BRITISH STANDARD

BS 5607:1998

Code of practice for the safe use of explosives in the construction industry

ICS 71.100.30; 91.200

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by Technical Committee B/513, Construction equipment and plant, and site safety, to Subcommittee B/513/3, Safe use of explosives, upon which the following bodies were represented:

British Tunnelling Society
Construction Health and Safety Group
Construction Industry Training Board
Health and Safety Executive
Imperial Chemical Industries Limited
Institute of Explosives Engineers
Institution of Chemical Engineers
Institution of Structural Engineers
Ministry of Defence
National Federation of Demolition Contractors

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Contents

Foreword

This revision of BS 5607 has been prepared by Subcommittee B/513/3 and supersedes BS 5607:1988, which is withdrawn.

This code of practice aims to define good practice in the handling, transport and storage of explosives during the varied uses to which explosives may be put by the construction industry. Emphasis throughout the code has been placed on safety, particularly the safety of those engaged in using explosives for work on site and the safety of others who may be in the vicinity of that work.

Clause **4** contains general recommendations and information on legislative requirements relating to most uses to which explosives are put in the construction industry. Clauses **5** to **10** address major specialist uses and are where particular general recommendations are extended and specific recommendations added.

The importance of security is recognized but this standard is not intended to address detailed security measures.

This code of practice also lists the legislative requirements at present in force concerning explosives. These should be closely studied and carefully followed.

All legislative requirements relating to explosives in Great Britain form "relevant statutory provisions" as defined in the Health and Safety at Work etc. Act 1974. The advice on legal requirements given in this code relates to the law at the date of publication of this code.

In this revision of the 1988 edition, changes have been made to take account of the following principal factors:

Legislation and the management of safety

Industry has developed new philosophies on the management of safety and this has been reinforced by the Construction (Design and Management) (CDM) Regulations. There has also been a total re-appraisal of the acquisition, storage, transport and use of explosives and accessories due to the re-writing of the 1875 Explosives Act and the harmonization with European Standards. Additionally the standard has taken account of other parallel legislation such as "The Explosives in Quarries Regulations".

Changes in technology

Since BS 5607:1988 was issued there have been significant changes in the types of explosives and initiation systems in general use and a greater awareness and sophistication has developed at the user end.

Training

There is now a recommendation for training leading to competency in the use of explosives and for management at all levels to achieve a successful outcome.

The text of the standard has been restructured to take into account the above factors with particular emphasis on training and course syllabi.

As a code of practice, this British Standard takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

It is the responsibility of contracting parties to invoke standards in such a way that their provisions can be enforced between them.

The use of explosives in civil engineering projects differs in some respects to other explosives use, for example, quarrying and mining, where specific regulations apply.

It is assumed that the execution of the procedures recommended in this British Standard is entrusted to appropriately qualified and competent people.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 46, an inside back cover and a back cover.

1 Scope

This British Standard gives recommendations for the safe storage, handling, transport and use of blasting explosives and accessories in construction and demolition operations.

Clause **4** covers general recommendations for handling and safety. Subsequent clauses are concerned with safety in the use of explosives in special applications and situations such as tunnelling, demolition, excavation and underwater working.

This standard does not apply to blasting on offshore oil and/or gas platforms or structures or any associated works.

2 Normative references

The following normative references contain provisions which, through reference in this text, constitute provisions of this British Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the publication referred to applies.

BS 4078-1, *Powder actuated fixing systems — Code of practice for safe use.*

BS 5930, *Code of practice for site investigations.*

BS 6031, *Code of practice for earthworks.*

BS 6164, *Code of practice for safety in tunnelling in the construction industry.*

BS 6187, *Code of practice for demolition.*

BS 6472, *Guide to evaluation of human exposure to vibration in buildings (1 Hz to 80 Hz).*

BS 6657, *Guide to prevention of inadvertent initiation of electro-explosive devices by radio-frequency radiation.*

BS 7385-1, *Evaluation and measurement for vibration in buildings — Guide for measurement of vibrations and evaluation of their effects on buildings.*

BS 7385-2, *Evaluation and measurement for vibration in buildings — Guide to damage levels from groundborne vibration.*

3 Terms and definitions

For the purposes of this British Standard, the following terms and definitions apply.

3.1

air blast

production of air over-pressure caused by an explosion

3.2

ANFO

mixture of ammonium nitrate and fuel oil that can be used as an explosive

NOTE The preparation of ANFO outside a licensed explosives factory is required to conform to the Health and Safety Executive licence granted under the provisions of the Ammonium Nitrate (mixtures) Exemption Order, 1967 [1].

3.3

approved

authorized for use by an authority having jurisdiction

3.4

authorized explosive

explosive that is available legally in the United Kingdom

NOTE Such explosives are listed annually by the statutory authority of central government.

3.5

blackpowder

gunpowder used in blasting

3.6

blast area

area within which all the debris from the blast is calculated to fall and come to rest

3.7

blast plan

charging plan and, where applicable, the drilling pattern

3.8

bulk explosives

explosives that fill the complete cross-section of a shot hole to provide 100 % coupling with the substrate

3.9

burden

shortest distance between explosives and any free face

3.10

canister

portable container specifically intended and designed to carry a small quantity of explosives or accessories

3.11

cap *(deprecated)*

American synonym for detonator

3.12

capped fuse

length of safety fuse fitted with a plain detonator

3.13

cartridge

wrapped or otherwise protected cylinder of defined size of a homogeneous explosive material

3.14

competent person

a person who, by reason of theoretical and practical training or actual experience or both, is competent to perform the task or function or assume the responsibility in question and is authorized to perform such task or function

3.15

deflagrating compounds

materials which enable the subsonic propagation of a reaction front

3.16

delay detonator

detonator with a predetermined delay between initiation and detonation

3.17

detonating cord

flexible cord of spun textile fibres containing an explosive, and with a plastics coating, which, when initiated, propagates a detonation along its length

NOTE There is a significant explosive effect outside the cord as the detonation propagates (see also **3.43**).

3.18

detonating relay

device for inserting into a detonating cord to produce a predetermined delay in the transmission of a detonation wave

3.19

detonator

initiator for explosives materials that contains a charge of high explosive fired by means of a flame, spark, electric current or shock tube

3.20

emulsion explosive

waterproof explosive that contains sensitizers, oxidizers and fuels dispersed as an emulsion

3.21

exclusion zone

zone from which all site personnel and the public are excluded

NOTE In certain situations the shotfirer may be positioned within the exclusion zone provided that they are protected.

3.22

exploder

device designed for firing detonators

3.23

explosive

article, substance or mixture of substances that is manufactured to produce a practical effect by explosion

3.24

explosives store

building or structure for the storage of up to 1 800 kg of explosive and licensed by a local authority

3.25

fly

projected material beyond the exclusion zone

3.26

fume characteristics

nature of fumes produced by the detonation of an explosive, particularly as regards the noxious gases contained therein

3.27

fuse-lighter

device designed for igniting safety fuse and igniter cord

3.28

high explosive

explosive that detonates and produces an intense shock wave

3.29

igniter cord

flexible cord with core of incendiary composition used mainly to ignite individual safety fuses when groups of shots are being fired in a sequence

NOTE An intense side flame is emitted when burning.

3.30

low explosive

explosive that produces large volumes of gases without creating an intense shock wave

3.31

magazine

building or structure used for the storage of explosive and licensed by the Health and Safety Executive for this purpose

3.32

Misfires

3.32.1

type A misfire

misfire in which testing before firing a shot reveals broken continuity which cannot be rectified

3.32.2

type B misfire

misfire in which any shot fails to explode when an attempt is made to fire it

3.33

Permitted explosives and detonators

3.33.1

permitted explosives

explosives of a type approved by the Health and Safety Executive for use in safety lamp mines (in compliance with regulation 5:1 of the Coal and Other Safety-Lamp Mines (Explosives) Regulations 1993 [2])

3.33.2

permitted detonators

detonators of a type approved by the Health and Safety Executive for use in safety lamp mines (in compliance with regulation 5:1 of the Coal and Other Safety-Lamp Mines (Explosives) Regulations 1993 [2])

3.34

pre-splitting

blasting technique to prevent overbreak by creating a fracture plane on the perimeter of an excavation using shot holes which are fired simultaneously before the main shot holes and which are lightly charged and closely spaced

3.35

primary blasting

blasting by which material is dislodged from its original location

3.36

primer

cartridge or container of explosive into which one or more detonators or detonating cord is inserted or attached, in order to initiate or boost a larger charge

3.37

registered premises

premises registered with the local authority and used for the keeping of small quantities of explosives

3.38

round

group of shots fired in one operation

3.39

safety fuse

flexible cord that contains an internal burning medium by which fire is conveyed at a continuous and uniform rate for the purpose of firing plain detonators or blackpowder, without initiating burning in a similar fuse that may be in lateral contact alongside

3.40

secondary blasting

blasting to reduce oversize material to the dimensions required

3.41

sensitivity

measure of ease with which a substance or article can be made to explode, or its liability to explode, when subjected to deliberate or accidental shock, friction or heat

3.42

shaped charge

explosive device designed to concentrate the explosive force in a particular direction

NOTE A shaped charge is sometimes known as a cavity or hollow charge.

3.43

shock tube

flexible tube coated on the inside with a reactive composition that, when initiated, propagates a shock wave along its length and initiates a detonator

3.44

shotfirer

appointed person in immediate control of the use of explosives

NOTE See annex A.

3.45

smooth blasting

blasting technique to minimize overbreak in which a number of shot holes, lightly charged and closely spaced, are positioned on the perimeter of an excavation and fired simultaneously after the main blast but in the same round

3.46

Signals

3.46.1

warning signals

predetermined visual and/or audible signals prior to the initiation of an explosion

3.46.2

all clear signals

predetermined visual and/or audible signals given after an explosion after checking that there have been no misfires and the area is safe to enter

3.47

slurry explosive

waterproof explosive which contains sensitizers, oxidizers and fuels dispersed in a gel

3.48

stemming

inert incombustible material used to confine explosives in a shot hole

4 General recommendations

4.1 Preliminary procedures

4.1.1 *General*

All uses of explosives should be preceded by consideration of the following:

— is the proposed procedure within the law (**4.1.2**)?;

— is it safe or does it put people at risk (**4.1.3**)?;

— who has responsibility and supervisory control of the operation (**4.1.4**) and for completion of the method statement (**4.1.5**)?

It may be decided that the use of explosives is inappropriate and an alternative approach is required.

To complete the preliminary procedures, site survey(s), blast design and development of the method statement (**4.1.5**) should be carried out.

4.1.2 *Legislation*

4.1.2.1 *General*

Legislation relating specifically to explosives and which may be referred to is listed in **B.1**.

Legislation relating to work on construction sites and which may be referred to is listed in **B.2**.

NOTE The lists are not exhaustive and all legislation is subject to review and amendment.

4.1.2.2 *Construction, Design and Management Regulations*

Although the Construction, Design and Management (CDM) Regulations [3] apply to most explosives work within the construction industry, their principles should be adopted for all explosives work (see annex C).

4.1.2.3 *Local authority powers of control*

Certain local authorities have special powers of control granted under local act of parliament; permission may be required before blasting can take place.

4.1.2.4 *Other regulations*

Special regulations may apply in Scotland, Northern Ireland, the Channel Islands, Isle of Man and the Scilly Isles, and should be checked prior to operations in these areas.

4.1.3 *Risk assessment*

4.1.3.1 *General*

The Management of Health and Safety at Work Regulations, 1992 [4] require, under Regulation 3, that an assessment of risks is carried out before commencing any operations. This risk assessment should:

— identify the significant risks arising out of the work;

— enable identification and prioritization of the measures that need to be taken to comply with the relevant statutory provisions;

— be appropriate to the nature of the work and be such that it remains valid for a reasonable period of time.

This assessment should include and take cognizance of the general considerations of **4.1.3.2** to **4.1.3.14**, but should not be limited by them.

4.1.3.2 *Survey*

4.1.3.2.1 *General*

Before any works involving the use of explosives are started, a detailed survey and examination of the site, buildings or structures and adjoining areas and property should be made. Procedures for the survey of sites are set out in BS 5930. When earthworks, tunnelling or demolition are involved, reference should be made to BS 6031, BS 6164 and BS 6187 respectively.

4.1.3.2.2 *Geological structure*

Attention should be given to the character and structure of the geological strata present on site and how they will react to blasting. Additionally, the interaction of the geological structure with excavations or cuttings should be considered and the stability and safety assessed. Due care should also be taken to avoid disruptions or damage to underground features such as wells, tunnels, storage tanks, mine workings and other underground voids.

4.1.3.3 *Utilities*

Special consideration should be given to the proximity of underground and overground services before blasting operations are carried out. Consultations should be carried out with the necessary bodies who are responsible for existing underground utilities.

4.1.3.4 *Ground/airborne vibrations*

Many excavation operations in construction have to be carried out in the proximity of existing buildings or existing and new structures such as bridges, retaining walls and underground services. Additionally, where the public are involved, their sensitivity to ground-borne vibration from blasting and their concerns in respect of potential damage to their property dictates that a great deal of attention should be paid to this aspect of the blasting operation.

Although no statute exists, a contractual limit may be specified or the relevant British Standards which address damage levels from vibration and human exposure levels to vibration should be consulted (BS 7385-1, BS 7385-2 and BS 6472 respectively). In situations where ground or airborne vibrations may constitute either a nuisance or a potential damage risk, structural surveys pre- and post-blasting, together with consultations with owners or occupiers of the buildings/structures concerned, should be undertaken.

Initial trial blasting may be carried out with small isolated charges to allow the transmission properties of the ground in that particular location to be characterized; vibration effects from production blasting operations can then be calculated with a degree of confidence.

Human beings are very sensitive to vibration and can perceive vibration levels of a very low order. This can readily lead to complaints during production blasting operations, therefore effective consultation and communication with owners and occupiers should take place, and vibration levels should be controlled by proper blast design.

4.1.3.5 *Hazards from electrical sources*

Attention should be paid to the presence of power cables and radar, radio and television transmitting stations near intended blasting operations, since under special conditions these can cause premature firing of electric detonators (see BS 6657). On-site use of citizen's band radios, site radio transmitters and mobile telephones should be strictly controlled during blasting operations.

Premature initiation may also result from electrical discharges, for example, direct lightning strikes or from resulting stray currents of sufficient magnitude.

No presently available initiation system offers complete protection against direct lightning strikes, therefore if a lightning storm approaches a blast site charging should cease and the blast area be vacated of all personnel. If stray currents from any sources are apparent, initiation systems offering protection against them should be employed, for example, shock tube detonators or transformer coupled detonators.

Extreme caution should be exercised when using electric detonators adjacent to public highways as illegal over-powered transmitters could be carried on vehicles passing close to the area of blasting. Consideration should also be given to the use of non-electric detonating systems or electric systems incorporating additional safeguards, for example, high firing current fuseheads or transformer coupled circuits. **WHERE ANY POSSIBLE DOUBT REMAINS NON-ELECTRICAL MEANS OF FIRING SHOULD BE ADOPTED.**

4.1.3.6 *Flammable or explosive substances*

Expert advice or help should always be obtained where the following sources of danger are found or could be expected:

a) flammable or toxic gases, liquids or dusts;

b) unexploded missiles or mines;

c) waste explosive.

NOTE In existing industrial plants or areas, the appropriate managements should be consulted.

4.1.3.7 *Exclusion zone*

The risk to third parties not directly involved in the blasting operation should be assessed and an exclusion zone established which ensures that the risk of injury to all personnel is prevented. Under the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) [5], the projection of material beyond the limit of exclusion is a reportable incident.

The shotfirer, who will always be positioned outside the blast zone but may be within the exclusion zone, should be protected by a blast shelter.

4.1.3.8 *Blast warning procedures*

Before any blasting commences on the construction site a suitable system of signs, signals and sentries should be established which uses both audible and visual signalling systems to give warning of blasting operations. It is essential that these signs and signals may be clearly seen and heard by site personnel working within the site areas, and also by others who may be affected, including the general public.

4.1.3.9 *Audible warning systems*

Audible warning systems should be used to signify to all persons that they withdraw from the exclusion zone. The warning should comprise a series of readily recognizable and identifiably different signals such as may be given by a hooter or whistle with a distinctive tone. A typical example may be:

a) five 5 s hoots at 5 s intervals made 5 min to 10 min before blasting, at which time sentries should go to their designated locations; followed by

b) a continuous hoot when blasting is imminent.

Before the blast is fired the blast and exclusion zones should be physically cleared by the shotfirer, perhaps in conjunction with site personnel and police in the case of major blasting operations where there are large blast and exclusion zones. Immediately before firing it is essential that the shotfirer makes contact with all sentries and supervisors of shelters where personnel are taking cover to ensure that all personnel are accounted for and that no-one has entered the exclusion zone.

Only after this process has been completed should the blast be fired.

The "all clear", which may be six to ten short, sharp hoots should be sounded after the shotfirer has checked that there have been no misfires and that the area is safe to enter.

No persons should return to any location within the exclusion zone until the "all clear" signal has been given.

The actual code of signals may be varied from the above to suit site conditions, but once established for a particular site, it is essential that they are not altered without good reason and adequate communication to all personnel.

4.1.3.10 *Visual warning systems*

Visual signs should comprise large clear notices in accordance with the Health and Safety (Safety Signs and Signals) Regulations [6], posted on all access roads to the site and located safely outside the exclusion zone. At blasting times the accesses should have sentries posted, with clear instructions as to when they have to stop access to the site, and when they can allow access. Where public roads pass close to the site there may be danger to traffic from projected material. The assistance of the police should be obtained in controlling traffic.

Where sentries are not in visual contact with the shotfirer a suitable means of communication should be introduced to stop blasting if anyone enters the exclusion zone. This may be by radio communication using hand-held radios provided that they are not taken within 10 m of a circuit containing standard electric detonators and are switched off at the firing point or preferably not taken within 5 m of the firing point.

Special sentries should be appointed to warn personnel who might fail to hear warning signals because of noisy machinery or other diversions during blasting.

In situations where control of public access to the site is difficult, it is important that the use of additional visual signals, such as a red flag or flags which are commonly indicative of danger should be considered. When blasting is in progress these should be displayed in prominent positions, e.g. on a tower, flag pole or high fence so as to be generally visible over a wide area.

Where control of site personnel is awkward because of the presence of different contractors and progression of different jobs on the site, special shelters with sentries should be appointed. Each sentry should check that all working groups and individuals under their control have retired to shelter during the blasting period.

4.1.3.11 *Advanced warning*

Advanced warning of the programme of blasting should be given to the owners or occupiers of any premises which are likely to be affected by the blasting events.

4.1.3.12 *Smoking and fires*

Smoking, fires, use of flame or heat producing equipment such as welding or cutting torches, or equipment which could cause or produce sparks should not be allowed near stored explosives or any place where explosives are being handled, transported or used.

Precautions should be taken when using explosives in the presence of waste paper, dry timber and vegetation, especially after a hot dry spell of weather which might produce unusual hazards. If an occasion arises where there is a need to burn rubbish on site, this should be done either before explosives are brought on site or after their removal. If explosives are already present on site, predetermined procedures should be followed to ensure that the fire produces no hazard. Any such fires should be closely contained and well supervised. Fire fighting procedures should be established.

4.1.3.13 *Advance notices and consultation*

Prior to carrying out the works, consultation should take place with the relevant authorities and advance notification given, where applicable, to:

— police;

— statutory authorities;

— local authority;

— building control;

— Health and Safety Executive;

— local residents;

— highways and roads authorities;

— fire authority;

— other interested or affected parties.

4.1.3.14 *Security and transport of explosives*

The acquisition of explosives is governed by legislation. The Control of Explosives Regulations 1991 [7] require that those purchasing and/or using explosives should obtain a certificate to either acquire or acquire and keep explosives; the certificate being issued by the local police authority.

The keeping of explosives, or their storage is also covered by these Regulations (see Table 1).

The following Regulations should be read and understood and advice obtained as required. Transfer of explosives is covered by The Control of Explosives Regulations 1991 [7] in terms of the requirements to record transactions, and possession of a Recipient Competent Authority (RCA) document is required under The Placing on the Market and Supervision of Transfers of Explosives Regulations [8]. However, any physical transport of explosives is required to conform to the relevant regulations covering packaging and transport i.e. The Packaging of Explosives for Carriage Regulations 1991 [9], The Carriage of Explosives by Road Regulations 1996 [10] and The Carriage of Dangerous Goods by Road (Driver Training) Regulations 1996 [11].

Movement of explosives within the site should be in sealed manufacturers' cases or containers and in vehicles clearly displaying that they are carrying explosives. Detonators should always be transported in a separate sealed and secured container designed for the purpose. Movement of explosives or detonators should always be under the direct control of an authorized person (see **4.1.4.1**).

Damaged or contaminated explosives should be handled with extreme care and disposed of in a safe manner on site if at all possible. If they are to be returned to a secure store it is essential that they be securely packed and labelled in accordance with the relevant regulations and with advice taken from the manufacturer.

Table 1 — Storage of explosives

Maximum quantity allowed kg	Method	Authority
5	Police Private Use Certificate	Under local authority control
7	Mode B Registered Premises	
30	Mode A Registered Premises	
75	Division A Licensed Store	
150	Division B Licensed Store	
450	Division C Licensed Store	
900	Division D Licensed Store	
1800	Division E Licensed Store	
Unlimited (by licence)	Magazine	Under HSE control
NOTE This table is a simplification of the requirement for bulk explosives and detonators but is not applicable to fireworks, gunpowder or ammunition.		

NOTE 1 An "acquire and keep" certificate is required for all the stored quantities of explosives given here.

NOTE 2 The storage of quantities of explosive in excess of 1 800 kg is covered by Home Office Regulations and can only be approved and a licence issued by the Health and Safety Executive, Explosives Inspectorate.

NOTE 3 Storage of quantities of less than 1 800 kg is covered by local authority certificates which are issued in consultation with the relevant local police authority. Construction and security requirements for these explosive stores are set out in updated Guidelines issued by the Health and Safety Executive under the Explosives Act 1875 [12].

4.1.4 *Supervision and responsibility*

4.1.4.1 When blasting operations are to take place or are taking place on a construction site, it is essential that they should be under the control of a person competent in explosives engineering and/or shotfiring. These competent persons should be responsible for the acquisition, storage, handling, transport and use of all explosives, detonators and accessories, and should be given a clear statement in writing of their duties and jurisdiction. Other persons who are to assist them in the performance of their duties in connection with the use of explosives should also be authorized in writing.

4.1.4.2 No person other than those designated in **4.1.4.1** should be in possession of explosives on site.

4.1.4.3 Competency in explosives engineering requires the ability to demonstrate the successful completion of a course of training which should include:

a) shotfiring (see annex A); and

b) explosives engineering (see annex D);

together with the accumulation of the practical and theoretical knowledge and experience necessary to carry out the full range of explosives engineering duties.

4.1.4.4 Competency in shotfiring requires the possession of evidence of the successful completion of a course of training which should cover the subjects set out in annex A and evidence of sufficient knowledge and experience for the performance of the full range of shotfiring duties.

4.1.4.5 When one or more contractors are taking part in the work on the same site, the main or managing contractor should ensure close liaison and collaboration with the explosives engineer and/or the shotfirer responsible for the explosives work, both in the planning and in the execution of the work so as to prevent any hazard to personnel, materials or equipment when carrying out work with explosives. All site personnel present during blasting operations should come under the control of the explosives engineer and/or shotfirer.

4.1.5 *Method statement*

4.1.5.1 *General*

On completion of the risk assessment (see **4.1.3**) the method statement for the works should be prepared (see **4.7**). The purpose of the method statement is to ensure that when explosives are used on a construction site they will not give rise to danger. Section 2(2) of the Health and Safety at Work etc. Act 1974 [13] requires the provision of safe systems of work; drawing up and gaining approval for a method statement should be seen as an essential step in demonstrating compliance with that obligation.

The method statement should include procedures and practices drawn from company instructions and site rules specified by the company to ensure compliance with current legislation, codes of practice and guidance notes. It should identify problems and their solution and form a reference for site supervision. The method statement should be easy to understand, be known and accepted by all levels of supervision including shotfirers and any contractors involved on the site.

On sites where the CDM Regulations apply, the method statement should be an integral part of the health and safety plan (see **C.8**) developed by the principal contractor.

4.1.5.2 *Shotfirer's responsibilities*

One of the shotfirer's responsibilities is to ensure that explosives are stored, handled and used in accordance with the method statement. When it is not possible to comply with the method statement, operations should be suspended until approval has been obtained for any amendments to it, which amendments would normally be made by the explosives engineer in consultation with site management.

4.1.5.3 *Explosives engineer's responsibilities*

Where amendments need to be made to the method statement, the explosives engineer should ensure that the amended version is passed to every person who was in receipt of the original, in time for their consideration before the operation continues.

4.2 Safety and security of explosives during acquisition, transport and storage on site

4.2.1 *General*

In Great Britain, the law requires that explosive materials or detonators should be stored in a magazine or local authority licensed store or, possibly, in the case of smaller amounts, in registered premises. Before explosives can be acquired it is necessary to obtain a certificate from the police which certifies that a named person is fit and proper to acquire and store explosives. Without a certificate it is not possible to acquire explosive materials from a manufacturer or supplier. In addition, the named person will be required to have an RCA document (see **4.1.3.14**) issued by the Health and Safety Executive unless the explosive is used immediately at the place of manufacture.

Persons wishing to keep explosives should apply for the necessary certificate and RCA document in ample time. The local authority officer responsible for explosives should be consulted as soon as the need to keep explosives has been established.

4.2.2 *Planning*

The requirements regarding transport and storage of explosives depend on the type and quantities of materials to be used. It is important, therefore, that the techniques which are to be applied should be decided before any action is taken to arrange storage or transport. Once this has been decided, the best position for any store needed should be determined in consultation with the local authority officer responsible for explosives. It may not be possible to obtain storage facilities for the required quantity of explosives because of the proximity of structures and services which need to be protected. It should be realized that the local licensing authority has no discretion whatsoever to reduce the safety distances required by the stores under the Stores of Explosives Orders [14]. The police should also be consulted when the matter of siting is under consideration as they will be concerned as to the vulnerability of any store to an attempt at theft. There are stringent requirements for the construction of stores to ensure that they are secure. Local authority explosives officers should be consulted for detailed advice as to the standards of construction required, sources from which stores may be purchased and the method of mounting such stores.

If it is proposed to use ammonium nitrate/fuel oil (ANFO) types of explosive (including either bulk emulsion or emulsion ANFO blends prepared on site) it will be necessary for the user to obtain a licence to mix such explosives. Application should be made to HM Explosives Inspectorate for the licence.

In general, the types of explosives used in Great Britain may all be stored in the same place whether they be nitro-glycerine, trinitrotoluene (TNT) based explosives, slurry explosives, emulsions or of the ANFO type. Detonating cord may also be stored in the same compartment, but it is essential that detonators be stored separately. Most of the commercially available explosives stores have attached to them a separate structure suitable for the storage of detonators. It should be noted that special conditions apply to explosive devices containing exposed iron or steel. Care should be taken to ensure that any store or magazine used is licensed for the type of explosive to be stored within it and where there is any doubt the explosives officer for the area concerned should be consulted.

NOTE Site mixed explosives are made for immediate use and in general are not stored except in exceptional circumstances.

The transport of classified explosives is subject to special regulations as prescribed by The Placing on the Market and Supervision of Transfers of Explosives Regulations 1993 [8] and The Carriage of Explosives by Road Regulations 1996 [10].

As the techniques to be used and the phasing of work on a site will influence both the size of explosives store needed and the transport arrangements necessary, it is essential that these be established at the planning stage

4.2.3 *Responsibility for storage*

The shotfirer should be made responsible for the explosives store or magazine, for its cleanliness, for the proper rotation of stock, the keeping of records (see **4.2.4**) and for good housekeeping in general.

NOTE It is a legal requirement that copies of the appropriate general rules for explosives stores (or magazines) be displayed in the place used to store explosives.

4.2.4 ***Storage procedure***

Extreme caution should always be exercised during the unloading of explosives. Cases containing explosives should never be roughly handled, slid on ramps or dropped. The explosives should be handled only by the supplier's own operatives, by the shotfirer, or by the storekeeper. If it is necessary to use unskilled operatives for this purpose, they should be allowed to handle the materials only under the direct supervision of the shotfirer. Care should be taken to ensure that, during delivery of explosives to a storage place or during the removal of material from it, no grit is allowed to contaminate either the cases or the store and the floor of any such storage place should be thoroughly swept after any delivery or withdrawal of explosives. The cleaning of such stores should be carried out by the shotfirer, by the storekeeper or by someone under the personal supervision of the storekeeper. During storage all cases of explosives should be stored flat with their top side uppermost and in such a way as to allow the identifying name of the explosive and of its manufacturer and the date of manufacture to be clearly visible. Cases of explosive should be so stacked that any pile of boxes is stable and is positioned so as to allow all-round ventilation.

It is legally required that an up-to-date record is kept of all incoming and outgoing explosives and explosive items (including detonators, detonating cords, safety and other fuses), as is checking that the weight of explosives in the store does not exceed the licensed quantity. The store licensee should retain records of receipts, issues and transfers from the store which should be kept at the office. For the purposes of such calculations, plain or electric detonators may be reckoned to weigh 1 kg per thousand. Linear cutting charges or similar explosive articles should be reckoned on net explosive quantity or charge. On delivery to the site all explosives should be transferred either to their place of immediate use or to the licensed place of storage without delay.

Care should be taken to ensure that explosives are used in the order in which they have been delivered and old stocks should not be allowed to accumulate. Stocks of explosives should be regularly checked for signs of deterioration.

If explosives have been issued in excess of requirement and it is desired to return them to their licensed place of storage, they should be examined by the shotfirer before return. If they are neither wet nor contaminated in any way, they should be taken into store as normal but should be kept separately and should be the first material to be re-issued.

When explosives are returned to store special care should be taken that detonators and blasting explosives are kept completely separate, each in its appropriate place and repackaged in accordance with the current packaging and labelling regulations.

Any explosives which have been contaminated, whether by water or dirt, should be examined to make sure that detonators and blasting explosives are separated. They should be specially wrapped to ensure that contamination of the store does not occur and should be placed in a clearly identified container within the store itself. Efforts should be made to use up or dispose of any such material within one week of its being returned to store. In any event, contaminated material should not be allowed to accumulate over long periods.

If deterioration is observed in any explosive, the material should not be touched and expert advice should be obtained as to the best method of removal from the place of storage. The first step should be to contact the manufacturer or agent for such advice.

4.2.5 ***Fire***

It is essential that contraband, i.e. smoking materials, matches, lighters or any other sources of ignition, is not taken into an explosives store. Fires, naked lights or lighted cigarettes are not permitted within 25 m of any explosives store. No petrol, oil, flammable solvents, wastepaper or similar material, the ignition of which might imperil the explosives store, should be permitted within 25 m of any place where explosives are stored. Furthermore, care should be taken that grass and undergrowth in the vicinity of an explosives store is cut regularly to minimize the fire hazard. (See also **4.2.13**.)

4.2.6 ***Tools and equipment***

No tools or equipment should be kept in an explosives store except those required for keeping the store clean. Cleaning equipment should not incorporate parts made of iron or steel.

Where tools are required for opening cases care should be taken to avoid frictional events which may generate sparks.

4.2.7 ***Store cleanliness***

The inside of an explosives store should be kept clean and free from dust or grit. This problem is best considered during the planning stage and the store should, if possible, be located so that it is protected from the prevailing wind across the site concerned.

When inside a store, personnel should take suitable precautions as regards footwear (e.g. rubber overshoes) to prevent contamination with grit. Under no circumstances should boots or shoes with exposed metal studs, nails or metal protectors be worn in an explosives store.

The cleanliness of the explosives store should be made the direct responsibility of the shotfirer or storekeeper (see **4.2.4**).

All sweepings from inside any explosives store should be removed from the store itself and treated as explosives for destruction (see **4.2.13**).

4.2.8 ***Repairs to stores***

Before any repairs or alterations are made to a store it is essential that all explosives are removed to another licensed store or placed under constant attendance and the police advised. Should welding, flame cutting or cold cutting be required then the wooden lining should be carefully examined for explosives contamination and the wood removed. Only after careful examination for sparks and after the cooling of any hot spots should the lining and the explosives be replaced.

4.2.9 ***Workshops for explosives***

When a considerable amount of work is envisaged on a site, a properly prepared and constructed workshop should be used for preparing charges for use on that site. There are legal requirements as to the positioning of such workshops and to the type of work which can properly be carried out within them (see section 47 of the Explosives Act 1875 [12]). It is necessary for any person keeping any explosives in a store to notify the local licensing authority of their intention to construct such a workshop. The local authority officer responsible for explosives will be in a position to give advice as to the siting which is permissible and as to the type of work which may be carried out within it.

4.2.10 ***Transport of explosives on site***

Where practicable all vehicles used for the conveyance of explosives on a working site should conform to the requirements for vehicles for the conveyance of explosives by road (see **4.2.2**). Where site conditions do not allow such vehicles to be used the following general conditions should apply to any vehicle used:

a) the vehicle should be cleaned out, and clean sheeting, for example, a tarpaulin, laid for receipt of explosives boxes;

b) the vehicle should be in a safe mechanical condition and carry an adequate fire extinguisher;

c) the vehicle should be supervised by the shotfirer;

d) no flammable liquids or gases should be carried other than in the vehicle's fuel tank;

e) detonators should be kept in a suitable container which should be kept locked when access is not required to the contents;

f) detonators should be carried, effectively separated from explosives by at least 1 m and both in accordance with **4.2.12**;

g) explosives should be protected from weather during transit;

h) it is essential that "No Smoking" restrictions are observed;

i) it is essential that charges of explosives which have already been fitted with detonators are not carried in any vehicle; and

j) it is essential that the vehicle should be clearly marked.

4.2.11 ***Transport of explosives by air***

4.2.11.1 *General*

The transport of explosives by air is regulated by The Air Navigation (Dangerous Goods) Regulations 1985 [15].

NOTE The Regulations permit only low hazard explosives, i.e. those of 1.4 or some of 1.3 division, to be transported routinely by air. Large consignments of more hazardous types are handled generally by charter flights from specified airports under individually specified conditions.

It is also necessary to comply with both The Technical Instructions for the Safe Transport of Dangerous Goods by Air [16], and the United Nations Recommendations on the Transport of Dangerous Goods [17], as per date issue. This latter is known colloquially as the "Orange Book".

It is strongly recommended that the advice of a forwarding agent or airline should be taken before attempting to transport any explosives by air.

4.2.11.2 *Methods of air transport*

In general terms, explosives may be carried as follows.

a) Passenger aircraft	Civil Aviation Authority (CAA) classification 1.4S (e.g. safety fuse, safety electric fuse, beanhole connectors)
b) Cargo aircraft	CAA classification 1.4S
	CAA classification 1.4G (e.g. igniter cord, portfires)
	CAA classification 1.4B (e.g. electric detonators in special packing)
c) Charter aircraft	All classes
	The aircraft is dedicated *solely* to transport of explosives and prior permission has to be obtained from the CAA by the airline concerned.

4.2.12 ***Portable containers***

4.2.12.1 *Explosives*

Small quantities of explosives being conveyed on site should be carried either in their original packing or in soundly constructed containers. The containers should be made of non-ferrous material such as leather, moulded rubber or plastics, wood or reinforced canvas.

Each container should be fitted with a strap attached to its main body and should be fitted with a closely fitting cover. The cover should be fitted with a non-ferrous lock.

4.2.12.2 *Detonators*

These should always be carried either in their original packing or in separate containers and separate from other explosives. Preferably they should be carried by a second person. It is recommended that, where practicable, the interior design of any container used to carry detonators be such that it is divided into compartments each allowing sufficient space for each detonator.

4.2.13 ***Disposal of unwanted explosives or explosives which have deteriorated during storage***

Extreme care should be taken when dealing with any blasting materials which have apparently deteriorated whether they be explosives or detonators. It is strongly recommended that before handling any such material or disposing of unwanted explosives, advice should be obtained from a supplier or manufacturer's literature; failing this from the local authority or finally from HM Inspectorate of Explosives (see HSE booklet *Disposal of explosives waste and the decontamination of explosives plant* [18]).

Care should be taken when disposing of packing materials such as cases, case linings wrappers, or other materials used in cleaning up waste explosives. These materials may have become impregnated with explosives. Disposal operations should not be carried out within 50 m of the magazine.

Burning on site should only be considered as a last resort and only for the disposal of very small quantities of explosives or explosives-contaminated material, because of the possibility of an explosion. The quantity burnt in any one fire should be limited to no more than the equivalent of 2.5 kg of blasting explosive. It is therefore essential that the quantities of explosives burnt on any one occasion should be related to the size of the disposal site and a procedure adopted for the safety of personnel and public as in any blasting operation.

4.3 Safety when using explosives

4.3.1 ***General***

This clause is concerned with those aspects and procedures of preparing blasts which relate to conducting such operations safely and efficiently. Since different blasting operations call for widely differing blasting methods and techniques, it is the main purpose of this clause to cover general principles applying to various stages of the blasting process.

Consideration should be given to introducing a formal "permit to blast" system.

Clauses **5** to **10** should be consulted for details of the safe handling of explosives under specific use conditions.

Whether very simple or very complicated in design terms, every blast design should be carefully considered. A simple design may only require a brief input by an explosives engineer, whereas a large complex design may require the input of several specialists.

In designing a blast, due consideration should be given to the site survey/risk assessment, the exclusion zone and the blast protection required.

The design should be set out formally on paper showing the number of shot holes, their placement and their depth and diameter. The type(s) and weights of explosives to be employed in each shot hole as well as the charge placement and stemming should be detailed. The time delays and sequences should be clearly shown.

In practice, the blast design drawings should become the blast charge schedule.

4.3.2 ***Maltreatment of explosives***

When shotfirers are handling and charging explosives at the blast site they should be conscious at all times that maltreatment of the explosives which involves shock and friction can cause accidental initiation of the charges.

Maltreatment may be from such causes as:

a) the over-vigorous use of stemming rods to force explosives into a shot hole;

b) the use of drill rods or other metal tools in a shot hole containing explosives;

c) drilling into sockets containing explosives;

d) vehicles running over explosives;

Other eventualities which have to be recognized as possible hazards are those involving impact or concussion.

NOTE 1 Major concerns in this context are, for example, vehicle collisions and runaway vehicles and the site conditions as regards, for example, traffic density, road or rail gradients and stability may well prompt the formulation of special local rules on individual sites.

e) projectiles — rock, stone or similar material projected from the blast can cause an accidental detonation of explosives. Excess explosives should be removed from the blast site to a place of safety before blasting takes place;

f) "snap, slap and shoot" — shock tube detonators may be initiated when subjected to a process known as "snap, slap and shoot". The process involves stretching the shock tube to breaking point so that it snaps and recoils producing a high velocity whiplash action. If the exposed core of the severed tubing then impacts against a hard surface during this motion, initiation may occur.

NOTE 2 "Snap, slap and shoot" incidents are very rare and only a small number have been recorded around the world. However, the consequences of such incidents can be very serious if a detonator fires.

To avoid the circumstances which may give rise to "snap, slap and shoot", shock tubing should never be subjected to excess pulling or sudden jerking. If explosives charging vehicles operate in a blast area it is essential that all excess tubing be coiled compactly to prevent tangling in any moving parts, for example wheels and other rotating parts, and extreme care be taken when driving between shot holes to avoid the coils. At no time should vehicles be driven directly over shock tube as damage can occur, giving rise to misfires.

4.4 Types of explosives

4.4.1 *General*

There are many types of explosives which have been classified and authorized prior to being supplied to the UK market. The properties of these explosives vary and many have been developed for specific applications, therefore care should be taken in selecting the most suitable explosive for the particular work activity. Annex E should be consulted for information on the general properties of explosives.

Due regard should be given to the shelf life of explosives and accessories. This may vary according to the conditions of storage. Manufacturer's data sheets should be consulted and the advice in **4.2.4** followed.

In certain conditions of extremes of temperature some types of explosives are unsuitable and can be dangerous, therefore manufacturers should be consulted, especially where work is proposed in prefrozen ground or in hot furnaces.

4.4.2 *Nitro-glycerine based explosives*

Nitro-glycerine (NG) can be obtained in powder and gelatine form for use in small diameter and more commonly in gelatine form for large diameter applications. The water resistance of gelatines is good, powders, however, have little or none.

No NG composition should be used if it shows signs of exudation, that is, a separation of the oily liquid NG from the cartridge.

CAUTION This should not be confused with surface moisture of salt solutions which can be present especially in humid conditions. NG has an oily appearance and remains as separate drops in water, the salt solutions dissolve immediately. If exudation is observed the explosive is very sensitive, has failed to an irreversibly dangerous condition and expert advice should be sought from the manufacturer. Respiratory and cutaneous contact with NG/nitro-glycol explosives may cause very unpleasant headaches but not everyone is affected by these. In some extreme cases, however, the headaches are so severe that work has to be suspended for those who have been affected.

NG based explosives are less prone to pressure desensitization and may be used where delayed action techniques are being employed in complex, closely spaced drill patterns.

4.4.3 *TNT based explosives*

A variety of both pressed and cast charges can be obtained based on TNT, the most common being:

a) cast mixtures of pentaerythritol tetranitrate (PETN) with TNT which have high detonation rates and can perform as good primers;

b) mixtures containing TNT and cyclotrimethylene trinitramine (RDX), sometimes with wax added.

4.4.4 *Plastic explosives*

Some commercially available explosives based on RDX and PETN which were developed for military demolition can be obtained for metal cutting. Care should be taken to ensure that priming is carried out according to the manufacturer's instructions.

4.4.5 *Slurry explosives*

Slurry explosives may have one or more of a large range of sensitizers which can be either explosive or non-explosive, the most common ones being methylamine nitrate, "paint grade" aluminium powder, TNT and smokeless powder.

Performance in field applications is dependent on formulation. The means of initiation is variable, some slurries are detonator or cord sensitive, others require boosters. Further, some slurries may be affected by shock, gas or hydrostatic pressure effects and technical advice should be sought from the manufacturer. Slurries contain water as part of the formulation and can be considered safer than other high explosives. Dried slurry residues, especially those with insoluble sensitizers, can burn to detonation and in practice when handling, storing, using or disposing by burning, slurries should be considered to be as dangerous as other high explosives.

4.4.6 *Emulsion explosives*

Emulsion explosives contain similar ingredients to slurries but their structure is quite different and this is reflected in their properties and performance. Generally, emulsions have a higher velocity of detonation than slurry explosives and better after-detonation fume characteristics than other explosives. However, when gas sensitized, emulsion explosives can suffer from the same pressure effects as slurry explosives.

4.4.7 ***ANFO mixes***

Ammonium nitrate is the cheapest chemical source of oxygen used in formulating explosives. It is used with solid fuels and sensitizing agents in a variety of products. The cheapest explosive available is a mixture of ammonium nitrate and fuel oil blended together on site and then loaded in bulk into the shot hole. A site mix ANFO licence is required to carry out this operation legally. Alternatively, factory made ANFO is available both in bulk and in packaged form. The sensitivity of ANFO is best achieved by creating an intimate mix and to this end a blasting grade porous ammonium nitrate prill with high specific surface area should be used. In order to reach the correct oxygen balance a mixture containing about 5.5 % by weight fuel oil is required. If ANFO is underoiled excess oxides of nitrogen are produced (brown fumes) whereas overoiling produces excess carbon monoxide in post-detonation fume. In both cases performance is adversely affected and in the former case the sensitivity is increased. Not only should the correct amount of fuel oil be added to ammonium nitrate but they should be thoroughly mixed together so that the fuel oil is uniformly distributed throughout the ammonium nitrate. Manufacturers of ANFO sometimes add aluminium to their compositions which has the effect of raising the temperature of the reaction and increasing available energy.

NOTE ANFO has minimal water resistance, it has a reasonable weight strength but because of its low density its bulk strength is very low.

4.4.8 ***Bulk emulsion ANFO blends***

When emulsion is added to and mixed with ANFO the emulsion adheres to the prills, coats them and starts to fill the voids between the prills. As further emulsion is added, the water resistance and bulk density increase. If it is required to load the product into wet shot holes, a mixture containing more emulsion should be used. It may then be pumped into the bottom of the shot holes where it displaces the water. Benefits include high shot hole loading and efficient coupling with the rock.

The combination of emulsion explosive and ANFO increases its bulk strength and waterproofs the ANFO. It is very important that adequate priming be used with these compositions.

4.4.9 ***Permitted explosives and detonators***

A range of products specially formulated and designed for use in gassy or flammable environments is known as permitted explosives (see **3.33**). For applications where explosive gases may be present, permitted explosives should be used. Permitted NG explosives, slurries and emulsions are available. A permitted initiation system should also be used.

4.4.10 ***Detonating cord***

Although this product was developed as an accessory for initiating charges it is available with a variety of core loadings. High energy detonating cords (above 12 g/m) may be used for smooth blasting in tunnels, for pre-splitting in surface excavations and for the demolition of concrete structures.

4.5 Initiation systems

In order to release the energy available in an explosive charge, sufficient energy should be delivered to cause it to detonate. A detonation wave passing through an explosive becomes a shock wave in whatever medium lies outside the explosive. As the intensity of a shock wave falls off very quickly with distance, it is important that any gaps between any one explosive component and another should be avoided.

Detonation usually originates in a detonator, which is a small device for converting a flash or a given signal into a detonation wave. The charge available in the detonator may be sufficient to initiate explosives, but an additional “primer” or “booster” may be required in order to initiate less sensitive compositions.

It is important that such products should be handled with care and not subjected to mechanical shock, high temperatures, and stray electrical discharges.

Non-primary explosive detonators are available which contain only secondary explosive. Shock tube detonators of this kind are less sensitive to heat, friction and shock than detonators which contain primary explosive but, nevertheless, these detonators should always be handled with respect.

The risk of cut-off with non-electric circuits should be considered and action taken to incorporate redundant circuitry (for example, parallel or twin path initiation) when planning large circuits.

It is common blasting practice in some sectors to double up on initiation systems for out of reach charges in deep shot holes. Where charges cannot be safely retrieved because, for example, ground conditions may be difficult, the possibility of using two detonators per charge should be considered if, where and when circumstances require.

4.5.1 ***Capped fuse***

Capped fuse is a length of safety fuse crimped into a plain detonator. A plain detonator is an aluminium tube open at one end and with a small charge of a mixture such as lead azide/lead styphnate pressed on top of a slightly larger base charge such as tetryl, RDX or PETN. Safety fuse means fuse consisting of gunpowder or any other substance which burns at a regular rate, enclosed in a suitable covering and of such a quality that the rate of burning does not vary more than 10 s above or below the rate of 100 s/m.

4.5.2 ***Electric detonators***

An electric detonator is essentially a fusehead crimped into a non-electric (plain) detonator, the fusehead being connected to two electric leading wires. A fusehead is formed by depositing a pyrotechnic mixture over a bridge wire. When a voltage is applied to the leading wires and an adequate current flows, the bridge wire heats up and initiates the fusehead which in turn causes the detonator to fire. Some detonators are instantaneous, other detonators have delay elements incorporated into them between the fusehead and the explosive charge and different delay ranges are available. Short delay detonators are supplied in ranges which typically have increments of 25 ms between adjacent delay numbers. These have been developed for use in surface blasting. They have many other applications. Long period delay detonators typically have delays of 500 ms between adjacent delay numbers. These have been developed for use in underground operations. Detonators with different electrical characteristics can be used to suit different circumstances. High firing current detonators give added protection against induced currents. Where gassy conditions are likely only low incendive detonators should be used.

4.5.3 ***Electronic detonators***

Where precise timing is required to reduce ground vibration and air overpressure, or to optimize fragmentation, programmable electronic delay detonators, which offer the most accurate delays, are available.

4.5.4 ***Inductively coupled firing circuits***

Another form of electrical initiation is based on an alternating current in a high frequency range passing through a single wire loop. The wire is passed through one or more ferrite toroidal transformers each encased with plastic. Each has its own secondary wiring connected to its detonator, which may be instantaneous or delay. This variety of initiation system has improved safety features and may be used where added protection against extraneous sources of electricity is required.

4.5.5 ***Shock tube initiation***

A shock tube detonator comprises a length of shock tube (see **3.43**) crimped into a plain detonator, and usually contains a delay element located between the end of the shock tube and the explosive charge. Non-electric initiation systems of this variety can be used where extraneous sources of electricity pose a hazard.

NOTE 1 Ranges of short delay and long period delay detonators are available.

NOTE 2 A widely used version of this system in the UK employs a long period delay detonator downhole with short delay period surface connectors for short delay surface blasting.

Multiple shots may be fired with non-electric systems, connectors being used to introduce a delay at each junction. The system is extremely versatile, as a large number of shots can be fired together and there is the advantage of variable delay intervals.

NOTE 3 Although electrical continuity checking cannot be carried out, non-electric systems are robust, highly visible, and the connectors are large and protected by plastic. A visual check should always be carried out on the completed circuit.

4.5.6 ***Exploding bridgewire detonators***

In applications where simultaneity is important "exploding wire" detonators should be used. In this technique a condenser is discharged through a short wire in a low inductance circuit causing it to vaporize and explode. The exploding wire detonator is designed to initiate fine PETN which is not a primary explosive.

Caution is necessary with this system; attention should be paid to ensuring good insulation because of the high voltages and the large amounts of electrical energy inherent in such systems. Exploding bridgewire detonators are free from radio frequency (RF) or stray current hazards because of the large firing impulse required. These detonators should be used where high security and simultaneity are paramount. It is essential that the exploder selected for firing should be designed for the purpose.

4.5.7 ***Detonating cords***

Detonating cord consists of a core of high explosive, often PETN (although other high explosives can be used) enclosed in a spun textile covering and an extruded waterproof case. Several strengths or explosive loadings are available. Many charges may be connected up for initiation when using detonating cord, by the formation of branch and trunk lines. Care should be taken to ensure that cords are connected properly. Further, where necessary or appropriate, cord ends should be protected against ingress of moisture. Detonating cord can be used to fire multiple charges but care should be taken to prevent unwanted cross-initiation which causes premature firing of some charges and "cut-off" in which the cord is severed before the arrival of the detonation wave. The latter results in charges being isolated from the initiation sequence and not being fired. Standard detonating cord (10 g/m, 12 g/m) may be used as a general purpose initiator and low energy detonating cord (2.5 g/m, 5 g/m) can be used to initiate large rounds of shock tubes. Detonating cords, when used to fire large rounds of shots, are simple to install and are robust. The connections are highly visible and checks on the circuitry are relatively simple. Because detonating cord on the surface is extremely noisy and produces air blast surface connections should be covered whenever possible. The air blast effect of surface cord should be considered even in underground excavations.

4.5.8 ***Arrangements for multiple firing***

Blasts may be fired as a round of several charges. The importance of their being fired simultaneously or alternatively in a precise sequence with controlled delays between charges in the round should be considered. It is essential that detonators are selected giving the accuracy in timing required and the system should incorporate the principle of advanced initiation. When firing a round of shots by delayed action shotfiring techniques, the charges and initiators should, where possible, be arranged in such a fashion that the firing impulse is transmitted to each of the initiators before any detonation occurs. A detonation which occurs before all the initiators are activated may cause disruption of the initiation circuitry before it had become redundant and result in misfires.

NOTE Some systems do not have any provision for advanced initiation, for example, detonating cord and detonating relays. Others may have the principle incorporated to some degree, for example, multi-channel electric detonator systems and, to a greater degree, the detonator shock tube system. Some systems provide total advanced initiation, for example, delayed action electric detonators when fired in single circuits. It is essential that, whichever system is employed, sufficient advanced initiation is provided to minimize the possibility of misfires caused by cut-off.

4.5.9 ***Electric detonator circuits***

Electric detonators in a single round are normally connected in series, but parallel and series in parallel circuits may be required:

a) where there is an increased likelihood of misfires due to current leakage if large numbers of detonators are simply connected in series;

b) to fire a number of rounds at one instant using a single energy source.

Care should be taken to ensure that the voltage drop across a single detonator does not exceed 50 V when firing from the mains. To achieve this in parallel circuits a shunt is often required to be positioned in parallel with the detonators.

NOTE Electrical initiation systems can be pre-checked for continuity whereas non-electrical systems cannot.

4.5.10 ***Multi-channel exploders***

These may be used to enable more charges to be fired successively than there are detonator delays available. Consideration should be given to the minimum delay interval between charges if compounding of the vibration levels from different charges is to be avoided. Ideally all channels should be activated before any detonator fires. In this way misfires due to cut-offs will be positively avoided. If this is not possible the distance between the detonating point of the blast and surface connections in uninitiated channels should be as large as possible.

4.6 Misfires

4.6.1 ***General***

A misfire is an occurrence where either:

a) testing before firing a shot reveals broken continuity which cannot be rectified (type A misfire); or

b) any shot or part of a shot fails to explode when an attempt is made to fire it (type B misfire).

For either type of misfire specific procedures should be followed to safely resolve the situation. Figure 1 provides a pictorial representation of the procedures which are described in detail below.

In the event of a misfire being identified the shotfirer in charge of the shot should disconnect from the shotfiring apparatus the removable handle or key together with the shotfiring cable, short or ground the bared wires together and consult the site manager who should ensure, so far as is reasonably practicable, that:

a) apart from himself, no person other than the shotfirer, trainee shotfirer or any other person authorized by him enters the exclusion zone:

— where the shot was fired by means of safety fuse, until a period of 30 min has elapsed since the misfire; or

— where the shot has been fired by other means, until a period of 5 min has elapsed since the misfire and any electrical shotfiring apparatus has been disconnected from the shot;

b) appropriate steps are taken to determine the cause of and to deal with the misfire;

c) a suitable record is kept of the misfire (which is a statutory requirement); and

d) appropriate steps are taken to prevent theft of the explosives and detonators or their initiation by an unauthorized person

NOTE A suitable record includes a written report to site management, a special book provided for the purpose, or the blasting/charging pattern endorsed with details of any misfire.

All misfires should be reported to the Health and Safety Executive on form 2508 as required by RIDDOR [5].

It is essential that the shotfirer, having informed site management of the occurrence, erects danger notices giving warning of the location of the misfire, and such barriers as are necessary to prevent any person approaching the location.

Until such time as the misfire has been remedied, no drilling or any other site work should be carried out in the vicinity of the misfire, unless this is directly involved in the treatment of the misfire.

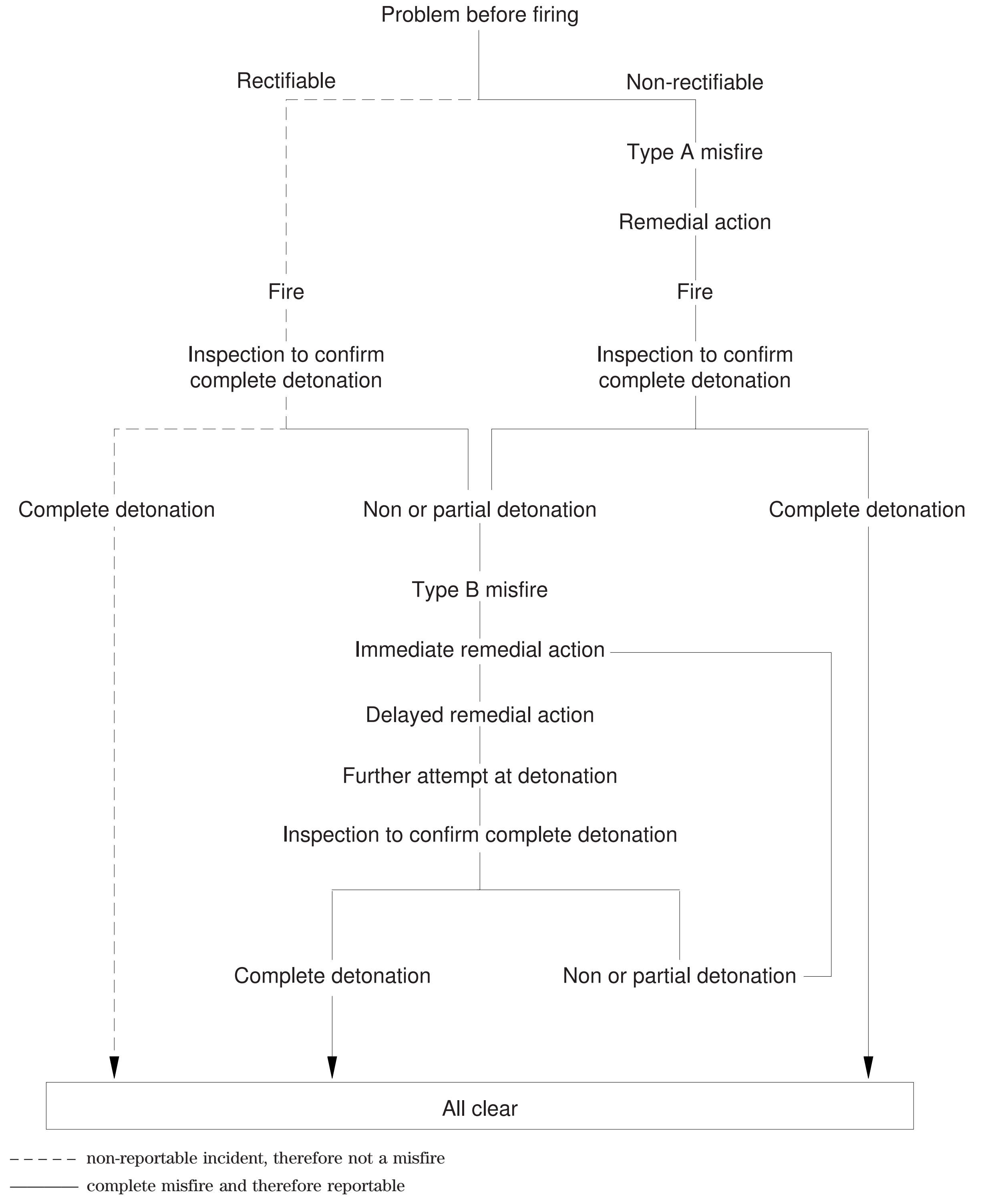


Figure 1 — Procedure to remedy misfires

4.6.2 ***Dealing with problems before firing***

In the event that broken continuity which cannot be repaired is revealed by circuit testing, the shotfiring cable should be disconnected from the blasting ohmmeter and the exposed ends of the conductors shorted together. A visual examination should then be made of the complete circuit to try and identify any obvious defect such as a broken wire or connection. If this fails to reveal the fault the shotfiring cable should be disconnected from the detonator part of the circuit and re-tested for continuity. If the shotfiring cable is found to be satisfactory the fault is probably due to a broken wire within a shot hole or an incomplete circuit within the detonator. To identify the fault the detonator circuit should be split into two halves at the face and each connected in turn to the shotfiring cable. By testing the continuity of each half of the detonator circuit it will be possible to identify in which half the fault lies. The faulty half of the circuit should then be halved again, the tests repeated and the faulty quarter of the circuit identified. This procedure is repeated until the individual shot hole containing the fault is found. All circuit testing should be carried out from the firing point with all personnel in a place of safety; testing at the face should not be undertaken even if the blasting ohmmeter is specially designed for this purpose.

In deep, large diameter shot holes where two detonators are used to prime each charge the faulty detonator can be isolated from the circuit and the blast fired using normal shotfiring procedures, the faulty unit being consumed in the blast.

When detonators are attached to downlines of detonating cord at the surface and a faulty detonator is traced it should be replaced with another and the blast fired using normal shotfiring procedures after the circuit has been tested again.

If a visual inspection of the shot firing circuit reveals a faulty shock tube connector it should be replaced before the round is fired.

4.6.3 ***Dealing with misfires before firing***

Where a single detonator is used to prime each charge in a blast the faulty unit should again be isolated. A number of options exist to deal with such a situation. The most appropriate will depend upon the particular set of circumstances encountered. The options which may be considered include:

a) firing all the detonators up to the delay number of the misfire in a single round. If the misfire is not dislodged the rest of the round should be fired singly or in groups if it is safe to do so. Often the face adjacent to the misfire is disturbed and the burden may be reduced;

b) firing the whole round at once;

c) removing the stemming with water where it is capable of being removed in this manner, inserting a second primer cartridge in direct contact with the existing charge and firing the round in the normal manner.

If options a) or b) above fail to dislodge the misfire a relieving shot hole may be drilled parallel to the hole containing the unexploded charge (see **4.6.4**). This should then be charged and fired using normal shotfiring procedures.

Any debris containing a misfired charge should be carefully examined for explosive and detonators. If a round or part of a round is fired containing a misfire it may help to locate the detonator and primer cartridge in the debris if the leading wires of the detonator are attached to a distinctive marker.

4.6.4 ***Dealing with misfires after firing***

4.6.4.1 *Initial actions*

In the event of a misfire no-one should be allowed to approach a misfired shot until a period of at least 5 min has elapsed, or at least 30 min in the case of shots fired by safety fuse.

It is essential that the shotfirer informs the site management of the occurrence and erects danger notices giving warning of the location of the misfire, and such barriers as are necessary to prevent any person approaching the location.

At this point any exposed explosives should be collected before further action is taken. Following collection, the "all clear" may be sounded.

Until such time as the misfire has been remedied, no drilling or any other site work should be carried out in the vicinity of the misfire, unless this is directly involved in the treatment of the misfire.

The procedure for dealing with misfires is that the shotfirer should:

a) disconnect from the shotfiring apparatus any removable handle or key and the shotfiring cable, and shunt or ground the bare wires together;

b) after waiting 5 min, examine the cable and connections for any defects, and remedy any defect so found;

c) make a further attempt to fire the shot.

Different blasting practices and procedures will be adopted according to the nature of the work in progress. The method of dealing with misfires depends on the blasting technique in use, but in all cases the procedures to be adopted should be established before blasting operations take place. These procedures should be specified in the form of written working instructions to the shotfirer and other personnel who may be involved.

4.6.4.2 *Written instructions*

The written instructions may be based on the following.

After notifying the site management the first factor to consider is whether it is safe to attempt to re-fire the misfired shot. This would be done by re-priming the shot, either by attaching a new detonator to any remaining line of detonating fuse leading to the charge, or by trying to expose the charge so that another primer can be inserted.

It should be borne in mind when making this decision that the rock surrounding the misfired charge will have been loosened by the explosion of adjacent shot holes and much of the rock burden will probably have been swept away. This is likely to be the situation where the primary purpose was to fragment and displace the rock in preparation for excavation. The distance over which rock might be projected in re-firing a misfired shot hole in this condition will be much greater than would have been anticipated from the original blast. An increase in the distance of rock projection by a factor of ten would not in fact be abnormal. Remedial action of this kind can therefore only be considered where private properties, site installations, public roadways, etc. are outside the likely range of projection, or where the risk of damage can be accepted. In any such eventuality, the safety of the general public and of the site personnel should be the prime consideration, and it will often be necessary to inform the police or other local authority about the action to be taken.

4.6.4.3 *Attempts to re-fire*

Attempting to re-fire may however be precluded by inability to regain access to the charge. In most cases this would require the safe removal of the stemming to allow re-priming. It should be noted however that where a misfired shot hole contains a detonator, removal of the stemming should not normally be attempted, as this might subject the detonator to maltreatment and set off the charge.

In circumstances where the misfired shot hole cannot be re-primed, or where it would be dangerous to attempt to re-fire it, the next approach is to drill and fire relieving holes placed so as to work away the rock surrounding the stemming and charge of the misfired shot holes (see **4.6.5**).

In surface blasting operations the procedure will vary according to the circumstances. Where the normal primary blasting technique involves the use of relatively shallow (up to about 4.5 m) small diameter shot holes, the firing of lightly charged 55 g to 115 g relieving holes of 1 m to 1.2 m depth, and drilled not nearer than 0.3 m away from the misfired shot hole, will eventually remove sufficient rock to expose the charge. At this stage, a decision can be taken on whether to insert a new primer and attempt to fire the charge, or to continue with the relieving holes procedure with a view to recovering the misfired cartridges from the rock pile as the work proceeds.

In deep faces, and with large diameter shot holes, this procedure obviously has its limitations, but again it may be possible, through the successive firing of relieving holes, to gain access to the misfire so that it can be re-primed. The heavy charge concentration in a large diameter shot hole will obviously mean widespread rock projection can be expected in these circumstances, especially as the charge will not be effectively stemmed. It may be possible to contain or reduce this by removing part of the misfired charge by hand, if the cartridges are relatively loose in the shot hole. Removal of explosives from a misfired shot hole in this manner should only be undertaken as a last resort. It is clearly the case that in such situations, a choice is involved between a number of options, none of which appears attractive. The possible consequences of each course of action should be carefully considered as part of the contingency plan for misfires before deciding upon the most appropriate action in the circumstances prevailing.

The only situations in which the above-mentioned procedure may be relaxed are in demolition or tunnelling operations where shot holes are normally concentrated in a tight and closely spaced pattern.

Conditions may be hazardous for drilling relieving holes because of the danger of drilling into a charged shot hole, or because of the risk of disturbing loose rock at the tunnel face. The use of compressed air should be avoided in shot holes containing detonators since the release of compressed air down a tube, accompanied by the motion of particles of grit or similar substances, can generate charges of static electricity which are capable of initiating either electric or plain detonators. This hazard does not exist, however, when using water to clear the stemming from a shot hole.

Where the misfired shot hole does not contain a detonator, the stemming may be removed by means of compressed air or water under pressure. The air or water should be fed only through a tube made of plastics or rubber. Metal tubes should not be used for this purpose. Removal of the stemming by these means is only likely to be effective, however, if the stemming material is sand or grit. If it consists of compacted material such as clay, it is virtually impossible to remove by compressed air or water, and other remedial action becomes necessary.

During the process of removing the stemming from a misfired shot hole, care should be exercised as the compressed air or water pipe approaches close to the charge, so that rough treatment of the explosives is avoided. After the stemming has been cleared from the shot hole, another primer can be inserted and the shot hole fired in the usual manner. ANFO charges are liable to be desensitized by water, so that re-priming in this manner is unlikely to be satisfactory.

4.6.5 *Drilling relieving holes*

When stemming or explosives cannot be safely removed from a misfired shot hole then drilling a relieving hole may be considered. The object of the relieving hole is to break the rock close to the charged hole in order that the undetonated explosives and perhaps primers and detonators may be recovered.

As shot hole diameters and depths may vary considerably attention should be given to a number of factors before commencing to drill a relieving hole. Such factors will involve addressing the following questions as part of a revised risk assessment.

a) How accurately can the direction of the misfired shot hole be determined? The objective is to drill the relieving hole parallel to the misfired shot hole.

b) How accurately can the relieving hole be drilled? This will to some extent determine the stand-off distance of the relieving hole.
Whilst 300 mm may be sufficient stand-off distance in a tunnel round where, for example, 38 mm holes are drilled to a depth of 2 m, it would be very unwise to use such a stand-off distance on 15 m holes drilled at a diameter of 100 mm.

c) Can the relieving hole be safely fired? The shotfirer should consider whether the relieving hole will have sufficient burden so that it does not create a danger when fired. The possibility that sympathetic detonation may occur when firing a shot hole very close to another one should also be considered.

CAUTION The drilling of a shot hole into any charge or socket remaining from a previous shot may result in loss of life and should be prohibited.

NOTE 1 The underlying tenet to the above is that very careful planning and execution are required to ensure that the misfire can be safely recovered.

4.7 Method statement

4.7.1 *Preparation*

The following points should be considered in preparing the method statement:

a) scope of the operation;

b) risk assessment factors which influence the proposed method of work;

c) names, qualifications, experience and training of key personnel, including engineers, shotfirers, explosives storemen, persons authorized to handle explosives and siren operators;

d) an organization chart showing the relationship between the key personnel;

e) plant to be employed;

f) determination of services, buildings and structures which may be at risk from blasting operations;

g) factors to be considered in the determination of the potential exclusion zone and arrangements to ensure the protection of site personnel and the public, and the placing of sentries for each blast;

h) system of audible and visible signals agreed with site management and methods of communication to all site personnel giving clear warning of impending blast, actual blast event and all clear;

i) the arrangements to be made for the acquisition, storage (if required), transportation and if necessary, disposal of explosives to comply with current legislation and regulations;

j) the arrangements and timing of suitable trial blasts to confirm the way in which the target will respond to the blasting regime being considered;

k) provision to be made for the preparation of a blast plan for each blast to be carried out, made up of a charging plan and (where applicable) a drilling pattern;

l) that a number of typical blast plans may be required to indicate to what extent different situations will affect the blast design and execution;

m) type and position of any containment measures to prevent fly;

n) the positioning and recording of environmental impact measurements, for example, ground vibration and air overpressure;

o) the method of recording the above information and the list of records needed for legal and management purposes;

p) where applicable, a programme of blasting operations;

q) procedures in the event of and procedures to rectify misfires;

r) contingency planning in the event of an emergency or an unforeseen occurrence arising during the operation, including the names and telephone numbers of the emergency services or others that may have to be contacted.

4.7.2 *Application*

The shotfirer should have possession of all the documents making up the method statement and in particular should be in possession of and understand any drilling pattern and charging plan.

Before charging commences the shotfirer should check that any shot holes drilled conform to the plan. Where they do not conform, they should be re-drilled, or permission to amend the plan should be obtained unless the method statement empowers the shotfirer to make variations to the plan. Changes by the explosives engineer to the method statement should be completed at this stage before any explosives are delivered to the blast site.

The shotfirer should ensure that each shot hole is charged in accordance with the method statement, and that detonators, explosives and stemming are positioned in their correct location in the shot hole.

Where the shotfirer is unable to comply with the method statement or when the exclusion zone appears to be different from that shown in the method statement, operations should be suspended until the method statement has been suitably modified by the explosives engineer, unless the shotfirer has been empowered to make variations of such nature and extent as have been authorized by the explosives engineer in the method statement.

Any variations in the method statement made during charging should be recorded in detail.

It is assumed that on each occasion when a blast is planned at a construction site all other procedures and practices as outlined in this code will have been given due consideration up to the stage of the explosives being available at the blast site and ready for charging.

Detonators should not normally be inserted into explosives until the charges are about to be finally placed.

Where it is not possible to achieve the safest conditions at the charging place, carefully considered additional planning will be necessary for the construction of a suitable priming station and for the transport of primed explosives to the blast site. The planning should extend to include the adjacent operations and equipment that might affect the safety of the priming and transport of the primed explosives.

5 Tunnelling and shaft sinking

5.1 General

The tunnelling operations referred to in this code of practice include all works where drilling and blasting are used for the excavation of underground spaces and the means of access thereto.

Recommendations for the use of explosives in tunnelling should be applied with equal emphasis to shaft sinking, and all the practices and precautions to secure safe working should be followed and observed with equal attention. Additional comments are included where necessary to highlight particular hazards arising in shaft sinking.

BS 6164 should be consulted for detailed guidance on safety in tunnelling.

Excluded from these recommendations are underground works carried out for the purpose of exploiting mineral reserves and extensions to voids left following ore extraction. Such works are governed by legislation.

5.2 Special considerations

5.2.1 *General*

The tunnel face is normally advanced by means of a repeating cycle of operations. The basic sequence is drilling, blasting and loading out the rock. In addition, time should be allowed within the cycle of operations for essential activities and functions, e.g. fume clearance after blasting, extension of rail track, compressed air and water pipes, ventilation ducts, lighting cables. In weak ground, it may also be necessary to erect roof supports after each blasting operation. BS 6164 should be consulted for guidance on gases in tunnels and on ventilation.

Excavation underground is frequently carried out in confined and wet conditions with the use of only artificial light. Because of the repetitive nature of the work, the application of explosives in tunnelling usually settles into a fixed routine. It is particularly important, therefore, that unsafe or undesirable practices should not be allowed to creep in through increasing familiarity with the day to day handling of explosives in the cyclic operations, which may continue over periods of several months or more.

5.2.2 *Method statement* (see **4.7**)

Rock is usually heterogeneous and a method statement for one location in a shaft or tunnel will not be relevant to the full length to be excavated. Basic method statements should be produced for each anticipated rock type prior to the commencement of blasting.

5.2.3 *Survey*

An assessment of the geological structure, particularly bedding, jointing and faulting, in the vicinity of a shaft and along the route of a tunnel should be carried out to determine the possible effects of blast-induced vibrations on underground and surface structures.

Notification of the work to be carried out should be given to all owners and occupiers of properties along the tunnel route as tunnelling operations could commence some distance away and they might be unaware that a tunnel will pass beneath their property. All buildings along and adjacent to the tunnel route should be surveyed and appropriate blast-induced vibration limits should be determined for each one.

The nature of the work carried out in all properties beneath which a tunnel will pass should be determined. If these contain, for example, sensitive computer installations, such as those in banks and main police stations, existing ambient vibration levels should be determined. Special restrictions on blast-induced vibrations may have to be specified in such locations.

5.2.4 ***Containment measures***

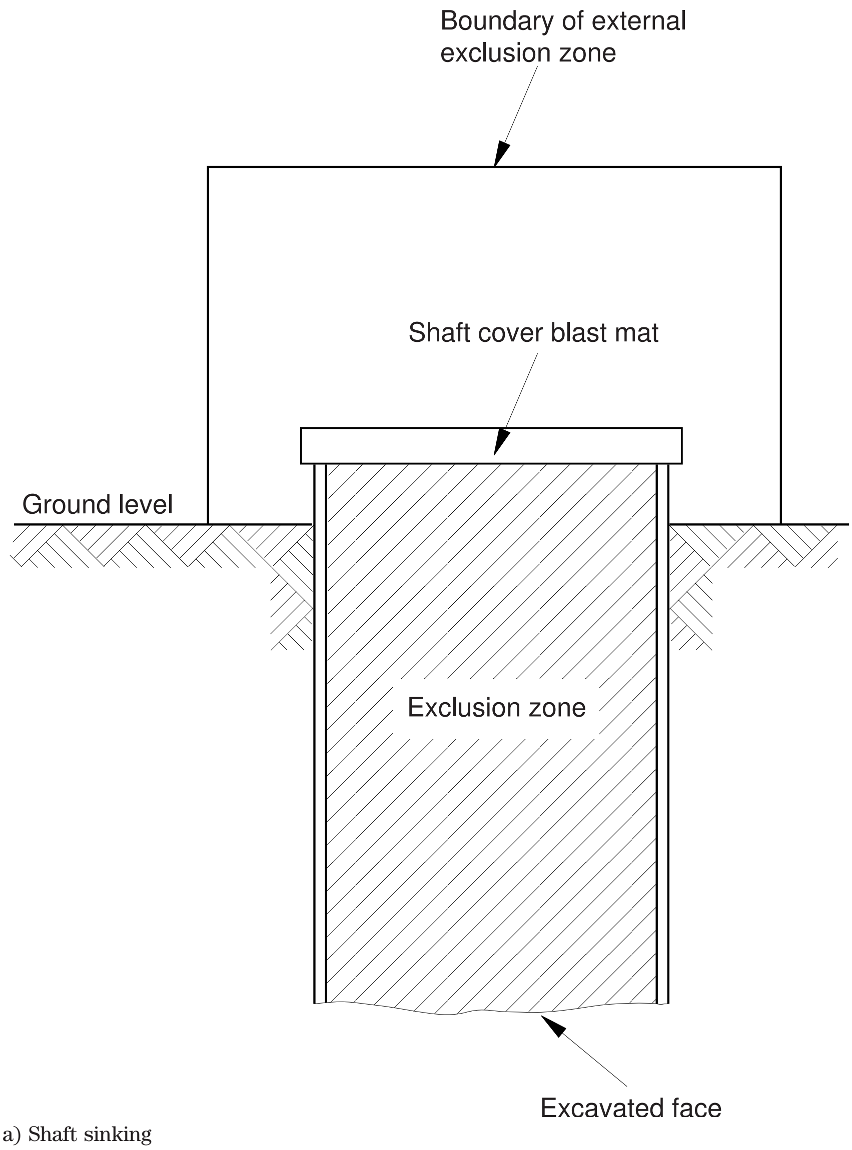
In shaft sinking, containment measures will normally be required as fly rock cannot be tolerated during blasting operations, particularly in urban areas. When initiating the sinking of shafts, the land excavation exclusion zone should be used [see Figure 4 in conjunction with Figure 2a)]. In addition, a shaft cover/blast mat should be placed over the top of the shaft prior to the initiation of explosives.

NOTE The drop zone for the fly rock will be inside the shaft.

Once the shaft is established, the exclusion zones recommended in Figures 2b) and 2c) should be used. In both Figures 2a) and 2b), the distance that the exclusion zone extends from the excavated face should be determined in consultation with the site safety officer.

In tunnel breakouts at shaft bottoms where fixed plant may be installed, containment measures may be necessary. Such measures normally comprise blast mats and blast doors and frequently are designed to provide noise attenuation as well as prevent damage to adjacent structures from fly rock. It is necessary for blast mats to be secured against lifting when the charge is fired.

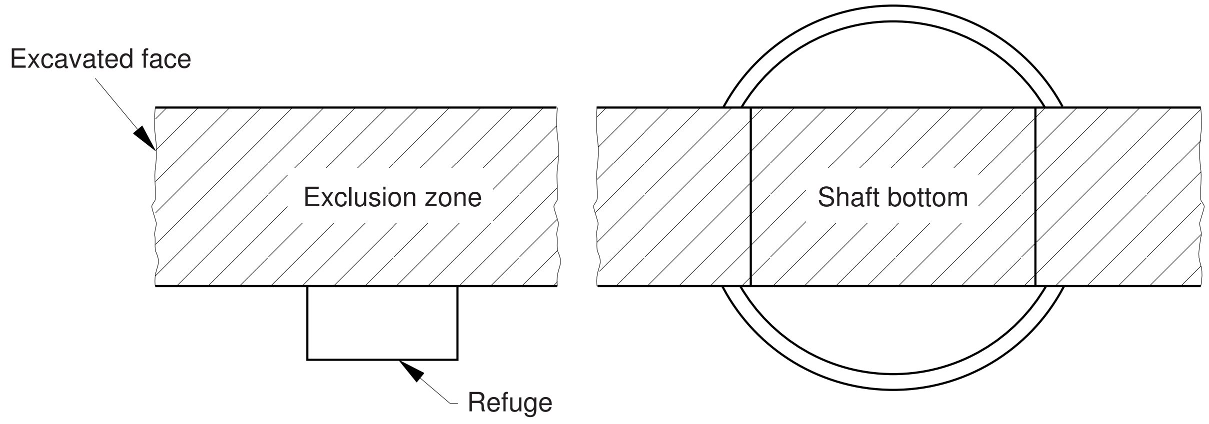
Blast mats and doors may be constructed from steel reinforcement fabric mesh, heavy duty netting, conveyor belting or combinations of these materials. Where noise attenuation is required blast mats and/or doors may be filled with sand or similar non-combustible material. Where blast mats are loaded with sand or similar soil material, these should be structurally robust enough to withstand the additional loading.



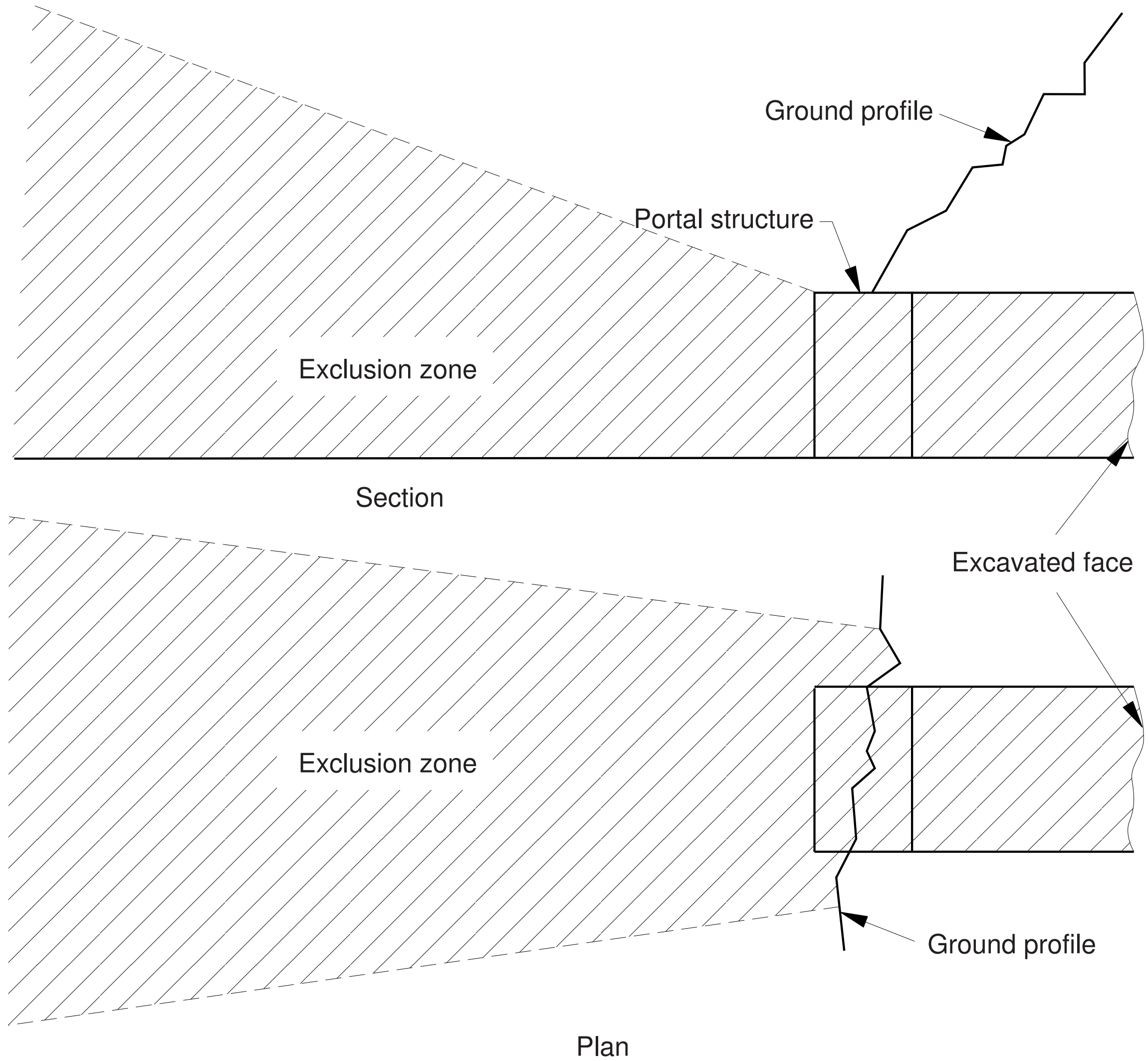
a) Shaft sinking

NOTE All figures are diagrammatic and not to scale.

Figure 2 — Exclusion zones for shaft sinking and tunnelling



b) Tunnelling from a shaft



c) Tunnelling from a portal

NOTE All figures are diagrammatic and not to scale.

Figure 2 — Exclusion zones for shaft sinking and tunnelling *(continued)*

5.3 Explosives

5.3.1 *Explosive types*

It may be necessary to use waterproof explosives in shafts and tunnels as conditions can be very wet.

As the working area is usually very confined and emphasis is placed on advancing the face as rapidly as possible, the type(s) of explosive to be used should be selected on the basis of good fume characteristics and with due regard to the effectiveness of the method(s) of ventilation.

Only permitted explosives (see **4.4.9**) should be used in tunnels where there is a possibility of encountering flammable gases. This is most likely to occur in sedimentary strata but could also arise, for example, as a consequence of spillage of hydrocarbons in surface installations above the tunnel route.

5.3.2 *Transport*

On construction sites where tunnelling operations are conducted, the general recommendations for storage and transport of explosives as laid down in **4.1.3.14** and **4.2** are applicable and should be read in conjunction with the following additional recommendations which relate specifically to tunnelling operations.

Normal systems of transportation in tunnel driving are by locomotive and mine cars or rubber tyred vehicles. Explosives and accessories should be transported to the tunnel face in separate, lockable containers. The security and supervision of the explosives underground should be detailed in the method statement.

With all systems of tunnel transportation precautions should be taken to prevent explosives spilling on to the tunnel floor.

It is essential that explosives or accessories are not placed on the driving locomotive itself. There is not only the danger that the packages of explosives and accessories or their contents may fall on to the track and be detonated by mine cars in the train or later journeys of the locomotive, but also because, particularly with detonators, there is a risk of accidental ignition by stray electric currents on the locomotive due to devices such as batteries or accumulators, electric motors, generators and lights.

From the inbye terminus of the locomotive, the explosive should normally be transported manually to the tunnel face. The conditions are often cramped and confined, which introduces difficulty in handling. Wherever possible it is good practice to keep the explosive packages in a wooden transport box so as to provide some protection to the explosives cases, particularly from water lying at the tunnel face.

5.3.3 *Storage*

Explosives remaining after charging a round should be carefully collected, packed into a portable container and conveyed out of the tunnel to a licensed store or an attended place of safety. It is essential that surplus explosives should not be left unattended in lay-bys, manholes or similar locations inside the tunnel.

Where the length of the tunnel, or some other similar factor, would render this difficult or unreasonable during a shift, the site management may permit the temporary storage of surplus blasting materials in reserve stations underground between blasting events.

Where reserve stations are permitted they should preferably be excavated in a tunnel wall and fitted with lockable steel doors to protect the contents and to prevent unauthorized access. They should be located on the opposite side of the tunnel to the electric cables, not close to any transformers or switchgear and not nearer than 300 m to the tunnel face or any other location where blasting is taking place.

A reserve station should not be used for long-term storage of explosives. Any explosives remaining in it at the end of the shift should be returned to the licensed explosive store. Longer storage periods may be permitted but the reserve station should be emptied, and the explosives returned to the licensed store, at least at weekly intervals, or when blasting operations cease for more than one shift or whenever the tunnel is unoccupied. A log of explosives deposited and removed for use or returned to surface should be maintained within the reserve station to complement the licensed explosives store log and the face charging records.

5.4 Safety and operations

5.4.1 *Drilling and blasting methods*

Explosives, detonators and delay sequences for use in tunnels and shafts should be selected with reference to the rock types to be excavated and on the basis of fume characteristics and water resistance.

Tunnelling methods using explosives involve the placement and charging of shot holes so as to form a "cut" or entry into the rock face followed by the successive firing of shot holes placed so as to break into the initial cavity formed. In sinking shafts, the technique is basically similar, and in circular shafts, for example, the drilling patterns commonly used are based on concentric rings of shot holes with the innermost ring being a grouping of shot holes forming a conical or diamond "cut". Ground vibrations can be minimized by careful design of the charge and delay pattern.

In most operations, the rate of driving is an important consideration. It is normal practice to drill a full round of shot holes in the face, so that the complete face area may be blasted in a single operation, and the full cross-section of the tunnel or shaft advanced a planned distance each time. This practice may vary according to tunnel cross-section, ground conditions and other operational constraints.

According to the scale and size of the tunnelling operation, shot holes may be drilled by hand-held drifter machines, airleg mounted machines or combinations of these with drilling gantries or "jumbos" fitted with machines flexibly mounted on drill carriages. A regular pattern of shot holes should be drilled for each round. The design of the drilling pattern, utilizing a wedge cut, burn cut, fan cut or drag cut, will be governed by the rock type, the tunnel size and shape and the planned rate of advance.

Blast initiation can be by means of electrical or non-electrical systems. Selection of the initiation system should take cognizance of the high risk of stray electrical currents in the often wet conditions in shafts and tunnels. Initiation of the blast should be via a single path if electrical or non-electrical bunch blasting methods are used. Non-electrical harness blasting provides two paths of initiation, thereby reducing the risk of misfires. The shot hole pattern and delay sequence should be designed, and drilled accurately, to avoid the possibility of sympathetic detonation or desensitization of charges in adjacent shot holes.

5.4.2 ***Precautions during drilling***

Explosives and blasting accessories should not be conveyed to the face until all drilling operations on the round to be charged have been completed. This will eliminate the hazards of heavy drilling equipment striking explosives or blasting accessories as a result of accidental mishandling and of drill rods being inserted either deliberately or inadvertently into a shot hole containing an explosive charge.

In tunnels and shafts, shot holes often do not break to their full depth and sockets are left. These may contain residual explosive which is almost certain to be detonated by the hammering effect of a drill if it enters the socket during drilling for a subsequent round. It is not good practice to leave sockets, and the blast design should be adjusted to prevent this occurring. If sockets are left they should all be identified and washed out or sealed with substantial wooden plugs as a precaution against the drill accidentally slipping into one during collaring of a new shot hole.

CAUTION Direct drilling into sockets remaining from a previous shot may result in loss of life and should be prohibited. In shafts all loose rock should be removed after each round and the floor should be kept as free of standing water as possible to ease the location of sockets.

5.4.3 ***Precautions during charging operations***

The precautions and safety procedures detailed in **4.1** and **4.3** are relevant to tunnelling and shaft sinking operations. The exclusion zone should be designed in accordance with Figure 2.

In the context of tunnelling and shaft sinking the shot holes are relatively long but of small diameter, and particular attention should be paid to the following points during charging and associated operations.

a) The shot holes should be thoroughly cleaned out before charging commences.

NOTE Cleaning out the shot holes has two purposes: to remove the sludge formed by drill cuttings and the water applied for dust suppression and to dislodge and remove any stones or chippings which may break off from the sides of the shot hole and obstruct the insertion of the charge. If such obstructions are not removed they may also fall or build up between cartridges as they are inserted into the shot hole. This creates a risk of part of the charge failing to explode.

b) Stemming rods should be made from wood, anti-static plastic or soft, non-ferrous metal and should be used to check the shot hole for depth and clearance before the primed cartridge is inserted.

c) After inserting the charge, each shot hole should be stemmed with inert material so as to give the charge maximum confinement. This helps the explosive to perform the most effective work and also helps to minimize the amount of fume or smoke produced.

d) Great care should be taken during the charging operation to avoid damaging the shock tube or the insulation of electrical detonator leading wires. If the insulation is split or abraded through, or stripped off even a very short length of the leading wires on an electric detonator, short circuits and current leakage from the blasting circuit is likely in wet conditions, and misfires will be the probable result. Kinks in the leading wire should be carefully loosened and removed before inserting the primed cartridge into the shot hole. If shock tube is abraded to such an extent that in wet conditions water penetrates the explosive core, it will misfire.

Over-vigorous use of the stemming rod should also be avoided, as this may cause damage to the shock tube or abrasion of the leading wire insulation against the sides of the shot hole, particularly if particles of sand or grit have become embedded in the stemming rod.

5.4.4 *Precautions against faults and hazards*

The electrical hazards outlined below may be encountered when standard electrical detonators are employed. Non-electrical initiation systems, transformer coupled detonators and high energy detonators may be used to protect against such hazards.

NOTE 1 Ground water often contains dissolved mineral salts, which greatly increase its electrical conductivity. Short circuiting or current leakage from the circuit to the earth is therefore more likely to occur where conditions are wet.

NOTE 2 The hazard in electrical storms is that lightning discharges may strike surface objects which connect with, for example, pipes or rails inside the tunnel. The lightning strike to earth can also give rise to powerful electrical currents circulating in the earth's crust. Premature detonation of tunnel rounds has been known to occur through such phenomena.

All shotfiring operations in tunnels should be stopped during electrical storms (thunderstorms). Where these are liable to be sudden or at frequent intervals, shotfiring (including all operations involving handling and charging explosives) should be suspended when notice is given of an approaching storm. This rule should be applied whatever blasting method is being employed.

In certain circumstances, in tunnels and shafts, dangerous accumulations of static electricity can occur, particularly when atmospheric conditions are dry, and charges can be built up sufficient to fire an electric detonator. Dangerous charges can be built up in plastic ventilation ducting by compressed air discharging along pipes and hoses, and in processes which involve the discharge of granular or powder materials such as ANFO along pipes and hoses. All such equipment should be securely earthed.

The firing cable may be a permanent installation and liable to damage by flying rock in the confinement of a tunnel or shaft. The connection between the firing cable and the charged round at the face should be made by insulated copper connecting wire so that the permanent firing cable may be kept out of the damage zone. The connecting wire used in this way should not be re-used in subsequent rounds. Occasionally, rock projection from a blast will be greater than normal. The shotfiring cable should be examined for damage when this occurs, and any damaged portion should be discarded and should not be used for any other purpose.

The suspension points for the firing cable should be wooden or non-conducting stakes secured into the side walls. Care should be taken not to suspend the shotfiring cables close to electric cables.

Before standard electric detonators and explosives are taken to the face or shaft bottom in preparation for charging, all lights and other electrical equipment, such as drill carriages and pumps, should be withdrawn a safe distance from the face.

NOTE This precaution is not required for shock tube and transformer coupled detonators.

As a general rule, electrical equipment, other than protected cap lamps, should not be allowed within 10 m of the face when preparing or charging blasts. At the same time, in order to avoid unnecessary activities in the vicinity of a charged face, all mobile equipment should be withdrawn to a distance where it is safe from damage from flying rock and barriers or protective coverings should be erected to protect permanent fixtures such as manifold pipe fittings.

5.4.5 *Firing the blast*

On the completion of charging operations, the round should be connected up in preparation for firing. A set procedure and pattern should be followed in connecting the detonators so that errors such as missing out a detonator or group of detonators from the circuit are less liable to happen. A final visual check should be carried out. This is the only check possible for non-electric initiation systems. If electric detonators are being used, the last operation at the face before connecting the detonator circuit to the shotfiring cable should be for the shotfirer to check the electrical continuity of the shotfiring cable.

Before leaving the tunnel face or shaft bottom the shotfirer should ensure that all personnel have retired to a place of shelter either outbye of the firing station or above ground. The firing station should be not less than 300 m from the face, but a shorter distance may be acceptable, for example when a cross tunnel allows personnel to be outside the direct line of the blast. Due consideration should be given to the possibility of ricochet in deciding the appropriate safe distances.

Electric detonator circuits should be checked at the firing point for continuity of resistance before any attempt is made to fire them. Rounds normally include relatively large numbers of detonators, and any irregularity in the blasting circuit can cause partial firing of the round and complete failure to achieve the desired advance.

After firing the blast, no-one should be allowed to enter the tunnel until sufficient time has elapsed for the blasting fumes to be diluted and dispersed.

WARNING These fumes contain poisonous or asphyxiating gases such as carbon monoxide and some oxides of nitrogen. Such gases are not all readily detectable by the human senses, and exposure to blasting fumes may be injurious to health and can lead to unconsciousness or death in extreme cases. Pollution levels should be monitored systematically. If a forced ventilation system is being employed (i.e. air is being blown to the face) it is likely that pockets of polluted air will form in the tunnel, and in such cases the full length of the tunnel should be monitored.

Before work recommences, the shotfirer, having removed the exploder handle and disconnected the cable from the exploder, should with the chargehand examine the shaft bottom or the tunnel face for misfires and the general face area for dangerous rock overhangs, loosened, damaged or dislodged supports and loose roof rock.

5.4.6 *Misfires*

The approach to misfires, their avoidance, recognition and treatment, outlined in **4.6**, also applies to misfires encountered in tunnelling operations. Blasting operations in tunnels are normally conducted by delay blasting rounds, each round comprising a comparatively large number of closely spaced shots, and each individually primed with a delay detonator. The close shot hole spacing, the interdependence of the shots in a round and the fact that successive rounds are drilled in the face left by the immediately previous blast, make it important that the procedure laid down for the recognition of and treatment of misfires should be appropriate to the circumstances which are particular to tunnelling if drilling into misfired shot holes is to be avoided.

When electric initiation systems are being employed, after the tunnel round has been charged and connected up, all personnel removed to a place of safety, and all other preparations for blasting completed, the shotfirer should return to the firing station and make the test for circuit continuity and resistance in preparation for firing the round.

If this testing procedure identifies a down-the-hole fault the procedure in **4.6.3** should be followed. If the stemming is capable of being readily removed with water, the shotfirer may remove it by this method, insert a second primed cartridge in direct contact with the existing charge and fire the round in the normal manner. The detonator leads from the redundant primed cartridge should be anchored with string or cord to a secure place to assist recovery of the charge in case it fails to detonate.

Where the stemming cannot be removed the shotfirer should isolate it and fire all the detonators up to the delay number of the misfire. If the misfire is not dislodged the rest of the round should be fired singly or in a group. In some circumstances it may be preferable to fire the whole round at once. In either case the detonator leads of the misfired shot should be anchored as described above.

If this procedure fails to dislodge the misfire a relieving shot hole should be drilled not closer than 300 mm at any point to any unexploded charge and the normal shotfiring procedures followed.

In the case of misfires which are encountered after firing a round, the fact that part of the round has fired is likely to leave the rock at the face in a fractured and weakened state. The shotfirer should call upon the tunnel foreman for whatever assistance is required to render conditions safe from falls of rock, so as to secure their own safety when dealing with the misfires. The shotfirer should then, after assessing the situation with regard to safe procedures, reconnect the misfires to the cable, and attempt to fire them by the normal procedure. If any misfires remain after this procedure, the shotfirer should attempt to fire them singly. Any misfire which fails to explode should be dealt with either by washing out the stemming and repriming, or its recovery attempted by the use of relieving holes.

In all cases when dealing with misfires the debris should be carefully examined for undetonated explosives and detonators.

6 Demolition

6.1 General

Explosives are used to weaken a structure sufficiently to engineer a collapse.

Explosives can be used to advantage as cutting and felling charges on steel or iron structures where other methods may be uneconomical, impracticable or dangerous.

Explosives have proven to be a very useful tool when dealing with pretensioned or post-tensioned, prestressed structures.

For high rise structures, demolition by explosives when properly executed can be considerably safer than other methods both in respect of the public and the workforce.

The use of explosives in demolition requires specific consideration of, for example, the exclusion zone and in all cases where explosives are used BS 6187 should be consulted for detailed guidance.

6.2 Special considerations

6.2.1 *General*

For demolition work the CDM Regulations [3] apply. The demolition of all types of structures needs contingency planning which should be detailed in the method statement. A non-collapse, partial collapse, partial misfire or complete misfire may require that the exclusion zone be maintained outside the predicted times, and consequently that roads and services be kept in a shutdown situation and people prevented from returning to their homes or offices.

For complex structures the person in charge should preferably be a competent engineer (see annex F) with a sound understanding of explosives, particularly when used to demolish high rise structures. This position may not necessarily be held by the principal explosives engineer on site.

Before a decision to use explosives in the demolition is made, expert structural engineering advice may need to be taken. An investigation of the nature and condition of the structure may be required and a planned sequence of demolition should be established.

On large complex jobs involving many thousands of individual charges an independent audit of the blasting proposal should be carried out.

6.2.2 ***Method statement***

For the demolition of structures, the shotfirer should consult with the explosives engineer before making amendments to the charging plan.

6.2.3 ***Site survey/risk assessment***

Demolition often has to be carried out in congested areas, and the site survey prior to the introduction of blasting operations is therefore important. In conducting this survey the following points should be given particular consideration.

a) What is adjacent to the site of work?

b) Do access points to the site need to be sealed off or guarded?

c) How were the structures due for demolition constructed?

d) Is it a complex structure, where removal of individual members may result in progressive collapse of large sections?

e) What adjoining installations, machinery etc. exist? Are they vulnerable to vibration?

f) What services exist, e.g. gas, electricity, volatiles, acids?

g) What control measures are necessary in the work area?

h) Is the general noise level sufficiently low for warning signals to be audible?

i) What other properties adjoin the site and will processes in these buildings be affected by blasting?

j) Where can explosives be stored?

k) Will there be any weakening of foundations and supports?

l) Is there likely to be any objection to blasting from neighbours to the site?

m) Are hazardous materials present? (For example, asbestos.)

n) Is there sufficient room to fell the structure safely?

o) What will be the effect of impact of the structure on the ground? Will it remain in one piece or will it burst apart?

p) Will it obstruct, for example, access for public roads and railways?

q) What other structures will have to be protected?

It should be recognized that in many cases, even though blasting would facilitate the work, explosives cannot be used. This is not only because of the risks from blasting but also because of unpredictable hazards to adjacent properties from projected debris and falling parts of the building.

The site survey should examine these possible hazards and consider whether blasting techniques are appropriate.

6.2.4 ***Exclusion zone***

On all demolition work an exclusion zone will normally be established as described in **4.1.3.7**.

In urban situations where high rise buildings are to be demolished, however, the design of the exclusion zone may require special additional considerations, for example, the nature of the building to be collapsed, the method of collapse, the position of explosive charges, the degree of blast protection to be used and the safety of the general public.

NOTE Because conditions can vary so widely in the type of structure to be blasted, the charge weights to be employed, the delay sequences to be used and the type and efficiency of blast protection which may or may not be used, it is inappropriate to give an indication of safety distances in this standard.

The buffer area should be designed to collect unpredicted primary or secondary fly.

It should be recognized that some demolition events involve a high level of public interest and under such circumstances crowd management and control will be required prior to, during and after the event.

6.2.5 ***Blast protection***

Blast protection should be considered as part of the blast design and may include one or more of the following:

a) sand, both loose and in bags or drums;

b) nets, both rope and steel;

c) wire and steel mesh;

d) corrugated steel sheets;

e) timber;

f) rubber belting;

g) straw;

h) tyres;

i) water bags;

j) any combination of the above.

NOTE 1 Materials which can absorb energy give better results than hard materials such as steel sheets and sleepers, which may in themselves become missiles.

When timber, carpets and other materials emanating from the building to be demolished are to be used for protection they should satisfy the criteria demanded by the method statement [see **4.7**, items f), g) and l)].

A recent development which may be considered is the use of water filled bags placed to absorb energy and/or dust.

Protection may be either placed directly over the blast to give protection at source, or may be of the stand-off variety, or, commonly, a combination of both.

NOTE 2 When close protection is used it is essential that it is designed to allow for the expansion of the material being broken or until the gas expansion phase of the blast is over.

When stand-off protection is used, such as blocking windows in high rise flats, it is essential that it is constructed so that it can resist not only material being projected at it but also air blast which may be several seconds in front of the main blast. If it is required during part of the collapse sequence of the building it is essential that it should be designed to stay in place.

6.2.6 *High rise structures*

The demolition of high rise structures, particularly blocks of flats and offices, is likely to take place in an urban environment, thus, the works are brought directly in touch with most of the public services and local authority bodies as well as the general public. It is often the case that the media, including radio and television, are involved and that the demolition can become a public spectacle. It is therefore essential that the method statement considers these aspects in detail.

It is likely that a committee will be set up to monitor the project and to assist in preparations for the blowdown. It is essential therefore that on such works a comprehensive management structure be set up, so that all aspects of the undertaking may be properly controlled.

It is normal in the demolition of high rise structures to seek structural engineering advice when calculating the strength of the building, the effects of pre-weakening and the effects of blasting concerning the mode of collapse. These calculations should be audited as they would have been for the erection of the building.

With regard to drilling and blasting, full proposals should be prepared in advance detailing where and how shot holes will be placed and how they will be charged, primed, coupled and delayed. All alterations to the method statement proposed should be noted and major changes should be notified immediately to the site manager.

The blasting of high rise flats or offices normally involves the placing of charges at several levels in the building. This means that large quantities of explosives may be detonated at considerable heights. Thus in a normal urban environment a considerable amount of blast protection is required and this should be adequately designed, taking account of both the effect of blasting and perhaps movement of the building prior to a particular blast area detonating.

The method statement should therefore contain adequate details of blast protection. Trial blasts should be fired early on in the preparation of a building for demolition. These blasts should be designed to test both the adequacy of the blasting method proposed and the efficiency of the blast protection. If a trial blast proves to be unsatisfactory a further trial blast or blasts should be performed before proceeding further. Trial blasting should be performed well in advance so that alterations to the method statement can be fully considered.

6.2.7 *Other structures*

6.2.7.1 *General*

Demolition of certain types of structure may best be carried out by explosive means. This may be because of some elements in the design of the structure, time constraints on the duration of the demolition or simply because it is the safest method.

Such structures include, for example:

a) precast concrete panel and framed buildings;

b) pretensioned or post-tensioned prestressed structures;

c) slung structures;

d) large span roofs;

e) stressed skin or shell structures;

f) bridges;

g) chimneys.

6.2.7.2 *Metal structures*

In any type of work involving the blasting of metal particular care should be taken to assess the exclusion zone. The degree of blast protection should be carefully determined when blasting cut sections from structural metal elements. The sections should be firmly anchored so that they do not become missiles.

WARNING Metal fragments from either explosive demolition or cutting charges can travel very long distances at extremely high velocities.

6.2.7.3 *Ground conditions*

In demolition work exclusion zones should be set to ensure that “fly” material from the demolition is not a hazard.

NOTE Most fly emanates directly from the blast or from material falling onto the ground and rolling or bouncing outwards. Several accidents have occurred when structures such as chimneys have been dropped onto wet or water logged ground. The force of the structure hitting the water surface displaces water at high velocity from under the structure and water and solids shoot out on a fairly flat trajectory. The water tends to fall away fairly quickly but the solids have been known to travel up to 800 m.

6.3 Explosives: types and accessories

6.3.1 *Transport*

Normally transport of explosives will be from a licensed store or magazine or directly from the manufacturer. The transport of explosives is covered in **4.2.2** and **4.1.3.14**.

6.3.2 *Storage*

Storage on site should not normally be required. Where it is required, the recommendations given in **4.2.4** apply.

6.3.3 *Use*

In demolition work explosives are placed either in shot holes for shattering, or as surface-mounted charges for cutting or kicking. Most frequently the explosives are of the nitro-glycerine or emulsion type but occasionally high energy detonating cord may be used as the primary explosive, usually in shot holes.

Initiation of these charges may be by electric detonators, non-electric detonators, detonating cord or a combination of these systems.

More detailed advice on the use of explosives in demolition is given in BS 6187.

6.3.4 ***Security***

The shotfirer is required to be in personal control of all the explosives at all times and to ensure that all unused explosives are accounted for. Only the amount of explosive which can be readily charged in one day should be taken into the structure. Uncharged explosives should be removed to a location where they may be legally stored until the following day.

On large demolition sites where structures such as high rise flats are to be brought down it is essential that special consideration be given to security. It may take a week or more to charge up the structure and at any time there can be thousands of shot holes ready primed. It is essential that the site of such a building or buildings is fully fenced to prevent unauthorized access to the site and that if possible the building itself should be protected.

Police and fire authorities should be made aware of the charged status of the building.

The building should be guarded 24 h per day until blowdown.

If possible the number of entrances to the building should be limited to restrict entry and make control easier.

6.4 Safety and operations

6.4.1 ***Before charging***

Small-scale demolition or work that can be completed in a single day should be carried out in accordance with the recommendations in **4.1**.

In large, complex jobs such as high rise flat demolition, a comprehensive method statement on charging procedures should be used.

The method statement should include a plan showing each floor of the building to be charged and should be detailed so that each individual panel or column can be identified. The plan for each section should show the shot hole location, the weight of charge per shot hole and the detonator delay sequence and timing to be used.

Each panel or column in the building should be marked with its own identification to prevent confusion and make control of charging much simpler.

6.4.2 ***During charging***

Charging should be carried out in a systematic manner, preferably from one end of the building to the other and from the top of the building to the bottom. Unauthorized access to previously charged areas should be prevented at all times.

It is good practice not to wire up or connect together large sections of the explosive charges as charging proceeds. The connection of individual charges, and sections and floors should be left to the closing stages of the charging process. This reduces the risk of accidental initiation of the explosives.

6.4.3 ***After charging***

After the charging sequence is complete it is good practice to check that all connections are complete and secure and, where electric detonators are used, the resistance of each circuit should be checked to ensure electrical continuity.

Where a blast is to be left overnight it should be broken up into separate elements and electric detonators should be short-circuited for safety.

On the day of the blast a detailed procedure and programme should be used and copies of it should be given to all who require it. The procedure should include the steps to be taken in the event of a misfire.

6.5 Misfires

All misfires should be dealt with in accordance with **4.6**.

In demolition, particular problems may occur due to the nature of the tasks being carried out. A misfire may occur in a particular section of a structure and result in only partial collapse or even non-collapse of the structure being demolished. Alternatively, a structure may collapse and it is known or suspected that a misfire occurred in a section of the collapsed structure. It is essential that these possibilities are addressed in the contingency planning section of the method statement.

The possible types of misfire and the dangers from both unexploded charges and partial or total non-collapse of the structures are many. In the aftermath of such an event it is important that the new situation is thoroughly analysed and a new risk assessment carried out. This may lead to exclusion zones being maintained and site security being kept at a high level until the situation has been satisfactorily resolved.

7 Underwater blasting

7.1 General

Underwater blasting for rock excavation ranges from small scale operations conducted in shallow water for the deepening of rivers, for the excavation of foundations and for the excavation of foreshore trenches, to major harbour works involving the extension or construction of deep water berth facilities for large ships.

Underwater blasting may also be required for the levelling of the sea bed or for the demolition or clearance of offshore obstacles and structures.

7.2 Special considerations

7.2.1 *General*

Water is an excellent transmitter of shock, and the compression wave set up by underwater explosions can cause severe injury to divers or swimmers in the vicinity. Even if the peak pressure transmitted through the water is below the injury threshold, it may cause temporary discomfort and alarm to a diver or swimmer.

Even when small charges of a few kilograms only are being fired, such as in underwater demolition, all personnel, including the divers who place the charges, should be out of the water.

The severity of the shock wave at a distance from an underwater blast can be assessed using the parameters of peak over-pressure and impulse. The strength of the shock wave is reduced with increasing distance from the blast. It is also affected by other factors, such as type of explosive, the degree of burial of the explosive within the sea bed, the depth of water at the location of the blast, the blast geometry and depth of the water at the measuring point. Any reflection from a solid surface can increase the severity of the shock wave.

Blast vibrations are more easily transmitted through waterlogged ground than dry ground and consequently vibration levels at a given point may well be higher than expected; therefore, it is important to employ suitable instrumentation in order to measure vibrations so that the site characteristics may be determined.

7.2.2 *Method statement*

The method statement for underwater drilling and blasting should take into consideration any submerged/buried cables, power or service lines, ducts or pipes in the proximity of the works the location and route of which should be precisely identified prior to commencement of the works.

7.2.3 *Survey*

The following should be taken into account when carrying out the survey:

a) the effect that climatic and sea conditions such as prevailing wind direction and strength, tidal range and current and wave and swell heights may have on the operations. The possibility of ice conditions or debris in the water which could cause damage to or break initiation lines;

b) the frequency of shipping and pleasure vessel movements, and whether there are any water sports activities in the area, including diving operations;

c) site geological conditions, including the presence and type of any overburden overlying the rock;

d) environmental conditions, including protection of marine life;

e) the proximity of structures, residential buildings and the location of any submarine cables and pipelines which may be affected by the works.

7.2.4 *Exclusion zones and blast warning procedures*

A "code of signals" in accordance with **4.1.3.8** to **4.1.3.10** should be established. It is essential that adequate warning systems are set up to ensure that during blasting operations there are no swimmers within the prohibited area, that all vessels are clear of the blast area and that all divers are out of the water.

In many situations it is essential that two separate exclusion zones are defined and established in the immediate vicinity of the blast area (see Figure 3).

a) A **blast area** should be established to exclude all vessels, plant and personnel, including those of the blasting contractor, when blasting is about to take place.

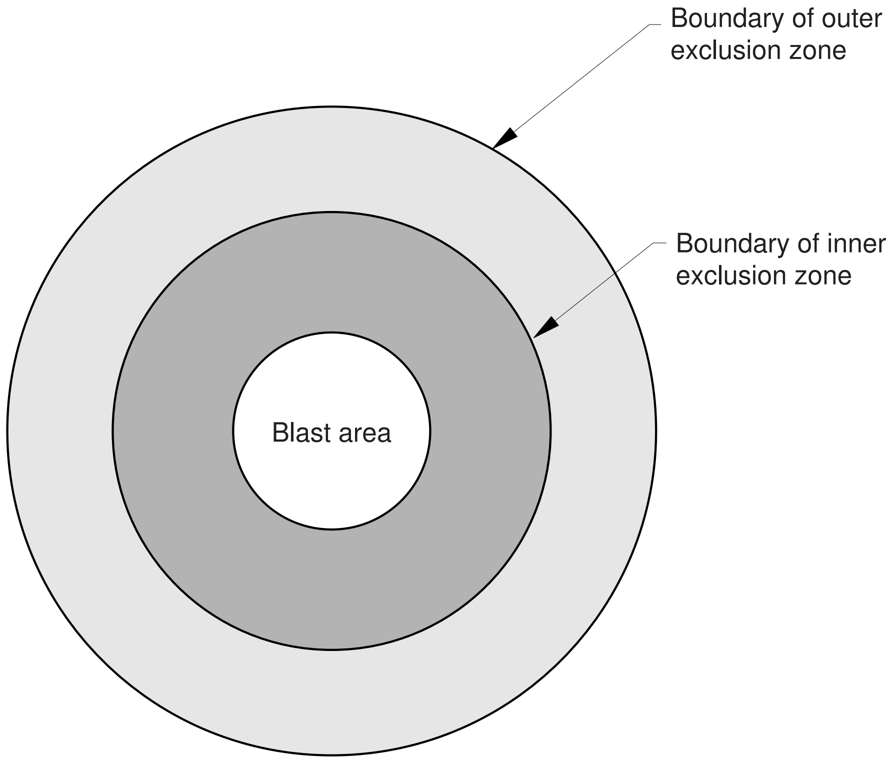
b) An **inner exclusion zone** should be established for commercial shipping and set at a distance from the blast site sufficient to avoid any damage to the vessel's hull or machinery from the effect of the blast.

c) An **outer exclusion zone** for swimmers should be established in accordance with Table 2 which gives recommended minimum distances swimmers should be from underwater blasting operations in open water. Where work is to be carried out within the vicinity of any bathing beaches, arrangements should be made with the relevant authorities to establish and maintain these exclusion zones. Within any such zone all swimming, diving, boating and other sports should be prohibited during blasting operations.

NOTE The extent of the blast area and exclusion zones will depend upon the size and type of the shot being fired. In intertidal areas and in water depths where fly rock is possible, the land excavation exclusion zone should also be applied.

For charges greater than 50 kg it is not possible to reliably predict the safe distances because of the compounding factors mentioned in **7.2.1**, and until more conclusive information is available swimmers should never be close enough to an underwater blast to be exposed to a shock wave whose impulse at that point is greater than 14 Pa·s (2 psi·milliseconds) or whose peak over-pressure is greater than 170 kPa (25 psi).

If there is any doubt it is recommended that pressure and impulse measurements using suitable instrumentation should be taken at representative locations.



NOTE Diagrammatic and not to scale.

Figure 3 — Relationship of blast area and exclusion zones in underwater blasting

Table 2 — Recommended minimum distances from underwater blasting operations

Size of charge kg	Minimum distance m
Up to and including 10	600
Over 10 and up to and including 20	750
Over 20 and up to and including 30	900
Over 30 and up to and including 40	1050
Over 40 and up to and including 50	1200

NOTE The above minimum distances are based on freely suspended TNT explosive charges. Considerably less water shock is produced for a given charge when the explosives are contained in shot holes.

7.3 Explosives

7.3.1 *Explosives types*

The explosives used in underwater blasting need to have adequate resistance against water for the likely period of immersion, and also the capability of detonating completely in long narrow columns (simulating a shot hole charge) under water. They should also be desensitized in water after an extended period of time so that the material will be rendered safe, should any misfires occur. Slurries and emulsions can be used in this context and where subsequent dredging is likely to occur.

For deep water operations (greater than 30 m) a more water resistant type of explosive that is not desensitized by pressure may be necessary. Such explosives will have a long immersion life and this point should be taken into account when considering misfires.

When using delay blasting techniques in wet or waterlogged ground, it is advisable to use explosives of low sensitivity to reduce the possibility of sympathetic detonation.

Two-part liquid explosive mixtures are also available for use in specialized charges, neither of the components being explosive in themselves until they are mixed together. The main advantage of using this type of explosive is the ease of handling, transporting and filling the special cutting charges.

The use of lay-on charges creates a larger waterborne shock wave than when explosives are placed in shot holes. In underwater blasting using lay-on charges, accurate positioning of the charges is of primary importance. It is also essential that, once they are placed, it should not be possible for the charges to be moved by tidal action or strong currents. This can be prevented by use of weights or holding down devices.

Multiple charges should be used when a large area is to be blasted by this method. A rigid frame should be used for the assembly of the charges prior to lowering. A relatively large deck area, which should be kept free from other operations, will be needed to carry out this assembly with due care and proper regard to safety. A lifting crane of adequate capacity, and having sufficient reach, should be used to raise the frame and charges clear of the deck and fixtures, and to swing the frame for lowering into the correct position. The attachment of the charges may be such that they can be manoeuvred into position by the divers.

For larger groups of charges a rope mesh may be a more convenient method of stringing charges together and, particularly where the water is not deep, it may facilitate charging by a method of paying out the roped assemblies over the stern of the barge.

For these methods, the attention which should be given to firmly securing the charges in place, and to the making of reliable connections of initiating mechanism between charges is of the utmost importance, both as regards ensuring satisfactory results and freedom from misfires.

7.3.2 ***Blasting accessories***

The blasting accessories most commonly used in underwater blasting are detonators, either electric or shock tube, and detonating cord. Plain detonators and safety fuse methods of initiation should be considered unsuitable because these devices may be desensitized by water.

In extremely arduous conditions, for example deep water, where divers in heavy equipment or submersibles have to handle the detonators, special detonators designed for use in deep water should be used. Information on the suitable types available should be obtained from the explosives manufacturer.

Electric detonators are normally designed to have a high degree of water resistance but when the depth exceeds 30 m, or the period of immersion exceeds 24 h, the manufacturer should be consulted.

Detonating cord is normally finished with an outer plastic sheath which is sufficiently waterproof to prevent water penetrating to the internal explosive core. Moisture can however penetrate down the core of the cord from a cut or abrasion and impair its sensitivity to initiation.

Any cut ends which may become submerged should therefore be sealed against moisture entry by means of sealing compounds, blanking off tubes and waterproof taping.

The same consideration should be applied when using the shock tube method of initiation, where again water can penetrate into the explosive core if any cut or abrasion has occurred in the outer tube.

When used in underwater operations, the initiation lines which link up individual charges may be subjected to excessive tension due to tidal or current action. This tension can easily exceed the levels which the wire or cord are designed to withstand, thus leading to breakage with consequent misfires, and possible loss of a charge or charges. Wherever such forces are likely to be encountered, any linking together of charges should be done by rope or by a rigid framework arranged so as to take the strain.

7.3.3 ***Transport***

The recommendations for the transport of explosives in **4.1.3.14** and **4.2** should be followed.

NOTE The movement of explosives within a harbour or harbour area is controlled by the Dangerous Substances in Harbour Areas Regulations 1987 [19]. If a harbour is not licensed for loading or unloading of explosives these regulations allow the movement of quantities of less than 1 t intended for immediate use in connection with harbour works in the harbour or harbour area provided that the written consent of the harbour master has been obtained.

7.3.4 ***Storage***

Adequate land-based licensed storage accommodation should be provided for all underwater blasting operations requiring the regular use of explosives. The recommendations regarding the operation of explosives stores and handling practice given in **4.1.3.14** and **4.2** should be observed.

When drilling and blasting operations are conducted from a pontoon, floating barge, or other small craft close to land, explosives and blasting accessories should not be taken onto the barge until required immediately for blasting. Surplus explosives should be removed as soon as practicable after completion of charging and before firing the blast.

Whenever the system employed requires that each shot hole be charged immediately after it has been drilled, it may be necessary to keep a stock of explosives on the drilling barge. In such circumstances wood-lined steel containers should be used for separate storage of explosives and the detonators, until they are required for immediate use. The main purpose of this on-deck storage is to protect the explosive from accidental maltreatment, such as by impact from drill rods, bits, spanners, etc. thrown down onto the deck. In the constricted conditions on deck there is also a risk that loose explosives cases or cartridges may be washed overboard by a sudden swell or movement of the barge, with subsequent problems of recovery. Provision should be made for the containers to be jettisoned in an emergency, such as fire, and to be suitably buoyed for eventual recovery.

7.3.5 ***Precautions***

The explosives manufacturer should always be consulted regarding suitable explosives and accessories for the particular operation.

7.4 Safety and operations

7.4.1 ***Before charging***

Every shot hole should be drilled in accordance with a predetermined pattern and should be positioned using a system of such accuracy that will not permit the possibility of drilling into the previously charged area.

Before charging, each shot hole should be checked for depth and clearance using a stemming rod or rods. Charging should not proceed until the depth corresponds to the planned depth and the shot hole is clear.

In all underwater blasting operations, charging of shot holes is liable to be much more difficult than working in the dry. On many occasions soft deposits varying from silt to sand or clay containing boulders can over-lie the rock to be blasted, and unless some means is adopted to case the top of the shot hole, charging will at best be difficult and will often be impossible. In many instances, a system which forms a hole in the soft material sufficient for a casing to be fixed in it becomes essential. Whatever method is used for the casing of the soft material, it should be of a sufficient strength to allow the shot hole to be drilled within it and into the rock below. Where such tubes are used they should extend above the maximum water or tide level, so that they can subsequently be used as a loading tube, through which the shot hole is charged.

It is essential that each shot hole location should be carefully recorded together with the rock level and charging quantities for the shot hole on record sheets intended for such a purpose.

7.4.2 ***During charging***

When charging underwater shot holes, it is essential that the same safe handling procedures should be observed as required normally in land based blasting operations (see **4.3**).

As charging proceeds, frequent checks with the stemming rods should be made on the shot hole depth, to ensure that each cartridge has been pushed fully home.

If detonators are used in the shot holes, particular care should be exercised to prevent the breakage of the wires or tubes.

Where conditions are severe, heavy duty wire or tubing should be used.

The detonators should be inserted in the first cartridge loaded in the shot hole.

All connections between detonators, and elsewhere in the blasting circuit, should be well insulated, so as to prevent current leakage and short circuits.

The use of detonators, either electric or shock tube, on drilling barges fitted with electrically operated machinery and equipment, for example, pumps, winches or lights, can be hazardous if proper precautions are not taken. Great care should be taken to ensure that there are no risks of stray electric currents anywhere on the craft. All equipment should be properly earthed and high standards of wiring and maintenance should be maintained to ensure that these conditions prevail.

An electric storm can also cause accidental initiation of detonators of either the electric or shock tube type. All work with explosives should cease and special precautions taken to isolate the detonators when such climatic conditions occur.

Strict rules should be laid down concerning the handling and use of electric detonators. Risks of premature ignition should be minimized by using high resistance fuse heads or transformer coupled detonators. As an additional precaution, each electric detonator should be shorted by connecting together the bare ends of the leading wires until immediately prior to connection into the blasting circuit. Shock tube detonators may be used for underwater works if they are fitted with tubing of sufficient strength.

If detonating cord is used for the initiation of charges, it should be threaded through the first cartridge inserted in the shot hole with the open end sealed as indicated in **7.3.2**. Where conditions are exceptionally severe, the detonating cord may have to be protected by taping, or by lengths of non-metallic tubing to prevent abrasion through the outer plastic covering. After the shot hole depth has been checked, the length of detonating cord required should be cut from the reel, leaving sufficient slack to allow for the motion of the barge in swell or tidal movements.

Detonating cord lines from groups of charged shot holes should not be connected together until the final preparation for firing the blast.

When connecting the shotfiring cable to the detonators the cable should be firmly attached in such a way that it is not possible to pull the detonating lead wires from the detonator, as this may cause premature ignition.

It is essential to recognize that detonating cord is a high explosive, which can be initiated by impact. Care should be taken to ensure that it is protected from impact.

7.4.3 ***After charging***

When withdrawing to fire a blast, the firing cable or detonating cord line should be paid out slowly to avoid stretching it to breaking point, and floats should be used at intervals to support the cord or cable.

Accurate means of locating the firing point relative to the blast area should be adopted (e.g. distance measuring instrument) so that there is no hazard to personnel due to the firing craft or barge being too close to the blast when it is fired. With blasts in shallow water, rock or stones may be thrown clear of the water surface and projected for considerable distances. This possibility should also be considered.

Immediately prior to firing, a final check should be carried out to ensure that all blast warning procedures have been complied with and that the exclusion zones are being maintained.

As soon as practicable after firing a blast an examination should be made for misfires.

After the blast has been successfully fired the "all clear" should be given and normal operations can be resumed.

7.5 Misfires

Misfires in underwater blasting can cause exceptional problems. The charging and firing operation should be designed in such a way as to ensure as far as possible that misfires do not occur. For example, double lines of the detonating cord or other initiating system should be led to each charge, detonating systems that minimize the risk of misfires due to earth leakage should be employed and particular care should be taken to avoid lines of detonating cord or lead wires becoming entangled or subjected to excessive strain.

A regular routine of drilling, charging and firing small blasts should be followed rather than attempting to blast large areas in one operation, where the explosives, detonators and other detonating devices may be immersed for long periods before blasting takes place.

A number of points of general guidance can be made which are appropriate to different circumstances.

— If a whole blast has misfired, then with the aid of divers, it may be possible to re-prime each shot hole and attempt to fire the blast again.

— If a blast has partially misfired and the ground remains relatively undisturbed, again, re-priming of the misfired shot holes may be possible.

— Where a minority of shot holes in a blast has misfired the ground may be extensively disturbed and re-priming of charges is likely to be extremely difficult. However, attempting to re-prime and re-fire the misfired holes is again the only reasonable option available.

— If, after taking action to remedy a misfire, a suspicion remains that the charge has not fired, markers should be placed which indicate the location of the possible misfire so that subsequent digging or dredging operations can proceed cautiously in the suspect area.

— Because of the relatively close spacing of shot holes, the difficulty of accurately locating the drilling barge and precisely spotting the shot holes, the re-drilling of an area where misfires have occurred is extremely hazardous. The placing and firing of heavy lay-on charges may rectify poor breakage in areas affected by misfires or inadequate blasting results and may also help in detonating misfired charges.

8 Land excavation

8.1 General

Land excavation covers the use of explosives to assist in the fragmentation and excavation primarily of rock for trenches, pipelines, roads, bridges, etc. The scale of material to be blasted may vary from a few cubic metres for small drainage ditches and site levelling, to millions of cubic metres for major road or infrastructure projects.

In every situation drilling is required in order that the explosives can be accurately positioned and distributed through the volume to be excavated.

8.2 Special considerations

8.2.1 *General*

As excavations are almost entirely associated with works of civil engineering or building construction, they may therefore be necessarily close to existing or new structures and/or may have to be carried out in locations where the general public are at risk.

The topography of the area and the volume to be excavated may also be very irregular and, when taken in conjunction with the additional risk of proximity to structures and to the general public, dictates that a thorough and professional survey and risk assessment should be carried out. This professionalism and attention to detail should be carried through to the execution of the blasting operation by way of detailed survey, method statements and blast design.

Not only should physical damage from fly-rock be eliminated from these operations but potential damage and complaints as a result of ground or airborne blasting vibrations should also be effectively controlled.

8.2.2 *Survey*

8.2.2.1 *General*

The survey, in terms of excavation operations, should include or take cognizance of the following:

a) ground conditions/geotechnical properties;

b) response of structures to ground vibration/air over-pressure;

c) detailed survey of blast site;

d) third party/public interaction.

8.2.2.2 *Ground/rock conditions*

Prior to any blasting for excavation works, and afterwards on an ongoing basis, all available information on the geotechnical properties, for example, strength, fracturing and stratification of the material to be blasted should be investigated and assessed. This assessment should also take into account the ground water conditions. It is likely that in most situations a ground investigation will already have been carried out from which this information can be collated. In the event that no such information is available the explosives engineer should give consideration to this fact in the risk assessment and take such action deemed appropriate.

Having commenced drilling, blasting and excavation operations it is equally important that relevant observations should be made as to the material being excavated and amendments made if required to the method statement or blast plan.

8.2.2.3 *Detailed survey*

The location of sensitive buildings or structures in relation to the blast site should be accurately known prior to preparation of the blast plan. A plan of the area surrounding the blasts at a suitable scale should be provided for this purpose.

At the blasting site, however, more detailed survey information is required. The commencing level, pattern and depth of boreholes should be accurately fixed in relation to the initial and proposed excavation level such that the true burden and spacing of each shot hole can be accurately determined; depending on the particular conditions on site this may necessitate the use of laser face and borehole survey systems.

8.2.2.4 *Third parties/general public interaction*

The survey of the blast site should take into account the potential hazard to other contractors and third parties in the exclusion zone (see **4.1.3.7** and **8.2.4**). The survey should also identify any potential hazard to the general public. Measures to ensure that all third parties are aware of blasting events and are prevented from exposure to any hazard or risk should be fully addressed in the method statement. The blast design and designated exclusion zone should take account of these factors.

8.2.3 ***Method statements***

General guidance for the preparation of method statements is given in **4.7**. When a series of blasts is carried out, it is common for changes in ground conditions and blast geometry to be encountered. In most cases, a single method statement will not be appropriate to accommodate the effect of these changes.

The method statement should, at least, address the following topics:

a) identification of the blast area and boundary of the exclusion zone;

b) statement of who will be responsible for drawing up the blast plan;

c) statement and/or demonstration of how the volume to be blasted has been measured with sufficient accuracy in three dimensions i.e. topography, face position(s) and orientation(s) (if relevant) and the shot hole positions and orientation;

d) adherence to the charging plan by those empowered to charge blasts and their allowable deviations from the plan (see **4.7.2**);

e) storage of explosives on site (see **4.1.3.14** and **4.2**);

f) transport of explosives to and from site if there is not site storage (see **4.2**);

g) transport and handling of explosives on site (see **4.2**);

h) visual and audible warning systems (see **4.1.3.8** to **4.1.3.10**);

i) management and control of sentries in ensuring the integrity of the exclusion zone;

j) misfire procedures (see **4.6**).

8.2.4 ***Exclusion zones and blast protection***

8.2.4.1 *General*

The procedure and responsibility for identifying the blast area and the limit of the exclusion zone should be addressed in the method statement, which should identify any requirements for blast protection or methods of containment.

Blast protection or containment should only be used as added insurance against fly rock when blasting is to take place in close proximity situations; the containment/protective measure should not be used to justify a higher risk blast design.

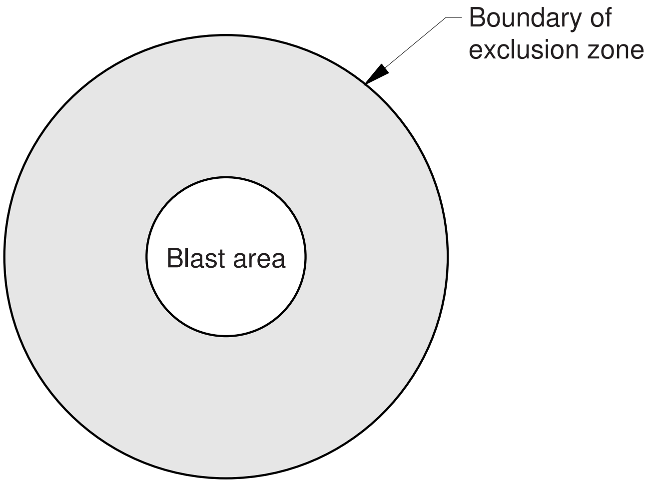
8.2.4.2 *Exclusion zones*

The explosives engineer or shotfirer responsible for designing the blast should apply the following methodology to the risk of rock movement or projection from the blast (see Figure 4 and also **4.1.3.7**):

a) identify an immediate zone around the blast to the limit of expected rock displacement. All plant and equipment should be removed from this area prior to blasting;

b) identify an area in which some scatter may be possible;

c) identify the limit of an exclusion zone from within which all other personnel, other than the shotfirer are excluded. (The shotfirer may fire from within this area provided that he uses a blast shelter). This zone should allow for a margin of safety outside the potential scatter area and may be enlarged to take into account natural barriers or features (see Figure 4). This zone should be controlled by sentries to ensure that no personnel remain within it during blasting times.



NOTE Diagrammatic and not to scale

Figure 4 — Exclusion zone for land excavation

8.2.4.3 *Containment measures*

8.2.4.3.1 *General*

Containment measures should normally only be applied in circumstances where absolutely no scatter or fly rock can be tolerated and blasting is being carried out in close proximity to structures and/or the general public.

It is important that any containment measures do not incorporate materials which may themselves be projected by the force of the blast.

8.2.4.3.2 *Netting/meshing*

Netting/meshing can be of various types and can be used in a number of different configurations. Netting types used as containment can vary from standard steel mesh net, through polypropylene rope nets to very heavy duty "submarine" netting.

These nets can be hung or draped over vertical or sub-vertical faces to prevent sub-horizontal projection of material or placed over sub-horizontal surfaces to prevent vertical or sub-vertical projection.

In extreme circumstances netting/meshing may also be used as overnetting to provide complete aerial coverage to a blast site.

8.2.4.3.3 *Matting*

Where blasts have only the surface as a free face (for example, sinking or ramping excavations, or more typically trenching and pipeline excavations), scatter may be controlled by matting and/or covering.

This may take the form of used conveyor belting or similar material laid directly on the blast surface and weighted down to provide containment by the addition of locally available inert material, for example, topsoil, sand or gravel.

8.2.4.4 *Protective measures*

Protective measures should only be utilized to prevent or limit damage to structures.

Such measures should be designed to absorb and/or dissipate some of the energy and movement of the displaced materials and may take the form of a protective bund of sand or similar material. More specific protection may be achieved by the use of straw bales, which can be very effective in certain situations.

8.3 Explosives

8.3.1 *Transport*

As stated in **4.1.3.14** and **4.2**, transfer and transport of explosives is governed by legislation and regulations.

Delivery to site will normally be in road vehicles which should conform to the legislative requirements.

Transport on site should be in boxes or containers (see **4.2.12**) and in clearly marked vehicles (see **4.2.10**).

8.3.2 *Storage*

Temporary daytime storage, if required, should be in secure containers or boxes and should be under the direct control of the appointed shotfirer.

NOTE Longer term and overnight storage is only permitted in a secure store, the construction and security of which conforms to the current requirements of the Explosives Inspectorate and the local police force. The amount of explosives which may be stored is given in Table 1.

8.3.3 *Explosives and initiation systems*

8.3.3.1 *Explosives*

Surface blasting operations for land excavation may utilize a wide range of explosive types based on the application. Where small diameter shot holes are used, as may be required in controlled/restricted blasting or for pipelines and trenches, explosives will generally be nitro-glycerine, slurry or emulsion based.

These types of explosive may also be used for specialist applications such as pre-splitting. Further detail on explosive types may be found in **4.4**.

In larger diameter shot holes ($\geq$ 75 mm diameter) the explosive can be a mixture of packaged or cartridged slurry or emulsion with ammonium nitrate/fuel oil mixtures either mixed on site or supplied pre-mixed from the supplier. Additionally, two-part bulk emulsion/ammonium nitrate mixtures, heavy ANFOs, may be mixed on site in a suitably designed lorry mounted mixing unit and pumped directly into the shot hole.

8.3.3.2 *Initiation*

Conventionally, initiation utilizes detonators which are fired electrically or by shock. Electric detonators, either instantaneous or incorporating a delay element, can be fired either by direct electric current, or, in areas subject to electrical hazard from, for example, stray currents, by indirect current induced by magnetic coil. Alternatively, a non-electrical shock tube detonator may be used.

Detonating cord may also be used to initiate explosives, although any delay element between shot holes or charges should still be controlled by detonators.

See **4.5** for more detail on initiation systems.

A number of factors will determine the system that should be used in any particular application but those which exert most influence are:

a) the maximum allowable charge which may be detonated per time delay;

b) the presence of any electrical hazard;

c) the number of individual charges which need to be fired in one blast.

8.4 Safety and operations

8.4.1 *Before charging*

All preliminary procedures, method statements and blast warning procedures should be in place before charging.

Shot holes should be checked to ensure that the intended pattern has been drilled, that they are open and unobstructed to the depths required and that their orientation and inclination are as intended.

If the blasting is to a free face then its position relative to the shot holes should be known with sufficient accuracy to ensure a safe and efficient blast and thus avoid fly and excessive air over-pressure.

The charging regime and intended firing pattern should be planned and calculated before charging commences to ensure that the blast ratios and actual burdens and spacings are as intended and will lead to a safe and efficient blast.

8.4.2 *During charging*

Only sufficient explosives for the blast should be on site and under the direct control of the appointed shotfirer. Boxes of packaged explosives should not be opened before their intended use and in no circumstances should explosive cartridges be lying loose around the blast site. Charging should take place in accordance with the planned intention and the rise of explosives in the shot hole should be checked at regular intervals to ensure that either cartridges are not stuck at a high level or that bulk explosives such as ANFO or site mixed two-part emulsions are not being lost into cavities or voids in the ground.

If down-the-hole initiation methods are employed the shotfirer should ensure that the planned initiation sequence is implemented in accordance with the prepared blast plan.

On completion of charging the shot holes should be stemmed to the surface, ideally with single size crushed rock aggregate, except for pre-split shot holes which require special stemming arrangements.

It is good practice to cover any blast initiation products which are on the surface to prevent unwanted noise.

If charging has been completed well in advance of the proposed blasting time, or if the blast is delayed, the shotfirer should ensure that any electrical circuits remain open and unconnected and that a responsible person is in charge of the blast site until blasting takes place.

Immediately prior to blasting the shotfirer should ensure that the agreed blast warning procedures are implemented and that sentries are in place to maintain the integrity of the designated exclusion zone.

8.4.3 ***After charging***

Following initiation of the blast the shotfirer should check that it has been successfully fired, as far as he can determine from a visual inspection, and only when he is satisfied should the all-clear be given.

A complete misfire can only be evaluated on the spot, taking account of the type and method of initiation; for example it may be possible to reconnect and fire an electrically initiated blast again if the problem can be located with a degree of certainty.

Partial misfires may not become immediately apparent, but all misfires should be treated in accordance with the misfire procedures identified in the method statement [see **4.7**, item q)], which normally as a minimum would require a shotfirer to be present during excavation to assist and advise the excavator operator on safety.

See **4.6** for further guidance on misfires, their identification, reporting and remedial action.

9 Other forms of blasting

9.1 Mini-blasting

This is a system of blasting small structures or parts of structures where full size blasting is unlikely to be acceptable. Shot hole sizes and drill patterns and amounts of explosive can all be very much reduced.

Whilst the dangers may be very much reduced because of scale, this type of blasting should still be subjected to the same criteria as full scale blasting.

9.2 Deflagrating compounds (low velocity explosives)

These are fireworks type compounds which burn rather than detonate. They may be used like a low powered explosive and consequently in use they should be treated as any other explosive.

9.3 Cardox

This is a system which utilizes the rapid release of gas from a previously charged or pressurized shell or container placed in a borehole. This rapid release of energy can be used to break out rock. Such a system should follow the same procedures in use as for conventional explosives.

9.4 Expanding grouts

In this system a grout powder is suitably mixed with water and placed in shot holes. As the grout sets it expands and given the correct configuration will break rock or concrete.

The grout setting times vary with temperature and manufacturing but results are normally expected within 24 h, except in cold weather. The unpredictability of the grout setting time should be allowed for when considering any protective or control measures.

Care should be taken with fast setting grouts as they can cause an explosive-like ejection from the top of the shot holes.

10 Cartridge operated fixing tools

The cartridges used in cartridge operated fixing tools are explosive and for advice on the explosives BS 4078-1 should be consulted.

Annex A (informative)
Shotfiring training

A.1 Appointment

The minimum age for a shotfirer should be 21 years.

An appointment as a qualified shotfirer should be made only after the trainee has successfully completed a training course and a period of practical experience under qualified supervision amounting to a minimum of one year.

A.2 Training courses

The syllabus for the course should cover the following areas.

a) Explosives, explosive devices, detonators, accessories and shotfiring equipment:
- — types available, their characteristics, properties and safe handling;
- — site mixed explosives;
- — acquisition, storage, issue and conveyance of explosives on site and on the highway;
- — recognition, handling and safe disposal of deteriorated explosives and detonators.

b) Drilling:
- — methods and equipment;
- — surveying the blast site and the production and interpretation of plans and sections of the affected area;
- — setting up and alignment of drills;
- — checking and measurement of shot holes;
- — arrangement of blasting patterns;
- — recognition of natural joints, breaks in the strata, and other relevant information from drill holes;
- — drilling records.

c) Understanding, preparation and interpretation of blast plans:
- — examination and inspection of the target area;
- — determination, examination and preparation of the drop zone;
- — design and installation of any protection from flying debris;
- — factors to be considered in determining the exclusion zone;
- — geographical factors influencing the extent of the exclusion zone.

d) Shotfiring operations:
- — safe shotfiring procedures, posting sentries, notification of neighbours, warning signals, evacuation and shelter;
- — charging and stemming shot holes;
- — placing and securing charges ;
- — methods and principles of initiation;
- — connecting up initiation circuits;
- — testing equipment and circuits;
- — firing shots;
- — examination of the blast site after firing, including ventilation and unstable conditions;
- — all clear;
- — record keeping.

e) Miscellaneous:
- — misfires, their causes and avoidance, dealing with them, and records;
- — relevant legislation and guidance material.

In addition, one or more specific training courses for explosives applications should be undertaken, for example:
- — courses for surface or underground work;
- — specialist course for underground work in quarry and dusty mines;
- — specialist courses for demolition, and underwater blasting;
- — specialist courses where blasting requires additional survey skills;
- — refresher courses for recent developments, for example, new firing systems.

A.3 On site training and experience

In addition to attendance at "off the job" training courses, the trainee shotfirers should receive training "on the job" until such time as they are able to demonstrate that they have the knowledge, training and experience to enable them to carry out a full range of shot firing duties in their own specialist fields.

During the time that they are training, they should work under the direct supervision of a competent and reliable trained shotfirer, to a training programme devised by or agreed with their employer.

Trainee shotfirers should not be required to fire except under the supervision of their supervising shotfirer until they are deemed to have the necessary qualifications and have been certificated.

The training programme should include the following operations as they apply to the trainee's particular discipline:

a) receipt and storage;

b) transport and handling;

c) checking the blast site;

d) security of explosives on site;

e) mixing explosives (for example, ANFO);

f) priming a cartridge;

g) charging and stemming a shot hole and laying charges (wherever appropriate);

h) linking or connecting a round of shots;

i) coupling a shotfiring circuit to a detonator circuit, circuit tester or exploder;

j) identifying the factors to be considered in the determination of an exclusion zone;

k) the determination of an exclusion zone;
l) the procedures for the withdrawal of persons;
m) testing a shotfiring circuit;
n) firing a blast;
o) examination of the blast site to ascertain whether a misfire has occurred and whether it is safe for personnel to return;
p) maintenance of a detailed record of the trainee's supervised practical training, kept until he has qualified;
q) maintenance of a detailed logbook by the trainee, this being the record of the trainee's experience.

Annex B (informative)
List of legislation

B.1 Explosives legislation in chronological order

Year	Statutory Instrument[a]	Title or subject
1875		The Explosives Act
1875	O in C No. 1	Classification of Explosives
1875	O in C No. 2	General Rules for Factories for Explosives other than Gunpowder
1875	O in C No. 3	General Rules for Magazines for Explosives other than Gunpowder with or without Gunpowder
1875	O in C No. 4	Small Fireworks Factories
1875	O in C No. 5	Gunpowder Stores
1875	O in C No. 6	Stores for Mixed Explosives
1875	O in C No. 9	Sale of Explosives
1875	O in C No. 11	Accidents during the Carriage of Explosives other than Gunpowder
1875	OSS No. 1	General Rules for Floating Magazines for Gunpowder
1875	OSS No. 2	General Rules for Floating Magazines for Explosives other than Gunpowder whether with or without Gunpowder
1883		The Explosives Substances Act
1883	O in C No. 6A	Prohibits Keeping Fulminates in Stores
1884	O in C No. 10A	Importation of Fireworks
1891	O in C No. 1A	Amending Definition of Fireworks
1894	O in C No. 15	Prohibiting Sulphur/Chlorate Mixtures in Fireworks
1896	O in C No. 16	Registered Premises for Mixed Explosives
1898	OSS No. 5	Relating to Compressed Acetylene in admixture with Oil Gas
1905	OSS No. 5A	Relating to Compressed Acetylene in admixture with Oil Gas
1905	O in C No. 19	Prohibiting Phosphorous/Chlorate Mixtures in Fireworks
1906	O in C No. 16A	Registered Premises and the Keeping of Fireworks
1907	O in C No. 6B	Amending General Rules for Stores for Mixed Explosives
1909	O in C No. 6C	Amending General Rules for Stores for Mixed Explosives
1912	O in C No. 16B	Amending O in C No. 16 (1896)
1913	O in C No. 1B	Classification of Explosives
1917	O in C No. 21A	Revoking Order Exempting TNT from Provisions of Explosives Act 1875
1919	OSS No. 9	Relating to Compressed Acetylene in admixture with Oilgas
1923		The Explosives Act
1923	O in C No. 2A	Amending General Rules for Factories
1923	O in C No. 3A	Amending General Rules for Magazines
1923	O in C No. 4A	Amending General Rules for Small Fireworks Factories
1923	O in C No. 6D	Age of Person entering Stores
1923	OSS No. 2A	Amending OSS No. 2
1923	OSS No. 10	Young Persons Employed in Danger Buildings
1924	OSS No. 11	Carriage of Explosives by Boat; Prohibition on Placing Explosives in Refuse
1926	O in C No. 26	Picric Acid, Picrates etc.
1927	O in C No. 27	Dinitro-phenol and Dinitro-phenolates
1928	O in C No. 29	The Liquid Oxygen Explosives Order
1937	O in C No. 30	Classing Acetylene as an Explosive and Prohibiting it under Certain Conditions
1939	OSS No. 11A	Carriage of detonators and electric detonators with other explosives Order
1947	No. 805	The Compressed Acetylene Order
1951		The Fireworks Act
1951	No. 869	The Conveyance of Explosives Bye-Laws
1951	No. 1163	The Stores for Explosives Order
1951	No. 1164	The Magazines for Explosives Order
1953	No. 1197	The Stores for Explosives Order
1954	No. 635	The Visiting Forces (Application of Law) Order

Year	Statutory Instrument[a]	Title or subject
1956	No. 1050	The Conveyance by Road of Government Explosives and Explosives of Visiting Forces Regulations
1958	No. 230	The Conveyance of Explosives Bye-Laws
1959	No. 1311	The Keeping of Fireworks Order
1964		The Fireworks Act
1965	No. 1536	The Visiting Forces and International Headquarters (Application of Law) Order
1967	No. 1485	The Ammonium Nitrate Mixtures Exemption Order
1968		The Hovercraft Act
1969	No. 1389	The Clean Air (Emission of Dark Smoke) (Exemption) (Scotland) Regulations
1971	No. 969	The Isles of Scilly (Explosives) Order
1974		The Health and Safety at Work etc. Act
1974		The Control of Pollution Act
1974	No. 1885	The Explosives Act 1875 and 1923 (Repeals and Modifications) Regulations
1974	No. 2040	The Health and Safety Licensing Appeals (Hearing Procedure) Rules
1974	No. 2068	The Health and Safety Licensing Appeals (Hearing Procedure) (Scotland) Rules
1974	No. 2166	The Explosives Act 1875 and 1923 (Repeals and Modifications) (Amendment) Regulations
1976		The Explosives (Age of Purchase) Act
1976	No. 2003	Fire Certificates (Special Premises) Regulations
1978	No. 1723	The Compressed Acetylene (Importation Regulations)
1979	No. 1378	The Explosives Act 1875 (Exemptions) Regulations
1979		The Customs and Excise Management Act 1979
1983	No. 1140	The Classification and Labelling of Explosives Regulations
1984	No. 510	The Explosives Act 1875 etc. (Metrication and Miscellaneous Amendment) Regulations
1985	No. 1939	Air Navigation (Dangerous Goods) Regulations 1985
1986	No. 2129	Air Navigation (Dangerous Goods) (Amendment) Regulations 1986
1987	No. 37	The Dangerous Substances in Harbours Regulations
1987	No. 52	The Health and Safety (Explosives and Petroleum Fees) (Modifications) Regulations
1988	No. 1930	The Quarries (Explosives) Regulations
1988	No. 2133	Air Navigation (Dangerous Goods) (Second Amendment) Regulations
1989	No. 1903	The Health and Safety (Enforcing Authority) Regulations
1990		Environmental Protection Act
1991	No. 1531	The Control of Explosives Regulations
1991	No. 2097	The Packaging of Explosives for Carriage Regulations
1992	No. 2932	The Provision and Use of Work Equipment Regulations (PUWER)
1993	No. 208	The Coal and Other Safety-Lamp Mines (Explosives) Regulations
1993	No. 2714	The Placing on the Market and Supervision of Transfers of Explosives Regulations
1994	No. 3187	The Air Navigation (Dangerous Goods) Regulations
1995	No. 415	The Fireworks (Safety) Revocation Regulations
1996	No 890	The Marking of Plastic Explosives for Detection Regulations
1996	No. 972	Special Waste Regulations
1996	No. 2089	The Carriage of Dangerous Goods by Rail Regulations
1996	No. 2092	The Carriage of Dangerous Goods (Classification, Packaging and Labelling) and Use of Transportable Pressure Receptacles Regulations
1996	No. 2093	The Carriage of Explosives by Road Regulations
1996	No. 2094	The Carriage of Dangerous Goods by Road (Driver Training) Regulations
1996	No. 2095	The Carriage of Dangerous Goods by Road Regulations

[a] Not all Acts are published as Statutory Instruments.

Abbreviations

O in C = Orders in Council

OSS = Orders of Secretary of State

B.2 Related legislation in chronological order

Year	Statutory Instrument[a]	Title or subject
1959		Building (Scotland) Act
1961		Factories Act (Where no PRESCRIBED NOTICE, copies of relevant Regulations to be available)
1961	No. 1580	Construction (General Provisions) Regulations as amended by SI 1988 No. 1657, SI 1989 No. 635, SI 1992 No. 2932 and SI 1992 No. 2793
1961	No. 1581	Construction (Lifting Operations) Regulations as amended by SI 1989 No. 1141 and SI 1992 No. 195
1974		Health and Safety at Work etc. Act
1976	No. 2063	Mines and Quarries (Metrication) Regulations
1981	No. 1499 (S.152)	The Building (Procedure) (Scotland) Regulations
1983	No. 1026	Quarries (Metrication) Regulations as amended by SI 1992 No. 1213 and SI 1993 No. 1122
1984	No. 1244	Classification, Packaging and Labelling of Dangerous Substances Regulations as amended by SI 1986 No. 1922, SI 1988 No. 766 and SI 1990 No. 1255
1984		The Roads (Scotland) Act
1984		The Police and Criminal Evidence Act
1984		The London Transport Act
1985	No. 1065	The Building Regulations
1985		The Local Government Act
1986		The Statute Law (Repeals) Act
1986	No. 1922	(See No. 1244, 1984)
1987		The Consumer Protection Act
1988	No. 766	(See No. 1244, 1984)
1988	No. 1657	Control of Substances Hazardous to Health Regulations as amended by SI 1990 No. 2025, SI 1991 No. 2431 and SI 1992 No. 2382 (See also No. 1580, 1961)
1989	No. 1790	Noise at Work Regulations as amended by SI 1992 No. 2966
1989	No. 2209	Construction (Head Protection) Regulations as amended by SI 1992 No. 2966
1989	No. 635	(See No. 1580, 1961)
1989	No. 1141	(See No. 1581, 1961)
1990	No. 1255	(See No. 1244, 1984)
1990	No. 2025	(See No. 1657, 1988)
1990	No. 2179 (S.187)	The Building Standards (Scotland) Regulations
1991		New Road and Street Works Act
1991	No. 472	Environmental Protection (Prescribed Processes and Substances) Regulations (See No. 1657, 1988)
1991	No. 2431	Personal Protective Equipment at Work Regulations
1991	No. 2966	Environmental Protection (Duty of Care) Regulations
1991	No. 2839	Street Works, Qualifications of Supervisors and Operatives Regulations
1992	No. 195	(See No. 1581, 1961)
1992	No. 1213	(See No. 1026, 1983)
1992	No. 2051	Management of Health and Safety at Work Regulations
1992	No. 2382	(See No. 1657, 1988)
1992	No. 2793	Manual Handling Operations Regulations (See also No. 1580, 1961)
1992	No. 2932	(See No. 1580, 1961)
1992	No. 2966	(See No. 1790, 1989 and No. 2209, 1989)
1992	No. 1122	(See No. 1026, 1983)
1993	No. 1746	Chemicals (Hazard Information and Packaging) Regulations
1994	No. 3140	The Construction (Design and Management) Regulations 1994
1994	No. 3246	Control of Substances Hazardous to Health Regulations
1995	No. 3163	Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR)
1996	No. 0341	The Health and Safety (Safety Signs and Signals) Regulations
1996	No. 1592	The Construction (Health, Safety and Welfare) Regulations
1996	No. 1656	The Work in Compressed Air Regulations
1996	No. 2075	The Health and Safety at Work, etc. Act 1974 (Application to Environmentally Hazardous Substances) Regulations 1996
1996	No. 2791	The Health and Safety (Fees) Regulations

[a] Not all Acts are published as Statutory Instruments

Full details of current health and safety legislation can be found in:

List of current health and safety legislation 1996, obtainable from:

HSE Books, PO Box 1999, Sudbury, Suffolk CO10 6FS
Tel. 01787 881165

Annex C (informative)

Summary of the Construction (Design and Management) (CDM) Regulations 1994

C.1 Introduction

The CDM Regulations [3] place duties on clients, (clients' agents where appointed) designers and contractors to manage explosives projects for health and safety. The Management of Health and Safety at Work Regulations 1992 [4] already place general duties on employers and the self-employed to make effective arrangements for managing health and safety. These duties make more explicit the requirements of sections 2 and 3 of the Health and Safety at Work etc. Act 1974 [13]. Central to the Management of Health and Safety at Work Regulations 1992 is the requirement for employers and the self-employed to make and maintain a suitable and sufficient risk assessment. The underlying principle of risk assessment is that it enables risk to be evaluated, allowing the whole system or situation to be considered fully. This allows for the identification of measures required to be taken to comply with health and safety law. The CDM Regulations establish new duties and build on those imposed by the Management of Health and Safety at Work Regulations.

The CDM Regulations identify a number of duty holders: the client, planning supervisor, designer, principal contractor and contractor. It is recognized that, for some explosives work, especially smaller work, the contractor may embrace several of these roles.

The CDM Regulations recognize the importance of the role of the designer. For explosives work the role of the designer under The CDM Regulations may be that of professional adviser who may be a professional engineer or may be included in the remit or expertise of the demolition contractor.

C.2 The client

The client should be satisfied that only competent people are appointed as planning supervisor and principal contractor. This also applies when making arrangements for the appointment of designers and contractors. They should also ensure that sufficient resources, including time, are allocated to enable the project to be carried out in safety.

The client plays a positive role in making the key appointments and in the way in which health and safety is managed throughout the project. Some clients may need to seek professional help so that they can meet these duties but The CDM Regulations ensure that the planning supervisor is there to advise them and that designers are required to inform clients of their duty to appoint a planning supervisor.

The client's key duties are to ensure that:

— only competent planning supervisors and principal contractors are appointed;

— adequate resources have been allocated for health and safety;

— demolition work does not start until the principal contractor has prepared a satisfactory health and safety plan (see **C.8**);

— the health and safety file is available for inspection, after the project is completed.

C.3 The planning supervisor

The planning supervisor co-ordinates the health and safety aspects of project design and the initial planning to ensure that:

— designers comply with their duties; in particular, the avoidance and reduction of risk;

— designers co-operate with each other for the purposes of health and safety;

— a pre-tender health and safety plan (see **C.8.2**) is prepared before arrangements are made for a principal contractor to be appointed;

— they are able to give advice, if requested, to the client on the competence and allocation of resources by designers and all contractors; advise contractors appointing designers; and also advise the client on the health and safety plan before the blasting events start;

— the project is notified to the Health and Safety Executive; and

— the health and safety file is prepared and delivered to the client at the end of a project.

C.4 The designer/specifier

The designer should ensure that the health and safety of those who are going to use explosives are considered during the design process, including the preparation of the specification and contract documents. Failure to do this may make it difficult for a contractor to devise a safe system of work. Contractors have to manage the risks on site, but they may be eliminated or at the least reduced at the design stage.

The designer's key responsibilities are to:

— take reasonable steps to alert clients to their duties under The CDM Regulations and to the existence of the Approved Code of Practice [20];

— consider during the development of designs the hazards and risks which may arise to those using explosives;

— design to avoid risks to health and safety;

— design to reduce risks at source if they cannot be avoided;

— consider measures which will protect all workers if neither avoidance nor reduction to a safe level is possible;

— ensure that the documentation (for example drawings/specifications) includes adequate information on health and safety;

— pass this information on to the planning supervisor so that it can be included in the health and safety plan;

— co-operate with the planning supervisor and other designers involved in the project;

— carry out a review of all existing information on the structure;

— where necessary, arrange for the site to be surveyed and determine its integrity, history of maintenance and the presence of contamination;

— advise the client on any further necessary information required by the tenderers and how it should be obtained;

— prepare contract documentation and specifications;

— provide an outline method statement, where necessary, and assess the method statements proposed by the contractors;

— assess the tenders and advise on the most suitable contractor;

— provide a continuous role throughout the explosives phase of the project.

C.5 The principal contractor

The principal contractor takes over and develops the health and safety plan and co-ordinates the activities of all contractors to ensure compliance with the health and safety regulations.

The principal contractor's key duties are to:

— develop and implement the health and safety plan;

— arrange for competent and adequately resourced contractors to carry out the work where it is subcontracted;

— ensure the co-ordination and co-operation of contractors;

— obtain from contractors the main findings of their risk assessments and details of how they intend to carry out high risk operations;

— ensure that contractors have information about risks on site;

— ensure that workers on site have been given adequate training;

— ensure that contractors and workers comply with any site rules which may have been set out in the health and safety plan;

— monitor health and safety performance;

— ensure that all workers are properly informed and consulted;

— make sure only authorized people are allowed onto the site;

— display the notification of the project to HSE;

— pass information to the planning supervisor for the health and safety file.

C.6 Contractors and the self-employed

The key duties of contractors are to:

— provide information for the health and safety plan about risks to health and safety arising from their work and the steps they will take to control and manage the risk;

— manage their work so that they comply with rules in the health and safety plan and with directions from the principal contractor;

— provide information about injuries, dangerous occurrences and ill health for the health and safety file;

— provide information about health and safety to their employees.

The self-employed also have these duties when they act as contractors.

C.7 Employees

Employees are entitled to information about health and safety during the explosives phase of the project, and should be able to express their views about health and safety to the principal contractor.

C.8 The health and safety plan

C.8.1 ***General***

The health and safety plan provides the health and safety focus for the explosives phase of a project. The pre-tender health and safety plan should be prepared in time so that it is available for contractors tendering or making similar arrangements to carry out or manage explosives work. The planning supervisor is responsible for ensuring that this is done. After being appointed by the client it is the responsibility of the principal contractor to develop the health and safety plan and to keep it up to date.

C.8.2 ***The pre-tender health and safety plan***

The pre-tender plan should include:

— a general description of the work;

— details of timings within the project;

— details of risks to workers as far as possible at that stage;

— information required of potential principal contractors to demonstrate competence or adequacy of resources;

— information for preparing a health and safety plan for the explosives phase and information for welfare provision.

C.8.3 ***The health and safety plan for the explosives phase***

The plan supplied to and developed by the principal contractor is the foundation on which health and safety management of work involving explosives is based. It should include:

— arrangements for ensuring the health and safety of all who may be affected by the use of explosives;

— arrangements for the management of health and safety of work involving explosives and the monitoring of compliance with health and safety regulations;

— information about welfare arrangements.

Annex D (informative)

Explosives engineering training

The explosives engineer should be able to demonstrate that he has successfully completed a course of training covering the following:

a) hazard assessment and safety management;

b) legislation and Codes of Practice relating to the acquisition, carriage by road, transfer in harbour areas, storage, use and disposal of explosives in as much as it relates to that part of the construction industry in which he operates;

c) legislation relating to the packaging and labelling of explosives;

d) characteristics and types of explosives;

e) the advantages and limitations of various initiation systems available;

f) blast calculations and design;

g) production of plans and method statements, their application and amendment;

h) effects of explosives and their applications, including throw, fragmentation, ejection of material, vibration and air over-pressure;

i) shotfiring (see annex A).

Annex E (informative)

General properties of explosives

The strength of an explosive is its energy content and this gives an indication of its potential to do work.

The power of an explosive is the rate at which it can do work and this is effectively the speed at which the energy content is delivered.

The potential energy of a high explosive is released by detonation, an extremely rapid process whereby the explosive is converted to gases by the passage of a detonation wave. The speed of travel of this detonation wave is the velocity of detonation; that is the speed at which the conversion of potential energy takes place.

The detonation pressure of a high explosive is the force per unit area exerted on surrounding matter by the passage of a detonation wave. This pressure is related by a scaling factor to the square of the velocity of detonation and the density of the explosive through which the detonation wave travels.

The sensitivity to initiation of an explosive is an indication of the amount of energy which has to be provided in order to achieve the required initiation. This is normally a relatively small charge called a detonator which converts a given signal or flame front into a detonation wave. If the main charge is sensitive to this detonation wave, initiation of the main charge takes place. The main charge would be referred to as “detonator sensitive”, that is, capable of being initiated by a Number 8 detonator. Not all explosives can be initiated in the foregoing way. Some main charges have a lower sensitivity and require a larger impulse than that which can be provided by a detonator. The additional impulse is provided by the introduction of a “booster” or “primer” where the function is to pick up the detonation wave from the detonator and increase the energy available by consumption of the primer. The new level of energy now released is (by correct selection of size and type of primer) sufficient to cause initiation of the main charge.

Annex F (informative)

Competent engineer in charge of demolition work

The engineer in charge should be of chartered status. A chartered engineer is a person who has obtained the relevant academic qualifications and passed the Institution examinations and interviews so that they have achieved full membership of either the Institution of Structural Engineers (MIStructE) or the Institution of Civil Engineers (MICE).

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[2] The Coal and Other Safety-Lamp Mines (Explosives) Regulations 1993 SI No. 0208. London, The Stationery Office.

[3] The Construction (Design and Management) Regulations 1994 SI No. 3140. London, The Stationery Office.

NOTE The above Regulations are commonly referred to as the CDM Regulations.

[4] The Management of Health and Safety at Work Regulations 1992. London, The Stationery Office.

[5] Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995 SI No. 3163. London, The Stationery Office.

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[6] The Health and Safety (Safety Signs and Signals) Regulations 1996 SI No. 0341. London, The Stationery Office.

[7] The Control of Explosives Regulations 1991 SI No. 1531. London, The Stationery Office.

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[10] The Carriage of Explosives by Road Regulations 1996 SI No. 1996. London, The Stationery Office.

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[20] Managing construction for health and safety: Construction (Design and Management) Regulations 1994: Approved Code of Practice L54[1)]

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1) Available from: HSE Books PO Box 1999 Sudbury Suffolk CO10 6FS. Tel. 01787 881165.

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