



Australian Explosives Industry And Safety Group Inc.

Code of Practice

Elevated Temperature and Reactive Ground

Version 1.1 March 2007



About the AEISG

The Australian Explosives Industry and Safety Group (AEISG Inc) was formed in 1994. It was originally known as the Australian Explosives Manufacturers Safety Committee and was initially comprised of representatives from Dyno Nobel Asia Pacific Ltd (previously Dyno Wesfarmers Limited), Orica Explosives (previously ICI Explosives), Union Explosives Español (UEE, previously ERT) and Total Energy Systems (TES).

Since formation, the AEISG Inc membership has expanded and broadened. Current membership includes:

- ◆ Applied Explosives Technology Pty Ltd
- ◆ Thales Australia
- ◆ Dyno Nobel Asia Pacific Limited
- ◆ Maxam Explosives (Australia) Pty Ltd
- ◆ Orica Australia Limited
- ◆ Quin Investments Pty Ltd
- ◆ Roche Blasting Services Pty Ltd

The goal of the AEISG is to continuously improve the level of safety throughout our industry in the manufacture, transport, storage, handling and use of, precursors and explosives in commercial blasting throughout Australia.

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PREAMBLE

The use of explosives to break rock is an intrinsically hazardous process. These hazards have been studied over the years and modern mining methods have evolved to minimise the inherent risks of blasting under most conditions.

This Code has been developed to assist the safe use of explosives in situations where a specific additional hazard may exist due to the possible unwanted reaction between an explosive and the rock being blasted. In such situations the unwanted reactions may result in premature detonations with potentially fatal results. The reactions can be caused by rock chemistry, temperature or a combination of both.

The purpose of this Code is to provide a scientific and objective basis for predicting the potential unwanted explosive/rock reaction and to provide practical advice on preventive mechanisms available.

The information is provided in good faith and without warranty.



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Section 1.

Scope and Definitions

1.1 Scope and Interpretation of the Code

The aim of this Code is to enhance the safety of AEISG Inc members and their customers when handling explosives and charging in elevated temperature and/or reactive ground conditions.

The Code covers the following areas:

- Outlines the nature of elevated temperature and reactivity, and the current understanding on the mechanisms of elevated temperature and reactive ground chemistry.
- Summarises the hazards and risks associated with blasting in elevated temperature and/or reactive ground.
- Provides recommended risk assessment methods including sampling and testing for reactivity and measuring elevated temperature conditions at new and existing sites
- Provides guidelines for the risk management of operations at an elevated temperature and/or reactive ground sites including blasting methods and systems.
- Provides guidelines for managing misfires and premature detonations in elevated temperature and/or reactive ground.

Based on the determination of sites with elevated temperature and/or reactive ground as detailed in the Code, AEISG Inc members will ensure that appropriate risk assessments are carried out and that appropriate risk management procedures are put in place for the handling of explosives on these sites to ensure the safety and wellbeing of all working on the site. AEISG Inc members will not supply product for use in situations where the risk assessments undertaken based on the guidelines of this Code indicate that the risks are unacceptable.

It is the 'duty of care' of AEISG Inc members to advise customers of the risks associated with elevated temperature and/or reactive ground and to offer products appropriate to the site application. If the customer chooses to operate contrary to this advice, AEISG Inc members reserve the right to withdraw their products and services. If a request is received by an AEISG Inc member from a regulator, the member will inform the regulator of sites that have elevated temperature and/or reactive ground conditions as assessed by this Code.

1.2 Definitions

“Customer” – the person with direct management responsibility for the design of blasting practices in any mining situation including the selection of explosive products.

“Elevated temperature” – material that is above 55°C and includes both hot ground and high temperature ground conditions as defined in AS2187.2-2006.

“Elevated temperature products” – explosive products that have been formulated and/or packaged and tested to withstand a nominated temperature for a recommended period of time before they will deteriorate or become unstable and possibly decompose violently or explode.

“High temperature ground” – High temperature blasting is defined as the blasting of material at 100°C or greater [AS 2187.2-2006 – Section 12.7]

“Hot ground” – material shall be defined as hot if its temperature is 55°C or more but less than 100°C [AS 2187.2-2006 – Section 12.6.1]

“Inhibited product” – explosive product that chemically suppresses the reaction between nitrates and sulphides.

“Reactive ground” – rock that undergoes a spontaneous exothermic reaction after it comes into contact with nitrates. The reaction of concern involves the chemical oxidation of sulphides (usually of iron or copper) by nitrates and the liberation of potentially large amounts of heat. The process is unpredictable and can be so violent that it results in mass explosions.



“**Reactivity**” – this term may be defined in two ways:

- The induction time for the sulphide/nitrate reaction in a constant temperature situation (ie a short induction time indicates a higher level of reactivity);

or

- The onset temperature for the sulphide/nitrate exotherm in a temperature ramping situation (ie a lower onset temperature indicates a high level of reactivity).

“**Site Operator**” – definition as for “Customer”.

“**Sleep time**” – the period of time that an explosive is left in a blast hole until it is fired. The time is measured from the time of loading until the time of firing.

1.3 List of Regulations, Standards, and References

In the development of this Code a number of relevant references were consulted and are listed. These references may be useful to the reader in gaining a further understanding of the issues associated with the use of explosives in elevated temperature and/or reactive ground.

Various State Regulations (Detailed references in Section 2 and Appendix 1)

- AS 2187.2 – 2006 Explosives – Storage and Use. Part 2: Use of Explosives.
- AS 4360 – Risk Management

- P Bellairs, “Explosive Ground Reactivity Indicators And Strategies To Overcome This Phenomena”, International Society Of Explosives Engineers, 1997
- M Littlefair, R Rounsley, F Beach, D Jazzini and G Pugh, “Reactive Ground and Ammonium Nitrate Explosive Interactions”, Proceedings 5th Large Open Pit Conference 2003, p15-21.
- G M Lukaszewski, “The Reaction of ANFO Explosives with Mineral Sulfides”, Proc.Aust.Inst. Min.Met 228, December 1968, p61-70.
- B J Kennedy and N Tyson, “Blasting in Reactive Ground”, Proceedings EXPLO 2001, p55-61.
- Y Miron, T C Ruhe, R W Watson, “Reactivity of ANFO with Pyrite containing weathering products”, US Bureau of Mines Report of Investigations 8373 (1979).
- Y. Miron, T C Ruhe and J E Hay, US Bureau of Mines Report of Investigations 8727 (1982).
- John Alfred Rumball, “The Interaction of Partially Weathered Sulphides in the Mt McRae Shale Formation with Ammonium Nitrate”, PhD Thesis, Murdoch University, 1991
- D Tunaley, “An Emulsion explosive system for blasting in reactive volcanic conditions”, Proceedings Fragblast 1999, South African Institute of Mining and Metallurgy, p313-319.



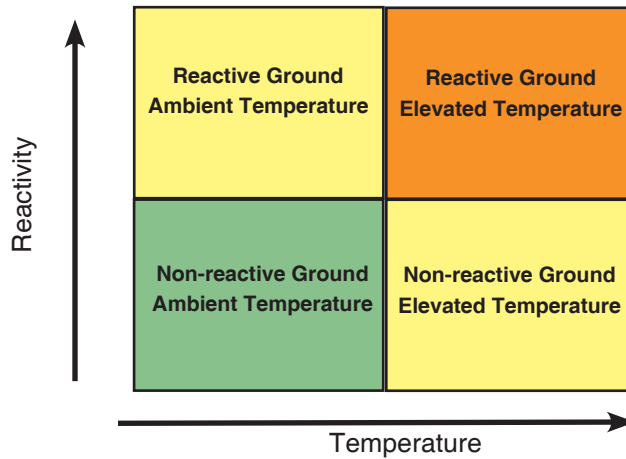
SECTION 2. Regulatory Requirements

The Regulatory requirements for blasting in elevated temperature and/or reactive ground vary significantly from State to State. Some guidance is given in Sections 12.7 to 12.9, AS2187.2 but this does not adequately address how elevated temperature and reactive ground are determined and the precautions that need to be taken in the use of explosives in such ground. This Code attempts to address these shortcomings.

A summary of relevant current legislation is given in Appendix 1.

SECTION 3. Background

When dealing with the issue of elevated temperature ground and reactive ground, there are four main ground conditions that can apply:



With this Code elevated temperature ground conditions will be covered first, followed by reactive ground conditions. For the case of both elevated temperature and reactive ground conditions, the risks associated with both conditions need to be considered during product selection and in determining operational requirements.

3.1 Case Histories

There have been a number of incidents that have occurred across the mining industry that have been associated with elevated temperature and/or reactive ground. Some examples are listed below:

Table 1 Examples of known incidents caused by elevated temperature and/or reactive Ground

Date	Location	Type1	Details of Incident
2006	Curragh	H	Two blastholes detonated due to slumped hot material that was undetected when drilled.
2005	Black Star	HR	Premature detonation.
2005	Moura	H	Melted primer.
2003	Ernest Henry	R	Melted lead lines (2 leads in one hole).
2003	Drayton	H	Detonating cord caught fire on bench surface.
2002	Collinsville	R	Melted primer.
2000	Parkes	R	Spillage fire.
1998	Century	R	AN spilt on the bench started to burn several days after the shot was fired.
1998	Ok Tedi	HR	Drill cuttings caught fire.



1998	Sons of Gwalia	R	Several holes at Jacoletti pit started smoking within 20 minutes of being loaded with heavy ANFO.
1998	Southern Cross	R	ANFO spillage fire.
1998	Collinsville	R	A hole loaded with sawdust/ANFO detonated prematurely.
1997	Minahasa	U	Premature detonation.
1995	Saraji	R	Spillage on bench reacted with drill cuttings from sulphide band above K seam.
1995	Collinsville	R	Holes containing emulsion (heavy ANFO) caught fire.
1994	New Hope	H	Blasthole detonated while blast crew and drill on shot due to burning of stringer coal seams.
1992	Mt Leyshon	R	Emulsion in a shot which had been sleeping for several months detonated.
1991	USA	U	Paradise Peak Gold – premature detonations with ANFO.
1990?	Dominican Republic	U	Heavy ANFO caused burning and premature detonation.
1989	Mt Lyell	U	Explosive ejection – premature detonation of AN emulsion within 10 hours of loading.
1989	USA	U	Battle Mountain Gold – premature detonations with ANFO.
1989/90	Faro, Canada	U	Premature detonation.
1987	Mt Whaleback	R	A hole which was lined and loaded with ANFO detonated when the hole liner split.
1983	Mt Whaleback	R	A hole loaded with ANFO detonated prematurely.
1968	Russia	R	Gaiskii Combine copper, spontaneous detonation with AN explosives.
1963/64/65	Mount Isa	R	Holes in 500 ore body became incandescent on contact with ANFO. Premature detonations.

Note 1: H = Elevated temperature ground only.
R = Reactive ground only.
HR = Elevated temperature AND reactive ground.
U = Information unavailable.



SECTION 4. Risk Assessment

Due to the serious nature and high risk of premature detonations associated with the use of explosives in reactive ground there are a number of strong indicators that mine and quarry operators (at both proposed and existing sites) should constantly monitor. If any of these indicators are found then a detailed risk assessment of the use of explosives on the sites should be carried out and, as the site develops, the risk assessment should be regularly reviewed.

Indicators for the presence of reactive ground are:-

1. The presence of sulphides (normally greater than 1%).
2. The presence of black sulphide bearing sediments.
3. Sulphides within mineralised rock.
4. The presence of white or yellow salts on rock. This is an indication that oxidation is taking place.
5. Acidic conditions (generally resulting from oxidation) as indicated by the colour of run off water, usually yellow-red brown in colour.
6. Significant corrosion of rock bolts, safety meshing and fixed equipment associated with the mining operation.
7. The spontaneous combustion of overburden or waste rock/ore either in dumps or in the pit, especially as it is exposed to the air.
8. The acrid smell of sulphur dioxide caused by the naturally occurring sulphide oxidation reaction.
9. The rock type occurring in the transition zone just below the limit of the oxidation line (ie where light coloured bleached rock ends and darker coloured rocks begin).



SECTION 5. Elevated Temperature Blasting

5.1 Principles for Elevated Temperature Management

The preferred approach to elevated temperature ground management is to mitigate the risks highlighted in the risk assessment process by quantifying the hazards and selecting the most appropriate mitigation measures. This will be achieved through a combination of suitable procedures and product selection.

Elevated temperature may be caused by reactive ground, however this section deals with ground that is at an elevated temperature but is NOT reactive.

5.2 Causes of Elevated Temperature Ground

Elevated temperature ground can exist due to one of the following conditions:

- Geothermal heating – eg volcanic activity.
- Geothermal gradients.
- Burning coal seams.
- Sulphide oxidation – reactive ground is a special case of elevated temperature ground.
- Cement fills in stopes.
- Thermal heating of ground surfaces by solar radiation.

5.3 Risks and Hazards of Blasting in Elevated Temperature Ground

Elevated temperatures (ie temperatures above 55°C) will affect bulk, packaged and initiating products over time, increasing the rate of degradation and potential failure which may lead to an explosion.

Some of the major hazards associated with elevated temperature ground can be summarised as follows:

- Exposure of operators to high temperatures.
- Exposure of operators to toxic vapours.
- Ignition of vapours associated with emulsion and ANFO type products.
- Softening of plastic components of initiating products.
- Melting and decomposition of bulk, packaged and initiating products.
- Detonation following decomposition.

5.4 Risk Management through Operating Practices

Once a site has been identified as having elevated temperature ground conditions, the operating procedures and on-bench practices need to be adjusted accordingly to minimise the hazards outlined above. These should include:

5.4.1 Site Specific Operating Procedures

Site specific operating procedures need to be developed involving all key stakeholders based on a risk assessment and including all appropriate control measures. Documented control procedures must be put in place to ensure all key stakeholders are formally notified of any intention to change these procedures and agreement reached on the changes.



Areas to be included in site specific operating procedures include:

- Training.
- Sleep time.
- Hole temperature monitoring.
- Hole loading sequence.
- Delineation of zones.
- Product selection.
- Spillages

5.4.2 Training

The customer is responsible for ensuring that training in these procedures occurs. Training is to extend to all personnel operating on the bench or involved in the management of these personnel. Training shall also include regular reassessment. (See also Section 13.)

5.4.3 Sleep Time

The sleep time of product in elevated temperature ground shall be minimised to prevent unnecessary heating of products, which may lead to product deterioration and possible catastrophic failure.

5.4.4 Hole Temperature Monitoring

Hole temperature monitoring is a critical part of the risk management process for the following reasons:

- Allows for hole-by-hole classification of temperature – not all holes may be hot and hence different products may be suitable for different areas;
- Hole temperature is often linked with the recommended sleep times (the higher the temperature, the lower the sleep time);
- To monitor if hole temperature is changing with time;
- Allows holes that are too hot to be charged to be left uncharged or backfilled.

The temperature logging procedure, including the frequency of logging, shall be recorded in the site specific procedures generated. Key principles for effective temperature logging include:

- Selection of a measurement device with a suitable temperature range and a measuring system suitable to the conditions (eg infra-red cannot be used in wet holes or steaming holes)
- Hole-by-hole logging
- Recording maximum hole temperature
- Frequency of measurement
- Recommendations on how to act on the temperature information

5.4.5 Hole Loading Sequence

When working in elevated temperature areas, it is preferable that loading occur near the initiation point first (ie load in the sequence in which the blast will be fired). This is to allow the pattern to be quickly tied up and fired in the event of a change in conditions (eg weather or approaching maximum allowable sleep time). Where practical, allow for the hottest holes to be loaded last.



5.4.6 Occupational Health and Safety Considerations

Areas of elevated temperature ground may lead to exposure of personnel to scalding from steam and hot water. Toxic gas such as hydrogen sulphide and carbon monoxide may also be generated under these conditions.

5.4.7 Delineation of Zones

Delineation of ground into elevated temperature and non-elevated temperature zones can occur as it is possible to take multiple hole-by-hole measurements. Delineation allows for the choice of different products, the use of physical barriers, the setting of sleep time and if necessary the backfill of holes on a hole-by-hole basis.

5.4.8 Spillages

During charging of blast holes there is a possibility that spilt explosives may react where benches are at an elevated temperature or contain reactive ground. Procedures for minimising spillages of explosives need to be developed and where possible spillages must be cleaned up immediately. The procedures should also ensure that initiating systems do not come into contact with the spilt explosives as the possible decomposition of the explosive may cause the initiation system to detonate.

5.5 Risk Management through Physical Separation

Generally the use of physical separation to insulate explosives from elevated temperature ground is not recommended. If this approach is taken then the associated risk assessment must take into account all hazards and all likely failure modes to ensure that an appropriate level of safety is achieved and can be maintained. (Note:- Details in Section 6.5 should also be considered.)

5.6 Risk Management through Product Selection

Choice of bulk, packaged and initiating product can be a particularly effective way of addressing the risks associated with elevated temperatures. All products must be used in applications stated as per Technical Data Sheets. AEISG Inc members shall indicate in Technical Data Sheets whether products are suitable in elevated temperature applications.

Where a site is known to have elevated temperature ground conditions, the following products may be suitable for use:

- Bulk products – these need to be formulated to withstand elevated temperatures; and
- Initiating and packaged products – these need to be formulated and/or packaged to withstand elevated temperatures.



SECTION 6. Reactive Ground Blasting

6.1 Principles for Reactive Ground Management

Reactive ground may be a condition specific to individual sites. Case histories (see Section 3.1) indicate that in the past this type of condition has only been identified following an incident. The preferred approach to reactive ground management is to be as pro-active as possible, minimising the recognised risks rather than responding post incident. It is not possible to completely eliminate all risk as it is not possible to account for the characteristics of every section of rock. However, there are risk management approaches that can be and have been successfully adopted that provide acceptable safety margins thus preventing further incidents occurring.. The following Section of the Code covers a number of recommended risk management approaches.

6.2 Chemistry of Reactive Ground

The reaction of nitrates with sulphide containing minerals is an auto-catalysed process that can, after some induction time, lead to a runaway exothermic decomposition even if the starting temperature of the mixture is at an ambient temperature. Typical nitrates used in the mining industry (including but not limited to) are ammonium nitrate, calcium nitrate and sodium nitrate. The reaction scheme developed over the last 30 years of research by groups such as the US Bureau of Mines (USBM) and others is described in a simplified form below (reference - John Rumball's thesis, "The Interaction of Partially Weathered Sulphides in the Mt McRae Shale Formation with Ammonium Nitrate").

Natural oxidative weathering of iron sulphides such as pyrites by atmospheric oxygen generates solutions of ferrous ions and acid. This process occurs whenever the sulphides are exposed to air along cracks, in drilled holes, in the muck pile after blasting, on pit walls and in old stopes. No nitrates are required for this to occur.

Iron Sulphides + Oxygen + Water

→ Ferrous Ions + Sulphuric Acid

This reaction is exothermic and can lead to hot blast holes for particularly reactive ores. This temperature increase can be as little as 2°C or as much as several hundred degrees.

On contact with ammonium nitrate, the ferrous and acid species from weathering can begin to catalyse the breakdown of nitrate. The breakdown process is auto-catalytic in that it generates its own catalysts as it proceeds.

Nitrates + Iron Sulphides + Ferrous Ions + Sulphuric Acid

→ Nitric Oxide + Ferric Ions + HEAT

The nitric oxide and ferric ions produced in this stage react with more pyrites, generating more ferrous ions and sulphuric acid.

Iron Sulphides + Nitric Oxide + Ferric Ions

→ Ferrous Ions + Sulphuric Acid

Although these reactions are exothermic, their rate may be initially so slow that little or no temperature rise is detectable. This is due to the concentration of catalytic species building up to some critical level. The time taken for this to occur is often referred to as the induction period. When sufficient catalysing species have built up, the reaction rate increases sharply and the heat generated causes the temperature to become so high that a rapid, potentially violent decomposition of the remaining ammonium nitrate is inevitable.

Nitrates + Fuels (sulphides, diesel etc) + Heat

→EXPLOSION



6.3 Risks and Hazards – Blasting in Reactive Ground

The hazards associated with blasting reactive ground can be summarised as follows:

- Sudden violent decomposition of nitrates;
- Evolution of toxic NO_x and SO₂ fumes;
- Premature detonation of detonators due to the heat generated;
- Mass detonations:
 - o Deflagration-to-detonation in single holes (heat generated causes the contents of the hole to catch fire and then to detonate)
 - o Communication to other holes via cord.

6.4 Risk Management through Operating Practices

Once a site has been identified as having reactive ground conditions, the operating procedures and on-bench practices need to be adjusted accordingly to minimise the risks outlined in Section 6.3. These should include:

6.4.1 Site Specific Operating Procedures

The customer is responsible for ensuring that site specific operating procedures are developed involving all key stakeholders. Appropriate document control procedures shall be put in place to ensure all key stakeholders are formally notified of any intention to change the procedures and agreement is reached on these changes.

Areas to be included in site specific operating procedures include:

- Training
- Sleep time
- Hole temperature monitoring
- Surface temperature monitoring
- Buffer margin between testing temperature and maximum potential surface temperature or in hole temperature
- Hole loading sequence
- Delineation of zones
- Product selection
- Product spillage
- Stemming material

6.4.2 Training

The customer is responsible for ensuring that training in these procedures occurs. Training is to extend to all personnel operating on the bench or involved in the management of these personnel. Training shall also include reassessment. (See also Section 13.)

6.4.3 Sleep Time

The sleep time of product in reactive ground shall be kept to a minimum to reduce the exposure time of nitrate based products in potentially reactive material.

More information on how sleep time is determined can be found in Section 8.3.



6.4.4 Hole Temperature Monitoring

In reactive ground, there is a risk that after drilling holes, the hole temperature may rise above ambient conditions due to oxidation with air. It is important to monitor hole temperature to confirm that the ground temperatures do not rise above a level in which the selected product is no longer appropriate for both elevated temperatures and reactivity conditions.

Temperature logging may be used as part of a process of mapping the temperature and reactivity zones in an existing site. Where it can be shown, through a reasonable measurement campaign, that in hole temperatures in reactive ground do not exceed those considered ambient, it may not be necessary to monitor hole temperature on an ongoing basis. The requirement for monitoring of hole temperature (or not) must be specified in site specific procedures.

6.4.5 Surface Temperature Measurement

Any elevated temperature or reactive ground risk assessment must consider the possibility of bench surfaces reaching higher temperatures than in the hole due to solar radiation. Based on the risk assessments consideration should be given to testing the bench materials in the isothermal test with the proposed explosives to be used at the temperatures reached by the surface rocks plus an appropriate buffer.

6.4.6 Hole Loading Sequence

When working in reactive ground areas, it is preferable that loading occur near the initiation point first (ie load in the sequence in which the blast will be fired). This is to allow the pattern to be quickly tied up and fired in the event of a change in conditions (eg weather or approaching maximum allowable sleep time).

6.4.7 Stemming

When blasting in reactive ground applications it is highly recommended that stemming is carried out with non-reactive materials. In particular stemming with drill cuttings is to be avoided. This is because the fine particle sizes associated with drill cuttings maximises the surface area available for contact with ammonium nitrate resulting in an increased likelihood of reaction.

It is a well established principle that increasing the surface area of contact between two potentially reactive materials significantly increases the probability and rate of reaction.

6.4.8 Product Spillage

At all times the spillage of explosives on the bench needs to be minimised and eliminated if possible. This is due to the possible interaction of the explosive and potential or proven reactive surface rock/drill cuttings

6.4.9 Occupational Health and Safety Considerations

Areas of reactive ground may generate sulphur dioxide and sulphuric acid which may affect both people operating in the area and process equipment. Site specific procedures need to include guidelines for:

- Evacuation procedures when sulphur dioxide reaches a critical limit
- Personnel to wear appropriate gas monitoring equipment and breathing apparatus when necessary



6.4.10 Ongoing Review of Risk Assessment

Risk assessments should be reassessed on a regular basis to check whether conditions have changed since the initial conditions. This will include:

- Changes in geology – eg different levels of sulphides.
- Changes to blasting practices – eg sleep time requirements.
- Changes in product.
- Changes in explosives provider.

No ongoing reactive ground testing is required if the following apply:

- None of the above changes have occurred
- Site has been classified as non-reactive
- Sulphides are absent from site geology

If any changes have occurred or the site is a known reactive ground area, ongoing reactive ground testing shall occur at both reactive and non-reactive areas to ensure the following:

- Ground conditions at the site are monitored to understand ongoing conditions as production moves into different areas – this applies to both known reactive ground areas and also areas that have not been classified as such.
- For reactive ground sites, to assist product selection in response to the current level of reactivity, in order to reduce the risk of a reaction.
- To increase understanding of the critical areas of reactivity in a pit or to uncover reactivity in areas that have not previously been identified.

Refer to Section 8 for frequency of ongoing reactive ground testing based on the risk profile of the site.

6.4.11 Delineation of Zones

Delineation of a site into reactive and non-reactive ground shall only occur after significant research into the nature and extent of reactivity has been carried out. In some cases it may not be possible to delineate and the entire site should be classified as reactive.

Delineation requires close cooperation between those with geotechnical expertise and explosive providers based on reactive ground sampling and testing.

Delineation of a site should not occur if there are no clear indicators as to what ground is reactive and what is not. Delineation may be possible if there are:

- Clear zones of geological type.
- Clear zones based on sulphide levels.
- Drill cuttings are geologically logged for the presence of sulphides and a procedure is in place for utilising this information to determine what product is to be loaded into the reactive and non reactive holes.
- Temperature profiles across the site.

If delineation is established across a site appropriate buffer zones between reactive and non-reactive areas must be established and rigorously managed. Procedures for the loading of explosives into the two areas needs to be developed, and must include a detailed emergency action plan should the wrong product be loaded into the wrong area.



6.5 Risk Management through Physical Separation

Barriers which prevent rock from contacting the ammonium nitrate have been used in the past for reactive ground applications. Blast hole liners are one option, however, there are limitations, which impose a significant increase in risk, such as:

- Liners may split exposing uninhibited product to reactive ground.
- Overall strength and suitability of the liners may not be applicable for all conditions or to changes in conditions that may occur (eg variations in temperature with time) on the bench to which they are being subjected.
- Liners do not prevent material that is spilt on the bench from reacting.
- Bulk explosives may be spilt down the side of the liner potentially allowing uninhibited product to contact reactive ground.
- If a primer misfires damaging the liner but leaving bulk product unfired, uninhibited product would be left to react.
- Loading times may increase due to handling issues associated with liners on the bench.

The total cost of using liners and standard uninhibited products, and assessing the associated increased risks at a particular site will be a commercial decision that the site operator will need to consider.

The use of packaged products where the plastic outer casing acts as a physical barrier is also an option. Generally this is an option only for small shots as costs may become prohibitive. The loading of packaged product can involve the splitting of the casing (for the insertion of the initiators or damaged during charging) which will compromise the layer of protection. In some cases the packing material may not be acid and/or tear resistant leading to the packaging being breached and thus allowing uninhibited product to be exposed to reactive ground.

For reactive ground applications, the use of blast-hole liners (with uninhibited bulk explosives) and uninhibited packaged products should be discouraged. This is not industry 'best practice' and has led to unacceptable incidents of uninhibited products being exposed to reactive ground at an extremely high risk.

6.6 Risk Management through Product Selection

Choice of bulk, packaged and initiating product can be a particularly effective way of addressing the risks associated with reactive ground. All products must be used in applications stated as per Technical Data Sheets and through compatibility testing with the ground in question (see Section 8 for further details). Explosives providers shall indicate in Technical Data Sheets whether products are suitable in reactive applications.

Where a site is known to have reactive ground conditions, the following products may be suitable for use:

- Bulk products – inhibited products with recommended sleep times based on compatibility testing with reactive ground.
- Initiating products – products suitable for reactive applications.
- Packaged products – inhibited products with recommended sleep times based on compatibility testing with reactive ground.



SECTION 7. Sampling for Reactivity Testing

7.1 Sample Selection

Reactivity sampling and testing is a crucial component of reactive ground management. It must be noted that it is rarely possible to statistically take enough rock samples to fully characterise the geology and hence the reactivity of a site. Testing, and in particular screening for reactivity, needs to be targeted to analyse the rocks containing sulphides in order to identify the “worst case” reactive rock samples and hence to minimise the risk of incidents. Other indicators listed in Section 4 may be used to identify the most likely locations from where rock samples should be taken.

The role of geotechnologists (eg site and consulting geologists) is essential for the identification of high potential samples. Where possible, the expertise of site geotechnologists shall be employed and geological knowledge (targeting sulphides) shall be used to implement safety margins and to allow for the limited numbers of representative samples. The sampling method requires selection of “worst-case” samples present on the site at that point in time

Samples should be taken so that their exact location is known. Samples picked from a wall or drill core samples are the most useful for screening purposes. Samples picked up from the floor may have fallen from a much higher point or been moved from a different location and hence are less useful when it comes to identifying risk zones. Drill cuttings can result in “diluted” rock samples and allow for some oxidation to occur before testing – hence the best samples are whole rocks from known locations.

7.2 Handling of Samples

In order to obtain accurate results, testing shall occur just prior to explosive supply commencing using fresh samples (ie newly exposed rock rather than old core drill samples). This is to ensure that the effects of oxidation do not “hide” potentially reactive samples.

7.2.1 Sample Size

Sample size should be appropriate for the testing that is to be carried out. For standard laboratory scale screen testing or verification work, a minimum of 0.5kg with the maximum rock size approximately “fist-size” (ie 50mm diameter).

7.2.2 Sample Identification

To ensure the traceability of samples back to their location on the site, records are to be kept of sample ID's, collection points and date of collection.

7.2.3 Sample Packaging

The following considerations need to be made when packaging:

- Packaging can easily be linked with a sample (eg indelible markings).
- Packaging is to be robust enough to prevent rupture (and potential mixing) of samples.
- Where it is not possible to collect whole rock samples (eg rock chips or drill cuttings), samples are to be taken immediately after drilling and stored in vacuum sealed plastic bags to minimise oxidation through exposure to oxygen.

7.2.4 Sample Timing

Allow a suitable time between the collection of samples and the time frame in which the area is to be blasted.



7.3 Sampling for Initial Screening

A “green field” site refers to the following scenarios:

- New site lease that has never been excavated
- Excavation commencing in a new development on an existing site
- Excavation commencing in an area of untested geology
- Where this Code has not been applied

Before site development commences a risk assessment of the site should be carried out based on Section 4. If no indicators are present then it may be assumed that the site is non-reactive.

If the risk assessment indicates the likelihood of reactive ground the ground is to be tested for sulphides and hence potential for reactive ground interaction (as per the Regulations quoted in Section 2). The role of site geotechnologists is essential when identifying high potential samples that characterise the most potentially reactive ground. At this initial stage, sulphide analysis can be used to target areas (as a minimum) to eliminate the need to take samples from areas that contain no sulphides.

The minimum recommended number of samples is 12. The most suitable number is difficult to quantify but a well-chosen set of samples (ie obtained with assistance from geotechnologists) may mean fewer samples are required.

Refer to Flowchart in Section 12 for further information.

7.4 Sampling for Ongoing Testing

Periodic testing at a known reactive ground site is an important part of the reactive ground risk management process for the following reasons:

- To clarify the extent of reactivity at a known reactive site.
- To confirm that the level of chemical inhibitor used at the site remains sufficient to continue to inhibit a reaction within the recommended site sleep times.
- To allow for extensions of sleep time to meet the needs of the customer.
- To assess whether changes in raw material sourcing effects the ongoing suitability of the product for the established conditions.

7.4.1 Existing site – No previous reactivity

Even if sites have shown no previous signs of reactivity, ongoing testing shall continue on a regular basis according to the risk profile of the site (if there is no major excursions from the initial risk assessment, then retesting may not be required). The level of ongoing testing, based on the risk profile, may need to be agreed between the site operator and the explosive supplier.

Site geologists shall initiate retesting if entering a “green field” zone or an area that is yet to be blasted and contains geology that has not been tested for reactivity. Retesting, however, is not required if the indicators as detailed in Section 4 are absent from the geology of the specific zone/area.

The minimum recommended number of samples is 12. Samples are to be selected based on records of core sampling and mineral analysis or ore body mapping.

7.4.2 Existing site – Reactive ground site

For sites that have shown evidence of reactivity (through either incidents or positive reactive ground testing results), a suitable ongoing sampling program shall be set up and included in site operating procedures. At a minimum, retesting shall occur every 12 months. A qualified site geologist shall select 12 samples in order to try and obtain the most reactive samples.



The aim of this testing is to ensure that the recommended products are still sufficient to prevent a reaction and hence maintaining the basis of safety.

Table 2 -- Frequency of Sampling Summary – Based on a Risk Profile of the Site

Type of Site or Scenario	Frequency of Testing	No. of Samples
Screening at “Green Field” sites:	Before commencing development in the new area.	Minimum of 12. (Number of samples to be determined between Explosives Provider and Customer.)
<ul style="list-style-type: none"> • New site lease that has never been excavated. 		
<ul style="list-style-type: none"> • Excavation commencing in a new development on an existing site. 		
<ul style="list-style-type: none"> • Mining commencing in an area of untested geology (identified by on-site geology). 		
<ul style="list-style-type: none"> • Where this Code has not been applied. 		
Ongoing testing at:		
<ul style="list-style-type: none"> • Non-Reactive sites (non-inhibited products in use). 		
<ul style="list-style-type: none"> • Reactive ground sites (inhibited products in use, no change in geology). 	Annual testing.	Minimum of 12.



SECTION 8. Reactive Ground Testing and Product Selection

8.1 Introduction

In order to identify reactive ground and to determine the effectiveness of inhibited product in preventing reactions, laboratory scale test methods have been developed to simulate the conditions in the field. There are two separate steps that need to be considered when discussing testing procedures:

- Reactivity Screening – this test method is used to identify whether ground samples are reactive with ammonium nitrate.
- Product Selection Testing – this test method is used to confirm whether an inhibited product is suitable for a specific reactive application.

It may also be appropriate on some sites to carry out additional large scale testing for reactivity and to ensure the ongoing suitability of selected bulk products for use in reactive ground. This form of testing is also suitable if laboratories are not readily available and may give customers the opportunity to carry out their own evaluations of products under local site conditions.

8.2 Reactivity Screening

Two laboratory screening tests may be used in determining the reactivity of ground samples and in determining the suitability of explosive products to be used within the ground.

8.2.1 Isothermal Reactive Ground Test

The Isothermal Reactive Ground Test has been developed for use in screening reactive samples and for carrying out sleep time analysis. “Standard” test conditions cover blasting in normal temperature ground (ie <55oC). However if the risk assessment indicates that a higher temperature may be experienced then this temperature should be adopted as the standard.

A summary of the test method is as follows with the detailed test procedures given in Appendix 2:

- Rock samples are crushed to a fine powder.
- The rock powder is then mixed with chemically pure ammonium nitrate and a solution to simulate the by-products of sulphide rock weathering.
- The mixture is heated to and kept at 55oC (for non elevated temperature ground sites) the adopted standard temperature and monitored for exothermic reactions. For elevated temperature ground sites, the test is carried out at the maximum recorded in-hole temperature based on temperature logging and historical data, or at the maximum nominated temperature limit at the site.
- Unless a reaction is observed first, the test is run at least up to the nominated sleep time (or longer when testing inhibited explosives). If exceptionally long sleep times are required in specialised blasting applications, it may be more appropriate to use a Temperature Ramping Test (see Section 8.2.2).
- The mixture is monitored for any visual reactions (such as colour change or signs of chemical reactions such as gas liberation) and reactivity is identified by a change in temperature, detected using thermocouples with continuous temperature logging.
- This test method is capable of picking up exotherms greater than 2oC above the background temperature. Samples that exhibit an exotherm greater than 2oC are classified as reactive and require further investigation.
- Samples that exhibit a greater rate of increase while ramping up to the test temperature need to be investigated further.



The experimental conditions have been selected based on the following reasoning:

- Temperature at 55°C –the location specific standard temperature; by definition, this is the maximum temperature anticipated under non-elevated temperature operational conditions.
- Finely ground particles – this allows for the presence of very fine particles generated during the drilling process.
- Ammonium nitrate – chemically pure ammonium nitrate is used as the additives in other grades of ammonium nitrate, particular those in porous prilled ammonium nitrate, may have an effect on the test method.
- Weathering by-product – research has shown that the chemical by-products of weathering contribute to the reactivity of the ground.
- Sleep time – four times the anticipated sleep time has been selected as a reasonable margin of safety to allow for possible abnormal blasting situations (eg misfires) and to compensate for a necessarily limited degree of rock sampling. This may be adjusted based on a detailed risk assessment of actual site conditions and practices.

In carrying out the “Isothermal Reactive Ground Test” there are a number of precautions that must be taken:

- Samples must not be dried prior to testing as drying presents an opportunity for premature air oxidation.
- A standard milling time shall be adopted to ensure that samples are not oxidised before testing.
- Once samples have been milled, they shall be tested for reactivity immediately or stored appropriately.
- Milled samples that are not used immediately shall be stored in vacuum-sealed bags or under nitrogen and stored in a freezer. Where possible, unused samples shall be kept in rock (uncrushed/milled) form.

A reactive response is identified by an increase in temperature from the base line test temperature. As outlined in the definitions (Section 1.2), the “reactivity” of a sample or the ease at which a sulphide/nitrate reaction occurs is related to the induction time. For example, a series of samples can be ranked as “most reactive” to “least reactive” under the same test conditions according to the time taken to react with the “most reactive” sample reacting first. The “intensity” of a reaction is related to the size of the exotherm and does not relate to the induction time. The intensity may be a reflection of the overall sulphide content but the size of the exotherm cannot be relied upon to classify a sample as more or less reactive.

8.2.2 Temperature Ramping Test

The Temperature Ramping Test may be a useful test for efficiently identifying samples which could be reactive from a large number of samples or when the sleep time of the explosive is too long for the isothermal method to be carried out on a large number of samples.

Sample preparation is as for the “Isothermal Reactive Ground Test”. Testing is carried out by subjecting the prepared sample to a linear temperature increase over time until a reaction occurs. Samples which exhibit exothermic reactions at temperatures below the normal decomposition temperature of ammonium nitrate would be considered reactive. While this test does not give a direct measure of induction time, samples can at least be ranked according to the onset temperature of the exothermic reaction (the most reactive samples having the lowest onset temperature). The most reactive samples can then be checked for induction time in the isothermal test.



A detailed test method for the Temperature Ramping Test is not provided in this Code as the Test is not widely used. AEISG Inc will need to endorse the details of any proposed Ramping Test Method and the intended interpretation of results before it can be adopted into the Code.

8.3 Product Selection Test

Once reactivity screening tests indicate any sign of reactivity, rock samples, including the most reactive samples identified, are retested against the intended explosive to be used in the ground. This must be done to determine the most appropriate formulation that is required to prevent an exotherm and its suitability for the blasting application. (Note: Chemical inhibition and physical separation are the only options for loading explosives in reactive ground. Chemically inhibited explosives products offer the lowest risk, are industry best practice and hence the preferred option.)

The “Isothermal Reactive Ground Test” is repeated replacing the ammonium nitrate with the inhibited bulk explosive. A range of bulk products may need to be assessed to determine which one is suitable for use in the reactive ground so that adequate sleep time is achieved. Each explosive provider will use their own methods (formulation, ingredient selection and inhibitor levels) of ensuring that their products are suitable for the reactivity conditions under investigation.

8.3.1 Sleep Time Testing

Product selection is closely linked to sleep time and products selected for use in reactive ground must also have an appropriate sleep time. Sleep time testing involves testing reactive ground with inhibited product using the “Isothermal Reactive Ground Test” for a period equivalent to four times the required product sleep time, up to a maximum test period of one month. Should the product be required to sleep for greater than one week (ie laboratory test for one month) then the test period may be increased accordingly.

For existing reactive ground sites, the maximum recommended sleep time in reactive ground is one week (ie laboratory test for one month). Beyond this period, a risk assessment involving the explosives provider and the customer should be carried out. There may be a requirement to advise the outcome of the risk assessment to the appropriate regulator.

8.3.2 Additional Product Testing

As well as using “Isothermal Reactive Ground Test” for product selection with an appropriate sleep time additional product testing must be carried out should any of the following changes occur:

- Use of a new or different bulk product especially from a new supplier.
- Raw material sourcing or significant formulation changes of the existing bulk product.
- Increases in the required product sleep times.
- Changes to site geology.
- Changes in ground temperatures.

8.4 Large Scale Testing

For some sites and as part of on going reactive ground management, testing in the form of the on bench Bucket Tests may be appropriate. In the Bucket Test several kilograms of rock are combined with the inhibited product and left on bench for an extended period.

The Bucket Test is in effect a large scale version of the Isothermal Reactive Ground Test Method **but without** any temperature control. It can be used to confirm the results of laboratory scale testing.



The method involves using several kilograms of sample rock which is stored in a bucket on the bench, where it is exposed to ambient temperatures (ie day and night temperatures) over an extended period. Details of the Test are given in Appendix 3. In carrying out the Test appropriate measures must be taken to ensure the security of the bucket and its contents as per the relevant Explosives Regulation.

The Bucket Test offers a number of advantages:

- Enables the on site testing with fresh ground samples from known locations and with site manufactured explosive products.
- Is visible to the site operator.
- Larger sample size gives the ground more opportunity to react.
- The last evaluation step prior to introduction of a bulk product to a site.

The Bucket Test, using ANFO and if carried out regularly, may be used as a method of monitoring the ongoing “reactivity” across a site.

8.5 Recommended Testing Agencies

The test methods outlined above for screening potentially reactive samples and selecting suitable inhibited products should be carried out by the following groups:

- Explosives providers with the appropriate laboratories and trained personnel.
- Site and independent laboratories with the appropriate equipment and trained personnel. These laboratories should only carry out the initial screening test using ammonium nitrate as the use of fully formulated explosives within their laboratories may introduce hazards which they are not familiar with or are in breach of relevant Explosive Regulations. The performance of laboratories must be assessed annually to ensure compliance with this Code.

Within the laboratory appropriate precautions must be in place to ensure the safety and security of ammonium nitrate and explosives at all times. In some jurisdictions the laboratory may need to be approved and licensed to handle ammonium nitrate and explosives by the relevant statutory authority.



SECTION 9. Elevated Temperature and Reactive Ground Blasting

Where a site is known to have both elevated temperature and reactive ground conditions, products that are suitable for withstanding the elevated temperature conditions in addition to the level of reactivity must be used. All the precautions as detailed in Sections 5, 6, 7 and 8 of the Code must be applied. Greater vigilance in determining the “reactivity” of the ground is required due to the high ground temperatures promoting the nitrate/sulphide reaction.



SECTION 10. Selection of Accessories

Initiating explosives used in elevated temperature and/or reactive ground conditions must be compatible with the high explosives they are to be used with and the environment in which they are to be used. Relevant technical data sheets should be consulted and the suitability or otherwise of the initiating explosives discussed with the supplier.

As a guide the temperatures at which some common initiating explosives melt and start to become unstable are detailed in the following table.

Explosive	Melting Point
HMX	275°C
HNS	318°C
Pentolite	70°C
PETN	141.3°C
RDX	204°C
TACOT	378°C
TATB	350°C

Some initiating explosives, particularly boosters, may contain nitrates and therefore appropriate precautions as detailed in this Code must also be taken when used in reactive ground. Booster formulations must be enclosed in a suitable packaging capable of withstanding the chemical environment and temperatures encountered in the application of use. This can range from plastic coating, treated cardboard, tin cans and other metal containers or high temperature plastics.



SECTION 11. Treatment of Misfires in Reactive and/or Elevated Temperature Ground

Misfire procedures need to take into account the increased risk of blasting reactive and/or elevated temperature ground and in particular, the increased exposure time of products to elevated temperature and/or reactive ground in the event of a misfire.

A risk management process is required in both the event of a misfire and the instance that sleep times are extended beyond the recommended values. In the event of a misfire, the explosives provider shall be involved in the misfire investigation. The customer shall contact the explosives provider to inform them of the situation. Details of the product used in the area will be provided and a reassessment of the recommended product range may be required.

In the first instance it is critical that for any misfire:

- Personnel on bench be minimised to only those directly involved with the management of the misfire.
- An exclusion zone be put in place around the misfire area for activities not directly associated with the recovery of the misfire.
- An Emergency Evacuation Plan be developed, and communicated to all personnel involved in managing the misfire, covering what should be done should a reaction be observed during the recovery of the misfire.
- The charging of associated patterns, which are hot/reactive and whose firing could negatively impact on misfire recovery proceedings, immediately cease.

11.1 Misfires in Elevated Temperature Ground

Standard misfire procedures are applicable unless explosive exposure time is likely to go beyond the recommended sleep times. Additions to standard misfire procedures would include:

- Water may be used to wash out elevated temperature holes though it must be noted that water temperature may become hot with exposure to hot ground conditions.

11.2 Misfires in Reactive Ground

Due to the importance of sleep time minimisation, timely action and prioritisation of misfire activities is essential, including, but not limited to:

- Location of misfired holes and refiring immediately.
- Consideration of washing out (with an appropriate approved material – see comments below).
- Excavation within rated product sleep time.

Timely action is particularly critical if physical separation (ie liners) is used as there is a higher risk of uninhibited product coming into contact with potentially reactive surfaces. Limitations on sleep time for initiating systems must also be considered.

Standard misfire procedures are applicable unless explosive exposure time is likely to go beyond the recommended sleep times. Additions to standard misfire procedures would include:

- Observers to monitor for any abnormal behaviour such as smoke or heat haze.
- Water must not be used to wash out holes in reactive ground due to the potential of accelerating reactivity and to spread nitrates to other areas while diluting any inhibitor if present. If washing out is required, an inhibited solution (ie 5% urea solution) should be used.



SECTION 12. Premature Reaction/Detonation Events in Reactive and/or Elevated Temperature Ground

Whilst the measures described in the Code are designed to minimize and mitigate the risks associated with blasting in reactive and/or elevated temperature ground, the possibility still exists that a premature reaction/detonation event may occur. This Section of the Code provides some guidelines to assist with the management of such an event.

In the first instance, it is critical that all personnel evacuate the area and the incident is reported immediately to senior mine officials, the explosives provider and the relevant statutory authorities.

Subsequent management of the event should take into consideration the following:

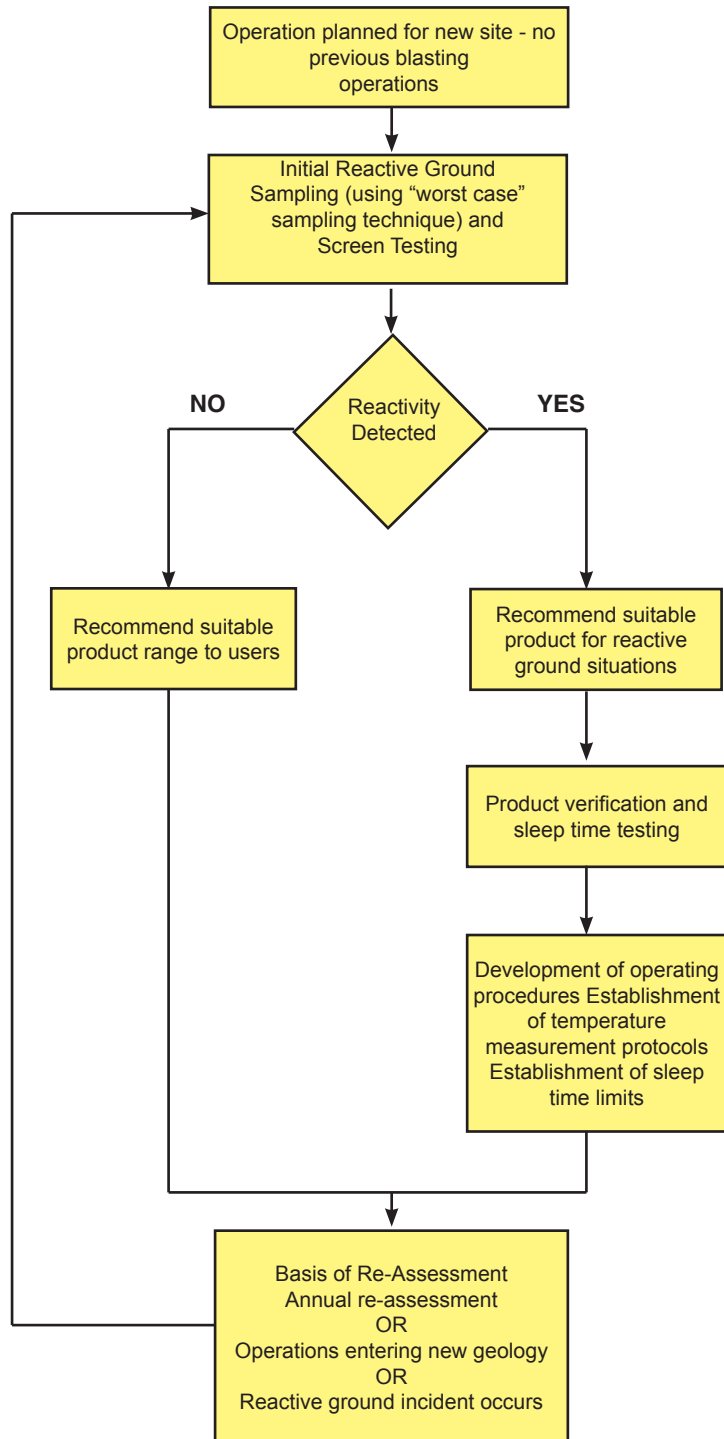
- Setting up and maintaining an appropriate exclusion zone.
- Identifying from a safe distance the detonated/fuming/reacting blast hole/s.
- Constantly monitoring the complete loaded pattern and recording any unusual events and times these occur.
- Prohibiting re-entry until any signs of chemical activity have completely ceased.
- Establishing an agreed plan for tie-in and firing of the loaded portion of the blast pattern taking into consideration:
 - The need to minimise the number of personnel and their duration on the pattern.
 - An Emergency Evacuation Plan which all parties clearly understand.
 - Ensuring all personnel have means of rapid egress from the blast pattern (and immediate area) at all times.
 - Utilising a simple design to minimise the time to tie-in and to minimise opportunity for on-bench confusion.
- Taking steps to tie-in and fire the pattern as soon as practicably and as safely as possible.
- Ensuring that, whilst ever there are personnel on the blast pattern, they are in radio contact with at least one observer located at a safe distance from the pattern. The observer must immediately advise by radio of any unusual observations and the pattern immediately evacuated.
- It is highly recommended that detonating cord NOT be used for surface tie-in.
- The tie-in sequence must take into consideration the location of the detonated/reacted hole/s. Initially it is recommended that a buffer be set up around these hole/s whilst the remainder of the pattern is tied-in. The buffer area should be tied in at the latest possible time before firing. Depending on reactivity level of the ground, affected holes may not to be tied in. In case they are not tied in, refer to the Misfire section of the Code.
- Where signal tube based surface connectors are used, their tie-in should be sequenced in a manner that ensures the shot-firer is walking away from tied-in holes and thus can distance him/herself from possible multiple-hole initiation.
- Video record the blast from a safe vantage point that allows a reasonable post-blast analysis for misfires
- Conduct a thorough post blast inspection of the muck-pile for potential misfired blast holes.



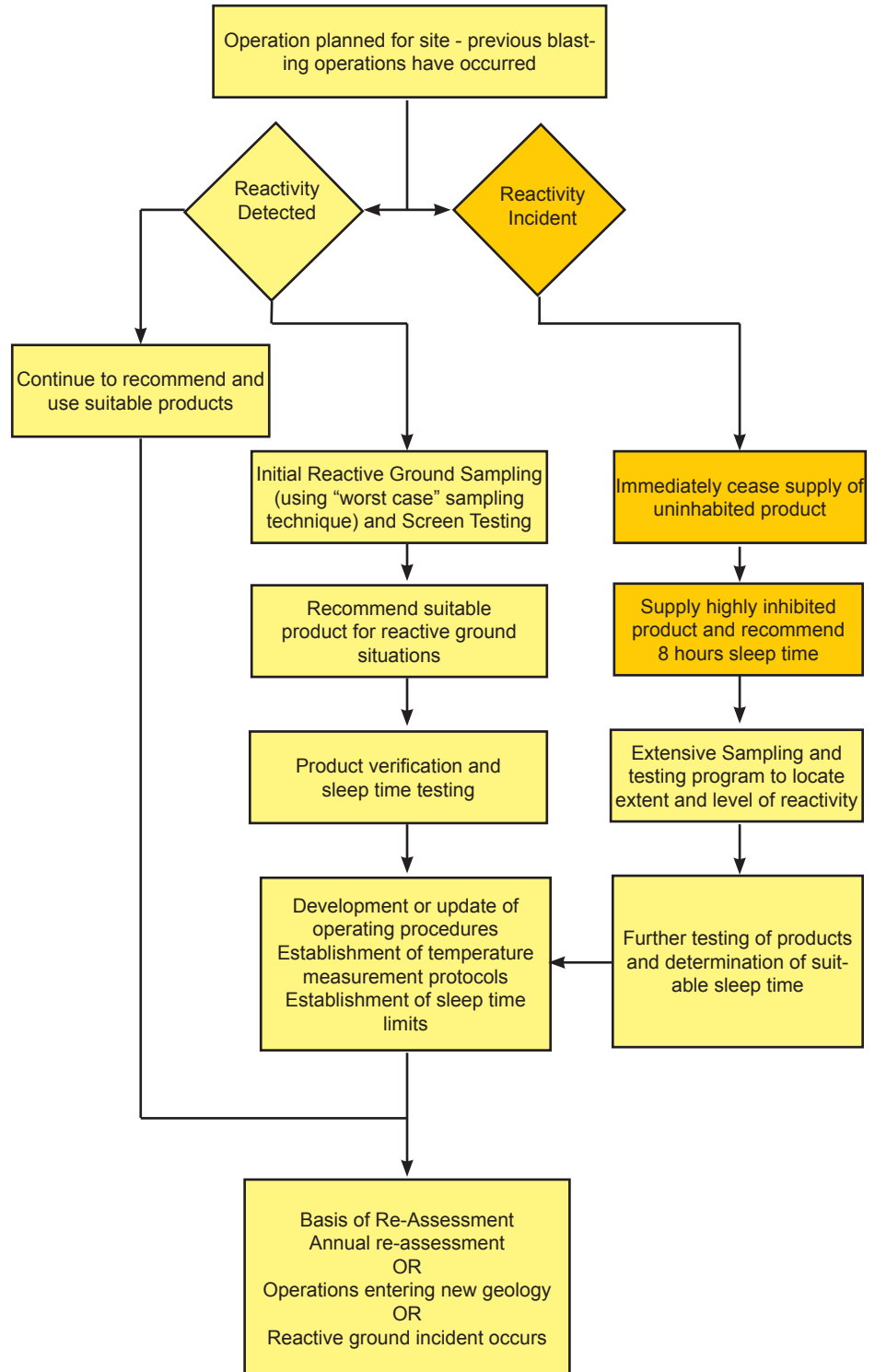
SECTION 13. Activity Sequence – Management Flowcharts

The following flowcharts are designed to show the logic in assessing a site which may have potentially elevated temperature and/or reactive Ground conditions.

13.1 Identification and Analysis for the Risk of Reactivity at Green Field Sites



13.2 Identification and Analysis for the Risk of Reactivity at Existing Sites





SECTION 14. Training

Based on this Code and other relevant documentation a comprehensive training package will be developed for all involved in the handling and charging of explosives in elevated temperature and/or reactive ground conditions by the operator or owner of each affected site. The training will ensure that each employee and contractor has a full and comprehensive understanding of:

- ④ ➤ Standard operating procedures developed for the handling and charging of explosives in elevated temperature and/or reactive ground conditions.
- ④ ➤ Site specific procedures
- ④ ➤ Job responsibilities.
- ④ ➤ Hazards associated with the handling and charging of explosives in elevated temperature and/or reactive ground conditions.
- ④ ➤ The use and ongoing maintenance of personal protective equipment (PPE). In some application specialised PPE may be specified for the employee to use.
- ④ ➤ Emergency procedures especially where explosives exhibit any violent reaction during charging.

All training will be documented and a process of verification and validation of competencies established. Re-training is to be carried out on a regular basis the frequency of which must be established on a site by site basis taking into consideration the site complexities of dealing with reactive and elevated temperature ground.



APPENDIX 1. Summary of Regulations.

Summary of the main points that are raised in the various State Acts and Regulations regarding hot and / or reactive ground:

- **ACT, South Australia, Victoria** – hot and high temperature ground is defined as for the Australian Standard AS2187.2 and blasting is to be carried out in accordance with this Standard.
- **Queensland** – provides additional requirements such as:
 - ◇ SSE is responsible for ensuring that a risk management process to identify hazards must be carried out before explosives are introduced to a site (includes high temperature and reactive ground).
 - ◇ SSE responsible for ensuring there are procedures in place to limit the risk of heating and uncontrolled firing of ground due to temperature and/or reactivity and that procedures include how to get to a safe location in the event of an incident.
- **WA** – provides additional requirements such as:
 - ◇ Hot material is anything above 57oC.
 - ◇ Procedures must be in place for how to manage hot and / or reactive ground.
 - ◇ Site managers are responsible for informing the district inspector when they are blasting in hot and /or reactive ground.
 - ◇ The district inspector may request additional management measures be used to minimise the risk (and these need to be adopted by the site operator or face penalties).
- **NSW, NT, Tasmania** – no information found regarding these issues

Extracts from relevant Regulations

Queensland

Mining and Quarrying Safety and Health Regulation – 2001 – Subdivision 2 – Blasting Procedures: Chapter 2 – Ways of achieving an acceptable level of risk. Part 7 – Hazardous substances and dangerous goods. Division 2 Explosives 17.

69 Identifying interaction hazards before explosives are used

- (1) The site senior executive must ensure that, before explosives are used at the mine, a risk management process is carried out to identify the hazards that may arise or interact from the use.
- (2) Without limiting subsection (1), the process must consider the following-
 - (a) ground at elevated temperature;
 - (b) radiation;
 - (c) reactive ground;
 - (d) lightning;
 - (e) extraneous electricity;
 - (f) sympathetic detonation;
 - (g) the triggering of secondary dust or gas explosions;
 - (h) unstable ground;
 - (i) energy originating from friction, impact, static and heat;
 - (j) unusual applications.

71 Blasting in Hot Material

- (1) This section applies if blasting is carried out at a mine in material that is at least 55°C or in known, or potential, reactive ground.



Example of reactive ground - Ground containing sulphides that oxidise easily.

- (2) Before the blasting is carried out, the site senior executive must ensure the mine has a written procedure or standard work instruction to ensure-
- (a) heat induced initiation does not happen before firing; or
 - (b) each person involved in loading or firing the blast has time to reach a safe place before heat induced initiation happens.

Victoria

Dangerous Goods (Explosives) Regulations 2000 – No. 61/2000 – Consolidated to 1 Jan 2006. Part 7 – Use of Blasting Explosives. Division 6 – Special Blasting Operations

759. Hot material and high temperature blasting

- (1) A shotfirer must ensure that when blasting in hot material or carrying out high temperature blasting, all operations are performed in accordance with the relevant provisions of AS2187.2.
- (2) In this regulation, “hot material” and “high temperature blasting” have the same meanings as they have in AS2187.2.
- (3) If any conflict between the requirements of this regulation and any other regulation in this Part arises, the requirements of this regulation prevail.

South Australia

Occupational Health, Safety and Welfare Regulations 1995 – No. 12 of 1995 – Consolidated to 1 July 2005. Part 5 Hazardous Work. Division 5.12 Mining Work

5.12.47 Blasting in hot material.

Any blasting in hot material or high temperature blasting must be conducted in accordance with clauses 10.6 and 10.7 of AS 2187 Part 2.

Western Australia

Mines Safety and Inspection Regulations 1995 – Consolidated to 1 July 2005. Part 8 – Explosives. Division 2 – General

8.54. Blasting in hot material

- (1) In this regulation — “hot material” means material having a temperature exceeding 57 degrees Celsius.
- (2) When blasting is to be undertaken in hot material, any person involved in that blasting must use explosives, adopt charging and firing practices, and take precautions in accordance with the relevant procedure.
- Penalty: See regulation 17.1.
- (3) The manager of a mine must notify the district inspector of any blasting that is to be undertaken in hot material at the mine.
- Penalty: See regulation 17.1.
- (4) The district inspector may specify additional precautions that must be taken when the blasting referred to in sub-regulation (3) is undertaken.
- (5) A person involved in blasting in hot material at a mine must take any additional precautions specified by the district inspector under sub-regulation (4).
- Penalty: See regulation 17.1.



8.55. Blasting in oxidising or reactive ground

(1) When blasting is to be undertaken in oxidising or reactive ground, any person involved in that blasting must use explosives, adopt charging and firing practices, and take precautions in accordance with the relevant procedure.

Penalty: See regulation 17.1.

(2) The manager of a mine must notify the district inspector of any blasting that is to be undertaken in oxidising or reactive ground at the mine.

Penalty: See regulation 17.1.

(3) The district inspector may specify additional precautions that are to be taken when the blasting referred to in sub-regulation (2) is undertaken.

(4) A person involved in blasting in oxidising or reactive ground at a mine must take any additional precautions specified by the district inspector under sub-regulation (3).

Penalty: See regulation 17.1.

Australian Capital Territory

Dangerous Substances (Explosives) Regulations 2004 – No 10 – Consolidated to 21 Oct 2005 – as in force 21 Oct 2005. Chapter 2 Explosives Generally – Part 2.9 Using Explosives. Division 2.9.12 Special blasting operations.

248 Hot-material and high-temperature blasting

(1) This section applies if blasting is to be carried out in hot material, or at high temperature, within the meaning of AS 2187.2.

(2) Blasting must be carried out in accordance with the standard.

(3) If the requirements of this section and any other section in this part are inconsistent, the requirements of this section prevail.



APPENDIX 2. Isothermal Reactive Ground Test.

This test is used to assess rock samples for exothermic reactivity with ammonium nitrate. The general aim of the test is to measure the induction time of the reaction at a constant temperature. The test conditions are intentionally designed to mimic a 'worst likely case' of rock particle size, temperature, exposure time and the presence of by-products from oxidative weathering of the rock.

The test mixture consists of finely powdered rock, ammonium nitrate and a solution of ferrous and ferric sulphates.

The term 'isothermal' is used to indicate that rock is being tested in an environment with a constant and pre-determined background temperature. Exothermic events are signified by an experimentally significant increase in the temperature of the sample mixture beyond that of the background.

For normal temperature blasting applications, the background temperature to be used is 55°C and the test is run for a minimum of 48 hours but at least up to the 'sleep time' used in the blasting application (the occurrence of an exothermic reaction at any time before that period terminates the test).

For elevated temperature ground, the same test is run but the test temperature is at least equal to the highest in-hole temperature, or at the maximum nominated temperature limit at the site. If the mine changes its nominated maximum temperature then the isothermal testing must be repeated at this new temperature.

1. Equipment Required.

- Aluminium blocks – these are metal blocks with holes drilled to accommodate the glass tubes and distribute heat to the tubes evenly. The holes must be 75mm deep with a 15mm radius rounded bottom, 30mm diameter. If there is more than 1 hole per block, the holes must be separated by a minimum of 10mm between the walls of the holes. The blocks may also feature a shallow depression on the top to capture any overflow from vigorous reactions.
- Ammonium nitrate – technical grade pure.
- Data logger – any data logger able to log temperatures at a rate of at least one data point per 30 seconds. It should be accompanied by a computer system to process the data.
- Dry block heater – an electrically heated tray able to heat the aluminium blocks uniformly and keep them at a pre-set temperature in the range 10 - 200°C and to maintain that temperature to $\pm 1^\circ\text{C}$.
- Ferric sulphate – $\text{Fe}_2(\text{SO}_4)_3 \cdot 9\text{H}_2\text{O}$ technical grade or better.
- Ferrous sulphate – $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ technical grade or better.
- Jaw crusher – Any crusher allowing fist-sized rocks to be broken into pieces of suitable size for the pulverising mill.
- Pan balance – any electronic pan balance may be used provided it can weigh at least 300g to an accuracy of 0.2g or better.
- Protective clothing and equipment – safety glasses, rubber gloves, ear muffs or plugs, disposable dust mask and face visor.
- Pulverising mill – A mill with a capacity of 600 – 1000cc and capable of milling samples from the jaw crusher down to a sieve size of ~ 250 micron within 60 seconds. A commercially available mill that meets these requirements is the Labtechnics LM1-P.
- Reaction vessels – glass centrifuge tubes of approximately 50ml capacity, 26mm ID neck and wall thickness of 2mm.
- Rubber stoppers - the stoppers fit into the glass tube have two 2mm diameter holes, one for a thermocouple probe, the other for pressure release.
- Sample bags – thermally sealable plastic vacuum bags able to hold at least 200g of powdered rock.



- Sieve – a stainless steel sieve with aperture size of 250 micron. The sieve should be inspected prior to use to ensure the mesh is not damaged.
- Vacuum bag sealer – commercially available household vacuum bag sealers are suitable for this test.

2. Test method

STEP	KEY POINTS	SAFETY/QUALITY
Rock crushing	Check that the rock sample can fit into the jaw crusher. If required, use a hammer to break the whole rock into smaller pieces first.	Wear safety glasses, hearing protection and full face visor.
	Ensure the collection tray for the crushed rock is clean, dry and in place.	
	Feed rock into the crusher. Activate the crusher and allow enough time for all sample to be consumed. Collect a minimum of 200g of crushed rock.	The sample should be milled and bagged within 15 minutes of crushing to guard against premature aerial oxidation of sulphides.
Rock milling	Ensure the internal surfaces of the mill are clean and dry.	
	Load the mill with 200g of freshly crushed rock and mill for not more than 1 minute.	The short milling time will help to minimise aerial oxidation of sulphides.
Sieving	Remove the powdered rock from the mill. Sieve it using a 250-micron sieve and collect the material that passes through in a heat-sealable plastic vacuum bag.	
Milled sample storage	Immediately vacuum seal the bags for storage. The bagged samples may also be refrigerated for further protection against aerial oxidation, but this should not be necessary if the vacuum seal is effective.	The integrity of the vacuum and seal should be verified by visual inspection of the bags.
Weathering by-products preparation.	Dissolve 3g of $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ in 22g distilled water.	
	Dissolve 5g of $\text{Fe}_2(\text{SO}_4)_3 \cdot 9\text{H}_2\text{O}$ in 13g distilled water.	
	Combine 2g of the FeSO_4 solution with 2g of the $\text{Fe}_2(\text{SO}_4)_3$ solution in a small glass vial.	The resulting 4g of 'weathering by-products' solution from this step is sufficient for 1 test.



Preparation of reactivity test mixture	In a 100ml glass beaker, combine 18g of milled rock sample, 18g of ammonium nitrate and 4g of the weathering by-products solution.	Re-seal the vacuum bag immediately after taking the sample.
	Mix the contents with a spatula and immediately transfer the mixture to the glass reaction vessel.	The test steps following this must be done without delay since reaction may start at any time.
	Insert a 2-holed rubber stopper into the glass vessel.	
STEP	KEY POINTS	SAFETY/QUALITY
Temperature probe set-up	Place the reaction vessel containing the test mixture into an aluminium block on the Dry Block Heater.	The Dry Block Heater is to be set up in a well ventilated fume hood.
	Insert a thermocouple through the rubber stopper such that the tip of the thermocouple sits in the test mixture.	
Data logger set up	Configure the data logger to log one data point every 30 seconds.	Refer to the operating instructions of the data logger.
Testing the rock sample	Set the temperature of the Dry Block Heater to the appropriate background temperature.	For regular blasting applications, use 55°C. For testing related to ground at elevated temperatures, the test should be run at a temperature equal to or greater than the highest temperature actually measured at the site concerned
	<p>Allow the sample to reach the pre-set background temperature and continue the test by monitoring the sample temperature for a run time at least equal to the 'sleep time' of the explosive in the application.</p> <p>The test is terminated if an exothermic reaction occurs or the run time is reached without reactions occurring.</p>	The minimum run time for the isothermal test must be 48 hours, even if the 'sleep time' in the field is less than this



3. Interpretation of Results.

An exotherm that qualifies a sample as 'reactive' in this test has the following characteristics:

- It is at least 2°C above the background temperature in the temperature/time trace of that particular sample.
- It shows both a rise from, and a return to the background temperature when the reaction is completed.

(Note: the background temperature is best measured just before and after the exotherm to exclude fluctuations caused by experimental artefacts such as physical movement of the thermocouple, changes caused by air conditioning, etc.)

- Reactions may be accompanied by visible signs, such as bubbling, and/or the generation of brown nitrogen oxides.

If a reaction occurs during the period that the sample is still being brought up to the isothermal set point, an exotherm is harder to distinguish. Nevertheless, a reaction would be indicated by physical signs such as bubbling and/or brown NO_x fumes, and/or a temperature rise that was faster than in other (non-reacting) samples being done at the same time. In such cases, it may be advisable to re-test at a lower set-point temperature, in order to delay the onset of the exotherm to a time when a constant background temperature has been established.

Mixtures that show visible signs of reaction but indefinite (<2°C) thermal responses are classed as marginal. Depending on the cause it may be advisable to prepare fresh samples and re-test, or to perform sulphide analyses to check the amount present. Marginal results may be due to very low levels of sulphide, premature aerial oxidation of the sample or reactions other than sulphide oxidation (eg carbonates reacting with acid) etc.



APPENDIX 3. Bucket Test for Reactive Ground.

The Bucket Test is designed as a large scale test to determine whether or not selected ground samples are reactive to ammonium nitrate based explosives. The Test is carried out by mixing equal weights of explosive and ground in a 20l plastic bucket and examining the contents on a regular basis to detect whether or not a reaction has occurred.

The Test may be affected by the prevailing ambient conditions at the time the Test is carried out and this may be needed to be taken into consideration when interpreting the outcomes of the Test.

The bucket and its contents must be placed in a remote location and access to the site restricted to within 100m as, for safety reason, it must be assumed that a violent reaction and detonation may occur during the test. Where multiple tests are being carried out buckets must be separated by at least 5m.

1. Test Method:

The test method is as follows:

1. The selected ground sample is crushed to 5mm particle size in a jaw crusher, then to sub-2mm particle size in a roll crusher. 2kg of crushed ground is required.
2. 1kg of ground is placed in a 20l plastic bucket. 54ml of water is added and thoroughly mixed into the ground with a flat stake. The amount of water added at this stage is half the total amount required for the Test. The total amount of water used is 5.4% w/w based on the ground mass (ie 108ml of water).
3. 2kg of the explosive to be tested is added evenly on top of the ground.
4. The remaining 1kg of ground and 54ml of water is added and thoroughly mixed in with a flat stake until a homogenous mixture is achieved.
5. Breather holes are placed through the side of the bucket and the lid placed on the bucket to protect the contents from the weather.
6. The bucket is inspected on a regular basis to determine whether any reaction between the explosive and the ground has occurred. Inspection should be carried out at six regular intervals in the first 24 hrs; then three times per day for the remainder of the first week; and thereafter twice daily until the test is concluded.

2. Precautions:

The buckets and their contents must be placed in a remote location with access restricted to within 100m. If there are any signs of reaction as indicated by the evolution of gases/fumes the site must not be entered or immediately evacuated until at least two hours after all signs of reaction have ceased.

The generation of orange coloured fumes indicates that a violent reaction is underway and evacuation from the site must be immediate.

When inspecting buckets it is recommended that this be carried out by two people – one carrying out the inspection of the buckets and the other as an observer watching for the start of any reaction. Unless adequate lighting is available at the site all inspections should be carried out in day-light hours.



3. Interpretation of Results.

A reaction between the explosive and the ground is deemed to have taken place if:

- There are obvious signs that an explosion has occurred.
- The bucket has melted or caught fire.
- Evidence of charring and discoloration within the contents of the bucket.
- Any signs of the generation of fumes and/or steam from the bucket.

It is recommended that the Test be carried out in triplicate for each ground sample. Generally, the Test is carried out with ANFO over seven days as a first indication as to whether or not the ground is reactive. Should a reaction occur in any of the triplicate samples the ground is deemed to be “reactive” and appropriate precautions as detailed in this Code must be adopted in charging blast holes within the ore body.

If a decision is made to use an inhibited explosive within the ore body then the test should be repeated on the selected inhibited explosive with those ground samples, which reacted with ANFO, over a period of at least 21 days.



Australian Explosives Industry And Safety Group Inc.