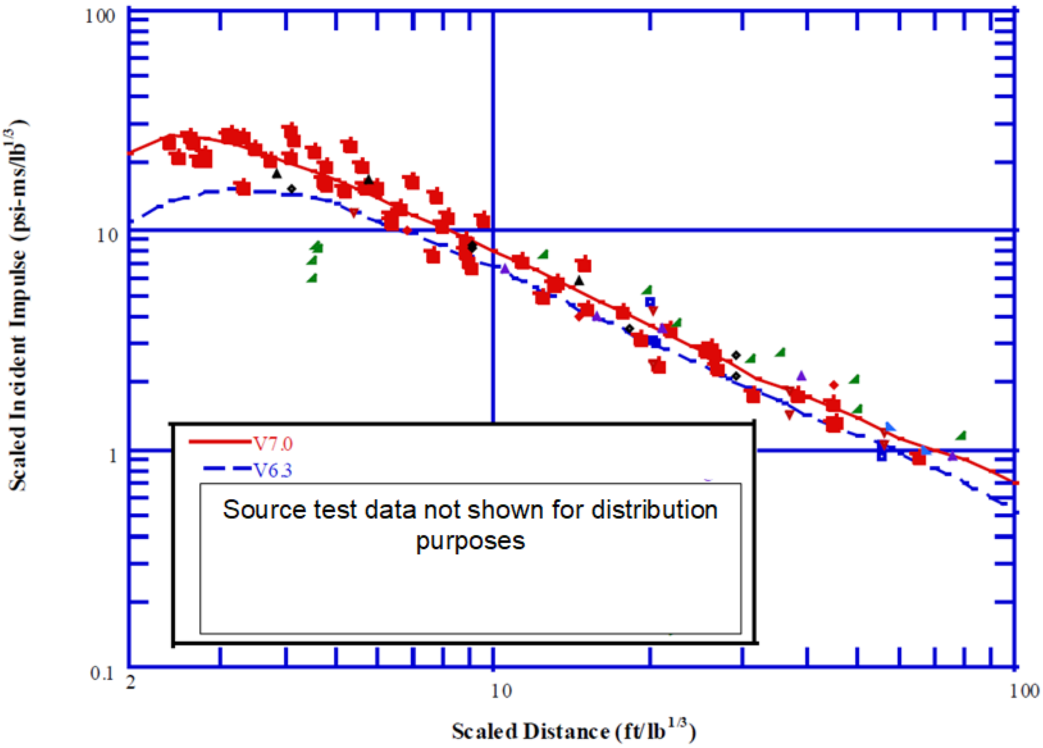


Figure 5: ECM – Front: incident overpressure and impulse vs. scaled distance. (Source: [4])

In spite of these mathematical differences, we can observe (in Figure 6, for example) that the two models are essentially identical. BEC does allow users to go to smaller scaled distances, which can be of great value in some instances. While there is a very small deviation visible in the pressure plot for rear loading at smaller standoffs, all five of the other metrics (rear impulse, side pressure/impulse, and front pressure/impulse) show curves that are indistinguishable from one another. Thus, for all practical purposes, we may refer to both these models as the BEC model.

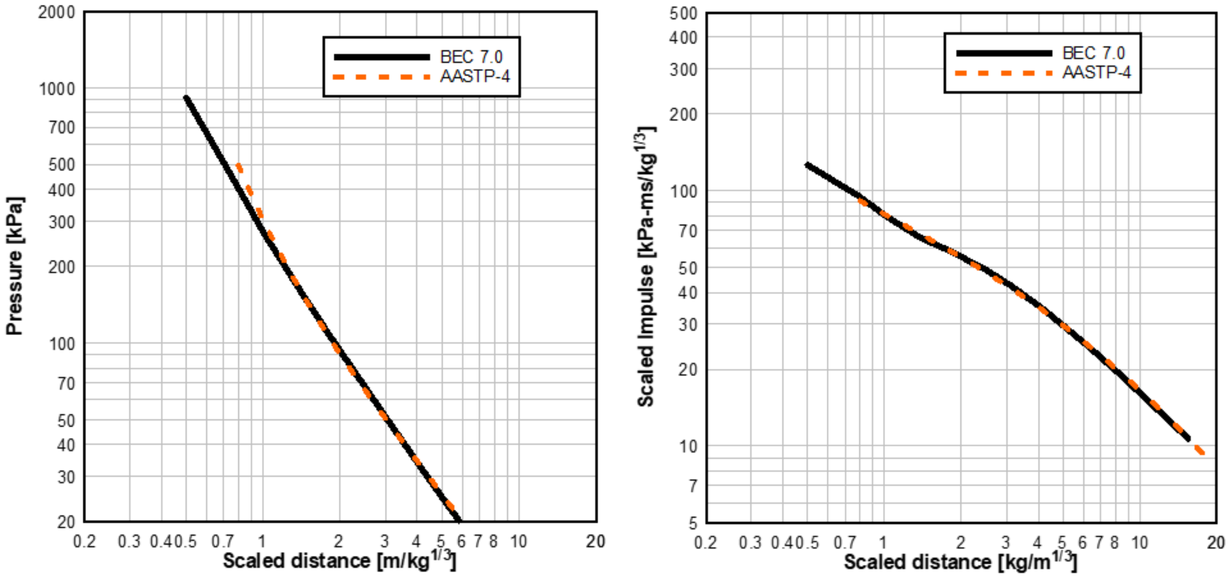


Figure 6: ECM rear loading, BEC 7 vs AASTP-4.

OBJECTIVES OF ANALYSIS

The original context of this study was for evaluation of a particular ECM design that happened to be rectangular in design. Since the data points on which BEC is based included a combination of both rectangular as well as arched magazine data, it seemed prudent to try and segregate the two sets of data and see whether the curves would still apply when data points from rectangular magazines alone were retained.

The second purpose was to determine whether loading density (the ratio of charge weight to building volume, *W/V*) played a role in the resulting pressure and impulse. All the data has been scaled to remove sensitivity to *W*, but perhaps there is some sensitivity to (*W/V*) that the model does not currently reflect.

ARCHED VS FLAT-ROOFED DATA

The plots in the succeeding three figures present the available data from flat-roofed magazine tests, plotted against the BEC curves. Figure 7 presents the loading emanating from the front of the donor (PES) magazine, Figure 8 the side loading, and Figure 9 the rear loading.

Our first and most significant observation is that, by and large, the BEC 7 curves do not exhibit any perceptible bias relative to the flat-roofed data. In other words, by considering flat-roofed data alone, one would arrive at essentially the same curve fits as when considering the entire body of data (mixing flat-roofed with arched data). Certainly, there would be some minor differences, and the curves would likely differ somewhat especially at their extremes to better match this subset of data, but the overall variability in the central domain would be minor.

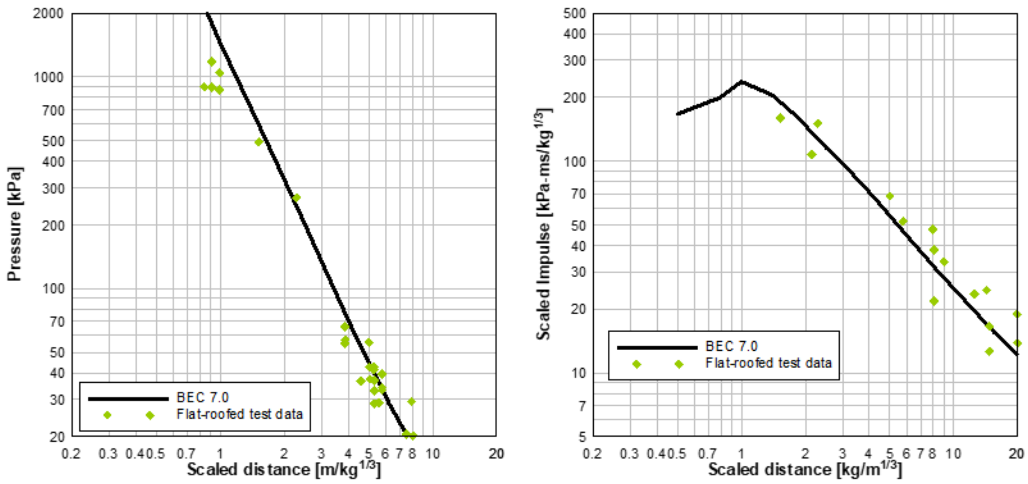


Figure 7: ECM front loading, BEC 7 vs flat-roofed data.

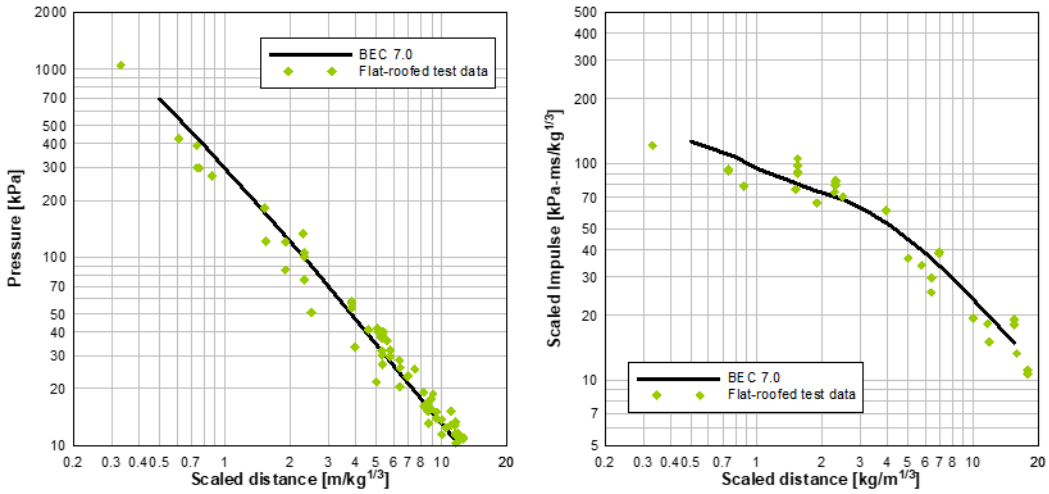


Figure 8: *ECM side loading, BEC 7 vs flat-roofed data.*

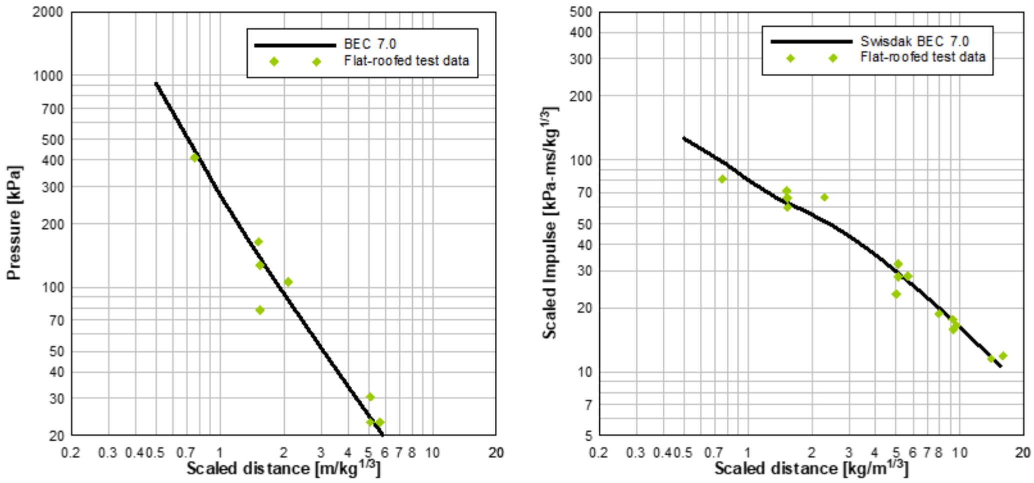


Figure 9: *ECM rear loading, BEC 7 vs flat-roofed data.*

Second, we can be encouraged by the size of the data set for flat-roofed magazines. While not nearly as populous as the full data set (which includes arched magazines), the flat-roofed data are not trivial in number. The least-populated graphs are those for loads from the rear (Figure 9) with 8 or 15 data points in the domain of interest. The others contain several times more data points, lending greater credence to the curve fits.

Third, we observe that for all three directions, the data set is not limited to the larger standoffs. Admittedly, in most cases the data are more sparse at the close standoffs than at the more distant ones, but they do cover the entire domain of interest with reasonable density.

From this assessment, we may conclude that the BEC curves are equally applicable to flat-roofed as to arched structures, and that there is no appreciable difference in the predicted loads from those two types of magazines, within the uncertainty limits of the data set.

LOADING DENSITY AS PARAMETER: TP 17

The data in TP 17 comes from tests with a wide variety of loading densities, which is defined as the weight of explosive, *W*, divided by the magazine's internal volume, *V*. However, to date no one has formulated a functional relationship that would allow a modification of the ECM loading as a function of (*W*/*V*) of the donor. In this section of the paper, we attempt to do just that.

Intuitively, the effect of (*W*/*V*) on loads is expected to be non-trivial. All test data are reduced by plotting against scaled distance, and thus the effect of *W* is intrinsically captured. However, if that same *W* were confined in a very small volume (as opposed to a larger one), the resulting gas pressure would be larger and would cause the structure to break up more rapidly. That in turn should lead to higher pressures in all directions, because the break-up of the door and headwall would be just as much enhanced as the break-up of the roof and side walls and the blowing away of the soil overburden.

Consequently, our expectation would be that, if the data could be segregated by (*W*/*V*), we would find higher loads as (*W*/*V*) increased, and lower loads as it decreased. To evaluate this hypothesis, not only do we need to identify the (*W*/*V*) of each data point, but also to compare values in three dimensions (as a function of both scaled standoff *Z* and [*W*/*V*]), which complicates matters.

The TP 17 data encompasses a broad range of loading densities, as documented in Table 1. The average value is 46 kg/m^3, with a min and max of 2.5 and 182, respectively. Most of the data points fall between 20 and 65 kg/m^3.

Regrettably, the TP 17 documentation does not identify the individual data points associated with the various tests in Table 1. Thus, while we may note the range of loading densities represented by the data, we cannot use this data to identify any possible functional relationship between loading density and blast loading.

Table 1: Loading density values for flat-roofed tests in TP 17

Test	Loading Density (*W*/*V*) [kg/m^3]
Singapore	10
Singapore	20
Singapore	10
Singapore	20
Singapore	20
Singapore	10
Singapore	2.5
Singapore	20
STACKFRAG	55
ESKIMO VI	74
MSM	182
Buffered Storage	37
Buffered Storage	55
Buffered Storage	64
Buffered Storage	64
Buffered Storage	25
Buffered Storage	49
Buffered Storage	97
Buffered Storage	65
AVERAGE	**46.3**

LOADING DENSITY AS PARAMETER: BRL 2680

Fortunately for our purpose, there is one well documented set of data that can be evaluated for information related to loading density. The BRL 2680 report [6] documents a series of three tests conducted in 1976, at very small scale (1:50). A schematic view of the test bed is shown in Figure 10, indicating that the donor structure was arched and constructed of sheet metal. Three radials of in-ground gauges measured incident pressure histories, the peak pressure and impulse values from which are documented in the report. The tests also investigated the effect of varying earth cover over the crown of the magazine, but we only considered the tests with “standard” earth cover and with varying (*W*/*V*), in order to isolate our parameter of primary interest.

The magazine volumes and tested charge weights (all of them converted to full-scale values) are listed in Table 2. The resulting three loading densities (90 – 450 kg/m^3) overlap somewhat with the values in TP 17, although the BRL 2680 data extends out to significantly higher loading densities. Note that all the tests used the same magazine and berm configuration, such that the only variable was charge weight.

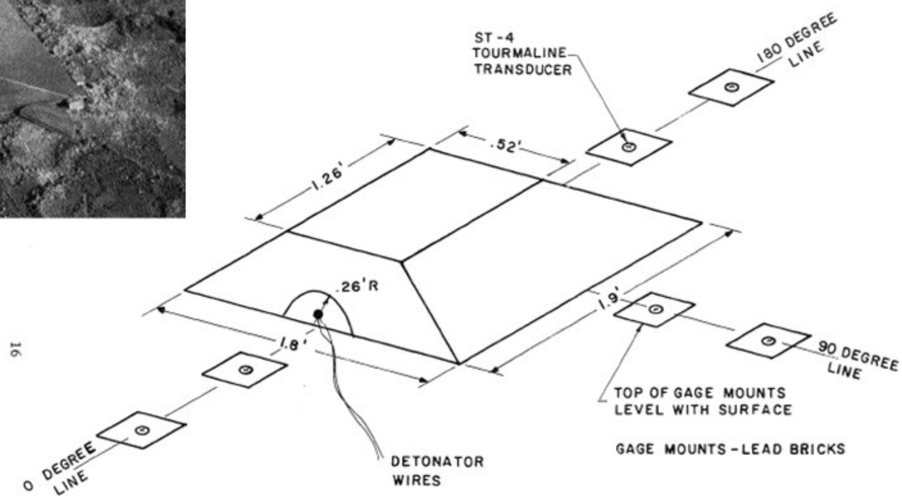


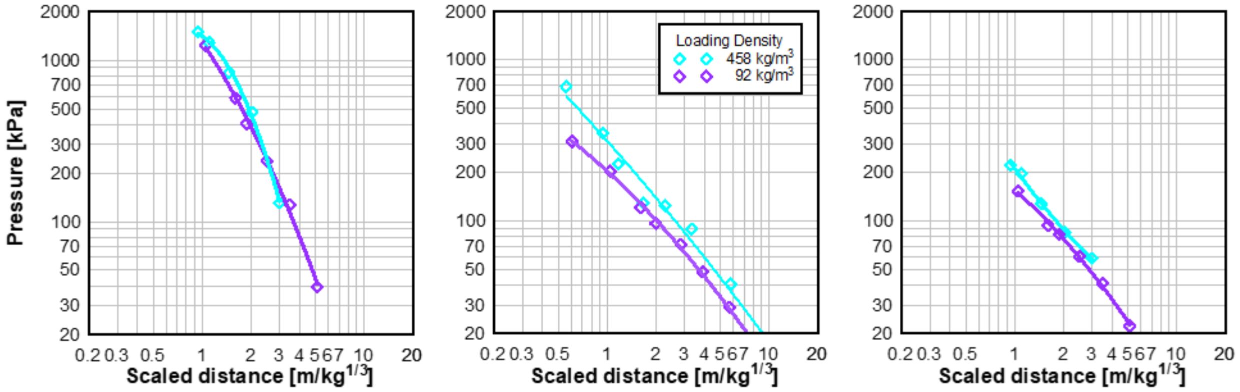
Figure 10: Schematic of test setup used in BRL 2680.

Table 2: Loading densities in BRL tests.

Configuration	*W* [kg TNT]	*V* [m^3]	(*W*/*V*)
Small *W*	45,500	496	92
Medium *W*	136,000	496	275
Large *W*	227,000	496	458

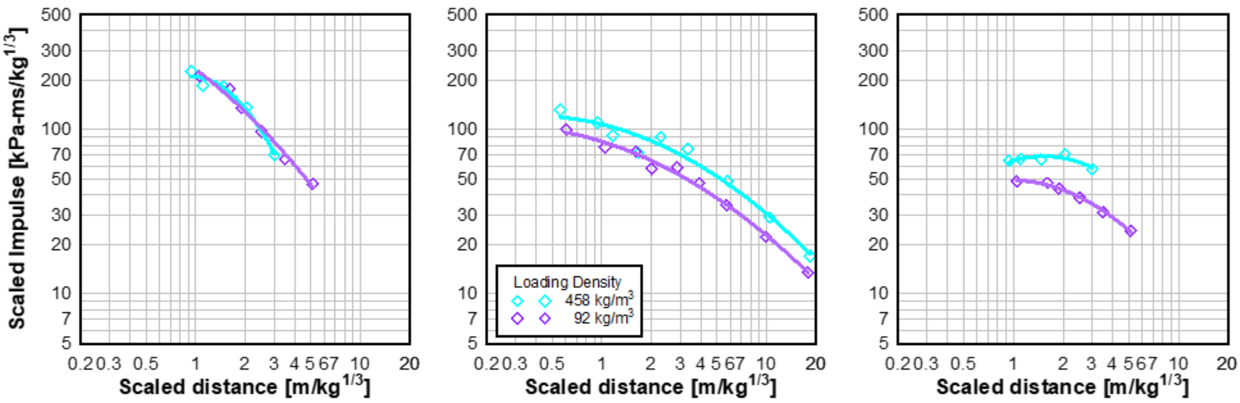
For quantifying the effect of (*W*/*V*), the decision was made to ignore the BRL tests with medium weight, and simply use the two tests with small and large weights. The objective was to quantify a factor on pressure and impulse which could be used to establish the effect of increasing (*W*/*V*) by a factor of (458/92) ≈ 5. As will be subsequently evident, the effect of (*W*/*V*) on the data is not very profound, and by limiting the analysis to the two outermost data sets, that effect can be most clearly perceived.

In Figure 11 and Figure 12, we plot the pressure and impulse curves as a function of scaled standoff *Z*, from the two BRL tests of interest. The light cyan points come from (*W*/*V*) = 458, while the purple ones from (*W*/*V*) = 92. A 2nd order polynomial curve was then fit to each of those data sets, to enhance the visibility of the trends. These polynomials represent the source data with very good accuracy, as the data are not very scattered. Visually, it is apparent that the five-fold increase in (*W*/*V*) does in fact lead to an increase in the blast parameters, although the effect is neither uniform nor completely consistent. With regard to pressure, the greatest effect is observed for the side load; the rear load has a lesser effect, and in the front the curves actually reverse themselves (the smaller load density producing a higher pressure) over a small portion of the domain. With regard to impulse, the greatest effect is observed towards the rear, but the side loads are also perceptibly affected. Here as well, the front load shows the least sensitivity to (*W*/*V*) and in a portion of the domain the curves reverse themselves.



(a) Front *(b) Side* *(c) Rear*

Figure 11: Pressure from ECMs in BRL tests with large and small loading densities.



(a) Front *(b) Side* *(c) Rear*

Figure 12: Impulse from ECMs in BRL tests with large and small loading densities.

To consolidate the data and make it more manageable, we can now take the ratio of the two curves over the range of standoffs where the curves are defined. This ratio represents the increase in each metric due to the five-fold increase in (*W*/*V*) from 92 to 458 kg/m^3, as a function of standoff. Since the gap between the two curves does not vary tremendously, we can then take the average of this factor across all scaled standoffs to simplify the results by eliminating standoff as a parameter. A scalar value is thus produced for each of the six metrics using the following equation:

$$K = \text{AVG}\left\{\frac{M_{458}}{M_{92}}\right\}\Bigg|_{\text{all } Z}$$

where *K* is the factor, *M* is the metric of choice (pressure or impulse, front, side, or rear), and the subscripts 458 and 92 indicate the (*W*/*V*) value in kg/m^3.

The factors produced by this procedure are listed in Table 3 and plotted in Figure 13. The effect of (*W*/*V*) is clearly least felt for loads from the front of the ECM. Side and rear have roughly the same effect, and it is significant. The greatest effect is for impulse from the rear, where the increase in (*W*/*V*) produces an increase in impulse of about 50%. There is no clear pattern in terms of pressure or impulse factors being consistently high or low.

Table 3: *Factors for airblast metrics due to 5´ increase in (W/V).*

Metric	Front	Side	Rear
Pressure	1.16	1.43	1.19
Impulse	1.00	1.30	1.51

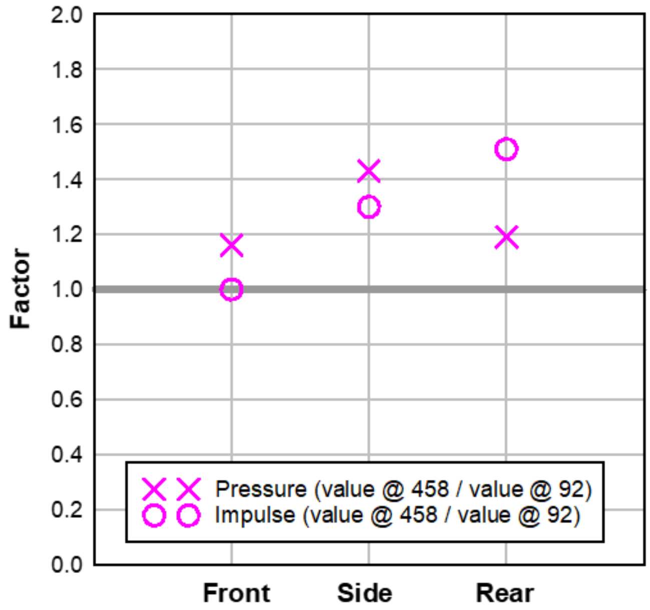


Figure 13: *Factor for airblast metrics due to 5´ increase in (W/V).*

The factors calculated earlier do show a weak trend in blast pressure and impulse as a function of (*W/V*): increasing loading density by a factor of 5 leads to increases of between 0% and 50% in the various metrics. These are not large increases and are far smaller than the ratio of loading densities. It is possible that the high densities used in these tests were sufficient to overwhelm the structure and earth overburden, and that the outcome may have been different had that same five-fold increase been evaluated over a range of, say, 20 to 100 kg/m^3 instead of 90 to 450. Clearly, we can intuitively expect two results in the extremes: at very small loading densities, the structure and overburden will provide nearly complete containment and lead to near-zero values of pressure and impulse; conversely, at very large loading densities, the structure will have a negligible effect and the Kingery-Bulmash relationships will apply without a need for directionally dependent models such as BEC.

CONCLUSIONS

The data evaluated above leads to the following conclusions:

- When estimating blast load from an ECM, the current state-of-the-art in predictive techniques is embodied in either TP 17 (BEC v.7) or AASTP 4. The two models are mathematically different but produce numerically nearly identical results.
- Segregating flat-roofed magazine from arched magazine data shows no significant difference in the resulting curve fits. Thus the BEC model may be applied equally to flat-roofed as well as arched ECMs.
- Available data from BRL 2680 suggests a weak relationship between loading density (*W/V*) and blast from ECMs; an increase of 5´ in loading density leads to a 0-50 percent increase in the blast metrics.

We would further recommend that available data from the TP 17 database be mined and subjected to further analysis. That data set represents a larger variation in loading density and extends down to lower values than BRL 2680 in which domain effects on blast metrics may be more pronounced and easily quantified.

ACKNOWLEDGMENT

The authors acknowledge with gratitude the support of Mr. Hariharasankaran Vaidyanathan of the Department of National Defence, Canada, who funded the research presented in this paper.

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ANNA Conference 2022
Houston, TX

Sunday Oct 02 2022 — Friday Oct 07 2022

In the interest of your safety, the ANNA Executive has decided to postpone the 2021 Conference until 2022. Many producers and exhibitors indicated that they were unsure whether they would be able to attend the conference due to government and company travel restrictions.

The ANNA Executive and Exhibitors Group are currently planning the next meeting for October 2 - 7, 2022 at the Royal Sonesta Hotel in Houston, Texas. We will have a full slate of technical presentations, an exhibit hall, participant and spouse activities, and a few surprises planned for next year's event.

Be sure to mark these dates on your calendar and watch for further announcements, including a call for technical presentations.

Some Finishing Thoughts
from
Ken Price

Newsletter time again.

In my last article on Major Hazards, I threatened to write next on how explosives regulations are changing, the responsibilities of Competent Authorities and some alternatives to Q/D tables. I lied! Geoff Downs wrote enough about regulations and Competent Authorities in newsletter 74 and I can't top that. Suffice to say that we are seeing a continuation of the world-wide trend over the past 30 years of diminishing technical competence in Competent Authorities, and a corresponding increasing reliance on blind adherence to the written law with no room for interpretation.

This can't be a good thing. Our technical world develops and evolves at a rapid rate; much faster than regulations. (Could it be that the British parliament in the 1870's thought the same way when they drafted the 1875 Explosives Act? That Act was one of the world's first performance-based pieces of legislation, though it may not have been described as such at that time. The legislation made provision for a Chief Inspector of Explosives (CIE) whose job was to interpret and apply the legislation, allowing for technical developments.)

Like or hate the CIE, the position had to make decisions applying technical competence. Some CIEs were good, some not so good, but they allowed for flexible application of technical developments.

Fast forward to the mid-20th century and we find the United Nations Model Regulations for the Transport of Dangerous Goods recognise the need for flexibility in regulations in response to developments in technology. In the absence of an international Competent Authority, the Advisory Committee that drafts the Model Regulations regularly amend and update the regulations to try to keep pace with technological developments. They have done this over the past fifty years or so.

Unfortunately, all that most national governments can do is amend their legislation to put responsibility in the hands of an administrative bureaucrat. Have you tried to explain the properties of the steel in a vented pipe test to a classics graduate whose idea of maths is simple arithmetic?

Who'd try to work in a federation?

The above issues are hard enough to manage in relatively cohesive government systems, but it can be a nightmare in a federation like Australia; a federation of six states and a few territories.

Or so they say.

From my experience as a Competent Authority for 25 years and working in industry for more than 20 years, Australia is more like a collection of about 10 sheikdoms or principalities, each governed by Competent Authority who knows more about everything than all his fellow princes. (They all seem to be males – even the women.)

And add to that the political testosterone (also called state rights) and it can be an impossible mix.

Late last century I participated in several attempts in a few forums to bring a level of uniformity to this conglomeration. Half a dozen of us got together to try to develop some common principles and model regulations to manage explosives across the country. There was a true spirit of cooperation in the group and we made a good deal of progress. But, like so many other attempts it withered and died on the vine of political competition.

An anecdote from a dangerous goods forum serves to illustrate the problem. In a group working on uniformity in the gas/energy industry the department head of one of the State participants was looking particularly disturbed; he wasn't participating to his usual (high) level of expertise. When asked if there was anything bothering him, he recounted that just before leaving his office to come to the meeting his Minister had called him into his office. The public servant was told to participate in the meeting and: "whichever way Canberra votes, you vote the opposite". Classic State vs Commonwealth confrontation.

So here we are in 2021 this century old problem shows no sign of diminishing:

- When setting separation distances for ammonium nitrate storages, one state applies a TNT equivalence factor of 25%, others use 32%;
- Drivers of explosives vehicles are recognised across several state borders without a licence for each individual state – but not all;
- Victoria has set a Major Hazards threshold of 5 tonnes for explosives. This triggers the requirement for a Safety Case including a quantitative risk analysis, a $100 000 licence fee, as well as application of the Q/D tables;
- The Commonwealth government has just instigated a regulatory review process to apply to the exclusion of State and Territory laws.

I stand back and look at our systems in Australia and they are a marked contrast to how Europe manages to regulate explosives across thirty or so different countries.

Finally, thanks to the editor for the comments in red on my last paper in this newsletter.

With respect to the major hazards definition, indeed, it is not easy to get a simple clear definition of a major hazards site agreed by multiple parties. Unfortunately, many governments don't apply common sense to this matter. Simply setting quantity thresholds of dangerous goods is the usual criterion. It works well too, if you are a government. Money for jam. Typical licence fees start with six-figure sums and there is rarely, if ever, any justification of the licence fees. [Do you get a sense that I dislike MHF regulation? You could be right. Over 40 years I have worked with or consulted with many MHF regulatory groups around the world and have encountered only two who can administer their regulations with common sense and value for money.]

And with respect to hazards from emulsions, my data are very old. Process hazards from pumps were the main contributor to accidents and still present the biggest risk, but fires (particularly on vehicles) seem to have overtaken pumps as the most common cause of incidents.

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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 April 2022 Newsletter is 31 March 2022 .I look forward to your continued support .

SAFEX thanks all the authors and contributors as well as the editing team Andy Begg and Noël Hsu for their for their invaluable support.