Government of **Western Australia**
Department of **Mines, Industry Regulation and Safety**

CODE OF PRACTICE

Safe storage of solid ammonium nitrate

Fourth edition (reissued)

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Disclaimer

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Foreword

The Act

A key focus of the *Dangerous Goods Safety Act 2004* (the Act) is the duty to minimise risk from dangerous goods. This duty not only applies to employers and employees, but to all persons, including members of the public. This duty is placed on everyone involved with dangerous goods and goes beyond the workplace duties of the *Occupational Safety and Health Act 1984* and the *Mines Safety and Inspection Act 1994*. Public safety is one of the most important features of the Act.

Regulations

The Act is supported by several sets of regulations. The Dangerous Goods Safety (Storage and Handling of Non-explosives) Regulations 2007 (Storage Regulations) deliver safety outcomes and the Dangerous Goods Safety (Security Sensitive Ammonium Nitrate) Regulations 2007 (SSAN Regulations) deliver security outcomes for ammonium nitrate (AN).

All storages of AN require a security licence under the SSAN Regulations, except where less than 3 kg of AN is stored for use at laboratories under specific conditions.

Safety requirements exist for the storage and handling of AN above 1 t, with quantities exceeding 10 t also requiring licensing under the Storage Regulations.

Some sites where AN storage and/or handling occurs at manufacturing sites are classified as major hazard facilities (MHFs) and will also be subject to the Dangerous Goods Safety (Major Hazard Facilities) Regulations 2007 (MHF Regulations), with the requirement to produce and comply with an approved safety report.

Dangerous Goods Safety regulations are actively enforced by Dangerous Goods Officers and breaches are likely to result in remediation notices to improve safety requirements, and in serious cases can lead to prosecution or the suspension of a licence.

Codes of practice

Approved codes of practice provide safety recommendations to assist people in meeting their obligations under the Act and related regulations. The codes are approved and gazetted by the Minister under section 20 of the Act, and compliance with them may be used as a defence in law (s. 62 of the Act). Although compliance with an approved code is not mandatory, it is expected that deviations from recommended practice 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 codes allow flexibility of the means to achieve the desired safety outcomes and do not prevent innovations that improve safety performance by an alternate method as long as the same level of safety or better is achieved.


PRILLED AMMONIUM NITRATE
AMMONIUM NITRATE
1942
1Y
OXIDIZING AGENT
5.1
IN EMERGENCY DIAL
000, POLICE OR
FIRE BRIGADE

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1 Introduction

1.1 Scope

This code of practice has been produced to assist those storing or handling solid ammonium nitrate (AN) to meet their safety obligations under the *Dangerous Goods Safety Act 2004* (the Act) and associated regulations (see Appendix 1). The code provides practical guidance on managing many of the risks associated with AN. It describes the preferred safe work practices that can be readily used at places such as ports, merchant stores, mine sites, manufacturers' facilities and the parking of vehicles loaded with AN on private property.

The risk control information is based on the current understanding of the properties and hazards of solid AN gained from testing, research and the experience of past fires and explosions. However, people who have duties under the Act and relevant regulations should remain alert to developments and hazards that may not be fully dealt with by this code of practice or other guidance material. They should assess what further measures may be necessary or desirable, considering good working practice and local circumstances.

This code does not address the security requirements for AN, which are required under the SSAN Regulations and the approved code of practice, *Ammonium Nitrate Guidance Note No. 2 Storage* (COAG, 2004).

1.1.1 Glossary

A glossary of terms used in this code of practice is given in Appendix 2.

1.2 Application

1.2.1 Where this code applies

The code applies to the storage of solid AN in Division 5.1 – oxidising agent, as classified internationally by the United Nations Dangerous Goods Classification System as belonging to UN 1942 and UN 2067 and defined by the *Australian Code for the Transport of Dangerous Goods by Road and Rail* (ADG Code).

1.2.2 Where this code does not apply

This code does not apply to:

(a) sites storing less than 1 t of AN

(b) "rural dangerous goods locations", where AN is stored and used (not retailed) on an agricultural site of more than 5 hectares that is used exclusively for primary production

(c) AN transfers between ship and berth and AN transfers to and from vehicles stationed at the berth, which are dealt with by AS 3846 *The handling and transport of dangerous cargoes in port areas*, another approved code of practice under section 20 of the Act

(d) AN containing substances classified as Class 1 explosives or Class 9 miscellaneous dangerous goods. It also does not address the hazards of hot concentrated ammonium nitrate solutions UN 2426

(e) ammonium nitrate containing mixtures that are not classified under the UN Dangerous Goods Classification System. The most prominent example of this type is Calcium Ammonium Nitrate (CAN) with no more than 80% of AN and with 20% or more of calcium carbonate. CAN is significantly safer than AN, and is a non-dangerous goods under the UN Dangerous Goods Classification System. It essentially lacks the explosion hazard of AN. SSAN Regulations still apply as for all SSAN substances. In some countries in Europe, CAN is mandated as a substitute fertiliser for all AN fertilisers of Division 5.1

(f) the transport of dangerous goods.

2 Hazard and risk control measures

2.1 Hazards of AN

Pure AN (NH_4NO_3) is a white, odourless salt with a melting point of about 170°C.

Solid AN is stable to mechanical shock and does not burn. AN is a potentially explosive substance, because it is a combination of the oxidising nitrate ion in intimate contact with a fuel, the ammonium ion.

2.1.1 The hazards of AN

To ensure the safe storage of AN, the focus of this code is on the top three hazards and their associated safe storage control measures.

The hazards of AN in order of significance – from most significant being the explosion hazard to the least significant being the health hazard – are listed as follows:

(a) explosion hazard

(b) reaction hazard – AN is an oxidising substance and reacts dangerously with many materials potentially causing fires and explosion

(c) toxic gas hazard – high-temperature decompositions evolve ammonia, nitric acid vapours and nitrogen dioxide

(d) environmental hazard – AN is a nitrogen fertiliser and has the potential to cause algal blooms and the eutrophication of inland and coastal waters

(e) health hazard – AN is moderately toxic on ingestion, like all inorganic nitrates. Continued skin contact leads to skin irritation.

2.1.2 The explosion hazard

When heated by an external fire, the explosion sensitivity of the decomposing melt increases dangerously with increasing temperature and is further increased:

(a) if the AN is impure, or the melt mixes with contaminants and/or fuels

and/or

(b) if molten AN becomes confined in drains, pipes, plant or machinery and the decomposition gases cannot escape freely.

Decomposing AN can also explode if mechanical shock impacts the hot melt. Fires involving AN have caused explosions, but there have been more fires involving AN without explosions, depending on the circumstances.

AN has a long history of involvement in accidental explosions, usually as the result of an uncontrolled fire due to the presence of combustible substances.

Recent storage explosions caused by intense external fires occurred in Beirut, Lebanon (2020) Tianjin, China (2015), West, Texas (2013), Saint-Romain-Jarez, France (2003). Accidental explosions without an uncontrolled fire, as a result of reactions between AN and incompatible substances are the exception. The Toulouse chemical plant explosion in France (2001) is the only known example. Appendix 4 contains a summary of these five storage explosions.

2.1.3 Toxic gas and explosion chemistry of AN

Appendix 3 explains in detail how the decomposition chemistry of heating AN above its melting point produces a number of toxic gases, and the circumstances that result in an explosion.

2.2 Required risk control measures

This code outlines the required risk control measures that need to be implemented to guard against the top three hazards. All risk control measures required by this code can be grouped under one of the following six safe storage principles.

1. Prevent external fires from impacting on the AN by removing all combustible material and sources of ignition from the vicinity of the AN. This is the most important of the six principles.
2. Preserve the purity of AN and prevent incompatible material mixing with AN. All substances must be suspected of being incompatible unless known to be compatible; hence dedicated AN storage buildings are normally required.
3. Guard against theft and sabotage by preventing unauthorised access to the storage site.
4. Do not confine decomposing molten AN. Make sure that gaseous decomposition products can escape freely by providing natural ventilation, channel the flow of molten AN to the outside of the building and prevent the flow from entering confining drains and spaces.
5. Implement safety distances to reduce the consequence of an explosion at nearby occupancies:
   (i) the storage location should be separated from exposed sites or protected works by minimum safety distances
   (ii) AN should be divided into sufficiently separated stacks to prevent a sympathetic detonation between stacks and reduce the consequence of an explosion.
6. Prepare a site-specific emergency plan, practise the evacuation of people, and ensure firefighting equipment is kept in good condition and maintained as per the relevant Australian Standard.

3 Store design and construction

Figure 3.1 A 9,000 tonne, high security, steel and concrete building for dedicated, stand-alone IBC storage

Figure 3.2 A modern, light-weight, cost effective dome structure for dedicated, stand-alone IBC storage

3.1 Types of stores and general requirements

AN may be stored in a number of ways, including:

(a) open-air storage of intermediate bulk containers (IBCs)
(b) freight container storage of IBCs or loose bulk
(c) dedicated, stand-alone building storage which includes dome structures for packages, IBCs or loose bulk (Figures 3.1 and 3.2)
(d) storage attached to, or within, a non-AN dedicated building for packages or IBCs (10 t limit) (Figure 3.3)
(e) storage in silos and bins of loose bulk
(f) storage in blasting explosive magazines of packages.

3.1.1 General considerations

The presence of reactive or hot ground should be considered when designing, constructing and locating an AN store.

Providing AN is in a secure area away from combustible materials and sources of contamination, storage in a completely open-air store, freight container or in silos and bins offers distinct safety advantages compared with storage in a building.

3.1.2 Lightning protection

Protect the storage building, silo or bin against lightning strike as specified in AS/NZS 1768.

Silos and bins are in direct contact with AN and are therefore more vulnerable. In assessing the level of lightning protection required, AN is deemed to be non-flammable and non-explosive.

AS/NZS 1768 involves a risk assessment taking into account topography, location and other factors to determine what level of lightning protection is needed.

3.2 Open-air storage

In open-air stores, the risk from accidental fire, arson and explosion is reduced due to the lack of combustible materials, sources of ignition and situations leading to confinement.

For safe storage in open-air stores, no special construction requirements apply except to provide adequate protection from the weather, as well as security controls.

IBCs in an open-air store should be located on slightly raised ground to prevent the accumulation of rainwater. Plastic pallets are acceptable in remote locations to keep AN off the ground. The ground should slope such that, in the event of a fire, any molten AN flows away from surrounding structures or storages.

3.2.1 AN security requirements

Adequate security for open-air storage in IBCs usually involves security fencing as one of the security control measures. For guidance on AN security requirements, see the SSAN Regulations and the *Ammonium Nitrate Guidance Note No. 2 Storage* (COAG, 2004).

3.3 Freight container storage

A freight container may be used for the dedicated storage of AN provided it is constructed in accordance with AS/NZS 3711.1 *Freight containers, Part 1 – Classification, dimensions and ratings*. It should not contain any wood lining or have a wooden floor.

Freight containers should be stacked no more than two containers high and two containers deep in a close-packed chain that never exceeds a maximum stack size of 500 t.

The maximum stack size has to be smaller if required by Table 4.1. Each stack has to be separated by 10 m from the next stack at the head and tail of the chain. Parallel chains are required to be separated sufficiently to allow safe access to both sides of the stack with the usual handling equipment and at least 10 m apart.

3.4 Building storage

All buildings used for AN storage should be designed and constructed to comply with the requirements listed below. Where relevant, these requirements also apply when AN is stored in a dome structure.

(a) Provide adequate ventilation.

(b) Store the AN on a level that has immediate ground access from outside the building.

(c) Construct the entire building, including the roof, from non-combustible material, with the floor made of concrete (protected from AN attack where necessary) or other suitable material.

(d) Ensure any materials or fittings used in the building construction that could come into contact with AN during normal operations or in the event of spillage, do not contain zinc, copper or other incompatibles unless suitably protected (e.g. by coating with suitable epoxy-based materials or chlorinated rubber). Mild steel may require suitable protection to prevent corrosion by AN.

(e) Design the AN store and its surrounds so that, in the event of fire, molten AN does not become confined within the building in which it is being stored or other enclosures such as covered drains, pipes, and tunnels. Any molten AN should flow clear of the storage area, all other storages, buildings and combustible materials, and be retained on the site.

(f) Design and construct the AN store, including any shelving or racking, so that spilt AN can be easily detected and cleaned up.

(g) Do not store AN in a cabinet or similar enclosed and confined manner.

(h) Keep the entire building dry and free from water seepage.

(i) Provide additional securing devices for ceiling lighting to prevent a hot light from falling on top of the AN.

(j) Where there is a risk of corrosion from AN, ensure electrical equipment has a rating of not less than IP65 in accordance with AS 60529 *Degrees of protection provided by enclosures* (IP Code).

(k) Where an AN store of 10 t or less is either attached to another building or located inside a building that is not dedicated to the storage of AN, isolate the store by a horizontal distance of at least 5 m that is left clear (Figures 3.3a, 3.3b). This distance may be measured around a wall extending 1 m above the roof of the AN store and having a 240/240/240 fire resistance level (FRL), as per the National Construction Code of Australia (Figures 3.3c, 3.3d).

(l) If an AN store is located inside a building, at least one wall of the store should be an external wall of the building so this wall is constructed to allow:

    (i) natural ventilation and the escape of potential decomposition gases

    (ii) molten AN to flow clear of the building in the event of a fire

    (iii) firefighting using water jets from outside of the building.

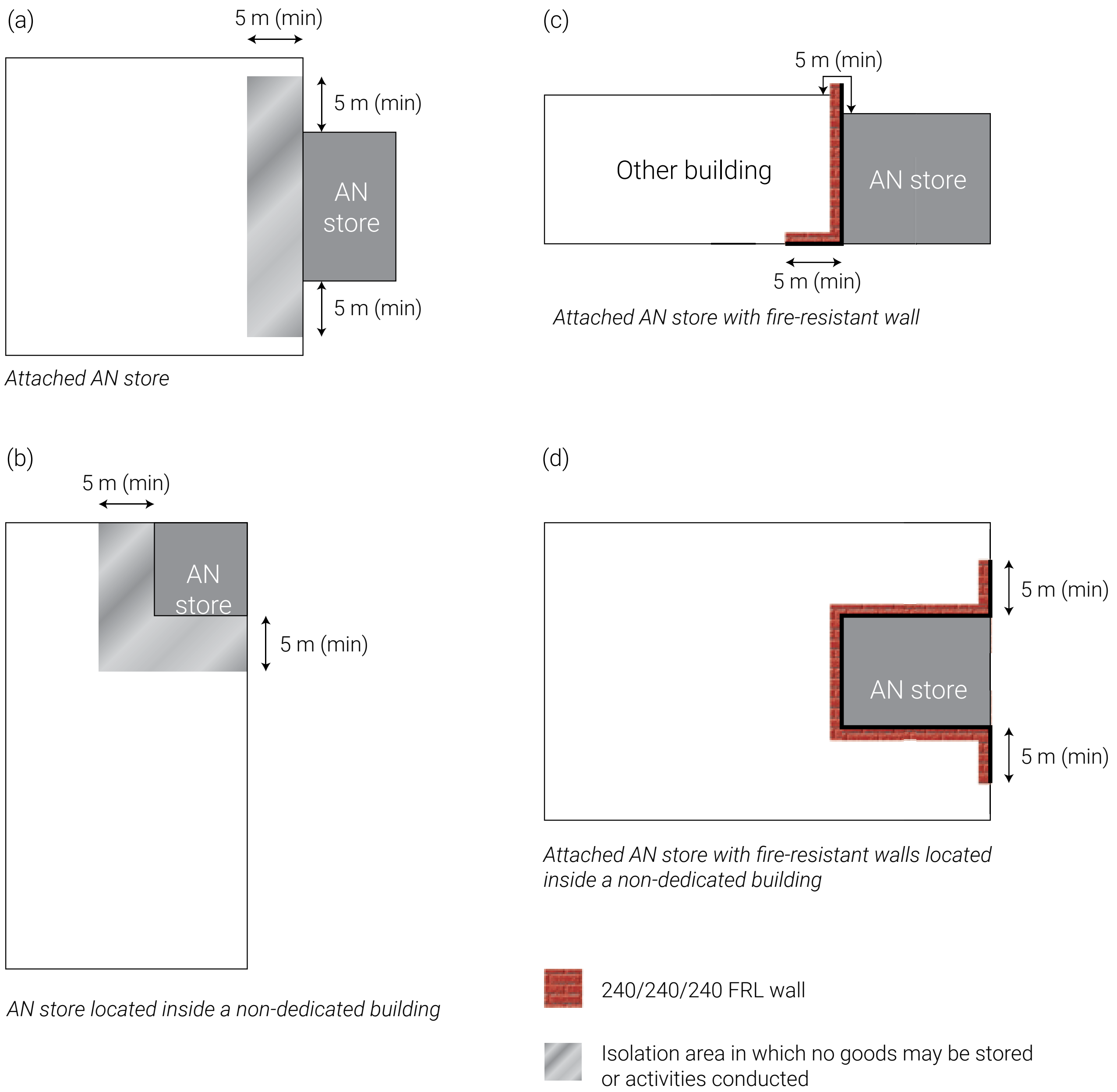


Figure 3.3 Examples illustrating the required isolation of AN stores of 10 t or less

3.5 Silo and bin storage

All silos and bins used for AN storage should comply with the requirements listed below.

(a) Construct the silo or bin from non-combustible, corrosion-resistant materials.

(b) Ensure any materials or fittings used in the building construction that could come into contact with AN during normal operations or in the event of spillage do not contain zinc, copper or other incompatibles unless suitably protected (e.g. by coating with suitable epoxy-based materials or chlorinated rubber). Mild steel requires suitable protection to prevent corrosion by AN.

(c) Galvanised steel should be protected from direct contact with AN by coating as above.

(d) Design and construct the silo or bin so it is capable of resisting all foreseeable forces to which it may be exposed. It is important to take into account AN's tendency to cake and the impact from large caked lumps of AN when determining the magnitude of potential forces.

(e) The design should be such to ensure the empty container structure can withstand wind and seismic forces, which may be encountered in some locations.

(f) Construct the area beneath the AN silo or bin from concrete (protected from AN attack where necessary) or other suitable material.

(g) Where there is a risk of corrosion from AN, ensure electrical equipment has a rating of not less than IP65 in accordance with the IP Code.

(h) Design and construct the silo or bin to prevent the ingress of water and allow for the release of gases in the event of a fire.

(i) Position the silo or bin so that, in the event of a fire, molten AN cannot enter any enclosure such as a drain, bund, pit or tunnel, and will flow clear of all other storage areas, buildings and combustible materials, and be retained on the site.

(j) Ensure silos are stand-alone AN storages. Do not locate them inside or attached to buildings.

(k) Silos are vulnerable to vehicle impact and collapse and should be protected from damage by traffic.

(l) AN in silos should be separated by at least 10 m from the next silo, otherwise the quantities of AN in separate silos need to be aggregated to establish the required distances to off-site occupancies in Table 4.1. The maximum aggregated quantity should not exceed 500 t.

3.6 Magazine storage

Storage of packaged AN is allowed inside a blasting explosive magazine subject to it being treated as an explosive. AN stored in a blasting explosive magazine must comply with the Dangerous Goods Safety (Explosives) Regulations 2007 (Explosives Regulations).

4 Store location and separation distances

4.1 Separation distances

The location of an AN store is subject to acceptance by the regulator regarding the proximity to protected works including off-site occupied buildings, places of public assembly, and pipelines. The separation distances in Table 4.1 are best applied for town planning decisions and/or before licensing a site.

For high population densities, an additional assessment of societal risk may be necessary, because Table 4.1 is based on individual fatality risk and individual injury risk. The need for consideration of societal risk may arise for places with high population density such as a large sports stadium, a large shopping centre or a high-rise apartment. Guidance should be sought from HIPAP4 and the Chief Dangerous Goods Officer.

4.1.1 Separation distances from the boundary and from on-site protected works

Where AN is stored in quantities exceeding 10 t, it should be separated from the boundary of the site and from on-site protected works by a distance of at least 10 m. For quantities between 1 and 10 t these distances may be reduced to 5m. Measuring these distances around firewalls or earth mounds is not appropriate.

4.1.2 Separation distances to off-site occupied buildings – Table 4.1

Recommended minimum separation distances for quantities exceeding 1 t to four types of off-site occupied buildings are described below and set out in Table 4.1.

This code has chosen the separation distances of Table 4.1 to harmonise with the risk criteria from the *Hazardous Industry Planning Advisory Paper No. 4 – Risk criteria for land use safety planning* [HIPAP4] (NSW Planning, 2011). These distances are intended to provide additional protection to the community and are a consequence reduction control. They do not replace the need for the diligent application of the prevention controls of this code.

Table 4.1 distances are based on the historic frequency of explosions taken from the *Good Practice Guide: Storage of Solid Technical Grade Ammonium Nitrate* (SAFEX International, 2014), which together with HIPAP4 provides guidance regarding risk assessment in relation to AN storages. These separation distances do not provide complete protection in case of an accidental explosion and hence the Table 4.1 distances should be regarded as minimum distances. It is also true that any AN storage in full compliance with this code may have a very small chance of an accidental explosion.

Table 4.1 requires the adoption of sufficient inter-stack distances to prevent sympathetic detonations. The inter-stack distances for IBCs are shown in Table 5.1. This includes sufficient distances between stacks of closed-packed freight containers.

For all off-site occupied buildings, section 8 of the Act allows for a reduction in separation distances from those provided by Table 4.1 under the following conditions:

(a) it is not reasonably practicable to achieve the full Table 4.1 distances
(b) a sound risk assessment demonstrates compliance with this code and in particular the absence of material that may sustain a fire with the ability to decompose some of the AN as far as is reasonably practicable
(c) the risk assessment demonstrates that HIPAP4 risk criteria are met without assuming a successful evacuation of off-site occupancies
(d) the off-site occupancies house fewer than 10 to 20 people
(e) the operator has complete control over all the persons that need to be evacuated and all persons can be alerted and evacuated in a timely manner (e.g. 30 to 45 minutes)
(f) a site-specific emergency plan covers the off-site occupancies and allows for their efficient evacuation
(g) the predicted explosion overpressure does not exceed 14 kPa for residential buildings
(h) the Chief Dangerous Goods Officer has consented to the reduced separation distances.

4.1.3 Separation distances on mine sites

HIPAP4 criteria and Table 4.1 distances do not apply to mine site premises if the AN storage is permitted by the mine it serves. Under these circumstances, mine site premises are not regarded as "off-site occupied buildings", but as on-site premises.

Nevertheless, it is recommended to utilise the Table 4.1 distances column for "industrial plant and factories" for such on-site premises. If these are not reasonably practicable, the AN operator should do a site-specific risk assessment to determine the most appropriate separation distance that is in keeping with the corresponding risk criteria from HIPAP4, while seeking to maximise the separation as much as is reasonably practicable.

4.2 Storage with high explosives and detonators

A store of AN must be separated from high explosives and detonators by the minimum distances given in
AS 2187.1 *Explosives – Storage, transport and use – Storage*. Where mounding is used, it must comply with the requirements of AS 2187.1.

If AN is stored with high explosives, treat it as though 50 per cent of the quantity of AN is an explosive and the AN storage must comply with the Explosives Regulations.

Table 4.1 Recommended minimum separation distances for AN stores

Quantity of AN stored in the largest stack (kg)	Recommended minimum separation distances (D)			
	Vulnerable facilities and critical infrastructure (m)	Residential buildings (m)	Commercial buildings (m)	Industrial plant and factories (m)
* 1,001	140	110	>15	>15
* 3,000	200	160	>15	>15
* 5,000	240	190	>15	>15
* 7,000	270	210	>15	>15
10,000	300	240	140	110
15,000	350	280	160	120
20,000	380	300	180	130
30,000	440	350	200	150
40,000	480	380	220	170
50,000	520	410	240	180
75,000	590	470	280	210
100,000	650	520	300	230
125,000	700	560	330	240
150,000	740	600	350	260
175,000	780	630	370	270
200,000	820	660	380	290
250,000	880	710	410	310
300,000	940	750	440	330
350,000	990	790	460	350
400,000	1,030	825	480	360
450,000	1,070	860	500	380
500,000	1,110	890	520	390

Notes:

** Asterisks indicate AN stores of less than 10 t and more than 1 t. The separation distance should be at least 15 m for off-site protected works. However, residential development and vulnerable facilities should be separated by the respective distances indicated in Table 4.1.*

- *"Quantity of AN stored" means the quantity in the largest individual stack or pile, not the total quantity stored, subject to sufficient separation between stacks or piles to prevent a detonation in one propagating to another (see Section 5 for guidance on inter-stack separation distances)*
- *Distances in Table 4.1 were obtained by using the following formulae:*
  - *$D = 22.2\ Q^{1/3}$ for vulnerable facilities and critical infrastructure corresponding to 5.5 kPa blast overpressure*
  - *$D = 17.8\ Q^{1/3}$ for residential buildings including hotels, motels and other accommodation places corresponding to 7 kPa blast overpressure*
  - *$D = 10.4\ Q^{1/3}$ for commercial developments including retail centres, offices and entertainment centres corresponding to 14 kPa blast overpressure*
  - *$D = 7.8\ Q^{1/3}$ for industrial buildings corresponding to 21 kPa blast overpressure*

  Q is the quantity of TNT – see note below. Distances have been rounded to the closest multiple of 10 m.

- *In calculating separation distances, AN is taken to have a TNT equivalence of 25%, as sourced from "Proceedings No. 580 – Safety Testing of Ammonium Nitrate Products" (The International Fertiliser Society, 2006), which indicates: "The TNT equivalence, used for practical situations, is a combination of the 'explosive power' and the 'efficiency' (i.e. the part of the bulk which contributes to the blast effect in a detonation). The 'explosive power' is based on the TNT equivalence of the full scale test. Based on a combination of the results of the tests and the TNT equivalence in accidents for TGAN (Technical Grade AN) a TNT equivalence of 20-25% appears appropriate for practical situations."*

5 Storage requirements

5.1 General

AN should be stored in an adequately ventilated place away from possible sources of excessive heat, fire or explosion, such as oil storages, gas pipelines, timber yards, flammable liquids, flammable solids and explosives.

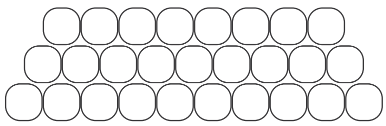
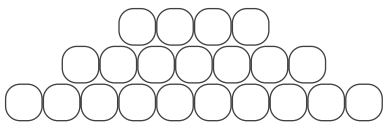
5.1.1 Maximum stack size and inter-stack separation

AN in packages, IBCs or as loose prill may be stored in maximum stack sizes of 500 t, separated from each other in a manner that prevents sympathetic detonation (see Table 5.1 for IBC stack separation distances).

5.1.2 Stack height

The stacking height should not exceed three IBCs of AN or three pallets of AN packages, with stack stability being maintained at all times.

Table 5.1. Table showing the recommended minimum distances to be maintained between stacks of AN IBCs in order to minimise the likelihood of a detonation event in one stack from propagating to an adjacent stack. Separation distances were derived from small-scale gap tests performed between ANFO and AN to determine the critical initiation pressure to produce sympathetic detonation, followed by simulations. Based on Erik Nygaard; "Storage of technical (porous) ammonium nitrate", International Society of Explosives Engineers 2008G Volume 1.

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 (750 kg/m^3)*
- *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*

5.1.3 Clearance around stores

Every AN store should have a clear area of at least 5 m surrounding it, with no vegetation, combustible materials, vehicles or non-associated equipment within this area. Trees should be cleared for at least 10 m from the AN store. If the location is in a high bushfire risk area, then larger clearances of vegetation should be considered.

5.1.4 Parking of AN vehicles

Vehicles loaded with AN should be parked no closer than 10 m from an AN store, except for the loading of mobile processing units.

5.1.5 Operating procedures

Appropriate operating procedures should be in place to cover all operations at the facility.

Unused wooden pallets, empty bags and packaging should be removed promptly from the AN store and kept at least 5 m from the store.

Do not allow pallets, ropes, covers or other equipment to become impregnated with AN.

5.1.6 Preventing contamination

Ensure appropriate measures are in place to prevent the introduction of contaminated AN (e.g. contaminated through spillage and mixing with dirt, or otherwise contaminated with incompatible substances as defined in section 5.5) into an AN store of uncontaminated product. Any contaminated AN needs to be isolated and suitably managed in a separate store and disposed of as soon as reasonably practicable.

Take into account the topography around the AN to prevent any flammable or combustible liquids at the site from flowing towards the AN storage.

5.2 Caking of AN

Solid AN occurs in five different stable crystalline forms, depending on the temperature. Pure AN undergoes phase changes when heated. Of most commercial significance is the phase change occurring near ambient temperatures at 32°C. This transition results in a density change with an increase of 3.6% in volume and heating and cooling cycles destroy the prill structure.

The sensitivity of pure AN to detonation increases after it has gone through a few cycles at 32 ºC, presumably due to the formation of fines. AN is very hygroscopic and the fines absorb water more readily than the prill. The process is termed “caking”, whereby the AN sets into a solid mass and becomes unusable and needs to be disposed of. Small amounts of various proprietorial additives are used to minimise the effects of hygroscopicity and phase changes.

A suitable means of protecting AN from rain and direct sun is important to help prevent caking and deterioration of the AN prill structure, which is particularly important if it is to be used to make AN fuel oil (ANFO) explosives. Given AN’s tendency to cake, appropriate measures should be in place to ensure that it is not stored for longer than necessary, especially when stored loose, such as in a silo.

5.3 Disposal of caked and contaminated AN

Caked AN and AN that is contaminated, thereby increasing the explosion sensitivity, should be segregated from usable product and should be either recycled, used or safely disposed of as soon as reasonably practicable.

The preferred method of disposal is dissolving in water for use as a fertiliser. Do not use incineration and do not dispose in sewers or waterways.

Never use explosives or detonators to break up caked AN, only use mechanical means.

5.4 Requirements in a storage building

(a) For packaged AN and AN in IBCs, maintain a free air space of a least 1.2 m between the AN and the outer walls of the buildings and the lowest support beam of the roof.

(b) Do not permit smoking and naked lights inside AN stores, and display notices to this effect.

(c) Any hot work inside the storage building should be avoided if possible.

(d) Any hot work inside or outside to the storage building should be controlled by a "Hot Work Permit System" to ensure that no fire is initiated.

(e) Floors, walls and equipment should be kept clean and any rubbish, foreign matter or spillages cleared promptly. Organic materials (e.g. sawdust) should not be used to clean floors.

(f) Pallets should not be used when storing more than 10 t of AN in IBCs in a building. Plastic pallets are acceptable for dome structures in remote locations to keep AN off the ground.

5.4.1 Storing more than 10 t of AN

A dedicated store is required when storing more than 10 t of AN. For a building, this means a stand-alone structure that contains no other substances or equipment unless approved by the regulator.

5.4.2 Storing 10 t or less of AN

For a store containing 10 t or less of AN, any building in which the AN store is located should not be used for any other purpose.

However, if this is not practicable then all other substances (including compatible substances) and equipment should be located at least 5 m from the AN store, as indicated in Figure 3.3.

Where the other substances are liquid and incompatible with AN, provide fire-resistant spillage containment capable of holding at least 100 per cent of the liquid volume stored, and designed so that liquid cannot encroach within 5 m of any stored AN.

5.5 Loose prill

For loose prill stores in AN manufacturing plants, where no impact to residential buildings can occur, the 500 t maximum stack size does not apply, but additional control measures beyond those required by this code must be applied in accordance with the safety report for the major hazard facility.

5.5.1 Separation of piles of loose prill

There is no need to separate bulk piles of loose prill. The only requirement is that the "toes" should not overlap. If the "toes" do overlap, the total mass of the two piles is the defining mass of a potential explosion.

Where piles of loose AN prill are separated by only a single concrete wall, assume that sympathetic detonation between piles is possible and use the aggregate quantity of AN in the piles when calculating separation distances.

5.6 Compatible and incompatible substances

Those substances listed at section 5.6.2 as "Incompatible substances" should never be stored in the same building as AN nor within a building attached to an AN store.

Unless substances are known to be compatible with AN, assume they are incompatible and treat them accordingly.

5.6.1 Compatible substances

The following fertilisers are considered compatible with AN, but should still be separated from AN by at least 5 m:

- potassium nitrate
- sodium nitrate
- calcium nitrate
- ammonium sulphate
- AN-based fertiliser mixtures of the nitrogen, phosphate or potash type
- calcium sulphate
- ammonium phosphate
- calcium ammonium nitrate
- calcium or magnesium carbonate.

Seek expert advice when deciding on the compatibility of other fertilisers.

5.6.2 Incompatible substances

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

(a) liquid fuels such as flammable or combustible liquids such as petrol, kerosene, solvents, diesel fuel, lubricating and fuel oils or hydrocarbon formulated pesticides

(b) solid fuels such as combustible solids such as rubber tyres, conveyor belt matting, wax, wood, paper, hay, straw, grain, grain husks, animal feed, urea and cotton

(c) flammable gases such as LP gas, acetylene, ethylene and hydrogen

(d) reducing agents such as sulphur, hexamine, finely divided metals, organic and inorganic amines and ammonium compounds, organic and inorganic sulphides

(e) explosives substances

(f) Division 5.1 dangerous goods such as calcium hypochlorite, chromates, chlorates, nitrites, perchlorates, chlorites, permanganates, chloroisocyanurates, tetranitromethane or di- or tri-chloroisocyanuric acid. Sodium nitrite (as opposed to sodium nitrate) is used to sensitize ammonium nitrate emulsions by reacting to form nitrogen bubbles. The same reaction has led to accidents when mixed accidentally with AN

(g) acids

(h) alkaline substances react to liberate ammonia gas if mixed with AN

(i) impurities of copper, cadmium, chromium and zinc metals and their salts increase AN's explosion sensitivity in a fire

(j) impurities of metal chlorides, such as potassium chloride (a potash fertiliser), which increase AN's explosion sensitivity in a fire.

6 Emergency response and fire protection

6.1 Emergency response

Fire caused four of the most recent accidental explosions referenced in Appendix 4 and is almost always the initiating factor. The resulting casualties were predominantly emergency personnel. They fought the fires at a time when the molten AN was undergoing dangerous decomposition.

Deciding on the correct time for firefighters to evacuate to a safe distance can be difficult. Most fires involving AN do not result in an explosion and that is partly because they are successfully extinguished before the fire had a chance to decompose the AN to any degree.

There is uncertainty whether the decomposing molten AN can flow into confining places, or mix with sensitising substances such as fuels of any type including plastics, wood, any organic substances, or all manner of incompatible substances. Without such circumstances, AN is able to decompose safely.

The best strategy is to withdraw all firefighters once the fire is judged out of control, or once it encroaches on the AN storage and results in the melting of AN. At this stage the fire should only be fought remotely.

Thick snow-white fume is evidence of the first stage of decomposition and is a warning to withdraw firefighters immediately to a safe place. The early decomposition gases are ammonia and nitric acid and they recombine in the air to give white fumes of finely divided AN, as well as condensing steam and invisible nitrous oxide.

The evolution of toxic orange-brown nitrogen dioxide is a sign that an explosion is imminent.

The visible indication of AN decomposition is often disguised by the different types of smoke created by the burning fuels that are causing the AN to decompose. The time it takes from the first decomposition of the melt to an explosion is unpredictable and may range from five minutes to longer than one hour, or it may not occur at all.

6.1.1 Emergency plan

The process of promptly evacuating on-site and off-site people in the event of a fire involving AN should be documented in detail in the site-specific emergency plan required by r. 75 of the Storage Regulations. The emergency plan should establish an efficient process for assigning specific roles and alerting key managers that take part in the evacuation and control of the fire. The emergency plan should be practised in order to ensure it works efficiently.

The emergency plan should alert fire fighters to protect against the release of toxic nitrogen oxides that would result from an uncontrolled fire causing the decomposition of AN. Nitrogen dioxide and gaseous nitric acid are heavier than air (1.6 and 2.25 times respectively) and tend to travel some distance along the ground before dispersing. This is especially true for nitric acid that condenses into a fine mist.

The emergency plan should determine at what point emergency personnel and non-emergency persons need to evacuate to a safe distance to protect from a potential explosion.

If inter-stack distances (defined in Table 5.1) are adequate to prevent sympathetic detonation, then the evacuation distances can be taken according to the quantity of AN in the largest stack. However if they are inadequate, then the total storage quantity will determine the evacuation distance.

6.1.2 Evacuation distances

Table 6.1 provides recommended evacuation distances for persons not involved in the emergency operation and for emergency personnel.

Table 6.1 Recommended evacuation distances

A. For persons not involved in the emergency operation	
Quantity of AN in tonnes	**Evacuation distance in metres**
1 to 10 t	600 m
10 to 50 t	1,000 m
50 to 100 t	1,300 m
100 to 500 t	1,600 m
B. For emergency personnel	
Evacuation distances should be as set out for "vulnerable facilities" in Table 4.1.	

The chance of being hit by flying debris increases greatly the shorter the distance from a potential explosion. For distances less than 300 to 400 m, emergency personnel should seek additional barrier protection against debris.

6.2 Fire protection

Regulation 73, "Fire control equipment required on site" of the Storage Regulations, must be complied with and the fire control equipment must be designed and constructed to extinguish any fire that is reasonably foreseeable at the site.

The chemical and physical properties of AN, the mass in the largest stack and the location of the store influence the firefighting requirements and these should be determined by a site-specific fire risk assessment carried out by competent personnel.

6.2.1 Fire protection strategy

The fire protection strategy should be based on eliminating, or at least rigorously minimising, the presence of combustibles around AN that are known to be present, or that could potentially be present.

Any fire protection strategy should recognise the chemical properties of AN.

AN is an oxidising substance of Division 5.1 and a fire involving AN cannot be extinguished by oxygen deprivation. AN does not burn, but it will promote the combustion of many materials that may be contaminating the AN.

Do not fight fires involving AN, evacuate the site.

6.2.2 The application of water

For a fire involving AN, the prompt remote application of water is the most effective means of control. Prompt application of large quantities of water is the only effective means of firefighting due to the cooling effect of water.

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

6.2.3 Firefighting requirements

Fire protection should meet the following requirements:

(a) water from hoses and fixed monitors should be able to reach all parts of the store

(b) foam and dry chemical extinguishers should be available to deal with vehicle and electrical fires before the fire gets out of control and involves the AN

(c) firefighting systems should be automated or capable of single person operation where AN stores are operated by a small number of people

(d) for stores located within cities, towns and major hazard facilities consideration should be given to installing automatic fire water sprinkler systems and “Very Early Smoke Detection Apparatus”, known as VESDA fire detection systems.

Firefighting requirements can be reduced for isolated stores where a potential explosion or toxic gas emission will not impact on people and property on or away from the premises.

7 Powered transfer equipment

7.1 General

Powered transfer equipment refers to all powered equipment that may be used to move AN into, within or from a store, and includes forklift trucks, front-end loaders, augers, chain-conveyors and belt-conveyors.

The use of suitably designed, constructed and maintained powered transfer equipment is essential where AN is involved in order to reduce the risk of contamination, fire and explosion.

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.

7.2 Equipment requirements

7.2.1 Permitted powered transfer equipment

Unless approved by the regulator, powered transfer equipment (other than vehicles such as forklift trucks and front-end loaders) should only be used to move AN if:

(a) it is powered by electricity, diesel fuel or LP gas
(b) its power source (i.e. power outlet or generator) is located outside, and at least 5 m from, the AN store
(c) it is electrically or hydraulically driven.

7.2.2 Prohibited powered vehicles and transfer equipment

Petrol powered vehicles and transfer equipment must not be used to move AN into, within or from an AN store.

7.2.3 Powered transfer equipment requirements

All powered AN transfer equipment should:

(a) be free of any leaks of fuel, lubricating oils or hydraulic fluid
(b) not include in its construction any copper, zinc (including galvanised iron), cadmium or their alloys that can come into contact with AN
(c) be constructed from materials that, if in contact with AN, will not corrode
(d) 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*
(e) 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 should be in place to prevent contaminants (e.g. dirt, other products) being brought into the AN store on vehicles (e.g. vehicles such as front-end loaders should be dedicated to AN activities)
(f) be refuelled or recharged at a distance of at least 10 m from the AN store

(g) be provided with a dry-powder fire-extinguisher having a rating of not less than 40(B) and consider the need for an additional foam fire extinguisher to deal with tyre, brake, bearing and conveyor belt fires that respond poorly to dry powder
(h) if it incorporates a battery, be provided with a clearly marked battery isolation switch and insulated cover for the battery terminals*
(i) all transfer equipment should be attended when in operation
(j) 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 clearance 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
(k) if it is a conveyer belt, have fire-resistant belt and rollers
(l) be regularly maintained
(m) unless it is a vehicle, be provided with a clearly labelled and readily accessible emergency stop
(n) be cleared of as much AN as is reasonably practical after each use.

Note: Items that are asterisked do not apply to vehicles that deliver AN to the site but do not enter the actual AN store.

7.2.4 Road vehicles

All road vehicles that enter the storage building should:

(a) be attended at all times when they are inside the AN store and have direct egress from the store that does not involve the vehicle having to manoeuvre or reverse
(b) remain inside the store only for the time required to unload or load the vehicle.

Petrol powered road vehicles must not be used to move AN into, within or from an AN store.

8 Parking of vehicles loaded with AN on private property with restricted access

Figure 8.1 AN in IBCs on a combination vehicle

8.1 Overview

The WA dangerous goods legislation caters for two different types of parking arrangements for dangerous goods vehicles depending on the location of the parking site:

1. those for vehicles parking on public roads and places controlled by the Australian Dangerous Goods Code (ADG Code) regulated under the Dangerous Goods Safety (Road and Rail Transport of Non-explosives) Regulations 2007 (Transport Regulations)
2. those for vehicles parking on private property with restricted access regulated through the Storage Regulations.

All parking arrangements require AN to be kept secure in accordance with the licensee's SSAN transport security plan – regulated through the SSAN Regulations.

This chapter deals only with the safety aspects of the parking arrangements on private property with restricted access as regulated under the Storage Regulations. It does not apply to public areas or road train assembly areas controlled by Main Roads WA and addressed by the ADG Code.

8.2 Parking requirements on private property with restricted access

8.2.1 Introduction

Section 8.2 addresses the hazards arising from the parking of dangerous goods vehicles carrying AN in a private yard with restricted access, where vehicles are in transit.

"In transit" means vehicles carrying AN do not park for longer than five consecutive days and the AN is in containers that are not opened or used at the site.

The transiting of AN on private property with restricted access may require a Dangerous Goods Site Licence under the Storage Regulations.

8.2.2 Inter-vehicle distances for parked dangerous goods vehicles

All parked dangerous goods vehicles, including those carrying AN should be separated in parallel from each other by at least 3 m. This separation distance enables:

- effective fire fighting of any vehicle fires, and
- sufficient room to move adjacent vehicles away from the vehicle on fire.

The potential scenario of a burning trailer loaded with AN, or other explosion-risk dangerous good, assumes that the required parking arrangements and emergency plan will facilitate the immediate and efficient evacuation of the two adjacent vehicles (on either side of the burning vehicle) to prevent the spread of the fire and potentially any sympathetic explosions.

8.2.3 Parked vehicles carrying flammable or combustible liquids or gases

Vehicles carrying flammable or combustible liquids and/or flammable gases should be parked in a separate area, at least 10 m from vehicles carrying AN or other oxidising agents.

8.2.4 General parking requirements for all dangerous goods vehicles

The following applies to the parking of all dangerous goods vehicles including those carrying AN:

(a) the parking areas and vehicle bays should be clearly marked

(b) all vehicles with AN should be separated from any dangerous goods storages, combustible materials, on-site office buildings and open flames by at least 10 m

(c) access and escape routes should be clearly defined and kept clear at all times

(d) parked vehicles should be able to drive away without reversing and with minimal manoeuvring

(e) spill kits should be available to clean up and recover any dangerous goods spill and fuel and oil spills. Separate spill kits should be available for AN and fuel/oil spills

(f) before leaving the parked vehicle, the driver should ensure that wheel and bearing temperatures of the parked vehicles are within safe operational limits to prevent vehicle fires

(g) disconnected lead trailers should be supported by braced landing legs, or equivalent external support, to prevent a potential trailer collapse.

8.2.5 Separation distances to off-site occupancies for AN vehicles

Very large AN transport yards, apart from requiring a Dangerous Goods Site Licence, may have manifest quantities of AN (i.e. more than 10 t) in transit on a 24-hour, daily basis for most of the year. In this situation, the operation will need to establish sufficient separation to the following off-site occupancies.

The required separation distances for these operations are taken from Table 4.1 based on the scenario of a single trailer loaded with AN being involved in an uncontrolled fire, leading to a potential explosion.

The required separation distances will help to protect the following off-site occupancies from a potential explosion from AN:

- vulnerable facilities
- residential and accommodation occupancies
- commercial buildings.

The separation distances should correspond to the quantity of AN in the largest commonly encountered load on any one trailer of a combination vehicle parked at the site.

For example, if the largest commonly encountered load is a trailer with 24 t of IBCs on a flattop trailer, then the required separation distances from the closest AN vehicle are:

- 403 m for vulnerable facilities
- 323 m for residences
- 190 m for commercial buildings.

8.2.6 Emergency response

For AN vehicles in transit, the emergency response requirements and fire protection requirements of sections 6.1 and 6.2 of this code apply.

8.2.7 Fire suppression

There is a need to supplement the dry powder fire extinguishers on the AN vehicle with water-based foam extinguishers, as these extinguishers are more effective in cooling fires caused by hot brakes and wheel bearings.

Unless the road trains are already supplied with their own 70 L foam (aqueous film forming foam - AFFF) extinguishers, additional water-based extinguishers should be placed so that they are readily accessible to each AN vehicle in the yard.

The following is required:

(a) at least one 90 L mobile foam (AFFF) extinguisher

or

(b) at least one fire hose reel that complies with AS 1221 *Fire hose reels*.

8.2.8 Temperature checking stations

Some companies operate a temperature checking station, a place where vehicles cool down for 15 minutes, or are temperature checked, prior to proceeding to their designated parking area. Water-based fire extinguishers should be located near this area unless AN vehicles are already fitted out with foam extinguishers.

Appendix 1 References

Dangerous Goods Safety legislation

Dangerous Goods Safety Act 2004
Dangerous Goods Safety (Explosives) Regulations 2007
Dangerous Goods Safety (Major Hazard Facilities) Regulations 2007
Dangerous Goods Safety (Security Sensitive Ammonium Nitrate) Regulations 2007
Dangerous Goods Safety (Storage and Handling of Non-explosives) Regulations 2007
Dangerous Goods Safety (Road and Rail Transport of Non-explosives) Regulations 2007

Other legislation

Land Administration Act 1997
Mines Safety and Inspection Act 1994
Occupational Safety and Health Act 1984
Planning and Development Act 2005

Australian Standards

AS 1221	*Fire hose reels*
AS 2187.1	*Explosives – Storage, transport and use, Part 1: Storage*
AS 4326	*The storage and handling of oxidising agents*
AS 3846	*The handling and transport of dangerous cargoes in port areas*
AS 60529	*Degrees of protection provided by enclosures (IP Code)*
AS/NZS 1768	*Lightning protection*
AS/NZS 3711.1	*Freight containers, Part 1 – Classification, dimensions and ratings*

Other references

Ammonium Nitrate Guidance Note No. 2 – Storage (Council of Australian Governments [COAG], 2004)
Australian Code for the Transport of Dangerous Goods by Road and Rail (ADG Code)
Erik Nygaard, "*Storage of technical (porous) ammonium nitrate*", International Society of Explosives Engineers 2008G Volume 1
Good Practice Guide: Storage of Solid Technical Grade Ammonium Nitrate (SAFEX International, 2014)
Major hazard facility: Development and submission of a safety report – Guide (DMIRS, 2020)
National Construction Code of Australia
Risk criteria for land use safety planning – Hazardous Industry Planning Advisory Paper No. 4 [HIPAP 4] (NSW Planning, 2011)
Safety Testing of Ammonium Nitrate Products (International Fertiliser Society, 2006)
UN Manual of Tests and Criteria

Appendix 2 Glossary

Ammonium nitrate or AN: Substance which meets the classification as a dangerous good UN 1942 or UN 2067. AN has the formula NH_4NO_3.

ANFO: Ammonium nitrate fuel oil mixture is made by mixing approx. 6% of diesel with low density AN prill.

Commercial buildings: Includes offices, retail centres, warehouses with showrooms, restaurants and entertainment centres.

Compatible: In relation to AN and another substance that will not react together to cause a fire, explosion, harmful reaction or the evolution of flammable, toxic or corrosive vapours, and will not increases the explosion sensitivity of AN.

Critical infrastructure: Those physical facilities, supply chains, information technologies and communication networks that, if destroyed, degraded or rendered unavailable for an extended period, would significantly impact on the social or economic wellbeing of the nation or affect Australia's ability to conduct national defence and ensure national security. Critical infrastructure involves the sectors of energy, utilities, transport, communications, health, food, supply, finance, government, services and essential manufacturing.

Dedicated, stand-alone building storage: A stand-alone building used only for AN storage and no other purpose.

Detonation: An explosive process of very high speed involving a sustained shock wave. Detonation velocities lie in the approximate range of 1500 to 9000 m/s (slower explosive reactions below the velocity of sound are propagated by thermal conduction and radiation and are known as deflagration).

Intermediate bulk container (IBC): A rigid or flexible portable packaging for the transport of dangerous goods that:

- has a capacity:
  - for solids of Packing Group I packed in a composite, fibreboard, flexible, wooden or rigid plastics or wooden container – of not more than1,500 L
  - for solids of Packing Group I packed in a metal container – of not more than 3,000 L
  - for solids or liquids of Packing Groups II and III – of not more than 3,000 L
- is designed for mechanical handling
- is resistant to the stresses produced in usual handling and transport.

Loose bulk: Refers to AN, which is not contained in a package or an IBC.

Oxygen balance: The amount of oxygen, expressed in weight percent, liberated as a result of complete conversion of an explosive substance to CO_2, H_2O, N_2, SO_2, Al_2O_3, etc. (positive oxygen balance). If the amount of oxygen bound in an explosive is insufficient for the complete oxidation of the substance (negative oxygen balance), the deficient amount of the oxygen needed to complete the oxidation reaction is reported with a negative sign. Commercial explosives usually have an oxygen balance close to zero in order to minimise toxic gases, particularly carbon monoxide and nitrogen oxides, but also to maximise the energy output of the explosive.

Package: Refers to a container designed to hold not more than 500 kg of solid AN.

Protected works: These are deemed to include a dwelling and any public building, school, place of worship, theatre, or other building or structure where the public is accustomed to assemble; a shop, factory, warehouse, store, or other building in which any person is employed in any trade or business; as well as a depot or store for the keeping of flammable or dangerous goods and a major dam.

Regulator: The Chief Dangerous Goods Officer as per the *Dangerous Goods Safety Act 2004*.

Residential buildings: Includes places of continuous occupancy such as hotels and tourist resorts.

Rural dangerous goods location: A place that:

- is outside the part of the State that comprises the metropolitan region as defined in the *Planning and Development Act 2005* [s. 4(1)] or a townsite as defined in the *Land Administration Act 1997* [s. 3(1)]
- occupies an area of 5 hectares or more
- is used by the operator for agricultural, horticultural, floricultural, aquacultural or pastoral purposes
- at which dangerous goods are stored or handled for the purposes other than for sale.

Security sensitive ammonium nitrate (SSAN): Any substance that contains more than 45% AN is security sensitive ammonium nitrate unless it is an:

- explosive

or

- aqueous solution, being a homogeneous mixture of two or more components in a single phase.

Standard operating procedures or SOPs: Written procedures containing an explicit description of how a job is to be performed. SOPs identify precautions required to complete a task safely, including:

- personal protective equipment (PPE) required
- hazards specific to the job and/or the 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 (TGAN): Porous prill AN used to make commercial explosives with a bulk density of less than 0.9 g/cc. It is classified as UN 1942.

Tonne (t): Also referred to as metric tonne, equal to 1,000 kg.

UN number: The four-digit identification number assigned to dangerous goods by the United Nations Committee of Experts on the Transport of Dangerous Goods, as published in the ADG Code.

UN 1942: Ammonium nitrate, with not more than 0.2% total combustible material, including any organic substance calculated as carbon, to the exclusion of any other added substance, Division 5.1, PGIII. This entry must be used for any TGAN and any pure AN with a bulk density greater than 0.85 g/cc.

UN 2067: Ammonium nitrate-based fertiliser, Division 5.1, PGIII. This entry may only be used for ammonium nitrate-based fertilisers classified in accordance with the procedure as set out in the *UN Manual of Tests and Criteria*, Section 39. This entry may only be used for mixtures of AN and other fertiliser ingredients.

Vulnerable facility: A category of facility that includes, but is not restricted to, multistorey buildings (e.g. above four storeys), large glass-fronted buildings of high population, health care facilities, childcare and aged care facilities, schools, major traffic terminals (e.g. railway stations and airports), major public utilities (e.g. gas, water and electricity works) and sports stadiums.

Appendix 3 Toxic gas and explosion chemistry of AN

Physical properties

Pure AN is a white, odourless salt with a melting point of 169.6°C, molecular formula NH_4NO_3 and molecular weight 80.

The amount of carbonaceous additives must be kept below 0.2% of carbon in order for the product to be classified as a Division 5.1 oxidising agent. The UN classification system for dangerous goods classifies AN with a higher carbon content as a classification code 1.1D explosive.

AN is highly soluble in water, with solubility increasing rapidly with temperature. At 20°C, 1 mL of water will dissolve 1.877 g of AN, and at 50°C, it will dissolve 3.440 g of AN.

AN is hygroscopic and deliquescent in that it tends to absorb water from the atmosphere at high humidity. It is capable of attracting so much water under hot and humid conditions that it dissolves into an aqueous solution (deliquescent). Aqueous solutions are slightly acidic (i.e. a 0.1 Molar solution has a pH of 5.4).

Pure AN is difficult to detonate under ambient conditions of temperature and pressure. Flame, spark, rough handling, impact or friction are not known to cause a propagated detonation.

An explosion of pure AN can be initiated with high explosives under ambient conditions, and explosives must never be used to break up caked AN. Under ambient conditions, it is not possible to initiate AN by means of a rifle bullet. However, the shock sensitivity of molten AN increases significantly and severe mechanical impact can lead to detonation.

Fire hazard

AN itself does not burn but, being an oxidising agent, it can facilitate the initiation of fire and intensify fires in combustible materials, even if air is excluded.

Hot concentrated AN solutions can initiate fires when coming into contact with rags, wooden articles and clothing. Other combustible materials impregnated with AN have been known to start burning spontaneously when left on hot surfaces. Similarly, AN products contaminated with oil or combustible materials can start a fire when hot.

Fires involving AN cannot be extinguished by the prevention of air ingress because of the in situ provision of oxygen from AN, which makes dry powder and carbon dioxide fire extinguishers ineffective.

Decomposition of AN without explosion

Molten AN decomposes at about 210°C to give off toxic gases.

If pure AN is heated in an open and unconfined situation, it will decompose completely to give gaseous products in a steady controlled way with white fumes and vapours. The primary reaction is irreversible, exothermic and produces nitrous oxide and water.

$NH_4NO_3 \rightarrow N_2O + 2H_2O$ (+ 450 kJ/kg)

Once the temperature exceeds 250°C, an endothermic reaction producing ammonia (NH_3) and nitric acid (HNO_3) occurs.

$NH_4NO_3 \rightarrow HNO_3 + NH_3$ (- 2200 kJ/kg)

Providing gases can escape freely (i.e. unconfined and in the absence of fuel and contaminants), this combination of exothermic and endothermic reactions can provide a temperature limiting mechanism so that the temperature does not rise above 300°C, even with the input of a considerable amount of external heating. This process is capable of consuming all available AN relatively harmlessly in the absence of fuel, contaminants, confinement and mechanical shock.

The intense whiteness of the fumes is due to the recombination of ammonia and nitric acid vapours in the air to reform AN in the form of very small (fume) particles in a reversible reaction.

Decomposition of AN with explosion

AN can also explode without shock if heated sufficiently, but only if contaminated, under confinement, or both. Under these circumstances, the temperature will quickly rise above 300°C, giving off other gases including orange-brown toxic nitrogen dioxide (NO_2). The temperature will rise through self-accelerating reactions, and a detonation is likely to occur. Fires involving AN have caused explosions in the past, but there have been many more fires involving AN that did not lead to explosions.

AN is set up as an explosive substance, albeit an insensitive one, since it carries the oxidising nitrate ion in intimate contact with the fuel element, the ammonium ion.

Once the ionic structure is weakened or destroyed above 300°C, all that is required are small amounts of contaminants or fuel to promote the following more energetic nitrogen-forming (explosive) reactions. These reactions occur with the formation of orange-brown clouds of nitrogen dioxide (NO_2) and colourless nitric oxide (NO) and nitric acid (HNO_3).

The primary explosion reaction is thought to be reaction No.4 and the excess oxygen reacts with nitrogen to give toxic nitrogen oxides as shown in reactions No.1 to 3.

1. $2NH_4NO_3 \rightarrow N_2 + 2NO + 4H_2O$ (+ 350 kJ/kg)
2. $4NH_4NO_3 \rightarrow 3N_2 + 2NO_2 + 8H_2O$ (+ 1160 kJ/kg)
3. $5NH_4NO_3 \rightarrow 4N2 + 2HNO_3 + 9H_2O$ (+ 1540 kJ/kg)
4. $2NH_4NO_3 \rightarrow 2N2 + O2 + 4H_2O$ (+ 1580 kJ/kg)
5. $3(NH_4NO_3) + CH_2 \rightarrow 3N_2 + 7\ H_2O + CO_2$
   (+ 4017 kJ/kg)

No. 4 reaction has an Oxygen Balance of (+) 20%, as is easily calculated from the balanced equation.

To maximise the heat of explosion and to minimise the emission of toxic gases an Oxygen Balance of 0% is required. In this case, 0% is achieved by adding 5.83% by weight of diesel to the AN as can be calculated from the balanced equation No. 5, which is the explosion reaction for ANFO.

(The addition of any fuel greater than 0.2%, calculated as organic carbon, will also markedly increase the explosion sensitivity of AN and turn AN into a 1.1D explosive UN 0222.)

The average carbon to hydrogen ratio in diesel fuel (a complex mixture of non-aromatic and aromatic hydrocarbons) is approximately 1:2, represented by units of CH_2.

The addition of just the right amount of diesel for a zero oxygen balance (5.83%) can therefore be represented by a single unit of CH_2 in reaction No. 5.

Appendix 4 Accidental storage explosions 2000–2020

Toulouse, France, 21 September 2001

The only known industrial accident where chemical contamination was most probably the root cause took place at the AZF fertiliser plant. This marks it as an exception in the history of accidental storage explosions; the other exception from the normal fire-initiated explosion was the shock-initiated explosion at Oppau, Germany in 1921.

The explosion occurred in a warehouse used for the temporary storage of out-of-specification AN, which was waiting to be recycled into AN-based fertiliser mixtures.

While the original cause of the explosion is not agreed between the numerous investigating parties, it is generally agreed that the most likely cause was identified as a reaction between AN and sodium dichloroisocyanurate, or AN and trichloroisocyanuric acid; both reactions release trichloramine (NCl_3), an explosion sensitive substance. There seemed to have been poor management of a warehouse allowing different contractors to operate it independently, which explains the mixing of AN with sodium dichloroisocyanurate, a pool chlorine biocide.

INERIS estimated that the TNT equivalent of the explosion was in the range 20 to 40 t involving approximately 400 t of AN.

The explosion resulted in 31 fatalities and 2,442 injured persons. The blast wave shattered windows up to 3 km away. The crater was 10 m deep and 50 m wide.

Saint Romain en Jarez, France, 2 October 2003

A fire broke out in a farmer's barn containing a petrol-powered forklift, two 13 kg gas bottles, farm machinery, 500 wooden crates, 6–7,000 plastic crates, bales of hay and straw and 6 x 500 kg IBCs of AN.

The explosion occurred approximately 70 minutes after the start of the fire and injured 26 persons, mainly firefighters. The force of explosion was estimated to be 80 to 160 kg of TNT, which indicates that only two IBC were involved in the explosion, with a total TNT equivalence of 8 to 16%.

West, Texas, US, 17 April 2013

A warehouse from a fertiliser and seed company caught fire holding approximately 30 tonnes of AN. The building and storage bins were made of wood. There was no segregation from combustible materials. AN was stored as a fertiliser, without attention to its hazards. The explosion occurred 20 minutes after the fire was first reported and resulted in 15 fatalities, including 13 firefighters, and 260 injured persons. The crater was 3 m deep and 9 m wide.

Port of Tianjin, China, 12 August 2015

An overheated container of dry nitrocellulose was the cause of a fire in a dangerous goods warehouse that triggered two explosions 30 seconds apart. Based on the seismic waves generated, the detonations were estimated to be equivalent to 2.9 t and 21.9 t of TNT respectively. There were 173 fatalities and 797 people injured. Of the fatalities, 93 were firefighters.

Beirut, Lebanon, 4 August 2020

A major fire broke out in a Port of Beirut warehouse containing, among other things, fireworks and 2,750 t of AN. The AN had been impounded and stored for six years after it was seized from an abandoned ship in 2014. The explosion occurred as the result of a fire involving fireworks. An intense shock wave caused cause immense damage throughout the city resulting in over 190 fatalities, 6,500 injured persons, 300,000 displaced persons and $10-15 billion (US) in property damage. A giant orange-brown cloud was present just before and during the explosion.

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