

# **CBI**

**EXPLOSIVES INDUSTRY GROUP**

**Management Guidance  
for the Safe Decommissioning  
of Explosives Sites**

# CBI

**EXPLOSIVES INDUSTRY GROUP**

## **Management Guidance for the Safe Decommissioning of Explosives Sites**

A guide to the safe decommissioning  
of Explosives Sites, the relevant  
legislation, and the techniques  
used for decontamination

**July  
2003**

© Confederation of British Industry  
Centre Point  
103 New Oxford Street  
London WC1A 1DU

**ISBN 0-85201-598-4**

## **CONTENTS**

	<b>Page No</b>
<b>SECTION 1.....Foreword</b>	<b>3</b>
<b>SECTION 2.....Introduction</b>	<b>4</b>
<b>SECTION 3.....Aim of this guide</b>	<b>5</b>
<b>SECTION 4.....Safety Management Systems</b>	<b>6</b>
<b>SECTION 5.....Legislative Requirements</b>	<b>11</b>
<b>1. Health and Safety Requirements</b>	<b>11</b>
<b>2. Environmental Legislation</b>	<b>15</b>
<b>SECTION 6.....Principal Explosive Contaminants</b>	<b>18</b>
<b>SECTION 7.....Safety Aspects of Decontamination of Equipment and Buildings</b>	<b>21</b>
<b>SECTION 8.....Decommissioning and Decontamination of Explosives Facilities</b>	<b>24</b>
<b>Stage 1 - Project Management</b>	<b>25</b>
<b>Stage 2 - Desk Top Study (DTS)</b>	<b>25</b>
<b>Stage 3 - Investigation</b>	<b>27</b>
<b>Stage 4 - Decommissioning and Decontamination Plan</b>	<b>29</b>
<b>Characterisation and Remediation of Land</b>	<b>29</b>
<b>SECTION 9.....Decontamination Techniques</b>	<b>30</b>
<b>SECTION 10.....Remediation Technologies</b>	<b>37</b>
<b>SECTION 11.....A Brief History of Incidents and Accidents</b>	<b>40</b>
<b>Glossary of Terms</b>	<b>47</b>
<b>Bibliography</b>	<b>55</b>
<b>Acknowledgements</b>	<b>58</b>

## **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, the Health and Safety Executive and the Environment Agencies.

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.

This guide is not intended to be used as a technical manual by those inexperienced in explosives site decontamination, to enable them to carry out decontamination activities. Those not experienced in explosives site decommissioning should seek expert assistance.

## **SECTION 2                      INTRODUCTION**

The history of explosives manufacture has seen the production of a diverse range of explosive compounds such as nitroglycerine, nitrocellulose, TNT, PETN, RDX, HMX, and metallic azides. Strong acids, metals and solvents have been used extensively in their manufacture. The explosives industry has also manufactured and used a range of explosive mixtures such as blackpowder, pyrotechnics, slurries and emulsions and has manufactured a wide range of explosive articles such as detonators, shells, mines and bombs.

The health and safety issues associated with explosives materials tend to be well known but the potential impacts on the environment may be less certain. Many of these substances are complex organic chemicals, which do not readily degrade in the environment and may therefore present an explosive risk for many years. In addition, many compounds produce complex bi-products during their manufacture or during their natural degradation.

It is estimated that there have been over 20,000 sites in the United Kingdom involved in the manufacture and storage of explosive materials, components and articles. As the explosives industry continues to decline, it becomes necessary to close sites and to make them safe and available for future development. It is necessary therefore, for the industry to have a common understanding of the issues involved in rendering a site "safe" and potentially making it available for future use.

The explosives industry uses terms, which apply in everyday language and to avoid the danger of misinterpretation, the following definitions are included at the outset for clarity and will apply throughout this document;

**Decommissioning – the process of taking plant, equipment and buildings out of normal use and leaving in a safe condition by the removal of bulk explosives.**

**Decontamination - the process of removing the residue (of explosives or ingredients used in their manufacture) from plant, equipment, buildings.**

**Remediation – the process of preparing a site to ensure that it is suitable for its intended use.**

A glossary of common terms used by the explosives industry is included in this document.

### **SECTION 3**

### **AIM OF THIS GUIDE**

The aim of this report is to provide guidance on the safe management of decommissioning of explosives sites, focusing on plant, equipment and buildings. The report does not set out to provide detailed technical advice on how to carry out particular decommissioning activities, but rather to provide an overview and highlight issues that need to be considered when planning and undertaking such activities.

The guidance focuses on those aspects of the explosives industry that are peculiar to the industry, and does not attempt to deal with health and safety issues that are common to other operations, for example handling asbestos, as guidance to these issues is available in other publications.

In addition to health and safety and other management requirements, the environmental implications of decommissioning are considered in brief. It is not the intention of the guide to cover these issues in detail, and the reader is directed to other sources of information, including publications, professional advice and the environmental regulators.

This guidance is aimed at those responsible for the planning and implementation of decommissioning activities at explosives sites and their advisors. The report may also be of interest to members of the public.

## **SECTION 4 SAFETY MANAGEMENT SYSTEMS**

Decommissioning and decontamination activities in the explosives industry are high hazard. A fully developed and functional safety management system (SMS) is essential to ensure that all aspects of the work are conducted in a safe manner. It is not the intention here to prescribe in detail the elementary aspects of SMS since this information is readily available in HSE publications and guidance.

The key elements of successful health and safety management are set out in the summary below. Diagram 1 outlines the relationship between them.

### **Policy**

Effective health and safety policies set a clear direction for an organisation contemplating decommissioning activities to follow. They contribute to all aspects of business performance as part of a demonstrable commitment to continuous improvement. Responsibilities to people and the environment should be met in ways which fulfil the spirit and letter of the law.

Stakeholders' expectations in the activity (whether they are shareholders, employees, or their representatives, customers or society at large) should be satisfied. There are cost-effective approaches to preserving and developing physical and human resources, which reduce financial losses and liabilities.

### **Organising**

An effective management structure and arrangements should be in place for delivering the policy. All staff should be motivated and empowered to work safely and to protect their long-term health, not simply to avoid accidents. The arrangements should be:

- underpinned by effective staff involvement and participation; and
- sustained by effective communication and the promotion of competence which allows all employees and their representatives to make a responsible and informed contribution to the health and safety effort.

There should be a shared common understanding of the organisation's vision, values and beliefs. A positive health and safety culture should be fostered by the visible and active leadership of senior managers.

### **Planning**

There should be a planned and systematic approach to implementing the health and safety policy through an effective health and safety management system. The aim is to minimise risks. Risk assessment methods are used to decide on priorities and to set objectives for eliminating hazards and reducing risks. Wherever possible, risks should be eliminated through selection and design of facilities, equipment and processes. If risks cannot be eliminated, they should be minimised by the use of physical controls or, as a last resort, through systems of work and personal protective equipment. Performance standards should be established and used for measuring achievement. Specific actions to promote a positive health and safety culture should be identified.

An important part of planning is risk assessment, which is covered in some detail at the end of this section.

### **Measuring performance**

Performance should be measured against agreed standards to reveal when and where improvement is needed. Active self-monitoring reveals how effectively the health and safety management system is functioning. This looks at both hardware (premises, plant and substances) and software (people, procedures and systems) including individual behaviour and performance. If controls fail, reactive monitoring discovers why, by investigating accidents, ill health or incidents, which could cause harm or loss. The objectives of active and reactive monitoring are:

- to determine the immediate causes of sub-standard performance; and
- to identify the underlying causes and the implications for the design and operation of the health and safety management system.

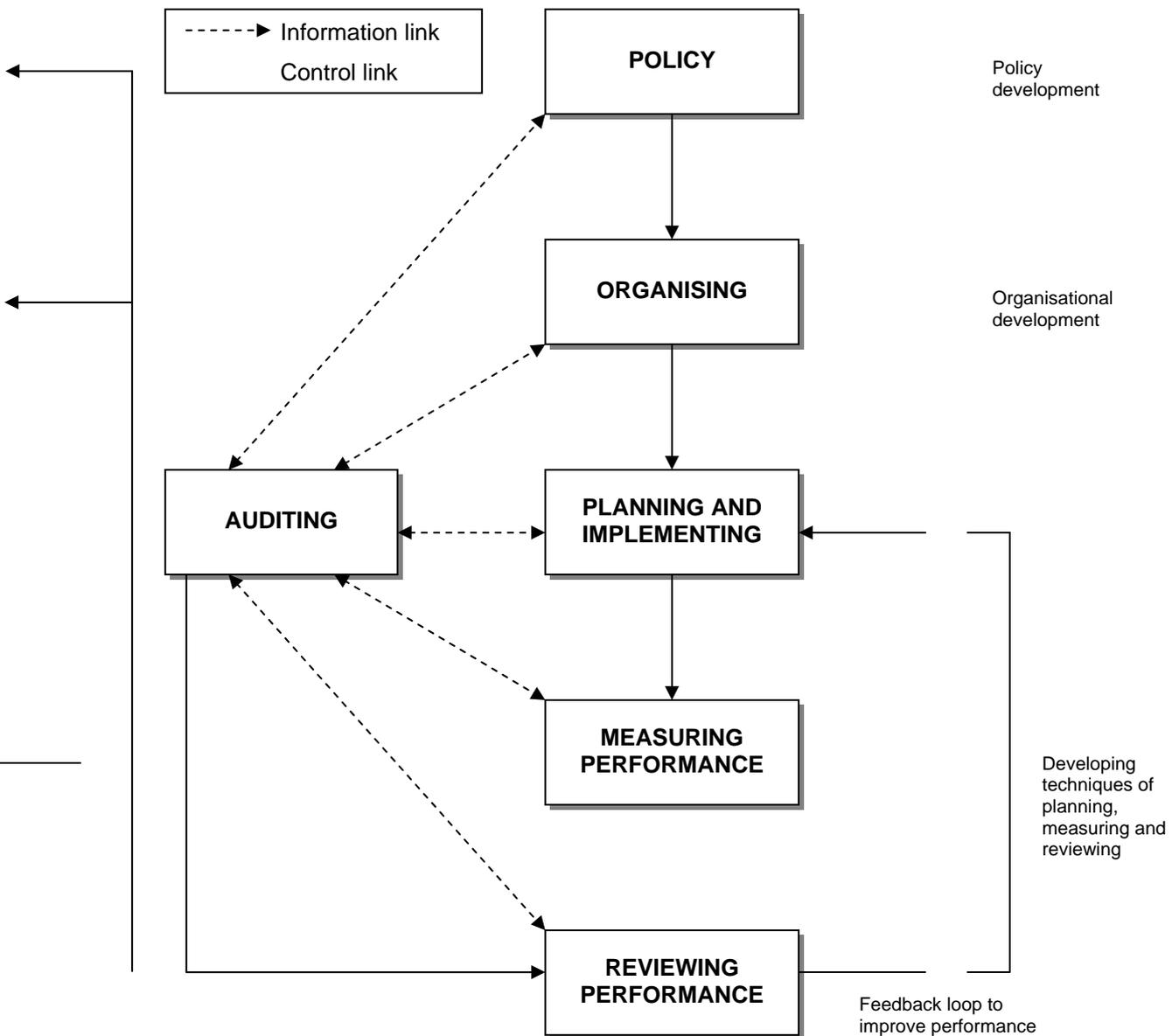
Longer-term objectives are also monitored.

### Auditing and reviewing performance

The organisation should learn from all relevant experience and apply the lessons. There should be a systematic review of performance based on data from monitoring and from independent audits of the whole health and safety management system. These form the basis of self-regulation and of complying with sections 2 to 6 of the Health and Safety at Work etc Act 1974 (HSW Act) and other relevant statutory provisions. There should be a strong commitment to continuous improvement involving the constant development of policies, systems and techniques of risk control. Performance should be assessed by:

- internal reference to key performance indicators; and
- external comparison with the performance of business competitors and best practice, irrespective of employment sector.

Performance is also often recorded in annual reports.



**Diagram 1** The key elements of successful health and safety management

## Risk Assessment

An essential element of the planning process is hazard identification and risk analysis. The normal method of undertaking this is by carrying out suitable and sufficient risk assessments. It is not the purpose of this document to describe the essential elements of risk assessments. Many HSE publications exist and cover this subject in far greater depth. The flowchart below (Diagram 2), demonstrates the essential role of risk assessment in the risk reduction process. Risk assessment is a critical step in determining the appropriate risk control system and workplace precautions.

The processes listed below are particularly relevant to decommissioning and decontamination:-

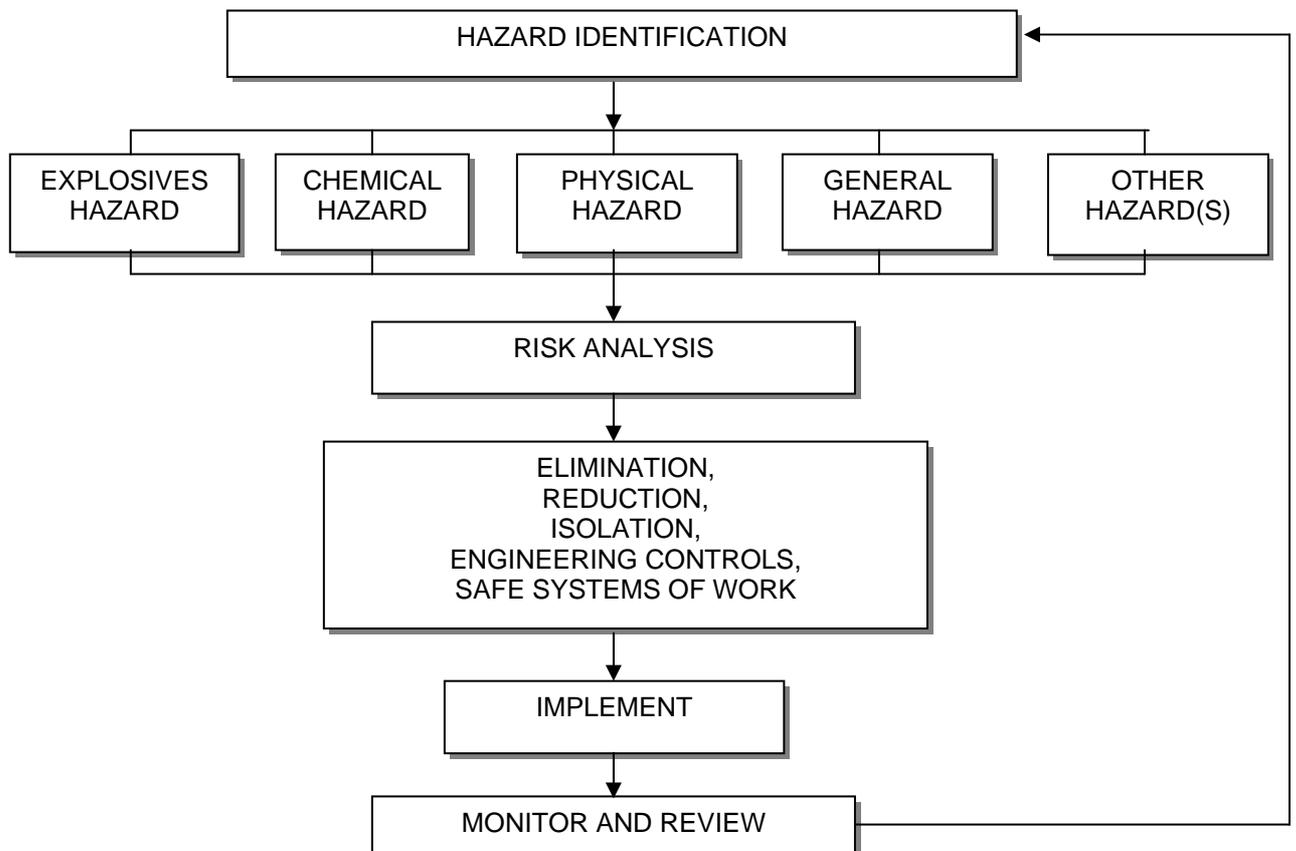
- Permit to Work procedure.
- Internal Transfer of Materials.
- Off-site Waste Disposal.
- Asbestos Work.
- Fire controls.
- Free from Explosives Certificate.
- Control of Contractors.
- Change of Use of a Building.

The following are general points to consider whilst conducting risk assessment during decommissioning:

- operators should be “competent” and, trained in safety management. Operatives carrying out investigative and remedial works on sites where explosives may be encountered should have experience of this type of investigation, be familiar with the issues relating to explosives contamination and unexploded ordnance and have received adequate training in the handling of explosives;
- those carrying out investigations on sites with any risk from explosive devices must have training and experience in the recognition and safe management of such devices;
- a great deal of care and experience is needed when choosing the type of equipment for the investigation and the implications the equipment has for the health and safety of those using it;
- of primary importance is the need to be vigilant, and if conditions change or unusual substances/items such as UXBs (unexploded bombs) are encountered - stop, review the situation and procedures and alter the health and safety plans accordingly;
- a contingency plan detailing the procedures which should be followed in the event of UXO (unexploded ordnance) being uncovered during the investigation should be included as part of the overall health and safety plans. Contingency plans should also detail procedures for the evacuation of a site;
- smoking and use of ‘naked flame’ equipment should not be permitted anywhere on these sites, except under controlled conditions. This includes sites where there is no longer any production of explosive;
- The use of communication equipment needs to be considered in the risk assessment. Certain explosives and devices, such as some initiators, can be initiated by emissions from mobile telephones or radio equipment;
- the possible presence of contaminants other than explosives should also be considered. Contaminants with specific health and safety implications, such as radioactive sources, chemicals and asbestos can also be found on explosives sites;
- during investigation or remediation work unauthorized persons must be excluded. Suitable and sufficient fencing and signs should be established at an appropriate position to provide a safe working area and to prevent any non-essential workers from entering the area;
- handling of samples is important; care should be taken not to accumulate materials since this would pose a greater explosive risk, also if unearthed explosives are left to dry they may pose a greater risk. The discovery of which may mean the requirement for emergency guarding and other security measures;
- contingency plans should be prepared.

Experience of previous decommissioning projects has shown there to be a range of circumstances leading to accidents and incidents. Summarised below are the common issues associated with explosives hazards leading to fire and explosion within the overall decommissioning process.

- Friction
- Impact
- Ignition by flame
- Ignition by spark
- Ignition by heat
- Electrostatic discharge
- Inadequate procedures
- Poor maintenance
- Ignition of solvent vapour or dust
- Inadequate removal of explosive material
- Lack of knowledge of presence of explosive material
- Lack of knowledge of the properties of explosive materials
- Explosive material present in confined spaces ( Threads of bolts, in floor or wall cavities)
- Presence of explosive material in operational drains
- Presence of explosive material in redundant equipment, process pipe lines and drains
- Presence of explosive dust in extraction ducts
- Presence of explosive material in ducts or in cool surfaces
- Poor control of equipment requiring treatment, modification or disposal at facilities outside of the process area
- Lack of historical information on previous use of old facilities
- Inadequate marking / control of plant or buildings



**Diagram 2** Risk assessment flowchart

The overriding messages are:

- the need for use of risk assessments to develop appropriate risk control measures and workplace precautions within a developed and functional SMS
- those carrying out risk assessments and work on explosives sites should be experienced, trained and competent to make such decisions;
- those working on operational sites must be aware of the Health and Safety Plan specific to the particular site.

## **SECTION 5**

## **LEGISLATIVE REQUIREMENTS**

The aim of this section is to provide a general overview of the key health and safety requirements that apply to explosives decommissioning. Further in this section reference will be made to environmental legislation, the aim is to make the reader aware of its existence but not to provide detailed guidance since this already exists in other published references.

### **1. Health and Safety Requirements**

There is a considerable amount of health and safety legislation, which has a bearing on decommissioning of explosive sites but there is no specific regulation dealing solely with this activity. The list below demonstrates the principal legislation dealing with decommissioning.

- Health and Safety at Work etc Act 1974
- Explosives Act 1875 and 1923 and Subsidiary Legislation
- Noise at Work Regulations 1989
- Electricity at Work Regulations 1989
- Manual Handling Operations Regulations 1992
- Workplace (Health, Safety and Welfare) Regulations 1992
- Personal Protective Equipment at Work Regulations 1992
- Construction (Design and Management) Regulations 1994
- Provision and Use of Work Equipment Regulations 1998
- Lifting Operations and Lifting Equipment Regulations 1998
- Management of Health and Safety at Work Regulations 1999
- Control of Major Accident Hazard Regulations 1999
- Control of Substances Hazardous to Health Regulations 2002
- Control of Asbestos at Work Regulations 2002
- Control of Lead at Work Regulations 2002
- Dangerous Substances and Explosive Atmospheres Regulations 2002

#### **Health and Safety at Work etc Act 1974 (HSWA)**

This Act covers the health and safety of people through work activities. It has a number of objectives, primarily to secure the health, safety and welfare of persons at work. It applies to all persons at work irrespective of the work done or the premises where it is done.

Under Section 2, employers are required to ensure, so far as is reasonably practicable, the health and safety at work of their employees.

Duties placed on employers and the self employed under Section 3 of HSWA are relevant to persons who are not employees, for example contractors.

The Act also protects people other than those at work (i.e. the general public) against risks to their health and safety arising out of work activities.

The Act imposes duties on everyone concerned with work activities ranging from employers, employees, self-employed, manufacturers, designers, suppliers and importers, people in control of premises and even extends to members of the public.

#### **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.

### **Noise at Work Regulations 1989**

These are relevant to the control of noise exposure in working areas. 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 the workplace. Amongst the areas that the 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 inter alia 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. There is a Health and Safety Executive Guidance Note PM82, 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.

### **Manual Handling Operations Regulations 1992 (MHOR)**

The requirements of these Regulations need to be considered for any activity that requires manual handling. There is Health and Safety Executive guidance on these Regulations.

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

The requirements of these regulations need to be met to ensure that workplace facilities meet certain standards. There is Health and Safety Executive guidance on these Regulations. In addition, the Construction (Health, Safety and Welfare) Regulations, 1996 (CHSWR), state the requirements to be met regarding workplace facilities on construction sites, and are aimed at protecting construction workers and other people who may be affected by construction activities.

### **Personal Protective Equipment at Work Regulations 1992**

MHSWR requires employers to identify and assess risks to health and safety in the workplace. The risks should then be reduced to an acceptable level by the most appropriate means. Engineering controls or safe systems of work should be considered first in the hierarchy of controls. PPE should be regarded as the last resort to protect against risks. When PPE is necessary, it only protects the person wearing it, theoretical maximum levels of protection are seldom achieved and PPE restricts the wearer by limiting mobility or visibility. It is therefore essential that appropriate PPE and training in its use is provided when there is a risk to health and safety that cannot be adequately controlled by other means. The regulations place requirements on employers to provide PPE that is suitable for the purpose, that it is maintained or replaced as necessary, that it is provided with suitable accommodation when not in use and that suitable information, instruction and training is given in its use.

The regulations also place duties on employees to make full and proper use of PPE when it is provided. Employees also have a duty to report any loss or defect.

### **Construction (Design and Management) Regulations 1994 (CDM)**

The construction industry covers a wide range of activities, hazards, materials, techniques, employment patterns and contractual arrangements. In these circumstances, good management of construction projects from concept through to demolition is essential to maintain health and safety standards.

CDM is intended to protect the health and safety of people working in construction, and others who may be affected by their activities. The Regulations require the systematic management

of projects from concept to completion: hazards must be identified and eliminated where possible, and the remaining risks reduced and controlled. This approach reduces risks during construction work and throughout the life cycle of a structure (including eventual demolition). There is Health and Safety Executive guidance on these regulations.

### **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. PUWER 98 came into force in December 1998, but some of the regulations dealing with mobile work equipment did not come into effect until 5 December 2002. 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. 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 and 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. 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. 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. They cover for example, the guarding of dangerous parts of work equipment, the provision of appropriate controls and suitable warning markings or devices.

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

### **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.

### **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 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. There is an approved code of practice and guidance for these regulations.

### **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 emphasised 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.

### **Control of Substances Hazardous to Health Regulations 2002 (COSHH)**

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 Packaging for Supply Regulations) 2002 (CHIP 3) as amended, and to those substances, which have maximum exposure limits (MELs) or occupational exposure standards (OESs). COSHH also covers other substances that have chronic or delayed effects, for example substances that are carcinogenic, mutagenic or teratogenic and biological agents. 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 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 that a suitable and sufficient assessment to be undertaken of the health risks created by work involving substances hazardous to health, and Regulation 7 requires that exposure to substances hazardous to health is prevented, or failing this, controlled. 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 with workplace monitoring and Regulation 11 with health surveillance. Regulation 12 deals with information, instruction and training. Regulation 5 exempts certain substances, which are subject to more specific legislation on the control of health hazards, such as asbestos and lead, from the requirements of Regulations 6 to 12 inclusive of COSHH.

There is an approved code of practice for these regulations.

### **Control of Asbestos at Work Regulations 2002 (CAWR)**

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

- Work with asbestos insulation, asbestos coating and asbestos insulating board
- Work with asbestos, which does not normally require a licence.

### **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.

### **Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR)**

These regulations apply to all dangerous substances at nearly every business in Great Britain. They set minimum requirements for the protection of workers from fire, explosion and similar (energy releasing) events, which are caused by dangerous substances and potentially explosive atmospheres. The regulations are complementary to the general duty to manage risks under the Management of Health and Safety at Work regulations 1999. The main requirements are that employers and the self-employed must:

- Carry out a risk assessment of work activities involving dangerous substances
- Provide technical and organisational measures to eliminate or reduce as far as is reasonably practicable the identified risks
- Provide equipment and procedures to deal with accidents and emergencies
- Provide information and training to employees
- Classify places where explosive atmospheres may occur into zones, and mark the zones where necessary.

### **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 deadline for receipt of comments on the Consultative Document was June 2002, and the Regulations are currently expected to come into force in 2004.

## **2. Environmental Legislation**

The following sections are not intended to be a comprehensive guide to environmental legislation and its application to the decommissioning of explosives sites. Compliance with the law remains the responsibility of those involved in the planning and implementation of decommissioning programmes.

There are many aspects of a decommissioning project that can have an impact on the environment, directly or indirectly, and which may be subject to statutory control, for example:-

- Vehicle movements – noise, dirt and disruption to the locality;
- Wastes – keeping, treating or disposal of liquid and solid wastes on and off site;
- Effluvia – smoke, odours, discharges to watercourses;
- Any activity which may create nuisance, smoke, odours, noise etc;
- Existing statutory controls on prescribed process – IPC, LAPC, PPC etc;
- Contamination of land, surface water and groundwater.

Once the scope of the project has been defined, operators embarking on a decommissioning project should consult with the appropriate authorities to ensure that appropriate controls, permissions/consents are obtained before starting work.

The Environment Agency (EA) in England and Wales, the Scottish Environment Protection Agency (SEPA) in Scotland and the Environment and Heritage Service in Northern Ireland, are the regulatory authority for waste management activities, regulation of discharges to controlled waters, IPC/PPC (Part A (1)) and designated Part IIA special sites.

It is also advisable to contact the local authority in whose area the site is situated to discuss the proposals for the site.

### **Statutory Nuisance**

There are a number of Acts and Regulations, which vary across the UK, which incorporate some element of nuisance. If any aspect of the decontamination process generates noise, smoke, fumes, gas, dust, steam, odours, deposits or accumulations of refuse which affects the health of people in the locality or adversely affects their legitimate use of land, these could be subject to statutory control. Such activities may attract complaints, either directly or to the Environmental Health Office of the Local Authority. It is good management practice to have in place procedures for monitoring activities which may impact on the wider population and to take measures to reduce or eliminate where possible such impacts.

## **Wastes**

Where the decommissioning project will generate 'controlled waste', waste management legislation will apply. Where the operation will keep (store), treat or finally dispose of waste, then the relevant environmental regulator should be contacted to establish whether a Waste Management Licence is required.

If there is uncertainty as to whether the project will generate controlled wastes, advice can be obtained by contact with the environmental regulator.

A company involved in decommissioning activities has a Duty of Care to take all reasonable measures:

1. To prevent the unauthorised or harmful disposal of waste by another person.
2. To prevent the escape of the waste from the company's or any other person's control.
3. On the transfer of the waste, to secure:
  - (i) that the transfer is only to an authorised person or to a person for authorised transport purposes; and
  - (ii) that there is transferred such a written description of the waste as will enable other persons to avoid the unauthorised or harmful disposal of the waste and to comply with their own Duty of Care.

The proper and safe disposal of waste even after it has been passed on to another party such as a waste contractor, scrap merchant, recycler, local council or skip hire company must be ensured. The Duty of Care has no time limit, and extends until the waste has either been disposed of or fully recovered.

## **Controlled Processes**

The activities which are or have been carried out on the site may be controlled processes under the Environmental Protection Act, 1990 e.g. IPC, LAPC. Under these regimes there is a general requirement to apply Best Available Techniques Not Entailing Excessive Cost through good management in the form of:

- preventive maintenance;
- proper operation and supervision of processes (including associated pollution control equipment);
- proper training and instruction of all staff;
- good housekeeping;
- minimising pollution that might arise during delivery, storage and handling of materials.

Since new regulations were introduced in 2000, existing processes are being phased into the Integrated Pollution Prevention and Control regime.

## **Pollution of Controlled Waters**

It is an offence to cause or knowingly permit pollution (poisonous, noxious or polluting matter or any solid waste matter) to enter controlled waters. Controlled waters include rivers, lakes, ponds, lochs, docks, streams, canals, coastal waters, estuaries and groundwater.

The environment agencies regulate discharges to controlled waters, for which authorisation is required. These usually stipulate that discharges should be free of polluting matter, but may also set limits on the concentrations of specific substances with a requirement to monitor and report the quality of the discharge.

The environmental regulator has the power to serve a Works Notice (s161A Water Resources Act 1991) to prevent or remedy water pollution. Such notices can be served before pollution has occurred if, in the opinion of the regulator, a polluting substance is likely to enter

controlled waters. The regulator may also serve a Works Notice to ensure that waters are cleaned up after pollution has occurred. (This is only true in England and Wales)

Some useful guidance for the construction industry has been produced by CIRIA in conjunction with the Department for Trade and Industry and the Environment Agency – “Guide to good practice on site”.

### **Contaminated Land**

Where land is contaminated in its current state, regulatory control may apply through Part IIA EPA 1990. Part IIA defines land, which “appears to the local authority in whose area it is situated to be in such a condition, by reason of substance in, on or under the land, that significant harm is being caused; or pollution of controlled water is being, or is likely to be caused.” Statutory guidance for this describes regulatory responsibilities for identifying contaminated land and securing its remediation.

Where land is found to be a ‘special site’, EA/SEPA take over regulatory responsibility from the local authority. Special sites are described in the Regulations and include “land on which any of the following activities have been carried on at any time – the manufacture or processing of explosives.”

The enforcing authority is required to seek remediation of the land wherever possible by the ‘appropriate person’ i.e. the one who caused or knowingly permitted the land to be contaminated land, or in some cases the owner/occupier of the land.

It is in the interests of those who may be responsible for contamination, or own land where contamination may be present, to seek advice to identify and deal with contamination.

When buying, selling or leasing land that could be affected by contamination, it is important to be aware of possible implications and liabilities associated with contamination.

Where land is to be redeveloped for a new land use, the local planning authority is responsible for regulating the development of the land, under the planning regime set out in the Town and Country Planning Acts.

### **Records**

Many items of environmental legislation require the keeping of records. In addition, it is good management practice to prepare and maintain good records of your activities, particularly where the objectives for decommissioning include the sale of the site. Records of what has been done to land and buildings, and verification of their condition, can increase confidence for potential purchasers.

### **Guidance**

A great deal of useful information on environmental legislation can be obtained from the following two sources: -

1. The “NetRegs” website (address below) is sponsored by the EA, SEPA and the Environment and Heritage Service (Northern Ireland) and provides guidance on many aspects of environmental legislation for small and medium sized businesses.

<http://www.environment-agency.gov.uk/netregs/>

2. The Pollution Handbook published by the National Society for Clean Air and Environmental Protection, ISBN 0 9034 7453 0, is revised annually and contains useful summaries of most aspects of environmental legislation.

## SECTION 6 PRINCIPAL EXPLOSIVE CONTAMINANTS

Generally, explosive materials are categorised into compounds or compositions. Organic materials form the majority of high explosive compounds. They may be used individually or as part of a composition. Pyrotechnics and propellants are almost always mixtures of materials, and may include organic compounds together with inorganic materials such as metals and oxidisers.

Explosives may be categorised by their function (high explosives, initiators, propellants, pyrotechnics etc.) or by UN Hazard Classification.

The explosives mentioned in this section are just some of the materials that may be encountered during decommissioning work. Other materials may also be present and not be expected.

Some of the materials have very specific properties. A range of properties therefore has to be considered. The person responsible for the decommissioning work must ensure that they have a detailed understanding of the nature and properties of explosive materials. A comprehensive literature search is essential to identify the specific properties. This information may be found in Explosive Hazard Data Sheets or Explosives Safety Data Sheets.

### Organic explosive compounds

Many explosives exist as individual compounds. The compounds fall into three main classes: nitrate esters, nitro aromatics and nitramines. They contain their own oxygen to support the decomposition reaction and provided with the right stimulus will detonate. Typical examples of the most commonly encountered organic explosive compounds are:

- EGDN ethylene glycol dinitrate or nitroglycol
- HMX cyclotetramethylene tetranitramine
- HNS hexanitrostilbene
- NC nitrocellulose
- NG nitroglycerine
- PETN pentaerythritol tetranitrate
- picric acid 2,4,6- trinitrophenol
- picrite nitroguanidine
- RDX cyclotrimethylene trinitramine
- tetryl trinitrophenylmethylnitramine
- TNT 2,4,6- trinitrotoluene

Details of the chemical structures, official technical terms and the commonly used alternative names may be found in standard references such as Explosives (5<sup>th</sup> Ed) - R Meyer, J Köhler and A Homburg (2002), which details many of these technical and colloquial terms.

### Metal salts of organic molecules

In addition to the individual organic explosive compounds there are a number of inorganic compounds with explosive properties. Many of these substances are highly sensitive and will detonate readily with only the slightest stimulus. They are commonly used as initiators. Typical examples of such explosives are:

- lead azide;
- lead azotetrazole;
- lead dinitroresorcinate (LDNR);
- lead monoresorcinate (LMNR);
- lead styphnate;
- mercury fulminate.

## Pyrotechnics

Pyrotechnic is a name given to mixtures of fuel and oxidant that may contain other ingredients such as a binder or burning rate moderant. They are almost always solid mixtures. Materials used in compositions will be dependent on the type of pyrotechnic effect desired and on the colours of smoke or flares. The compositions burn rapidly to produce effects such as heat, flame, light, sound, smoke, gas production or burning delays. Applications include:

- delay compositions;
- igniter compositions;
- primer compositions;
- signal/flare compositions;
- smoke compositions;
- tracer compositions.

Typical materials used in the production of pyrotechnics include:

- Oxidisers - molybdenum trioxide, bismuth trioxide, potassium nitrate, potassium perchlorate, sodium nitrate, barium nitrate, barium peroxide, strontium nitrate, potassium chlorate
- Fuels - Magnesium, aluminium, boron, silicon, manganese, phosphorus, tungsten, charcoal
- Other additives - acaroid resin, chlorinated rubber, boiled linseed oil, calcium oxalate, butyl rubber, zinc stearate, various waxes, dyes, PVC, Viton

## Chlorate and perchlorate based explosives

These explosives consist of intimate mixtures of hydrocarbons (e.g. waxes or polymeric binders and rubbers) as the fuel, and metal chlorates, perchlorates or ammonium perchlorate as the oxidiser. Certain commercial mining explosives were chlorate or perchlorate based explosives. However, the main current application of this family of explosives is in composite propellants in which ammonium perchlorate is incorporated into a rubbery composition. Although technically a powerful oxidising agent, ammonium perchlorate can under certain conditions detonate.

## Ammonium nitrate based explosives

When mixed with a fuel, ammonium nitrate is a powerful explosive. ANFO (ammonium nitrate and fuel oil), slurry and emulsion explosives are all mixtures of ammonium nitrate and fuels. They are mainly used as commercial explosives for blasting operations. Slurry and emulsion explosives often contain other additives as sensitisers e.g. aluminium powder which modifies their explosive properties. During the First World War, amatol compositions (mixtures of ammonium nitrate and TNT) were widely used as military high explosives. Ammonium nitrate can under certain conditions detonate without a fuel being present.

## Raw Materials

Raw materials/precursors used in the manufacture of the explosives may also be explosive in their own right. They may also be toxic.

## Breakdown Products

Most explosives remain relatively stable under the correct storage conditions. However, some materials may suffer degradation as they age, and may in some circumstances produce breakdown products, which pose explosive or toxic hazards.

The decomposition rate of explosives is dependent upon a number of factors, which may include the following:

- the prevailing conditions, e.g. temperature; relative humidity around the explosives; moisture content
- pH of soil - certain explosives can decompose in acidic soils by a process known as acid catalysed decomposition

- physical form of the explosive material
- concentration of the explosive

Examples:

NC/NG based gun propellant may contain a stabilising mineral jelly to counteract the breakdown of the two explosive constituents. As the stabiliser chemically depletes, breakdown of the NC and NG occurs, especially when stored in dry, warm conditions. This chemical breakdown can accelerate to the point where heat builds up. If this heat is not dissipated spontaneous combustion can result. Storage of such gun propellant e.g. bulk cordite, over decades has been known to result in a deflagration and destruction of buildings.

Picric acid will react with metals, corroding them and forming impact sensitive salts (picrates). These picrates are very sensitive explosive compounds, which are far more hazardous than the picric acid, which formed them.

In some circumstances, the rate of decomposition can become autocatalytic, leading to thermal runaway and the risk of explosion.

Additionally, metals contamination may occur from the corrosion of shell casings, paints, pyrotechnic or initiator compounds.

### **Thermal decomposition and combustion products**

Some of the decontamination methods used may involve the burning of materials. Very careful consideration may have to be given to the concentrations and toxicity of any thermal decomposition or combustion products that may be formed.

These products may consist of polyaromatic hydrocarbons (PAHs), carbon monoxide, nitrogen oxides, etc.

### **Other factors**

There may be other factors, which have to be considered related to the properties of explosives and their ingredients, which may affect the way in which decontamination has to be conducted.

Consideration has to be given to the manufacturing processes used and any additional reagents that may have been used as part of the process. Disposal of any reagents also has to be considered. It is possible that explosive materials and/or ingredients of explosive compositions may have been carried or flowed great distances due to their solubility in some of the reagents. It is also possible that some materials may leach into groundwater and become mobile via this route, resulting in the materials being carried considerable distances.

## **SECTION 7 SAFETY ASPECTS OF DECONTAMINATION OF EQUIPMENT AND BUILDINGS**

This section covers issues relating to explosive contamination only.

- The explosive contamination may be any known explosive material. Where possible, this section is written in general terms to cover all explosives. Where this is not possible, specific explosives and their treatment are described.
- It also considers the removal or in situ desensitisation of unwanted explosive material contaminating redundant equipment prior to removal or building structures prior to demolition.
- Decontamination by the deliberate engulfment by flame, as in the burning down of a building, or flame treatment of removed equipment, is included; but, since this is a deliberate act, the process requires careful planning with the appropriate control measures in place.

### **Operation characteristics**

The main risk associated with the decontamination of equipment and buildings is: -

- Exposure to fire and explosion of the contaminant. This may arise from the accidental ignition of unknown material during activities or the ignition of known material by incorrect procedures, tools or equipment.

All explosives will initiate when subjected to the input of sufficient energy from such sources as:

- Impact
- Friction
- Sparks
- Flame
- Shock

The amount of energy required will vary from explosive to explosive, primary explosives (e.g. lead azide) being in general more sensitive than secondary explosives (e.g. PETN).

It should be assumed that all explosive contamination could be initiated given sufficient energy under fault or accidental conditions.

- The amount of injury and damage caused by the explosion will vary with the quantity and type of explosive, and the conditions under which it is initiated. It should be remembered that even small quantities, less than one gram, for example, could cause serious injury if in close proximity to a person or if they generate shrapnel/projectiles.

### **Typical sources of ignition and aggravating circumstances**

Friction - can set off explosives, and can come from a wide range of sources, often associated with operator actions, including:

- Dismantling, including unbolting or unscrewing
- Machine/equipment movement or collapse.
- Removal of building structures.
- Building structure movement or collapse.
- Scraping material off surfaces.
- Using incorrect tools; non-metal tools are less likely to cause ignition than metal tools.
- Threading or pushing items through openings, including detonating cord or other explosives, which are being used for, controlled explosion/decontamination.
- Mishandling explosives during collection.
- The presence of grit will sensitise explosives to initiation by friction.

The possibility of chemical sensitisation having taken place with time should be considered, e.g. the formation of copper azide from lead azide in the presence of copper and moisture. Copper azide is much more sensitive to friction than the original "expected" lead azide.

Impact - from a variety of sources can cause ignition, including:

- Dismantling of machinery/equipment leading to movement or collapse.

- Building movement or collapse.
- Using incorrect tools; non-metal tools are less likely to cause ignition than metal tools.
- Mishandling explosive contamination during collection.
- Walking on contaminated floors, remembering that the contamination may be below the floor surface, i.e. hidden from view.
- The presence of grit will sensitise explosives to initiation by impact.

The possibility of chemical sensitisation having taken place with time should be considered, e.g. the formation of copper azide from lead azide in the presence of copper and moisture. Copper azide is much more sensitive to impact than the original "expected" lead azide.

Static - Particularly important when treating/handling primary explosives or electrically initiated devices such as detonators. Static can arise from many sources, including:

- Incorrect clothing and non-conductive footwear.
- Use of incorrect tools and equipment, such as plastic collectors and containers.
- Inappropriate techniques for gathering materials, such as sweeping up dry powders.
- Static and sources of static are a greater problem when the contamination and the ambient air conditions are dry.

Spark (Incendive or electrical) - Sparks of all types present a possible source of ignition, either directly or as a source of fire. Some sources of spark are:

- Incorrect use of sparking (ferrous) tools.
- Thermite reaction, i.e. aluminium struck or rust.
- Hot work such as use of grinding tools.
- Electrical equipment.
- Debris thrown from controlled explosions, including "jet" from shaped charges, etc.
- Debris from controlled burning operations.

Flame - Some sources of flame are:

- Hot work such as flame cutting.
- Controlled explosion or burning operations.
- General fires from grass/vegetation fire spread.

Decomposition - Some sources of decomposition are:

- Old explosive, particularly if kept under hot conditions.
- Acidic explosive, particularly for nitrated explosives (NG, PETN, etc.).
- Use of excessive amounts of chemical "destroyer" in inappropriate conditions such as excessive contamination in a confined condition where the heat from the chemical reaction cannot escape.
- Incorrect use of desensitiser or destroyer, e.g. use of PETN destroyer can increase the sensitiveness of TNT.

### **Controls and actions to avoid sources of ignition**

Correct action and the application of controls will prevent ignition. If there is a known desensitisation method for the suspected explosive contamination, e.g. NG destroyer for NG and NG based explosives, or PETN destroyer for PETN, or water for black powder, then apply the appropriate desensitiser and wait the required time before further treatment. However, always be careful if there is the possibility of more than one explosive in the contamination in case the treatment of one explosive leads to adverse effects on, or sensitisation of the other(s).

Even where effective chemical desensitisation is not possible, the addition of water as a coolant may help to reduce the possibility of ignition.

Ensure that the desensitisation method is clearly understood.

For example, the addition of large amounts of NG destroyer onto NG based explosives, particularly when confined, should be avoided in case the heat generated by the desensitisation reaction causes over-heating and ignition of the explosive; or the use of PETN destroyer can sensitise TNT.

When initiating controlled explosions or controlled fires, ensure that the initiation procedure is safe; this includes correct selection of detonator type for the working environment, e.g. shock

tubing and electric detonators where there is electrical equipment or sources of radio frequency (R.F.) - overhead or buried cables, transmitters, radio signals, etc.

#### Impact/Friction

- Avoid excessive force in areas of known or suspect contamination.
- Use tools made of suitable material, e.g. non-sparking metal with secondary explosives such as NG based and PETN or non-metal tools with primary explosives.
- When collecting exposed explosive, use suitable method with minimum force, correct tools and a suitable container.
- Avoid getting grit mixed in with any explosive contamination found.

#### Static

- Wear correct clothing, including socks, and antistatic or conductive footwear, as appropriate.
- Regularly test footwear for conductivity using an approved tester.
- Avoid build-up of dirt, oil, etc. on soles of footwear, which may cut down antistatic or conductive properties. Consider other means of effective earthing e.g. conductive wrist straps.
- Use correct tools and equipment for all operations involving explosives or explosive contamination, including collection, storage and transport, and particularly for static sensitive primary explosive.
- Only use correct handling procedures.

#### Spark (incendive or electrical)

- Use non-sparking hand tools.
- Use electrical equipment of correct classification whenever possible.
- If using non-classified electrical equipment, e.g. a portable generator, then only use under fully permitted conditions.
- Ensure electrical isolation, when required.
- Avoid hot work where possible, or if hot work is necessary, consider need for remote operation.
- When possible, cover controlled explosions, e.g. with sand bags.
- When carrying out controlled fires, hose down with water any area not requiring to be burnt, and put up a water curtain downwind of the fire.

#### Flame

- Avoid hot work/open flame in areas of known or suspect explosive contamination.
- When deliberately producing a flame, as in a controlled burn/fire, ensure procedures for remote ignition and observation.
- After a controlled burn/fire, always allow plenty of time for any residual hot spots to have become thoroughly cold before any approach or intervention.

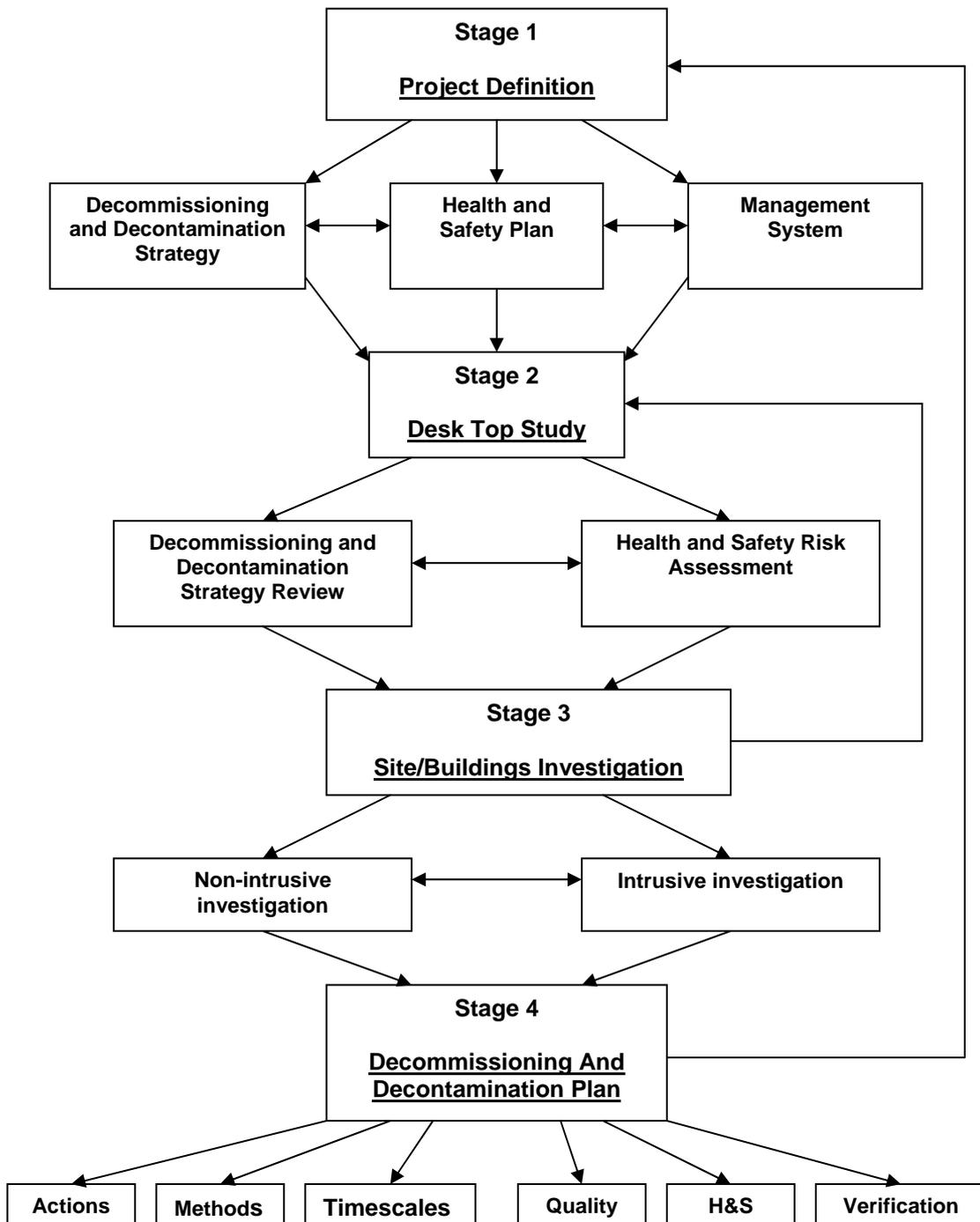
#### Decomposition

- Always treat any discovered explosive or explosive contamination that is old or in poor condition with more care/caution than for the same explosive in good/standard condition.
- This particularly applies to explosives, including propellants that may contain NG, which could have "weeped", i.e. separated out from the explosive giving free NG liquid.
- Before using any chemical destroyer, ensure that it is appropriate to the explosive or mixture of explosives to be treated, and that its use cannot generate excessive heat in large quantities of hidden contamination, or cause decomposition or sensitisation of one explosive in the mixture.

**SECTION 8 DECOMMISSIONING AND DECONTAMINATION OF EXPLOSIVE FACILITIES**

This section describes the management processes involved in the decommissioning and decontamination of plant, equipment and buildings. The processes described provide assurance that as far as reasonably practicable the areas decommissioned and decontaminated are free from explosive risk.

Diagram 3 shows a flowchart of the common stages of the decommissioning process and decontamination of plant and buildings.



**Diagram 3** Stages of the overall decommissioning process

The decommissioning and decontamination of an explosive facility may be achieved in 4 defined stages. These are described as follows:

### **Stage 1 - Project Definition**

Clear aims and objectives should be developed for the decommissioning and decontamination process. The scoping exercise should establish the extent of the exercise, the no of buildings, resources available, timescales etc. A management system should be developed for all aspects of the decommissioning and decontamination activities. The management system should address standards for the defined activities, organisational arrangements, planning, implementing, audit and review.

### **Stage 2 - Desk Top Study (DTS)**

The aim of this stage is to develop a strategy for decommissioning and decontamination of the site and its infrastructure. The development of an accurate and authoritative Stage 2 study is critical to the achievement of an effective decommissioning and decontamination strategy. A detailed DTS initiates the process. This involves researching the site history to build as full a picture as possible of the development and redevelopment of the site over its complete history.

An important primary aspect of the DTS is to gather information on:-

- Past uses of the land. This information can be obtained from examining historical maps of the site obtainable from Ordnance Survey
- Past uses of the buildings on site
- Bulk chemical storage
- Chemical plant
- Filling & assembly
- Magazines
- Laboratories
- Railway network
- Water features (e.g. ponds or canals)
- Disposal sites
- Burning grounds
- Firing ranges
- On site heat & power stations and electrical substations
- Engineering workshops
- Laundries
- Establish the operational period of the site
- Properties of materials used in any operational activities
- Environmental pollution incidents
- Current map of the site, showing location of buildings and transport infrastructure
- Building drawings
- Service drawings, including drainage and power lines
- Past environmental surveys
- Environmental licences
- Fire certification.

The following issues are of particular importance in relation to the desk study stage, when considering sites where explosives may be encountered:-

- lack of information (in particular in relation to sites involved with military explosives) may be a major barrier to understanding the activities carried out and the contaminants which may be encountered;
- a lack of information does not mean that explosives are not present. Inquiries to MoD often result in a response that they do not have any records of explosives or explosives devices being processed on a site. Reliable corroborative negative or positive evidence should be sought if possible.
- historical "free from explosives" certificates should be treated with care as often the

- inspections only involved visual checks for surface contamination;
- knowing where to look for the relevant information, and how to interpret the information which is available, are important considerations. Also, as with other MoD sites, this will often mean that specialist assistance must be sought from independent organisations familiar with explosives manufacturing and processing sites;
- it is unlikely that MoD departments would be able to effectively answer issues on explosive manufacturing or processing;
- due to the possible acute hazard from explosives contamination of explosives buildings, the desk study needs to address building history and use.

Sources of information may include:

- Historical maps
- Aerial photographs
- Local site records
- Interviews with past and present employees
- Local historical societies; local libraries
- Local Authority records
- Public Records Office

Some information (concerning military explosives sites) may still be classified as restricted or secret due to its sensitivity. In many cases the information may be made available for viewing or declassified at request after review. Where viewing or declassification is not possible, specific questions can be asked and information provided where it is considered that such information is in the “public interest”. The period of site operation is an important factor in determining which explosives may be present.

Common mistakes made during the desk top study stage are:-

- pseudonyms may have been used for documents, plans and other information for a site;
- operational army units may have a code regiment number. For example, a maintenance regiment may actually be identified as an explosives disposal unit;
- manufacturing terminology used may be confusing or innocuous using words such as: Cap; motor; starter; primer; booster; sieving; drying; stoving; incorporation; steeping; mixing; rolling; pressing; doping.
- explosive processes always require certain infrastructure. These may not be readily identified by documentary evidence but they should still be assumed to be present. For example, explosive disposal areas, burning grounds;
- if only one explosive process is detailed, then it is often incorrectly assumed that there is only one explosive to consider. Changing site history, site processes, explosive mixtures and the degradation of explosives, can give rise to a range of other explosives being present;
- assuming that non explosive process areas are free from explosive contamination is a common mistake. Demands of wartime operations meant that often rules for danger areas were relaxed and explosives may have been transported, stored or processed outside of the areas designated for explosives;
- unfamiliarity with explosive manufacturing may lead to misinterpretation of structures and site layouts. A trained specialist can often establish a site use and individual building use from its structure and general site layout. Commonly, buildings are wrongly interpreted as being explosive process or storage buildings when in fact they may have been used for more conventional uses, or vice-versa. This indicates the need for some peer review or input during the desk based review by a specialist consultant with appropriate training, experience, and knowledge.

Specialist information sources will have to be consulted during the DTS stage in order to establish precise information related to past use of explosives sites. Typically the following sources will be searched:-

- MoD — Historical Army Section
- MoD — Defence Estates/Defence lands
- MoD — Library Whitehall

- MoD — Safety Services
- MoD — Land Quality Assessment (LQA) groups
- Home Office — Emergency Planning Office
- Public Records Office
- HM Inspectorate of Explosives
- Local Libraries and Historical Archives
- Explosives manufacturing companies— Historical Archives
- Specialist Consultant

The output from the Desk Top Study will inform a Health and Safety Risk Assessment, which is an essential precursor to the next stage, the site walkover. The site walkover should:

- Verify the current Site Plan
- Visually assess the condition of the buildings and the nature of the contents
- Visually identify any unusual features of the site, e.g. areas of landfill, land raise and abnormal topography.

The walkover involves visiting each building on site to establish its current condition and to gather information on:-

- Contents.
- Condition.
- Presence of hazards (Check access is safe)
- State of services.
- Construction details. (Required for checking details on drawing)
- Condition of drains
- Condition of floor (Possible contamination)
- Asbestos presence
- Condition of mound
- Confirm usage of building
- Identify suspected contamination issues and need samples to be taken.

When visiting buildings, it is useful to take photographs of buildings both internally and externally, to record additional data such as possible contamination and the results of any sampling undertaken. The walkover should cover the full area of the site and not be confined to those areas, which are easily accessible, by road. It must be undertaken with proper management of health and safety risks.

The output from the Stage 2 is a Decommissioning and Decontamination Strategy document. This is a graphical or textual description of the plant and buildings, which identifies and characterises all significant risks to human health. The Decommissioning and Decontamination Strategy describes those actions, which on the evidence of the Stage 2 study must be undertaken to decommission and decontaminate the site to a state where it does not present a significant risk to human health. The Decommissioning and Decontamination Strategy are living documents, which may be amended and refined by the Stage 3 Investigation.

### **Stage 3 - Investigation**

The Stage 3 Investigation involves the measurement and delineation of contamination by ordnance and energetic materials for sites being decommissioned and can be extended to include other contaminants where the site is to be redeveloped and may require remediation. Actions can include:

- The sampling and analysis of dust and residues within buildings and plant
- The sampling and analysis of residues in drainage systems
- The sampling and analysis of soils
- The use of geophysical techniques to locate items of buried ordnance (non-intrusive Investigation).

Site inspection visits should always be based on the maximum available information, which

can possibly be obtained from the desk study stage. The site inspection may be conducted in two parts where a return visit is conducted if the initial visit identifies areas that require further documentary research. Phased visits can be particularly important to ensure due consideration is given to acute hazards which may be present.

Site inspection staff will need to be equipped with the relevant level of PPE and should have appropriate training and experience.

At operational sites, access may be restricted due to site safety or security procedures and site specific procedures may need to be followed when carrying out inspection or intrusive works.

Site inspections should only be conducted by persons competent in the management and assessment of explosives risks and the ability to identify buildings, processes, materials associated with explosive operations.

When investigating the risk from explosives or explosive devices, it is essential that a clear methodology based on safety risk assessment be adopted. All works, depending on the anticipated risk, should be either supervised or conducted by a person trained and qualified with suitable experience in explosive safety management.

Due to the hazards of explosives, processes such as disposal or testing may have been conducted in remote areas of the site away from the main manufacturing area. Little visible evidence may be available of historical activities due to demolition, covering with earth or simply vegetation grow back. Some of these remote activities may not have been fully documented. Consequently such remote areas may in fact carry a higher risk of explosive contamination and consideration should be given to allocating a higher than normal level of priority.

Alternatively appropriate geophysical techniques may be considered to scan certain areas of the site for evidence of buried structures, metal objects or disturbed soils.

Buildings that have been used for the manufacture or processing of explosives are likely to contain residues of explosives and represent a significant potential explosives hazard.

Process buildings on operational or derelict sites should only be inspected and assessed by a competent person trained in the potential hazards that may be present.

Investigation techniques:

- **non-intrusive techniques** - a range of non-intrusive geophysical techniques are available that can help identify areas of waste disposal, disturbed ground and other relevant features.
- **intrusive techniques** - such work needs to be supported by a safety risk assessment conducted by competent persons. Remote intrusive investigation should be considered where the risk to operatives is considered unacceptable. Boring and probing methods are to be avoided until characterisation by other methods has proved a low explosive contaminant risk.
- surface swabs and core sampling - clean cotton wool soaked in a suitable solvent (e.g. acetone) is appropriate for surface swabbing of building fabric surfaces. Unless the risk assessment demonstrates acceptable risk, building core samples should be taken using a remotely operated coring machine. Persons with specialist knowledge of the explosive manufacturing processes employed should be involved in the selection of areas for swab or core sampling.
- samples should be taken using non-sparking implements only. Samples suspected of or to be tested for explosives contamination should be tested prior to transport on the public roads, unless special exemption has been granted by HM Inspectorate of Explosives. Samples, which are suspected or proved to contain >1% by weight of explosives, may require a licence for storage and transportation. All sample packaging of such soil samples should comply with the Packaging of Explosives for Carriage Regulations 1991, and the Classification and Labelling of Explosives Regulations 1983.
- on-site explosives screening using appropriate equipment and methods can be cost effective and improve safety of sample handling. It can be used to detect or map higher level contamination using semi-quantitative methods and has the benefit of fast sample turnaround.

Intrusive investigation is not always necessary, particularly where the risks can be adequately

defined by the DTS stage.

The information from the investigation stage can be used to refine the Decommissioning and Decontamination Strategy but the eventual outcome should be a clearly defined Decommissioning and Decontamination Plan.

#### **Stage 4 - Decommissioning and Decontamination Plan**

The output from the Phase 4 should be a detailed report (Decommissioning and Decontamination Plan) defining the decommissioning and decontamination activities, and if appropriate, remediation processes.

The Plan should:

- Define what actions are required to decontaminate and, if appropriate, remediate the site.
- Define the most appropriate methods.
- Identify timescales and interdependencies.
- Establish Quality Control Procedures.
- Identify the procedures required to demonstrate that decontamination, and if appropriate, remediation, has been fully effective.
- Include verification that the process has been applied effectively.

#### **Characterisation and Remediation of Land**

This report does not provide guidance on the characterisation and remediation of land affected by explosives and other contamination. However, when planning the decommissioning of explosives sites, this is a very important aspect that needs to be considered in conjunction with the investigation and decommissioning of buildings and plant. The ultimate fate of the site will play an important part in identifying and setting goals for the characterisation and remediation of the land, and needs to be considered at the earlier stages of planning.

Much of the information collected in relation to site operations and layouts will be essential to the characterisation, physical investigation and remediation of a site. It is therefore important that teams working on decommissioning activities for both buildings, plant and land work in liaison.

In general terms the characterisation and remediation of land is undertaken in a phased approach:

- Hazard identification and assessment
  - collection of documentary information and walk over survey
  - identification of contaminants of concern
  - development of conceptual model for the site
  - review data and conduct exploratory investigations (if appropriate)
  - undertake hazard assessment
- Risk Estimation and Assessment
  - design and implement ground investigation
  - undertake risk assessment
- Evaluation and selection of risk management measures
  - identify and evaluate options for remedial treatment based on risk management objectives
  - select preferred remedial strategy
- Implementation of risk management
  - design and implement remedial works
  - undertake verification of remedial action
  - implement monitoring and maintenance programmes
  - complete project

The assessment and remediation of land is a complex technical area, which should be managed and undertaken by suitably qualified and experienced people and organisations.

## **SECTION 9    DECONTAMINATION TECHNIQUES**

### **Introduction**

Buildings, plant or equipment that have been, or may have been, in contact with an explosive or other hazardous material, must be decontaminated to render them as safe as is practicable prior to demolition or scrapping.

Often the decontamination process is iterative and can involve several stages. Proving or testing the effectiveness of each stage may be required before further treatment is applied and is necessary before any form of sign off or certification can be issued. Ultimately controlled destruction may be the only sure way of ensuring total decontamination.

Decontamination methods will also vary with the type of explosives (or explosive articles) and the differences in building, plant or equipment layouts and complexity.

The decontamination technique applied depends on the end objective. If buildings, plant or equipment are required to be reused then complete destruction would be inappropriate. For repair work, it may be necessary to design methods, which include the possibility of handling and use of ordinary equipment by staff that may not be familiar with explosive properties.

Reuse, sale of items or offsite transportation for further treatment may require special risk and legal considerations.

Each stage in the decontamination process should be recorded and certification should accurately describe what has been done, how far the process has been taken and any residual hazards or risks.

### **General Precautions**

Before commencement of decommissioning and decontamination, always establish as much information as possible about any building or equipment, including likely contaminants, before any intervention or treatment.

If details of contamination are not known, always use a worst-case approach.

During any operation, if in doubt or the circumstances change or new contamination is found, etc - then **STOP**.

Collection of washings and product residues need special consideration.

The possible generation of noise should be considered and control measures implemented, as appropriate.

The dilemma of whether to remove asbestos from explosives or remove explosives from asbestos is a common problem and it can only be addressed by a detailed risk assessment.

Controlled fires must be just that! – Firebreaks may need to be constructed and water spray curtains installed.

The possibility of onward propagation of an explosive train within a building and its infrastructure, cables, pipes, ducts and drains must be considered in detail.

Use remote initiation for controlled explosions or fires.

Choose personnel safety distances based on the quantity of explosive present.

Consideration must be given to the possibility that there may be quantities of unknown contamination present.

Carefully select firing and observation point(s) at the maximum distance away from any possible underground explosive contamination, as in drains or groundwater leakage routes.

For remote operations, particularly fires where fume may be a problem, choose a firing and observation point(s) allowing for the prevailing wind direction.

Where appropriate, particularly for fires and possible fume generation, consider the wind direction with respect to inhabited buildings, gorse or undergrowth, roads, general public areas, etc.

Ensure a system to keep unauthorised people out of any exclusion zone established for controlled explosions or fires, and maintain this for as long as is required by the particular operation.

Ensure good communication procedures both within the group carrying out the decontamination procedures and, where relevant, others, including the general public, who may be affected by the decontamination procedure. Good communications are necessary with local fire brigade officers and local authority environmental health officers.

### **Decontamination Methods**

People with a direct knowledge of the plant and equipment and the contamination involved should ideally, carry out the decontamination. This would normally be plant personnel and/or specialist teams experienced in the work.

The overall method may entail removal of individual plant items for further treatment and some work can be facilitated by removal to a remote facility. This especially applies to small items of a movable nature or those that can safely be disconnected. However, some work can only be carried out in situ.

Typical decontamination techniques that may be applied after an appropriate safety assessment are :

- Bulk Removal
- Disconnection and removal of small items for treatment elsewhere
- Brushing and sweeping
- Washing with water or solvents
- Desensitising with chemicals including steeping in baths of an appropriate chemical
- Use of Proving Ovens
- Use of mechanical means (including scraping, water jet cutting, remotely controlled cutting etc.
- Treating with explosive (chemical) destroying agents
- Treating with a light flame i.e. a torch on a long lance
- Treating by total immersion in a fire (including incineration)
- Treatment by deliberate detonation

The exact decontamination method to be followed will depend on the type of explosive concerned, the nature of the plant items and the residual effects if the process goes wrong. It is often the case that more than one of the above procedures may be required, with there being a progression from less to more severe methods, for example, before starting vigorous scraping, treatment with a desensitising liquid might be necessary.

Once any phase of decontamination is finished, a record of the work done should be prepared specifying the decontamination activity carried out to date and any residual contamination problems.

## **Bulk Removal**

Once a process has been stopped, ideally the bulk of contaminating material will be removed from the plant by standard carry/movement operations. This should always be done to reduce and remove as much inventory as possible before performing subsequent decontamination operations.

## **Disconnection and Removal of Small Items for Treatment Elsewhere**

Anything that can be safely moved out of a facility for treatment or sentencing elsewhere should be done before any other process takes place. Any reduction in the inventory will make future processes less complex.

## **Brushing and Sweeping**

Brushing and sweeping is usually considered as the first option in the start of any decontamination processes. While straightforward enough, a means of disposal for the collected material needs to be considered. Vacuuming can sometimes be used, but the effects of static, friction, and the presence of electrical power should be assessed.

## **Decontamination by Washing**

Washing is a recognised method in the decontamination process but should be considered as only a preliminary step in the application of more rigorous methods.

Asphalt floors, which are cracked, present a particular problem and must be thoroughly washed with water, including a substantial surrounding area. With the area wet, asphalt can be carefully chipped away using non-ferrous tools and the complete area re-washed.

Lead covered floors can be cleaned by washing with warm water and with subsequent use of NG destroyer – see later.

## **Washing of particular contaminants**

### **Nitrocellulose or Paste Contamination**

The main consideration is to ensure that all areas of plant, which could possibly be contaminated, are thoroughly wetted and maintained wet during dismantling until all traces of the contaminant have been removed. After being washed externally, with special attention being paid to flanges, plant may (if possible) be disconnected and removed to a suitable area where, if accessible, the interior of the plant can be washed with warm water and a scrubbing brush.

If possible complicated plant should then be dismantled in stages, washing by the above procedure at each stage. Large vessels can be washed with warm water on site after being disconnected and the connections blanked off. Disconnections and subsequent dismantling of the plant should only be carried out with the plant wet. Particular attention should be devoted to welds, pipes containing bends, pumps and overlapping surfaces, especially if the plant has not been used for a considerable time, thus allowing the contaminant to dry out.

### **Nitroglycerine Contamination**

Before dismantling, plant should be washed first with warm water and flanges cleaned with a suitable solvent.

During and after dismantling, the plant should be treated with a desensitising agent and re-washed with warm water before it is removed.

### **Picrite Contamination**

Plant contaminated with picrite is treated using procedures similar to those used for nitrocellulose-contaminated plant except that hot water is used since the solubility of picrite in water increases with temperature. In addition, complicated plant may be placed in a tank of

boiling water for as long as is necessary to ensure complete removal of all traces of picrite. After this treatment the plant should be rewashed with hot water.

#### Propellant Contamination

Contamination by soft dough can be treated by thoroughly cleaning the plant with acetone. Hard dough may require steeping in acetone before cleaning.

Loose dried propellant contamination is normally collected by sweeping, and the collected material removed for burning. The area should then be washed with water.

#### PETN

During and after dismantling, the plant should be treated with PETN destroyer – see Use of Destroying Agents.

#### TNT/RDX

Before dismantling, the relevant plant can be washed with warm water and any flanges cleaned with acetone. During and after dismantling, the plant must be treated with a suitable destroyer and rewashed with warm water before it is removed.

#### Other Contaminants

It should be noted that there are several other raw materials and intermediates, which are not explosives themselves but are commonly used in explosive production processes and these must be treated with care when they are in contact with plant requiring repair or decontamination. The treatment of guanidine nitrate and ammonium nitrate may be an identical procedure to that used for picrite. Carbamate contamination, which poses a dust hazard, may be removed with water. Cotton dust, which when in contact with oil is liable to spontaneous combustion may be removed by vacuum cleaner or with water.

### **Washing with Desensitisers**

A typical desensitising solvent, which is used, is acetone. Great care must be taken to collect and subsequently destroy the washing solution as the process, which is one of absorption, is reversible and product may reform.

### **Proving Ovens**

Proving ovens can be used for smaller items of moveable plant or for dealing with lead, to demonstrate that the decontamination method has been removed

The oven is heated to the working temperature and maintained for typically 3 - 12 hours. The oven is then allowed to cool overnight to ambient temperature before the 'proved' item is removed and stored in an area designated for decontaminated metal – usually a secure compound.

Normal working temperatures are 300 deg C for aluminium, 350 deg C for iron and steel and 400 deg C for lead.

In the case of lead, 'proving' is only effective if the lead reaches melting point as it may contain absorbed product (lead flooring and lead vessels are usually associated with nitroglycerine manufacture).

During 'proving', molten lead flows into moulds positioned within the oven floor and solidifies into ingots, which are then readily removed when cool. This process may require regulatory approvals to prevent release of lead into the atmosphere.

Proving oven procedures should include exclusion zone rules and visible warnings (red flags, red lights etc) while heating is in progress. Final material should be sent to a refining manufacturer.

## **Mechanical Methods**

Various methods of working remotely have been developed. Spanners, wrenches, cutting machines and saws have all been operated using remote methods. They can be cumbersome and slow but can reduce risks to operating staff.

Cracks in asphalt are particularly hazardous, as explosives may have travelled under asphalt after having found access at a crack. For this reason, the areas that are to be chipped away must be considerably larger than just the obvious faulty area.

Bolted flanged joints in pipes and vessels are an area of major concern even with the use of liberal amounts of desensitising agents.

Lead can also be cut using high pressure jetting which has been successfully carried out using small remotely operated mobile units.

Avoid excessive force in areas of known or suspect contamination. Use tools made of a suitable material, e.g. non-sparking metal with secondary explosives such as NG based explosives and PETN, or non-metal tools with primary explosives.

## **Use of Destroying Agents**

The use of chemical destruction agents is a useful tool in the decontamination process, however once again great care must be taken with handling these products and effective processes for subsequent destruction and collection systems must be available for any liquid waste materials.

These destroyers can be highly caustic and must only be handled when wearing protective clothing. It must never be applied to large quantities of nitroglycerine as the surface reaction, which takes place is exothermic. The plant must be washed with warm water before being treated with NG destroyer.

With lead floors, small areas can be cut out using a knife or by use of remotely controlled equipment and the edges bent up in order to apply the destroying agent.

Correct identification of the type of explosive being treated is very important. For example the use of PETN destroyer can increase the sensitiveness of TNT.

## **Proving Decontamination using a Gas Flame**

### **Flame Testing**

A gas flame test is sometimes used for items, which have already been subjected to other methods of decontamination, and in manufacturing operations this has traditionally been used as a final proving operation prior to equipment being worked on for maintenance or repair. A suitably trained operator using remotely controlled equipment can carry this out. It can be done in situ (as in the case of a floor, wall or similar), or in a purpose built flame-testing area.

Running water should always be immediately available and nobody allowed to approach the area while flame testing is in progress. If a specific area of the plant is being tested, water may be continuously passed over the surrounding area of the plant.

Special care must be given to operator safety even with the use of long lances and suitable protective screens. Under no circumstances should close proximity hand flaming of plant be attempted.

An important difference between treatment with a gas flame and treatment in a remote fire is the control of temperature and time of treatment. Additional consideration should be given to this before choosing this method.

## Decontamination by fire or incineration

Decontamination by controlled fires either in situ or at a defined burning location is a useful means of decontamination or of checking or proving the effectiveness of any previous decontamination. Procedures should include exclusion zone rules and visible warnings (red flags, red lights etc) while fires are in progress. Initiation of the fire must be carried out remotely.

Following use of this technique, a suitable time should be allowed to elapse to let the plant items return to ambient temperature before further handling.

### Using Small Fires

For small items, a small fire using paper, straw or woodshavings, is a more severe way of applying heat than a gas flame, as the localised heating gives more confidence that the treated item is free from explosive contamination. The increased severity of using fires may cause an item to be detrimentally affected. Purpose built cages are usually employed in this type of operation.

### Using Large Fires

A large fire is even more severe and is used for items with cracks, crevices or of complex shape where access for other forms of decontamination is difficult. Items destined for scrap would ordinarily be subject to a large fire.

### Burning on an Open Fire

Large open fires can be constructed using wood and the large plant to be 'proved' placed on top.

This method of proving is especially useful for pipes containing bends, which could contain hidden hazards. However, water must be passed through pipes before proving commences to ensure that there are no blockages. Running water should always be available and the area surrounding the fire would normally be thoroughly wetted before the fire is laid.

It is usual for metallic items from explosives manufacturing areas to be passed through a fire prior to scrapping. As with buildings the media used and design of a fire must be adequate to ensure effective treatment.

Open hearth burning of explosives and explosive devices is currently exempted from the Integrated Pollution Prevention and Control (IPPC) Regulations. The use of existing exempt facilities on explosives manufacturing sites is a possible remediation method for soils or explosives devices excavated from a site under remediation. There are complex safety procedures and approvals required involving HM Explosives Inspectorate before such materials can be transported. Alternatively it may be the best practicable option to establish a temporary burning facility on the remediation site.

A rotary kiln facility designed to destroy obsolete ammunition is operated by QinetiQ at Shoeburyness. This facility can be used to destroy excavated explosive materials and explosives devices. Approvals to transport such materials are again required from HM Explosives Inspectorate.

### In Situ Burning of Buildings

This is a recognised technique for the decommissioning and decontamination of explosives contaminated buildings. The methodology needs to be carefully planned and should only be carried out by organisations experienced in the use of such techniques. The basis of the technique involves:

- removal of bulk or confined explosives;
- removal or control of asbestos, e.g. gutters, downpipes, wall boards, roof sheeting etc;
- removal of materials likely to produce black or toxic smoke;
- development of a 'worst case' scenario risk assessment;
- the establishment of an exclusion zone;
- controlled firing of the building ensuring that heat penetrates all areas where explosives contamination is possible;
- temperature monitoring to ensure that adequate temperatures are achieved;

conventional demolition of the structure.

The main problems with burnings are likely to be:

- The condition of the item or building after burning, although this is obviously not a problem if the item is to be scrapped.
- The generation of dark smoke from, for example, the presence of asphalt in floors or rubber linings in plant and felts.
- Noise (in the event of a detonation).
- The atmospheric release of asbestos fibres if not removed
- The propagation of a fire to adjacent areas.
- Local drains, sumps and interconnecting drains may have blockages or a build up of explosive materials, which could propagate to adjacent areas if accidentally detonated.
- Wooden items can absorb explosive dusts and liquids, as can cracks in concrete floors, walls and columns.

When burning buildings or parts of buildings the design and position of the fire is critical to effective decontamination. Straw, timber, coal and coke are common media used.

As heat rises, floors can be particularly difficult to treat in this manner. Heat indicators or glass 'tell tales' can be an effective 'proving' item to establish that enough heat has been applied to critical areas.

As with all other methods the effectiveness of the process must be established, and the method repeated where there is any doubt, or another method used.

### **Treatment by Deliberate Detonation**

The use of controlled explosions should only be considered in extreme instances and then only by employing explosives experts in the risk assessment and design of such projects. The use of explosives to effect demolition or partial demolition of buildings is relatively common. However care is required in the use of such techniques on buildings known to be contaminated with explosives.

Lead floors, pipes and vessels can easily be cut by using explosive cord or linear shaped charges. A difficulty with some lead floors is that it may have been installed on top of a 'millboard' construction, which contains asbestos.

Explosive techniques can also be used on other metallic items where no other possible means of access for inspection is available. Suitable barricading is required.

Vessels and tanks can be split for further examination by filling with water and firing a small hanging internal charge.

Drains can be treated and 'proved' by floating/feeding detonating cord through the system.

Any initiation plan must include the possibility of propagation and the consequential effects of initiation of large 'pockets' of explosive material.

Wherever possible cover controlled explosions with sand bags or blast mats.

### **Certification**

Any work should always be covered by a suitable risk assessment and appropriate certification or chain of custody documentation e.g. a Permit to Work or decontamination certificate.

On completion, certification should be issued regarding the condition in terms of decontamination. Such certification should be unambiguous in meaning to future handlers of the work. This could be the implementer of a further stage of the decontamination process or the end user or final owner of the asset including where that owner is a receiver of special waste or a scrap processor.

## SECTION 10 REMEDIATION TECHNOLOGIES

This intention of this section is to provide examples of remediation technologies, which are currently available (or are likely to be available in the near future) on a commercial scale within the UK. Comprehensive documentation and guidance is available elsewhere.

Remediation may be delayed until a development plan has been approved for the site. As a consequence decontamination of buildings and their contents may also be delayed for a number of years.

Although under certain conditions some explosives or their degradation products can contaminate groundwater, the most significant media for such contamination are soil, buildings and associated utilities.

Explosives contamination has the potential to increase the public's negative perceptions of contaminated land. This concern is often driven by a lack of knowledge and understanding of the facts, which can be compounded in the case of military explosives sites by the secrecy, which often surrounded them. However, the public has a desire to know that these issues are being managed sensibly and professionally.

When an explosives manufacturing site is being remediated for redevelopment it is important to address these social concerns and perceptions, by a mix of technical and managerial actions such as:

- a risk communication strategy may need to be developed. Decisions about contaminated land are not made on a purely technical basis. Risk communication needs to address risk management issues in order to gain public and stakeholder confidence;
- it may be necessary to demonstrate the successful remediation of other similar sites;
- the standard of remediation criteria may have to take some account of public concerns - especially where residential development is contemplated.

The principal remediation technologies can be grouped into the following categories:

- Civil Engineering Approaches;
- Biological Based Technologies;
- Chemical Based Technologies;
- Physical Based Technologies;
- Solidification and Stabilisation Based Technologies;
- Thermal Based Technologies.

### Civil engineering approaches

Containing or covering explosives contamination is only an option if the concentrations in soil are well below the concentration likely to sustain an explosive event or underground fire. A cover/barrier solution is not normally considered appropriate for surplus or buried explosives devices or munitions. If such devices are present on a site planned for remediation or redevelopment, such devices should be recovered and destroyed. However it may be appropriate to use a cover/barrier solution for soil in which there is a small but acceptable risk of explosive devices remaining and where identification and removal cannot be justified. Disposal to licensed landfill of explosives contaminated soil has occasionally been permitted where:

- the explosives concentration is demonstrably < 1%.
- there are no visible discrete explosives present.
- the explosives contaminated soil forms a small proportion of the landfill contents.

Disposal to licensed landfill is a particularly appropriate technology where the mix of explosives and other contamination types present would require the use of several remediation technologies to be effective. If space and geology permits, consideration should be given to creation of an on-site licensed landfill as this may significantly reduce environmental impact.

While cover/barrier systems can be effective for reducing or removing the risk of exposure of receptors to the contaminants, the contaminants are not destroyed and therefore future risks

could persist.

On sites where explosives devices could be present there is always a concern that small numbers of these devices may have been dropped or dumped on the site, but not deliberately buried. For example detonators are very small and a few dropped on the ground could easily become covered by vegetation. To address this risk a so called 'confidence scrape' is often undertaken. It is common practice as part of a remediation strategy, to undertake a so called "confidence scrape" of near surface soils (e.g. the upper 300mm). This allows removal of vegetation cover and rapidly demonstrates the absence of explosive devices/fragments as a means of reassuring the public regarding a site. In essence, should a discarded device or local spillage of explosives be present in the near surface soils, this would be removed as part of the confidence scrape excavation and disposal of surface soils. This not only helps to minimise the actual risk, but also reassures any purchaser or potential site user, i.e. also addresses the perceived risks. This is particularly important in residential development or open space land which will have regular and unrestricted public access and may be more cost effective than extensive metal detection or geophysical scanning.

Bentonite slurry and grout walls can, under appropriate geological and hydrogeological conditions, be used to contain groundwater contaminated by explosives, their degradation products or soil contaminated by more mobile explosives. Under certain conditions active containment can be considered using a 'funnel and gate' approach to focus groundwater towards part of the barrier wall where a sorbant material, such as activated carbon, traps the contaminants.

### **Biological based technologies**

Biological based techniques can only be successful if the explosive contamination is of a small enough particle size (< 1 mm). Where larger discrete explosives particles are present e.g. in granules, flake or lumps, bioremediation is an inappropriate technique without some form of pre-treatment.

#### *Ex situ* Bioremediation

With the exception of certain initiator compositions such as lead azide or mercury fulminate, most explosive compounds are persistent in soil. However *ex situ* bioremediation using composting or biopile techniques employing microbes or fungi have been demonstrated to be viable techniques with many organic explosives. Verification analysis needs to demonstrate that the degradation process has not stopped at a metabolite, which is itself toxic. Some literature recommends a two-stage biodegradation for explosives such as TNT, where the first phase is anaerobic resulting in the reduction of certain nitro groups to amino groups before converting the process to aerobic biodegradation.

#### *In situ* Bioremediation

Certain organic explosives will respond to *in situ* technologies used to remediate organic contamination of groundwater, saturated and vadose zones of soils. However there is little experience of the use of such remediation techniques for explosives contamination in the UK. Assessment of the viability of any of the *in situ* technologies are analogous to that required for any other organic contaminant.

Phytoremediation (using plants to remove explosives from soil) is currently at the research stage. However the technique has the potential to be applied to various explosives in soil. The technology is likely to be most useful where contamination is low and diffuse, and where treatment times can be long.

### **Chemical based technologies**

Chemical based technologies such as soil flushing, solvent extraction and surface amendments for the remediation of explosives contamination are currently untried outside the lab or pilot scale. However liming of soil to raise pH can be appropriate to reduce the mobility of the degradation products of metal salt explosives.

### **Physical based technologies**

Soil washing or screening can be used to remove discrete solid explosives from soils. In addition soil screening may be an appropriate way of removing smaller explosives devices from soil. However in each case experienced persons should conduct a detailed safety risk assessment. Additionally it is technically possible to use soil-washing technology to treat explosives contamination in soils chemically (e.g. by the addition of alkalis). However, currently such treatment is unlikely to be commercially viable.

Thermal based systems (including the use of fire and controlled explosions)

Thermal based systems can be divided into those utilising incineration, thermal desorption, controlled explosions and controlled firing. Incineration, controlled explosions and controlled firing have been described in Section 9.

Use of thermal desorption technology to treat explosives contaminated soils is technically proven. However as explosives produce large amounts of NO<sub>x</sub>, the thermal desorption plant will require appropriate acid gas scrubbing. As such plants are usually mobile, explosives contaminated soil can be treated on-site.

## **SECTION 11**

## **A BRIEF HISTORY OF INCIDENTS AND ACCIDENTS**

### **Unidentified Sites**

1. A landowner had held a site of a few hundred hectares in its land bank for many years. The site was mainly used for agriculture and forestry. Maps indicated that the land had been fields and woodland for over 100 years. The landowner was aware of a few building foundations on some parts of the site. A local inhabitant understood that the site had been a WW1 munitions factory. Research showed this to be true. Information including layout plans was found which enabled a picture of land use, potential contamination, and focused site investigation and risk assessment to be carried out.
2. A geotechnical study was commissioned that covered an area of farmland to assist an improved drainage scheme. As members of the drilling crew were setting up, the farmer informed them that according to his father they were on the site of a WW1 explosives factory. The search of usual record sources had indicated that the land had always been used for agricultural purposes. A trained observer revealed rectangular features in the ground profile in one area of the field. Subsequent research showed that the farmer was correct and that a factory manufacturing military explosives had operated there during WW1.
3. Several hundred acres of a factory were unused by the current factory complex. The area consisted of mature trees and bushes and was poorly drained. The current factory (designed and built during WW II) had not utilised this area. The thick undergrowth and mature trees gave the appearance of being natural ground. Strong anecdotal evidence told of this area being the site of a WW I ammunition filling factory, but no records of this remained in the operating factory. Public record research unearthed a wealth of evidence including plans of the WW I factory. Using these plans, it was possible to locate foundations of the buildings buried under vegetation and peat. The information enabled an appropriate site investigation to be designed.

### **Unexpected Site Investigation Findings**

1. A site investigation of an ordnance depot revealed explosives contamination in a field thought to be outside the danger area. It was found that contaminated ash from the burning ground had been spread across the surrounding land.
2. A former commercial pyrotechnic and rocket factory in the SE of England contained a pond in which hundreds of explosive devices had been dumped over many years. After closure, parts of the site were accessible to the general public and the pond was drained. As the mud dried out a number of suspect devices were revealed in the pond bottom.
3. Test boreholes were being made on a piece of wasteland in preparation for redevelopment. One bore hole hit a deposit of red sludge, which smelled of "almonds". Chemical analysis revealed that it contained 40-50% TNT. Subsequent examination of records revealed that the site had been used by a chemical works, which had manufactured TNT during wartime. The area where the deposit was found had been the location of the red liquor settling building and it is likely that the deposits were due to leaks or spills from the building or the pipelines supplying it. No effort had been made to decontaminate the site when the chemical works was finally demolished.

### **Inadequate Investigation**

In 1948 surplus solventless propellant plant had to be uplifted and shipped to Canada. The items in question included rolling and press equipment and as it was already Autumn, there was a pressing urgency to get the equipment shipped before

the St. Lawrence river became frozen up. During WWII an explosives factory had been under such pressure to produce propellant that a propellant press had been installed without the safety asphalt floor being laid. A temporary linoleum floor had been installed instead, which was subsequently never replaced. When the press was to be removed in 1948 it seemed inconceivable that any of the propellant could have become trapped under the bedding plate, which was sealed to the floor. Oxy-acetylene torches were used to cut through the securing bolts. Almost immediately jets of flame shot from under the press. The fire quickly became very violent and engulfed the building. Fortunately no one was seriously injured in the accident. Subsequent investigation showed that the plant had been operated for some time before being sealed and substantial quantities of explosive had accumulated under the bedding plate and in the cracks of the linoleum floor. This incident shows clearly the error of assuming a location to be free of explosives just because it is difficult to see how it could be otherwise. The fact that the press had been used for extruding propellant for some years and the discovery already made about the stripping room should have prompted a more cautious approach and the area should at least have been flooded with water.

It is informative also to note how the pressure of events influenced the incident. That is, the urgency to get war production started in the first place and the haste to get the equipment uplifted and shipped before the onset of the Canadian winter. It also illustrates that any slipshod work done today may have serious repercussions for someone else in ten or twenty years time.

### **Non-obvious risks**

1. An experienced explosives worker was using an oxy-acetylene torch to cut through some steel pipe work thought to be free from explosives. Approximately 250 grams of explosives remained in the pipe and the ensuing explosion shattered all of the workers limbs and caused significant burns. The worker died some 2 hours later.
2. During a controlled burning of a NG Tellex mixer, a detonation occurred 21 ½ hours after the fire was lit. Normal practice had been to maintain a 24 hr exclusion zone. This was increased to 36 hrs. Nobody was injured.

### **Unsuccessful Controlled Explosions**

1. On a closed NG production plant in Canada a controlled underground explosion was set up to demonstrate that any NG in the soil did not pose an acute risk. The explosion detonated an unknown reservoir of NG trapped underground, resulting in a massive explosion and several fatalities.

Waverly, Nova Scotia, 25th July 1935

*Extract from a History of Accidents in the Explosives Industry by G S Biasutti -*

“An extraordinary accident occurred in an abandoned explosives factory during decontamination operations to destroy nitroglycerine which could have been present in the old building or in depressions in the ground.”

“After having exploded several cartridges without success, it was decided to fire a cartridge in a low point near a lake where nitroglycerine might have leaked from the old nitration house which had not been in service since 1910. The three men performing the operation sought a safe place behind a stone building 75 feet distant from the shooting spot. A frightful detonation took place leaving a 30ft deep and 150ft wide crater. The building behind which the men were hiding collapsed and killed them. The amount of nitroglycerine involved in the explosion was later estimated to be 8 tons.”

2. Detonating cord (a linear explosive used to transmit an explosive train in engineered explosions) was used to detonate significant explosive residues within drains on an explosives site. The resulting controlled explosion only succeeded in shattering the drain and moving the explosive residues into the surrounding soil.

## Waste Disposal

Scotland 1884. An example of typical past waste practice, dating circa 1884, is illustrated as follows: -

*....."A large amount of weak nitric acid produced in the long retort in which the refuse acid was first treated was not of a profitable nature at this time, but the very reverse. The contents of hundreds of carboys were tipped out on the sand and allowed to drain away; further large quantities were sent to the sulphuric acid makers, and there sold at a price which barely covered the cost of transport".*

## Other Incidents resulting from maintenance, cleaning, decontamination or decommissioning activities

1. Detonation in Nitroglycerine Pre-wash Tank.  
The pre-wash tank had been removed from the building and had been subjected to a prolonged cleaning procedure, scrubbing before and after removal, rubbing over with alcoholic caustic soda.  
It had been filled with water until the plumbers were ready to tackle it. A detonation occurred whilst a plumber was using a flame on the "heel" of the tank. This was made of 30lb lead thickened up to 50lb lead by welding. There must have been a fissure in the welding that allowed entry of Nitroglycerine into a crevice between two imperfectly welded surfaces, and there it had remained undisturbed by the cleaning operations. Enquiries from the Foreman plumber brought to light that a preliminary heating with a "long handed flame" under protection had not been carried out as specified in the factory procedures; a finding which is encountered again and again in the history of events. Fortunately in this case there were no injuries sustained by any of the personnel involved.
2. Detonation at the Lead Pound.  
The melting pot had been in use all morning and was being fed with pieces of lead from an old style Nitroglycerine wash tank, having a double bottom and perforations to provide for air agitation. There was a detonation and molten lead was thrown all over the melting bay.  
From an examination of the debris it was established that Nitroglycerine had remained trapped and had remained untouched by the Nitric Acid pickling treatment it had received. With the type of construction used, inaccessible cavities were virtually unavoidable.  
The melting was, however, conducted from behind protective baffle walls designed to cope with such an eventuality and no damage or injury was sustained. The incident is quoted mainly to draw attention to the potential hazards associated with designs of Nitroglycerine plant, which is difficult, if not impossible, to clean properly.
3. Accident resulting in the Death of a Plumber.  
A leading hand plumber was engaged in cutting up a Nitroglycerine Pre-wash Tank, which was also of the type having a perforated double bottom. The tank had been partly cut down the sides into 6" (150 mm) strips and the plumber was cutting the strips free from the bottom by means of a knife and hammer. These pieces were to be pickled for six hours in Nitric Acid of 1.1-1.2 specific gravity before being re-melted. Contrary to instructions, the plumber was making a cut through a burning into an air pipe and it was when the knife entered this pipe that the explosion took place. He was kneeling at the time and received the force of the explosion in the face. He died almost immediately. A NG hill man who was assisting him, and was a few yards away, was knocked over on his back. The tank had previously been treated under the personal supervision of the Process Foreman. It had been washed through twice with a solution of 5% aqueous soda after which alcoholic caustic soda was put through the air channels into the false bottom and allowed to stand for a week. It was then replaced by a fresh dose and left for a further week before cutting was started.

It may well be asked why the authorities persisted in this double bottom construction for so long in the knowledge of the hazards involved when disposal of a vessel became necessary.

The alternative construction in vogue at that time took the form of a plain lead tank fitted with an easily removable three pronged air sparger made of lead piping simply laid in the tank bottom. The success of this design relied on the continued effectiveness of the rubber rings slipped over the sparge pipes at short intervals to prevent metal-to-metal contact against the bottom of the tank during agitation. This is of course the main problem, and plants have been lost where the cause was attributed to failure of the rubber rings in maintaining adequate separation from the bottom of the tank. The double-bottomed tank may, therefore, be regarded as an advance in terms of processing safety. Unfortunately, in the cases on record, the net result was merely to transfer the problem from the user to the repairer.

The air holes enlarged so rapidly and their working life was so short that those concerned with their cutting up and salvage tended to become overwhelmed by an ever-increasing backlog of work. At the time of the accident, for example, the tank involved was one of 20, which had arrived that week, and two or three of the batch had already been cut to pieces that morning before the accident took place.

The accident, therefore, was caused by a particular tank design which became unserviceable all too quickly, and whose construction made the effectiveness of cleaning uncertain. These features were unhappily complicated by a disregard for the instructions that not only prohibited cutting across a joint, but also stipulated that cutting should not approach closer than 6" (150 mm) from it.

It is obvious that the cutting up operation was one which would be difficult to monitor and control with the staff resources then available, and it will come as no surprise to learn that such tanks should no longer be cut, but should be melted down whole.

4. Wash Water Settling House Explosion.

A different type of accident, where failure to carry out regular periodic cleaning was the root cause of an explosion is exemplified by an event in 1941. The Nitroglycerine process in use was a batch one, but in common with present day plants. All spent process waters passed through a Wash Water Settling House containing a large wooden vat, lead treatment tanks and a succession of labyrinths through which the wash water effluent made its way to the settling pond. There were the usual provisions for keeping the vat contents alkaline and recovering and stabilising deposited Nitroglycerine after filtering off corrosion products and other impurities. At the rate of production then in being, it was considered prudent, from past experience elsewhere, to clean out the contents of the Wash Water Settling House at least once per week, rendering the recovered Nitroglycerine alkaline and returning it to the washing stage. However, attention had become so focused on production to the exclusion of all else that the very important ancillary operations in this particular building had been lost sight of completely. Indeed a period of more than a month had elapsed without the building receiving any real attention when it suddenly blew up and was completely destroyed. The Court Of Inquiry attributed the cause to the spontaneous decomposition of acidic Nitroglycerine. The building had been visited periodically to record the temperature but as the thermometer was near the boot change no one apparently thought of carrying his or her inspection any further.

5. Accident during refurbishment of a Valve.

A plumber selected the valve in question from a pile of other valves in the fitters' workshop with a view to refurbishing it for further service. The valves were not identified in any way and the man assumed that they were clear for use. No clearance certificate had been provided, but despite this he took the valve to a grinding wheel and proceeded to dress one of the flanges. There was a sudden explosion and the plumber was killed instantly by a fragment of metal, which was driven into his chest.

It emerged later at the Inquiry that the pile of valves had received only the minimum treatment to allow them to be removed from the plant and that they were in no way fit for work to be done on them without further treatment for the removal of Guncotton.

There was no clear indication of their identity or explosive status and they were not segregated in any way so that access to them was unrestricted

6. Accident during conversion to Combustible Cartridge Case manufacture.  
A further accident again illustrates not only the problem of decontaminating heavy equipment in situ but also the hazards involved in producing on adjacent plant units simultaneously.  
The accident took place in the building at the time it was being converted for the manufacture of Combustible Cartridge Cases. Parts of the plant, which had already been installed and commissioned, were producing while other items of plant were still being installed or modified. In the building in question, three beaters had been left in position on the upper floor and these were being refurbished to take up duty on the beating of Kraft pulp. Repairs to a section of the asphalt floor around a cable duct were being carried out following the fitting of new cables to a beater motor. Temporary screening had been erected to isolate the area from the working plant. The asphalter had roughly laid hot asphalt, from an authorised outside fire, on the portion of floor, which had been bared. The beaters still stood on isolated islands of asphalt and the man was in the act of heating the junction between the old and the new with a blowtorch when there was a sudden explosion.  
A piece of hot asphalt was projected over the protective screening into a corner of the building where it ignited a bin of case trimmings which presented an immediate hazard to adjacent assemblies of finished cases. The operator, who sustained burns to his hands from flames emerging from under the bedplate of the beater motor, dropped his blowtorch still alight on the asphalt floor. This ignited further Nitrocellulose deposits concealed in the cable channels leading to the ground floor where stillages of Cartridge Cases in transit to the finishing stages narrowly escaped ignition.  
The Nitrocellulose contamination under the bedplate of the beater motor had obviously lain hidden since the earlier use of the building for Nitrocellulose production. It must have been washed there in the course of hosing the floor over a period of many years.  
A similar incident took place in 1959. In this case a Contractor pulled up a beater from the floor by means of a crane before the process supervisors had time to complete their arrangements to flood the immediate area with water. There was a heavy detonation of Nitrocellulose, which must have accumulated under the bedplate as a result of many years of floor washing. The Contractor had tackled the job by thrusting the jib of the crane through a window and as the building happened to be vacated at the time, no one was injured.
7. Detonation of a Brass Plunger Head whilst it was being cleaned with a Steel Scraper.  
A Hydraulic Press Worker was cleaning the brass plunger of a solvent propellant press when a detonation took place within the metal of the plunger. The operator received a slight injury to his right wrist. He had been using the approved scraper for the job, which was made of steel.  
A group of four men including the operator were preparing to press cordite and the latter was using the scraper to remove the last traces of adherent propellant dough from the plunger face prior to starting work.  
The plunger head had been modified by machining two diametrical slots at right angles on the plunger face so that it would withdraw the heel from the cylinder after a pressing. The brass of the plunger head contained areas of porosity, one of which had been exposed by the machining. This was not obvious to the naked eye but the porosity had been sufficient to allow ingress of explosive and from the sensitivity it is likely that it was Nitroglycerine. A piece of metal the size of a man's thumb had been thrust back from the surface showing an internal texture like pumice stone. The explosion had penetrated to a depth of 6 mm. At the inquiry it appeared that this accident was not unique and that some minor detonations of brass plunger heads had also taken place during machining in the Machine Shop.  
This was an accident which arose despite the fact that all existing regulations had been obeyed and it was obvious that the trouble lay in the metallic texture of the

plunger head, and that the solution was to specify freedom from porosity with a requirement for assurance by radiological means.

8. Detonation of a pipe.

The pipe in question conveyed wet mixed paste slurry from the Pre-mix House to the Sheeting House at the factory.

Some years previously it had been cleaned sufficiently to allow its removal in the course of converting the plant to bulk wet mixing but had become hidden under a pile of similar plant items within the traverse of the Sheeting House.

Towards the completion of the conversion work the pipe came to light and was duly taken to a hearth for proving.

The proving oven was not available due to a long-standing cable fault and the pipe was too long to be adequately dealt with in the lead hearth. It was therefore laid out on an open fire and after about 15 minutes there was a violent detonation and large jagged portions of the pipe were projected over a wide area. Fortunately the man in charge of the fire had retired behind the proving oven to be out of the wind while having his tea break and in that way escaped injury.

It is specially to be noted in this incident that the pipe contained two right angle bends which ruled out methods of cleaning by means of pull-throughs etc., and water flushing alone had obviously been insufficient to dislodge deposits of paste which presumably had been retained at the bends.

In view of the importance of decontamination of scrap by solvent treatment or chemical action, it is perhaps advisable to add a cautionary note regarding the latter. Nitroglycerine has commonly been destroyed by the application of caustic alkali or sodium sulphide to which industrial alcohol has been added to increase miscibility and hence its effectiveness. The sodium sulphide mixture has a long history of use but it has an offensive smell and carries a toxic risk, a consequence of which has been the preferred use of alcoholic caustic soda.

While acceptable for the hydrolysis of last traces on Nitroglycerine which have survived ordinary methods of cleaning, the treatment is not recommended for paste, Nitrocellulose or Guncotton and it is alleged that application of alcoholic caustic to pockets of dry paste can, and has, led to ignitions and detonations.

Also, it may be seen from the accounts of incidents detailed earlier in this report, this treatment does not necessarily penetrate fissures.

It should also be emphasised that the purpose of the final treatment by the various forms of heating is to prove freedom from explosive contamination.

9. Fatal Accident at a Decontamination Compound.

A length of 1 inch diameter stainless steel pipe having a right angle bend in it, one arm being 10 feet and the other 4 feet in length, was being heated by a flame from an oxyacetylene torch, 8 feet in length. The object was to prove that the chemical treatments given to the pipe had been effective in destroying all the explosive contamination and that it was safe for cutting and welding operations.

The plant chemist was carrying out the flaming but instead of working from the protection of the heavy steel pillbox provided, he was flaming the pipe in the open with no protection whatsoever.

He had gone about 6 inches along the pipe when the explosion occurred. Three to four feet of pipe were fragmented and he had both legs completely shattered from below the knee.

The amount of explosive involved was estimated to be about half to two-thirds of a pound. In the ambulance on the way to hospital he said that he was working outside the shelter because it made the job easier. He died shortly afterwards.

This accident has a number of similarities to an accident, which fortunately did not result in injury. The pipe had a bend in it and was too long for complete immersion in the treatment tanks used, so only one end could be submerged at a time. It was probable that the longer limb had not been properly submerged at all. At least half a pound of explosive in the longer limb had not been hydrolysed despite the 8 hours boiling in 10% caustic.

It was claimed that the pipe had been swilled out with alkaline sulphite (to test for Tetryl) and that water passed through by a hose had failed to produce any traces of white crystal (which would have indicated RDX or HMX).

There was a proving oven but it had been damaged to such an extent by a succession of detonations in equipment being proved that it could no longer be used. This seems a clear indication that the decontamination procedures being used were simply not effective enough, and there was also dubiety in this particular case as to whether the pipe had been in contact with Tetryl, RDX or HMX. The identification and segregation of contaminated and uncontaminated scrap was stressed by the Court of Inquiry.

### **Other explosives**

Most of the accidents reported have occurred with Nitroglycerine or Guncotton or mixtures of the two and while this has to be accepted as the pattern of events, it does not follow that the hazards with other materials is to be overlooked. All hazardous materials demand respect and it has to be noted that the hazardous nature of some materials only came to be appreciated in fairly recent times. At the start of the First World War for example, the manufacture of TNT and Picric Acid was carried out in open unprotected buildings, in the manner of dyestuffs manufacture. Sometimes this was in built-up areas. A disastrous explosion occurred in 1917 with much loss of life. More recently, a nasty accident took place in a Midlands Factory in similar circumstances, except that the product was an artificial musk containing only one nitro group and believed on this account to be completely safe.

An accident, in which Tetryl was involved, took place with asphalt flooring. The explosive had become so thoroughly trampled into the asphalt floor of a particular building that the whole floor became explosive. It was subsequently initiated by sparks during repair work and a number of people were killed. It was usual in such circumstances to make a small pond on the floor using putty round the area where repair work was to proceed but this had not been done in this case. The root of the trouble, of course, lay in the continued assimilation of nitro-body into the asphalt, a possibility of which everyone should be aware.

## GLOSSARY OF TERMS

<u>Amatols</u>	Pourable mixtures of ammonium nitrate and trinitrotoluene of widely varying compositions.
<u>Ammonium Nitrate</u>	A constituent of commercial explosives, e.g. ANFO, slurries, emulsions. Also a constituent of fertiliser.
<u>ANFO</u>	Ammonium nitrate plus fuel oil. A common commercial blasting explosive.
<u>Attenuate</u>	Used to describe the weakening of a shock wave by decreasing its amplitude or duration.
<u>Azides</u>	Salts of hydrazoic acid (N <sub>3</sub> H).
<u>Ball Powder</u>	Small arms propellant manufactured in the form of small spheres.
<u>Ballistic Modifier</u>	An additive incorporated in a propellant composition to alter its rate of burning.
<u>Baratol</u>	Barium nitrate and TNT, used in grenades and anti-tank mines.
<u>Base Charge</u>	An increment of secondary high explosive (commonly tetryl or PETN) in the base of a composite detonator to enhance the shock wave.
<u>Bioremediation</u>	The use of biological agents, such as bacteria or plants, to remove or neutralize contaminants, as in polluted soil or water.
<u>Black Powder</u>	Gunpowder consisting of charcoal, potassium nitrate and sulphur.
<u>Blast</u>	A supersonic longitudinal wave produced in the surrounding atmosphere by an explosion.
<u>Blast Impulse</u>	The time integral of the overpressure exerted by a blast wave.
<u>Blasting Explosive</u>	An explosive designed for industrial mining, quarrying, civil engineering and demolitions.
<u>Blast Wave</u>	A shock front with an area of high pressure behind it, followed by a rarefied zone.
<u>Blending</u>	The mixing of gun propellant grains or sticks to achieve regular ballistics.
<u>Booster</u>	Used in an explosive train interposed between a detonator and high explosive charge (see also primer).
<u>Bridgewire</u>	An electrical filament used to ignite a pyrotechnic or primary explosive in contact with it in an igniter or detonator.
<u>Brisance</u>	The shattering property of an explosive.
<u>Burning</u>	The propagation of combustion by a surface process. (See deflagration).
<u>Calorimetric Value</u>	The amount of heat evolved by the combustion of a propellant in a closed vessel in the absence of air or oxygen.
<u>Cap</u>	A small metal container filled with a flame producing explosive composition. See also detonator.

<u>Cartridge</u>	A general term that can have a wide range of usage. It usually refers to a package or assembly of propellant explosive although it can sometimes describe a complete round of ammunition. In commercial explosives it is a general term for an individual explosive package.
<u>CE</u>	"Composition Exploding", (also called Tetryl). N-methyl-N-nitro-2,4,6-trinitroaniline. A secondary high explosive.
<u>Charge</u>	A bagged, wrapped or cased quantity of explosive without its own integral means of ignition.
<u>Cleaning</u>	The removal of bulk materials from a piece of plant, building or facility followed by removal of visible traces of contamination from exposed surfaces using a brush, water or solvent wash-down.
<u>Colloid State</u>	A dispersion of one substance in another in which the particles of the dispersed substance (colloid) have dimensions 0.1 to 0.001µm.
<u>Combining</u>	The mixing of different explosives, stabilisers or other ingredients.
<u>Combustion</u>	An exothermic oxidation reaction producing flame, sparks or smoke.
<u>Compatibility</u>	The possibility of one or more substances remaining in contact with an explosive without adverse physical or chemical effect.
<u>Compatibility Group</u>	A system of classifying bulk explosives and live ammunition into groups, so that items are not transported or stored together, which would, if accidentally initiated, increase the hazards by their interaction.
<u>Composite Propellant</u>	A solid propellant, usually for rockets, which comprises an inorganic and a polymeric fuel matrix.
<u>Cook-off</u>	The initiation of an enclosed explosive by the conduction of heat through its container. E.g. Live ammunition left loaded in hot guns.
<u>Cordite</u>	Historical name for double base (nitroglycerine/nitrocellulose) gun propellants in the UK and can be extended to triple base propellants.
<u>Decommissioning</u>	The process of taking plant, equipment and buildings out of normal use and leaving in a safe condition by the removal of bulk explosives.
<u>Decomposition, Thermal</u>	The breakdown of materials into smaller constituent molecules by the action of heat alone.
<u>Decontamination</u>	The process of removing the residue (of explosives, or ingredients used in their manufacture) from plant, equipment, buildings or land to allow demolition or remediation to be carried out.
<u>Deflagration</u>	Reaction where materials decompose at a rate much below the sonic velocity of the material without any excess of atmospheric oxygen being required. It is propagated by the liberated heat of reaction. Hazards produced are fireball, thermal radiation and jets of flame.
<u>Detonating Fuze (Cord)</u>	Plastic tubing filled with powdered secondary high explosive. Used to transmit a detonation wave over any required distance.
<u>Detonation</u>	A form of reaction given by an explosive substance in which the exothermic chemical reaction produces a shock wave. High temperature and pressure gradients are created in the wave front so that the chemical reaction is

initiated instantaneously. Hazards are blast, fragments and collapse of buildings.

- Detonation Pressure The dynamic pressure in the shock front of a detonation wave.
- Detonator The component within an explosive train which, when initiated, in turn detonates a less sensitive but larger high explosive (usually the booster), or when containing its own primer initiates the detonation. A cap is a similar component designed to initiate a deflagration.
- Doping The addition of a marker material to an explosive composition.
- Double base Group of gun propellants based on nitrocellulose and nitroglycerine. Usually more energetic than single base propellants.
- Drying Drying of explosives or ingredients in a drying room or over a desiccant to facilitate the removal of solvents (used in some mixing processes) or to achieve a specified moisture level.
- Dynamite Explosive containing typically 20-50% NG, 4% NC, sodium nitrate and woodmeal.
- EGDN Ethylene glycol dinitrate.  $(\text{CH}_2\text{ONO}_2)_2$ . A liquid secondary high explosive.
- Emulsion Explosive A blasting explosive consisting of ammonium nitrate with added fuels and other ingredients.
- Exothermic Reaction A chemical reaction accompanied by a loss of heat into the surroundings.
- Explosive A chemical substance or mixture which can react to produce an explosion.
- Explosiveness The rate at which a particular explosive, when subjected to a given stimulus, gives up its energy, and/or the degree to which it does so.
- Explosive Power The work capacity of an explosive, usually referred to high explosives.
- Explosion Chemical reaction or change of state effected in an exceedingly short period of time with the generation of a high temperature and generally a large quantity of gas. An explosion can produce a shock wave in the surrounding medium. (See also detonation and deflagration).
- Explosive train A train of combustible and explosive elements arranged in order of a decreasing sensitivity. The explosive train accomplishes the controlled augmentation of a small impulse into one of suitable energy to actuate the main charge. May be igniferous or detonative.
- Figure of insensitiveness A figure determined by a Rotter Impact Test, which is a measure of the sensitiveness of an explosive to an impact. The higher the result, the less sensitive the explosive. E.g. RDX = 80.
- Flame Luminous phenomenon accompanying gas phase combustion.
- Flare Pyrotechnic device designed to produce a single source of intense light.
- Flash A brief radiation pulse accompanying an explosion.  
A short lived flame used to ignite safety fuze, a detonator or igniter.

<u>Flash over</u>	Sympathetic detonation/deflagration from a cartridge to another one adjacent to it.
<u>Fragmentation</u>	The shattering effect of an explosive upon its container.
<u>Free from explosives</u>	Items can be certified free from explosive contamination when the competent person who signs the certificate is certain that the item has come from a non-explosives building, or that the decontaminated item has gone through a proving procedure.
<u>Fuel</u>	Any substance capable of reacting with oxygen and oxygen carriers with the evolution of heat.
<u>Fulminate</u>	Salt of fulminic acid. Most commonly encountered is mercury fulminate, a primary explosive, $\text{Hg}(\text{ONC})_2$ .
<u>Fusehead</u>	A hot wire bridge ignition system coated/filled with explosive composition. Used to initiate an explosives train.
<u>Fuze or fuse</u>	A compact engineered assembly with explosive or pyrotechnic components and safety devices, designed to initiate the main charge of a munition. Cord or tube for the transmission of detonation or flame.
<u>Gain</u>	Small explosive charge that is sometimes placed between the detonator and the main charge, designed to achieve, maintain or enhance detonation.
<u>Gelignite</u>	A gelatinous blasting explosive of plastic consistency, containing about 60% NG, 5% NC, potassium nitrate and woodmeal.
<u>Glazing</u>	The addition of a surface lubricant coating usually to propellant grains. A typical glazing agent would be graphite.
<u>Guncotton</u>	Nitrocellulose with a nitrogen content of > 12.9%.
<u>Gunpowder</u>	See Black Powder.
<u>Hazard Assessment</u>	The assessment of degree of hazard posed to personnel and property by the storage, handling, transportation, use, etc., of a particular explosive.
<u>Hazard Division</u>	A system of classifying bulk explosives and live ammunition, etc. into categories, based on the nature of hazard, which they pose if accidentally initiated.
<u>High explosives</u>	A true explosive is characterised by the fact that in its combustion process an exothermic (that is, heat liberating) reaction wave passes through it, following and supporting a 'shock front'. This phenomenon is described as 'detonation' and the velocity of the wave is the 'velocity of detonation'.
<u>High Order Detonation</u>	Detonation at a velocity approaching the maximum stable velocity of detonation for the system.
<u>HMX</u>	Cyclotetramethyleneteranitramine. A secondary high explosive.
<u>Hollow Charge (Shaped Charge)</u>	A charge, usually cylindrical, having a cavity opposite the point of initiation, to exploit the Munroe Effect. The cavity may be lined with metal to enhance performance.
<u>Hot Spot</u>	A small localised region in an explosive substance which is characterised by a temperature much higher than that of its surroundings. Of relevance to the mechanisms of initiation.

<u>Hydrolysis</u>	The decomposition of a compound by the action of water. Relevant to the chemical stability of explosives.
<u>Hygroscopic</u>	The property of a substance to absorb and retain moisture from the atmosphere.
<u>Hypergolic</u>	Term to describe certain liquid bipropellant combinations which ignite spontaneously on mixing.
<u>Incendiary</u>	A highly exothermic composition or material that is primarily used to start fires.
<u>Incorporators</u>	Used in the pour filling of high explosive munitions. Usually TNT mixtures are melted in an incorporator to form a slurry which is then poured into a shell casing and allowed to solidify. Also used to mix explosive compositions, e.g. propellants.
<u>Initiating Explosives</u>	Explosives that can detonate by the action of a relatively weak mechanical shock, heat or by an electric current used to initiate the main explosive charge. Sometimes called primary explosives.
<u>Initiation</u>	To set off explosives. To detonate.
<u>Initiator</u>	A device for igniting or detonating explosives. Also an abbreviation for initiatory compositions, i.e. primary explosives.
<u>Low Explosive</u>	An explosive which does not detonate under normal conditions of use.
<u>Low Order Detonation</u>	A detonation in which the charge is completely consumed but the velocity of detonation is well below its maximum value, and therefore its effect is lessened.
<u>Magazine</u>	Any building or structure approved for the storage of explosive materials. Also a removable case holding several rounds or cartridges used in some types of firearms.
<u>Mothballed</u>	A term used to describe plant or facilities which have been deemed to be surplus to current operational needs but may be required at some stage in the future. Such plant and facilities are maintained to a standard that will keep them in a state of readiness for future operational use. Plant may be disconnected and put into storage. Services are left connected.
<u>Munroe Effect</u>	A local concentration of shock wave energy, which occurs when the wave emerges from a detonating charge via a re-entrant shape in the charge surface, e.g. a cone.
<u>NC</u>	Nitrocellulose. Nitric esters of cellulose.
<u>NG</u>	Nitroglycerine. Glyceryl 1,2,3-trinitrate. $\text{CH}_2(\text{ONO}_2)\text{CH}(\text{ONO}_2)\text{CH}_2(\text{ONO}_2)$ . A liquid secondary high explosive.
<u>Nitration</u>	The process of adding a nitro- group to an organic molecule. Usually achieved using concentrated nitric acid (sometimes in admixture with other concentrated acids).
<u>Non-permitted Explosive</u>	An explosive which is not among those authorised for use in gassy coalmines.

<u>Out of Use</u>	A term used to describe plant or facilities, which have been temporarily taken out of operational use. (e.g. For repair to be carried out.)
<u>Oxygen Balance</u>	The percentage of oxygen by weight (+ve or -ve) of an organic explosive containing carbon, hydrogen, oxygen and nitrogen, remaining after combustion, assuming that all the carbon and hydrogen is converted to carbon dioxide and water. It is the oxygen content of an explosive in relation to the fuel elements.
<u>Partial Detonation</u>	A detonation which fails to propagate right through a charge leaving it partly chemically unchanged.
<u>Partial Ignition</u>	An ignition in which the burning fails to propagate throughout the sample.
<u>PBX</u>	Polymer bonded explosive. Generally explosive constituents bound in a rubber matrix, which improves their mechanical properties and thermal resistance, making them inherently safer and less vulnerable to accidental initiation. Used in insensitive munitions.
<u>PE</u>	Plastic explosive. Used for improvised demolitions. Achieved by mixing powdered explosive with oil or grease.
<u>Permitted Explosive</u>	Explosive authorised for use in gassy coalmines. Characterised by a low explosion temperatures and low detonation velocities.
<u>PETN</u>	Pentaerythritol tetranitrate. A secondary high explosive. $C(CH_2.ONO_2)_4$
<u>Phlegmatisation</u>	The desensitisation of an explosive by mixing soft or viscous substance with it, e.g. wax, grease, oil, polymer. Such substances are phlegmatisers.
<u>Phytoremediation</u>	The use of plants or algae to remove or neutralise contaminants in soil or water.
<u>Picric Acid</u>	2,4,6-Trinitrophenol. A secondary high explosive. $(NO_2)_3.C_6H_2OH$ . Can react with metals to form impact sensitive salts (picrates).
<u>Polymorphs</u>	Different crystalline forms of chemically identical substances.
<u>Primary Explosive</u>	An explosive, which is readily ignited or detonated by a small mechanical or electrical stimulus.
<u>Primer</u>	In a gun cartridge is the explosive device containing a cap and a flame producing pyrotechnic or gunpowder, which ignites the propellant charge. The term is also used for the percussion cap in a small arms cartridge. Also used to indicate a high explosive blasting primer.
<u>Propellant</u>	An explosive, which burns to produce high pressure gas used to propel a projectile, missile or to do other work, e.g. for starting engines.
<u>Proving</u>	Proving is a process that follows after decontamination when there is a requirement to demonstrate that the decontaminated item is free from explosives.
<u>Pyrotechnic</u>	A stable mixture of an oxidising agent and a fuel, capable when initiated, of combustion to give a desired special effect, such as, heat, flame, smoke, gas, noise or delay.
<u>Rate of Burning</u>	The rate of regression of the burning surface of an explosive, usually referred to propellant grains.

<u>RDX</u>	Cyclotrimethylenetrinitramine. A secondary explosive.
<u>Redundant</u>	A term used to describe plant or facilities for which there is no foreseeable operational use.
<u>Remediation</u>	The process of preparing a site to ensure that is suitable for its intended end use.
<u>Resorcinate</u>	Salts of resorcinol. Lead salts of mononitroresorcinol (LMNR) and dinitroresorcinol (LDNR) are primary explosives.
<u>R F Hazard</u>	The danger of accidental initiation of an electro-explosive device by radio frequency electromagnetic radiation.
<u>Rotter Test</u>	An empirical test to determine the sensitiveness of explosive materials to mechanical impact. Results are calculated as Figure of Insensitiveness.
<u>Safety Fuze</u>	Flexible tube for the transmission of flame in an explosive train.
<u>Secondary Explosive</u>	Explosives in which the detonation is initiated by the detonation impact of an initial (primary) explosive.
<u>Sensitise</u>	To increase the sensitiveness or the sensitivity of an explosive.
<u>Sensitiveness</u>	A measure of the relative probability with which an explosive may be ignited or initiated by a prescribed stimulus.
<u>Sensitivity</u>	A measure of the stimulus required to cause reliable design-mode functioning of an explosive system.
<u>Shock Front</u>	A discontinuous change in the pressure propagating through a medium at supersonic speed.
<u>Shock Wave</u>	A shock front, together with its associated phenomena, e.g. blast, elevated temperature.
<u>Shutter</u>	A safety device in an explosive train for isolating the initiating explosive.
<u>Sieving</u>	The sieving of explosives is undertaken in order to achieve a known particle size. Also used in propellant manufacture to remove fuses or unwanted particles. May also be used in processing of 'wet' mixed compositions to achieve granulation.
<u>Single Base</u>	Collective term for gun propellant compounds based on nitrocellulose with small amounts of stabiliser, plasticiser or coolant added.
<u>Slurry Explosive</u>	A blasting explosive consisting of solid ammonium nitrate suspended in a gelled, saturated, aqueous solution of same, with added fuels and other ingredients.
<u>Small arms ammunition</u>	Ammunition with a calibre up to 12 mm. Shotgun cartridges up to 20mm.
<u>Stabilisers</u>	Compounds which when added in small amounts to other chemical compounds or mixtures impart stability to the latter.
<u>Steeping</u>	Where an explosive or ingredient is submerged in a liquid in order to either coat it, add a further ingredient, change its properties or to remove a solvent.

<u>Stoving</u>	The process of heating to cure paints, lacquers, or thermosetting Polymer Bonded Explosives (PBX). Can also be used to describe solvent removal from nitroglycerine based propellants.
<u>Styphnate</u>	Salts of trinitroresorcinol (styphnic acid). Lead and barium styphnates are the most common. They are used as primary explosives.
<u>Sympathetic Detonation</u>	The initiation of an explosive charge without a priming device by the detonation of another charge in close proximity.
<u>Temperature of Ignition</u>	The temperature at which an explosive ignites.
<u>Tetrazene</u>	1-amino-1-[(1H-tetrazol-5-yl)azo] guanidine hydrate, a primary explosive used as a sensitising ingredient in primary compositions.
<u>Tetryl</u>	“Composition Exploding”, N-methyl-N-nitro-2,4,6-trinitroaniline. A secondary high explosive.
<u>TNT</u>	2,4,6-Trinitrotoluene. $\text{CH}_3\text{C}_6\text{H}_2(\text{NO}_2)_3$ . A secondary explosive.
<u>Tracers</u>	Slow burning pyrotechnic compositions used in tracer bullets, signalling charges, tracer rockets etc. Colour is due to the presence of added salts such as sodium, barium, and strontium etc.
<u>Triple Base</u>	Group of gun propellants based on nitrocellulose, nitroglycerine and nitroguanidine.
<u>UXB</u>	Unexploded bomb. Sub group of UXO.
<u>UXO</u>	Unexploded ordnance.
<u>Velocity of Detonation</u>	The speed at which the detonation wave progresses through an explosive. When it attains a value that it will continue without change, it is called the stable velocity of detonation.

## BIBLIOGRAPHY

British Drilling Association (Operations) Ltd. Essex (1992). Guidance for the safe investigation by drilling of landfills and contaminated land.

Construction Industry Research and Information Association (1996) A guide to safe working on contaminated sites. Report 132. CIRIA, London.

Department of the Environment, Transport and the Regions. CLR 11. Model Procedures for the Management of Contaminated Land. Contaminated Land Research Report.

Department of the Environment (1994) Documentary Research on Industrial Sites. Contaminated Land Research Report No. 3. Department of the Environment, London.

Department of the Environment (1995a) DoE Industry Profile. Chemical Works: Explosives, Propellants and Pyrotechnics Manufacturing Works. Department of the Environment, London.

Department of the Environment (1995b) DoE Industry Profile. Engineering Works: Mechanical Engineering and Ordnance Works. Department of the Environment, London.

Environment Agency (2000) - Contaminated Land Part IIA Environmental Protection Act 1990 (England). Process Documentation. The Environment Agency, Bristol.

Environment Agency (in preparation) Collation of Toxicological Data and Development of Guideline Values for Explosive Substances: Collation of physiochemical data: R&D Project Record P5/036/01. The Environment Agency, Bristol.

Environment Agency (2001) R&D Technical Report P5-042/TR/O1 Land Contamination Technical Guidance on Special Sites: MoD Land. Produced by WS Atkins for The Environment Agency, Bristol.

Environment Agency (2001) R&D Technical Report P5-042/TR/O3 Land Contamination Technical Guidance on Special Sites: Explosives Manufacturing and Processing Sites. Produced by WS Atkins for The Environment Agency, Bristol.

Health and Safety Executive (1986) HSG36, Disposal of explosive wastes and the decontamination of explosive plant. ISBN 0 11883296 8, HSE Books, Sudbury.

Health and Safety Executive (1998) CS23 Disposal of explosives waste. ISBN 0 7176 1624 X. HSE Books, Sudbury.

Health and Safety Executive (1991) Protection of workers and the general public during the development of contaminated land, HSE Guidance note HS(G) 66. Stationery Office, London.

Kirk Othmer Encyclopaedia of Chemical Technology (1993) Volume 10 (4th Ed). Explosives and Propellants, Wiley Interscience, New York, 1993.

Meyer, R., Kohler, J., Homburg, A. (2002) Explosives (5th Ed), Wiley-VCH Verlag GmbH, Weinheim. ISBN 3-527-30267-0.

SNIFFER (1999) Communicating Understanding of Contaminated Land Risks. Environment Agency R&D Technical Report P142.

Thomas Telford (1993) Guidelines for the Safe Investigation by Drilling of Landfills and Contaminated Land. Site Investigations Steering Group Publications No.4. Thomas Telford, London.

Trimm, G.A. (1986) Decontamination of Explosives Buildings and Plant at RO/XD Bridgwater. Journal of Hazardous Materials 13 (1986) 27-37.

Decontamination of Explosives Process Buildings and Sites. Report of Proceedings of ESTC, RARDE, Fort Halstead (1983).

Environmental Agency P5-036/01 "Toxicological Data and Guidance Values for Explosives Substances".

EASSP: Code of Good Practice "Decontamination /Dismantling and Upgrading of Installations and Equipment in Propellant Manufacturing" Publication 1/2000.

SAFEX Conference Proceedings 1999 Dublin " Various Papers on Decontamination"

DoE Industry Profile 1996 " Explosive Manufacturing Facilities"

FEEM "Guidance notes to Member Companies" various

Nobel Enterprises "Basis of Safety for Decontamination of Redundant Equipment or Buildings".

1994 Luxembourg International Symposium on the Rehabilitation of Former Military Sites and Demilitarisation of Explosive Ordnance.

A Guide to the Control of Major Accident Hazards Regulations 1999. L111, ISBN 0 7176 1604 5, HSE Books, Sudbury.

Successful Health and Safety Management. HSG65, ISBN 0 7176 1276 7, HSE Books, Sudbury.

Management of Health and Safety at Work. L21, ISBN 0 7176 2488 9, HSE Books, Sudbury.

Control of Substances Hazardous to Health (4<sup>th</sup> Ed). L5, ISBN 0 7176 2534 6, HSE Books, Sudbury.

Safe use of work equipment. L22, ISBN 0 7176 1626 6, HSE Books, Sudbury.

Workplace health, safety and welfare. L24, ISBN 0 7176 0413 6, HSE Books, Sudbury.

Memorandum of guidance on the Electricity at Work Regulations 1989. HSR25. ISBN 0 7176 1602 9, HSE Books, Sudbury.

The selection, installation and maintenance of electrical equipment for use in and around buildings containing explosives. HSE Guidance Note PM82. ISBN 0 7176 1217 1, HSE Books, Sudbury.

Reducing Noise at Work. L108, ISBN 0 7176 1511 1, HSE Books, Sudbury.

Safe use of lifting equipment. L113, ISBN 0 7176 1628 2, HSE Books, Sudbury.

Control of lead at work. COP2. ISBN 0 7176 1506 5, HSE Books, Sudbury.

Work with asbestos insulation, asbestos coating and asbestos insulating board (4<sup>th</sup> Ed). L28, ISBN 0 7176 2563 X, HSE Books, Sudbury.

Work with asbestos which does not normally require a licence (4<sup>th</sup> Ed). L27, ISBN 0 7176 2562 1, HSE Books, Sudbury.

Manual Handling. L23, ISBN 0 7176 2415 3, HSE Books, Sudbury.

Managing Health and Safety in Construction. HSG224, ISBN 0 7176 2139 1, HSE Books, Sudbury.

A Guide to the Packaging of Explosives for carriage Regulations 1991.  
L13, ISBN 0 11 885728 2, HSE Books, Sudbury.

A Guide to the Classification and Labeling of Explosives Regulations 1983.  
HS[R]17, ISBN 0 11 883706 0, HSE Books, Sudbury.

The Pollution Handbook. ISBN 0 9034 7453 0, Stationery Office, London.

Manufacture and Storage of Explosives Regulations – Consultative Document.

Is it Explosive? Dangers of explosives in metal recycling. Health and Safety Executive  
information leaflet, INDG335, 02/2002.

## **ACKNOWLEDGEMENTS**

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

HSE Explosives Inspectorate

Scottish Environment Protection Agency

Environment Agency

Ministry of Defence

BAe Systems

RO Defence

Nobels Explosives Company

Exchem Explosives