Nitro Sibir Australia

Norton Goldfields Australia – Enterprise Pit Bulk Explosive Trial

27 February 2015

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Introduction

Nitro Sibir Australia (NSA) was invited by Norton Goldfields Australia (NGF) to participate in a bulk explosives trial. The trial was to evaluate the capability of NSA to supply NGF with the required quantities of bulk explosives, along with accessing the service level and product performance that was provided during the trial period.

As part of the trial, NSA and a Drill and Blast consultant (DBC) to assist in the evaluation of current drill and blast practices at the NGF Enterprise pit. The consultant was present on site during the loading of the two trial NSA shots.

While on site at the Enterprise pit, NSA's Drill and Blast consultant evaluated the following criteria:

- Matching bulk explosives to ground conditions;
- Ensuring quality control of blast to ensure that blast results are due to blast parameters and not blast parameter quality control related issues;
- Assisting NGF with blast initiation designing, that can optimise blast fragmentation and wall control;
- Current wall control blasting techniques results;
- Initiating Explosives and High Explosives suitability for application;
- Benefits of electronic detonators to improve fragmentation.

The above topics will be evaluated and where required recommendations for improvements supplied.

Quality Control

Prior to loading of the NSA blast 1, the NSA Drill and Blast consultant dipped approximately 50% of the blast hole depths for this blast. The blast holes were all shorter than the design bench height, 7.5m. The blast hole depths were checked against the plan and were correct. It was discussed that the majority of the subdrill material had been mined off the bench also. The blast hole depths varied between 7.0m and 7.5m. Quality control of the blast hole depths would be considered accurate, as all holes were with ±300mm.

Approximately 25% of the NSA trial blast hole stemming heights were dipped. Out of all of the holes the majority were within 200mm, with one being at 1.8m. The 1.8m stemming height was rectified by the Shotfirer, after he was informed. On the sample set examined, the drill and blast quality control is within acceptable tolerances.

Subdrill being excavated below the design RL level, in hard rock material, can have negative effects. With 2.4m of stemming material, the subdrill typically would precondition 0.5m of the rock mass in this zone. This would leave approximately 1.9m of uncharged rock mass that would require fragmentation. This area of the blast will be the coarsest fragmentation. By excavation out the subdrill, up to 1.0m in places would deliver a negative effect on the fragmentation on the next bench. It would be recommended that all benches in the harder material types are excavated to the design RL, this will assist in improving fragmentation in the stemming zone.

Bulk Explosives

NSA can supply ANFO, Heavy ANFO and Gassed Emulsion bulk explosives products. The bulk explosives are supplied under the brand name Polar SX, with the emulsion products being considered to have one of the higher Relative Weight Strengths (RWS) due to the lower water content, when compared to other available commercial bulk explosives.

NSA's Drill and Blast consultant has worked in the open cut mining, quarrying and construction drilling blasting industry for over 20 years and has become familiar with bulk explosive performance characteristics. He has worked with several companies over the past few years, to optimise bulk explosives properties. An optimised bulk explosives has specifications that are matched to the geological situation (confinement), to ensure maximum energy is transmitted into the surrounding rock mass. Energy matching bulk explosive to the geological conditions assist in optimising rock movement and fragmentation, while ensuring that unwanted gaseous by-products are minimised (NOx and CO).

Most of the bulk explosives industry has moved towards the theory that the higher the bulk explosives density the higher the blast energy per hole. If the explosives does not perform optimally the benefits of using a denser bulk explosives is lost. A key bulk explosives indicator is Velocity of Detonation (VOD). VOD is influenced by many factors, with these including the following:

- Geological confinement, the ability of the rock mass to maintain bore hole pressure whilst the explosive chemical reaction propagates up the explosive column;
- Blast hole diameter, the smaller the blast hole, typically the lower the VOD measured;
- Bulk explosives formulation;
- Bulk explosives sensitivity, a more sensitive bulk explosives requires less confinement to achieve optimal VOD, e.g. ANFO performs very well in soft clay and overburden material as it has a high sensitivity;
- Bulk explosive that has infinite confinement, theoretical conditions (Ideal Detonation), will support detonation conditions for higher density bulk explosives (> 1.15 gcm^{-3}). To achieve high VOD's, e.g. +5500 ms^{-1}, massive hard rock geology e.g. Basalts, Granites, ground condition are required to support the higher density bulk explosives.

In average ground condition a 1.1 gcm^{-3} density will deliver the same or greater energy than a 1.15 gcm^{-3} or 1.20 gcm^{-3} density bulk explosives, due to the higher sensitivity of the product in the average ground conditions.

The NSA Chemist and NSA Drill and Blast consultant examined the geological conditions that the first NSA trial was going to be blasted in and selected a wet hole emulsion bulk explosives (Polar SX) at a target in hole density of 1.1 gcm^{-3}.

NSA emulsion could be considered the lowest water content bulk emulsion explosive available commercially, without making a specific request to the supplier. The lower water content adds additional energy to the emulsion formulation, as there is a greater percentage of fuel and oxidiser per unit weigh of emulsion, if comparing to other commercial bulk emulsion products. The lower water content also assists in reducing any potential fume events.

Bulk Explosives Properties

Type:	Polar SX Emulsion (70% ANE / 30% AN)
Nominal Density:	1.1 gcm^{-3} (Range 0.85 to 1.2 gcm^{-3})
Velocity of Detonation:	4100 to 4400 ms^{-1} (Not measured)
Hole Diameter Range:	76mm to 311mm
Minimum primer:	150 g Cast Booster

If the NSA bulk explosive is to be used on a more regular basis at NGF operations multiple VOD measurement must be taken to evaluate the optimal bulk explosives density in each geological domain. A product that is optimised to the ground conditions can provide the same fragmentation or improved fragmentation due to the higher VOD. There is significant amount of evidence on matching the blast impedance, e.g. matching the geology seismic velocity and density to the bulk explosives density and VOD. By maximising the bulk explosives VOD, by adjusting the bulk explosives density, the blast impedance is being optimised.

Up to a 10% savings in bulk explosives could be realised by matching bulk explosives to the specific geology. If the optimised bulk explosive density delivers a higher energy, further saving could be realised through dig rate improvements, crusher throughput increases or pattern expansion.

Blast Fragmentation

A key requirement of the client was to evaluate techniques that could assist in improving blast fragmentation in the harder geological type. Blast fragmentation is driven by 4 factors:

- Geology (Joint spacing, rock strength, rock type);
- Powder factor (kg/BCM);
- Energy distribution (Hole size, stemming length compared to bench height);
- Initiation timing, Burden relief (ms/m).

The geology is a given at any mine site and therefore the direction of firing is the only variable that can be manipulated to improve fragmentation that is solely driven by the geological properties. Powder factor influences the fragmentation adjacent to the charge column. Typically no more than 2 to 5 times the hole diameters into the stemming zone can be influenced by increasing the blast powder factor.

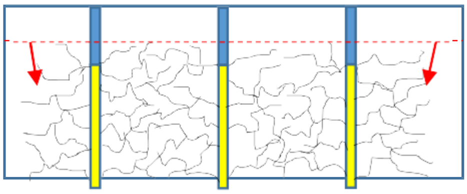

Figure 1 Powder Factor Driven Fragmentation

Initiation timing can will also assist in improving fragmentation. Typically fragmentation of a blast will further improve when using an initiation sequence that provides a burden relief of 15 ms/m or less. Without suitable relief to enable blast movement, the faster the burden relief may affect the looseness of the blasted muck pile, e.g. slower dig rates. When optimising a blast initiation sequence, to improve blast fragmentation, the initiation sequence must create relief and also have a burden relief that will further promote rock on rock breakage. Figure 2 displays a relative scale to display the benefits of burden relief, when referring to fragmentation size. Burden relief assists in reducing the size of the fragmentation in the stemming zone, rock on rock comminution.

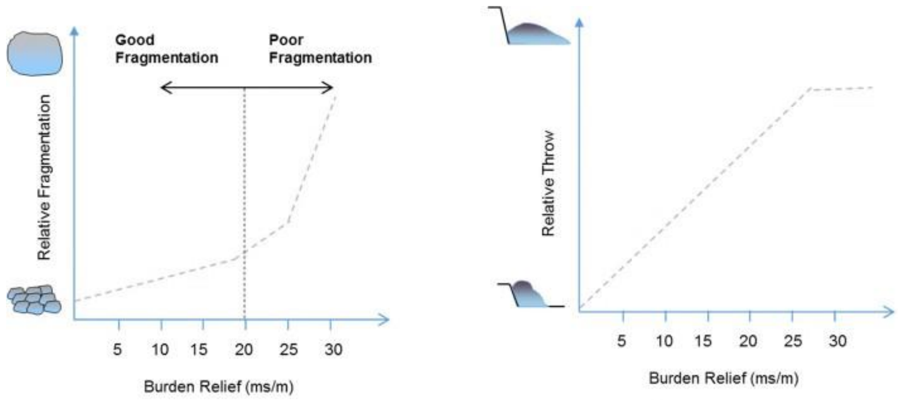

Figure 2 Effects of Burden Relief on Fragmentation and Muckpile Movement.

On the first NSA trial blast, the initiation sequencing was approximately 15 ms/m, a good starting point for fragmentation. NSA Drill and Blast consultant worked with the site Drill & Blast engineer to optimise burden relief for blast movement and optimise the burden relief for fragmentation improvement. A key consider for both trial shots was to create enough relief against the interim wall, +25ms/m, to prevent damage to the wall.

All recommendations suggested by NSA Blast Consultant were implemented by the NGF Drill and Blast engineer. Figure 3 displays a view from above of NSA's first trial blast results.

Figure 3 Blast Fragmentation NSA Bulk Explosives Trial 1

For the second blast NSA implemented tie up designs with the approval of NGF to demonstrate their MS Maxnel Non-Electric detonators (down hole detonators), Maxnel Trunkline non electric detonators (surface delays), Maxprime Primers (Boosters) and also the Davey Bickford Daveytronic™ electronic detonators. The 2nd blast, 3475_340_25, was divided into two section to demonstrate both initiation systems. The non-electric section had a centre lift that had additional timing added, to ensure that relief was promoted and then a burden relief of 15 ms/m similar to NGF previous designs. The initiation timing and burden relief is displayed in Figure 4. It should be noted that the burden relief was slowed for the last 3 rows adjacent to the wall to further develop relief and reduce the pressure into the walls.

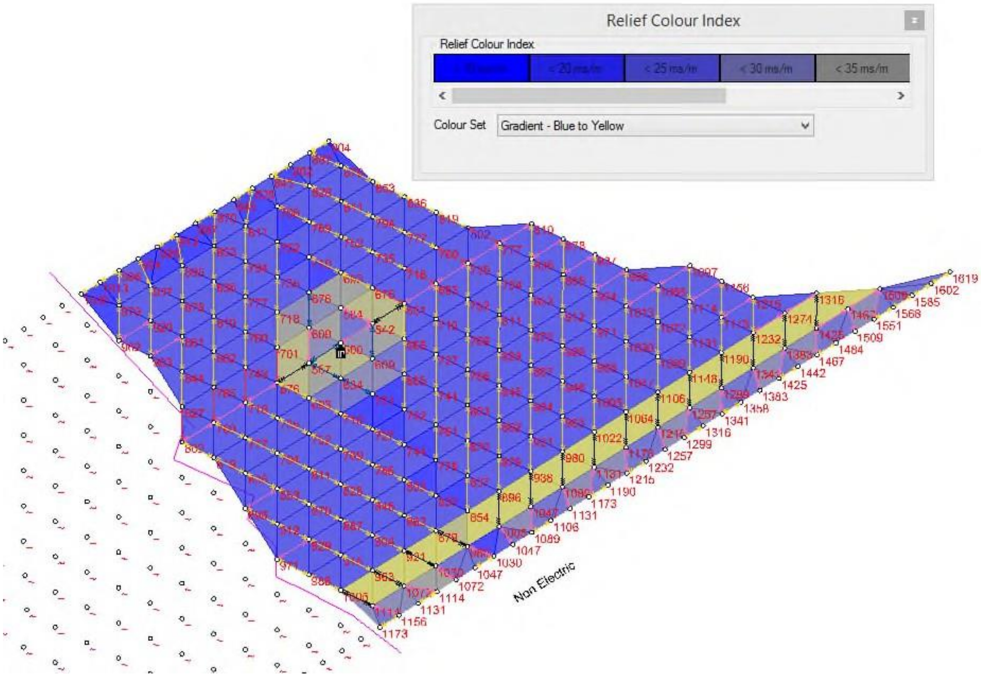

Figure 4 Blast 3475_340_25 Initiation Timing & Burden Relief Non Electric Section.

It had been noted that from NSA blast 1 that the initiation timing required modification to reduce blast pressure into the wall. This advice was taken on board by the NGF Drill & Blast engineer and the design modified. Figure 5 displays the angle of initiation required to promote relief in a centre lift shot, an open diamond.

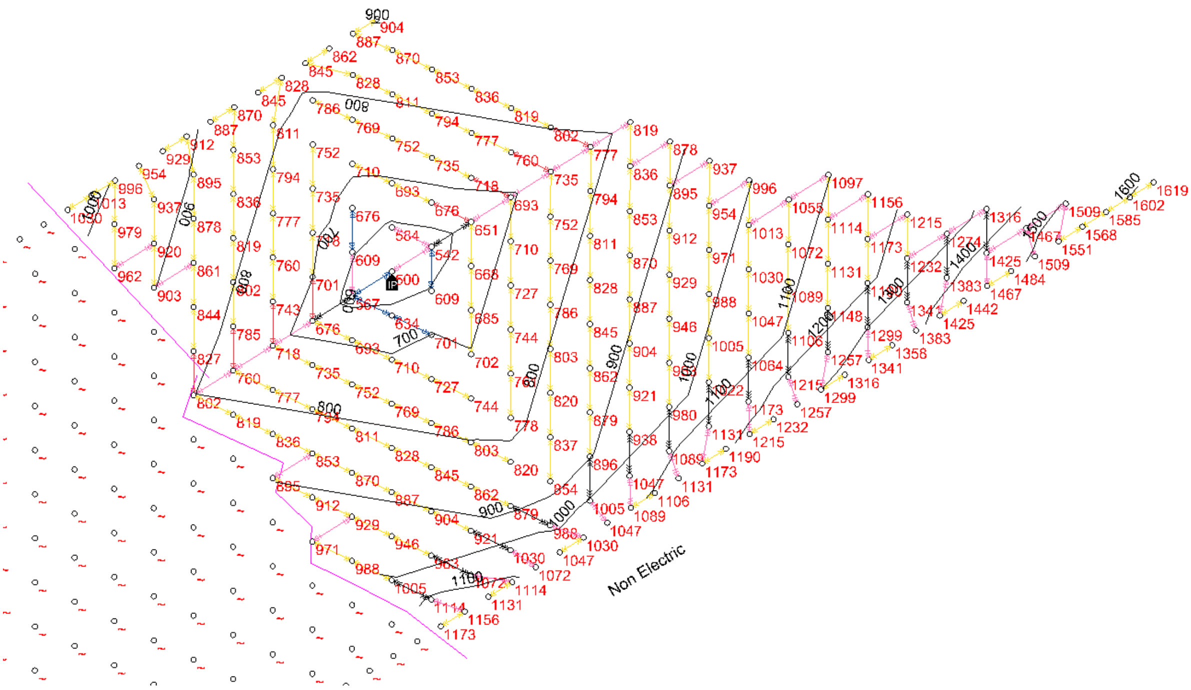

Figure 5 Blast 3475_340_25 Timing Contours

The initiation sequencing for the electronic section was aimed at promoting relief for a centre lift shot, followed by using seismic wave reflection to drive energy into the stemming zone, along with reduced burden relief to improve rock on rock comminution and then finally provide relief against the interim wall and the blast edge. The angle of initiation is displayed in Figure 6

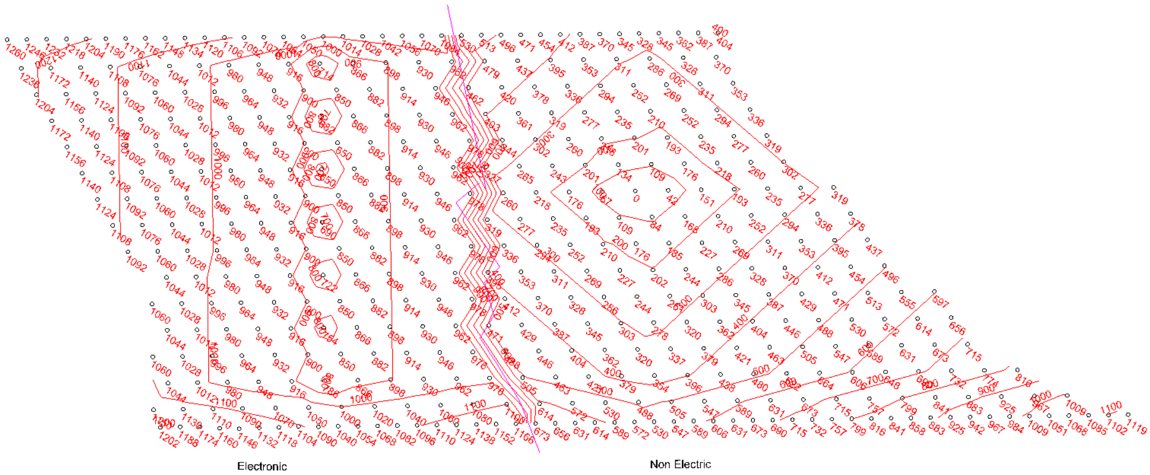

Figure 6 Electronic and Non-Electric Angle of Initiations

The burden relief for the electronic section of the blast targeted a burden relief of 8 ms/m. Reducing the burden relief improves the fragmentation and therefore in equal rock types should deliver an improved fragmentation profile in the stemming zone. The burden relief for both the non-electric and electronic section is displayed Figure 6. Current feedback from NGF is suggesting that there is not much difference in dig rates between the non-electric and electronic sections of the blast. Further optimisation may be required, but it would be preferred to have a blast not adjacent to a wall to refine the burden relief to the optimal.

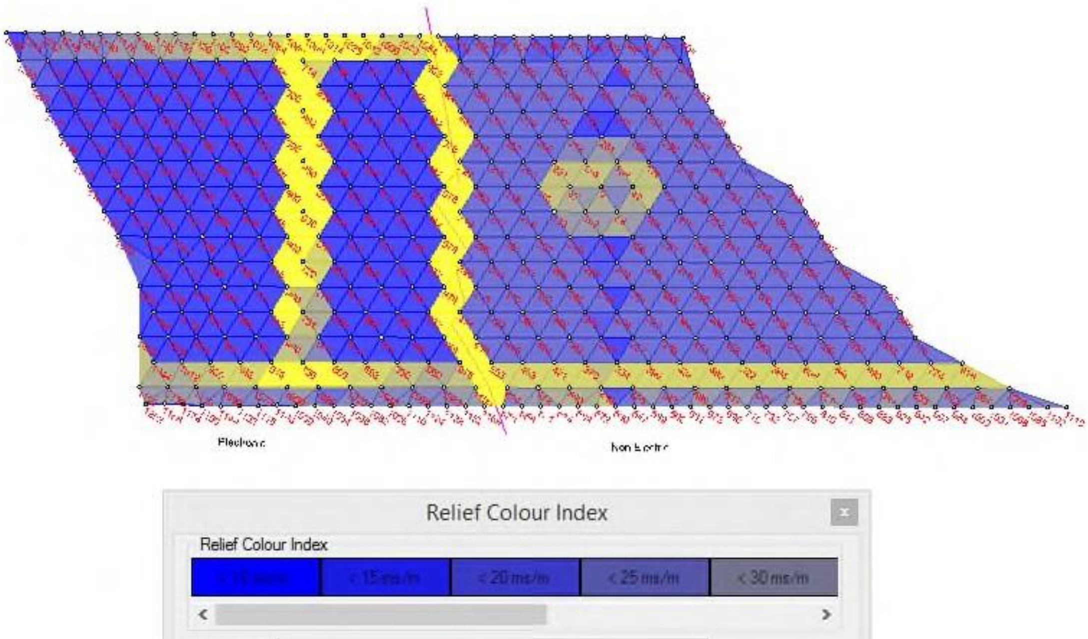

Figure 7 Burden Relief for Non-electric and Electronic 3475_340_25 Trial Blast 2

The electronic section of the blast also used a unique timing that promotes improved fragmentation, by firing blast holes in the same row at the same time, instantaneously. This technique allows for the blast pressure fronts to collide mid holes and reflect energy into the stemming zone. In some rock types this technique combined with optimal burden relief will significantly improve the fragmentation profile in the stemming zone. In harder rock formations, heavily jointed rock formations or dominant horizontally bedded rock formations an additional pocket charge may be required to improve the fragmentation in the stemming zone. A screen capture from blast 3475_340_25 is displayed in Figure 8.

Figure 8 Blast Fragmentation NSA Bulk Explosives Trial 2_ Electronic Section

Blast Initiation

The 3475_340_25 was separated into two halves. One half utilised the NSA Maxnel™ range of surface delays and down hole detonators and the other half utilised the electronic initiation system. The blast was divided into two section to demonstrate the potential benefits of using the electronic system, compared to the non-electric system.

If NGF were to continue using the NSA range of product, they would like to firstly optimise the initiation timing sequencing using the NSA non electric range. After demonstrating an optimised, and repeatable, initiation sequence for the non-electric system, NSA would like to conduct further trials with the electronic initiation system to improve blast productivity. NGF and NSA would have to work together on developing Key Performance Indicators (KPI) that could be measure to identify and value any improvements that were realised through optimised initiation sequencing.

During the trial of using the electronic initiation system, two faulty detonators were identified. One of the detonators was identified as having moisture in the detonator shell. It is believed that the issues had developed due to chemical compatibility issues between the NSA emulsion formulation and the electronic detonator shell or plug. Further work had to be conducted by the supplier to identify the cause. The supplier did have an alternate shell that had been implemented into the only other site where this same issue occurred during 2014. Once the supplier had conducted a thorough investigation, the finding was made available to NGF and NSA

for review. Figure 9 displays the supplier Blast Technician logging blast holes to ensure the detonator functionality, prior to the stemming commencing.

Figure 9 Logging of Electronic Detonator

The non-electric Maxnel™ range of detonators were used to initiate the non-electric section of the blast with no reported problems. The non-electric tubing was noted to be very easy to use, not tangling.

Wall Control Blasting

During the first site visit by the NSA Drill & Blast consultant, special attention was paid to the interim wall that was adjacent to the first trial blast. The wall had been presplit, using 25mm packaged emulsion explosives. Presplitting, when successful, can create a very safe wall. If the technique is not optimised it can become very costly to produce average final or interim wall conditions.

Some sections of the wall there was evidence of block heave damage. This is where the adjacent blast does not have enough relief (time delay) to be able to move the blasted material away from the presplit surface. The lack of relief creates excess pressure adjacent to the presplit and the material moves towards the wall, closing the presplit fracture and compressional forces are exerted into the wall causing damage.

NSA's Drill and Blast consultant worked with the NGF Drill and Blast engineer on optimising the blast initiations timing to improve the relief adjacent to the presplit, better promoting a smooth wall presplit finish.

NSA's Drill and Blast consultant believes that a more cost effective wall control technique could be implemented using bulk explosives presplitting techniques. This will enable the use of larger diameter blast holes and spacing that will match the 115 mm blast hole diameter. The bulk explosives technique could be trialled adjacent to a standard packaged presplit shot, to enable a relative comparison.

It is understood that the presplit result is partly driven by the rock type that the design is being applied in. NSA would also like to work with NGF to develop wall control blasting techniques, which is optimised to each specific geological domain that occurs on the interim and final walls. Figure 10 displays the presplit wall.

Figure 10 Presplit Wall Surface (Left Hand Side of Screen)

Recommendations

By implementing the following recommendations NGF wold be able to introduce blasting improvements that would cost benefits and/or production benefits:

- Bulk explosives densities require optimising to match geological material type. This will ensure the optimally performing product id used. This will reduce bulk explosive consumption and reduce cost. NSA can assist with this improvement item;
- Optimise burden relief to promote improved fragmentation. Designs are currently targeting a burden relief of 15 ms/m. The optimal burden relief for fragmentation improvement may be as low as 6 ms/m. This optimisation will require a targeted approach to ensure that the initiation timing does not negatively affect dig rates. NSA can assist with blast initiation sequencing optimisation;
- Create wall control blast domains. Map different geological types and structures, so that a one pattern fits all approach is not used. Some domains may use presplit while other areas may use modified production hole loading to achieve the same or improved result;
- Excavate blasted material to RL, do not excavate subdrill material;
- Trial bulk presplit holes using 89mm blast holes and evaluate the results. Less costly than packaged presplit explosives.

Conclusion

NSA conducted two bulk explosives loading trials to enable NGF to evaluate their equipment, MPU's, bulk explosives performance and technical support. NSA also provided their non-electric initiation system and the electronic initiation systems for evaluation. The non-electric range performed as expected, the electronic system had to detonator communications issues that caused a misfire. This misfire was being investigated by the supplier and they were working on a potential solution.

NSA were able demonstrate to NFG their equipment and product capability, to enable a true evaluation of their products and services.