GUIDANCE ON OCCUPIED BUILDINGS ON LICENSED EXPLOSIVES SITES
July 2013

Centre Point
103 New Oxford Street
London, WC1A 1DU
http://www.eig.org.uk

FOREWORD

This guide has been produced by the Explosives Industry Group (EIG) of the Confederation of British Industry (CBI), in cooperation with the Health & Safety Executive, on behalf of the explosives industry. The EIG/CBI is comprised of representatives from the explosives sector, fireworks companies, pyrotechnic companies, defence sector companies, storage and transport companies and the Ministry of Defence.

This guide will assist those who manage explosives sites, licensed by the HSE under the Manufacture and Storage of Explosives Regulations (MSER) 2005[1](as amended), if they need to justify that it is acceptable, for persons not directly involved in explosives operations, to ***occupy a non-explosives*** building that is inside the Inhabited Building Distance (IBD) of a Potential Explosion Site (PES). Such justification will require demonstration that an equivalent level of safety is provided for those people, to that which would be achieved by the application of the relevant Separation Distance.

This guide describes accepted practice within the explosives industry. By following the guidance, persons would normally be compliant with their legal duties. HSE and the explosives industry may refer to this guidance as illustrating good practice.

Nothing in this guide should be read as setting a higher standard than that required by legislation.

Whilst every effort has been made to cover appropriate legislation and relevant industry practice at the time of publication of this guide, neither the EIG/CBI nor its servants or agents can accept responsibility for, or liabilities incurred directly or indirectly as a result of, any errors or omissions within this document. Those persons involved in the explosives industry are responsible for taking their own legal and other advice as they see fit. Readers are strongly advised to check for any changes in legislation since the publication of this guide.

Nor do the EIG/CBI, its servants and agents make any representation expressed or implied that the products and product ranges or the processes, equipment or materials referred to in this guide are suitable, satisfactory or appropriate for the purpose or purported purposes set out or referred to in this guide and the EIG/CBI, its servants and agents accept no responsibility or liability therefore.

CONTENTS

SECTION 1 AIM AND SCOPE

1.1 Relevance of this guidance

The guidance has been developed for use by people familiar with the process for applying for, and administering, Explosives Sites Licences issued by the Health and Safety Executive, Explosives Inspectorate under the MSER[1]. It assumes:

- That the reader is familiar with MSER
- A broad knowledge of health and safety at work legislation. Note that simply following this Guide will not fulfil all your obligations arising from other legislation.

The guide specifically addresses the occupancy of buildings, within the Inhabited Building Distance (IBD) of a Potential Explosion Site (PES), by people not directly involved in explosives operations.

Note Separation distances are measured from the outside edge of the building / place where explosives are stored to the nearest point of the building / place to which the distance applies. The distance should be measured in the horizontal plane and any traverses / mounds are to be ignored.

This guidance is:

- Relevant to sites that are licensed by the HSE under MSER

It is not appropriate**:**

- where the licensing authority is the police or local authority
- where the HSE has issued a fixed rule licence subject to MSER regulation 5(1) and Schedule 2
- where relevant HSE Separation Distances can be achieved
- to the occupancy of control rooms for remote explosives manufacture operations (see CBI Requirements for Remote Explosives Manufacturing Facilities)
- to distances required for disposal operations (see CBI Guidance for the Safe Management of the Disposal of Explosives).

1.2 Intent of this guidance

This guidance will be of value to:

- Licensees, where the siting of occupied buildings cannot be achieved through the use of relevant Separation Distances
- Inspectors in assessing the suitability for the location of an occupied building and the feasibility for licensing.

Application of relevant MSER[1] Separation Distances provides a level of safety. Legislation allows for buildings to be sited and licensed inside the relevant Separation Distance where an equivalent level of safety can be achieved by other

means. The document aims to enable a consistent approach to the justification of those other means.

1.3 Scope of this guidance

The guidance:

- Discusses the rationale behind limiting occupation close to hazardous installations (Section 2)
- Explains that the onus is on a Company to demonstrate that occupancy of a building within IBD, by people not directly involved in explosives operations, is essential (Section 3)
- Discusses who may have a justifiable reason to be within Inhabited Building Distance (Section 4)
- Discusses the steps that may be taken to minimise the hazards (Section 5)
- Suggests how, if required, a Licensee may demonstrate that occupancy of building inside IBD is acceptable (Section 6).

The placing and occupation of temporary structures in support of construction activities is not overtly addressed, however the same principles apply.

The guidance does not address the control of people working in the open / outside maintaining the explosives estates / infrastructure

1.4 Consistency of approach with the Inspector

Following this guidance should enable a structured approach for assessment of the location of buildings used for occupation by people not directly involved in the manufacture, storage and testing of explosive materials.

Early engagement with the Inspector is strongly recommended where a Licensee believes an occupied building is required inside relevant Separation Distances. Early discussion will ensure any necessary assessment and acceptance criteria are agreed, ensuring time and money are spent to best effect; also when and how further interaction is to take place should be agreed.

Arguments that rely on numbers from risk assessments, i.e. those based on claiming a reduced frequency and/or reduced exposure rates, are unlikely to find favour with the Inspector, unless they are based on the risk of an event per operation (not per annum).

The location and occupation of a new building or major refurbishment may require higher standards to be met, compared with an existing building. Early engagement with the Inspector is recommended where a Licensee is designing a new building or a major refurbishment.

SECTION 2 INTRODUCTION

2.1 Associated incidents

There are numerous incidents where people who were not directly involved in an explosives operation or other hazardous operation have been killed or harmed by those operations:

- On April 17th 2013 a factory, that used ammonium nitrate in fertilizer production, exploded causing 14 fatalities, injury to more than 200 people and significant damage to the near by town of West, in Texas USA.
- On September 21st 2001 a huge explosion destroyed the AZF fertilizer plant at Toulouse, France. That explosion killed 30 people, injured around 3000 others and damaged thousands of buildings around the plant, including schools, hospitals and domestic properties. The high casualty figures were partly due to the "spontaneous" nature of the incident, there having been no preceding fire before the explosion and thus no opportunity to evacuate the site and the surrounding area. Amongst those killed was a pupil at a school 250 yards from the site.
- On July 11th 2011 the head of the Cyprus Navy was among 13 people killed when containers of mainly HT3 propellant exploded at the main naval base. A further 62 people were injured and the island's largest power station was damaged, resulting in widespread power cuts.
- On March 11th 2008 an explosion, in the dynamite mixing line at Austin Powder's St Lambrecht factory in Austria, caused significant building damage in the surrounding area. The explosion shattered windows in surrounding buildings and considerable debris was thrown around an office located 240m from the explosion site (see example in Annex A).

  The factory reopened in April 2013 after a rebuild costing 6 million Euros. Of the 130 people who worked there before the explosion, 50 lost their jobs.

- On December 11th 2005 a series of explosions occurred at the Hertfordshire (Buncefield) Oil Storage Terminal causing 43 injuries. The first and largest explosion occurred at 06:01; there were reports that it was heard up to 125 miles (200 km) away. Several nearby office blocks were hit so badly that almost every window, front and back, was blown in as the explosion ripped through them.

  During the working day, those offices would have been full of people, and many deaths may have resulted. Claimants, including local small businesses and about 280 families whose properties were damaged or destroyed, claimed £1 billion in damages.

- On March 23rd 2005 a fire and explosion occurred at BP's Texas City Refinery killing 15 and injuring more than 170. A vapour cloud, created when a raffinate splitter overflowed with liquid, was ignited by a contractor's pickup truck as the engine was left running. All of the fatalities occurred in and around temporary contractor accommodation that was as close as 121 feet (37m) from the release.

For further reading on this issue see “Failure to Learn” by Professor Andrew Hopkins.

2.2 Background

People, property and other explosives are primarily protected against the consequences of a fire or an explosion by distance. The simple principle being that the larger the quantity of explosives, the larger the separation distance necessary to give a defined level of safety.

A number of separation distance tables and formulae, that take into account the Quantity Distance (QD) relationship, have been developed (using information collected from trials data, accidental explosions, and wartime bombing zones). Application of the tables and formulae has enabled designers to site buildings and infrastructure such that explosives, people and property, are separated so as:

- To prevent the instantaneous propagation of explosion/fire from building to building, and
- To provide explosives workers with a reasonable degree of protection against fatal injury in the event of an explosion elsewhere on site
- To provide others with a very high level of protection against fatal or serious injury in the event of an explosion on site

Where the distances between buildings, roads, footpaths etc. are already established, the tables / formulae are used to calculate the maximum quantity of explosives that can be stored or processed at a Potential Explosion Site (PES) without exceeding the levels of harm at the defined distances. In practice the maximum quantity will be dependent on:

- The distance between the PES and the nearest Exposed Site (ES), i.e. the nearest building, traffic route or public place to the PES, and
- The Hazard Division / Hazard Type of the explosives at the PES, and
- The construction (design type) of the PES, and
- The construction (design type), occupancy and activity at the ES.

Aligning to the separation distance principle, when HSE grants a licence, it applies the “External Separation Distances” given in the relevant look-up table in MSER ACoP [2] Annex 3 (i.e. the distances applicable for the Hazard Type and PES building design type). Note that these distances are consistent with those given in Schedule 2 of the Regulations (Para 395).

Within the look-up tables is the minimum distance to be maintained between explosives and any “building” used for accommodation or for work (as required by MSER Regulation 5). HSE Explosives Site Licences show this distance as the Class D Distance, within industry it is generally referred to as the Inhabited Building Distance (IBD);

2.3 Protection provided by IBD

The protection provided at IBD is judged to be acceptable, for example, in the event of an ignition of Hazard Type 1 (HT1) explosives, at IBD:

- People in the open would not suffer direct injury from the blast itself [5]
- The density of potential lethal debris[6] would be of the order of one per 56m^2
- Serious structural damage by flame, blast, or projectiles to ordinary types of inhabited buildings is unlikely.

IBD does not guarantee absolute safety; it is the distance at which the risk to an individual is deemed to be “broadly acceptable”. This is based on the risk of fatal injury, should an ignition of HT1 explosives occur, being no greater than 1 in 100, combined with the probability of an explosion occurring being no greater than 10^{-4} per annum.

SECTION 3 DEFINITION OF AN OCCUPIED BUILDING

3.1 What is an occupied building?

For the purposes of this guide an occupied building is: "A non explosives building in which people are present who are not directly involved in the explosives operations". Note that the meaning of "present" has not been strictly defined; the onus is on each Company to consider and to be able to demonstrate that an individual's presence in the building is essential.

Generally where presence within a building can be shown to be transient, that building may be considered to be unoccupied. Examples of unoccupied buildings are toilets, changing rooms, switch-rooms and stores (where a storekeeper is not resident).

Note: Several interpretations of unoccupied have been acknowledged; for example, a building where no people are present for more than 90% of the day (shift) has been accepted as unoccupied.

Generally where presence within a building is non-transient in nature, that building should be considered to be occupied. Examples of occupied buildings are offices, access control points, rooms where lunch breaks are taken, rooms where people congregate for meetings and stores (where the storekeeper spends a significant part of the working day).

3.2 Monitoring occupied buildings

The Terms of Licence impose a continuing duty on a Company to maintain the separation distances associated with their explosives licence. In order to do this it will be necessary to define, record and periodically review the function, use and occupancy of all buildings, traffic routes and public places within the internal and external safeguarded zones.

External and internal tours / inspections should be carried out periodically (dependant on the nature / extent of the site) in order to confirm that unplanned changes of occupancy etc. have not occurred.

SECTION 4 NATURE OF WORK AND PROTECTION OF WORKERS

4.1 Expected application of separation distances to occupied buildings

Occupied buildings should, wherever it is reasonably practicable, be at or beyond full IBD, so as to provide the occupants with a broadly acceptable level of safety. MSER requires that any non-explosives building that is within ½ IBD from the nearest PES is **not** occupied (as defined in paragraph 27).

MSER requires any non-explosives building, that is not under the control of the applicant, to be at or beyond the "building" distance (IBD) defined in Annex 3 Tables 3 to 8 (inclusive) from the nearest PES.

MSER permits occupancy of a non-explosives building within the "building" distance (IBD) defined in Annex 3 Tables 3 to 8 (inclusive) providing that:

- The building has not more than one storey, suitable for occupation, above ground, and
- The building is not occupied by more than 20 people, and
- Those people are under the control of the Licensee.

4.2 Protecting people, the separation distance principle

The minimum number of people should be exposed to the minimum amount of explosives for the minimum time. To this aim:

- People who do not need to be exposed to the explosives hazard are to be afforded the level of protection provided by IBD. This group includes members of the public, staff not directly involved in explosives operations and, where a site is shared, staff of the Company that is not the Licensee
- People with a justified reason to be within IBD:
- who are not directly engaged in an explosives activity, are expected to be at or beyond ½ IBD
- who are directly engaged in an explosives activity, are expected to move to at least Process Building Distance (PBD) when practicable.

Those who manage and work within explosives areas should be vigilant in maintaining the principle that "people not directly involved in an explosives operation should not be at risk from those explosives". Whilst it is acknowledged that there will be occasions when their duties require justified staff to stay within an explosives area, they should, for example, be discouraged from arranging meetings that involve bringing people into buildings within IBD.

4.3 Who has a justifiable reason to be within IBD?

Justifying presence within IBD should be determined on a case by case basis and should be dependant upon the individual being:

- An Explosives Worker, Explosives Support Worker or Justified Worker and

- Required to spend the majority of his/her time directly engaged in explosives work or essential explosives area support activities, and/or
- The first line manager / supervisor of an Explosives Worker or Explosives Support Worker.

Additional line management may be justified, so that they may be co-located with their operational teams. In such situations, the safety and/or operational requirement should be clearly demonstrated.

Other personnel may be justified, where their activities can be demonstrated to directly support explosives operations and cannot reasonably be carried out elsewhere.

Example: one Company defines “Justified Workers” as:

- Production staff who spend at least 70% of their contracted hours working with explosives materials, or
- Research staff who spend at least 70% of their contracted hours characterising explosives and non-explosives materials, utilising a unique facility necessarily located within an Explosives Area.

4.4 Behaviour of people justified to be within IBD

People justified to be within IBD are expected to keep away from the hazard whenever possible. In practice this means that when not involved in a task that requires them to be closer, they will move to at least the Process Building Distance (PBD). They should not undertake activities within IBD that could reasonably be undertaken outside IBD.

Due to the nature of Explosives Sites, distances between buildings are frequently large. When the site was constructed it may not have been considered reasonably practicable for workers to change their clothes, take breaks, complete documentation, and enter data at a location remote from the PES where they would undertake their main task. In such cases facilities such as offices; break areas; toilet facilities; etc. may have been provided adjacent to the PES.

In reaching a judgement as to whether continuing to use of an Exposed Site remains appropriate consider the following:

- Can the protection afforded there reasonably be enhanced by mitigating measures?
- Could work on the explosives within the PES and adjacent PES stop whilst the facility is occupied?
- What are the implications of delaying the activity undertaken at the amenity?
- Is the number of people at risk the minimum necessary?
- How many additional people would need to be employed, and placed at risk, to compensate for the reduction in an individual’s effective working hours if the amenity was moved to beyond IBD?

- If people are exposed to risk from other explosives stores / processes whilst moving to beyond IBD, would they be effectively safer by staying within the facility?

SECTION 5 STEPS THAT CAN BE TAKEN TO MINIMISE THE HAZARD

5.1 New Build

For new sites and new buildings there is a clear expectation that people not directly involved in an explosives activity should be afforded the protection provided by full IBD. Where this cannot be achieved, glazing should be enhanced (see paragraph 49) and/or a technical justification will be needed to indicate how an equivalent level of protection has been achieved. Advice on how this justification could be prepared will be found in HSE EIG Specialised Industry Report - Use of Structural Justification to Underpin an HSE Explosives Licence [3].

5.2 Existing Sites

Where constraints, such as the size of the site, make meeting published separation distances a challenge, HSE has the discretion to approve a reduced IBD providing other hazard reduction measures are taken that ensure an equivalent level of safety. The application of hazard reduction measures should follow the hierarchy:

1. Move people to beyond IBD
2. Reduce the hazard at the Potential Explosion Site
3. Harden the Exposed Site
4. Justify occupation within IBD (see paragraph 44 and Section 6)

5.3 Move people to beyond IBD

Affording people the level of protection provided by IBD should always be the goal, it may be achieved in a number of ways:

- Move people out of ES to alternative accommodation at or beyond IBD
- Move the process to another PES that offers at least IBD protection
- De-conflict activities so that ES is unoccupied when the explosives process is running.

5.4 Reducing the hazard at the Potential Explosion Site

Hazard reduction can be achieved in a number of ways:

- Redesign the process to reduce the quantities of explosives to a level that achieves IBD protection at the ES
- Unitise the building, using suitable internal partitions that prohibit sympathetic communication of explosion within the building; thus separation distance may be based on the maximum credible event, not total building inventory
- Modify the building structure to contain the effects of blast, heat and fragments or direct harmful effect into a sanitized area
- Use blast suppression technology (e.g. water barriers) to reduce the hazard.

Notes Other separation criteria will apply (e.g. minimum fire protection and security distance, distance to tall structures, etc.)

Where claims are made on the engineered measures at the structure (PES or ES) the Inspector will expect on-going assessment and maintenance to substantiate that the claim remains valid.

5.5 Harden the Exposed Site

The ES may be hardened to provide the occupants with at least the same level of safety as that offered by full IBD protection. Hardening might be achieved in a number of ways:

- Erect an interceptor barrier around the building; note that this would protect against fragments but not against blast
- Install a higher standard of glazing so that the “low hazard threshold” (see Annex A) would not be exceeded in the event of an explosion at the PES (see below)
- Brick-up windows that are in the direct line of site of the PES.

5.6 Glazing arrangements to meet the Low Hazard Threshold

At an Exposed Site that is between ½ IBD and full IBD, the glazing / windows will meet the low hazard threshold providing that they comply with the standard below:

1. The Exposed Site must be of a construction type that is capable of withstanding the blast overpressure.
2. If the explosives at the PES present a fragment and/or debris hazard (i.e. HT1 and HT2), those windows at the ES that face the PES should be effectively protected against fragments and debris.
3. Window frames (including structural supports), mullions, fittings and fixings should be constructed of strong and ductile materials (e.g. mild steel, hot rolled high yield steel, or appropriate grades of aluminium) using ‘plastic’ sections (e.g. box sections) able to maintain moment capacity after yielding. Other materials and/or sections will be acceptable if their response has been proved by an approved explosive test.
4. Windows may be single or double glazed:
    - If single glazed, 7.5mm (minimum) thick laminated security glass should be used
    - If double glazed, 6mm (minimum) thick toughened glass should be used for the outer and 7.5mm (minimum) thick laminated security glass should be used for the inner
    - Internal glazing should be 6.8mm (minimum) thick laminated glass.

Not: Annealed glass, even when backed by anti-shatter film, is not suitable.

5. Laminated glass should be fixed into deep rebates to allow membrane action to develop. Typically this means for a window where the span is:
    - Less than 0.75m the rebate should be 25mm

- Between 0.75m and 1.5m the rebate should be 35mm.

6. Laminated Glass should be bedded on both sides, and to the full depth of the rebate, with silicone or polysulphide adhesive sealants, or suitable resilient gaskets, generally in accordance with BS6262. Where gaskets are used, they should be full bed width. Care must be exercised to ensure that a sufficient positive clamping action is developed to prevent premature pull-out of the pane.

Notes Further information on windows and glazing is provided in Annex A.

Software is available that models glazing performance. Before embarking on the use of software it is advisable to confirm that it is acceptable to the HSE.

If the standard above is achieved this will satisfy the HSE Licensing Authority without further justification.

SECTION 6 JUSTIFYING OCCUPANCY WITHIN IBD

Where hierarchy steps 1, 2 and 3 (listed above) cannot be achieved / have not been taken and the Licensee believes occupation of a building inside IBD is essential, the justifying argument should be demonstrable. Such demonstration might take the following form.

6.1 Summary & Conclusion

An explanation of what is to be justified and why (i.e. why it is necessary for non-justified workers to occupy a non explosives building inside IBD). How the equivalent level of safety to that provided by Separation Distance has been achieved.

6.2 Site and building description

A description of the building layout and building construction. Typical content:

- The building use
- A description of building construction
- Plans of the site, showing:
    - the location of other explosives and non explosives buildings
    - traverses/mounding (if present) of the building in question and surrounding buildings
    - the location of explosives and non-explosives workers during explosives operations
- Plans showing building layout with cross-sections

6.3 People description

Who will be in the building?

6.4 Key issues

Why alternative locations have been deemed unsuitable and why the quantity of explosives at the PES cannot be reduced.

6.5 The justification

The applicant should provide evidence that either:

- The licensing intent will be met, i.e. the consequences, at the occupied building, of an explosion at the relevant Potential Explosion Site will be no greater than those expected at the relevant Separation Distance
- The measures taken are reasonably practicable when tested using cost benefit analysis. Guidance is provided at Appendix 3 of Reducing Risks, Protecting People – the HSE's decision making process [8].

ABBREVIATIONS

ASF	Anti Shatter Film
BBNC	Bomb Blast Net Curtains
ES	Exposed Site (acceptor/receptor building/site)
HD	Hazard Division
HT	Hazard Type
IBD	Inhabited Building Distance
NEQ	Net Explosive Quantity
PES	Potential Explosion Site (donor site/building)
PBD	Process Building Distance
QD	Quantity Distance / Separation Distance

GLOSSARY

Item	Description
Explosives Worker	An Explosives Worker is a person who is working on explosives and as such is required to be exposed to the explosives hazard. The term includes the immediate supervisors of those explosives workers with hands on contact with explosives. The term only applies: • in relation to the process they are working on, they should be afforded the appropriate protection from other areas or tasks where explosives are present • whilst the worker is conducting the explosives work. At other times the person would not be considered an Explosives Worker, but they may be an Explosives Support Worker or Justified Worker.
Explosives Support Worker	Explosives (Area/Site) Support Workers do not work directly on explosives, but their work supports the storage, packing, unpacking, loading, unloading, handling, manufacture, processing, testing, research and use of explosives. The term includes those assessing, managing and controlling explosives work; and those involved in routine inspections, maintenance and breakdown repair of supporting buildings, plant, equipment and other infrastructure of the explosives site. The term only applies to a worker whilst conducting the work requiring their presence within the area/site. At other times the person would not be considered an Explosives Support Worker, but they may a Justified Worker.
Exposed Site (ES)	A generic term for the nearest building or public traffic route to a Potential Explosion Site (PES). Note that an explosives building may be both a PES and an ES.
Justified Worker	A Justified Worker is an explosives worker, an explosives support worker, a site-based contractor (who has received the training to support that status) or their supervisor whose accommodation has been justified within IBD, i.e. • those people who are allowed to remain resident in IBD when not working on explosives or work physically supporting the infrastructure; or • additional management supporting / managing explosives operations co-located with their staff; or • people working with specialist equipment sited in an explosives area, though (the relevant) work does not involve explosives (e.g. experiments involving laboratory analysis).

Item	Description
Inhabited Building Distance (IBD)	This distance is the Class D Distance.
Potential Explosion Site (PES)	A place where explosives may be held. The nature of the hazard depends on the quantity and hazard type of the explosives.
Process Building Distance (PBD)	The minimum permissible distances between a *PES* and a process building required to protect against immediate or subsequent propagation of explosion. PBD provide a reasonable degree of protection for persons within a process building at the Exposed Site. The actual risk depends on the type of structures involved as well as the quantity of explosives at the potential explosion site. PBD do not take account of structural requirements, space for roads / access for fire fighting. These practical considerations may require greater distance or other necessary mitigation measures, such as use of appropriate glazing and films.
Quantity Distance (QD)	The distance between the explosives store or the building in which explosives are, or are to be, manufactured and a building, or other place in or at which people are or are likely to be present either all the time or from time to time. This distance is calculated based on the quantity and hazard type of explosives.
Separation Distance	This term encompasses quantity distance (above) and all other distances associated with explosives, i.e. distance from volatile / hazardous materials, distance from tall structures, distance from overhead electrical cables, minimum fire break and security distances.
Structural Engineering	The engineering that demonstrate that the protective measures provide the minimum levels of protection required to explosives and people.
Structural Justification	A document that demonstrates that an explosives facility provides the minimum levels of protection required to explosives and people.

REFERENCES / POTENTIALLY USEFUL DOCUMENTS

1. Manufacture and Storage of Explosives Regulations 2005, SI 2005/1082, The Stationery Office 2005 ISBN 0 11 072764 9.
2. Manufacture and Storage of Explosives Regulations Approved Code of Practice, Health and Safety Executive, L139, 2005, ISBN 0 7176 2816 7.
3. HSE EIG Specialised Industry Report - Use of Structural Justification to Underpin an HSE Explosives Licence
4. Manufacture and Storage of Explosives Regulations 2005 - Guide For Those Applying To The Health And Safety Executive For A Licence To Manufacture Or Store Explosives, 3rd edition, 2006
5. HSE, Controlling risks around explosives stores, review of the requirements on separation distances, HSE, 2002 (http://www.hse.gov.uk/research/misc/qdwgrep.pdf)
6. Moreton P A and Merrifield R, The debris hazard from portable steel magazines, Minutes of the Twenty-ninth Explosives Safety Seminar, New Orleans, Louisiana, US Department of Defense Explosives Safety Board, 2000.
7. Buildings and Traverses for Military Explosives, ESTC Leaflet No. 6 Part 3, Explosives Storage and Transport Committee, July 1996.
8. ESTC Standard No.5, Building and traverses for military explosives, predicted damage levels to structures, glazing hazards 2002.
9. Reducing risk, protecting people – HSE's Decision-Making Process, HSE Books 2001, ISBN 0 7176 2151 0 (free issue of the HSE Website).
10. BS EN 13541:2012 - Glass in building - Security glazing - Testing and classification of resistance against explosion pressure
11. BS EN 356:2000 - Glass in building - Security glazing - Testing and classification of resistance against manual attack
12. BS EN 1063:2000 - Glass in building - Security glazing - Testing and classification of resistance against bullet attack
13. BS EN 13123-1 - Windows, doors and shutters - Explosion resistance - Requirements and classification
14. BS EN 13124-1:2001 - Windows, doors and shutters - Explosion resistance - Test methods
15. ISO 16933, First edition 2007-07-01, Glass in building - Explosion-resistant security glazing - Test and classification for arena air-blast loading
16. ISO 16934, First edition 2007-07-01, Glass in building - Explosion-resistant security glazing - Test and classification by shock tube loading

ACKNOWLEDGEMENTS

The HSE / CBI Explosives Industry Group partnership working together through the Explosives Industry Forum wish to gratefully acknowledge the following for their valuable efforts made in the preparation and production of this guidance:

HM Explosives Inspectorate of HSE
Ministry of Defence
AWE plc
BAE Systems Munitions Weapon Systems & Support
Black Cat Fireworks
British Fireworks Association
CarnDu Ltd
Chemring Countermeasures Ltd
Chemring Energetics UK
Fireworks World Ltd
Haliburton Ltd
OnePoint4 Ltd
QinetiQ Ltd
Roxel (UK Rocket Motors) Ltd

ANNEX A WINDOWS AND GLAZING

At an Exposed Site (ES) the windows will almost certainly be the weakest components. During an explosion, plain glass typically breaks into “knives and daggers” and will be responsible for most of the injuries. Thus enhancing the glazing within windows is an obvious way to limit the effects of an explosion. Note that it is important, however, to remain aware that glazing that resists a blast load will transmit that load to the window frame and in turn to the main building structure, so these will need to be sufficiently robust in order to provide adequate protection.

Levels of enhancement

There are three common options for enhancing glazing to improve its blast resistance and reduce potential hazards:

1. The use of Anti-Shatter Film (ASF) and Bomb Blast Net Curtains (BBNC)
2. Laminated Glass
3. Blast Resistant Glazing in Blast Enhanced Frames.

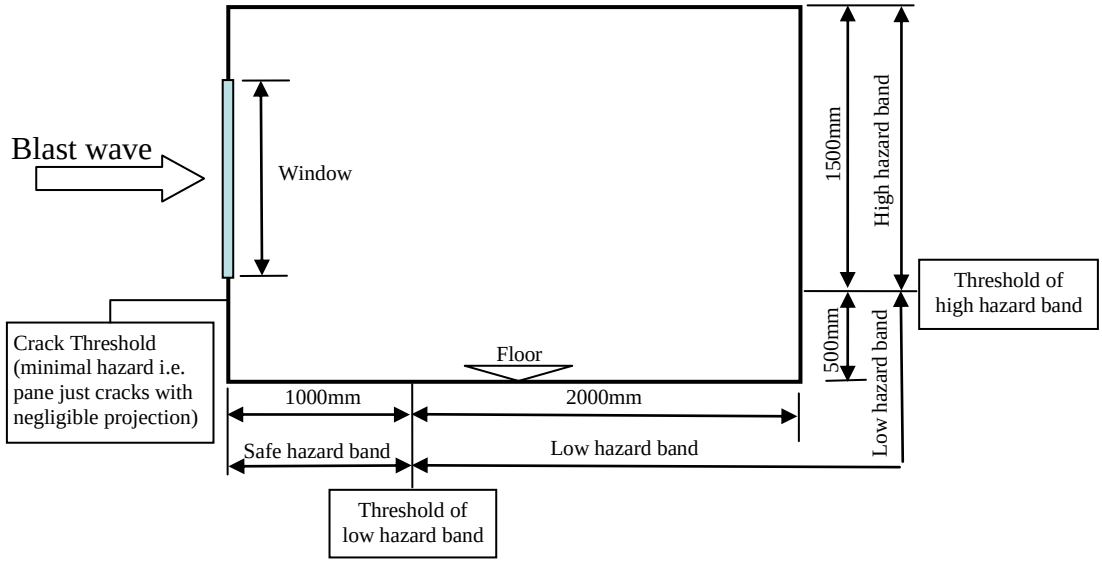
Upgraded glazing should be tested against recognised standards; windows should be properly designed and installed by competent professionals. Pane sizes should be limited; sizes larger than $3m^2$ are not recommended.

Categorising the hazard from glazing

The hazard from glazing that will be experienced from an explosion at the nearest Potential Explosion Site (PES) may be categorised as:

- **Cracks** – The distance at which the pane just cracks. If it is plain glass, then it may fall outside or into the room, but with no projection of fragments inwards. If the pane is laminated glass it should remain securely in place and the hazard will be classed as **Minimal Hazards**, i.e. the crazed pane is retained, is not significantly torn or pulled away from its rebates and fragment dust inside is minimal. Where the glazing or fragments fall within 1m inside, the hazard will be classed as **Very Low Hazard**
- **Low Hazard Threshold** – The distance at which glazing fragments or whole panes reach 1m into the room
- **High Hazard Threshold** – The distance at which any fragments or whole panes hit the back wall of a 3m deep room at a height of 0.5m above the floor. If the glazing is fully fixed laminated glass (deep rebate with sealant bonding), it is predicted to remain securely in place at the High Hazard Threshold, but is at risk of becoming highly hazardous at any closer stand-off or higher charge weight.

Threshold	Effect
Crack	No projection of fragments inward
Low Hazard	Fragments may fall more than 1 metre in to the room
High Hazard	Glazing fragments and debris may project more than 3 metres in to the room



An example of the addition protection provided by enhanced glazing

Within the main text, there is a summary of an incident at Austin Powder's factory in Austria. There were, in fact, two explosions, occurring about a second apart, the more powerful involving 1575kg of dynamite.

The upper photograph shows the effect on a normal window in the main office which was located at 240m from the explosion site. The main office suffered no serious structural damage, though considerable debris was scattered inside the building.

The lower photograph shows the effect on an enhanced window in a smaller office located at 150m from the explosion site. The smaller office sustained much less damage, the inner pane of glass in the window was shattered but remained in place.

Reproduced by kind permission of Austin Powder

Glazing Options

Normal 4mm annealed glass shatters when subjected to a relatively low level of blast loading to produce shards. Injuries can be reduced by:

- The application of anti-shatter film (ASF) to the inside surface of glazing
- Glazing / re-glazing with toughened or laminated glass
- Fitting blast enhanced double / secondary glazing
- Hanging bomb blast net curtains on the inside face of windows (should only be used in conjunction with ASF)
- Bricking up those windows in the direct line of site of the PES.

Plain glass (also referred to as annealed glass) is relatively weak; it has no ductility and produces hazardous fragments. It should not be used in new constructions and major refurbishments within IBD. Where it exists within IBD Anti-Shatter Film should be applied as a minimum.

Double glazing is generally less hazardous than single glazing. An effective arrangement is 7.5 mm laminated inner pane and 6 mm toughened outer pain. The outer pane will a) withstand knocks and impacts received in normal use without cracking and b) shatter but attenuate blast pressures when blast loads are high. The inner pane will a) play the major part in absorbing the blast energy and b) help retain fragments.

Toughened or tempered glass is annealed glass that has been subjected to heat treatment or chemical strengthening to increase tensile strength. It:

- Is typically 3 to 5 times stronger than plain glass, having greater resistance to knocks and impacts during normal service
- Can resist high blast pressure if supported well but when it shatters it produces many small cubical fragments
- Produces fragments that cause less bodily injury than the fragments from plain glass
- Has no ductility and can therefore absorb no blast energy after initial cracking
- Must be made to size, i.e. cannot be cut to shape on site.

Anti-Shatter Film (ASF) is considered inappropriate for new construction or major refurbishment as it does not give comparable protection to laminated glass.

ASF is usually manufactured from polyester based materials; it can be applied to the inside surface of plain and toughened glass (not patterned or frosted glass) to limit fragments and splinters. It should:

- Be a minimum of 175µm thick and compliant with BS6206 Class A or BS EN 12600 Class 1 (B)
- Be applied in clean dust free conditions and replaced every 10 to 15 years
- If applied to new glazing, fold over the edges of the pane

- When applied to internal glazing, be fitted to the least vulnerable side of all plain glass i.e. the side remote from the most likely blast source
- If used on secondary glazing (where the inner frame can be opened independently) applied to both panes.

Very small panes (e.g. 300mm across) in wood framed windows may be fitted with ASF and backed with Bomb Blast Net Curtains (BBNC). When this is done the thickness of the ASF may be reduced to 100µm. Such film should be certificated to pass BS6206 Class 'B' or BS EN 12600 Class 2 (B).

Although most currently available ASF carries a 10 year manufacturer's warranty if installed by an approved installer over time it loses strength and becomes brittle. Other problems can include lose of adhesion, bubbles, cloudiness, cuts, scratches, abrasions and de-lamination at the edges. Very old films may also only be 50 microns thick. A survey to assess existing films suitability, and to estimate the remaining life expectancy, should be carried out by an approved contractor or other experienced advisors.

Bomb Blast Net Curtains (BBNC) is recommended for very small panes (e.g. 300mm across) in wood framed windows. BBNC should be constructed:

- From plain white warp kitted polyester net to BS 4407; flame retardant to meet BS5867 Part 2 Type C and with minimum burst strength of 550kN/m^2
- Having stitching and seaming made from continuous filament polyester (ticket No. 70 - 120 [BS 6157])
- With a slotted heading able to take a 16mm diameter polished aluminum tube - held with thimble type brackets (e.g. C & T No. 543 or 544)
- With a continuous hem tape of lead weighted at 400g per metre of curtain width.

There must be at least 2 metres of BBNC for each metre of curtain rod.

Laminated “security / safety” glass is the preferred choice for new build or replacement of single glazing panes where the building may be subjected to overpressure.

Laminated glass is produced by reinforcing plain glass with layers of polyvinyl butryal (PVB), it has excellent resistance to blast pressure as the inclusion of the PVB layer(s) gives the glazing ductility and the ability to absorb blast energy by catenary or membrane action:

- When failure occurs much of the glass remains adhered to the PVB layer
- Commercially available options offer additional benefits such as acoustic, reflective and anti-glare properties
- It requires support in robust frames with deep rebates with special seals to develop the full strength of the glazing

Where laminated glass is fitted:

- Single glazed windows should be fitted with not less than 7.5mm laminated glass

- Double glazed units should be fitted with not less than 7.5mm laminated glass inner and a 6mm toughened or laminated glass outer pane
- Further slight improvements in safety may be achieved for laminated glass by selective strengthening of the glazing assembly; e.g. by adding fixing screws to beading and/or frame.

Laminated Toughened Glass combines the high strength of toughened glass with the quality of safety laminated glass. Toughened laminates less than 9.5mm thick are not recommended. Additionally when they crack in normal use, crazing spreads quickly through the pane.

Polycarbonate should normally be avoided as it degrades over time and the fragments it produces are difficult to detect within the human body. If it is considered for use as secondary glazing it will need to be well secured in deeply rebated robust frames in order to counter the high flexibility of the material. Specialist advice should be sought.

Georgian Wired Glass includes a steel mesh layer provides added fire resistance but weakens the pain reducing blast resistant. Both glass and metal fragments (shards with protruding wire) are produced. Its use should be avoided where possible.

The Explosives Industry Group of the CBI publishes a number of guides for businesses that manufacture, store, transport and use explosives in the UK. For more information about becoming a member of EIG and for access to other guides please visit the EIG website.

http://www.eig.org.uk