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Separation Distances for Explosives

Explosives Regulatory Division
Lands and Minerals Sector
Natural Resources Canada

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1. FOREWORD

The Explosives Regulatory Division (ERD) is a regulatory body within Natural Resources Canada (NRCan). ERD's mandate is to ensure the safety and security of the public and workers in the Canadian explosives industry by administering the *Explosives Act* (the Act) and the *Explosives Regulations, 2013* (the Regulations).

This document was developed to supersede the Bureau de normalisation du Québec (BNQ) Standard *CAN/BNQ 2910–510/2015* entitled *Explosives – Quantity Distances*. This document will be amended from time to time and the latest version will be published on ERD's website.

2. PURPOSE AND SCOPE

Regulatory provisions that require acceptable separation distances are the cornerstone of safety controls to protect people and property from an accident involving explosives.

This document was written to inform explosives sector stakeholders how ERD determines acceptable separation distances for manufacturing (factory) licences and certificates, and their associated client sites, and storage (magazine) licences issued under paragraph 7(1)(a) of the *Explosives Act*, and in accordance with requirements in Parts 5-7 of the Regulations.

This document does not address acceptable distances for activities taking place underground that fall under the *Explosives Act* and the Regulations.

Stakeholders that use this document outside of NRCan's jurisdiction may also find this information useful, but they should consult their Authority Having Jurisdiction (body or agency that may choose to use this document in full or in part in support of their legal regime) for determinations or approvals.

3. DEFINITIONS

barricade is an effective barrier, such as a natural ground feature, artificial earth mound or wall that meets the principles set out in *Annex C - Barricades*. The purpose of a barricade, in accordance with *Annex C - Barricades*, is to intercept high velocity, low-angle projections in the event of an explosion, which otherwise could cause the direct propagation of the explosion to other magazines and process buildings. Barricades can be used to reduce separation distances between magazines and/or process buildings for only hazard category PE1 explosives, as per table 9.2.

containment barricade is intended to deal with all fragmentation, including high trajectory lobbed fragments and secondary debris from sources such as magazine break-up.

dividing wall is a wall or structure designed to prevent a sympathetic detonation between explosives located on either side.

explosives area is an area used for the manufacturing, storage, or handling of explosives that may contain within its boundaries one or more potential explosion sites (PES) and/or exposed sites (ES).

exposed site (**ES**) (synonyms: vulnerable site, susceptible site, receptor, acceptor) is a building or site where people live, work or occupy; a public road, railway or other transportation infrastructure; a pipeline, energy transmission, energy infrastructure or communication infrastructure; or any place in which a substance that increases the likelihood of a fire or explosion is likely to be stored including, but not limited to, a site containing aboveground or underground storage of ignitable liquids, or a site containing explosives (magazine, tanker loaded with explosives, factory or mobile process unit).

gross mass is the mass of the explosives plus the mass of any packaging or container.

ignitable liquid is any liquid or liquid mixture that has a measurable closed-cup flash point (for examples combustible liquids, volatile fuels, etc.).

inhabited building is any building or structure in which any person(s) lives, works or occupies. Buildings or structures meeting the definition of uninhabited location are excluded.

net explosive quantity (**NEQ**) is the mass of an explosive excluding the mass of any packaging or container, and in the case of an explosive article, excluding any component that is not an explosive substance.

net effective explosives quantity (NEEQ) is a concept that can be used in certain situations when testing shows that the effective quantity of explosive is significantly different from the NEQ.

picking area is a designated location where the selection and re-packing of fireworks or pyrotechnic articles takes place. This cannot be located in a magazine.

potential explosion site (**PES**) (synonym: donor site) is the location of a quantity of explosives that will create a blast that could be associated with the projection of fragments or debris, or a fire hazard if its contents should explode.

ski patrol hut is a building at a ski area used only by personnel engaged in the ski area's avalanche risk management program.

surface blasting and mining operations are transient operations at a mine or quarry, such as mine development, drilling, blasting, extraction, milling, crushing, screening, sizing of minerals at a mine, waste management, water sampling, or repair of immobilized equipment. The following permanent installations are not considered surface blasting and mining operations, and are treated as inhabited buildings if they are attended: scale houses, mine process equipment (i.e. grinding, processing plants, crushers, etc.), office buildings, and workshops for maintenance.

type of explosive refers to an authorized explosive classified according to their intended use, as one of the following types:

1. E — high explosives:
    i. E.1 — blasting explosives
    ii. E.2 — perforating explosives
    iii. E.3 — special-application explosives
2. I — initiation systems
3. P — propellant powder:
    i. P.1 — black powder and hazard category PE 1 black powder substitutes
    ii. P.2 — smokeless powder and hazard category PE 3 black powder substitutes
4. C — cartridges:
    i. C.1 — small arms cartridges
    ii. C.2 — blank cartridges for tools
    iii. C.3 — percussion caps
5. D — military explosives and law enforcement explosives
6. F — fireworks:
    i. F.1 — consumer fireworks
    ii. F.2 — display fireworks
    iii. F.3 — special effect pyrotechnics
    iv. F.4 — fireworks accessories
    v. F.5 — novelty devices
7. R — rocket motors:
    i. R.1 — model rocket motors
    ii. R.2 — high-power rocket motors
    iii. R.3 — rocket motor accessories
8. S — special purpose explosives:
    i. S.1 — low-hazard special purpose explosives
    ii. S.2 — high-hazard special purpose explosives.

uninhabited location is any building, structure or place that is not a permanent dwelling, workplace or area that a person(s) occupies, and that is entered by only a few people at a time for a limited duration. Buildings meeting the definition of inhabited buildings are excluded.

4. SEPARATION DISTANCES

ERD has determined that the acceptable distances mentioned in subsections 63(1) and 147(1) of the Regulations, and any related terms and conditions of an explosives licence or certificate, refer to the separation distances outlined within this document.

Acceptable distance is determined by ERD on the basis of risk of harm to people or property, taking into account the quantity and type of explosives to be manufactured, the raw material to be used, the manufacturing operation(s) to be carried out, the strength, proximity and use of surrounding infrastructure and the number of people likely to be in the vicinity of the explosives.

ERD primarily determines acceptable distances using Quantity Distance (QD) tables. This determination aims to balance safety and practical considerations while addressing the consequences of an accidental explosion during the manufacturing, storage, and handling of explosives. QD tables are consequence-based, which means that the occurrence of an accidental explosion is assumed to have happened (the probability of an event is not considered). The use of QD tables does not guarantee absolute protection in all situations but offers a high degree of safety. The QD tables have been used effectively in Canada to control the risks of harm caused by an accidental explosion for many decades.

It is important to note that in special cases ERD may determine acceptable separation distances based on a quantified risk assessment or blast analysis.

5. DETERMINATION OF MINIMUM SEPARATION DISTANCES USING QD TABLES

The methodology for determining minimum separation distances is as follows:

a) Determine the hazard category of the explosives.

b) Determine the net explosive quantity (NEQ).

c) Using the explosive hazard category and NEQ, determine the minimum separation distance based on the classification of any Exposed Sites (ESs) within the area of effect for the Potential Explosion Sites (PESs).

6. DETERMINATION OF HAZARD CATEGORIES

Product authorization is the process by which an explosive substance or explosive article, as defined in the Act and the Regulations, is declared authorized by the Chief Inspector of Explosives (CIE). Once the product is authorized, it becomes legal to manufacture, sell, store, transport, import, export, possess and use in Canada. As part of the authorization process, the explosive substances or explosive articles are classified by the CIE by type, hazard category and UN number.

All explosives are classified into one of the following Potential Effect (PE) hazard categories, listed from most to least hazardous:

a) PE 1: mass explosion hazard;

b) PE 2: projection hazard, but not a mass explosion hazard;

c) PE 3: fire hazard and a secondary blast or projection hazard (or both), but not a mass explosion hazard;

d) PE 4: fire hazard or slight explosion hazard, or both, with only local effect; or

e) PE N/A: hazard category is not applicable.

It is important to note that classification by hazard category is different from the classification used for transport. Separation distances in this document are based on hazard categories and not on transport classification.

Explosives classified for transport as Class 1, Divisions 1.1 or 1.5 will always be hazard category PE 1. Explosives classified as Class 1, Divisions 1.2, 1.3 and 1.4 are often hazard categories PE 2, PE 3, and PE 4 respectively, but may also have a different hazard category compared to the transport division (for example, division 1.4 explosives may be authorized as hazard category PE 1).

Table 6.1 – Typical Relationship Between Transport Classification and Hazard Category

Transport Classification	Hazard Category
Division 1.1	PE 1
Division 1.2	PE 2 (or PE 1)
Division 1.3	PE 3 (or PE 1)
Division 1.4	PE 4 (or PE 1 or PE 3)
Division 1.4S	PE 4 (or PE N/A)
Division 1.5	PE 1
UN3375	PE 1

The correct hazard category is determined by consulting the List of Authorized Explosives on NRCan's webpage. For type D (military and law enforcement explosives), stakeholders preparing their application should consult ERD's notice of authorization for the product or contact ERD.

The following special situations may increase the hazard category:

a) In-process conditions of explosives, for example:
    i. increased confinement;
    ii. processing at elevated pressure and/or temperature;
    iii. critical diameter or height being exceeded; or
    iv. articles handled in a mass propagating format.

b) Storage conditions, for example:
    i. increased confinement;
    ii. critical height being exceeded; or
    iii. not in original transport packaging and/or configuration.

c) Any other situation when the assigned hazard category does not represent the actual hazard of the explosive.

Principles for determining the Hazard Categories in these specific cases are listed in *Annex B - Determination of Hazard Categories in Special Situations*.

6.1 Storing Multiple Explosive Hazard Categories in a Single PES

When a PES contains explosives with different hazard categories, all explosives within that PES would be treated as the hazard category of the most hazardous explosives present (with PE 1 being the most hazardous and PE 4 being the least; this does not apply to PE N/A). This should be described in the explosives licence application.

7. DETERMINATION OF EXPLOSIVES QUANTITY

Reference to explosive quantity or mass in this document refers to the net explosives quantity (NEQ) to be stored, manufactured, or handled at a specific location (in kg), unless otherwise specified. In certain cases, the explosives quantity can be also determined using the principles below.

7.1 Estimating NEQ Based on Explosive Type

If the actual NEQ of an explosive is unknown by the stakeholder during the application process, or not considered for simplicity by the stakeholder, then the NEQ for certain types of explosives can be estimated based on the following principles:

Type I detonators, Type F.4 E-Matches, and Type R.3 Igniters

The NEQ can be estimated as 0.001 kg per detonator, e-match or igniter.

Type F.1 – Consumer Fireworks

The NEQ can be estimated as 25% of the gross mass.

Type F.2 – Display Fireworks & Type F.3 – Special Effect Pyrotechnics

The NEQ can be estimated as 75% of the gross mass.

However, ERD can insist on the actual NEQ being used on the application if the principles above do not adequately represent the NEQ of the explosive(s).

7.2 Net Effective Explosive Quantity (NEEQ)

The Net Effective Explosive Quantity (NEEQ) is a concept that can be used in certain situations when testing shows that the effective quantity of explosive is significantly lower than the NEQ.

If using NEEQ to determine minimum separation distances, it must be described in the explosives licence application so that it is clear that the above provisions are satisfied.

The following scenarios are cases where NEEQ may be applied:

7.2.1 Type E.1 - UN3375 and UN0332

NEEQ of 75% of NEQ can be applied for bulk product storage if the product has been authorized by ERD, and the following conditions are met, and approved by ERD:

a) The product does not contain perchlorates in emulsions; and does not contain sensitizers (microballoons, gas bubbles, or any other physical or chemical sensitizers);

b) The product passes UN Test Series 8, and is a candidate for inclusion as an Ammonium Nitrate Emulsion, Suspension or Gel, or for UN0332, the product has a Minimum Burning Pressure greater than or equal to 5.6 MPa; and

c) The product has a calculated heat of explosion of less than 75% of TNT (based on a value of 4564 kJ/kg for TNT).

7.2.2 Type E.2 - Shaped Charges

NEEQ of 25% of NEQ can only be applied under the following provisions for UN0440 and UN0441 explosives:

a) NEQ of 200 kg or less for the licence;

b) Shaped charges are stored as packaged for transport; and

c) Shaped charges are stored by themselves and without any mass detonating explosive such as detonating cord.

7.2.3 Type F.2 – Display Fireworks Classified as PE 1 hazard category

NEEQ of 50% of the NEQ can be applied. NEEQ may not be used for display fireworks shells containing more than 25% flash powder by mass.

8. DETERMINATION OF MINIMUM SEPARATION DISTANCES

Each ES that could be exposed to hazards from a PES (for example, debris or blast effects) must be identified and evaluated to ensure that they are located at a distance greater than or equal to the minimum separation distance from the PES. Minimum separation distances from a PES to an ES are determined using the NEQ, and the QD table corresponding to the hazard category of the PES, as set out in this document.

8.1 Explosives Areas with a Single PES

For an explosive area with a single PES, the minimum separation distance between the PES and each ES are determined from the principles corresponding to the hazard category of the PES, as follows:

a) PESs classified as hazard category PE 1 follow the principles specified in section 9;

b) PESs classified as hazard category PE 2 follow the principles specified in section 10;

c) PESs classified as hazard category PE 3 follow the principles specified in section 11; and

d) PESs classified as hazard category PE 4 follow the principles specified in section 12.

If the minimum separation distance between a PES and an ESs cannot be achieved, the following should be considered by the stakeholders:

a) Reducing the maximum NEQ allowed at the PES;

b) Relocating either the PES or the ES; or

c) Using the means set out in section 8.3 to reduce the minimum separation distances.

8.2 Explosives Areas with More Than One PES

When an explosive area has more than one PES, the minimum separation distance between each PES would first be determined from the principles corresponding to the hazard category of the PES, as follows:

a) PESs classified as hazard category PE 1 follow the principles specified in section 9;

b) PESs classified as hazard category PE 2 follow the principles specified in section 10;

c) PESs classified as hazard category PE 3 follow the principles specified in section 11; and

d) PESs classified as hazard category PE 4 follow the principles specified in section 12.

Once the minimum separation distances between PESs have been established, then the minimum separation distances between each PES and ES are determined as outlined in section 8.1.

If the minimum separation distances between PESs cannot be achieved, the following should be considered by the stakeholders:

a) Reducing the maximum NEQ allowed at the PESs;

b) Relocating the PESs;

c) Aggregating the PESs as outlined in section 8.2.1; or

d) Using the means set out in section 8.3 to reduce the separation distances.

8.2.1 Aggregation of Explosive Quantities at a Single Licensed Site

When two or more PESs are not separated by the minimum separation distance set out in this document, the PESs may be considered a single PES. In that case, the NEQ used to determine the minimum separation distances would be the sum of the maximum NEQs allowed at each PES. The hazard category is then based on the PES with the most hazardous hazard category. Aggregation of process buildings with occupants should be avoided as much as possible to keep the number of exposed workers to a minimum. Stakeholders should contact ERD prior to aggregating process buildings with occupants to ensure that the arrangements are suitable for licensing.

8.2.2 Aggregation of Explosive Quantities for Separately Licensed Sites

Where explosives magazines from more than one licence holder are situated within inhabited building distances from each other, there should be a signed letter of understanding between the parties detailing the hazards.

If magazines from separate licences are to be aggregated, they must be described in the explosives licence application so that it is clear that the combined quantities of all aggregated magazines are being used for the purposes of establishing minimum separation distances. A letter of understanding between the licencees should be included in the licence application.

Process units from separately licenced sites are not to be aggregated.

8.3 Means to Reduce Minimum Separation Distances

The following are ways to potentially reduce the minimum separation distances required at a PES.

8.3.1 Use of Effective Barricades to Reduce Separation Distances

When two or more unbarricaded PESs of hazard category PE 1 do not meet the minimum separation distance, effective barricades can be used to reduce the minimum separation distance between the PESs as specified in the QD tables. A barricade is considered effective if it meets the principles set out *in Annex C - Barricades*.

8.3.2 Use of Dividing Walls in a PES Building

A PES building may be divided into individual compartments using dividing walls approved by ERD. Typical demonstration of an effective dividing wall would be a blast analysis conducted by a qualified person.

When dividing walls are used, the minimum separation distances can be calculated from the QD tables on the basis of the maximum NEQ present in each compartment instead of the aggregate maximum NEQ allowed in the building.

8.4 Measurement of Minimum Separation Distances

Minimum separation distances are measured using the shortest straight line possible between the nearest point of a PES and the nearest point of an ES, regardless of barricades or intervening buildings or structures. If aggregating multiple PESs (as outlined in section 8.2.1 and 8.2.2), then the separation distance is measured using the shortest straight line possible between the nearest point of the PES that is closest to the nearest point of each ES, as shown in Figure 8.1.

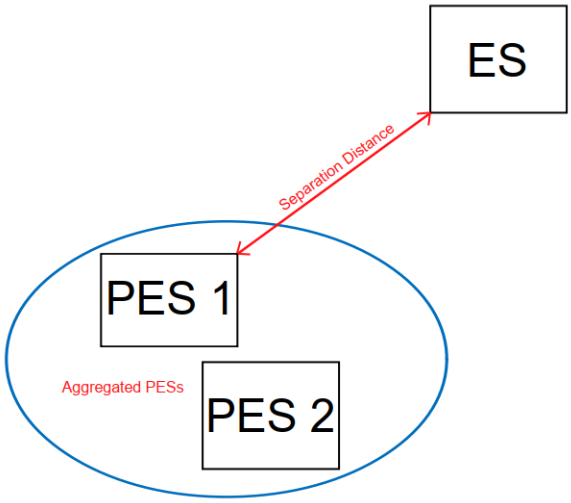

Figure 8.1 - Measurement of separation distances when aggregating multiple PESs

8.5 Provisions When Separation Distances do not Apply

There are some special situations where ESs and PESs do not need minimum separation distances.

Separation distances do not apply to any explosive types and hazard categories that are stored below the explosives licence limits stated in the Regulations and stated in section 8.5.2, whether or not they are stored at a licensed site, if the storage areas would not increase the chances of accidental ignition or the hazardous effects of an accidental ignition in any adjacent explosive storage areas.

8.5.1 Provisions for Lower Risk ESs

Minimum separation distances do not need to be applied for the following ESs:

a) Public traffic routes that convey on average the equivalent of fewer than 20 vehicles per day[1] as well as ski runs with less than 40 skiers per day;

b) Private roads, mine roads and private pathways/trails;

c) Any site in an explosives area (other than a magazine ES or a process building ES) that is used exclusively by personnel involved in explosives-related operations (such as process vehicle maintenance, raw material storage, wash facility, lunchroom, etc.);

d) Ignitable liquid storage in an explosives area used for a manufacturing process;

e) Any building, structure or place meeting the definition of an uninhabited location;
(Any locations that are deemed by ERD to meet this definition must be detailed on the licence, including # individuals accessing the location and duration/frequency of access. Deviations from these specifications are to be communicated to ERD to ensure that compliance is met/maintained.)

f) Ski patrol huts;

g) Private helipads, runways and taxiways;

h) Private communications towers;

i) Temporary projects at controlled mines sites that are directly related to and support the mining operations (such as construction and environmental works) involving no more than 10 people and lasting no more than 30 days; or

j) Open areas with no permanent structures where infrequent transient activities to perform a task take place with no more than several people present at a time.

[1] Average means what is typical for a 24-hour period in any given month or a season. See *Annex A – Equivalent Number of Vehicles per Mode of Transport* if needing to determine the number of vehicles for situations other than roads.

8.5.2 Provisions for Lower Hazard PESs and ES

No separation distances need to be applied if the storage areas would not increase the chances of accidental ignition, or the hazardous effects of an accidental ignition in the adjacent storage areas, for a PES storing:

a) Explosives with hazard category PE N/A, with the condition that sellers cannot have any quantities of type S and F stored in a dwelling, and only a maximum of 100 kg gross mass of type S and F can be stored in a retail establishment that contains a dwelling;

b) 1 kg NEQ or less of hazard category PE 1, PE 3, or PE 4 explosives if the following conditions are met:
   i. quantities are separated into amounts of no more than 25 g NEQ (100 g NEQ for water-based explosives); and
   ii. individual amounts are packaged and stored in such a manner as to minimize the probability of accidental ignition and propagation. It is recommended to store the explosives in containers that have been tested to withstand the effect of the explosion of small quantities

c) Type R.2 PE 3 explosives of no more than 200 kg gross mass;

d) S.1 PE 3 explosives of no more than 200 kg gross mass, with the condition that sellers cannot have any quantities of type S.1 stored in a dwelling, and only a maximum of 100 kg gross mass of type S.1 can be stored in a retail establishment that contains a dwelling;

e) Type S.2 PE 3 explosives of no more that than 20 kg gross mass; however, sellers cannot store type S.2 explosives in a dwelling, or a retail establishment that contains a dwelling;

f) Type F.3 and F.4 PE 3 explosives of no more than 25 kg gross mass, with the condition that sellers cannot store types F.3 and F.4 explosives in a dwelling, or a retail establishment that contains a dwelling;

g) Type F.2 PE 3 explosives of no more than 100 kg of NEQ to be used in a fireworks display when not stored in a dwelling;

h) Type R, S and F PE 4 explosives of no more than 500 kg NEQ, with the condition that sellers cannot have any quantities of type S and F stored in a dwelling, and only a maximum of 100 kg gross mass of type S.1 and F can be stored in a retail establishment that contains a dwelling; and

i) A magazine storing type F.1 non-aerial fireworks (sparklers, flares, fountains, snakes, ground spinners, strobe pots, wheels and ground whistles) when fire considerations are approved by ERD, such as:
   i. the packing density is no more than 10 kg NEQ per m^3;
   ii. the storage area is sprinklered; and
   iii. the storage area has firewall with a fire-resistance rating of at least 1 hr to any adjoining space or area in a building.

8.5.3 Provisions for Seller Locations with Type P Explosives

No separation distances need to be applied if the following conditions are met:

a) Individual containers of type P.1 do not exceed 500 g NEQ;

b) Maximum limit for type P.1 is 25 kg NEQ; and

c) Maximum limits for type P.2:
   i. distribution centre/warehouse (no retail with public access): 2,200 kg NEQ, in magazines of 125 kg NEQ or less;
   ii. retail location: 750 kg NEQ of which no more than 375 kg NEQ can be on the retail floor, in magazines of 125 kg NEQ or less.

If a magazine stores both P1 & P.2, then the maximum total quantity of 25 kg NEQ applies.

Indoor propellant magazines should be separated by no less than 10 m.

8.5.4 Provisions for Manufacturing Locations with Type P Explosives

No separation distances need to be applied if the following conditions are met:

a) Maximum indoor limit for type P.1 is 25 kg NEQ and individual containers of type P.1 do not exceed 500 g net explosive quantity;

b) Maximum indoor limits for type P.2 is 75 kg NEQ; and

c) If a magazine stores both P1 & P.2, then the maximum total quantity of 25 kg NEQ applies.

8.5.5 Provisions for Type D Explosives

As type D explosives may vary in their risk and properties, they are to be stored based on their characteristics and as per any applicable principles in this document. Stakeholders should contact ERD to assess unique storage scenarios for Type D explosives.

8.5.6 Provisions for Law Enforcement Agencies

Law enforcement agencies should also refer to G06-02 E - *Guidelines for Law Enforcement Agencies*.

9. MINIMUM SEPARATION DISTANCES FOR HAZARD CATEGORY PE 1

Each ES that could be exposed to hazards from a PES (for example, debris or blast effects) must be identified and evaluated to ensure that they are located at least the minimum separation distance from the PES. The minimum separation distances between a PES classified as hazard category PE 1 and each ES are determined from Table 9.1.

The minimum separation distances between the PES and each ES are listed as either a formula, fixed distance, or as a variable distance expressed as D1-D8. The minimum separation distance values of D1-D8 depend on the maximum NEQ at the PES and are determined from the QD table (see Table 9.2).

If the maximum NEQ allowed at the PES falls between two listed NEQs in the QD table, then the greater of the two values is used to determine the minimum separation distance.

The minimum separation distance values can also be calculated directly based on the NEQ using the scaled factor equations at the end of Table 9.2, provided that any calculated values are no lower than the equivalent values present in the table. This method can also be used to calculate the minimum separation distance values for NEQs not listed in the table, provided that they are no lower than the distances associated with the next lowest NEQ listed in the table.

Table 9.1 - Minimum Separation Distances for PESs Classified as Hazard Category PE 1

	Exposed Site (ES)	Minimum Separation Distance (m)
1	Magazines used for the storage of explosives (includes tankers, mobile process units, silos and UN portable tanks) and shipping areas that are protected by a barricade (this includes barricades located at the PES site).	**D2 or D1**[1]
2	Magazines for storage of explosives (includes tankers, mobile process units, silos and UN portable tanks) and shipping areas that are not protected by a barricade.	**D6**
3	Process buildings and areas used for manufacturing of explosives (including assembly, testing, packaging and destruction) that are protected by a barricade.	**D4**
4	Process buildings and areas used for manufacturing of explosives (including assembly, testing, packaging and destruction) that are not protected by a barricade.	**D7**
5	Light public traffic routes and public pathways, trails, or waterways that convey on average the equivalent of 20 vehicles to fewer than 500 vehicles per day[2] and ski runs that convey on average more than 40 skiers per day.	**D4**

[1] D1 may be used only if the PES contains explosives packaged for transportation as UN0331, UN0332, or UN3375

[2] Average means what is typical for a 24-hour period in any given month or a season. See *Annex A – Equivalent Number of Vehicles per Mode of Transport* if needing to determine the number of vehicles for situations other than roads.

	Exposed Site (ES)	Minimum Separation Distance (m)
6	Medium public traffic routes including public pathways, trails, or waterways that convey on average the equivalent of 500 vehicles to fewer than 5 000 vehicles per day[1], as well as the following: a) parks and other areas where people may be present without structures (1 000 or less persons on average per 24-hour period); and b) ski lifts.	**D5**
7	Heavy Public traffic routes including public pathways, trails, or waterways that convey on average the equivalent of 5 000 vehicles or more per day[1].	**D7**
8	Inhabited buildings with fewer than 20 people in total as well as parks and other areas where people may be present without structures (over 1 000 persons on average per 24-hour period).	**D7**
9	Inhabited buildings or built-up areas of inhabited buildings with 20 people or more, as well as: a) warehouses and shops that should not be placed at risk, because of their vital nature or high intrinsic value; b) runways and taxiways at public airports; and c) helipads.	**D7 (≥ 400 m)**
10	Vulnerable buildings and buildings of high importance (examples include: buildings of national and historic importance; large factories; multi-storey office or apartment buildings; public buildings of major value; educational facilities; hospitals; major sports stadiums; and major traffic terminals like railway stations and airports).	**D8**

[1] Average means what is typical for a 24-hour period in any given month or a season. See *Annex A – Equivalent Number of Vehicles per Mode of Transport* if needing to determine the number of vehicles for situations other than roads.

	Exposed Site (ES)	Minimum Separation Distance (m)
11	Aboveground ignitable liquid storage up to 10 000 L and any amount of fuel storage directly related to the explosives site operations, such as fueling islands.	**25 m**
12	Aboveground ignitable liquid storage over 10 000 L and pipelines for ignitable liquids.	**D5**
13	Underground ignitable liquid storage and pipelines for ignitable liquids (with a minimum cover of 1.2 m of earth or 100 mm of concrete). This does not include fuel lines supplying buildings and infrastructures.	**0.5 × D2**
14	Power lines < 15 kV and private power lines.	**From overhead cables, the greatest of** **a) Distance of 15 m** OR **b) Distance from formula** **D = S/2 – H** (where D: minimum separation distance (m), S: span between the pylons or the power line supporting structures (m), H: height of the insulators on the pylon or the power line supporting structure (m)).
15	Public power lines ≥ 15 kV.	**D5**
16	Public communications towers.	**D5**
17	Surface blasting or mining operations.	**D5**

Table 9.2 - QD Table for Hazard Category PE 1

NEQ (kg)	Minimum Separation Distances (m)							
	D1	D2	D3	D4	D5	D6	D7	D8
≤ 50	5	10	18	30	180	45	270	400
60	5	10	19	32	180	45	270	400
70	5	10	20	33	180	46	270	400
80	5	11	21	35	180	48	270	400
90	5	11	22	36	180	50	270	400
100	5	12	23	38	180	53	270	400
120	5	12	24	40	180	55	270	400
140	5	13	25	42	180	60	270	400
160	5	14	27	44	180	63	270	400
180	5	14	28	46	180	65	270	400
200	5	15	29	47	180	65	270	400
250	6	16	31	51	180	70	270	400
300	6	17	33	54	180	75	270	400
350	6	17	34	57	180	80	270	400
400	6	18	36	59	180	83	270	400
450	7	19	38	62	180	88	270	400
500	7	20	39	64	180	90	270	400
600	7	21	42	68	180	95	270	400
700	8	22	45	72	180	100	270	400
800	8	23	48	75	180	105	270	415
900	8	24	50	78	180	108	270	430
1 000	8	24	53	80	180	113	270	445
1 200	9	26	58	86	180	120	270	475
1 400	9	27	63	90	180	125	270	500
1 600	10	29	68	94	180	130	270	520
1 800	10	30	73	98	180	135	270	540
2 000	11	31	78	105	180	140	270	560
2 500	11	33	90	110	185	153	275	610
3 000	12	35	105	120	205	163	305	640
3 500	13	37	115	125	220	170	330	680
4 000	13	39	130	130	235	178	350	710
5 000	14	42	140	140	255	190	380	760
6 000	15	44	150	150	270	203	405	810
7 000	16	46	155	155	285	213	425	850
8 000	16	48	160	160	300	223	445	890
9 000	17	50	170	170	310	235	465	930

NEQ (kg)	Minimum Separation Distances (m)							
	D1	D2	D3	D4	D5	D6	D7	D8
10 000	18	52	175	175	320	240	480	960
12 000	19	55	185	185	340	255	510	1 020
14 000	20	58	195	195	360	270	540	1 080
16 000	21	61	205	205	375	280	560	1 120
18 000	21	63	210	210	390	295	590	1 180
20 000	22	66	220	220	405	305	610	1 220
25 000	24	71	235	235	435	325	650	1 300
30 000	25	75	250	250	460	345	690	1 380
35 000	27	79	265	265	485	365	730	1 460
40 000	28	83	275	275	510	380	760	1 520
50 000	30	89	295	295	550	410	820	1 640
60 000	32	94	315	315	580	435	870	1 740
70 000	33	99	330	330	610	460	920	1 840
80 000	35	105	345	345	640	480	960	1 920
90 000	36	110	360	360	670	500	1 000	2 000
100 000	38	115	375	375	690	520	1 040	2 080
120 000	40	120	395	395	730	550	1 100	2 200
140 000	42	125	420	420	770	580	1 160	2 320
160 000	44	135	435	435	810	610	1 220	2 420
180 000	46	140	455	455	840	630	1 260	2 520
200 000	47	145	470	470	870	650	1 300	2 600
250 000	51	155	510	510	940	700	1 400	2 800

QD values are based on the following:

a) $D1 = 0.8(NEQ)^{1/3}$
b) $D2 = 2.4(NEQ)^{1/3}$
c) D3 is based on smaller distances for certain process buildings
d) $D4 = 8.0(NEQ)^{1/3}$
e) $D5 = 3.6(NEQ)^{1/2}$ for NEQ < 4500 kg and $D5 = 14.8(NEQ)^{1/3}$ for NEQ ≥ 4500 kg
f) $D6 = 11.1(NEQ)^{1/3}$
g) $D7 = 5.5(NEQ)^{1/2}$ for NEQ < 4500 kg and $D7 = 22.2(NEQ)^{1/3}$ for NEQ ≥ 4500 kg
h) $D8 = 44.4(NEQ)^{1/3}$

9.1 Storage of Bulk Ammonium Nitrate Close to Explosives

When bulk ammonium nitrate storage is in the same explosive area as a PES classified as hazard category PE 1, the minimum separation distance between the bulk ammonium nitrate storage and the PES specified in Table 9.3 should be maintained so that the bulk ammonium nitrate storage does not need to be considered as a PES.

If the minimum separation distance specified in Table 9.3 cannot be maintained, 50 % of the maximum mass (in kg) for the bulk ammonium nitrate storage is to be added to the maximum NEQ allowed at the PES before using the applicable QD table.

EXAMPLE — A licensed 30 000 kg bulk ammonium nitrate silo is located near a 20 000 kg blasting explosives magazine classified as hazard category PE 1. To determine whether or not the bulk ammonium nitrate silo is located far enough from the PES, Table 9.3 states that the minimum separation distance is to be as follows:

a) 6.6 m if there is a barricade at least 0.87 m thick between the bulk ammonium nitrate silo and the 20 000 kg blasting explosive magazine;

b) 40 m if there is no barricade between the bulk ammonium nitrate silo and the 20 000 kg blasting explosive magazine or if the barricade is not at least 0.87 m thick.

If the minimum separation distance specified above is maintained, the bulk ammonium nitrate is not treated as a PES.

If the minimum separation distances are not achieved, then 50% of the maximum mass that is allocated by the explosives licence for the bulk ammonium storage is to be added to the maximum NEQ allowed at the PES. This means that the NEQ to be used for determining the minimum separation distance is 35 000 kg (the sum of 20 000 kg and 50% of 30 000 kg).

Table 9.3 - Minimum Separation Distance Between PESs Classified as Hazard Category PE 1 and Bulk Ammonium Nitrate

PES NEQ (kg)	Barricaded Facility*		Facility Without a Barricade
	Minimum Separation Distance (m)	Minimum Thickness of Barricade (m)	Minimum Separation Distance (m)
> 0 – 50	0.9	0.31	5.4
> 50 – 135	1.2	0.31	7.2
> 135 – 275	1.5	0.31	9.6
> 275 – 450	1.8	0.31	10.8
> 450 – 725	2.1	0.31	12.6
> 725 – 900	2.4	0.31	14.4
> 900 – 1 400	2.7	0.38	16.2
> 1 400 – 1 800	3.0	0.38	18
> 1 800 – 2 800	3.4	0.39	20.4
> 2 800 – 3 600	3.7	0.50	22.2
> 3 600 – 4 500	4.0	0.51	24
> 4 500 – 5 500	4.3	0.51	26
> 5 500 – 7 250	4.6	0.63	28
> 7 250 – 9 000	4.9	0.64	29
> 9 000 – 11 500	5.5	0.65	33
> 11 500 – 13 500	5.8	0.76	35
> 13 500 – 16 000	6.1	0.76	37
> 16 000 – 18 000	6.4	0.76	38
> 18 000 – 20 000	6.6	0.87	40
> 20 000 – 23 000	7.0	0.89	42
> 23 000 – 25 000	7.3	0.89	44
> 25 000 – 28 000	7.6	0.89	46
> 28 000 – 32 000	7.9	1.02	47
> 32 000 – 36 000	8.5	1.02	51
> 36 000 – 40 000	9.0	1.02	54
> 40 000 – 45 000	9.7	1.02	58
> 45 000 – 54 000	10.4	1.26	62

PES NEQ (kg)	Barricaded Facility*		Facility Without a Barricade
	Minimum Separation Distance (m)	Minimum Thickness of Barricade (m)	Minimum Separation Distance (m)
> 54 000 – 64 000	11.3	1.27	68
> 64 000 – 73 000	12.3	1.27	74
> 73 000 – 82 000	13.4	1.27	80
> 82 000 – 91 000	14.6	1.28	88
> 91 000 – 100 000	15.8	1.52	95
> 100 000 – 113 000	17.1	1.52	103
> 113 000 – 125 000	18.3	1.52	110
> 125 000 – 136 000	19.5	1.52	117
> 136 000 – 140 000	20.1	1.80	121
> 140 000 – 150 000	21.3	1.86	128
> 150 000 – 160 000	22.4	1.91	135
> 160 000 – 170 000	23.5	1.97	142
> 170 000 – 180 000	24.7	2.02	149
> 180 000 – 190 000	25.8	2.08	155
> 190 000 – 200 000	27.0	2.14	162
> 200 000 – 210 000	28.1	2.19	169
> 210 000 – 220 000	29.2	2.25	176
> 220 000 – 230 000	30.4	2.30	183
> 230 000 – 240 000	31.5	2.36	189
> 240 000 – 250 000	32.6	2.42	196

* The minimum separation distance for barricaded facilities applies only if the barricade between the bulk ammonium nitrate storage and the PES has the specified minimum thickness. If this minimum thickness is not observed, the minimum separation distance for facilities without a barricade shall be used.

If the ammonium nitrate cannot be located at least at the minimum separation distance, half the mass of the ammonium nitrate is to be considered for QD purposes as set out in section 9.1.

9.2 Provisions for Containment Barricades (CBs)

The D4, D5, D7 and D8 distances may be reduced by using CBs that are approved by ERD. If a CB is used, it must be described in the explosives licence application and the minimum separation distances applicable to D4, D5, D7 and D8 can be reduced to D4CB, D5CB, D7CB and D8CB respectively in accordance with Table 9.4.

NOTE — It is not possible to define the design parameters that apply to CBs since the ability to meet the specified criteria is based on a number of varying factors, including, but not limited to: the type of explosives, quantity of explosives, type and construction of magazines, position of explosives within magazines or structures, construction and volume of workshops or structures, and blast overpressure behaviour within structures.

Table 9.4 - Use of CBs to Reduce the D4, D5, D7 and D8 Distances

NEQ (kg)	Minimum Separation Distance (m)			
	D4CB	D5CB	D7CB	D8CB
1	9	16	21	42
2	9	16	21	42
3	12	16	21	42
4	12	21	29	58
5	12	21	29	58
6	14	25	34	68
7	14	25	34	68
8	14	25	34	68
9	14	25	34	68
10	14	26	34	68
11	16	29	39	78
12	16	29	39	78
13	16	29	39	78
14	16	29	39	78
15	16	29	39	78
16	17	32	44	88
17	17	32	44	88
18	17	32	44	88
19	17	32	44	88
20	17	32	44	88
21	20	36	48	96
22	20	36	48	96
23	20	36	48	96
24	20	36	48	96
25	20	40	48	96
26	22	40	53	106

NEQ (kg)	Minimum Separation Distance (m)			
	D4CB	D5CB	D7CB	D8CB
27	22	40	53	106
28	22	40	53	106
29	22	40	53	106
30	22	40	53	106
31	22	40	53	106
32	22	40	53	106
33	22	40	53	106
34	22	40	53	106
35	22	40	53	106
36	23	43	58	116
37	23	43	58	116
38	23	43	58	116
39	23	43	58	116
40	23	43	58	116
41	23	43	58	116
42	23	43	58	116
43	23	43	58	116
44	23	43	58	116
45	23	43	58	116
46	23	43	58	116
47	23	43	58	116
48	23	43	58	116
49	23	43	58	116
50	30	43	58	400
60	32	43	63	400
70	33	46	70	400
80	35	49	70	400
90	36	52	75	400
100	38	55	75	400
120	40	60	80	400
140	42	65	85	400
160	44	70	85	400
180	46	74	92	400
200	47	78	92	400
250	51	87	100	400
300	54	95	106	400
350	57	103	112	400
400	59	110	118	400
450	62	117	121	400
500	64	123	129	400
600	68	135	141	400
700	72	135	146	400

NEQ (kg)	Minimum Separation Distance (m)			
	D4CB	D5CB	D7CB	D8CB
800	75	135	156	415
900	78	143	165	430
1 000	80	148	174	445
1 200	86	157	191	475
1 400	90	166	206	500
1 600	94	173	220	520
1 800	96	180	233	540

9.3 Provisions for Perforating Gun Loading Facilities (GLFs)

A GLF approved by ERD (for example, Walker Holdings) may be sited in accordance with Figure 9.1 for the storage of up to 25 kg NEQ of industrial explosives in each designated area of the GLF. ERD has accepted the 1.3 and 0.7 psi distance contours around the GLF as being equivalent to the D5 and D7 distances of Table 9.2. For a GLF, these reduced distances are referred to as D5W and D7W in order to distinguish them from normal minimum separation distances. The D5W and D7W distances for a GLF are fixed and apply to the storage of up to 25 kg NEQ of industrial explosives in each designated area; these distances cannot be reduced by storing less than the 25 kg NEQ of explosives.

A single GLF is considered as one PES. A site with more than one GLF needs to maintain a minimum separation distance of at least 3 m between each GLF.

If a GLF is located in an industrial area, it is recommended that the entire D7W contour footprint be contained within the site property limit (fenced area).

A minimum separation distance of D2 (≥ 10 m) is to be maintained between all explosives PESs and radioactive storage areas.

The main doors, gun doors and any externally mounted air conditioning units must be barricaded outside of the GLF in order to prevent these entities from becoming potentially hazardous projectiles. Concrete blocks are considered an effective barricade if they meet the following requirements:

a) The blocks should be approximately 0.6x 0.6 x1.2 m and weigh approximately 1000 kg.

b) The barricade wall made up of these blocks should extend 30 degrees either side of the main door opening and 2 degrees above the main door opening. If not possible to meet the 30-degree rule because this would prevent the loading and unloading of guns, then in the 30- degree requirement would only need to be met on the hinge side of the door provided the blocks are as close as possible to the main door, allowing for the door to open and reasonable space to avoid pinch points.

c) Gun doors are not required to have barricading if security bars are in place or the gun doors are welded shut.

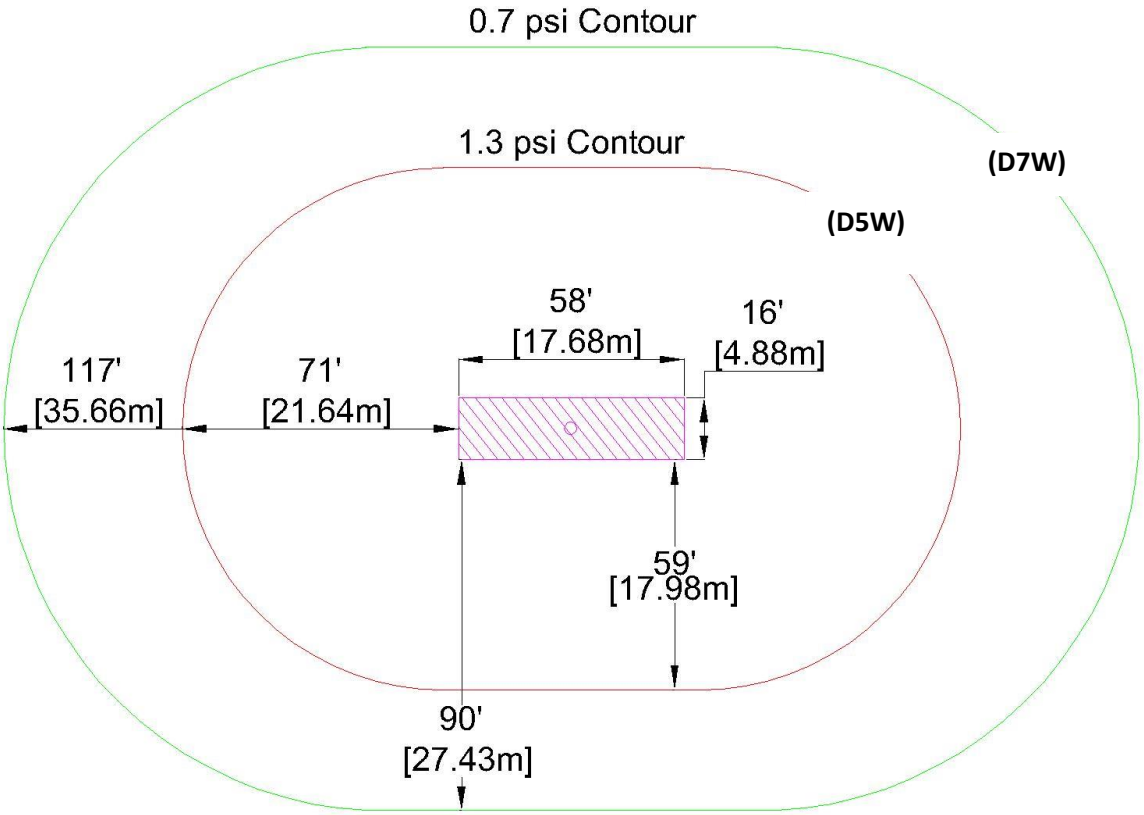

Figure 9.1 – D5W & D7W Distance Contours for the GLF

9.4 Provisions for Less Than 100 kg Gross Mass of Large-Calibre Pyrotechnic Shells and Sound Shells (Hazard Category PE 1)

9.4.1 Storage Treated as Hazard Category PE 3 for the Purposes of Determining Minimum Separation Distances

A magazine that stores less than 100 kg gross mass of large-calibre pyrotechnic shells and sound shells (classified as hazard category PE 1) may follow the separation distance principles for hazard category PE 3, as outlined in section 11 if the following conditions are met:

a) the magazine has 50% free space;

b) the magazine is not an explosives process building (assembly or picking); and

c) there is only one such magazine per licensed site.

If this provision is utilized, it must be described in the explosives licence application so that it is clear that the above conditions are satisfied.

9.4.2 Storage with Hazard Category PE 2 Fireworks

A magazine that stores less than 100 kg gross mass of large-calibre pyrotechnic shells and sound shells (classified as hazard category PE 1) may also be used to store hazard category PE 2 fireworks if the hazard category PE 2 fireworks are separated from each other by a dividing wall or airgap of 1 m.

If an air gap is used, the 50% free space applies to the entire magazine space.

If the dividing wall is used, the 50% free space applies to the area where the hazard category PE 1 fireworks are stored.

The combined quantity of hazard category PE 1 and hazard category PE 2 in the magazine would be considered as hazard category PE 2 for determining the minimum separation distances.

If this provision is utilized, it must be described in the explosives licence application so that it is clear that the above conditions are satisfied.

9.4.3 Storage with Hazard Category PE 3 Fireworks

A magazine that stores less than 100 kg gross mass of large-calibre pyrotechnic shells and sound shells (classified as hazard category PE 1) may also be used to store hazard category PE 3 fireworks if the hazard category PE 3 fireworks are separated from each other by a dividing wall or airgap of 1 m.

If an air gap is used, the 50% free space applies to the entire magazine space.

If the dividing wall is used, the 50% free space applies to the area where the hazard category PE 1 fireworks are stored.

The combined quantity of hazard category PE 1 and hazard category PE 3 in the magazine would be considered as hazard category PE 3 to determine the minimum separation distances.

If this provision is utilized, it must be described in the explosives licence application so that it is clear that the above conditions are satisfied.

9.5 Provisions for Sites Storing Water-Based and ANFO Bulk Explosives

Ignitable liquid storage, generators, compressors or other equipment using fuel is to be at least 25 m from explosives and bulk ammonium nitrate.

Mobile process units (MPUs), empty tankers, tanks, silos, and contaminated equipment, each with no more than a heel contained (250 kg of explosives), do not need separation distances to vulnerable locations that are part of the licensed operation, other than a separation distance of 25 m from the MPUs to manufacturing and storage locations for explosives and bulk ammonium nitrate (unless approved by the Minister on the licence).

ANFO-only MPUs with just residual explosive (washed auger) do not need separation distances to internal or external ES, other then 25 m to manufacturing and storage locations for explosives and bulk ammonium nitrate (unless approved by the Minister on the licence).

9.6 Provisions for MPUs Operating at Client Sites Located at Mines and Quarries

No separation distances need to be applied for MPUs manufacturing/loading boreholes at client sites that are located at mines and quarries. However, any thing or activity that could increase the likelihood of an accidental ignition must not be allowed within 15 m of an MPU and its charging hose.

Note: separation distances, as specified in this document, still apply for the operation of transferring of bulk explosives from a tanker/bin/pot into an MPU.

10. MINIMUM SEPARATION DISTANCES FOR HAZARD CATEGORY PE 2

Each ES that could be exposed to hazards from a PES (for example, debris or blast effects) must be identified to ensure that they are located at least the minimum separation distance from the PES. The minimum separation distances between a PES classified as hazard category PE 2 and each ES are determined from Table 10.1.

The minimum separation distances between the PES and each ES are listed as either a formula, fixed distance, or a variable distance expressed as either D1, or D2. The separation distance values of D1 and D2 depend on the maximum NEQ at the PES and are determined from the QD table (see Table 10.2).

If the maximum NEQ allowed at the PES falls between two listed NEQs in the QD table, then the greater of the two values is used to determine the minimum separation distance.

The minimum separation distance values can also be calculated directly based on the NEQ using the scaled factor equations at the end of Table 10.2, provided that any calculated values are no lower than the equivalent values present in the table. This method can also be used to calculate the minimum separation distance values for NEQs not listed in the table, provided that they are no lower than the distances associated with the next lowest NEQ listed in the table.

Articles of PE 2 are generally Type D military and law enforcement explosives. For purposes of determining separation distances, a distinction depending on the size and range of fragments is made, according to principles in INTERNATIONAL AMMUNITION TECHNICAL GUIDELINES (IATG 0150):

a) explosives articles that produce fragments with considerable range are considered as PE 2 hazard category, group 1 (equivalent to SsD 1.2.1 in IATG). These items have individual NEQ greater than 0.73 kg.

b) explosives articles that produce fragments with moderate range are considered as PE 2 hazard category, group 2 (equivalent to SsD 1.2.2 in IATG). These items have individual NEQ less than or equal to 0.73 kg.

Table 10.1 Minimum Separation Distances for PESs Classified as Hazard Category PE 2

Exposed Site (ES)		Minimum Separation Distance (m)	
		PES with group 1 explosives	PES with group 2 explosives
1	Magazines for storage of explosives and transient shipping areas for explosives.	**90 m**	
2	Process buildings and areas used for manufacturing of explosives (including assembly, testing, packaging and destruction).	**135 m**	**90 m**
3	Light public traffic routes and public pathways, trails, or waterways that convey on average the equivalent of 20 vehicles to fewer than 500 vehicles per day[1] and ski runs that convey on average more than 40 skiers per day.	**135 m**	**90 m**
4	Medium public traffic routes including public pathways, trails, or waterways that convey on average the equivalent of 500 vehicles to fewer than 5 000 vehicles per day[1], as well as the following: a) parks and other areas where people may be present without structures (1 000 or less persons on average per 24-hour period); and b) ski lifts.	**135 m**	**90 m**
5	Heavy public traffic routes and public pathways, trails, or waterways that convey on average the equivalent of 5 000 vehicles or more per day[1].	**D2**	**D1**
6	Inhabited buildings with fewer than 20 people in total as well as parks and other areas where people may be present without structures (over 1 000 persons on average per 24-hour period).	**270 m**	**180 m**

[1] Average means what is typical for a 24-hour period in any given month or a season. See *Annex A – Equivalent Number of Vehicles per Mode of Transport* if needing to determine the number of vehicles for situations other than roads.

Exposed Site (ES)		Minimum Separation Distance (m)	
		PES with group 1 explosives	PES with group 2 explosives
7	Inhabited buildings or built-up areas of inhabited buildings with 20 people or more, as well as: a) warehouses and shops that shall not be placed at risk, because of their vital nature or high intrinsic value; b) runways and taxiways at public airports; and c) helipads.	**D2**	**D1**
8	Vulnerable buildings and buildings of high importance (examples include: buildings of national and historic importance; large factories; multi-storey office or apartment buildings; public buildings of major value; educational facilities; hospitals; major sports stadiums; and major traffic terminals like railway stations and airports).	**D2**	**D1**
9	Aboveground ignitable liquid storage up to 10 000 L and any amount of fuel storage directly related to the explosives site operations, such as fueling islands.	**25 m**	
10	Aboveground ignitable liquid storage over 10 000 L and pipelines for ignitable liquids.	**D2**	**D1**
11	Underground ignitable liquid storage and pipelines for ignitable liquids (with a minimum cover of 1.2 m of earth or 100 mm of concrete). This does not include fuel lines supplying buildings and infrastructures.	**25 m**	

Exposed Site (ES)		Minimum Separation Distance (m)	
		PES with group 1 explosives	**PES with group 2 explosives**
12	Power lines < 15 kV and private power lines.	**From overhead cables, the greatest of** **a) Distance of 15 m** OR **b) Distance from formula** **D = S/2 – H** (where D: minimum separation distance (m), S: span between the pylons or the power line supporting structures (m), H: height of the insulators on the pylon or the power line supporting structure (m)).	
13	Public power lines ≥ 15 kV.	**135 m**	**90 m**
14	Public communications towers.	**135 m**	**90 m**
15	Surface blasting or mining operations.	**135 m**	**90 m**

Table 10.2 - QD Table for Hazard Category PE 2

NEQ (kg)	Minimum Separation Distances (m)	
	D1	D2
≤ 50	180	270
60	180	270
70	180	270
80	180	270
90	180	270
100	180	270
120	180	270
140	180	270
160	180	270
180	180	270
200	180	270
250	180	270
300	180	270
350	180	270
400	180	270
450	180	270
500	180	270
600	180	270
700	180	270
800	180	270
900	185	270
1 000	185	270
1 200	190	270
1 400	195	270
1 600	200	270
1 800	205	270
2 000	210	270
2 500	220	280
3 000	225	290
3 500	230	300
4 000	235	310
5 000	245	320
6 000	255	330
7 000	260	340
8 000	270	345

NEQ (kg)	Minimum Separation Distances (m)	
	D1	D2
9 000	275	355
10 000	280	360
12 000	290	370
14 000	300	385
16 000	305	390
18 000	310	400
20 000	320	410
25 000	330	425
30 000	345	440
35 000	350	450
40 000	360	460
50 000	375	480
60 000	390	500
70 000	400	520
80 000	410	530
90 000	410	540
100 000	410	560
120 000	410	560
140 000	410	560
160 000	410	560
180 000	410	560
200 000	410	560
250 000	410	560

QD values are based on the following:

a) $D1 = 53(NEQ)^{0.18}$

b) $D2 = 68\ (NEQ)^{0.18}$

11. MINIMUM SEPARATION DISTANCES FOR HAZARD CATEGORY PE 3

Each ES that could be exposed to hazards from a PES (for example, debris or blast effects) must be identified to ensure that they are located at least the minimum separation distance from the PES. The minimum separation distances between a PES classified as hazard category PE 3 and each ES are determined from Table 11.1.

The minimum separation distances between the PES and each ES are listed as either a formula, fixed distance or variable distance expressed as D1-D4. The separation distance values of D1-D4 depend on the maximum NEQ at the PES and are determined from the QD table (see Table 11.2).

If the maximum NEQ allowed at the PES falls between two listed NEQs in the QD table, then the greater of the two values is used to determine the minimum separation distance.

The minimum separation distance values can also be calculated directly based on the NEQ using the scaled factor equations at the end of Table 11.2, provided that any calculated values are no lower than the equivalent values present in the table. This method can also be used to calculate the minimum separation distance values for NEQs not listed in the table, provided that they are no lower than the distances associated with the next lowest NEQ listed in the table.

Table 11.1 - Minimum Separation Distances for PESs Classified as Hazard Category PE 3

	Exposed Site (ES)	Minimum Separation Distances
1	Magazines for storage of explosives and shipping areas; picking areas of no more than 2 000 kg NEQ.	**D1**
2	Process buildings and areas used for manufacturing of explosives (including assembly, testing, packaging, and destruction); picking areas over 2 000 kg NEQ.	**D2**
3	Light public traffic routes including public pathways, trails, or waterways that convey on average the equivalent of 20 vehicles to fewer than 500 vehicles per day[1] and ski runs that convey on average more than 40 skiers per day.	**D2**
4	Medium public traffic routes including public pathways, trails, or waterways that convey on average the equivalent of 500 vehicles to fewer than 5 000 vehicles per day[1], as well as the following: a) parks and other areas where people may be present without structures (1 000 or less persons on average per 24-hour period); and b) ski lifts.	**D3**
5	Heavy public traffic routes including public pathways, trails, or waterways that convey on average the equivalent of 5 000 vehicles or more per day[1].	**D4**
6	Inhabited buildings, parks and other areas where people may be present without structures (over 1 000 persons on average per 24-hour period).	**D4**
7	Inhabited buildings or built-up areas of inhabited buildings with 20 people or more, as well as: a) warehouses and shops that shall not be placed at risk, because of their vital nature or high intrinsic value; b) runways and taxiways at public airports; and c) helipads.	**D4**

[1] Average means what is typical for a 24-hour period in any given month or a season. See *Annex A – Equivalent Number of Vehicles per Mode of Transport* if needing to determine the number of vehicles for situations other than roads.

	Exposed Site (ES)	Minimum Separation Distances
8	Vulnerable buildings and buildings of high importance (examples include: buildings of national and historic importance; large factories; multi-storey office or apartment buildings; public buildings of major value; educational facilities; hospitals; major sports stadiums; and major traffic terminals like railway stations and airports).	**D4**
9	Aboveground ignitable liquid storage up to 10 000 L and any amount of fuel storage directly related to the explosives site operations, such as fueling islands.	**25 m**
10	Aboveground ignitable liquid storage over 10 000 L and pipelines for ignitable liquids.	**D3**
11	Underground ignitable liquid storage and pipelines for ignitable liquids (with a minimum cover of 1.2 m of earth or 100 mm of concrete). This does not include fuel lines supplying buildings and infrastructures.	**25 m**
12	Power lines < 15 kV and private power lines.	**From overhead cables, the greatest of** **a) Distance of 15 m** OR **b) Distance from formula** **D = S/2 – H** (where D: minimum separation distance (m), S: span between the pylons or the power line supporting structures (m), H: height of the insulators on the pylon or the power line supporting structure (m)).
13	Public power lines ≥ 15 kV.	**60 m**
14	Public communications towers.	**60 m**
15	Surface blasting or mining operations.	**D3**

Table 11.2 - QD Table for Hazard Category PE 3

NEQ (kg)	Minimum Separation Distance (m)			
	D1	D2	D3	D4
≤ 75	25	25	28	30
100	25	25	30	35
125	25	30	35	40
250	25	30	40	40
300	25	35	40	45
350	25	40	45	50
400	25	45	45	55
500	25	45	50	60
600	25	50	50	60
700	25	55	55	60
800	25	55	60	60
900	25	55	60	62
1 000	25	60	60	64
1 200	25	60	60	69
1 400	25	60	60	72
1 600	25	60	60	75
1 800	25	60	60	78
2 000	25	60	60	81
2 500	25	60	60	87
3 000	25	60	60	93
3 500	25	60	60	98
4 000	25	60	60	105
5 000	25	60	60	110
6 000	25	60	60	120
7 000	25	60	60	125
8 000	25	60	60	130
9 000	25	60	60	135
10 000	25	60	60	140
12 000	25	60	60	150
14 000	27	60	60	155
16 000	28	60	60	165
18 000	30	60	60	170
20 000	32	60	60	175

NEQ (kg)	Minimum Separation Distance (m)			
	D1	D2	D3	D4
25 000	35	60	60	190
30 000	39	60	60	200
35 000	42	60	60	210
40 000	44	60	60	220
50 000	50	60	60	240
60 000	54	60	60	255
70 000	59	60	60	265
80 000	60	60	60	280
90 000	60	60	60	290
100 000	60	60	60	300
120 000	60	60	60	320
140 000	60	60	60	335
160 000	60	60	60	350
180 000	60	60	60	365
200 000	60	60	60	375
250 000	60	60	60	405

QD values are based on the following:

a) $D1 = 0.22(NEQ)^{1/3}$

b) $D2 = 3.2\ (NEQ)^{1/3}$

c) $D3 = 4.3(NEQ)^{1/3}$

d) $D4 = 6.4(NEQ)^{1/3}$

12. MINIMUM SEPARATION DISTANCES FOR HAZARD CATEGORY PE 4

Each ES that could be exposed to hazards from a PES (for example, debris or blast effects) must be identified to ensure that they are located at least the minimum separation distance from the PES. The minimum separation distances between a PES classified as hazard category PE 4 and each ES are determined from Table 12.1.

The minimum separation distances between the PES and each ES are listed as either a formula, fixed distance or variable distance expressed as D1-D4. The separation distance values of D1-D4 depend on the maximum NEQ at the PES and are determined from the QD table (see Table 12.2).

If the maximum NEQ allowed at the PES falls between two listed NEQs in the QD table, then the greater of the two values is used to determine the minimum separation distance.

Table 12.1 - Minimum Separation Distances for PESs Classified as Hazard Category PE 4

	Exposed Site (ES)	Minimum Separation Distances (m)	
		PES Type F.1 & F.5	PES (all other types)
1	Magazines for storage of explosives and shipping areas.	**D1**	
2	Process buildings and areas used for manufacturing of explosives (including assembly, testing, packaging, and destruction).	**D2**	
3	Light public traffic routes including public pathways, trails, or waterways that convey on average the equivalent of 20 vehicles to fewer than 500 vehicles per day[1] and ski runs that convey on average more than 40 skiers per day.	**D3**	
4	Medium public traffic routes including public pathways, trails, or waterways that convey on average the equivalent of 500 vehicles to fewer than 5 000 vehicles per day[1]; as well as the following: a) parks and other areas where people may be present without structures (1 000 or less persons on average per 24-hour period); and b) ski lifts.	**D3**	
5	Heavy public traffic routes including public pathways, trails, or waterways that convey on average the equivalent of 5 000 vehicles or more per day[1].	**D3**	
6	Inhabited buildings, parks and other areas where people may be present without structures (over 1 000 persons on average per 24-hour period).	**Up to 12,500 kg - D4 Above 12,500 kg - 50 m**	**D4**
7	Inhabited buildings or built-up areas of inhabited buildings with 20 people or more, as well as: a) warehouses and shops that shall not be placed at risk, because of their vital nature or high intrinsic value; b) runways and taxiways at public airports; and c) helipads.	**Up to 12,500 kg - D4 Above 12,500 kg - 50 m**	**D4**

[1] Average means what is typical for a 24-hour period in any given month or a season. See *Annex A – Equivalent Number of Vehicles per Mode of Transport* if needing to determine the number of vehicles for situations other than roads.

	Exposed Site (ES)	Minimum Separation Distances (m)	
		PES Type F.1 & F.5	PES (all other types)
8	Vulnerable buildings and buildings of high importance (examples include: buildings of national and historic importance; large factories; multi-storey office or apartment buildings; public buildings of major value; educational facilities; hospitals; major sports stadiums; and major traffic terminals like railway stations and airports).	**Up to 12,500 kg - D4 Above 12,500 kg - 50 m**	**D4**
9	Aboveground ignitable liquid storage up to 10 000 L and any amount of fuel storage directly related to the explosives site operations, such as fueling islands.	**25 m**	
10	Aboveground ignitable liquid storage over 10 000 L and pipelines for ignitable liquids.	**Up to 12,500 kg - D4 Above 12,500 kg - 50 m**	**D4**
11	Underground ignitable liquid storage and pipelines for ignitable liquids (with a minimum cover of 1.2 m of earth or 100 mm of concrete). This does not include fuel lines supplying buildings and infrastructures.	**25 m**	
12	Power lines < 15 kV and private power lines.	**From overhead cables, the greatest of a) Distance of 15 m** OR **b) Distance from formula D = S/2 – H** (where D: minimum separation distance (m), S: span between the pylons or the power line supporting structures (m), H: height of the insulators on the pylon or the power line supporting structure (m)).	
13	Public power lines ≥ 15 kV.	**60 m**	
14	Communications towers (excluding private towers).	**60 m**	
15	Surface blasting or mining operations (see definitions).	**60 m**	

Table 12.2 - QD Table for Hazard Category PE 4

NEQ (kg)	Minimum Separation Distances (m)			
	D1	D2	D3	D4
≤ 50	9	12	9	16
100	9	12	10	16
200	9	12	11	19
300	9	12	13	22
400	9	12	14	25
500	9	12	15	29
750	9	12	17	31
1 000	9	12	18	33
1 250	10	15	18	36
2 500	13	21	21	37
5 000	17	25	23	42
10 000	21	27	25	46
12 500	23	27	26	50
15 000	24	27	27	52
20 000	25	27	28	54
25 000	26	27	29	55
30 000	27	27	30	59
40 000	27	27	30	60
50 000	27	27	30	60
75 000	27	27	32	65
100 000	27	27	33	70
125 000	27	27	38	77
150 000	27	27	39	80
175 000	27	27	40	82
200 000	27	27	41	84
250 000	27	27	43	88

ANNEX A - EQUIVALENT NUMBER OF VEHICLES PER MODE OF TRANSPORT

For the purposes of this document, modes of transportation are assessed as follows:

Mode of transport	Equivalent number of vehicles
Mode of transportation that typically carries only one person (including a moving person, such as a hiker)	0.5 vehicle
1 car (2 persons)	1 vehicle
1 bus (20 persons)	10 vehicles
Passenger train: 45 persons per train car	22.5 vehicles per train car
1 freight train (4 persons)	2 vehicles
Ferries, cruise ships and other watercrafts, and aircrafts	To be determined by ERD

ANNEX B - DETERMINATION OF HAZARD CATEGORIES IN SPECIAL SITUATIONS

GENERAL

The following principles apply, unless appropriate tests (which might include the UN Manual of Tests and Criteria) are performed and used to support a different hazard category classification. The tests should be done on the explosives in the form that they will be encountered.

DETERMINATION OF PE HAZARD CATEGORIES

Type P Propellants

Hazard category PE 3 bulk propellant (does not include retail packaging) may behave as hazard category PE 1 if the propellants are:

a) Confined in metal, such as closed blending barrels (unless provided with blow-out panels);

b) Above their critical height, typically more than the equivalent of two large, or three small fibre drums high (unless provided with venting and demonstrated by testing); or

In barrels stored in stacks of more than 2000 kg, with the separation between any side of the stack to another stack of propellant being at least 40 cm.

Propellants in factories in an “in process” storage scenario (e.g. in a hopper, transient drying storage, etc.) will be considered on a case-by-case basis by ERD to determine the applicable hazard category.

Type I Detonators

Manufacture

In-process detonators can be considered as hazard category PE 4 if they are in non-propagating blocks or cassettes, and non-propagation has been demonstrated by testing. Otherwise, they are to be considered as hazard category PE 1.

Storage

Detonators classified as hazard category PE 4 can only keep this classification if kept in their original transport packaging and configuration, otherwise they are to be considered as hazard category PE 1.

Type F Fireworks Containing Pyrotechnic Compositions & Some Type S Special Purpose Explosives Containing Pyrotechnic Compositions

Manufacture

In-process pyrotechnic compositions are typically considered as hazard category PE 3 except for flash powder, black powder or whistle composition, which are considered as hazard category PE 1.

ANNEX C - BARRICADES

GENERAL

To be considered effective, barricades would meet the principles of this annex.

Design criteria can be summarized as follows:

a) The barricade height extends at least 0.3 m above the line of sight between the top of the stacks (the PES or ES type are in this respect not relevant).

b) The barricade is at least 2.4 m wide at the line of sight and at least 1.0 m wide on the crest of the barricade.

c) The barricade extends at least 1 m in the length direction on both sides of the stacks,

These criteria are illustrated in Figures C.1, C.2 & C.3

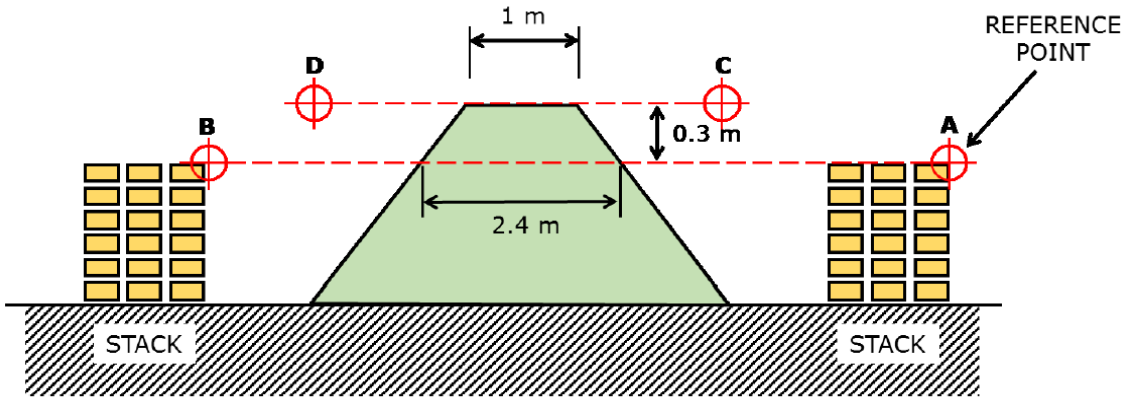

Figure C.1 - Barricade height on level terrain (reference NATO Standard AASTP-1.1.)

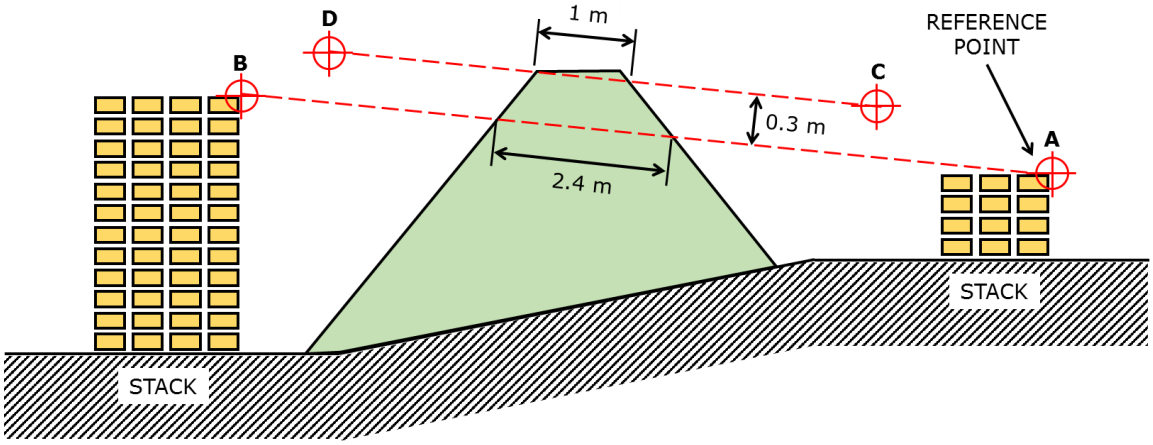

Figure C.2 - Barricade height on sloping terrain (reference NATO Standard AASTP-1.1.)

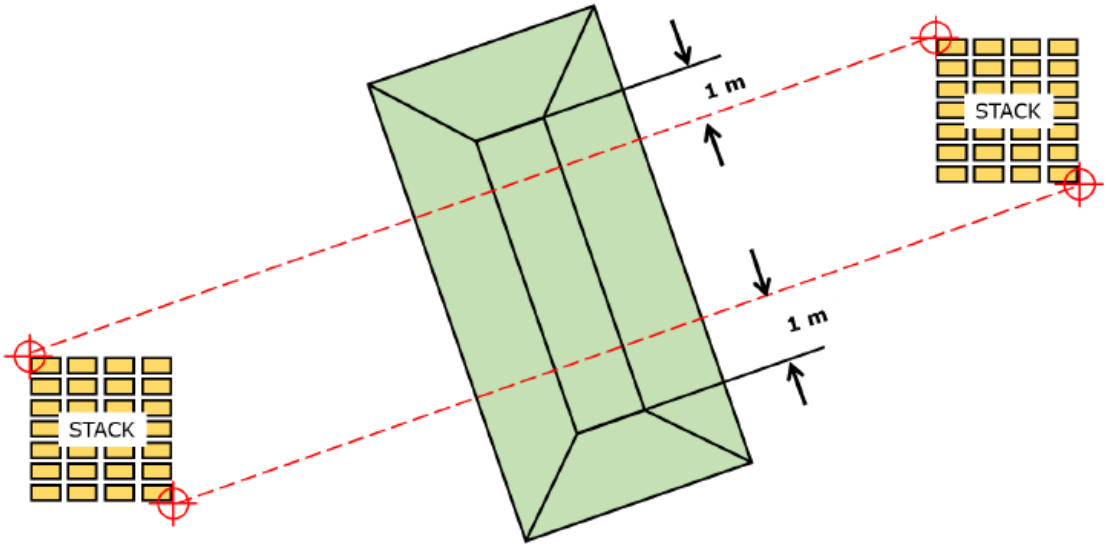

Figure C.3 - Barricade length (reference NATO Standard AASTP-1.1.)

MATERIAL FOR BARRICADES

The most common type of barricade is one made of earth. If earth is not readily available, a rock barricade may be used as long as no rocks greater than 0.3m in circumference (approximate size of a person's fist) are used. If larger rocks are unavoidable, consult with ERD.

NATURAL LAND FORMATION AND OTHER BARRICADE DESIGNS

Upon the approval of ERD, a natural land formation may be used as a barricade. Thick vegetation (e.g. dense trees) is normally not considered an effective barricade but may be approved by ERD if an equivalent level of protection is demonstrated. Other barricade designs may be approved by ERD on a case-by-case basis.

ANNEX D - BACKGROUND INFORMATION ON BLAST DAMAGE ASSESSMENTS

BLAST OVERPRESSURE

To understand the expected effects from a detonation of a PES classified as hazard category PE 1, it is important that the separation distance between the PES and ES, as well as the maximum net explosive quantity (NEQ) allowed at the PES, be known. As barricades have no significant effect on blast overpressures, they are ignored.

The expected effects from a detonation of a PES classified as hazard category PE 1 are classified by scaled factors as follows:

$$\mathrm{SF} = \frac{d}{\sqrt[3]{NEQ}}$$

where SF : scaled factor;

d : separation distance between the PES and the ES, in metres;

NEQ : maximum net explosive quantity allowed at the PES, in kilograms.

It can be assumed that the blast overpressures from stocks in the open or aboveground magazines are as follows:

Scaled Factor	**Peak Incident (Side-On) Overpressure Expected,** in kPa
44.4	1.5
22.2	5.0
14.8	9.0
8.0	21.0
3.6	70.0
2.4	180.0
The expected outcomes associated with each scaled factor are described below. For scaled factors falling between those that are provided, the expected effects are to be estimated.	

SCALED FACTOR 55.5

The expected outcomes are as follows:

a) The overpressures at this distance will cause little or no damage to an unstrengthened structure.

b) Vulnerable construction buildings or buildings with large areas of glass, especially if they face the PES, may suffer some glass breakage or cladding displacement.

c) Personnel are afforded a very high level of protection from death or injury. The primary hazard is from broken glass or cladding falling from a considerable height and striking people at high speed.

SCALED FACTOR 44.4 (D8)

The expected outcomes are as follows:

a) Unstrengthened structures are likely to suffer only superficial damage.

b) If large panes of exposed glass are facing the PES, breakage may be 50 % or greater.

c) Personnel are afforded a high level of protection from death or serious injury. Injuries that do occur will be caused primarily by broken glass.

This is the scaled factor used for calculating the separation distances between a PES and vulnerable buildings (twice the inhabited building distances).

SCALED FACTOR 22.2 (D7)

The expected outcomes are as follows:

a) Unstrengthened buildings will suffer minor damage, especially to parts such as windows, door frames and chimneys. in general, damage is unlikely to exceed approximately 5 % of the replacement cost, but some buildings may suffer serious damage.

b) Personnel are afforded a high level of protection against the direct effects of an explosion but are likely to suffer injuries from broken glass and flying or falling debris.

c) Metal buildings will have corrugated aluminum or steel panelling moderately buckled with joints separated.

d) Roof rafters in wood frame structures will crack.

e) Large and small glass windows will shatter, and frames will occasionally fail.

This is the scaled factor used for calculating the separation distances between a PES and inhabited buildings and public traffic routes for heavy traffic.

SCALED FACTOR 17.6 (BETWEEN D5 AND D7)

The expected outcomes are as follows:

a) Unpressurized liquid storage tanks will be slightly damaged.

b) Aircraft will suffer minor damage to control surfaces and other areas.

SCALED FACTOR 14.8 (D5)

The expected outcomes are as follows:

a) Unstrengthened buildings will suffer average damage that will cost approximately 10 % of the total building replacement cost to repair.

b) Personnel under cover are afforded a high level of protection from death or serious injury. injuries that do occur will be mainly caused by broken glass and building debris.

c) Personnel in the open are not likely to be seriously injured by the blast.

d) Corrugated asbestos siding will shatter.

e) Unreinforced concrete-block or brick walls will be severely damaged or shattered.

f) Metal buildings will suffer severe buckling, and some panels will be torn off.

g) Large and small glass windows will suffer severe frame failure; however, frame failure will not occur if the glass is thin and breaks easily.

h) Aircraft that are landing or taking off could lose control and crash.

i) Unsheltered aircraft will likely sustain minor damage due to blast, but should remain airworthy.

This is the scaled factor used for calculating the separation distances between a PES and public traffic routes for medium traffic.

SCALED FACTOR 9.6 (BETWEEN D4 AND D5)

The expected outcomes are as follows:

a) Unstrengthened buildings can be expected to suffer damage to main structural members that will require repair. repairs may cost more than 20 % of the replacement cost of the building. strengthening of buildings to prevent damage and secondary hazards is feasible and not excessively expensive.

b) Personnel could suffer temporary hearing loss; however, permanent ear damage is not likely. other injuries from the direct effects of overpressure are unlikely.

c) There will be some personnel injuries caused by translation of the individual(s) involved.

d) Automobiles may suffer some damage from the blast to metal portions of the roof and body. windows facing the blast may be broken; however, the glass should not cause serious injuries to the occupants.

e) Aircraft will suffer some damage to appendages and sheet metal skin; however, they should be operational with only minor repairs.

f) Cargo ships will suffer minor damage from the blast to deck houses and exposed electronic gear.

g) Wood frame structures will experience cracked studs and sheathing.

h) Injury from secondary blast effects, such as building debris and impact with hard surfaces, can be expected.

SCALED FACTOR 8.0 (D4)

The expected outcomes are as follows:

a) Unstrengthened buildings can be expected to suffer serious damage that is likely to cost more than 30 % of the total replacement cost to repair.

b) There is some possibility of delayed communication of the explosion as a result of fires or equipment failure at the ES. direct propagation of the explosion is not likely.

c) Cargo ships will suffer damage to decks and superstructures. in particular, doors and bulkheads on the weather-deck are likely to be buckled by overpressure.

d) Aircraft are expected to sustain considerable structural damage.

e) Metal buildings will have the siding and interior completely destroyed. frame failure may occur if the siding has been reinforced or strengthened.

This is the scaled factor used for calculating the separation distances between a PES and public traffic routes for light traffic as well as process buildings protected by a barricade.

SCALED FACTOR 7.2

The expected outcomes are as follows:

a) A high level of protection is provided against the direct propagation of an explosion.

b) There is some possibility of delayed communication of the explosion as a result of fires or equipment failure at the ES.

c) Damage to unstrengthened buildings will be serious. repairs are likely to cost 50 % or more of the total replacement cost.

d) Cargo ships will suffer some damage to doors and bulkheads, and the weather-deck will be buckled by overpressure.

e) Aircraft can be expected to suffer considerable structural damage from the blast. in some cases, the aircraft may have to be salvaged.

f) Unpressurized liquid storage tanks will be severely damaged.

g) Reinforced concrete walls will exhibit moderate cracking.

h) Reinforced concrete blocks or brick walls built between rigid supports will shatter or experience severe damage.

i) There is a 10 % chance of eardrum damage to personnel.

j) Transport vehicles will incur extensive, but not severe, body and glass damage, consisting mainly of dented body panels and cracks in shatter resistant window glass.

This scaled factor is used by the US Department of Defense for the process-building distance called the *unbarricaded intraline distance*.

SCALED FACTOR 4.4

The expected outcomes are as follows:

a) Heavy machinery (e.g. generators and compressors) will be completely displaced with moderate damage.

b) Unpressurized liquid storage tanks will collapse.

c) Reinforced concrete walls will suffer severe spalling and wall displacement.

d) Unstrengthened concrete block or brick walls will collapse.

e) Wood frame structures will collapse.

f) Personnel will incur serious injury to eardrums and lungs or possible death due to the blast.

SCALED FACTOR 3.6

The expected outcomes are as follows:

a) A high level of protection is provided against the direct propagation of an explosion when barricades are placed between the two PESs.

b) Explosions may subsequently occur in adjacent sites from fire spread by lobbed debris from blast site.

c) Unstrengthened buildings will suffer severe structural damage approaching total demolition.

d) Severe injuries or death to occupants of the ES are to be expected from direct blast, building collapse or translation.

e) Aircraft will be damaged by the blast to the extent that they will be beyond economical repair.

f) Improperly designed barricades or protective structures may increase the hazard from flying debris and may collapse in such a manner as to increase the risk to personnel and equipment.

g) Heavy machinery (e.g. generators and compressors) will be destroyed.

h) Vehicles and trailers will be destroyed.

SCALED FACTOR 2.4 (D2)

The expected outcomes are as follows:

a) Steel towers will be blown down.

b) Reinforced concrete walls will be completely destroyed.

c) Personnel will be killed by the direct action of the blast.

d) Vehicles will be overturned and crushed by the blast.

e) Aircraft will be destroyed.

FRAGMENTS/DEBRIS

An important consideration in analyzing the hazard associated with an accidental explosion is the effect of the projections generated by the explosion. These projections are known as primary or secondary projections depending on their origin.

Fragments are primary projections formed as a result of the shattering of the explosive container. The container may be the casing of conventional ammunition, the kettles, hoppers or other metal containers used in the manufacture of explosives, the metal housing of rocket engines or similar items. These projections are usually small and travel initially at velocities of thousands of metres per second.

Debris are secondary projections formed as a result of high blast pressures on structural components and items close to the explosion. These projections are somewhat larger in size than primary projections and travel initially at velocities of hundreds of metres per second.

The minimum separation distances for PESs classified as hazard category PE 1 are a reflection of minimum separation distances for protection from fragments.

THERMAL RADIATION

Detonation of an explosive typically results in the production of a visible flash of flame. Normally, the thermal radiation from this short-lived flame is of negligible hazard in comparison with the blast and missile effects and may be ignored.

Propellants and pyrotechnic substances and articles (PES classified as PE 3) differ from detonating explosives (PES classified as PE 1) in that, unless heavily confined, their reaction does not result in the generation of high-pressure gases. Their energy is released in the form of an intense flame and may cause a hazard by thermal radiation and additionally by direct impingement of the flame.