A guide on measures other than personal protective equipment to protect people in explosives working areas

NOVEMBER 2003
PROTECTIVE MEASURES

A guide on measures other than personal protective equipment to protect people in explosives working areas

November 2003

© CBI
Centre Point
103 New Oxford Street
London WC1A 1DU

ISBN 0 85201 572 0

CBI Members £5.00
Non-members £11.00
<table>
<thead>
<tr>
<th>CONTENTS</th>
<th>Page No</th>
</tr>
</thead>
<tbody>
<tr>
<td>SECTION 1 ................ Foreword</td>
<td>4</td>
</tr>
<tr>
<td>SECTION 2 ................ Definitions</td>
<td>5</td>
</tr>
<tr>
<td>SECTION 3 ................ Abbreviations</td>
<td>7</td>
</tr>
<tr>
<td>SECTION 4 ................ Introduction to Protective Measures</td>
<td>8</td>
</tr>
<tr>
<td>SECTION 5 ................ Relevant legislation</td>
<td>10</td>
</tr>
<tr>
<td>SECTION 6 ................ Health and Safety Management Systems</td>
<td>18</td>
</tr>
<tr>
<td>6.1 Legal requirements for Risk Assessments</td>
<td>19</td>
</tr>
<tr>
<td>6.1.1 General principles of Risk Assessment as required by the Management of Health and Safety at Work Regulations 1999</td>
<td>19</td>
</tr>
<tr>
<td>6.1.2 Risk Assessment requirements of other sets of Regulations</td>
<td>22</td>
</tr>
<tr>
<td>6.2 The Five Steps Approach to Risk Assessment</td>
<td>23</td>
</tr>
<tr>
<td>6.3 General principles of hazard identification</td>
<td>25</td>
</tr>
<tr>
<td>6.4 Activities which may generate hazards</td>
<td>25</td>
</tr>
<tr>
<td>6.5 The hierarchical approach to control measures</td>
<td>27</td>
</tr>
<tr>
<td>6.5.1 Elimination</td>
<td>28</td>
</tr>
<tr>
<td>6.5.2 Substitution</td>
<td>28</td>
</tr>
<tr>
<td>6.5.3 Reduction</td>
<td>28</td>
</tr>
<tr>
<td>6.5.4 Isolation</td>
<td>29</td>
</tr>
<tr>
<td>6.5.5 Engineering controls</td>
<td>29</td>
</tr>
<tr>
<td>6.5.6 Safe systems of work</td>
<td>30</td>
</tr>
<tr>
<td>SECTION 7 ............... Human factors, including ergonomic</td>
<td>33</td>
</tr>
<tr>
<td>7.1 Organisational Factors</td>
<td>33</td>
</tr>
<tr>
<td>7.2 Job Factors</td>
<td>33</td>
</tr>
<tr>
<td>7.3 Personal Factors</td>
<td>34</td>
</tr>
<tr>
<td>SECTION 8 ............... Acknowledgements</td>
<td>35</td>
</tr>
<tr>
<td>ANNEX 1: ................ Information on guidance and British and harmonised European Standards</td>
<td>36</td>
</tr>
<tr>
<td>ANNEX 2: ................ Risk assessment examples</td>
<td>44</td>
</tr>
<tr>
<td>ANNEX 3: ................ Hazard identification checklist</td>
<td>59</td>
</tr>
</tbody>
</table>
SECTION 1. FOREWORD

This Guide has been produced by a joint working party of the Explosives Industry Group of the Confederation of British Industry, including the Ministry of Defence, and the Health and Safety Executive.

This document has been prepared to provide guidance on protective measures for explosives working areas. The terminology used in this Guide is defined within Section 2 and relates to this Guide only. Information on current legislation and advice on good practice are included.

Whilst every effort has been made to cover appropriate legislation, regulations and good practice when this Guide went to print, neither the CBI nor its servants or agents can accept responsibility for, or liabilities incurred directly or indirectly as a result of, any errors or omissions in this Guide. Those 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 whether there is any change in legislation or regulation since the publication of this Guide.

Nor do the 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 CBI, its servants and agents accept no responsibility or liability therefor.
SECTION 2. DEFINITIONS

The definitions given below relate only to terms as used in the context of this Guide.

Accident: An event involving death, major injury, minor injury, material damage, or environmental damage.

Dangerous Materials: Articles or substances which are capable of posing a significant risk to health, safety, property or other material.

Deflagration: A reaction of combustion through a substance at a sub-sonic velocity.

Detonation: A reaction which moves at a supersonic velocity in the explosive material.

Engineering Controls: Physical controls and procedures intended to protect personnel (an element within protective measures).

Explosion: A chemical or physical process leading to the sudden release of energy (and usually gases) giving rise to external pressure waves and in some cases fire, blast and flying debris.

Explosives Working Area: An area (room, building or open area) where work involving explosive articles/substances takes place.

Hazard: Something with the potential to cause harm (this can include articles, substances, plant or machines, methods of work, the working environment and other aspects of work organisation).

Hazard Analysis: The process by which hazards are identified and assessed with the aim of their elimination or minimisation.

Manufacture: The process of creating substances/articles by physical labour or machinery (in the particular context of UK explosives legislation this also includes dismantling).

Product: Any goods or components, which constitute a finished article. Whilst not part of the product, packaging, instructions and warnings are taken into account in determining its overall safety.
<table>
<thead>
<tr>
<th><strong>Protective Measures:</strong></th>
<th>Measures other than personal protective equipment to protect people in explosives working areas.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Risk:</strong></td>
<td>The likelihood of potential harm from a particular hazard being realised. The extent of the risk will depend on:</td>
</tr>
<tr>
<td></td>
<td>i) the likelihood of that harm occurring;</td>
</tr>
<tr>
<td></td>
<td>ii) the potential severity of that harm, i.e. of any resultant injury or adverse health effect; and</td>
</tr>
<tr>
<td></td>
<td>iii) the population which might be affected by the hazard, i.e. the number of people who might be exposed*1.</td>
</tr>
<tr>
<td><strong>Safety:</strong></td>
<td>Freedom from those conditions that can lead to an accident.</td>
</tr>
<tr>
<td><strong>Sensitiveness:</strong></td>
<td>A measure of the relative probability of an explosive being ignited or initiated by a prescribed stimulus.</td>
</tr>
<tr>
<td><strong>Severity:</strong></td>
<td>An assessment of the credible accident that could be caused by a specified hazard.</td>
</tr>
</tbody>
</table>

* Figures refer to references in Annex 14
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACOP</td>
<td>Approved Code of Practice</td>
</tr>
<tr>
<td>ALARP</td>
<td>As low as reasonably practicable</td>
</tr>
<tr>
<td>CAWR</td>
<td>Control of Asbestos at Work Regulations 2002</td>
</tr>
<tr>
<td>CBI</td>
<td>Confederation of British Industry</td>
</tr>
<tr>
<td>CLAW</td>
<td>Control of Lead at Work Regulations 2002</td>
</tr>
<tr>
<td>COMAH</td>
<td>Control of Major Accident Hazards Regulations 1999</td>
</tr>
<tr>
<td>COSHH</td>
<td>Control of Substances Hazardous to Health Regulations 2002</td>
</tr>
<tr>
<td>DSEAR</td>
<td>Dangerous Substances and Explosive Atmospheres Regulations 2002</td>
</tr>
<tr>
<td>EA 1875</td>
<td>Explosives Act 1875</td>
</tr>
<tr>
<td>EC</td>
<td>European Community</td>
</tr>
<tr>
<td>EED</td>
<td>Electro explosive device</td>
</tr>
<tr>
<td>EMC</td>
<td>Electromagnetic compatibility</td>
</tr>
<tr>
<td>HSE</td>
<td>Health and Safety Executive</td>
</tr>
<tr>
<td>HSWA</td>
<td>Health and Safety at Work etc. Act 1974</td>
</tr>
<tr>
<td>LEV</td>
<td>Local exhaust ventilation</td>
</tr>
<tr>
<td>LOLER</td>
<td>Lifting Operations and Lifting Equipment Regulations 1998</td>
</tr>
<tr>
<td>MHOR</td>
<td>Manual Handling Operations Regulations 1992</td>
</tr>
<tr>
<td>MHSWR</td>
<td>Management of Health and Safety at Work Regulations 1999</td>
</tr>
<tr>
<td>MSER</td>
<td>Proposed Manufacture and Storage of Explosives Regulations</td>
</tr>
<tr>
<td>MTV</td>
<td>Magnesium Teflon Viton</td>
</tr>
<tr>
<td>NWR</td>
<td>Noise at Work Regulations 1989</td>
</tr>
<tr>
<td>PPE</td>
<td>Personal protective equipment</td>
</tr>
<tr>
<td>PUWER</td>
<td>Provision and Use of Work Equipment Regulations 1998</td>
</tr>
<tr>
<td>RF</td>
<td>Radio frequency</td>
</tr>
</tbody>
</table>
SECTION 4. INTRODUCTION TO PROTECTIVE MEASURES

The aim of this Guide

To provide guidance on protective measures for explosives working areas to safeguard the health and safety of people who may be present in such places.

A targeted guide is needed for the explosives industry because there are a number of special factors to be taken into account when approaches to hazard and risk control are being considered, namely:

i) there is often no scope for the elimination of hazard through the elimination of explosives from a work activity;

ii) the scope for substitution of an explosive by another less hazardous explosive (or less hazardous form of the same explosive) is often limited;

iii) the scope for elimination or reduction of hazard through process change can be limited for those explosives manufactured to meet stringent performance requirements or quality control standards;

iv) each assessment of each process or activity must be taken on its own merits;

v) standard equipment for engineering control of health and safety hazards can be unsuitable for use in explosives working areas without first being modified;

vi) the manufacture and storage of explosives is subject to the controls of the Explosives Act 1875 (see Section 5), some of which form part of, or interface with, certain protective measures (see Section 2 and Annex 12);

vii) there is no specific legislation dealing with engineering controls and other protective measures for the explosives industry.

Scope of this Guide

The Guide is intended to cover normal working operations and does not consider approaches required by those who have to deal with an emergency event.

This guide covers all protective measures, except the use of Personal Protective Equipment (PPE). The use of PPE is covered in a series of four guides already published.

This Guide deals with protective measures within explosives working areas rather than exterior and civil engineering measures. Hence, it does not deal directly with engineering controls in the form of building structural features (such as barrier walls or remote process control rooms) to protect against the effects of fire and explosion arising from the accidental initiation of explosives. HSE's Explosives Inspectorate has a project underway to review the provision of barrier walls and remote process...
control rooms for explosives manufacturing processes. It is expected that this project will result in the issue by HSE of guidance on the subject.

This publication does not deal with protection against radioactive materials.

The Approach Taken

The need for protective measures is identified by hazard identification and risk assessment. The following flowchart summarises the process used in this Guide for the selection, implementation and maintenance of protective measures.

**Figure 1.** The approach taken
SECTION 5. RELEVANT LEGISLATION

The Figure below indicates some principal relevant legislation:

<table>
<thead>
<tr>
<th>Health and Safety at Work etc. Act 1974</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explosives Act 1875 and 1923, and Subsidiary Legislation</td>
</tr>
<tr>
<td>Management of Health and Safety at Work Regulations 1999</td>
</tr>
<tr>
<td>Control of Substances Hazardous to Health Regulations 2002</td>
</tr>
<tr>
<td>Provision and Use of Work Equipment Regulations 1998</td>
</tr>
<tr>
<td>Workplace (Health, Safety and Welfare) Regulations 1992</td>
</tr>
<tr>
<td>Electricity at Work Regulations 1989</td>
</tr>
<tr>
<td>Noise at Work Regulations 1989</td>
</tr>
<tr>
<td>Control of Lead at Work Regulations 2002</td>
</tr>
<tr>
<td>Lifting Operations and Lifting Equipment Regulations 1998</td>
</tr>
<tr>
<td>Manual Handling Operations Regulations 1992</td>
</tr>
<tr>
<td>Dangerous Substances and Explosives Atmospheres Regulations 2002</td>
</tr>
<tr>
<td>Control of Major Accident Hazards Regulations 1999</td>
</tr>
<tr>
<td>European Communities Act 1992</td>
</tr>
<tr>
<td>The Supply of Machinery (Safety) Regulations 1992, as amended, and other legislation bringing into effect EC Directive requirements on product safety</td>
</tr>
</tbody>
</table>

*Figure 2. Some principal relevant legislation*
Health and Safety at Work etc. Act 1974 (HSWA)

Under Sections 2(1) and 2(2) of HSWA employers are required to ensure, so far as is reasonably practicable, the health and safety at work of their employees. It has always been good practice that safety is achieved through protective measures such as engineering controls and that the protection of employees by personal protective equipment should be regarded as a last resort. This hierarchy is an important principle embodied in the requirements of the Management of Health and Safety at Work Regulations 1999 and the Control of Substances Hazardous to Health Regulations 2002.

Duties placed on employers and the self employed under Section 3 of HSWA are relevant to the provision of protective measures for visitors to an explosives working area and others who are not employees, for example contractors, working there.

Section 6 of HSWA is relevant to manufacturers, importers and suppliers of equipment forming part of collective protective measures. Examples of such equipment are safety screens or guards for use in explosives working areas.

The full commitment and co-operation of employees is important in ensuring that protective measures put in place by their employer are, and remain, effective. For example, employees should adhere to the laid down safe systems of work and report promptly any defects in engineering controls. Section 7 of HSWA is relevant to the responsibilities of employees in this area.

Section 8 of HSWA would be contravened where a person intentionally or recklessly interfered with any protective measure in an explosives working area, for example by deliberately overriding or disabling the interlock mechanism of a machine guard.

Explosives Act 1875 (EA 1875)

EA 1875 requires that, with certain exceptions, explosives may only be manufactured in a factory licensed under the Act (licensed factory), and only be kept at a licensed factory, licensed magazine, licensed store, or premises registered under the Act. All licenses and the conditions of registration of premises specify the locations where explosives may be stored (and also in the case of a licensed factory, manufactured), and the maximum quantities and types of explosives which may be present at each location. Factory and magazine licenses also place limitations on the number of people who may be present at each location.

The General Rules for places licensed or registered under EA 1875 and the model Special Rules for licensed factories and magazines contain requirements relating to safe systems of work.
Control of Major Accident Hazards Regulations 1999 (COMAH)

These regulations apply to any establishment which has, or anticipates having, any substance specified in Schedule 1 to COMAH above the qualifying quantity. The qualifying quantities of explosives for the application of COMAH are such that currently there are relatively few sites licensed under the Explosives Act 1875 which are subject to COMAH. At establishments where COMAH does apply, advice in the guide will be relevant to various aspects of the general duty under the regulations for the operator of the establishment to take all measures necessary to prevent major accidents and limit their consequences to people and the environment. It should be emphasized, however, that the protection of the environment per se is outwith the scope of this publication.

There is Health and Safety Guidance on these regulations.

Management of Health and Safety at Work Regulations 1999 (MHSWR)

An important requirement of these regulations is for an employer to make a suitable and sufficient assessment of the risks to the health and safety of employees and other persons arising from the employer's undertaking in order to identify the measures the employer needs to take to comply with health and safety legislation. Similar duties are placed on the self employed. These regulations, for which there is an ACOP, also (in Schedule 1) lay down a set of principles to be followed in identifying the appropriate protective measures to control the risks identified by the risk assessment. These principles are reflected in the requirements of many of the sets of regulations dealing with specific hazards and risks described below.

Control of Substances Hazardous to Health Regulations 2002 (COSHH)

Regulation 2 of COSHH applies to substances that have already been classified as being very toxic, toxic or harmful, corrosive, or irritant under the Chemicals (Hazard Information and Packing for Supply) Regulations 2002 (CHIP 3), to those substances which have maximum exposure limits (MELs) or occupational exposure standards (OESs) and to biological agents. COSHH also applies to dusts which, whilst not satisfying any of the foregoing criteria, are present at a concentration in air equal to or greater than 10 mg/m$^3$ as a time weighted average over an 8 hour period of inhalable dust or 4 mg/m$^3$ as a time weighted average over an 8 hour period of respirable dust.

Furthermore, the guidance to Regulation 2 advises that there may be dusts with no formal occupational exposure limit and not listed in CHIP 3 for which limits lower than 10 mg/m$^3$ or 4mg/m$^3$ would be appropriate because of evidence of potential hazards to health, and advises employers to set their own in-house standards in such cases. A substance should be regarded as hazardous to health if it is hazardous in the form in which it occurs in the work activity, whether or not its mode of causing death or injury to health is known, and whether or not the active constituent has been identified. A substance hazardous to health includes mixtures as well as single substances.
Regulation 3 places duties on an employer in respect of employees and extends to any other person who may be affected by the work of the employer. These regulations apply to a self-employed person as if that person were both an employer and an employee.

Regulation 6 requires a suitable and sufficient assessment to be undertaken of the health risks created by substances hazardous to health. It also requires that the steps identified by the assessment are implemented and that the assessment is reviewed if the results of any monitoring show it to be necessary. Employers who employ five or more employees are required to record the significant findings of the assessment as soon as is practicable after the risk assessment is made and the steps taken to meet the requirements of Regulation 7.

Regulation 7 requires that exposure to substances hazardous to health is prevented or, failing this, controlled, and includes a list of control measures to be applied in order of priority. Regulation 8 places duties on employers and employees to properly use or apply control measures.

Regulation 9 deals with the maintenance, examination and test of control measures. Regulation 10 deals with workplace monitoring and Regulation 11 with health surveillance. Regulation 12 deals with information, instruction and training, whilst Regulation 13 covers arrangements to deal with accidents, incidents and emergencies.

Regulation 5 exempts certain substances that are subject to more specific legislation on the control of health hazards, such as asbestos and lead, from the requirements of Regulations 6 to 13 inclusive of COSHH.

There is an approved code of practice and guidance for COSHH.

Provision and Use of Work Equipment Regulations 1998 (PUWER 98)

PUWER 98 applies to the provision and use of all work equipment, including mobile and lifting equipment, and to all workplaces and work situations where HSWA applies. The Regulations define work equipment as "any machinery, appliance, apparatus, tool or installation for use at work (whether exclusively or not)".

Regulation 4 deals with the suitability of work equipment and includes requirements that it is so constructed or adapted as to be suitable for the purpose for which it is used or provided, that its selection takes into account ergonomic risks and that it is used only for operations for which, and under conditions for which, it is suitable.

In Regulation 5 there is a requirement that work equipment is maintained in an efficient state, in efficient working order, and in good repair. Regulation 6 deals with inspection, including inspection of equipment after installation or reinstallation, before it is put into service. It also deals with inspection of equipment such as complex automated equipment where the safe operation is critically dependent on its condition in use and deterioration would lead to a significant risk to the operator or other worker(s). This Regulation also requires that a record of the latest inspection is kept until the next inspection has been recorded.
Regulation 7 addresses cases where the use of work equipment is likely to involve a specific risk to health or safety. For example, where adequate control cannot be ensured by hardware measures such as guards and other measures such as following safe systems of work. In such cases, this Regulation requires that equipment is only allowed to be used by those whose task it is to use it, and that repairs, modifications, etc. shall only be carried out by a specifically designated person (who could also be the operator of the equipment).

Regulation 8 deals with information and instruction and Regulation 9 with training.

Regulation 10 covers the conformity of work equipment with legislation which brings into effect the requirements of EC Directives on product safety, such as the Supply of Machinery (Safety) Regulations 1992 as amended.

Regulations 11 to 24 of PUWER 98 deal with the physical aspects of work equipment (as opposed to the management duties covered by the Regulations so far mentioned). They cover the guarding of dangerous parts of work equipment, the provision of appropriate controls, suitable and sufficient lighting and suitable warning markings or devices. Regulation 12 deals with protection against specified hazards and includes the hazard of the unintended or premature explosion of the work equipment or any article or substance produced, used or stored in it.

Regulations 31 to 35 deal with the management requirements for the safe use of power presses.

There is an approved code of practice and guidance for PUWER 98.

**Workplace (Health, Safety and Welfare) Regulations 1992**

The requirements of these regulations need to be borne in mind when designing and implementing protective measures into a workplace, for example ensuring that the introduction of a safety screen does not interfere with the provision of suitable and sufficient lighting. There is Health and Safety Executive guidance on these Regulations.

**Electricity at Work Regulations 1989**

These regulations place duties on employers, the self-employed and employees and apply to all workplaces. In the context of this guide, their requirements will need to be complied with in relation to any item of electrical equipment which forms part of an engineering control measure to be introduced into an explosives workplace, for example electrically powered local exhaust ventilation. The requirements of these Regulations will also need to be considered in relation to any proposal to introduce an engineering control measure of any sort in order to ensure that this does not affect the safety of any existing electrical installation in the building such as the electrical earthing installation.
Amongst the areas that these Regulations address, there are two that are especially important in relation to equipment in explosives working areas. Regulation 6 deals with adverse or hazardous environments, and requires that electrical equipment which may reasonably foreseeably be exposed to any flammable or explosive substance including dusts, vapours or gases shall be of such construction or, as necessary, protected to prevent, so far as is reasonably practicable, danger arising from such exposure. Regulation 8 deals with earthing or other suitable precautions. There is general Health and Safety Guidance on these regulations\textsuperscript{10,11} and a Health and Safety Executive Guidance Note PM \textsuperscript{82} which gives detailed advice relevant to meeting the requirements of Regulations 6 and 8 for electrical equipment for use in and around explosives working areas.

**Noise at Work Regulations 1989 (NWR)**

These are relevant to protective measures to control noise exposure in explosives working areas and also to the introduction of protective measures to deal with other hazards where such measures introduce noise into explosives working areas, for example extraction fans. There is Health and Safety Executive guidance on these Regulations\textsuperscript{13,14}. It should be noted that some of the present noise action levels specified in NWR will be affected by future legislation to implement the EC Physical Agents Directive.

**Lifting Operations and Lifting Equipment Regulations 1998 (LOLER)**

Although PUWER 98 applies to all lifting equipment, LOLER applies over and above the general requirements of PUWER 98 with regard to specific hazards and risks associated with lifting equipment and lifting operations. There is an approved code of practice and guidance for these Regulations\textsuperscript{15}.

**Control of Lead at Work Regulations 2002 (CLAW)**

The main requirements for employers are:

- to assess health risks created by work involving exposure to lead;
- to prevent or control exposure to lead;
- to provide controls on eating, drinking and smoking;
- to maintain, examine and test control measures;
- to undertake air monitoring;
- to undertake medical surveillance;
- to provide information, instruction and training.

There is an approved code of practice for these Regulations\textsuperscript{16}.
Control of Asbestos at Work Regulations 2002

The requirements of these Regulations are relevant to any situation where asbestos or asbestos-containing materials are encountered. There are three approved codes of practice for these Regulations.

Manual Handling Operations Regulations 1992 (MHOR)

The requirements of these Regulations need to be considered, for example, in relation to the ease of handling of portable safety screens and covers. There is Health and Safety Executive guidance on these Regulations. Information on guidance can be found in Annex 1 which also contains information on British and harmonised European Standards.

Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR)

The Regulations:

- implement the safety aspects of EC Directive 98/24 (the Chemical Agents Directive) on the protection of the health and safety of workers from risks related to chemical agents at work;
- implement EC Directive 1999/92 (also referred to as the ATEX Directive) on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres.

The Regulations apply to explosives working areas, with the exception of

- Regulation 5(4)(c) (some aspects of the duty of an employer having 5 or more employees to record the significant findings of a risk assessment);
- Regulation 7 (classification and zoning of places where explosive atmospheres may occur, equipment selection for such places, marking of places, verification of explosion safety and provision of appropriate protective clothing);
- Regulation 11 (co-ordination of any measures required to protect against risks from explosives atmospheres where two or more employers share the same workplace).

The Regulations are disapplied by Regulation 3 from the manufacture, handling, use, storage and transport of explosives or chemically unstable substances.

The main requirements of these Regulations which apply to explosives working areas may be summarised as follows. Regulation 4 deals with the duties of employers to persons other than employees under the Regulations and Regulation 5 deals with risk assessment. Regulation 6 covers the elimination or reduction of risks from dangerous substances and Regulation 8 arrangements to deal with accidents, incidents and emergencies. Regulation 9 requires employers to provide information, instruction and training. Regulation 10 requires the marking of containers and pipes.
containing dangerous substances where they are not marked in accordance with the relevant requirements of legislation concerned with the marking of containers and pipes listed in a Schedule 5 to DSEAR. This list includes legislation dealing with the classification and labelling of explosives and carriage of explosives by road. Finally, Regulation 17 covers transitional provisions for equipment, protective systems and workplaces which are in use on or before 30 June 2003. Of the schedules to the Regulations which deal with technical matters, only Schedule 1 (General Safety Measures) and Schedule 5 will apply to explosives working areas because of the exemption from Regulation 7 described in the previous paragraph.

Four Approved Codes of Practice (ACOPs) are to be published later in 2003. These will reflect good practices in old legislation relating to flammable substances and dusts which DSEAR has, or will, repeal. It is expected that these Codes of Practice will make reference to certain BS or CEN standards or documents.

Proposed Manufacture and Storage of Explosives Regulations (MSER)

These will replace most of the remainder of the Explosives Act 1875 and 1923 and subsidiary legislation. The Regulations are currently expected to come into force in the second half of 2004. As far as issues relating to this Guide are concerned, it should be noted that the requirements for the registration and licensing of sites manufacturing or storing explosives will be continued in MSER, although the detail of licensing arrangements will be significantly different from those under the Explosives Act 1875.

An important feature of MSER will be its Approved Code of Practice (ACOP) and guidance, which will cover many of the aspects of safety for explosives working areas dealt with in this Guide. Requirements for General Rules and Special Rules under the Explosives Act 1875 will not be continued by MSER – the matters that those rules cover will be addressed in the ACOP to MSER.
SECTION 6. HEALTH AND SAFETY MANAGEMENT SYSTEMS

The key elements of a successful health and safety management system are set out in Figure 3.

An effective health and safety policy sets a clear direction for an organisation to follow and contributes to all aspects of business performance by providing demonstration of commitment to comply with statutory obligations. An effective management structure and arrangements supported by adequate resources are required to deliver this policy. The arrangements must promote effective staff involvement and communication to ensure competence within the organisation.

There must be a planned and systematic approach to implementing the health and safety policy through an effective health and safety management system. Risk assessment is key to this process in order to decide on priorities and to set objectives for eliminating hazards and risks. Wherever possible, risks should be eliminated through selection and design of facilities, equipment and processes.

Active self monitoring is used to determine how effectively the health and safety management system is functioning. If controls fail, reactive monitoring determines why through investigation. Organisations will learn from their experiences through auditing and reviewing their performance and by continually improving policies, procedures and systems of risk assessment and control.

Small businesses must tailor their safety management systems to the size of their operation and available resources. However, the key element of the system (i.e. the risk assessment) is a very important requirement both to help ensure that the disruption from accidents is minimised and also to enable the company to meet its statutory requirements.
Figure 3. Key elements of successful health and safety management
(Source: Successful health and safety management, HSG 65^{30})

6.1 Legal requirements for Risk Assessment

6.1.1 General principles of Risk Assessment as required by the Management of Health and Safety at Work Regulations 1999 (MHSWR)

There is a legislative requirement placed on employers and self employed persons to assess risks to workers and to others and to record the significant findings of that assessment. The legislation requires employers to undertake a systematic examination of their work activities and the formal recording of the findings of the risk assessment. The risk assessment involves identifying the hazards present in any undertaking (whether arising from the work activities, or from other factors e.g. the layout of the premises) and then evaluating the extent of the risks involved, taking into account whatever precautions are already being taken. In this context:
A hazard is something with the potential to cause harm (this can include articles, substances, plant or machines, methods of work, the working environment and other aspects of work organisation);

- Risk is the likelihood of potential harm from a particular hazard being realised;

- The extent of the risk covers the population which might be affected by a risk i.e. the number of people who might be exposed and the consequences for them.

Risk therefore reflects both the likelihood that harm will occur and its severity.

The purpose of the risk assessment is to help the employer or self employed person to determine what measures should be taken to comply with the employer’s or self employed person’s duties under the ‘relevant statutory provisions’. This phrase covers the general duties of the Health and Safety at Work etc. Act 1974 and the more specific duties under the various Acts and Regulations associated with the HSWA.

Regulations do not in themselves stipulate the measures that must be taken as a result of the risk assessment but guide the judgement of the employer or the self employed person as to the measures they ought to take to fulfil their statutory obligations.

A suitable and sufficient risk assessment should:-

- Identify the significant risk(s) arising out of the work by focusing on those risks which are liable to arise because of the work activity. Trivial risks usually can be ignored, as can risks arising from routine activities associated with life in general, unless the work activity compounds those risks;

- Enable the employer or self employed person to identify and prioritise the measures that need to be taken to comply with the relevant statutory provisions;

- Be appropriate to the nature of the work and such that it remains valid for a reasonable period of time. This allows findings to be used positively by management e.g. to change working procedures or to introduce medium to long term controls.

- Where possible, be checked by another competent person.

Employers and self employed persons are expected to take reasonable steps e.g. by consulting HSE guidance, guidance produced by industry bodies, the trade press, company or supplier manuals etc. to familiarise themselves with the hazards and risks in their work.
Employers and self-employed persons are required to review assessments periodically, and if necessary modify their risk assessments to take account of work changes. A risk assessment is not a once and for all activity. As the nature of work changes, the appreciation of hazards and risks may develop. Monitoring of processes is required and this may reveal near misses or defects in plant. Adverse events may take place even if a suitable and sufficient risk assessment has been made and appropriate preventative and protective measures taken.

Employers and self-employed persons need to review their risk assessments if there are developments that suggest they are no longer valid or can be improved. In most cases it is prudent to plan to review risk assessments at regular intervals - the time between reviews being dependent on the nature of the risks and the degree of change likely in the work activity. Such review should form part of the standard management practices and procedures.

There are no fixed rules as to how a risk assessment should be done although the assessment will depend on the nature of the work being undertaken and the type and extent of the hazards and risks. The assessment process needs to be practical and should involve both management and operators, whether or not advisors or consultants assist with the detail.

For simple processes where there are few or minor hazards, a suitable and sufficient risk assessment can be a very straightforward process based on judgement and requiring only basic training in risk assessment and a knowledge of the task. At the other end of the spectrum, e.g. a complex manufacturing process involving many stages, it may need to be developed so far as to produce the basis for a complete safety case or report for the plant incorporating such techniques as quantified risk assessment.

In many intermediate cases it is not possible to make a suitable and sufficient assessment without specialist knowledge and advice on unfamiliar risks. For example, an assessment may require some knowledge of ergonomics.

In some cases a single exercise covering all risks in a workplace may be appropriate. In other cases separate assessment exercises for the risks arising from particular operations or groups of hazards may be more effective. In all cases it is important that the employer or self-employed person adopts a structured approach to risk management.

The structured approach should ensure that:

- All relevant risks and hazards are addressed;
- The assessment addresses what actually happens in the workplace and considers non routine operations e.g. maintenance, loading and unloading, as well as the normal activities. Interruptions to work activities are often causes of accidents;
• All groups of employees and others who might be affected are considered e.g. office staff, night cleaners, maintenance staff, security guards and visitors;

• Groups of individuals who are particularly at risk are identified e.g. young or inexperienced persons, those who work alone and disabled persons;

• The assessment takes account of existing preventative and precautionary measures, which must be in place, maintained and working properly.

The level of detail contained in a risk assessment should be broadly proportionate to the risk, the assessment need not catalogue every hazard but concentrate on the significant ones. A suitable and sufficient risk assessment will reflect what it is reasonable to expect an employer to know about the hazards in the workplace.

Where employees of different employers work in the same workplace, their respective employers would have to consider risks to their own employees and to the other employer’s employees and may have to co-operate to produce an overall risk assessment.

In some cases employers may make a first rough assessment, to eliminate from consideration those risks on which no further action is required. This should also show where a fuller assessment is needed, if appropriate using more sophisticated techniques. However, care should be taken not to exaggerate the level of sophistication needed.

Employers who control a number of similar workplaces containing similar activities may produce a basic model risk assessment reflecting the core hazards and risks associated with these activities. Model assessments may also be developed by trade organisations, employers bodies or other professional organisations concerned with a particular hazard. Such model assessments may only be applied where local management have satisfied themselves that the model is appropriate and they can adapt the model to take account of their own work situations and cover hazards and risks not referred to in the model.

Examples of risk assessments that utilise protective measures are given in Annex 2.

6.1.2 Risk Assessment requirements of other sets of Regulations [Manual Handling Operations Regulations 1992 (MHOR), Noise at Work Regulations 1989 (NWR), Control of Substances Hazardous to Health Regulations 2002 (COSHH), Control of Asbestos at Work Regulations 2002 (CAWR), Control of Lead at Work Regulations 2002 (CLAW)]

Many of the requirements of MHSWR outlined in Section 6.1.1 above are mirrored in the requirements for risk assessment under other regulations, but there are some significant differences between MHSWR risk assessment requirements and those of other regulations, amongst which are:
The stated purpose of assessment is different for each set of regulations; each set of regulations requires risks from different specific hazards to be addressed, rather than covering hazards in a general way as under MHSWR; NWR specifically require that assessments are made by a competent person; MHOR only require risks to the employee or self employed person carrying out the manual handling to be assessed, and NWR require only the risks to those at work to be assessed. Any risks not covered by these sets of regulations, for example risks from noise exposure to people who are not employees, are covered by the risk assessment requirements of MHSWR; Instead of requiring a "suitable and sufficient risk assessment", NWR and CLAW require an "adequate assessment", but the two expressions can be taken to mean the same in this context; Whereas MHSWR makes no explicit specification as to when assessment should be done, COSHH, CAWR and CLAW clearly require assessments before the event and the NWR and MHOR imply that position; The requirements for recording risk assessments differ between sets of regulations.

More detailed and comprehensive information on risk assessment requirements will be found in the HSE leaflet "A Guide to Risk Assessment Requirements".

6.2 The Five Steps Approach to Risk Assessment

A risk assessment is a careful examination of what, in your workplace, could cause harm to people, in order to consider whether you have taken sufficient precautions or whether more could be done to prevent harm. The aim is to ensure that no one gets hurt or becomes ill. Accidents and ill health can ruin lives, and affect your business through lost output, damaged machinery and increased insurance costs. There is also a legal obligation to assess risks in your workplace.

An HSE guidance leaflet outlines a five steps approach to risk assessment, the key points of which are as follows:-

**STEP 1. Identify the hazards**

Walk around your workplace and look afresh at what could reasonably be expected to cause harm. Ignore the trivial hazards and concentrate on significant hazards which could result in serious harm or affect several people.

Ask your employees or their representatives what they think; they may have noticed things which are not immediately obvious. Manufacturers' instructions or data sheets can also help you spot hazards and put risks in their true perspective. The same applies for accident and ill health records*.

*More detailed information on hazard identification is given in Section 6.3 of this Guide.
STEP 2. **Decide who might be harmed and how**
Consider young workers, trainees and expectant mothers who may be particularly at risk;

Consider cleaners, visitors, contractors, maintenance workers etc. who may not be in the workplace all the time;

Consider members of the public, or people you share your workplace with.

STEP 3. **Evaluate the risks and decide whether existing controls are adequate or whether more should be done.**
Consider how likely it is that each hazard could cause harm. This will determine whether or not you need to do more to reduce the risk.

Even after all precautions have been taken, some risk usually remains. What you have to decide for each significant hazard is whether the remaining risk is high, medium or low.

Consider whether you have done all the things that the law requires you to do e.g. there are requirements to prevent access to dangerous parts of machinery. Consider whether generally accepted industry standards are in place, but do not stop there, the law requires you to do what is reasonably practicable to keep your workplace safe. Your real aim is to make all risks low by adding to your precautions as necessary. If you find that something needs to be done, draw up an action list and give priorities to the actions, identifying the highest priorities for immediate action. Ask ‘can I get rid of the hazard altogether?’; if that is not possible, then ask ‘how can I control the risks so that harm is unlikely?’.

Improving health and safety need not cost a lot, there are many simple solutions e.g. a mirror on a dangerous blind corner to help prevent vehicle accidents or fitting non-slip material on slippery steps. Failure to take simple precautions can cost you a lot more if an accident does occur.

STEP 4. **Record your findings**
If you have fewer than 5 employees you do not need to write anything down, although it is good practice and useful to keep a written record of what you have done. If you employ 5 or more persons you must record the significant findings of your assessment. This means writing down the significant hazards and conclusions e.g. electrical insulation and earthing checked and found to be sound, local exhaust ventilation provided and regularly checked.

You must tell your employees about your findings.

Risk assessments must be suitable and sufficient. You must be able to show that a proper check was made, that those persons affected were
identified, that the significant hazards were identified, that the precautions in place were reasonable and that the residual risk is low.

STEP 5. Review your assessment and revise it if necessary
Sooner or later you will introduce new machines, substances and procedures which will lead to new hazards (or the reduction of existing hazards). If there is any significant change, add to the assessment to take account of the new hazard. If a job introduces significant new hazards of its own, you will want to consider them in their own right and how you intend to keep the risks low. It is good practice to review your assessments from time to time to make sure that the precautions are adequate and are still working.

6.3 General principles of hazard identification

There is a requirement on employers to identify hazards which occur within the workplace or are associated with a particular activity and to consider what steps can be taken to eliminate or reduce them. This must include checking that all statutory obligations are met e.g. fitting of guards to dangerous machinery. Hazard identification and hazard analysis should focus on identifying and analysing the significant hazards which may result in serious injury or may affect a number of people. Hazard analysis is a more detailed and formal approach to hazard identification, typically applied to high risk areas.

The process of hazard identification involves identifying the circumstances under which a hazard that is present may have the potential to lead to an accident. The hazard identification checklist in Annex 3 provides a structured approach to identifying and recording hazards (primary and secondary hazards) which may occur in working areas across the explosives industry.

The process of hazard identification also involves identifying those individuals or groups who could be harmed by the hazards. Special consideration must be given to vulnerable groups such as those receiving training in the process, young persons, contractors and visitors. Further consideration must be given to potential hazards which may affect members of the public or other bystanders.

The overall objective of hazard identification is to identify all the significant hazards associated with the process or activity and to identify those individuals who are likely to be affected by them with the aim of hazard elimination or minimisation. Risks may therefore be minimised through this approach.

6.4 Activities which may generate hazards

The main activities carried out within the explosives industry are identified in Table 1. These activities have been referenced against the primary hazards listed in the Hazard Identification Checklist contained in Annex 3. For example, Table 1 indicates that within manufacturing operations across the explosives industry as a whole, all primary hazards may occur. However, some hazards may be particular to some processes but not others. The aim of the checklist is to determine which hazards are present in the individual activity. It is not anticipated that a single process would contain all the hazards as listed.
<table>
<thead>
<tr>
<th>Hazard</th>
<th>Activity</th>
<th>Manufacture</th>
<th>Storage</th>
<th>Internal Transport</th>
<th>Use, proofing and testing</th>
<th>Disposal and Decontamination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire and Explosion</td>
<td>Detonation</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Vapour Ignition</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Powder Ignition</td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Event transmission</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Chemical</td>
<td>Toxicity</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Contact</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Contamination</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Corrosion</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Compatibility</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Stability</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Oxygen</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Physical</td>
<td>Temperature</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Humidity</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Lighting</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Noise</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Vibration</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Repetitive Actions</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Radiation</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Electricity &amp; Static</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Biological</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Weather</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
### 6.5 The hierarchical approach to control measures

The controls should be selected to meet the following criteria:

- Meet or exceed standards set by a legal requirement;
- Comply with a recognised industry standard;
- Represent good practice;
- Reduce the risk as far as is reasonably practicable;
- Provide adequate instructions;
- Provide adequate training;
- Be ergonomically designed;
- Be achievable within normal levels of competence.

A hierarchical approach is applied to the control of hazard and risk as follows:

<table>
<thead>
<tr>
<th>Activity</th>
<th>Manufacture</th>
<th>Storage</th>
<th>Internal Transport</th>
<th>Use, proofing and testing</th>
<th>Disposal and Decontamination</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mechanical</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Stored Energy</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Entrapment</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Manual Handling</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Traffic</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hazards which could arise from</th>
<th>Manufacture</th>
<th>Storage</th>
<th>Internal Transport</th>
<th>Use, proofing and testing</th>
<th>Disposal and Decontamination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organisational Factors</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Packaging and storage</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handbooks</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Automated systems</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Human Factors</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
6.5.1 Elimination

Elimination refers to removing a hazard by eliminating the source of the hazard. Thus, the fire or explosion hazard presented by an explosive in a given operation can be eliminated by eliminating the explosive.

Examples in the explosive industry are:

- in quarrying, replacing the breaking of rock using explosive by breaking using machinery;
- in the assembly of explosives articles, postponing the introduction of the explosive substance or component to a later stage in the assembly, so that the presence of explosives during earlier stages is eliminated.

6.5.2 Substitution

This refers to the replacement of a substance or a process by a less hazardous one. There is a Health and Safety Executive publication which gives advice on the substitution of substances hazardous to health, but states that its ideas can also be applied to substitutions that are made for safety reasons.

Examples of substitution in the explosives industry are:

- the substitution of an explosive which is toxic by one which is non toxic or less toxic;
- the substitution of a gluing or sealing operation involving the application of heat by one which does not;
- the substitution of an explosive by one which is less susceptible to accidental initiation by friction, impact, etc.;
- the substitution of one physical form of an explosive by another physical form that is less susceptible to accidental initiation by friction, impact, etc.

6.5.3 Reduction

This refers to reducing the quantity of hazardous material involved in a given operation and hence the potential hazard.

Examples of reduction in the explosives industry are:

- the progressive scaling down of the size of a reactor and hence the inventory of explosive in it. For nitroglycerine manufacture, the reactors of tens of litres capacity in use around the turn of the 19th century have eventually been replaced by the modern eductor of 2 – 4 millitres capacity;
The reduction of the mix quantity for the machine or hand mixing of pyrotechnic compositions.

6.5.4 Isolation

This refers to the means of isolating people from the hazard by their being in a location where they will not be affected by it. The commonest, and usually the simplest way of achieving isolation is by distance, for example the positioning of the firing point, firer and observers at a proof ground at or beyond a required minimum distance from the explosive. Where it is not possible to achieve isolation using separation by distance alone, it may be necessary to use a combination of distance and engineering controls such as barriers and screens. Thus at a proof ground where it is not practicable to achieve the minimum separation distance for isolation, it is common to locate the firing point, firer and observers in a protective bunker positioned as far away from the explosives as practicable, i.e. isolation is achieved by a combination of distance and barrier protection.

6.5.5 Engineering controls

These are essentially items of hardware (for example, plant, devices, tools, guards, enclosures), intended to prevent a hazard arising, or to reduce or mitigate its effects. In the explosives industry, and indeed in any industry where there is a potential of fire and explosion, engineering controls can be divided into two categories:

- controls to prevent ignition (initiation), and
- measures to limit the effects of fire and explosion on people.

Examples of engineering controls used to prevent initiation in explosives working areas are:

- All substances and equipment used in an explosives working area are tested for chemical compatibility with each other and machines will not, for example, incorporate copper or lead in their construction in circumstances where they may come into contact with azides;

- Machinery will be designed to have smooth surfaces to lessen the chances of initiation through friction. Similarly, explosives samples will be stored in bottles with plastic tops, rubber bungs or loose fitting lids rather than screw threaded lids;

- Electrical equipment will be designed, constructed and installed so as not to present an ignition source. Thus the electrical category of the building will be appropriate to the hazard from the substances used in it, which may, for example, require the use of intrinsically safe electrical plugs and wall sockets;

- Appropriate precautions will be taken against initiation through electric discharge. Thus, in many explosives work areas it will be necessary to provide lightning protection. All surfaces in such areas may well also be earthed (and conducting conditions employed for explosives sensitive to initiation by static electricity).
An example of an engineering control to limit the effects of fire and explosion on people is the design of hoppers for explosives powders such that the maximum depth of powder in the hopper cannot exceed that at which an accidental ignition could lead to a detonation. Explosives packages or containers can be designed to reduce the hazard if the explosives they contain are initiated. For example, fibreboard packages can have an internal mesh reinforcement to trap the fragments arising from the ignition of pyrotechnic articles. A safety screen placed between explosives and the operator may be designed to limit the effects of a fire or explosion of the explosives.

Engineering controls such as enclosures and local exhaust ventilation systems are commonly used to mitigate the hazards from substances hazardous to health, and can also be a precaution against the build-up of dangerous concentrations of flammable gases or vapours in the workplace atmosphere.

Important principles for the successful use of engineering controls are that they are:

- properly designed to be fit for the application;
- properly installed;
- properly used;
- properly maintained (including, where appropriate, periodic examination and testing).

### 6.5.6 Safe systems of work

These are concerned with the achievement of safety through people taking the correct action in the correct way at the correct time. To a greater or lesser extent, all the measures so far described depend for their success on safe systems of work. For example, a system of work to ensure that engineering controls are properly designed, installed, used and maintained. When considering the hierarchy of measures to prevent, reduce or mitigate hazards, dependence on a safe system of work alone should only be resorted to when it is not reasonably practicable to achieve control through one or more of the measures already described.

Examples of safe systems of work to prevent explosives hazards arising in the explosives industry are controls on the introduction of sources of ignition such as matches and cigarette lighters.

One measure commonly relied upon to reduce hazard is the control of the maximum quantities of explosives allowed to be introduced into or exposed in any particular explosives working area. Whilst for some plant such control may, at least partially, be achieved by engineering controls, it commonly depends purely on safe systems of work, i.e. people adhering to the laid down restrictions on the quantities, forms and types of explosives allowed in the area at any one time.
Safety is commonly achieved in explosives operations by keeping people at a safe distance. Whilst engineering or other physical measures to achieve this are relatively easy to provide at permanent explosives sites, there may be considerable reliance on safe systems of work to ensure that employees remain at a safe distance when conducting test firings of explosives in the field or when firing firework displays.

The key to developing a safe system of work is a thorough risk assessment, and taking all the actions suggested by the findings of that risk assessment after considering what risks will remain after precautions involving elimination, substitution, isolation or engineering controls are in place. The definition and development of safe systems of work needs to involve the management, those in supervision and those who will carry out the work. Before a safe system of work is implemented, it needs to be ensured that all the required information, instruction and training has been provided and that there will be adequate supervision. The maintenance of a safe system of work will, amongst other things, require refresher training at suitable intervals for those who carry out and supervise the work.

The approach to hazard identification and risk assessment and the subsequent hierarchy of control measures is summarised diagrammatically in Figure 4.
SECTION 7. HUMAN FACTORS, INCLUDING ERGONOMICS

Accidents, incidents and ill health are rarely random events and the root cause is often organisational failings. Both people and technology should be controlled in order to exploit the strengths of employees while minimising weaknesses. The structure of the organisation and the design of jobs and systems can achieve this. Here are three key areas of influence on human behaviour:-

7.1 Organisational Factors

Within the establishment, efforts should be made to promote a positive safety culture and a climate involving the co-operation and participation of employees. The emphasis should be on establishing the unacceptability of ignoring the safety standards. Key factors to consider are:-

- Safety climate – commitment to health and safety from the top of the organisation;
- Standard setting – for evaluating new plant, processes, substances, procedures, modification of existing procedures, non standard procedures;
- Monitoring – monitoring standards and managing non-compliance;
- Supervision – arrangements for ensuring adequate levels of supervision, trained in recognition of unsafe behaviour e.g. failing to use or abusing protective measures or personal problems which may adversely affect performance or safety e.g. stress;
- Incident reports – reporting of accidents, incidents or near misses and the investigation and reporting procedures, monitoring ill health.

7.2 Job Factors

These factors directly influence job performance. Tasks should be designed according to ergonomic principles to minimise human limitations. Individuals whose capabilities are not matched to job requirements are likely to make mistakes and this may lead to accidents, incidents or ill health. Matching can be physical i.e. design of the workplace, equipment and environment, or mental, which involves perception of the task, job satisfaction, decision making, and so on. Both mental and physical matching reduce the potential for error. Key factors to consider are:-

- Task analysis – identification of safety critical tasks, analysis of tasks including physical and mental aspects, design and rotation of tasks;
- Decision making – capability and competence of individuals to make decisions, checks that perceptions of risk are consistent, fall-back arrangements;
- Man-machine interfaces – are controls accessible and easy to use, are good ergonomic principles taken into account in design of processes?
• Procedures and operating instructions – clear unambiguous written procedures, written at the right level of knowledge and understanding, authorisation of specific tasks, permit to work system, feedback and records;

• The working environment – physical factors such as heat, light, noise and ventilation are controlled. Working positions designed to promote good posture with equipment clearly labelled;

• Tools and equipment – correct tools used for the task, PPE requirements clearly identified;

• Work patterns – assess over-load and under-load working, fatigue in abnormal working conditions, rotation of tasks to improve skills;

• Communication – inter-departmental communications, conveying of information between working groups e.g. hand over logs and communications for accident and emergency situations.

7.3 Personal Factors

Personal factors are the physical and mental attributes which an employee brings to their task. Included in this area are skills, habits, attitudes and personality, any of which can influence behaviour. Skills and attitudes can be modified by training and experience, whilst personality is a permanent characteristic. Key factors to consider are :

• Personnel selection – a job description which defines physical abilities, qualifications, aptitude (particularly important for explosives work), personality etc. where these are relevant to job performance and safety;

• Training – a written training policy identifying objectives, laying down arrangements for assessing competence and monitoring employees through their full employment and maintaining records;

• Health assessment and monitoring – pre-employment and periodic health assessments for tasks where employees must reach defined medical standards. Systems in place for health review, including counselling and professional advice for employees returning after periods of prolonged absence or following an accident.

More detailed guidance on human factors can be found in an HSE publication\textsuperscript{34}. 
SECTION 8. ACKNOWLEDGEMENTS

The CBI gratefully acknowledges the valuable contribution made to this Guide by the following:

HSE's Explosives Inspectorate

The Health and Safety Laboratory of the HSE

MBDA (UK) Ltd.

The Institute of Explosives Engineers

BAE Systems, RO Defence

Chemring Countermeasures

Flight Refuelling Ltd., Wallop Defence Systems

Live Action FX Limited

Defence Science and Technology Laboratory (Dstl)

Kimbolton Fireworks Limited
ANNEX 1 - INFORMATION ON GUIDANCE AND BRITISH AND HARMONISED EUROPEAN STANDARDS

Part 1. Guidance

HSE publications

General


Working alone in safety, INDG 73 (free leaflet).

Permit to work systems, INDG 98 (free leaflet).

Control of Substances Hazardous to Health

COSHH Essentials, HSG 139.


Seven steps to successful substitution of hazardous substances, HSG 110.


Lighting

Lighting at work, HSG 38.

Machinery Guarding etc

Safety in the use of metal cutting guillotines and shears, HSG 42.

Industrial robot safety, HSG 43.

Application of electro-sensitive protective equipment using light curtains and light beam devices to machinery, HSG 180.

Health and safety in engineering workshops, HSG 129.

Safe use of power presses, L 112.

Safe use of woodworking machinery, L 114.

Electrical


Electricity at work. Safe working practices, HSE Books, ISBN 0 7176 0442X.

The selection, installation and maintenance of electrical equipment for use in and around buildings containing explosives, HSE Guidance Note PM 82, ISBN 0 7176 1217 1.

Maintaining portable and transportable electrical equipment, HSG 107.

Fire/Explosion Prevention and Mitigation

Safe Handling of Combustible Dusts - Precautions against explosions, HSG 103.

Lift trucks in potentially flammable atmospheres, HSG 113.

The spraying of flammable liquids, HSG 178.

Lifting and Manual Handling

Manual Handling - Solutions you can handle, HSG 115.

Work-related upper limb disorders - A guide to prevention, HSG 60.

A pain in your workplace? - Ergonomic problems and solutions, HSG 121.

If the task fits - Ergonomics at work, INDG 90, ISBN 0 7176 1379 8 (free leaflet).

Workplace Conditions


Thermal comfort in the workplace - Guidance for employers, HSG 194.


Guidance relating to specific explosives work areas or activities


Guidance on the handling, storage and transport of airbags and seat belt pretensioners, HSG 184.

Working together on firework displays. A guide to safety for firework display organisers and operators, HSG 123.

Disposal of explosives waste, CS 23.

Industry Publications – selected titles

Institution of Chemical Engineers publications


Major Hazards and their Assessment, 1997; Wells G ISBN 0 85295 368 2.


A full list of I Chem E publications is available on-line at www.icheme.org/learning.

Chemical Industries Association publications


Risk Assessment of Existing Substances, 1993; Ref PA 31; No ISBN.


A full list of CIA publications is available on-line at www.cia.org.uk.

Part 2. British and harmonised European Standards

Control of Hazardous Substances


Lighting


Machinery Guarding etc

BS 8753:1986 Specification for shotbolts (solenoid operated) for guarding machinery.


BS EN 294:1992 Safety of machinery. Safety distances to prevent danger zones being reached by the upper limbs.

BS EN 999:1999 Safety of machinery. The positioning of protective equipment in respect of approach speeds of parts of the human body.


Electrical


BS 6651:1999 Code of practice for protection of structures against lightning.


98/541503 DC Potentially explosive atmosphere. Explosion prevention and protection. Terms and definitions for equipment and protective systems intended for potentially explosive atmospheres (prEN 13237-1).

00/243930 DC Electrical apparatus for explosive atmospheres. Part 18.


BS 5501-8:1988, EN 500028:1987 Electrical apparatus for potentially explosive atmospheres. Electrical and potentially explosive atmospheres. Encapsulation "m".


BS EN 50014:1993 Electrical apparatus for potentially explosive atmospheres. General requirements.
BS EN 50014:1998 Electrical apparatus for potentially explosives atmospheres. General requirements.


Guidance and recommendations for the avoidance of hazards due to static electricity. Technical Report published by CENLEC.

Control of undesirable static electricity, BS 5958.

Electrical apparatus for use in the presence of combustible dusts, Part 3: Classification of areas where combustible dusts are or may be present, IEC 6241-3.

**Fire/Explosion Prevention and Mitigation**


Safety of Machinery – Fire prevention and protection, BS EN 13478.

Classification of areas where combustible dusts may be present IEC 6/241-3.

Classification of areas where combustible dusts are or may be present BS EN 50281-3.
Part 3. Other sources of information

List of web sites

Health and Safety Executive  www.hse.gov.uk
British Standards Institution  www.bsi-global.com
CBI  www.cbi.org.uk
Institution of Chemical Engineers  www.icheme.org.uk
Institution of Electrical Engineers  www.iee.org.uk
Institution of Electrical and Electronics Engineers  www.ieee.org.uk
Institute of Explosives Engineers  www.iexpa.org.uk
Chemical Industries Association  www.cia.org.uk

Information on specific topics may be obtained from specialist laboratory web sites such as

Health and Safety Laboratory  www.hsl.gov.uk
Defence Science and Technology Laboratory  www.dstl.gov.uk

or by using standard search engines e.g.

Google  www.google.com
Yahoo!  www.uk.search.yahoo.com

or other search engines accessible through your Internet Service Provider.
ANNEX 2 - RISK ASSESSMENT EXAMPLES

A2-1 Pressing take over cups.
A2-2 Pyrotechnics general (MTV pellet milling).
A2-3 Carrying primary explosives by hand.
A2-4 General experimental explosive firings.
A2-5 Replacing the separation sensor enabling shaft 'seal' on live missiles – Incorporation of ECR G9PA-1570.
### A2-1 RISK ASSESSMENT: PRESSING TAKE OVER CUPS.

<table>
<thead>
<tr>
<th>Description of the process or activity</th>
<th>List the Hazards present in the activity</th>
<th>List groups of people who are especially at risk from significant hazards identified</th>
<th>List existing controls and note where further information may be found</th>
<th>List the level of control of the risk and any action where it is reasonably practicable to do more. Cost may be considered unless the risk is high</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process overview</td>
<td>General information relating to this composition and process activity: SR57A composition is designated as very sensitive to friction, impact and static. This composition contains a mixture of boron, bismuth trioxide and Viton and is unaffected by water i.e. none of the components dissolve out when wetted. Once dried the composition is fully viable. Composition is very fine and presents a dust hazard, cleaning needs to be carried out thoroughly and accumulation of composition dust must be avoided.</td>
<td>Process is operated on both day shift and night shift with a team of two process operators per building. There are frequent visits from line supervision and infrequent visits from line management and engineering staff.</td>
<td>Refer to composition safety data sheets for details of sensitiveness. Copy held in manufacturing office. Building is licensed by the HSE to weigh, fill and press priming and delay compositions. Licence posted in building. All process operators are fully trained and the process is fully documented, see Process Instruction 1425-025. Humidity is controlled within this building between 40 – 70% RH. All conductive arrangements, materials and equipment are to current European standards.</td>
<td>Fully conductive PPE is required for all activities within this building to minimise the risk of an ignition caused by static discharge from the operator. Overall the residual risk is considered to be low and adequately controlled.</td>
</tr>
<tr>
<td>Dispensing SR57A composition into conductive pots.</td>
<td>Ignition of the composition caused by static discharge.</td>
<td>Process operators.</td>
<td>Composition is dispensed wet to reduce its sensitiveness to static and allowed to dry under warm room conditions with extraction. Bulk composition sub divided from 250 gms into 5-6 units of approximately 45 gms each to minimise overall effect should ignition occur. Full conductive arrangements are in place for dispensing operation. All containers for composition are conductive rubber. Composition is dispensed wet to reduce its sensitiveness to friction and allowed to dry under warm room conditions with extraction. Composition is sub divided into 40gm units in lidded conductive rubber pots to minimise overall effect should ignition occur.</td>
<td>Fully conductive PPE provided and tested on a daily basis to ensure full conductivity of operator and minimise risk of static discharge from the operator. Residual risk is considered to be low and adequately controlled.</td>
</tr>
<tr>
<td>Description of the process or activity</td>
<td>List the Hazards present in the activity</td>
<td>List groups of people who are especially at risk from significant hazards identified</td>
<td>List existing controls and note where further information may be found</td>
<td>List the level of control of the risk and any action where it is reasonably practicable to do more. Cost may be considered unless the risk is high</td>
</tr>
<tr>
<td>--------------------------------------</td>
<td>------------------------------------------</td>
<td>---------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Transporting dispensed composition to production building.</td>
<td>Ignition of composition caused by static discharge.</td>
<td>Departmental runner.</td>
<td>Conductive rubber pots are placed into conductive outer box for transport to process building. Runner trained in handling static sensitive compositions.</td>
<td>Fully conductive PPE provided for runner and tested on a daily basis to ensure full conductivity and minimise risk of static discharge from runner.</td>
</tr>
<tr>
<td></td>
<td>Ignition of composition caused by friction.</td>
<td>Departmental runner.</td>
<td>Composition is in lidded containers within outer box. Box is cleaned to ensure there are no accumulations of spillages and any that occur are safely removed and disposed of.</td>
<td>Residual risk is considered to be low and adequately controlled.</td>
</tr>
<tr>
<td></td>
<td>Ignition of composition caused by impact – dropping the container.</td>
<td>Departmental runner.</td>
<td>Boxes are light and easy to handle but designed for two handed lifting. Runners are trained in handling techniques.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Trip hazard from pot holes or uneven surfaces.</td>
<td>Departmental runner.</td>
<td>Runner follows prescribed route between process buildings. Roads are maintained and subject to regular audit.</td>
<td></td>
</tr>
<tr>
<td>Weighing composition to float</td>
<td>Ignition of composition caused by static discharge.</td>
<td>Process operators.</td>
<td>Weighing operation uses intrinsically safe scales and scoop, which are earthed. Scale is located behind a clear plastics screen to protect the operator in the event of an ignition. Screen has been type tested. Composition is weighed into conductive scoop boats for ease of handling and pouring. Process Instruction sheet No. 1425-025 documents correct procedures and weighing parameters.</td>
<td>Fully conductive PPE is provided for this task and is tested on a daily basis to ensure full conductivity for operator and to minimise risk of static discharge from operator.</td>
</tr>
<tr>
<td>Pressing composition into take over cup.</td>
<td>Ignition of composition caused by static discharge.</td>
<td>Process operators.</td>
<td>Press is fully earthed. Press tooling is of polished steel and brass to minimise risk of spark and tool wear. Press tooling is cleaned on a regular basis to eliminate build up of composition.</td>
<td>Fully conductive PPE is provided for this task and is tested on a daily basis to ensure full conductivity for the operator.</td>
</tr>
<tr>
<td>Description of the process or activity</td>
<td>List the Hazards present in the activity</td>
<td>List groups of people who are especially at risk from significant hazards identified</td>
<td>List existing controls and note where further information may be found</td>
<td>List the level of control of the risk and any action where it is reasonably practicable to do more. Cost may be considered unless the risk is high</td>
</tr>
<tr>
<td>---------------------------------------</td>
<td>------------------------------------------</td>
<td>-------------------------------------------------</td>
<td>-------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Operation of machinery.</td>
<td>Process operators.</td>
<td>Process instruction (PI) sheet 1425-025 documents correct method of operation of the press. PI is posted in building. Press controls are offset from front of press and guards are in place which are interlocked to the control panel.</td>
<td>Residual risk is considered to be low and adequately controlled.</td>
<td></td>
</tr>
<tr>
<td>Brushing surplus composition from pressed surfaces.</td>
<td>Ignition of assembly caused by static discharge. Ignition of assembly caused by friction. Ignition of composition caused by impact through dropping take over cup or other object onto pressed cups.</td>
<td>Process operators. Process operators. Process operators.</td>
<td>Holding jig is constructed from polished stainless steel and is earthed. Natural bristle brushes are used for this task to minimise static. Metal barrel of brush is taped to minimise friction contact. The brushing operation is carried out behind a clear plastics screen. Cleaned cups are stored in lidded conductive box behind second screen to prevent communication. Fully conductive PPE is provided for this operation and is tested on a daily basis to ensure full conductivity for the operator. Fine leather gloves are provided to improve tactile handling – ensure no holes in finger tips. Residual risk is considered to be low and adequately controlled.</td>
<td></td>
</tr>
<tr>
<td>Storage of pressed take over cups in building.</td>
<td>Ignition of assembly caused by static discharge. Ignition of assembly caused by impact from dropping cup or other item onto pressed cups.</td>
<td>Process operator. Process operator.</td>
<td>Work in progress and completed work is kept in conductive lidded containers. Work in progress and completed work is kept in lidded conductive containers. Fully conductive PPE is provided for this activity and is tested on a daily basis to ensure full conductivity for operator and to minimise risk of static discharge from the operator. Residual risk is considered to be low and adequately controlled.</td>
<td></td>
</tr>
<tr>
<td>Cleaning of press tooling.</td>
<td>Ignition of trapped composition caused by friction during cleaning.</td>
<td>Section chargehand and engineers.</td>
<td>Written instruction available for this task, posted in building. Cleaning operation is carried out in separate bay from pressing operation to minimise the risk of spread should an ignition occur during cleaning of the tooling. Cleaning task is carried out under water to minimise extent of any ignition. Tooling designed to eliminate points of accumulation and for ease of cleaning. Fully conductive PPE is provided for this operation and is tested on a regular basis. However, rubber gloves are used for this cleaning operation and therefore insulate but the risk of static discharge is minimal. Residual risk is considered to be low and adequately controlled.</td>
<td></td>
</tr>
<tr>
<td>Description of the process or activity</td>
<td>List the Hazards present in the activity</td>
<td>List groups of people who are especially at risk from significant hazards identified</td>
<td>List existing controls and note where further information may be found</td>
<td>List the level of control of the risk and any action where it is reasonably practicable to do more. Cost may be considered unless the risk is high</td>
</tr>
<tr>
<td>---------------------------------------</td>
<td>----------------------------------------</td>
<td>---------------------------------</td>
<td>-------------------------------------------------</td>
<td>---------------------------------------------------------------------</td>
</tr>
<tr>
<td>Packing, collection and disposal of waste.</td>
<td>Ignition of pressed cup or composition from static discharge. Ignition of pressed cup caused by impact from dropping cup onto composition or other cups. Ignition of waste composition through static discharge.</td>
<td>Process operator or Disposal Technician. Process operator or Disposal Technician. Process operator or Disposal Technician.</td>
<td>Reject cups are stored in lidded conductive box with felt pad soaked in mineral oil to damp down surface of composition and reduce sensitiveness of both friction and impact. Waste mix is packed in conductive bags ready for disposal. Code of Practice 035 for further details.</td>
<td>Fully conductive PPE is provided for this operation and is tested on a daily basis to ensure full conductivity for the operator and Disposal Technicians. Residual risk is considered to be low and adequately controlled.</td>
</tr>
<tr>
<td>Daily cleaning of the building and equipment.</td>
<td>Ignition of dust and/or spilled composition caused by static discharge. Ignition of dust and spilled composition caused by impact during cleaning. Ignition of dust and/or spilled composition caused by chemical incompatibility. Ignition of composition contamination in corners and recesses etc. caused by impact and friction.</td>
<td>Process operators. Process operators. Process operators. Process operators.</td>
<td>A cleaning schedule is in place for this building detailing tasks and frequency of cleaning. The schedule also details cleaning materials and equipment required. Building has been designed to minimise the opportunity for accumulations of composition and for ease of cleaning with rolled edge floor/wall and bench/wall interfaces. There are gallows type legs on benches for ease of access of cleaning. Press has been redesigned for ease of access and cleaning. All cleaning materials are assessed to determine their compatibility with the composition and the components of the composition. All cleaning materials are compatible with the conductive rubber bench tops, flooring and conductive containers. All joins, seals and edges are filled in to prevent the ingress of composition. Air lines are not permitted for cleaning purposes in this building. Building is inspected to a planned schedule to ensure standards of housekeeping and cleanliness are maintained.</td>
<td>Fully conductive PPE is provided for this task and is tested on a daily basis to ensure full conductivity for operators and to minimise the risk and effect of ignition through static discharge or friction. Residual risk is considered to be low and adequately controlled.</td>
</tr>
</tbody>
</table>
Building 67A is a dedicated facility for the milling of pressed MTV flare pellets. The building has three compartments; two milling rooms and an operating compartment. Each of the milling compartments contains one milling machine designed and set up for milling a particular type of flare pellet. Only one milling compartment is in operation at any one time and each is designed to mill only one flare at any one time. Each milling compartment has a main access door, which is interlocked to the control panel ensuring that the machine cannot be operated with the door open, and a safety cut out which stops the machine should the door be opened during milling. A second door, which is bolted and locked, is only used for maintenance and by tooling engineers. Directly above each milling machine there are 50cm square chimneys to allow for venting should an ignition occur during the milling operation. The floors and workbench tops are covered with conductive material and operators wear conductive footwear and conductive wrist straps connected to earth clips when working or handling the flares. Each flare is wrapped in a conductive bag and stored in an approved "Pyro box" prior to and after milling, each having a closure lid with restricting device to prevent the box being left open at any time. The process written (bench) instruction ensures that only one flare pellet is ever exposed to the operator at any one time. Swarf waste from the milling operation is swept down a shoot and collected in a small tray which is emptied after a set number of flares have been milled, the waste swarf is then removed from the building and deposited into fuel oil in a special explosive waste container ready for disposal.

**Identification of Hazards**
1. Ignition of MTV pellet during milling (friction).
2. Ignition of MTV pellet during handling (electrostatic discharge).

**Personnel likely to be affected**
1. Operators during milling operations.
2. Operators handling MTV flares.
3. Visitors/Supervisors within the compartment should an event occur.

**Existing Controls to Reduce Risk**
1. Building limits for quantity of explosive, type of work and number of operators working.
2. All operations carried out to written (bench) instructions with approved machinery.
3. Operators instructed and trained in milling cleaning and swarf disposal procedures.
4. Full precautions against static are in place.
5. Safety data sheets specifying safety PPE (reduce injury from any unforeseen risks).
6. Interlocking fitted to access door and ignition venting installed in the compartment.
7. Only one milling operation/type in use at any one time.
8. Strict cleaning regime and disposal of milling swarf.

**Recommended action if risks not adequately controlled**
1. No further action required or recommendations.
# A2-3 RISK ASSESSMENT: CARRYING PRIMARY EXPLOSIVES BY HAND

<table>
<thead>
<tr>
<th>List hazards here:</th>
<th>List groups of people who are especially at risk from the significant hazard you have identified:</th>
<th>List existing controls here or note where the information may be found:</th>
<th>List the risks which are still not adequately controlled and the action you will take where it is reasonably practicable to do more. You are entitled to take cost into account, unless the risk is high:</th>
</tr>
</thead>
</table>
| 1. Loading pot to carrier  
   Dropping filled pot  
   Electrostatic discharge  
   Friction between pot and carrier. | Operators and powder carriers. | Buildings licensed by HSE to manufacture explosive composition Zirconium Potassium Perchlorate (ZPP), registry no XI 4111/712/sub1 (6/92). Copy held by Group1 Safety Adviser.  
   The following Authorised Control Procedures apply:  
   Building 1P11B: ACP 1/E/006  
   Building 1N1: ACP 1/E/023  
   Carrying of compositions: ACP 1/E/022.  
   Master copy held by management document control.  
   Working copy displayed in process building.  
   Use both hands to carry pot.  
   Where possible work over a bench.  
   Prepare carrier box to receive pot before commencing operation.  
   External surfaces of composition pot to be checked for contamination.  
   Contaminated pots not to be used.  
   Conducting conditions to apply to floor, benches personnel and all equipment, excluding carrier box.  
   Pot to be handled in a manner which prevents creation of a dust cloud.  
   Only trained operators to undertake this activity.  
   Operator to ensure correct carrier is used.  
   Quantity of ZPP carried to be limited to 160 gm (8 x 20gm).  
   All non-essential materials and explosives to be withdrawn from the immediate area. | Potential Severity Rating = 3  
   Probable Frequency Rating = 1  
   Risk Rating Factor = 3  
   Conclusion: Risk is considered Low and Adequately Controlled. |
<table>
<thead>
<tr>
<th>Section</th>
<th>Activity</th>
<th>Instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Transfer and handling of mixed composition ZPP from inside building to outside of building.</td>
<td>Dropping carrier box Friction between pots and carrier box Trip hazards on route.</td>
<td>Material to remain in mixer pot. Maximum to be carried in one carrier box to be 160 gm (8 x 20gm). Access doors to be locked in open position before accessing. Operator to ensure route is clear and that powder rests are clear for use. Carrier box must be carried in the approved manner. Carrier should carry the box without undue haste. Operator must be a trained carrier. <strong>Potential Severity Rating = 3</strong> <strong>Probable Frequency Rating = 1</strong> <strong>Risk Rating Factor = 3</strong> (the above ratings are based on historical data from within the site. Only two (2) known incidents of carrying boxes being dropped in 50 years (neither resulting in an event). Conclusion: Risk is considered <strong>Low</strong> and <strong>Adequately Controlled</strong>.</td>
</tr>
<tr>
<td>3. Transfer of ZPP from building to building.</td>
<td>Operators, powder carriers and visitors.</td>
<td>Operator should comply fully with requirements of Manufacturing Instructions (MI)100 and 101, including their requirements for PPE. Operator should check route for obstructions and hazards prior to making journey. Operator should deposit carrier box gently onto powder rest outside destination building. Operator should avoid undue movement of carrier box in-accordance with MI. Operator should be a trained powder carrier. <strong>Potential Severity Rating = 3</strong> <strong>Probable Frequency Rating = 1</strong> <strong>Risk Rating Factor = 3</strong> (the above ratings are based on historical data from within the site. Only two (2) known incidents of powder carrying boxes being dropped in 12 years (neither resulting in accidental ignition). Conclusion: Risk is considered <strong>Low</strong> and <strong>Adequately Controlled</strong>.</td>
</tr>
</tbody>
</table>
4. Transfer from outside to inside of receiving building.

   - Dropping carrier box
   - Friction between pots and carrier box
   - Trip hazards on route.

Transfer to be undertaken only by trained powder carriers in accordance with Manufacturing Instructions 100 and 101.
Access doors to be locked in open position before accessing.
Operator to ensure route is clear and that powder rests are clear for use.
Carrier box must be carried in the approved manner.
Operator to transfer carrier box from powder rest outside building to transit shelf inside the building.
Operator to open the carrier box and remove pots individually.
Pots to be carried using both hands.

Potential Severity Rating = 3
Probable Frequency Rating = 1
Risk Rating Factor = 3

Conclusion: Risk is considered Low and Adequately Controlled.

<table>
<thead>
<tr>
<th>Assessor</th>
<th>Name :</th>
</tr>
</thead>
<tbody>
<tr>
<td>Review Date</td>
<td>Date :</td>
</tr>
</tbody>
</table>
A2-4 RISK ASSESSMENT: GENERAL EXPERIMENTAL EXPLOSIVE FIRINGS

Please fill in the Assessment Number on the first page only, it will automatically fill in pages 2, 3 etc for you, select print preview to confirm this. For the Residual Risk rating use the Tab key to browse the cells and then enter the numbers, the result will be automatically calculated for you.

| Site: Southern | Assessment No: 490 |
| Location: XXX | Assessor (Name): |
| Sector/Dept: LWS - WS4A | Assessor (Signature): |
| Activity/Process: General Experimental Explosive Firings. | No of Persons at Risk (Please Check/Tick box.) |
| | Employees | Others |
| 1 | [ ] | [ ] |
| 2-5 | [x] | [ ] |
| 6-10 | [ ] | [ ] |
| 10+ | [ ] | [ ] |

Hazards Involved with Activity/Process:

This Risk Assessment concentrates on general experimental explosive firings in the Old Fort Area and the hazards specifically associated with this activity - It does not address those hazards covered in the 'General Working in the XXX' Risk Assessment.

This is a generic assessment of risk, covering the general experimental explosive firing of 'standard' explosive substances and articles in the XXX area - specialised mixtures/compositions and other deviations from normal 'standard' practices will need to be covered in a separate specialist risk assessment.

Slips, Trips & Falls.

Experimental Explosive Firings in Bomb Chamber, Detonation Laboratory & G5 Gun Tunnel (noise, fragmentation & blast).

Rough/Sharp surfaces and protrusions in Bomb Chamber & Detonation Laboratory.

Smoke and Fumes - Products of Detonation/Combustion from Explosive Firings, Noise.

Visitors are covered by a separate risk assessment.
**Existing Safety Measures/Controls (Including Health Surveillance):**

Ensure the various procedures concerning High & Low Voltage Firings in the Bomb Chamber and Detonation Laboratory (D/LWS/WS4/DP/ 061/1 to 070/1 are closely followed.

Trip Hazards are to be clearly marked & workers are not to stray from the hard paths around the XXX Area, unless their work specifically requires it - in which case they must provide their own risk assessment for this activity.

Nobody is to enter a firing chamber until the fumes have cleared.

Exposure to smoke and fumes carried on the wind is to be avoided (by keeping out of its path).

Hearing protection to be worn in the control room.

---

**Residual Risk (After applying Control Measures):**

<table>
<thead>
<tr>
<th>Risk Description</th>
<th>Likelihood</th>
<th>Severity</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk of General Injury: Slips, Trips &amp; Falls, etc.</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Risk of Impact/Blast Injury Due to Explosive Firing</td>
<td>1</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Cuts, Grazes and Bangs from surfaces/protrusions inside firing chambers.</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Lung Damage from Smoke &amp; Fumes.</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Hearing Damage from high noise levels during firings.</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

**Rating (range 1 – 16)**

(see key to assessment)

(Calculations are automatic)

\[ \text{Likelihood} \times \text{Severity} = \text{Rating} \]

---

**Additional Controls Required (Required for Ratings 6 or above):**

None

---

**Health Surveillance Required: Yes ☐ No ✗** (Please Tick or Check box as appropriate.)

If “Yes” give details:

---

**Additional Controls Agreed: Yes ☐ No ✗** (Please Tick or Check box as appropriate.)
I have noted the above assessment and will take appropriate action.

Name (Block Capitals): G Supervisor
(Manager responsible for the activity)

Signed: Date: 08/12/2002

Assessment Review
I confirm that the assessment remains valid, controls remain effective and there has been no increase in risk.

1st Review Date: Name: Signed: 8/12/2003

2nd Review Date: Name: Signed: 8/12/2004

3rd Review Date: Name: Signed: 08/12/2005

N.B. If the above statement cannot be verified then a reassessment will be required to confirm that there has been no significant change to the activity/process.

Key to assessment:

Table of risks

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Rating value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Likelihood of Injury</strong></td>
<td></td>
</tr>
<tr>
<td>Most unlikely (probability close to zero)</td>
<td>1</td>
</tr>
<tr>
<td>Unlikely (injury possible)</td>
<td>2</td>
</tr>
<tr>
<td>Likely (injury highly possible)</td>
<td>3</td>
</tr>
<tr>
<td>Most likely (injury probable)</td>
<td>4</td>
</tr>
<tr>
<td><strong>Severity of Injury</strong></td>
<td></td>
</tr>
<tr>
<td>Trivial (injuries treated by local first aider from first aid box)</td>
<td>1</td>
</tr>
<tr>
<td>Slight injuries that may require more expert treatment administered at a sick bay or outpatients</td>
<td>2</td>
</tr>
<tr>
<td>Condition</td>
<td>Value</td>
</tr>
<tr>
<td>---------------------------------------------------------------------------</td>
<td>-------</td>
</tr>
<tr>
<td>Serious chronic conditions or injuries involving urgent hospital treatment</td>
<td>3</td>
</tr>
<tr>
<td>Major injuries involving major trauma or death</td>
<td>4</td>
</tr>
</tbody>
</table>
This risk assessment covers only the operators doing the work or supervisors. All other people (e.g. visitors) are excluded from the work area.

<table>
<thead>
<tr>
<th>PROCESS</th>
<th>POTENTIAL HAZARD/RISK</th>
<th>CONTROL MEASURES</th>
<th>SEVERITY</th>
<th>PROBABILITY</th>
<th>SAFETY ACCEPTANCE CRITERIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>If applicable, remove Container Lid.</td>
<td>As set out in Operations Manual.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The remainder of this process should be a 'Witnessed' process, and certified accordingly. If not already fitted, re-fit the Ventral Fin Tooling Safety Pins, through the Rear Cover (2 off).</td>
<td>No risks.</td>
<td>WARNING – Ensure that no personnel are near the Ventral Fins. Ensure that there are no heavy objects above the Missile, in particular near the Separation Sensor. e.g. the overhead hoist, Tools, Lifting Beam must not be anywhere near the Missile.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Remove Separation Sensor 'Enabling Shaft Handle' – by pushing the Handle in and rotating it from 'Ground' to 'Flight'.</td>
<td>Once the Separation Sensor has been rotated to 'Flight' the Missile Separation Sensor is 'Armed' and if the top of the Separation Sensor receives an impact of 200N or greater the 'Percuter' will fire and the Ventral Fins will deploy creating possible severe personnel hazards.</td>
<td>Ventral Fin Tooling Safety Pins are re-fitted, which prevent the Ventral Fins being deployed. Warnings have been added to these instructions to ensure there are no personnel near the Ventral Fins and there are no potential heavy objects above the Missile during the process. This process of setting the Separation Sensor to 'Flight' is exactly the same process that the Flight Ground Crew will perform.</td>
<td>Catastrophic.</td>
<td>Improbable.</td>
<td>Acceptable with endorsement of project safety panel.</td>
</tr>
<tr>
<td>Remove 'Environmental Seal' from the shaft of the Handle by hand, and replace with new 'Production Std Seal' 234714/001.</td>
<td>No risks.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PROCESS</td>
<td>POTENTIAL HAZARD/RISK</td>
<td>CONTROL MEASURES</td>
<td>SEVERITY</td>
<td>PROBABILITY</td>
<td>SAFETY ACCEPTANCE CRITERIA</td>
</tr>
<tr>
<td>---------</td>
<td>----------------------</td>
<td>------------------</td>
<td>----------</td>
<td>-------------</td>
<td>---------------------------</td>
</tr>
<tr>
<td>Replace Separation 'Sensor Enabling Shaft Handle' – by pushing the handle in and rotating it from 'Flight' to 'Ground'.</td>
<td>Same risks and control measures as above for removing the Separation Sensor ‘Enabling Shaft Handle’.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>If Missile already delivered in its Container, remove Ventral Fin Tooling Safety Pins. Replace Container Lid.</td>
<td>As in Operational Missile planning.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Record on Missile Paperwork (Route Card) that new seal has been fitted, i.e. ECR G9PA 1570 has been incorporated. NB. Batch 2 Missiles – declare the ECR as a 'Plus Mod' Batch 3 onwards – ECR is already in the build standard, remove concession raised on the Inert Missile.</td>
<td>No risks.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NB. If possible, this process should be done on the inert missile prior to starting the live build.

Author:  
Date:  

Approved:  
Date:  

58
# HAZARD IDENTIFICATION CHECKLIST

<table>
<thead>
<tr>
<th>HAZARD</th>
<th>Applicability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Primary</td>
</tr>
<tr>
<td>1. FIRE AND EXPLOSION</td>
<td></td>
</tr>
<tr>
<td>Detonation or Deflagration</td>
<td>Friction (with external materials)</td>
</tr>
<tr>
<td></td>
<td>Internal heat</td>
</tr>
<tr>
<td>Flammable liquid, vapour ignition</td>
<td>Friction</td>
</tr>
<tr>
<td>Powder and solids ignition</td>
<td>Friction</td>
</tr>
<tr>
<td>Event transmission and enhancement (domino effects)</td>
<td>Confinement (leading to enhancement of effects)</td>
</tr>
</tbody>
</table>

*Note, these factors will not by themselves lead to ignition, they will, however, affect the threshold for ignition when combined with a means of ignition.
<table>
<thead>
<tr>
<th>Primary</th>
<th>Secondary</th>
<th>Applicability</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HAZARD</strong></td>
<td><strong>Secondary</strong></td>
<td><strong>Yes</strong></td>
</tr>
<tr>
<td><strong>2. CHEMICAL</strong></td>
<td><strong>Secondary</strong></td>
<td></td>
</tr>
<tr>
<td>Toxicity (COSH)</td>
<td>Inhalation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Absorption (skin)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ingestion</td>
<td></td>
</tr>
<tr>
<td>Contact</td>
<td>Burn</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Skin sensitisation</td>
<td></td>
</tr>
<tr>
<td>Contamination</td>
<td>Reaction</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increased sensitiveness</td>
<td></td>
</tr>
<tr>
<td>Corrosion</td>
<td>Strength</td>
<td></td>
</tr>
<tr>
<td>Stability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compatibility</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxygen</td>
<td>Enrichment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Deficiency</td>
<td></td>
</tr>
<tr>
<td><strong>3. PHYSICAL</strong></td>
<td><strong>Secondary</strong></td>
<td></td>
</tr>
<tr>
<td>Heat – contact</td>
<td>Burn</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Scald</td>
<td></td>
</tr>
<tr>
<td>Heat – environment</td>
<td>Fatigue/exhaustion/stroke</td>
<td></td>
</tr>
<tr>
<td>Cold – contact</td>
<td>Burn</td>
<td></td>
</tr>
<tr>
<td>Cold – environment</td>
<td>Hypothermia/Frostbite</td>
<td></td>
</tr>
<tr>
<td>Humidity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lighting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Noise – inc. Impulse</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vibration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repetitive action/force</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiation</td>
<td>Ionising</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non-Ionising (UV, IR, Laser)</td>
<td></td>
</tr>
<tr>
<td>Electricity / EMC / RF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Static</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biological</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weather</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>4. GENERAL</strong></td>
<td><strong>Secondary</strong></td>
<td></td>
</tr>
<tr>
<td>Mechanical</td>
<td>Falling objects</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stationary objects</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Falling</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tripping</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Moving parts</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Projections &amp; Sharp Edges</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ejected parts and fragments</td>
<td></td>
</tr>
<tr>
<td>Stored Energy</td>
<td>Strain</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pressure (hydraulic/pneumatic)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Potential</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Electrical charge</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mechanical</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Heat</td>
<td></td>
</tr>
<tr>
<td>Entrapment</td>
<td>Parts of the body</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Clothing/hand tools</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Restricted escape route</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No escape route</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Load Bearing Structures</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Structures affected by 'break-up' systems</td>
<td></td>
</tr>
<tr>
<td>Manual handling</td>
<td>Excessive weight</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Excessive lever action</td>
<td></td>
</tr>
<tr>
<td>Traffic</td>
<td>People</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Powered vehicles</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Overhead movements</td>
<td></td>
</tr>
<tr>
<td>HAZARD</td>
<td>Applicability</td>
<td></td>
</tr>
<tr>
<td>-----------------------------</td>
<td>---------------</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Primary</td>
<td>Secondary</td>
</tr>
<tr>
<td>5. OTHERS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organisational Factors</td>
<td>Roles and responsibilities</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Resources (numbers, skills, competence, etc.)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Work patterns (shifts, etc.)</td>
<td></td>
</tr>
<tr>
<td>Packaging &amp; Storage</td>
<td>Packaging of explosives for transport</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Packaging of explosives for storage</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Packaging of other dangerous goods</td>
<td></td>
</tr>
<tr>
<td>Handbooks / Work Instructions</td>
<td>Misleading Information</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dangerous Procedure</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Not Best Practice</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Errors</td>
<td></td>
</tr>
<tr>
<td>Automated Systems</td>
<td>Software Controlled Triggering</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Computer Error Triggering</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mechanical Triggering</td>
<td></td>
</tr>
<tr>
<td>Human Factors</td>
<td>Human Error</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fatigue</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Personnel Training</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Clarity of Information</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Decision Making</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Supervision</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ergonomics</td>
<td></td>
</tr>
</tbody>
</table>
ANNEX 4 - DESIGN PRINCIPLES FOR SCREENS AND SHIELDS

So far as protection against fire and explosion from explosives is concerned, this Annex is concerned only with the design of screens and shields for applications where that hazard arises from an accidental ignition. Whilst some of the principles here may also be relevant to applications where explosives are deliberately ignited as part of, for example, a laboratory test procedure, there will be specialist considerations over and above those explored below, and not covered in this Annex, for the design of such screens and shields.

General Approach

Screens or shields in the explosives workplace may be provided to protect people from one or more of the following hazards:

- fire involving explosives;
- missiles arising from an explosion involving explosives;
- fire involving materials other than explosives;
- missiles arising from an explosion involving materials other than explosives;
- excessive noise from sources other than an accidental explosion;
- non-ionising radiation;
- dangerous moving parts of machinery;
- substances hazardous to health;
- explosion of pressure vessels;
- electrical hazards;
- ionising radiation (outside the scope of this Guide);
- strong magnetic fields;
- high temperatures;
- low temperatures.

An effective screen or shield will provide adequate protection against all the hazards for which it has been provided. In designing such a screen or shield, the requirements to provide adequate protection will need to be considered for each hazard in turn to confirm that the proposed design will provide the required protection. In considering what constitutes adequate protection for each of the hazards listed above, the principle of reducing exposure to as low a level as is reasonably practicable is very important. Where there is legislation dealing specifically with the hazard under consideration, for example noise or substances hazardous to health, ACOPs and/or guidance to the relevant regulations will assist in assessing the degree of protection to be achieved. In the case of an explosion generating missiles, the screen should be strong enough to withstand the highest energy missiles which could be generated without itself being significantly damaged. In the case of fire, the screen should not be significantly damaged by the fire (i.e. not be damaged to the extent that flame could pass through it, nor should its ability to deflect flame be affected).
Such confirmation may be sought through one or a combination of the following approaches:

- use of already proven design (for example as described in a research paper, code or standard);

- theoretical calculation;

- practical ("type") testing.

If either of the first two approaches above is taken for protection against the effects of an accidental explosion of explosives, it will, in the vast majority of cases, also be necessary to conduct a type test to confirm suitability of the proposed screen design for the specific application under consideration.

Use of Already Proven Design

There are a number of research papers describing results of experimental work to examine the effects of the explosion of various types and quantities of explosives on screens of various materials and designs.

Such results will only provide sufficient information to design a screen if:

- the application for which it is to be used is exactly the same as that described in the research paper (exactly the same type and quantity of explosive, distance from explosive to screen the same, etc.);

- the screen is not required to protect against any other hazards than explosion of the explosives.

Information in British/European Standards and Codes may also be sufficient to design a screen for a particular application, but the limitations noted above for research paper information apply here also.

Theoretical Calculation

Essentially this approach involves calculation of the magnitudes of the maximum overpressure, heat, flame and fragment energies which would arise from the explosion of the type and quantity of explosive under consideration, and then carrying out further calculations using data to derive information on the stresses that the explosion would impose. Finally calculations using mechanical properties data for the screen design/ material(s) under consideration are carried out to check that the proposed screen would be strong enough to withstand (ie not be significantly damaged by) the stresses of an explosion. Any other hazards to be protected against (for example, noise) will also have to be taken into account in the design calculations.
Practical ("Type") Testing

Whilst data from research papers, etc. or theoretical calculation are often not sufficient in themselves to design a screen, they can often be useful in identifying candidate designs, the performance of which can then be examined in practical ("type") tests.

A type test is a practical trial to examine the effectiveness of a screen in containing or deflecting the effects of an ignition of an explosive in the quantity and form in which it will be handled.

If the findings of a type test are to be of use in the development or validation of a screen, the test needs to be carefully designed and executed. A type test should simulate as closely as possible the conditions under which the explosive is to be handled, and hence the way that it would behave if accidentally initiated during handling. Ideally, the type test will be carried out in the building where handling will take place, using any equipment which is to be used in handling, but this may not always be possible on safety grounds or because possible damage to the building or equipment would be unacceptably expensive or disruptive.

In designing a type test, it must be remembered that the effects of the initiation of an explosive depend on the environment in which the explosion occurs as well as on the mass and form of the explosive and its degree of containment. For example, the performance of a screen in deflecting flame can be markedly affected by the presence of a wall on other sides of the burning explosive, and a type test to determine the performance of a screen in such a situation is of little value unless it is carried out in the proposed handling location or includes a simulation of the walls.

The following are some key points that need to be confirmed as the protocol for a type test is developed:

- will the explosive be present in the same quantity, form and geometry as it would be during handling?
- will the explosive be at the same temperature, and under the same pressure/degree of confinement as it would be during handling?
- for handling operations involving machinery, for example pressing, is the actual tooling to be used in the type test, or, at least, is equipment to be used which will simulate that tooling?
- will the screen be located in the same position and orientation relative to the explosive as would be the case during handling?
- will the type test be carried out in the location where handling is to occur, or, failing that, under conditions which will simulate the building to be used, for example a temporary construction to simulate the walls, roof, benches, etc. which would be present?
- will the strength of features such as walls, roof, screen mountings, etc. be the same as they would be during handling?

- will there be means to take measurements during the test that will enable an assessment of the effectiveness of the screen in protecting people to be made, for example radiometer, overpressure gauges, still or video cameras, manikins dressed with any personal protective clothing and positioned appropriately?

- will all materials involved in the type test be the same as, or equivalent to, the corresponding materials which would be involved in handling?

- in the case of a portable screen, will the type test replicate the proposed method of attaching the screen to the bench or other fixed structure? (It is very important to adequately secure a portable screen so that, in the event of an explosion behind it, the screen does not itself become a very dangerous missile).

- has a risk assessment for the type test been carried out and all actions arising from its findings been implemented?

**Ease of Maintenance, Durability, Compatibility**

The screen should be designed to be easy to clean with (where applicable) no corners or recesses where explosives dust could accumulate and be difficult to remove.

Portable screens should be strong enough to withstand normal handling without risk of any damage which could impair efficiency. Such screens should also be of such a weight that they are easy to handle.

The materials of construction of screens need to be compatible with the explosives being handled or processed behind them.
ANNEX 5 - DESIGN PRINCIPLES FOR EXTRACTION SYSTEMS

Extraction systems or more correctly Local Exhaust Ventilation systems (LEVs) are systems that use extract ventilation to prevent or reduce levels of operator exposure to airborne hazardous substances by drawing contaminants away from the process or operation. They range from simple systems serving single machines or processes to extensive plant providing contaminant (dust or fume) control throughout a large process or factory.

The basic components of an LEV system are:

- **Inlet** such as a booth, hood, slot, canopy, cabinet or enclosure to collect and contain the contaminant close to the source of generation;

- **Inlet Duct** circular or rectangular in shape, may contain bends, junctions, changes of section and dampers and be of flexible or rigid construction. Its function is to convey the contaminant away from the source;

- **Filter** or other air cleaning device such as dust filter, wet scrubber or solvent recovery device to remove the contaminant from the extracted airstream;

- **Fan** or other air moving device such as a compressed air venturi to provide the necessary airflow;

- **Exit Duct** to discharge the cleaned air to the outside atmosphere or a room via a stack, diffuser, grille or open duct.

**INLET**

Inlets range in size from small apertures to large canopies and may be positioned above, below or to the side or rear of the source. They should be located as close as possible to the source, enclosing it if possible. When handling explosives, careful consideration must be given to the effects of an ignition on such a system.

Inlets come in many forms i.e. booths, hoods, slots, canopies or enclosures, all should be designed to capture the maximum amount of contamination for the volume of air handled and the operation concerned. Any system with more than one inlet must be correctly balanced with the correct amount of air being drawn in through each inlet. The airflow at each branch will be determined by the resistance of the inlet, the length, diameter and flow resistance of the branch duct and the flow conditions at the junction with the main duct. Standard procedures exist for balancing ductwork systems.
INLET DUCT

The ductwork carries the extracted air and the contaminant to the air cleaning device or directly to the fan in the case of simple systems carrying low levels of contaminant. The duct must be designed so that the air velocity within the duct is high enough to keep the contaminants suspended in the airstream. The length of duct runs and the number of changes of direction should be kept to a minimum to avoid excessive resistance to flow, this may allow the contaminant to settle and accumulate. Where changes of direction are necessary, they should be smooth with the minimum number of joints and be designed to prevent 'points of collection' for contaminants.

The most common material used for ducting is galvanised steel sheet although for lighter duties aluminium or plastics such as PVC may be used.

Flexible ducting is often used on simple systems or where movement is required. There are limits to the flexibility of such ducting and flow resistances tend to be high which may allow settlement of contaminants; these may be difficult to remove from the duct. Runs of ducting should be earthed to a common point especially if non-conducting gaskets are used to seal flanges.

The type of ducting provided for the removal of dust from explosive operations must be carefully considered because of the propagation effects should an ignition occur. Runs of ducting should be provided with access holes or removable sections to allow for internal inspection and cleaning. Pressure relief panels may be fitted where appropriate.

AIR FILTERS / CLEANERS

When selecting air filters, the form and nature of the contaminant must be considered e.g. temperature, flammability, corrosive and abrasive properties and the explosive properties of the materials. Air cleaning devices can be divided into three basic types: -

- **Air Filters** these are used to handle low concentrations of dust and large air volumes. High Efficiency Particulate Air (HEPA) filters are used for ultra-clean applications and for particularly hazardous dusts such as asbestos;

- **Dust/Fume** These include cyclones, collectors, and electrostatic precipitators and are designed to extract large quantities of particulate material;

- **Others** These include charcoal absorbers or chemical scrubbers and are designed to remove mists, gases and vapours.
When selecting an air cleaner for a particular purpose, a wide range of characteristics, features and properties of the contaminant need to be considered. Waxy or greasy materials may permanently clog fabric filter materials rendering them useless for filtration purposes. Flammable and explosive materials require special precautions such as electrostatic protection and compatibility testing.

**FANS**

There are a number of different types of fan used in LEV systems however the two most common types are:

- **Centrifugal**

  These are the standard type of fan used in most LEV systems and consist of a ring of fan blades. Air enters the centre of the fan and is picked up by the rotating blades and thrown off at high velocity into the fan casing. The casing is designed to collect the air and guide it towards the discharge opening, which is normally at right angles to the air inlet. These fans can deliver the required airflows against considerable resistance.

- **Axial flow**

  These systems have aerofoil shaped blades and cylindrical casings, the blade tips run close to the casing. The fan motors are normally in the air stream and operate by accelerating the airflow causing suction. These systems are noisy and the fans are liable to stall when resistance against them is high.

Other types of fan include turbo-exhausters and compressed air driven air movers; they are less common and usually relate to special processes or conditions.

**EXIT DUCT**

Many simple LEV systems, particularly those for fume, consist of a cabinet and an extract fan venting directly to atmosphere. With such systems, discharge points and stack heights should be designed to prevent contaminated air being drawn back into the building and to ensure proper dispersion of the contaminant.

For larger systems with in-line filters, scrubbers etc., ductwork is used to carry cleaned air to a suitable point for discharge to atmosphere. Ductwork outside the building may need to be extended to a height of 3 metres or more above the roof level to prevent re-entry into the building. The ductwork must be strong and well supported to withstand high wind conditions.

Specialist advice may be required on discharge stacks in order to comply with current health and safety, environmental or local planning regulations.
MEASURING THE PERFORMANCE OF VENTILATION SYSTEMS

Ventilation systems must be checked on a regular basis to ensure that the design specifications are being maintained. Systems used to control air contaminants hazardous to health must be routinely inspected in accordance with the Control of Substances Hazardous to Health Regulations 2002.

There are three main ways of checking the performance of ventilation systems:

- Pressure measurement: Vertical u-tube manometers; Inclined manometers; Diaphragm pressure gauges; or Electronic manometers.

- Air velocity measurement: Vane anemometers; Heated head anemometers; Pitot static tubes; or Pressure gauges.

- Visual assessments: A smoke tube is used to determine air flow patterns and to check that air movement is in the required direction.

MAINTENANCE, INSPECTION AND TESTING OF LEV SYSTEMS

The planned maintenance of LEV systems considers the four types of component:

- Static items such as rigid ducts, hoods etc which should not wear unduly with time unless mechanically damaged by external materials and or worn or corroded by materials carried into the duct;

- Moving items that wear more quickly, e.g. fan bearings, drives and motors, filter shakers, adjustable baffles and some fume cupboard components;

- Components which deteriorate with use, e.g. filter fabric, flexible ducts;

- Items which need frequent attention, e.g. filter bins and waste containers, both of which need emptying on a daily or weekly basis, and cell type filters on paint spray booths which may need replacement at the end of each working shift.

Regular planned maintenance is required to ensure that LEV systems are functioning correctly and such systems should be inspected on a regular basis. The purpose of inspecting the system is to:

- Determine that the LEV system is running when hazardous substances are being emitted or are likely to be emitted;
- Ensure that the condition of the suction at the inlet e.g. hood, booth etc. has not changed, been obscured or moved;

- Check the condition of any visible ductwork and dampers by the inlet to ensure that they are in a good state of repair;

- Determine any evidence of control failure e.g. dust deposits or a stronger than usual odour immediately outside the LEV;

- Check that local instrumentation that has been fitted to the LEV is functioning correctly e.g. pressure gauge on a filter or air flow device on a fume cupboard;

- Ensure planned servicing such as changing filters or emptying dust containers has been carried out.

The extent and frequency of the inspections will depend on the complexity of the system and any specific requirements under the COSHH regulations, and all maintenance, inspection and testing carried out on an LEV system must be documented.
ANNEX 6 - ELECTROMAGNETIC COMPATIBILITY

Articles containing electrically operated initiation devices, such as fuseheads, electric matches or detonators (for simplicity hereafter called Electro-Explosive Devices - EEDs) are susceptible to initiation by Radio Frequency (RF) energy, conducted and induced transient currents. Such devices can be found in rocket motors, detonators, piston gas motors, retractors, protractors and other electrical initiation systems. EEDs are also used extensively in stage, film, television pyrotechnic special effects and electrically fired firework displays.

A number of hazards that affect EEDs can be identified:

1. Static electricity, either from atmospheric conditions or a built up charge resulting from synthetic substances.
2. Conducted transients from surrounding equipment or hardware can easily be transferred accidentally into an EED, through wiring and earth bonding of both electrical and none electrical equipment.
3. Induced current. This may result when lead wires are inadvertently laid next to lighting or sound cables.
4. Leakage currents from electrical cables (signal cables in addition to power cables), in wet and/or fully conductive conditions can provide substantial leakage currents which may be picked up by EEDs, particularly when they are laid on the ground.
5. RF induction. This hazard is likely when long wire connections are made which can form large loop or di-pole antennae, making the EEDs susceptible to RF energy.
6. Lightning: Conditions which lead to a lightning strike are preceded by the development of very considerable voltage gradients, which can pose a serious hazard.

During assembly and test it is vital that RF and transient energy does not cause EEDs to function. British Standard BS 6657:1991 "Guide to the Prevention of Inadvertent Initiation of Electro-Explosive Devices by Radio-Frequency Radiation" and Ordnance Board Pillar Proceeding P101 (2nd edition) will be of assistance in making assessments of the energy levels from nearby RF transmitters for both civilian and military users, respectively.

Prior to live assembly and testing it is important to ensure that a suitable safety margin below the No Fire Threshold (NFT) is maintained throughout the work area. Any energy above the NFT and below the All Fire Threshold (AFT) can desensitise EEDs, such that they may not operate in their desired role, causing a loss of reliability. Induced energy above the AFT will cause EEDs to function, potentially with disastrous effect.

As an alternative to assessment, substituting the EED, in an explosive article with a measuring device will allow practical measurements of induced energy to be monitored.
The following table gives some examples of NFT, AFT and other information about EED's used in missile systems, commercial detonators, pyrotechnic special effect devices and firework displays:

<table>
<thead>
<tr>
<th>Electrical Sensitivity</th>
<th>EED NFT Current (Energy)</th>
<th>Single EED AFT Current (Energy)</th>
<th>Multi EED in Series AFT Current</th>
<th>Bridge Wire Resistance</th>
<th>Example of Typical Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>4.2 Amp (500mJ)</td>
<td>7 Amp (1000mJ)</td>
<td>13 Amp</td>
<td>0.05 Ohm</td>
<td>Commercial 'Safety' Detonators</td>
</tr>
<tr>
<td>Standard</td>
<td>0.65 Amp (8mJ)</td>
<td>1 Amp (15mJ)</td>
<td>1.7 Amp</td>
<td>0.45 Ohm</td>
<td>Standard Commercial Detonators</td>
</tr>
<tr>
<td>Low</td>
<td>0.3 Amp (1.5mJ)</td>
<td>0.55 Amp (4.1mJ)</td>
<td>1.35 Amp</td>
<td>0.9 Ohm</td>
<td>Theatrical Pyrotechnics &amp; Fireworks</td>
</tr>
<tr>
<td>Ultra Low</td>
<td>0.02 Amp (0.064mJ)</td>
<td>0.11 Amp (0.48 mJ)</td>
<td>1 Amp</td>
<td>20.0 Ohm</td>
<td>Missile &amp; Weapon Systems</td>
</tr>
</tbody>
</table>

RF transmitters such as military and civil radar, mobile telephone handsets and base stations, emergency services, civil and security radios etc. are common. The Radiocommunications Agency (www.radio.gov.uk) can provide power and frequency information on fixed and registered mobile RF transmitters for any specified area within the UK. As unregistered (generally low powered) transmitters (i.e. mobile phones) are prolific, it is not always possible to ensure that all transmitters, not in your control, are assessed or are operating when measurements are taken. As such, it may not be possible to ensure that a suitable safety margin exists. For example, in the case of the ultra low intensity device in the Table above, a mobile phone will not induce enough energy to function or damage an EED as long as it is at least 7.5 metres away from the EED and any cables connected to it. This is only an example; each type of EED must be individually assessed in conjunction with its functional surroundings.

**Potential Preventative Measures**
The substitution of susceptible EEDs for less sensitive initiation components is the obvious approach when designing an explosive device. Examples of this include Exploding Bridge Wire (EBW) detonators that require many Amps to fire and the use of shock tube/Nonel (non-electric) detonators in the demolition, quarrying and mining industries (shock tube detonators are immune to RF radiation and transient current induction). Although substitution is not a practicable solution in many explosive applications, however there are a number of steps that can be taken to reduce the potential for accidental initiation of EEDs:

- **Minimise RF**
  - Erect clear and obvious signs around any area where EEDs are in use, stating that mobile phones and radio transmitters are not allowed and must be turned off.

- **HT Cables**
  - Avoid the use of EEDs close to high voltage overhead or buried power cables.
RF Screening - The system is enclosed in a 'Faraday Cage' to shield it from RF energy. For example, some missile systems contain EEDs that are highly sensitive to RF energy, as such the systems are enclosed in metalised 'over-socks' during storage and transport to provide RF screening. Some systems containing similar EEDs use the metallic body of the missile to provide suitable RF screening.

Min. Lead Length - Shorter lead wires on an EED make it more susceptible to high frequencies, while longer leads on EEDs make it more susceptible to lower frequencies. High frequencies do not travel as far or penetrate through structures or the ground as easily as low frequencies. As such, the susceptibility to lower frequencies is generally of greater concern during manufacture and storage.

Shorted Ends - Closing the loop of a firing circuit by shorting out the ends of the EED lead wires and/or the ends of the firing cable in a complete firing circuit will prevent the wires acting as a di-pole antenna, in addition to preventing accidental initiation from a directly applied voltage. However with the ends shorted this will create a loop antenna potentially making EED's more susceptible to RF radiation (see 'Twisted Wire' below). Ideally, firing systems should maintain a 'short' on the firing circuit until immediately before firing commences.

Twisted Wire - The use of 'Twisted Pair' firing cable and twisting the EED lead wires together will prevent large loops forming in the firing circuit, thus preventing loop antennae being created. Using tightly twisted wire will also help prevent the occurrence of induced currents, as equal and opposite currents will be generated in the wire simultaneously and these will cancel each other out.

During testing, test equipment can induce transients onto firing lines of EEDs, and can act as a path for conducted transients from the infra-structure/surroundings into the EED. It is therefore recommended that any such equipment is manufactured in accordance with BS EN 55022. In addition to this, appropriate 'Safety Ohmmeters' should be used for 'no volts' circuit testing of EEDs – Multimeters and general Ohmmeters must never be used to test EEDs or firing circuits as their power output is often high enough to cause EEDs to function.
A detonation break (alternatively called a detonation trap or detonation breaker) is a physical system built into a process to prevent a detonation or deflagration in one part of the process spreading or propagating through the entire mass of explosive, so limiting the extent of damage and injury. A commonly used form of detonation break is to isolate the various stages of an explosives process into different buildings that are separated from each other by distance such that an initiation of explosives originating in one building cannot initiate the explosives in neighbouring buildings. Alternatively, separation can be achieved by physical constructional features within a building (compartmentalisation). In process lines using conveyor belts, maintaining a separation distance between each explosive article moving on the conveyor will prevent propagation to neighbouring articles should ignition occur.

In the chemical manufacture of explosives it may be necessary to transfer liquid explosives by pipeline or gutter from one location to another. For example, in nitro-glycerine manufacture various types of detonation break can be used, as follows:

- The pipeline or gutter includes several bends, on the basis that any explosion of liquid nitro-glycerine might be quenched at one of the curves;

- Replacing part of the pipeline or gutter between buildings with narrow bore hose of such a diameter that nitro-glycerine cannot readily detonate within the section;

- Interrupting the stream of nitro-glycerine by passing it through a lead tank in which the flow of nitro-glycerine into the top of the tank has to pass through a layer of water before flowing out from the bottom of the tank.

In the manufacture of items such as detonating cord, where the length of explosive detonating is long, it is possible to use an equally fast explosive to activate a mechanism which stops the original detonation, usually by removing part of the explosive thus preventing propagation. In the manufacture of munitions, pyrotechnics and propellants, ultra high-speed water deluge systems can be used. These consist of multi spectrum high speed detectors and pressurised water discharge vessels located in close proximity to a process area and connected to an ultra fast response control system. In the event of an ignition the system responds in milliseconds to deluge the area with water, suppressing and extinguishing the explosive article or substance and preventing propagation and reducing the risk of injuries.

Finally, mechanical features in articles such as artillery ammunition can act as a detonation break preventing accidental functioning of the fuse from propagating to and initiating the main charge.
ANNEX 8 - INTERLOCKING PRINCIPLES

The definition of an "Interlocking Device" is a mechanical, electrical or other type of device, the purpose of which is to prevent the operation of machine elements under specified conditions.

Generally, the interlocking device is fitted to a guard or shield or in a remote processing operation, to a safety access gate and/or to the process power supply isolator. The types of interlocking devices available on the market are wide and varied, including mechanical, pneumatic, hydraulic, electrical and magnetic.

Having completed a risk assessment and identified a requirement to control any risks by the use of engineering controls in the form of interlocked guards, shields or remote processing, it is important to ensure that the interlocking device or devices selected are compatible with the process. For example, an electrical interlocking device used in a flammable vapour atmosphere would have to be intrinsically safe.

In the manufacture of explosives/pyrotechnics where opening guards are required, these are normally fitted with pneumatic or hydraulic interlocking devices associated with the process, to ensure that the risk is suitably controlled before access is gained into a danger zone.

It is also important that any type of interlocking device cannot be simply defeated using readily available objects such as screws, keys, coins and tools. This can be achieved by physical obstruction or shielding to prevent access to the interlocking device.

Certain processes in the explosives/pyrotechnics industry, such as the manufacture of primary explosives, mixing pressing and extruding propellants, making detonators, mixing and pressing of some pyrotechnic compositions, for which the assessment shows both the potential to kill or seriously injure, should be carried out remotely whenever practicable.

Systems must be put in place to prevent access into the remote processing area or danger zone during manufacture. A common system is by the use of "trapped or captive key" interlocking devices. There are numerous variations of these systems and they can be designed specifically for individual applications. Typically, a coded key is used to operate the power isolator (main power switch, valve or control circuit switch). Before access may be gained into the remote process area, the main power must first be isolated before the key is released from the power isolator. The operator then takes the coded key and unlocks a safety access barrier or gate into the danger zone, the key being "trapped" in the safety barrier or gate lock. Colleagues cannot inadvertently restart the process while the operator remains in the danger zone. It is important to note that if more than one coded key to the same power isolator or system exists, these must be strictly controlled so as to prevent the system from being defeated by the use both keys at the same time.

Further guidance and information may be found by referring to Annex 1, Part 1 and Part 2 of this publication.
CONFINEMENT CONSIDERATIONS

When an explosive reaction occurs, the degree and type of confinement in the local area will influence the event and may lead to increased levels of damage and injury.

Accidental explosions tend to start as a deflagration (burning reaction), the confinement of such an effect allows the gases generated to build up pressure thus raising the temperature and accelerating the reaction.

As the speed of reaction climbs, more and more energy is released into the confined area until a ‘Deflagration to Detonation Transition’ (DDT) occurs generating a massive shockwave capable of shattering most materials and creating high numbers of lethal fragments.

Confinement and the effects of confinement are not only limited to encased explosives. For example, a suitably high pile of explosive material can generate ‘Self Confinement’ where a deflagration within the heap is unable to vent, resulting in a pressure build up that may lead to DDT.

Materials do not have to be in contact with explosives to increase the effects of confinement. If the gas generated can rise in pressure and is unable to escape easily, the rate of reaction will be effected. As such walls, screens, and other hardware (such as ducts) can act as confinement even when they are relatively removed from the immediate area of effect.

The initial deflagration of some of the more sensitive high explosives may only last a fraction of a second before DDT occurs. As such they appear to be immediate detonations and local confinement has little or no effect on the reaction.

This knowledge can be used to create a safer working area, by designing the process, hardware used and procedures to minimise the total effect resulting from an accidental explosive reaction.

Some points to consider are:

- Minimise quantities: This reduces the possibility of self confinement and limits the potential total effect of a reaction;
- Use of heavy confinement to contain explosive events with suitable vents to direct the effects through a safe path to atmosphere;
- Use of blow-out/break-away sections designed to contain small events and release the pressure and confinement effects of larger reactions;
- The use of temporary/permanent explosion containment/mitigation systems and materials.

Complex computer programs are available that use finite element analysis, material algorithms and hydrocodes to predict the effects of explosions on people and structures. These can be used to model accidental explosions that could occur in
manufacture and storage, thereby allowing production engineers and civil engineers to design preventative measures, confinement release systems, mitigation and other safety features into production and storage.

References to some computer programs and codes will be found in Chapter 5 of the Health and Safety Commission Advisory Committee on Dangerous Substances publication "Selection and use of explosion effects and consequence models for explosives" published by HSE Books, ISBN 0 7176 1791 2.
ANNEX 10 - PERMITS TO WORK

A permit to work system\textsuperscript{39} is a formal written system used to control certain types of work that are potentially hazardous. A permit to work is a document which specifies the work to be done and the precautions to be taken. Such permits form an essential part of safe systems of work for many activities in the explosives industry where the job is not covered by other permanent written instructions e.g.:

- Non routine maintenance;
- Maintenance operations which compromise critical safety systems or remove them from service e.g. fire detection systems;
- Hot work;
- Entry into confined spaces and work inside them;
- Work where a risk assessment has identified a need for a permit to control the risks likely to arise.

The key elements of the systems will include:

Information on how the system works, the jobs it is to be used for, the responsibilities of those involved and how to check its operation. There must be clear identification of authorised signatories and those responsible for specifying precautions to be taken. The permit to work form(s) should be clearly laid out with no misleading or ambiguous statements and designed to cover appropriate circumstances. An example of a suitable form is shown below.

Selection and training for those issuing and/or authorising permits must include competence in recognising the hazards and precautions associated with the job. Staff and contractors must understand the system and be trained in its use.

The work to be done under the permit must be clearly identified, with its associated existing hazards and those arising out of conducting the work. Plans and diagrams can be used to assist in description and location of the task. The plant may need to be identified by asset number or tag. Detailed method statements may be required for more complicated tasks.

The system may require the removal or effective control of hazards e.g. by purging or forced ventilation. The permit should state the precautions to be taken, both before work commences and while work is in progress, to control the hazards including those introduced by the work e.g. solvent vapour while cleaning, welding fume. Where the job involves entry to a confined space, the Confined Spaces Regulations 1997\textsuperscript{40} will apply.
The procedures for implementing the system should cover control if the job has to be suspended or abandoned, both in an emergency, or other circumstances. If the job is likely to be prolonged, there should be a clear procedure for hand over between different shifts or teams. Where two or more jobs are subject to permits to work and may affect each other, these should be cross-referenced to ensure reinstatement after one task does not affect the safety of another. A copy of the permit should be displayed at the job, or point of entry to the plant. As with all systems of work, the permit to work system should be audited regularly to ensure that it is still relevant and being properly applied.

Permit to work forms

Examples of permit to work forms are given below. Instructions for completion of the first of these are:

Section 1 Permit No.
A unique reference number to identify the permit and facilitate cross-referencing.

Section 2 Other permits
A reference to other permits used in conjunction with this form eg another permit to work on related plant, or a separate permit authorising hot work or the use of special tools.

Section 3 Job location
A clear description of the workshop, vessel, area where the job is to be carried out.

Section 4 Plant identification
A clear description of the plant to be worked on. This may require a tag or plate to be fitted where there is chance of misidentifying items of identical plant.

Section 5 Description of work to be undertaken
The originator should describe the task to be carried out as precisely as possible, together with any limitations that may apply.

Section 6 Hazard identification
These should include all pre-existing hazards, those identified by the risk assessment at the start of the job, and any likely to arise during its completion.

Section 7
The originator should identify any isolations and/or lockoffs required. Details of the isolation(s) should be recorded and certified by the person(s) carrying out the isolation.

Section 8
The originator should identify any other precautions identified by the risk assessment to remove or control hazards eg use of specific type of tool or personal protective equipment.
Section 9
Where explosives are/have been present, the originator must decide whether the work requires segregation of explosives eg barriers to restrict access to part of the work area, or removal and cleaning of plant before work commences. In some cases a suitable competent supervisor/operator may be required to standby or visit to deal with any unusual circumstances which may arise as work progresses.

Section 10
The originator (or authorised signatory) must sign to confirm that isolations and other precautions have been made and validate the permit.

Section 11
The person responsible for carrying out the job must sign to confirm that they understand the terms of the permit and, where applicable have brought it to the attention of other people involved.

Section 12
Subsection i) is to be completed by the signatory from section 11.
Subsection ii) is to be completed by the originator or authorised signatory from section 11. Where an extension is required to complete the job, they must insert the revised duration.
Subsection iii) is to be completed by the person responsible for continuing the incomplete job.

Section 13
Subsection i) is to be completed by the person responsible for carrying out the job.
Subsection ii) is to be completed by the person responsible for removing the isolation(s), or where appropriate, by the originator or other authorised signatory e.g. maintenance or facilities manager/supervisor.

Section 14
The originator must sign to confirm that the work has been carried out to their satisfaction, and cleaned, restored and tested as appropriate and that the permit is cancelled.
**Examples of Permits to Work**

### PERMIT TO WORK - GENERAL

<table>
<thead>
<tr>
<th>1. Permit No.</th>
<th>2. Other permits</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/03.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3. Job Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building 1123 Acid processing area.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>4. Plant identification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lighting system LS/23</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>5. Description of work to be undertaken</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical test and replace/repair light fittings as required.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>6. Hazard identification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric shock.</td>
</tr>
<tr>
<td>Acid in adjacent pipe lines.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>7. Isolations/lockoffs (Tick where required)</th>
<th>Details of isolation carried out</th>
<th>Isolation certified by</th>
<th>Isolation removed/services restored by</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>☑ Isolate and lock off at switchboard GN/1/23.</td>
<td>A Leckie</td>
<td>A Leckie</td>
</tr>
<tr>
<td>Steam</td>
<td>☑</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>☑</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compressed air</td>
<td>☑</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fire protection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other (specify) Acid lines</td>
<td>☑ Drain and isolate nitric acid line CNA/23. Insert blanking plate and lock off at Valve 23/7.</td>
<td>A Fitter</td>
<td>A Fitter</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>8. Other precautions including PPE required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goggles type EG22 and Rigger gloves STS 65 to be worn when drilling.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>9. Explosives Clearance</th>
</tr>
</thead>
<tbody>
<tr>
<td>i) Removal of explosives is not necessary. Plant and equipment has been cleared and the work specified may proceed.</td>
</tr>
<tr>
<td>ii) Building, plant etc have been cleaned of explosives and the work specified may proceed.</td>
</tr>
<tr>
<td>iii) An operator has been/will be appointed to standby/visit and is aware of the precautions on the permit.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Signature</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24/11/02</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>10. Authorisation to proceed</th>
</tr>
</thead>
<tbody>
<tr>
<td>I confirm that the isolations and precautions in sections 7 &amp; 8 above have been made (except where these can only be taken during the course of the work) and the work specified may proceed.</td>
</tr>
</tbody>
</table>

| This permit is valid between ...0700-1500....hrs on ...25/11/02................. |

<table>
<thead>
<tr>
<th>Signature</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24/11/02</td>
</tr>
</tbody>
</table>
11. Acceptance

I confirm that I understand the work to be done, hazards involved and precautions required as detailed in sections 5, 6, 7, 8, 9 above. This information has been explained to the workers involved.

Signature: T M Leader
Date: 25/11/02

12. Extension/shift handover

<table>
<thead>
<tr>
<th>i) I certify that the plant/machinery has been left in a safe condition and notices affixed as required.</th>
<th>ii) I confirm that the plant/machinery has been left in a safe condition and notices affixed as required. This permit may be extended to ...........hrs on ...........</th>
<th>iii) I confirm that I understand the work to be continued, hazards involved and precautions required are as detailed in sections 5, 6, 7, 8, 9 above. This information has been explained to the workers involved.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signature</td>
<td>Signature</td>
<td>Signature</td>
</tr>
<tr>
<td>Date</td>
<td>Date</td>
<td>Date</td>
</tr>
</tbody>
</table>

13. Completion/handback

<table>
<thead>
<tr>
<th>i) I certify that the work detailed in section 5 has been completed, men, tools, equipment and waste have been withdrawn and guards replaced. Isolations may be removed and services restored.</th>
<th>ii) I confirm that all isolations/lockoffs in section 7 have been removed and all services restored.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signature: T M Leader</td>
<td>Signature: A Lockie A Filter</td>
</tr>
<tr>
<td>Date: 25/11/02</td>
<td>Date: 26/11/02 26/11/02</td>
</tr>
</tbody>
</table>

14. Cancellation

I confirm that the work specified in section 5 has been completed, all isolations removed and all services restored. All necessary tests have been carried out and this permit is now cancelled.

Signature: S Head
Date: 26/11/02
PERMIT TO WORK - HOT WORK

This permit is applicable to all operations involving flame, hot air or welding and cutting equipment, brazing and soldering equipment, blowlamps, bitumen boilers and other equipment producing heat or having naked flame.

Part 1. Issue
This permit is hereby given to ...........................................................................................................(print), to undertake the work detailed below. Work can only commence once all questions on this permit have been answered.

Part 2. Work to be Carried Out
Location .............................................................................................................................................
Equipment to be worked on ................................................................................................................
Reason for Work ................................................................................................................................
This Permit is issued for the following work ......................................................................................
..............................................................................................................................................................

Part 3. Additional Permits Required. YES / NO *
List all additional permits including permit No's ................................................................................
..............................................................................................................................................................
..............................................................................................................................................................

Part 4. Fire Permit
Permitted Area Limits: ....................................................................................................................
..............................................................................................................................................................
The following are permitted

<table>
<thead>
<tr>
<th>Welding</th>
<th>Yes / No*</th>
<th>Burning</th>
<th>Yes / No*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naked Flame</td>
<td>Yes / No*</td>
<td>Power operated tools</td>
<td>Yes / No*</td>
</tr>
<tr>
<td>Tools which may cause sparks</td>
<td>Yes / No*</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Precautions Required

| Fire Screens | Yes / No* | Fire Extinguishers | Yes / No* |
|             |           |                   |           |
| Explosimeter Alarm | Yes / No* |                   |           |

A person will be standing by with an extinguisher/hose reel while the operation is in progress. He/she and the operative have had the nearest fire alarm/telephone pointed out to them and have been told what to do in the event of a fire.
Remarks/other precautions: .................................................................

Other Precautions:
- Danger Notices to be posted: Yes / No *, specify: .................................................................
- Caution Notices to be posted: Yes / No *, specify: .................................................................
- Barriers/Screens to be erected: Yes / No *, specify: .................................................................
- Fire Alarms have been isolated: Yes / No *, specify: .................................................................
- Security Departments authority: Print: .................................................................
- Fire Officers authority: Print: .................................................................

* delete as appropriate

Part 5. Issuing Authority
Department Head or Nominated Representative
This certifies that the work to be carried out and the surrounding area authorised by this certificate have been inspected.
Signed: ................................................................. Time ................................................................. Date .................................................................
Print name: .................................................................
THIS PERMIT IS VALID FROM ................................................................. UNTIL ................................................................. (MAXIMUM 8 HOURS)
SECURITY MAIN CONTROL HAVE BEEN INFORMED.

Part 6. Receipt
I acknowledge receipt of this Permit to Work, that the above equipment to be worked on has been identified to me and that I understand the safety precautions that are to be observed.
Signed: ................................................................. Time .................................................................
Print name/names*: ................................................................. Date .................................................................
In the Employ of .................................................................
THIS PERMIT IS NOT VALID UNTIL PARTS 1 TO 6 HAVE BEEN COMPLETED.

Part 7. Local Managers Notification
I have been made aware that work is being carried out in the area under my control and I shall communicate this to the personnel in the area.
Signed: ................................................................. Date .................................................................
Print name/names*: .................................................................
Area Manager in location of work.

Part 8. Clearance of Work
I hereby declare that the work detailed in Parts 2 of this permit has been completed/STOPPED* and that the equipment worked on has been restored to operational conditions and all tools removed from it. The work area and all areas to which sparks and heat might have spread were thoroughly inspected on completion of the operation, at thirty minutes (30 minutes) and at one hour (1 hour) later. I confirm no smouldering fires were discovered.
Signed: ................................................................. Time ................................................................. Date .................................................................
Print name: .................................................................
In the Employ of .................................................................

Part 9. Cancellation
I hereby declare this Permit cancelled. The duplicate permit has been returned to me. The Danger notices detailed in Part 4 have been removed.
Signed: ................................................................. Time .................................................................
Print name: ................................................................. Date .................................................................
Issuing authority.
SECURITY MAIN CONTROL HAVE BEEN NOTIFIED OF COMPLETION.
Notes:

1. The Person/s named in Part 1 is to
   (i) Acknowledge receipt of this Permit by signing Part 6 of original and the photocopy.
   (ii) Retain the photocopy Permit whilst work is in progress.
   (iii) Return the photocopy Permit to the Issuing Authority when work is completed or suspended and complete
       and sign Part 8 of the original.

2. The Issuing Authority is to destroy the photocopy Permit when Part 8 of the original Permit has been
   completed and to complete Part 9 of the original.

3. 24 hour clock to be used.

delete as appropriate*
1. Cleanliness in buildings

All explosives buildings are to be kept as clean as possible commensurate with the tasks in progress.

2. Cleanliness of benches, fittings and floors

All benches, fittings and fixtures, and floors are to be maintained in a clean condition. Under no circumstances is polish to be applied to floors. Special attention is to be paid to the cleaning of conducting floors and only those cleaning agents recommended by the installers of the floors should be used. Sticky mats may be placed at all pedestrian entrances to process buildings to prevent contamination.

3. Permitted work in explosives areas

The types of work and processes permitted in an explosives area are initially prescribed in the relevant explosives factory licence, and elaborated in the relevant site standing orders. No work other than that prescribed is to be undertaken.

Having regard for the explosives limits, only the minimum quantity of explosives essential to the operation should be exposed in any bay, room or compartment in which the work is being undertaken. Explosives other than those actually involved in the operation are to be kept covered, positioned as far as is reasonably practicable from the operation or process in hand and their quantities minimised.

Only the minimum number of work persons essential to the effective and efficient operation of the task are to be present in the bay, room, compartment or building in which the work on explosives is being undertaken. No other persons are to be present except supervision, inspection, management, Safety Advisor, or authorised visitors, so long as such additional persons are not engaged in any operation of the task and do not create an additional hazard.

All work on explosives is to be conducted in an established and approved manner. Approved procedures are to be posted or otherwise made available in each bay, room, compartment or building in which work on explosives is undertaken. The introduction of ad hoc or makeshift procedures is prohibited.
4. Use Lists

The tools, materials, appliances etc, permanently required for any operation in each explosives bay, room or compartment, are to be detailed in the use list which is to be posted in the relevant bay, room, compartment or building in which the operations are to be carried out. The use list is also to detail the person and explosives limits and the permitted operations.

The use list does not include details of the explosives and components required for the operation.

Use lists are to be prepared by the relevant site management or engineer-in-charge and approved by the Safety Advisor.

If any changes are required to the use list, a new use list shall be produced.

5. Chairs and sundry fittings

All chairs and fixtures in an explosives area with a conducting floor shall be conducting or clearly marked 'Non Conductive'.

Any metallic fitting for dispensing paper towels or holding components shall be adequately earthed.

Any waste containers or bags or wrappings shall be anti static, if appropriate.

6. Approval to Process

Before any new process or modified process is undertaken, there should be a procedure to ensure that the location, tools and equipment etc. are suitable for the process to be carried out safely, through hazard and risk assessment and taking all measures suggested by that assessment. After this has been done, commissioning of the new or modified process should include carrying out the process using inert materials prior to the introduction of explosives.

For articles, substances and preparations, all the following activities shall be fully documented before approval to process is given by the Site Management and Safety Advisor.

6A. Articles

Before a new or modified article or sub-assembly can be assembled or disassembled the following points should be considered:

So far as reasonably practicable, jigs and fixtures shall be capable of withstanding initiation of the article or sub assembly without moving or releasing the equipment. This shall also apply to any fixtures used during test.

The area where the equipment is being processed should be of sufficient strength to withstand the effects of an accidental initiation. Reference 41
includes details of computer models which will enable the required strength to be calculated.

The process documents shall be proven on an inert item. Once the documentation has been proven, the facility and system shall be cleared in accordance with locally required procedures.

An assessment shall be made of the safety margins for all EED's against the RF environment of the facility (see Annex 6).

6B. Substances and Preparations

When determining a regime for mixing, filling and pressing new experimental preparations or compositions, the following could be considered when developing safe operating procedures:

a. Does a similar preparation or composition exist which has a safety certificate and to which a reasonable comparison can be made?

b. Using a small sample, conduct an explosiveness or burn test of loose material on an open hearth to determine the type of effect i.e. explosive/energetic, rapid/slow burning.

c. From the results of the explosiveness or burn test, by observation determine the risk as low, medium or high in relation to how the material will be used i.e. loose, semi pressed or fully consolidated, into a liner or without a liner.

d. If the material is to be consolidated or pressed, giving rise to the potential for ignition by friction or nipping by tooling, it should first be pressed into pellets or discs using small quantities of the material in order to determine, with the minimum of risk, the sensiveness of the material under working conditions.
a) Relationship to Factory and Magazine Licensing

The following points need to be borne in mind when considering engineering controls and other protective measures for explosives working areas in a licensed factory or magazine.

Compliance with the terms of a factory or magazine licence will go some way to ensure that risks to peoples health and safety within explosives working areas at the factory or magazine are properly controlled, but there will usually be a number of aspects of health and safety which are outside the scope of the terms of licence and the scope of licensing under the Explosives Act 1875 which will also need to be addressed. The position is best explained by considering i) what the licence controls ii) what is outside the scope of the licence, as summarised in the following table.

<table>
<thead>
<tr>
<th>What the licence controls</th>
<th>What is outside the scope of the licence</th>
</tr>
</thead>
<tbody>
<tr>
<td>The location of the site of the factory or magazine, and the location and size of the</td>
<td>In most cases, the location and extent of explosives working areas within buildings and other places.</td>
</tr>
<tr>
<td>buildings and other places such as burning grounds within the site</td>
<td></td>
</tr>
<tr>
<td>The broad application(s) of each building or place.</td>
<td>The detailed processes and operations which may be carried on under each broad application. How each operation or process is done.</td>
</tr>
<tr>
<td>The maximum quantities of explosives and other flammable or dangerous materials which</td>
<td>The safe quantities for any given process or operation, which may be less than the maximum quantity allowed by the licence. The maximum quantity of explosives which may safely be exposed at any one time in any given process or operation. Compatibility of explosives being processed.</td>
</tr>
<tr>
<td>may be present in each building, compartment or place at any given time, for each broad</td>
<td></td>
</tr>
<tr>
<td>application.</td>
<td></td>
</tr>
<tr>
<td>The maximum number of workers allowed in each building, compartment or place at any</td>
<td>The maximum number of workers for any given process or operation, which may be less than the maximum allowed by the licence. The maximum number of supervisors and visitors. Competence and training of those operating the factory or magazine.</td>
</tr>
<tr>
<td>given time for each broad application.</td>
<td></td>
</tr>
</tbody>
</table>
The basic construction of the floor, walls and roof of each building, the finish of internal surfaces, and the provision of mounds (traverses) where these are required.

The tools, machinery, equipment and plant used in the building. Protective measures such as portable screens, local exhaust ventilation, for those in the explosives working area.

The separation of explosives buildings and areas from each other, to prevent instantaneous communication of an accidental fire or explosion from one building to another, and thus, in the event of an accidental fire or explosion in any given building, provide protection from serious injury for those working in adjacent buildings.

The control of ignition sources and the prevention of an accidental fire or explosion.

The prevention of the communication of an accidental fire or explosion within a building, compartment or place.

Precautions against injury from any hazard for those in the explosives working area, and from hazards other than fire and explosion for those in adjacent buildings.

The provision of detonation breaks other than through building construction or separation by distance.

From the above it will be appreciated that the specification of most engineering controls and other protective measures in explosives working areas of a factory or magazine are outside the scope of the licence. It is therefore not sufficient, in order to ensure safety in such areas, to merely comply with the terms of licence, even for fire and explosion hazards. To ensure safety there also needs to be compliance with other requirements of the Explosives Act 1875 (for example the General Rules and Special Rules), the Health and Safety at Work etc Act 1974 and relevant explosives and general legislation made under that Act as summarised in Section 5 of this Guide.

b) Relationship to Licensing of Stores and Registration of Premises by the Local Authority

Local authority store licences and the registration of premises cover only the storage of explosives, although certain exemptions within the Explosives Act 1875, or provided later by a Certificate of Exemption under the Explosives Act 1875 (Exemptions) Regulations 1979, allow certain acts of explosives manufacture to be carried out in connection with a store or registered premises without the need for a factory licence. The following needs to be borne in mind when considering engineering controls and other protective measures in a licensed store, registered premises and explosives manufacture carried out under an exemption.
Licensed Stores and Registered Premises

A store licence specifies just the address of the store, the occupier and the Division (A, B, C, D or E) in which the store is licensed. For Registered Premises, the registration document specifies just the address of the premises, the occupier and usually the Mode (A and/or B) of keeping explosives.

All other specific safety requirements for Licensed Stores and Registered Premises are in the Explosives Act 1875 and its subsidiary legislation, and cover:

- prohibition on location of a store or Registered Premises below ground, etc.;
- type of construction and internal finish;
- exclusion of water from the store or Registered Premises in cases where explosives may be dangerously affected by water;
- the maximum quantities of explosives which may be kept, and the safety distances to be maintained, for each of the five Divisions of store, and maximum quantities of explosives which may be kept for each Mode of Registered Premises;
- explosives mixing rules and a prohibition on the keeping of certain explosives;
- conditions under which a small-arms cartridge filling room may be established in connection with a Licensed Store or Registered Premises and a workshop in connection with a Licensed Store;
- the material of tools and implements to be used in the store (Licensed Stores only);
- a requirement to prevent the introduction of grit, exposed iron or steel and sources of ignition into a Licensed Store, and, for Registered Premises, a requirement not to keep explosives dangerously near oils, paints and matches etc.;
- a prohibition on smoking;
- minimum age for employees (Licensed Stores only);
- removal of explosives before repairs are carried out (Licensed Stores only);
- general rules for Licensed Stores and Registered Premises;
- a requirement to take all due precaution to prevent accidents by fire and explosion and unauthorised access to the explosives;
- for Registered Premises, a requirement that the building or receptacle in which explosives are kept must be exclusively appropriated to such keeping.
It is not sufficient to ensure safety in the operation of a Licensed Store or Registered Premise to merely comply with the above legal requirements. There also needs to be compliance with the Health and Safety at Work etc Act 1974 and relevant explosives and general legislation made under that Act as summarised in Section 5 of this Guide.
Firing circuits are used widely within the explosives industry for the electrical firing of EEDs in applications ranging from the firing of firework displays and theatrical pyrotechnic effects, through the testing and proofing of products to the firing of the actual product by the customer.

**SIMPLE FIRING CIRCUIT DIAGRAM**

Firing circuits should be so designed that when initiation of an EED is unacceptable, there should be at least two independent circuit breaks, connected in series between the EED and its source of firing power. All switches associated with the launch or firing sequence should be designed so that it is possible to return them to their open-circuit condition in the event of a misfire or cancellation of firing, so that the required level of safety can be restored. The use of double-pole switches is recommended.

The last switch to be closed (the switch which completes the firing circuit and thus initiates the EED) and the firing lines between that switch and the EED should be fully screened to provide protection against radiated Electro Magnetic Interference (EMI). The capacitance across a switch should be as low as possible and preferably not greater than 1pF.

Switches should be designed to respond only to their intended stimuli. Electrically operated switches should be immune to operation by EMI; electromagnetic relays and solenoid operated rotary switches are generally suitable in this respect. Cyclic time delay switches, programmable motors and similar devices used in a firing circuit, where safety is dependent on a rotor being set at a start position, should be provided with positive means of checking that the rotor is at the start position.
Post firing safety switches should utilise an operating stimulus which can only be experienced as a consequence of operation. Examples of such stimuli are acceleration, rocket motor pressure, force exerted by a lanyard.

**FIRING LINES**

Firing lines should be kept as short as possible and positioned close to any shielding structure, avoiding apertures likely to be exposed to the Electro Magnetic (EM) environment. They should also be routed separately from lines which carry other electrical services in order to avoid induction of EM energy (caused by, for example, transients and low-frequency power supplies) and to minimise the risk of an accidental short circuit to power lines. When it is unavoidable that firing lines share a wiring loom and an electrical connector with other conductors, the connector pins used for the firing lines should be protected from the electrical services connected to the other pins by an isolating barrier or a ring of earthed pins.

**Single pole systems**

These systems are not generally recommended since they can be susceptible to voltage breakdown arising from high currents induced into a system e.g. by lightning. If such systems are used it is necessary to ensure that the resistance to earth is as low as possible, not greater than 50m Ω.

**Double pole systems**

Twisting the firing leads can reduce susceptibility to EMI by minimising wire separation and irregularities. Whether the firing lines are closely laid parallel pairs or twisted pairs, a double pole circuit will be susceptible to common modes EMI to exactly the same extent as a single-pole circuit.

**Screening firing lines**

Flexible braiding or rigid screening such as conduit placed around the firing lines will significantly reduce pick-up across the frequency spectrum. If firing lines share a wiring loom with other power/signal lines, they should be separately screened and not share the overall loom screen. Where a system employs more than one EED, the firing lines to each EED should be individually screened to prevent mutual electromagnetic coupling.

In order that the effectiveness of the electromagnetic shielding of the system is not degraded, the screening braid of firing lines must always make a 360° peripheral contact with the backshell of any connector. It is essential to ensure that the braid is not formed into a pigtail and fed through a plug and socket via one of the pins as this will reduce the shielding effects by introducing RF (radio frequency) into the shielding enclosure. The screening braid of a firing line should not be used as a return circuit. For this reason, coaxial firing lines are not recommended.
Firing Line Connectors

Electrical connectors employed in firing lines should be designed so that:-

- It is only possible to make a connection with the intended connector;
- When disconnected, it is impossible for an operator or an external structure to accidentally touch any pins connected to an EED. Whenever possible, firing lines connected to EED should be terminated at recessed female pins;
- The connector shells have a good conducting finish and they make connection and provide 360° RF shielding before any pins make connection;
- The termination arrangements for cable screening braid provide 360° peripheral contact;

To ensure a sound RF leak-proof connection, the mating halves of a connector should be secured by a threaded coupling preferably fitted with RF fingers (method of RF screening). Bayonet coupling connectors, for example, are unsatisfactory unless they incorporate spring finger grounding contacts. Fixed connectors should make a reliable and consistent contact with the bulkhead to which they are fitted. Circular flange connectors secured by a single nut are satisfactory in this respect. Rectangular connectors secured by fixing bolts may be less satisfactory as the connector flange may distort between the fixing bolts and allow RF energy through the gap created. In such cases it will be necessary to fit an effective RF gasket between the connector and the bulkhead.

When a firing line connector is mated in a high intensity RF field, arcing may occur which could result in some rectification of the pick-up, producing signals within the pass band of any low pass filter. This may be circumvented by careful choice of connector.

EED CONFIGURATIONS

Electro-Explosive Devices (EEDs) such as fuseheads are used in a wide variety of these applications. However, there are only two configurations (in-line or out-of-line) in which the EED can be applied.

EED IN-LINE SYSTEMS

The term in-line is used for EEDs that are permanently aligned with the explosive train which they are intended to initiate. If the EED is inadvertently initiated, the device with which it is employed will function.

The safety of a manually controlled firing system, used, for example, to fire a gun or fire a rocket motor, is dependent on the degree of isolation of the EED from the source of firing power, i.e. the reliability of conventional, manual switches (of the toggle, push button or rotary type), and on prevention of inadvertent manual operation.
In applications such as the operation of gas generators or explosive bolts, the EED may be initiated automatically on receipt of signals from timers or sensors which respond to stimuli experienced during deployment. Safety is again dependent upon isolating the EED from the source of firing power until initiation is required. The reliability of associated timers and sensors etc, and any potentially hazardous failure modes they may have, needs careful consideration.

Currently, low-voltage bridgewire EEDs use relatively sensitive primary explosive compositions which preclude their use in in-line fuzing systems. There are currently two types of EED available for use in in-line fuzing systems, the Explosive Bridge Wire and Exploding Foil Initiator.

**EED OUT-OF-LINE SYSTEMS**

An out-of-line system, until it is armed, contains a mechanical shutter which interrupts the explosive train and may also interrupt the EED firing circuit. Mechanically shuttered systems are normally employed in conjunction with low voltage EEDs. Almost all applications of out-of-line EED systems are concerned with the initiation of explosive warheads.

When the EED is out-of-line, i.e. in the safe position, the design is such that, should the EED be inadvertently initiated, the effect will be contained and not result in functioning of the explosive filling or device. The EED is thus isolated explosively, and its inadvertent initiation is normally a reliability problem and not a safety problem. A carefully designed and installed shutter mechanism can ensure a satisfactory standard of safety during transport, storage and handling operations.

The availability of firing power is controlled by safety switches and arming switches which are closed in a predetermined sequence thus preventing arming until required. Some safety switches are designed to function upon the application of a physical stimulus e.g. pressure or acceleration. Electromechanical and electronic switches will require an electrical stimulus i.e. a trigger-signal.

If the power supply used to initiate an EED also powers other services, as much as possible of the total system should be screened. Sections far removed from the EED firing lines may appear to have no bearing on the safety of an EED but there is always the danger that Electro Magnetic Interference (EMI) may be fed to an EED via a stray capacitance or common impedance coupling.
ANNEX 14 - REFERENCES


12. The selection, installation and maintenance of electrical equipment for use in and around buildings containing explosives, HSE Guidance Note PM 82, ISBN 0 7176 1217 1.


22. Safety of Machinery – Fire prevention and protection BS EN 13478.


24. Electrical apparatus for explosive atmospheres, Part 10: classification of areas (or places) BS EN 60079-10.

25. Classification of areas where combustible dusts may be present IEC 6/241-3.

26. Electrical apparatus for use in the presence of combustible dusts Part 3: Classification of areas where combustible dusts are or may be present BS EN 50281-3.

27. Electrical equipment for explosive gas atmospheres – Electrical installations in hazardous areas BS EN 60079-14.

28. Guidance and recommendations for the avoidance of hazards due to static electricity. Technical Report published by CENLEC.

29. Control of undesirable static electricity BS 5958.


33. Seven steps to successful substitution of hazardous substances, HSG 110, ISBN 0 7176 0695 3.

34. Human Factors in Industrial Safety, HSG 48, ISBN 0 11 885486 0.


