GOOD PRACTICE GUIDE FOR THE SAFE STORAGE OF SOLID TECHNICAL GRADE AMMONIUM NITRATE

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ABSTRACT

This Good Practise Guide (GPG) for storage of Solid Technical Grade Ammonium Nitrate was developed by global manufacturers of ammonium nitrate to provide guidelines for the storage of Technical Grade Ammonium Nitrate (TGAN) at manufacturing, distributors' and end-user sites. The ultimate goal is to promote safety and health of personnel, to prevent damage to property and to avoid hazards to the environment.

The industry group consists of representatives from AEL, Austin, CSBP, Dyno Nobel, ENAEX, Orica, Terra, Sasol and Yara

There are varied approaches on Safety and Security of AN being taken by the Competent Authorities around the world. Global AN manufacturers want to adopt a single approach, which will be independent of geography. Some Competent Authorities have been supportive of an Industry developed GPG for AN.

A Risk-based approach was advocated by the group, which is the current methodology being used in Industry.

- For manufacturing plants, or for large storage quantities of AN, a Quantified Risk Assessment (QRA) needs to be carried out.

- If a manufacturer or user does not want to apply a Risk-based approach, e.g., if the quantity stored is very small and the siting straightforward so that applying a full QRA will be excessive, guidance is provided through a minimum set of conditions that provides protection to the public

The GPG contains information on design, location, construction and operation of stores for TGAN. In addition it outlines the recommended content of a Safety Management System (SMS) catering to the health and safety of the community, employees, property and the environment. Such a SMS should be in place at all TGAN storage facilities covered by the GPG

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. To facilitate such an evaluation the GPG also contains a risk assessment flowchart as well as several examples.

INTRODUCTION

Ammonium nitrate (AN) is a product manufactured and used in increasingly significant quantities, both in the agricultural industry as fertilizer 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.

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.

SCOPE

This GPG 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.

The GPG 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 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).

OVERVIEW OF CONTENT OF GPG

- Definitions
- Safety and Management System
- Regulatory Requirements
- Site Design, Construction & Management
- Location of Storage Facilities
- Operation of Stores
- Security Requirements
- Appendices
    - Storage facility location
    - Risk assessment process
    - Security plans
    - Properties of Ammonium Nitrate
    - Hazards of Ammonium Nitrate

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:

- Safety Policy
- Plan Framework
- Training
- Procedures
- Emergency Response

REGULATORY REQUIREMENTS

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

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.

General Requirements

The general requirements focus on:

- Electric
- Construction
- Signage
- Security
- Emergency

Specific Recommendations for Various Types of Storages

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

- Open Air Compounds
- Freight Containers for Storage
- Silos or Bins
- Buildings

Storage of large Amounts of TGAN at Mine Site

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 review and approve 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.

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.

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.

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 AN. 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 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 risk is minimised.
- Each contaminated material must be segregated.
- Contaminated material must be handled as explosive 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.

LOCATION OF STORAGE FACILITIES

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.

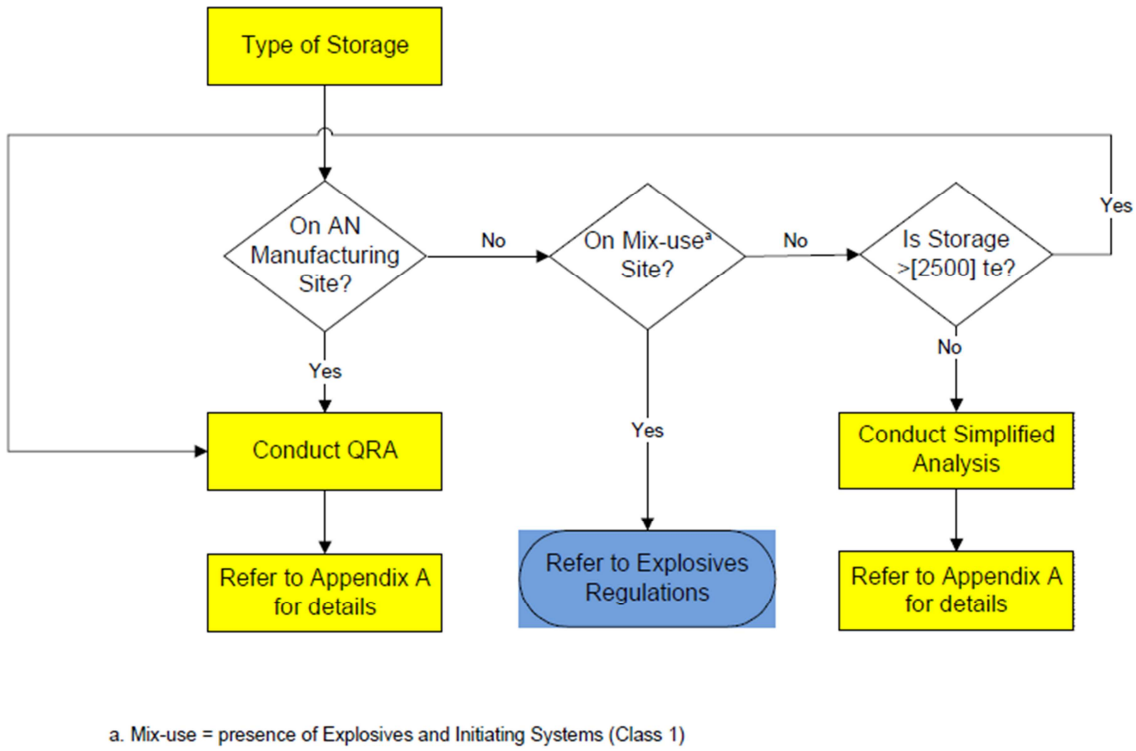
The possibility of detonation of a significant mass of TGAN is the dominant issue for the siting and layout of TGAN storage facilities. While toxic combustion products may be a key consideration in designing fire detection, suppression and emergency response measures, they are not specifically addressed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

Risk-Based Approach for Siting and Layout

The general approach for risk-based assessment is represented in Figure 1. For a large manufacturing site, a QRA shall be conducted which includes an assessment of the risk controls. If storage is less than 2,500 tonnes 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 Assessment methodology are found in Appendices A and B of the GPG.

Figure 1: Overall Risk-Based Approach



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

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.

The GPG contains an extensive list of general as well as special recommendation for operation of different types of stores.

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 of the GPG.

STORAGE FACILITIES LOCATION

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 TGAN Storage such as whether it is on a TGAN manufacturing plant or a site on which explosives are manufactured / stored (i.e. mixed use) or an independent storage facility.

- 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.

- Determine whether a full QRA is required. For example, if the mass being stored is small a full QRA may be considered excessive and a simplified Risk Analysis can be conducted.

- If the site is on a TGAN manufacturing plant, or if the mass of TGAN stored is above 2,500 tonnes:

    - 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 there is no need to carry out a QRA (e.g. the storage quantities are small and/or the siting layout is simple), the layout can be set by carrying out a simplified Risk or Consequence Analysis. The mitigation methods are the same as above – i.e. reduce the mass or separate the piles of TGAN (manage the consequence) or implement additional controls (reduce the Likelihood) and hence the overall level of Risk.

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 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.

Bags and IBCs

The gap separation distances between each stack shall be maintained as follows (1) 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 (2). 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 metre (The basis of which is still to be confirmed by field tests).

It has been shown (3) by simulations that configuration (geometric layout) of the stack affects separation distance (still to be confirmed by field tests). 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.

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.

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 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 Reasonably practicable (or ALARP (4)) requirements.

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 with less than 2,500 Tonnes Storage Capacity [(5)]: If the proposed or existing quantity of TGAN to be stored is less than 2,500 tonnes, a simplified Risk Analysis should be conducted. This will indicate if the separation distance should be determined by either a Consequence or a Risk based analysis. 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. Should the Q-D calculation indicate

there is a risk that local communities could be impacted by an event, then a simplified Risk Assessment SRA should be conducted to determine the control measures required to minimise the Likelihood of a harmful event on the surrounding communities.

Storage summary

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

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]	

Table 1: Separation Distances for Various TGAN Types

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

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.

NEQ (Q) = Overall TNT Equivalence (Eo) x 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 (Eo) of TGAN it is necessary to combine Chemical TNT Equivalence with the Explosive Yield. The relationship is:

Overall TNT Equiv (Eo) = Chemical TNT Equiv. (Ec) x Explosive Yield (Ey)

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 (Ey) is an estimate of the TGAN mass that is consumed in the detonation.

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

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

A variety of measures can be used to reduce the likelihood of each of these scenarios are listed in the GPG.

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 Organisation and Competent Authority can then decide whether this level of

risk is acceptable or not. The competent authority will 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 the GPG.

LOGIC

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.

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- Determine whether a full QRA is required. For example, if the mass being stored is small a full QRA may be considered excessive and a simplified Risk Analysis can be conducted.

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- If there is no need to carry out a QRA (e.g. the storage quantities are small and/or the siting layout is simple), the layout can be set by carrying out a simplified Risk or Consequence Analysis as shown in the flowchart below (Figure A.1). The mitigation methods are the same as above - i.e. reduce the mass or separate the piles of TGAN (manage the Consequence) or implement additional controls (reduce the Likelihood) and hence the overall level of Risk

This logic is shown schematically in Figure 2:

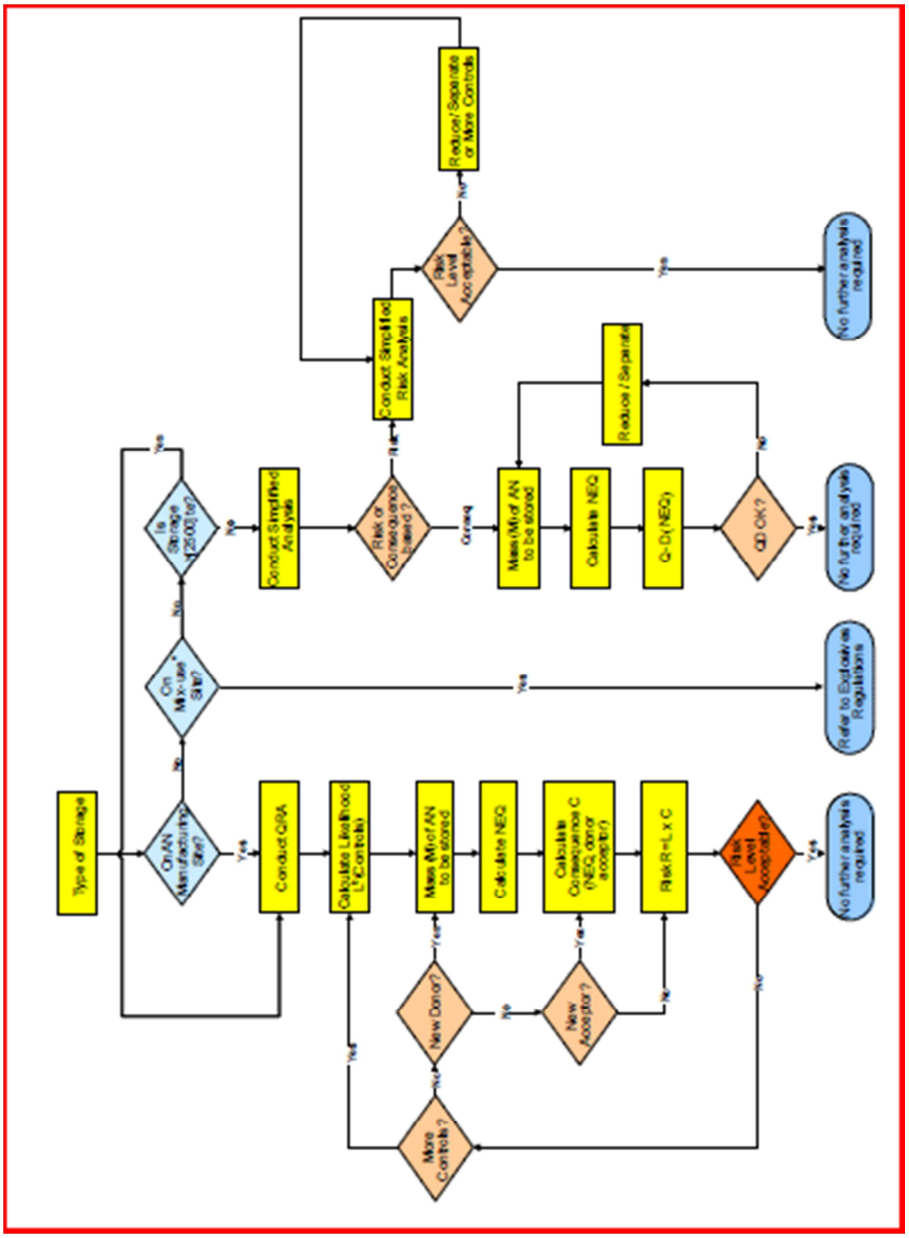

Figure 2: Flowchart depicting the logic for a simplified Risk Analysis

CONCLUSIONS

This “Good Practice Guide for the Safe Storage of Solid Technical Grade ammonium Nitrate” is an initiative by Global AN manufacturers to adopt a single approach, which will be independent of geography.

It contains information on design, location, construction and operation of stores for TGAN. 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.

The intention is that the GPG shall be a “live” document and will be revised when updated background information is available (e.g. TNT equivalence, stack configuration)

ACKNOWLEDGMENTS

Thanks to:

- The participants of the International Industry Working Group on Ammonium Nitrate
- SAFEX for issuing the guidelines under their “umbrella”

REFERENCES

(1) Nygaard, E., Storage of Technical (Porous) Ammonium Nitrate, Proceedings of ISEE Conference 2008
(2) Reference to Yara International publications
(3) Nygaard, E., Storage of Technical (Porous) Ammonium Nitrate, Proceedings of ISEE Conference 2008
(4) 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.
(5) 2,500 tonnes of TGAN storage is the threshold value at which specific regulatory requirements come into force in various jurisdictions (e.g. Major Hazard Facilities regulations in Australia and the European Seveso II directive)