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FROM THE SECRETARY GENERAL'S DESK

Covid-19 is still affecting lives and economies on a global scale. In most countries there are very strict lockdowns and travel restrictions. As a result of this the Board of Governors though it prudent to postpone the SAFEX XX till 3-8 April 2022. It will still be held in Salzburg and further information will be communicated during the course of this year.

As a result of these postponements the Board decided to hold two webinars during 2021. The first was held on 8 March and was rated as extraordinarily successful in the subsequent survey. The participants exceeded 150 in number and rated the content, presentation, and applicability in their operations more than 90%. A second webinar will be planned for the 3rd quarter of this year – and further information will be forthcoming over the next few months. SAFEX again looks forward to your active participation.

The Board also initiated a series of initiatives to build on current member offerings and broaden the training base. We are asking for volunteers as participants in the Working Teams as well as Leads for the Primaries and Shock Tube Working groups:

GPG's and eLearning		
GPG	**Lead**	**Team Members (Pledges for assistance)**
Eplosives Transport	Noel Hsu	Ken Price(Individual Associate),Edward Felix(AECI), Nadia Engler(Austin)
Shocktube		Ronald Huggins(AECI),Lenka Mikulencakova (Austin Powder),Jan Jidestig (Austin Powder)
Primaries		Ralf Weber(Austin),Christo Peltz(AECI), Tony Rowe(Consultant), Wen Yu(Expert Panel), Roman Vala (Austin Powder),Jan Jidestig (Austin Powder)
PETN	Joao Roorda	Markus Troger(SSE), ,Guilherme Ferreira(ENAEX), Johan Barnard(AECI), Tony Rowe(Consultant), Paulo Siquera (Expert Panel), Ralf Weber (Austin), Wen Yu (Expert Panel), Mervyn Traut (Expert Panel)
Process Safety Incidents	Neil Franklin	Neil Franklin (AECI), Wen Yu(Expert Panel)
Next module using the Sierra/Alpha Piper incidents as a base-	Andy Begg/Martin Held	Andy Begg (Individual Associate), Martin Held (Austin)
eLearning		
Russian Translations	Elisheva Chernilovskaya	Elisheva Chernilovskaya(AZOT)
French Translations	Johanne Della Rovere	Johanne Della Rovere (EPC)
Spanish Translations	Joao Roorda	Guilherme Azevedo Ferreira (ENAEX)

Sheet1

Meetings have already commenced on a virtual basis in most of the areas and the plan is complete all the work within the next 2 years. Please contact me if you are interested in participating especially if you are prepared to lead the Shock Tube or Primary GPG's. The PETN Work Group led by Joao Roorda has already made great progress.

We have a Newsletter full of quality articles, and for the first time a Safety Quiz presented by Dr Martin Braithwaite. Test your own knowledge and ability against the answers at the end of the Newsletter.

Part 1 of an interesting paper on Relevant Good Practice for explosive demolition of structures is also published with Part 2 coming in the October Newsletter.

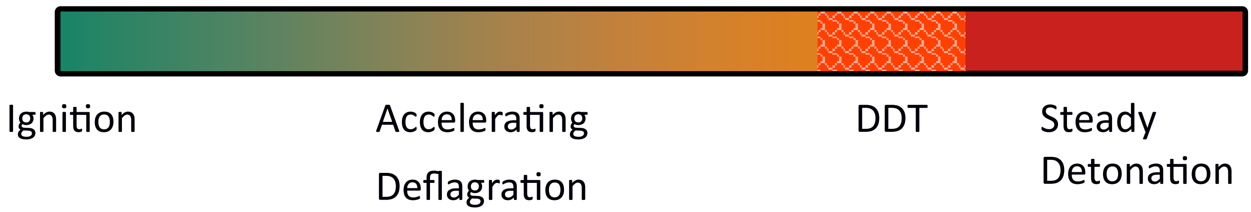
TEST YOUR EXPLOSIVES SAFETY KNOWLEDGE

DR MARTIN BRAITHWAITE

(Answers at end of Newsletter)

DDT in pipes – design pressure for containment

Two gas mixtures are present in a long pipe of a diameter sufficient for stable detonation. One mixture is propane air and the other acetylene air, both stoichiometric) and initially at 1 atmosphere and 300 K. Calculated detonation pressures and velocities are 1.65 MPa and 1720 m/s. The basis of safety adopted for complete containment following any event caused by static electricity, which system requires the highest design pressure for containment and roughly, ratioed to the quoted detonation pressure is required? 2, 5, 7 or 10 x (approximate) detonation pressure and why?



(Minimum Burning Pressure) MBP use – basis of safety & relief for deflagrations

A progressive cavity pump is used for the conveyance of an emulsion matrix at a design exit pressure of 4 MPa. The particular pump and associated pipework will disintegrate at 10 MPa. The particular emulsion matrix has a minimum burning pressure of 6 MPa. For the specific case of a deflagration (neither explosion nor detonation) pressure relief will, in principle, be effective. Is a bursting (rupture) disk required? If so, what would be a recommended pressure rating for it?

Ammonium Nitrate based propellants

A specific rocket propellant design was based on tests with cheaper AN based propellant and a metal casing designed to ensure containment. The design pressure of the casing was based on standard strand burner and bomb tests. The rocket motor exploded shortly after launch.

Ignoring contamination and high external temperatures which of the following are the likely causes and why:

(i) Ostwald ripening

(ii) AN particle damage by moisture ingress

(iii) Phase transitions/ omission of crystal habit modifiers

(iv) Poor mixing with other components eg fuels

(v) Channeling of combustion front ahead of the combustion front

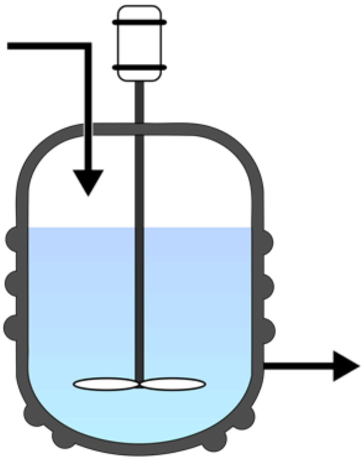
(vi) Blockage

Stirred pot in a flow system with no/low flow check

A stirred pot reactor (CSTR) is used to allow and control the reaction of an exothermic process for the manufacture of a liquid propellant ingredient. Entrance and exit flows are carefully controlled and the temperature is monitored utilizing temperature-sensitive paint on the exterior of the vessel. The material in the pot explodes though there is no indication of any temperature deviation from the paint. Contamination, external fire or altered input/ output flows of reactant/ product/ heat transfer media can be ruled out. What is the most likely cause?

Undertaking exothermic reactions in chemical plant reactors can introduce a reaction runway hazard. The temperature of the reactor contents is governed by a balance of heat inputs and heat output:

Heat Input	Heat Loss
Exothermic chemical reactions & environs	Heat loss through reactor walls environs
Mechanical agitation	Loss of hot reaction products
External or internal heating (if required)	Evaporation
	Cooling by heat transfer media (if required)



Continuous Stirred Tank Reactor

Gas void compression – propellant press

A safe pressurization regime in a propellant press requires the gas temperature to remain in fix bounds and avoid any chemical reaction. Suppose a pressing operation starts at 30 deg C, the maximum allowable temperature in the void was 200 deg C and a pressure of 10 MPa had to be achieved. Consider initial void diameters of 0.01m, 0.04m and 0.15m and assume that the ratio of "safe" times between the small void and medium void and the medium void and large void is similar. The adiabatic Gamma for the gas can be assumed to be 1.4. What, roughly, is the ratio of safe pressurization times (time to 10 MPa for larger void/time to 10 MPa for smaller void) – is it 5, 10, 15 or 30?

Post-Detonation Fume prediction- NOx, CO, CH_4

Explosion fume generated from explosive charge firing can be caused by water, weak confinement, inadequate initiation or dead pressing. Assuming that none of these conditions would apply why would one not use values taken from an ideal detonation computer code equilibrium thermodynamics)?

(i) Chosen product equation of state and associated allowed species unreliable

(ii) Freeze out of some chemical processes during expansion

(iii) loss of fume (NOx, CO) to rock mass

(iv) Mixing with external air

(v) late reaction with air (oxygen negative systems)

Domino effects– storage separation distances – Ammonium Nitrate (AN)

To avoid the propagation of an event from a storage unit to an adjacent one, several strategies can be employed. These can include the total absence of combustible material (in the case of oxidizers) or the assured elimination of all sources of initiation. Mitigation of any event can be considered eg inerting, water deluge etc. An additional option is to have separation distances sufficient that an event in one storage unit cannot propagate to its nearest neighbour. Traditionally scaling laws based on TNT explosion data have been employed, frequently ending up in large separation distances. Which, if any, of the following strategies or combinations of these would be credible in arguing the case for different distances:

(i) Determination of mode of energy transfer – fragment, fire or shock – as a check on scaling law used

(ii) Full quantitative risk analysis

(iii) More storage units containing less material

(iv) Containment eg barricades or earth mounding

Beirut Ammonium Nitrate Explosion (August 2020) – early analysis of blast effects

The tragic explosion of 2750 tonnes of ammonium nitrate and some other materials resulted in catastrophic damage to people, buildings and the infrastructure of Beirut. Many publications have appeared analysing this event in terms of an equivalent mass of TNT damage eg from 400 to 2000 tonnes, the first of which published suggested 1500 tonnes.

Why is this result from a technical standpoint immediately spurious?

Thermite – the role of thermite in commercial explosives processing

In the past, there have been some questionable debates on the benefits of adding thermite powders to commercial explosives, with support based on the large exothermicity of these reactions but ignoring the fact that the thermite solid-solid reaction rates are slow compared to a condensed phase detonation. Supposing thermite was mixed with an emulsion matrix and pumped through a long pipe – would this have any implications for safe operation and if so, what?

Transport

A man had to export a liquid in drums to the tropics. He knew that liquids exert vapour pressures that increase with temperature and that they expand on heating. The extremes in temperature which the drums would experience were 0°C and 30°C. The vapour pressure and linear volumetric expansion for the liquid were:

Temperature °C	0	15	30
Vapour pressure (kPa)	20.7	41.4	82.7
Expansion (0°C to 30°C)	3%		

He therefore decided, to be on the safe side, that the drums would be filled to 90% of their volume to allow plenty of room for expansion, and that he would use drums with bursting pressures of twice the vapour pressure of the liquid at the highest temperature it would experience, ie 2 x 82.7 = 165.4 kPa. It was a cold day (0° C) when the drums were filled but he thought this had been allowed for in his margins for safety. He was very surprised to learn that all the drums burst when the ship arrived in the tropics. Why did the drums burst?

Comparison of Quantity-Distance Standards for Earth-Covered Magazines in Various National/International Manuals

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Keywords: earth-covered magazine, igloo, separation distance, IMD, standards

ABSTRACT

National and multi-national agencies tasked with regulation of explosives storage have produced a number of different manuals governing the maximum amounts of HD 1.1 material that can be stored in an earth-covered magazine (ECM). These quantity-distance (Q-D) requirements are set forth in prescriptive language in manuals published for use by the engineering and planning community.

A recent comprehensive review of five such manual sources resulted in a compilation of a set of comparative tables in which the requirements for minimum separation distance, as well as for blast loading on various elements of the ECM, were outlined side by side. The five manuals represent requirements for the United Kingdom, Canada, and U.S.A., as well as multinational entities such as NATO and the United Nations. All manuals use the same designations for categories of ECMs (namely, 7-bar, 3-bar, or undefined). But the actual requirements, both in terms of scaled distances and the applied loading (pressure and impulse), are not entirely consistent across the various requirements. This paper identifies some of those inconsistencies, as well as potential inconsistencies in the correlation between separation distance and its corresponding pressure and impulse.

BACKGROUND

In early 2017, BakerRisk was engaged by the Department of National Defence, Canada, to evaluate their long-span earth covered magazine (ECM) design for blast loads from an accidental detonation in an adjacent magazine. The study was a comprehensive one involving high-fidelity finite element models of structural response as well as the latest analytical estimates of blast loads from ECMs. That study is documented in a separate paper [1], as well as a fully detailed technical report [2].

In the course of that study, the authors were tasked to review a broad range of national and international safety standards for storage of ammunition, particularly as they related to design requirements for siting of ECMs. Five such standards were identified representing the US, UK, UN, NATO, and Canadian requirements. All are formulated in terms of quantity-distance (Q-D), and so they all provide minimum separation distances; in addition, most provide at least some design loads (pressure and impulse) that ECMs must satisfy in order to qualify for one of three different standard ratings, depending on the load that the headwall of the ECM is designed to resist:

7-bar

3-bar

Undefined

It may come as no surprise that, when aligned against one another, the five references do not align perfectly, and in fact present certain glaring points of dissimilarity. This paper attempts to compare those standards and highlight their areas of agreement as well as disagreement. We are not so bold as to offer a suggested path towards harmonization of the standards, but it is our hope that this paper may stimulate discussions among the various parties involved that may, one day, result in such a harmonization.

DEFINITIONS

For clarity, the assumed configuration of ECMs in a constructed array is shown in Figure 1. The requirements for separation distance from the donor (or potential explosion site, PES) to the acceptor (or exposed site, ES) are prescribed in terms of clear distances from the nearest surfaces of each ECM. These are termed the inter-magazine distance, or IMD. Note that these would *not* be the same distances one might use to calculate blast load as a function of charge weight and distance. In the latter case, an alternate set of dimensions would be used from the centroid of the explosive mass (generally the centroid of the magazine, unless one knows that the storage arrangement would be deliberately skewed or off-center) to the center of the structural component being evaluated. This is illustrated in Figure 2. For example, the side-to-side load on the roof of an acceptor would be calculated from the centroid of the donor to the centroid of the acceptor, and could be a significantly larger distance than that used for the side-to-side separation distance, depending on the plan dimensions of

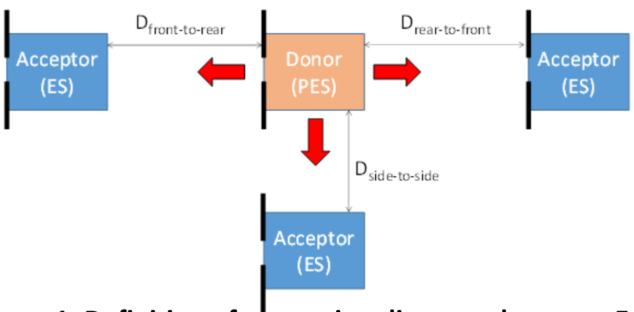

Figure 1: Definition of separation distances between ECMs

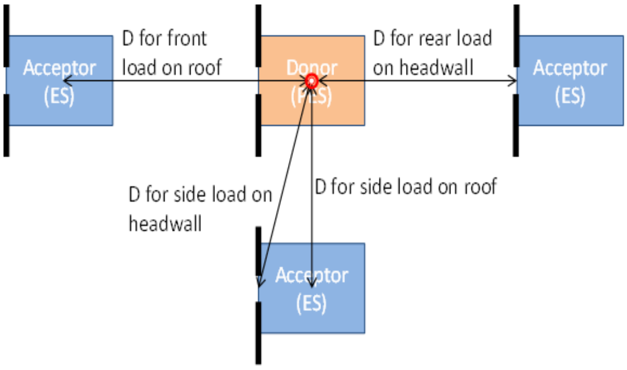

Figure 2: Examples of definition of distances for blast load computations.

We mention this here because this too is a potential source of confusion for novice users of the published standards, and to our knowledge, none of the standards go to any length in clarifying this distinction. Use of similar verbal terms (side-to-side distance, for example) referring to two different quantities carries the potential for misunderstanding and misapplication, and may be avoided with the use of clarifying graphics such as those above.

SOURCES

The five jurisdictions consulted were the United States, United Kingdom, United Nations, North Atlantic Treaty Organization, and Canada. Each publishes a voluminous body of technical literature, from which the relevant documents were identified. The specific documents and the sources for the data to be presented in the tables in the remainder of this paper are cited below.

- United States: DoD 6055.09-M [3] establishes safe stand-off distances between various PESs and ESs. For IMD, the pertinent tables are Table V3.E3.T6 (HD 1.1 IMD Hazard Factors) and Tables V3.E3.T7 (QD for HD 1.1 AE for K = 1.1, 1.25, 2, 2.75, 4.5 and 5) and V3.E3.T8 (QD for HD 1.1 AE for K = 6, 8, 9, 11, 18 and 40). ECM component design blast loads are defined in Vol. 2, Para. V2.E5.5.2.4.

- United Kingdom: JSP 482 [4] establishes safe stand-off distances between various PESs and ESs. For IMD, the pertinent tables used are in Chapter 10, Section 2, Annex A, Table 1A (HD 1.1 QD Matrix for Earth Covered Storage). ECM component design blast loads are defined in Chapter 6, Annex A, Para. 1.2 (Design Loads for Igloos as Exposed Site).

- United Nations: IATG 02.20 [5] establishes safe stand-off distances between various PESs and ESs. For IMD, the pertinent tables used are in Annex A, Table D.2 (Hazard Division 1.1 QD Matrix (above ground storage, NEQ > 50 kg). ECM component design blast loads are defined in a separate document, IATG 05.20 [6], Annex C, Para. C.1.1 (Design Loads for Igloos as Exposed Site).

- NATO: AASTP-1 [7] provides IMDs for ECMs in Section II, Table 1A (HD 1.1 QD Matrix for Earth Covered Storage). ECM component design blast loads are defined in Section II, Para. 2.3.2.2-2 (Design Load for Head-Walls and Doors).

- Canada: DND Canada has issued C-09-005-0021 [8] as that country's explosive safety standard. QD tables are provided in Appendix A, Section II, Table A-2 starting on p. A-13. These are identical in form and content to those in the NATO standard AASTP-1 (at least with regard to the ECM PES and ES combinations). However, to the best of our ability to determine, tables or paragraphs providing design loads for ECMs are not provided.

SEPARATION DISTANCES

We first consider the IMD separation distances between adjacent ECMs, which once again are defined in terms of the distances shown in Figure 1. The required distances are listed in Table 1 for all three loading directions, all three PES types, and all five jurisdictions. Where divergences regarding level of protection were present in the manuals, those are noted in the footnotes. The values are provided in metric scaled distances, where the distance is normalized by the cube root of the net explosive quantity (NEQ). Cells containing values that seem at odds with the consensus are highlighted with color.

Consideration of the table indicates many areas of consistency across all five jurisdictions, as well as a number of areas of inconsistency. Roundoff aside, all five documents agree identically on all three distances for 7-bar magazines. There is near unanimity for 3-bar magazines with only two exceptions. One is the UK which allows 0.8

instead of 1.8 m/kg$^{1/3}$ separation from rear to front and is thus less conservative than the others. This is doubly curious because it is the only instance of disagreement between the UK and UN/NATO/Canada. Furthermore, keeping the rear-to-front distance (which controls headwall loads) the same between 3-bar and 7-bar magazines seems inappropriate, given the very definition of the 3-bar and 7-bar values. The other exception, the absence of a side-to-side value from Canada, appears to be a formatting issue in the published version of the table, where the schematic figure and the D-value have been cut off at the top of the table (Figure 3).

Note that JSP 482 provides separation distances for a receptor (ES) magazine that is "a standard UK igloo designed in accordance with Chapter 6" without distinguishing between 3-bar and 7-bar designs, both of which are covered in Chapter 6. We have interpreted this to mean that the separation distances should be applied equally for both designation. Other manuals (NATO, UN, Canada) clearly distinguish the 3-bar from the 7-bar ES in their tables.

Table 1: Minimum scaled separation distances [m/kg$^{1/3}$] for ECMs.

Receptor (PES) ECM Type	Direction		US	UK	UN	NATO	Canada
Undefined	Side-to-side		0.79[a] 0.50[b]	1.8[c] 0.8[d]	1.8[c] 0.8[d]	1.8[c] 0.8[d]	1.8[c] 0.8[d]
	Rear-to-front		2.38	2.4[e]	2.4[e]	2.4[e]	2.4[e]
	Front-to-rear		0.79	1.8[c]	1.8[c]	1.8	1.8
3-bar	Side-to-side		0.5	0.5	0.5	0.5	—
	Rear-to-front		1.79	0.8	1.8	1.8	1.8
	Front-to-rear		0.79	0.8	0.8	0.8	0.8
7-bar	Side-to-side		0.5	0.5	0.5	0.5	0.5
	Rear-to-front		0.79	0.8	0.8	0.8	0.8
	Front-to-rear		0.79	0.8	0.8	0.8	0.8

(a) for NEQ < 113,400 kg
(b) for NEQ > 113,400 kg
(c) for virtually complete protection

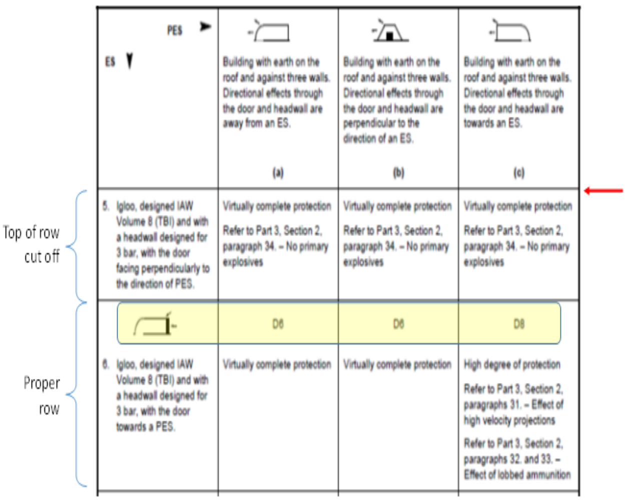

Figure 3: Missing information for 3-bar magazine, side-to-side loading (extract from [8]).

For the Undefined magazine, there are two values that stand in contrast with the majority consensus, and both belong to the US. For both side-to-side as well as front-to-rear loads, the US allows significantly smaller separation distances. The comparison is less clear because of the ambiguities in application (US distinguishes large from small NEQs, while the others distinguish between varying levels of protection). Nevertheless, the US is significantly less conservative than the other jurisdictions in the side-to-side and front-to-rear spacing, but it is quite consistent in the rear-to-front spacing.

DESIGN LOADING

We turn next to the loads for which an ECM is to be designed (Table 2), and here the situation grows more complex. First, there are two load values to consider, pressure *and* impulse. Second, the standards are far less thorough in prescribing loads than they were in prescribing IMDs; in this case, much of the table is blank. Third, since there are fewer "votes," it is harder to determine a consensus opinion and identify outliers.

Table 2: Prescribed design pressures and scaled impulses for ECMs.

Metric	Donor (PES) ECM Type	Acceptor (ES) Component	US	UK	UN	NATO	Canada
Pressure [kPa]	Undefined	Head wall	—	—	—	—	—
		Roof	745	—	—	—	—
		Side wall	—	—	—	—	—
	3-bar	Head wall	300	300	300	—	—
		Roof	745	600	600	—	—
		Side wall	—	300	300	—	—
	7-bar	Head wall	700	700	700	700*	—
		Roof	745	600	600	—	—
		Side wall	—	300	300	—	—
Impulse [kPa-ms/kg$^{1/3}$]	Undefined	Head wall	—	—	—	—	—
		Roof	170	—	—	—	—
		Side wall	—	—	—	—	—
	3-bar	Head wall	100	100	100	—	—
		Roof	170	100	100	—	—
		Side wall	—	100	100	—	—
	7-bar	Head wall	123	200	200	200*	—
		Roof	170	100	100	—	—
		Side wall	—	100	100	—	—

(*) for NEQ ≤ 75,000 kg

Let's begin with the obvious: Canada does not prescribe any design loads at all. Coming close behind, NATO only gives head wall loads for 7-bar magazines and nothing else. Those loads apply for NEQ of 75,000 kg or less; for larger NEQs, designers are advised to consider using higher values (but no actual value is prescribed).

The remainder of our discussion will pertain to the US, UK, and UN documents. First, for Undefined magazines, the only requirement comes from the US and applies to the roof load only. Second, for 3-bar magazines, the US requirement for the roof is higher than that of its peers: 745 instead of 600 kPa for the pressure, and 170 instead of 100 kPa-ms/kg$^{1/3}$ for the impulse. Thus, for the roof of the 3-bar, the US is more conservative than other nations, but for the head wall it is in agreement; for the side wall, it is silent. Third, looking at the 7-bar values, the UK and UN agree closely with one another, but the US is of another opinion altogether in virtually every load metric. It is more conservative for the roof load (both pressure and impulse), but on the head wall impulse it is less conservative. The US abstains on side wall loads altogether.

In the current climate of international military co-operation between these countries and/or agencies, it is often desirable to construct a magazine that satisfies all relevant jurisdictions. Table 3 presents the worst-case design loads for 3-bar and 7-bar magazines from all the standards considered (Undefined not having enough requirements to merit inclusion in the table). Were one to design to the loads in Table 3, one could confidently assert that the magazine in question satisfies all five standards. As the table indicates:

- The US is most conservative in the roof loads;
- The UK and UN are most conservative in the side wall loads;
- And with the exception of the US, all agree on the head wall loads.

Table 3: Worst-case design pressures and impulses.

Metric	Component	QD Standards for 7-bar ECM		QD Standards for 3-bar ECM	
		Value	Source	Value	Source
Pressure [kPa]	Head wall	700	US / UK / UN / NATO*	300	US / UK / UN
	Roof	745	US	745	US
	Side wall	300	UK / UN	300	UK / UN
Impulse [kPa-ms/kg$^{1/3}$]	Head wall	200	UK / UN / NATO*	100	US / UK / UN
	Roof	170	US	170	US
	Side wall	100	UK / UN	100	UK / UN

(*) Limited to NEQ ≤ 75,000 kg

SOME QUALITATIVE QUESTIONS OF CONSISTENCY

We may pause to reflect on the IMD and blast load requirements, and make some inquiries regarding their consistency. Obviously, distance should correlate to pressure and scaled impulse, and so it is appropriate to expect that if one changes, so should the others.

Consider the design loads for the roof prescribed by the US. For all magazine types, p=745 kPa and i=170 kPa-ms/kg$^{1/3}$. And yet the prescribed side-to-side distance (which presumably controls the roof) varies from 0.79 to 0.50 m/kg$^{1/3}$. Might we not expect the roof load to increase when the scaled distance is reduced?

The rear-to-front standoff for 3-bar magazines, as prescribed by the UK, seems erroneous as discussed previously. If head wall loads are reduced from 7 bar to 3 bar for the two different categories, how can the rear-to-front separation distance remain constant at 0.8 m/kg$^{1/3}$ between those categories?

Speaking more generally, one may wonder at the necessity of prescribing both a separation distance (in scaled terms) as well as a design load. Would not one or the other suffice? Given a scaled distance and a loading model (such as the Kingery-Bulmash model for TNT), distance directly correlates to pressure and scaled impulse. Clearly that would not account for some of the complexities of interaction between the detonation and the donor magazine structure, or the impact of debris on the acceptor magazine, but if the designer was given a separation distance and a loading model, the loads could be calculated directly without having to be specified separately. Specifying both distance and loading seems like a duplication and leads to ambiguity. Is it sufficient merely to satisfy the IMDs, or must the structure be designed for the specified loads even when it satisfies IMD? What if the site layout exceeds the IMD requirements (larger spacings), do the design loads remain unchanged? Surely they should be reduced in that case.

A QUANTITATIVE CHECK ON CONSISTENCY

A blast model does in fact exist that, unlike Kingery-Bulmash, is directly applicable to ECMs and can be used to calculate a distinct pressure and impulse in each of three directions from a donor ECM: front, side, and rear. This model [9] and its associated spreadsheet tool (the Blast Effects Computer, or BEC) have been sponsored by the US DDESB, but they are not (yet) approved for use in design. A closely related model was also sponsored by NATO [10]; while there is no official prohibition against its use in design, there is also no official endorsement for that purpose. Both represent curve fits to a large set of experimental data and are accepted within the community as state-of-the-art with regard to blast loads from an ECM. Both models yield results that are essentially identical from a numerical point of view, even though they are formulated quite differently in mathematical terms. The main application of this model (considering both BEC and AASTP-4 as a single model) is in risk analysis methods. However, using it as a check on design would be natural to anyone who knew of its existence.

For demonstration purposes, we have devised a “sample problem” in which a rectangular array of ECMs, each one measuring 8 ´ 12 meters, has been sited with the prescribed minimum scaled standoff distances for 7-bar magazines (per Table 1). Note that for the 7-bar ECM, all five manuals are in unanimous agreement on the distance requirements, which streamlines our problem. We assume each ECM will store a quantity of 27,000 kg of TNT,

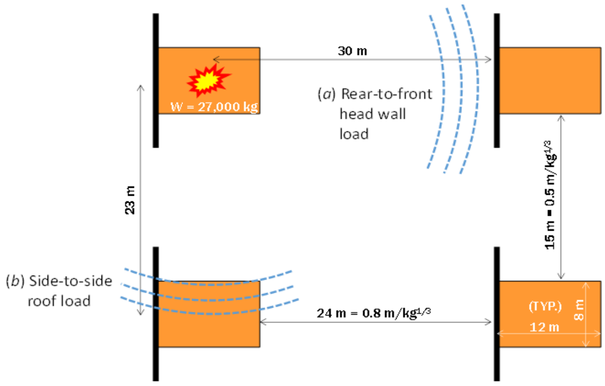

Figure 4: Dimensions and layout of ECMs for sample calculation.

Let us, for demonstration purposes, calculate two loadings: (*a*) the rear-to-front loads on the headwall, and (*b*) the side-to-side loads on the roof. Both of these are illustrated in Table 4. For case (*a*), the actual distance from the center of the charge to the headwall component is 30 m (including half the length of the ECM), while for case (*b*) it is 23 m (including one full width of the ECM) from the center of the donor to the center of the roof of the acceptor. Using these distances and the appropriate loading model in BEC (ECM rear for (*a*) and ECM side for (*b*)), we calculate values of pressure and impulse that are listed in Table 4. The table also lists the relevant values of the design pressure and impulse, as obtained from the respective countries’ standards and as tabulated in Table 2. Clearly, there are disparities here to be reckoned with. For the headwall, BEC produces about 50% higher pressure than the standards; its impulse is either 10% high or 80% high, depending if one considers the US standard or the UK/UN/NATO. For the roof load, the situation is reversed: BEC indicates a lower pressure by 50% relative to the US and by 30% relative to UK/UN/NATO. The BEC impulse value agrees well with UK/UN/NATO, but is 30% lower compared to the US standard.

These results should be of concern to those who manage and administer these standards documents. True, BEC is not currently authorized for use in design, but any designer working in the explosives safety domain will know about it and will be curious to apply it to a problem such as this. Seeing such divergent results as those illustrated herein will surely raise eyebrows and call into question the applicability of either the loading model and the prescribed standoffs, or the prescribed loads, or both. Perhaps if BEC was consistently non-conservative relative to the standards, the situation could be explicable as a case of the standards being overly conservative, with the experienced user free to adopt meth-

Table 4: Comparison of ECM design loads from BEC and standards for 7-bar sample problem.

		BEC	US	UK/UN/NATO
(*a*) Rear-to-front headwall reflected load	Pressure [kPa]	1009	700	700
	Impulse [kPa-ms/kg$^{1/3}$]	222	123	200
(*b*) Side-to-side roof incident load	Pressure [kPa]	412	745	600
	Impulse [kPa-ms/kg$^{1/3}$]	109	170	100

RECOMMENDATIONS

We make the following recommendations, which we believe to be clearly and objectively desirable:

- Correct the formatting deficiency of the Canadian C-09-005-0021, Table A-2, row 5, to show the necessary separation distances for the 3-bar side-to-side configuration (see Figure 3).
- Investigate the 0.8 value for rear-to-front separation distance in the UK’s JSP 482 and, if appropriate, update to 1.8 for consistency with other standards.
- Provide simple schematic graphics in the standards, similar to Figure 1 and Figure 2, to clarify the definitions of the two different sets of distances relevant to ECM siting and design.

Beyond these, the path forward is somewhat subjective and depends on whether greater consistency is desired *within* each standard as well as *among* them. As a starting point, we do see a need for greater inter-jurisdiction coordination and collaboration on the following key questions:

- Should standards be prescribed in terms of distance, loading, or both?
- Is there a loading model that can be adopted as part of a standard? If so, can the loading prescriptions be omitted?
- Is it desirable that the separation distance standards of these (and possibly other) jurisdictions be aligned for consistency? If so, what steps can be taken to align the US with the UK/UN/NATO/Canadian values?

ACKNOWLEDGMENTS

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Are explosives Major Hazards?

Ken Price

Of course that's a loaded question and it begs numerous other questions. What sort of explosives? What phase of their life? And what is a Major Hazard? These are questions that immediately spring to mind.

What is a Major Hazard?

My understanding or the term "Major Hazard" comes from the reports on the UK Advisory Committee on Major Hazards, set up following the Flixborough explosion at the Nypro plant in 1974.

UK had two major accidents in early 1970s. In 1972 almost an entire generation of the village of Aberfan was wiped out when a waste dump collapsed and buried 116 children and 28 adults. Then Flixborough followed in 1974, with 28 fatalities and major off-site effects from the explosion. Interestingly, in the weeks before the explosion, the health and safety inspectorate had visited the site and advised the management to instal reinforced glass in the control room windows. The inspectors completely overlooked the dodgy 50 cm diameter flexible pipework between two of the reaction/distillation columns, which, when it failed, released the huge cloud of cyclohexane. The resultant unconfined vapour cloud explosion wiped out the entire control room and most of the plant.

Es muss etwas geschehen!

After those two catastrophes the UK government of the day (god – the ultimate authority) decided that something must be done; so they set up a committee. (Of course! This is government after all.) But in this case the committee was a beauty. The Advisory Committee on Major Hazards (ACMH) produced three reports over the next few years and, uncharacteristically for most governments, the recommendations were acted upon.

The UK government, acting on the ACMH recommendations, drafted the Control of Industrial Major Accident Hazards (CIMAH) Regulations. (These were followed some years later by the European Seveso Directive, instigated after the Seveso disaster in 1976 and the UK version has been redrafted as COMAH regulations to align with the Seveso Directive.)

The main objectives of the CIMAH regulations were the *"prevention of major accidents arising from industrial activities, the limitation of the effects of such accidents both on man and on the environment, and the harmonization of the control measures to prevent and limit major accidents in the EEC.*

If you're still with me, you may have realized I still haven't answered the question above.: "what is a major hazard?"

My version of the answer is that a major hazard site is one where:

Operations on the site are complex and interconnected so simple changes in one part of the process may have effects in one or more other parts of the plant;

An accident on site has the potential to cause significant off-site effects;

Processes are sufficiently complex that they can't be managed by simple regulation.

Does there have to be the risk of significant consequences in the event of an incident – on-site or off-site? Not so easy to get a simple clear definition that would be agreed by multiple parties.

As these criteria are not easy to put into regulation, governments around the world who have CIMAH type regulations in place resort to a simple list of chemicals or classes of chemicals with threshold quantities which define what sites may fall into the major hazards category. Thus, the threshold quantity for cyanide is typically set around 20 tonnes. You store more than that and you will be a major hazard site. The more intelligent among those governments also build some flexibility into their regulatory systems to allow their Competent Authorities (this is the UN term for a government regulator with responsibility for an area) some discretion when defining sites as major hazards.

For example, in a former life I would use the hippopotamus definition for major hazard sites: you can't easily define one, but you know what it is when you see it. To go back to the cyanide example, it took about 10 seconds to decide that a static store of 500 tonnes of cyanide solid in sparge tanks, not connected to any process, could never be a major hazard site. Sure it is within the scope of requiring regulatory controls but simple compliance with a national standard was adequate.

In contrast to that, a petrochemicals plant with high pressures, high temperatures, large inventories, inter-related processes where stopping one part of the process will generate consequences either upstream, downstream or both clearly is going to be a major hazard site.

Once a site is declared to be a major hazard site, simple regulatory requirements need to be supplemented and we start to move into the realm of Safety Reports, Safety Cases and Quantitative or qualitative Risk Assessments. In this environment, risk is often expressed in terms of a function of the consequences of an event and the associated likelihood of occurrence.

Explosives

We in the explosives industry know how different our products are from other dangerous goods. The most obvious difference is that explosives are made to function according to their classification. Dangerous Goods with toxic properties for example are not usually made to poison people but to make other things. Class 8 dangerous goods (corrosives) are not made to corrode stuff but to react with other things in processes. And so on.

Another difference is that, for over a century, explosives stores have been positioned by following simple quantity distance tables. (Q/D). Based on data accumulated from many explosions (accidental and deliberate) over many years, we have a reasonable idea of what sort of damage to expect from any quantity of explosive. And from that, we know what sort of protections to put in place. In risk assessment terms this is described as a simple hazards-based approach which considers only consequences and not risk levels.

Another difference, though not unique to explosives, is that manufacturing processes are simple and the ingredients in many cases, though reactive, have fairly high threshold energies for initiation. Of course there are many exceptions to this, particularly for primary and initiating explosives, but over the past 50 years, the vast majority of blasting explosives are made on site, sensitized "down the hole" and require at least a detonator for initiation.

Primary explosives aside, in most cases, the actual manufacturing processes are quite simple. Since the thinking world moved away from nitroglycerin based explosives in the 1970s, and into water based emulsions, suspensions and gels, the biggest process (I believe most reported emulsion incidents have resulted from fire, not the pump) hazard from explosives manufacture is associated with pumping. With controls on energy inputs and release (bursting discs, temperature, pressure and flow controls) it is generally not difficult to safely stop any manufacturing process. It is usually just a simple matter of turning off the power.

Finally, unlike nitroglycerin based explosives, modern explosives generally become less sensitive as they age. So a magazine storage of emulsion or watergel explosive is going to present a diminishing risk as it ages. Of course, the hazard remains largely unchanged.

So What!

With no processing involved and the application of quantity/distance provisions, it is hard to see any justification for a storage magazine to be a major hazard site.

With respect to processing plants, the processes are simple, they can be easily controlled and the quantity/distance provisions also apply, again, it seems unjustifiable to categorize an explosives plant for bulk mining explosives as a major hazard site.

Next steps

Next edition of the newsletter I will put together a few words on how explosives regulations are changing, the responsibilities of Competent Authorities and some alternatives to Q/D tables.

SHE AUDITS

MERVYN TRAUT

INTRODUCTION

The definition of "a SHE audit" is:
"the identification of opportunities for improvement, by employing a process of an independent and systematic examination, to assess the extent to which there is conformance with the Company's defined Safety, Health and Environmental, Standards, Policies and industry's recognised Good Practice Guidelines."

Normally those persons carrying out the audit should be independent from those carrying out the audited activity.
The ISO 19011 is the usual guidance document used for auditing management systems and differentiates between internal and external auditors.
Internal auditors, generally an organization's own employees, perform first-party audits. Meanwhile, external auditors, who are not the organization's own employees, perform second- and third-party audits.
In some organisations the independent element of monitoring, forms part of the SHE audit process and this includes compliance audits carried out by staff independent of the unit being audited.
It has to be clear what the '**conformance with defined standards**' are. I.e. these are the standards against which an activity is being audited.
In summary the following should be established

- **What should be done?** (i.e. the relevant standards, guidelines and other good practice)
- **What those being audited say is done** (i.e. the procedures for operation of the unit)
- **What is actually done.**(i.e. what is done on a day to day basis during operations)

Note:
<u>Resources expended on any auditing programme are wasted unless correction and improvement result from it.</u>

A greater danger is that poorly conducted audits may fail to flag serious issues and instead falsely signal that all is well.
Reasons for audits to fail in this way can be highly varied, including anything from inadequate scope of the audit investigation to the lack of support from higher management.

To summarise the principles, the aim should be to implement an audit process which can be described as follows (to quote one company):
"Audit: a positive and helpful force for improvement owned and welcomed by management and conducted on a planned and regular basis."

WHY AUDIT?

From experience it is known that;

- A systematic approach to auditing is required. This is to ensure adequate safety, health and environmental protection of industrial operations.
- A management system will, as a control system, tend to deteriorate with time or become obsolete as a result of changing standards, practices and or organisation structure.
- To avoid degradation, the system must be monitored and verified on a systematic basis.
- Auditing underpins the **monitoring and verification** process, with the overall objective of providing assurance, that all aspects of SHE, are being managed in accordance with the pertinent requirements.
    - ◊ ***Monitoring*** comprises of the checks and inspections that are carried out to ensure that operations are conducted in accordance with the required practices and procedures. They are in the main, carried out by the unit staff and they should provide the answer to the question "What should be done?"
    - ◊ ***Verification*** is an examination/audit of the required practices and procedures to test and assess them against appropriate standards. These will include Statutory Regulations, National Standards and Codes of Practice, Industry Standards and Codes, Company Standards and Codes and other appropriate recognised good practice. This examination is primarily carried out by appropriately experienced persons from outside the unit who seek to give local management with the answer to the question "Is what they say is being done, good enough?"

While audits should be focused on critical systems, one must not lose sight of the other supporting systems. Where deviations are found, the correction of these must stimulate and drive ongoing improvement and correction of the situation and ultimately lead to <u>a preventative strategy and </u>enhanced and continuous performance.

It should be borne in mind that in some types of auditing the examination of the audit findings are clear cut and essentially or usually only require answers to yes/no questions (e.g. as for much of financial auditing) . However for SHE auditing, the issues are not "black and white" and audits are in essence "assessments" of the extent/level of conformance based upon gradations, on a scale from zero to full.
To ensure that the true situation is revealed, audits need to be searching and probing (though not inquisitorial). Such an approach can be promoted by appropriate aids by using for e.g. pre-prepared question sets for auditors to refer to.

WHEN TO CONDUCT AN AUDIT

Audits should be regular, scheduled and have well defined improvement goals.

- ♦ The audit may be a one-time verification/examination of a required practice/action, limited in scope to a specific issue or a scheduled action with a systematic approach to address a number of key practices and procedures to test and assess them against appropriate standards. These could include: Statutory Regulations, National Standards and Codes of Practice, Industry Standards and Codes, Company Standards and Codes and other appropriate recognised good practices.
- ♦ An organised response to new information eg. As a result of a formal change or
- ♦ Acting upon a perceived or specific problem.

- AUDIT COMPONENTS

A systematic approach is required whereby audits are conducted to a plan, at regular/ defined intervals. Operational units are targeted for attention on the basis of their SHE risks. Audits should be carried out in a structured way to ensure that all identified issues are addressed in a thorough and consistent manner

THE FOLLOWING ARE KEY AUDITING COMPONENTS:

⇒ **FOCUS ON INPUTS TO MEET DEFINED OUTCOMES**

A complete audit programme should always include the two **KEY** components namely Monitoring and Verification.

These should be combined with suitable corrective actions to ensure improvement. I.e. The audit brings together "what is actually being done" with "what should be done"

The amount of time dedicated/allocated to the persons conducting the audit may change over time. This would normally be in response to the condition of the audited entity and the degree to which previous audit findings have been closed out.

⇒ **OPTIMISE AUDITORS' SKILLS**

Added value is gained from auditing if it is an interactive process in which auditors and auditees both learn from each other.

Auditors need to have sufficient independence from the management of the unit being audited. In most cases this can be achieved by using auditors from a different part of the same company/organisation. Sometimes when a more independent assessment is judged to be necessary, it could be appropriate to involve one or more auditors from outside of the company

Auditors must be competent and have appropriate training and experience to ensure their credibility in the eyes of those being audited.

Auditors need to have, through training, acquired the necessary qualities, knowledge, and skills in the basic requirements of personal behaviour, as well as technical knowledge and skills.

Auditors need to acquire through training the necessary qualities, knowledge, and skills in the basic requirements of personal behaviour, as well as technical knowledge and skills.

Successful auditors also need to be conversant with the:

- Requirements of a safety and health management system such as for e.g. OHSAS 18001, which may sometimes referred to as the audit criteria
- Applicable and current legal requirements
- Good safety-management practice
-

Auditors' skill sets are a critical determining factor of the quality and reliability of the audit. While specialist experience and familiarity with equipment or systems is valuable, these are not more important than training in the auditor role.

NOTE: Previous experience on an auditing team should not necessarily be assumed to be a substitute for training, although of course experience is also of great importance.

THE KEY SKILLS FOR AN AUDITOR SHOULD INCLUDE BEING:

ORGANISED, OBJECTIVE, OBSERVANT, A GOOD COMMUNICATOR, DISCIPLINED, WELL TRAINED

◊ **AN AUDITOR SHOULD ALSO BE:**

PREPARED, USE CHECK LISTS, TAKE THEIR TIME, CONTROL THE AUDIT, CONCENTRATE, OBSERVE LISTEN AND LOOK INTERESTED, OBTAIN INFORMATION BY CONCISE QUESTIONING, VERIFY THE INFORMATION GLEENED, ASSIST CO-AUDITORS, LEARN KEEP CALM, COMPLIMENT, SHARE INFORMATION WITH THOSE BEING AUDITED,

NOTE:

IT IS IMPORTANT THAT AUDITS ARE CARRIED OUT IN THE RIGHT SPIRIT AND WITH THE RIGHT ATTITUDE. THIS IS RELEVEANT FOR THOSE DOING THE AUDITING AS WELL AS THOSE BEING AUDITED.

◊ **AUDITORS' "SINS" OR "DO NOTS"**

DO NOT:

BE LATE, ARGUE, MAKE COMPARISONS WITH OTHERS, BE SARCASTIC, CRITICAL, BE ABUSIVE, GET SIDETRACKED OR DISCUSS PERSONALITIES

◊ **AN AUDITOR WHEN SEEKING INFORMATION SHOULD ASK:**

WHEN IS THIS RECORDED?
WHO CHECKS THESE RECORDS?
WHICH PAGE IS THAT ON?
SHOW ME THE..?????.

◊ **AN AUDITOR WHEN TESTING UNDERSTANDING SHOULD ASK:**

◊

"MAY I JUST CHECK THAT WE ARE TALKING ABOUT THE SAME THING HERE?"

◊ **AN AUDITOR WHENSEEKING PROPOSALS SHOULD ASK:**

"HOW DO YOU THINK WE SHOULD DEAL WITH THIS TO IMPROVE IT?"

◊ **AN AUDITOR WHEN SUPPORTING A SUGGESTION SHOULD USE THE PHRASE:**

◊

"YES I GO ALONG WITH THAT"
OR
"THAT IS A GOOD IDEA"

◊ **AN AUDITOR SHOULD WHEN QUESTIONING:**

USE SIMPLE LANGUAGE, GET A TRANSLATOR IF NECESSARY, USE SHORT SENTENCES, ASK DIRECT BUT OPEN QUESTIONS AND MAKE EYE CONTACT .

AUDIT OUTPUTS

- Issues raised in audits should be considered objectively and handled both by auditors and the management of the audited unit in a transparent manner.
- Audit findings should be related to management system references with which the person audited can perform the correct and consistent follow up.
- Positive feedback should be given on the;
- Adherence to company policies / company standards/procedures
- Corrective actions that have taken place (based on previous audits)
- Improvements that have taken place (based on previous audits)
- Suggestions for improvements should be given on any area where performance has been judged deficient The audit should highlight areas for improvement such as systems defects or non compliances which may lead to a non-conformance or an unplanned event
- Reporting a problem without also including a potential change to solve it is unhelpful. If audit scores are being used any score less than 100% should be paired with recommendations for methods to bring performance up to 100%.
- All audits should have a uniform approach and should include a list of all the required corrective actions to be taken and the follow up on the closing out of these

CONCLUDING REMARKS

THE AUDIT WILL GIVE AN OVERVIEW OF PERFORMANCE BUT WILL NOT GUARANTEE SAFE OPERATIONS.
TAKEN AS BEING A HIGH LEVEL PROCESS OF VALIDATION AND INVESTIGATION, IT IS UNREASONABLE TO EXPECT THE PROCESS OF SHE AUDITING TO FIND EVERY NON-CONFORMANCE.
AN AUDIT CANNOT BE SAID TO HAVE FAILED IF LATER A SIGNIFICANT BUT LOW LEVEL FLAW IS DISCOVERED.
ON THE OTHER HAND AN AUDIT PROGRAMME COULD BE SEEN TO HAVE FAILED, IF SYSTEMATIC PROBLEMS HAVE REMAINED UNCORRECTED AND REMAINED PRESENT OVER MULTIPLE AUDITS. A LESS SIGNIFICANT FORM OF FAILURE COULD BE THE LACK OF IMPROVEMENT THAT WOULD FOLLOW FROM A STAGNANT AUDIT PROGRAMME ACTING WITHIN A POOR SAFETY CULTURE.

THIS ARTICLE MAKES REFERENCES TO THE DOCUMENT ENTITLED: "Process Safety Auditing European Process Safety Centre

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A Guide to the use of Relevant Good Practice (RGP) for Explosive Demolition of Structures.

PART 1

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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).

Photograph J Wolstenholme ©

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 first part of a two-part paper presenting the authors 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 covers the client's and project team's SMS and aims to capture RGP seen in industry that can help contractors and guide client's (including Nuclear Licensees) when considering resources, risk balance, management arrangements and control that need to be in place as part of an effective contractor-intelligent customer relationship.

Part 2 starts at the contractual process and follows through to the day of the blow down and will appear in a later edition of this magazine.

Differences in the regulatory framework

Although the regulatory regime on UK nuclear sites is different to that encountered on non-nuclear sites, the relevant good practice necessary to safely undertake the high hazard (and potentially high risk activity) of explosive demolition is common.

The Office of the Nuclear Regulator (ONR) regulates the UK nuclear industry (including demolition activity on nuclear sites) through a permissioning regime made against the Safety Assessment Principles (SAPS). Its principal focus is ensuring that the demolition activity is undertaken in a way that is compatible with the principles of nuclear safety. In comparison, demolition activities elsewhere within Great Britain are regulated by the Health and Safety Executive (HSE), principally acting in an enforcement rather than permissioning role and solely focussed on ensuring that risks to employees and others arising out of the demolition activity are subject to proportionate control.

Challenges

As experienced shotfirers retire and commercial long term demand for explosive demolition on nuclear and non-nuclear sites increases, the industry will be challenged in its ability to satisfy that demand.

Most previous incidents during explosive demolition have led to property or commercial loss and not loss of life.

However, there have been fatal and serious incidents such as Gorbals felled Block Glasgow (1993)[1], Royal Canberra Hospital (1997) [2], Bakersfield USA[3] and Didcot Power Station (2016)[4]. These have resulted in long-term consequences to individuals, businesses and society. These highlight the importance of the available learning from past incidents during explosive demolition and developing safe and robust systems of work.

General safety considerations

Safe and effective explosive demolition requires a detailed engineering analysis integrated with a robust SMS to produce a clear, coherent, conservative, justifiable fault tolerant design and safe system of work. In the UK, this is achieved through a series of robust engineering and process reviews that compare the design to RGP and seek to reduce the risk "So far as is Reasonably Practical"[5] (SFAIRP).

The SMS together with the selection of a competent contractor and appropriate contractual arrangements influence the engineering design and how the works are undertaken and supervised. The client's involvement is fundamental to providing the resources and setting the culture and expectations of this process.

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[1]https://www.heraldscotland.com/news/12719259.woman-dies-in-demolition-blast/
2https://www.canberratimes.com.au/story/6030620/katie-benders-family-commemorate-20-years-since-royal-canberra-hospital-implosion/
[3]Enr.com news article August 19 2013 Pacific Gas and Electric Co incident 3 August 2013
[4] https://www.independent.co.uk/news/uk/home-news/didcot-power-station-reports-of-explosion-at-building-in-oxfordshire-a6891596.html
[5]ONR and HSE do not discriminate between the levels of safety expected by the terms 'So Far as is Reasonably Practicable', 'As Low as is Reasonably Practicable' and 'All measures necessary'.

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Definitions

SFAIRP

The concept of reasonably practicability is fundamental to UK health and safety legislation as key part of the general duties of the Health and Safety at Work etc. Act 1974 (HSWA).

"So Far As Is Reasonably Practicable" (SFAIRP) involves weighing a risk against the trouble, time and money needed to control it. SFAIRP describes the level to which we generally expect to see risks arising out of work activities to be controlled and is core to the consideration of RGP in the nuclear industry and elsewhere. Whether activities are taking place on a nuclear site or not, a proportionate identification and analysis of the hazards associated with a specific activity, as part of an overarching system of risk assessment, should be undertaken to demonstrate that the overall level of risk is acceptable.

Relevant Good Practice (RGP)

RGP is "an aid to making a judgement". The word "Relevant" is an important qualifier, because what may be good practice in one scenario may be less applicable to others. It allows a test of applicability in situations where there might be an alternate applicable standard.

RGP is defined[6] as "those standards for controlling risk which have been judged and recognised by HSE/ONR as satisfying the law when applied to a particular case in an appropriate manner."

Meeting RGP is therefore the starting point in demonstrating that risks are being appropriately controlled and an activity is SFAIRP safe.

[6]**https://www.hse.gov.uk/risk/theory/alarp2.htm**

Intelligent Customer

The concept of an Intelligent Customer (IC) has gained international acceptance in both the civil and nuclear industries. An IC is defined[7] as "an organisation" (rather than individual post holders) "that has the competence to specify the scope and standard of a required product or service and assess whether the supplied product or service meets the specified requirements".

It is the summation of the capability of an organisation to understand what work is needed, the hazards involved, to specify what needs to be done; to set suitable standards; to supervise and control the work, to review, assess and evaluate whether relevant standards and legal requirements have been met. Most importantly, the client or Nuclear Licensee are responsible for the overall control of site activities. This includes any work commissioned from consultants and subcontractors.

Explosives demolition contractor

Depending upon the scale, complexity and contractual arrangements of the project, the Principal Contractor (PC) as defined in the Construction Design and Management Regulations 2015 (CDM 2015), may be the explosives demolition contractor, or the explosives specialism may be subcontracted out. Whatever the arrangements, in this paper both are referred to as the "contractor".

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Project team

The project team comprises the client and their internal engineering and project management resource advised in some cases by competent external consultants. Those consultants should be selected by the client based on a judgement of their demonstrated competence in specialist areas of expertise for the specific project under consideration. The basis of that judgement should be documented to allow audit.

Independent Structural Assessment (ISA)

In the nuclear industry, ISA provides the licensee with an independent third-party review of the adequacy of the licensee's own structural engineer's or any contractors design proposal including any temporary works. This check would be independent from any Category 3 (CAT 3) check referred to in BS5975:2019 undertaken by the contractor.

In the civil industry, an ISA may be disproportionate to the scale and scope of the project however its role and use should not be precluded. The client should record the basis for that decision and keep it under review should circumstances change. Requirements for ISAs should be included in the contract specification and documentation.

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[7] **ONR Technical Assessment Guide NS-TAST-GD-049 Revision 6 http://www.onr.org.uk/operational/tech_asst_guides/ns-tast-gd-049.pdf**

Safety Case

Safety cases for a nuclear site should include the Construction Phase Plan (CPP) required under CDM 2015. Irrespective of the format it should be:-

- Understandable and useable by those with direct responsibility for safety.
- Communicate a clear and comprehensive argument and evidence that an activity such as explosive demolition, can be undertaken safely.
- Demonstrate that the risks and hazards have been assessed, an adequate and detailed engineered design has been undertaken, appropriate limits and conditions defined and adequate safety measures identified with clear arrangements to implement and supervise them.

UK Regulatory environment

All parties should comply with the legal requirements and regulations of the country in which they are working. These may differ from the UK and how those requirements are to be met. In GB, the primary legislation is the Health and Safety at Work etc. Act 1974 (HSWA), and in Northern Ireland the Health and Safety at Work (Northern Ireland) Order 1978 fulfils a similar function. A number of further Acts and Statutory Instruments support these key pieces of legislation.

The UK regulatory regime is a "goal-setting" regime rather than a more prescriptive standards-based regulatory regime. Such a principle is flexible and supports goals and principles underpinned by codes of practice and guidance. This is designed to deliver a proportionate, accountable, consistent, transparent and targeted approach. This encourages continuous improvement and the adoption of RGP as a mechanism for demonstrating compliance with the goal setting requirements of the law.

Construction activities in GB are largely regulated by CDM 2015. Standards for what compliance looks like under these regulations can be found in recognised standards such as BS5975:2019 on Temporary Works, BS6187:2011 Code of Practice for Full and Partial Demolition, BS5607:2017 Code of Practice for the Safe Use of Explosive in the Construction Industry. The Project Team and contractor(s) should be able demonstrate compliance with those regulations and relevant guidance throughout their undertaking.

The legal requirements for the acquisition, manufacture and storage and security including tracking tracing and recording of explosives in GB are found in the Explosives Regulations 2014. HSE's website www.hse.gov.uk and the overarching guidance supporting those regulations identifies relevant standards and industry guidance on how to deliver those requirements.

Clients or contractors undertaking works in the UK should be conversant with and are expected to comply with the requirements of UK legislation and regulations.

Key elements to demonstrate compliance with RGP

The key elements that will demonstrate that RGP is being followed are:

- An Intelligent Customer complying with legal requirements and providing the finance and information to deliver a safe project. The client should set a high expectations with respect to behaviours and recognition of human factors.
- A competent project team assembled by the client to;

  - ♦ Collect together all obtainable, relevant information on the structure[8] and its environment,produce the CDM2015 Pre-Construction Information (PCI) and any required Safety Case;
  - ♦ Advise the client on the choice off the most appropriate risk balanced form of contract, support the client in procuring a competent contractors(s); manage, control and supervise the works through a SMS; and

[8]This will generally involve the project team undertaking a comprehensive and effective survey of the existing structure (including where appropriate use of intrusive techniques) to identify and confirm the structural information from the clients existing records. This survey should also identify any missing structural or contamination information not previously identified. This will enable the tenderer to develop and produce the preliminary engineered design. The tenderer should be provided with sufficient resource by the client to undertake any additional structural or contamination investigations. The tenderer can then clarify or confirm any doubts in the adequacy of the Pre Construction Information required in Appendix 2 of CDM 2015.

Detailed planning to identify and control the demolition risks. A detailed plan provides focus to assure the production of a safe design and site works whilst providing commercial certainty with a reduced risk of increased costs and time.

- An adequate Safety Case and CPP that demonstrates that risks are controlled and the demolition activities are SFAIRP safe.
- A documented SMS capable of ensuring that controls are proportionate to each hazard and that include robust peer review, challenge, monitoring and supervision.
- A contractual process clearly identifying and balancing the risks owned by both the client and the contractor.
- An engineered demolition design that is technically underpinned, conservative, fault tolerant and safe to undertake.The design should be demonstrably robust, and be supported by a transparent audit trail[9].
- A competent explosives contractor retained to:
  - identify appropriate blow down methodologies;
  - develop, produce, justify and implement a detailed engineered design.
  - produce a detailed method statement to demonstrate how the works are to be implemented and undertaken safely.
- A robust system of site supervision to ensure works are undertaken as specified in the agreed Safety Case and CPP.
- A change management system that identifies and addresses all aspects of change decision and records all changes or modifications to the original design and method statement.
- Thorough, well planned and practiced command and control arrangements for the day of the blow down which address contingencies, emergencies and mitigation if issues arise.
- Evidence that key elements of the engineered design and the supporting information have been subject to both appropriate internal challenge and 3rd party peer review.

Demolition works are often outside of the clients core business activities but they should recognise they need to be an "Intelligent Customer" (IC) before the start of the planning and procurement phase. On a Licensed Nuclear site the Licensee is solely responsible for the site activities and this responsibility cannot to be transferred to another commercial entity or organisation.

Experience indicates that effective clients:

- Recognise their legal duties and have a core capability of competent staff able to manage and control the safety of their undertaking and works carried out by contractors.
- Have IC capability and show that they are a learning organisation, sourcing information and knowledge from appropriate engineering institutions, organisations and professional bodies in the UK or overseas as well as from other private, public organisations and industry which have undertaken similar projects. This approach helps them to learn from previous shortfalls and past incidents together with examples of good practice on safety culture.
- Ensure that members of the Project Team attend an explosives awareness course. Details of providers can be obtained from the Institute of Explosives Engineers (IExpE) or Mineral Products Qualifications Council (MPQC).
- Provide appropriate levels of resource and information to safely deliver a particular project.

Effective project teams generally include a Temporary Works Designer (TWD) and Coordinator (TWC) with experience of similar explosive demolition projects. Their early involvement can provide valuable assistance in preparing adequate tender docu-

[9]The design should be developed within a 3D Building Information Modelling (BIM) model where appropriate. This facilitates the demonstration and accurate simulation of the demolition philosophy in order to design out risks. It has advantages for the decision-making processes whilst providing improved visibility and communication both within the project and to external stakeholders. For small-scale works, the use of BIM may not be appropriate but as uptake and familiarity of digital technology increases its use or other forms of Virtual Reality (VR) should not be precluded.

ments, assisting design development, peer review of contractors design and constructability.

Similarly, project teams should be aware of sources of RGP for structural engineering from Structural Safety (SCOSS) and the Temporary Works Forum.

On a nuclear licensed site, the Licensee should also ensure that an Independent Nuclear Safety Assessment (INSA) is undertaken to provide the Licensee with assurance that the overall project is being undertaken safely. The role of INSA is to challenge the assumptions, philosophy and details of the developing project. All parties should be clear in their roles and responsibilities as defined in CDM 2015. For large scale or complex demolitions or demolitions taking place on a major civil hazard site or environment, a client may choose to appoint a similar form of 3rd party organisation to fulfil a similar function mirroring the INSA methodology.

Planning

Detailed planning is important for any demolition work, particularly where the overall characteristics of the structure and its hazards are not fully quantified. This is particularly significant in explosive demolition where the blowdown is a single operation. The degree and rigour of planning should reflect the complexity, hazards, unknowns and risks from the structure to be demolished. Greater information provides better understanding and certainty whilst information gaps lead to higher uncertainty so requiring extra caution, conservatism and contingency planning.

The planning process should aim to deliver:

- A comprehensive CDM2015 PCI document, together with a procurement and tender strategy and arrangements for how the design and works are to be developed and reviewed. Similarly there should be clear expectations on how the method statement and any Safety Case are to be produced, peer reviewed and approved, then supervised and implemented on site.
- A project risk register which is regularly reviewed to identify changes in existing conditions and address any new arising risks.
- Optioneering and feasibility studies to seek and assess all available information relating to the structure and different blowdown techniques and methodologies. Planning requires identifying the conditions, hazards, methods and opportunities that provide certainty and reduce risks SFAIRP. Competent planning includes consideration of options and their feasibility which generally reduces design risks and improves the safety of the works and certainty of programme delivery and costs.
- Early Contractor Involvement (ECI) from the explosives demolition contractor. Their experience of hazard identification and working methods can inform decision making during concept design stage. The timing of engagement depends on the selected contractual process, together with the scale and complexity of the project.
- Appropriate contingency plans and command and control procedures. This should cover not only site issues but also interfaces and communications with external stakeholders and the public.

Capturing Existing Information

The project team should collect all reasonably available, relevant information held by the client. An assessment should be undertaken to identify the degree of confidence that can be put in its accuracy. Any gaps or identified shortfalls should be resolved by undertaking further investigations. If there has been a change in site ownership, then information should still be available as part of the legal “due diligence” procedure. Post 1994, the clients should have a Health and Safety File under the extant CDM 1994 / 2007 regulations. However it is recognised that the content of this file is often incomplete, unreliable or entirely missing. On a nuclear Licensed Site it would be expected that this information would be available through existing safety cases.

A valuable source of information is that held by current or previous employees who can provide “unrecorded” details of the design, construction, contamination sources and other hazards, modifications or changes, maintenance or operation of the plant or structure. This information should be captured for inclusion in the PCI.

The client and the project team should follow the guidance in BS6187:2011, BS5607:2017, BS5975:2019 and CDM 2015 which, for example, covers such areas as:-

- The identity and location of services on the site, including gas, electricity and steam, telephone and other cabling, chemical gases, demineralised water and all wastewater drains.
- The original structural design and construction details with any refurbishments or changes of the structure to be demolished.
- Similarly any structural or geotechnical information required for the temporary work design and construction.
- The identity and location of any adjacent structure sensitive to vibration, blast loading, dust, or impact. Any limits, conditions, protection requirements or other safety requirements should be included in the Pre-Construction Information.
- The type, extent and implications of the hazard from any contamination arising from the demolition, together with the implications for the safe containment and treatment of that waste, which may introduce its own hazards and risks.

The aim should be to accumulate as much information as reasonably practical to be included in the PCI. This information is essential for adequate tender submissions, demolition design and safe systems of work.

Information on expected standards of construction forms can be sourced from withdrawn BSI Codes of Practice and technical guidance for structures in different materials. Other sources are technical papers submitted to professional institutions, conferences, industries and other organisations such as the UK Building Research Establishment (BRE). However confirmatory studies should be undertaken to provide assurance that historical standards were followed. Publicly available HSE accident and research reports, together with information on the internet are another useful source.

SMS – summary of key requirements

The client and design team should have arrangements that demonstrate the appropriate levels of controls including robust, auditable and transparent reviews and internal challenge within the SMS. Milestones or gateways should define where and how rigorous the reviews and challenges should be. Examples of gateways include contractor pre-selection and tender award together with design reviews and 3rd party checks of the contractor’s method statement.

The system should identify who is responsible, what they are responsible for, and how they exercise the appropriate level of control. It should also identify the process for undertaking monitoring, reviews, and audit as well as recording decisions and retaining documents.

On a nuclear licensed site these requirements would be included in the Licensee's safety case as the Licensee remains responsible for safety. On other sites, the responsibility for safety may change as the project progresses in accordance with CDM 2015. Such changes should be clearly identified, suitably authorised and effectively managed to ensure that the SMS continues to operate effectively and as designed.

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

GOLDEN RULES

- **WEAR MASK**
- **ALWAYS SANITSE**
- **MAINTAIN SOCIAL DISTANCE**

STAY SAFE AND HEALTHY!!!!

GALVANIC CORROSION

STEPHEN CALDWELL

Galvanic corrosion is a problem in most industries and in particular the chemical, explosives, marine, aircraft, and motor Industries. It is normally considered during Hazard Study II – Material Compatibility Study, or in the Modification Proposal Process but these processes often rely on engineers of sufficient experience and training being part in the hazard study team or being included in the Modification Proposal circulation list.

Galvanic corrosion is not the same as direct chemical corrosion. Each material on it's own may be resistant to direct chemical corrosion,but when placed in close proximity to one another, in the presence of an electrolyte, the combination may lead to severe galvanic corrosion of one of the metals. Metals close to one another on the galvanic series generally do not have a strong galvanic effect on one another, but the farther apart any two metals are separated in the series, the stronger the corroding effect on the one higher, or the more the anodic one, on the list.

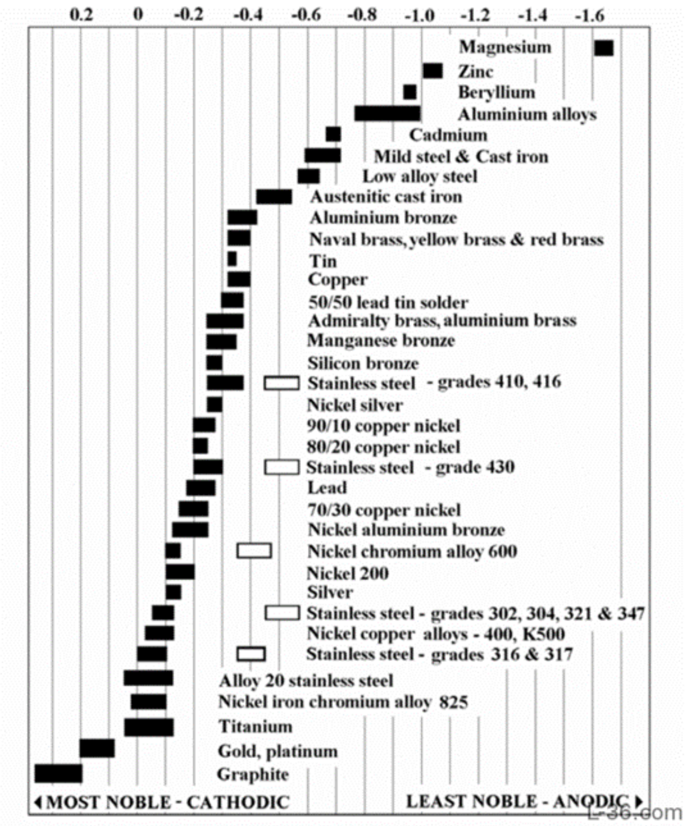
Technical terms:

Anode – material that is negatively charged, electrons leave this

Cathode – material that is positively charged, electrons enter this Electrolyte – liquid that aids in the process of electron transfer

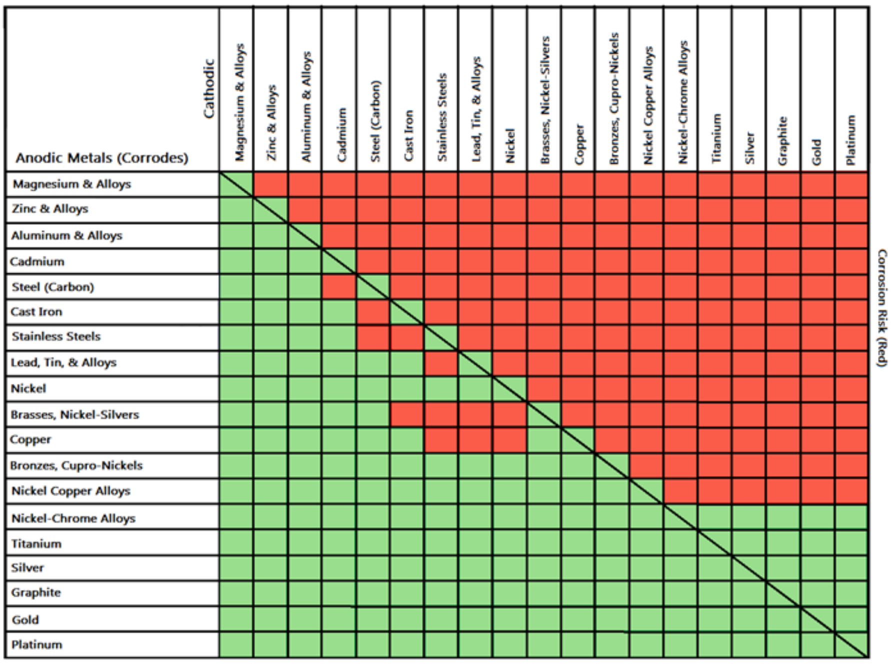
Corrosion – Destroy or weaken metal gradually

The Galvanic Series



Another Way of presenting the list is as follows:

Incompatable Materials list.



An example

In the 1980s, it was discovered that the Statue of Liberty had a serious structural issue: the statue's internal wrought iron structure was rusting badly because in some places the insulating layer of shellac between the iron and the copper cladding had failed and galvanic corrosion had begun. Fortunately, the structure had not been badly damaged but it was a serious enough problem. It took millions of dollars and months of work to correct.

Exceptions and Normal Practice

Each assembly or system has it's own unique characteristics. Metals rely on environmental factors to corrode, and there may be places where some metals can be used together without these effects. If the environment is very dry, sheltered from weather and dirt then it is possible to use seemingly incompatible metals together. However, in most situations the environment is not temperature and humidity controlled, and galvanic corrosion will occur.

In a few cases plant or equipment life span is not a important, such as for disposable equipment, but where maximum plant or equipment life is a requirement, it is normally recommended never to use different metals together. Use stainless steel with stainless steel, aluminium with aluminium, brass with brass, etc.

Mixing metals can affect the strength of the application, the lifespan of the fasteners, the corrosion of the materials, etc.

Environmental Factors

Many factors need to be considered when choosing the correct material for an installation.

Factor	Importance
Duration of contact	The longer an electrolyte is in contact with the metals used, the more likely there is to be a transfer of electrons and galvanic corrosion. For example: Frequent washing or decontamination of explosive equipment leads to increased duration of electrolytic contact.
Electrolyte Resistance	The lower the electrolyte resistance the easier it is for electron transfer to occur. Example: salt water has a very low electrolyte resistance. **Most explosives plants will handle ammonium nitrate – which in solution has a very low electrolyte resistance – and corrosion is therefore a very serious issue to be considered.**
Stagnant Water	Water that sits and takes a very long time to dissipate can lead to extended exposure to electrolytes.
Dirt	Dirt (especially not in direct sunlight) can absorb an electrolyte and hold it for a very long time. This can result in increased exposure if the the assembly if not kept clean.
Humidity/Fog	This leads to increased water in the air. Greater humidity or fog increases the exposure to electrolytes.
Crevices	Crevices provide traps for moisture (electrolyte) which can stay in contact with the materials for a long time.
Flow and Turbulence	Higher electrolytic flow and turbulence increases electrolytic contact.

Prevention of Galvanic Corrosion

When incompatible materials must be used, the following steps can be considered:

- Include an insulator between the two materials so they no longer connect. Without electrical connection, electron transfer cannot occur. Well Nuts are a commonly used fastener to help separate materials that can suffer from galvanic corrosion.
- Use materials with the same potential or at similar position on the galvanic series. Metals with the same corrosion resistance can be acceptable to use together.
- It may be possible that the equipment design can be done in such a way that only one of the materials will come into contact with an electrolyte, then transfer of electrons and hence galvanic corrosion will not occur. Pumps with all "wetted surfaces" of stainless steel are examples of this.
- A strong and well bonded non-conductive coating on the cathode can prevent electron transfer.
- Consider the environment and application, choose non-metallic or non-conductive or partially conductive materials of construction. Wood, partially conductive filled rubbers and plastics are examples.
- Coat or paint the assembly (properly and completely) so that the electrolyte cannot make contact with the anodic materials.
- Use nitrile, neoprene, EPDM or bonding washers as a barrier between the metals.
- Ensure the cathode area is very small when compared to the anode area.

SACRIFICIAL ANODES.

Marine structures such as ship hulls are predominantly made of steel. Seawater is an electrolyte which flows often turbulently across or along the structure. This results in rapid transfer of ionised molecules from the steel structure causing corrosive oxidation. This process of gradual material reduction can degrade the structural integrity to the point of failure.

Besides high quality coatings, the standard protection method is the use of sacrificial anodes. These are made of a more active or less noble metals (usually zinc or aluminium). The sacrificial anodes are attached to the steel structure and since they oxidize more easily, they turn the structure itself into a cathode. The electrons leave the structure through the anodes which slowly dissolve. This protects the steel structure against corrosion. The sacrificial anodes are replaced from time to time.

This process can even be electrically enhanced by inducing a cathodic protective electrical current to protect the ships hull or propeller.

ALUMINIUM AND STAINLESS STEEL

if left on its own in the presence of an electrolyte, aluminium will lose it's electrons eventually, but having stainless steel present will speed up this process significantly. The electrons from the aluminium (anode) will transfer to the stainless steel (cathode) at a much higher rate causing the aluminium to corrode. (On the other hand, this process can extend the life of the stainless steel).

Having said this, aluminium and stainless steel are in fact often used together as indicated in the last point of the discussion of Methods to Prevent Galvanic Corrosion: When the base material is a large sheet of aluminium, then using very small stainless steel screws will not dramatically decrease the life of the aluminium sheet.

It is important to note that conversely, if aluminium fixtures are used to attach a large sheet of stainless steel, the life of the aluminium fixtures will be dramatically shortened. For example: aluminium pop rivets used to secure stainless steel sheets.

Electrolytes include liquids or films such as humidity, rainwater, seawater and of course product mediums and chemicals such as emulsions, nitrates, acids etc. When such electrolytic fluids are present, electron transfer will occur. Depending on the level of resistance in an electrolyte, this transfer can happen much faster. This is why salt water or ammonium nitrate electrolytes with a very low resistance, must be taken into account when considering what metal to use. Corrosion can be so severe in salt water environments that it may even be necessary to consider the type of stainless steel to use, such as 316 rather than 304L.

CARBON FIBRE

Carbon fibre is not commonly used by chemical and explosives manufacturers but it's day may be yet to come. Already it's use has become common place in the marine, aircraft and auto industries. While it is not a metal, is does exhibit many properties similar to metals particularly because it is electrically conductive. It is not included in the galvanic series above but if it was, it would be much lower down in the series i.e. much more cathodic than aluminium alloys and a bit more cathodic than stainless steel. This means that in the presence of carbon fibre and an electrolyte such as rainwater, sea water, ammonium nitrate etc, aluminium alloys would tend to corrode quickly while stainless steel would corrode, but more slowly.

Honeycombed aluminium is often used sandwiched between layers of carbon fibre in composite materials. This can result in serious corrosion of the aluminium if an electrolyte like salt water or even fresh water is present. Most manufacturers of such composites include thin layers of fibreglass and resin between the aluminium honeycomb and the carbo fibre skin to electrically insulate the two materials from one another, thus preventing galvanic corrosion.

Some typical examples of galvanic corrosion are shown below:

Managing Upset Conditions

Dan Reinke, PE, CSP

Chemring Group

A recent survey of 100 major onshore oil, gas and petrochemical insurance claims from 1996 to 2015[1] found that 63% of non-mechanical integrity failure losses were associated with non-routine or abnormal operating conditions. This is consistent with anecdotal information from our industry that many accidents occur during process upsets. In these upset conditions there are often no set procedures, leaving operators on their own to quickly identify corrective measures to bring a process back under control. Because of this, companies must have both clear procedures for managing upsets as well as a strong culture to support front line personnel in both identifying and reacting to deviations.

What is a process upset?

Upset conditions can be defined in several ways, but in general they are production conditions outside of normal operating limits where there are not clear procedures on how to proceed. For automated operations, they may be considered activities where the operator has to take the equipment from automatic to manual mode in order to proceed. Providing a simple and clear definition of an upset condition helps operators understand when to follow the site upset condition procedure.

Upset condition definitions work best for production processes, but can be expanded to other areas such as testing, material handling and maintenance work when that work entails repeatable practices.

Time to SWIM

The acronym 'SWIM' provides an easy reminder for operators on what to do in case of a process upset. Key is to first Stop the process. In many cases the process stops automatically due to control interlocks and safeguards. In some operations an operator may be required to activate an e-stop or shut down equipment. In manual processes it is important for operators to not proceed continue but rather to react immediately.

Once the process is stopped the operator needs to Warn others nearby of the potentially unsafe condition. By warning others they can prevent someone else restarting equipment before a plan has been developed.

In the Inform step, operators engage with their supervisor. If there are no pre-established procedures to respond to the specific conditions they will then involve others as needed, such as representatives of operations, maintenance, engineering and safety, to work as a SWIM team to address the situation. It is important that the right team be assigned to address the upset to ensure conditions and hazards are properly understood.

The SWIM team will Manage the upset, taking the time to understand the conditions and activities that led to the process upset in order to develop a path forward. This evaluation can include interviewing operators and witnesses, reviewing CCTV recordings and SCADA data, and gathering information on process equipment and failure mode analyses. All this information is especially important for remote operations involving energetic materials where these processes are separated from personnel by shielding or blast walls.

Once a path forward is defined by the SWIM team the approach needs to be reviewed, documented and approved by the appropriate personnel. Approvals of senior leaders may be required if residual risks remain high, and partial action plans may be developed, following which the actions stop and the team regroups to evaluate new information and possible paths forward. Operators involved in executing the mitigation measures need to be trained in the response and actions to take based on the condition of equipment and materials. Prior to execution of the corrective measures it is typical to remove or reduce the sensitivity of excess energetic materials in the area to minimize the likelihood or impacts of an event in case of ignition.

Ranking and managing upset conditions

Different upset conditions require different levels of responses. One way to categorize process upsets is based on the potential hazard associated with mitigating the response. This can be done either solely based on the potential consequence of ignition during the mitigation measures, or based on a risk evaluation factoring in both severity and likelihood of an event. For example, a firm could classify those scenarios that can be addressed without exposing personnel to a serious injury in case of ignition as low risk; those that require the donning of additional PPE or shielding to prevent injury in case of ignition as medium risk, and those that can only be mitigated through exposing personnel to situations where an ignition would cause serious injury as high risk. The level of review and approval for the upset condition response then varies with severity, requiring senior management review and approval for the high risk scenarios. High risk scenarios would also trigger in depth post-event investigations to fully understand contributing and root causes and develop corrective actions to prevent recurrence.

KPIs and management reviews

With the proper classification and investigation of upset conditions, management can develop KPIs and evaluate causes to identify trends and emerging issues. In reporting, appreciation should be given to the operators that recognize the upsets and initiate the SWIM process, as each of these process upsets provides a learning opportunity to prevent future events with potentially serious consequences.

In developing KPIs a challenge is defining normalization factors to allow easier identification of patterns and trends. Examples include equipment run hours, production outputs, and direct labor hours. Good normalization factors can allow comparisons across similar processes or sites.

Conclusions

Process upsets pose a significant hazard to energetic operations. Increasing attention to these events by identifying, managing and measuring process upsets allows company leaders to reduce their risks.

References:

R. Jarvis and A. Goodard (2016). An Analysis of Common Causes of Major Losses in the Onshore Oil, Gas and Petrochemical Industries, Lloyds Market Association, September 2016 https://www.lmalloyds.com/LMA/Underwriting/Non-Marine/Onshore_Energy/Onshore_Energy_Wordings/Common_Causes_of_Losses_in_the_Oil%20_Petro_Industry.aspx

More on Detonation Traps

Andy Begg

In a previous issue of the Newsletter, we had an article on detonation traps. That article focussed on what we normally consider as processes where a trap interrupts detonation transmission in a continuous flow of explosive: for example, powdered PETN in a detonating cord spinning/reeling line or NG/water flow in a transfer line between nitration and washing. Detonation traps are an integral part of many of our processes to reduce the total amount of explosive in process which detonates so helping to reduce the number of people injured and the extent of damage caused by explosions. However, the principles of detonation traps can be extended to include explosives cartridging and packaging operations and many non-continuous processes such as detonator assembly.

From the paper in the previous Newsletter the writer state:

"*Numerous methods can be utilized to stop detonation propagation should an initiation occur in a liquid/slurry flow process. Typically, they can be divided into the following categories:*

Dilution
Reduction of Dimensions
Disruption of Flow Pattern
Energy Absorption
Flow Disruption
Stoppage of Flow"

In many of the incidents that have been reported there has been propagation of explosion from an initial source to other material not in direct contact with it. In such cases propagation is typically by direct shock and/or high velocity impact from missiles created by the initial explosion. Shock tends to be short range as the shock energy reduces quickly at increasing distance. Missile impact can be short and longer range. These mechanisms can be interrupted and give us methods of stopping the propagation. I would call this "product separation" and would include it in the methods of halting propagation – and I would also include deflagration propagation. The first time I became aware of this practice was in the dynamite cartridging and packaging complex locally called "the MixPack" in Ardeer Factory many years ago. Previously it was common to have the cartridging machine and cartridge packing in the same building or to load the filled cartridges into a trolley for onward transfer to a packing house. The former would involve many of the operators who were doing the manual packing – a relatively low risk operation – being continuously exposed to the higher hazard posed by the cartridging machine. Both systems resulted in a large inventory of product building up in the cartridging house. The Mixpack unit was designed so that the cartridging machine operated continuously and each cartridge was automatically transferred by a conveyor system to a physically separated packing house. The MixPack took advantage of the "gap test" (the maximum distance 2 cartridges can be separated by before detonation of one – the donor - will not result in the initiation of the other – the acceptor). Each cartridging machine was located in its own building and was linked to a packing house by a high-speed conveyor. The speed of the conveyor was chosen to ensure that there was always a separation distance greater than the gap test between the cartridges on the conveyor thus ensuring a propagation trap between the 2 buildings. The speed of the conveyor could be adjusted for products of different "gap test".

This principle is much used today in many dynamite and cartridged emulsion plants and was effective in stopping the propagation of detonation in the explosion in the emulsion plant in Brazil in 2004. The conveyor system in emulsion plants often functions as both propagation trap and cooling system.

The distance between cartridges ensured by adjusting transfer conveyor speeds. The conveyor is enclosed within blast walls so protecting the hot cartridges from missile impact if there was a detonation at the mixing/cartridging stations.

In this operation consecutive cartridges are mechanically “flipped” to another parallel conveyor so giving good separation.

The next photo shows the aftermath of a series of explosions in the emulsion mixing/cartridging building in Brazil. Here the cooling bath transfer acted as the detonation trap.

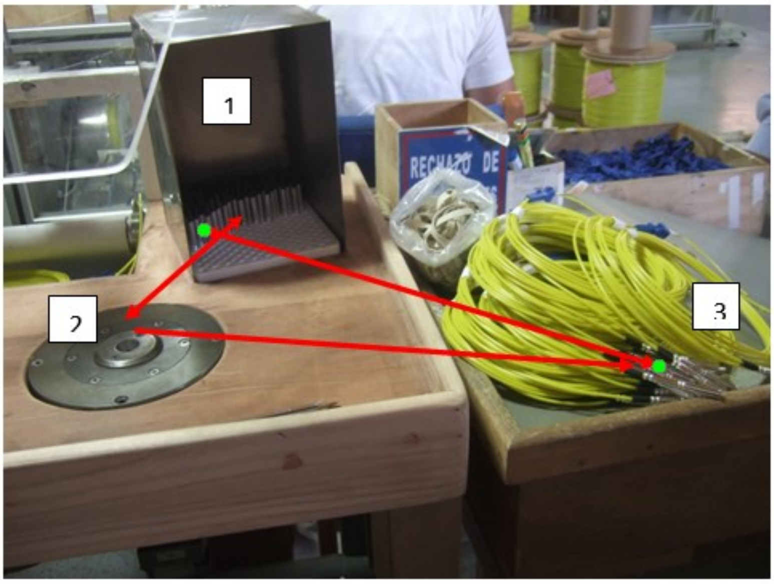
Detonation in cartridged emulsion plant in 2004

Therefore, separation of product units in an operating line can be regarded as providing the opportunity to install a propagation trap. The units can be cases, cartridges, single detonators, spools of cord and so on. To ensure the separation functions as a propagation trap there only has to be one gap greater than the “gap test” distance in the production line between consecutive operations. In the case of an operation involving the continuous production of high volumes of units it is more practical to have in effect empty “cells” in the line. For example in small diameter emulsion production with 2 cartridging machines there could be in excess of 240 cartridges produced per minute – clearly trying to separate these individually would be operationally challenging. However, a functioning trap only requires there to be one “gap distance” in the transfer line between 2 consecutive buildings. In such situations the “gap” can be achieved by accumulating cartridges for a very short period on the transfer lines then releasing them – this will insert a gap.

Product separation by distance and position – detonator assembly

Another situation where a detonation trap is effective in preventing propagation is in a simple operation such as manual detonator crimping. Here the flow of explosive is from a stock of loaded detonators (1) to a crimper (2) and then to accumulation for packing (3) – often all carried out at one station. At any one time during the normal operation the operator is only handling one detonator and therefore should only be exposed to the effects of one detonator should an initiation occur. However, if the stock of loaded detonators or the completed detonators are within the "line of fire" of the detonator being crimped then it is possible for there to be propagation from the single detonator to all the detonators on the bench – typically this could be more than 100 detonators. And worst still – if there is another crimping station adjacent to the first there could be propagation to that station and so on. Sadly, there have been several very serious incidents of this type reported. Propagation can be avoided by very simple "propagation traps" where the detonators at the 3 steps in the operation are out of line of sight of one another. This usually involves providing a solid barrier between the steps. For the stock of loaded detonators this is typically a steel bench magazine/container/screen positioned such that the operator can easily move the detonators from stage 1 to stage 2 to stage 3.

In the photo below the stock of detonators is in a steel container – but the container is not fixed in position and is easily moved by the operator to a position that suits them – but defeats the "no line of fire protection".



Below we see 2 photos of a similar operation. In both cases there is no direct "line of fire" between the stages of the operation. The open detonators in the bench magazine box are protected against falling hot debris by the top of the box.

Separation by standard operating procedure – safety fuse reeling

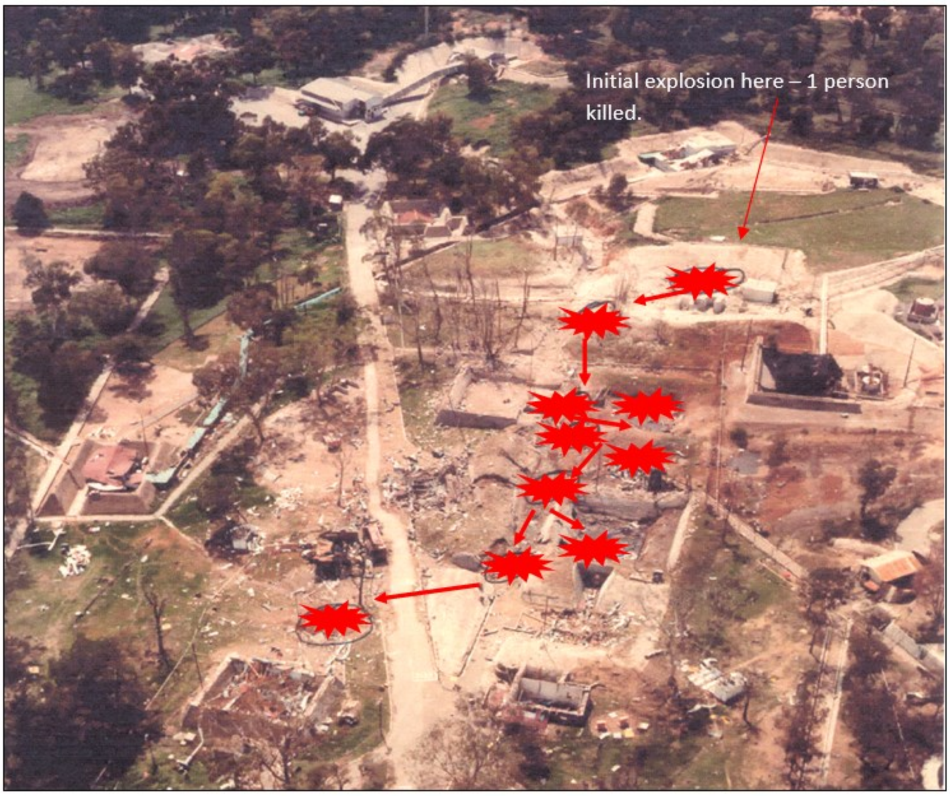
Traps are not restricted to detonation. The principles can also apply to other forms of explosion propagation such as deflagration. In the illustration below we see the method used to prevent a deflagration at a safety fuse operation propagating to the in-process inventory in the building. This shows a very simple cabinet with clear instructions that the doors must be kept

Separation by blast walls and quantity/distance arrangements – cartridged explosives operation (dynamite in these examples)

These are the normal limitations and requirements for explosives plants and are usually set by the local authorities.

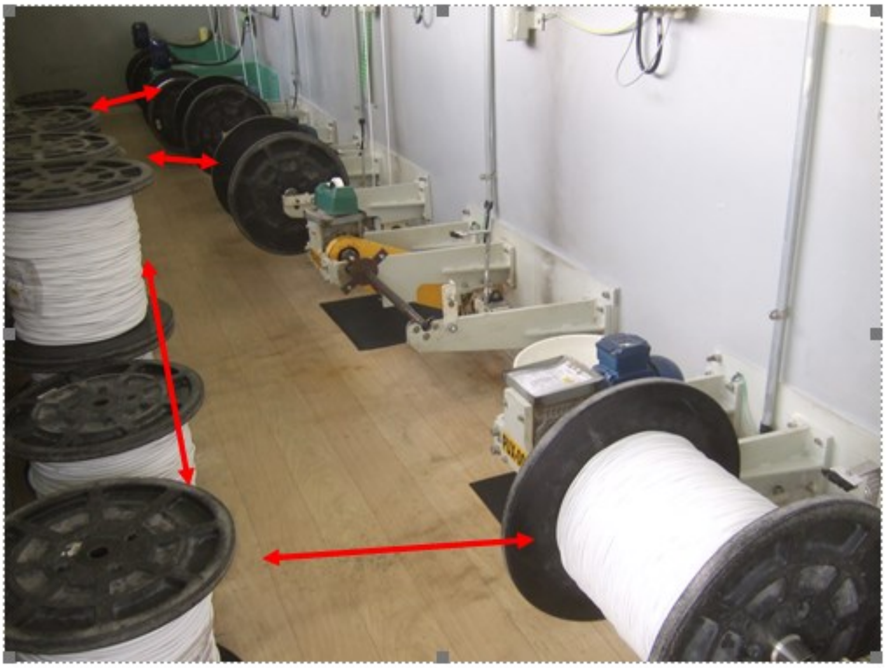
Below we see a historical example of unsafe in-process short term storage of buggies of dynamite in a cartridging line that was observed during an audit. The line consists of several independent cartridging compartments separated by blast walls so that in the event of an explosion the detonation will not propagate to the other lines. However, in the photograph each buggy visible apart from one is full of dynamite. In the event of an explosion in any one of the several cartridging buildings it is most likely that propagation would take place between all the buggies – and the respective cartridging compartments. The practice was changed following an audit.

The photo below shows what did happen in a dynamite mixing and cartridging line when buggies of NG and mixed dynamite were placed between consecutive buildings by the operators– presumably for convenience. An explosion in the NG weighing compartment propagated to all the buildings in the line – and 14 lives were lost.



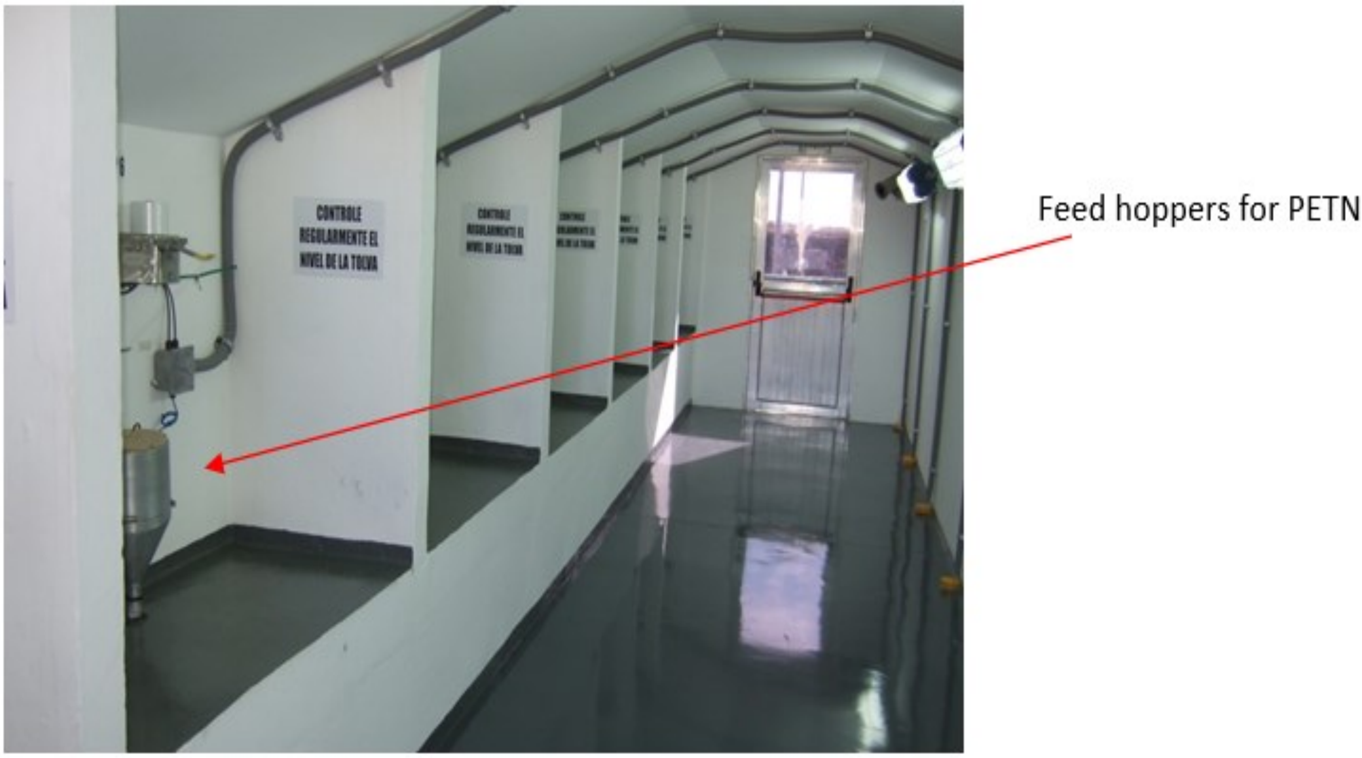
Internal blast constraint barriers

The next picture shows a typical detonating cord spinning line but unfortunately an explosion in one of the reeling lines will likely propagate to the semi-fuse being temporarily stored and from there it will likely propagate to the other reeling lines and back into the process area on the other side of the wall where the operators are positioned.

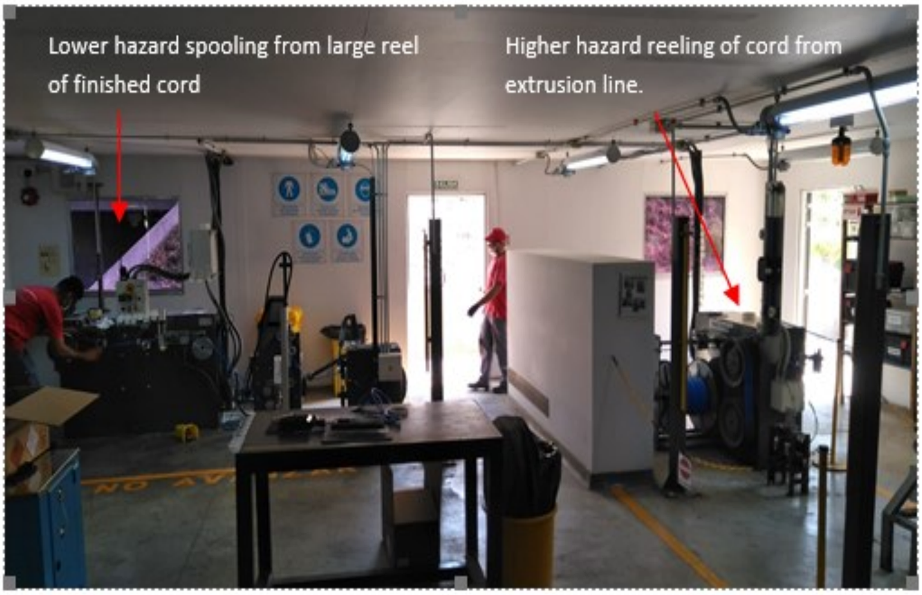


Reducing the probability of propagation between consecutive lines can be achieved by the introduction of small blast walls between the lines and removing completed reels as below.

Similarly with walls between PETN feed hoppers to the spinning machines – there is no “line of fire”.



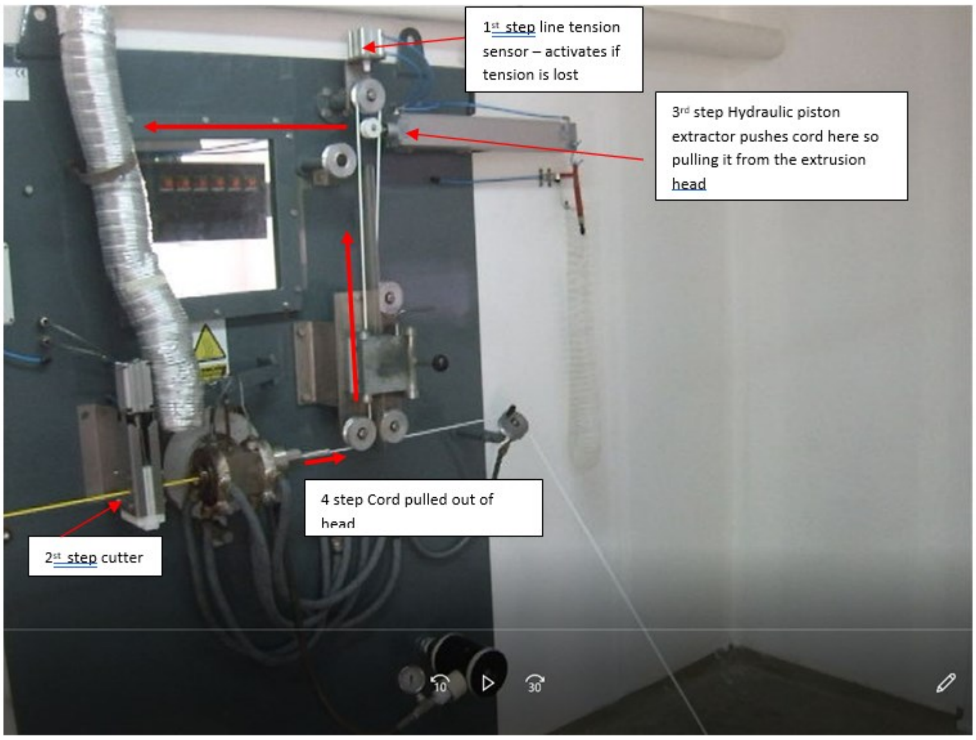
The photo below shows a small blast wall that was built after this detonating cord plant had been operating for some time. The need for the wall was raised in a plant inspection. It separates the relatively low energy operation of transferring the cord from a bulk reel to smaller reels for sale from the higher energy extrusion/reeling line.



In many operations it is good design to position small blast walls or barriers between consecutive workstations. This is particularly useful where one of the operations is relatively low hazard in relation to the other and this is frequently the case.

Separation by product movement - detonating cord extrusion head

Another form of trap used this time to prevent initiation of PETN in detonating cord manufacture is the cutter/extractor system at the plastics extrusion head. In the event of a line stoppage this will cut the cord immediately after the extrusion head and extract it back out of the head automatically so avoiding the static cord being exposed to high temperature and possibly initiating in the head and propagating to the in-process cord.



Curved "line of fire"??

The examples so far have mainly focussed on avoiding the "line of fire" which is taken as the direct straight line that can be drawn between the source and the target and indeed this is the most common situation to be found. However, there can be a "line of fire" propagation that is not a straight line! Such a situation can arise with ejected debris produced in the initial event. This debris can be ejected at many angles and the individual particles ejected up and out will come under the force of gravity and will follow a curved trajectory and so can "jump" barriers and then can fall almost vertically on the target. Clearly hot debris falling into an open loaded detonator tube will almost certainly cause initiation hence the covering provided by the. Curved trajectories can also be seen when quantities of units or items are ignited and some are scattered by the initial blast/fireball before they react. An example of this can be found when loose fuseheads are ignited. The photo below illustrates this when 1000 fuseheads in a workstation were ignited in a test. Fuseheads were seen to be ejected up and over the protective screen separating the workstation from the one next

In summary, the principles of detonation traps can be expanded to include propagation traps in many explosives' operations. This can be achieved by introducing some form of barrier between consecutive stages of the operation and by moving to a safe position any in-process inventory that is not actively in process. Barriers and distance can provide protection against propagation from sources to targets in many operations.

And finally

How robust is your detonation trap? Has the system been designed to operate under real-life plant conditions? Has the system been inspected and maintained to ensure that it is still functioning as original design?

Traditional detonation traps

Detonation traps are widely used in detonating cord plants and several methods of activating the cutting mechanism are used. Some of these methods are suitable for different powder core loads but not all are. It is therefore critical for the basis of safety to be assured that the methods used are designed and tested routinely to ensure that they are suitable for all products being made. Additionally they must also function within the worst case out-of-spec cord that could be processed to ensure that even in a fault condition in the process the system will still operate satisfactorily – this often means designing the system to be effective at core loads perhaps up to 20% lower than specification. (This figure will depend on the powder charge monitoring system on the line which should stop the line at preset out-of spec loads).

If the cord is modified by changing core load or core explosive or outer coverings the trap system should be tested. If the line speed is increased the system may again need to be tested. Similarly, if the pulley/wheels arrangements is changed as this could alter the length of cord between the sensor and cutting device and hence also the response time of the cutter.

In NG manufacture it is common to use an emulsion to transfer the NG between buildings. This relies on maintaining the correct ratios of water:NG and that there is always turbulent flow in the lines. These must be checked on a regular basis.

Once installed, all traps must be inspected routinely, and their function confirmed on a regular basis.

Separation type traps

To some extent these tend to have a greater degree of reliance on plant personnel following operating instructions and it is for all personnel to check that in-process and finished product is only placed where it is supposed to be and that quantities are kept to the minimum.

Physical barriers to propagation should be inspected for condition and position. If the process changes, for example a new product or increased quantities, does the system still provide adequate protection or does it need to be modified?

With thanks to Orica, Austin Powder, ENAEX and AECI for permission to use photos for illustration.

Emergency Response and Specialist Advice

Geoff Downs

I was recently listening to the Safex webinar where Noel Hsu gave a presentation on emergency response. This reminded me of the days when I was involved with emergency plans from an industry perspective, as an emergency responder assisting the police and fire services during chemical emergencies and as a regulator in several regulatory agencies. I had been the main author of two emergency planning guidelines. The first one was for the implementation of legislation for major hazard facilities which arose from the Seveso directives. The second one was for emergency plans for hazardous industry which was done in conjunction with the Australia and New Zealand Hazardous Industry Planning Task Force.

The aim of this paper is to discuss significant key issues I found in my different roles and to share some of these learnings. This may help in providing an underlying background for those developing and preparing an emergency plan and offering specialist advice.

Emergency plans can be set up under the four phases of emergency management which are -

- Prevention – regulatory and physical measures to prevent emergencies or mitigate their impact;
- Preparedness – arrangements to mobilise and deploy all necessary resources and services;
- Response – actions taken during and immediately after an emergency to minimise the impact; and
- Recovery – arrangements to restore the facility to normal as quickly and efficiently as possible and to as-

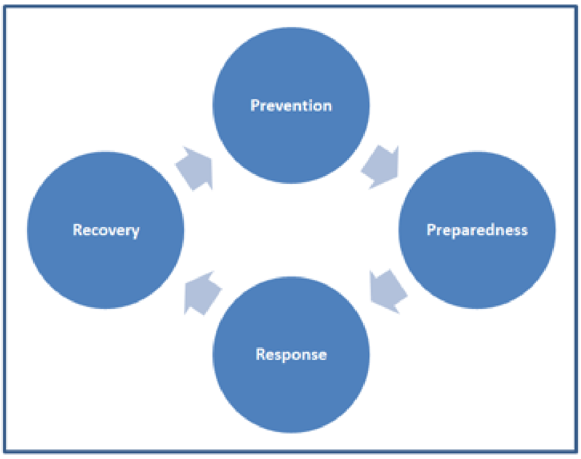


Figure 1 – Emergency management

Preparing for an emergency is different from preparing for every day job activities. It requires a different mindset and if and when the emergency plan needs to be activated, leadership and the look of leadership are critical. Under our duty of care, we prevent incidents from occurring and should they occur we minimise the impacts that may follow. For our normal everyday activities we know what the job is, we use risk control measures and known information to ensure the operations are conducted at acceptable risk to prevent incidents from occurring. This is a controlled environment where we have the opportunity to review, audit and implement improvements across the board for safety, security, productivity and efficiencies. We operate under a system with an organisational structure where everybody has known roles and responsibilities, skills, knowledge operating in a defined culture and is under control. We have time to plan and organise as we see fit and have the time to have timeout if required.

When we have an emergency, we do not have that luxury even though we have prepared for what we believe may happen. The emergency will happen when it happens and where it happens. The emergency may not happen anywhere in your plant, it may be anywhere else in transport or at other sites and at any time regardless of who is and isn't there. The emergency plan will have an emergency organisation chart which will list people and backups who have roles, responsibilities and functions, equipment, resources etc to support any emergency situation regardless of whether it is small, medium or large. When the emergency happens those roles must be carried out regardless of who is there, when it happens or when it happens. We can't put the emergency on hold necessarily or have timeout because the timing is not convenient. Preparation and planning must account for this situation. This is challenging because the emergency puts us into a situation which is outside our normal everyday experiences, knowledge and skills for not only the chemicals and explosives involved but for anything and everything that is associated with any operation to be accounted for. You may have to step up to the plate and provide specialist advice on behalf of somebody else who has different skill sets or is more knowledgeable and skilled than yourself. You may need to have ready access to others who can contribute to the best possible outcome under the circumstances.

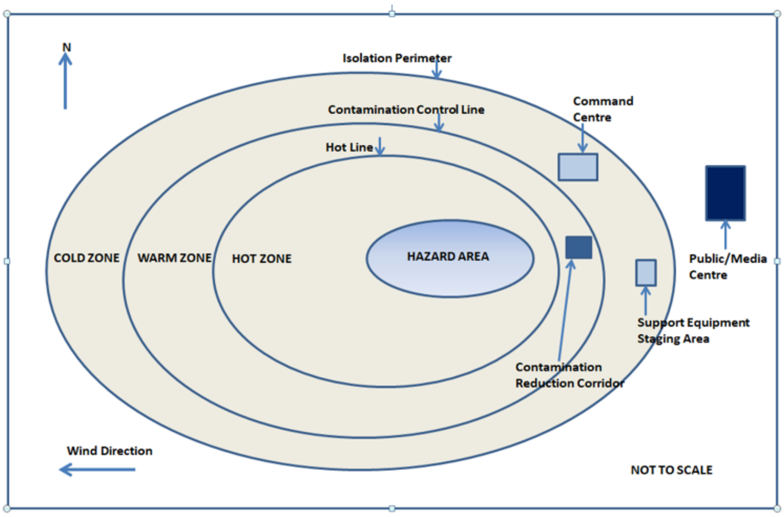
In one of my roles as the manager of a chemical plant, we had to prepare an emergency plan as required by the local government authority, State government safety authority and the fire services. The facility was unpopular with the local community and in the past (before my time) had been shut down because of the decomposition of the calcium hypochlorite during repacking operations. The fire service responded using water which exacerbated the situation because the use of water liberates the release of much larger quantities of chlorine gas. The interesting question here is for those of you who manage ammonium nitrate, how would you go explaining to emergency responders how the decomposition of ammonium nitrate would affect people in the surrounding areas and what action you would be recommending should be taken including the extent of how far these recommendations would apply to make those people safe? These are credible scenarios.

As a part of the liaison with the government agencies including the fire services, the question was asked when you have a decomposition and chlorine is released, which people will be affected and how far away will those people be affected? This was a very interesting question to which at that time I had no idea of the answer even though in hindsight I see it was a part of my employer's and my duty of care. My experiences had been preventing incidents from occurring and a part of my day job this was way outside of anything that I did or had experienced. This involved plume modelling and estimation of release rates. When I came to think about it, this is the part of understanding what can happen when things go on and go wrong outside of our everyday expertise. Should I have the knowledge and skills to determine this and provide advice for incident management to minimise the impacts when an incident occurs. During an emergency, can I expect anyone else to have the answers and be readily available to understand the situation and to provide the necessary estimates and guidance. Under emergency management this is about response and in particular understanding what can happen when things go wrong. Sounds like specialist advice for situations where there are credible scenarios that may not happen, but we need to be prepared for should they happen. Most people are particularly good at understanding their jobs and their roles for normal every day activities including how plant, equipment and materials they process behave under controlled conditions. However, they may not necessarily have suitable knowledge and skills when things are totally different and where exposures and impacts are way beyond everyday work practices and understanding. To not be fully across the issues can be seen as understandable when you have not prepared for the scenarios and had sufficient time to think about what could possibly happen. The provision of this type of advice as required under stressful and emergent situations are not a part of our everyday activity. We are put into a situation under pressure where we may not have full knowledge of the current situation and yet somebody should provide specialist advice. You also need to be prepared to carry these activities out under duress. At the pool chemical plant, we carried out full scale emergency exercises with police, fire services, state emergency service, regulatory agencies and even emergency rescue helicopters. The exercise was well prepared. A significant learning I found from the full-scale emergency exercises with sirens going in the background and lots of other noise going on was my thought processes were getting scrambled by the extreme noise. It was extremely difficult to think and communicate with others when in the centre of the action. By the way, we did have a consultant prepare an emergency plan together with all the plume modelling required.

I believe it is important to understand what the expectations that will be placed upon you or others when you are called upon in an emergency situation for interacting with emergency responders. For larger events you may have to respond in person or over the phone with the police, the fire services and other agencies. It is important to understand how they operate, what their expectations are and what you can do to support them to get the best outcome possible under the circumstances. You are the specialist advice and your advice is extremely important to the outcome not only for the emergency management and your operations but also for any negative fallout that may occur to your company from the regulatory agencies, local community and media. The incident commander needs to manage the emergency. They set up emergency control zones, see Figure 2 below, which includes hot, warm and cold zones, command posts, etc. For the imminent threat of explosion, the emergency control zones will look different. They want very sharp information that they can act upon. They need to set up the boundaries for the hot, warm and cold zones based upon credible advice for fire, explosion and toxic release. They need a person who can provide answers directly that they can understand without jargon and can be readily implemented. They do not want to hear someone who is indecisive and can't give a straight answer or any type of answer. Those people may be viewed as a waste of time and will be treated accordingly. Decisions have to be made and the specialist advice is critical in that area. The management of an emergency is done using the best of available information with people who have the knowledge and skills to assist as required. The one important thing to remember is that it is advice and advice may not always be taken but will be considered in conjunction with everything else.

I had a situation when I was a scientific adviser assisting the fire service during a chemical emergency. I had information about the chemicals but I needed to talk to somebody to get more detailed information than was in the safety data sheets to assist the incident commander in problem solving. The chemical was a product of a well-known company that had a 24 hour emergency contact number. I contacted the number and seemingly waited a long time through the announcements before I finally spoke with the person who was providing the specialist advice. I was extremely disappointed because I didn't get satisfaction. The person read from a safety data sheet and could not provide any additional information about the chemicals and equipment. This was information I could get elsewhere and already had without contacting the specialist advice. When I asked that I wanted to talk to somebody who knew more about the chemical and could help in the emergency situation, they were unable to do so. This was not my idea of specialist advice and meeting your duty of care or even being helpful.

It is important to have a detailed understanding of all aspects of plant, equipment, chemicals, articles and other things that will be involved in an emergency. The most common form of chemical emergency as an emergency responder when I was assisting the fire services was an ammonia gas leak and these were generally in residential communities. Ammonia gas is the most common refrigerant gas used in larger scale refrigeration facilities. When there was a leak, the incident commander would send firemen in level 3 protection suits into turn off the valves and equipment. The



Cold Zone (clean zone, clear zone, support zone, outer hazard zone)	**Command Centre, Support functions (first aid)**
Warm Zone (decontamination zone, limited access zone, protective action zone)	Support for direct response personnel and equipment decontamination
Hot Zone (exclusion zone, restricted zone, actual hazard zone, initial isolation zone)	Area in which direct response personnel are working
Hazard Area (spill, total exclusion zone, exclusion zone, contamination area)	Area involved in the actual incident

Figure 2 - Emergency Control Zones

firemen have their own specialist skills but not necessarily with individual refrigeration plants. What would happen is that the firemen would be kitted up and sent in to turn off the valves and all this had to be done in 20 minutes because that's the time available for level 3 protection equipment. This was not successful because the building and/or valves could not be located. Every time I attended, I would ask the incident commander to find the engineer who knows the plant. The engineer would be kitted up directly assisted by the firemen and the situation was rendered safe. The issue here is you need somebody who knows the plant and equipment in order solve the problem in the best possible manner.

There can be confusion when an emergency is reported. The report may not be accurate in some or all aspects. People may not be familiar with plant, equipment and hazardous materials involved in the emergency and relaying information to people. They also may not be necessarily familiar with the terminology, names and details. Citizens can report an emergency. It is reasonable to understand that errors, omissions and identification matters can occur in communicating the initial details of an emergency for many reasons. I estimated that 80% of the time the initial information for a hazardous materials incident that I was advised of was not correct while supporting the emergency services as an emergency responder. Some of my colleagues believed that it wasn't as high as that. The issue here is that if you are advised about information and details, you need to validate that information and details are correct otherwise your specialist advice may not be as good as you would like it to be.

From my experience, the times I had problems at a hazardous materials incident was when I didn't validate the information. I've been involved in responses where the details are either not correct or change during communication based upon the knowledge and experience of people involved. Examples of this include hydrochloric acid had been reported as sulphuric acid, aqueous ammonia being reported as anhydrous ammonia. In another case, a large quantity of sodium cyanide labels together with some other nonhazardous salts in the form of a paste were identified and treated as if it was a sodium cyanide incident. During the 'cyanide' incident I spoke to my assisting chemist who told me that he could smell cyanide. I told him that I couldn't and he insisted that he could. The suspected cyanide was taken away for treatment. Afterwards we found out the suspect sodium cyanide was a shipment of sodium cyanide labels. I asked him why he told me he could smell cyanide. His response was not everybody is capable of smelling cyanide but he was one of those people who can. You can see there are so many different traps you can potentially fall into. At an ANE plant, an exothermic reaction occurred when concentrated acid was mixed with water and due to the exothermic reaction, the water heated and steam was emitting (like hot water does from a hot water tap) from the tank openings, an emergency ensued where it was believed that a runaway reaction was imminent. While the outcome was not serious, the negative publicity and media attention was.

We don't plan to have emergencies as our efforts are aimed at preventing them. We need to be prepared should they happen and to a degree we need to be 'street smart'. We should be able to understand and identify what could happen during a specific emergency. Due to the nature of an emergency we do not have perfect information but we should have the knowledge and skills to be capable of providing credible advice. We should be the best people to know how our own plant, equipment, materials and products will behave under all credible conditions and circumstances in less than ideal conditions and circumstances.

Preventive Transport Management and Transport Emergency Plan in AUSTIN POWDER ARGENTINA.

Authors: Nadia Engler – Cenci, Ma. Laura

Introduction

Nowadays, the value of companies lies less in their physical assets (plants, machinery, buildings, etc.), while its intangible assets (safety, knowledge and experience of its employees, the company's public image, product positioning, etc.) are becoming increasingly important worldwide.

Transportation is one of the most complex processes that take part of the explosives industry. Many aspects cannot be controlled that easily once the unit leaves the plants and hard work needs to be done constantly on foreseeing the risks and preventive incidents.

A transport emergency is defined as an event where there is either a major transport operational problem (a fire, explosion, major spill or serious traffic incident), or where there is a loss of life or considerable environmental damage and there is a possibility of media coverage.

An effective response to a road transport emergency is essential to eliminate the hazards and lessen their impact if an incident occurs. A Road Transport Emergency Preparedness Plan takes this one-step further by looking at the actions and initiatives that need to be developed prior to any such incident.

Effective transport emergency planning is a continuing process. Hazard vulnerability, organizational structure, transport conditions and emergency facilities and equipment change over time, so the emergency planning process must detect and respond to these changes. Planning does require written documentation, but effective planning also includes elements that are tough to document on paper or developed in hardware.

These include the development of emergency responders' knowledge about resources available from public and private organizations, getting the knowledge about emergency demands and other agencies' capabilities, and the establishment of collaborative relationships across organizational boundaries.

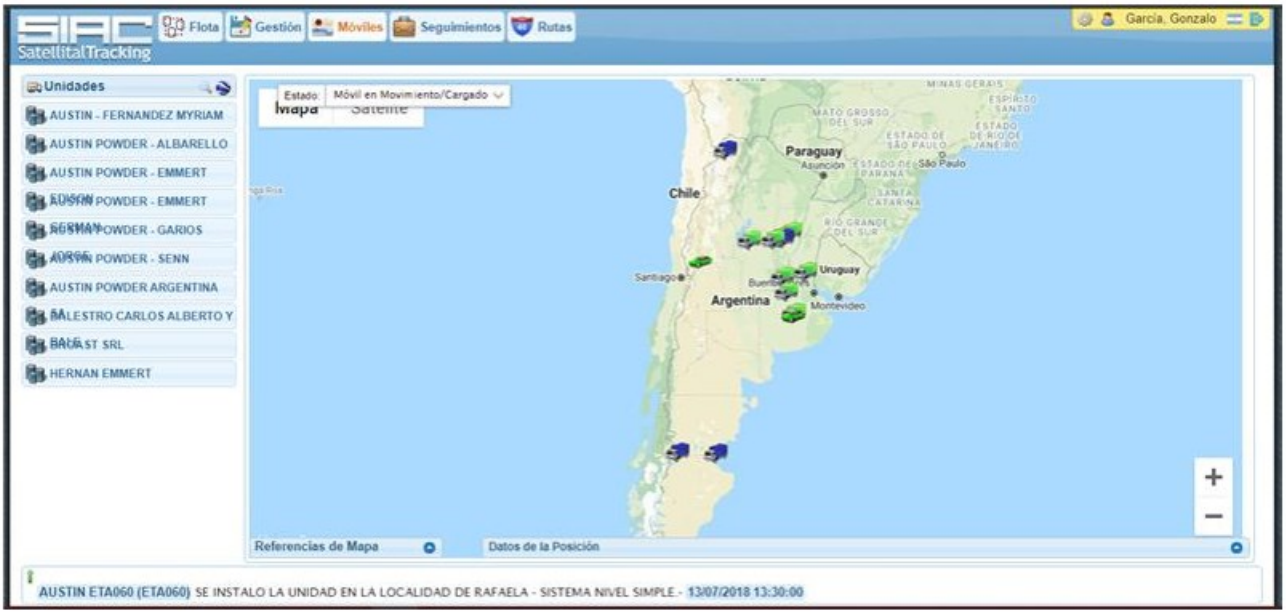
This article presents the Transport Emergency Response Plan that Austin Powder Argentina has developed through years, taking into account either public or private responders as well as the strategy for facing media interaction.

A few examples of activities and implementations, are presented in order to show how the system works and what improvements were required. What we have learned is that you can never get distracted and proactivity is a key point to evolve in order to deal with a dynamic context and to challenge the system is strategical to consolidate a safe working environment.

Another learning is that Technology and people are two fundamental bases to build a confident and strong Transport system capable to adapt to different scenarios and situations.

Background

Austin Powder Argentina S.A. transports by road AN, explosives, accessories and bulk emulsion all through the country, also export to Chile, Uruguay, Paraguay and EEUU through transit by Chile. Main clients are set at the South of the Argentina, at about 2500km from the production plant. Other clients are in the North of the country, at about 1300km. AN is also shipped to the country from Chile.



SIAC Monitoring System

Transport is done through main roads, but when getting closer to mining projects, this became very tough, because of the road conditions itself, geographic or weather conditions.

Mainly contractors (transport agencies) provide transportation services. As part of the Corporate SHES Manual development, Austin Powder Argentina has put lots of effort on making the transportation of explosives safer and being ready for emergencies.

The main objectives for the work were:

- To assess, analyze and prevent risks in transport units and roads.
- To avoid or mitigate injuries that emergencies may cause to APA own staff and/or contractors and third parties.
- To avoid or minimize the impact of incidents related to health and the environment.
- To reduce or minimize economic losses and damages that may result to transport units as a result of incidents
- To train permanently APA own staff and/or contractors in risk prevention and training in response actions in emergencies.
- To have procedures to be followed during emergency response operations.
- To define the responsibilities and functions.
- To establish an emergency communications plan.

Results

As mentioned, transportation is one of the most complex processes that take part of the explosives industry. Many aspects cannot be controlled that easily once the unit leaves the plants.

In order to control them, a series of actions were developed:

1. **100% closed trucks** for explosives and detonators, with seals and padlocks.

2.**Risk analysis during different stages of Transport Process.** This tool helps to identify risks in detail and determine action plans to minimize them. (Example of Risk Assessment on loading and unloading explosives

	EVALUACIÓN DE RIESGOS						ER-A-APA-001
Planta:	AUSTIN POWDER ARGENTINA S.A.	Sector	TRANSPORTE	Versión	01	Fecha	23/3/2018
Situación/Actividad a Evaluar	CARGA / DESCARGA DE CAMIONES						
Equipo Evaluador	1 Gonzalo García 2 Florencia Fornero				3 4		

Identificación y evaluación de Riesgos											
Secuencia de pasos	Afectado	Peligro Potencial	Severidad	Probabilidad	Medidas de Control actuales	Riesgo	Medidas a implementar	Severidad	Probabilidad	Riesgo Residual	Responsable
Ingreso del camión al predio	Personas	Atropello o golpe por vehículo.	3	2	Velócidad máxima 30 km/h Ingreso exclusivo de tránsito pesado Comunicación fluida entre Portería y Expedición.	Tolerable	Establecimiento de circuito	3	1	Aceptable	Transporte / SHES
	Bienes	Choque contra objetos.	3	2	Velócidad máxima 30 km/h Ingreso exclusivo de tránsito pesado Delimitación de estacionamiento en área de Expedición	Tolerable					
Posicionamiento en playa para carga											
Apertura de puertas de semi / camión	Personas	Golpe/Corte por objetos.	1	1	Carrocería en buen estado. Manipulación con guantes.	Aceptable	Agregar cartelería de uso obligatorio de EPP				
Colocación de conos y calzas	Personas	Atropello o golpe por vehículo.	3	1	La colocación de calzas y conos se realiza con el motor apagado y se encarga el mismo chofer evitando descoordinación entre las partes.	Aceptable					
Carga / descarga de pallets en semi / camión	Bienes	Golpe de maquinaria en movimiento.	3	2	Coordinación de tareas con la colaboración del chofer del camión y supervisor de carga. Capacitación para conductores de autolevadores.	Tolerable					
	Personas	Atropello o golpe por vehículo.	3	3	En la zona de carga sólo tiene permitida la permanencia el chofer del camión. El acompañanate permanece dentro del tractor o queda en portería.	Tolerable	Incorporación de un espacio exclusivo para permanencia en sector de Expedición.	3	1	Aceptable	Transporte / Proyectos
	Personas Bienes	Explosión.	5	1	Manipulación cuidadosa de explosivos. Consideración de las compatibilidades. Correcta estiba, palletizado y disposición de la carga.	Tolerable					
Salida de la unidad del predio											

3.**Induction and annual training for truck drivers on dangerous goods**, BOS on transport, how to react on emergencies,fire extinguishers use.

4.**Instructions in case of emergency** on the road are given to each truck driver to carry on a visible part of the truck, as well as the "red folder" that contains all the information for first responders: Emergency Protocol, MSDS, Information about explosives, important numbers.

AUSTIN POWDER INTERNATIONAL

INFORMACIÓN PARA EMERGENCIAS

SECUENCIA DE LLAMADAS

1°- CIPET: 0800 666 2282

2°- AUSTIN POWDER ARGENTINA: 03492 424775

3°- GERENCIA SHES: 03492 15528741

4°- JEFE DE TRANSPORTE: 03492 15590528

INFORMACIÓN A REPORTAR:

	Tema	Detalles
1	Identificación personal	• Su nombre • El de su empresa
2	Número de quien llama	• Su número de teléfono o número donde ubicarlo
3	Descripción del incidente	• Accidente sin fuego ni derrames, Accidente con solo fuego o Accidente con solo derrame.
4	Lugar del incidente	• Número de ruta, km, o distancia aproximada de la intersección o poblado más cercano
5	Información de la carga	• Descripción y cantidades de las sustancias peligrosas cargadas
6	Información de daños y lesiones	• Accidente fatal, accidente no fatal y daños en el vehículo
7	Información de derrame	• Descripción de las cantidades de sustancias peligrosas derramadas
8	Información del vehículo	• Descripción del vehículo y número de Patente

AUSTIN POWDER INTERNATIONAL

EN CASO DE FUEGO

NUNCA INTENTAR EXTINGUIR EL FUEGO, SI ÉSTE SE ENCUENTRA EN LA CARGA

- Si el vehículo está en movimiento, detenerlo en el primer lugar seguro que encuentre. Hacer lo posible para evitar detenerse cerca de cualquier puente, edificio ocupado o salida de ruta.
- Después de detener el vehículo, inmediatamente apague el motor y accione el freno de emergencia. Al salir del vehículo, recupere los documentos de emergencias. Tome medidas para luchar contra el fuego y accione el cortacorrientes
- Reporte el incidente siguiendo la **secuencia de llamadas** y los detalles de la **información a reportar**
- Si el fuego está fuera de control, tome medidas para avisar al público del peligro y manténgalos alejados del fuego hasta el arribo de los equipos de respuesta.
- Proveer a los equipos de respuesta los documentos de emergencia, si es que pudo retirarlos del vehículo. Avíseles si accionó el cortacorriente. Ayude en la emergencia si es seguro hacerlo.
- Si es posible, separe la fuente de fuego de la carga (ruedas, desenganche)

EN CASO DE DERRAMES

- Reporte el incidente usando la **secuencia de llamadas** y la lista de **información a reportar**.
- Accione el cortacorriente, si es seguro hacerlo.
- Retire los extintores y deposítelos en un lugar seguro, lejos del vehículo, para ser usado en caso de necesitar combatir el fuego.
- Ubique las señalizaciones de seguridad (chapas balizas, conos)
- Mantenga todas las personas y elementos iniciadores de llamas lejos del vehículo, hasta la llegada de equipos de respuesta.
- Proveer a los equipos de respuesta los documentos de emergencia, si es que pudo retirarlos del vehículo. Avíseles si accionó el cortacorriente. Ayude en la emergencia si es seguro hacerlo.

5.**Inspection Check List** prior leaving the plant: taking into account the material transported, legal requirements for circula tion, conditions of the units, PPE, emergency equipment.

CHECK LIST - TRANSPORTE DISTRIBUCION

Fecha: Hora: Cliente:

Transporte: Tractor: Semi:

Chofer: Acompañante:

CONTROLA PORTERIA

Sistema Webcompliance - Transporte - Vehiculo - Choferes	SI	NO	Observaciones
Empresa Transporte			
Estado Recurso - Chofer			
Estado Recurso - Chofer Acompañante			
Estado Vehículo - Tractor / Camioneta / Chasis / Balancin.-			
Estado Vehículo - Semirremolque.-			

Control Documentacion Física - Vehículos (Tractor / Semi)	SI	NO	N/A	Observaciones
Registro Único de Transporte Automotor (RUTA)				
Poliza/Certificado Seguro Automotor y No Repetición (A favor de Austin y otros)				
Comprobante de pago - Seguro Automotor				
Certificado de realización de la Revisión Técnica Obligatoria (VTV)				
Cédula de identificación del vehículo sin vencimiento (Tarjeta Verde)				

Control Documentacion Física- Chofer	SI	NO	N/A	Observaciones
Documento Nacional de Identidad				
Licencia Nacional de Conducir - Categoria Acorde a vehículo				
Licencia de Conducir CNRT - Mercancias Peligrosas				
Curso de Mercancias Peligrosas - Vigente				
Seguro de vida Obligatorio - Nomina (vigente)				
Seguro de ART - Nomina y No Repetición (A favor de Austin y otros)				

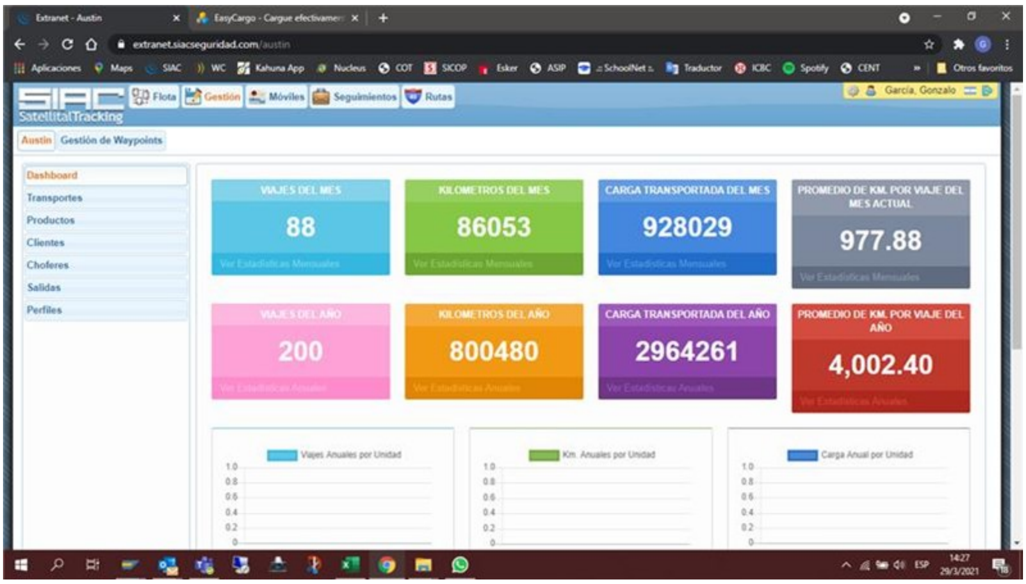
Control Documentacion Física- Chofer Acompañante	SI	NO	N/A	Observaciones
Documento Nacional de Identidad				
Licencia Nacional de Conducir - Categoria Acorde a vehículo				
Licencia de Conducir CNRT - Mercancias Peligrosas				
Curso de Mercancias Peligrosas - Vigente				
Seguro de vida Obligatorio - Nomina (vigente)				
Seguro de ART - Nomina y No Repetición (A favor de Austin y otros)				

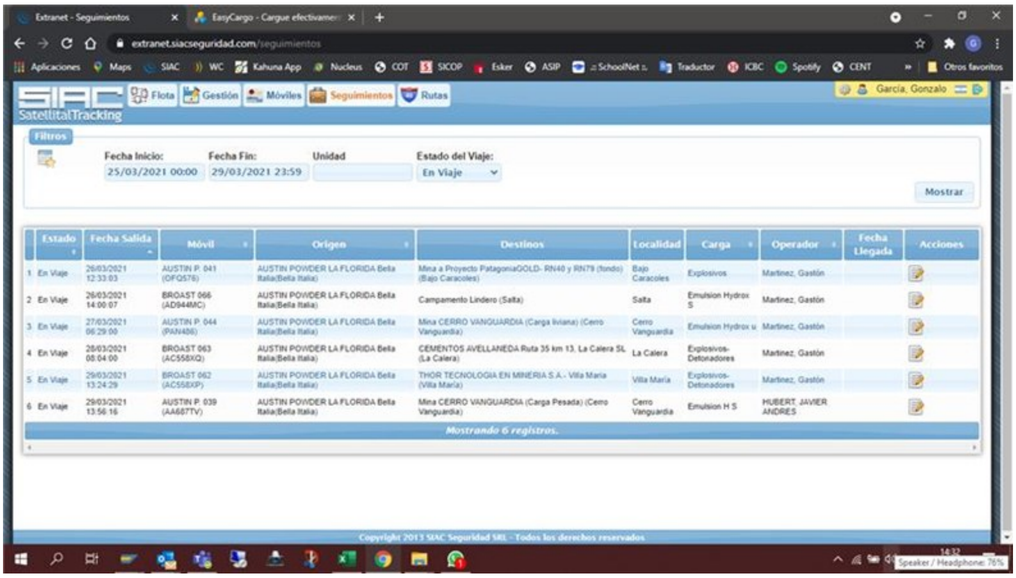
Inspeccion de Vehículo (Tractor / Semi)	SI	NO	N/A	Observaciones

6.**Periodical Mechanical Inspections to Trucks**. Maintenance of the vehicle is crucial for Transport, especially in danger-ous goods. Make sure that proper inspections take place, particularly on tires, brakes and electric circuit to avoid incidents with overheated or fire.

6.**GSM tracking** for each unit with daily reports and online tracking of irregularities (speed, travel schedule, unauthorized stops)

8.**Special REPORTS** from SIAC, the GPS Monitoring service. This service facilitates the Transport Planning, Transporters distribution to different roads and sites to optimize times and resources. Good tariffs according to safety standard and Transport Management are essential for excellence in the Supply Chain of explosives.





9.**Risk assessment of different roads** to evaluate locations for overnight stay, difficult roads, etc. Also, the **Police of each city or town is notified** when a truck with explosives stay overnight.

IDENTIFICACION DE PELIGROS.

Tramo n° 1	DEBILIDADES	FORTALEZAS
DESDE RN 34 KM 223 (RAFAELA) HASTA INT RN34 KM 721 Y RN DE ACCESO A "LA BANDA" (SGO DEL ESTERO). (**498 KM POR RN 34**).	Gran cantidad de transito de todo tipo, especialmente de camiones. Cinta asfáltica angosta. Banquinas en regular estado especialmente los días de lluvia. Regular demarcación en algunos tramos. Algunos tramos sin señal telefónica. Animales sueltos en la ruta.	Ruta concesionada, en líneas generales buen estado, bien demarcada y bien señalizada Reparación en los tramos con deterioro. Buenos paradores para camiones.

Tramo n° 2	DEBILIDADES	FORTALEZAS
DESDE INT. RN 34 (KM 721) Y RN DE ACCESO A "LA BANDA" (SANTIAGO DEL ESTERO)	Cinta asfáltica angosta. Banquinas en regular estado especialmente los días de lluvia. Regular demarcación en algunos tramos.	Reparación en los tramos con deterioro. Buenos paradores para camiones.

7º TRAMO. DESDE PUMAMARCA HASTA MINA PIRQUITAS. (POR RN 52 INT. CON RP 70-HASTA INT. RP 70 Y RN 40-RN 40) **329 KM.**

10.**Drills and workshops to train first responders** and to develop coordinated actions among public institutions and Austin Powder. This activity gives Austin the possibility to know personally the people responsible for each Institution, establish a direct contact in case of any situation during Transport. It is important to develop this network.

11.With the information from risk assessment, a defined **plan schedule is given to every single trip** in order to specify time of driving (during daylight) and places for overnight. Established stops for resting, walking and do some body movements are also determined every 3 hours.

HOJA DE RUTA

Destino:	HINOJO	**Horario autorizado:**	06:00 a 20:00	**FECHA:**	27/10/2016
Transporte:	TRANSPORTE HERNAN EMMERT	**Camión:** HXA678	**Semi** OPK164	**Cist./Isot.**	-
Chofer:	DIEGO COLOMBERO	**Acompañante:**	MARIO DAYER	**REMITO Nº:**	34-2428/29/30 // 33-1685
Paradas autorizadas:	JUNIN	-	-		

HORARIO	LOCALIDAD	DISTANCIAS en KM. A Rafaela	Punto ant.	Promedio Velocidad	Tiempo Estimado	Tiempo de Marcha	Horario paso Aproximado
13:30 hs	RAFAELA	0	0	0	00:00 hs	00:00 hs	13:30 hs
13:30 hs	Cruce RN 34 y RN 19 (ANGELICA)	31	31	68	00:27 hs	00:27 hs	13:57 hs
13:57 hs	SAN VICENTE	50	19	68	00:16 hs	00:44 hs	14:14 hs
14:14 hs	PEAJE CORRALITO	67	17	68	00:15 hs	00:59 hs	14:29 hs
14:29 hs	CAÑADA ROSQUIN	90	23	68	00:20 hs	01:19 hs	14:49 hs
14:49 hs	SAN GENARO	131	41	68	00:36 hs	01:55 hs	15:25 hs
15:25 hs	Cruce RN 34 y A 012 (ROLDAN)	204	73	68	01:04 hs	03:00 hs	16:30 hs
16:30 hs	Cruce A 012 y RP 18	253	49	68	00:43 hs	03:43 hs	17:13 hs
17:13 hs	PERGAMINO	345	92	68	01:21 hs	05:04 hs	18:34 hs
18:34 hs	ROJAS	381	36	68	00:31 hs	05:36 hs	19:06 hs
19:06 hs	**JUNIN**	**429**	**48**	**68**	**00:42 hs**	**06:18 hs**	**19:48 hs**
06:00 hs	LOS TOLDOS	472	43	68	00:37 hs	06:56 hs	06:37 hs
06:37 hs	9 DE JULIO	536	64	68	00:56 hs	07:52 hs	07:34 hs
07:34 hs	SAN CARLOS DE BOLIVAR	632	96	68	01:24 hs	09:17 hs	08:59 hs
08:59 hs	OLAVARRIA	742	110	68	01:37 hs	10:54 hs	10:36 hs
10:36 hs	**HINOJO**	**762**	**20**	**68**	**00:17 hs**	**11:12 hs**	**10:53 hs**

TELEFONO DE EMERGENCIA

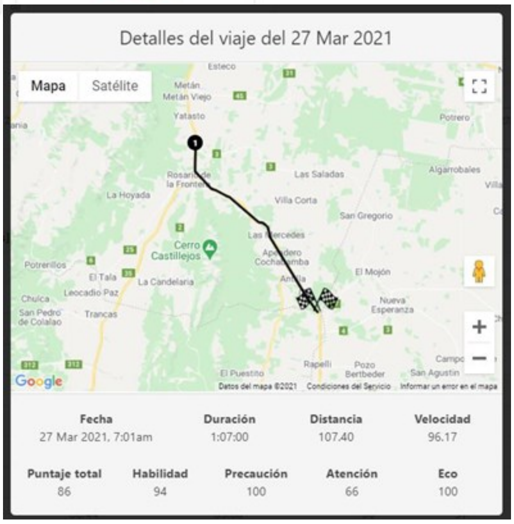
CIPET: 0800-666-2282

Número gratuito con atención las 24 horas los 365 días del año para la coordinación de la emergencia. CIPET luego de verificar la llamada, iniciará el proceso de coordinación de la emergencia, dando el alerta y asistiendo telefonicamente a los organismos de respuesta mas cercanos al lugar (bomberos, policía, Gendarmería, hospitales, etc.).-

COMUNICARSE ADEMAS CON AUSTIN POWDER:

GUARDIA:	**03492 - 424775 - Int. 114**
Gonzalo García JefeTransporte APA	**03492 - 1 5590528**
ENGLER Nadia	**03492 - 15528741**

12.**WOOCAR** Mobile APP to detect the use of mobiles devices during the journey, while driving. This tool helps to monitor drivers behavior and obtain a punctuation of their performance in order to coach drivers and improve their performance.



13.**Driver Brochure**: complete written instruction for driver to provide them with the necessary information needed in case of emergence, preventive actions, relevant contact information, applicable law, etc.

Manual del Conductor

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MANUAL DEL CONDUCTOR

Manual del Conductor

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OBJETIVO

El presente Manual tiene como ***objetivo*** describir las ***responsabilidades del conductor (chofer)***, que transporta productos de ***Austin Powder.***

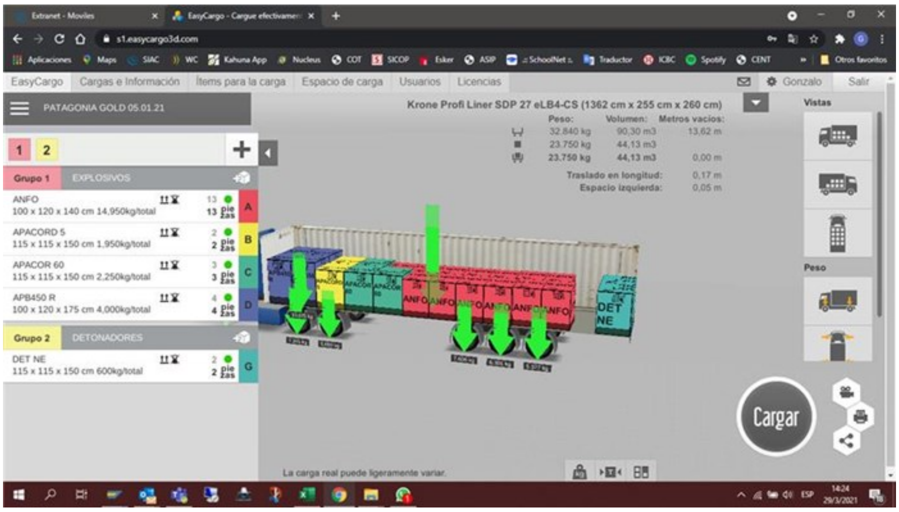
INDICE

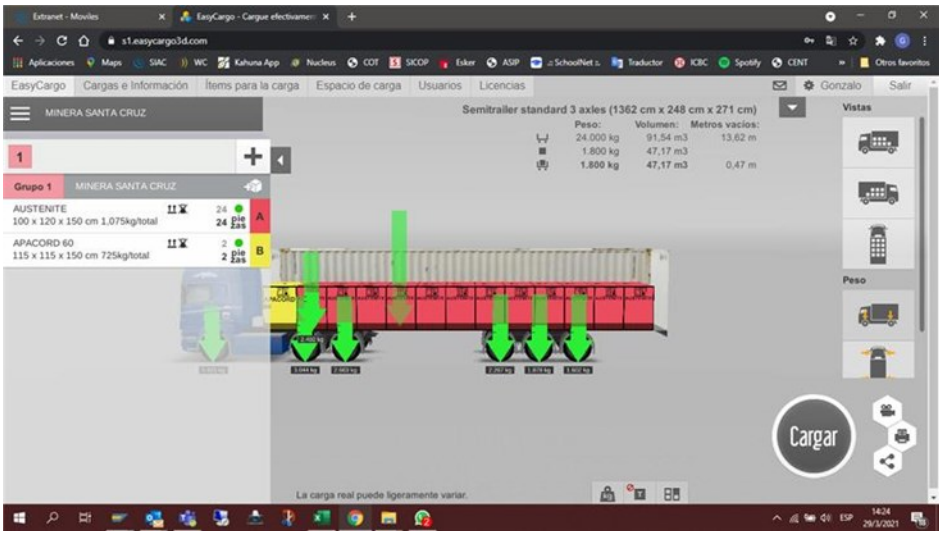
SECCION 1 - Especificaciones Generales del Transporte.
1.1 – El Conductor – Definición.
1.2 – Funciones Generales del Conductor.
1.3 – Documentación a Presentar en Portería.
1.4 – Inspecciones/Controles Previas a cada viaje.
1.5 – Reglamentaciones para el Transporte de MP por carretera.
1.6 – Listado Infracciones. Medida Preventiva. Subsanación.
1.7 – Listado Productos AUSTIN. Identificación Vehículos.

SECCION 2 - Especificaciones Generales Instalaciones AUSTIN POWDER.
2.1 – Ingreso Vehículos.
2.2 – Carga / Descarga de vehículos.
2.3 – Otros.

SECCION 3 - Acciones a Tomar en caso de Emergencia.
3.1 – Que hacer en caso de una emergencia.
3.2 – Como se debe actuar ante distintos escenarios.

14.**EASY CARGO System** to optimize the cargo into the truck, in order to have a stable and balanced loading, with a good distribution of waits. Helping to be more efficient and REDUCE the number of journeys with explosives.





But, not always things develop as expected, so the company needs to be prepared to face an emergency, and one of the most important things is information and training, not only for the internal actors, but also for first responders.

One of the first evaluations done by the APA team was that there were not enough resources for attending an emergency within the company, either because of the long distances, as well as the equipment needed.

So a specialized company was hired to become the coordinators and responders to the emergency.

This company will coordinate resources as well as first responders in order to minimize the consequences during the emergency. APA signed a contract that includes the services not only in Argentina, but also in Chile and Brazil.

However, this seemed not to be enough, after one incident in a very remote area, as communication with first responders in the area became very difficult. So, a new tool was introduced in the plan.

APA found out about a National Information Center for Emergencies during transport (CIPET)

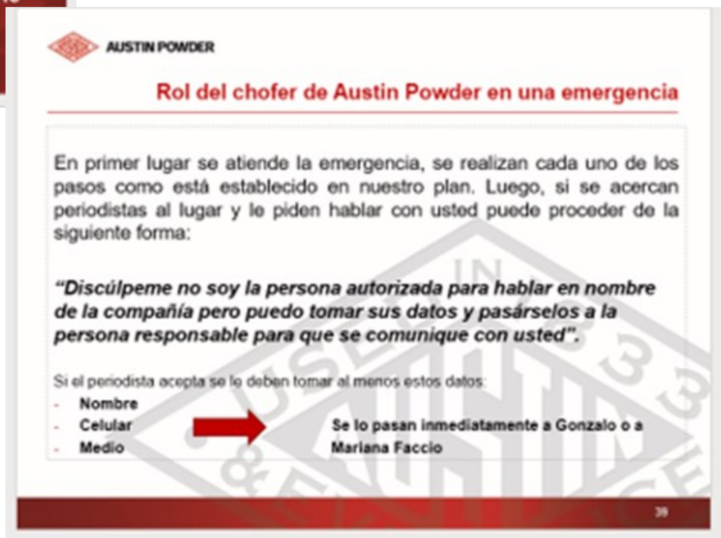
This Center is a service of the Argentina Chamber of Automotive Transport of Dangerous Goods and Hazardous Waste in cooperation with the National Civil Protection of the Ministry of Interior of Argentina.

It will not respond to the emergency itself, but as every truck has a CIPET number displayed, anyone can call them and they will inform APA and all the first responder in the area about an emergency.

They also give regular reports on the status of the roads, so changes to the travel schedule can be done prior to getting to the conflict area.

Last, but not least, if was identified that not all first responders were capable of responding to AN or explosive involved emergency, so together with the Emergency on Road Company, a training program was defined.

We organize special trainings for drivers in topics related to communication, their role in a Transport incident, the message to press and the importance of their professional behavior during the process.



Some events of crisis in an organization dictate the need for strong communication with employees, customers, suppliers, government officials and other key audiences.

The strategic decision of the ways of communication during and after a crisis is one of the most important in crisis management decisions. Establishing and agreeing on a communication strategy can make the difference between a crisis that is forgotten about within a few days or being around the organization for many years.

Conclusions

Austin Powder Argentina has been working for the last 10 years in building a solid TRANSPORT SYSTEM considering all the preventive actions that are necessary in order to mitigate risks during Transport Process, this is to say not only the road but also the loading and unloading stages.

What we have learned, is that it is not only 1 or 2 factors that influenced the Transport of explosives, there are several variables involved, many of them incontrollable so we have focused on those that we can check and have the obligation to do so. The particular characteristic of Transport is that you not only depend on driver, the truck, proper separation of goods, etc. there are many external elements such as the road condition, weather, other drivers, infrastructure, etc. that operates during a Journey with explosives. For this reason, all controllable variables must be treated as professionally as possible, with a proactive and preventive view.

The main elements in Transport of dangerous goods to be revised for a successful Transport Planning are driver, truck, goods conditioning, communication, road analysis, emergency plan and legal requirements.

It is essential to establish an **Integrated Plan** for the company that covers all the mentioned aspects, with **dynamic development**, and an **approach of continuous improvement.**

Natural justice

Geoff Downs

I have seen many times where people are disgruntled, dissatisfied, upset, angry, frustrated and so on with the decisions and rulings of the explosives regulator particularly when they genuinely believe that they meeting their obligations and requirements under the legislation. Even though people feel this way, they do not want to challenge the decisions and rulings and exercise their rights which exist under legislation. We understand that explosives based legislation is primarily developed to prevent process incidents from occurring and these are generally safety and security based incidents. This is essentially achieved by providing a framework to ensure amongst other things that those involved in the entire life cycle meet their duty of care and also by ensuring that only persons who should be control of explosives and have access to explosives do have control and access as appropriate and those who shouldn't don't. This means that persons in control of explosives and in contact with explosives are suitable by being a fit and proper person and competent. This can be achieved through licensing and permitting and the processes. Activities are regulated and where appropriate should be carried out in accordance with the legislation and good practice which may include codes of practice and standards.

These are not the only matters covered by legislation. The legislation provides a framework for which the system can work to address the obligations of all people whether they be individuals or corporations, administration, and enforcement and general matters within the scope and application of the legislation. For inspectors, it should provide for the appointment of inspectors, the functions of inspectors, and the powers of inspectors. It should also provide for the review of decisions which include internal review of decisions and external reviews by civil administrative tribunals or court equivalents. These provisions are provided to ensure that natural justice prevails and are essential in all legislation. To complicate matters further, legislation can be hierarchical where fundamental legislative principles and interpretations of Acts etc are provided in different legislation and will not be repeated in lower level legislation such as explosives legislation. The important point to appreciate is that inspectors and regulators can only enforce matters within the scope of their authority provided under legislation and that all persons who are covered by legislation have rights under that legislation and are afforded natural justice. One example of natural justice is that a person is not forced to answer the question that will incriminate themselves.

This leads to asking the question why are people reluctant to stand up for the rights when they genuinely believe they are meeting all the requirements and are being prevented from achieving their goals in accordance with their own systems of safety and security. The reasons can be varied and may include any of the following –

- Regulatory overload. People have to comply with so many pieces of legislation within one jurisdiction. Many companies operate across many countries and jurisdictions. This makes understanding and setting up systems under many pieces of legislation across many jurisdictions an extremely difficult task. Understanding your rights in addition to all of the other regulatory requirements is complex and extremely time-consuming. Keeping abreast of changes adds to the complexity of meeting and understanding obligations, requirements and ensuring compliance across the board becomes extremely difficult.
- Operators do not fully understand their rights that exist under legislation to review a decision even though they should have been advised of their rights when a decision has been communicated.
- Operators do not have the confidence that the system is just and fair.
- Operators feel that they and their management systems are not being properly understood.
- Relationship with the regulator. Operators have worked hard to build up a relationship with the regulator and if their decisions are challenged they believe they will be compromising the relationship they have worked hard to establish and do not want to be seen as adversarial.
- Review of decisions can be time-consuming and in other cases can be expensive when seeking legal assistance. Operators are normally very busy and don't have the time or resources to plead their case.
- Operators wish to maintain a low profile and do not want to challenge the regulators decisions and rulings under the perception that should their challenge be successful they will then be served with another ruling and decision.

There are always challenging times where an operator genuinely believes that they are meeting their duty of care and yet the regulator who should be attempting to establish that the operator is also meeting their duty of care differ in their assessment or interpretation of the requirements. Does breakdown in communication play a role? During my time as a regulator, I operated under the premise that my duty of care to the community was to ensure that the operator (industry) was capable of meeting their duty of care when they worked to their safety and security management systems. I had a discussion with an operator who advised that they had to change the set up at their site to suit the particular inspector who was coming to carry out that inspection. This example brings into question the system as a whole. This example should show that if the management system was deficient then the management system needs to be amended to meet duty of care or alternatively that the management system met duty of care but the local operator was violating that system. In this case the matter was dealt locally. The issue that I was concerned about is that operators felt obliged to step outside the management system to make local changes to satisfy the individual inspector's wishes rather than satisfying their own system. This provides a local solution but is not holistic. This can then lead to a potential breakdown of the system where the system can be unofficially changed based upon good intention to suit the situation but the precedent is being set.

As a young regulator I learnt a very valuable lesson that I must know legislation. In my experience, the legislation is not fully understood by most parties. Regulators should regulate the legislation within their powers and not 'regulate' personal opinion. It is unfortunate that it occurs so often that both industry and regulators who are trying to achieve the same goal to prevent incidents and meet their objectives and duty care can differ when adopting the same philosophies and tools. My advice to operators who feel aggrieved is that they should appreciate that they have rights as provided in legislation and be prepared to exercise them (it is not personal), they should be afforded natural justice and they should validate the legitimacy of the decision and ruling considered by them to be adverse.

ANSWERS TO
"TEST YOUR EXPLOSIVES SAFETY KNOWLEDGE"

DDT in pipes – design pressure for containment

This is a common problem in gas and dust handling of potentially energetic media but not a basis of safety for the much higher pressures involved with commercial explosives (other than possibly anomalous borehole expansion in the field). A stable detonation would have a shock pressure of ~ 2 x detonation pressure which would give the solution as 2. However, in a slow DDT build-up to detonation. the gas ahead of the combustion front is pre-compressed which will result in a higher local detonation and shock front pressure. In an estimate, one has to establish the most conservative pre-compressed state (constant volume explosion impinging on unreacted gas) and undertaking a detonation calculation on this perturbed state – giving a revised detonation pressure of 5.6 MPa and a shock pressure ~ 2 x this value. Accidents like this have happened in practice.

(Minimum Burning Pressure) MBP use – basis of safety & relief for deflagrations

Originally based on strand burner technology for propellants, the design of equipment for and measurement of MBPs have been well described in CERL reports (Turcotte, Lightfoot, Badeen, Jones, Chan, Propellants, Explosives and Pyrotechnics (2005)) and the latest generation of equipment designed there is commercially available (OZM).

In some other guides and publications, the use of MBP criteria has been misunderstood. It is not sufficient to assume that the operation will be safe merely by having design pressures less than this minimum. Firstly, in some fault conditions, the physical state of the pump inventory will deviate from the design intent and the measured MBP may be too conservative. Secondly, in a fault condition such as an internal explosion of explosive that had ingressed into a coupling, the pump inventory may reach pressures much higher than the measured MBP. The purpose of pressure relief is to prevent the propagation of deflagration by reducing the pressure sufficiently so that this is not possible. The bursting disc failure pressure would be best set at between 6 and 8 MPa so that the pump's contents end up at nearly ambient pressures and this might limit the onset if premature rupture that might occur in practice due to the disc characteristics changing with age when in situ. Note that this hazard would not normally be identified by no-flow devices. (Chan, Deshaies, Propellants, Explosives and Pyrotechnics (1988)).

Ammonium Nitrate based propellants

Ammonium Nitrate (AN) has been used in some propellant applications as it allows the use of a less expensive oxidizer and one that can generate gas efficiently. Solid ammonium nitrate has some anomalous properties, notably its morphology in terms of solid phase changes and also its hygroscopicity. Though the former can be largely mitigated using crystal habit modifiers and the moisture ingress can be prevented by hermetic sealing, accidents have happened. Rocket motors are designed based on the deflagration characteristics of the propellant ie it's burning velocities at different pressures. This velocity-pressure dependence is dependent on the nature of the particulates, AN and fuel. If these materials become physically damaged their combustion characteristics can change, the deflagrations become more violent and loss of containment of the rocket can occur.

If one assumes that crystal habit modifiers have been included in the AN, then (ii) comprises the major and most likely hazard which can result in (v) and possibly (vi). Moisture will hinder the action of the habit modifiers and during thermal cycling, crystals may fracture introducing the prospect of the combustion front travelling in advance of the reaction front through channels generated by the fragmentation as well as an increased area for chemical reaction.

Stirred pot in a flow system with no/low flow check

If the agitation failed the nature of the heat transfer in the reactor would change and temperature gradients introduced hottest at the centre of the vessel and coolest at the walls. The paint colour would not indicate the high-temperature deviation in the central core of the vessel and a reaction runaway could ensue.

Gas void compression – propellant press

The use of gas voids (or spheres containing gas) allows the less hazardous manufacture of the precursor explosives matrix before mechanical sensitization in the field. Where voids are not present the introduction of high pressures for processing does not introduce any explosion hazard as liquids are comparatively incompressible. Where voids are present and significant increases in pressure required controlled start-up of high-pressure explosives pumps and propellant presses are required to avoid reaction in the energetic material, dieseling etc. The severity of the hazard of compressing voids rapidly depends on void size and concentration.

For a propellant press in this example, three void sizes are considered. From experience, or numerical modelling or literature search it can be established for a spherical void (worst case) the answer is ~15.

Post-Detonation Fume prediction- NOx, CO, CH4

Explosion fume, noxious or explosive gas by-products from an explosive detonation, is dependent on the explosive formulation itself (its oxygen balance), the reliable initiation of the explosive charge, the environment in the borehole (eg water, porous rocks, reactive ore body) and the expansion and venting processes. Inevitably these factors cannot be readily accounted for by equilibrium thermodynamics within an ideal detonation computer program which inevitably assumes infinite charge diameter for the tertiary explosive. Even discounting these factors, as suggested by the question, these codes cannot adequately address kinetic effects such as freeze out (dependent on expansion rate/ confinement), gas mixing or absorption by the rock fragments. Beyond the simple guide of firing undamaged explosive, there is little advance on the use of an oxygen balance criteria in the absence of full-scale mine experience.

Domino effects– storage separation distances – Ammonium Nitrate (AN)

There is not a definitive answer to this issue that the author is aware of and what is included here are suggestions. The general bases of safety are:

(i) the avoidance of contamination eg fuels, transition metal and their salts, halides, acid etc

(ii) the absence of any combustible material including building and environs

(iii) the elimination of all credible initiation sources (fire (as (ii)) electrical, static, energetic material, high-velocity projectiles)

(iv) where necessary, the separation of inventories by appropriate distances to prevent onward propagation (domino effect)

Assuming the adherence to the bases of safety of (i)-(iii) pure AN is not a hazardous material to store. When these cannot be verified and guaranteed then a full quantitative risk analysis is required, one that would allow the use of mitigation by detectors, water quenching, inspections and site security to be taken into account as well as detailed characteristics and response to shock and impact stimuli of the receptor. If the hazard is still at an unacceptable level than storage separation is the final resort.

Some procedures that base separation on shock damage and some version of TNT tables, though the inference is, in early USBM work, that fragment impact is the major cause. Overpressure calculations may lead to very large, albeit very safe, separation distances.

Different strategies might be considered for reducing these distances. For the overpressure/ shockwave scenario, earth mounds or barricades should mitigate and reduce the required distance. Where high-velocity impact dominates, the use of frangible materials in any containing structure should substantially decrease the risk.

To conclude more physical structures (iii) are not an answer. (i) , (ii) and (iv) should be considered.

Beirut Ammonium Nitrate Explosion (August 2020) – early analysis of blast effects

The reports from Beirut were consistent about the 2750 tonne quantity of AN present along with some discussion of much smaller amounts of other energetic materials. A simple energy estimate which assumes complete reaction/ ideal detonation limits the maximum TNT equivalent mass to 1200 tonne. Prior experience from other AN blasts suggests a practical TNT equivalence ration of ~ 0.2 – 0.3 which would suggest a figure in the range ~550 – 700 tonnes. The upper estimate might be more realistic due to some confinement and contamination but the 1500tonnes TNT equivalent is not credible.

Thermite – the role of thermite in commercial explosives processing

Thermite comprises a mixture of metal and metal oxide powders, typically ferric oxide and aluminium. This mixture, when ignited, undergoes a very exothermic redox reaction. Being a solid-solid reaction, this process is slow and further hindered by an oxide coating compared to a detonation and suggestions of obtaining more energy from commercial explosives with the benefit of added thermite reaction are largely spurious. Such benefit to the detonation process that has been observed will most likely be caused by shock wave interactions with the particulates generating more “hot spots” and aiding the chemical decomposition of the non-thermite components of the charge.

The handling of a commercial explosive with thermite would be expected to:

(i) reduce the shock sensitivity of the medium

(ii) contribute substantially in the case of an accidental fire

(iii) possibly introduce some wear and tear on plant components

(iv) require more careful handling of explosive waste in burning ground applications

Transport

The drums were filled at 0°C by pouring in liquid until they were 90% full. The drums were open to the atmosphere during the filling so that, when the drums were closed, the pressure inside was 1 atmosphere which was made up of 20.7 kPa of the vapour of the liquid and 80.6 kPa of air. On warming the drums to 30° C, the liquid expanded to 92.7% of the volume of the drum and the vapour pressure of the liquid increased to 82.7 kPa. The vapour space occupied by the air decreased from 10% to 7.3% of the drum volume. Therefore, the air pressure rose from 80.7 kPa to 124.3 kPa (80.7 x 10/7.3) x (307/273). The solubility of the air in the liquid was very small and the increase in pressure did not cause any transfer of air from the vapour space into the liquid. Therefore, the pressure in the drums rose to 124.3 + 82.7 = 204.7 kPa and the drums burst.

SAFEX BOARD OF GOVERNORS

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 October 2020 Newsletter is 30 September 2021 .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.