7. Health, safety and environment

Maastricht Conference Proceedings 2022, R. Holmberg et al

Cold case investigation - Who blasted the transmission tower and killed four people?

M. Ruspeckhofer
Naarn, Austria

ABSTRACT: In 1967, a transmission tower, holding a 220 Kilovolt powerline, located at the Italian-Austrian border on a mountain pass (altitude 2,300 m) was blasted by terrorists. Approaching soldiers stepped on hidden bombs or mines. Four people were killed, and one person was severely injured. Suspects from Austria were arrested and put on trial in Austria and in Italy. After more than fifty years, a historian found new evidence in old records. Because of his findings the blasting of the tower and the bombs were reinvestigated. The results exculpate the three young men (two of them still living) and suggest a completely different story.

1 PREFACE

In 1967 an electricity transmission tower located directly at the border of Austria and Italy was blasted. Italian forces were alarmed and went to the location. Near the tower, a young soldier was killed by a mine. Four specialists were brought in and investigated the case. They found electric installation material at the foundation of the pylon. When they returned, they triggered another mine which killed three of them and injured one.

That is the official Italian version of the incident.

2 HISTORICAL CONTEXT

After WWI, the province of Southern Tyrol was given to Italy. The 98 % German speaking population was not asked if they liked it or not. The fascist regime of Mussolini did everything to make Italians out of Tyroleans. After WWII, Italy industrialised the country. Mountain rivers produced electricity. Jobs were created in great numbers and apartments were built. Just: German speaking Tyroleans got neither jobs nor apartments. These were only for immigrants from the south. In 1961, some farmers decided that this could not continue and started to blast infrastructure objects, especially transmission towers, which were considered symbols for the suppression. Also, other objects were blasted, e.g. an aluminium statue of the Duce Mussolini which was (in the 1960s!) placed next to a power plant. Finally, the Italian government backed down and started serious negotiations concerning an autonomy. Some people did not agree with these negotiations. On the one side, a certain group within the BAS 'Befreiungsausschuß Südtirol' (Board for Freedom in Southern Tyrol) who pushed for a referendum concerning the nationality of Southern Tyrol, and on the other side, Italian fascists who considered this part of the country a colony and did not want to change anything.

Italy assumed that this terrorist attack was committed by Austrians and applied strong diplomatic pressure to get appropriate results. Among other things, Italy threatened to block negotiations of the non-EG member Austria with the EG concerning trade tariffs. The whole Austrian economy was at stake. Then the Austrian police arrested 3 suspects.

Figure 1. The twisted tower.

These three young men claimed that they were asked to take over the transport of an injured member of the BAS to an Austrian hospital. The meeting point was a mountain pass next to Mt. Porze (Cima Palombino), which forms the border between Italy and Austria (altitude: 2,300 m). They claimed that they did not reach the pass because they realised in time that something was wrong. Suspicious from the beginning (the letter which informed about this task did not contain certain security signs), they turned and went back. A train ticket later helped to reconstruct the timing. For the lawsuit, two independent certified experts concluded that they had a maximum time span of thirty minutes to commit the crimes. The three Austrians were put on trial in Austria and were acquitted. In Italy they were also put on trial – in absence and without even informing them – and were convicted. To calm the situation Austria ordered the army to secure the border and prevent further attacks.

Fifty years later, a historian from the Austrian Army investigated this operation and found documents which suggested a completely different story. Protocols of engineers who were at the location one day after the bombing stated that they did not find any evidence of bombing and killing. Lots of other information (documents from the archives) was worked into a book which was published in 2015. However, the historian did not look closely enough at the details of the blast and of the bombs. When I criticised, he assigned me to investigate the blasting side of the event.

3 AVAILABLE SOURCES OF INFORMATION

- Book by the historian Dr. Speckner, containing numerous files, interviews etc.
- Local witnesses
- Technical literature (Vogel, Oriard etc.)
- Historic expertise by Massak from 1967 (as presented in the book by Dr. Speckner)
- Expertise by Dr. Melzer, static engineer specialist in construction blasting
- Blasting instructions for the BAS (as described in the book by Herlinde Molling)
- Interviews with contemporary witnesses

4 ISSUES

4.1 Why did the tower fall to the northeast when the ropes pull towards southwest?

The transmission tower is on the highpoint of the

Table 1. Safety distance for stray current from high voltage power lines.

Streustrom-verursacher	Sicherheitsabstände ❶ ❷ ❸				
	ohne weitere Maßnahmen		mit zusätzlichen Maßnahmen		
	bei Verwendung		bei Verwendung		Erforderliche Maßnahmen ❺
	U-Zünder	HU-Zünder ❹	U-Zünder	HU-Zünder ❹	
(1)	(2)	(3)	(4)	(5)	(6)
01 Hochspannungs-freileitungen mit Holzmasten	10 m	10 m	10 - 0 m	10 - 0 m	▫ Absolute Isolation des Zündkreises ❻ ▫ Zündleitung mit erhöhter elektrischer Festigkeit
02 Hochspannungs-freileitungen mit Stahl- od. Stahl-betonmasten	50 m	10 m	50 - 25 m	10 - 0 m	▫ Keine Wieder-verwendung von Verbindungsdraht
03 Leitungen elektrischer Bahnen	200 m	100 m	200 - 100 m	100 - 10 m	▫ Zünderdrahtisolation bei Stahlbeton mit erhöhter Festigkeit
				10 - 0 m	▫ Streustrommessung durch Sachverständigen ▫ Zündbedingung: $I_{St} \times 30 \leq I_N$

Anmerkungen:

❶ Alle Sicherheitsabstände sind nach Bild 3/110 anzuwenden.
❷ Abstände gelten insbesondere bei Bahnen auch zu parallelen oder seitlich wegführenden leitfähigen Einrichtungen (z.B. Wasserleitung).
❸ Diese deutschen Werte gelten auch für Österreich.
❹ Für die Schweiz tritt anstelle Sp. (3) und (5) die Sp. (2) aus Tabelle 3/35.
❺ Bei meßtechnischem Nachweis der Streustromabwesenheit bzw. des Einhaltens ungefährlicher Streustromwerte kann aus fachlicher Sicht von dieser Tabelle auch abgewichen werden; Achtung: Rechtsvorschriften beachten!
❻ Dazu zählen insbesondere: isolierte Drahtverbindungen, kein Berühren von Leitungen des Zündkreises mit sonstigen metallischen Teilen, kurze Leitungen.

220 Kilovolt powerline from Italy to Austria. At this point it also changes direction. Dr. Melzer, expert for structural engineering, concluded that the ropes exert a power of 300 kg to one side. But if the tower is blasted as the contemporary Massak expertise suggested, it would not topple but stay upright because of its weight. Only if somebody would remove a part of the corner profiles on the northwest side it would topple to this side. The northwest is uphill. The mast toppled slowly against the pull of the ropes. The outrigger was not damaged at all. There was also no stress relief of the power lines, so the neighbouring towers were not damaged. Had the mast fallen to the southwest, downhill, the situation would have been quite different, resulting in strong damage of the tower itself, and also the neighbouring towers due to stress relief of the cables. It is therefore not very likely that the tower was blasted by 'terrorists'.

4.2 The materials, how were they used?

Italy presented electric installation material. How was it used? Was it possible to prepare a blast with these materials?

The presented material consisted of several cables, plugs, remains of electric igniters class 'A', pocket watches (for a time delayed ignition) and batteries. It is quite doubtful that a person would risk working with these very sensible igniters of the safety class 'A' (Antistatic) directly on an electricity tower of a 220 KV high voltage power line. Also, how long would it take during night hours without any artificial light (the place can be monitored from a nearby Italian army base)?

The electric igniters of that time had a bridge wire resistance of 1.5 Ohm and were safe up to a current of 0.18 amps. Current igniters are safe up to 0.45 amps. Blasting at altitudes of 2,300 m or in the vicinity of high voltage power lines is restricted to highly insensitive igniters which are safe up to 4 amps.

In the 1980s the US-blasting consultant Lewis Oriard investigated the response of 0.18-amps-igniters when used in blasting near 220 KV powerlines. To his surprise these high-sensitive igniters proved safe even in unfavourable settings within 8 m of the powerline. But despite these results Mr. Oriard decided to use highly insensitive 4 amps igniters from Schaffler & Co, Austria, for all blasting operations near these power lines.

However, blasting near power lines is different than using these igniters directly at a tower which

Figure 2. Phase of the blasted electricity corner tower Nr. 119, grounded, which lead to the ground fault.

is, at that time of the night, moist from dew. Especially if there is an alternative: BAS-members usually used detonating cord, which made things much faster, easier and safer to work. Especially at night.

The registration of the ground fault by the power plant and the perception of the blasting noise by the nearest army base differ by 35 minutes. It is safe to assume that somebody grounded the power line half an hour before it was blasted. If several people are working, this is a reasonable time frame for preparing a blast, and therefore a reasonable assumption.

4.3 Ground fault

When a 220 KV-cable causes a ground fault, you may expect some sign of burning. However, Figure 2 shows nothing like this. The power plant in Soverzene tried to restart operation of the power line about five minutes after the first ground fault, without success. The records show that the second ground fault was caused by the same line as the first. This tells us that Figure 2 should show the site of the original ground fault (if the blasting of the tower was the reason for the ground fault). The engineer who later repaired the tower also concluded that the tower tilted rather slowly because there was no damage on the outrigger, which would benefit the formation of an electric arc. But according to picture 2 there were no signs of burning. This would again support the assumption that somebody grounded the power line before loading.

4.4 First victim: the radio operator Amando Piva

When the first soldiers approached the site, a hidden bomb went off and killed the radio operator. (Official Version.) Later the experts did not find any hint of a trigger mechanism.

The first information from Italy to Austria stated that: “An electricity tower was blasted. Of four charges only three went off.”

We can assume that in the (first) blast, one charge did not detonate. The size of the charge for the corner profile and of the bomb: 0.5 – 1 kg high explosive (Source: contemporary experts). When a radio comes close to an undetonated charge with a highly sensitive igniter, it is possible to set off the charge (see Table 2). The radio operator must have been very close to the charge because of his injuries. Also a few hundred metres away was another very strong radio in a vehicle.

4.5 Second mine

After the radio operator was killed, a group of specialists was brought in to investigate the case. These were trained in finding and defusing bombs.

Table 2. Technical report: Calculated safe distance for radios according to frequency and strength of the signal.

✶ *Der zitierte "Technical Report" gestattet die Berechnung von Sicherheitsabständen aus Sendeleistung und Sendefrequenz für jede Zünderempfindlichkeit. Für U-Zünder liegt beispielhaft die Tabelle 3/35 vor (die Sp. 2 aus Tab. 3/34 wurde zum Vergleich aufgenommen). Tabelle 3/35 hat gegenwärtig noch inoffiziellen Charakter, ihr Inhalt ist jedoch richtungsweisend.*

Sendeleistung	**Frequenz [MHz]**							**Vgl.**
	0,1 - 1,5	**1,5 - 10**	**10 - 30**	**30 - 70**	**70 - 150**	**150 - 800**	**> 800**	**UVV**
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
01 ≤ 1 W	3 m	1 m	3 m	2 m	1 m	0,5 m	0,1 m	0 m
02 > 1 W - 5 W	6 m	3 m	7 m	4 m	2 m	1 m	0,2 m	2 m
03 > 5 W - 100 W	26 m	10 m	32 m	20 m	10 m	5 m	1 m	20 m
04 > 100 W - 1 kW	81 m	32 m	100 m	62 m	31 m	15 m	3 m	20 m
05 > 1 kW - 10 kW	256 m	100 m	315 m	195 m	97 m	46 m	9 m	50 m
06 > 10 kW - 100 kW	810 m	314 m	996 m	614 m	306 m	143 m	27 m	100 m
07 > 100 kW - 400 kW	1620 m	628 m	1991 m	1228 m	612 m	268 m	54 m	150 m
08 > 400 kW - 1 MW	2560 m	992 m	3147 m	1942 m	967 m	451 m	85 m	200 m
09 > 1 MW - 3 MW	4435 m	1718 m	5451 m	3363 m	1670 m	781 m	147 m	300 m

Tabelle 3/35 Sicherheitsabstände elektrischer U-Zünder von Funksendeanlagen
(gemäß [Z 229] - Vorläufige Berechnung nach Hauke und Röh)

Table 3. Recommended distances for 1 ohm electronic detonators from RF sources such as fixed and mobile transmitters including cellular telephone service, amateur radio and citizens' band. Minimum distance in feet.

Transmitter[1] Power (Watts)	MF 1.7 to 3.4 MHz Fixed, Mobile, Maritime	HF 28 to 29.7 MHz Amateur	VHF 35 to 36 MHz Public Use 42 to 44 MHz Public Use 50 to 54 MHz Amateur	VHF 144-148 MHz Amateur 150.8-161.6 MHz Public Use	UHF 450 to 470 MHz Public Use Cellular Telephones Above 800 MHz
1	15	47	37	12	8
3	25	81	64	21	14
5	33	105	82	27	18
10	46	148	116	38	25
50	102	331	259	85	55
100	144	468	366	120	78
180 [2]	193	627	491	161	104
200	204	661	518	170	110
250	228	739	579	190	123
500 [3]	322	1045	818	268	174
600 [4]	353	1145	897	294	190
1,000	455	1,478	1,157	379	245
1,500[5]	557	1,810	1,417	464	300
10,000[6]	1,438	4,673	3,659	1,198	775

Data from: Institute of Makers of Explosives, December 2011.

These four specialists stepped on a contact device and another bomb went off (size about 2 – 3 kg TNT - official version: 6 kg). Three of the specialists were killed, one life-threateningly injured. This suggests that these four specialists were walking very closely together while searching for bombs. Quite an unusual and unlikely behaviour. The first bomb, killing the radio operator, went off on the upper side of the road which leads to the tower. The other bomb went off on the lower side. The expert at the time, Massak, considered this a very logical array. Massak had plenty of experience from WWII. The Italian experts seemingly did not expect a bomb at this place. But why? Massak was led to the site for investigation. He found the contact device. On the contact device was a message from the BAS: "You shall never have our land!" But when the news published the incident, one picture showed the device with the message. Almost identical to the original but with one spelling difference. It seems that there were two almost similar devices. One for the Austrian expert, and another one for the press.

Two of the victims were found more than fifty metres from the bomb crater. How did they come to this place? The average inclination is about 30 - 35 degrees with the fall line leading to a different direction. The snowfield nearby did not show any signs of blood. The explosion seems to have torn and burnt away all clothing, leaving strong signs of burning. This would not happen with a buried charge of roughly 2 kg. Trial blasts did not show any signs of burnt clothes on dummies.

The contemporary expert, Alois Massak, also found remains of batteries in the bomb crater. Later they were identified as batteries of a type which were sold in Austria. Trials show that batteries near a blast of two kg TNT will simply disappear (evaporate). Mr. Massak therefore found evidence which simply could not have been there.

5 A MORE REASONABLE VERSION OF THE STORY

Looking at these findings, a different version of the crime story is more likely. Two of the three Austrian suspects were well known for their activities in Southern Tyrol. So, a letter was written to lure them to the mountain pass. At the same time, a team of blasting specialists prepared the site. They waited for the Austrians to reach the pass. As they did not show up, they decided to blast the tower. First, they applied some device to ground the power line. The night before, the power plant switched off the line for a few hours (maintenance work). This time could have been used to prepare the grounding for the next night. After electricity was switched off (the line grounded), they went to work. Unfortunately, a little mistake caused the failure of one charge. This is a quite common problem when blasting on metal structures. Sometimes the current takes a shortcut through the metal structure. Somehow the radio operator came close to this charge and set it off. Later the tower was once more charged and blasted. This time three charges were placed on the northeast side. That was the 'safe side', and it determined the direction of the fall. The accident was declared a bomb attack. At the same time, another accident (perhaps with explosives, or a traffic accident, or an air crash) happened elsewhere. The corpses were brought to the mountain pass. There were rumours that there was an accident during a mine-training lesson at the army base at Kreuzbergpass (another mountain pass nearby). So, two independent events or accidents were combined to tell a new story. That was not unusual at the time. The author can prove that an alleged bombing of a custom guard building was in fact a deflagration of heating gas from the kitchen.

6 WHO WAS RESPONSIBLE FOR THIS INCIDENT?

This question cannot be answered by a blasting expert. But the historian Dr. Speckner offers circumstantial evidence.

A fragment of a letter was found by the engineers of the electricity company at the mast. This fragment contained an address of a known member of the radical Gladio organisation.

Dr. Speckner therefore assumes that the blasting of the mast was performed by members of some fascist organisation with the purpose to hinder progress in autonomy negotiations.

REFERENCES

Beyling-Drekopf: Sprengstoffe und Zündmittel.

Bureau of Mines: A study of rf hazards at low and medium frequencies to blasting in underground coal mines. Vogel, G.: Zünden von Sprengladungen.

Hasler, H. 1967. Wissenschaftliche Neubeurteilung der Rechtssache Porzescharte 25. June 1967.

Institute of Makers of Explosives: Safety guide for the prevention of radio frequency radiation hazards in the use of commercial electric detonators (blasting caps).

Leidel, S., Shimer: RF hazards to electric detonators – *The New IME SLP-20*.

Molling, H.: So planten wir die Feuernacht.

Oriard, L.L.: Explosives engineering, construction vibrations and geotechnology.

Schaffler *et al.*: Die elektrische Minenzündung.

Speckner, H.: Zwischen Porze und Rosskarspitz.

Speckner, H.: Von der 'Feuernacht' zur Porzescharte.

Speckner, H.: Unpublished materials.

Maastricht Conference Proceedings 2022, R. Holmberg et al
 ISBN 978-0-9550290-7-3

Key learning from Beirut ammonium nitrate accident - Evaluation of warehouse safety management in Indonesia

A. Wibowo, & A. Sutoyo
PT Multi Nitrotama Kimia, Jakarta, Indonesia

ABSTRACT: The ammonium nitrate explosion in Beirut on August 4th, 2020, was a wake-up call for ammonium nitrate stakeholders in the mining and construction sectors, particularly regarding the deadly risks associated with explosives raw material management. The explosion destroyed most of the city of Beirut, and was caused by the unsafe, prolonged storage of 2,750 tons of ammonium nitrate. The explosion resulted in over 100 of fatalities, destroyed surrounding buildings, and incurred losses amounting to billions of dollars. This does not include the thousands of people injured, and lengthy socio-economic impacts on the country, made worse by the COVID-19 pandemic. In Indonesia, there are nearly 100 explosives warehouses managed by warehousing service companies, mining companies, and explosives providers. They are mostly located within the mining facilities, or in specialised warehousing areas. This study was conducted to analyse the potential, risks, and probability of a similar incident occurring in Indonesia.

1 INTRODUCTION

The incident in Lebanon is a cautionary case regarding the deadly risks associated with explosives management. On August 4th, 2020, an explosion shocked the city of Beirut, predominantly caused by about 2,750 tons of ammonium nitrate, which was stored unsafely and for a prolonged period, in the same facility as other, incompatible chemicals (Seddon & Shiotani 2020). According to World Bank Group (2020), nearly 200 people lost their lives, and damages were estimated to be between \$3.8 billion to \$4.6 billion, excluding the losses incurred. The blast damaged structures up to 6.5 miles away from the centre, and nearly 40,000 buildings in total were affected.

Ammonium nitrate (chemical formula NH-4NO3) is commonly used as an explosive in mining industry, and as a fertiliser in the agricultural industry. On its own, it is a very stable compound and quite insensitive to accidental detonation through impact or friction. Pure ammonium nitrate is difficult to detonate under ambient conditions of temperature and pressure. Flame, spark, rough handling, impact or friction are not known to cause a propagated detonation. An explosion of ammonium nitrate can be initiated with high explosives under ambient conditions (Western Australia - Code of Practice Storage Solid Ammonium Nitrate 2021).

In Indonesia, there are almost 100 commercial explosives warehouses managed by mining companies and licensed explosives companies. These warehouses are located in both mining and industrial areas, and have various capacities, ranging from 50 tons to 7,000 tons of ammonium nitrate and with varying environmental conditions. With so many of these high-capacity facilities, it can be said that there is a possibility of a similar accident occurs in Indonesia.

Ammonium nitrate in Indonesia is mostly used in the mining industry, particularly in coal mining, where the consumption of ammonium nitrate is

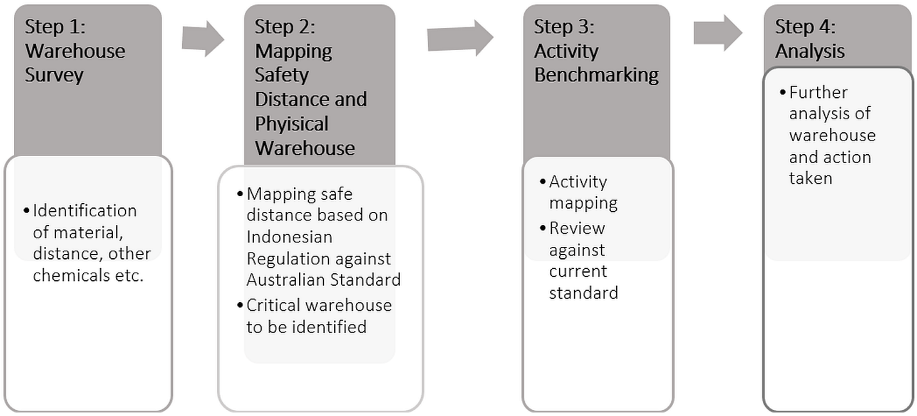

Figure 1. Methodology of study.

around 400,000 tons per year. This number remained steady in the last two years and is expected to remain that way for the next five years. According to the Indonesia Department of Energy and Resources (2021), Indonesia produced up to 600 million tons of coal in 2021, and approximately 75% of the production is on the island of Kalimantan.

The scope of this study is limited to the sample of ammonium nitrate warehouses in Indonesia with capacities of 200 tons up to 5,000 tons; both end-user and transit warehouses. This study excludes warehouses belonging to ammonium nitrate production facilities in Indonesia.

2 METHODOLOGY

Using the Beirut incident as a learning material, this study analyses the best practice of storing ammonium nitrate as one of the important factors that caused the explosion in Beirut. Moreover, one of the main indications of the explosion in Beirut was the prolonged storage of AN and indications of incompatible materials being stored in the same warehouse.

This study was carried out by conducting a warehousing survey, inspection of things in the warehouse and arrangement of materials in the warehouse, then compared with International Standards (from other countries), in this case using standard from Australia. This evaluation is mainly carried out for several warehouses located in Kalimantan, and Karimun Island.

The flowchart of this study is described in Figure 1.

To strengthen the analysis, the standards used are not only those currently enforced in Indonesia; the Western Australian Code of Practice had been used as a reference (Step 2). Evaluation of warehouses at risk (Step 3) is carried out on warehouses that have indications or potential to have large-scale (major) incidents. In order for the study to remain within the scope, the risk being assessed is limited to the impact on the surrounding environment, particularly regarding the risks of fire and explosion. There are several key terms to be analysed, such as:

– Possibility of an activity that triggers a fire
– Possibility of incompatible materials stored in the warehouse or nearby
– Possibility of warehouse fires escalating into widespread fires (local emergency plan)
– Possibility of explosion of the warehouse
– The impact of the explosion on the surrounding environment
– Emergency response.

The analysis used in this study is best practice by analysing the worst case scenario of each warehouse, especially warehousing that is outside the mining lease.

According to *Western Australia Code of Practice Storage of Solid Ammonium Nitrate 4^{th} edition* (2021), there is a hazard in relation of explosion (in term of Ammonium Nitrate storage). When heated by an external fire, the explosion sensitivity of the decomposing melt increases dangerously with increasing temperature and is further increased:

– if the AN is impure, or the melt mixes with contaminants and/or fuels; and/or

– if molten AN becomes confined in drains, pipes, plant or machinery and the decomposition gases cannot escape freely. Decomposing AN can also explode if mechanical shock impacts the hot melt. Fires involving AN have caused explosions, but there have been more fires involving AN without explosions, depending on the circumstances.

The risk of an explosion is decreased by reducing the potential for the AN to be:

– heated, such as in a fire
– contaminated
– confined.

Given the nature of modern formulations of AN, explosions of solid AN (excluding those initiated by explosives) without prior fire is unlikely. If all potential sources of fuel can be eliminated, the chance of an accidental explosion is remote.

3 STUDY ANALYSIS

The study was conducted by survey and physical inspection of Indonesian warehouses, located in both industrial areas and mining lease. The *National Police Chief No. 17/2017 which regulates Permit, Security, Monitoring and Control of Commercial Explosives* regulation is used for the permit and control of explosives in general. In the mining areas, the explosives warehouse management system is regulated by the *Ministry of Mining and Energy's Decree No 209/2018 Regarding Explosives Safety and Blasting Practice for Indonesia Mining Industry,* which states that explosives warehouses must be at an adequate distance away from surrounding communities and other storage facilities; the regulation also regulates the overall management system, and analysis of potential impacts on the surrounding environment. These two regulations are inter-correlated.

Safety management of AN warehouse from these regulations are then compared to the Australian Standard, in this case the *Western Australia Department Mines, Industry Regulation and Safety; Code of Practice – Safe Storage of Solid Ammonium Nitrate 4th edition (2021)* being referred to.

The data obtained are listed in Table 1. The data is a sampling of several mining areas with

Table 1. Initial data for ammonium nitrate storage in warehouses.

#	Ware-house Name	Type of Location	Province	Ammonium nitrate volume (kg.)	Other & type of dangerous goods nearby	Capacity other DG (kg.)	Distance to Community (m)	Distance of ammonium nitrate warehouse to another DG warehouse (m)
1	W1	Coal Mine	East Kalimantan	120,000	DG Class 1	10,000	7,000	20
2	W2	Coal Mine	East Kalimantan	4,000,000	DG Class 1	200,000	2,000	120
3	W3	Coal Mine	East Kalimantan	500,000	DG Class 1	200,000	5,000	100
4	W4	Coal Mine	East Kalimantan	350,000	DG Class 1	5,000	5,000	50
5	W5	Coal Mine	East Kalimantan	2,500,000	DG Class 1	50,000	10,000	250
6	W6	Coal Mine	Cent. Kalimantan	2,000,000	DG Class 1	100,000	6,000	700
7	W7	Coal Mine	Cent. Kalimantan	1,000,000	DG Class 1	20,000	10,000	150
8	W8	Coal Mine	South Kalimantan	500,000	DG Class 1	5,000	10,000	30
9	W9	Coal Mine	Cent. Kalimantan	1,000,000	DG Class 1	15,000	10,000	50
10	W10	Coal Mine	South Kalimantan	550,000	DG Class 1	30,000	4,000	50
11	W11	Quarry	Riau Island	300,000	DG Class 1	75,000	2,000	100
12	W12	Coal Mine	South Kalimantan	260,000	DG Class 1	3,000	20,000	20
13	W13	Coal Mine	Cent. Kalimantan	200,000	DG Class 1	1,000	16,000	20
14	W14	Standalone complex	South Kalimantan	3,000,000	DG Class 1	200,000	600	50
15	W15	Standalone complex	South Kalimantan	1,000,000		-	2,000	0
16	W16	Standalone complex	East Kalimantan	5,000,000		-	2,000	0
17	W17	Stand lone complex	East Kalimantan	2,000,000		-	650	0

Figure 2. Ammonium nitrate warehouse.

general warehouses representing the overall condition of explosives warehousing in Indonesia and stand-alone warehouses. There was total 17 warehouse surveyed and evaluated. The warehouses are commonly made from steel structure, have a concrete floor, natural lighting

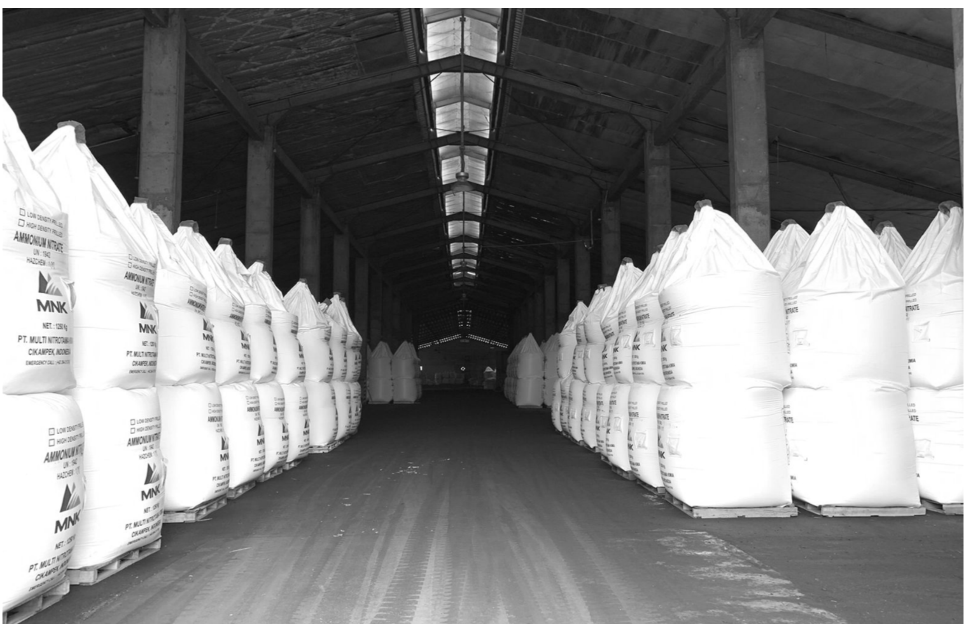

Figure 3. Ammonium nitrate stacking in the warehouse.

and ventilation. No electricals are allowed in the warehouse. Ammonium nitrate stored mostly low density type in in a bulk bag of 1250 kg, 1000 kg or 25 kg. Most commonly used is 1250 kg bag.

Ammonium nitrate warehouses in mining areas are located in a specific complex, where other explosive materials are stored in other buildings. Separation distance is maintained according to Indonesia regulations. Typical explosive materials (DG Class 1) stored include *pentolite* boosters, emulsion cartridges, and detonators. All of those materials are to be kept in separate buildings. Whilst ammonium nitrate warehouses located outside the mining areas are stored in specialised and dedicated locations. Most of ammonium nitrate warehouse in Indonesia is designed as stand- alone dedicate steel and concrete building structure (Figure 2 & Figure 3).

All warehouses within the mining area are at an adequately safe distance from the surrounding communities rather than warehouses outside the mining lease areas (Table 2).

Apart from the safe distance criteria tabulated above, there are other standards according to *Western Australia Code of Practice Safe Storage of solid ammonium nitrate – (4th edition) and* the *National Police Chief Decree No 17/2017* that has been compared to that provided below (but are not limited to):

- Warehouse buildings are to be made from non-combustible material and with adequate ventilation
- Floors shall be made of concrete
- The warehouse design must have adequate natural lighting
- Dedicated ammonium nitrate - warehouses are to only be used for ammonium nitrate (no other material allowed within the same building)
- Equipped with a lightning protection system
- The area is clear of vegetation or materials that can cause fire (at a distance of 10 m)

Table 2. Actual distance vs distance as per regulation and standard.

#	Warehouse name	Ammonium nitrate volume (kg)	Actual distance to community (m)	Distance to community according to Australia standard (m) *)	Distance to community cccording to Indonesia regulation (m) **)	Distance to Other DG Class 1 warehouse s (m)
1	W1	120,000	7,000	560	509	20
2	W2	4,000,000	2,000	1,805***)	700	120
3	W3	500,000	5,000	890	700	100
4	W4	350,000	5,000	790	647	50
5	W5	2,500,000	10,000	1,546***)	700	250
6	W6	2,000,000	6,000	1,436***)	700	700
7	W7	1,000,000	10,000	1,143***)	700	150
8	W8	500,000	10,000	890	700	30
9	W9	1,000,000	10,000	1,143***)	700	50
10	W10	550,000	4,000	938***)	700	50
11	W11	300,000	2,000	750	597	100
12	W12	260,000	20,000	750	581	20
13	W13	200,000	16,000	660	557	20
14	W14	3,000,000	600	1,642***)	700	50
15	W15	1,000,000	2,000	1,143***)	700	0
16	W16	5,000,000	2,000	1,943***)	700	0
17	W17	2,000,000	650	1,436***)	700	0

**) Distance according to Department of Mines, Industry Regulation and Safety, 2021, Safe Storage of solid ammonium nitrate – code of practice (4th edition) reissued: Department of Mines, Industry Regulation and Safety Western Australia, 35 pp*

***) Maximum Safety distance according to Indonesia Regulation, SK Dirjen ESDM No 209.K/2018 " Safety Explosives and Blasting Practice for Indonesia Mining Industry. (page 30-34)*

****) distance of warehouse over 500 ton of ammonium nitrate is calculated based on "$D = 17.8\ Q^{1/3}$ for residential buildings including hotels, motels and other accommodation. Where Q is NEQ of explosives (0.3*total AN stored)*

Table 3. Identified warehouses having potential safety issues.

#	Ware-house	Ammonium nitrate volume (kg.)	Distance to Community: Actual distance (m)	Distance to Community: Distance according to Australia Standard (m)	Distance to Community: Distance according to Indonesia Regulation (m)	Distance to other DG warehouses: Actual distance (m)	Distance to other DG warehouses: Distance according to Australia Standard (m) *)	Distance to other DG warehouses: Distance according to Indonesia Regulation (m) **)	Note
1	W14	3,000,000	600	1,642	700	50	35	21	Issue in regard distance AN warehouse to community
2	W17	2,000,000	650	1,436	700	-	-	-	Issue in regard distance AN warehouse to community

**) Maximum Safety distance according to Indonesia Regulation, SK Dirjen ESDM No 209.K/2018 " Safety Explosives and Blasting Practice for Indonesia Mining Industry. (page 30-34)*
***) Distance according to Department of Mines, Industry Regulation and Safety, 2021, Safe Storage of solid ammonium nitrate – code of practice (4th edition) reissued: Department of Mines, Industry Regulation and Safety Western Australia, 35 pp*

- No smoking, no naked flames and other activities that cause fire. Any hot work activities shall be managed according to SOP.
- There are fire extinguishers available outside the warehouse building and security post, as well as adequate fire hydrants
- There are three keys for each warehouse. The keys are kept by the Warehouse Keeper(s), Security Officer(s), and Police Officer(s) - specifically Indonesia National Police Regulation
- No electrical systems (equipment, wiring and lighting) allowed (specifically Indonesia National Police Regulation)
- There is a security post, and CCTV cameras installed in and around the warehouse - specifically Indonesia National Police Regulation - specifically Indonesia National Police Regulation
- Warehouses must have adequate telecommunications equipment (to communicate to emergency services and local authorities) - specifically Indonesia National Police Regulation
- Warehouse Keeper to be trained and certified in Managing Explosives Warehouses (by the Police Force) - specifically Indonesia National Police Regulation.

4 RESULTS

The results of the evaluation of the sample warehouses against both Indonesian Regulations and Australian Standards are presented in Table 3.

- Inadequately distanced warehouse W14 from community
- Inadequately distanced warehouse W17 from community

The next step is identification any control measures to ensure risk of being in fire situation and explosion is reduced. This means that there is a risk happen to community, especially quantities of ammonium nitrate stored in W14 & W17 are quite significant (3,000 tons and 2,000 tons, respectively), and the fact that these warehouses are relatively nearby to villages, roads, and other public facilities. At least 20,000 people live within a 10 km radius of both W14 and W17.

Apart from the distances, both W14 and W17, as well as other warehouses in Indonesia have adapted good explosives warehousing practices, because the warehouse keepers have complied with the National Police Chief Regulation (2017) and have also maintained 24-hour warehouse supervision. In the case of these warehouses, it is important to make sure that current controls (Table 4) are maintained.

Table 4. Risk assessment result, current control and further action.

Warehouse	Major Risk	Control in Place	Action
W14 – issue with safety distance to community	Small Fire knockdown to the building and storage	Supervised by security officer for 24 hours; any possible fire will be quickly identified. SOP and warehouse management are in place. Fire Emergency System in place, but bigger fires may require Local Emergency Services. DG nearby is considered a safe distance away (with safety mounding in place); the possibility of knock down effect is unlikely.	Reducing quantity of AN to reduce possibility of explosion (less than 25 % of current capacity). Review Regulatory Standards; consider 'good practice' or International Standards. Emergency drill with Local Emergency Services to be conducted on a regular basis. Regular monitoring
W17 – Issue with safety distance to community	Small Fire knockdown to the building and storage; escalated into bigger fire and explosion	Supervised by security officer for 24 hours hence any possible file will be identified in timely manner. No incompatible material stored nearby. SOP and warehouse management are in place. Fire Emergency System in place, however bigger fire requires Local Emergency Services.	Reducing quantity of AN to reduce possibility of explosion (less than 25 % of current capacity) Review. Regulatory Standards; consider 'good practice' or International Standards. Emergency drill with Local Emergency Services to be conducted on a regular basis. Regular monitoring.

The fact that all warehouse keepers are trained and certified in Managing Explosives Warehouse (by the police force) is a good start.

However, to ensure safety in both warehouses in question, it is recommended to reduce the quantity of ammonium nitrate stored, in order to meet both Indonesian and International Standards. Regulation or Standard review must also be carried out in order for reduce explosion risks and knock down effect to community.

5 CONCLUSION

There are two (2) warehouses identified as critical based on this study, due to significant amounts of ammonium nitrate stored and inadequate safety distance. Also, in this perimeter there are some schools, markets and other public facilities at risk (if there is a failure of current control systems).

There are some takeaways to consider, to avoid a similar explosion from occurring in Indonesia. They are as follows:

- Management of ammonium nitrate warehouse shall also refer to international standard as additional best practice.
- SOP to ensure safety requirement shall be in place. This covers ownership of ammonium nitrate products which are to be made clear, and owners must be held responsible for its safekeeping (including warehouse security, control, and monitoring).
- High standard regulations regarding the storage of explosives shall be maintained, it should cover consideration of the knockdown effect caused by fire or incompatible materials that are able to initiate ammonium nitrate material.
- Availability of fire emergency system and fire brigade that are able to reduce the potential of small fires and uncontrolled fires.

REFERENCES

Department of Mines, Industry Regulation and Safety, 2021, Safe storage of solid ammonium nitrate – code of practice (4th edition) reissued: *Department of Mines, Industry Regulation and Safety Western Australia, (pp 35).*

Indonesia National Police. *Peraturan Kapolri Republik Indonesia No 17 (2017*). Chief National Police *Regulation No 17/2017 regarding Permit, Security, Monitoring and Control of Commercial Explosives. (pp.65-70)*.

International Chemical Safety Card. International Labor Organization (ILO). Ammonium Nitrate Properties (ISCS:0216). *https://www.ilo.org/dyn/icsc/showcard.display?p_lang=en&p_card_id=0216&p_version=2.*

Ministry of Energy and Mineral Resources Republic Indonesia. Surat Keputusan Direktur Jendral Energi dan Sumber Daya Mineral. Mining and Energy's Decree No 209 (2018). *Explosives*

Safety and Blasting Practice for Indonesia Mining Industry. (pp. 30-34).

Seddon. B & Shiotani. H. 2020. The Beirut Port explosion: understanding its impact and how to reduce risks from explosive precursors. Geneva, Switzerland: *UNIDIR. (pp. 4-24).*

Wibowo, A. 2022. Ammonium nitrate explosion at Beirut and key leaning to improve supervision and management of explosives managerial in Indonesia. ISEE 2022.

World Bank Group (2020). Beirut rapid damage and needs assessment. Washington DC. (pp. 23).

Maastricht Conference Proceedings 2022, R. Holmberg et al
 ISBN 978-0-9550290-7-3

The effects of dynamic pressure in blasting

G. Cavanough & A. Torrance
QMR, Brisbane Australia, Kilmorie Consulting, Cooks Hill, Australia

ABSTRACT: Effective blasting requires delays between the firing of blast holes to allow movement of the burden and good fragmentation. Detonating holes will induce a pressure in adjacent undetonated holes. This dynamic pressure may be large enough to either crush the detonator and lead to a failure of the internal firing chain, either pyrotechnic or electronic, or be sufficiently high to cause detonators to fire sympathetically and initiate the explosive column at the incorrect time. Failure of the detonator will result in a misfire. The pressure may also interfere with the explosive consistency and can sufficiently desensitise the product to cause poor detonation performance, misfire and potentially a fume event. Tensile dynamic pressure events may also cause back-break. This paper presents field measurements into the potential contribution of dynamic pressure to the misfire of detonators, back-break and the generation of post blast fume.

1 BACKGROUND

Misfires are an unwanted blasting event but are still a regular occurrence in a wide range of mining and quarrying applications. They are more likely to occur in wet formations or if clay seams are present. This paper reports on field measurements of dynamic pressures in large scale blasting activities in open cut mining and quarry operations. In addition to the pressure level, the velocity of propagation of the pressure between holes is quantified. This provides a method to understand ways to limit the risk of misfire by using the appropriate inter-hole timing and primer position in the explosive column.

Post blast fume may be observed when using high density emulsion products in soft ground conditions. Generally, no fume is observed if ANFO is used in place of emulsion in this rock type, provided it is not damaged by water ingress. The propensity of higher density and VOD products to generate fume in soft ground is attributed to lack of confinement. ANFO is relatively unaffected by dynamic pressure whereas emulsion will be desensitised under pressure.

Breakage of ground occurs at much lower levels of tensile force as compared to compressive force. Hence tensile dynamic pressure can contribute to back-break.

This paper presents research into the potential contribution of dynamic pressure to the misfire of detonators, back-break and the generation of post blast fume.

2 PRODUCT 'IN HOLE' SENSITIVITY

Most emulsion explosive products use micro balloons or chemical gassing to provide sensitisation. Detonation performance and the ability of bulk emulsion explosive products to be initiated is influenced by the instantaneous density of the product. The density is in effect a measure of the sensitivity. The lower the density the more heat generated by the compressive shock wave propagating along the explosive column which in turn ensures complete and sustained detonation of the explosive column. Normal porous ammonium nitrate used in ANFO has a bulk density of around 0.75 g/cc. Higher, non-porous Prill with a density of up to 1.10 g/cc may also be used. The lower density ANFO is capable of absorbing fuel throughout the Prill and is easier to initiate than the high density Prill for which the fuel sits on the surface. The low density allows ANFO to have a high degree of sensitivity and is constant throughout the borehole.

In contrast, ammonium nitrate based emulsions that are sensitised by chemical gassing have a varying density along the length of a borehole. There is an increased hydrostatic pressure at the bottom of the long explosive columns that increases the density of the explosive in that location and can cause a decrease in the likelihood of successful detonation. A theoretical density of these products can be calculated from first principles, taking into account the density of the product, its compressibility and frictional effects on the walls of the blasthole, but this is rarely tested in the field. Compression testing in laboratories shows that the resulting emulsion is always denser, meaning a loss in gas volume within the product causing the product to desensitise.

Glass or plastic micro-balloons mechanical sensitisers may be added to emulsion in some specific examples to provide a constant density over the entire length of the explosive column. The addition of micro balloons increases the cost and also the risk of having to transport a sensitised product.

When gassed emulsions are placed under pressure, the density increases as the gas bubbles compress and eventually dissolve in the emulsion, in a similar manner to CO_2 gas in water to make soda water. When the pressure is released, the emulsions will return to the original density. Therefore, to desensitise a gassed emulsion requires the detonation to occur when the emulsion is under pressure. This is readily observed in the field when detonation cord is used to initiate emulsion products. Poor overall product performance and post blast fume is often the result due to deflagration. Deflagration occurs instead of detonation due to the much higher shock wave velocity of the detonation cord pressurising the emulsion at the time of detonation.

In the case of micro balloon sensitisation, the application of pressure can break the micro

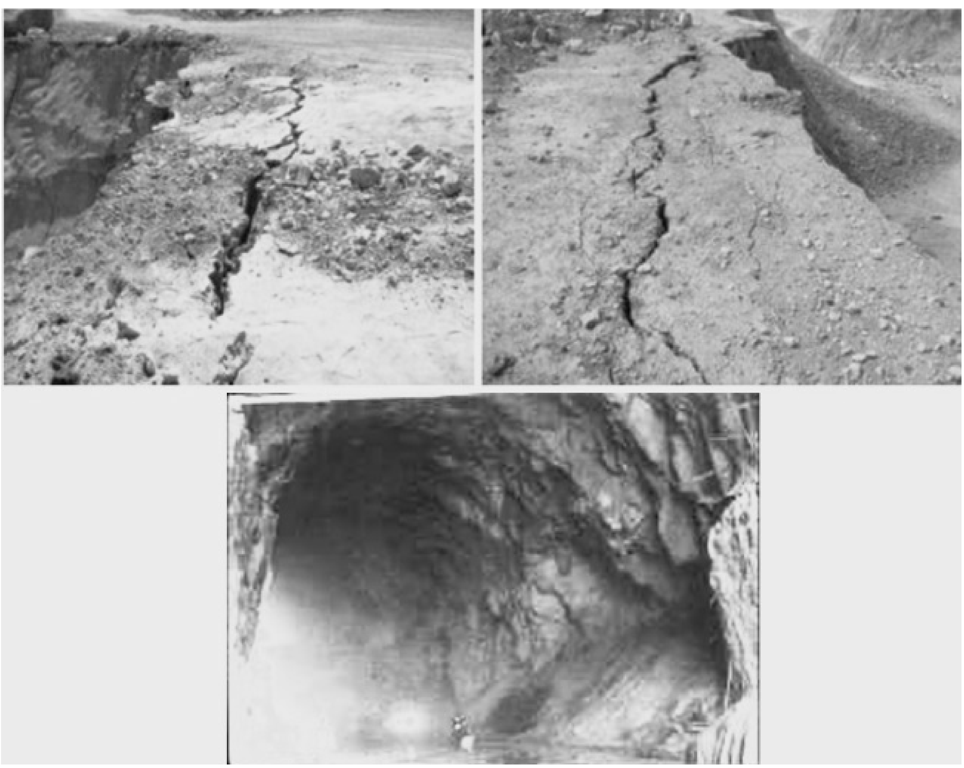

Figure 1. Examples of back break in open cut and underground mines.

balloons and desensitise the product.

3 DETONATOR FAILURE

Detonators general sympathetically detonate at high pressure (>350MPa) due to high pressure and physical deformation of the detonator shell initiating the base charge. Crushing and shrink wrapping may occur at a lower pressure (~190MPa) and prevent the detonator from firing due to damage to the internal firing chain.

4 BACK-BREAK

Back-break induced from blasting adversely affects the pit walls in open cut mining and causes dilution and instability in underground mining. Most importantly, the safety conditions of a back-broken region can be significantly compromised and it must be addressed to prevent injury to personnel and/or damage to equipment. This occasionally results in the necessity to alter mine plans to prevent an incident from occurring in a back-broken region increasing costs. Figure 1 shows examples of back-break in open cut and underground mines.

5 INSTRUMENTATION

QMR Dynamic Pressure Sensors are placed in the explosive column. This provides a true measure of the pressure level at that particular location in the explosive column. It is necessary to locate the sensor close to the detonator to measure the pressure at this critical position. Figure 2 shows a QMR Dynamic Pressure Sensor located above the primer.

Figure 2. QMR Dynamic Pressure Sensor taped to downline just above the primer.

Electrical disturbances were used to determine detonator firing times to allow calculation of the propagation velocity of the dynamic pressure, initiation of the primer and products and identification of sympathetic detonations.

6 DYNAMIC PRESSURE

Dynamic pressure is induced in a blast hole by the detonation of adjacent holes. The velocity of propagation and the peak pressure level decreases with an increase in ground hardness. Figures 3 and 4 show a schematic of dynamic pressure events measured in a large open cut iron ore mine. A hole is initiated by top and bottom primers with identical delay times. The detonation induces a dynamic pressure in an adjacent hole with a propagation velocity of 400 $msec^{-1}$. The duration of the dynamic pressure event is the same as duration of the detonation. The dynamic pressure was 100 MPa at the bottom sensor and 20 MPa at the top sensor indicating top priming is a method to reduce the risk of detonator failure due to dynamic pressure. Pressure is readily transmitted by water and clay seams with dynamic pressure levels higher in soft ground conditions.

In wet clay formations the propagation velocity can be less that 500 m sec^{-1} at pressure greater than 150 MPa.

Sustained dynamic pressure events were also measured. Figure 4 is the same data as in Figure 2 with a second event after the pressure event described in Figure 3. This event had a maximum pressure of 110Mpa and was the same level by both sensors.

Figure 5 shows dynamic pressure measurements taken in a hard rock quarry. The rock structure contained near vertical clay seams. Detonation of the holes on the bottom bench induced a sustained dynamic pressure in the top bench. Propagation velocity was calculated from the start time of the events at 350 $msec^{-1}$.

Figure 6 is a dynamic pressure event at a large open cut coal mine. The product used plastic micro-balloons for sensitisation. The detonation of the adjacent holes induces a typical dynamic pressure pulse with a 55 MPa maximum pressure at the sensor. There was no detonation pressure signal from the sensor indicating the product did not initiate. Analysis of the associated data confirmed the bottom primer detonated but failed

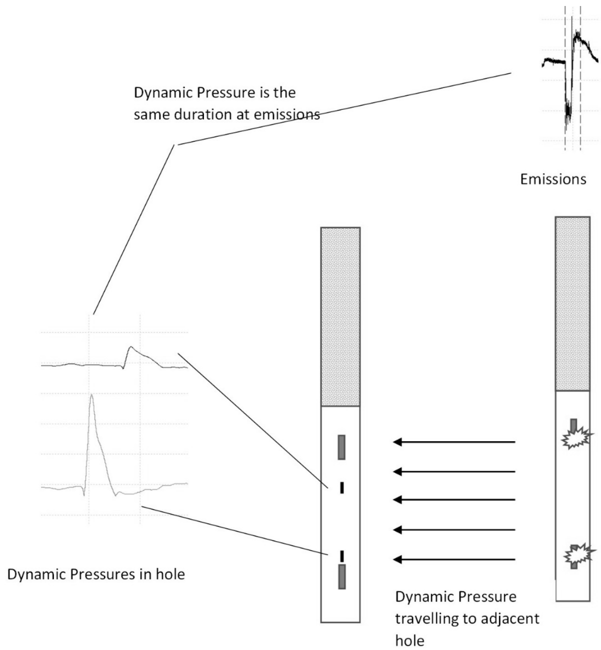

Figure 3. Typical dynamic pressure induced by detonation of adjacent hole. Note, pressure is lower at the top of the explosive column (i.e. 100 MPa at bottom and 20 MPa at top).

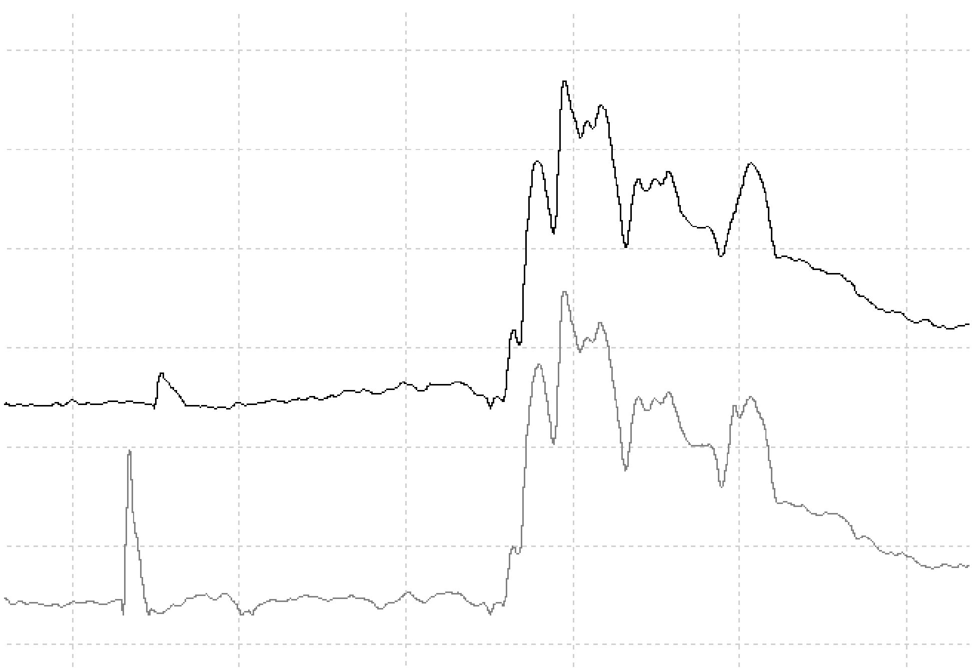

Figure 4. The short duration event as per Figure 2 were followed by a longer duration event that was the same pressure (maximum 110 MPa) at both top and bottom sensors.

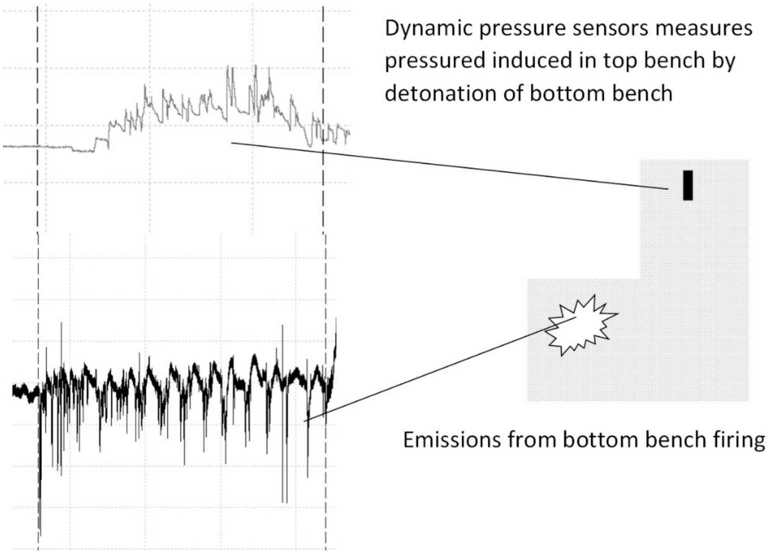

Figure 5. Detonation of middle section and resulting dynamic pressure experienced at top section with identical time slices.

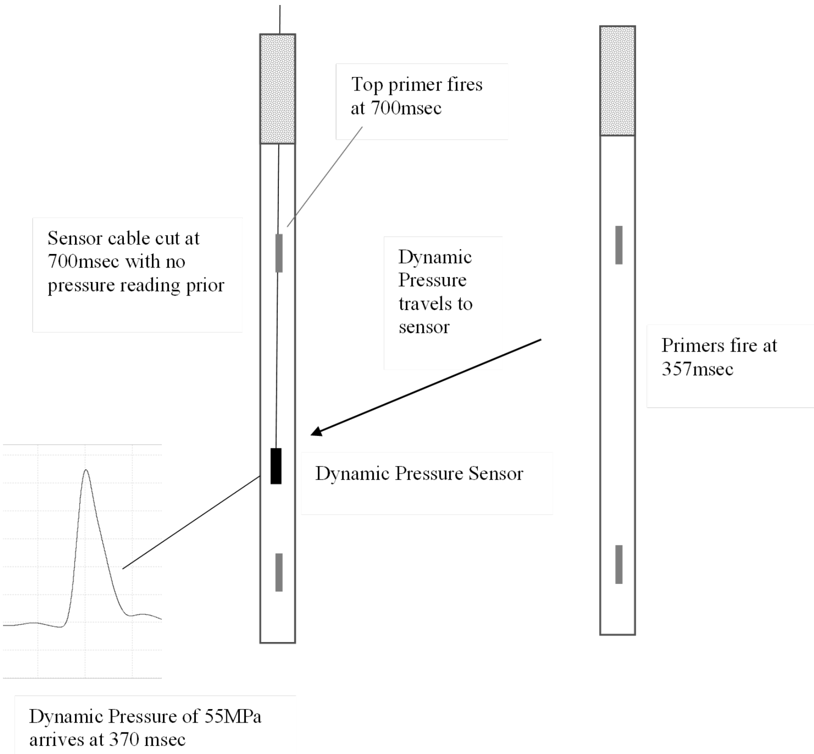

Figure 6. Dynamic pressure caused desensitisation of the product in the toe of the hole resulting in only top primer initiating the explosive column and creating a significant fume event.

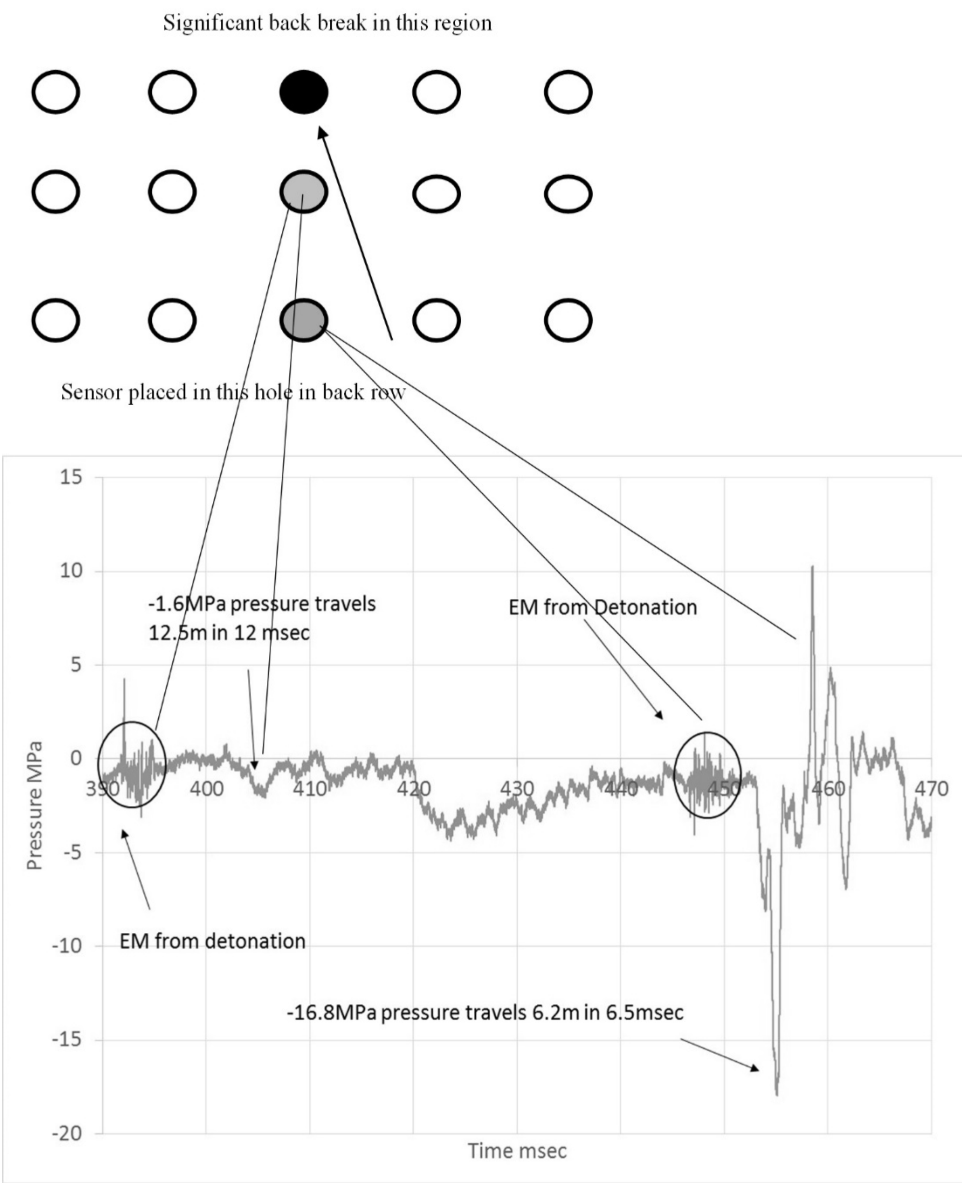

Figure 7. Electrical disturbance and dynamic pressures measured in the back row hole of ground with significant back-break.

to initiate the explosive column. The dynamic sensor cable was cut at the precise delay time of the top primer which confirmed that the top primer initiated the explosive column. This blast resulted in significant post blast fume. It is likely the dynamic pressure crushed the micro-balloons preventing initiation of the explosive column by the bottom primer and deflagration induced by detonation of the top of the explosive column.

Figure 7 is a dynamic pressure event at a large open cut coal mine in a hole in the backrow of a blast that resulted in significant back-break. The firing times of adjacent holes was identified and allowed calculation of the propagation velocity of the dynamic pressure as approximately 950 $msec^{-1}$. The dynamic pressure has a tensile pressure of 16.8 MPa which is sufficient to break ground of hardness of up to 100 MPa compressional strength and hence is the likely cause of the back-break.

7 CONCLUSION

Dynamic pressure is induced in a blast hole by the detonation of earlier fired holes. The velocity of propagation and the peak pressure level decrease with an increase in ground hardness. Pressure is readily transmitted by water and clay seams with key features of the pressure pulse being:

- The pulses are the same duration as the duration of detonation of the hole that is creating the pressure
- Is at higher pressure at the bottom of the explosive column
- Arrival time at the top of the explosive column is later than at the bottom detonation of the explosive column.

Large ground movement can result in long duration events that are the same pressure level over the entire explosive column.

Dynamic pressure can result in sympathetic detonation, misfire, back-break and fume events and should be measured and used to develop delay timing of blast patterns to prevent these events.

REFERENCES

Cavanough, G., Onederra, I. & Torrance, A. 2011. In situ measurement of detonation pressure and temperature of commercial explosives. *European Federation of Explosive Engineers Lisbon Conference* 2011, 19-20 September 2011, pp 391-400.

Torrance, A., Cavanough, G.L., Lusk, B. & Seo, M. 2019. Large scale measurement of velocity of detonation. *International Society of Explosives Engineers 45th Conference*, January 27-30, 2019, Nashville USA.