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An analysis of some explosive related accidents

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ABSTRACT: It is imperative that handling and use of commercial explosives achieves the highest possible standard and performance in occupational health and safety. This is essentially for the benefit of those working in the industry dealing with explosives, but also to ensure its sustained viability, as the community at large enjoys significant economic support from employment scopes. Safe and healthy working environments and correspondingly low occurrence of accidents can be accomplished in any operational unit. The success of this depends on all persons involved being committed to achieving this target through consultation, cooperation, recognition of accountability, and integrating safety with production. It is imperative that there is a clear, demonstrable and unambiguous commitment and instruction from the chief of the operational unit, which is grasped by every employee. The mechanisms by which that commitment is communicated, and by which feedback is given, are vital components in achieving high levels of performance and satisfaction. A few case studies, pertinent to the points mentioned above, is cited and discussed in this paper.

1 INTRODUCTION

There is a need for an entrenched Safety Culture where all accidents irrespective of how small or insignificant are reported without fear or hesitation, and all incidents are thoroughly investigated, controlled and analysed. Control measures have to be implemented and monitored to ensure that they are successful and are not creating additional hazards.

The thrust of this paper is to highlight the importance of discussing the total circumstances that have caused some problems. The following case studies, pertinent to the points mentioned above, will be cited and discussed in this paper. However, the authors stress that they are not challenging the investigations or findings, nor criticising the companies concerned, but are emphasising the importance of sound Occupational Health and Safety Programmes (Integrated Management Systems, incorporating Safety, Occupational Health, Environment, Security, Quality and Production) in preventing accidental loss of production.

- The Porgera Mine Explosion, PNG. 2nd. August 1994.
- The Royal Canberra Hospital Implosion, ACT. 13th. July 1997.
- Shotfirer's Utility Vehicle Explosion; Hunter Valley, NSW, 6th. February 2003
- Major Fly-Rock Incident, S.E Qld. 3rd.September 2004.

2 PORGERA MINE EXPLOSION

2.1 Incident description

On 2nd. August 1994, Dyno Wesfarmers Limited (DWL), Papua New Guinea (PNG), explosive manufacturing facility at the Porgera Gold Mine was totally destroyed by two explosions, with the loss of eleven lives. Extensive damage was done to nearby mine facilities and numerous mine employees suffered other injuries. Two out of thirteen DWL employees survived the first explosion because they were working inside storage containers at the time (Anon. 1996a; Anon. 2004).

The mine is situated at an altitude 7700ft. in a remote and rugged part of the Enga Province of PNG, which produced 35,977 kg of gold from both open-cut and underground mining operations in 1993. The explosive facility consisted of the following plant and equipment: cap–sensitive manufacturing and packaging; non-electric detonators (Nonel) assembly and testing; ANFO and ANFOPs manufacturing; Bulk Emulsion manufacturing with delivery by a Triple T (TTT) bulk truck. Main storage facilities were suitable for: 40 Containers of Ammonium Nitrate/ Sodium Nitrate; 20,000 l oxidising solution; 25,000 l fuel phase; 85,000 l of un-sensitised bulk emulsion in two tanks (some government agencies now class this substance as an explosive product of other than Class 1); and up to 10,000 l of fuel oil stored approximately 18 m from the fore-mentioned product storage tanks. All finished explosive products, including Nonel detonators and elemented caps, were stored in underground magazines.

The first explosion occurred at about 09:45hrs on 2nd August 1994, at which time the following operations were taking place: manufacturing of ANFO, packaging of S.D. Emulite 100 (cap-sensitive) explosives, loading Ammonium Nitrate into the Bulk Explosives truck, and assembling of non-electric detonators.

Approximately 4,300 kg of explosives consisting of 120 x 25 kg bags of ANFO on the 4x4 canter truck, 25-30 kg ANFO in the Coxon Mixer, 1250 kg of cap-sensitive explosives in the Emulite 100 explosives production line and hopper, plus a small quantity of Emulite 100 explosives chubs 30x400mm in the cooling tray (Anon 1996a; Anon 2004).

All fatalities are believed to have occurred in this first explosion, which destroyed the manufacturing plant, office and main plant shed. Fires on the bulk truck, around and underneath the bulk emulsion and process oil tanks subsequently led to the second explosion, just after 11:00 hrs. This explosion involved approximately 70-75t of emulsion matrix and between 10-15 t of emulsion and ammonium nitrate in the bulk truck. This explosion may have started a very intense fire in the Nonel detonator assembly plant, which had been partially knocked over by the first explosion. Mine rescue personnel had reported hearing popping sounds when they entered the site after the first explosion, which might have come from the Nonel detonator assembly containers, indicating that the fire was started by the first explosion (Anon 1996a; Anon 2004).

Members of the Porgera Mine Rescue team entered the plant shortly after the first explosion, but found no survivors. Because of the intensity of the fires on the explosives truck and in the bulk emulsion bunds, and the popping noises it was decided to evacuate nearby mine personnel and set up a security/exclusion zone. Mine Management implemented a controlled shutdown of all mining and process operations (Anon 1996a; Anon. 2004).

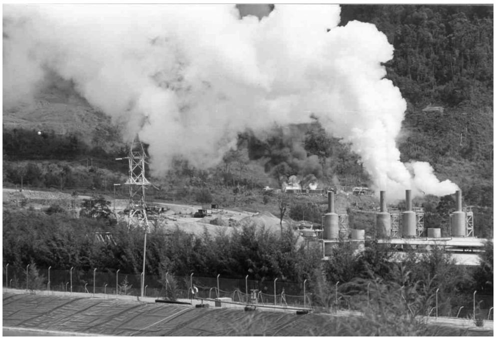

Figure 1. Fires burning shortly before the 2nd.explosion.

2.2 Investigation

The Deputy Chief Inspector of Mines (DCIM) headed the official investigation, with assistance from Mine Management and DWL. PNG Police assisted with the recovery and identification of bodies as well as initial security control. The Department of Mines Investigation and DWL investigation was primarily tasked with finding the cause and origin of the first explosion occurred.

The DWL investigation team initially consisted of Australian-based staff, but was soon joined by experts from Scandinavia and North America. Two months into the Investigation a forensic specialist from the Australian Government Analytical Laboratory, to confirm or dispute the team's findings, joined the team. In turn for verification purposes assistance was also sought from the UK's Health & Safety Executives' Analytical Lab (Anon 1996a; Anon 2004).

Although the incident occurred on 2nd August the formal onsite investigation did not commence until 4th August when the DCIM arrived at the mine and all bar one small fire had burnt out. Until then reconnaissance had been carried out from the air and from the haul truck tray lay-down yard, which was situated on higher ground to the South. From both vantage points the Investigation team was able to determine where the fires were and what most probably was burning. The last fire burning was in the Nonel detonator tube store. The investigation team's initial task was to clear a safe track for the fire engine, to enable the fire crew to extinguish the Nonel detonator tube store fire and recover unexploded detonators and human remains.

With all fires extinguished, the Investigation team, assisted by Porgera Joint Venture Mine Rescue personnel, was able to recover unexploded detonators as well as unexploded Emulite 100 explosives and emulsion matrix, which were scattered far and wide across the whole site. Unexploded and suspect detonators were placed in buckets containing light hydraulic oil. Simultaneously the PNG Police and other team members searched and recovered deceased employees. During this period the DCIM interviewed mining staff and DWL employees.

Once all visible detonators and explosives had been recovered and the site declared safe, identification and recovery of plant and equipment commenced under the supervision of DCIM. The approximate boundary of the production slab was pegged out. Before being moved, each item was photographed, numbered, tagged and pegged to enable it to be plotted onto a site plan by the PJV Surveyors. This was very important and painstaking work, as it was used to determine Trajectory evidence. However, it had to be viewed in the context of two separate explosions, the second being considerably larger, with smaller/ lighter pieces of equipment being moved in the second explosion (Anon 1996a; Anon 2004).

The area searched covered a radius of 500 m around the site. All key pieces of equipment recovered (< 300 items) were taken down to the lay-down area (an old tennis court), where they were examined closely for telltale signs of explosive shock wave and shrapnel marks, after which they were placed in their original position. A front end loader was used to speed up the search and recovery process and clear the site, using 250-450 cm slices. Although members of the investigation team closely monitored this operation, it is highly probable that some key components were not recovered. A spare-parts container was totally destroyed and its contents scattered across the site, which made the process of identification very difficult and taxing.

The large crater caused by the second explosion was divided into segments and carefully searched before being filled in. The mine returned to normal operations after a memorial service on the 13/08. Gold production was suspended for four days.

The first explosion left a crater 7 × 5 × 2 m, in the vicinity where the Canter truck had been parked. The second crater was considerably larger, approximately 40 m in diameter and 15 m deep in the area where the bulk emulsion tanks had been located (Anon 1996a; Anon 2004).

Figure 2. The 'Large Hole', left by the second explosion.

2.3 *Key findings*

The first explosion occurred in the Emulite 100 explosives packaging line, specifically within the Mono pump. This was determined after extensive analysis of internal pump components, which was found in the subsequent search and recovery operation. It is believed from extensive analytical studies that the initiation point for the first explosion took place inside the rotor boss-head cavity, where the Emulite 100 explosives compound had managed to leach pass O-rings and a possibly missing packing gland over a period of time.

The exact mechanism of the initiation point is not known, but it is thought that microscopic cracks, flexing of components, heat, and perhaps back pressure were sufficient to create the right conditions to initiate the explosive compound in the cavity. Emulite 100 explosives exhibit strong exothermic reaction above 230°C (Anon 1996a; Anon 2004).

Note: Since this major incident the pump manufacturer and industry has conducted exhaustive studies to replicate exactly the damage caused to the progressive cavity pump during the first explosion and verify/challenge the scientific findings. Subsequently there are differing schools of thought as to the initiation point for the first explosion.

2.4 Recommendations

These suggestions for improvement are taken in part from the Investigation reports of Dyno Wesfarmers Limited and the PNG Department of Mining and Petroleum, and are also based on the experience of the authors.

2.4.1 Engineering design and management skill

Companies involved in High Risk Industries should without hesitation ensure that adequate engineering controls are implemented from the initial concept through to the post commissioning/final inspection stage before signing the plant/facility over to operations. Legislation, National and Industry Standards should be consulted and included from the preliminary design stage by Engineers so that crucial items such as 'Table of Distances' for manufacturing and storage can be taken into consideration and addressed by management, if required.

Engineering reviews, Hazard And Operability Study (HAZOPS), What If Analysis, etc., should be part of this process, including the provision of safe operating procedures, spare parts list as well as acceptable maintenance schedules. Standard Operating Procedures (SOP) should be simple/easy to follow, should cover all steps of the task in a logical sequence, and use photographs employed to identify key levers or parts.

Note: the use of photographs in SOPs, particularly in third world countries, is strongly recommended.

Critical controls for temperature, flow, pressure, etc., should be tamper-proof, with keys held by senior maintenance or operations supervisor. An enforced, documented and well understood Change Management program is essential to prevent deviations creeping into operating procedures or maintenance programmes.

2.4.2 Employee training

Establishing an in-depth training programme covering all levels of an organization pays dividends not only in safety but also in quality, production and maintenance. An analysis of training needs is essential to ensure that all tasks and positions, including management, are adequately covered. Competency-based training and assessment should start immediately for those employees who are operating or servicing critical equipment.

2.4.3 Leadership and administration

Sound leadership and well-established administrative support is essential today for any business to survive. Not just for head office, it should be available for sites, projects and factories. The plant manager requires a good understanding of Safety, Quality, Human Resources and Environment, and also requires production, managerial and accounting skills.

2.4.4 Risk management, Critical Task Analysis and task observation

Companies involved in high risk industries such as Mining, Quarrying and Explosive Manufacturing should have sound risk management programmes in place covering both manual work site as well as corporate (major) risks to the organization and/or site. A well-documented risk register should be developed shortly after the establishment of a site. Adequate controls should then be developed and regular reviews implemented.

Should the explosives facility be on a Mining Lease or Government Reserve, these organizations have a responsibility to ensure that the explosives company and/or supplier has identified all potential hazards and risks, and conducts their operations in a safe manner.

Task Analysis should be conducted on all operations to identify those tasks that are 'CRITICAL'. Developed SOPs should be reviewed as part of this process and for those tasks, which are found to be critical, but do not have SOPs, priority should be given to develop them. Companies with High Risk Operations should practice Critical Task Observation to ensure operators are not deviating from the SOP (Anon 1994).

2.4.5 Planned inspections and maintenance

A rigorous, well-documented maintenance programme should be in place from day one of the contract, project or manufacturing plant. All items of plant and equipment should be included, with particular attention given to critical pieces of equipment such as pumps. This work should be done by competent personnel, using genuine parts in a well maintained and equipped workshop. Maintenance personnel should also be trained to recognize components where the wear and tare of components has been caused by operator abuse.

A planned inspection program covering critical plant and equipment, parts and items, and general and housekeeping inspections, with a documented reporting and follow-up system, are also crucial in controlling and minimizing accidental loss. Personnel conducting these inspections should receive appropriate training.

Incident investigations should be conducted when maintenance personnel report any abnormal wear and tear or abuse of critical pieces of plant and equipment. Examples are pumps, brakes, clutches, and lock-out devices.

2.4.6 Emergency preparedness

Reviews of Emergency Response plans should be conducted after the completion of 'on-site' Risk Register and Assessment to ensure that the site has the correct type of automated emergency equipment and that it is located correctly. Personnel must know how to respond in an emergency, and drills need to be conducted with Emergency Services personnel who are familiar with the site and what hazards are faced in the event of fire.

2.4.7 Incident investigation

A culture of understanding without blame has to be established to help ensure that all unsafe acts and conditions, including all incidents no matter how small or trivial, are reported and thoroughly investigated. The degree or level of investigation should depend on the possible outcome of a similar event if not controlled or there is an increase in energy.

Supervisors should feel comfortable in calling on more experienced colleagues to assist with investigations, but most importantly, all investigations should be done systematically to enable all basic causes to be established, as should failures in the management systems that led to the breakdown. It is crucial that staff receive suitable incident investigation training and that companies ensure that adequate tools/ systems are available, such as ICAM or SCAT (Anon 2000, Anon 1994).

Structured photography combined with a clearly marked grid pattern for search and recovery operations and measurement data analysis are the essential ingredients of a thorough investigation.

2.4.8 Communications and culture

Effective communications in any organisation play a critical part in preventing and reducing accidental loss. These include clear concise messages, easy to follow procedures and work instructions. Signs and instructions should be in different languages, if required. The above are all frequently forgotten or not considered with respect to effective Safety Management.

Cultural sensitivities should be considered for all companies that operate in other countries or employ groups of migrant workers or indigenous people. A frequent issue when working in Asia or Africa is that people there do not want to lose face, particularly in front of persons from another tribe or village. Then an indirect approach is more effective.

3 CANBERRA ACCIDENT (BIRD, F.E. & GERMAIN, G.L. 1992)

3.1 The event

A young girl was hit by a flying projectile and died instantly while watching the demolition by implosion of hospital buildings in Canberra on 13th July 1997. She was standing approximately 430 m away from the explosion site, and there was a crowd of between 30-40,000 people in that area. Her death was caused by a fragment of steel expelled from one of the corner columns of the building. This lethal fragment, which weighed nearly 1 kg, struck the girl's head. This impact caused the girl's scalp and skullcap to sever from her head.

It is estimated that the impact velocity of the steel fragment was 128 –130 m-s with an associated energy of 8.172 kJ. Subsequent evidence showed that the lethal fragment was mild steel, and was part of the webbed portion of a steel column.

A piece of fractured steel fragment from another backing plate was found embedded in the grounds of a house about 400 m from the hospital building. The plate was warm to the touch. Other metal debris was also recovered from the blast. The fragmentation pattern on the steel and the surrounding piece showed the same qualitative characteristics that generally occur when steel is intimately exposed to a sudden explosive impact.

3.2 Background

The hospital buildings to be demolished were located in Acton Peninsula within Lake Burley Griffin, and belonged to the Federal government. After the demolition the land was to come under the jurisdiction of the Australian Capital Territory,