



SAFEX International

Good Practice Guide: Storage of Solid Technical Grade Ammonium Nitrate

by

**International Industry Working
Group on Ammonium Nitrate**

**SAFEX Good Explosives Practice Series
GPG 02 rev02**

SAFEX Good Explosives Practice Series

The Good Explosives Practice (GEP) initiative is an attempt to capture the expertise that is still available in our business. This expertise is under threat due to influences such as the transfer of classical processes to newer technologies; the concentration of companies inside the explosive business; the retirement of experienced colleagues grounded in the fundamentals of explosives; and the shorter time explosives practitioners have available to acquire an appreciation of the basis of safety in their operations.

To assess hazards and risks systematically without such a basic understanding of explosives practices is almost impossible.

The GEP approach will hopefully grow to a database of good practices in our business over time and address this need.

SAFEX regards all Good Practice Guides as dynamic documents which should be updated regularly. Therefore, we invite anyone to bring to our attention any errors, omissions, enhancements or suggestions for inclusion in subsequent editions. This can be done by contacting the Secretariat at secretariat@safex-international.org

Good Practice Guide for the Safe Storage of Solid Technical Grade Ammonium Nitrate

Prepared by:
International Industry Working Group on Ammonium Nitrate

SAFEX Good Explosive Practice Series GPG 02 rev02

Published: March 2014

The information contained in this document is the result of the collective efforts of the companies listed above. None of the members of the Working Group, nor their respective individual representatives, nor their corporate affiliates, nor SAFEX International shall be liable or responsible in any way whatsoever for any loss or damage arising from the use or misuse by anyone of the contents of this document and all such liability or responsibility is expressly disclaimed.

CONTENTS

1. INTRODUCTION	4
2. SCOPE	5
3. DEFINITIONS	6
4. SAFETY MANAGEMENT SYSTEMS	10
4.1. <i>Safety Policy</i>	<i>10</i>
4.2. <i>Plan Framework</i>	<i>10</i>
4.3. <i>Training</i>	<i>10</i>
4.4. <i>Procedures</i>	<i>11</i>
4.5. <i>Emergency Response</i>	<i>12</i>
5. REGULATORY REQUIREMENTS	12
6. SITE DESIGN, CONSTRUCTION & MANAGEMENT... ..	13
6.1. <i>General Requirements</i>	<i>13</i>
6.2. <i>Open Air Compounds</i>	<i>16</i>
6.3. <i>Freight Containers for Storage</i>	<i>16</i>
6.4. <i>Silos or Bins</i>	<i>17</i>
6.5. <i>Buildings</i>	<i>18</i>
6.6. <i>Storage of Large Amounts of TGAN at Mine Sites</i>	<i>18</i>
6.7. <i>Fire Fighting Considerations</i>	<i>19</i>
6.8. <i>Contaminated TGAN Storage</i>	<i>20</i>
7. LOCATION OF STORAGE FACILITIES	21
7.1. <i>General</i>	<i>21</i>
7.2. <i>Risk-Based Approach for Siting and Layout</i>	<i>21</i>
8. OPERATION OF STORES	22
8.1. <i>General Considerations</i>	<i>23</i>
8.2. <i>Packaged Stores</i>	<i>25</i>
8.3. <i>Bulk Stores</i>	<i>25</i>
9. SECURITY REQUIREMENTS	25
10. ACKNOWLEDGMENTS	26

APPENDICES

A. STORAGE FACILITIES LOCATION	27
A.1. <i>Separation of TGAN Stacks, Piles and Silos</i>	<i>30</i>
A.1.1. <i>Bags and IBCs</i>	<i>30</i>
A.1.2. <i>Bulk Storage</i>	<i>31</i>
A.1.3. <i>Transient Storage</i>	<i>33</i>
A.1.4. <i>Storage Summary</i>	<i>33</i>

A.2. Estimation of Net Explosives Quantity (NEQ).....	34
A.3. Estimation of Separation Distance using the Q-D Tables	35
A.4. Estimation of Risk	35
B. RISK ASSESSMENT PROCESS	37
B.1. TNT Equivalence of Ammonium Nitrate	38
B.1.1 Chemical TNT Equivalence of Ammonium Nitrate	38
B.1.2 Explosive Yield (or Efficiency)	38
B.1.3 Recommended Overall TNT Equivalence Values	39
B.2. Net Explosives Quantity (NEQ).....	41
B.3. Risk Assessment of TGAN Stores	42
B.3.1. Risk Targets.....	42
B.3.2. Determination of Consequence	43
B.3.3 Likelihood Estimation.....	47
B.3.4. Risk Control Measures	49
B.4. Key References	49
C. SECURITY PLANS.....	50
C.1. General	50
C.2. Security Risk Assessment	50
C.3. Personnel Management.....	51
C.3.1. List of authorised persons	51
C.3.2. Staff recruitment	51
C.3.3. Maintaining the security plan	52
C.4 Site Security.....	52
C.5. Procedures.....	53
C.5.1. Control of Access.....	53
C.5.2. Movements and inventories of TGAN.....	53
D. PROPERTIES OF AMMONIUM NITRATE.....	55
D.1. General	55
D.2. Product quality	56
D.2.1. Ammonium nitrate form	56
E. HAZARDS OF AMMONIUM NITRATE	57
E.1. General	57
E.2. Fire.....	57
E.3. Decomposition	57
E.4. Chemical Reaction.....	58
E.5. Explosion.....	58
F. SAFETY DATA SHEET FOR AMMONIUM NITRATE ..	59

1. INTRODUCTION

This document was developed by the global manufacturers of ammonium nitrate to provide guidelines for the storage of Technical Grade Ammonium Nitrate (TGAN) at manufacturing, distributors' and end-user sites (see Section 3, Definitions).

Ammonium nitrate (AN) is a product manufactured and used in increasingly significant quantities, both in the agricultural industry as fertiliser and in the mining industry as an explosives precursor. Due to its chemical properties, ammonium nitrate is classified as a Dangerous Goods under the United Nations Recommendations on the Transport of Dangerous Goods – Model Regulations 16th Edition and the International Maritime Dangerous Goods Code.

TGAN (within specification) does not burn, but if exposed to elevated temperatures, for example in a fire, it will decompose emitting toxic gases. In some situations, for example under confinement and intense fire and/or with contamination a decomposing mass of TGAN can explode, and even undergo transition to detonation. Another hazard associated with this material is a detonation initiated by an intentional act, a fire, chemical contamination and/or a high velocity projectile. The probability of a detonation of pure TGAN occurring without one of these four scenarios is extremely low (See p. 47, Table B.3 Appendix B).

This document has been developed to provide guidance to organizations that store TGAN to further minimize the unlikely potential for an incident by applying prudent risk management principles and practices.

The information contained herein is to be used as a guide only. However, adherence to this code will reduce the possible consequences of an unplanned event. The values used for separation distances and TNT equivalences are based on currently available information and are subject to change. Any such changes may be incorporated into subsequent revisions.

The ultimate goal of this document is to promote safety and health of personnel, to prevent damage to property and to avoid hazards to the environment.

2. SCOPE

This document sets out the guidelines for the storage of Technical Grade Ammonium Nitrate at manufacturing, distributor, storage and end-user sites.

TGAN is covered mainly by UN Numbers UN1942 and also by UN2067; in some countries e.g. US and Canada, it is classified as Class 5.1 Dangerous Goods under the United Nations Recommendations on the Transport of Dangerous Goods – Model Regulations, 15th Edition. Classification is subject to individual national regulation but generally is in accordance with the United Nations Recommendations on the Transport of Dangerous Goods – Manual of Tests and Criteria, Fourth (Revised) Edition.

This document also addresses the storage of out-of-specification AN (which is outside UN1942) generated as a result of:

- Off-spec product from process
- Spillages during either transport or handling (at manufacturing plants, storage and end-users sites)
- Product which has been exposed to possible contamination with unknown material (for example: product returned from a customer in bags which are either unsealed or not original).

This document does not cover:

- Fertiliser grade ammonium nitrate (UN2067)
- Ammonium nitrate grades that fall under UN 1942 and with a density greater than 0.90 g/cc
- Ammonium nitrate mixtures, which are Class 1 Dangerous Goods (UN0082, UN0222, UN0331).
- Packaging and transport requirements.
- Ammonium nitrate solutions or emulsions, suspensions or gels (UN3375).

3. DEFINITIONS

Ammonium nitrate or AN: Substance which meets the classification as a Dangerous Good UN1942 and UN2067 See also the definitions for Technical Grade Ammonium Nitrate (TGAN).

Ammonium Nitrate stack configuration. In this Guide two configurations are defined:

- (i) Bags stacked to height with a vertical face to the stack
- (ii) Bags stacked to height with each layer set back from the one below to profile a stack face with a slope of at least 45° to the vertical on the relevant face.

Authorised person: A person (in addition to the authority holder) who is named in the security plan and authorised under that plan by the organisation, or where required the regulatory authority, to have unsupervised access to TGAN.

Basis of Safety: Set of guiding principles for any operation. It contains the hazards and controls for a given process, engineering standards, design standards, etc.

Bulk bags: Refer definition for IBCs.

Constant surveillance: The presence of an authorised person or the continuous monitoring by video or electronic surveillance.

Contaminated TGAN: Covers, for example, TGAN which is contaminated with materials or chemicals that are not part of the manufacturing process. It also includes contamination of product returned from off site. Note that product contaminated with organic material at a total organic content greater than 0.2% is to be treated as explosive (UN0222) and is not covered by this code.

Critical machine register: Inventory of fixed and mobile equipment, (i.e. those that can fail catastrophically) requiring a risk assessment to facilitate the development of Standard Operating Procedures (SOPs) and appropriate emergency response procedures.

Explosive Yield (or Efficiency): The explosive yield allows for the proportion of the TGAN mass that directly contributes to the explosion or detonation energy/blast effect

Hazmat: Is the abbreviation for the words "hazardous materials".

Intermediate Bulk Container (IBC): Portable packaging for hazardous substances that (1) has a capacity of not more than three cubic meters or 3000 litres; (2) is designed for mechanical handling; (3) is resistant to stresses produced in handling and transport, as determined by tests; and (4) conforms to the standards in the chapter on Recommendations On Intermediate Bulk Containers (IBCs) of the UN Recommendations On The Transport Of Dangerous Goods.

Material Safety Data Sheets (MSDSs): See Safety Data Sheets

Net explosive mass (NEM): Also known as net explosive quantity (NEQ) or net explosive weight (NEW) for Class 1 articles is the total mass of the explosive substances contained in the article(s), without the packaging, casings, bullets, etc

Off-spec TGAN: Product that meets the criteria of UN1942 but does not meet the manufacturers' detailed product specification.

Q-D Table: Quantity-Distance table, which gives the minimum permissible distance (D) between a donor site containing a quantity of explosives and a susceptible site requiring protection.

Safety Data Sheet (SDS): Also called Material Safety Data Sheets, are a widely used system for cataloguing information on chemicals, chemical compounds and chemical mixtures. SDS information may include instructions for the safe use and potential hazards associated with a particular material or product. SDSs will be available wherever chemicals are being used.

Safety Management System (SMS): That part of the overall management system which includes organizational, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining the safety policy, and so managing the risks associated with the business of the organization.

Secure: Secure from detectable theft, unexplained loss, sabotage, and unauthorised access.

Secure store or compound: A physically secure place where ammonium nitrate is kept under lock and key or constant surveillance and where there are procedures for controlling access; the secure control of keys; and documenting the receiving and dispatching of measured quantities of TGAN.

Security Plan: Is a plan that has been put in place to minimize effectively all security risks relevant to the storage of TGAN.

Security risk: Risk of theft; unexplained loss, possible sabotage, tampering and/or unauthorised access to TGAN. Note that this also applies to Fertiliser Grade AN.

Site Emergency Response Plan (SERP): A document developed specifically for a location that defines all the potential emergencies and the actions to be taken as a result of the emergency. Actions are defined for on-site and off-site responses (e.g. site fire brigade, evacuation, local fire department).

Standard operating procedures (SOP's): Written procedures containing an explicit description of how a job is to be performed. The SOP's identify precautions required to complete the task safely, including -

- Personal protective equipment (PPE) required.
- Hazards specific to the job and/or site.
- The level of authority, responsibility and training required to complete the job safely.

- Reporting relationships identified by management as well as any other relationships that may interact with other jobs, SOPs, or work instructions.

Technical Grade Ammonium Nitrate or TGAN: Ammonium nitrate, which meets the definition of UN1942 and UN2067 [North America only] (HSE) and has a bulk density of less than 0.9g/cc. Generally, TGAN is in the form of porous prills and is used in the manufacture of commercial explosives. TGAN is also known as Porous prilled AN (PPAN), Low Density AN (LDAN) or Industrial Grade (IGAN).

Tonne: Also referred to as a **metric ton**. It is not an SI unit but accepted for use with the SI as a measurement of mass equal to 1,000 kg.

TNT equivalence: The TNT equivalence of AN provides an estimate of the blast energy of AN relative to trinitrotoluene (TNT). To determine the overall TNT equivalence of AN, it is necessary to combine chemical TNT equivalence with the Explosive Yield (also called Efficiency).

UN Numbers: These are four-digit numbers ranging from UN0001 to about UN3500 that identify dangerous goods, hazardous substances and articles (such as explosives, flammable liquids, toxic substances, etc.) in the framework of international transport. They are assigned by the United Nations Committee of Experts on the Transport of Dangerous Goods and are listed in *Recommendations on the Transport of Dangerous Goods*, also known as the *Orange Book*. These recommendations are adopted by the regulatory organization responsible for the different modes of transport.

Under lock and key: Would normally include one of the following:

- Locked building; or
- Secure shed with lockable entrances, and if windows are in the shed, they are locked or barred; or
- Secure and lockable freight container or explosives magazine.

4. SAFETY MANAGEMENT SYSTEMS

A Safety Management System (SMS) catering to the health and safety of the community, employees, property and the environment should be in place at all TGAN storage facilities covered by this document. It should be compliant with local regulations and company policy.

The SMS should apply to all employees at the facilities as well as visitors and contractors involved. The SMS should be documented and contain the following key aspects, which should be considered depending upon the site complexity:

4.1. Safety Policy

This is generally a short, public, formal statement of policy by the Chief Executive Officer of the organization that sets out the safety expectations of the organization and outlines how these will be achieved.

4.2. Plan Framework

The safety plan should include the following features:

- Programs for regular safety meetings with minutes of the meetings and agreed actions recorded in writing.
- A safety audit program.
- A requirement for investigation of accidents, near-misses and incidents which should include management reporting, analysis, follow-up and review.
- A contractor evaluation and selection process.
- A requirement for an annual review of the safety plan.

4.3. Training

Training is recommended in the following areas:

- Induction for new employees, contractors and visitors, including use of PPE; any specific hazards on site; the evacuation plan; the location of first aid stations; communications; permits to work; hot work permits; confined space entry; and any other additional safety or environmental considerations applicable to the site.

- An employee training system, covering SOPs, site-specific procedures and job responsibilities. The system should include documentation of training, re-training and verification of competency.
- A system to train employees in the correct procedures for the selection, maintenance and use of PPE. As a minimum requirement safety glasses and safety steel tip (or equivalent protective toe-cap) footwear shall be worn. Additional PPE may be required for site-specific hazards.

4.4. Procedures

Procedures should be in place to cover the scope of operations at a particular site. The following should be considered depending upon the facility and company policy:

- Obtaining SDSs for all hazardous chemicals on the site.
- The preparation of SOPs for all tasks
- Control of energy isolation.
- Approval and authorisation of all processes being conducted on site including commissioning and waste disposal.
- Control of the modification of processes and equipment i.e. management of change.
- Sampling, sample retention, product testing and recording of pertinent information.
- Safe disposal of waste materials.
- Management of off-spec and contaminated TGAN material
- System to check trips and alarms including the documentation of test results.
- Preventative maintenance programs.
- First aid system including the provision of first aid boxes and an inventory of personnel trained to provide first aid. There should be at least one person trained in first aid present on the site.
- Supervision of visitors and contractors in all areas where TGAN is stored.
- Vehicle operation, control and maintenance.
- Prohibition of smoking and open flames, re-fuelling, and flammables around TGAN.
- Permit to Work, Hot Work Permit System
- Critical machine register.

4.5. Emergency Response

A Site Emergency Response Plan (SERP) should be maintained and will include as a minimum:

- Signage (showing emergency contact numbers and “Do Not Fight Fires Involving Ammonium Nitrate”).
- A site and area evacuation plan.
- Appropriate fire fighting controls and fire risk management plans.
- Procedures to address emergencies such as accidents involving serious injuries or fatalities, fire, explosion, toxic gas release, any likely natural disasters and civil unrest.
- Procedures that address the loss of normal communication systems.
- A communication system throughout the organisation that covers employees; management; regulatory authorities; media; remote sites; contractors; visitors; neighbouring communities; and local emergency services.

Training and Practices

Persons on site who may be exposed to hazards relating to a facility, or expected to assist in an emergency, should be trained to an appropriate level. The SERP should be tested annually and updated as needed.

Evacuation Guidelines

In the event of an uncontrolled fire capable of engulfing the TGAN stores, TGAN should be treated as a potential explosive with appropriate and timely evacuation of all personnel who may be affected both on-site and off-site. Any required evacuation should be as specified in the site emergency procedures. For a large AN storage facility (e.g. >1000 tonne), this would typically be one kilometer.

5. REGULATORY REQUIREMENTS

Operators of TGAN stores must comply with legislation applicable to the storage and handling of TGAN.

If TGAN is currently regulated the following requirements should be noted:

- The owner or operator of the store shall have a copy of relevant licences on site.
- The owner or operator of the store shall meet applicable local regulations and should make every effort to abide by this code of practice to reduce the possibility of an unplanned event
- The manufacturer, supplier, transporter, and importer of TGAN are responsible for ensuring the TGAN has been properly classified.
- When designing new facilities, the relevant standards and regulatory requirements shall be incorporated in the design of the facility.
- Known incompatible materials must be segregated and separated from TGAN.
- The supplier of TGAN should, where applicable, only sell to organisations holding appropriate licences or bona-fide clients.
- A copy of this Good Practice Guide should be made available by the supplier of TGAN to an organisation or person purchasing or storing TGAN.

Note: The above requirements do not include the security requirements that are detailed in Appendix C on p. 50.

6. SITE DESIGN, CONSTRUCTION & MANAGEMENT

The following types of stores are commonly used to contain TGAN:

- Open air compounds – IBCs, packages
- Freight containers – IBCs, packages, bulk
- Silos/Bins – Bulk TGAN
- Buildings – IBCs, packages, bulk

Construction should be consistent with the local and national or federal requirements.

6.1. General Requirements

The general requirements are:

Electric

- Electrical devices which are used in a TGAN environment must conform to the relevant electrical codes
- Ensure proper protection against electrical storms according to local codes and practices
- Lighting should have additional safeguard to prevent it from falling onto the product.

Construction

- Storages should be built at appropriate distances from each other. Different classes of materials should be stored according to Dangerous Goods regulations and company policy.
- Means of minimising confinement should be reviewed, including options of pressure relief where appropriate.
- Any AN storage facility should not contain wood lining or an exposed wooden floor. In the case of freight containers wooden floors may be protected by sealing with mild steel, plastic sheet or a suitable coating such as polyurethane or epoxy paint. The coating option is not recommended if the seams are not tight and cannot be sealed properly as AN spillage can impregnate the wood resulting in a fire hazard. If the AN is stored in bags in the freight container, the bag will provide sufficient separation of the AN from the floor.
- Galvanised steel should be protected from direct contact with TGAN (e.g. coat with epoxy tar or chlorinated rubber).
- The use of exposed copper should be avoided, as copper is incompatible with TGAN.
- Flooring should be constructed of non-combustible material (concrete, compacted road base, asphalt with low bitumen content ¹, or earth.) Note that some types of cements may react with AN, which causes ammonia release.
- TGAN stores must not be erected on locations that have pyrites, hot or other reactive ground that can react violently with the TGAN.

¹ R.H. Dyson, P Waller and K.D. Shah; "Safety assessment of bitumen asphalt (TARMAC) flooring in ammonium nitrate fertiliser stores"; Proceedings No 628, IFS, 2008

- Drainage systems must be constructed according to applicable environmental standards and should be designed to avoid the accumulation of any significant amount of TGAN in the event of a spillage. Such systems can include the following:
 - Open drains to prevent the possibility of molten TGAN becoming trapped and confined in drains
 - Other potential areas of confinement include drains and channels.
 - Prevention of the contamination of surface and ground.
 - A system for collecting and disposing of contaminated waters including fire water effluent
 - Isolation from other storage areas, buildings and combustible materials. Separation from potentially incompatible effluent streams
 - Additional information on storage and the potential for offsite environmental issues associated with TGAN can be found in the website of the Agricultural Industries Confederation²

Signage

- Signs which meet regulatory requirements should be displayed. It is recommended that the words “Ammonium Nitrate” (at least 100mm high) be displayed. Also signs indicating the amount, UN number and class 5.1, HAZMAT should be displayed as required by local regulations.
- Additional signs reading “Danger - No Smoking”, “No Open Flames”, “No sources of ignition”, “Report Fire Immediately”, “Do Not Fight Fires Involving Ammonium Nitrate” and “Prohibited articles – detonators, explosives, flammable materials” may be provided at all entrances.
- “No Trespassing - Authorised Access Only” must be posted every 100 metres on the perimeter, or as required by regulation or company policy.
- Signage should be in the language(s) appropriate to the country where the store is located.

2

http://www.agindustries.org.uk/documents/tradeAssurance/Solids_Code_of_Practice.pdf, accessed on 23/09/09

Security

- There are also additional security requirements, which may be applicable, detailed in Appendix C on p.50.

Emergency

- Emergency Response Procedures shall be provided and readily available on site.
- Unimpeded exits for personnel and vehicles shall be maintained.

Further key requirements of each type of store are detailed in the following paragraphs.

6.2. Open Air Compounds

Key requirements:

- The base may be concrete, compacted road base, low (less than 9%) bitumen asphalt or compacted earth. In the case of compacted earth, which could be porous, if an impermeable layer cannot be added, then a monitoring regime should be established to ensure there is no ground contamination.
- Security fencing must be provided to meet local standards
- Adequate protection against rain and direct sunlight must be provided (e.g. pallet covers). Pallet covers and tarpaulins must ensure the free ventilation of air and should not be draped over the TGAN leading to increased temperature cycling and condensation.
- All bags should be handled with care to avoid damage. Pipes should be fitted over sharp edged tines on fork-lift trucks to avoid damage to the lifting loops. Damaged bags should be placed immediately into secondary bags to prevent further spillage wherever possible.

6.3. Freight Containers for Storage

Key requirements:

- If used for long-term AN storage, it is recommended that the container be dedicated to TGAN and specified compatible materials.

- The use of freight container or railcars must meet local or company standards.

6.4. Silos or Bins

Key requirements:

- The material of construction should be resistant to attack by TGAN or protected from attack with appropriate surface coating (e.g. epoxy). This is especially important in high-humidity environments. An example of a resistant material of construction is 304 Stainless Steel.
- If mild steel is used, it must be protected by an internal epoxy coating, as it will be corroded by TGAN. This coating must be checked and properly maintained, since the abrasive TGAN will wear away the epoxy coating and the exposed mild steel will corrode rapidly.
- Galvanised steel should be protected from direct contact with TGAN (e.g. coat with epoxy tar preferably or chlorinated rubber), and ensure proper checking and maintenance of coating, since TGAN is abrasive and the coating could wear off.
- The Design must be sufficiently robust to withstand the stresses caused by the impact of large caked lumps of TGAN falling from the top of the silo/bin.
- The Design should be such to ensure the empty container arrangement can withstand wind and seismic forces, which may be encountered at the particular location.
- The supporting structure must be protected from TGAN attack with appropriate surface coatings as required (e.g. epoxy tars, chlorinated rubbers, epoxy paints, etc.).
- The Design must prevent the ingress of water into the silo/bin – particularly during the loading of the silo/bin.
- Adequate venting must be provided to prevent pressure or vacuum build up during loading and unloading.
- Adequate protection against electrical storms (i.e. lightning strikes) should exist. This will be the higher standard of company and regulatory requirements.
- The design should take into consideration the fact that TGAN has a tendency to cake.
- No combustible materials (including flammable liquids in tanks) should be underneath or in the vicinity of the silo.

- The topography in the area of the silo should be taken into account to prevent spilled flammables running towards the silo.

6.5. Buildings

Key requirements:

- Well ventilated and single storey
- Floors may be of concrete, compacted road base, low bitumen (less than 9%) asphalt or earth. Regulations may limit the choices for the storage of bulk TGAN in some countries
- Water ingress, which will cake TGAN, must be avoided
- Mobile haulage equipment should not be in the AN Store unless it is in use.

6.6. Storage of Large Amounts of TGAN at Mine Sites

There are situations where, in remote locations, a large quantity of AN must be shipped in and stored. The storage of large quantities of AN is not without attendant hazards and risks, especially, at remote locations such as mine sites or isolated communities where emergency response or evacuation may be complicated by the location and elements.

In situations at mine sites where large amounts of TGAN are stored (even as transit storage), it is recommended that:

- The size and layout of individual storage stacks/piles are determined by the risk assessment.
- Community or mine site emergency response and evacuation procedures be reviewed to ensure that they adequately cover fire and / or explosive events at a bulk TGAN storage facility.
- The design of the TGAN storage & handling facilities and equipment include all reasonable means to prevent and control fire, and that local authorities are notified of the design and construction of the building and its equipment, e.g., following of US NFPA guidelines for the storage of large quantities of AN
- Appropriate local standards for transportation of AN be met.

6.7. Fire Fighting Considerations

TGAN is an oxidising agent. It does not burn but is a strong supporter of combustion. The presence of some contaminants may increase the probability of a fire. In a fire, TGAN will decompose and produce toxic combustion products such as oxides of nitrogen, ammonia and nitric acid fumes.

The properties of TGAN, its mass and location of the store influence detailed fire-fighting requirements. They should be determined by a fire risk assessment carried out by competent personnel.

Key design and operational considerations:

- Fires involving Ammonium Nitrate should never be fought. If the fire involves Ammonium Nitrate the facility must be evacuated. (See p. 12 Section 4.5 for evacuation distance guidelines.)
- Only those employees on the site who are trained in the hazards of ammonium nitrate should provide support and guidance to the fire fighters during the evacuation.
- Appropriate PPE including self-contained breathing apparatus (SCBA) should be made available should there be a fire that does not involve Ammonium Nitrate and needs to be fought.
- Fire protection strategies should be based on minimising the presence (both potential and actual) of combustibles around TGAN.
- For a fire involving TGAN, the prompt **remote** (*Please note*) application of water is the most effective means of control. It is the cooling effect of water that controls the fire.
- Water from hoses and fixed monitors must be able to reach all parts of the store.
- Foam and/or dry chemical extinguishers must be available to deal with vehicle or electrical fires.
- Fire fighting systems for incipient fires or fires not involving Ammonium Nitrate should be capable of single person operation (Typically TGAN stores would be operated by a small number of people. An exception is if the TGAN store is part of a large complex. Equipment operated by a fire fighting team may be appropriate.)

- The SERP should provide guidance for scenarios which involve the release of NOx.

The fire fighting requirements can be reduced for isolated stores where a potential explosion or fume emission will not impact on people or property on or away from the premises.

It is important to remember the impact of firewater effluent on the environment through the construction of effective drainage systems as discussed on p. 15.

6.8. Contaminated TGAN Storage

After the Toulouse accident, a new category for AN materials was created by the European parliament. Therefore the Council Directive 96/82/EC was amended to create the “Off-spec” category for AN³. Off-spec AN is more common in AN manufacturing plant and large storage sites rather than end-user sites. This code has addressed “contaminated” TGAN as a special category.

Key requirements:

- The maximum amount of contaminated product to be stored should not be higher than 50 tonnes per independent stack/pile.
- The holder of the material must conduct a risk assessment on each batch of off-spec AN to ensure that the detonation (or decomposition) risk is minimised.
- Each contaminated material must be segregated.
- Contaminated material must be evaluated as to its explosive nature whether or not the material has been contaminated with organic material.
- Contaminated materials disposal must be done through methods such as dissolving it in water or blending. The selection of one method or another will depend on a proper risk assessment

3

<http://eur-ex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32003L0105:EN:HTML>,
accessed on 23/09/09

More details on the treatment of off-spec AN material can be found in the document issued by the Agricultural Industries Confederation ⁴.

7. LOCATION OF STORAGE FACILITIES

7.1. General

The siting and layout of TGAN storage is based on minimising the risk from an event within the storage facility. Factors considered in the location of a TGAN store take into account the likelihood and the related possible consequences of an incident. Owners and operators of TGAN storage facilities are encouraged to continually manage safety and security aspects of operations through control measures that reduce the likelihood of any incident.

The possibility of detonation of a significant mass of TGAN is the dominant issue for the siting and layout of TGAN storage facilities. While toxic combustion products may be a key consideration in designing fire detection, suppression and emergency response measures, they are not specifically addressed in this section.

Owners and operators of TGAN stores should adhere to the Quantified Risk Assessment (QRA) method mandated by their relevant regulatory authority(ies). Where this mandate is absent, other QRA processes accepted by the industry, for example IMESA^{FR}, should be employed.

7.2. Risk-Based Approach for Siting and Layout

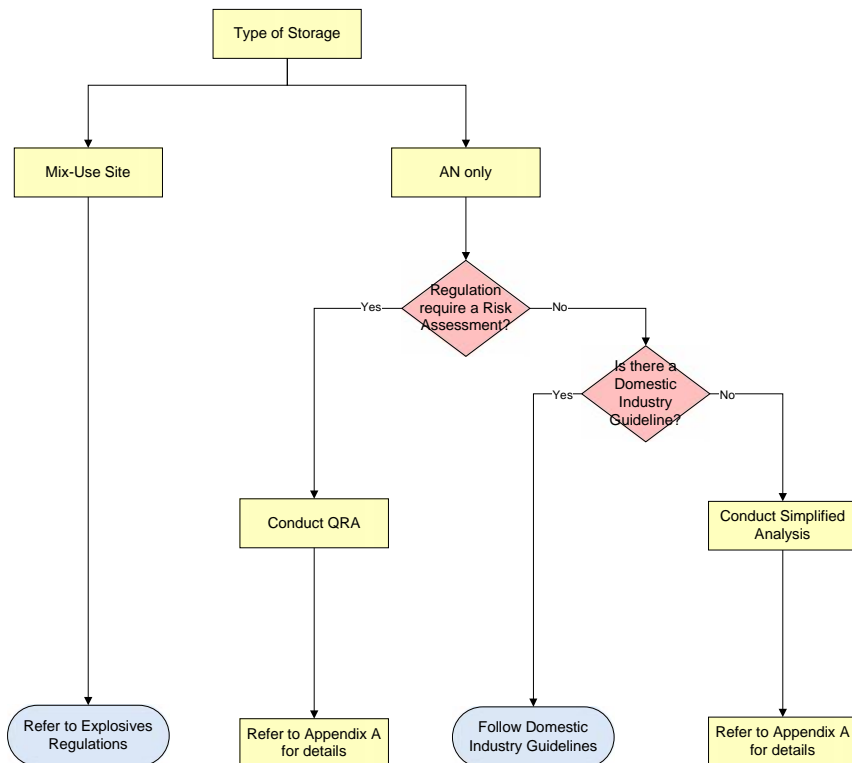
The general approach for risk-based assessment is represented in Figure 1 on the next page. For a site that only has TGAN stored, the domestic industry guidelines may be used if the regulations do not require a QRA be conducted. If no domestic guidelines are available a simplified assessment may be undertaken in lieu of a full QRA. For sites with mixed storage (TGAN and explosives) the Explosives Regulations that pertain will determine the siting and layout. More details on locating TGAN storage facilities, and a sample Risk

4

http://www.agindustries.org.uk/document.aspx?fn=load&media_id=2173&publicationId=680 accessed on 21/07/10

Assessment methodology are found in Appendices A and B respectively.

Figure 1: Overall Risk-Based Approach



a. Mix-use = presence of Explosives and Initiating Systems (Class 1)

8. OPERATION OF STORES

The operating procedures and layout of stores are designed to ensure safe operation (e.g. adequate access, stack stability) and to minimise the contact of TGAN with combustible materials (e.g. vehicle fuel, pallets). These control measures are aimed at reducing the likelihood of an incident.

Other factors may include the separation of stacks and piles. The size of an individual stack or pile is a key factor in determining the required separation distances between stacks and piles. Details of the separation requirements in which a stack or pile is considered as a single potential explosive source are given on p. 30 in Appendix A.1 – Separation of TGAN sources.

8.1. General Considerations

The following requirements are applicable to all stores (in- and off-specification AN whether stored in bulk, bulk bags or packaged AN):

- Internal combustion power operated vehicles and machinery shall not be left unattended within any TGAN store if the engine is running.
- Internal combustion and electrically powered vehicles and machinery should be:
 - provided with a readily accessible dry chemical fire extinguisher rated for fighting electrical and vehicle fires only.
 - located outside the TGAN store when not in use.
 - attended at all times while the engine is running inside the store
 - free of any leaks of fuel, lubricating oil and hydraulic fluid.
 - fitted with a spark arrestor or similar device.
- Store layouts must ensure unimpeded exits for personnel and vehicles.
- The open floor of every store, including any vehicle access area should be kept clean of any spilled TGAN or other material spillages at all times. Spills must be cleaned up immediately.
- Smoking and open flames shall not be permitted inside the TGAN store and notices to this effect shall be displayed.
- Unguarded electrical lights shall not be permitted inside the TGAN store and notices to this effect shall be displayed.
- In areas where there are electrical storms, proper protection against lightning strikes must be provided and maintained.
- Lifting equipment shall conform to the local codes

- Lighting should have additional safeguard to prevent it from falling onto the product.
- Security systems should be in place to prevent unauthorized access and to enable early detection of, and appropriate response to, unexplained loss of product (Refer Appendix C on p.50).

Housekeeping

- Storages should be kept clean at all times and inspected regularly and particularly when maintenance is being carried out
- Housekeeping standards should prevent contamination of TGAN and accumulation of combustible and/or flammable materials in proximity to TGAN.
- The use of combustible materials (e.g. pallets for storing AN) should be avoided as far as reasonably possible
- Floors, walls, pallets and equipment must be clean and spillages cleaned promptly. Spilt AN must be stored in the off-spec AN area if it cannot be recovered in a clean state.
- Organic materials (e.g. sawdust) must not be used to clean floors.
- Necessary precautions must be taken to prevent the ingress of TGAN into areas out of view (e.g. hollow tubes).
- It is recommended that all floor and ground surfaces should be level and free from sharp objects which might tear or puncture bags. Rats and other rodents should be controlled to avoid damage to bags (open air compounds and buildings).
- AN storage area must not be used for any other purpose (storage of cleaning products, tools, consumables, etc).
- Vegetation (and combustible materials such as empty pallets) must be cleared according to local regulations. A minimum distance of 8 metres around the store is recommended as a guideline.
- Haulage/reclaim equipment used in the building should be well maintained with particular focus on oil and grease leaks/contamination.

Special Note:

Under no circumstances should explosives or detonators be used to clear blockages or chokes in TGAN silos or to loosen caked piles of TGAN.

8.2. Packaged Stores

Key points:

- For packages and IBCs, individual stacks should be separated by the distance determined by the QRA.
- Stacking of pallets and IBCs shall be limited to three high, with each pallet containing no more than 1.3 tonnes.
- Stack stability must be maintained in all stack configurations
- For packages and IBCs stacked on wooden pallets, storage should be in maximum stack sizes of 200 tonnes, or as determined by the QRA.
- For packages and IBCs stored on either non-combustible (steel) pallets OR without any pallets, the maximum stack size will be determined by the QRA.
- A free air space of at least one meter (1m) should be maintained between stacks of packaged TGAN and the outer walls of the buildings.
- A minimum clearance of one meter (1m) shall be maintained between the top of the stack and the roof or lowest support beam of the building, or to the lowest lighting fixture.

8.3. Bulk Stores

Key points:

- A minimum clearance of one meter (1m) shall be maintained between the top of the pile and the roof or lowest support beam of the building, or to the lowest lighting fixture.
- Lighting should be positioned or protected so that it cannot fall into the bulk pile.

9. SECURITY REQUIREMENTS

Security plans may be required by the regulatory authority and good business practices. However, even if this is not a requirement, developing such a security plan based on the vulnerability (→ control of contaminated product) of the storage facility and the threat in the area of operation must be a serious consideration.

Where appropriate, provision of additional levels of security may reduce the Likelihood of a given event. Guidelines for addressing security issues are given in Appendix C.

10. ACKNOWLEDGMENTS

SAFEX acknowledges with thanks the work done by the International Industry Working Group on Ammonium Nitrate.

APPENDICES

Whenever there is reference to “ammonium nitrate” or AN in the Appendices it is done generically and means TGAN.

A. Storage Facilities Location

Note: This section supplements Section 7

TGAN storage is based on minimising the risk of an event within the storage facility. It means that in the location of a TGAN store factors to be considered take into account the Likelihood and related Consequences of an incident associated with TGAN at the storage facility. Owners and operators of TGAN storage facilities are encouraged to continually manage safety and security aspects of operations through control measures aimed at reducing the Likelihood of any incident. By the use of best management and handling practices by manufacturers, TGAN has been and can continue to be stored safely without incident.

The following steps provide the logic for siting such a storage facility:

- Determine the type of site, i.e. whether it has only TGAN stored or is a site on which explosives are manufactured / stored (i.e. mixed use).
- If the site is mixed-use then the Explosives Regulations must be consulted and the TGAN facility sited accordingly, using a Q-D approach, followed by a Risk-based approach as appropriate.
- If the site only stores AN determine whether the regulations require a full QRA be carried out. If the regulations do not require a QRA, then domestic industry guidelines should be used, if they exist.
- If the regulations require that a QRA be carried out:
 - Determine mass of TGAN (M)
 - Determine TNT equivalence (NEQ)
 - Determine the Risk by carrying out a QRA. The process involves estimating both the Likelihood of the event occurring and the Consequences if it does occur.

- If the level of Risk identified through the QRA is acceptable, no further analysis is required.
- If the level of Risk is not acceptable, it should be lowered through a combination of additional control measures that will reduce the Likelihood, and/or reduce the donor/acceptor quantity (i.e. the Consequence).
- If regulations do not require one to carry out a QRA, and there are no domestic industry guidelines, the layout can be set by carrying out a simplified Risk Analysis (if the capability exists) or a Consequence Analysis if there is no risk capability. This logic is shown in the flowchart below (Figure A.1).

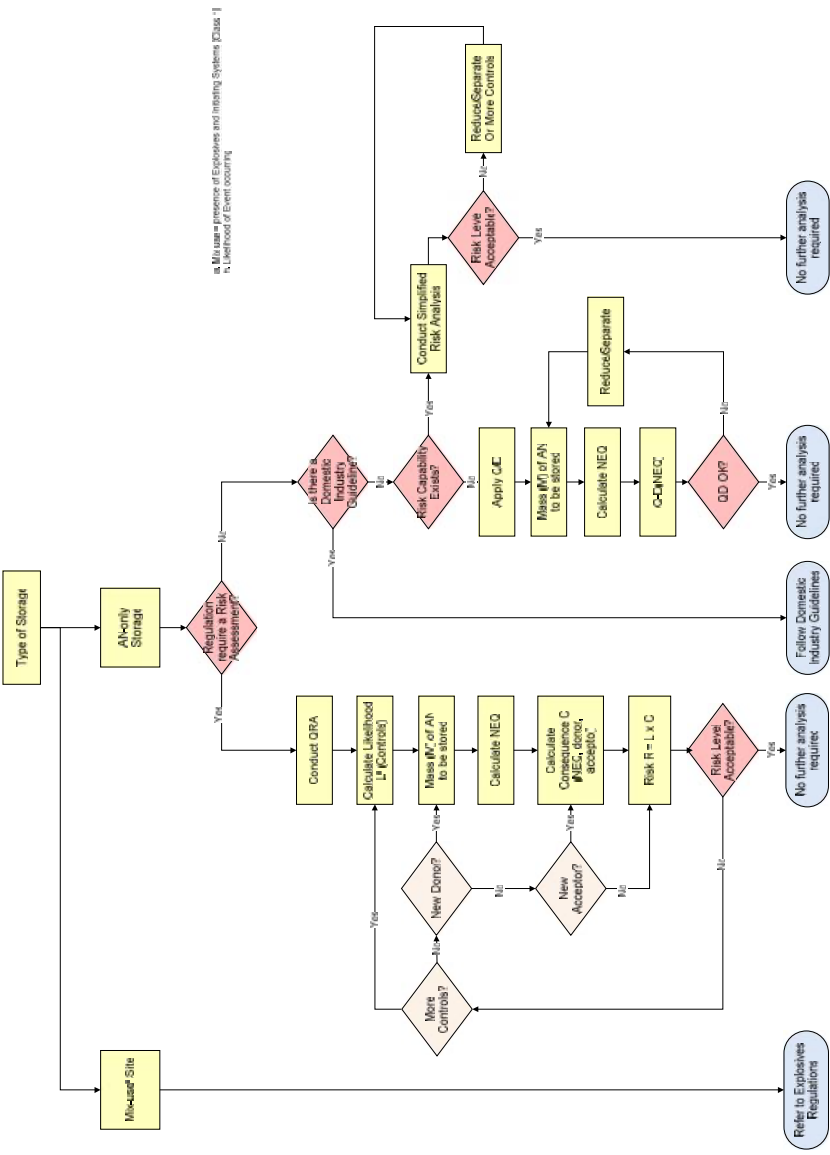
The dominant issue for the siting and layout of TGAN storage facilities is the possibility of an explosion of a significant mass of TGAN. While toxic combustion products may play a key role in design aspects such as fire detection, suppression and emergency response, they are not specifically addressed in this section.

Mitigation of the risk of a mass explosion of TGAN requires reducing the:

- Likelihood of an incident by implementing control measures and procedures
- possible Consequences through:
 - minimising the mass of TGAN in a given storage unit (bulk pile, bin, or bag stack); and/or
 - increasing the separation distance between TGAN storage units.

Separation of storage units is discussed in more detail in Appendix A.1 below.

Figure A.1: Flowchart depicting the logic for a simplified Risk Analysis



A.1. Separation of TGAN Stacks, Piles and Silos

A storage facility may contain one or more bag stacks, bulk piles or silos of TGAN. The following paragraphs set out the separation requirements for these situations. These separation requirements are intended to prevent a detonation in a stack or pile initiating adjacent stacks or piles.

If these separation requirements are met, the quantity of TGAN considered as a potential explosive source is the quantity in each individual stack or pile. If the separation requirements are not met, the quantity of TGAN in the individual stacks or piles must be summed to give the size of the potential explosive source. This has important consequences in a risk assessment process (see Appendix B)

In this section, the following are addressed:

- A stack of TGAN consisting of packages (e.g. bags), IBCs or a cluster of shipping containers.
- A pile of TGAN consisting of loose bulk ammonium nitrate, including storage in silos/bins.

A.1.1. Bags and IBCs

The gap separation distances between each stack shall be maintained as follows ⁵ for the various densities of TGAN:

- Low density (less than 750 kg/m³ or 0.75 g/cc), high porosity TGAN stacks that are “normally” configured (i.e. set back by ½ bag at each layer) should be separated by 16 metres ⁶. For a “pyramidal” stack, the separation can be reduced to 9 metres.
- Medium density (between 0.75 and 0.85 g/cc) TGAN stacks should be separated by 9 metres for a normal configuration and reduced to 7 metres for a pyramidal configuration
- High density (greater than 0.85 and less than 0.90 g/cc) TGAN should have a separation gap between stacks of 1

⁵ Nygaard, E., Storage of Technical (Porous) Ammonium Nitrate, Proceedings of ISEE Conference 2008

⁶ Reference to Yara International publications

metre (The basis of which is still to be confirmed by field tests).

It is known ⁷ that configuration (geometric layout) of the stack affects separation distance. This may need to be considered when determining appropriate separation distances for the stacks.

The separation distances between stacks may be reduced if a barrier capable of inhibiting initiation of the neighbouring stack is installed.

Example:

Consider the following bag store of low density TGAN, i.e. bulk density less than 0.75g/cc, and where the bags are stored in a “pyramidal” configuration (see Definitions: AN stack configuration (ii))

- Store capacity = 5,000 tonnes of bagged TGAN.
- Mass of each stack of bags = 500 tonnes
- Separation distance of each stack = at least 9 metres (side-to-side and end-to-end)

Each stack meets the guidelines. Therefore, the maximum stack size considered as a potential detonation source is 500 tonnes.

If the separation distance between any two stacks is less than required and there are no approved blast protection barriers, the masses of these individual stacks must be summed.

A.1.2. Bulk Storage

Large quantities of solid TGAN have been stored successfully in bulk stores around the world for extended periods and without harmful consequences. The very limited number of incidents that have occurred can be traced to poor handling or management practices. The objective of this document is to identify those good practices for managing the bulk storage of TGAN that will minimise/eliminate the Likelihood of a harmful event.

The following should be considered in the design of bulk storage of TGAN:

⁷ Nygaard, E., Storage of Technical (Porous) Ammonium Nitrate, Proceedings of ISEE Conference 2008

- Based on the simulations carried out on bulk piles of about 4,000 tonnes⁸, there is no need to separate bulk piles. The only requirement is that the 'toes' should not overlap. If the 'toes' do overlap, the total mass of the 2 piles is the defining mass.

The Flowchart in Figure A.1 outlines the logic to be followed when determining the quantities and separation distances required for the bulk storage of TGAN.

Major Manufacturing Sites:

When designing a facility for storage of TGAN on major manufacturing sites, the amount of storage incorporated into the design should be minimised without compromising the facility's viability and operational efficiency. Off-specification material as manufactured, should be handled as required by any local regulations e.g. Seveso. The cyclical nature of the given markets and the quality control of the final product should also be considered. Typically, bulk storage of 3,000 to 6,000 tonnes of TGAN is sufficient to enable the efficient operation of a large (~350,000 tonnes per annum) TGAN manufacturing site. The proposed location and quantity of the storage facility for TGAN must be incorporated in the QRA for the manufacturing site.

Globally there are a significant number of TGAN bulk storage facilities on manufacturing sites that have an existing capacity in excess of 10,000 tonnes. These manufacturing sites are unique in that they are attended by highly skilled operations personnel for 24 hours a day, seven days a week. They also have well-developed Safety Management Systems, normally incorporating Process and Engineering Safety management to comply with local regulatory requirements (e.g. PSM for ammonia in the US; COMAH in UK; MHF in Australia). Existing manufacturing sites should review the QRA for the site taking into account the most recent technical information regarding the storage of TGAN. Where the site does not have a QRA, then one shall be undertaken to ensure sufficient controls are in place to reduce the risk of a harmful incident to As Low As

⁸ Simulations studies by TNO for Yara International; Results not yet published; 2008

Reasonably Practicable (or ALARP ⁹) requirements (see Appendix B.3.1 on p. 42).

Mixed Sites:

Where it is proposed to store TGAN on sites where other potentially explosive materials (e.g. boosters, detonators and other Class 1 Explosives) are or will be stored, additional criteria apply. The siting of the TGAN storage facilities with respect to other storage areas and external communities shall be in accordance with the relevant local explosives regulations.

Sites that do not manufacture but only store AN::

If the site only stores AN, and the regulations do not require a QRA, nor are there domestic industry guidelines, a simplified Risk Analysis should be conducted if the capability to carry out a risk assessment exists.. An example of a simplified Risk Assessment is provided in Appendix B on p.38.. If there is no risk capability available, then a Q-D calculation can be carried out to determine the required siting.

For example, if the proposed storage is in an isolated area and well away from residential and other local community establishments, then a simple Q-D calculation could be used to determine the appropriate separation distance.

A.1.3. Transient Storage

Trucks/trailers/railcars which are used to store TGAN on-site for longer than 60 hours should be considered as stores. Local regulations may override this.

A.1.4. Storage Summary

A summary of separation distances for different types of TGAN and storage methods is given in Table A.1

⁹ From 'The Tolerability of Risk from Nuclear Power Stations', (HSE, 1988). In weighing the costs of extra safety measures the principle of reasonable practicability (ALARP) applies in such a way that the higher or more unacceptable a risk is, the more, proportionately, employers are expected to spend to reduce it. Legally speaking, this means that unless the expense undertaken is in gross disproportion to the risk, the employer must undertake that expense.

Table A.1: Separation Distances for Various TGAN Types (Ref 5)

TYPE OF AN	TYPE OF STORAGE	MAX. MASS PER PILE (TE)	SEPARATION BETWEEN PILES (M)	COMMENTS
High density TGAN	Bags, IBCs		[1]	
Medium Density TGAN	Bags, IBCs	As determined by the QRA	[9]	Normal Configuration
Medium Density TGAN	Bags, IBCs		[7]	Pyramidal Configuration
Low density TGAN	Bags, IBCs		[16]	Normal Configuration
	Bags, IBCs		[9]	Pyramidal Configuration
	Bulk	>500	Tbd	
	Bulk	<500	[8]	

[] in Table denotes values to be confirmed by data
Tbd = To be determined

A.2. Estimation of Net Explosives Quantity (NEQ)

The first step to minimise the Consequence of any TGAN event focuses on the mass involved - whether as loose prills in a bulk pile or prills contained in a silo / bags. To this end, the equivalent quantity of explosive substance (NEQ) in the TGAN mass under consideration must be determined. The NEQ is calculated by estimating the overall TNT Equivalence of TGAN and multiplying that by the total mass of TGAN.

$$\text{NEQ (Q)} = \text{Overall TNT Equivalence (E}_o\text{)} \times \text{Mass of TGAN, (M)}$$

The TNT equivalence provides an estimate of the blast energy of TGAN relative to TNT. To determine the Overall TNT Equivalence (E_o) of TGAN it is necessary to combine Chemical TNT Equivalence with the Explosive Yield. The relationship is:

$$\text{Overall TNT Equiv (E}_o\text{)} = \text{Chemical TNT Equiv. (E}_c\text{)} \times \text{Explosive Yield (E}_y\text{)}$$

The Chemical TNT Equivalence is a ratio based on the relative Heat of Combustion of the material compared to TNT. For the purposes of this calculation, the chemical equivalence for each TGAN event

scenario is estimated as 32%. (Note: this value is used for illustrative purposes only. There is an active program underway to determine this value for AN storage piles. New information will be included in the next revision of this document.)

The Yield or Efficiency (E_y) is an estimate of the TGAN mass that is consumed in the detonation.

A.3. Estimation of Separation Distance using the Q-D Tables

Once the NEQ (Q) has been estimated, the distance (D) of the storage site to nearby facilities can be obtained from the Explosives Q-D Tables.

If the required distance D is too large for a given storage mass M, the process can be repeated with a smaller mass, if such a mass is practicable. If it is not practicable to reduce the quantity of TGAN stored further, then a risk assessment approach may be required, as shown in Figure A.1 (risk assessment flowchart).

A.4. Estimation of Risk

Risk is the product of the Consequences of an event and the Likelihood (Frequency) of the occurrence of the event. Hence, risk can be reduced by control measures, where practicable, that decrease the potential Consequences and/or Likelihood of the occurrence.

The four likely scenarios for an explosion involving a TGAN manufacturing or storage site are:

1. Fire
2. Contamination
3. Shock impact with high velocity projectile
4. Malicious act

LIKELIHOOD

Means of reducing the Likelihood of each of these scenarios include:

1. **Fire:**
 - Construction of the building

- Type and the standards of haulage equipment used
- Type of conveyors (self-extinguishing) used
- Rigour of safety management
- Use of non-combustible oils and greases
- Fire suppression – both within the stores and for vehicles
- Hot-work clearance procedures
- No combustibles in the store
- Vehicle access
- Strict enforcement of no smoking policy
- Electrical standards
- Lightning protection
- Minimise electrostatic discharge

2. Contamination:

- Procedure for handling returned or off-spec product
- Truck/Tanker control
- Dedicated manufacturing/storage site
- Use of non-combustible oils and greases
- Process control (pH, organics, etc)
- Control of chemicals on site (nitrite, water treatment, etc.)
- Other incompatible Class 5.1 substances
- Dedicated equipment (pallets, etc)
- Material of construction of vessels, piping, etc.
- Procedures in place for cleaning up spillages as well as enforcement of such procedures

3. Shock impact with high velocity projectile

- Dedicated storage site
- Proper separation from other potential explosion sites
- Mounds/berms around the site
- Locate away from flight paths
- Inventory reduction and pile separation

4. Malicious act

- Access control (people and vehicles)
- Fencing and lighting
- Closed Circuit television (CCTV)
- Site security plan

- Security clearances of employees and contractors
- 24-hr security guard
- Good Human Resource management systems in place
- Clearance and Inspection systems
- Pre-startup checks

The estimated Likelihood of an explosion can be site specific and may require detailed study for industrial and mixed storage sites.

CONSEQUENCE

The major Consequence of an explosion is related to the overpressures generated by the explosion. The overpressure at a particular location is determined by the explosive energy from the TGAN involved in an explosion and the location of the persons or property at risk from the explosion i.e. the Distance. For off-site people and property, sufficient separation distances from the potential explosion sources can reduce the risks to acceptable levels.

If this control measure is not adequate, changes in the Quantity and layout of the TGAN storage may be sufficient as an additional control. However, further controls may be required if it is not practicable to reduce the overall risk sufficiently using the above measures.

If necessary, a full QRA should be carried out to determine the level of risk for a given TGAN storage site. The competent authority may review any QRA by a close examination of assumptions and risk examination.

The process of carrying out a QRA is not within the scope of this document.

B. Risk Assessment Process

Note: This section supplements Section 7

The following is an example of an analysis done for siting TGAN stores:

B.1. TNT Equivalence of Ammonium Nitrate

As mentioned in Appendix A.2 the TNT Equivalence of TGAN provides an estimate of the blast energy of TGAN relative to TNT. To determine the Overall TNT Equivalence of TGAN it is necessary to combine Chemical TNT Equivalence with the Explosive Yield. The relationship is:

$$\text{Overall TNT Equivalence} = \text{Chemical TNT Equivalence} \times \text{Explosive Yield}$$

The Chemical TNT Equivalence and the Explosive Yield are discussed briefly in the following sections.

B.1.1 Chemical TNT Equivalence of Ammonium Nitrate

For the purposes of this document, this equivalence is taken to be a value of 32%¹⁰ relative to TNT for each TGAN event scenario.

B.1.2 Explosive Yield (or Efficiency)

The Explosive Yield (or Efficiency) is the proportion of the TGAN mass that is consumed in the explosion. Factors which directly affect the TGAN Explosive Yield include:

- The physical characteristics of the TGAN
 - low density vs. medium density vs. high density
 - porous vs. non-porous
 - prills vs. granules vs. crystalline
- Confinement – including bulk vs. packaged or containerised
- Initiation mode
 - chemical contamination
 - fire
 - shock (e.g. high velocity projectiles/high explosives)

Depending on the above factors, estimates of the TGAN explosion yields (efficiencies) range from a low of 10% to 100%.¹¹

¹⁰ "Storage of Technical (Porous) Ammonium Nitrate", Erik C. Nygaard, Yara International ASA, Porsgrunn, Norway, presented at International Society of Explosive Engineers Conference, 2008

¹¹ Orica Mining Services Professional Judgement

B.1.3 Recommended Overall TNT Equivalence Values

GENERAL

Use of the recommended values in Table B.1 on the next page is contingent on the use of procedures that control all potential initiation sources. The recommended factors for Overall TNT Equivalence may need to be altered in the following situations:

- If the TGAN store is a multi-use store; or the area of TGAN storage has been used previously for storing various other chemicals; or the store is to be used to store out of specification TGAN with low turnover (i.e. high residence time); then the Overall TNT Equivalence for “Detonation from Chemical Contamination” in Table B.1 should be taken at the higher level of 16%.
- It should be noted that storage of TGAN on wooden pallets may increase the propensity for any fire to be sustained and may increase the affected area of TGAN.
- For a high velocity projectile to initiate an explosion of solid TGAN it must have a very high momentum. Such a projectile may originate from a process plant explosion or detonation. This mode of initiation can be eliminated for stores at sufficient distances from sources of highly energetic projectiles (e.g. process plant, trucks carrying explosives or other potentially detonable substances, etc).

LOW AND MEDIUM DENSITY TGAN

For low and medium density, porous TGAN the yield (efficiency) values shown in Table B.1 are recommended for the various modes of initiation.

Table B.1: Overall TNT Equivalences for Various Event Scenarios¹²

¹² Global Industry Group Professional Judgement

PROPERTY	EVENT TYPE		
	Detonation from Chemical Contamination	Fire - Molten AN Detonation from "Low Energy" Radiation and/or Confinement	Detonation from High Velocity Projectiles "High Density Energy"
Chemical TNT Equivalence	0.32	0.32	0.32 ^{Note 1}
Explosives Yield	10-50% ^{Note 2}	Low around 10% ^{Note 3}	High close to 100%
Overall TNT Equivalence Range	Range 3% to 16%	Range 3% to 5%	Range 25% to 32%
Recommended Overall TNT Equivalence	16%	5%	32%

Notes:

1. Subject to confirmation based on further large scale testing.
2. Dependent upon the extent of contamination. Contamination such as chlorides, chlorates, hypochlorite or chloroisocyanurate, dichloroisocyanuric acid, permanganates and metal powders, iron oxides, sulphur, bitumen, nitrites react readily with TGAN, some will even react at room temperature posing an extreme hazard. Other organic compounds such as oils, internal and external additives used in TGAN manufacture, wood and other combustibles will enhance any decomposition or reaction of TGAN and increase its yield in an explosion.
3. Assumes only partial mass is in the radiation impact or melt zone. Based on externally fuelled heating in conjunction with partial confinement; heat radiation from various external sources such as malfunctioning conveyor belts, Front-end loaders, friction, electrical sources etc

HIGH DENSITY TGAN

For high density, porous TGAN the maximum Overall TNT Equivalence is 9.6%. This is based on 32% TNT equivalence and 30% Explosives Yield as a maximum ¹³. These estimates are currently being reviewed in the light of large scale field tests and the

¹³ HSE SRAG - Chemical Warehouses Version 6 26 June 2002 - section on ammonium nitrate

TNT equivalence estimates will be updated when data becomes available.

B.2. Net Explosives Quantity (NEQ)

The Net Explosives Quantity (NEQ) in the event of an explosion involving TGAN prill is calculated as follows:

$$\text{NEQ (kg)} = \text{Mass of TGAN to be considered (kg)} \times \text{Overall TNT Equivalence.}$$

The appropriate value for the Overall TNT Equivalence is given in Table B.1 on the previous page. The mass of TGAN to be considered is determined from the layout of the store. If the store meets the separation requirements as outlined in Appendix A.1, then the mass of one pile/stack may be assumed. If these requirements are not met, then the mass is the sum of the masses of all individual stacks/piles that do not meet the separation requirements

Example:

Consider the following bulk store of low density within specification TGAN:

- Capacity - 2,000 tonnes of bulk TGAN
- Contains five separate piles, each does not exceed 400 tonnes
- The separation distance between each pile (toe-to-toe; & normal angle of repose) is at least 8 meters
- It is a stand-alone store with no adjacent processing facility.

As the separation distances meet the requirements of this document then the maximum pile size is 400 tonnes or 400,000 kg for use in the calculation of NEQ. Furthermore, as the store is not near processing facilities, and therefore not susceptible to projectile impact, the maximum overall TNT Equivalence (from Table B.1.) is 16%.

Therefore, the equivalent NEQ for the pile is:

$$\text{NEQ} = 0.16 \times 400,000 \text{ kg} = 64,000 \text{ kg}$$

B.3. Risk Assessment of TGAN Stores

The risk assessment process allows for evaluation of the overall risk associated with a facility. It takes into account:

- the Likelihood of possible events,
- possible Consequences of those events; and
- the impact of achievable control measures that can be put in place to maintain safe operation of the facility and meet required risk targets.

It is important that the risk assessment process takes into account previous experience in operating that site..

The risk assessment process involves the following stages:

- a) Determination of Consequence. This entails the calculation of overpressure impact distances for representative AN event scenarios. (This may be all that is required)
- b) Determination of event Likelihoods to provide the frequency component of the risk contours. This requires the quantification of frequency estimates, which together with the calculated Consequence estimates allows a simplified QRA to be undertaken.

For some TGAN storage situations the regulatory authorities may require a full risk assessment as part of the approval/licensing processes. The risk assessment methodology must then be consistent with the requirements of the appropriate authorities.

B.3.1. Risk Targets

With respect to TGAN storage, the assessed risk is the risk of fatality from an explosion. Risk of fatality from toxic gas inhalation is not considered here.

The objective of the risk assessment process is to determine the Consequence and Likelihood reduction measures required such that the overall risk is “as low as reasonably practicable” (ALARP). For the purposes of this document, the following targets are provided to assist in the demonstration of ALARP:

- The risk of individual fatality at residential and community living areas is less than 1×10^{-6} per year for new facilities;

- The risk of individual fatality at vulnerable or sensitive areas is less than 0.5×10^{-6} per year for new facilities;
- The risk of individual fatality at public use or works administrative areas is less than 5×10^{-6} per year for new facilities; and
- Further reduction of either Consequence or Likelihood is not practicable.

Existing facilities can adopt an order of magnitude dispensation for each of the targets above (with exception of the public use and works administrative target) provided there is a robust risk reduction program in place at the facility. Societal risk evaluation may be required where there is a concentration of population in a single location or building. If there are other regulatory risk targets to be considered at the location of the TGAN storage, then these may be substituted for those above. Installations where the calculated risk is higher than the targets provided above may still be appropriate for continued operation if it can be demonstrated that further risk reduction is not practicable.

A suitably qualified risk engineering practitioner may be required to provide appropriate analysis of the outcomes from the risk assessment process.

B.3.2. Determination of Consequence

Consequence is determined by estimating overpressure at any given location based on the size of the TGAN storage and the distance between the storage and that location.

The following information is required:

- A layout of the TGAN storage facility which shows the proposed maximum storage quantities. It must also show the masses of the TGAN stacks, containers, piles configuration and truck locations as well as the separation distances between them.
- A scaled map of the surrounding area which shows exposed locations and buildings

The following steps constitute the process for assessing Consequence:

- a) Determine the size of each TGAN source. Table A.1 on p. 34 details separation requirements that determine whether a stack, etc. may be considered as a single source or must be combined.
- b) Determine the Overall TNT Equivalence of each TGAN source. This will depend on the nature of storage, the type of product and adjacent plant/equipment as discussed in Appendix A.
- c) Determine the NEQ (as adjusted for TNT equivalence) of each TGAN source. This is also discussed in Appendix A.
- d) Calculate the distance to the Maximum Allowable Overpressures for the various exposed locations and buildings in Table B.2 on the next page. The Table highlights the following:
 - Relationship between receptor type and maximum allowable overpressure (OP),
 - A qualitative description of the effect of the overpressure; and
 - A simple overpressure impact versus distance correlation using the Quantity-Distance (Q/D) formula.
- e) From the map of the surrounding area, determine which potentially exposed locations and buildings are within the impact distance of the Maximum Allowable Overpressure. Distance measurements are taken from the nearest point of the TGAN source to each exposed location or building, or the boundary of each adjacent industry as indicated in Figure B.1 on p. 46

Steps (a) to (e) are repeated for each significant TGAN source and each class of exposed site. If there is

- no exposed location or building within the impact distances to the Maximum Allowable Overpressures referenced in Table B.2
- an adequate buffer zone between the TGAN storage facility and exposed sites

then there is no need to continue the risk assessment process.

Table B.2: Quantity-Distance Relationship to Maximum Allowable Overpressures at Exposed Sites ¹⁴

RECEPTOR TYPE	MAX. OP (KPA)	EFFECT OF OVERPRESSURE	QD FORMULA FOR MAX OP
Industrial Works	21	<ul style="list-style-type: none"> Reinforced structures distort Storage tanks fail 20% chance of fatality to a person in a building 	$D = 7.8Q^{1/3}$
Public Use or Works Administrative	14	<ul style="list-style-type: none"> Building uninhabitable and badly cracked 	$D = 10.4Q^{1/3}$
Residential & Community Living Areas	7	<ul style="list-style-type: none"> Damage to internal partitions and joinery, but can be repaired Probability of injury is 10% No fatality 	$D = 17.8Q^{1/3}$
Vulnerable or Sensitive	3.5	<ul style="list-style-type: none"> 90% Glass Breakage No fatality and very low probability of injury 	$D = 30.5Q^{1/3}$

Where:

OP = Overpressure

Q = NEQ (TNT Equivalent in kg)

D = Distance (m)

Example of using the Table:

The maximum allowable overpressure at a private house (*Residential and Community Living Areas*) is 7 kPa. For an NEQ (as Overall TNT Equivalence) of 1,000 kg the minimum distance to an overpressure of 7 kPa or less is calculated as follows:

$$D = 17.8 \times Q^{1/3} \text{ metres} = 17.8 \times 1000^{1/3} \text{ metres} = 180 \text{ metres (approx)}$$

¹⁴ Explosives Information Bulletin No 53, Department of Mines and Energy, Queensland, Australia.

If distance (D) is known, the overpressure can be determined by the following equation:

$$D = Q^{1/3} \times 10^{(2.061 - 1.092 \log_{10}(OP) + 0.158((\log_{10}(OP))^2))}$$

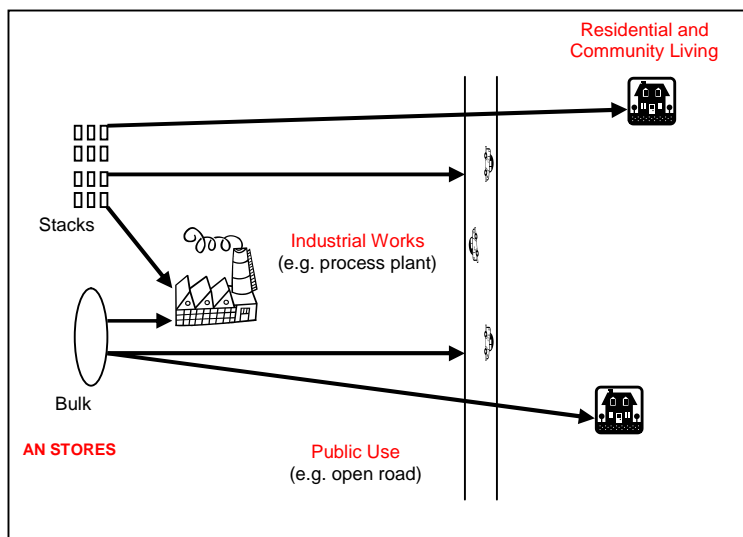
Where:

D = Overpressure impact distance (m)

OP = Overpressure (kPa)

Q = NEQ (TNT Equivalent) (kg)

Figure B.1: Basis of the Separation Distances



If the actual distance between the source and exposed location or building is less than the calculated minimum separation distance then the following options exist:

- Reduction of the NEQ by altering site configuration (stack/pile size and/or separation) where practicable in order to reduce the minimum separation distance to below that of the actual distance; and/or
- Increasing separation distance from TGAN sources to populated areas; and/or
- Use of barrier protection to reduce stack / pile; and/or

- Continuation of the risk assessment process.

B.3.3 Likelihood Estimation

Once Consequence of an event is known, then risk at a potentially exposed site can be calculated by calculating Likelihood of fatality at the site. Likelihood of a fatality is a combination of the Likelihood of an incident occurring and the probability of a fatality due to overpressure at the potentially exposed sites.

Table B.3. shows baseline event Likelihoods based on history of such events. These Likelihoods can be reduced based on implementation of “best practice” control measures.

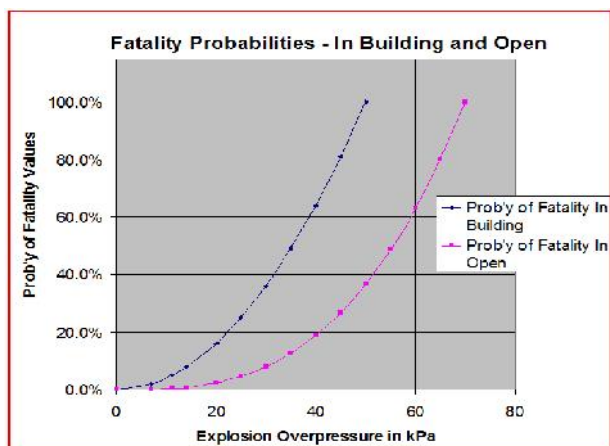
Table B.3: Baseline Event Likelihoods (F_{event}) for an AN Manufacturing Site¹⁵

STORAGE TYPE	F_{event} BY INITIATION MECHANISM			
	Contamination	Fire	High Energy Impact	Malicious Acts
AN Bulk (Per pile up to 5,000 tonnes)	$[10 \times 10^{-6}/\text{yr}]$	$[50 \times 10^{-6}/\text{yr}]$	$[10 \times 10^{-6}/\text{yr}]$	Consult National Security Authority
Off-spec pile (Per pile up to 500 tonnes)	$[50 \times 10^{-6}/\text{yr}^1]$			
AN Bags or Containers (Per stack up to 2,500 tonnes)	$[25 \times 10^{-6}/\text{yr}]$	$[50 \times 10^{-6}/\text{yr}]$ (with pallets) $[25 \times 10^{-6}/\text{yr}]$ (no pallets)	$[5 \times 10^{-6}/\text{yr}]$	

Figure B.2 shows the probability of fatality (both indoor and outdoor) for a given overpressure (P_{fatalOP}). The overall Likelihood of fatality (R_{fatal}) is a combination of these two measures, and is the Risk of fatality.

$$R_{\text{fatal}} = F_{\text{event}} \times P_{\text{fatalOP}}$$

¹⁵ Derived from historical incident data

Figure B.2: Probability of Fatality ($P_{fatalOP}$) vs. Overpressure ¹⁶

In order to determine the risk at any given location (i.e. a receptor at a potentially exposed site) the following approach should be undertaken:

For each source of TGAN (nearest stack, nearest pile, etc.):

- Determine the distance from source to receptor
- Calculate Overpressure at the exposed site (see Table B.2, p. 45).
- Based on personnel location (indoor or outdoor), obtain $P_{fatalOP}$ for the calculated Overpressure from Figure B.2. Note this Figure is not specific for this type of explosion (as detailed in the reference of footnote 17) but is currently the best available estimate. Work is being done in this area and this Figure may be replaced should that work generate more directly applicable data.
- Calculate the Risk of Fatality ($R_{fatal(i)}$) at the potentially exposed site for each plausible scenario i.e. contamination(c), fire(f), projectile(p).

¹⁶ “Managing Risk and Reliability of Process Plants” Prof. Mark Tweeddale, University of Sydney, Gulf Professional Publishing (Elsevier), 2003. ISBN-13: 978-0-7506-7734-9, p 117.

$$R_{fatal(c)} = F_{event(c)} \times P_{fatalOP(c)}$$

$$R_{fatal(f)} = F_{event(f)} \times P_{fatalOP(f)}$$

$$R_{fatal(p)} = F_{event(p)} \times P_{fatalOP(p)}$$

- The Risk of Fatality for that TGAN source is the sum of the Risk of Fatality calculations of each scenario.

$$R_{fatal(source1)} = R_{fatal(c)} + R_{fatal(f)} + R_{fatal(p)}$$

- Add together the Risk of Fatality from the different TGAN sources to give the Overall Risk of Fatality (R_{fatal}) for the potentially exposed population and compare this to the overall risk targets.

$$R_{fatal} = R_{fatal(source1)} + R_{fatal(source2)} + R_{fatal(source3)}$$

Note that large sites may have multiple sources (where bulk storage >5,000 tonnes or bag/container storage >2,500 tonnes) as well as different initiating mechanisms.

B.3.4. Risk Control Measures

Risk control measures (both Consequence and Likelihood based) should be implemented and risk recalculated until the desired targets are met. Analysis should then determine whether or not there are any further practicable risk reduction measures.

(Note: If the risk targets cannot be met then it is important to ensure that ALARP is demonstrated.)

A key step in the risk assessment process will be to list those measures relied upon to generate suitable risk profiles at potentially relevant sites.

B.4. Key References

Lees, F.P. 1995 "Loss Prevention in the Process Industries," 2nd Edition. pp 17/130-134. Reference for Kingery and Bulmash's Overpressure Model.

Kersten, R J A, E I V van den Hengel and A C van der Steen. 2006. "Safety testing of Ammonium Nitrate products", The International Fertiliser Society Proceedings No: 580, London.

C. Security Plans

C.1. General

Security plans may be required by the regulatory authority. If not, developing a plan based on vulnerability and threat in the area of operation should be undertaken. The suggestions below might be implemented based on your risk assessment.

The appropriate level of security can vary significantly from facility to facility. It depends on the number of employees, the level of pedestrian and vehicular traffic into and out of the facility, the attractiveness of the facility as a target for various threats, the proximity of the facility to populated areas, and many other factors.

The principal objectives of a security plan are:

- To provide secure storage for TGAN
- To enable theft to be detected quickly and the authorities to be advised.
- To identify and report security related incidents
- Prevent deliberate contamination
- Control access to product

The security plan will have four main elements:

- Security risk assessment;
- Personnel management;
- Site security; and
- Procedures.

Key points of the security plan elements are described in the following paragraphs.

C.2. Security Risk Assessment

This assessment will describe existing security measures and examine the level and type of security risks to particular stores and location

Key Points:

- Consider outside threats and the Security risk (see p. 6, Section 3, Definitions) from staff or contractors who have access to the premises and to ammonium nitrate.
- Consider whether current security arrangements leave the TGAN vulnerable to theft or sabotage
- Consider appropriate security improvements to manage the assessed risk.

Security risk assessments should be reviewed periodically, particularly in light of any security incidents that occur.

C.3. Personnel Management

The following paragraphs describe the minimum requirements to meet the personnel requirements of the site security plan.

C.3.1. List of authorised persons

Key points:

- The list must contain those personnel including contractors who are authorised to have unsupervised access to TGAN.
- Persons on the list must undertake the necessary clearances as specified by the organisation, or where required the regulatory authority, to have unsupervised access to TGAN.

C.3.2. Staff recruitment

Key Points:

- New personnel to be added to the list of authorised persons will be required to have the necessary clearances. When cleared, they may be added to the security plan in the form of a dated amendment to the list.
- The security plan must detail the checks that will be made to confirm the identity of new workers who will have unsupervised access to TGAN.
- Checks should also be made with the applicant's references and previous employers.
- New staff should be trained in the security requirements as part of the induction training.

C.3.3. Maintaining the security plan

Key Points:

- Nominate the responsible person/security manager to implement and maintain the security plan
- Train relevant personnel in the access controls, recording procedures and reporting of security incidents.
- Institute regular audits to ensure the security plan is operating effectively.
- Non-conformances must be recorded and followed up.
- The security plan should be reviewed and updated annually, preferably by an external expert, and testing the robustness of the Plan should be considered.

C.4 Site Security

TGAN may be required by an Authority Having Jurisdiction to be in a secure store (see p. 6, Section 3, Definitions) with a secure perimeter or under constant surveillance. Details of the secure store should be included in the Security Plan. These details would cover a description of the storage facility and will include:

- The type and dimensions of the structure.
- The number and type of doors and windows.
- The types of security devices selected, etc.

Depending on the location, vulnerability, complexity and size of the site, the following physical controls can be considered, depending on the security risk analysis:

- Post “No Trespassing” and “Authorised Access Only” signs;
- Install fencing
- Install metal/concrete posts and trenches that prevent vehicles from driving into the site at points other than official entrances;
- Install vehicle gates with retractable barriers;
- Install personnel gates and turnstiles;
- Provide lighting that makes it easier for employees and even passers-by to observe and possibly identify intruders;
- Employ natural surveillance by arranging reception, production, and office space so that unescorted visitors can be easily noticed;

- Install appropriate locks on exterior and interior doors, fencing, gates, etc.;
- Install appropriate, penetration-resistant doors and security hinges;
- Install secure windows with appropriate locks; and
- Install electronic security measures such as motion sensors, monitored alarms and closed-circuit television (CCTV)

C.5. Procedures

C.5.1. Control of Access

Key Controls:

- Persons having unsupervised access to the store must be clearly identified and on the list of authorised persons (see Section C.3.1).
- Persons not on the list of authorised persons may enter the store under the supervision of an authorised person.
- A 'key control plan' must exist that identifies who has access to the keys of the secure store and where the keys are secured.
- An audit plan to maintain the effectiveness of the controls.

Depending on the location, risk assessment and complexity of the site, the procedures may incorporate:

- A system for determining which cars, trucks or rail cars may enter the site, through which gates, docks or other entrances and under what conditions;
- An access control system relying on access cards;
- An independent system relying on staffed security posts;
- A requirement for visitors to be signed in and escorted;
- Specific procedures at loading and unloading areas to ensure correct delivery and dispatch quantities.

C.5.2. Movements and inventories of TGAN

Systems should be in place to record the movements of TGAN and to enable reconciliation of actual and theoretical stocks. This will include keeping of relevant records especially with regard to:

- Purchases/acquisitions and sales/supply of TGAN to ensure that changes in custody occur only between licence holders. Formal acknowledgment of receipt of each complete shipment by the purchaser should be considered.
- Movements of TGAN into and out of the secure store, so that reconciliation is possible.
- Security incidents (including thefts, attempted thefts, unexplained losses, sabotage or attempted sabotage, break-ins, attempted break-ins and any other security incidents) to enable these incidents to be investigated and reported to the regulatory authority and the police.

Records must be kept for a minimum of five years or the period dictated by the regulatory requirements.

D. Properties of Ammonium Nitrate

D.1. General

Pure ammonium nitrate (NH_4NO_3) is a white, water-soluble, crystalline substance with a melting point of 170°C . Decomposition starts at 210°C . Technical grades may start to decompose at temperatures lower than 210°C because of impurities. Additives and coating agents can have a marginal effect on the decomposition temperature; other chemicals can have significant effects.

The substance is classified as an oxidising agent Class 5.1 (UN1942).

As an oxidizer AN can support the burning of fuels relatively easily and is used extensively to support the “fast” burning required in explosives. Decomposition of AN takes place through several reactions. In the early stages sublimation to ammonia (NH_3) and nitric acid (HNO_3) dominates. At slightly higher temperatures, nitrous oxide (N_2O) is the main decomposition product. Above 260°C nitrous gases (NO_x) are formed in considerable amounts and these are toxic.

AN is used worldwide mainly as fertilizer. This is because of its unique combination of nitrogen bound as nitrate and as an ammonium ion. The substance is readily soluble in water and solubility is highly dependent on the temperature.

AN is manufactured by neutralising nitric acid with ammonia, resulting in a solution with a high mass fraction of AN. This solution can be delivered as hot solution as a raw material for slurry or emulsion explosives. AN has at least five different crystal modifications existing at different temperature intervals. The most interesting transition point is at 32°C . In passing this temperature a volume change takes place in each particle, which results in a breakdown to powder. In practice, this means an increased risk of caking. Caking also takes place due to AN's tendency to absorb water.

D.2. Product quality

D.2.1. Ammonium nitrate form

The Product for explosives manufacturing can be delivered in different forms depending on the type of explosives to be manufactured:

The most convenient form for the manufacture of the base emulsion or slurries is a concentrated hot solution of AN. However for storage, transport and cost reasons AN is often used in its prill form to manufacture the base emulsion by dissolving them in water. This base emulsion can then be mixed with more prills or ANFO.

The prill or crystalline form treated and/or coated with an anti-caking agent is also the most convenient form that is used for the manufacture of dynamites or TNT sensitised explosives. It is important that any anti-caking agent which may be added does not interfere with either the quality of the product or the manufacturing process of any explosive. In some instances the prills and crystalline AN are crushed or milled as part of the manufacturing process.

AN in prill form is preferable for Ammonium Nitrate Fuel Oil (ANFO) mixtures. In this case the porosity, density and strength (measured as friability) of the prills may vary depending on the particular application.

E. Hazards of Ammonium Nitrate

E.1. General

AN has three main hazards:

- fire due to oxidising nature
- decomposition with formation of toxic gases
- explosion

E.2. Fire

AN itself is not combustible and does not burn, but being an oxidising agent it can facilitate the initiation of fire and will assist the combustion of other materials, even if air is excluded. Under confinement and exposed to heat from external fire, TGAN can thermally decompose. This reaction can, in turn, accelerate to an explosion.

AN products contaminated with oil or combustible materials can initiate a fire when hot. Similarly, combustible materials impregnated with AN have been known to start burning spontaneously when left on or near hot surfaces.

Hot AN melts or solutions can initiate fires when it comes into contact with combustible materials such as rags, wooden articles or clothing. Hot AN solutions present the additional hazard of causing burns if in contact with the skin.

E.3. Decomposition

If AN is heated it will decompose to give off toxic gases. In an open and unconfined situation, it will decompose completely to give gaseous products of ammonia (NH_3) and nitric acid (HNO_3) in a steady controlled way with white fumes and vapours.

If heated sufficiently (such as in a fire) combined with contamination, confinement or both (such as in drains or enclosed parts of equipment), other gases including brown vapours of toxic nitrogen dioxide (NO_2) will be given off **and the explosive sensitivity of ammonium nitrate increases**. Through self-accelerating reactions the temperature will keep on rising and a detonation is likely to occur.

Fires involving AN have caused many explosions in the past. Conversely, many more fires involving AN have **not** lead to explosions.

E.4. Chemical Reaction

In the presence of moisture, ammonium nitrate can undergo an electrochemical reaction with copper to form copper tetramine nitrate $[\text{Cu}(\text{NH}_3)_4](\text{NO}_3)_2$, which is of the same order of brisance and sensitivity to impact as lead azide (a primary explosive). For this reason, brass or bronze should not be used for equipment or tools that come into contact with TGAN. (Reference: Encyclopaedia of Explosives and Related items, Volume I, Picatinny Arsenal, Dover, New Jersey, USA, 1960).

E.5. Explosion

AN is ideally set up as an explosive precursor substance since it carries the oxidising nitrate ion in intimate contact with the fuel element, the ammonium ion. All that is required are small amounts of contaminants to act as a catalyst which explains the **unpredictability of AN under fire conditions**. As a result of the decomposition reactions of AN, the risk of an explosion is increased by heating AN in combination with contamination, confinement or both.

In a fire situation, pools of molten AN may be formed. If the molten mass becomes confined, such as in drains, pipes, plant or machinery, or combines with contaminants, it could explode.

F. Safety Data Sheet for Ammonium Nitrate

Safety Data Sheet

Medical attention and special treatment:

Treat as for exposure to nitrates. May cause methemoglobinemia. Clinical findings: The smooth muscle relaxant effect of nitrate salts may lead to headache, dizziness and marked hypotension.

Cyanosis is clinically detectable when approximately 15% of the haemoglobin has been converted to methaemoglobin (ie. ferric iron).

Symptoms such as headache, dizziness, weakness and dyspnoea occur when methaemoglobin concentrations are 30% to 40%; at levels of about 60%, stupor, convulsions, coma and respiratory paralysis occur and the blood is a chocolate brown colour. At higher levels death may result. Spectrophotometric analysis can determine the presence and concentration of methaemoglobin in blood.

Treatment:

1. Give 100% oxygen.
 2. In cases of (a) ingestion: use gastric lavage, (b) contamination of skin (unburnt or burnt): continue washing to remove salts.
 3. Observe blood pressure and treat hypotension if necessary.
 4. When methaemoglobin concentrations exceed 40% or when symptoms are present, give methylene blue 1 to 2 mg/kg body weight in a 1% solution by slow intravenous injection. If cyanosis has not resolved within one hour a second dose of 2 mg/kg body weight may be given. The total dose should not exceed 7 mg/kg body weight as unwanted effects such as dyspnoea, chest pain, vomiting, diarrhoea, mental confusion and cyanosis may occur. Without treatment methaemoglobin levels of 20-30% revert to normal within 3 days.
 5. Bed rest is required for methaemoglobin levels in excess of 40%.
 6. Continue to monitor and give oxygen for at least two hours after treatment with methylene blue.
 7. Consider transfer to centre where haemoperfusion can be performed to remove the nitrates from the blood if the condition of the patient is unstable.
 8. Following inhalation of oxides of nitrogen the patient should be observed in hospital for 24 hours for delayed onset of pulmonary oedema.
- Further observation for 2-3 weeks may be required to detect the onset of the inflammatory changes of bronchiolitis fibrosa obliterans.

5. FIRE FIGHTING MEASURES

Do Not Fight Fires Involving Ammonium Nitrate

Hazards from combustion products:

Oxidizing substance. Nitrate salts on their own are not combustible, however they support the combustion of other materials. Decomposes on heating emitting irritating white fumes. Brown fumes indicate the presence of toxic oxides of nitrogen.

Precautions for fire fighters and special protective equipment:

Increases intensity of a fire. Nitrate salts on their own are not combustible, however they will support the combustion of other materials. Decomposes on heating emitting irritating white fumes. Brown fumes indicate the presence of toxic oxides of nitrogen. On detection of fire the compartment(s) should be opened up to provide maximum ventilation. Fire-fighters to wear self-contained breathing apparatus and suitable protective clothing if there is a risk of exposure to products of combustion/decomposition. Fires should be fought from a protected location. Keep containers and adjacent areas cool with water spray. If safe to do so, remove containers from path of fire. A major fire may involve a risk of explosion. An adjacent detonation may also involve the risk of explosion. Heating can cause expansion or decomposition of the material, which can lead to the containers exploding.

Suitable Extinguishing Media:

Alcohol resistant foam is the preferred firefighting medium but, if it is not available, normal protein foam can be used. Water spray (large quantities).

Unsuitable Extinguishing Media:

Dry agent (carbon dioxide, dry chemical powder).

Hazchem Code: 12

Safety Data Sheet

6. ACCIDENTAL RELEASE MEASURES

Emergency procedures:

Shut off all possible sources of ignition. Clear area of all unprotected personnel. Wear protective equipment to prevent skin and eye contact. Avoid breathing in dust. Work up wind or increase ventilation.

Methods and materials for containment and clean up:

Contain - prevent run off into drains and waterways. Sweep up, but avoid generating dust. Collect and seal in properly labelled containers, bags or drums for disposal or re-use. (Loose fitting lids). DO NOT return spilled material to original container. Ensure that contaminated material (clothing, pallets) is thoroughly washed. If contamination of sewers or waterways has occurred advise local emergency services.

This material is classified as Security Sensitive Ammonium Nitrate (SSAN). Spillage recovery needs to be appropriately documented and material accurately accounted for.

7. HANDLING AND STORAGE

Conditions for safe storage:

Store in a cool, dry, well ventilated place and out of direct sunlight. Store away from sources of heat or ignition. Keep containers closed when not in use - check regularly for spills. Store away from combustible materials including organic materials, reducing agents, metal powders, strong acids, nitrites, chlorates, chlorides and permanganates. Store away from incompatible materials described in Section 10. Store away from possible contaminants. Ammonium Nitrate is incompatible with, and must be stored away from, tetranitromethane, dichloroisocyanuric acid, trichloroisocyanuric acid, any bromate, chlorate, chlorite, hypochlorite or chloroisocyanurate or any inorganic nitrite.

If using wooden pallets, these must be hardwood and periodically washed down with large amounts of water to remove all traces of the material. Concrete floors are recommended for storage. If ammonium nitrate is to be stored in bulk, the surface must be treated so that it is resistant to attack by an oxidising agent. Bulk ammonium nitrate should not be stored on a bituminous floor.

This product when stored in a confined, unventilated space/hold can give off ammonia or other odour and lead to the depletion of oxygen within this space and other confined spaces. It is therefore essential that ventilation is carried out prior to entry to all ship holds.

Ensure ammonium nitrate is stored securely and in accordance with regulations/controls issued by relevant authority. The secure storage of ammonium nitrate within Australia includes but is not limited to the use of site security plans, locking the facility/container with physical restraining items, validation and record keeping of all stock, and where deemed necessary through a risk management approach constant surveillance.

Within Australia all persons who have unsupervised access to Security Sensitive Ammonium Nitrate (SSAN), will require security clearances. The issuing of security clearances is controlled and issued through the local Government authorities. The checks include a criminal history check (CHC), and a politically motivated violence check (PMV).

Precautions for safe handling:

Avoid skin and eye contact and breathing in dust. Avoid handling which leads to dust formation.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Occupational Exposure Limits: No value assigned for this specific material by the National Occupational Health and Safety Commission.

Engineering controls:

Use in well ventilated areas. Avoid generating and breathing in dusts. Use with local exhaust ventilation or while wearing dust mask. Keep containers closed when not in use.

Product Name: AMMONIUM NITRATE
Substance No: 000000050222

Issued: 29/07/2010
Version: 1

Safety Data Sheet

Personal Protective Equipment:

The selection of PPE is dependant on a detailed risk assessment. The risk assessment should consider the work situation, the physical form of the chemical, the handling methods, and environmental factors.

OVERALLS, SAFETY SHOES, SAFETY GLASSES, GLOVES, DUST MASK.

Wear overalls, safety glasses and impervious gloves. Avoid generating and inhaling dusts. If excessive dust exists, wear dust mask/respirator meeting the requirements of AS/NZS 1715 and AS/NZS 1716. Always wash hands before smoking, eating, drinking or using the toilet. Wash contaminated clothing and other protective equipment before storage or re-use.

9. PHYSICAL AND CHEMICAL PROPERTIES

Physical state:	Granular Solid / Prills
Colour:	White to Off-white
Odour:	Negligible
Solubility:	Soluble in water.
Specific Gravity:	0.72 - 0.78 g/cm ³ (bulk density)
Flash Point (°C):	Not applicable
Flammability Limits (%):	Not applicable
Autoignition Temperature (°C):	Not available
Boiling Point/Range (°C):	Decomposes
pH:	4.6 - 5.2 (10% solution @ 20°C)

10. STABILITY AND REACTIVITY

Chemical stability:	Powerful oxidising agent. May explode under confinement and high temperature, but not readily detonated.
Conditions to avoid:	Avoid exposure to heat, sources of ignition, and open flame. Will react with organic materials and reducing agents. Avoid contact with combustible substances. Avoid contact with other chemicals. Avoid dust generation. Hygroscopic - adsorbs moisture from the air.
Incompatible materials:	Ammonium nitrate is a powerful oxidising agent. It is incompatible with tetranitromethane, dichloroisocyanuric acid, trichloroisocyanuric acid, any bromate, chlorate, chlorite, hypochlorite, perchlorate, chloroisocyanurate, any inorganic nitrite, and metal powders. Incompatible with combustible materials. Incompatible with reducing agents.
Hazardous decomposition products:	Oxides of nitrogen. Ammonium nitrate fumes.
Hazardous reactions:	Oxidising agent. Supports combustion of other materials and increases intensity of a fire. Will react with organic materials, and reducing agents. Reacts with nitrites, chlorides, chlorates, permanganates and metal powders. When mixed with strong acids, and occasionally during blasting, it produces an irritating toxic brown gas, mostly of nitrogen dioxide. When molten may decompose violently due to shock or pressure. Heating can cause expansion or decomposition of the material, which can lead to the containers exploding. Hazardous polymerisation will not occur.

11. TOXICOLOGICAL INFORMATION

Product Name: AMMONIUM NITRATE
Substance No: 000000050222

Issued: 29/07/2010
Version: 1

Safety Data Sheet

No adverse health effects expected if the product is handled in accordance with this Safety Data Sheet and the product label. Symptoms or effects that may arise if the product is mishandled and overexposure occurs are:

Ingestion:	Swallowing can result in nausea, vomiting, diarrhoea, and abdominal pain. Swallowing large amounts may result in headaches, dizziness and a reduction in blood pressure (hypotension).
Eye contact:	May be an eye irritant. Exposure to the dust may cause discomfort due to particulate nature. May cause physical irritation to the eyes.
Skin contact:	Repeated or prolonged skin contact may lead to irritation. See effects as noted under 'Inhalation'. Can be absorbed through cut, broken, or burnt skin with resultant adverse effects.
Inhalation:	<p>Breathing in dust may result in respiratory irritation. Blasting may produce a toxic brown gas of nitrogen dioxide. Inhalation of the gas may result in chest discomfort, shortness of breath and possible pulmonary oedema, the onset of which may be delayed.</p> <p>Absorption of ammonium nitrate by inhalation, ingestion or through burnt or broken skin may cause dilation of blood vessels by direct smooth muscle relaxation and may also cause methaemoglobinaemia.</p>

Long Term Effects:

No information available for the product.

Toxicological Data:

Oral LD50 (rat): 2,217 mg/kg for ammonium nitrate

Following the ingestion of nitrates in humans and animals methaemoglobinaemia has occurred.

12. ECOLOGICAL INFORMATION

Ecotoxicity	Avoid contaminating waterways.
Aquatic toxicity:	Ammonium nitrate was evaluated at 5, 10, 25 and 50 mg (NH ₄ ⁺)/L. The fertility of <i>Daphnia magna</i> was decreased at 50 mg/L. Post embryonic growth of crustacea was impaired at 10, 25 and 50 mg/L.

13. DISPOSAL CONSIDERATIONS

Disposal methods:

Refer to Waste Management Authority. Dispose of material through a licensed waste contractor. Empty containers must be decontaminated by rinsing thoroughly with water. Rinsing water needs to be disposed of carefully.

Disposal of material needs to be appropriately documented and material accurately accounted for.

14. TRANSPORT INFORMATION

Road and Rail Transport

Classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for Transport by Road and Rail; DANGEROUS GOODS.

UN No:	1942
Class-primary	5.1 Oxidizing Agent
Packing Group:	III
Product Name:	AMMONIUM NITRATE
Substance No:	000000050222

Issued: 29/07/2010
Version: 1

Safety Data Sheet

Proper Shipping Name: AMMONIUM NITRATE
Hazchem Code: 1Z

Marine Transport

Classified as Dangerous Goods by the criteria of the International Maritime Dangerous Goods Code (IMDG Code) for transport by sea; DANGEROUS GOODS.

UN No: 1942
Class-primary: 5.1 Oxidizing Agent
Packing Group: III
Proper Shipping Name: AMMONIUM NITRATE

Air Transport

Classified as Dangerous Goods by the criteria of the International Air Transport Association (IATA) Dangerous Goods Regulations for transport by air; DANGEROUS GOODS.

UN No: 1942
Class-primary: 5.1 Oxidizing Agent
Packing Group: III
Proper Shipping Name: AMMONIUM NITRATE

15. REGULATORY INFORMATION

Classification: Based on available information, not classified as hazardous according to criteria of Safe Work Australia; NON-HAZARDOUS SUBSTANCE.

Poisons Schedule: None allocated.

All the constituents of this material are listed on the Australian Inventory of Chemical Substances (AICS).

Various regulations/controls/authorisations/licences may apply governing the manufacture, importation, exportation, use, handling, storage, sale/supply, transport and disposal of ammonium nitrate. Ammonium nitrate in Australia is considered a security sensitive material and loss, theft, attempted theft and unexplained discrepancies shall be reported to authorities. Record keeping and licensing of individuals shall be required and maintained.

16. OTHER INFORMATION

Reason(s) for Issue:
First Issue

About SAFEX International

SAFEX International is a global organisation with the fundamental objective of improving the safety of operations and their impact on people and the environment. Operations cover the development, manufacture, storage, and transport of commercial explosives, military explosives and pyrotechnic products throughout the world. The term "explosives" includes initiating devices, propellants, industrial and military powders as well as the raw and intermediate materials associated with the explosives industry.

Current membership of SAFEX is over 150 companies from all the continents in the world and operating in more than 40 different countries.

SAFEX is a non-profit making association of manufacturers of explosives and was founded in 1954 with the aim of exchanging experiences within the explosives industry. The way SAFEX works is to exchange health, safety, and environmental (HS&E) information about major accidents, serious incidents, and near-events. The objective is to avoid other manufacturers experiencing the same or similar occurrences. In this way SAFEX contributes to improving the health and safety of operations within the explosives business as well as the well-being and standing of the explosives industry. As a voluntary organisation, SAFEX is not organised for the pecuniary gain of any of its members.



SAFEX International is registered in Switzerland as an international association operating not for profit

Registered Office:

c/o Modoux Services Sàrl, Route du Village 13, CH-1807 BLONAY, Switzerland

Tel: +41 21 943 0101; Fax: +41 21 943 0109;

Web: www.safex-international.org

Please direct all communication to the Secretary General

Tel: +1 919 342 5848; Tel/Fax +27 21 854 4962

e-Mail: [secretariat @safex-international.org](mailto:secretariat@safex-international.org)