Angellala Creek Ammonium Nitrate Incident – 10 years on

By Geoffery Downs, Expert Panel

It has now been ten years since the Angellala Creek ammonium nitrate incident at Bakers Bend near Charleville in Queensland, Australia. At the time of the incident, I was the chief inspector of explosives in Queensland and shortly afterwards vacated that position and had no further role in the investigation. I visited the scene shortly after the incident and observed and photographed many things firsthand. There have been a number of presentations and discussion on the Angellala Creek AN explosion and many may consider there may have been enough discussion on the event. However, in the light of this significant time frame and my direct observation of the scene which can provide additional detail, I feel that I have additional contributions and learnings from this event in addition those made so far.

Background

For the information of the reader and as a background information only to this article as a given, the following information is a summary that has been provided by the Regulator about the incident –

- Date – September 5, 2014
- Type 1 road train consisting of prime mover and two trailers connected by a converter dolly carrying 52.8 tonne of ammonium nitrate in woven polypropylene intermediate bulk containers with 26.4 tonne in the forward trailer and 26.4 tonne in the rear trailer
- Driver was approx. 13 hours into trip at time of incident; 30 minutes from rest stop for the night
- Driver departed Charleville approximately 20 minutes earlier when the vehicle heading south leaves highway at Angellala Creek. The time was approximately 20:54 hours. Exact time fire started unknown, likely result of crash
- No phone signal at site; 30 minutes to contact emergency services
- First fire truck arrives at 22:03
- Second fire truck arrives 22:10
- Police car arrives 22:10
- Fire burned for about 1 hour 20 minutes before explosions at 22:10 and 22:12
- Two explosions about 1-2 minutes apart
- Explosion measured 2.1 on Richter Scale at the site
- Estimated to be equivalent to 10 to 15 t TNT
- Approximately 2500 pieces of shrapnel collected up to 1000m radius
- Burnt out prime mover and rear trailer largely intact
- The cause of the first and second explosion could not be determined
- A number of findings, conclusions and recommendations were made by the Regulator. These are attached as an annex to this article again for the sake of completeness and information

purposes only to provide a shared understanding from the investigation for those who are not familiar with this information.

Note: In Australia, we call the heavy-duty towing engine that provides motive power for hauling a towed or trailered load a Prime Mover. In other places it is called a Tractor. Hence where you read prime mover, you may wish to substitute tractor.

My information and observations

I wish to highlight and discuss a number of things about the incident. Generally, information provided is global in nature and the finer details are passed over and not identified. These points I am identifying are -

- Information provided directly to me
- The initial incident
- The explosion
- Fire engine and driver first aid treatment
- The diesel fuel
- Angellala Creek Bridge today
- Conclusion

Information provided directly to me

The driver had taken a rest break at Charleville where he showered, ate a meal and refuelled the prime mover and was close to his designated overnight stop.

Anecdotal evidence suggested that there had previously been several incidents at the Angellala Creek bridge. There were rumours that there was a slight kink in the road at the bridge in an otherwise very straight section of road.

The Charleville Police confirmed that they knew that the load was ammonium nitrate. They advised that the local farmer who reported the accident to them was dangerous goods trained and reported that the load was ammonium nitrate.

During a private discussion with the Fire Commissioner, I was advised that they would look at why their systems failed.

The initial incident

The vehicle was heading south along a straight section the Mitchell Highway. Picture 1 below shows the approach to the bridge at Angellala Creek in the direction of travel taken at an unknown time before the incident. In Australia, vehicles travel on the left-hand side of the road and hence the vehicle was travelling on the left-hand side of the road in the direction of travel and the focus should be on the left-hand side of the bridge.

The vehicle leaves the left-hand side of the road and proceeds towards the creek between the trees on the left-hand side, shown by the red arrow in Picture 1, and the railings of the bridge on the right hand side, shown by the yellow arrow in Picture 1. The vehicle continues through the Armco guard rail and into the dry creek bed. The prime mover and trailers jack knifed into the creek bed. There was a fire with explosions following. The Armco guard railing can be seen in Picture 1 before the incident. The guard rail was destroyed by the vehicle passing through it with the remains shown in Picture 2.

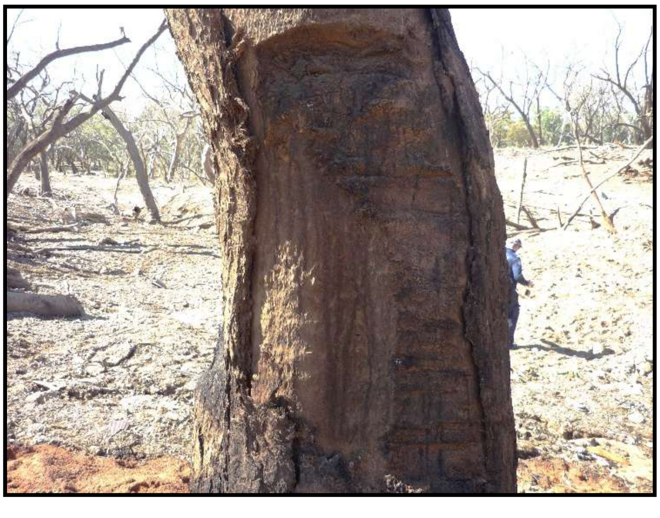
The point of entry between the trees and the bridge from roughly the same position as Picture 1 is shown in Picture 2 after the explosions. The two trees in Picture 1 are barely recognisable.

The tree identified in Picture 1 was sideswiped by the left-hand side of the trailers when passing through. The scar left on the tree from the prime mover and trailers passing through are shown in Pictures 3 and 4. The height of the scar is consistent with the vehicle height. Ammonium nitrate prill was found at the base of that tree.

As seen in Pictures 5 and 6, the right-hand side of the vehicle appears to have mounted the left hand edge of the bridge and destroying the supports for the railings from the parapets as it proceeded. The concrete parapets show black marks resembling rubber from the tyres. If this was the situation, the vehicle would have the right-hand side much higher than the left hand side and the rig would be rotating anticlockwise. Note how the brackets for the bridge rail are bent in the opposite direction to the blast and the rail is gone.

Picture 1 – Angellala Creek Bridge prior to incident

Picture 2 - Angellala Creek Bridge after the blast looking south



Picture 3 – Scar on tree next to bridge

Picture 4 – Close up of scar on tree

Picture 5 - Parapets show black marks and the bent rail brackets

Picture 6 – Parapet with black marks and bent supports

The Explosion

Two explosions were reported. The crater from the second explosion is presented in Pictures 7, 8 and 9. At the time of the incident, the creek and the countryside were very dry as seen in Pictures 7 and 8. A few days after the incident, it rained with lots of water in the creek. Picture 9 shows the crater full of water and that is the reason why water is seen in the creek, post incident, in many photos.

The wheels of the rear trailer can be seen in Picture 10 through the rubble under the bridge. There was a quantity of unconsumed ammonium nitrate adjacent to the wheels under the rubble. The wheels can be seen in the top left corner of the picture with an arrow pointing to its location.

Picture 11 shows the general impact on the vegetation in the close vicinity. The remains of the prime mover are seen more clearly in Pictures 12 and 13. The remains are highlighted with a red circle in Picture 12. The blast projected the prime mover up onto the top of the embankment.

The area was littered with all types of debris. An example of the debris is shown in Picture 14. Aerial photos of the scene are also shown in Pictures 15 and 16.

Picture 7 -Crater from north side of creek

Picture 8 – Crater from south side of creek

Picture – 9 – Crater from south side of creek after rain

Picture 10 - Trailer wheels

Picture 11 -

Picture 12 – Prime Mover after being projected to top of creek bank

Picture 13 – Prime Mover on edge of creek

Picture 14 – Debris around blast site

Picture 15 – Aerial photo of incident scene looking towards the east

Picture 16 – Aerial photo of incident scene looking towards the west

Fire engine and driver first aid treatment

Everybody is amazed at the damage to the fire engine from the blast. However, there is more about this I wish to draw your attention to. In the foreground in Picture 17, there is a blanket and an orange safety shirt on the ground. The injured driver was receiving first aid treatment where the blanket is located. At the time of the explosion, all responders were attending to the injured driver and were crouching on the ground beyond the edge of the creek in the vicinity of the blanket. The blanket can also be seen in Pictures 2, 11 and 14. These pictures give more perspective, dimension and angles to the creek bed, banks and the edge of the creek to identify their location.

We can see the damage to the fire engine in Pictures 17, 18 and 19. The interesting observation is that damage to the fire engine has occurred above a certain height which is approximately at the height of the wheels. The tyres were not punctured and there is little evidence of damage under that height. This area below the dividing line starting at the edge of the creek was in the shadow of the blast wave.

The depth of the creek bed and the angle of the creek bank together with their location at the edge of the creek provided the shadow of the blast wave and the degree of protection of the people and parts of the fire engine in the shadow. Pictures 8, 9, 21 and 22 give an idea of the angle of the banks of the creek. In Pictures 21 and 22, people are standing in the approximate location of where the driver was being treated. Anyone standing in that spot would have been directly exposed to the blast. Examination of Pictures 8, 9 and 21 also shows the approximate exposure of the fire engine to a blast wave and low angle debris.

Picture 17 – Site of first aid treatment for injured driver

Picture 18 – Frontal view of damage to fire engine from blast

Picture 19 – Rear view of damage to fire engine from blast

Picture 20 – Looking towards fire engine and first aid area from creek bed

Picture 21 – Different location looking towards fire engine and first aid area from creek bed

<u>The diesel fuel</u>

The vehicle was refuelled at Charleville. The long-range fuel tanks were virtually full of diesel fuel when the vehicle incident happened. That was a lot of fuel to spill in the bottom of a creek bed. Being fully aware of the research work of Bauer, I have always wondered whether there was a contribution from the diesel fuel to the explosion and what that may have been. There was a large quantity rupturing of the fuel tank(s) during the incident. The prime mover and trailers were in the creek bed. The crankcase oil from the engine block was also spilt after passing through the Armco railing.

The creek bed was dry at the time of the incident. The surface of the creek bed was sandy. Surface sand is shown in Picture 23 in the creek bed adjacent to the crater. Underneath the sand was clay as seen in Pictures 7 and 8 for the crater. It is also normal to expect significant amounts of dry and decaying vegetation from the trees, branches, twigs, leaves, grasses etc in the creek bed in addition to any other unknown significant features. We also know that reactive clay soils when dry can be porous due to cracks from the dry conditions. This is a hot and dry area.

The potential for dry and cracking clay soil reminded me of an incident back in about 1978 that I investigated at then Munitions Filling Factory at St Marys in Sydney, Australia. We operated the burning ground for destroying explosives, pyrotechnics, propellants and other materials and compositions. We had a contract to destroy the waste products for a local spectacles manufacturer. The process was to burn the waste materials which included solid frames and solutions. The products were burnt in an open-air bunker with an earth floor. On one occasion, there was an explosion during the burn. I recall that the crater was approximately 30cm to 50cm deep. This happened I believe about 15 – 30 minutes after the start of the burn.

I was appointed as the investigation officer to identify the nature and cause of the explosion. The process included placing a pile of timber in the pit and the solid and liquid products for destruction were poured and placed over the timber. The waste cellulose nitrate products were allowed to soak for a while before ignition. The remaining ground in the bunker was dry. The clay floor had cracks as you see when clay has dried. It expands when wet and contracts when dry, just like we see certain cast explosive compositions I have worked with when cooling and solidifying. The finding of the investigation was that the liquids had and soaked and penetrated the ground due to the porosity of the ground. The sources of heat from the burn eventually penetrated to the liquids below the surface resulting in ignition and initiation of a runaway reaction.

I also thought about other events where there are massive events caused during a pool fire. We learnt about tank fires during our chemical response training for the support of emergency services during chemical emergencies. There are well documented events we learnt about during fires at fuel storage depots and in particular with floating top tanks. A fire can start between the wall of the tank and the floating lid. When the tank is engulfed in the fire the lid and any sludge are very hot due to the fire and can sink to the bottom of the tank. They are naturally very hot from the fire and subsequently boil the flammable or combustible liquids during their descent and at the bottom of the tank. The heat transfer boils the liquid which then forms a vapour cloud above the tank which results in ignition of the vapour cloud and a massive fireball.

Have any of these contributed to the possible mechanisms to create a vapour cloud ignition in the presence of an already sensitised ammonium nitrate? The potential for a pool fire is understood. However, were there sources enabling a vapour cloud ignition? There were numerous sources present including molten metal, charcoal from burning timber, pressure bursts and heat transfer from prolonged heating.

Picture 22 – Sandy creek bed adjacent to crater

Angellala Creek Bridge today

To complete the story, the site is seen in Pictures 24, 25 and 26 heading south, heading north and from overhead courtesy of Google Earth. The new bridge has been called Heroes Bridge. The railway bridge has been removed leaving the piers as a reminder. There is a pull off area suitable for caravans, motorhome and camper trailers to the south of the new Heroes Bridge. This area is shown in Picture 26 and is the dedicated and fitting tribute called the Angellala Bridge Monument.

The remains of the tree identified at the beginning of this paper is standing alone. The other interesting point is when looking at the overhead of the highway using Google Earth, I used a ruler to see if the road was gun barrel straight heading south. I observed that there was a slight kink in the road at the bridge, not quite 180^0.

Picture 23 – Heroes Bridge at Angellala Creek heading south

Picture 24 – Heroes Bridge at Angellala Creek heading north

Picture 25 – Overhead of Angellala Creek Bridge and monument site

Concluding Comments

My aim was to provide a shared understanding of certain aspects of the Angellala Creek incident through certain captured information which I considered was important to better understand the anatomy of the incident. You may review the information and use your own informed judgement and opinions.

Without the photos, this article would not have been possible to explain or give a clear shared understanding. As an investigator, it is critical to take as many photos as you can in the early stages of an investigation. Photos are one key element of evidence. The photos can be reviewed and reviewed when trying to identify nature and cause of an incident. Sometimes it may take hours to review photos and videos to understand the situation. It is virtually impossible to take in all the information on first visit to the scene and to retain that memory photographically and by note taking. It is also important to take photos from all angles to eliminate the parallax errors and to get the full perspective. These are some of the skills of a good investigator. This is the skill where the evidence will speak for itself to support the findings, conclusions and recommendations rather than in some investigations where I have been exposed where the investigator tries to prove or justify their own theory with the information at hand. This fits in with the old saying that you can only make a first impression once. There are quite a few investigations where I have regretted not getting more photos from different angles and positions to make identification for the task outcomes easier. All possible scenarios have to be considered and inputs from multi-disciplinary have many benefits.

When I worked in the dangerous Goods transport area of the Department of Transport in Queensland in the time frame of 1985 to 1989, the emergency services and in particular the fire services which were staffed by volunteer and auxiliary firefighters were briefed along the transport routes regarding ammonium nitrate and emergency response. This general practice ceased for ammonium nitrate even though it was in place for sodium cyanide and other cyanides transportation routes.

I estimated the overpressure in the open and not in the shadow for location of the first aid treatment area adjacent to the fire engine being approximately 50 metres from the blast site. Using IMESAFR and the reported blast being equivalent to between 10 tonnes and 15 tonnes of TNT, the estimated overpressure in the open at that point would have been in the order of between 200 kPa to 275 kPa.

I was privileged to have the work of Bauer's research material shared with me regarding ammonium nitrate by the late Spencer Watson during the 2013 Chief Inspectors Conference in Spain.

Annex

This annex is provided for information purposes, educational and reference purposes only for completeness regarding the investigation by the Regulator for the benefit of those who are not familiar with this information.

Findings

- The ammonium nitrate was within specification and classified as UN1942
- The vehicle involved in the accident was mechanically sound and regularly maintained
- The vehicle contained a large amount of combustible material
- The crash led to a spill of fuel across the site
- Some ammonium nitrate was contaminated with diesel fuel and metals
- An arc event has occurred on the starter motor circuit

Conclusions

- The cause of fire could not be determined.
- Based on analysis the following probable scenarios are proposed:
  - Spilt fuel from the crash contacted hot engine exhaust and ignited
  - Electrical arc from crash and leaking fuel
- The cause of the first explosion could not be determined.
- The analysis of evidence gave the following possible scenarios:
  - A pressurised piece of equipment (e.g. tyre or air tank) has ruptured from the fire
  - A thermal explosion from heating and decomposition of ammonium nitrate
  - Molten aluminium has mixed with water or molten ammonium nitrate causing a violent reaction
- The cause of the second explosion could not be determined.
- Explosion was estimated to be between 10 – 15 tonnes of TNT.
- The second explosion caused significant destruction to nearby infrastructure and vehicles and blast injuries to people nearby.
- The possible causes of the second explosion include:
  - Continued heating of the ammonium nitrate leading to a runaway reaction and thermal explosion
  - An explosion of ammonium nitrate under pressure
  - A detonation of ammonium nitrate from direct shock detonation or deflagration to detonation transition

- Water hammer or void concerted collapse leading to detonation (via hot spot)

Actions Taken

- The Explosives Inspectorate released Explosives Safety Alert 86 *Ammonium nitrate explodes during transport incident*
- Hazchem code for ammonium nitrate of UN 1942 changed from 1Z to 1Y to consider the risk of an explosion (via Competent Authorities Panel)
- National Working Group to review vehicle design for ammonium nitrate transport
- Public release of investigation report and video

Recommendations

- Develop appropriate design criteria for vehicles transporting ammonium nitrate that includes safety design features to prevent, reduce and isolate a fire.
- A steel vertical and horizontal firescreen be fitted to flat deck trailers transporting ammonium nitrate.
- Reduce the quantity of combustible material on a vehicle, particularly in proximity to ignition sources.
- Increase the fire extinguisher capacity and provide additional water/foam on vehicles transporting ammonium nitrate.
- Review the appropriate hazard information on vehicles, including documentation and vehicle marking, and systems to alert external parties to an incident involving ammonium nitrate.
- Communicate ammonium nitrate transport routes to emergency services and remote communities for pre-planning of emergency response.
- Update the initial emergency response guide to reflect the appropriate initial response and evacuation response to an ammonium nitrate fire.
- Conduct further research into the causes of initiation of an ammonium nitrate explosion in a transport incident, particularly the interaction of molten metals with molten ammonium nitrate in large loads.
- Informal Working Group to Competent Authorities Panel (CAP)
- IMESAFER – APT Research