ALLIED AMMUNITION STORAGE AND

TRANSPORT PUBLICATION 1

(AASTP-1)

MANUAL OF NATO SAFETY PRINCIPLES

FOR THE STORAGE OF MILITARY

AMMUNITION AND EXPLOSIVES

MAY 2006

Conditions of Release

The Nato Manual on Safety Principles for the Storage of Ammunition and explosives (AASTP-1) is a NATO Document involving NATO property rights.

The understanding and conditions agreed for the release of the Manual are that it is released for technical defence purposes and for the use by the defence services only of the country concerned.

This understanding requires that the release of the whole, or any part, of the Manual must not be undertaken without reference to, and the written approval of, NATO.

NORTH ATLANTIC TREATY ORGANIZATION

MILITARY AGENCY FOR STANDARDIZATION (MAS)

NATO LETTER OF PROMULGATION

August 1997

1. AASTP-1 - MANUAL OF NATO SAFETY PRINCIPLES FOR STORAGE OF MILITARY AMMUNITION AND EXPLOSIVES is a NATO UNCLASSIFIED publication. (The agreement of interested nations to use this publication is recorded in STANAG 4440 (Edition 1)).

2. AASTP-1 is effective upon receipt.

3. AASTP-1 contains only factual information. Changes to these are not subject to the ratification procedures; they will be promulgated on receipt from the nations concerned.

A. GRØNHEIM
Major General, NOAF
Chairman, MAS

RECORD OF CHANGES

CHANGE	DATE OF CHANGE	SIGNATURE	REMARKS

LIST OF ABBREVIATIONS

In this Manual the following abbreviations have been used, but not necessarily in all places where the word combinations appear.

Depleted Uranium	=	DU
Electro-Explosive Device	=	EED
Exposed site	=	ES
Exterior Quantity-Distance	=	EQD
Hazard Division	=	HD
Inhabited Building Distances	=	IBD
Interior Quantity-Distance	=	IQD
Inter-Magazine Distance	=	IMD
Net Explosive Quantity	=	NEQ
Potential Explosion Site	=	PES
Public Traffic Route Distance	=	PTRD
Quantity-Distance	=	Q-D

PREFACE

1. *General*

This Manual is in four parts. PART I sets out general principles, PART II gives detailed information on above-ground storage, Part III deals with certain special types of storage, such as underground storage, and Part IV deals with special circumstances where operational effectiveness has to be taken into account when deciding on the quantity-distances to be used, such as on military airfields and during the transfer of ammunition and explosives in naval ports.

2. *Basis*

The Manual is based on and supersedes NATO DOCUMENT AC/258-D/258 (1976) and its numerous corrigenda, but recognises the simultaneous preparation of AASTP-3, which deals with classification of ammunition and explosives according to hazard.

3. *Updating*

The "Group of Experts on the Safety Aspects of Transportation and Storage of Military Ammunition and Explosives (AC/258)", as custodian of this Manual, intends to maintain its value by publishing corrigenda.

4. *Conditions of Release*

The Nato Manual on Safety Principles for the Storage of Ammunition and explosives (AASTP-1) is a NATO Document involving NATO property rights.

The understanding and conditions agreed for the release of the Manual are that it is released for technical defence purposes and for the use by the defence services only of the country concerned.

This understanding requires that the release of the whole, or any part, of the Manual must not be undertaken without reference to, and the written approval of, NATO.

5. *Inquiries*

Any questions or requirements for further information should be addressed to the Secretary of the AC/258 Group at NATO Headquarters, B-1110 Brussels, Belgium.

MANUAL OF NATO SAFETY PRINCIPLES

FOR THE STORAGE OF MILITARY

AMMUNITION AND EXPLOSIVES

PART I

MAY 2006

TABLE OF CONTENTS

PART I

CHAPTER 1 - INTRODUCTION

Section I - Purpose and Scope of the Manual

1.1.1.1.

a) The primary object of this Manual is to establish safety principles to be used as a guide between host countries and NATO forces in the development of mutually agreeable regulations for the layout of ammunition storage depots and for the storage of conventional ammunition and explosives therein. These principles are intended also to form the basis of national regulations as far as possible.

b) The Manual is intended to serve as a guide for authorities who are engaged in the planning and construction of ammunition storage depots of a capacity of not less than 500 kg of Net Explosives Quantity (NEQ) per storage site and for those who are responsible for the safe storage of ammunition. It also gives principles and criteria for other related matters such as design environment criteria, etc. The Manual does not authorize the use of the principles and criteria without consent of the host countries.

c) NEQ per storage site of less than 500 kg are given special treatment (see subparagraph 1.3.1.1.b)).

d) It is impracticable to prescribe distances which would be safe distances in the true sense, i.e. which would guarantee absolute immunity from propagation, damage or injury. An attempt has therefore been made in the recommendations in this Manual to allow for the probability of an accident and how serious the resulting damage or injury would be. The separation distances (quantity distances) between a potential explosion site and an exposed site recommended in this Manual therefore represent a compromise deemed tolerable by AC/258 between absolute safety and practical considerations including costs and operational requirements.

The risk deemed tolerable depends upon many factors, some of which are objective, such as the quantity of explosives involved, the nature of the explosives, the packaging of dangerous items, their distribution within premises or in the open air, distance, the nature of the terrain and its contours, etc. Other factors are subjective to what extent are damage and injuries resulting from an explosive accident tolerable? For example, how many deaths, how many serious injuries, how many buildings destroyed or damaged and other costs are tolerable? It is therefore clearly essential to have a good knowledge of the nature of the main hazard, namely blast or projections or fire, as well as the foreseeable development of the accident: instantaneous, progressive, sporadic etc.

Consideration of these factors will yield the concept of hazard divisions, the net explosives quantity and the mutual influence of potential explosion site and exposed site. Quantity-distances are proposed in each case in the form of tables. These quantity distances imply a degree of harm or damage which is difficult to quantify but which most NATO nations regard as tolerable.

There may be occasions when cogent economic or operational considerations, usually of a temporary nature, warrant the acceptance of a significantly greater risk to life and property. The granting of waivers or relaxations in such cases is outside the scope of this Manual. Nevertheless, it is stressed that a detailed assessment of the risks involved must be made by a competent agency before the appropriate authorities grant such dispensations. Conversely, authorities which might find unacceptable the risks deemed "tolerable" in this Manual can always reduce the risks by using suitable protective devices and/or by increasing the recommended distances. However, this will be possible only with a higher operating cost.

e) Under certain circumstances operational requirements demand a degree of relaxation from the guidelines given in Parts I-III of the Manual. This applies mainly to basic load holding areas, field storage and missile installations. In the same way, problems connected with airfields used only by military aircraft and those relating to transfer of ammunition in naval ports call for specific measures. The principles to be followed in preparing flexible but consistent safety guidelines in those cases will be found in Part IV of the Manual.

f) A Manual of this type cannot provide the answers to all problems which arise. In circumstances where the answer is not provided the problem should be submitted to the Secretary of the "NATO Group of Experts on the Safety Aspects of Transportation and Storage of Military Ammunition and Explosives (AC/258)".

g) The users of this Manual are invited to communicate with the Secretary of the "NATO Group of Experts on the Safety Aspects of Transportation and Storage of Military Ammunition and Explosives (AC/258)", when an accidental explosion has been thoroughly analysed, or trials have been staged, so that the validity of the quantity-distance tables can be verified. For details of accident reports required: see Part I, Chapter 8.

h) Since this Manual is a guide rather than a set of mandatory regulations the words "must", "should" "may/can" and "is/are" are used in the following sense:

MUST - Indicates a technical requirement which is vital for the safety of a depot and the avoidance of a catastrophe.

SHOULD - Indicates a safety requirement which is important but not essential.

MAY/CAN - Indicates optional courses of action and possibilities.

IS/ARE - Indicates a fact or a valid technique.

Section II - Historical Background of the Manual

1.1.2.1.

This Manual is the result of successive revisions, over a period of 30 years, of a document (AC/106-D/5 dated 1st September 1963) drafted by an AC/106 Restricted Sub-Group consisting of representatives of France, Germany, the United Kingdom and the United States. These experts, meeting as specialists and not as national representatives, made a study of the systems used in France, the United Kingdom and the United States which took into account national trials and an analysis of archives relating to damage from accidental explosions or acts of war. This attempt at consolidation involved each member waiving some of his own nation´s regulations. This difficulty was overcome by accepting that each nation would be free when authorizing implementation of the NATO system in its territory to refrain from applying any regulation relating to particular items for which, in its view, no compromise was possible. It was hoped, however, that in view of the very abundant information which had been used to prepare the document new ideas would become acceptable in the interests of NATO even if they were not always in accordance with host nation practice up to that point.

1.1.2.2.

The four specialists from the AC/106 Restricted Sub-Group met again in 1964 to form the AC/74 Restricted Group of Experts on Ammunition Storage in order to supplement the initial document. The resulting document, AC/106-D/5 (revised), was published in 1965.

1.1.2.3.

The Group of Experts on the Safety Aspects of Transportation and Storage of Military Ammunition and Explosives (AC/258) was created in 1966 to continue this work. A Storage Sub-Group, set up under its aegis with broader representation, prepared a new revised version published under reference AC/258-D/70 dated December 1969. This was a very full document, including both the basic principles from the original document and recommendations dealing with special cases such as storage on military airfields, on board ship, underground, in the vicinity of petroleum products or near radio transmitters.

1.1.2.4.

Detailed annexes were prepared at the same time, e.g. those describing tests to be applied to ammunition to decide on its hazard classification. The quantity-distance tables were simplified and rationalized and expressed solely in the metric system.

1.1.2.5.

In 1970, the Conference of National Armament Directors (CNAD) officially invited nations, on a recommendation by AC/258, to adopt the NATO principles to form the basis of their national regulations.

During this period the United Nations Group of Experts on Explosives recommended a classification system for use in the transport of explosives. In the interests of standardization, AC/258 in 1971 adopted the United Nations classification system for storage of military ammunition and explosives.

1.1.2.6.

The reputation of the Manual grew with time: several no-NATO nations requested copies of it. Member nations requested more and more information on the subjects covered.
In 1974, it was decided to carry out a general revision to consolidate the corrigenda which had been issued since the beginning and to improve general presentation, as a Manual in three parts:

- Part I dealing with the general principles;
- Part II containing more detailed information on above-ground storage and the historical background of the Manual;
- Part III dealing with special types of storage.

1.1.2.7.

During this period the Group was involved in designing and evaluating field trials, both on mockups and at full scale, in order to improve its quantity-distance criteria (in particular the "ESKIMO" series of trials in the United States). Group members also took part in several large-scale trials relating to underground explosions.
The resulting conclusions and recommendations were incorporated in the Manual which was revised once more under the new reference AC/258-D/258.

1.1.2.8.

In 1981, the Group recognized the fact that in some circumstances the principles set out in Part I of the Manual could not be applied without seriously affecting operational efficiency. It was therefore decided to instigate a new part, Part IV, dealing with the principles to be applied in such cases. At the same time, some chapters (field storage, missile installations and depots containing basic loads) which had been included in Parts II and III up to that time but were better suited to Part IV were moved to part IV.

1.1.2.9.

Throughout ten years, since 1981, 23 corrigenda to the Manual were issued.
In addition, the idea grew that a presentation more in accordance with NATO standards should be adopted. This was achieved by restructuring the Manual in the form of an Allied Publication (AP) and producing Standardization Agreements (STANAG) with which to implement the AP.

CHAPTER 2 - CLASSIFICATION CODES AND MIXING OF AMMUNITION AND EXPLOSIVES IN STORAGE

Section I - Hazard Divisions

1.2.1.1. *General*

In order to promote the safe storage and transport of dangerous goods, an International System for Classification has been devised. The system consists of 9 classes (1-9) of which Class 1 comprises ammunition and explosives. Class 1 is divided into divisions. The hazard division indicates the type of hazard to be expected primarily in the event of an accident: mass explosion (Division 1.1), projection effects (Division 1.2), fire and radiant heat (Division 1.3), no significant hazard (Division 1.4), mass detonation with very low probability of initiation (Division 1.5) and detonation of a single article, with low probability of initiation (Division 1.6). Ammunition and explosives must be classified in accordance with STANAG 4123. National authorities competent for the classification of ammunition and explosives are given in AASTP-3.

1.2.1.2. *Definitions of the Hazard Divisions*

a) Hazard Division 1.1

Substances and articles which have a mass explosion hazard (a mass explosion is one which affects the entire load virtually instantaneously.)

1. The major hazards of this division are blast, high velocity projections and other projections of relatively low velocity.

2. The explosion results in severe structural damage, the severity and range being determined by the amount of high explosives involved. There may be a risk from heavy debris propelled from the structure in which the explosion occurs or from the crater.

b) Hazard Division 1.2

Substances and articles which have a projection hazard but not a mass explosion hazard

1. The explosion results in items burning and exploding progressively, a few at a time. Furthermore fragments, firebrands and unexploded items may be projected in considerable numbers; some of these may explode on or some time after impact and cause fires or explosions. Blast effects are limited to the immediate vicinity.

2. For the purpose of determining quantity-distances a distinction, depending on the size and range of fragments, is made between those items which give fragments of moderate range (classified as HD 1.2.2) and those which give fragments with a considerable range (classified as HD 1.2.1). HD 1.2.2 items include HE projectiles (with or without propelling charges) with an individual NEQ less than or equal to 0.71 kg and other items not containing HE such as cartridges, rounds with inert projectiles, pyrotechnic items or rocket motors. HD 1.2.1 items are generally HE projectiles (with or without propelling charges) with an individual NEQ greater than 0.71kg.

c) Hazard Division 1.3

Substances and articles which have a fire hazard and either a minor blast hazard or a minor projection hazard or both, but not a mass explosion hazard.

1. This division comprises substances and articles:

(a) which give rise to considerable radiant heat, or

(b) which burn one after another, producing minor blast or projection effects or both.

2. This division includes some items which burn with great violence and intense heat emitting considerable thermal radiation (mass fire hazard) and others which burn sporadically. Items in this division may explode but do not usually form dangerous fragments. Firebrands and burning containers may be projected.

d) Hazard Division 1.4

Substances and articles which present no significant hazard

1. This division includes items which have primarily a moderate fire hazard. They do not contribute excessively to a fire. The effects are largely confined to the package. No fragments of appreciable size or range are to be expected. An external fire does not cause the simultaneous explosion of the total contents of a package of such items.

2. Some but not all of the above items are assigned to Compatibility Group S. These items are so packed or designed that any explosive effect during storage and transportation is confined within the package unless the package has been degraded by fire.

e) Hazard Division 1.5

Very insensitive substances which have a mass explosion hazard

This division comprises substances which have a mass explosion hazard but are so insensitive that there is very little probability of initiation or of transition from burning to detonation under normal conditions.

NOTE 1: The probability of transition from burning to detonation is greater when large bulk quantities are transported or stored.

NOTE 2: For storage purposes, such substances are treated as Hazard Division 1.1 since, if an explosion should occur, the hazard is the same as for items formally assigned to Hazard Division 1.1 (i.e. blast).

f) Hazard Division 1.6

Extremely insensitive articles which do not have a mass explosion hazard.

This division comprises articles which contain only extremely insensitive detonating substances and which demonstrate a negligible probability of accidental initiation or propagation.

NOTE: The risk from articles of Hazard Division 1.6 is limited to the explosion of a single article.

1.2.1.3.

All the information necessary for hazard classification of ammunition and explosives will be found in AASTP-3. Ammunition which does not contain any explosive or other dangerous goods (for instance dummy bombs, cartridges and projectiles) is excluded from the system of hazard classification.

1.2.1.4. *Depleted Uranium (DU) Ammunition*

Ammunition containing DU in the form of a penetrator or projectile is assigned to the Hazard Classification appropriate to the explosives content of the ammunition only. The normal storage rules associated with the Hazard Classification may need to be modified to take account of the slight radioactivity and chemical toxicity of DU and therefore rules may be prescribed for DU ammunition as a separate class of ammunition, or for specific types of DU ammunition (see Part I, Chapter 9).

1.2.1.5. *Effect of Package on Classification*

As the packaging may have a decisive effect on the classification, particular care must be taken to ensure that the correct classification is determined for each configuration in which ammunition and explosives are stored or transported. Therefore every significant change in the packaging (e.g. degradation) may well affect the classification awarded.

Section II - Compatibility Groups

1.2.2.1. *General Principles*

a) Ammunition and explosives are considered to be compatible if they may be stored together without significantly increasing either the probability of an accident or, for a given quantity, the magnitude of the effects of such an accident.

b) Ammunition and explosives should not be stored together with other goods which can hazard them. Examples are highly flammable materials, acids, and corrosives.

c) The safety of ammunition and explosives in storage would be enhanced if each kind was kept separate. However, a proper balance of the interests of safety against other factors may require the mixing of several kinds of ammunition and explosives.

d) The principles of mixing compatibility groups may differ in storage and transport circumstances. Detailed information on mixing compatibility groups is to be found in AASTP-3.

1.2.2.2. *Determination of Compatibility Groups*

On the basis of the definitions in paragraph 1.2.2.3. ammunition and explosives are formally grouped into thirteen Compatibility Groups: A to H, J, K, L, N and S.

1.2.2.3. *Definitions of the Compatibility Groups*

<u>Group A</u> Primary explosive substance.

<u>Group B</u> Article containing a primary explosive substance and not containing two or more effective protective features.

<u>Group C</u> Propellant explosive substance or other deflagrating explosive substance or article containing such explosive substance.

<u>Group D</u> Secondary detonating explosive substance or black powder or article containing a secondary detonating explosive substance, in each case without means of initiation and without a propelling charge, or article containing a primary explosive substance and containing two or more effective protective features.

Group E Article containing a secondary detonating explosive substance, without means of initiation, with propelling charge (other than one containing a flammable liquid or gel or hypergolic liquids).

Group F Article containing a secondary detonating explosive substance with its own means of initiation, with a propelling charge (other than one containing a flammable liquid or gel or hypergolic liquids) or without a propelling charge.

Group G Pyrotechnic substance, or article containing a pyrotechnic substance, or article containing both an explosive substance and an illuminating, incendiary, tear- or smoke-producing substance (other than a water-activated article or one containing white phosphorus, phosphides, a pyrophoric substance, a flammable liquid or gel, or hypergolic liquids).

Group H Article containing both explosive substance and white phosphorus.

Group J Article containing both an explosive substance and a flammable liquid or gel.

Group K Article containing both an explosive substance and a toxic chemical agent.

Group L Explosive substance or article containing an explosive substance and presenting a special risk (e.g. due to water activation or presence of hypergolic liquids, phosphides or a pyrophoric substance) and needing isolation of each type.

Group N Articles which contain only extremely insensitive detonating substances and which demonstrate a negligible probability of accidental initiation or propagation.

Group S Substances or articles so packed or designed that any hazardous effects arising from accidental functioning are confined within the package unless the package has been degraded by fire, in which case all blast or projection effects are limited to the extent that they do not significantly hinder or prohibit fire-fighting or other emergency response efforts in the immediate vicinity of the package.

1.2.2.4. *Classification Code*

The classification code is composed of the number of the hazard division (see Section I) and the letter of the compatibility group (see this Section) for example "1.1 B". Guidance on the practical procedure of classifying an item by hazard division and compatibility group is given in AASTP-3.

Section III - Mixing of Ammunition and Explosives in Storage

1.2.3.1. *Mixed Storage*

Ammunition and explosives of different hazard divisions may be stored together if compatible. The required quantity-distances and the permitted quantities must be determined in accordance with Part II of this Manual.

1.2.3.2. *Storage Limitations*

The rules which apply to the mixing of hazard divisions and compatibility groups in above ground storage are detailed below. Special rules apply to underground storage. The basic rules are given in the form of three tables as follows:

TABLE 4: Aboveground Storage, Mixing and Aggregation Rules for Hazard Divisions.

TABLE 5: Aboveground Storage of Explosive Substances. Rules for mixing of Compatibility Groups.

TABLE 6: Aboveground Storage of Explosive Articles. Rules for Mixing of Compatibility Groups.

Special circumstances are addressed at paragraph 1.2.3.3. and suspect ammunition and explosives at paragraph 1.2.3.4.

Mixed hazard divisions (HD) should be aggregated in the following table:

Table 4 - Aboveground Storage, Mixing and Aggregation Rules for Hazard Divisions

Hazard Division	1.1	1.2.1	1.2.2	1.3	1.4	1.5	1.6
1.1	1.1	1.1	1.1	1.1	[1]	1.1	1.1
1.2.1	1.1	1.2.1	1.2.1	[2]	[1]	1.1	[3]
1.2.2	1.1	1.2.1	1.2.2	[2]	[1]	1.1	[3]
1.3	1.1	[2]	[2]	1.3	[1]	1.1	[3]
1.4	[1]	[1]	[1]	[1]	1.4	[1]	[1]
1.5	1.1	1.1	1.1	1.1	[1]	1.1	1.1
1.6	1.1	1.2.1	1.2.1	1.3[3]	[1]	1.1	1.6[3]

NOTES:

[1] 1.4 may be stored with any other HD without aggregation of the NEQ.

[2] Mixed 1.2.1/1.2.2 will usually behave as aggregated 1.2 or 1.3. However, there is a significant risk that, in certain circumstances, a mix of 1.2.1/1.2.2 and 1.3 will behave as an aggregated quantity of 1.1.

If any of the following circumstances exists, the mix must be aggregated as 1.1, unless relevant trials or analysis indicate otherwise:

a) The presence of 1.2 shaped charges.
b) High energy propellants (e.g. as used in some tank gun applications).
c) High loading density storage of 1.3 in conditions of relatively heavy confinement.
d) 1.2.1 articles with an individual NEQ > 5 kg.

[3] If demonstrated by testing or analogy. If not: 1.1.

Substances may be mixed in aboveground storage as shown in the following table:

Table 5 - Aboveground Storage of Explosive Substances Rules for Mixing of Compatibility Groups.

Compatibility Group	A	C	D	G	L	S
A	X					
C		X 1)	X 1)	3)		X
D		X 1)	X 1)	3)		X
G		3)	3)	X		X
L					2)	
S		X	X	X		X

LEGEND: X = Mixing permitted

NOTES:

1) Mixing permitted provided substances have all passed UN Test Series 3. Storage of substances of any Compatibility Groups C, D or G which have failed UN Test Series 3 will require special consideration by the National Competent Authority.

2) Compatibility Group L substances must always be stored separately from all substances of other compatibility groups as well from all other substances of Compatibility Group L.

3) The mixing of Compatibility Group G substances with other compatibility groups is at the discretion of the National Competent Authority.

Articles may be mixed in aboveground storage as shown in the following table:

Table 6 - Aboveground Storage of Explosive Articles - Rules for Mixing of Compatibility Groups.

Compatibility Group	B	C	D	E	F	G	H	J	K	L	N	S
B	X		X[1]	X[1]	X[1]							X
C		X	X	X	[2]	[4]					X[5]	X
D	X[1]	X	X	X	[2]	[4]					X[5]	X
E	X[1]	X	X	X	[2]	[4]					X[5]	X
F	X[1]	[2]	[2]	[2]	X	[4]						X
G		[4]	[4]	[4]	[4]	X						X
H							X					X
J								X				X
K									X			
L										[3]		
N		X[5]	X[5]	X[5]							X[6]	X[7]
S	X	X	X	X	X	X	X	X			X[7]	X[6]

LEGEND: X= Mixing permitted

NOTES

1) Compatibility Group B fuzes may be stored with the articles to which they will be assembled, but the NEQ must be aggregated and treated as Compatibility Group F.

2) Storage in the same building is permitted if effectively segregated to prevent propagation.

3) Compatibility Group L articles must always be stored separately from all articles of other compatibility groups as well as from all other articles of different types of Compatibility Group L.

4) Mixing of articles of Compatibility Group G with articles of other compatibility groups is at the discretion of the National Competent Authority.

5) Articles of Compatibility Group N should not in general be stored with articles in other compatibility groups except S. However, if such articles are stored with articles of

Compatibility Group C, D and E, the articles of Compatibility Group N should be considered as having the characteristics of Compatibility Group D and the compatibility groups mixing rules apply accordingly.

6) It is allowed to mix 1.6N munitions. The Compatibility Group of the mixed set remains N if the munitions belong to the same family or if it has been demonstrated that, in case of a detonation of one munition, there is no instant transmission to the munitions of another family (the families are then called "compatible"). If it is not the case the whole set of munitions should be considered as having the characteristics of Compatibility Group D.

7) A mixed set of munitions 1.6N and 1.4S may be considered as having the characteristics of Compatibility Group N.

1.2.3.3. *Mixed Storage - Special Circumstances*

a) There may be special circumstances where the above mixing rules may be modified by the National Competent Authority subject to adequate technical justification based on tests where these are considered to be appropriate.

b) Very small quantity HD 1.1 and large quantity Hazard Division 1.2.1/1.2.2.
It should be possible to arrange storage in such a manner that the mixture will behave as 1.2.1/1.2.2.

c) Mixing of Hazard Division 1.1, Hazard Division 1.2.1/1.2.2 and Hazard Division 1.3
The quantity distance to be applied in these unusual circumstances is that which is the greatest when considering the aggregate NEQ as Hazard Division 1.1, Hazard Division 1.2.1, Hazard Division 1.2.2 or Hazard Division 1.3.

d) With the exception of substances in Compatibility Group A, which should not be mixed with other compatibility groups, the mixing of substances and articles is permitted as shown in Tables 5 and 6.

1.2.3.4. *Suspect Ammunition and Explosives (Mixed storage)*

Suspect ammunition and explosives must not be stored with any other ammunition and explosives.

CHAPTER 3 - ABOVEGROUND STORAGE IN DEPOTS

Section I - Principles of the Quantity-Distances

1.3.1.1. *General*

a) PES such as buildings, stacks and vehicles (trucks, trailers and railcars) present an obvious risk to personnel and property. Such sites are located at carefully calculated distances from each other and from other buildings and installations to ensure the minimum practicable risk to life and property (including ammunition). These distances are called Quantity-Distances and are tabulated in Annex A, Section II.

b) The tables in Annex A, Section II are concerned with storage sites containing more than 500 kg NEQ. Storage of NEQs less than 500 kg needs special consideration and nations requiring advice should contact the Secretary of AC/258.

1.3.1.2. *Basis of Quantity-Distances*

The quantity-distances are based on an extensive series of trials and a careful analysis of all available data on accidental explosions in different countries. However, quantity-distances are subject to uncertainty owing to the variability of explosions. These quantity-distances are generated by distance functions subject, in certain cases, to fixed minimum or maximum distances. The fixed values are independent of the NEQ because they are based on the projection hazard from individual rounds or operational factors (see Part II, Annex A). As regards the rounding of values of quantity-distances, see Annex A, paragraph 2. Criteria and formulae for quantity-distances are given in Part II, Annex A.

1.3.1.3. *Kinds of Quantity-Distances*

a) There are two kinds of Interior Quantity-Distances for each hazard division:

1) Inter-Magazine Distances (see paragraphs 1.3.1.8. - 1.3.1.11)
2) Explosives Workshop Distances (see paragraphs 1.3.1.12. - 1.3.1.13)

b) There are two kinds of Exterior Quantity-Distances for each hazard division:

1) Public Traffic Route Distances (see paragraph 1.3.1.14)

2) Inhabited Building Distances (see paragraph 1.3.1.15)

1.3.1.4. *Quantity-Distances for Hazard Division 1.1*

Annex A, Table 1 gives Interior and Exterior Quantity-Distances for ammunition and explosives of Hazard Division 1.1. The Inter-Magazine Distances should not be used for packages of primary explosives and other very sensitive explosive substances like blasting gelatine which require individual assessment when at an ES.

1.3.1.5. *Quantity-Distances for Hazard Division 1.2*

a) General

Annex A, Table 2 gives Interior and Exterior Quantity-Distances for ammunition and explosives of Hazard Division 1.2 but before appropriate quantity-distances can be selected there are two factors to be considered. The first is the range of fragments and lobbed ammunition which are projected from a PES. The second is the total number of such projections likely to hazard an ES. If comprehensive data is available for a particular item, then the quantity-distances for Hazard Division 1.2, which are based on trials with individual rounds considered to be representative, may be replaced by this more appropriate data taking into account the vulnerability of the ammunition, explosives and buildings at the Exposed Sites under consideration (see Part II, Chapter 5, Section II.).

b) Fragments and Lobbed ammunition from Rounds greater than 0.71 kg individual NEQ.

This, the most hazardous part of Hazard Division 1.2 comprises those rounds and ammunition which contain a high explosive charge and may also contain a propelling or pyrotechnic charge. The total explosives content of these rounds, etc will be greater than 0.71 kg. It is impractical to specify quantity-distances which allow for the maximum possible flight ranges of propulsive items but the likely range of packaged items, if involved in an accident during storage, is typical of this part of Hazard Division 1.2. Munitions which explode during an accident will rarely detonate in their design mode. In a fire situation explosive fillings may melt and expand, breaching their casings and then explode via cook-off or burning to detonation reactions. These explosions may involve anything from 100% to very little of the fill dependent on the amount of the filling that has escaped through the breach. The fragmentation produced by such reactions is totally different to that generated in a design detonation. The case splits open producing large (for a 105mm shell, for example 2-3kg) but comparatively few fragments with velocities of 100-500ms^{-1}. These are likely to be projected further than the smaller fragments from the full detonation of similar munitions in a HD 1.1

reaction. Quantities of unexploded munitions, sub-assemblies or sub-munitions also may be projected to considerable ranges and will, due to thermal or mechanical damage, be more hazardous than in their pristine state. Data on individual round characteristics obtained from tests and accidental explosions may be used to determine the validity of including a specific round in this category or to reduce it to the lesser category described in Paragraph c) below. These items are hereafter called rounds of HD 1.2.1.

(c) Fragments and Lobbed Ammunition from Rounds less than or equal to 0.71 kg individual NEQ.

This less hazardous part of Hazard Division 1.2 comprises those rounds and ammunition which contain a high explosive charge and may also contain a propelling or pyrotechnic charge. The total explosives content of these rounds, etc will be less than or equal *to* 0.71 kg. It will also typically comprise ammunition which does not contain HE and will include pyrotechnic rounds and articles, inert projectile rounds. Tests show that many items of this type produce fragments and lobbed ammunition with a range significantly less than that of items in b) above but of course greater than that of ammunition and explosives of Hazard Division 1.4. These items are hereafter called rounds of HD 1.2.2.

(d) Subdivisions for Storage

It is important not to exaggerate the significance of the value of 0.71 kg used in b) and c) above. It was based on a break point in the database supporting the Quantity Distance relationships and tables and the NEQ of the rounds tested. If comprehensive data is available for a particular item, then the item may be placed in that category of HD 1.2 supported by the data and allocated the relevant Quantity Distances. It may also be necessary to take into account the vulnerability of ammunition, explosives and buildings at the ES under consideration, see Part II, Chapter 5, Section II.

(e) Number of Fragments and Lobbed Items at an Exposed Site

Following the initiation of an event in storage there will be a delay before there are any violent events and projections. This delay will be highly dependent on the nature, dimensions and packaging of the items involved. For 40mm HE rounds it can be as short as two or three minutes and for 105mm HE rounds 15-20 minutes. Once ammunition starts to react the rate of reactions increases rapidly and then decreases more slowly. Reactions may still occur hours after the event. The ability of the storage structure at the PES to contain the fragments etc will determine both in time and density the effects at the exposed site. For medium and lightly constructed PES where, at some stage, walls and/or roofs will be destroyed, the modifying effect of the building on the fragmentation is not taken into account. In the light of the indeterminacy of the fragmentation effects both in time and quantity, fire fighting will, in general, be inadvisable. However the installation of automatic fire-fighting arrangements could be invaluable from the stock preservation and event containment points of view. Evacuation from PTR and beyond may be possible. However the quantity-distances given at Annex A assume no amelioration from fire-fighting or evacuation. They are based on the total fragmentation at the exposed site from the event at the PES.

f) Arrangements for Fire-Fighting

The levels of protection afforded by the Inter-Magazine Distances in Annex A are based on the fragment density at the Exposed Site for the total incident and the degree of protection afforded by the structure at the Exposed Site. It is assumed that an incident involving Hazard Division 1.2 cannot be promptly curtailed by fire-fighting. It is considered unlikely that any significant attempts could be made to fight a fire involving Hazard Division 1.2 explosives as it is anticipated that such efforts would have to be made from such a distance and from behind protective cover so as to make those efforts ineffective. In addition some storage areas are too remote from professional fire-fighting services, and other lack suitable protective cover from behind which firemen could even attempt to attack a fire involving ammunition of Hazard Division 1.2. The levels of protection take into account the fact that the Explosives Area is endangered by firebrands, projections and lobbed ammunition which would most likely propagate fire or explosion if the quantity-distances were insufficient. The available fire-fighting effort should be directed at preventing the spread of fire and the subsequent propagation of explosions.

Fuller recommendations are given in Chapter 4, Part II of the Manual.

Situations which require no QDs

(g) Where either the PES or the ES is an earth covered building or a building which can contain the effects generated in an accidental explosion of the HD 1.2 then, in general, no Q-Ds are necessary. The separation to other explosive storehouses, explosive workshops, public traffic routes or inhabited buildings will be dependent on constructional details, access for rescue and fire-fighting personnel or other administrative arrangements. For public traffic routes and inhabited buildings consideration should be given to the use of fixed distances of 30 m for ammunition of HD 1.2.2 or 60 m for HD 1.2.1. However where there is an aperture such as a door in the PES and the ES has either an unprotected and undefined door pointing towards the PES or offers little or no protection to its contents then the Q-Ds recommended at Annex A Table 2 column b should be applied.

1.3.1.6. *Quantity-Distances for Hazard Division 1.3*

a) General

Annex A, Tables 3A and 3B give Interior and Exterior Quantity-Distances for ammunition and explosives of Hazard Division 1.3 but the selection of appropriate quantity-distances requires separate consideration of two types of explosives, namely propellants (Compatibility Group C) and other items (Compatibility Group G). Although many hazardous effects are common to both types, the dominant hazards used as the basis of certain quantity-distances are different in the two cases hence there are two tables.

b) Explosives producing a mass fire effect

The explosives producing a mass fire effect are likely to be propellants which produce a fireball with intense radiant heat, fire brands and some fragments. The firebrands may be massive fiery chunks of burning propellant. (The effect of quite normal winds may augment a calculated flame radius by 50 %. A building with marked asymmetry of construction such as an igloo or building with protective roof and walls, but with one relatively weak wall or a door, induces very directional effects from the flames and the projection of burning packages.)

c) Ammunition and Explosives not Producing a Mass Fire Effect

Items other than propellants produce a moderate fire with moderate projections and firebrands. The projections include fragments but these are less hazardous than those which characterize Hazard Division 1.2.

1.3.1.7. *Distances for Hazard Division 1.4*

Separation distances from ammunition and explosives of Hazard Division 1.4 are not a function of the NEQ. Separation distances prescribed by fire regulations apply.

1.3.1.8. *Inter-Magazine Distances - General Considerations*

a) These distances are the minimum permissible distances between PES and storage sites containing ammunition or explosives. These distances are intended to provide specified degrees of protection to the ammunition and explosives at the ES. The degree of protection is highly dependent upon factors such as sensitiveness of explosives, type of ammunition, type of packaging, and type and construction of building at the PES or ES or both. In general the provision of stronger buildings allows the use of smaller quantity-distances for a given degree of protection, or achieves a better standard of protection at a given distance, especially in the case of a PES containing ammunition and explosives of Hazard Division 1.1 or 1.2.

b) The selection of the optimum combination of types of construction of the buildings, quantity-distance and degree of protection involves a balance between the cost of construction, the availability and cost of land, and the value of the stocks of ammunition and explosives which might be rendered unserviceable at ES in the event of an accident at the PES. The hazard divisions and compatibility groups of the ammunition and explosives and the need for flexibility in the use of the sites should be taken into account.

c) The following paragraphs describe the levels of protection corresponding to common combinations of buildings or stacks and quantity-distances for each hazard division as a guide for decisions on the optimum solution. These levels of protection are incorporated in the Inter-Magazine Distances in Annex A, Tables 1 to 3. Some entries in the tables show only one level of protection owing to a lack of information at the present time. In a few cases it is not possible to predict the level of protection as it depends on the type of structure at the ES and the sensitiveness of its contents. An indication of the full range of possibilities is given in Part II, Chapter 5.

1.3.1.9. *Inter-Magazine Distances for Hazard Division 1.1*

a) Protection of Stocks

The observed damage to stocks at an Exposed Site from an accidental explosion varies widely and, although detailed prediction of such effects is outside the scope of this Manual, a measure of guidance is given here. Since an igloo is designed to resist external blast, primary fragments or secondary projections, the design ensures that the stocks survive and would be expected to generally remain serviceable. However, at the D3-distances the ground shock may render unserviceable sensitive electrical and electronic components of guided missiles, etc. For open stacks and buildings, other than those covered with earth, a general assessment is that for distances less than D5-distances it is probable that, even though propagation may not have taken place, the stocks are likely to be unserviceable and covered by debris from the collapsed building. Stocks at D7-distances and greater are only likely to be serviceable if the building has not suffered serious structural damage although some structural damage at the D7-distances, dependent on the type of building, can be expected.

b) Alternative Levels of Protection at an ES

As described above, the igloo design affords extremely good protection to its contents. Weaker buildings and open stacks would not be expected to give such good protection although concrete structures are considered to be superior generally to brick from an Exposed Site point of view. The level of protection also depends on the vulnerability or robustness of the ammunition stored at the Exposed Site and the type of traversing used. The following paragraphs describe the three levels of protection which are incorporated in Annex A, Table 1 and which are intended to provide an adequate basis for the selection of a particular quantity-distance. Some entries in the table show only one level of protection due to a lack of data. The three levels of protection are:

1) There is virtually complete protection against practically instantaneous propagation of explosion by ground shock, blast, flame and high velocity projections. There are unlikely to be fires or subsequent explosions caused by these effects or by lobbed ammunition. The stocks are likely to be serviceable. However, ground shock may cause indirect damage and even explosions among specially vulnerable types of ammunition or in conditions of saturated soil. These exceptional circumstances require individual assessment rather than use of the quantity-distances in Annex A.

2) There is a high degree of protection against practically instantaneous propagation of explosion by ground shock, blast, flame and high velocity projections. There are occasional fires or subsequent explosions caused by these effects or by lobbed ammunition. Most of the stocks are likely to be serviceable although some are covered by debris.

3) There is only a limited degree of protection against practically instantaneous propagation of explosion by ground shock, flame and high velocity projections. There are likely to be fires or subsequent explosions caused by these effects or by lobbed ammunition. The stocks are likely to be heavily damaged and rendered unserviceable; they are sometimes completely buried by debris. This level of protection is not recommended for new construction.

1.3.1.10. *Inter-Magazine Distances for Hazard Division 1.2*

The Inter-Magazine Distances for Hazard Division 1.2 relate essentially to three levels of protection of ammunition and explosives at an ES:

1) There is virtually complete protection against immediate or subsequent fires and explosions caused by blast, flame, firebrands, projections and lobbed ammunition. The stocks are likely to be serviceable.

2) There is a high degree of protection against immediate propagation of explosion by blast, flame, projections and lobbed ammunition. The larger the donor event the lower will be the degree of protection given, particularly where ammunition with NEQ greater than 0.71 kg is involved, propagation becoming more likely the longer the event continues. Local fire fighting measures may reduce stock losses. The use of this level of protection is penalised in Table 2 by the imposition of D5 (for HD 1.2.2) and D6 (for HD 1.2.1) inter magazine separation distances between unprotected stacks of ammunition. It is likely that stocks at the ES will not survive as a result of subsequent propagation.

3) There is only a limited degree of protection against immediate or subsequent propagation of explosion by blast, flame and projections and lobbed ammunition. The protection afforded may be minimal when the donor event involves large quantities of ammunition and continues for a prolonged period. Local fire fighting measures will be essential to the preservation of stocks. The use of this level of protection is penalised in the Table 2 by the imposition of D5 (for HD 1.2.2) and D6 (for HD 1.2.1) inter magazine separation distances between unprotected stacks of ammunition. The stocks at the ES will not survive as a result of subsequent propagation.

1.3.1.11. *Inter-Magazine Distances for Hazard Division 1.3*

The Inter-Magazine Distances for Hazard Division 1.3 relate essentially to two levels of protection of ammunition and explosives at an ES:

1) There is virtually complete protection against immediate or subsequent fires among the contents of an ES by flame, radiant heat, firebrands, projections and lobbed ammunition. There may be ignition of combustible parts of the building but this is unlikely to spread to the contents even if it were not possible to provide prompt and effective fire-fighting services.

2) There is a high degree of protection against immediate propagation of fire to the contents of an ES by flame, radiant heat, firebrands, projections and lobbed ammunition. There is a considerable risk that one or more of these effects, especially lobbed ammunition, is likely to ignite the contents directly or as the result of ignition of combustible parts of the building unless effective fire-fighting is able to prevent such consequences.

1.3.1.12. *Explosives Workshop Distances*

a) General Considerations

These distances are the minimum permissible distances between Potential Explosion Sites and explosive workshops. The distances are intended to provide a reasonable degree of immunity for personnel within the explosives workshops from the effects of a nearby explosion, such as blast, flame, radiant heat and projections. Light structures are likely to be severely damaged, if not completely destroyed. These distances also provide a high degree of protection against immediate or subsequent propagation of explosion.

b) Explosive Workshop Distance for HD 1.1

1) For HD 1.1 the standard Explosive Workshop Distance should be the D10 distances prescribed in Annex A Table 1. At this distance the major effects to be considered are the peak side-on overpressure, which is anticipated to be no greater than 20 kPa (3 psi) and debris, which is extremely difficult to quantify, but would be a very significant effect.

2) When siting and designing explosive workshops the following effects should be borne in mind amongst others. A person in a building designed to withstand the anticipated blast loading and without windows would be merely startled by the noise of the explosion at an adjacent site whereas a person in a brick building with windows might suffer eardrum damage or suffer indirect injuries through his translation by blast and subsequent impact on hard objects or through possible collapse of the building upon him.

3) Where the quantity-distance tables specify a Explosive Workshop Distance less than 270 m this may not give protection to personnel in explosive workshops having light roofs from debris projected from the Potential Explosion Site. Therefore consideration should be given to maintaining this 270 m distance as the minimum separation from the nearest storage site containing explosives of HD 1.1, in order to provide additional protection from debris.

c) Explosive Workshop Distance for HD 1.2

1) Since debris and/or fragmentation hazards are considered to be dominant for HD 1.2 and the Inhabited Building Distance is based on an appreciation of this hazard then the Explosive Workshop Distance is generally determined as 36% of the IBD.

2) However where the PES is an earth covered building or a building which can contain the effects generated in an accidental explosion of the HD 1.2 then no Q-Ds are necessary to adjacent explosive workshops although the separation between them and the explosive storehouses will be dependent on constructional details and access for rescue and fire-fighting personnel.

3) Where the PES is an earth covered building or a building which can contain the effects generated in an accidental explosion of the HD 1.2 but has a door or other aperture in the direction of the ES then the Explosive Workshop Distance is determined as 36% of the IBD.

4) Where the explosive workshop is protected by a traverse and has a protective roof it is considered that the occupants are afforded a high degree of protection which decreases to limited if the building is either not traversed or does not have a protective roof. In the absence of any protective features, such as a traverse or a protective roof, not only is the level of protection limited but it is recommended that such explosive workshops should only be sited at an increased separation equivalent to PTR.

d) Explosive Workshop Distance for HD 1.3

1) For the more hazardous explosives of HD 1.3, the D2 distances prescribed at Annex A Table 3A should be used.

2) For the less hazardous explosives of HD 1.3 the distances are fixed values given in Annex A Table 3B.

1.3.1.13. *Separation of Explosives Workshops from Storage Sites*

The D10-distances in Annex A, Table 1 less than 270 m may not give protection to personnel in Explosives Workshops having light roofs. If greater protection is required against projections than that The D10-distances in Annex A, Table 1 less than 270 m may not give protection to personnel in Explosives Workshops having light roofs. If greater protection is required against projections than that provided by D10-distances for example to protect personnel and valuable test equipment, then the workshop must be provided with a protective roof. If there is a possibility of a serious fragment hazard then consideration should be given to observing a minimum separation distance of 270 m between Explosives Workshops having light roofs and storage sites containing ammunition and explosives of Hazard Division 1.1 as is already required in certain circumstances.

1.3.1.14. *Public Traffic Route Distances (PTRD)*

a) General Considerations

1) These distances are the minimum permissible distances between a Potential Explosion site and routes used by the general public, which are generically referred to as Public Traffic Routes. These routes include :

Roads

Railways

Waterways, including rivers, canals and lakes, and

Footpaths

2) Where debris or fragmentation hazards are considered to be dominant and the Inhabited Building Distance is based on an appreciation of this hazard then the PTR is determined as 67% (or 2/3) of the IBD. This rule is applied to both HD 1.1 and HD 1.2 situations. Attempts have been made within AC 258 to determine a relationship between debris hazards for IBD and PTR without success primarily because the variation of hazard with distance is too dependent on the specific hazard generator.

3) It is important to appreciate that PTR's or common access areas should not be treated independently of each other or of any other constraints around an explosives site. They should be viewed within the overall picture and the above guidelines used to indicate whether a particular situation is likely to be worth consideration. Ideally a full risk analysis should be conducted to ascertain how these additional risks would fit into the overall risk picture. Only then can informed decisions be made regarding the soundness of a particular license.

b) Traffic Density Considerations

1) Since the exposed sites presented by public traffic routes are so diverse three alternatives are provided as follows :

The use of full IBD protection for heavily used routes

The use of a reduced Public Traffic Route distance, generally 2/3 of the appropriate IBD for less heavily used routes, and

The use of a lower distance for routes which are used intermittently or infrequently by low numbers of people.

2) The dominant factors which determine the number and severity of road casualties are the traffic speed and density, the width of traffic lanes and their number, the presence of crash barriers, the surface condition and the radius of any curves. Factors of less importance are the presence or absence of roadside trees and ditches and of separated carriageways for opposing traffic. For other types of routes it is essentially the density and speed of the "traffic" which are the critical factors.

3) Because of the variety of waterway borne traffic some cognisance may need to be taken of special factors, e.g. passenger carrying ferries which, although traversing the hazarded area much quicker than other craft, may merit special consideration because of the number of passengers carried.

1.3.1.15. *Inhabited Building Distances*

a) General

These distances are the minimum permissible distances between PES and inhabited buildings or assembly places. The distances are intended to prevent serious structural damage by blast, flame or projections to ordinary types of inhabited buildings (23 cm brick or equivalent) or caravans and consequent death or serious injuries to their occupants.

b) Inhabited Building Distances for Hazard Division 1.1.

1) The distances for Hazard Division 1.1 are based on tolerable levels of damage expected from a side-on overpressure of 5 kPa. They are intended to ensure that the debris produced in an accidental explosion does not exceed one lethal fragment (energy > 80 J) per 56 m² at the Inhabited Building Distance. They are not sufficiently large to prevent breakage of glass and other frangible panels or cladding used in the three types of buildings of vulnerable construction. This broken glass, cladding etc. can cause injury to occupants and those in the

immediate vicinity of the buildings. Such buildings of vulnerable construction should be situated as follows:

(a) Types 1 and 2: are considered to be of similar vulnerability and such buildings should normally be situated at distances not less than two times Inhabited Building Distances (i.e. > 44.4 $Q^{1/3}$) (see paragraph 1.3.7.6.). However, such buildings, but probably not schools or hospitals, may be acceptable within the 44.4 $Q^{1/3}$ distances, particularly if the population outside the building (on whom the displaced glass etc. would fall) is small or virtually nil. When vulnerable buildings have been allowed within the 44.4 $Q^{1/3}$ distances on these grounds, it will be necessary to check at regular intervals that the original conditions (i.e. area around building free of people) have not changed.

(b) Type 3: presents a difficult problem and it is intended to cover the multiplicity of new construction types which have been introduced since the curtain wall concept was first thought of. Each such building has to be treated on its merits, the hazard assessed and an appropriate quantity-distance selected. It is likely, however, that this will be in the 44.4 $Q^{1/3}$ region.

2) The Australian/UK Stack Fragmentation trials in the late 1980s have demonstrated that, for a Net Explosives Quantity of less than 5 600 kg, if the Potential Explosion Site is of light construction, typically 230 mm brick or equivalent or less, and traversed, then the hazard from projection is tolerable at D12-distances subject to a minimum of 270 m. However, if a medium or heavy walled construction, typically 200 mm concrete or greater, is employed at the Potential Explosion Site, then the hazard from projection requires a minimum separation distance of 400 m. For a Net Explosives Quantity greater than 5 600 kg, the prescribed Inhabited Building Distance D13 will provide an acceptable degree of protection from both blast and projections. These trials also demonstrate that the hazard from projections is not constant and shows a marked directional effect. Basically, there is a very low density of projections in directions directly away from the corners of the structure. The projection density rises almost as an exponential function to a maximum in the direction normal to any face of the structure. This is repeated on all sides of the structure irrespective of whether the structure is traversed or not. It is extremely difficult to interpret the results to give general guidelines and it is advised that where it is considered that siting of the Exposed Site with respect to the Potential Explosion Site might be beneficial, then the Stack Trial results should be considered in detail for each specific case.

3) A 400 m minimum Inhabited Building Distance is required to protect against structural debris from igloos, other earth-covered structures or untraversed buildings.

4) The distances for explosives of Hazard Division 1.1 are based on the behaviour of typical packaged military explosives. They take account of trials using bulk demolition explosives in wooden boxes or pallets in open stacks. In certain special circumstances, for Net Explosives Quantities of less than 4 500 kg, these distances would be unduly conservative, since hazardous projections cannot arise. Such circumstances may occur at test sites and factories where bulk explosives, devoid of metal casing or components, are in fibreboard packagings, not on pallets, and are either in open stacks or in light frangible buildings. In these special circumstances use D13-distances, as appropriate, without any overriding minimum distance for projections.

5) There is a significant hazard even at 270 m from ammunition and explosives of Hazard Division 1.1 due to fragments and a considerable amount of debris unless these projections are intercepted by structural protection. This hazard may be tolerable for sparsely populated areas, where there would be a small expectation of damage and injury from such projections, but in densely populated areas considerations should be given to the use of a minimum Inhabited Building Distance of 400 m. This distance is required for earth-covered magazines and for heavy-walled buildings.

c) Inhabited Building Distances for Hazard Division 1.2.

The distances for Hazard Division 1.2 are based on an acceptable risk for fragments. Under normal conditions D1- or D2-distances given in Annex A, Table 2 must be used for inhabited buildings. A fixed distance of 180 m or 270 m, as appropriate, independent of quantity, is permitted if arrangements are made to evacuate or shelter in an emergency persons who may be located within the D1- or D2-distances as appropriate. However, in any case, the D1- or D2-distances must be used for hospitals, schools, churches, factories etc..

d) Inhabited Building Distances for Hazard Division 1.3.

1) The distances for Hazard Division 1.3 are based on a thermal flux criterion of 1.5 cal per cm^2. It is anticipated that occupants of traditional types of inhabited buildings would not suffer injury unless standing in front of windows; such persons and other in the open are likely to experience reddening of any exposed skin areas.

2) If venting from the Potential Explosion Site is directed towards the Exposed Sites at Inhabited Building Distances, then a minimum distance of 60 m should be employed.

Section II - Determination of Quantity-Distances

1.3.2.1. *Quantity-Distances Tables*

a) The quantity-distances required for each hazard division are given in tables in Annex A, Section II.

b) For an intermediate quantity between those given in the tables, the next greater distance in the tables should be used when determining a quantity-distance. Conversely the next lesser quantity in the tables should be used when determining an explosives quantity limit for a given intermediate distance, alternatively, the distances corresponding to an intermediate quantity may be either calculated from the distance function shown in the tables of Annex A or found by interpolation and then rounded up in accordance with Annex A, Section I, paragraph 2.

c) Quantity-distances for a quantity of explosives greater than 250 000 kg are determined by extrapolation using the appropriate formula in Part II, Annex A, as far as the explosives safety factors are concerned, but adequate consideration should be given to the economic and logistic implications of such a large quantity in a single storage site.

d) The tables in Annex A provide quantity-distances for an earth-covered magazine up to 250 000 kg NEQ. However, certain designs of earth-covered magazines require a lower limit in the case of Hazard Division 1.1. The reason is that the blast load from an exploding earth-covered magazine is a function of the NEQ, whereas the blast resistance of an exposed earth-covered magazine depends on its design. The limitation for a particular earth-covered magazine must be obtained from the design authority.

e) Examples of the use of the quantity-distance tables are given in Annex A, Section III.

1.3.2.2. *Measuring of Quantity-Distances*

a) Quantity-distances are measured from the nearest point of the PES to the nearest point of the ES. Distances are measured along a straight line without regard to barricades.

b) Where the total quantity of ammunition and explosives in a storage site or explosives workshop is so separated into stacks that the possibility of mass explosion is limited to the quantity in any one stack, distances are measured from the outside of the wall adjacent to the controlling explosives stack to the nearest outside wall of another structure. If the separation to prevent mass explosion is provided by one or more substantial dividing walls, then the distances are measured from these walls, if appropriate, instead of from the outside walls of the building. Where not so separated the total quantity subject to mass explosion is used for quantity-distance computations.

1.3.2.3 *Net Explosives Quantity*

a) The total Net Explosives Quantity of ammunition in a single PES is used for the computation of quantity-distances unless it has been determined that the effective quantity is significantly different from the actual NEQ.

b) Where two or more PES are not separated by the appropriate Inter-Magazine Distances, they are considered as a single site and the aggregate NEQ is used for determining Quantity-Distances. If two or more hazard divisions are involved the principles in paragraph 1.3.2.5. apply.

c) The total explosives content of rounds or ammunition classified as HD 1.2 is used in the computation of the NEQ for quantity-distance purposes.

d) The quantity of single base (NC) propellants, having a web size of 0.5 mm or more, in fixed or semifixed ammunition and mortar ammunition in Hazard Division 1.1 is excluded from the total NEQ used for computation of quantity-distances, except where this ammunition is stored underground or in an earth-covered magazine. (Joint UK/US tests with small stacks of ammunition in the open have shown that such propellants do not contribute significantly to the blast from the high explosives in the projectiles. The effects of severe confinement as in underground storage or in an earth-covered magazine are not known).

e) The effects with double- or triplebase propellants require specific evaluation.

1.3.2.4. *Determination of Quantity-Distances*

a) The location of buildings or stacks containing ammunition or explosives with respect to each other and to other ES is based on the total NEQ in the individual buildings or stacks unless this total quantity is so subdivided that an incident involving any one of the smaller concentrations cannot produce a practically instantaneous explosion of the whole contents of the building or stack.

b) The quantity-distances required from each of two or more nearby storage sites or explosives workshops to contain ammunition and explosives of one hazard division are only determined by considering each as a PES. The quantity of explosives permitted in the storage sites or explosives workshops is limited to the least amount allowed by the appropriate table for distances separating the storage sites or explosives workshops concerned.

c) The quantity-distances required from each of two or more nearby storage sites to contain given quantities of ammunition and explosives of different hazard divisions at different times are determined as follows:

1. Consider each building or stack, in turn, as a PES.

2. Refer to the table of each hazard division which can be stored in the building or stack considered as a PES.

3. Determine the quantity-distances for each hazard division as the minimum to be required from the building or stack.

4. Record the quantity-distances in terms of each hazard division in each instance as those to be required from the building or stack.

d) Alternatively calculate the permitted quantity of each hazard division based upon the available distances.

1.3.2.5. *Required Quantity-Distances of Ammunition or Explosives of more than one Hazard Division in a Single Site*

When ammunition or explosives of different hazard divisions are kept in a single site at the same time, the required quantity-distances are determined as follows using the Q-D Tables in Annex A, Section II:

1) When ammunition or explosives of Hazard Division 1.4 are kept in the same site as ammunition or explosives of one or more other hazard divisions, the Hazard Division 1.4 is ignored subject to the overriding requirement of 25 m where appropriate, see Annex A, Section II, paragraph 9.

2) When different types of ammunition of Hazard Division 1.2 are kept in the same site, the required quantity-distance is that given for the aggregate quantity taken as the more hazardous type (see subparagraph 1.3.1.5.b)).

3) When different types of ammunition of Hazard Division 1.3 are kept in the same site, the required quantity-distance is that given for the aggregate quantity requiring the largest quantity-distance in Tables 3A or 3B (see subparagraphs 1.3.1.6.a) - c)).

4) When ammunition or explosives of Hazard Division 1.1 and 1.2 are kept in the same site, determine the quantity-distance for the aggregate quantity (i.e. the total quantity of Hazard Divisions 1.1 and 1.2) considered as Hazard Division 1.1. Next determine the quantity-distance for the aggregate quantity considered as Hazard Division 1.2, taking account of 2) above, when appropriate. The required quantity-distance is the greater of these two distances.

5) When ammunition or explosives of Hazard Division 1.1 and 1.3 are kept in the same site, determine the quantity-distance for the aggregate quantity considered as Hazard Division 1.1. Next, determine the quantity-distance for the aggregate quantity considered as Hazard Division 1.3. The required quantity-distance is the greater of these two distances.

6) When ammunition or explosives of Hazard Division 1.2 and 1.3 are kept in the same site, determine the quantity-distance for the amount of Hazard Division 1.2. Next, determine the quantity-distance for the amount of Hazard Division 1.3. The required quantity-distance is the greater of these two distances.

7) When ammunition or explosives of Hazard Divisions 1.1, 1.2 and 1.3 are kept in the same site, determine the quantity-distance for the aggregate quantity considered as Hazard Division 1.1, next as Hazard Division 1.2 and finally as Hazard Division 1.3. The required quantity-distance is the greatest of these three distances.

1.3.2.6. *Permissible Quantities of Ammunition or Explosives of more than one Hazard Division in a Single Site*

When ammunition or explosives of different hazard divisions are kept in a single site at the same time the permissible quantities are determined as follows using the Q-D Tables in Annex A, Section II:

1) When ammunition or explosives of Hazard Division 1.4 are kept in the same site as ammunition or explosives of one or more other hazard divisions, any quantity of Hazard Division 1.4 may be included subject to the availability of the 25 m distance where appropriate, see Annex A, Section II, paragraph 9.

2) When different types of ammunition of Hazard Division 1.2 are kept in the same site, the permissible aggregate quantity is that given for the more hazardous type (see subparagraph 1.3.1.5.b)).

3) When different types of ammunition of Hazard Division 1.3 are kept in the same site, the permissible aggregate quantity is the lower quantity in Tables 3A or 3B (see subparagraph 1.3.1.6.a) - c)).

4) When ammunition or explosives of Hazard Divisions 1.1 and 1.2 are kept in the same site, the permissible aggregate quantity of Hazard Division 1.2 is determined as described in 2) above. Next, determine the permissible quantity of Hazard Division 1.1. The permissible quantity of the combined hazard divisions is the smaller of these two quantities.

5) When ammunition or explosives of Hazard Divisions 1.1 and 1.3 are kept in the same site, determine the permissible quantity for each hazard division. The permissible quantity of the combined hazard divisions is the smaller of these two quantities.

6) When ammunition or explosives of Hazard Divisions 1.2 and 1.3 are kept in the same site, determine the permissible quantity for each hazard division separately. The two quantities may be stored together independently.

7) When ammunition or explosives of Hazard Division 1.1, 1.2 and 1.3 are kept in the same site, determine the permissible quantity of Hazard Division 1.1 alone, next, the permissible quantity of Hazard Division 1.2 alone, and finally the permissible quantity of Hazard Division 1.3 alone. The permissible quantity of the combined hazard divisions is the smallest of these three quantities.

1.3.2.7. *Relaxation of Quantity-Distances*

a) Interior Quantity-Distances

1) Relaxation of Inter-Magazine Distances may result in the total loss of stocks in other buildings or stacks or at least their being rendered unserviceable. Furthermore, a much larger explosion may result than that used as basis for Exterior Quantity-Distances. Disastrous damage to property and injury to the general public may be the consequence.

2) Relaxation of Explosives Workshop Distances may be permitted when a specially constructed building is available to protect against blast and debris or where the number of persons in the workshop is small.

b) Exterior Quantity-Distances

Relaxation of Exterior Quantity-Distances may increase the hazard to life and property. Relaxation should therefore be permitted only with the written consent of the appropriate authorities (see also subparagraph 1.1.1.1.d)).

Section III - Quantity-Distances for Certain Types of Ammunition and Explosives

1.3.3.1. *Barricaded Stacks of Ammunition*

a) Stacks (Modules) of Bombs etc.

D1-distances up to 30 000 kg and D2-distances from 30 001 to 120 000 kg as shown in Annex A, Section II, Table 1 may be used between unboxed bombs of Hazard Division 1.1 under the following conditions:

1) The stacks are to be separated by effective earth barricades.

2) The bombs must be relatively strong so as to withstand intense air shock without being crushed.

3) There should be the minimum of flammable dunnage etc., which could catch alight and lead to subsequent mass explosion of a stack.

4) When the D1-distances are used then the stacking height must not exceed 1 m.

In the event of an explosion in one stack the distances will provide a high degree of protection against simultaneous detonation of bombs in adjacent stacks. Some of the bombs in the ES may be buried and not immediately accessible, some may be slightly damaged. There may be occasional fires and delayed low order explosions, particularly if the bombs are stacked on concrete storage pads.

b) Other Unpackaged Ammunition of Hazard Division 1.1

In principle, the foregoing distances and conditions may be applicable to other kinds of unboxed ammunition of Hazard Division 1.1 and Compatibility Group D. An example is the 155 mm shell M107 which has a robust steel casing and a relatively insensitive high explosive filling. Each case must be judged on its merits, using ad hoc tests or analogy with existing test data as requisite.

c) Cluster Bomb Units

Tests have shown that certain packaged cluster bomb units (CBU) may be stored safely in accordance with subparagraph a) above. In this case, it is the robust containers rather than the heavy casings which prevent sympathetic detonation between stacks. Each type of bomblet and container must be carefully assessed to ensure a satisfactory combination for the application of this modular storage.

d) Buffered Storage

1) Tests have shown that stacks of certain types of bombs can be stored in the same facility in such a manner separated by using buffer materials (ammunition as well as inert materials), that even though a high order detonation will propagate through one stack it will not propagate to the second stack. Storage under these conditions presents the risk of explosion of a single stack only, rather than a mass risk involving all the stacks in one module, cell, or building. Hence, the Net Explosives Quantity (NEQ) of the larger stack plus the NEQ of the "buffer" material, if any, may be used to determine the quantity-distances requirement for each entire module or building so used.

2) The storage of bombs using the buffered storage concept and basing the NEQ of storage on the NEQ of the largest stack plus the buffer material is authorized provided nationally approved storage arrangements are used. See Part II, Chapter 3, Section I.

1.3.3.2. *Unbarricaded Stacks of TNT or Amatol Filled Shell*

Certain types of TNT or Amatol filled projectiles of Hazard Division 1.1 may be stored in stacks which comply with the principle that, although a high order detonation would propagate throughout a stack, it would be unlikely to propagate from stack to stack. Storage under these conditions presents the risk of explosion of a single stack only, rather than a mass risk involving all the stacks in one module or building. Hence the NEQ of the appropriate single stack may be used to determine the quantity-distances for each entire module or building so used. The special types of projectiles and the conditions are given in Part II, Chapter 3, Section I.

1.3.3.3. *Unbarricaded Storage of Fixed Ammunition with Robust Shell*

Trials show that ammunition comprising robust shell with an explosive content not exceeding about 20 % of the total weight (excluding propelling charges, cartridge cases and weight of packages) and with shell-walls sufficiently thick to prevent perforation by fragments produced by ammunition of Hazard Division 1.1 may be stored without barricades without the risk of practically instantaneous explosion provided an increased quantity-distance is used.

1.3.3.4. *Complete Rounds*

Complete rounds of fixed or semifixed ammunition of Hazard Division 1.1 involve also the risk of Hazard Division 1.2. Therefore, the greater of the distances given in Annex A, Table 1 or Table 2 is observed.

1.3.3.5. *Propulsive Rockets*

Rockets stored in a propulsive state (i.e. unpackaged propulsive rockets and missiles in the assembled condition, waiting to be placed upon a tactical launcher or vehicle) present special problems in which the flight range of the rocket is the main safety criterion rather than the explosive content. Consequently the rockets should be stored in special buildings or held by devices to prevent their flight (see Part II, Chapter 3, Section II). The quantity-distances for the appropriate hazard division apply only when these conditions are met, except for the special case of missiles on the launchers at a missile installation (see Part IV, Chapter 3). Rockets or missiles in either an assembled or unassembled condition, when packaged as for storage and transport, do not in practice present the risk of significant flight.

1.3.3.6. *Storage of Very Sensitive Explosives*

It is possible for the blast at an ES to cause practically instantaneous initiation of packaged primary explosive substances and certain other very sensitive explosive substances like blasting gelatine even when barricaded at the D4-distances in Annex A, Table 1. Storage conditions for such explosives are assessed individually taking account of the protection afforded by packaging and the building at the ES.

1.3.3.7. *Storage of Depleted Uranium (DU) Ammunition*

Quantity-distances will, in general, be those appropriate to the Hazard Classification of the particular ammunition stored. In some cases a special radiological safety distance may be required between a storehouse and the nearest point of public access if it is estimated that the adverse radiological/toxic effects of an atmospheric dispersion of DU could give rise to a possibility of injury to a member of the public comparable to that caused by the explosive components of the ammunition. In such a case the more restricted of the two distances, the radiological safety distance or the explosives quantity-distance, shall be the one applied.

Section IV - Quantity-Distances for Certain Exposed Sites

1.3.4.1. *Separation of Miscellaneous Occupied Buildings and Facilities in an Explosives Area*

Buildings containing empty packages or other inert materials should be separated from a PES by a distance based on the risk to the ammunition and explosives from a fire in the empty packages or other inert materials (minimum distance 25 m). Special consideration should be given to the separation of high value packages from a PES.

1.3.4.2. *Criteria for Siting of Holding, Marshalling and Interchange Yards*

a) Holding Yards

Each holding yard is considered to be a PES. Quantity-Distances and/or explosive limits are determined as for storage sites.

b) Marshalling Yards

1) Appropriate Inter-Magazine Distances must be applied to protect a marshalling yard from external explosions.

2) It is not necessary to treat a marshalling yard as a PES provided the vehicles are moved expeditiously from the yard. If a yard is used at any time for purposes other than marshalling, e.g. holding, it is considered to be a PES and appropriate quantity-distances as for storage site applied.

c) Interchange Yards

It is not necessary to treat an interchange yard as a PES, provided the vehicles are moved expeditiously from the yard. However, if a yard is used at any time for a purpose other than interchange, it is considered to be a PES and appropriate quantity-distances applied.

1.3.4.3. *Separation of Pipelines etc from an Explosives Area*

a) Aboveground Facilities

For the separation of POL facilities: see Chapter 5.

b) Underground Pipelines

For the separation of underground pipelines: see Chapter 5.

1.3.4.4. *Separation of Electric Supply and Communications Systems from an Explosives Area*

There may be mutual hazards created by siting an explosives area near to high voltage transmission lines, powerful transmitters, vital communications lines etc. Each case must be assessed individually to take account of the voltage and power involved, the importance of the transmission lines, the time for the necessary repairs and the consequences of losing communications at a time when assistance may be required following an explosion. The assessment should be based on the following factors:

1) Hazard from the Ammunition or Explosives

The Public Traffic Route Distance is a reasonable separation, subject to a minimum of 60 m, to protect public service or military emergency communication lines and overhead electrical power transmission lines exceeding 15 kV or associated substations. Particularly important installations such as the lines of a supergrid network should be given greater protection from fragments and debris by affording them one or even one and a half times the Inhabited Building Distance. This increased separation is also appropriate for microwave, ultra high frequency (UHF) reflectors which would be vulnerable to damage by air shock or debris and fragments. Minor transmission and communication lines such as those serving the buildings of the explosives area, may be sited in accordance with subparagraph 2) below.

2) Hazard to the Ammunition or Explosives

The quantity-distances determined on the basis of 1) above should be reviewed in the light of a possible hazard from electrical lines and transmitters to the ammunition and explosives themselves. If any overhead transmission line approaches nearer to a building containing ammunition or explosives than one span between the poles or pylons, consideration should be given to the consequences of mechanical failure in the line. Arcing and large leakage currents may be set up before the supply could be isolated. An overriding minimum separation of 15 m is prudent. Generating stations and substations should be at least 45 m from any building containing ammunition or explosives in view of the small but real risk of fire, explosions or burning oil in such electrical equipment. Powerful transmitters of electromagnetic energy may hazard electrically initiated ammunition. See Chapter 6.

1.3.4.5. *Explosives Storage Site/Depot Safety*

a) Protective Zones Around a Depot or Storage Site.

Subject to national regulations it is advisable that any depot or Potential Explosion Site be surrounded by zones, out to the distance at which the hazard is considered tolerable, within which construction is controlled or made subject to special authorization.

b) Procedures for Safety Site Plans.

1) Since all explosives areas require quantity-distance (QD) separations, a safety site plan is necessary to demonstrate these separation distances are provided before construction commences, or explosives are deployed into any given area. Maps and drawings will demonstrate graphically that separation distances are in compliance with appropriate tables in this Manual. The damaging effects of potential explosions may also be altered by barricades and specialized construction features. Site plan submissions will also demonstrate when these features exist and provide details for review by safety authorities. The following kinds of information constitute a safety site plan:

(a) A Q-D schedule providing the hazard division and net explosive quantity (NEQ) assigned to each potential explosion site (PES).

(b) A map of the explosives area in relation to other internal facilities and buildings, surrounding villages, highways and cities (exterior Q-D).

(c) Drawings showing the location of explosives buildings in relation to one another (interior Q-D).

(d) Drawings showing details of construction features which affect quantity-distances

2) The NATO force sponsoring the new facility should require the preparation of a safety site plan and its submission through appropriate military and national authorities for review and approval. Normally, the military command planning to use the new facility will provide the specific details to support preparation of the site plan document. However, administrative details are properly the business of individual member nations. The intent of this requirement is to ensure that documentation is provided for competent review before funds are committed.

1.3.4.6. *Levels of Protection*

A more detailed examination of the levels of protection afforded by the quantity-distances given in Annex A, Tables 1-3B, and of the structures and activities considered acceptable at each protection level is given in Section VII for Hazard Division 1.1.

Section V - Storage Buildings: General Principles and Influence on Quantity-Distances

1.3.5.1. *General*

a) It is not considered practicable to construct surface buildings which withstand direct attack by hostile activities but in order to reduce the hazards and the quantity-distances as far as practicable, certain precautions in building construction should be observed.

b) The construction of buildings for one hazard division only is uneconomic. Buildings may be used for storage of different hazard divisions because storage requirements vary in the course of time.

c) The distances in Annex A, Tables 1 to 3 are based on explosives safety. They do not take account of structural requirements, space for roads and access for fire-fighting. These practical considerations may require greater distances than given in the tables. Guidance on structural requirements is given in Part II, Chapter 3, Section II.

1.3.5.2. *Igloos*

a) A storage site comprising igloos gives the simplest and safest set of Inter-Magazine Distances when it is a rectangular array with the axes of the igloos parallel and the doors all facing in one direction. A front-to-front configuration should be avoided since this requires a very large separation of the igloos. It may be expedient to arrange the igloos back-to-back in two rows, but this configuration may be less flexible for further development of the storage area.

b) Igloos which conform to the minimum design criteria in Part II, paragraph 2.3.2.2. qualify for reduced Inter-Magazine Distances compared with other types of aboveground magazines and open stacks. Igloos of a strength exceeding the minimum prescription may warrant further reductions in Inter-Magazine Distances. Conversely, the earth-covered buildings described in Annex, subparagraph 6.d) require larger Inter-Magazine Distances. It is for the National Authority to balance the cost of various types of construction against the cost and availability of real estate and to determine the optimum balance in any particular situation.

1.3.5.3. *Blast Resistance of Structures at Exposed Sites*

It may be possible for a structure at an ES to fail under blast loading so that its contents are initiated practically instantaneously. This may be the result of major internal spalling from walls, implosion of the door(s) or catastrophic failure of the entire structure. The quantity-distances in Annex A, Table 1 presume that a structure at an ES is designed either to be strong enough to withstand the blast or to be so light that secondary projections from the structure do not initiate the contents taking account of their sensitiveness. An ES containing ammunition vulnerable to attack by heavy spalling (e.g. missile warheads filled with relatively sensitive high explosives) requires special consideration, see Part II, Chapter 5.

1.3.5.4. *Influence of Protective Construction upon Quantity-Distances*

a) A building with marked asymmetry of construction, such as an igloo or another building with protective roof and walls, but with one relatively weak wall, induces very directional effects from the flames and the projection of burning packages containing ammunition and explosives of Hazard Division 1.3. However, it is assumed for simplicity that the effects from Hazard Division 1.3 are symmetrical about a PES, although it is known that other structural characteristics and the wind can be significant.

b) Roofs may be designed to have special functions, such as:

1) Containment of fragments and prevention of lobbing of ammunition (the roof on a PES).

2) Shielding against blast, projections and lobbed ammunition (the roof on an ES).

The quantity-distances for buildings which contain fragments etc. depend upon the particular design specifications. The reduced quantity-distances resulting from shielding roofs are incorporated in the Tables in Annex A.

c) Walls may be designed to exclude firebrands, projections and lobbed ammunition. The resultant reduced quantity-distances are incorporated in the Tables in Annex A. However, a reduction often depends also on the provision of shielding roofs.

1.3.5.5. *Construction to Contain Fragments and to Prevent Lobbing*

a) The design of structures to contain projections or lobbed ammunition of Hazard Division 1.1 is an extremely complicated procedure and, unless warranted due to other special circumstances, is prohibitive in cost.

b) In practice, it is generally only feasible to design a structure when the NEQ is small or when the total content of the building is divided into smaller units by dividing walls which prevent the mass explosion of the entire content of the building in the event of explosion of one of the units. The design of a structure to contain projections and lobbed ammunition represents a more stringent requirement than that for dividing walls to prevent propagation.

1.3.5.6. *Structures to Protect from Flame, Projections and Lobbed Ammunition*

a) Protection from Effects of Ammunition of Hazard Division 1.1

1) Protection against High Velocity Projections from the Explosion of Stacks of Ammunition

Ammunition stacks in the open or in buildings can produce high velocity projections during an explosion. These projections may penetrate storage buildings and retain sufficient energy to initiate the contents practically instantaneously. Certain of the Q-Ds in Annex A (igloos, rows 7, 8 and 9) presume that the roof, headwall and door(s) of igloos at the ES will arrest these high velocity fragments. The presence of a barricade around the stack or building is always preferred because of the increased protection given against attack by high velocity projections.

2) Protection against the Explosion on Impact of Lobbed Ammunition

In the case of accident or fire, ammunition may be lobbed from any of the PES in Table 1. Ammunition is least likely to be lobbed from the PES described in columns a and b and more likely to be lobbed as the PES description changes from c to f. These lobbed items may explode on impact (see subparagraph 1.2.1.2.b)). The fragments from these may penetrate stacks in the open or in a storage building and retain sufficient energy to initiate the stacks practically instantaneously. Certain of the quantity-distances in Annex A (igloos, rows 7, 8 and 9) presume that the roof, headwall and door(s) at the ES will arrest these high velocity fragments, but not necessarily lobbed items larger than 155 mm shell (see subparagraph 1.2.1.2.b)). The presence of a barricade around a building is always preferred and gives increased protection against the high velocity projections, with the exception of those arising from items lobbed over the barricade.

b) Protection from Effects of Ammunition of Hazard Division 1.2 or 1.3

Certain types of construction provide a reasonable degree of protection against firebrands, comparatively low velocity projections, and lobbed ammunition (see Part II, paragraph 2.3.2.3.). Examples are:

1. An earth-covered building with a headwall and door(s) of 15 cm reinforced concrete or equivalent.

2. A heavy-walled building.

3. A barricaded explosives workshop with a protective roof.

In such cases the smaller Interior Quantity-Distances in Annex A, Table 2 or Table 3 are used. If the door or one weak wall etc. does not completely conform to the above requirements, such smaller distances should only be authorized after a special assessment of the relative orientation of the weak elements and the hazards involved.

Section VI - Barricades: General Principles and Influence on Quantity-Distances

1.3.6.1. *Functions of Barricades*

a) An effective barricade arrests high velocity projections at low elevation from an explosion which otherwise could cause direct propagation of the explosion.

b) A vertical faced barricade close to a PES also reduces the projection of burning packages, ammunition and debris.

c) A barricade may also provide limited protection against blast and flame arising either from an external or from an internal explosion when the quantity of explosives is relatively small as it usually is in explosives workshops.

1.3.6.2. *Influence of Barricades upon Quantity-Distances for Hazard Division 1.1*

a) Inter-Magazine Distances

An effective barricade avoids the use of very large Inter-Magazine Distances around a site containing ammunition of Hazard Division 1.1. This is a significant factor in the cost of a depot. The reduced quantity-distances are given in Annex A, Table 1.

b) Explosives Workshop Distances

An effective barricade avoids the use of large Explosives Workshop Distances from PES containing ammunition of Hazard Division 1.1. A barricade or heavy wall around an explosives workshop considered as an ES may provide some protection for personnel in the lee of the barricade.

c) Exterior Quantity-Distances

Investigation of damage caused by blast and projections in recorded accidents and trials shows that, in the case of Hazard Division 1.1, the difference between the Exterior Quantity-Distances required for barricaded and unbarricaded buildings or stacks respectively, is too small to be taken into account.

1.3.6.3. *Influence of Barricades upon Quantity-Distances for Hazard Division 1.2 or 1.3*

A barricade, other than a door barricade, does not itself generally provide sufficiently effective protection against flame, radiant heat, projections and lobbed ammunition to justify a reduction of the Inter-Magazine Distances around a PES containing Hazard Division 1.2 or 1.3. However, to achieve flexibility in the use of sites, each one should be effectively barricaded.

1.3.6.4. *Influence of Door Barricades upon Quantity-Distances for Hazard Division 1.1*

A door barricade is superfluous, as far as the use of Inter-Magazine Distances is concerned, when igloos or other earth-covered buildings are sited side-to-side or rear-to-rear. When the front of such a building at an ES faces the side or rear of an earth-covered building at a PES, a door barricade may intercept concrete debris but the major consideration is the blast resistance of the headwall and door(s) at the ES and this is not much affected by the barricade. When such buildings are sited front-to-front, a door barricade may be ineffective. As regards personnel hazards, a door barricade of reasonable height does not intercept debris which is lobbed or projected at a high elevation.

1.3.6.5. *Influence of Door Barricades upon Quantity-Distances for Hazard Division 1.2*

A fire in an earth-covered building containing ammunition of Hazard Division 1.2 produces a serious hazard through the doorway from fragments and ejected ammunition. This hazard is reduced by providing a separate barricade, with a vertical wall facing the door. Such a barricade at an ES permits reduced distances shown in Annex A, Table 2.

1.3.6.6. *Influence of Door Barricades upon Quantity-Distances for Hazard Division 1.3*

a) The deflagration of propellants in an igloo or similar earth-covered building produces marked directional effects in the hazardous sector which is taken to be the area bounded by lines drawn from the centre of the door and inclined 30° on either side of a perpendicular to the door. This hazard is reduced by a door barricade, at the PES, which has a vertical wall facing the door and is preferably backed with earth. Such a barricade permits the use of the reduced quantity-distances in Annex A, Table 3A. This door barricade is not necessary when the door of the building at the PES faces an earth-covered rear or side wall of a building at an ES, or faces an explosives workshop which has both a barricade and a protective roof.

b) The burning of items other than propellants in an igloo or similar earth-covered building produces a hazard from fragments and projected items in the sector in front of the door. This hazard is reduced by providing a separate barricade, with a vertical wall facing the door. Such a barricade at both a PES and at an ES permits reduced distances shown in Annex A, Table 3B.

1.3.6.7. *Quantity-distances between earth-covered buildings with common earth cover*

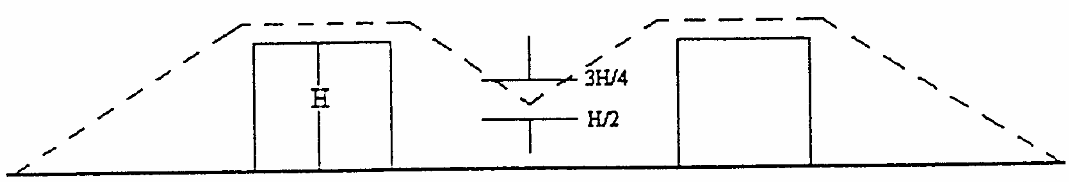
a) In the case of a detonation, the type of earth cover between earth-covered buildings affects the load on the acceptor igloo. The earth cover should be at least 0,6 m in depth. A slope of two to one, meaning one unit of vertical rise for every two units of horizontal run is recommended for the earth cover. The earth should comply with Part II, Para 2.3.3.3. An earth-covered building often provides virtually complete protection to its contents from the effects of an incident at a potential explosion site (PES) containing ammunition and explosives of Hazard Division 1.2 or 1.3. When two or more buildings share a common earth cover, the amount of ammunition and explosives permitted in them is less than it would be if the buildings had separate earth cover. This is due to the earth couple between the two PES´s, meaning the earth will transmit the explosive shock loading with greater efficiency than air. In order to accommodate various types of earth, the following Q-D is applied:

1) If the two earth covers intersect at a point 3/4 the height of the structures or higher, Column D5 distances apply.

2) If the two earth covers intersect at a point between 3/4 and 1/2 the height of the structures, Column D4 distances apply.

3) If the two earth covers intersect at, or below, a point 1/2 the height of the structures, there is no Q-D reduction and Column D3 applies.

These distances refer to earth-covered buildings as specified in Annex II B. In the case of unspecified earth-covered buildings in principle Column D6 distance applies.



b) When earth-covered buildings, which meet the requirements of subparagraph 1.3.6.7.a) and have an internal volume exceeding 500 m^3, are considered as PES, then for NEQ of Hazard Division 1.1 ammunition not exceeding 45 000 kg the following quantity-distances should be applied to side- and rear-configurations only:

1) Inhabited Building Distances

D15-distances in Table 1 may be used from the sides of the earth-covered building (PES) and D14-distances from the rear of the same building, but in no case must the quantity-distance be less than 400 m. Definitions of front/rear/side configurations are given in Annex A, Section I, Note 1.

2) Public Traffic Route Distances

The Public Traffic Route Distances may be reduced to 2/3 of the Inhabited Building Distances (D14- and D15-distances respectively) as calculated in subparagraph 1), with a minimum of 270 m. These distances (D16- and D17-distances) are shown in Table 1. However, the full Inhabited Building Distances (D14- and D15-distances) with a minimum distance of 400 m should be used, when necessary, in accordance with subparagraph 1.3.1.15.b).

1.3.6.8. *Partly Barricaded Buildings or Stacks*

Partly barricaded buildings or stacks are considered effectively barricaded only when both ends of the barricade extend 1 m beyond the ends of the protected sides of the buildings or stacks.

1.3.6.9. *Natural Barricades*

It is acceptable to take advantage of natural terrain where this provides protection equivalent to that of artificial barricades. However, it is found that hills are usually insufficiently steep or close to the ammunition or explosives and woods cannot usually be relied upon to provide the required protection.

1.3.6.10. *Barricade Design Criteria*

The details of what constitutes an effective barricade are given in Part II, Chapter 3, Section III.

Section VII -Injury and Damage to be Expected at Different Levels of Protection for Hazard Division 1.1 and Grouping of Structures and Facilities

1.3.7.1. *Introduction*

a) The purpose of applying Hazard Division 1.1 quantity-distances between PES and ES is to ensure that the minimum risk is caused to personnel, structures and facilities. In principle, those functions and facilities not directly related to operating requirements or to the security of ammunition and explosives should be sited at or beyond the Inhabited Building Distance.

b) In practice, it may not always be possible to provide this level of protection and some activities and facilities will of necessity be sited at less than the Inhabited Building Distance. In other cases, the nature of the facility or structure requires that greater protection than that afforded by the Inhabited Building Distance, should be provided.

c) Damage to buildings and injury to personnel can result from either blast overpressure effects or from projections (ammunition fragments and building debris from the PES). The severity of the effects will be dependent on both the type of structure at the PES and at the ES. The levels of damage considered in this section are when the PES is an:

1) Open or lightly confined stack of ammunition and explosives.
2) Earth-covered building containing ammunition and explosives.

d) The blast overpressure predictions in this section are relevant for quantities in excess of 4 500 kg. For smaller quantities the damage and injury levels may be pessimistic.

1.3.7.2. *Purpose of the Section*

The aim of this section is to provide guidance on the kind of injuries and damage which can be expected at different levels of protection and to propose typical personnel or facilities for which these levels of protection might be considered acceptable. The standard base line for predicting blast parameters is that outlined in Part II, Chapter 5, Section III, modified as appropriate for the charge configuration, suppression by earth-cover or other technical considerations.

1.3.7.3. *Levels of Protection*

a) The blast overpressure effects to be expected at a given scaled distance can be predicted with a high degree of confidence. The technique is fairly well developed and the effects of blast may be treated deterministically, however, the techniques for determining the hazards from projections are considerably less developed and the effects require a probabilistic approach.

b) Blast Effects - Open Stacks and Light Structures

It can be assumed that the blast overpressure from a light structure is the same as that to be expected from a bare charge. This assumption is especially true as the scaled distance increases. The following levels of protection (scaled distances) are considered:

Scaled Distance (Q in kg, distance in m)	Peak Incident (Side-on) Overpressure Expected (bar)
55.5 $Q^{1/3}$	0.015
44.4 $Q^{1/3}$ to 33.3 $Q^{1/3}$	0.02 to 0.03
22.2 $Q^{1/3}$	0.05
14.8 $Q^{1/3}$	0.09
9.6 $Q^{1/3}$	0.16
8.0 $Q^{1/3}$	0.21
7.2 $Q^{1/3}$	0.24
3.6 $Q^{1/3}$	0.70
2.4 $Q^{1/3}$	1.80

c) Blast Effects - Earth-Covered Magazines

Earth-covered magazines will generally attenuate the blast overpressure, although in the near field enhanced overpressure can be expected from the front of an earth-covered magazine. The degree of reduction in blast overpressure from the sides and rear of the magazine decreases as the scaled distance and/or as the NEQ increases. In general the greatest reduction will be obtained from the rear of the earth-covered building. The following levels of protection (scaled distance) are considered:

Direction	Scaled Distance (Q in kg) (distance in m)	Peak Incident (Side-on) Overpressure Expected (bar)
Side	$18.0\ Q^{1/3}$	0.05
Rear	$14.0\ Q^{1/3}$	0.05
Side	$12.0\ Q^{1/3}$	0.09
Rear	$9.3\ Q^{1/3}$	0.09

These overpressures do not apply when the NEQ is greater than 45 000 kg and when the volume of the building is less than 500 m^3.

d) Projection Hazards - All Types of Potential Explosion Sites

The projection hazard from a PES cannot be related to the scaled distance. However, for all practical purposes, there is likely to be a hazard from projections at all scaled distances less than $14.8\ Q^{1/3}$, this hazard will be greater when the PES is not barricaded. Unless the ES has been provided with protection against all projections, including high angle missiles, then minimum distances at which the projection hazard is considered to be acceptable for a particular situation, have been introduced as follows:

1) 180 m

There is a significant hazard from projections at 180 m. This hazard is tolerable for:

- Public traffic routes when the traffic is not dense and when the PES is an open stack or a light structure.

- The protection of unbarricaded ammunition i.e., to prevent propagation from low trajectory high velocity projections.

2) 270 m

There is a significant hazard from projections at 270 m. The hazard is tolerable for:

- Main public traffic routes or when the traffic is dense and when the PES is an open stack or light structure.

- Public traffic routes when the traffic is not dense and when the PES is a heavy-walled or earth-covered building.

- Sparsely populated areas when the PES is an open stack or a light structure; there would be a small expectation of damage or injury from projections.

3) 400 m

There is a minor hazard from projections at 400 m. This hazard is tolerable for:

- Main public traffic routes or when the traffic is dense and when the PES is a heavy-walled or earth-covered building

- Built-up areas when the PES is an open stack or a light structure.

- All "Inhabited Buildings" when the PES is a heavy-walled or earth-covered building.

1.3.7.4. *Reduction of the Hazard*

Strengthening of buildings to prevent or reduce the hazard is feasible and may not be prohibitively expensive. The hazard may be reduced by:

1) Suitably designed suppressive construction at the PES, this is only practicable when the NEQ is relatively small for example reinforced concrete cubicles used in explosive process building construction have a maximum practical limit of about 250 kg. Standard NATO igloos can suppress about 100kg as a PES.

2) By designing the structures at the ES to withstand the overpressures and the debris and fragment attack.

3) The use of light structures for ES which although they will be severely damaged by the overpressure will not produce hazardous debris. In this case protection from high velocity debris and fragments by receptor barricades is essential.

1.3.7.5. *Protection Level 55.5 $Q^{1/3}$ - Open Stacks and Light Structures*

a) Expected Blast Effects

1) The overpressure expected at this distance (55.5 $Q^{1/3}$) will cause little or no damage to unstrengthened structures.

2) Injuries and fatalities are very unlikely as a direct result of the blast effects. There may be a minor hazard from broken glass or cladding falling from a considerable height so as to strike people.

b) Personnel and Facilities Acceptable

At this distance and beyond there is no restriction on personnel, activities or facilities.

1.3.7.6. *Protection Level 44.4 $Q^{1/3}$ to 33.3 $Q^{1/3}$ - Open Stacks and Light Structures*

a) Expected Blast Effects

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

2) When large panes of glass are exposed so as to face the PES, 50 % or more breakages may occur.

3) Injuries and fatalities are very unlikely as a direct result of the blast effects. Injuries that do occur will be caused principally by flying glass.

b) Personnel and Facilities Acceptable

Because even superficial damage may in some instances be unacceptable, National Authorities may require siting at these distances for facilities of especially vulnerable construction or public importance. Examples are:

1) Large facilities of special construction of importance including:

- Large factories of vulnerable construction.
- Multi-storey office or apartment buildings of vulnerable construction.
- Public buildings and edifices of major value.
- Large educational facilities of vulnerable construction.
- Large hospitals.
- Major traffic terminals (e.g. large railway stations, airports etc.)
- Major public utilities (e.g. gas, water, electricity works).

2) Facilities of vulnerable construction used for mass meetings:

- Assembly halls and fairs.
- Exhibition areas.
- Sports stadiums.

3) Built-up areas which are both large and densely developed.

1.3.7.7. *Protection Level 22.2 $Q^{1/3}$ - Open Stacks and Light Structures*

The equivalent protection levels in respect of earth-covered buildings greater in volume than 500 m^3 and when containing a NEQ of Hazard Division 1.1 less than 45 000 kg are:

- From the side: 18.0 $Q^{1/3}$
- From the rear: 14.0 $Q^{1/3}$

a) Expected Blast Effects

1) Unstrengthened buildings will suffer minor damage, particularly 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.

2) Injuries and fatalities are very unlikely as a direct result of the blast effects. Injuries that do occur will be caused principally by glass breakage and flying/falling debris.

b) Personnel and Facilities Acceptable

This distance is termed "Inhabited Building Distance" and is the minimum distance, in conjunction with the overriding minimum distances given in paragraph 1.3.7.3., at which inhabited buildings not directly connected with the functions of the Explosives Area should be sited. This level of protection is proposed as acceptable for the following kinds of facility:

1) Unbarricaded stacks of ammunition and explosives.

2) Structures and facilities in the administration area of a depot or factory with a considerable number of occupants (more than 20), examples are:

- Main office buildings.
- Non-explosives workshops.
- Mess halls and kitchens.
- Main canteens.
- Main shower and changing facilities.

3) Structures and facilities in the administrative area of a depot or a factory which are important for the functioning of the installation, examples are:

- Manned fire stations.
- Central heating plants.
- Main vehicle pools.
- Gasoline storage and dispensing facilities.
- Unprotected water supply and power installations.

4) Inhabited buildings (as defined by the National Authority), whether single buildings, communities or areas of scattered habitations.

5) Structures and facilities in which people assemble, except as indicated in subparagraph 1.3.7.6.b) above.

6) Facilities serving the safety and needs of the general public, examples are:

- Gas, water and electricity supply installations.

- Radar and communications stations.

7) Important lines of transport, examples are:

- Main railway lines.
- Motorways and major roads.
- Major navigable waterways.

1.3.7.8. *Protection Level 14.8 $Q^{1/3}$ - Open Stacks and Light Structures*

The equivalent protection levels in respect of earth-covered buildings greater in volume than 500 m^3 and when containing a NEQ of Hazard Division 1.1 less than 45 000 kg are:

- From the side: 12.0 $Q^{1/3}$
- From the rear: 9.3 $Q^{1/3}$

a) Expected Blast Effects

1) Unstrengthened buildings will suffer average damage costing in the range of 10 % of the total replacement costs to repair.

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

3) There is a fairly high probability that injuries will be caused by glass breakage and flying/falling debris.

b) Personnel and Facilities Acceptable

This distance is termed the "Public Traffic Route Distance" and is the minimum distance, in conjunction with the overriding minimum distances given in paragraph 1.3.7.3., at which routes used by the general public, for purposes unconnected with the explosives facility, should be sited (except when the PES is a heavy-walled building and when the route is a main route or when the traffic is dense). This level of protection is proposed as acceptable for the following kinds of facility:

1) Structures and facilities within an administration area connected with the explosives installation with a limited number of occupants (less than 20).

2) Facilities in which people assemble only temporarily and which can be quickly cleared. Examples are:

- Public paths.
- Recreational areas where no structures are involved.
- Parking places.
- Small arms ranges.

3) Railways, public roads and navigable waterways of minor to medium importance. (For public roads the risk of secondary injury can be reduced by ensuring that the road sides are free from obstacles which are likely to result in injuries to the occupants of vehicles leaving the road as a result of the driver's reaction to the explosion).

1.3.7.9. *Protection Level 9.6 $Q^{1/3}$ - Open Stacks and Light Structures*

a) Expected Blast Effects

1) Buildings which are unstrengthened can be expected to suffer damage to main structural members. 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 prohibitively expensive.

2) Cars may suffer some damage to metal portions of the body and roof by blast. Windows facing the blast may be broken, however, the glass should not cause serious injuries to the occupants.

3) Aircraft will suffer some damage to appendages and sheet metal skin. They should be operational with only minor repair (see also Part IV, Chapter 5).

4) Cargo type ships will suffer minor damage from blast to deck houses and exposed electronic gear (see also Part IV, Chapter 6).

5) Personnel may suffer temporary loss of hearing, permanent ear damage is not to be expected. Other injuries from the direct effects of blast overpressure are unlikely, although there are likely to be injuries from secondary effects, i.e. translation of objects.

b) Personnel and Facilities Acceptable

This should normally be the minimum distance at which unprotected duty personnel (troops, military and civilian maintenance and security personnel and crews of ships) should be permitted when their duties are not closely and specifically related to the PES. Examples are:

1) Open air recreation facilities used only by military personnel and where dependants and the general public are not involved.

2) Training areas for unprotected military personnel.

3) All military aircraft when the PES is not for the immediate service of the aircraft.

1.3.7.10. *Protection Level 8.0 $Q^{1/3}$ - Open stacks and Light Structures*

a) Expected Blast Effects

1) Buildings which are unstrengthened can be expected to suffer serious damage which is likely to cost above 30 % of the total replacement cost to repair.

2) Serious injuries to personnel, which may result in death, are likely to occur due to building collapse or loose translated objects.

3) 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.

4) Cargo ships would suffer damage to decks and superstructure. In particular doors and bulkheads on the weather-deck are likely to be buckled.

5) Aircraft are expected to sustain considerable structural damage.

b) Personnel and Facilities Acceptable

This distance is termed "Explosives Workshop Distance", the level of protection is proposed as acceptable for the following kinds of facility:

1) Explosives workshops in which the personnel present are kept to the minimum essential for the task.

2) Packing and shipping (transit) buildings in the Explosives Area.

3) Minor transmission and communication lines.

1.3.7.11. *Protection Level 7.2 $Q^{1/3}$*

This distance is used by US Authorities to define explosives workshop separation in the US and is comparable to Protection Level 8.0 $Q^{1/3}$. However, a great deal of information is available in the US for Protection Level 7.2 $Q^{1/3}$ and is included in this section for completeness.

a) Expected Blast Effects

1) Damage to unstrengthened buildings will be of a serious nature. Repair is likely to cost 50 % or more of the total replacement cost.

2) Personnel injuries of a serious nature or possible death are likely from debris of the building at the ES and from translation of loose objects.

3) There is a 1 % chance of eardrum damage to personnel.

4) Some possibility of delayed communication of explosion as a result of fires or equipment failure at the ES. There is a high degree of protection against direct propagation of an explosion.

5) Cargo ships would suffer some damage to decks and superstructure by having doors and bulkheads buckled by overpressure.

6) Aircraft can be expected to suffer considerable structural damage from blast overpressure.

b) Personnel and Facilities Acceptable

1) Workers engaged in major construction in the vicinity of ammunition production areas, waterfront areas where ammunition is being handled or areas used for the loading of aircraft with explosives.

2) Labour intensive operations closely related to the PES, including inert supply functions serving two or more identical or similar PES.

3) Rest and buildings for light refreshment for use of workers in the immediate vicinity. Such facilities will normally only be used when work is stopped in the nearby explosives buildings and should be limited to a maximum of 6 persons.

4) Area offices with a permanent occupancy of not more than 6 persons directly supporting the work of the Explosives Area or process buildings.

5) Guard buildings in which those security personnel directly responsible for the security of the Explosives Area are housed when not on patrol.

6) Unmanned buildings containing immediate reaction fire-fighting appliances.

7) Operations and training functions that are exclusively manned or attended by personnel of the unit operating the PES. This includes day rooms, squadron operations offices and similar functions for units such as individual missile firing batteries, aircraft squadrons, or ammunition supply companies. Manoeuvre area, proving grounds tracks and similar facilities for armoured vehicles together with the armoured vehicles themselves may provide adequate protection to the crew from fragment and debris.

8) Areas used for the maintenance of military vehicles and equipment (trucks, tanks) when the PES is basic load or ready storage limited to 4 000 kg or less at each end when the maintenance work is performed exclusively by and for military personnel of the unit for which the basic load of ammunition is stored.

9) Auxiliary power and utilities functions, inert storage and issue sites and mechanical support at naval dock areas when not continuously manned, when serving only the waterfront area, and when the PES is a ship or an ammunition handling location at

the waterfront. When loss of the facility would cause an immediate loss of a vital function, Inhabited Building Distance must be used.

10) Minimum distance between separate groups of explosives loaded combat-configured aircraft or between aircraft and a PES such as a preload site which serves to arm the aircraft. The use of intervening barricades is required to further reduce communication and fragment damage and eliminate the necessity for totalling the NEQ. The loading of ammunition and explosives aboard aircraft can be accomplished within each group of aircraft without additional protection.

11) Parking lots for privately owned automobiles belonging to the personnel employed or stationed at the PES.

12) Separation of naval vessels from PES consisting of other naval vessels to which quantity-distance standards apply. When the PES is an ammunition ship or an ammunition activity, the separation will be determined by reference to special regulations established for piers and wharves of ammunition shiploading activities.

13) Container "stuffing" and "unstuffing" operations which are routine support of the PES. When the PES is a magazine in a storage area, containerizing operations may be considered as part of the magazine and separate quantity-distance rules will not be applied.

1.3.7.12. *Protection Level 3.6 $Q^{1/3}$ - Open Stacks and Light Structures*

a) Expected Blast Effects

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

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

3) Aircraft will be damaged by blast to the extent that they will be beyond economical repair. If aircraft are loaded with explosives, delayed explosions are likely to result from subsequent fires.

4) Explosions may occur in ES containing ammunition as a result of fire spread by lobbed debris or blast damage. A high degree of protection against direct propagation of an explosion is to be expected providing direct attack by high velocity fragments is prevented.

b) Personnel and Facilities Acceptable

1) Buildings housing successive steps of a single process in an explosives factory.

2) Separation of buildings for security guards from explosives locations, provided the risk of the personnel becoming militarily ineffective in the event of an explosive accident can be accepted.

3) Separations among buildings and facilities of a tactical missile site where greater distances cannot be provided due to technical reasons.

4) Temporary holding areas for trucks or railcars containing explosives to service production or maintenance facilities provided barricades are interposed between the explosives locations.

5) Unmanned auxiliary power facilities, transformer stations, water treatment and pollution abatement facilities and other utility installations which serve the PES, and loss of which will not create an immediate secondary hazard or prejudice vital operations.

1.3.7.13. *Protection Level 2.4 $Q^{1/3}$ - Open Stacks and Light Structures*

a) Expected Blast Effects

Unstrengthened buildings will almost certainly suffer complete demolition.

b) Personnel and Facilities Acceptable

1) Personnel stationed in magazine areas for one or two men.

2) Crews performing storage and shipping functions in the magazines may operate for short periods of time at adjacent magazines. In large magazine areas controls

should be exercised by management to reduce the length of time that unrelated operations are exposed to one another at distances less than $9.6\ Q^{1/3}$

Section VIII - Q-D Rules in the Particular case of Aboveground Storage of Ammunition Classified 1.6N

1.3.8.1. *Preliminary remark*

This section of the Manual is reserved for ammunition classified 1.6N. It was written at a time when very few statistical data were known on the behaviour of these articles in transport and in storage. Therefore it was difficult to derive from experience what should be the behaviour of a set of 1.6N ammunition of the same family in case of an accidental stimulus.

Among several options, the AC/258 Group took the decision to choose a middle way solution which leads to the recommendations listed below. In the future when the behaviour in storage of 1.6N ammunition will be better known it may be necessary to revise this decision.

1.3.8.2. *Most credible accidental event*

During storage of 1.6N ammunition belonging to the same family the most credible accidental event resulting from an accidental stimulus is the detonation of a single munition without instant transmission of the detonation to other munitions of the same family and/or moderate combustion of the whole quantities of ammunition.

1.3.8.3. *Q-D rules*

The Q-D distances between an ES and a PES which are given by the Q-D rules, are derived from the above-mentioned "most credible accidental event". The assessment of the hazard generated by the detonation of a single munition takes into account only the blast effect and neglects the projection effect of a single munition.

The Q-D distances are obtained by taking, for a given configuration "ES, PES" the largest distance determined by applying

a) the Table 1 (1.1 Q-D rules) to a single munition

b) the Table 3B (1.3 Q-D rules) to the whole quantities of ammunition with aggregation of the NEQ.

Table 4 (Annex I-A) hereafter has been built by applying these rules. It gives the Q-D distances of a stock of 1.6N ammunition (single family or compatible families as defined hereafter) in the case where theNEQ of a single munition is 1 000 kg. Tables can of course also be constructed to better cater for the storage of 1.6N ammunition where the HD 1.1 NEQ of a single munition is other than 1000 kg.

CHAPTER 4 – UNDERGROUND STORAGE IN DEPOTS

Section I - General

1.4.1.1. *Types and Effects*

a) Types

1. This section details how to predict QD based on criteria given in para 3.1.1.2. for the underground storage of military ammunition and explosives. Underground storage typically includes natural caverns and excavated chambers. Recommendations in this section shall only be used when the minimum distance from the perimeter of a storage area to an external surface exceeds 600 mm and $0.1 \cdot Q^{1/3}$ (m, kg). Otherwise, use aboveground siting criteria. This section addresses explosives safety criteria both with and without rupture of the cover.

2. Ground shock, debris, and air blast from an accidental explosion in an underground storage facility depend on several variables, including the local geology and site-specific parameters. These parameters vary significantly from facility to facility. Consequently, distances other than those listed below may be used provided approved experimental or analytical data indicate that the desired protection can be achieved. See below for default methods to determine QD.

3. The QD for tolerable ground shock is the same in all directions for homogeneous, geological media, whereas QDs for other hazards (blast, thermal, impulse, etc.) vary markedly in different directions. Variations in QDs in different directions arise from configuration-specific features such as the locations of adits and ventilation shafts, hazards mitigating designs, and terrain. The acceptable QD in a given direction is generally taken as the maximum QD determined for the various hazards.

4. QD siting requirements of this section may be determined from the applicable equations or by interpolating between figure entries.

b) Effects

The following effects, peculiar to underground storage sites, must be taken into consideration for quantity-distance purposes:

1. Inside the Underground Installation:

The volume available to an expanding shock front is less in an underground configuration than it is in an aboveground configuration. Because of this limited space, an explosion in an underground facility typically results in long-duration, high pressures and temperatures that spread throughout the entire volume available to the shock front. Unless robust engineered designs (doors and/or other closing devices) are used to separate various parts of the facility, these long-duration blast effects spread throughout the entire underground complex. Doors or other closing devices must be properly designed and, in the case of doors, closed to provide the desired separation.

An initial event in Hazard Division 1.2 and 1.4 materials usually starts a fire, which is sustained by burning packages and components of the ammunition. This process causes additional explosions, likely at increasing frequency, until combustible materials in the site have been consumed. The results of these repeated explosions in the confined space underground will depend on the type and quantity of the substances in each unit of ammunition and the type of explosion produced.

2. Outside the Underground Installation:

Blast waves from adits exhibit highly directional flow-fields along the extended centerline of the passageway. Consequently, the blast wave effects (overpressure and impulse) do not attenuate as rapidly along the centerline axis as they do off the centerline axis.

The following effects should be considered for an external ES:

(1) Blast from tunnel adits

(2) Blast from craters, if the rock cover is insufficient.

(3) Debris from tunnel adits

(4) Debris from cratering

(5) Ground Shock

(6) Flame and hot gases

1.4.1.2. *Quantity-Distances*

a) Inside the UG Installation

QD should be determined for the following:

1. Chamber Intervals

2. Loading/Unloading Dock

3. Explosives Workshop Distance (EWD)

4. Inspection

b) Outside the UG Installation

QD should be determined for the following:

1. Inhabited Building Distance (IBD)

2. Public Traffic Route Distance (PTRD)

3. Explosives Workshop Distance (EWD)

4. Earth-covered Magazine Distance (ECMD)

5. Aboveground Magazine Distance (AGMD)

1.4.1.3. *Net Explosives Quantity (NEQ)*

For siting purposes, the NEQ is the total quantity of explosives material that must be included in defining a potential event. Part I, paragraph 1.3.2.5. provides guidance for finding the appropriate NEQ for sites containing materials with different Hazard Classes.

1.4.1.4. *Measuring Quantity-Distances*

a) Inside the Underground Installation.

The Chamber Interval is the shortest distance between the walls of two adjacent chambers. The subdivision of a cavern requires construction of massive barricades to close the gaps in the natural rock and to isolate one site or chamber from any other. The thickness of these barricades should be equal to the chamber intervals.

b) Outside the Underground Installation.

Distances to ESs outside the underground facility are normally measured as radial distances (see below) unless conditions make such a procedure clearly unreasonable:

1. Distances determined for airblast, debris, and thermal effects issuing from tunnel openings shall be the minimum distance measured from the openings to the nearest wall or point of the location to be protected. Extended centerlines of the openings should be used as reference lines for directional effects.

2. A distance determined by ground shock should be measured from the nearest wall of a chamber or a cavern containing ammunition or explosives to the nearest wall or point of the location to be protected.

3. A distance determined for air blast and debris from a breached cover shall be the minimum distance from the centre of the breach (CCB), at ground surface level, to the location to be protected (See Annex IIIB, Figures 3-Ia and 3-Ib.).

Section II - Hazard Division Material Dependence

1.4.2.1. *Hazard Division 1.1, 1.3, 1.5 and 1.6 materials*

a) Distances shall be determined from the total quantity of explosives, propellants, pyrotechnics, and incendiary materials in the individual chambers, unless the total quantity is subdivided to prevent rapid communication of an incident between subdivisions. All Hazard Divisions 1.1, 1.3, 1.5, and 1.6 material subject to involvement in a single incident shall be assumed to contribute to the explosion yield.

b) A connected chamber or cavern storage site containing Hazard Division 1.1 or 1.3, 1.5 and 1.6 materials shall be treated as a single chamber site, unless explosion communication is prevented by adequate subdivision or chamber separation.

c) HD 1.3 material should be treated as HD 1.1 material when it is stored underground.

1.4.2.2. *Hazard Division 1.2 materials*

a) The hazard to exterior ESs from primary fragments where a line-of-sight path exists from the detonation point to the ES is the only explosives safety hazard of concern for HD 1.2 materials.

b) When line-of-sight conditions exist, use distances common to aboveground situations.

c) QD requirements do not apply if the exterior ES is located outside the line-of-sight or if barricades (constructed or natural) intercept fragments issuing from an opening.

1.4.2.3. *Hazard Division 1.4 materials*

Exterior: Exterior explosives safety hazards are not normally significant for Hazard Division 1.4 materials. Accordingly, QD requirements do not apply for Hazard Division 1.4 materials.

Section III - Chamber Interval

References [7-10] deal with chamber intervals.

1.4.3.1. *Hazard Divisions 1.1, 1.3, 1.5, and 1.6*

a) Three modes by which an explosion or fire can be communicated are rock spall, propagation through cracks or fissures, and airblast or thermal effects travelling through connecting passages. Minimum storage chamber separation distances are required to prevent or control the communication of explosions or fires between donor and acceptor chambers.

The minimum chamber separation (D_{cd}) is 5 m for HD 1.1, 1.3, 1.5, and 1.6 materials.

b) Prevention of major damage by rock spall.

The chamber separation distance is the shortest distance (rock/concrete thickness) between two chambers. When an explosion occurs in a donor chamber, a shock wave propagates through the surrounding rock. The intensity of the shock decreases with distance. For small, chamber separation distances, the shock may be strong enough to spall the rock/concrete walls of acceptor chambers.

For hard rock with no specific protective construction, the minimum, chamber separation distance, D_{cd}, required to prevent major damage by spall depends on the chamber loading density (γ) as:

$$D_{cd} = 1.0 \cdot Q^{1/3} \qquad (\gamma \le 50\,kg/m^3) \qquad \text{Eq. 1.4.3-1}$$

and

$$D_{cd} = 2.0 \cdot Q^{1/3} \qquad (\gamma > 50\,kg/m^3) \qquad \text{Eq. 1.4.3-2}$$

Example ($\gamma \le 50\,kg/m^3$):

Q = 200,000 kg

D_{cd} = 1.0 · 58.48 = 58.5 m

For soft rock (See para 1.4.4.3.a), at all loading densities, the separation distance is:

$$D_{cd} = 1.4 \cdot Q^{1/3} \qquad \text{Eq. 1.4.3-3}$$

Example:

$Q = 200{,}000$ kg

$D_{cd} = 1.4 \cdot 58.48 = 82$ m

c) Prevention of propagation by rock spall

If damage to stored munitions in the adjacent chambers is acceptable, the chamber separation distance can be reduced to the distance required to prevent propagation of the detonation by the impact of rock spall against the munitions. For smaller distances, propagation is possible. Propagation by rock spall is practically instantaneous because time separations between donor and acceptor explosions may not be sufficient to prevent coalescence of blast waves. Unless analyses or experiments indicate otherwise, explosives quantities subject to this mode must be added to other donor explosives to determine NEQ. For loading densities up to 270 kg/m³, when no protective construction is used, the separation distance, Dcd, to prevent explosion communication by spalled rock is:

$$D_{cd} = 0.6 \cdot Q^{1/3} \qquad \text{Eq. 1.4.3-4}$$

Example:

$Q = 200{,}000$ kg

$D_{cd} = 0.6 \cdot 58.48 = 35$ m

When the acceptor chamber has protective construction to prevent spall and collapse (into the acceptor chamber) the separation distance must be determined on a site-specific basis but may be as low as:

$$D_{cd} = 0.3 \cdot Q^{1/3} \qquad \text{Eq. 1.4.3-5}$$

Example:

$Q = 200{,}000$ kg

$D_{cd} = 0.3 \cdot 58.48 = 17.5$ m

d) Prevention of propagation through passageways

Blast, flame and hot gas may cause delayed propagation. Time separations between the original donor event and the potential explosions of this mode will likely be sufficient to prevent coalescence of blast waves. Consequently, for purposes of Q-D siting, only the maximum credible explosives quantity need be used to determine NEQ.

In order to protect assets, blast and fire resistant doors must be installed within multi-chambered facilities. Evaluations of design loads on doors must be made on a site-specific basis.

e) Propagation by Flame and Hot Gas through Cracks and Fissures

Consideration must be given to the long-duration action of the explosion gas. These quasi-static forces might form cracks in the rock that extend from the donor to an adjacent (acceptor) chamber, thus making it possible for hot gases to flow into this chamber and initiate an event. Significant factors for this mode of propagation include the strength of rock, the existence of cracks formed before the explosion incident, the type of barriers in cavern storage sites, the cover and the loading density in the chamber. This mode of propagation must be considered when final decisions about chamber separation distances are made.

Thus, because of these cracks and fissures, propagation may occur beyond

$$D_{cd} = 0.3 \cdot Q^{1/3} \qquad \text{Eq. 1.4.3-6}$$

Example:

Q = 200,000 kg

$D_{cd} = 0.3 \cdot 58.48 = 17.5$ m

but not likely beyond;

$$D_{cd} = 2.0 \cdot Q^{1/3} \qquad \text{Eq. 1.4.3-7}$$

Example:

Q = 200,000 kg

$D_{cd} = 2 \cdot 58.48 = 117$ m

Site-specific analyses, using a sound geological survey, should be made to determine proper intervals between chambers.

1.4.3.2. *Hazard Division 1.2*

Intervals between a chamber containing ammunition of Hazard Division 1.2 and adjacent chambers should be at least 5 m of competent rock unless structural considerations apply. This applies also to barriers used to isolate chambers in a cavern storage site.

1.4.3.3. *Hazard Division 1.4*

Intervals between chambers containing ammunition of Hazard Division 1.4 should be determined from structural considerations with no regard to the content of ammunition. This applies also to barriers used to isolate chambers in a cavern storage site.

Section IV - Inhabited Building Distance (IBD)

IBD must be the largest of the distances for protection against airblast, debris, and ground shock [1, 7].

1.4.4.1. *Airblast [8-15]*

a) The side-on overpressure of 5 kPa defines IBD.

b) An explosion in an underground storage chamber may produce external airblast from two sources; the exit of blast from existing openings (tunnel entrances, ventilation shafts, etc.) and the rupture or breach of the chamber cover by the detonation. Required IBDs are independently determined for each of these airblast sources, with the maximum IBD used for siting.

1. A breaching chamber cover will produce external airblast. Use the following table to site for IBD due to airblast produced by breaching of the chamber cover. Values of IBD for airblast through the ruptured cover are:

Cover Thickness	IBD	Equation
$Cover \leq 0.1 \cdot Q^{1/3}$	IBD for Surface Burst	Eq. 3.3.4 – 1(a)
$0.1 \cdot Q^{1/3} < Cover \leq 0.2 \cdot Q^{1/3}$	1/2 IBD for Surface Burst	Eq. 3.3.4 – 1(b)
$0.2 \cdot Q^{1/3} < Cover \leq 0.3 \cdot Q^{1/3}$	1/4 IBD for Surface Burst	Eq. 3.3.4 – 1(c)
$Cover > 0.3 \cdot Q^{1/3}$	Negligible Airblast Hazard	Eq. 3.3.4 – 1(d)

2

This paragraph defines airblast IBDs from openings in an underground storage facility. The IBD for airblast must be considered for any opening.

(a) To a first approximation, distance and overpressure along the extended centerline axis of an opening may be estimated with an algorithm of the form:

$$p_{SO} = 1900 \cdot \left[\frac{Q}{V_E}\right]^{0.5} \cdot \left[\frac{r}{D_{HYD}}\right]^{-n} \qquad \text{Eq. 1.4.4-2}$$

where:

k: constant, kPa

r: radial distance from opening, m

p_{SO}: overpressure at distance r, kPa

D_{HYD}: effective hydraulic diameter that controls the dynamic flow from the opening, m [A robust constriction within five tunnel diameters of an exit defines the hydraulic diameter used for predicting overpressures outside the underground facility.],

Q: Mass of explosives material, kg

V_E: Total volume inside the underground facility that is engulfed by blast waves at the time the blast arrives at the location of interest (m^3) (V_E is often the total volume of the underground complex.)

n: measure of attenuation rate of p_{SO} vs r (no units).

Site-specific analyses should be conducted where there are complex tunnel systems, tunnel constrictions, or significant tunnel roughness.

The value n for pressures between 200 Pa and 20 kPa varies from 0.91 to 0.66. The value of n that best fits available data over the range of interest for Workshops to IBD is 1/1.4. For the overpressure of interest at IBD, p_{SO} = 5 kPa, so:

$$IBD = 70 \cdot D_{HYD} \cdot \left[\frac{Q}{V_E}\right]^{\frac{1}{2.8}}$$ Eq. 1.4.4-3

(b) For a simple horizontal geometry (no barricade, a rapidly rising rock face, an extended centerline normal to the rock face) the following equation for off centerline axis can be used.

$$IBD(\theta) = IBD(\theta = 0) \cdot \left[1 + (\theta / 56)^2\right]^{-1/1.4}$$ Eq. 1.4.4-4

where:

θ: horizontal angle off centerline in degrees

Large variations in directivity have been observed (Annex IIIB Figure 3-II).

Therefore, it is recommended that carefully constructed models and realistic exit pressures should be used to investigate directivity for an actual site.

(c) High-Pressure Closure Block Designed to Remain Intact

References [4, 5] contain illustrative examples of a closure block designs.

For chamber loading densities greater than or equal to 10 kg/m^3, IBD may be reduced by 50% when a high-pressure closure block, designed to remain intact in case of an explosion, is used.

For chamber loading densities lower 10 kg/m^3 (but greater than 1.0 kg/m^3), determine the reduction by the formula:

$$y(\%) = 50 \cdot \log_{10}(\gamma) \qquad \text{Eq. 1.4.4-5}$$

where, y is the percentage reduction in IBD, and γ is loading density in kg/m^3. For loading densities lower than 1.0 kg/m^3, use y(%) = 0.

(d) Portal Barricade

When a properly designed and located portal barricade [5, 7] is in front of the opening, IBD for airblast along the extended tunnel axis may be reduced up to 50 percent. Although the total airblast hazarded area remains almost unchanged, its shape, for explosives safety applications, becomes more circular.

1.4.4.2. *Debris*

Debris from an explosion in an underground facility may issue from adits or other openings; failure of nearby structures (portal, barricades, etc.); and breaching of the geological cover over the PES (crater debris).

a) Adit Debris [16-17, 20]:

Recommended distance for IBD is based on a few data points from accidents and large-scale tests. IBD is defined as that distance where the fragment density is one hazardous fragment (energy greater than 79 Joules) per 56 m^2**.** If the ratio of the length of the main passageway to its diameter is greater than or equal to 11 (i.e. L/D 11) the dispersal angle should be taken as ± 10 degrees. If the ratio of the length of the tunnel is less than 11, i.e. L/D < 11, the dispersal angle should be taken as ± 20 degrees. Annex IIIB, Figure 3-III illustrates this.

1. ES Located Within the Sector Defined by the Maximum Angles of Dispersion:

Annex IIIB, Figure 3-IV contains IBD versus NEQ recommendations for this situation. Recommended distances are valid for storage facilities with:

(a) ES located within the sector defined by the maximum angles of dispersion. This sector is defined by two horizontal rays from the outer edges of the adit with angles equal to the maximum angle of dispersion relative to the extended centerline.

(b) relatively long, straight access tunnels (For installations where the tunnel is not relatively long and the dispersal angle is ± 20 degrees, a site-specific analysis may result in a reduced IBD.)

(c) total loading densities (storage chamber + tunnel volume) between 1 and 100 kg/m^3, and

(d) an NEQ less than or equal to 500,000 kg.

Example:

Given:
NEQ = 200,000 kg
ES is within the sector defined by maximum angles of dispersion.

Solution:

$$IBD = 79 \cdot Q^{0.233} = 1360\,m$$

A portal barricade [5, 7] provides a means of reducing IBD due to adit debris by intercepting the debris as it exits the tunnel. However, to ensure that debris is not simply redirected around the barricade, two debris-mitigating designs should be used in series, one inside the underground facility together with the portal barricade outside the facility. For this debris-mitigating configuration, IBD distance may be negligible but IBD must be determined on a site-specific basis.

2. ES Located Outside the Sector Defined by the Maximum Angles of Dispersion:

Debris from the adit need not be considered for IBD siting.

(a) Debris from Nearby, Failed Structures:

The dynamics of this debris will be highly dependent on site-specific parameters. Site-specific analyses should be done when this type of debris is of concern.

(b) Debris Arising from Failure of Cover, Crater Debris [18-22, 34]

1. The chamber cover thickness is the shortest distance between the natural rock surface at the chamber ceiling (or in some cases, a chamber wall) and the ground surface. If the cover consists of part rock and part soil, the effective thickness of the cover is determined based on mass. A conservative estimate is to treat soil as having one-half the mass of rock. Therefore, 10 m of rock and 2 m of soil, with one-half the density of the rock, equals 11 m of equivalent rock cover. If the percentage of soil to rock exceeds 20% a site-specific analysis should be conducted.

Unless the cover is adequate, an underground explosion will cause breaching of the cover. Rock, and to a lesser degree structural material, is projected as debris in all directions from the breached cover into the surroundings.

The hazard from this type of debris depends on the quantity of explosives (Q) involved, the scaled cover depth ($C/Q^{1/3}$), the chamber loading density (γ), and the slope angle of the overburden (α) and the type of rock.

2. The rock overburden of an underground installation is sufficient for a scaled cover depth ($C/Q^{1/3}$) equal to 1.2 $m/kg^{1/3}$. For larger values, the debris throw from the overburden can be neglected. This does not mean that the surface is undisturbed after an accident. It simply means that a crater is negligible and ejecta are unlikely.

For more information, see Part III, paragraph 3.2.1.1 and Figures 3-Ia and b. For smaller values the hazardous distance (Inhabited Building Distance) for installations in hard and moderately strong rock can be calculated with the following formula:

$$IBD = 38.7 \cdot Q^{1/3} \cdot f_y \cdot f_c \cdot f_\alpha \qquad \text{Eq. 1.4.4.6}$$

where:

IBD	=Inhabited Building Distance	[m]
Q	=explosives quantity (effective NEQ)	[kg]
f_γ	=loading density parameter	[.]
f_c	=cover depth parameter	[.]
f_α	=overburden slope angle parameter	[.]

The loading density parameter, $f_{\gamma,}$ can be taken from the graph in Annex IIIB, Figure 3-V and the cover depth parameter, $f_{c,}$ from Annex IIIB Figure 3-VI. Both values can also be calculated with the corresponding formula in Annex IIIB, Figures 3-V and 3-VI. To simplify the calculation processAnnex IIIB, Figure 3-VII contains tables for $Q^{1/3}$, f_γ and f_c over a wide range of commonly required values.

The loading density parameter, f_γ, and the Inhabited Building Distance increase with an increase in loading density. The cover depth parameter (f_c) is maximum at a scaled depth of $C/Q^{1/3}$ = approx. 0.5. The biggest crater is formed and the largest amount of crater debris is thrown out into the surroundings at this scaled depth, so the largest IBD results. As the scaled overburden thickness increases above or decreases below the optimum depth of burst, both the cover depth parameter (f_c) and Inhabited Building Distance decreases.

The influence of the slope angle of the overburden on the Inhabited Building Distance is shown in Annex IIIB, Figure 3-VIII.

Annex IIIB, Figures 3-Ia and 3-Ib show in general how the final IBD contour line has to be established and the consideration of the overburden slope angle parameter f_α.

Annex IIIB, Figure 3-IX, which is an example, illustrates a quantitative determination of IBD for crater debris.

3. IBD should be increased by 15 % for an installation built in soft rock.

4. Additional information:

The Inhabited Building Distance (IBD) has to be measured as a horizontal distance from the crater-centre at the bottom of the crater (CCB), at the level of the installation (Annex IIIB, Figure 3-Ia).

The slope angle α shall be established in the area where the crater-centre at the surface (CCS) has to be expected.

An average value for the slope angle α over the whole crater area shall be taken in case the surface is not plain in this area.

The increase ($f_{\alpha I}$) and the decrease ($f_{\alpha D}$) factor must be applied to the IBD in direction of the line with the largest gradient intersecting the centre of the crater (CCB). This line does not necessarily coincide with the axis of the adit tunnel.

No increase or decrease factors need applied to the side of the crater.

The shape of the IBD contour is elliptical.

In cases where more than one crater-centre is possible (e.g. in cases of a flat rock overburden surface), the IBD has to be applied from each possible crater-centre. The IBD contour shall be the outer connection of the single lines (Annex IIIB, Figure 3-Ib).

5. Limitations:

This crater debris throw model is based on an empirical evaluation of the available data and engineering judgment of a comparatively small number of tests and accidents. The overall accuracy is therefore limited to the range of the investigated cases. Thus, the crater debris throw model may be used only within the following boundaries:

quantity of explosives NEQ = 1 t - 2000 t chamber loading density $\gamma = 1\ kg/m^3 - 300\ kg/m^3$

scaled cover depth $C/Q^{1/3} > 0.1\ m/kg^{1/3}$

In case of parameters exceeding these values it is appropriate to take special care when applying the model.

1.4.4.3 *Ground Shock*

References [2, 23-33] deal with ground shock.

a) General

Damage to a building at IBD is limited so that personnel are protected to desired levels. Siting requirements are based on tolerable particle velocities whose magnitudes depend on the robustness of the facility to be protected and on the geological media in which the structure is located. Algorithms for predicting particle velocity and distance are from Reference [32].

The foundation geology of buildings may be divided into the following three categories:

Hard rock: Granite, gneiss, diabase, quartzite sandstone, and hard limestone

Soft rock: Firm moraine slate, shale stone, and soft limestone

Soil: Sand, gravel and clay

Descriptive parameters for various geological media are:

Material	**Density (g/cm^3)**	**P wave Velocity (m/s)**	**S wave Velocity (m/s)**
Granite	2.5-2.8	5500-5900	2800-3000
Basalt	2.7-3.1	6400	3200
Sandstone	2.0-2.6	1400-4300	700-2800
Limestone	2.5-2.8	5900-6100	2800-3000
Sand (Unsaturated)	1.7-2.3	200-1000	80-400
Sand (Saturated)	2.71	800-2200	320-880
Soil	1.7-2.3	300-900	120-360

b) Criteria for Ground Shock at IBD.

Criteria for Ground Shock are listed in para 3.1.1.2., where ranges for particle velocities are displayed. The smallest values, in a given range, are default particle velocities. Values for particle velocities other than the default values may be used only when supported by facility-specific analyses.

1. Hazard Divisions 1.1, 1.3, 1.5, and 1.6

(a) Factors governing the response and damage of buildings include the NEQ, chamber loading density, distance, structure type, foundation geology, and the frequency contents of the ground shock.

(b) Particle velocity and distance relationships for charges buried in soil or rock (tamped) are taken from Reference 33.

$$\frac{u_p(tamped)}{c_p} \cdot P_{bar}^{1/2} = \left[\frac{0.006169 \cdot Q_{bar}^{0.8521}}{\tanh(26.03 \cdot Q_{bar}^{0.30})} \right]$$ Eq. 1.4.4-7

(a)

where

$$P_{bar} = \frac{P_0}{\rho_s \cdot c_p^2}$$ Eq. 1.4.4-7 (b)

$$Q_{bar} = \frac{E_Q \cdot Q}{\rho_s \cdot c_p^2 \cdot r^3}$$ Eq. 1.4.4-7 (c)

and:

u_p(tamped) = ... peak particle velocity, (m/s)

r = ... radial distance (m)

E_Q =...........effective energy/mass [3] for explosives material (J/kg)

Q = ... net explosives quantity (kg)

ρs = ... mass density of soil or rock (kg/m^3)

c_p = ...seismic velocity of p-wave (m/s)

P_0 = ... atmospheric pressure (N/m^2)

Particle velocities based on Equations 1.4.4-7 together with test results are shown in Annex IIIB, Figure 3-X.

(c) Equation 1.4.4-8 applies for charges that are buried in soil or rock (tamped) with an estimated loading density (γ) of about 1600 kg/m^3. Based on this limited set of data, the IBD over the range of loading densities up to 50 kg/m^3 is almost constant and equal to about 50% of the IBD for a tamped charge. Following are recommendations for particle velocity versus loading density:

$$\gamma \leq 50\, kg/m^3 \qquad u_p = 0.6 \cdot u_p(tamped)$$
$$\gamma > 50\, kg/m^3 \qquad u_p = u_p(tamped) \cdot e^{0.00048\cdot(\gamma - 1600)}$$

where:

u_p(tamped) is from Equation 1.4.4-7.

Example:

Given: Q = 200,000 kg of TNT-equivalent material (E_Q = 4.56 X 10^6 joules/kg).

γ = 60 kg/m^3
Geology = soil (ρ = 2800 kg/m^3, P-wave velocity = 5900 m/s)
P_0 = 1.01 X 10^5 kg/m^2

Criteria chosen:

Dry sand: ....u_p = 0.06 m/s
Weak rock: ....u_p = 0.115 m/s
Strong rock:...u_p = 0.23 m/s

Solution for IBD:

Iterative techniques are required to solve the ground shock algorithms for distance. The following table lists the results of an iterative solution for the parameters assumed. E_Q is the heat of detonation for TNT (4.56E6 J/kg) as listed in Reference [3]. Note that the particle velocities are the default acceptable values for their associated geological media. Therefore, the listed, scaled IBDs are the default acceptable values for the geological media listed.

MEDIA	**Dry Sand**	**Weak Rock**	**Strong Rock**	**Units**
u_p	0.06	0.115	0.23	m/s
ρ_s	2000	2200	2800	kg/m^3
c_p	600	2850	5900	m/s
P_{bar}	1.408E-04	5.674E-06	1.040E-06	
Q_{bar}	3.785E-05	6.656E-07	1.408E-07	
Scaled IBD (tamped)	5.5	7.3	6.9	m/kg$^{1/3}$
Scaled IBD ($\gamma \leq 50$ kg/m^3)	2.8	3.7	3.5	
CONSTANTS	E_Q = 4.56 E+06			Joules/kg
	p_0 = 1.01E+05			Newton/m^2

Example:

Given: Strong Rock

Q = 125,000 kg at a loading density of 40 kg/m^3

Solution: The required, scaled IBD is 3.5 m/kg$^{1/3}$ from the preceding table, so

$$IBD = 3.5 \cdot Q^{1/3} = 3.5 \cdot 50 = 165 \text{ m}$$

1. Hazard Division 1.2

Siting for ground shock is not required for HD 1.2 materials.

2. Hazard Division 1.4

Siting for ground shock is not required for HD 1.4 materials.

Section V - Public Traffic Route Distance (PTRD)

1.4.5.1 *Public traffic route distance (PTRD) (For all Hazard divisions)*

1. Ground Shock QD is 2/3 of IBD for ground shock.

2. Debris QD is 2/3 of IBD for debris.

3. Airblast QD is 2/3 of IBD for airblast.

4. For heavy traffic use the maximum IBD determined in the previous three paragraphs.

5. Because of the hazards arising from the strong on-axis jetting, special considerations should be given when ES is on the extended centreline of the main passageway.

Section VI - Explosives Workshop Distance (EWD)

1.4.6.1 *General Considerations*

An Explosives Workshop (EW) may be either an aboveground structure or an underground chamber with its own entrance tunnel. Except for HD 1.4 ammunition, an underground EW should not be connected (air ducts, passageways, etc.) to other underground storage chambers. Otherwise, an underground ES should be sited as a storage chamber. Distances between PES and EW are intended to provide a reasonable degree of personnel protection within the EW from the effects of a nearby explosion (blast, flame, debris, and ground shock).

1.4.6.2 *Impulsive Load*

An explosion in an underground facility produces a directional impulsive load along the extended centerline axis of an adit. This impulsive load is considerably more intense at a given distance than that from a comparable above ground detonation. Little work has been done to quantify the on-axis impulsive load as a function of distance.

1.4.6.3. *Potential Crater*

An Aboveground EW should be sited so it is at least outside the potential crater of an underground explosion.

1.4.6.4. *Aboveground EW Located within the Maximum Dispersal Angle*

An unhardened EW should be sited at the corresponding IBD found above.

1.4.6.5. *Aboveground EW Located Outside the Maximum Angle of Dispersal*

An EW may be sited at 1/3 of the corresponding IBD found above.

Section VII – Above Ground Earth-Covered Magazine (ECM)

1.4.7.1. *Site-Specific Analysis*

A site-specific analysis should be conducted and siting decisions should be based on the protection the ECM provides.

Section VIII – Above Ground Magazine Distance (AGMD)

1.4.8.1. *Siting*

An unbarricaded AGM should be sited at 2/3 of the corresponding IBD found above. A barricaded AGM should be sited at 1/3 of the corresponding IBD found above.

CHAPTER 5 - SEPARATION OF POL-FACILITIES WITHIN MILITARY INSTALLATIONS

1.5.0.1. *Separation of Small Quantities of POL*

Small quantities (not exceeding 100 litres) of petroleum, oils, and lubricants (POL) held as immediate reserves for operational purposes within a military installation require no specific quantity-distances from buildings or stacks containing ammunition or explosives.

1.5.0.2. *Separation of Unprotected Aboveground POL Tanks and Drums*

If required, unprotected aboveground POL steel tanks and drums are separated from buildings or stacks containing ammunition or explosives by the Inhabited Building Distance (Annex A, Section II). Where the POL-facilities are vital a minimum distance of 450 m must be observed from buildings or stacks containing ammunition or explosives of Hazard Divisions 1.1 and 1.2.

1.5.0.3. *Separation of Protected Aboveground POL Tanks and Drums*

a) If required, quantity-distances less than those for unprotected tanks and drums (see paragraph 1.5.0.2.) may be used where a surface storage tank or a drum storage area is provided with structural protection against blast and fragment hazards. For purposes of applying this paragraph, "protected" will be considered to mean that the POL storage tank or drum as an ES is provided with structural protection sufficient to ensure that the POL storage tank or drum and contents will experience no more damage than if sited at inhabited building distance.

b) The criteria specified for the separation of POL from explosives areas are intended primarily for use in determining separations at large permanent ammunition depots. For basic load sites, missile sites and similar small tactical installations, it may be desirable to weigh the cost of distance/protective construction against strategic value of the POL supplies and the ease of replacement in the event of an incident. Reduced distances may be approved if the POL loss can be accepted, and if the POL-facilities are sited and provided spill containment so as not to endanger the explosives. Such reduced distances must be acceptable to both host and user nations.

1.5.0.4. *Separation of Buried POL Tanks*

Buried POL tanks should be separated from buildings or stacks containing ammunition or explosives of Hazard Divisions 1.2, 1.3 and 1.4 by a minimum distance of 25 m. The distances from ammunition in Hazard Division 1.1 are given in Annex A, Table 1 (½ D7-distances) with a minimum of 25 m.

1.5.0.5. *Separation of Buried POL Pipelines*

Buried POL pipelines should be separated from buildings or stacks containing ammunition or explosives of Hazard Divisions 1.2, 1.3 and 1.4 by a minimum distance of 25 m. The distances from ammunition in Hazard Division 1.1 are given in Annex A, Table 1 (½ D7-distances) with a minimum of 25 m.

1.5.0.6. *Separation of POL-facilities from Underground Storage Sites*

It is not practical to specify quantity-distances to cover all cases of underground ammunition storage and POL-facilities. Each case must be assessed to take account of the crater, blast, ground shock, debris and possible seepage of fuel.

CHAPTER 6 - HAZARD FROM ELECTROMAGNETIC RADIATION TO AMMUNITION CONTAINING ELECTRO-EXPLOSIVE DEVICES

1.6.0.1. *Introduction*

a) Over recent years there has been a significant increase in the use of communications equipment throughout the military and civil environment including all forms of transportation in support of management functions, control of resources and area security. These equipments produce electro-magnetic radiation of varying intensity according to their output and antenna gain and are potentially hazardous when used in close proximity to explosive devices which have an installed electrical means of initiation known as electro-explosive devices (EED).

b) The advice contained in this chapter represents the minimum precautions to be observed in order to prevent hazard to EED resulting from exposure to the radio frequency (RF) environment at frequencies up to 40 GHz. It is intended that this chapter should provide guidance of officials concerned with the storage, movement and processing of EED or stores containing EED and the control of RF equipment which may be used within, or enter, those establishments/vehicles used for these purposes.

c) Consideration is not given to the precautions to be taken with regard to lightning and electrostatic discharge. These areas are covered by other chapters in AASTP-1 Part II and are also considered by AC/310 Sub-Group 3 and published in STANAGs 4235 and 4236.

1.6.0.2. *General*

a) Any firing circuit associated with an EED, or other electrical conductors such as wires, tools and fingers in contact with the EED, when placed in a RF field will act as an antenna with the inherent capability of picking up some electrical energy from the field.

b) When the leading wires of an EED are separated they could form a dipole antenna and provide an optimum match between the dipole and the EED leading to maximum transfer of power to the EED from the radiated source. Unseparated (short circuited) leading wires could form circular antennae which may also constitute good receiving systems.

c) Unless appropriate precautions are taken, the power/energy levels induced into the firing circuits from the standing RF fields may be sufficient to inadvertently initiate the EED.

d) Design criteria for the modern EED when installed in weapon systems require electromagnetic (EM) screening and specified orientation of firing leads to reduce the RADHAZ. For this reason, EED separated from their parent system are regarded as less safe than when installed into the system with all leads connected as intended by the designer.

e) The attachment of external cables and test sets to systems containing EED will usually increase their susceptibility to EM energy pick-up.

f) The protective switch in a circuit which prevents the initiation of an EED by direct current until the desired time is not an effective barrier to electromagnetic (EM) energy.

1.6.0.3. *Electro-Explosive Devices*

a) An EED is a one shot explosive or pyrotechnic device used as the initiating element in an explosive or mechanical train and which is designed to activate by application of electrical energy. In present use four techniques of electrical initiation are employed:

1) Bridge-wire (BW) and Film bridge (FB) EED.
2) Conducting Composition (CC) EED.
3) Exploding Bridge-wire (EBW) EED.
4) Slapper Detonator.

b) In general EED in Service use fall into two broad categories:

1) Those with long thermal time constants (typically 10 ms - 50 ms) such as BW which are known commonly as "slow responding power sensitive" EED.
2) Those with a short thermal time constant (typically 1 µs - 100 µs) such as FB and CC which are known commonly as "fast responding energy sensitive" EED. These techniques are described in greater detail at Part II, Chapter 7 of AASTP .

c) In determining hazard thresholds (known as No-Fire Thresholds (NFT)) both types of reactions are considered in relation to statistical sampling based on 0.1% probability of firing at a single sided lower 95% confidence level.

d) The electrical characteristics and behaviour of EED in an RF environment are further described in Part II, Chapter 7, Section I.

1.6.0.4. *RF Environment*

a) Radio and radar transmitters operate over a wide spectrum as shown in Figure 6-1. The minimum level CW of RF intensity in which all systems incorporating EED should be designed and proved to remain safe is given in Table 6-1. Where these levels are not met restrictions will be imposed or the equipment must be protected by other means.

b) The system should be designed and proved to remain safe and serviceable when subjected to self generated RF fields and those which might be generated by a weapon platform (eg, ship, aircraft or vehicle) and platforms likely to be in close proximity and which may exceed the field intensity given in Table 6-1.

1.6.0.5. *Storage and Transport*

a) EED are encountered in a variety of configurations between their manufacturing stage and their ultimate disposal. These configurations range from trade packaging in bulk, military packaging and sub-packages, and installed in munitions, to various stages of separate and exposed states which occur in processing and training.

b) It is important for users to understand how these configurations can influence the basic precautions to be adopted in storage and transportation. Precautions in transport should include measures to be covered in emergencies from straightforward vehicle breakdown to accidents involving fire and/or casualty evacuation.

c) Process and Storage Building

1) Building materials are generally ineffective in affording EM protection to EED. Structures provide no protection at all in transmission loss from frequencies below 1 MHz but may provide some protection in the form of reflection loss if the polarization and angle of incidence of the EM energy happens to be favourable, although this is rarely the case. Also, bars in reinforced concrete do not provide any significant degree of protection.

2) For all practical purposes, it should be assumed that the field strength which exists inside a building is as high as it would be if the building did not exist. However, if the protection level across the frequency spectrum for a specific building has been determined (screened room) then this level may be used to determine a safe

distance from sources of electromagnetic radiation although it should be borne in mind that, if doors or windows are opened, the screening integrity may be adversely affected.

3) EED and systems containing EED should be stored/processed in authorized depot and unit process and storage areas. These areas should be sited taking into account the following:

- The susceptibility of the EED, store or weapon system during processing or storage as appropriate.
- The radiated power of transmitters in the area related to the susceptibility radius of the most sensitive EED present.

d) Transport

1) It is not practical to ensure the safety of an EED during transport through the observance of safe distances. For this reason all EED and systems containing EED offered for transportation must be safe in the power density likely to be encountered, see Table 6-1.

2) Systems containing EED and which have not been cleared to the EM environment in Table 6-1 must be protected during transport by carriage in a closed metal box or by screening materials which afford adequate attenuation to the external RF environment. Primers fitted to rounds or cartridges are, for example, to be protected by felt pads or cartridge clips.

3) When it is considered necessary to transport systems containing EED whose susceptibility is unknown, advice is to be obtained from the National Authority.

4) All personnel engaged in the carriage of such articles should be made aware of the hazard that may be caused by RF and observe fully the consignor´s instructions. Note should be made of any special instructions required during loading/unloading and during handling when EED are most vulnerable to EM radiation.

e) Emergency Transport Procedures

1) In the event of an incident/accident during the transport of munitions, items which do not normally present a high RADHAZ risk may become susceptible if there is damage to their inherent protection, ie structural or packaging. Pending a detailed inspection, the undermentioned restrictions on RF transmissions in the immediate vicinity should be imposed:

- No radio to be allowed within 2 metres.
- No radio to be allowed within 10 metres unless authorised as being intrinsically safe.
- No radio with an ERP greater than 5 watts to be allowed within 50 m.

Table 6-1 - The Minimum Service Radio Frequency Environment

Serial	Frequency	Field Strength/ Power Density	
		(V/M rms)	(Wm $^{-2}$)
(a)	(b)	(c)	(d)
1	200 kHz - 525 kHz	300	
2	525 kHz - 32 MHz	200	
3	32 MHz - 150 MHz		10
4	150 MHz - 225 MHz		100
5	225 MHz - 790 MHz		50
6	790 MHz - 18 GHz		1000
7	18 GHz - 40 GHz		100

1.6.0.6. *Assessment of Hazard*

a) It will be evident from the previous paragraphs that degrees of risk of unintended operation arise in any situation in which EED are introduced into close proximity with RF fields. The degree of risk ranges from negligible to acute in terms of both the susceptibility of the EED and the power output of the transmitters creating the RF field.

b) There are no simple rules or procedures for assessing risk. Each situation requires individual examination which must consider the:

1) Susceptibility of EED whether:

- Installed.
- Exposed.
- Packaged.
- Specifically protected.

2) Characteristics of transmitters.

3) Distance between the EED and radiating systems such as radios etc.

c) System Susceptibility

1) Using the NFT parameters described in paragraph 1.6.0.3), the assessment of the EED firing circuit susceptibility to induced pick up from RF radiation and the method of calculating the resulting degree of risk are described in Part II Chapter 7.

2) For systems with an unknown susceptibility, the maximum safe power density in the vicinity of CW or pulsed transmission sources pulsed at more than 666 pulses per second (pps) can be determined from the graph at Figure 6-II. The electrical characteristics of the US MK 114 Primer, UK Fuzehead Type F 120 and the FRG EL 37 cap together with a safety factor (Table 6-2) for a system with a 5 metre firing line was used to calculate the maximum safe power density.

3) This will enable a worst case CW assessment to be made and used until appropriate advice can be obtained from National Authorities.

4) Where RF pulse environments are encountered, special care should be taken of energy sensitive EED whose susceptibility changes significantly according to the emitter's pulse and time constant. In the absence of specific advice, a 20 times multiple of the distance calculated for CW should be applied.

TABLE 6-2 - EED Electrical Characteristics

EED Type	Resistance Range Ω	No-Fire Threshold Values			Typical Safety Factor dB
		Energy MJ	Current A	Power mW	
(a)	(b)	(c)	(d)	(e)	(f)
US Mk 114 Primer	3 – 7	0.19	0.05	7.5	-4
UK F120	10 – 16	0.2	0.045	26	-7
FRG EL 37	0.8 - 1.7	0.3	0.015	20	-10

d) Safe Distance

1) Unless otherwise directed by the appropriate National Authority, it is accepted that the following basic far field formula should be used for safety evaluations:

$$S = \frac{GP}{4\pi d^2}$$

which rearranges to:

$$d = \sqrt{\frac{GP}{4\pi S}}$$

where:

S = Safe Power Density (Wm^{-2}) as shown in Figure 6-II

G = Antenna gain relative to an isotropic (numerical ratio not dB)

P = Mean power fed to antenna (W)

d = Safe distance (m)

1.6.0.7. *Management Radios*

a) For VHF/UHF transmitters, ie management radios, where the antenna gain in dB and the power in watts is known, safe distances can be established for known EED by reference to look-up graph at Figure 6-III.

b) The example below illustrates how this graph can be used:

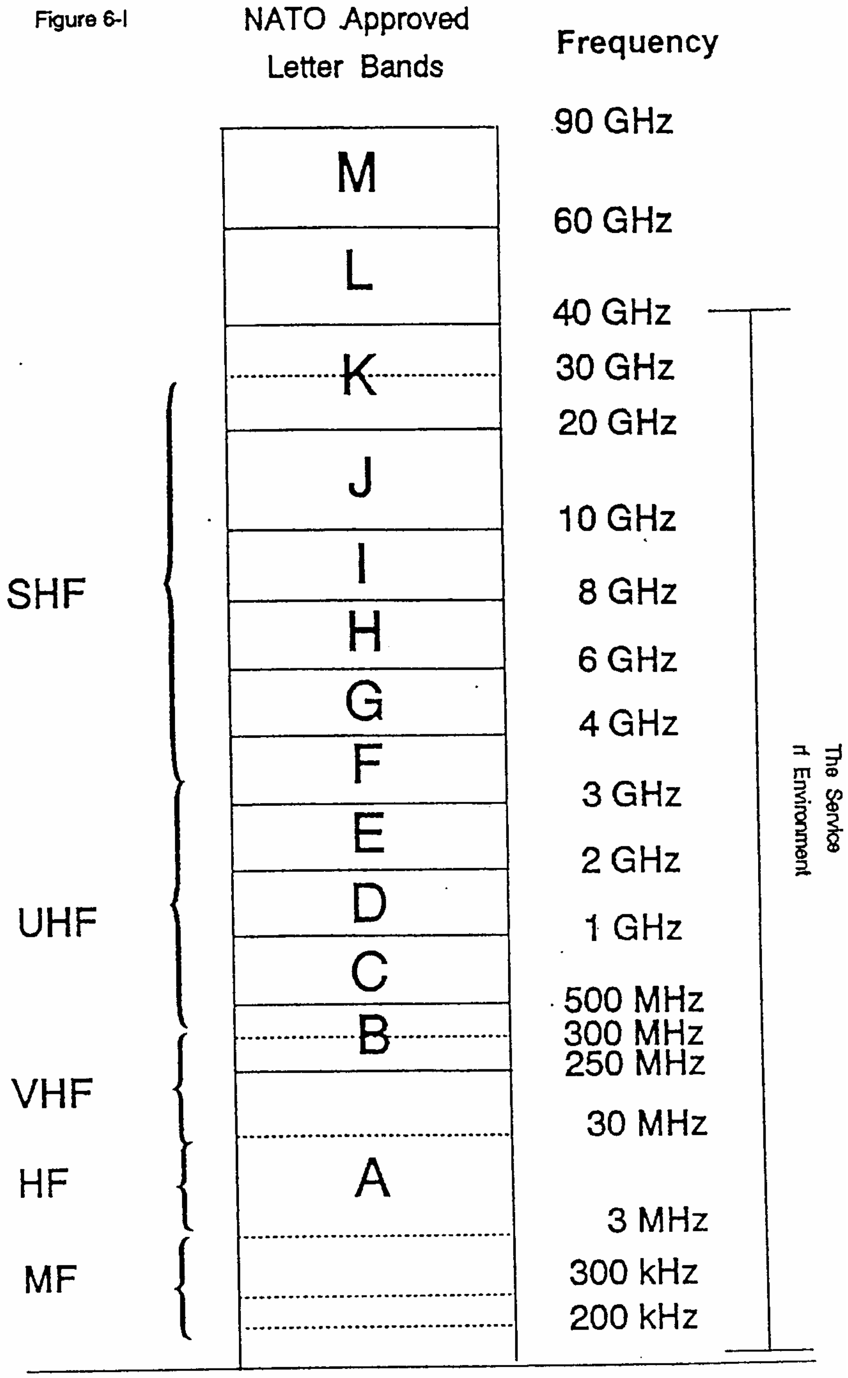
Equipment Data	Graph Line (Figure 6 - 2)	System Susceptibility
Antenna Gain 3dB Transmitter Power 20W	6	5.0 Vm^{-1}

Procedure: Read across from the right to left at 5.0 Vm^{-1} co-ordinate to graph line No. 6.
Read downwards vertically to the X axis (distance in metres).
This shows that the Safe Distance = 7 metres.

1.6.0.8. *Summary*

Where a worst case theoretical approach is considered restrictive, advice should be sought from National Authorities.

Figure 6-I



Letter Designators for RF Bands

FIGURE 6-II Safe Power Densities Exposed EED, CW and Pulsed Transmissions above 666 pps

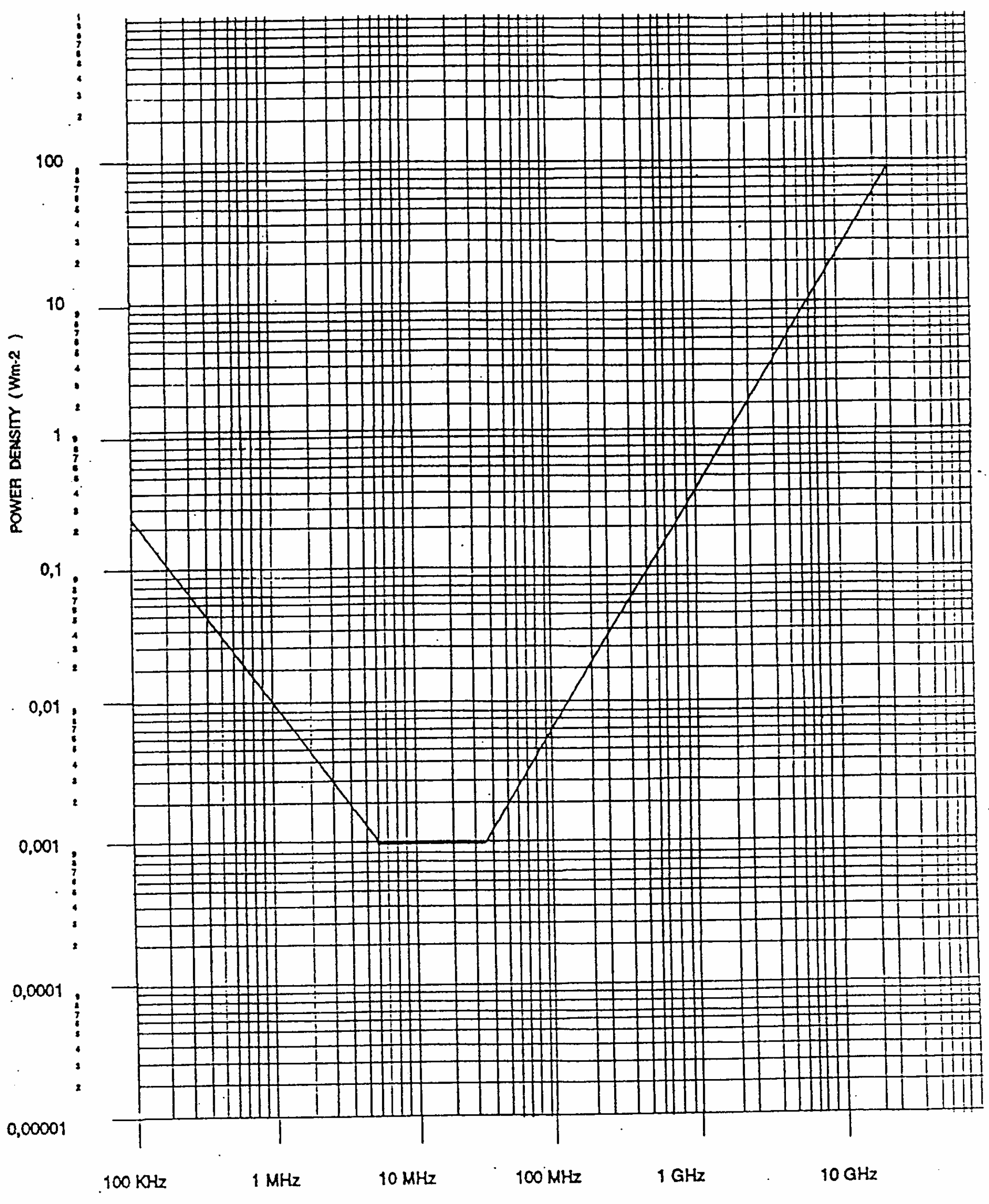
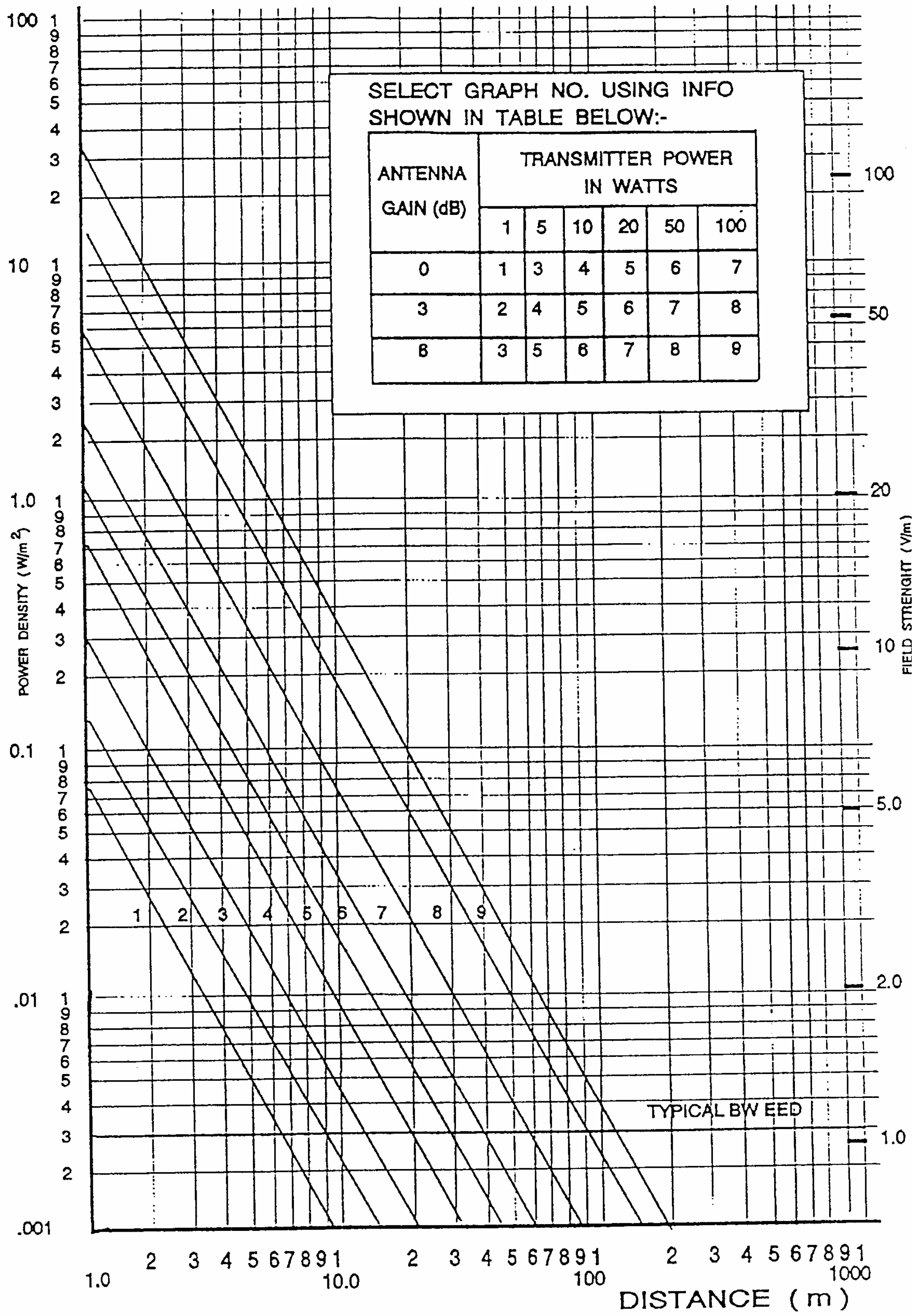


Figure 6-III VHF/UHF Management Radio RF Power Density Hazard Graph



ANTENNA GAIN (dB)	TRANSMITTER POWER IN WATTS					
	1	5	10	20	50	100
0	1	3	4	5	6	7
3	2	4	5	6	7	8
8	3	5	6	7	8	9

CHAPTER 7 - FIRE FIGHTING PRINCIPLES AND PROCEDURES

Section I - General

1.7.1.1. *Introduction*

The aim of these principles is to establish measures and procedures to ensure a minimum practicable risk in fighting fires involving ammunition and explosives at explosives areas.

These identification measures are based on the classification of fires into four fire divisions according to the hazard they present. This Chapter also establishes minimum guidelines for the development of emergency plans, including safety, security, and environmental protection, which have to be coordinated with local authorities.

Firefighting procedures, training of firefighting personnel, the use and maintenance of firefighting equipment and vehicles, the provision of water supply and alarm systems, the first aid measures, and other measures required in firefighting are outside the scope of this Chapter and shall be the responsibility of the national authority.

The ammunition hazard symbols and supplemental symbols including chemical agent symbols (see Figure F.2 below) are for firefighting situations only and are not necessarily applicable to normal operating conditions.

Section II - Fire Divisions

1.7.2.1. *Hazard Divisions involved:*

1.1 Mass explosion

1.2 Explosion with fragment hazard

1.3 Mass fire

1.4 Moderate fire

1.5 Mass explosion (blasting agents)

1.6 Non-mass explosion (EIDS article)

Fire division 1 indicates the greatest hazard. The hazard decreases with ascending fire division numbers as follows:

Hazard Division	Fire Division	Hazard involved
1.1; 1.5	1	Mass explosion
1.2; 1.6	2	Explosion with projection
1.3	3	Mass fire, or fire with minor blast or projections
1.4	4	No significant hazard

The fire divisions are synonymous with the Storage Hazard Divisions 1.1 through 1.4 ammunition and explosives. But in this case, as described in AASTP-1, Part I, Chapter 3, the HD 1.5 belongs to Fire Division 1 (mass expl) and HD 1.6 belongs to Fire Division 2 (non mass expl).

Each of the Fire Divisions is indicated by distinctive symbols in order to be recognized by fire fighting personnel approaching a scene of fire.

1.7.2.2. *Fire Division Symbols:*

Each of the four fire divisions is indicated by distinctive symbols (see Figure F.1) in order to be recognized by fire-fighting personnel approaching a scene of fire. To assist with identifying at long range, the symbols differ in shape as follows:

Shape	Fire Division
Octagon	1
Cross	2
Inverted triangle	3
Diamond	4

- The colour of all four symbols is orange in accordance with the colour on UN and IMCO labels for Class 1 (Explosives).

- The use of the specified fire division numbers is left to the discretion of national authorities. When numbers are used they are painted in black.

1.7.2.3. *Supplementary Symbols:*

a) Due to the peculiarity of hazardous substances in certain types of ammunition (Compatibility Groups G,H,J and L), the storage of this ammunition requires supplementary symbols. Those supplementary "Chemical Hazards Symbols" are used to indicate the precautions to be taken against the additional hazards proceeding from the chemical agents of that ammunition (see Figure F.2). The Chemical Hazard Symbols indicate the following precautions:
b) wear full protective suit,
c) wear respirator facepiece,
d) apply no water.
e) All three Chemical Hazard Symbols are circular in shape. They correspond to the ISO 3864 "Safety colours and safety signs". The symbols, their meanings and their sizes are shown in Figure F.2.
f) The prohibiting the use of water in fire-fighting (symbol No. 3 of Figure F.2) may be placed together with one of the other if required.
g) The indicating the requirement to wear full protective clothing should also indicate the type of full protective clothing to be worn, as the different kinds of chemical agents demand different protective measures. The type of full protective clothing to be worn at a chemical ammunition storage site and the method by which this is indicated are the responsibility of the nation concerned.
h) The chemical agents mostly used in ammunition, the compatibility groups of that ammunition and the required in storage are specified in Table T.1

1.7.2.4. *Protective Clothing:*

The following sets of full protective clothing are recommended:

- Protective clothing against casualty agents, consisting of protective respirator facepiece, impermeable suit, hood and boots, protective footwear and splash suit.
- Protective clothing against harassing agents, consisting of protective respirator facepiece.
- Protective clothing against white phosphorus (WP) smoke, consisting of fire-resistant gloves, chemical safety goggles and respirator facepiece.

The different sets of full protective clothing to be worn may be indicated by:

- a white number, corresponding to the set-no., on the blue background of the symbol, or
- a white rectangular plaque placed below the symbol listing in black letters the components of protective clothing to be worn.

Section III - Firefighting Principles

1.7.3.1. *Fire Prevention (preventive fire protection)*

Preventive fire protection comprises all measures suited to prevent the development and spreading of a fire. These are to develop a plan based on an estimate of the hazards and risk.. This analysis should comprise:

- employees,
- infrastructure and stockpile,
- exposed sites,
- public and the local environment.

The following measures are to addressed in all cases:

1.7.3.2 *Constructional Fire Prevention Measures*

The following basic criteria apply:

- Buildings designed for the processing or storage of ammunition shall be built of non-combustible or at least fire-resistant., (according to national standards) construction material. Supporting and surrounding structural elements shall resist to fire for at least 30 minutes in accordance with national standards.
- Chimneys in an explosives area must be provided with a trap to prevent flying sparks.
- Heating systems must not have uncovered glowing parts. The temperatures of exposed heating surfaces and lines must not exceed 120° C.
- An efficient fire alarm system shall be installed and maintained.
- Ammunition sites are to be equipped with an adequate fire fighting water supply according to national standards. Fire fighting water supply points shall not be sited closer than 25m to any process or storage building. They are to be positioned beside -not in - roads or traffic-ways and be provided with an area of clearance, such that vehicles will not cause an obstruction. Where alternative water supply points are not available, protection should be provided for the fire fighting vehicle and it's crew (e. g. barriers or traverses).
- Type, quantity and locations of fire fighting equipment are determined according to facility-related assessments and shall be adapted to the local conditions during annual fire fighting demonstrations.
- Fire prevention also includes lightning protection.

1.7.3.3 *Organizational Fire Prevention Measures:*

These are to be organized according to national regulations within the scope of general fire protection taking into account the following criteria:

- order and cleanness as well as strict observance of safety precautions count among the most effective fire prevention measures, equal to prohibition of smoking, fire and naked light,
- handling of flammable substances,
- prevention of additional fire loads such as stacking material, packaging material and the like,
- fire hazards of machines, equipment and tools during ammunition operations or in the case of overload of electrical lines,
- inflammable undergrowth, laying out fire lanes,
- clear zones, trimming of branches and the like,
- regular instruction of the personnel about actions to be taken in case of fire and in the use of first aid fire fighting equipment,
- preparation of an emergency planning[4] and an emergency map[5]:

[4] emergency planning: see section V

[5] emergency map: a map containing the essential details of a facility or an installation from the point of view of fire protection.

Section IV - Fire- Fighting Procedures

1.7.4.1. *General*

a) According to the stage of the fire, ammunition fires are divided into:

b) The following regulations deal with the special hazards connected with ammunition fires.

- developing ammunition fires and
- established ammunition fires.

Developing ammunition fires are fires in the vicinity of ammunition, but which do not immediately hazard it.

Established ammunition fires are those which are hazarding or about to hazard the explosives.

The term 'established ammunition fire' will be applied to all fires which cannot be positively identified as 'developing ammunition fires'.

Firefighters of ammunition and explosives fires shall have a thorough knowledge of the specific reactions of ammunition and explosives exposed to the heat or to the fire itself. The firefighting forces and other essential personnel shall be briefed before approaching the scene of the fire. They shall be informed of the known hazards and conditions existing at the scene of the fire before proceeding to the location of the fire.

Fire involving ammunition and explosives shall be fought according to the hazard classification, fire division, the stage of the fire, and the procedures specified by the Defense Component concerned. Special firefighting instructions addressing ammunition hazards shall be developed according to the needs of the Defense Components.

All fires starting in the vicinity of ammunition or explosives shall be reported and shall be fought immediately with all available means and without awaiting specific instructions. However, if the fire involves explosive material or is supplying heat to it, or if the fire is so large that it cannot be extinguished with the equipment at hand, the personnel involved shall evacuate and seek safety.

Before fighting ammunition fires in an unknown situation, the fire brigade has to analyze the situation.

Therefore it is suitable to use a car or a van, in order to provide those first at the scene a rapid means of escape if necessary.

The presence of buildings, earth barricades etc. to protect fire-fighting personnel during operations is a crucial factor for effective fighting of fires involving ammunition or explosives. The fire-fighting personnel, their vehicles and equipment must not be endangered unnecessarily.

1.7.4.2. *Detailed Fire Fighting Procedures*

Fires of ammunition and explosives are fought according to their classification in fire divisions and the stage of the fire.

(a) Fire Division 1

1. Developing fire: immediately sound the fire alarm, call the fire brigade, evacuate non-essential personnel and fight the fire for as long as it is safe to do so, in accordance with the prearranged plan. On arrival of the fire brigade, the competent person will advise them of the state of the fire. Provided that the explosives are still not hazarded, they will take immediate action to fight it. A close watch must be kept upon the fire, so that evacuation can be ordered immediately if it appears that the explosives are about to become hazarded.

2. Fully developed fire: these must not be fought. The fire alarm will be sounded and all personnel must evacuate immediately to a safe distance and take cover, in accordance with the pre-arranged plan. The fire brigade will be called from the vicinity of this point, giving its location and emphasizing that the fire is fully developed. If the brigade has already been summoned (e. g. from the incident site during the developing stage), a further call must be made to warn the fire brigade the fire is now fully developed. The brigade will rendezvous at the evacuation point to be briefed by the competent person.

3. Once the mass explosion has taken place, fire fighters should assess the situation and extinguish any secondary fires, concentrating upon those which hazard other explosives stores, as advised by the Control Officer, who should be available by this time.

(b) Fire Division 2

1. Developing fire: immediately sound the fire alarm, call the fire brigade, evacuate all non-essential personnel and fight the fire for as long as it is safe to do so, in accordance with the pre-arranged plan. On arrival of the fire brigade, the competent person will advise them of the state of the fire. Provided that the explosives are still not hazarded, they will take

immediate action to fight it. A close watch must be kept upon the fire, so that evacuation can be ordered immediately if it appears that the explosives are about to become hazarded.

2. Established ammunition fire: In the case of earth covered or heavy walled ammunition storage magazines the effects of the exploding ammunition will be contained within the magazine except possibly for those in the direction of the headwall or doors. Therefore external fires can be fought in close proximity of the magazines except in the direction of the head-wall or doors. An established fire must not be fought inside such a magazine nor external fires in front of it and no firefighting at all in case of light structure magazines. In all cases the fire alarm will be sounded, all personnel must evacuate immediately to a safe distance and take cover, in accordance with the pre-arranged that may take account of the above. The fire brigade is to be withdrawn behind the front wall line of the magazine or completely from the vicinity of this point, giving its location and emphasizing that the fire is fully developed. If the brigade has already been summoned (e. g. from the incident site during the developing stage), a further call must be made to warn the fire brigade that the fire is now fully developed. The brigade will rendezvous at the evacuation point to be briefed by the competent person.

3. Once the explosives have become involved, lobbed and self propelled items can be expected, some of which may function on impact. Secondary fires may be started. Where these hazard other explosives, attempts should be made to extinguish them without exposing crews to undue risk.

(c) Fire Division 3

1. Developing fire: immediately sound the fire alarm, call the fire brigade, evacuate all non-essential personnel and fight the fire for as long as it is safe to do so, in accordance with the pre-arranged plan. On arrival of the fire brigade, the competent person will advise them of the state of the fire. Provided that the explosives are still not hazarded, they will take immediate action to fight it. A close watch must be kept upon the fire, so that evacuation can be ordered immediately if it appears that the explosives are about to become hazarded.

2. Fully developed fire: these must not be fought. The fire alarm will be sounded and all personnel will evacuate immediately to a safe distance and take cover in accordance with the pre-arranged plan. The fire brigade is to be called from the vicinity of this point, giving its' location and emphasizing that the fire is fully developed. If the brigade has already been

summoned (e. g. from the incident site during the developing stage), a further call must be made to warn the fire brigade that the fire is now fully developed. The brigade will rendezvous at the evacuation point to be briefed by the competent person.

3. Once the explosives have become involved a particularly intense fire can be expected, with high levels of radiant heat, probably with flame jets from openings in the building. Packages may burst, some violently, but there will be no explosions. Secondary fires may be started by radiation or projected fire brands. Once the main fire is seen to be reducing to a level that enables these to be fought, action should be taken to extinguish them, keeping crews away from openings in the building. Visors and gloves are advised.

(d) Fire Division 4

1 Fires involving items of Fire Division 4 may be fought as dictated by the situation.

2 After an extended period of time the ammunition may explode sporadically. For protection against fragments and missiles the fire-fighting forces should not approach the scene of fire any closer than necessity dictates, certainly not any closer than 25 m. When possible the fire should be fought from a protected location.

(e) Ammunition requiring Supplementary Symbols

Ammunition containing explosives and additional hazardous agents (see Figure F.2) requires special attention and precautions in fire-fighting. Such ammunition belongs to different fire divisions depending on the kind and quantity of explosives contained in the ammunition. Such fires are fought in accordance with the fire division(s) involved taking into account the precautions indicated by the supplementary l. The issue of the corresponding special fire-fighting regulations is left to the discretion of the national authorities.

(f) Ammunition Containing Depleted Uranium:

1. Combustion of DU

i) The combustion properties of DU metal must be taken into account when dealing with a fire involving DU ammunition.

(ii) The colour of smoke produced by burning DU may be yellow but the absence of colour is not a reliable indication that DU metal is not involved; therefore it is prudent to assume from the outset that DU is burning and that DU oxide smoke is being produced and to apply the appropriate precautions, as follows.

2. Precautions

Once uranium metal has ignited and a vigorous self-sustaining oxidation reaction is started, the application of small quantities of conventional extinguishing agents is likely to be ineffective and may even add to the spread of the fire by dispersing the burning uranium. For example, insufficient water to cool the fire would react with hot uranium metal to form hydrogen. For a small fire involving uranium and no explosives, the most effective extinguishing agent is one of the inert powdered smothering agents (e. g. Pyromet) but when explosives are present the closeness of approach necessary to deliver such an extinguishing agent to the seat of the fire would be hazardous to the firefighters. In particular, propellants, the most likely explosives to be closely associated with the DU, may produce intense radiant heat, firebrands and some ejected fragments. The firebrands may be only small glowing of packaging materials but it is possible that they could be fiery fragments of burning propellant

3. Fire Fighting Methods

i) In all cases, treat as a radiological risk - i. e. wear respirator facepiece, ensure all parts of the body are covered and fight fire from up-wind direction. Put down smoke with spray jet. Prevent water from flowing-off, if possible (dikes).

(ii) DU without an explosive component. Use copious water at optimum jet/spray range. Do not use halons. No projections are likely, other than the minor spallations associated with metal fires hit by water.

(iii) DU <u>with</u> an explosive component. Fight in accordance with the fire division concerned.

(g) Underground Storage Sites

Fire precautions

In view of the confined nature of underground sites, the increased problems associated with access and the large quantities of explosives that could be held, special attention must be given to fire safety measures, pre-planning and the adequate provision and efficient maintenance of fire fighting equipment. It must be considered that local fire brigades may not be willing to commit personnel to fire fighting in such locations. This will include circumstances regarding any suspected fire, details of which are not known or corroborated by automatic telemetry or monitoring systems such as : close circuit television, automatic heat and humidity sensors, infra red/ ultra violet sensors, emergency lighting systems, water suppression/ drencher systems and alternative access points.

Fire prevention at underground storage sites requires special preplanning and in each individual case should be supported by facility-related emergency response plan.

The probability of a fire that could cause an "initial event" will be reduced substantially by installing an automatic smoke-detecting and fire-extinguishing system. Reserve water tanks should be aboveground well clear of a possible crater area and if water is carried to hydrants underground, consideration should be given to alternative supply.

An alarm system should be provided to operate throughout the whole area, both above and below ground. The system should be connected to a central control point, manned at all times, located where additional resources can be speedily summoned and the pre-arranged fire plan set in action.

In air-conditioned sites or in sites provided with forced ventilation, the need to shut these down on an outbreak of fire will have to be considered.

Fire-fighting equipment retained underground should be positioned where it is most likely to be accessible when an outbreak of fire is detected.

Self-contained breathing apparatus and training in its use are essential for underground fire-fighting. No person or volunteer fire fighter unless equipped with such apparatus, is to enter an underground site in which fire has broken out until the area has been certified free from noxious gas.

Special consideration should be given to the following aspects:

- installation of automatic fire-detecting and fire-extinguishing systems;
- assurance of fire fighting water supply under worst-case conditions;
- adequate means of escape, well signposted and lit, together with fire brigade access;
- assurance of an efficient alarm system - both above and below ground.

  All personnel must be trained in the use of fire equipment and fire parties must be detailed, trained and practiced.

Section V - Emergency Planning

1.7.5.1. *Standard Operating Procedures*

Installations or responsible activities shall develop standard operating procedures (SOPs) or plans designed to provide safety, security and environmental protection. Plans shall be coordinated with the applicable national, regional and local emergency response authorities (e.g. law enforcement, fire departments and hospitals etc.) and any established Local Emergency Planning Committees (LEPC).

At a minimum, those SOPs or plans shall include the following:

- Specific sections and guidance that address emergency preparedness, contingency planning and security. For security, those SOPs or plans shall limit access to trained and authorized personnel.
- Procedures that minimize the possibility of an unpermitted or uncontrolled detonation, release, discharge or migration of military munitions or explosives out of any storage unit when such release, discharge or migration may endanger human health or the environment.
- Provisions for prompt notification to emergency response and environmental agencies and the potentially affected public for an actual or potential detonation or uncontrolled release, discharge or migration (that may endanger human health or the environment).

To produce the necessary SOP's is in the responsibility of national authorities.

The commanding leaders of the installations are responsible for the training of their personnel and the coordination with the LEPC. They also have to ensure that all SOP's and Emergency Plans belonging to the special installation are reachable to external security and emergency authorities.

Competent persons belonging to the depot or to an external fire brigade are regularly be trained to be available to advise the fire chief and external fire fighters.

Emergency withdrawal distances for nonessential personnel are intended for application in emergency situations only and are not to be used for facility siting.

Emergency withdrawal distances depend on fire involvement and on whether or not the hazard classification, fire division and quantity of explosives are known. The withdrawal distance for essential personnel at accidents shall be determined by emergency authorities on site. Emergency authorities shall determine who are essential personnel.

If a fire involves explosives or involvement is imminent, then the initial withdrawal distance applied shall be at least the inhabited building distance while the appropriate emergency withdrawal distance for nonessential personnel is being determined. When emergency authorities determine that the fire is or may become uncontrollable and may result in deflagration and/or detonation of nearby ammunition or explosive material, all nonessential personnel shall be withdrawn to the appropriate emergency withdrawal distance listed in Table.T.2

Table T.1 Compatibility Group and Chemical Hazard Symbols Required for Storage of Chemical Ammunition and Substances.

Chemical Ammunition and Substances	Compatibility Group[2]	Full Protective Clothing			Breathing Apparatus	Apply No Water
		Set 1	Set 2	Set 3		
1	2	3	4	5	6	7
Toxic Agents[1]	K	X				
Tear Gas, O-Chlorobenzol	G		X			
Smoke, Titanium Tetrachloride (FM)	G		X			
Smoke, Sulpher trioxide-chlorosulphonic acid solution (FS)	G		X			
Smoke, Aluminum-zinc oxide-hexachloroethane (HC)	G				X	X
White Phosphorous (WP)	H			X		
White Phosphorous plasticized (PWP)	H			X		
Thermite or Thermate (TH)	G				X	X
Pyrotechnic Material (PT)	G				X	X
Calcium Phosphide	L				X	X
Signaling Smokes	G				X	
Isobutyl methacrylate with oil (IM)	J				X	
Napalm (NP)	J			X	X	X
Triethylaluminim (TEA)(TPA)	L			X		X

Notes:

1 Toxic Agents without explosives components that normally would be assigned to Hazard Division 6.1 may be stored as compatibility group K.

2 See Chapter 3.

Table T.2 Emergency Withdrawal Distances for Nonessential Personnel.

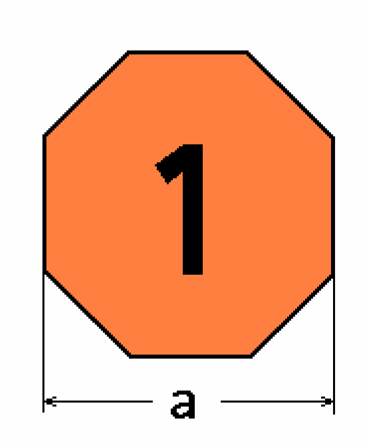
HD	Unknown Quantity	Known Quantity
Unknown, located in facility, truck and or tractor trailer	1250m	1250m
Unknown, located in railcar	1500m	1500m
1.1[1] and 1.5	Same as unknown facility, truck trailer or railcar as appropriate	For transportation, ≤ 7500kg → 870m; 7500<NEM≤16000 kg →1120m 1.5 → 1100m For facilities, ≤7000kg → 850m 7000 <NEM≤ 25000kg →1300m >25000kg → 1300m – 44,4 $Q^{1/3}$
1.2[1] and 1.6	560m	560m
1.3[2]	405m	6,4 $Q^{1/3}$ with a 120m minimum.
1.4	100m	100m

Notes:

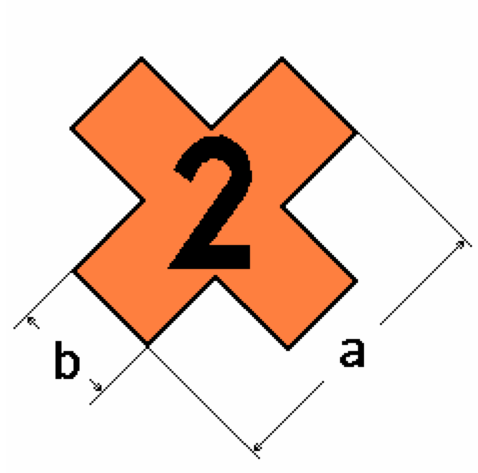
1 For HD 1.1 and HD 1.2 AE, if known, the maximum range fragments and debris will be thrown (including the interaction effects of stacks of items, but excluding lugs, strongbacks, and/or nose and tail plates) may be used to replace the distances given.

2 Emergency withdrawal distances do not consider the potential flight range of propulsion units.

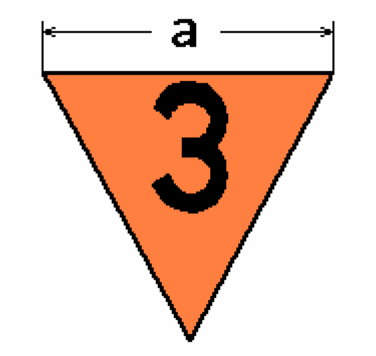
Figure F.1 Fire Division Symbols



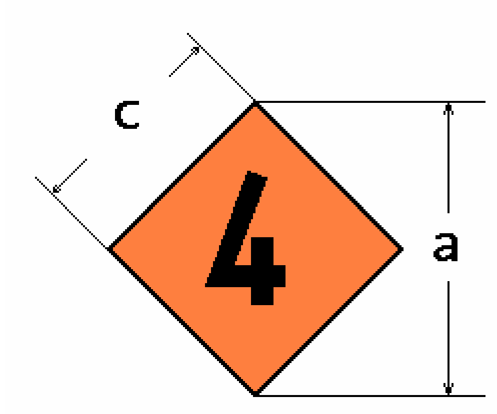
Fire Division 1



Fire Division 2



Fire Division 3



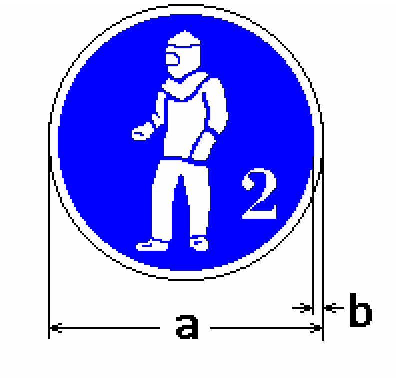
Fire Division 4

Sizes	large	small
	[mm]	[mm]
a	600	300
b	200	100
c	~424	~212
Letters (height)	~315	~158
Letters (width)	~50	~25

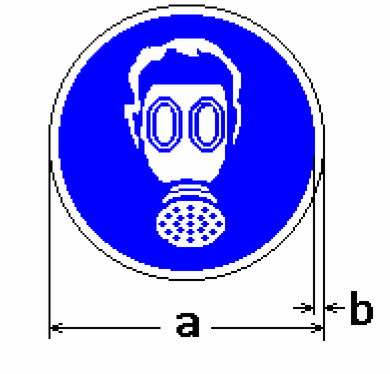
Colours*	
Background	orange
Numbers	black

* The specification of the colours is left to the discretion of the national authorities.
(Specification of signs and colours – except orange – is given in ISO 3864 "Safety colours and safety signs")

Figure F.2 Chemical Hazard Symbols



Symbol 1 Wear full protective clothing



Symbol 2 Wear breathing apparatus

Colours:*

Background is blue

Figure, rim and number are white when set-no. is indicated by number;

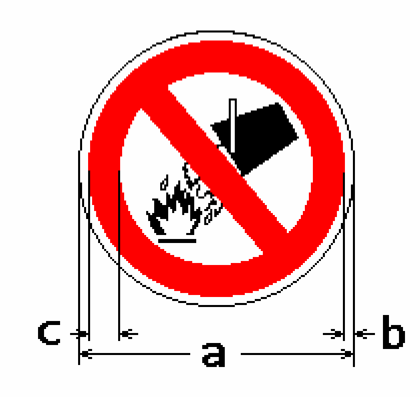
Figure and rim when used to indicate set-no. by colour:

- Red for Set 1 Protective Clothing
- Yellow for Set 2 Protective Clothing
- White for Set 3 Protective Clothing

Colours:*

Background is blue

Figure and rim are white



Symbol 2 Apply no water

Colours:*

Background is white

Circle and diagonal are red

Figure is black

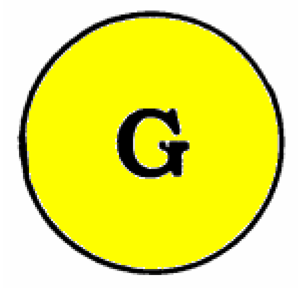
* The specification of the colours is left to the discretion of the national authorities.

(Specification of signs and colours – except orange – is given in ISO 3864 "Safety colours and safety signs")

Sizes	Large	small
	[mm]	[mm]
a	630	315
b	12	6

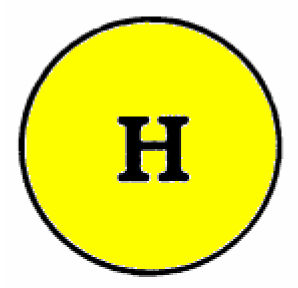
c	63	32

Figure F.3 Supplemental Chemical Hazard Symbols.[6]



G – Type Nerve Agents

VX Nerve Agents



H – Type Mustard Agents

Colours:*

Background: yellow

Letters: black

*The specification of the colours is left to the discretion of the national authorities.

(Specification of signs and colours – except orange – is given in ISO 3864 "Safety colours and safety signs")

	large	small
	[mm]	[mm]
Diameter	630	315
Letters (height)	315	158
Letters (width)	50	25

[6] Given as an example; Nations may use additional symbols which may differ in size, form and colour.

CHAPTER 8 - REPORTS ON ACCIDENTAL EXPLOSIONS

1.8.0.1. *Information Required*

In order that reports on damage resulting from accidental explosions be of value to the "NATO Group of Experts on the Safety Aspects of Transportation and Storage of Military Ammunition and Explosives (AC/258)" and useful in verifying the safety principles, the information should include the following:

1) Type and quantity of ammunition or explosives in the stack or building where the accident occurred.

2) NEQ and name of filling and weight of filled items.

3) Method of packing of the ammunition or explosives where the initial accident occurred and material of packages.

4) Distances between the articles in the packages.

5) Method of storing the ammunition or explosives where the initial accident occurred.

6) Information as above for neighbouring storage places of ammunition and explosives stating whether such neighbouring stacks were set off or otherwise affected.

7) The thickness of walls and roofs if ammunition or explosives were stored in buildings and whether there were windows through which fragments or debris got into the buildings.

8) Distances between buildings, or stacks, if buildings were not used.

9) The presumed influence of barricades upon the protection of neighbouring buildings and stacks.

10) Fire-fighting measures (attempts to fight fire).

11) The time between the first and last propagation from stack to stack.

12) The general effect on inhabited buildings in the vicinity and their inhabitants.

13) A map indicating the size and distribution of fragments and debris.

14) A brief summary of the causes and the effects.

1.8.0.2. *Summary Report*

A summary report is first required for translation and distribution by NATO. A full report should be forwarded to NATO as soon as possible. This report would be available on loan to NATO-countries in the language of the country of origin.

CHAPTER 9 - DEPLETED URANIUM AMMUNITION

1.9.0.1. *Use of Depleted Uranium*

Ammunition containing depleted uranium (DU) has been developed as an improved armour piercing weapon, mainly for anti-tank warfare. A round of DU ammunition may consist of a DU penetrator made of DU metal (or of a DU alloy) and a propellant charge which may be integral with the penetrator or loaded into the gun separately. The use of DU in armour piercing ammunition exploits the high density of the metal, which, when propelled at high velocity, results in the delivery of sufficient kinetic energy to effect penetration. The penetration is accompanied by disintegration of the projectile and a violent combustion of the fragments thus formed.

1.9.0.2. *Radioactivity*

a) DU is slightly radioactive and, if ingested, has a chemical toxicity about the same as lead. DU is not a fissile material and cannot be used in the absence of fissile material to construct a nuclear weapon. Therefore DU ammunition is in no sense, and cannot be described as, a nuclear weapon, a radiological, a chemical weapon or a weapon of mass destruction.

b) The radioactivity of DU results in the emission of low levels of ionising radiation from DU ammunition. The radiation levels external to bulk quantities of DU ammunition are not likely to be more than ten times the natural radiation background provided actual contact with the metal is avoided; therefore even prolonged personal exposure to the external radiation field does not constitute a significant hazard. Because the radiation levels from DU metal are so low, this material is used in civil applications requiring a high density metal, e.g. yacht keels, aircraft balance weights, machinery ballast, flywheels and gyro rotors. Although the radiation levels expected in the vicinity of stored quantities of DU ammunition are too low to present a significant risk of harm to personnel, the principle of keeping exposures of people to radiation as low as reasonably practicable should be followed by adopting simple precautions such as monitoring the radiation levels and keeping exposure times to the minimum.

1.9.0.3. *Effects of Fire and Explosion*

a) DU metal when subjected to a sustained high temperature in a copious supply of air will ignite and burn. A small fraction of the material may be dispersed into the atmosphere as a DU oxide fume or smoke and hence could be inhaled by persons situated downwind of an accidental fire or explosion involving DU ammunition. The risk of consequent damage to the health of members of the public would be very low indeed at the safety distances required to protect against the explosives hazards associated with the ammunition but the risk should be assessed for each type of DU ammunition in the proposed storage conditions. The existing safety procedures for the storage of ammunition generally will also apply to DU ammunition according to its hazard classification, but simple additional precautions may be needed in some instances to ensure that in the event of an accident any additional risk of harm to people due to the atmospheric dispersion of a DU oxide smoke will be small compared with the risk arising from the explosive content of the ammunition.

b) In Part II, Chapter 8 of this Manual a more detailed account is given of the properties of DU and their relevance to the storage of DU ammunition.

ANNEX I-A

QUANTITY-DISTANCE TABLES FOR ABOVEGROUND STORAGE

Net Explosives Quantities in Kilograms

Quantity-Distances in Metres

It is essential to study the text in Chapter 3
when using this Annex since they are complementary.

SECTION I : GENERAL NOTES AND EXPLANATION OF SYMBOLS

A.1.1 Quantity-Distance Criteria

Quantity-Distance criteria and the formulae used to generate values in the Q-D Tables are given in Part II Annex A.

A.1.2 Rounding of Quantity-Distances

The values of quantity-distances in the Q-D Tables 1 to 3 have been calculated using the formulae at the foot of the tables rounded up to the nearest metre.

A.1.3 Determination of Quantity-Distances or Permissible Quantities

The method of determining quantity-distances for different Potential Explosion Sites is given in Sections 1.4.2.4 – 1.4.2.6.

A.1.4 General Note on Pictographs

The pictographs in the following paragraphs are introduced to simplify the presentation of information in the Q-D Tables. The tables are intended to be used in conjunction with the principles given in the text of this Leaflet. The pictographs are purely diagrammatic; their shapes do not imply that actual structures should have similar shapes and proportions. The orientation shown is intended to indicate the direction of principal concern for blast, flame, radiant heat and projections as shown by arrows. In an actual situation every direction must be considered in turn. At a Potential Explosion Site there are relatively few significant variations but at an Exposed Site it is necessary to distinguish among different types of construction and among different functions of buildings. For these reasons a given building may require one symbol when it is being considered as a Potential Explosion Site and another symbol when it is considered as an Exposed Site.

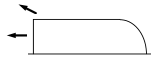
A.1.5 Symbols for Potential Explosion Sites (PES)

a. General

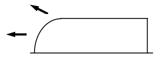
These descriptions are merely for easy identification of the pictograph used in the Q-D Tables. An Exposed Site is assumed to exist to the left of each pictograph.

b. Earth-covered Building (see NOTE 1 overleaf)

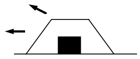
(1) Building with earth on the roof and against three walls. Directional effects through the door and headwall are towards an Exposed Site



(2) The same building as (1) but the directional effects through the door and headwall are away from an Exposed Site

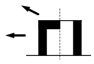


(3) The same building as (1) but the directional effects through the door and headwall are perpendicular to the direction of an Exposed Site



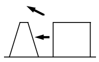
c. Heavy-Walled Building

Building of non-combustible construction with walls of 30 cm reinforced concrete with or without a protective roof, a protective roof being defined as constructed of 15 cm reinforced concrete with suitable support. The door is barricaded if it faces a PES



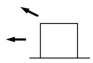
d. Barricaded Site

(1) Open-air stack or light structure, barricaded
(2) Truck, trailer, railcar or freight container loaded with ammunition, barricaded



e. Unbarricaded Site

(1) Open-air stack or light structure, unbarricaded
(2) Truck, trailer, railcar or freight container loaded with ammunition, unbarricaded



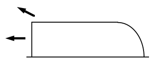
A.1.6 Additional Symbols for Potential Explosion Sites (PES) for HD 1.2

a. General

These descriptions are merely for easy identification of the pictograph used in the Q-D Tables. An Exposed Site is assumed to exist to the left of each pictograph. The descriptions are only valid for HD 1.2 purposes.

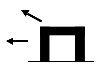
b. Earth-covered Building

(1) Building with earth on the roof and against three walls. Directional effects through the door and headwall are towards an Exposed Site. (see NOTE 2 overleaf)

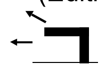


c. Hardened Building

(1) A building of non-combustible construction with walls of 30 cm reinforced concrete with a protective roof of 15 cm reinforced concrete with suitable support which will effectively contain the effects from HD 1.2 ammunition (except through the door). The building may or may not be barricaded.



(2) The same building as (1), Directional effects through a door or other large aperture, frangible or venting panel are towards an exposed site. . (see NOTE 2 overleaf)



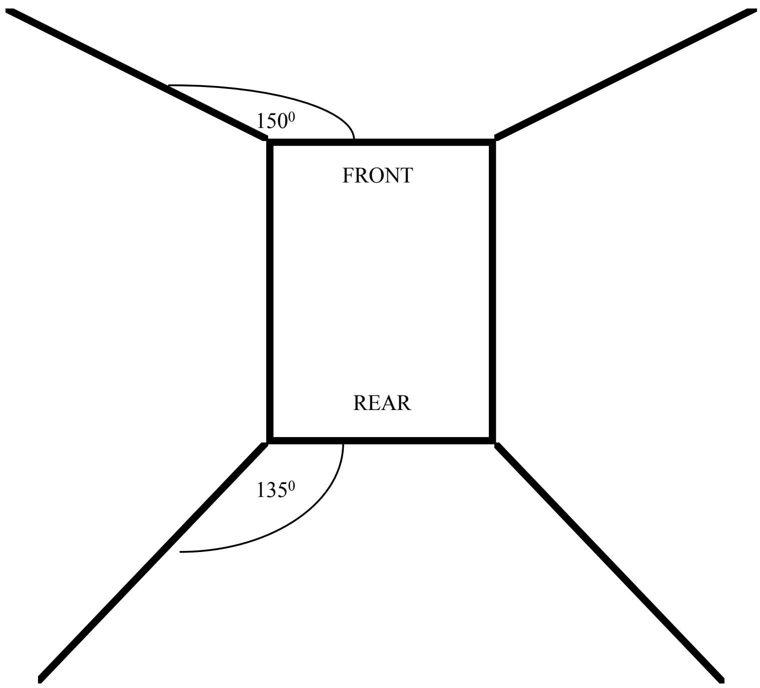
NOTE 1 (See figure below)

The directional effects for HD 1.1 from buildings which meet the design criteria for standard igloos are considered to occur :

a. through the front in the area bounded by lines drawn at 150^{o} to the front face of the PES from its front corners.

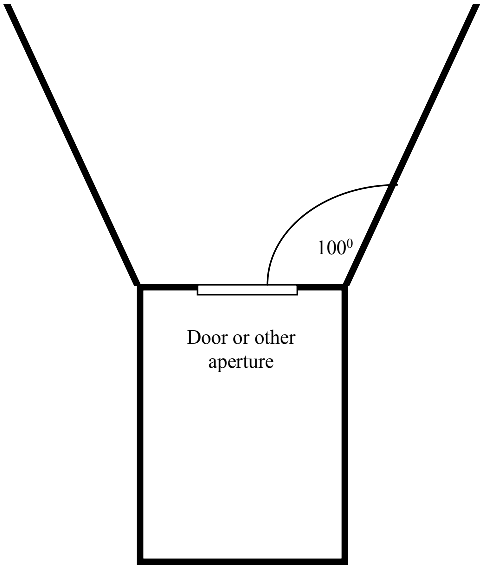
b. through the rear in the area bounded by lines drawn at 135^{o} to the rear face of the PES from its rear corners.

c. all area around a PES not included in a. or b. above are considered to be to the side of the PES. In those cases where an Exposed Site (ES) lies on the line separating rear/side etc. of a PES, the greater quantity-distance should be observed.



NOTE 2 (See figure below)

The directional effects for HD 1.2 from buildings which meet the design criteria for standard igloos or HD 1.2 containment buildings are considered to occur through the front in the area bounded by lines drawn at 100° to the front face of the PES from its front corners.



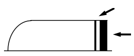
A.1.7 Symbols for Exposed Sites (ES)

a. General

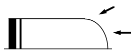
These descriptions are merely for easy identification of the pictographs used in the Q-D tables. A Potential Explosion Site is assumed to exist to the right of each pictograph.

b. Igloo designed for 7 bar

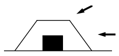
(1) Igloo designed in accordance with Part II, subparagraphs 2.3.2.2.a) and 2.3.2.2.b)2), with the door towards a PES.



(2) The same igloo as (1) but the door faces away from a PES.

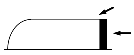


(3) The same igloo as (1) but the door faces perpendicular to the direction of a PES.

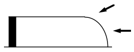


c. Igloo designed for 3 bar

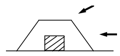
(1) Igloo designed in accordance with Part II, subparagraphs 2.3.2.2.a) and 2.3.2.2.b)1), with the door towards a PES.



(2) The same igloo as (1) but the door faces away from a PES.

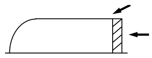


(3) The same igloo as (1) but the door faces perpendicular to the direction of a PES.

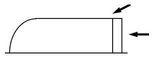


d. Other earth-covered buildings

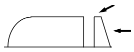
(1) Earth-covered building not complying with Part II, paragraph 2.3.2.2, but with a headwall and door(s) resistant to high velocity projections, subparagraph 1.3.5.6.a). The door faces a PES.



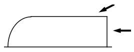
(2) Earth-covered building not complying with Part II, paragraph 2.3.2.2, but with a headwall and door(s) resistant to fire and low velocity projections, subparagraph 1.3.5.6.b). The door faces a PES.



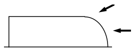
(3) Earth-covered building not complying with Part II, paragraph 2.3.2.2, but with a door barricade, paragraphs 1.3.6.4 – 1.3.6.6. The door faces a PES.



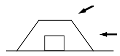
(4) Earth-covered building not complying with Part II, paragraph 2.3.2.2, with the door facing a PES.



(5) The same building as (4) but the door faces away from a PES.

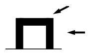


(6) The same building as (4) but the door faces perpendicular to the direction of a PES.

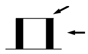


e. Heavy Walled Building

(1) Building of non-combustible construction with walls of [30 cm] reinforced concrete and protective roof of 15 cm reinforced concrete with suitable support. The door is barricaded if it faces a PES.

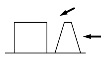


(2) The same building as (1) but without protective roof. The door is barricaded if it faces a PES.



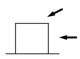
f. Barricaded Site

(1) Open air stack or light structure, barricaded.
(2) Truck, trailer, railcar or freight container loaded with ammunition, barricaded.



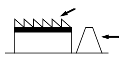
g. Unbarricaded Site

(1) Open air stack or light structure, unbarricaded.
(2) Truck, trailer, railcar or freight container loaded with ammunition, unbarricaded

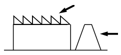


h. Process Building (Explosives Workshop)

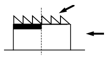
(1) Process Building with protective roof, barricaded (a heavy wall may constitute a barricade).



(2) Process Building without protective roof, barricaded (a heavy wall may constitute a barricade).



(3) Process Building with or without a protective roof, unbarricaded.



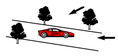
A.1.8 Symbols for Exposed Sites frequented by the general public

a. General

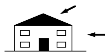
These descriptions are merely for easy identification of the pictographs used in the Q-D tables. A Potential Explosion Site is assumed to exist to the right of each pictograph. The descriptions are valid for all Hazard Division purposes

b. Exterior Site

(1) Public traffic Route.



(2) Inhabited Building.



SECTION II : QUANTITY-DISTANCE TABLES (Q-D TABLES)

A.2.1 General Instruction

This section presents tables which contain information to determine suitable quantity-distances between sites except for a Potential Explosion Site containing ammunition and explosives of HD 1.4 or inert ammunition. Each Q-D table comprises two pages. The left hand page presents a matrix in which each cell represents a combination of a Potential Explosion Site and an Exposed Site and refers to one or more D-distances or constant values of distance. The right hand page presents columns of tabulated values of D-distances generated from the distance function shown at the foot of each column, subject to any overriding minimum or maximum fixed distances. Where a cell in the matrix shows more than one option the selection is made on the basis of special conditions and the desired level of protection. References to specific subparagraphs appear for Table 1 at the foot of the matrix and for Tables 2 and 3 at the right hand pages.

A.2.2 HD 1.1, 1.2 or 1.3

See the corresponding Q-D Table 1, 2, 3A or 3B. Table 3A is used for the more hazardous items, mainly propellants (1.3) and Table 3B for the less hazardous items (1.3 *), see Section 3.5.

A.2.3 HD 1.4

Separation distances from ammunition or explosives of HD 1.4 are not a function of the Net Explosives Quantity. Separation distances prescribed by fire regulations apply. Stacks or non fire-resistant buildings should normally be separated by 10 m to prevent ignition by radiant heat.

A.2.4 Inert Ammunition

Separation distances from inert ammunition are determined by fire regulations. Stacks or non fire-resistant buildings should normally be separated from one another by 10 m to prevent ignition by radiant heat.

It is essential to study the text in Chapter 3 when using this Annex since they are complementary

TABLE 1	Q-D TABLE FOR HAZARD DIVISION 1.1					
PES / ES	(a)	(b)	(c)	(d)	(e)	(f)
1	D3[ag]	D3[ag]	D5[a]	D5[a]	D5[a]	D4[ag]
2	D3[ag]	D3[ag]	D5[b]	D5[b]	D5[b]	D4[ag]
3	D4[agh] or D5[ag]	D4[agh] or D5[ag]	D6[be]	D6[be]	D6[be]	D4[bghe] or D6[ae]
4	D3[ag]	D3[ag]	D5[b]	D5[b]	D5[b]	D5[ag]
5	D3[ag]	D3[ag]	D6[b]	D6[b]	D6[b]	D5[bg]
6	D4[bgh] or D6[a]	D4[bgh] or D6[a]	D6[ce]	D6[ce]	D6[ce]	D6[ce]
7	D4[ag]	D4[b] or D5[a]	D8[bde], D9[bje] or D12[ae]	D8[be]	D8[bde]	D8[bde]
8	D6[a]	D6[a]	D9[bde], D9[bje] or D12[ae]	D8[be]	D8[bde]	D8[bde]
9	D4[bgh] or D7[b]	D4[bgh] or D7[b]	D9[ce]	D4[cghe] or D9[ce]	D9[ce]	D9[ce]
10	D4[bgh] or D7[b]	D4[bgh] or D7[b]	D9[b]	D9[b]	D9[b]	D9[b]
11	D4[bgh] or D7[b]	D4[bgh] or D7[b]	D9[cje]	D4[cghe] or D9[ce]	D9[cje]	D9[cje]
12	D4[cgh] or D7[b]	D4[cgh] or D7[b]	D4[cghe] or D7[be]	D4[cghe] or D7[be]	D4[cghe] or D7[be]	D5[cghe] or D7[be]
13	D4[cgh] or D7[b]	D4[cgh] or D7[b]	D4[cghe] or D7[be]	D4[cghe] or D7[be]	D4[cghe] or D7[be]	D5[cghe] or D7[be]
14	D4[bgh] or D7[b]	D4[bgh] or D7[b]	D4[bghe] or D7[be]	D1[bie], D2[bie] D4[bghe] or D7[be]	D1[bie], D2[bie] D4[bghe] or D7[be]	D4[bghe] or D7[be]
15	D4[bgh] or D7[b]	D4[bgh] or D7[b]	D9[cje] or D12[fe]	D1[bie], D2[bie] D4[bghe] or D7[be]	D9[cje] or D12[fe]	D9[cje] or D12[fe]
16	D10	D10	D10	D10	D10	D10
17	D10 (∃270m)	D10 (∃270m)	D10 (∃270m)	D10[o]	D10[o]	D10 (∃270m)
18	D10 (∃270m)	D10 (∃270m)	D13	D10[o]	D13	D13
19	D11 (∃270m)[k] D16 (∃270m)[kn] D13 (∃400m) D14 (∃400m)[n]	D11 (∃270m)[k] D17 (∃270m)[kn] D13 (∃400m) D15 (∃400m)[n]	D11 (∃270m)[k] D13 (∃400m)	D11[k] D13	D11[k] D13	D11 (∃270m)[k] D13 (∃400m)
20	D13 (∃400m)[l] D14 (∃400m)[ln]	D13 (∃400m)[l] D14 (∃400m)[ln]	D13 (∃400m)[l]	D13[l] D13 (∃400m)	D13[l] D13 (∃400m)	D13 (∃400m)[l]

TABLE 1 (PAGE 1) - Q-D TABLE FOR HAZARD DIVISION 1.1

Net Explosives Quantity in kg	Quantity-Distances in metres											
	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12
500	3		4	7	9	15	20	29	39	64	180	180
600	3		5	7	10	16	21	31	41	68	180	190
700	4		5	8	10	16	22	32	43	72	180	200
800	4		5	8	11	17	23	34	45	75	180	210
900	4		5	8	11	18	24	35	47	78	180	215
1 000	4		5	8	11	18	24	36	48	80	180	225
1 200	4		6	9	12	20	26	39	52	86	180	240
1 400	4		6	9	13	21	27	41	54	90	180	250
1 600	5		6	10	13	22	29	43	57	94	180	260
1 800	5		7	10	14	22	30	44	59	98	180	270
2 000	5		7	11	14	23	31	46	61	105	180	280
2 500	5		7	11	15	25	33	49	66	110	185	305
3 000	6		8	12	16	26	35	52	70	120	205	325
3 500	6		8	13	17	28	37	55	73	125	220	340
4 000	6		8	13	18	29	39	58	77	130	235	355
5 000	6		9	14	19	31	42	62	83	140	255	380
6 000	7		10	15	20	33	44	66	88	150	270	405
7 000	7		10	16	22	35	46	69	92	155	285	425
8 000	7		10	16	22	36	48	72	96	160	300	445
9 000	8		11	17	23	38	50	75	100	170	310	465
10 000	8		11	18	24	39	52	78	105	175	320	480
12 000	9		12	19	26	42	55	83	110	185	340	510
14 000	9		13	20	27	44	58	87	120	195	360	540
16 000	9		13	21	28	46	61	91	125	205	375	560
18 000	10		14	21	29	48	63	95	130	210	390	590
20 000	10		14	22	30	49	66	98	135	220	405	610
25 000	11		15	24	33	53	71	110	145	235	435	650
30 000	11		16	25	35	56	75	115	150	250	460	690
35 000		15	17	27	36	59	79	120	160	265	485	730
40 000		16	18	28	38	62	83	125	165	275	510	760
50 000		17	19	30	41	67	89	135	180	295	550	820
60 000		18	20	32	44	71	94	145	190	315	580	870
70 000		19	21	33	46	75	99	150	200	330	610	920
80 000		19	22	35	48	78	105	160	210	345	640	960
90 000		20	23	36	50	81	110	165	220	360	670	1000
100 000		21	24	38	52	84	115	170	225	375	690	1040
120 000		22	25	40	55	89	120	180	240	395	730	1100
140 000			26	42	58	94	125	190	250	420	770	1160
160 000			28	44	60	98	135	200	265	435	810	1220
180 000			29	46	63	105	140	205	275	455	840	1260
200 000			30	47	65	110	145	215	285	470	870	1300
250 000			32	51	70	115	155	230	305	510	940	1400
Distance Functions	D1= 0.35 $Q^{1/3}$	D2=0.44$Q^{1/3}$	D3=0.5$Q^{1/3}$	D4= 0,8 $Q^{1/3}$	D5=1.1$Q^{1/3}$	D6= 1.8$Q^{1/3}$	D7=2.4$Q^{1/3}$	D8= 3.6$Q^{1/3}$	D9=4.8$Q^{1/3}$	D10= 8.0$Q^{1/3}$	D11=3.6 $Q^{1/2}$ for Q<4500 D11=14.8 $Q^{1/3}$ for Q≥4500	D12=22.2$Q^{1/3}$

a. see 1.4.1.9.a)&1.4.1.9.b)1)	- virtually complete protection against instantaneous propagation	h. see 1.4.5.3.	- excluding items at the ES vulnerable to attack by heavy spalling
b. see 1.4.1.9.a)&1.4.1.9.b)2)	- high degree of protection against instantaneous propagation	i. see 1.4.3.1.	- modular storage of bombs in open stacks
c. see 1.4.1.9.a)&1.4.1.9.b)3)	- moderate degree of protection against instantaneous propagation	j. see 1.4.3.3.	- untraversed stacks of robust shell
d. see 1.4.5.6.a)1)	- effect of high velocity projections	k. see 1.4.1.14.b)	- reaction of drivers on busy roads
e. see 1.4.5.6.a)2)	- effect of lobbed ammunition	l. see 1.4.1.15.b)	- flying and falling glass, etc.
f. see 1.4.1.8.c)	- degree of protection depends on structure at ES and sensitiveness of its contents	m. see 1.4.1.15.c)	- 400 m minimum to built up areas
g. see 1.4.3.6.	- excluding very sensitive explosive substances	n. see 1.4.6.7.b)	- reduced Q-D for large earth-covered buildings containing NEQ<45 000kg
		o. see 1.4.1.13.	- serious fragment hazard

It is essential to study the text in Chapter 3 when using this Annex since they are complementary

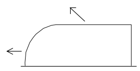
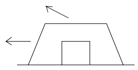
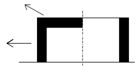
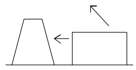
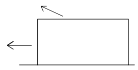
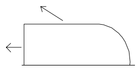
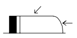
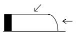
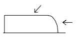
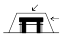
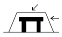
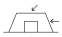
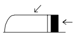
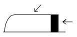
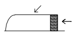
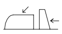
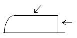
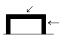
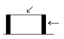
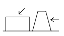
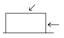
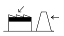
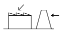
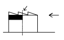
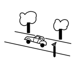
TABLE 1	Q-D TABLE FOR HAZARD DIVISION 1.1					
PES / ES	 (a)	 (b)	 (c)	 (d)	 (e)	 (f)
 1	D3[ag]	D3[ag]	D5[a]	D5[a]	D5[a]	D4[ag]
 2	D3[ag]	D3[ag]	D5[b]	D5[b]	D5[b]	D4[ag]
 3	D4[agh] or D5[ag]	D4[agh] or D5[ag]	D6[be]	D6[be]	D6[be]	D4[bghe] or D6[ae]
 4	D3[ag]	D3[ag]	D5[b]	D5[b]	D5[b]	D5[ag]
 5	D3[ag]	D3[ag]	D6[b]	D6[b]	D6[b]	D5[bg]
 6	D4[bgh] or D6[a]	D4[bgh] or D6[a]	D6[ce]	D6[ce]	D6[ce]	D6[ce]
 7	D4[ag]	D4[b] or D5[a]	D8[bde], D9[bje] or D12[ae]	D8[be]	D8[bde]	D8[bde]
 8	D6[a]	D6[a]	D9[bde], D9[bje] or D12[ae]	D8[be]	D8[bde]	D8[bde]
 9	D4[bgh] or D7[b]	D4[bgh] or D7[b]	D9[ce]	D4[cghe] or D9[ce]	D9[ce]	D9[ce]
 10	D4[bgh] or D7[b]	D4[bgh] or D7[b]	D9[b]	D9[b]	D9[b]	D9[b]
 11	D4[bgh] or D7[b]	D4[bgh] or D7[b]	D9[cje]	D4[cghe] or D9[ce]	D9[cje]	D9[cje]
 12	D4[cgh] or D7[b]	D4[cgh] or D7[b]	D4[cghe] or D7[be]	D4[cghe] or D7[be]	D4[cghe] or D7[be]	D5[cghe] or D7[be]
 13	D4[cgh] or D7[b]	D4[cgh] or D7[b]	D4[cghe] or D7[be]	D4[cghe] or D7[be]	D4[cghe] or D7[be]	D5[cghe] or D7[be]
 14	D4[bgh] or D7[b]	D4[bgh] or D7[b]	D4[bghe] or D7[be]	D1[bie], D2[bie] D4[bghe] or D7[be]	D1[bie], D2[bie] D4[bghe] or D7[be]	D4[bghe] or D7[be]
 15	D4[bgh] or D7[b]	D4[bgh] or D7[b]	D9[cje] or D12[fe]	D1[bie], D2[bie] D4[bghe] or D7[be]	D9[cje] or D12[fe]	D9[cje] or D12[fe]
 16	D10	D10	D10	D10	D10	D10
 17	D10 (∃270m)	D10 (∃270m)	D10 (∃270m)	D10[o]	D10[o]	D10 (∃270m)
 18	D10 (∃270m)	D10 (∃270m)	D13	D10[o]	D13	D13
 19	D11 (∃270m)[k] D16 (∃270m)[kn] D13 (∃400m) D14 (∃400m)[n]	D11 (∃270m)[k] D17 (∃270m)[kn] D13 (∃400m) D15 (∃400m)[n]	D11 (∃270m)[k] D13 (∃400m)	D11[k] D13	D11[k] D13	D11 (∃270m)[k] D13 (∃400m)
 20	D13 (∃400m)[l] D14 (∃400m)[ln]	D13 (∃400m)[l] D14 (∃400m)[ln]	D13 (∃400m)[l]	D13[l] D13 (∃400m)	D13[l] D13 (∃400m)	D13 (∃400m)[l]

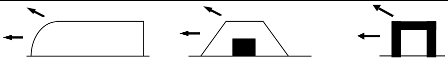
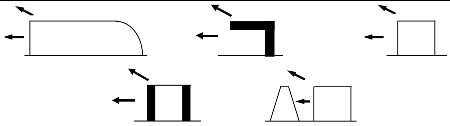
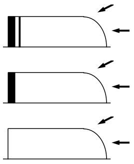
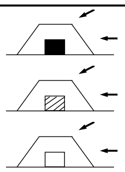
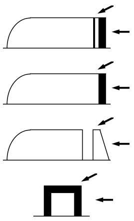
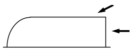
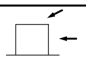
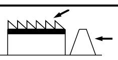
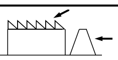
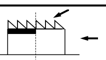
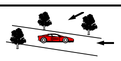
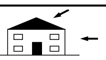
TABLE 1 (PAGE 2) - Q-D TABLE FOR HAZARD DIVISION 1.1

Net Explosives Quantity in kg	Quantity-Distances in metres				
	D13	D14	D15	D16	D17
500	270	400	400	270	270
600	270	400	400	270	270
700	270	400	400	270	270
800	270	400	400	270	270
900	270	400	400	270	270
1 000	270	400	400	270	270
1 200	270	400	400	270	270
1 400	270	400	400	270	270
1 600	270	400	400	270	270
1 800	270	400	400	270	270
2 000	270	400	400	270	270
2 500	280	400	400	270	270
3 000	305	400	400	270	270
3 500	330	400	400	270	270
4 000	350	400	400	270	270
5 000	380	400	400	270	270
6 000	405	400	400	270	270
7 000	425	400	400	270	270
8 000	445	400	400	270	270
9 000	465	400	400	270	270
10 000	480	400	400	270	270
12 000	510	400	415	270	275
14 000	540	400	435	270	290
16 000	560	400	455	270	305
18 000	490	400	475	270	315
20 000	610	400	490	270	330
25 000	650	410	530	275	355
30 000	690	435	560	290	375
35 000	730	460	590	305	395
40 000	760	480	620	320	415
45 000		500	640	335	430
50 000	820				
60 000	870				
70 000	920				
80 000	960				
90 000	1000				
100 000	1040				
120 000	1100				
140 000	1160				
160 000	1220				
180 000	1260				
200 000	1300				
250 000	1400				
Distance Functions	$D13=5.5Q^{1/2}$ for $Q<4500$ $D13=22.2Q^{1/3}$ for Q∃4500	$D14=14.0Q^{1/3}$	$D15=18.0Q^{1/3}$	$D16=9.3Q^{1/3}$	$D17=12.0Q^{1/3}$

a. see 1.4.1.9.a)&1.4.1.9.b)1)	- virtually complete protection against instantaneous propagation	h. see 1.4.5.3.	- excluding items at the ES vulnerable to attack by heavy spalling
b. see 1.4.1.9.a)&1.4.1.9.b)2)	- high degree of protection against instantaneous propagation	i. see 1.4.3.1.	- modular storage of bombs in open stacks
c. see 1.4.1.9.a)&1.4.1.9.b)3)	- moderate degree of protection against instantaneous propagation	j. see 1.4.3.3.	- untraversed stacks of robust shell
d. see 1.4.5.6.a)1)	- effect of high velocity projections	k. see 1.4.1.14.b)	- reaction of drivers on busy roads
e. see 1.4.5.6.a)2)	- effect of lobbed ammunition	l. see 1.4.1.15.b)	- flying and falling glass, etc.
f. see 1.4.1.8.c)	- degree of protection depends on structure at ES and sensitiveness of its contents	m. see 1.4.1.15.c)	- 400 m minimum to built up areas
g. see 1.4.3.6.	- excluding very sensitive explosive substances	n. see 1.4.6.7.b)	- reduced Q-D for large earth-covered buildings containing NEQ<45 000kg
		o. see 1.4.1.13.	- serious fragment hazard

It is essential to study the foregoing text in Chapter 3 when using this Annex since they are complementary

QUANTITY-DISTANCE MATRIX FOR HD 1.2 – TABLE 2

Potential Explosion Site / Exposed Site		 (a)	 (b)
	1	No QD_{ai}	No QD_{ai}
	2	No QD_{ai}	No QD_{ai}
	3	No QD_{ai}	No QD_{ai}
	4	No QD_{ai}	$D5_{bg}$ or $D6_{bh}$
	5	No QD_{ai}	$D5_{cg}$ or $D6_{ch}$
	6	No QD_{ei}	$D3_{eg}$ or $D4_{eh}$
	7	No QD_{ei}	$D3_{fg}$ or $D4_{fh}$
	8	No QD_{ei}	$D5_{fg}$ or $D6_{fh}$
	9	No QD_{I}	$D5_{gk}$ or $D6_{hk}$ $D1_{gl}$ or $D2_{hl}$
	10	No QD_{I}	$D1_{g}$ or $D2_{h}$

a. see 1.4.1.10.1)	virtually complete protection against propagation	g. see 1.4.1.5.c)	PES contains only the less hazardous items classified HD 1.2.2
b. see 1.4.1.10.2)	high degree of protection against propagation	h. see 1.4.1.5.b)	PES contains the more hazardous items classified HD 1.2.1
c. see 1.4.1.10.3)	limited degree of protection against propagation	i. see 1.4.1.5.g)	practical considerations will dictate specific separation distances
d.	unallocated	j. see	unallocated
e. see 1.4.1.13.c)4)	high degree of protection for personnel	k. see 1.4.1.14.b)	low density traffic
f. see 1.4.1.13.c)4)	limited degree of protection for personnel	l. see 1.4.1.14.b)	high density traffic

QUANTITY-DISTANCE MATRIX FOR HD 1.2 – TABLE 2

It is essential to study the text in Chapter 3 when using this Annex since they are complementary

NEQ	Quantity-Distances					
	D1	D2	D3	D4	D5	D6
Kg	m	M	m	m	M	m
10	30	60	20	20	30	60
20	36	60	20	20	30	60
50	44	88	20	32	30	60
70	47	108	20	39	32	73
80	49	116	20	42	33	78
90	50	123	20	45	34	83
100	51	129	20	47	35	87
120	53	140	20	51	36	94
140	55	149	20	54	37	100
160	57	156	21	57	39	105
180	59	163	22	59	40	110
200	60	169	22	61	41	114
250	64	182	24	66	43	122
300	66	192	24	70	45	129
350	69	200	25	72	47	134
400	71	208	26	75	48	140
500	75	220	27	80	51	148
600	78	230	29	83	53	155
700	81	238	30	86	55	160
800	83	245	30	89	56	165
900	86	251	31	91	58	169
1000	88	257	32	93	59	173
1200	91	266	33	96	61	179
1400	94	274	34	99	63	184
1600	97	281	35	102	65	189
1800	100	287	36	104	67	193
2000	102	292	37	106	69	196
2500	107	303	39	110	72	204
3000	111	313	40	113	75	210
3500	114	320	42	116	77	215
4000	118	327	43	118	80	220
4500	120	332	44	120	81	223
5000	123	337	45	122	83	226
6000	127	346	46	125	86	232
7000	131	354	48	128	88	238
8000	135	360	49	130	91	242
9000	138	365	50	132	93	245
10000	141	370	51	134	95	248
12000	146	379	53	137	98	254
14000	150	386	54	139	101	259
16000	154	392	56	142	104	263
18000	157	397	57	143	106	266
20000	160	402	58	145	108	270
25000	166	412	60	149	112	277
30000	172	420	62	152	116	282
35000	177	426	64	154	119	286
40000	181	432	66	156	122	290
45000	184	437	67	158	124	293
50000	188	441	68	159	126	296
60000	194	449	70	162	130	301
70000	199	455	72	164	134	305
80000	203	461	74	166	137	309
90000	207	466	75	168	139	313
100000	210	470	76	170	141	315
120000	217	477	79	172	146	320
140000	222	483	80	174	149	324
160000	227	489	82	177	153	328
180000	231	493	84	178	155	331

200000 250000	235 243	497 506	85 88	179 183	158 163	333 340

D1 = 28.127-2.364*LN(NEQ)+1.577*((LN(NEQ))^2) D2 = -167.648+70.345*LN(NEQ)-1.303*((LN(NEQ))^2)	D3 = 0.36*D1 D4 = 0.36*D2	D5 = 0.67*D1 D6 = 0.67*D2

It is essential to study the text in Chapter 3 when using this Annex since they are complementary

TABLE 3A	Q-D TABLE FOR HAZARD DIVISION 1.3					
ES / PES	(a)	(b)	(c)	(d)	(e)	(f)
1	2m[ag]	2m[ag]	2m[ag]	10m[ad] or 25m[a]	10m[ad] or 25m[a]	10m[ad] or 25m[a]
2	2m[ag]	2m[ag]	2m[ag]	10m[ad] or 25m[a]	10m[ad] or 25m[a]	10m[ad] or 25m[a]
3	2mag	2m[ag]	2m[ag]	10m[ad] or 25m[a]	10m[ad] or 25m[a]	D1[a]
4	2m[ag]	2m[ag]	2m[ag]	10m[ad] or 25m[a]	10m[ad] or 25m[a]	10m[ad] or 25m[a]
5	2m[ag]	2m[ag]	2m[ag]	10m[ad] or 25m[a]	10m[ad] or 25m[a]	10m[ad] or 25m[a]
6	10m[b] or 25m[a]	10m[b] or 25m[a]	10m[b] or 25m[a]	D1[b]	D1[b]	D1[b]
7	2m[adg] or 25m[a]	2m[adg] or 25m[a]	2m[adg] or 25m[a]	25m[ad] or D1[a]	25m[ad] or D1[a]	D1[ad], D1[bf] or 240m[b]
8	2m[adg] or 25m[a]	2m[adg] or 25m[a]	2m[adg] or 25m[a]	25m[ad] or D1[a]	25m[ad] or D1[a]	D1[ad], D1[bf] or 240m[b]
9	2m[ag]	2m[ag]	2m[ag]	25m[a]	25m[a]	D1[a]
10	10m[b] or 25m[a]	10m[b] or 25m[a]	10m[b] or 25m[a]	D1[a]	D1[a]	D1[bf] or 240m[a]
11	25m[a]	D1[a]	D1[a]	D1[b]	D1[b]	240m[b]
12	2m[ag]	2m[ag]	2m[ag]	10m[b] or 25m[a]	10m[b] or 25m[a]	D1[a]
13	25m[a]	D1[a]	D1[a]	D1[b]	D1[b]	240m[a]
14	25m[a]	D1[a]	D1[a]	D1[b]	D1[b]	240m[a]
15	25m[a]	D1[a]	D1[a]	D1[b]	D1[b]	240m[a]
16	D2	D2	D2	D2	D2	D2
17	D2	D2	D2	D2	D2	D2[f] or 240m
18	D2	D2	D2	D2	D2	240m[f] or D4 (∃240m)
19	D3[h] or D4	D3[h] or D4	D3[h] or D4	D3[h] or D4	D3[h] or D4	D3 (∃160m)[h] or D4 (∃240m)
20	D4	D4	D4	D4	D4	D4 (∃240m)

TABLE 3A - Q-D TABLE FOR HAZARD DIVISION 1.3

Net Explosives Quantity Q in kg	Quantity-Distances in metres			
	D1	D2	D3	D4
500	25	60	60	60
600	25	60	60	60
700	25	60	60	60
800	25	60	60	60
900	25	60	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	62	93
3 500	25	60	65	98
4 000	25	60	68	105
5 000	25	60	73	110
6 000	25	60	78	120
7 000	25	62	82	125
8 000	25	64	86	130
9 000	25	67	89	135
10 000	25	68	92	140
12 000	25	74	98	150
14 000	27	78	105	155
16 000	28	81	110	165
18 000	30	84	115	170
20 000	32	87	120	175
25 000	35	94	125	190
30 000	39	100	135	200
35 000	42	105	140	210
40 000	44	110	150	220
50 000	50	120	160	240
60 000	54	130	170	255
70 000	59	135	180	265
80 000	63	140	185	280
90 000	66	145	195	290
100 000	70	150	200	300
120 000	77	160	215	320
140 000	83	170	225	335
160 000	88	175	235	350
180 000	94	185	245	365
200 000	99	190	250	375
250 000	110	205	270	405
Distance Functions	$D1 = 0.22\ Q^{1/3}$	$D2 = 3.2\ Q^{1/3}$	$D3 = 4.3\ Q^{1/3}$	$D4 = 6.4\ Q^{1/3}$

a. see 1.4.1.11.1)	- virtually complete protection	e.	- (reserved)
b. see 1.4.1.11.2)	- high/limited degree of protection	f. see 1.4.6.6.a)	- door barricade at PES
c.	- (reserved)	g. see 1.4.5.1.c)	- practical considerations may require a greater distance
d. see 1.4.5.6.b)	- resistance of headwall and door(s) at ES	h. see 1.4.1.14.b)	- reaction of drivers on busy roads

It is essential to study the text in Chapter 3 when using this Annex since they are complementary

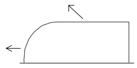
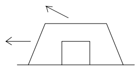
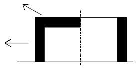
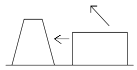
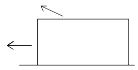
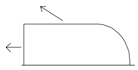
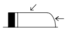
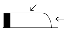
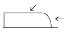
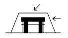
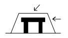
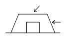
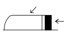
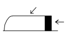
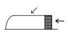
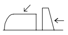
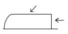
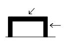
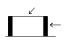
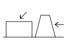
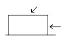
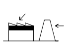
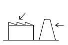
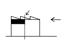
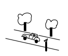
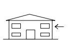
TABLE 3B	Q-D TABLE FOR HAZARD DIVISION 1.3					
PES / ES	 (a)	 (b)	 (c)	 (d)	 (e)	 (f)
 1	2m[ag]	2m[ag]	2m[ag]	2m[ag]	2m[ag]	2m[ag]
 2	2m[ag]	2m[ag]	2m[ag]	2m[ag]	2m[ag]	2m[ag]
 3	2m[ag]	2m[ag]	2m[ag]	2m[ag]	2m[ag]	2m[ag]
 4	2m[ag]	2m[ag]	2m[ag]	2m[ag]	2m[ag]	2m[ag]
 5	2m[ag]	2m[ag]	2m[ag]	2m[ag]	2m[ag]	2m[ag]
 6	2m[ag]	2m[ag]	2m[ag]	2m[ag]	2m[ag]	2m[ag]
 7	2m[ag]	2m[ag]	10m[ad] or 25m[a]	10m[ad] or 25m[b]	25m[ad] or 60m[a]	25m[ad] or 60m[a]
 8	2m[ag]	2m[ag]	10m[ad] or 25m[a]	10m[ad] or 25m[b]	25m[ad] or 60m[a]	25m[ad] or 60m[a]
 9	2m[ag]	2m[ag]	10m[a]	10m[a]	25m[a]	25m[a]
 10	2m[ag]	2m[ag]	10m[b] or 25m[a]	25m[b] or 60m[a]	25m[be] or 60m[ae]	25m[be] or 60m[ae]
 11	25m[b] or 60m[a]	25m[b] or 60m[a]	25m[bh], 60m[ahf] or 60m[bf]	60m[b]	60m[b]	60m[b]
 12	2m[ag]	2m[ag]	10m[a]	10m[a]	10m[a]	10m[a]
 13	25m[b] or 60m[a]	25m[b] or 60m[a]	25m[bh], 60m[ahf] or 60m[bf]	60m[b]	60m[b]	60m[b]
 14	25m[b] or 60m[a]	25m[b] or 60m[a]	25m[bh], 60m[ahf] or 60m[bf]	60m[b]	60m[b]	60m[b]
 15	25m[b] or 60m[a]	25m[b] or 60m[a]	25m[bh], 60m[ahf] or 60m[bf]	60m[b]	60m[b]	60m[b]
 16	25m	25m	25m	25m	25m	25m
 17	60m	60m	60m	60m	60m	60m[f]
 18	60m	60m	60m	60m	60m	60m[f]
 19	60m[f] or D4	60m[f] or D4	60m[f] or D4	60m[f] or D4	60m[f] or D4	60m[hi] or D4 (∃60m)[f]
 20	D4	D4	D4	D4	D4	D4 (∃60m)[f]

TABLE 3B - Q-D TABLE FOR HAZARD DIVISION 1.3

Net Explosives Quantity Q in kg	Quantity-Distances in metres			
	D1	D2	D3	D4
500	25	60	60	60
600	25	60	60	60
700	25	60	60	60
800	25	60	60	60
900	25	60	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	62	93
3 500	25	60	65	98
4 000	25	60	68	105
5 000	25	60	73	110
6 000	25	60	78	120
7 000	25	62	82	125
8 000	25	64	86	130
9 000	25	67	89	135
10 000	25	68	92	140
12 000	25	74	98	150
14 000	27	78	105	155
16 000	28	81	110	165
18 000	30	84	115	170
20 000	32	87	120	175
25 000	35	94	125	190
30 000	39	100	135	200
35 000	42	105	140	210
40 000	44	110	150	220
50 000	50	120	160	240
60 000	54	130	170	255
70 000	59	135	180	265
80 000	63	140	185	280
90 000	66	145	195	290
100 000	70	150	200	300
120 000	77	160	215	320
140 000	83	170	225	335
160 000	88	175	235	350
180 000	94	185	245	365
200 000	99	190	250	375
250 000	110	205	270	405
Distance Functions	$D1 = 0.22\ Q^{1/3}$	$D2 = 3.2\ Q^{1/3}$	$D3 = 4.3\ Q^{1/3}$	$D4 = 6.4\ Q^{1/3}$

a. see 1.4.1.11.1)	- virtually complete protection	e. see 1.4.6.6.b)	- door barricades at both PES and ES
b. see 1.4.1.11.2)	- high/limited degree of protection	f. see 1.4.1.14.c)	- traffic is stopped promptly to avoid worst attack
c.	- (reserved)	g. see 1.4.5.1.c)	- practical considerations may require a greater distance
d. see 1.4.5.6.b)	- resistance of headwall and door(s) at ES	h. see 1.4.5.4.	- building (PES) with heavy walls with protective roof
		i. see 1.4.5.4.	- building (PES) with heavy walls without protective roof

It is essential to study the text in Chapter 3 when using this Annex since they are complementary

TABLE 4	Q-D TABLE FOR HAZARD DIVISION 1.6 STORAGE OF 1.6N AMMUNITION WITH A UNIT NEQ EQUAL TO 1000 Kg					
ES \ PES	(a)	(b)	(c)	(d)	(e)	(f)
1	5m	5m	11m	11m	11m	8m
2	5m	5m	11m	11m	11m	8m
3	8m	8m	8m	18m	18m	8m
4	5m	5m	11m	11m	11m	11m
5	5m	5m	18m	18m	18m	11m
6	8m	8m	18m	18m	18m	18m
7	8m	8m	36m	25m	25m	25m[d] or 60m
8	18m	18m	36m, 48m[i]	36m	36m	36m[d] or 60m
9	8m	8m	48m	10m	48m	48m
10	8m	8m	48m	48m	48m[b] or 68m	48m[b] or 68m
11	25m[b] or 60m	25m[b] or 60m	48m[b] or 60m	60m[b]	60m[b]	60m[b]
12	8m	8m	10m	10m	10m	10m
13	25m[b] or 60m	25m[b] or 60m	25m[bh] or 60m[hbi]	60m[b]	60m[b]	60m[b]
14	25m[b] or 60m	25m[b] or 60m	25m[bh] or 60m[hbi]	60m[b]	60m[b]	60m[b]
15	25m[b] or 60m	25m[b] or 60m	48m[bh] or 60m[hbi]	60m[b]	60m[b]	60m[b]
16	80m	80m	80m	80m	80m	80m
17	80m	80m	80m	80m	80m	80m
18	80m	80m	174m	80m	174m	174m
19	107[k], 174m 93m[kn], 140m[n]	107[k], 174m 93m[kn], 180m[n]	107[k] 174m	107[k] 174m	107[k] 174m	107[k] 174m
20	D4 > 174m	D4 > 174m	D4 > 174m	D4 > 174m	D4 > 174m	D4 > 174m

TABLE 4- Q-D TABLE FOR HAZARD DIVISION 1.6

STORAGE OF 1.6N AMMUNITION WITH A UNIT NEQ EQUAL TO 1000 Kg

REMARKS

1. Inhabited Building Distance (IBD)

Line 20 gives the Inhabited Building Distance (IBD).
IBD is equal to D4 or to 174m if D4 < 174m.

D4 = 6.4 $Q^{1/3}$ and D4 ≥ 60m (For values of D4 according to values of Q: see Table 3B).
Q is the aggregated NEQ of the PES.

2. Legend

b.	see 1.4.1.0.2.	High/limited degree of protection against thermal flux
d.	see 1.4.4.0.b.	Resistance of headwall and door(s) at ES
h.	see 1.4.3.8.	Building (PES) with heavy walls with protective roof
i.	see 1.4.3.8.	Building (PES) with heavy walls without protective roof
j.	see 1.4.3.3.	Untraversed stacks of robust shells
k.	see 1.4.1.14.b)	Reaction of drivers on busy roads
l.	see 1.4.1.15.c)	Flying and falling glass
n.	see 1.4.6.7.b)	Reduced Q/D for large earth-covered buildings containing NEQ < 40 000 kg

ANNEX I-B

EXAMPLES OF THE USE OF Q-D TABLES

Section I - General

1. *Introduction*

This annex gives examples intended only as a guide to the use of Q-D tables. The size of buildings and their arrangement are not significant.

Net Explosives Quantities are in kg.
Quantity-Distances are in m.

2. *Definitions*

a) For the purposes of the examples only (see Sections II-III) the following definitions are used (see also subparagraph b) below):

1) Sparsely Populated Area

An area populated by maximum 25 persons (see subparagraph 1.3.1.15.b)5).

2) Light Traffic Route

A route that carries maximum 60 vehicles per hour (see subparagraph 1.3.1.14.b)).

3) Curtain Wall Building

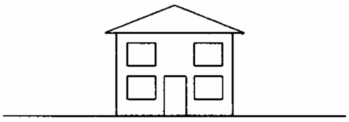
A building of skeleton frame construction, with exterior walls that carry no load other than their own weight. These non-load bearing walls are inherently weak to lateral forces associated with blast loads and when so stressed may shatter or be displaced as units, endangering exposed personnel both inside and outside the building (see paragraphs 1.3.7.5. and 1.3.7.6.).

b) It is emphasized that the definitions of sparsely populated area and light traffic route are for the purposes of the following examples only. In practice National Authorities will define these terms.

3. *Symbols*

a) The symbols below are used in the AC/258-FORM X (see Figure B-I) related to the examples which follow in Sections II-III.

1)

Sparsely populated area .... 

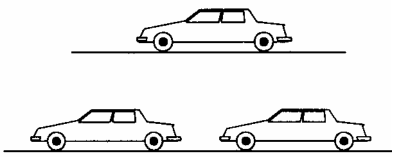
2)

Densely populated area .... 

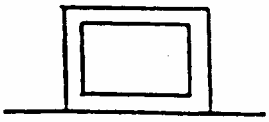
3)

Light traffic route 

4)

Heavy traffic route .... 

5)

Curtain wall building .... 

b) The arrows on AC/258-FORM X are used in the same way as in the Q-D tables.

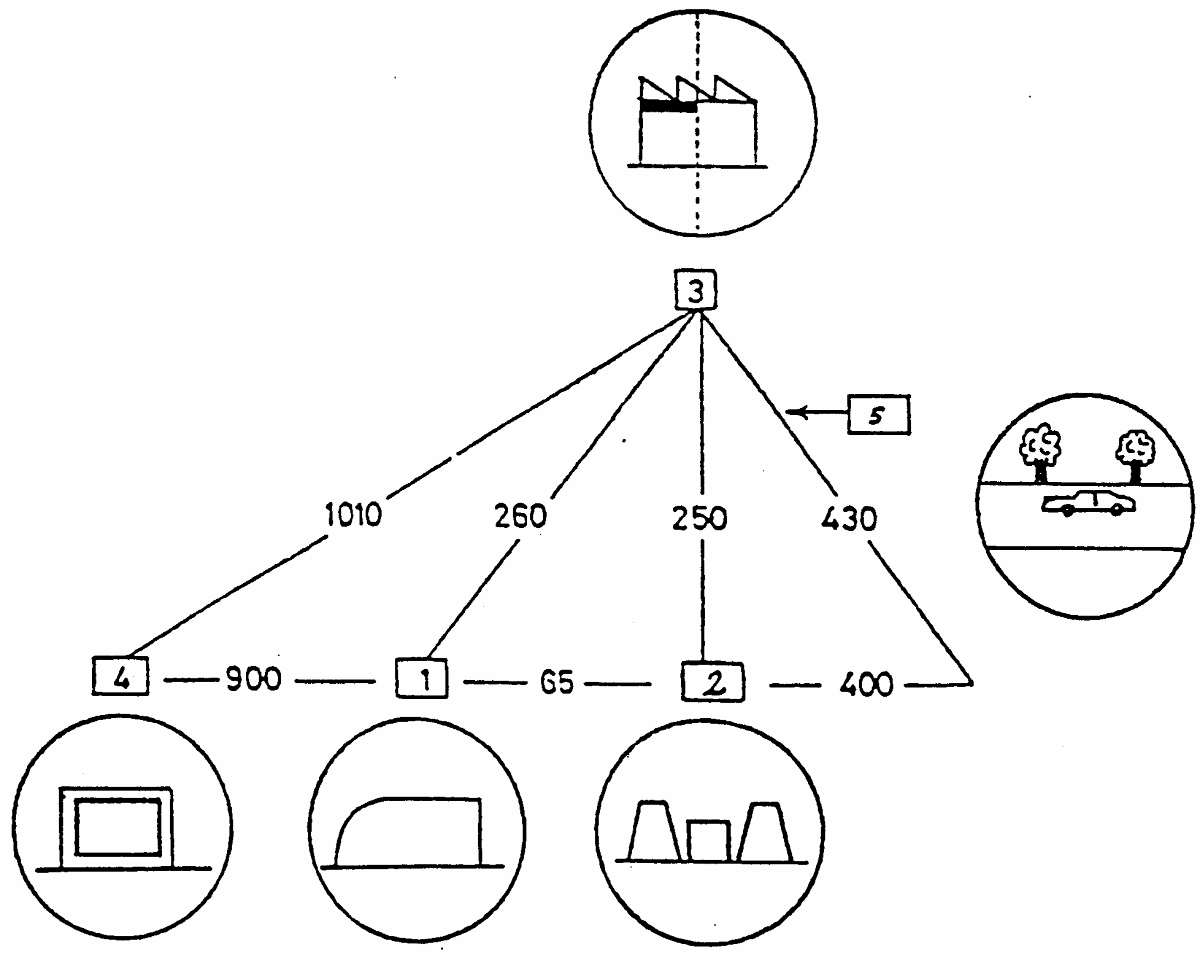
Section II - Example of the Use of Q-D Tables

at an existing Storage Area

4. *Introduction*

In the following diagrammatic plan of a small storage complex, determine the NEQ of each hazard division for the Explosives Storage House (ESH), the Explosives Storage Location (ESL) and the Ammunition Process Building (Workshop) (APB).

5. *Layout of Storage Complex*



(NOTES to layout: see next page)

NOTES:

(1) All distances are in metres.

(2) ESH 1 and ESL 2 size is 20 m x 13 m.

(3) IHB 4 is a curtain wall building; an office in which 50 people work.

(4) ESH 1 is barricaded and with an unspecified door and headwall (the symbol above represents ESH 1 considered as a PES, see subparagraph 7.a)).

(5) Fire-fighting arrangements are adequate.

(6) ESL 2 - the open stack - is barricaded on all sides.

(7) APB 3 is of light construction.

(8) ROAD 5 carries 40 vehicles per hour, e.g. a light traffic route.

6. *Procedure*

a) The procedure is basically to consider each PES in turn with relation to all ES. From this consideration will emerge which ES limits the NEQ in the particular PES being considered.

b) In this example intermediate distances between those given in the tables are treated in accordance with subparagraph 1.3.2.1.b) (in each case the NEQ has been rounded down).

7. *Consider ESH 1 as a PES*

a) ESH 1 is barricaded and has an unspecified door and headwall. The presence of a barricade is irrelevant when considering ESH 1 as a PES and in spite of subparagraph 1.3.6.1.b) is never taken into account for quantity-distances when considering igloos as PES.

b) The orientation of ESH 1 relative to ES must be considered. Reference to the layout shows that:

1) ESH 1 has its door and headwall facing both ESL 2 and ROAD 5.
2) ESH 1 is side-on to APB 3.
3) ESH 1 has its door and headwall away from the inhabited building IHB 4.

c) It follows that (see pictograms in Annex A, Section I):

Pictogram 5.b.1. applies to 1) above.

Pictogram 5.b.3. applies to 2) above.

Pictogram 5.b.2. applies to 3) above.

Draw these pictograms in the "PES column" of AC/258-FORM X (see Figure B-II).

d) Next consider the ES relative to ESH 1, these are:

1) APB 3 which is of light construction and unbarricaded, therefore pictogram 6.h.3 applies and the word "APB 3" should be written in the appropriate space on the "ES No./Name on Area Plan" line of AC/258-FORM X.

2) IHB 4 is a densely populated curtain wall building, pictogram 3.a.5 (see paragraph 3) applies. It should be noted that there are three columns in "No. 18" of AC/258-FORM X, the one with a single house indicates a single building or a sparsely populated area; the one with three houses indicates a densely populated area and the last symbol indicates a curtain wall building with an appreciable number of occupants. In this case the curtain wall symbol applies and the word "HOUSE" should be written in the appropriate space on the "ES No./Name on Area Plan" line of AC/258-FORM X. Attention is drawn to paragraphs 1.3.7.5., 1.3.7.6. and 1.3.7.7. which recommends that with appreciably populated curtain wall buildings, a minimum quantity-distance of 400 m or 1 ½ to 2 times D13-distances should be used. Although not applicable in this case attention is also drawn to subparagraph 1.4.1.15.b)5), which recommends consideration being given to using a minimum of 400 m for densely populated areas for ammunition and explosives of Hazard Division 1.1.

3) ROAD 5, this is a light traffic route, pictogram 6.i.1 applies, but it should be noted that there are two columns on AC/258-FORM X, the one with a single car indicates a light traffic route, whilst the column with three cars indicates a heavy traffic route. In this case the column with a single car applies and the word "ROAD" should be written in the appropriate space on the "ES No./Name on Area Plan" line of AC/258-

FORM X. Paragraph 1.3.1.14. should be noted with regard to the need for greater distances if there is heavy traffic on the road.

4) ESL 2 (the open stack) is barricaded on all sides and measures 20 m x 13 m, pictogram 6.f.1 applies. Write "ESL 2" in the appropriate space on the "ES No./Name on Area Plan" line of AC/258-FORM X.

e) Enter - in metres - the distances of the four ES listed above from the considered PES, i.e. ESH 1, in the appropriate spaces in the AC/258-FORM X. These distances are taken from the layout and are:

1)	ESH 1 to ESL 2	:	065 m
2)	ESH 1 to APB 3	:	260 m
3)	ESH 1 to ROAD 5	:	485 m (i.e. 400 + 65 + 20) *)
4)	ESH 1 to IHB 4	:	900 m

*) 20 is the width of the open stack

f) Now no. 19 (the grid) of AC/258-FORM X can be completed for each of the hazard divisions in turn.

8. *Calculations for Hazard Division 1.1*

Refer to Table 1 and consider each of the ES in turn, in each case the relevant PES column has to be used.

1) ESH 1 - ESL 2: column f, row 14 gives for D7-distances (without restriction of types of ammunition and explosives being stored) 18 000 kg for a distance of 65 m. Enter "D7/18" in the appropriate space in no. 19 of AC/258-FORM X.

2) ESH 1 - APB 3: column b, row 18 gives for D10-distances (minimum 270 m), it means no ammunition and explosives of Hazard Division 1.1 may be stored in ESH 1. Enter "270 m/nil" in the appropriate space in no. 19 of AC/258-FORM X.

(NOTE: Since the NEQ is found as NIL, in practice there would be no need to continue the calculations for Hazard Division 1.1. For the purpose of this exercise the calculations are continued to show the method of work for the other ES).

3) ESH 1 - ROAD 5: column f, row 19 gives D11-distances since the road only has light traffic. Reference to D11 gives 35 000 kg for a distance of 485 m. Enter "D11/35" in the appropriate space in no. 19 of AC/258-FORM X.

4) ESH 1 - IHB 4: the separation distance is 900 m, but since an appreciably populated curtain wall building is involved, a distance of 900 m x ½ = 450 m must be used in the calculation of the permissible NEQ. Column a, row 20 gives D13-distances with a minimum of 400 m. Reference to D13 gives 8 000 kg for a distance of 450 m. Enter "D13/8" in the appropriate space in no. 19 of AC/258-FORM X.

Hereafter it only remains to complete no. 20 of AC/258-FORM X in respect of "Maximum NEQ permitted" for Hazard Division 1.1. Enter "NIL" in the Hazard Division 1.1 space.

9. *Calculations for Hazard Division 1.2*

a) Subparagraph 1.2.1.2.b) states that, for the purpose of determining quantity-distances a distinction, depending on the site and range of fragments, is made between those items which give small fragments of moderate range and those which give large fragments with a considerable range. Paragraph 1.3.1.5. states that the more hazardous part of Hazard Division 1.2 includes most rounds and projectiles exceeding 60 mm calibre (HE), some pyrotechnic or lachrymatory rounds and many rockets and rocket motors, whilst the less hazardous part includes most rounds up to 60 mm calibre (HE), pyrotechnic or lachrymatory, rounds of any calibre with inert projectiles, fragmentation hand grenades, and fuzes with boosters.

b) For the purposes of AC/258-FORM X this sub-division of Hazard Division 1.2 is identified by

1. HD 1.21 - the more hazardous part of Hazard Division 1.2
2. HD 1.22 - the less hazardous part of Hazard Division 1.2

Attention is drawn to subparagraph 1.3.2.6.2) which states that when both types of Hazard Division 1.2 items are stored in the same site, and this is perhaps the most common situation, the aggregate NEQ is to be treated as of the more hazardous type of Hazard Division 1.2. For the purposes of this example the calculations have been made on the basis of ESH 1 containing either HD 1.21 or HD 1.22.

c) Hazard Division 1.2: refer to Table 2 and consider each of the ES in turn, in each case the relevant PES column has to be used. It is assumed that ESH contains either HD 1.21 or HD 1.22.

1) ESH 1 - ESL 2: column f, row 14 gives 90 m which means, since separation between ESH 1 and ESL 2 is only 65 m, that no ammunition and explosives of HD 1.21 may be stored in ESH 1. Table 2 does not in this instance differentiate between HD 1.21 and HD 1.22 and therefore "90 m/NIL" should be entered in the appropriate spaces in no. 14 of AC/258-FORM X.

(NOTE: Since the NEQ is found as NIL, in practice there would be no need to continue the calculations for Hazard Division 1.2. For the purpose of this exercise the calculations are continued to show the method of work for other ES).

2) ESH 1 - APB 3: column b, row 18 gives 90 m minimum for HD 1.22 and 135 m minimum for HD 1.21. Since 260 m are available, enter "135/250" and "90/250" in the appropriate spaces in no. 19 of AC/258-FORM X.

3) ESH 1 - ROAD 5: column f, row 19 gives, assuming traffic can be stopped promptly, 90 m minimum for HD 1.22 and 135 m minimum for HD 1.21. Enter "135/250" and "90/250" in the appropriate spaces of no. 19 of AC/258-FORM X.

4) ESH 1 - IHB 4: column a, row 20 gives, assuming the building is isolated and can be evacuated promptly, 180 m minimum for HD 1.22 and 270 m minimum for HD 1.21. Enter "270/250" and "180/250" in the appropriate spaces in no. 19 of AC/258-FORM X.

10. *Calculations for Hazard Division 1.3*

a) Paragraph 1.3.1.6. states that for quantity-distance purposes Hazard Division 1.3 is divided into two sub-divisions, a sub-division for propellants (Compatibility Group C) covered by Table 3A and other items (mainly Compatibility Group G) which are covered by Table 3B.

b) These sub-divisions are identified in AC/258-FORM X as follows:

1. HD 1.33 - propellants
2. HD 1.34 - other than propellants

In the case of a mixture of both sub-divisions of Hazard Division 1.3 in one ESH, the most common case, the NEQ are aggregated and the worst case is used (see paragraphs 1.3.2.5. and 1.3.2.6.). For this example, both sub-divisions of Hazard Division 1.3 are calculated.

c) Hazard Division 1.3: refer to Tables 3A and 3B and consider each of the ES in turn, in each case the relevant PES column has to be used.

1) ESH 1 - ESL 2: Table 3A, column f, row 14 gives a minimum of 240 m, since only 65 m are available, ammunition and explosives of HD 1.33 may not be stored in ESH 1. Enter "240/NIL" in the appropriate space in no. 19 of AC/258-FORM X.

(NOTE: Since the NEQ is found as NIL, in practice there is no need to continue the calculations for HD 1.33. For the purposes of this exercise the calculations are continued to show the method of work for other ES).

Table 3B, column g, row 14 gives 60 m minimum. Enter "60/250" in the appropriate space in no. 19 of AC/258-FORM X.

2) ESH 1 - APB 3: Table 3A, column b, row 18 for D2-distances over 250 000 kg for a distance of 260 m. Enter "D2/250" in the appropriate space in no. 19 of AC/258-FORM X. Table 3B, column b, row 18 gives a minimum of 60 m. Enter "60/250" in the appropriate space in no. 19 of AC/258-FORM X.

3) ESH 1 - ROAD 5: Table 3A, column f, row 19 gives distances to Public Traffic Routes. Since the road is a light traffic route, footnote h can be applied and D3-distances used. D3-distances give over 250 000 kg for a distance of 485 m. Enter "D3/250" in the appropriate space in no. 19 of AC/258-FORM X. Table 3B, column g, row 19 gives a fixed distance of 60 m because traffic can be stopped promptly (see subparagraph 9.c)3)), this gives over 250 000 kg for a distance of 485 m. Enter "60/250" in the appropriate space in no. 19 of AC/258-FORM X.

4) ESH 1 - IHB 4: Tables 3A and 3B, columns g, rows 20 both give for D4-distances over 250 000 kg for a distance of 900 m. Enter "D4/250" in the appropriate space in no. 19 of AC/258-FORM X.

11. *Further Calculations*

The above are the complete calculations for ESH 1 regarded as PES. Calculations now need to be done for ESL 2 and APB 3 as PES. These are carried out in a similar manner, but the calculations are not detailed in this example. Completed AC/258-FORM X's in respect of ESL 2 and APB 3 are, however, attached (see Figures B-III and B-IV) to enable anybody carrying out such calculations to check their result.

12. *Hazard Division 1.4*

Hazard Division 1.4 items may, of course, be added to the stocks in either ESH 2 or ESL 2 (in the case of ESH 1 up to its physical capacity) without affecting the quantity-distance requirement (see subparagraph 1.3.2.5.1)).

NOTE: It is again emphasized that this is only an example. The storage site is obviously uneconomic as only Hazard Division 1.34 in ESH 1 is allowed and this is a waste of an earth-covered, barricaded building, see subparagraph 1.3.5.1.b).

Section III - Example of the Use of Q-D Tables for Planning of a new Storage Area

13. *Introduction*

The aim of this example is to demonstrate the use of the Q-D Tables in the design of a new small ammunition depot.

14. *Background*

a) A plot of ground is owned by the Government and the intention is to use it for a small ammunition depot. A sketch of the ground available and of neighbouring facilities is shown at Figure B-V.

b) The depot is required to hold

Hazard Division	NEQ kg
1.1	40 000
1.2	10 000
1.3 (propellants)	35 000
1.3 (other than propellants)	35 000
1.4	20 000

c) In addition two Explosives Workshops (barricaded, with protective roofs) each with an explosives limit of 500 kg NEQ are required in the depot.

15. *Task*

The requirement is to design a depot using earth-covered magazines or barricaded light structures and to compare the two.

16. *Introduction to Calculations*

There is no "correct" solution to a problem of this type. There are many alternative solutions, all of which are satisfactory and the one adopted will depend on the circumstances pertaining at the time. In consequence the example only indicates the principles which must be considered and draws attention to many of the factors which influence the selection of the final solution.

17. *Considerations Related to the Choice of Number of ESH*

The holdings of the depot are detailed in paragraph 14 above. The number of ESH required to hold these amounts of ammunition will depend on many factors including:

1) Dispersion

The degree to which operational staff wish stocks to be dispersed within the depot in order to prevent the loss of the complete depot stocks of specific natures in the event of one ESH being destroyed.

2) Types of ESH

The size and type of ESH to be used will often depend on economical factors and the availability of standard approved designs of ESH.

3) Terrain

Suitability of the area allocated for the construction of various types of ESH and routes, rail etc.

18. *Number of ESH in the Example*

a) For the purpose of this example only it is assumed that:

1) Stocks are to be dispersed two ways within the depot.

2) Either standard igloos designed to 7 bar or standard barricaded, light structures both of capacity 25 000 kg NEQ are to be used.

3) The terrain imposes no particular restriction on construction.

b) It follows that the stocks of individual hazard divisions must each be divided between at least two ESH as shown below:

1) Hazard Division 1.1

2 ESH each containing 20 000 kg NEQ.

2) Hazard Division 1.2

2 ESH each containing 5 000 kg NEQ.

3) Hazard Division 1.3 (propellants)

2 ESH each containing 17 500 kg NEQ.

4) Hazard Division 1.3 (other than propellants)

2 ESH each containing 17 500 kg NEQ.

5) Hazard Division 1.4

2 ESH each containing 10 000 kg NEQ.

c) For economy by keeping the number of ESH required to a minimum, it will be necessary to mix the hazard divisions within ESH. The mixing rules are given in paragraph 1.3.2.6. and Annex C. There are a number of different ways of mixing the stocks, but for the purpose of this example the following will be adopted:

1) ESH No. 1 and 2

Each containing 20 000 kg NEQ of Hazard Division 1.1 and 5 000 kg NEQ of Hazard Division 1.4. Effective NEQ of each ESH is 20 000 kg of Hazard Division 1.1 since the NEQ of Hazard Division 1.4 is irrelevant (see subparagraph 1.3.2.6.1)).

2) ESH No. 3 and 4

Each containing 17 500 kg NEQ of Hazard Division 1.3 (propellants) and 5 000 kg NEQ of Hazard Division 1.2. Subparagraph 1.3.2.6.6) states that the quantity-distance for Hazard Division 1.2 and 1.3 must be calculated separately and the greater distance applied. The Hazard Division 1.2 includes ammunition of calibre both greater and smaller than 60 mm and therefore the quantity-distances to be used is that for the full NEQ of the more hazardous type (see subparagraph 1.4.2.6.2)).

3) ESH No. 5 and 6

Each containing 17 500 kg NEQ of Hazard Division 1.3 (other than propellants)

19. *Exterior Quantity-Distances*

a) The results of these calculations for both types of constructions (i.e. igloos and barricaded light structures) are shown in Table B-I.

b) A study of Table B-I shows that no major advantages accrue in terms of reduced exterior quantity-distances from the use of igloos rather than barricaded, light structures. Light structures may therefore at first glance appear attractive because of their reduced costs in construction, but interior quantity-distances must always be considered before any decision is made and this topic is considered further below.

20. *Interior Quantity-Distances*

a) The interior quantity-distances between magazines and explosives workshops need to be considered. These distances are designed to prevent propagation and to reduce damage to stocks and injuries to personnel working in such places in the event of an accidental explosion. It is rarely necessary to consider a workshop as a PES, because the NEQ in a workshop is normally so small that the quantity-distance between a workshop and a storage site is determined by the contents of the storage site, when this is regarded as a PES. This is true in this example and in consequence no calculations for the workshops as a PES have been done.

b) The necessary distances are detailed in Annex A, Tables 1-3B. A study of Table 1, or indeed of any of the tables, shows that the interior quantity-distances are in the case of igloos dependent on the relative orientation of the igloo as a PES to the igloo or workshop as an ES. For example in Table 1 an igloo as a PES with the door facing (column f):

1) Door of igloo (7 bar) as ES requires, at row 7, D12-distances (22.2 $Q^{1/3}$) for virtually complete protection.

2) Side of igloo (7 bar) as ES requires, at row 5, D5-distances (1.1 $Q^{1/3}$) for virtually complete protection, if primary explosives are excluded, and

3) Rear of igloo (7 bar) as ES requires, at row 1, D4-distances (0.86 $Q^{1/3}$) for virtually complete protection, if primary explosives are excluded.

c) It follows that in order to obtain full advantage from the use of igloos in terms of reduced areas of real estate required for a depot, igloos must never be sited so that they have doors facing each other. For the purpose of this example, therefore, it is assumed that igloos will be sited with doors facing rear of adjacent igloos.

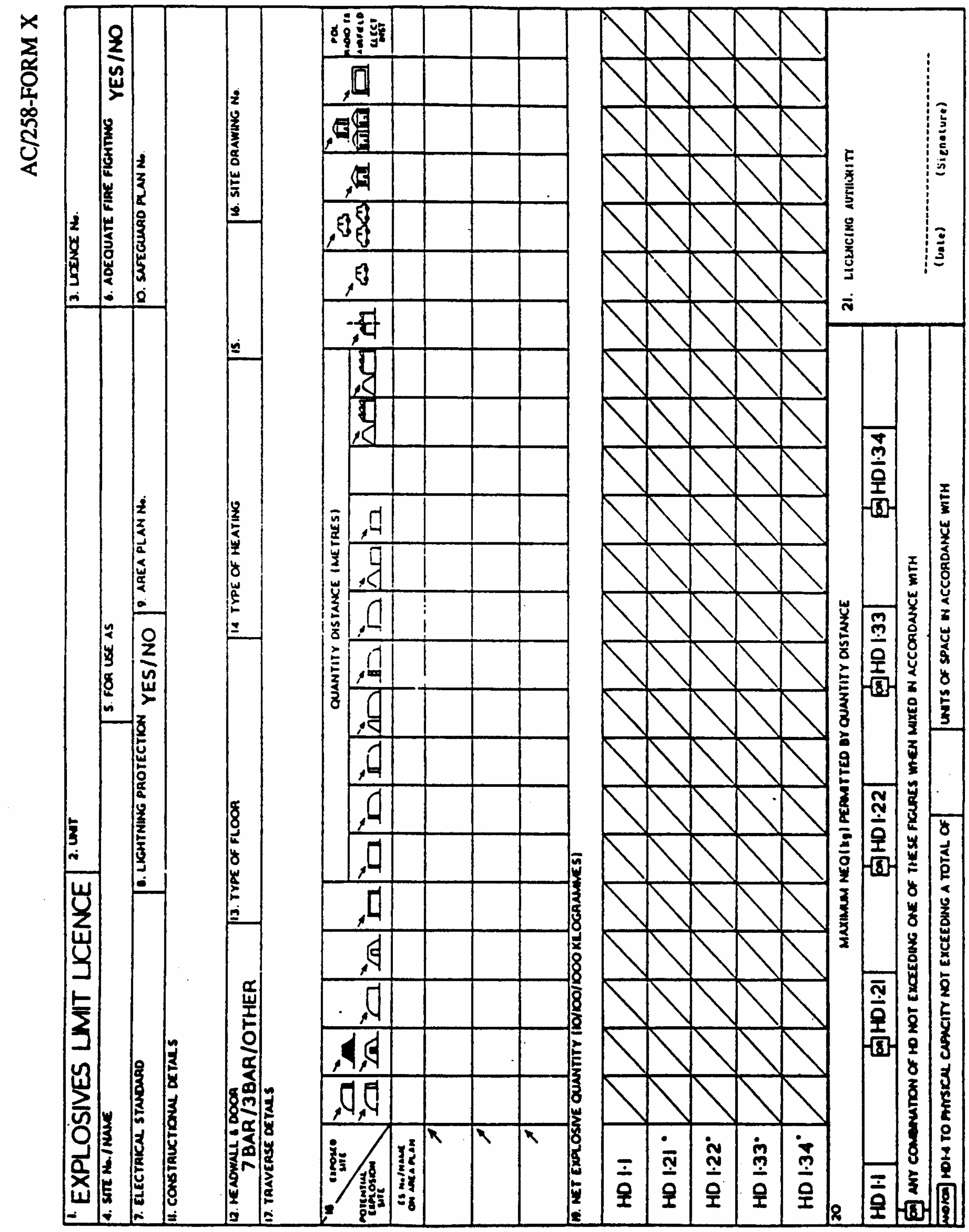
d) The interior quantity-distances are shown at Table B-II for both types of construction.

e) A study of Table B-II begins to reveal the advantages of using igloos. For example in the case of ESH 1 and 2 containing 20 000 kg NEQ of Hazard Division 1.1 only 22 m separation from other igloos is required for virtually complete protection for stocks in ES, whilst in the case of barricaded, light structures a separation of 66 m is required for less protection of stocks. It is this reduced separation with increased protection which is the main attraction of using igloos. The economics will have to be calculated for each individual site as the additional cost of construction of igloos must be balanced against the reduced length of routes, perimeter fences etc.

21. *Conclusion*

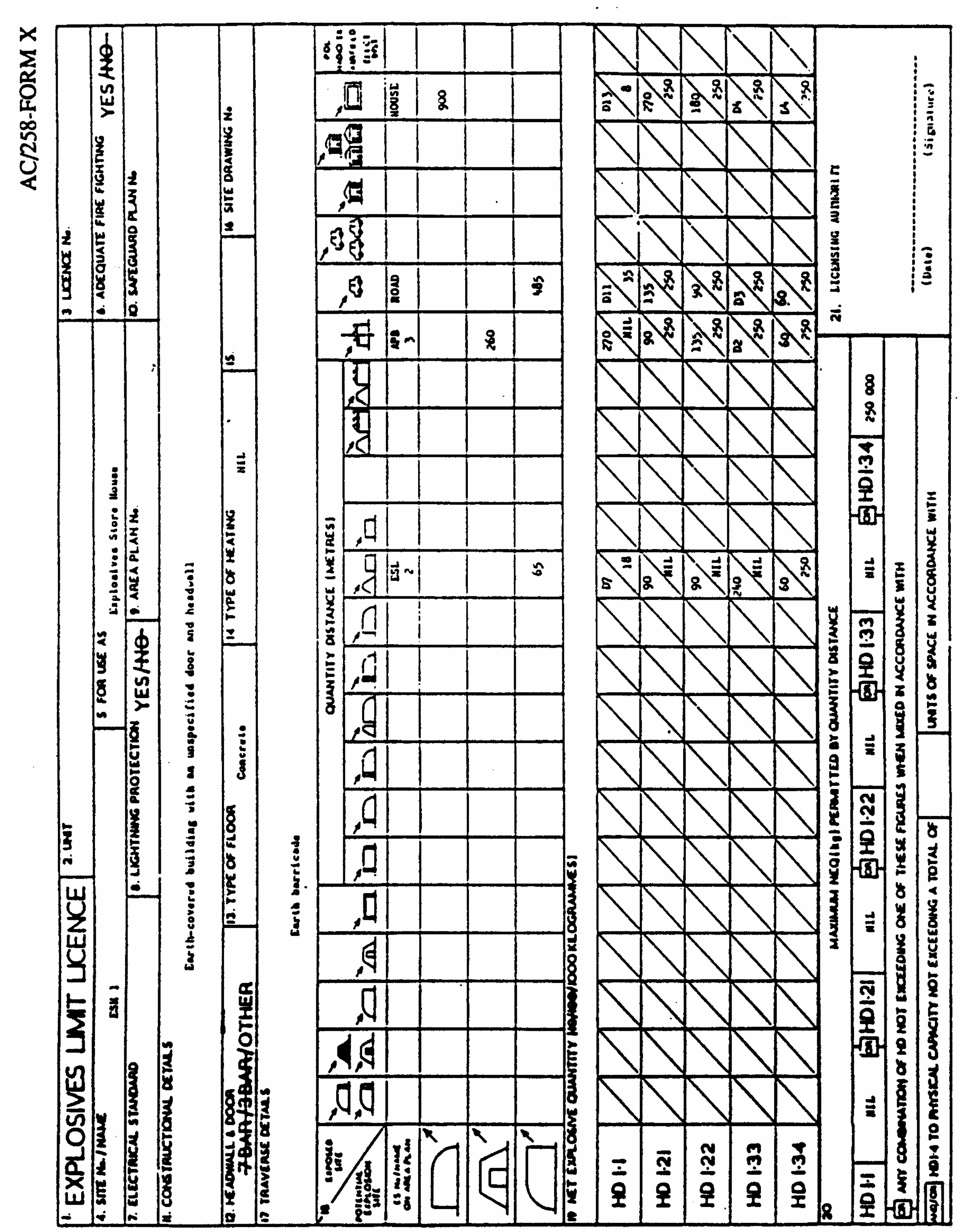
Tables B-I and B-II give in broad terms the applicable Exterior and Interior Quantity-Distances for both igloos and light structures. The decision on which type of structure to use depends on many factors beyond the scope of this example, such as detailed study of the land, availability of material and labour, and perhaps above all the economics of the alternatives.

Figure B-I



NOTE: see subparagraphs 9.b) and 10.b) respectively for explanation of Hazard Divisions 1.21/1.22 and 1.33/1.34

Figure B-II



AC/258-FORM X

1. EXPLOSIVES LIMIT LICENCE | 2. UNIT | 3 LICENCE No.

4. SITE No. / NAME: ESH 1 | 5 FOR USE AS: Explosives Store House | 6. ADEQUATE FIRE FIGHTING: YES/~~NO~~

7. ELECTRICAL STANDARD | 8. LIGHTNING PROTECTION: YES/~~NO~~ | 9. AREA PLAN No. | 10. SAFEGUARD PLAN No.

11. CONSTRUCTIONAL DETAILS: Earth-covered building with an unspecified door and headwall

12. HEADWALL & DOOR: ~~7 BAR/3 BAR~~/OTHER | 13. TYPE OF FLOOR: Concrete | 14 TYPE OF HEATING: NIL | 15. | 16 SITE DRAWING No.

17 TRAVERSE DETAILS: Earth barricade

18 EXPOSED SITE / POTENTIAL EXPLOSION SITE — QUANTITY DISTANCE (METRES)

ES No/NAME ON AREA PLAN: ESL 2; APB 3; ROAD; HOUSE

Distances: 900 (HOUSE); 260 (APB); 65 (ESL 2); 485 (ROAD)

19 NET EXPLOSIVE QUANTITY ~~(kg/100/1000 KILOGRAMMES)~~

	ESL 2	APB	ROAD	HOUSE
HD 1·1	D7 / 18	270 / NIL	D11 / 35	D13 / 8
HD 1·21	90 / NIL	90 / 250	135 / 250	270 / 250
HD 1·22	90 / NIL	135 / 250	90 / 250	180 / 250
HD 1·33	240 / NIL	D2 / 250	D3 / 250	D4 / 250
HD 1·34	60 / 250	60 / 250	60 / 250	D4 / 250

20 MAXIMUM NEQ (kg) PERMITTED BY QUANTITY DISTANCE

HD 1·1	NIL	OR HD 1·21	NIL	OR HD 1·22	NIL	OR HD 1·33	NIL	OR HD 1·34	250 000

OR ANY COMBINATION OF HD NOT EXCEEDING ONE OF THESE FIGURES WHEN MIXED IN ACCORDANCE WITH

AND/OR HD1·4 TO PHYSICAL CAPACITY NOT EXCEEDING A TOTAL OF | UNITS OF SPACE IN ACCORDANCE WITH

21. LICENSING AUTHORITY

(Date) (Signature)

Figure B-III

AC/258-FORM X

1. EXPLOSIVES LIMIT LICENCE | 2. UNIT | 3. LICENCE No.

4. SITE No. / NAME: ESL 2 | 5. FOR USE AS: Storage Site | 6. ADEQUATE FIRE FIGHTING: YES/~~NO~~

7. ELECTRICAL STANDARD | 8. LIGHTNING PROTECTION: YES/~~NO~~ | 9. AREA PLAN No. | 10. SAFEGUARD PLAN No.

11. CONSTRUCTIONAL DETAILS: NIL

12. HEADWALL & DOOR: ~~7 BAR/3 BAR~~/OTHER | 13. TYPE OF FLOOR: Earth/wood | 14. TYPE OF HEATING: NIL | 15. | 16. SITE DRAWING No.

17. TRAVERSE DETAILS: Earth barricades on all four sides.

18. Exposed site / Potential explosion site						QUANTITY DISTANCE (METRES)																	POL RADIO TO AIRFIELD ELECT DIST
ES No/NAME ON AREA PLAN									ESN 1								APB 3	ROAD				HOUSE	
									65								250	400				995	
19. NET EXPLOSIVE QUANTITY (10/100/1000 KILOGRAMMES)																							
HD 1·1									D9 2								D10 30	D11 18				D13 10	
HD 1·21									10 250								135 250	135 250				270 250	
HD 1·22									10 250								90 250	90 250				183 250	
HD 1·33									D1 80								D2 250	D3 250				D4 150	
HD 1·34									25 250								60 250	50 250				L4 250	

20. MAXIMUM NEQ (kg) PERMITTED BY QUANTITY DISTANCE

HD 1·1	2 000	OR HD 1·21	250 000	OR HD 1·22	250 000	OR HD 1·33	80 000	OR HD 1·34	250 000

OR ANY COMBINATION OF HD NOT EXCEEDING ONE OF THESE FIGURES WHEN MIXED IN ACCORDANCE WITH

AND/OR HD1·4 TO PHYSICAL CAPACITY NOT EXCEEDING A TOTAL OF ______ UNITS OF SPACE IN ACCORDANCE WITH

21. LICENSING AUTHORITY

(Date) ---------------- (Signature)

Figure B-IV

AC/258-FORM X

1. EXPLOSIVES LIMIT LICENCE	2. UNIT		3. LICENCE No.
4. SITE No./NAME APB 3	5. FOR USE AS Explosives Workshop		6. ADEQUATE FIRE FIGHTING YES/~~NO~~
7. ELECTRICAL STANDARD	8. LIGHTNING PROTECTION YES/~~NO~~	9. AREA PLAN No.	10. SAFEGUARD PLAN No.
11. CONSTRUCTIONAL DETAILS Light construction without protective roof			
12. HEADWALL & DOOR ~~7 BAR/3 BAR~~/OTHER	13. TYPE OF FLOOR Concrete	14. TYPE OF HEATING Steamheating	15. / 16. SITE DRAWING No.
17. TRAVERSE DETAILS unbarricaded			

18. EXPOSED SITE / POTENTIAL EXPLOSION SITE — QUANTITY DISTANCE (METRES)

ES No./NAME ON AREA PLAN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23 POL RADIO TX AIRFIELD ELECT DIST
				ESH 1								ESL 2						ROAD				HOUSE	
PES				260								250						430				1010	

19. NET EXPLOSIVE QUANTITY (~~10/100~~/1000 KILOGRAMMES)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
HD 1·1				D8 / 250								D7 / 250						D11 / 20				D13 / 10	
HD 1·21				2 / 250								90 / 250						135 / 250				270 / 250	
HD 1·22				2 / 250								90 / 250						90 / 250				180 / 250	
HD 1·33				D1 / 250								D1 / 250						D3 / 250				D4 / 250	
HD 1·34				2 / 250								60 / 250						60 / 250				14 / 250	

20. MAXIMUM NEQ (kg) PERMITTED BY QUANTITY DISTANCE

HD 1·1		OR HD 1·21		OR HD 1·22		OR HD 1·33		OR HD 1·34	
HD 1·1	10 000	OR HD 1·21	250 000	OR HD 1·22	250 000	OR HD 1·33	250 000	OR HD 1·34	250 000

OR ANY COMBINATION OF HD NOT EXCEEDING ONE OF THESE FIGURES WHEN MIXED IN ACCORDANCE WITH

AND/OR HD1·4 TO PHYSICAL CAPACITY NOT EXCEEDING A TOTAL OF ______ UNITS OF SPACE IN ACCORDANCE WITH

21. LICENSING AUTHORITY

(Date) ---------------- (Signature)

Figure B-V - Sketch of Ground available and surrounding facilities

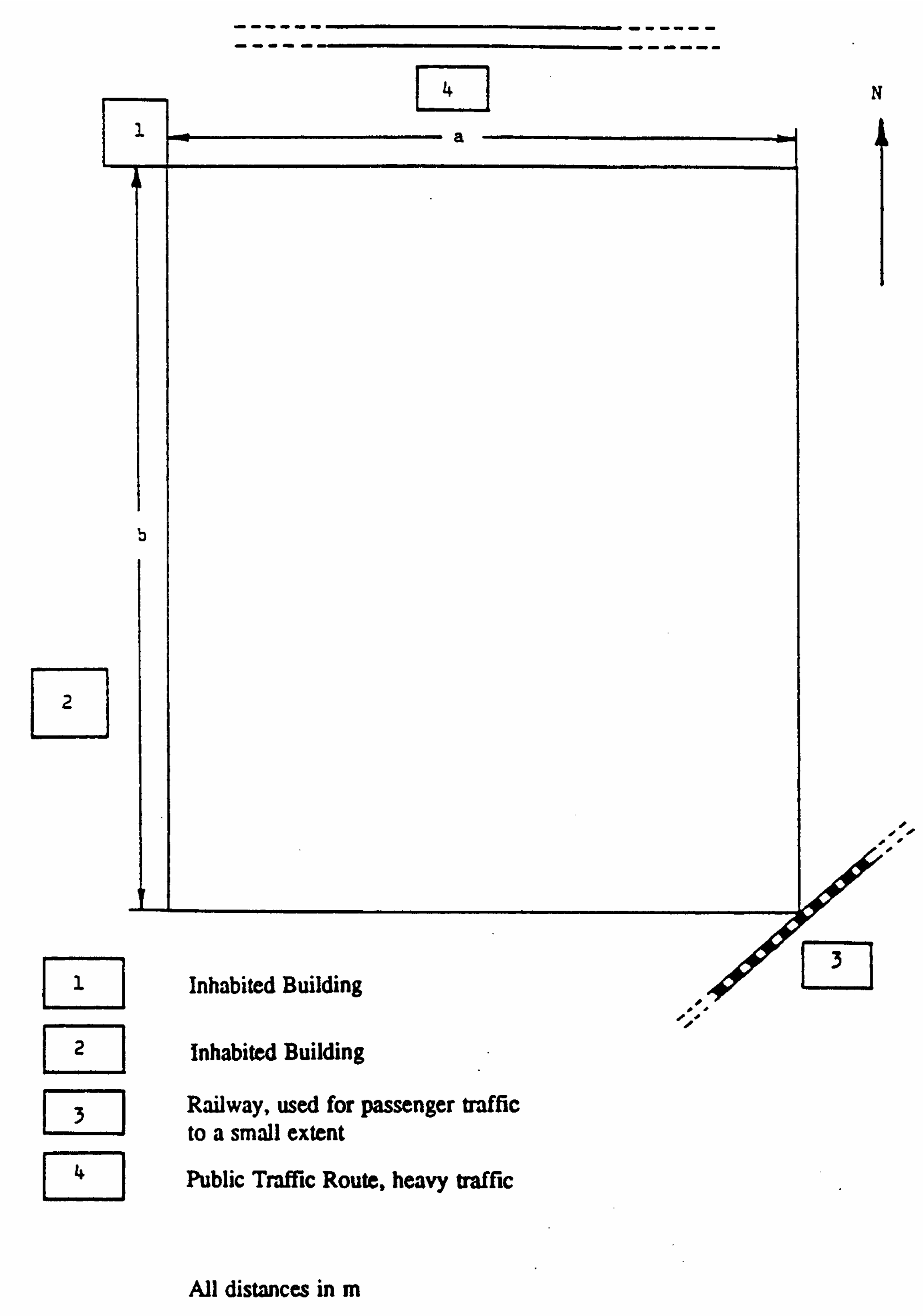


TABLE B-I (PAGE 1)

EXTERIOR QUANTITY-DISTANCES

ESH No. (PES) TYPE	NEQ kg/HD	Exterior Quantity-Distance to ES in metres					
		Inhabited Building Distance	Reference Column/-Row	Public Traffic Route Heavy Traf.[1)]	Reference Column/-Row	Railway Light passenger Traf.[2)]	Reference Column/ Row
IGLOOS 1 & 2 Face on Rear on Side on	 20 000/1.1	 610 610 610	 Table 1 f/20 a/20 b/20	 610 610 610	 Table 1 f/19(D13) a/19(D13) b/19(D13)	 405 405 405	 Table 1 f/19(D11) a/19(D11) b/19(D11)
3 & 4 Face on Rear on Side on Face on Rear on Side on	17 500/1.3 (prop.) 5 000/1.2	 240 170 170 320 320 320 *	 Table 3A f/20 a/20 b/20 Table 2 f/20(D2) a/20(D2) b/20(D2) *	 240 170 170 320 320 320 *	 Table 3A f/19(D4) a/19(D4) b/19(D4) Table 2 f/20(D2) a/20(D2) b/20(D2) *	 160 115 115 135 135 135 **	 Table 3A f/19(D3) a/19(D3) b/19(D3) Table 2 f/19[3)] a/19[3)] b/19[3)] **
5 & 6 Face on Rear on Side on	17 500/1.3 (other than prop.)	 170 170 170	 Table 3B f/20 a/20 b/20	 170 170 170	 Table 3B f/19 a/19 b/19	 60 60 60	 Table 3B f/19[3)] a/19[3)] b/19[3)]

NOTE 1: Heavy traffic on road - therefore full Inhabited Building Distance.

NOTE 2: Light passenger traffic, the railway can be easily stopped - therefore use 2/3 Inhabited Building Distance.

NOTE 3: Traffic is stopped promptly to avoid worst attack.

*) HD 1.2 Q-Ds govern.

**) Except for face on HD 1.2 Q-Ds govern.

TABLE B-I (PAGE 2)

EXTERIOR QUANTITY-DISTANCES

ESH No. (PES) TYPE	NEQ kg/HD	Exterior Quantity-Distances to ES in metres					
		Inhabited Building Distance	Reference Column/ Row	Public Traffic Route Heavy Traffic [1)]	Reference Column/ Row	Railway Light Passenger Traffic [2)]	Reference Column/ Row
LIGHT STRUCTURES, BARRICADED							
1 & 2	20 000/1.1	610	Table 1 d/20	610	Table 1 d/19	405	Table 1 d/19
3 & 4	17 500/1.3 (prop.)	170	Table 3A d/20	170	Table 3A d/19	115	Table 3A d/19
	5 000/1.2	320 *	Table 2 d/20 *	320 *	Table 2 d/19 *	135 *	Table 2 d/19 [3)] *
5 & 6	17 500/1.3 (other than prop.)	170	Table 3B e/20	170	Table 3B e/19	60	Table 3B e/19 [3)]
Explosives Workshops No. 1 & 2	The workshops are light structures barricaded and with protective roofs. These equate to a column C in Tables 1 and 2 as PES. Table 1 gives a minimum exterior quantity-distance of 400 m to an Inhabited Building or major Public Traffic Route and 270 m to a minor Public Traffic Route.						

NOTE 1: Heavy traffic on road – therefore use full Inhabited Building Distance.

NOTE 2: Light passenger traffic, the railway can be easily stopped - therefore use 2/3 Inhabited Building Distance.

NOTE 3: Traffic is stopped promptly to avoid worst attack.

*) HD 1.2 Q-Ds govern.

TABLE B-II

INTERIOR QUANTITY-DISTANCES

ESH No. (PES) TYPE	NEQ Kg/HD	Interior Quantity-Distances to ES in metres				
		Reference Table/column	Other ESH	Reference Table/row	Workshop	Reference Table/row
Igloo (7 bar)						
ESH 1 & 2	20 000/1.1	1/f	22 (virtually complete protection)	1/1	220 1)	1/16
ESH 3 & 4	17 500/1.3 (prop.)	3A/f	25 (high/limited degree protection)	3A/1	84	3A/16
	5 000/1.2	2/f	2	2/1 *	25 *	2/16
ESH 5 & 6	17 500/1.3 (other than prop.)	3B/g	2**	3B/1	25	3B/16
Light structure, barricaded						
ESH 1 & 2	20 000/1.1	1/d	66 (High degree protection)	1/14	220 1)	1/16
ESH 3 & 4	17 500/1.3 (prop.)	3A/d	32	3A/14	84	3A/16
	5 000/1.2	2/d	90 (limited degree of protection) ***	2/14 ***	25 ***	2/16 ***
ESH 5 & 6	17 500/1.3 (other than prop.)	3B/c	60	3B/14	25	3B/16

NOTE 1: Attention is drawn to paragraph 1.3.1.13. regarding separation of Explosives Workshops from storage sites containing HD 1.1 ammunition.

*) HD 1.3 Q-Ds govern.

**) Virtually complete protection - considerations may require greater distance.

***) HD 1.2 Q-Ds govern for ESH and HD 1.3 Q-Ds for workshops.