NATIONAL INSTITUTE FOR EXPLOSIVES TECHNOLOGY

GUIDELINE 01: SAFE HANDLING, STORAGE, and EMERGENCY RESPONSE of AMMONIUM NITRATE (PPAN/PGAN/TGAN)

V 1.0

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APPENDICES

This Guideline was generated using the best available knowledge and skills in the industry and NIXT is hereby indemnified against any actions, claims, liability or loss in respect of any act or omission (including any negligence, unlawful conduct, misinterpretation or lack of knowledge) that is a cause of an incident under conditions stipulated in the Guideline.

1. ACKNOWLEDGMENTS

NIXT acknowledges with thanks the work done by SAFEX International in the provision of the Guideline "Good Practice for the Safe Storage of Ammonium Nitrate (Part of the SAFEX Good Explosive Practice Series, GPG 02 rev02) on which this guideline was based.
NIXT also extends its thanks and gratitude to the NIXT AN Project Team for their dedicated effort in generating this document.

2. INTRODUCTION

This document was developed by the manufacturers of ammonium nitrate to provide guidelines for the storage of Technical Grade Ammonium Nitrate (TGAN) at manufacturing, distributors' and end-user sites within the Republic of South Africa (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 Dangerous Goods under the United Nations Recommendations on the Transport of Dangerous Goods – Model Regulations 16th Edition and the International Maritime Dangerous Goods Code.

AN (within specification) does not burn, but if exposed to elevated temperatures, for example in a fire, it will decompose above 210˚C, emitting toxic gases. In some situations, for example under confinement and intense fire and/or with contamination a decomposing mass of AN can 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 AN occurring without one of these four scenarios is extremely low (see Table B.3 Appendix B).

Although incidents involving AN are rare, these can have severe consequences.

For example, on September 21, 2001, a massive explosion occurred in a warehouse at the Azote de France fertilizer factory in Toulouse, France, involving 200-300 tons of AN, which was stored in bulk in a hangar. The explosion resulted in the death of 30 people, 2500 injuries, the destruction of the factory, and an additional 10,000 buildings being heavily damaged. The exact cause of this accident remains unknown. Storage of incompatible material with AN is believed to have been a factor.

On April 17, 2013, a fire at a fertilizer storage and distribution facility in West Texas, resulted in a detonation of AN fertilizer stored at the facility, killing 15 people, including some of the firefighters responding to the fire.

These incidents remind us of the hazard potential of ammonium nitrate and the lessons learned from them must be used in managing it. The properties of ammonium nitrate, (see Appendix D) and specifically those conditions which can lead to decomposition must be understood by the reader to place the recommendations in this guideline in context with the hazards that it can present.

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

Although compliance with an approved code or best practise is not mandatory, it is expected that deviations from recommended practices will be justified and it can be demonstrated that the use of alternative risk control measures provides an equivalent or lower level of risk.

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.

3. SCOPE

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

AN is covered mainly by UN Numbers UN1942 and also by UN2067 in some countries e.g. US under the United Nations Recommendations on the Transport of Dangerous Goods. It is classified as Class 5.1 Dangerous Goods – Model Regulations in SA in terms of SANS 10228. Classification is subject to individual national regulations by the relevant competent authority, 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-specification 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 mixtures, which are Class 1 Dangerous Goods (UN0082, UN0222, UN0331).
- Ammonium nitrate solutions or emulsions, suspensions or gels (UN3375).

4. DEFINITIONS

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

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

(i) Bags stacked to height with a vertical perpendicular face to the floor

(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 45º 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 AN.

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 AN: 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 AN 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.

IP 65: Ingress Protection rating to a piece of electronic equipment
First digit 6: Totally protected against dust ingress
Second digit 5: Protected against low pressure water jets from any direction. Limited ingress permitted.

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

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

Personal Protective Equipment(PPE): *Anything used or worn by a person to minimise risk to the person's health or safety and includes a wide range of clothing and safety equipment. PPE includes boots, face masks, hard hats, ear plugs, respirators, gloves, safety harnesses, high visibility clothing etc*

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 Critical Equipment (SCE): Equipment such as pipes, vessels, tanks, pumps etc. that are used in the processing of ammonium nitrate and have the potential to cause a catastrophic safety incident if they fail, and or equipment that are designed to mitigate the impact of the catastrophic safety incident.

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 AN.

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

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 (SOPs): Written procedures containing an explicit description of how a job is to be performed. The SOPs 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 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), Industrial Grade (IGAN) or PGAN (Porous Granular AN) .

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.

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.

5. 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 AN 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:

5.1. 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.

5.2. 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 mechanism for employees to submit concerns, notification of safety hazards and suggestions for improvement.
- 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.

5.3. 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.
- Employees working with hazardous processes need to understand the safety and health hazards associated with the chemicals and processes with which they work and the roles they play in controlling them. This is especially pertinent in the use of ammonium nitrate.
- 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.
- Training should cover abnormal operation and emergency response

5.4. 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. SOPs could as a minimum include the following

    - 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 AN material
    - System to check trips and alarms including the documentation of test results.
    - Preventative maintenance programs.
    - PPE requirements
    - 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 AN is stored.
    - Vehicle operation, control and maintenance.
    - Prohibition of smoking and open flames, re-fuelling, and flammables around AN.
    - Permit to Work, Hot Work Permit System
    - All Safety critical tasks must be covered by SOP
    - Safety Critical Equipment register including normal operating limit(s) for each critical parameter (e.g. within the design basis / limits such as maximum allowable operating pressure, etc.)
    - Special precautionary measures regarding operating AN equipment
    - Causes and consequences of deviation from normal operating limits (abnormal operation) and steps required for avoiding and correcting deviations.
    - The maximum allowable inventory

5.5. Emergency Response

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

- An introduction to MHI. Refer to the SANS standard (1460 in development)
- 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 (see below).
- 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 to be implemented throughout the organisation that covers employees; management; regulatory authorities; media; remote sites; contractors; visitors; neighbouring communities; and local emergency services. (see SANS 10263-0 for details).

Local emergency services and relevant authorities should be notified of any incidents, which activated the emergency procedures; this will be applicable where AN has been classified at a specific site according to RSA MHI Regulations .

Competence and Experience:

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

Evacuation Guidelines:

In the event of an uncontrolled fire capable of engulfing the AN stores, AN 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.

Fire Fighting Considerations:

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

The properties of AN, 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.

The following key considerations should be taken into account:

- Fires involving Ammonium Nitrate should never be fought. If the fire involves Ammonium Nitrate the facility must be evacuated. (See Section 4.5 for evacuation distance guidelines).
- When responding to a fire where AN is stored firefighters should:
    - Firstly, consider if they can safely fight the fire or whether they should just let it burn, move to a safe location, and focus on evacuating nearby residents and preventing further safety issues for the surrounding community.
    - Establish wind direction on a continuous basis;
    - Determine whether or not it makes sense to fight the fire or to let it burn.
    - Firefighters and emergency responders should **not** fight a AN fire and everyone, including fire fighters, should be evacuated to a safe distance if they observe any of the following which indicate that AN could be burning
    - The fire is judged to be out of control;
    - The fire is engulfing the AN; or

- Brown/orange smoke or fumes are detected, indicating the presence of nitrous oxides (which are toxic); or
- A rapid increase in the amount and/or intensity of smoke or fire in the area of AN storage.

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- 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 AN.
- For a fire involving AN, the prompt remote 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.
- Firefighting systems for incipient fires or fires not involving Ammonium Nitrate should be capable of single person operation (Typically AN stores would be operated by a small number of people. An exception is if the AN 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 firefighting 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 previously.

6. REGULATORY REQUIREMENTS

Operators of AN stores must comply with legislation and appropriate regulations applicable to the storage and handling of AN.

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

- The employer of the store shall have a copy of relevant licences on site.
- The employer 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 AN are responsible for ensuring the AN has been properly classified, packaged, marked, labelled and placarded.
- 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 AN.
- The supplier of AN should, where applicable, only sell to organisations holding appropriate permits to deal with 5.1 classified material.
- The supplier should provide the relevant safety information. A copy of the NIXT Guideline or other relevant safety information.)
- AN shall be handled with the correct personal protective equipment (PPE) e.g.
- Goggles or face shield. . Broom
- Light protective clothing.
- Protective gloves.
- Protective footwear.
- Eyewash bottle with clean water

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

6.1 Key roles and responsibilities

National, provincial and local authorities:

The authorities are responsible for the following:

- Issuance of the required licences, permissions and certifications.
- Provision of regulations and laws governing the production, handling, usage, transport and storage of AN.
- Provide guidance when necessary.

Producers of AN:

The producers of AN need to fulfil the following as a minimum:

- Obtain the appropriate licencing and permissions.
- Suitable appointments are made to manage and control the AN production process.
- Operating or work instructions developed, documented and approved.
- Training is given on the operation of the process and records are kept of the training.
- Explosive managers are appointed for the section as required.
- Access control of the production areas.

Manufacturers using AN:

Any company or organisation using AN in their process must have the following:

- Obtain the appropriate licencing and permissions.
- Suitable appointments are made to manage and control the AN using manufacturing process.
- Operating or work instructions developed, documented and approved.
- Training is given on the operation of the process and records are kept of the training.
- Explosive managers are appointed for the section as required.
- Access control of the manufacturing areas.

AN storage and warehousing:

The employer of the warehouse will comply with the requirements of SANS 10263-0 make sure the storage facility or warehouse complies with the standard and applicable regulations, with specific attention to the following:

- Suitable appointments are made to manage the storage and handling of AN.
- Training is given on the storage and handling of AN and record is kept of the training.
- Proper emergency procedure is developed for the warehouse or storage facility.
- Training on the emergency procedures and record is kept of the training.
- Documentation is kept up to date and easy accessible.
- Access control of the storage facility or warehouse.

Emergency services:

The emergency services, within whose area a AN producer, handler, user, transporter or storage facility falls, will have the following in place:

- Liaison with the AN facility and other emergency services as required.
- Assist the AN producers, handlers, users, transporters and storage facility managers in the development of an emergency plan.
- Ensure the emergency personnel are properly trained to respond to an emergency involving AN.
- Have the necessary equipment and systems in place to respond to an emergency involving AN.

- Each emergency service shall maintain in an orderly manner, all information, emergency plans and contact telephone numbers with respect to warehouses that operate within its area of control.

7. SITE DESIGN, CONSTRUCTION & PRODUCT SAFETY MANAGEMENT

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

- Open air compounds – IBCs, packages
- Silos/Bins – Bulk AN
- Buildings – IBCs, packages, bulk

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

7.1 Location of Storage Facilities

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

Based on the requirements of SANS 10263-0 the company or organisation requiring AN storage will at minimum consider the following:

- AN storage requirements.
- Suitability of the proposed location.
- Maintain a separate administrative building.
- Attain the necessary approval, permits and licences for the establishment of a AN storage facility.
- Site emergency plans including external emergency services.
- Facility and site will be constructed and operated in such a way to prevent to contravention of applicable environmental legislation.

(For further information ,see Appendix A)

7.2 General Requirements

The general requirements are outlined below.

Good housekeeping:

Housekeeping for AN production, handling, usage, transporting and storage facilities should satisfy the requirements as set out in SANS 10263-0, with the following minimum requirements:

- Flammable and combustible material will not be allowed to accumulate in the areas with clearly demarcated areas for their holding before removal or disposal.
- Areas must be kept clear of the build-up of waste AN.
- Areas clearly marked for the storage of waste or contaminated AN shall be maintained.
- A risk based approach should be adopted and kept to a minimum

Electrical:

See SANS 10263 (Note: Four standards addressing electrical equipment and installations)

- Electrical equipment and installations which are used in an AN environment must conform to the relevant electrical codes.
- Ensure proper protection against electrical storms according to local codes and practices as prescribed under SANS 10313 and in conjunction with SANS 62305 series.
- Where there is a risk of corrosion from AN, ensure electrical equipment has a rating of not less than IP65.

Construction:

- Storage facilities 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 AN.
- Use fire resistant walls in building design within proximity of a combustible building or materials (SANS 10263-0) Buildings should have adequate ventilation or be constructed to self-ventilate in the event of a fire to avoid pressurisation.
- Buildings should be kept dry and free of moisture.
- 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 cement may react with AN, which causes ammonia release.
- AN stores must not be erected on locations that have pyrites, hot or other reactive ground that can react violently with the AN.
- If a AN store is located inside a building, at least one of the walls of the store must be an external wall to allow molten AN to flow clear of the building in the event of a fire.
- Ensure that materials or fittings used in the building construction that could come into contact with AN, during normal storage or spillage, do not contain zinc, copper or other incompatibles.
- Drainage systems must be constructed according to applicable environmental standards and should be designed to avoid the accumulation of any significant amount of AN in the event of a spillage. Such systems can include the following:
    - Open drains to prevent the possibility of molten AN becoming trapped and confined in drains pipes and tunnels.
    - 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 AN can be found in the website of the Agricultural Industries Confederation [2]

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. The dimensions of the

[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

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

hazard class diamonds must conform to SANS 10263-5. Additional signs in accordance with SANS 1186-1 should be displayed. The signs should also conform to SANS 10263-5.

Security:

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

Emergency:

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

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

7.3 Open Air Compounds

- 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 AN 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.
- It is good practice to store the first layer of bags on pallets of suitable material to prevent damage from ground projections and to minimise water ingress from surface water.

7.4 Freight Containers for Storage

Freight Containers may not be used for storing AN.

7.5 Silos or Bins

- The material of construction should be resistant to attack by AN 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 AN. This coating must be checked and properly maintained, since the abrasive AN will wear away the epoxy coating and the exposed mild steel will corrode rapidly.
- Galvanised steel should be protected from direct contact with AN (e.g. coat with epoxy tar preferably or chlorinated rubber), and ensure proper checking and maintenance of coating, since AN 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 AN 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 AN 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 AN 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.
- Design and construct the silo or bin so it is capable of resisting all foreseeable forces to which it may be exposed.

7.6 Buildings

Buildings used to store AN have the following minimum requirements:

- Must comply with all National Building regulations.
- Must be licensed in terms of local, provincial and national legislation.
- Well ventilated or air conditioned.
- Single storey structure.
- Mobile haulage equipment should not be in the AN Store unless it is in use.
- Electrical installations shall be in accordance with SANS 10142-1 and SANS 10400.
- Buildings should not have internal drains, pits or channels so as to avoid trapping and confining of AN. However, if this is not practical, seal them securely, so that molten AN cannot run into them in the event of a fire.
- Galvanised items such as sheeting, vents and girders should be avoided in the construction as zinc is known to react with the AN.
- Copper or copper alloy fittings and equipment should be avoided as AN reacts with copper.
- Building frames shall be of concrete or steel.
- Internal walls or separations must satisfy the minimum fire resistance requirements (SANS 10263- 0 and 5).
- Cleaning of buildings without using water should be employed as far as possible.
- Lightning and electrostatic discharge protection will be provided.
- Sufficient doorways and emergency exits will be provided.
- Sufficient lighting shall be provided.
- Electrical installations and equipment must be of the correct standard.
- Signage will be provided to clearly identify the use of the buildings.
- Roadways and traffic arrangements must conform to the appropriate standards and regulations and be laid out in such a way to minimise a hazards.
- Rail sidings shall be according to the relevant national legislations.

7.7 Storage of Large Amounts of AN 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 AN 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 AN storage facility.
- The design of the AN 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.
- Appropriate local standards for transportation of AN be met.

7.8 Contaminated AN Storage

After the Toulouse accident, a new category for AN materials was created [3]. Off-spec AN is more common in AN manufacturing plant and large storage sites rather than end-user sites. This code has addressed "contaminated" AN as a special category.

Key requirements:

- The maximum amount of contaminated AN 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.

More details on the treatment of off-spec AN material can be found in the document issued by the Agricultural Industries Confederation **[3]**.

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 AN with combustible materials (e.g. vehicle fuel, pallets). These control measures are aimed at reducing the likelihood of an incident.

Unless substances are known to be compatible with AN, assume they are incompatible and treat them accordingly (see list of incompatible substances in Appendix G).

8.1. General

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 AN 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 AN 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 AN or other material spillages at all times. Spills must be cleaned up immediately.
- Piles or bins must be adequately sized, arranged and moved periodically to minimize caking. Smoking and open flames shall not be permitted inside the AN store and notices to this effect shall be displayed.
- Unguarded electrical lights shall not be permitted inside the AN 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.

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

- Lifting equipment shall conform to the local codes
- Lighting should have additional safeguard to prevent it from falling onto the product.
- The storage areas shall be separated or detached To be considered detached, a building for storage shall be separated from a flammable or combustible liquid store, a flammable gas store, combustible material in the open, and any inhabited building, passenger railroad, public highway, or tanks containing flammable substances.
- A detached storage area where sprinklers are not installed and that is used for storage of AN, should be a safe distance from other buildings and from a property line that can be built upon. (SANS 10263-5).
- A detached building where sprinklers are installed, should be separated from other buildings and from a property line that can be built upon.
- Separation walls shall have a fire- resistance rating.
- 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).
- Handling procedure for contaminated or out of specification ammonium nitrate

Housekeeping:

- Storage facilities should be kept clean at all times and inspected regularly and particularly when maintenance is being carried out
- Housekeeping standards should prevent contamination of AN and an accumulation of combustible and/or flammable materials in proximity to AN.
- The use of combustible materials (e.g. pallets made from combustible material 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 AN 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 AN silos or to loosen caked piles of AN.

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 a least one meter (1m) should be maintained between stacks of packaged AN and the outer walls of the buildings.

- The bags should be clearly labelled to indicate their contents. National and international regulations should also be complied with and where no regulations exist, the yellow “Oxidizing Agent” label and pictogram shall be on bags of class 5.1 oxidiser (Labelling in terms of SANS 10229….) .
- AN in packages should not be stored in maximum stacks exceeding sizes of 500t (consider if this is appropriate), separated from each at a distance dependant on the stacking configuration and density of the product.

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. TRANSPORTATION REQUIREMENTS

Depending on the mode of transport, the following requirements must be observed and complied with:

Road:

- National Road Traffic Act, 1996 (Act No 93 of 1996); and
- SANS 1518, SANS 10228, SANS 10229-1, SANS 10229-2, SANS 10231, SANS 10232-1 and SANS 10233.

Rail:

- National Railway Safety Regulator Act 2002(Act 16 of 2002); appropriate Regulations; SANS 10405 SANS 10228, SANS 10229-1, SANS 10229-2, SANS 10232-2, SANS 10233 and. Operator Internal: Train Working Rules, Instructions and Procedures.

Sea:

- IMDG Code.

Air:

- IATA Regulations.

Ammonium nitrate may only be transported under authority of the following permits issued in terms of the Explosives Act, 1956 (Act No 26 of 1956) or the Explosives Act, 2003 (Act No 15 of 2003), as required by the Chief Inspector of Explosives, irrespective of the mode of transport:

- Temporary transport permit (TTP);
- Continuous transport permit (CTP);
- Export permit (EXP);
- Import permit (IMP); or
- Transit permit (TRP).

11. REFERENCES

12.1 Regulatory:

(i) The General Regulation 1521 of 5 August 1988; Schedule A of the General Machinery Regulations, Regulation 6 of the RSA OHS Act.

(ii) App J. ANSI/ISA-S91.01-1995 – Identification of Emergency Shutdown Systems and Controls that are Critical to Maintaining Safety in Process Industries (is this needed?).

"IATA Dangerous Goods Regulations" means regulations published by the International Air Transport Association, as produced in consultation with the International Civil Association Organisation (ICAO);

"IMDG Code" means the International Maritime Dangerous Goods Code as published by the International Maritime Organisation;

"**SANS 1518**" means the South African National Standard for *Transport of dangerous goods – Design, construction, testing, approval and maintenance of road vehicles and portable tanks,* published by Standards South Africa, a division of the SABS;

"SANS 10228" means the South African National Standard for *The identification and classification of dangerous goods for transport*, published by Standards South Africa, a division of the SABS;

"SANS 10229-1" *means the South African National Standard for Transport of dangerous goods - Packaging and large packaging for road and rail transport Part 1: Packaging*, published by Standards South Africa, a division of the SABS;

"SANS 10229-2" means the South African National Standard for *Transport of dangerous goods - Packaging and large packaging for road and rail transport Part 2: Large packaging*, published by Standards South Africa, a division of the SABS;

"SANS 10231" means the South African National Standard for *Transport of dangerous goods - Transport of dangerous goods — Operational requirements for road vehicles*, published by Standards South Africa, a division of the SABS;

"SANS 10232-1" means the South African National Standard for *Transport of dangerous goods - Emergency information systems, Part 1: Emergency information systems for road transport*, published by Standards South Africa, a division of the SABS;

"SANS 10232-2" means the South African National Standard for *Transport of dangerous goods - Emergency information systems, Part 2: Emergency information system for rail transport*, published by Standards South Africa, a division of the SABS;

"SANS 10233" means the South African National Standard for *Transport of dangerous goods - Intermediate bulk containers*, published by Standards South Africa, a division of the SABS;

"SANS 10313" means the South African National Standard for *The protection of structures against lightning*, published by Standards South Africa, a division of the SABS.
(SANS 62305 series should be read in conjunction with SANS 10313).

"SANS 10405" means the South African National Standard for the *Transport of dangerous goods by rail - Operational and design requirements and emergency preparedness*, published by Standards South Africa, a division of the SABS;

12.2 Guidelines and Best Practices:

Good Practice for the Safe Storage of Ammonium Nitrate (Part of the SAFEX Good Explosive Practice Series, GPG 02 rev02).

Chemical Advisory: Safe Storage, Handling and Management of Ammonium Nitrate; EPA550-S-13-001

PVDM – Code Of Practice "Safe Storage of Solid Ammonium Nitrate"
www.dmp.wa.gov.au/.../DGS_COP_StorageSolidAmmoniumNitrate.pdf

APPENDICES

A. Storage Facilities Location

Note: This section supplements Section 7.1

AN storage is based on minimising the risk of an event within the storage facility. It means that in the location of a AN store factors to be considered take into account the Likelihood and related Consequences of an incident associated with AN at the storage facility. Owners and operators of AN 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, AN has been and can continue to be stored safely without incident.

The dominant issue for the siting and layout of AN storage facilities is the possibility of an explosion of a significant mass of AN. 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 AN requires reducing the:

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

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

A storage facility may contain one or more bag stacks, bulk piles or silos of AN. 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 AN 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 AN 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 AN consisting of packages (e.g. bags), IBCs or a cluster of shipping containers.
- A pile of AN 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 [4] for the various densities of AN:

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

- Low density (less than 750 kg/m^3 or 0.75 g/cc), high porosity AN stacks that are "normally" configured (i.e. set back by ½ bag at each layer) should be separated by 16 metres [5]. For a "pyramidal" stack, the separation can be reduced to 9 metres.
- Medium density (between 0.75 and 0.85 g/cc) AN 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) AN should have a separation gap between stacks of 1 metre (The basis of which is still to be confirmed by field tests).

It is known [6] 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 AN, 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 AN.
- 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 AN 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 AN that will minimise/eliminate the Likelihood of a harmful event.

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

- Based on the simulations carried out on bulk piles of about 4,000 tonnes [7], 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 storage facility should be well ventilated.

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 AN.

Major Manufacturing Sites:

When designing a facility for storage of AN 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 AN is sufficient to enable the efficient operation of a large (~350,000 tonnes per annum) AN manufacturing site. The proposed location and quantity of the storage facility for AN must be incorporated in the QRA for the manufacturing site.

Globally there are a significant number of AN 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

[5] Reference to Yara International publications

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

[7] Simulations studies by TNO for Yara International; Results not yet published; 2008

local regulatory requirements. Existing manufacturing sites should review the QRA for the site taking into account the most recent technical information regarding the storage of AN. 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 Reasonably Practicable (or ALARP SANS 10405) requirements (see Appendix B.3.1 on p. 42).

Mixed Sites:

Where it is proposed to store AN 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 AN 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 AN 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 AN and storage methods is given in Table A.1

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

TYPE OF AN	TYPE OF STORAGE	MAX. MASS PER PILE (TE)	SEPARATION BETWEEN PILES (M)	COMMENTS
High density AN	Bags, IBCs		[1]	
Medium Density AN	Bags, IBCs	As determined by the QRA	[9]	Normal Configuration
Medium Density AN	Bags, IBCs		[7]	Pyramidal Configuration
Low density AN	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 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 AN stored further, then a risk assessment approach may be required.

A.3. 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 AN 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 (wood 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 AN 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 AN 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 AN 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

B.1. 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.

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 AN
- 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. 8, Section 3, Definitions) from staff or contractors who have access to the premises and to ammonium nitrate.
- Consider whether current security arrangements leave the AN 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 AN.
- 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 AN.

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 AN.
- 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

AN may be required by an Authority Having Jurisdiction to be in a secure store (see p. 8, 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, 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 AN

Systems should be in place to record the movements of AN 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 AN 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 AN 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 (NOx) 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 (UN3379). 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.1.2. 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, AN 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.

Fires are avoided by rigorously eliminating and reducing the amount of potential fuel, combustible materials and dangerous contaminants in and around the AN store

Guidance regarding the application of water is available in the Australian Standard AS 4326. The storage and handling of oxidising agents

E.1.3. 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.

As AN solution becomes more acidic, its stability decreases, and it may be more likely to explode. *The o*xides of nitrogen resulting from decomposition will support combustion, even in the absence of oxygen

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.

Solid AN readily absorbs moisture, which can lead to caking, self-compression and self confinement. This in turn increases susceptibility to explosion in a fire.

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

E.1.4. Chemical Reaction

In the presence of moisture, ammonium nitrate can undergo an electrochemical reaction with copper to form copper tetramine nitrate $[Cu(NH_3)_4](NO_3)_2$, 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 AN. (Reference: Encyclopaedia of Explosives and Related items, Volume I, Picatinny Arsenal, Dover, New Jersey, USA, 1960).

E.1.5. 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

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

Do Not Fight Fires Involving Ammonium Nitrate

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 discrepencies 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

Unsuitable Extinguishing Media:
Dry agent (carbon dioxide, dry chemical powder).

Hazchem Code: 1Z

G. Chemical Compatibility

The following fertilisers are considered **compatible** with AN but should still be separated from AN as indicated above:

- Potassium nitrate
- Sodium nitrate
- Calcium nitrate
- Ammonium nitrate
- AN-based fertiliser mixtures of the nitrogen, phosphate or potash type
- Calcium sulphate
- Calcium ammonium nitrate
- Calcium or magnesium carbonate

Do not store the following **incompatible** substances in any building used to store AN nor within any building attached to an AN store:

- Flammable or combustible liquids such as petrol, kerosene, solvents, diesel fuel, lubricating and fuel oils or hydrocarbon formulated pesticides.
- Flammable gasses such as LP gas, acetylene, ethylene and hydrogen
- Sulphur, hexamine and finely divided metals
- Explosives and substances sensitive to explosive decomposition
- Readily combustible solids such as hay, straw, grain, husks, animal feed, wax, paper, wood and cotton.
- Division 5.1 dangerous goods such as calcium hypochlorite, chromates, chlorates, nitrites, perchlorates, chlorites, permanganates, chloroisocyanurates, tetranitromethane or di- or tri-chloroisocyanuric acid.
- Other known incompatible substances include: Include p.23
- Corrosive liquids
- Reducing agents
- Products that can liberate ammonia gas if mixed with AN, such as cement, lime, basic slag and other alkaline substances, powdered metals
- Urea
- Copper, cadmium, chromium and zinc metals and their salts
- Chlorides
- Organic and carbonaceous material

H. Powered Transfer Equipment

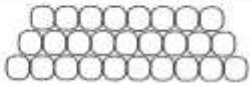
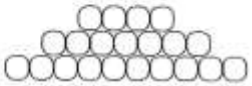
One of the most serious contamination hazards arises where AN comes into contact with combustible liquids, since AN readily absorbs spills such as oil and fuel by capillary action.
Vehicles used to move AN into, within or from an AN store may be powered by electricity, diesel fuel of LP gas, but not petrol.

H.1. Equipment Requirements

- All powered AN transfer equipment should:
    - Not include in its construction any copper, zinc (including galvanised iron), cadmium or their alloys that can come into contact with AN
    - Be constructed from materials that, if in contact with AN will not corrode
    - Have all non-essential electrical equipment removed, and all remaining equipment sealed against dust ingress in accordance with IP65 of the IP Code or, where such equipment is not produced, comply with the highest rating possible equipment should be designed and constructed to resist dust ingress as far as is reasonably practicable, and inspected and cleaned regularly
    - Where mobile, be kept outside of the AN store when not in use and parked at least 10 m from the AN store (unless alternative measures are in place to prevent any adverse impact

on the AN from the mobile vehicle, especially in a fire scenario) – control measures must be in place to prevent contaminants (e.g. dirt, other products) being brought into AN store on vehicles (e.g. vehicles such as front-end loaders should be dedicated to AN activities)
- Be refuelled or recharged at a distance of 10 m from the AN store
- Be fitted with a spark arrester and started outside of the AN store if they use diesel fuel or LP gas
- If it incorporates a battery, be provided with a clearly marked battery isolation switch and insulated cover for the battery terminals.
- If it is a vehicle, be attended at all times when it is inside the AN store, and for all other transfer equipment, be attended when operating.
- Be designed and constructed, including consideration of failure modes, to avoid situations where AN may become trapped, heated or brought into contact with incompatible substances – items to consider include suitability of seals, gaskets, bearings and clearances distances; use of solid rather than hollow equipment components; provision of alarms and shut-down systems for over-speed, under speed, no-flow and over-heat situations.
- If it is a conveyer belt, have fire-resistant belt and rollers.

I. Guideline for Stacking Bulk Bags

Type of storage	Stacking configuration	Separation between stacks (metres)
IBCs	Normal configuration where each successive layer is set back half an IBC diameter from the layer below 	16 (low density) 9 (medium density) 1 (high density)
IBCs	Pyramidal configuration where each successive layer is set back one and a half IBC diameters from the layer below 	9 (low density) 7 (medium density) 1 (high density)

Notes:

- *Low density AN: less than 0.75 g/cc*
- *Medium density AN: equal to or greater than 0.75 g/cc, but less than or equal to 0.85 g/cc*
- *High density AN: greater than 0.85 g/cc*

J. Safety Critical Equipment

The primary causes of the hazards (explosion) of Technical Grade Ammonium Nitrate may originate mainly due to contamination by organics or heavy metals, high acidity, (i.e. low pH) and high temperatures. High temperature and pressure conditions during processing, e.g. in pumps may have the potential for explosion and serious damages or fatalities. Equipment used to manufacture or process TGAN should be considered as Safety Critical Equipment (SCE)

J.1. Identification of Safety Critical Equipment

The identification of Safety Critical Equipment (SCE) can assist management to optimize decision making regarding the priority for deployment of available resources for inspection, testing and maintenance of the critical equipment that has the highest risk to ensure that priority and focussed preventative maintenance activities are performed on them.

Ref: ANSI/ISA-S91.01-1995 - Identification of Emergency Shutdown Systems and Controls that are Critical to Maintaining Safety in Process Industries.