National Operational Guidance

Introduction

This section of guidance examines the hazards encountered by fire and rescue service personnel, other responders and members of the public at hazardous materials incidents. It contains hazard and control measure knowledge relevant to the categories of physical hazards and health hazards as classified by the Globally Harmonised System of Classification and Labelling of Chemicals (GHS).

Hazard and control measure knowledge relating to generic hazardous materials incidents can be found in National Operational Guidance: Hazardous materials (tier one).

This guidance is supported by supplementary information contained within the Foundation for Hazardous Materials that may support training or pre-planning.

Fire and rescue services respond to a wide range of incidents involving hazardous materials that have the potential to cause harm to firefighters, the surrounding community and the environment. Fire and rescue services may be called specifically to deal with emergency spillages or releases, or they may encounter hazardous materials at fires and other emergency incidents.

This guidance primarily deals with accidental hazardous materials incidents. The operational principles are essentially the same for deliberate, malicious or terrorist events. However, terrorist or CBRN(e) events require a more specific response because of:

- Increased security measures
- Increased risks to fire and rescue service personnel
- Complexity of multi-agency working
- Potential for multiple events caused by secondary devices
- Potential for perpetrators to use virulent agents that may be both persistent and difficult to identify
- Potential to change, remove or conceal safety signage and material information
- Potential to select locations that exploit the characteristics of the agent
- Need to exchange information with off-site intelligence and scientific advisers
- Potential for increased public exposure

For these reasons there is guidance in National Operational Guidance: Hazardous materials for initial operational response (IOR) and special operational response (SOR) to a CBRN(e) incident.

The generic key roles of fire and rescue services at hazardous materials or CBRN(e) incidents are to:

- Save life
- Protect the public and other responders
- Fight and prevent fires

- Manage hazardous materials
- Protect the environment
- Mitigate damage from fires or firefighting and rescue
- Ensure the health and safety of fire service responders
- Ensure safety management inside the inner cordon, other than during the initial stages of terrorist incidents
- Provide health and safety management at incidents that involve other emergency responders
- Provide an urban search and rescue capability

This guidance does not give information on the specific hazards and control measures relating to environmental protection. Although these are integral to any hazardous materials response, they are covered separately in National Operational Guidance: Environmental protection.

Relevant knowledge

The term 'Hazardous materials' (also referred to as a HazMat or as dangerous/hazardous substances or goods) means solids, liquids, vapours or gases that can harm people, animals, other living organisms, property or the environment. They include materials that are:

- Toxic
- Radioactive
- Flammable
- Explosive
- Corrosive
- Oxidisers
- Asphyxiates
- Biohazards

It also includes materials with physical conditions or other characteristics that render them hazardous in specific circumstances, such as compressed gases and liquids, hot or cold materials. Other organisations and agencies may use more technical and specific definitions because of their own requirements, but the above definition is the most appropriate for fire and rescue services on which to base their risk assessments and planning assumptions.

A clear distinction relating to hazardous material operations that needs to be understood before using this guidance is the difference between 'contamination' and 'exposure':

Contamination occurs when a substance adheres to or is deposited on people, animals, equipment or the environment, creating a risk of exposure and possible injury or harm. Contamination does not automatically lead to exposure but may do so.

Exposure occurs when a harmful substance enters the body through a route, for example, inhalation, ingestion, absorption or injection, or when the body is irradiated.

Due to the technical nature of hazardous materials operations, fire and rescue services must ensure their responders have access to the appropriate advice, equipment, skills, knowledge and understanding to maintain safety.

Specific hazardous materials roles may also be required in fire and rescue services to support and manage their hazardous materials response. These may include a hazardous materials adviser (HMA), decontamination director, mass decontamination subject matter adviser (SMA) or tactical adviser (TacAd). The number, type and specification of these roles will vary according to the fire and rescue service's risk profile, risk management plan, equipment and appliances.

It should be noted that the term hazardous materials adviser (HMA) is a generic description for anybody with enhanced knowledge of emergency hazardous materials operations used by a fire and rescue service to provide independent specialist advice to the incident commander. It includes such roles as the hazardous materials officer, hazardous materials and environmental protection officer/adviser (HMEPO, HMEPA) and scientific adviser. Their primary functions are to:

- Gather, filter and interpret technical information on hazardous materials for the incident commander
- Assess the risks posed by emergency hazardous materials incidents
- Provide hazardous materials advice on the development of an incident plan which may be at a tactical or strategic level

Hazardous materials incidents are predominantly accidental, frequently involve human error, natural or technological causes. The fire and rescue service will usually lead on this type of incident.

The key difference between a hazardous materials incident and a CBRN(e) event involving deliberate, criminal, malicious or murderous intent is that the latter is declared by the police, who will co-ordinate the multi-agency response. Many possible scenarios could lead to an incident being identified as a suspected or confirmed CBRN(e) event.

If during an incident, the release or spill of hazardous materials is confirmed as accidental then the incident will be reclassified as one involving hazardous materials. Incidents involving biological infections that are not spontaneous are also classified as hazardous materials incidents. The challenges posed and the response requirement for deliberate CBRN(e) and accidental HazMat incidents differ, but are similar or the same in many respects. For that reason, some of the information contained within this document is equally applicable to both situations and can be implemented for all levels of incident. Similarities in response include:

- The requirement for a broad response process involving numerous organisations working together to bring the incident to conclusion
- Multi-agency decision making to enable the development and implementation of integrated response plans
- The need to protect the safety of emergency responders to enable them to carry out those plans

Legislation

A hazardous materials response can be complicated by numerous pieces of legislation and regulation. In the main, legislation and regulation are the responsibility of those who produce, transport, use or store the substances. However, some do relate directly to the fire and rescue service. All legislation relevant to fire and rescue services and industry is listed in Foundation for Hazardous Materials.

It is important for fire and rescue services to have personnel with specialist knowledge about hazardous materials to ensure that legal provisions designed to keep the community and responders safe are recognised, understood and maintained.

Risk management plan

Each fire and rescue authority must develop their strategic direction through their risk management plan. To determine the extent of their hazardous materials capability, strategic managers will consider their statutory duties and the foreseeable risk of hazardous materials emergencies occurring in their area.

Work to identify specific hazardous materials risks and prepare operational plans should be carried out with regard to all stakeholders, including local emergency planning groups and the fire and rescue service's risk management plan.

Personnel who may be exposed to hazardous materials must be provided with suitable and sufficient information, instruction and training on:

- Possible risks to their health
- Precautions that must be taken
- Proper use of control measures

Responsibility of fire and rescue services

Fire and rescue services are responsible, under legislation and regulations, for developing policies and procedures and for providing personnel with information, instruction, training and supervision on foreseeable hazards and the control measures used to mitigate the risks arising from those hazards.

This guidance sets out to provide fire and rescue services with sufficient knowledge about the potential hazards their personnel could encounter when attending incidents involving hazardous materials. Fire and rescue services should ensure their policies, procedures and training cover all the hazards and control measures contained within this guidance.

Hazard - Explosive materials: Not involved in fire

Hazard Knowledge

The fire and rescue service may be called specifically to deal with uncontrolled or unstable explosive materials (e.g. a road traffic collision involving a vehicle carrying explosives), or they may encounter these materials at fires (refer to Hazard – Explosive materials involved in fire). Uncontrolled situations or initiations can be caused by:

- Impact or friction
- Fire or heat
- Fragment attack or overpressure
- Electrostatic discharge
- Electromagnetic radiation (in the case of electro-explosive devices)
- Chemical reactions
- Drying out explosive materials that have been wetted
- Sensitisation from contact with other materials such as rust, aluminium or unsuitable storage conditions

If explosive materials receive sufficient energy and explode, the following hazards may be produced:

- Blast wave, resulting in:
    - Primary blast injuries – caused by the direct action of a blast wave on the body

    - Secondary blast injuries – which occur as a direct consequence of blast damage to buildings and structures
    - Tertiary blast injuries – resulting from body movement induced by the blast wave
- Fireball – severe burns may result even if no explosion takes place (the ignition of some types of explosives can result in a significant fireball)
- Noise – can cause hearing damage

Responders should be aware of the increased manufacture and use of improvised or home-made explosives and improvised explosive devices (IEDs). These have many forms but the most common group are peroxide explosives.

Peroxide explosives are extremely dangerous because:

- Only small quantities are needed to cause serious injury or explosions
- The precursor chemicals are readily available
- They are easy to make and instructions for their manufacture are easily available on the internet
- The emergency services may encounter them at routine incidents (e.g. domestic property fires)

The main constituents are:

- Hydrogen peroxide (e.g. for hair bleaching)
- Acid (e.g. battery acid, brick cleaner or citric acid used in brewing)
- Acetone (e.g. nail varnish remover)
- Hexamine (e.g. camping stove fuel tablets)

It is important for responders to know and remember these precursor chemicals because early recognition that home-made explosives may be present at an apparently routine incident can save lives.

For further information, the following government website has details of restricted precursor material

https://www.gov.uk/government/publications/licensing-for-home-users-of-explosives-precursors/licensing-for-home-users-of-poisons-and-explosive-precursors

Peroxide explosives can vary greatly in appearance. Pure substances form a white powder, but they may also be granular in texture like sugar, or even form a sticky 'goo'. Because of this, responders should not rely on physical appearance alone to identify this hazardous material. It is more important to recognise the precursor chemicals along with other indicators such as mixing jars and containers, a fridge or freezer to keep the substance cool.

For further information on explosives see the Foundation for Hazardous Materials

Control measure - Site specific risk information: Explosive materials

Control measure knowledge

This control measure should be read in conjunction with National Operational Guidance: Operations – Site-Specific Risk Information (SSRI)

Strategic actions

Fire and rescue services should:

- Contact the Health and Safety Executive (HSE) and other explosives licensing authorities with a view to identifying licensed sites in their areas so that they can undertake information-gathering visits.

- Treat sites owned and/or used by firework display operators as falling into the priority group for inspections

- Ensure effective and regular liaison is maintained with Ministry of Defence (MoD) establishments holding explosives and ensure they are fully aware of the emergency procedures for the establishment

- Ensure close information-sharing links on explosive risks are maintained with fire safety departments, neighbouring fire and rescue services, police services, local authority trading standards departments, etc.

Tactical actions

There are no tactical actions associated with this control measure.

Control measure - Emergency response plans

Control measure knowledge

The Civil Contingencies Act (CCA) places a responsibility on Category 1 responders to produce and have in place emergency plans, which may include procedures for determining whether an emergency has occurred.

There is a generic national framework for managing emergency response and recovery, irrespective of the size, nature and cause of an emergency. It also identifies the various tiers of single and multi-agency management, defining the relationship between them and a common framework within which individual agencies can develop their own plans and procedures.

For further information see Emergency Response and Recovery Guidance (England and Wales), Responding to Emergencies in Scotland and Emergency Planning, Northern Ireland Fire and Rescue Service

Strategic actions

Fire and rescue services should:

- Consider the roles and responsibilities of the fire and rescue service at emergency incidents when developing emergency plans

- Ensure that emergency plans are produced. Plans should be developed in consideration of the following:

    - Anticipation - horizon scanning for risks and potential emergencies
    - Preparedness - a clear understanding of roles and responsibilities and how they fit into the wider, multi-agency picture
    - Subsidiarity - managing operations and making decisions at the lowest appropriate level
    - Direction - establishing a clear and unambiguous strategic aim and objectives
    - Information - information management and appropriate preparatory measures being in place to build situational awareness and the development of a Common Recognised Information Picture (CRIP)
    - Integration - multi-agency involvement, roles and prominence
    - Co-operation - inclusive decision making processes, openness and mutual trust
    - Continuity - using established experience, expertise, resources and relationships to

manage and respond to emergencies in the usual way

Tactical actions

Incident commanders should:

- Access any available emergency response plan and implement appropriate predetermined actions

Control measure - Substance identification: Explosive materials

Control measure knowledge

Transportation recognition

Subject to some exceptions, road transport regulations require vehicles carrying explosives to be marked with placards in accordance with the regulations. For detailed information see A foundation for hazardous materials – Transportation and packaging.

Figure 1: Transportation hazard warning diamond for UN Hazard Division 1.1 to 1.3 and Compatibility Group

The 'bomb burst' pictogram indicates that the UN classification system recognises that UN Hazard Division 1.1 to 1.3 possess the energy to mass detonate/deflagrate.

Figure 2: Transportation hazard warning diamond for UN Hazard Division 1.4 to 1.6 and Compatibility Group (N.B. No 'bomb burst'

Vehicles carrying larger quantities of explosive materials, including fireworks, should carry the appropriate UN Hazard Division orange diamonds. However, fire and rescue services should be aware of the possibility of smaller loads of explosives being carried in vehicles without placards and of explosives being illegally carried. Incident commanders should always consider these possibilities if, for example, the driver of the vehicle involved cannot be easily identified at the incident.

Vehicles carrying more than five tonnes of UN Hazard Division 1.1 explosives must have a driver and attendant (carrying less than five tonnes or carrying materials from other hazard divisions mean no attendant is required); both will have received specific training to the UN ADR (Accord européan relatif au transport international des marchandises Dangereuses par Route) standard that enables them to take measures for their own safety, that of the public and the environment. Therefore, the vehicle crew should always be consulted.

All packages and the vehicle must be correctly identified in accordance with the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2009. The package labels and vehicle placards provide safety information for those involved in transportation and the emergency services, and must be displayed at all times.

On those occasions when the armed forces, in the interest of national security, do not comply with the carriage regulations, liaison with the crew of the vehicle is paramount.

Although small quantities of explosives may be carried in private vehicles without having to comply with the carriage regulations, the carrier still has a responsibility to move them safely and securely.

Even though up to 2kg of one or more specific items may be carried on public transport these items must remain with the person carrying them, be properly packaged and reasonable precautions must have been taken to prevent accidents.

Rail transport of explosives is strictly controlled under railway transport legislation. Explosives are clearly marked and packed in specific wagons or containers. Placards like those required for road transport are displayed on both sides of the wagon and on all four sides of containers. Written information is carried by the crew, detailing the explosive carried and any special action required. The crew will also have received specific training similar to that of road vehicle crews but to the European Agreement on Carriage of Dangerous Goods by Rail (RID) standard. Crews should always be consulted at an incident.

For further information on rail transportation hazards see National Operational Guidance: Transport.

Unless a licence has been granted, marine and inland waterways legislation prohibits (with certain exceptions):

- Explosives being brought into, or handled in, a harbour
- Loading/unloading explosives on a vessel

When this occurs on any part of the coast or in the tidal waters or within the territorial waters of the United Kingdom:

- The licence specifies any conditions or restrictions, including limits on the type and quantities of explosive handled and where in the harbour area the handling may take place
- Once the loading/unloading of a vessel or a vehicle is completed, the master of the vessel or the operator of the vehicle shall ensure that the vessel or vehicle is taken out of the harbour or harbour area as soon as is reasonably practicable, unless agreed by the harbour master and, if berthed, the berth operator
- Vessels carrying dangerous goods will display a red warning flag between sunrise and sunset and, when moored or anchored between sunset and sunrise (or during the day when there is restricted visibility), will display an all-round, uniform and unbroken red light
- The operator of any berth where explosives are being loaded/unloaded or stored before being loaded/unloaded shall ensure that their emergency plan is made available to the fire and rescue services

All Royal Navy vessels have a liaison officer who will inform the appropriate fire and rescue service whenever the vessel is in port.

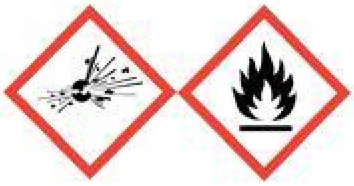
For further information on marine transportation hazards, see National Operational Guidance: Transport.

Site recognition

Licensed sites and military establishments storing and using explosives should conform to UK legislation and regulation. For further information, see A foundation for hazardous materials.

Supply and packaging recognition

Under The European Regulation (EC) No 1272/208 on classification, labelling and packaging of substances and mixture (the EU version of the Globally Harmonised System (GHS)), the symbols that can be seen in relation to explosive materials are:



For detailed information on classification and labelling see Foundation for Hazardous Materials.

Strategic actions

Fire and rescue services should:

- Provide procedures and support arrangements regarding the hazards that may be encountered and actions to take in recognising explosive materials and confirming their status
- Ensure that all personnel have an appropriate awareness of explosive materials that might be encountered in domestic and commercial premises

Tactical actions

Incident commanders should:

- Identify the type, quantity and location of explosive materials and confirm they are not involved in fire
- Use signs, labels, markings and container types to identify the presence of explosive materials
- Identify the location, physical state (solid, liquid, gas), type, and quantity of explosive materials
- Use detection equipment to identify and monitor the levels of explosive material involved
- Investigate and confirm that any explosive materials are not involved in fire
- If explosives are involved in fire, the fire should not be fought and personnel should withdraw to a safe distance (refer to the hazard area table in Hazard – Explosive materials involved in fire).
- Confirm that explosive materials are involved in fire

- Consider the potential risk from flame impingement on ISO containers holding fireworks or explosives

- Identify the type, quantity and location of ammonium nitrate fertiliser and confirm involvement in fire

Control measure - Control ammonium nitrate fertiliser

Control measure knowledge

This control measure should be read in conjunction with Hazardous materials – Substance identification.

Ammonium nitrate technical grades that are classified as an explosive and assigned to 'Class 1 explosive' of the UN transportation classification system are subject to controls under explosives legislation. Responders should apply the control measures for the control measure Cordons controls: Explosives in all such incidents.

Ammonium nitrate is often present in mixed fertilizers (sometimes called balanced mixtures and known as N:P:K fertilisers). A code will be found on the bag, e.g., 6-12-12.

The numbers, in order, refer to:

- N % of nitrogen
- P % of phosphorus as if it were phosphorus pentoxide (P_2O_5)
- K % potassium as if it were potassium oxide (K_2O).

N.B. the first number is the only one of interest to fire and rescue services. The higher it is, the greater the amount of nitrates or ammonium compounds, and thus the greater the danger from the mixed fertilizer if it is near, or becomes involved in fire.

Historically, any N% figure of 20 or more (maximum 35%) has been regarded as a potential explosive risk when the fertilizer is close to or directly involved in, any fire. However, it is possible for fertilisers with less than 20% nitrogen to explode if they have been contaminated and/or pressurised before being heated.

White/brown fumes coming from the fertiliser are a sign of potential explosion. In a fire, all types of ammonium nitrate may melt and decompose with the release of toxic fumes (mainly oxides of nitrogen), which may be white, yellow or brown.

Ammonium nitrate fertilisers that are slowly decomposing or smouldering can be managed by:

- Removing the heat source and extinguishing the fire or decomposition, if possible
- Recognising that decomposition is indicated by the release of white/brownish fumes from the fertilizer mass.

If an area of the ammonium nitrate-based fertilizer is slowly decomposing or smouldering, the following steps should be taken immediately:

- Identify the source of heat and, if found, turn it off or remove it
- If the area of decomposing material is still small and easily accessible, try to remove it from the main heap of the fertilizer using picks, shovels or a ship's grab, and cool it down by localised quenching with water
- If it is impossible to remove the decomposing mass, soak the fertilizer involved as rapidly as possible with a large quantity of water, preferably directed against the centre of the decomposition through high pressure jets. This may cause the additional problem of large quantities of contaminated water run-off.
- Fighting the decomposition by other means, such as foam, carbon dioxide, steam or covering with sand, is useless and may even promote the decomposition
- If fumes are present, use self-contained breathing apparatus (SCBA)
- If suppressing the slow decomposition is impractical or unsuccessful use defensive tactics and consider evacuation
- In ships or containerised stores, open doors, hatches, etc. immediately to maximise ventilation if it is safe to do so.
- Use defensive firefighting and evacuation if explosive decomposition is suspected

For further information see National Operational Guidance: Fires and firefighting.

The risk of fire or explosion is greatly increased if ammonium nitrate is mixed with combustible or incompatible materials, such as powdered metals, alkali metals, urea, chromium or copper salts, organic and carbonaceous materials, sulphur, nitrites, alkalis, acids, chlorates and reducing agents. Fertilisers that contain 28% or less nitrogen (see the label or safety data sheets (SDS) for the percentage of nitrogen present) do not normally present an explosion hazard and therefore, in agriculture, ammonium nitrate-based fertilisers can be divided into two groups to identify the precautions required:

- Fertilisers that contain more than 28% nitrogen – most of these are straight ammonium nitrate types, although they include a small number of compound fertilisers
- Fertilisers that contain 28% or less nitrogen – compound fertilisers form the major proportion of this group; the straight nitrogen types are usually a mixture of ammonium nitrate with limestone or similar inert materials

The Ammonium Nitrate Materials (High Nitrogen Content) Safety Regulations 2003 prohibit the importation and supply of relevant ammonium nitrate with more than 28% nitrogen without a supporting 'Resistance to Detonation certificate'.

Where a site contains 25 tonnes or more of dangerous substances, the Dangerous Substances

(Notification and Marking of Sites) Regulations 1990 (NAMOS) require the person in control of the site to notify the fire authority and the enforcing authority of certain details. For 'relevant ammonium nitrate mixtures' this threshold limit is 150 tonnes. Within the regulations ‘relevant ammonium nitrate mixtures’ are defined as ammonium nitrate and mixtures containing ammonium nitrate, where the nitrogen content exceeds 15.75% of the mixture by weight.

Strategic actions

Fire and rescue services should:

- Provide procedures and support arrangements regarding the hazards and actions to take in recognising ammonium nitrate fertiliser mixtures that have the potential to explode

- Ensure that all personnel can identify the presence and impact of ammonium nitrate fertilisers at operational incidents

Tactical actions

Incident commanders should:

- Prevent molten ammonium nitrate fertiliser from entering drains

- Prevent ammonium nitrate fertiliser from coming into contact with other combustible or incompatible materials

- Consider creating a firebreak between ammonium nitrate fertiliser and other combustible materials such as hay, straw, grain or feedstuffs

- Seek immediate medical help if anyone is suspected of inhaling ammonium nitrate fumes; these effects may be delayed

- Consider the explosion risks of confined, large stacks of ammonium nitrate fertiliser, even where the nitrogen content is below 20%

- Observe ammonium nitrate for signs of decomposition

- Isolate or remove heat sources from slowly decomposing or smouldering ammonium nitrate fertilisers

- Use copious amounts of water on decomposing or smouldering ammonium nitrate, being aware of contaminated run-off
- Consider defensive firefighting and evacuation if explosive decomposition of ammonium nitrate is suspected
- Consider the explosion risks of confined, large stacks of ammonium nitrate fertiliser
- Prevent ammonium nitrate fertiliser contacting combustible or incompatible materials

Control measure - Eliminate ignition sources

Control measure knowledge

From the smallest to the largest incident, the incident commander and firefighters need to be aware of, and take notice of, possible ignition sources that could create additional hazards.

Although eliminating ignition sources may not be an immediate priority in a fire situation because the fire is already burning, firefighters should be aware of the potential for additional ignition sources and their potential to start events such as fire gas ignitions in areas that may be remote from the initial seat of fire.

At incidents where there may be a release of gases or other flammable atmospheres because features such as storage vessels, tanks or pipework may fail or be damaged, incident commanders should consider this a concern and identify it in the incident dynamic or analytical risk assessments (DRA or ARA) and incident plan.

The amount of energy required to ignite a mixture of air and flammable gas or vapour (including smoke) is called the minimum ignition energy (MIE) and depends on the characteristics of the gas or vapour, concentration in air, type of oxidant, temperature and pressure.

An ignition source can be defined as a form of energy that, when added to a flammable mixture, is sufficient for the combustion process to start; an ignition source with energy greater than the minimum ignition energy (MIE) for a particular mixture is sufficient for a fire or explosion to occur. Generally, the energy required to ignite a flammable gas or vapour mixture is relatively low, though some low-energy ignition sources may not be incendiary enough for all flammable mixtures.

Ignition sources include:

- Open flames
- General firefighting operations, including cutting
- Frictional sparks and localised heating
- Impact sparks
- Sparks from electrical equipment
- Electrostatic discharge
- Vehicles
- Use of cigarettes or matches
- Hot surfaces
- Electrical equipment and lighting
- Hot processes
- Exothermic runaway reactions (water applied to reactive metals such as sodium and potassium)
- Heating equipment

It is often challenging for crews to identify and eliminate every ignition source at an operational incident. The first option for ensuring safety is therefore usually to prevent flammable gas or vapour mixtures being released or formed. All foreseeable ignition sources should also be identified and effective control measures taken.

In industrial premises, depending on the ignition sensitivity of the materials handled, the types of equipment involved and the process parameters (such as temperature and pressure), incident commanders should consult with on-site process safety professionals or the responsible person to address safety issues and provide recommendations to aid the safe resolution of the incident.

Strategic actions

Fire and rescue services should:

- Develop tactical guidance and support arrangements for the hazards and actions to be taken in eliminating ignition sources

Tactical actions

Incident commanders should:

- Extinguish the fire and eliminate all ignition sources

- Prevent escalation, contain and extinguish the fire considering all ignition sources

- Deal with any immediate fire risk and provide a means of extinguishing fires during the incident

- Identify all possible ignition sources and eliminate them as far as is possible

- Control ignition sources that cannot be eliminated as far as reasonably practicable

- Develop and communicate a firefighting plan and ventilation strategy to all personnel
- Use the appropriate extinguishing method, media, techniques and equipment
- Ensure that crews are briefed on all firefighting activities and provide regular updates on progress
- Consider removing fuel from any source of ignition

Control measure - Control explosive materials not involved in fire

Control measure knowledge

As soon as responders have recognised that explosive materials are present at an incident but not involved in fire, they can apply tactics to control them. Depending on their properties, the explosive materials may become unstable, such as through exposure to:

- Fire, heat or ignition sources
- Water ingress
- Shock or pressure

Reducing or eliminating exposure will be a priority to control the explosive materials.

Strategic actions

Fire and rescue services should:

- Have operational procedures for safely managing explosive materials not involved in fire

Tactical actions

Incident commanders should:

- Prevent any fire, heat or other energy source/stimuli from affecting the explosive material
- Protect explosives not involved in fire using firefighting media where appropriate and safe to do so

- Assess if an immediate life risk due to explosion is likely
- Assess proximity of explosive materials to neighbouring habitable properties
- Protect explosives not involved in fire using firefighting media where appropriate and safe to do so (for example, using branch holders and ground monitors)
- Consider ways to safely move explosive materials not involved in fire
- Ensure protection from the effect of explosion is available when undertaking firefighting operations
- Consider whether action already taken to control explosive materials is adequate/appropriate
- Consider boundary cooling/protection for explosives at marine incidents

Control measure - Use intrinsically safe equipment

Control measure knowledge

Any equipment that is not intrinsically safe can provide an ignition source for a gas within its flammable or explosive limits. This may cause combustion or explosion. The use of intrinsically safe equipment will preclude this.

In most confined spaces, it is impossible to classify the atmosphere present. For fire and rescue service operations, intrinsically safe equipment must meet the standards for use in Zone 1 under the ATEX directives.

For further information on fireground radios see: Fireground radios guidance: ATEX-approved radios

Strategic actions

Fire and rescue services should:

- Ensure that intrinsically safe equipment is available to crews trained to work in confined spaces

Tactical actions

Incident commanders should:

- Use only intrinsically safe equipment in confined spaces where there is a risk of a flammable or explosive atmosphere
- Use only ATEX approved equipment in flammable or explosive atmospheres
- Use only ATEX approved communications equipment when crews enter any potentially explosive atmosphere
- Use only ATEX approved equipment when crews enter any potentially flammable atmosphere

Hazard - Explosive materials: Involved in fire

Hazard Knowledge

This hazard should be read in conjunction with Explosive materials not involved in fire

Explosive materials involved in fire or at risk of ignition will produce unique hazards and therefore require more specific control measures. These are contained in this section but it must be stressed that they must be read in conjunction with Tier 1 Hazardous materials guidance as they are additional considerations.

Control measure - Substance identification: Explosive materials

Control measure knowledge

Transportation recognition

Subject to some exceptions, road transport regulations require vehicles carrying explosives to be marked with placards in accordance with the regulations. For detailed information see A foundation for hazardous materials – Transportation and packaging.

Figure 1: Transportation hazard warning diamond for UN Hazard Division 1.1 to 1.3 and Compatibility Group

The 'bomb burst' pictogram indicates that the UN classification system recognises that UN Hazard Division 1.1 to 1.3 possess the energy to mass detonate/deflagrate.

Figure 2: Transportation hazard warning diamond for UN Hazard Division 1.4 to 1.6 and Compatibility Group (N.B. No 'bomb burst'

Vehicles carrying larger quantities of explosive materials, including fireworks, should carry the appropriate UN Hazard Division orange diamonds. However, fire and rescue services should be aware of the possibility of smaller loads of explosives being carried in vehicles without placards and of explosives being illegally carried. Incident commanders should always consider these possibilities if, for example, the driver of the vehicle involved cannot be easily identified at the incident.

Vehicles carrying more than five tonnes of UN Hazard Division 1.1 explosives must have a driver and attendant (carrying less than five tonnes or carrying materials from other hazard divisions mean no attendant is required); both will have received specific training to the UN ADR (Accord européan relatif au transport international des marchandises Dangereuses par Route) standard that enables them to take measures for their own safety, that of the public and the environment. Therefore, the vehicle crew should always be consulted.

All packages and the vehicle must be correctly identified in accordance with the Carriage of

Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2009. The package labels and vehicle placards provide safety information for those involved in transportation and the emergency services, and must be displayed at all times.

On those occasions when the armed forces, in the interest of national security, do not comply with the carriage regulations, liaison with the crew of the vehicle is paramount.

Although small quantities of explosives may be carried in private vehicles without having to comply with the carriage regulations, the carrier still has a responsibility to move them safely and securely.

Even though up to 2kg of one or more specific items may be carried on public transport these items must remain with the person carrying them, be properly packaged and reasonable precautions must have been taken to prevent accidents.

Rail transport of explosives is strictly controlled under railway transport legislation. Explosives are clearly marked and packed in specific wagons or containers. Placards like those required for road transport are displayed on both sides of the wagon and on all four sides of containers. Written information is carried by the crew, detailing the explosive carried and any special action required. The crew will also have received specific training similar to that of road vehicle crews but to the European Agreement on Carriage of Dangerous Goods by Rail (RID) standard. Crews should always be consulted at an incident.

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When this occurs on any part of the coast or in the tidal waters or within the territorial waters of the United Kingdom:

- The licence specifies any conditions or restrictions, including limits on the type and quantities of explosive handled and where in the harbour area the handling may take place
- Once the loading/unloading of a vessel or a vehicle is completed, the master of the vessel or the operator of the vehicle shall ensure that the vessel or vehicle is taken out of the harbour or harbour area as soon as is reasonably practicable, unless agreed by the harbour master and, if berthed, the berth operator
- Vessels carrying dangerous goods will display a red warning flag between sunrise and sunset and, when moored or anchored between sunset and sunrise (or during the day when there is restricted visibility), will display an all-round, uniform and unbroken red light
- The operator of any berth where explosives are being loaded/unloaded or stored before being loaded/unloaded shall ensure that their emergency plan is made available to the fire and rescue services

All Royal Navy vessels have a liaison officer who will inform the appropriate fire and rescue service whenever the vessel is in port.

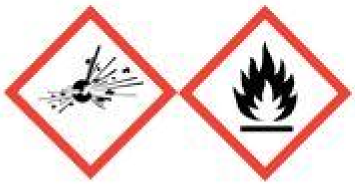
For further information on marine transportation hazards, see [National Operational Guidance: Transport.]()

Site recognition

Licensed sites and military establishments storing and using explosives should conform to UK legislation and regulation. For further information, see A foundation for hazardous materials.

Supply and packaging recognition

Under The European Regulation (EC) No 1272/208 on classification, labelling and packaging of substances and mixture (the EU version of the Globally Harmonised System (GHS)), the symbols that can be seen in relation to explosive materials are:



For detailed information on classification and labelling see Foundation for Hazardous Materials.

Strategic actions

Fire and rescue services should:

- Provide procedures and support arrangements regarding the hazards that may be encountered and actions to take in recognising explosive materials and confirming their status

- Ensure that all personnel have an appropriate awareness of explosive materials that might be encountered in domestic and commercial premises

Tactical actions

Incident commanders should:

- Identify the type, quantity and location of explosive materials and confirm they are not involved in fire

- Use signs, labels, markings and container types to identify the presence of explosive materials

- Identify the location, physical state (solid, liquid, gas), type, and quantity of explosive materials

- Use detection equipment to identify and monitor the levels of explosive material involved

- Investigate and confirm that any explosive materials are not involved in fire

- If explosives are involved in fire, the fire should not be fought and personnel should withdraw to a safe distance (refer to the hazard area table in Hazard – Explosive materials involved in fire).

- Confirm that explosive materials are involved in fire

- Consider the potential risk from flame impingement on ISO containers holding fireworks or explosives

- Identify the type, quantity and location of ammonium nitrate fertiliser and confirm involvement in fire

Control measure - Control ammonium nitrate fertiliser

Control measure knowledge

This control measure should be read in conjunction with Hazardous materials – Substance identification.

Ammonium nitrate technical grades that are classified as an explosive and assigned to 'Class 1 explosive' of the UN transportation classification system are subject to controls under explosives legislation. Responders should apply the control measures for the control measure Cordons controls: Explosives in all such incidents.

Ammonium nitrate is often present in mixed fertilizers (sometimes called balanced mixtures and known as N:P:K fertilisers). A code will be found on the bag, e.g., 6-12-12.

The numbers, in order, refer to:

- N % of nitrogen
- P % of phosphorus as if it were phosphorus pentoxide (P2O5)
- K % potassium as if it were potassium oxide (K2O).

N.B. the first number is the only one of interest to fire and rescue services. The higher it is, the greater the amount of nitrates or ammonium compounds, and thus the greater the danger from the mixed fertilizer if it is near, or becomes involved in fire.

Historically, any N% figure of 20 or more (maximum 35%) has been regarded as a potential explosive risk when the fertilizer is close to or directly involved in, any fire. However, it is possible for fertilisers with less than 20% nitrogen to explode if they have been contaminated and/or pressurised before being heated.

White/brown fumes coming from the fertiliser are a sign of potential explosion. In a fire, all types of ammonium nitrate may melt and decompose with the release of toxic fumes (mainly oxides of nitrogen), which may be white, yellow or brown.

Ammonium nitrate fertilisers that are slowly decomposing or smouldering can be managed by:

- Removing the heat source and extinguishing the fire or decomposition, if possible
- Recognising that decomposition is indicated by the release of white/brownish fumes from the fertilizer mass.

If an area of the ammonium nitrate-based fertilizer is slowly decomposing or smouldering, the following steps should be taken immediately:

- Identify the source of heat and, if found, turn it off or remove it
- If the area of decomposing material is still small and easily accessible, try to remove it from the main heap of the fertilizer using picks, shovels or a ship's grab, and cool it down by localised quenching with water
- If it is impossible to remove the decomposing mass, soak the fertilizer involved as rapidly as possible with a large quantity of water, preferably directed against the centre of the decomposition through high pressure jets. This may cause the additional problem of large quantities of contaminated water run-off.
- Fighting the decomposition by other means, such as foam, carbon dioxide, steam or covering with sand, is useless and may even promote the decomposition
- If fumes are present, use self-contained breathing apparatus (SCBA)
- If suppressing the slow decomposition is impractical or unsuccessful use defensive tactics and consider evacuation
- In ships or containerised stores, open doors, hatches, etc. immediately to maximise ventilation if it is safe to do so.
- Use defensive firefighting and evacuation if explosive decomposition is suspected

For further information see National Operational Guidance: Fires and firefighting.

The risk of fire or explosion is greatly increased if ammonium nitrate is mixed with combustible or incompatible materials, such as powdered metals, alkali metals, urea, chromium or copper salts, organic and carbonaceous materials, sulphur, nitrites, alkalis, acids, chlorates and reducing agents. Fertilisers that contain 28% or less nitrogen (see the label or safety data sheets (SDS) for the percentage of nitrogen present) do not normally present an explosion hazard and therefore, in agriculture, ammonium nitrate-based fertilisers can be divided into two groups to identify the precautions required:

- Fertilisers that contain more than 28% nitrogen – most of these are straight ammonium nitrate types, although they include a small number of compound fertilisers
- Fertilisers that contain 28% or less nitrogen – compound fertilisers form the major proportion of this group; the straight nitrogen types are usually a mixture of ammonium nitrate with limestone or similar inert materials

The Ammonium Nitrate Materials (High Nitrogen Content) Safety Regulations 2003 prohibit the importation and supply of relevant ammonium nitrate with more than 28% nitrogen without a supporting 'Resistance to Detonation certificate'.

Where a site contains 25 tonnes or more of dangerous substances, the Dangerous Substances (Notification and Marking of Sites) Regulations 1990 (NAMOS) require the person in control of the site to notify the fire authority and the enforcing authority of certain details. For 'relevant ammonium nitrate mixtures' this threshold limit is 150 tonnes. Within the regulations 'relevant ammonium nitrate mixtures' are defined as ammonium nitrate and mixtures containing ammonium nitrate, where the nitrogen content exceeds 15.75% of the mixture by weight.

Strategic actions

Fire and rescue services should:

- Provide procedures and support arrangements regarding the hazards and actions to take in recognising ammonium nitrate fertiliser mixtures that have the potential to explode

- Ensure that all personnel can identify the presence and impact of ammonium nitrate fertilisers at operational incidents

Tactical actions

Incident commanders should:

- Prevent molten ammonium nitrate fertiliser from entering drains

- Prevent ammonium nitrate fertiliser from coming into contact with other combustible or incompatible materials

- Consider creating a firebreak between ammonium nitrate fertiliser and other combustible materials such as hay, straw, grain or feedstuffs

- Seek immediate medical help if anyone is suspected of inhaling ammonium nitrate fumes; these effects may be delayed

- Consider the explosion risks of confined, large stacks of ammonium nitrate fertiliser, even where the nitrogen content is below 20%

- Observe ammonium nitrate for signs of decomposition

- Isolate or remove heat sources from slowly decomposing or smouldering ammonium nitrate fertilisers

- Use copious amounts of water on decomposing or smouldering ammonium nitrate, being aware of contaminated run-off

- Consider defensive firefighting and evacuation if explosive decomposition of ammonium nitrate is suspected

- Consider the explosion risks of confined, large stacks of ammonium nitrate fertiliser

- Prevent ammonium nitrate fertiliser contacting combustible or incompatible materials

Control measure - Cordon control: Explosives

Control measure knowledge

It is important to remember that the UN classifications are based on the behaviour of the explosive when burnt in its packaging, in the open air, on a test crib. However, the same explosive may behave very differently when under confinement, for example, explosives in International Standards Organisation (ISO) transport containers, thick walled steel stores or some process plant.

In such circumstances, the very rapid build-up of pressure can cause the explosives to react more violently than the classification would suggest and therefore present a much greater hazard.

In liaison with a hazardous materials adviser (HMA) or other specialist adviser, the risk and potential impact of an explosion should be assessed and a hazard area established, taking into account:

- The actual type/class and quantity of explosives involved
- The location of explosives
- The time they have been involved in fire/heat
- Any life risk and proximity to neighbouring habitable properties
- Any other hazards

When dealing with an incident at a firework storage or display operator's site, treat all structures, including shipping or International Standards Organisation (ISO) containers, as if they contain UNHD 1.1 explosives, unless there is reliable confirmation that they contain no explosives. Be aware that the external heating of an ISO container could have adverse effects on its contents. If combustion is initiated within an ISO container, the potential low oxygen levels could lead to a smouldering fire of the firework packaging. In such a situation, if the doors were opened, this could lead to rapid increase in the intensity of the fire which could lead to the container failing catastrophically. An assessment of the exterior of the container may identify hot spots indicating the presence of activity within the container. Where it is unclear whether there is activity within an ISO container, appropriate controls should be used in approaching/assessing the container.

If an explosion has occurred, secondary explosions can take place for some considerable time afterwards.

When buried under ash, explosives may remain live after the fire has been extinguished, even if they have been involved in a very intense fire. Unexploded parts may also have been projected some considerable distance. Simply stepping on these explosives, particularly detonators, can generate sufficient friction to set them off, potentially causing severe injury.

Fire investigation may be subject to the higher requirements of Health and Safety Executive (HSE), police, coroners or public enquiry investigations. In such circumstances, the fire and rescue service's strategic management should be consulted for further guidance.

For further information regarding cordon controls see National Operational Guidance: Incident command.

Guidance on hazard areas is contained in the following table:

Hazard areas for explosive related incidents			
Type	**Location**	**Maximum quantity and hazard classification**	**Hazard area radius**
Premises licensed for retail fireworks only	Retail outlet within residential or industrial area	250 kg HT1.4	100m

<table>
<tr><th colspan="5">Hazard areas for explosive related incidents</th></tr>
<tr><th>Type</th><th>Location</th><th colspan="2">Maximum quantity and hazard classification</th><th>Hazard area radius</th></tr>
<tr><td rowspan="3">Other licensed retail premises</td><td rowspan="3">Retail outlet within residential or industrial area</td><td colspan="2">30 kg HT 1.1</td><td rowspan="3">200m</td></tr>
<tr><td colspan="2">100 kg HT 1.3</td></tr>
<tr><td colspan="2">250 kg HT 1.4</td></tr>
<tr><td>Premises licensed storage of fireworks</td><td>Not normally in built up area</td><td colspan="2">Up to 2000 kg HT 1.1, HT1.3 and/or HT 1.4</td><td>600m</td></tr>
<tr><td>Premises licensed for storage by the police</td><td>Generally remote, e.g. quarries</td><td colspan="2">Up to 2000kg Generally HT 1.1</td><td>600m</td></tr>
<tr><td rowspan="2">Premises licensed site by Health & Safety Executive (HSE)</td><td rowspan="2">Not normally in built up area</td><td rowspan="2">Limited only by separation distances</td><td>Less than 2000 kg</td><td>600m</td></tr>
<tr><td>More than 2000 kg</td><td>1000m</td></tr>
<tr><td>Transportation incident</td><td>Public roads, rail undertaking</td><td colspan="2">HD 1.1
HD 1.2</td><td>600m</td></tr>
<tr><td>Transportation incident</td><td>Public roads, rail undertaking</td><td colspan="2">HD 1.3</td><td>200m</td></tr>
<tr><td>Transportation incident</td><td>Public roads, rail undertaking</td><td colspan="2">HD 1.4</td><td>100m</td></tr>
<tr><td>CBRN(e)* event</td><td>Any</td><td colspan="2">Suitcase-sized</td><td>100m</td></tr>
<tr><td>CBRN(e)* event</td><td>Any</td><td colspan="2">Car-sized</td><td>200m</td></tr>
<tr><td>CBRN(e)* event</td><td>Any</td><td colspan="2">Lorry-sized or when the size of device is unknown</td><td>400m</td></tr>
<tr><td colspan="5">* To be used in the absence of any reliable information/intelligence regarding the nature of the substance involved. Consideration should always be given to being out of line of sight of the device and behind substantial cover, if available. See National Operational Guidance: Hazardous materials.</td></tr>
</table>

Hazard type relates to site storage while hazard division relates to transportation. For additional information see Foundation for Hazardous Materials – Explosive hazards.

Where terrorist or improvised explosive devices (IEDs) are suspected, other explosives may have been strategically placed to harm responders. These are known as secondary devices.

When considering appropriate cover, be aware that small buildings and vehicles offer little protection. Sheltering behind walls can be dangerous because they will only stop small projectiles and any blast wave may overturn vehicles and/or demolish walls, creating more projectiles.

Once explosives are involved in fire, applying water will not extinguish them.

IEDs or home-made peroxide explosives can be encountered at the most routine incidents (e.g. house fires, car fires). They are detonated easily by shock, impact, flame impingement, sparks, etc. and may react similarly to UN Hazard Division 1.1 explosives. As soon as responders believe that home-made explosives may be involved they should:

Not touch anything suspicious (especially white powders in unmarked jars) Not tread on anything suspicious (peroxide explosives can explode when stepped on, especially in granulated forms)

- Consider defensive tactics if no life is at risk
- Carefully retrace their route away from the scene
- Preserve the scene and any potential evidence
- Establish cordons and secure the site
- Inform the police and Explosive Ordnance Disposal (EOD) service

No radio frequency transmission is to be allowed within a radius of 10 metres from an electro-explosive device (EED). Emergency services using mobile phones or vehicle borne radios with an effective radiated power (ERP) greater than five watts should not transmit within 50 metres of the explosive devices. All non-essential transmitters should be either switched off or removed to a distance greater than 50 metres.

Strategic actions

Fire and rescue services should:

- Develop procedures to ensure incidents involving explosive materials are appropriately resourced

- Ensure crews have access to information regarding the appropriate cordon size for incidents involving explosives

Tactical actions

Incident commanders should:

- Establish exclusion zones, inner and outer cordons based on level of risk from explosive materials
- Assess any immediate crew and public life risks from a safe location
- Confirm that explosive materials are involved in fire (applying water will not extinguish them)
- Consider potential for improvised explosive devices (IEDs) and secondary devices
- Set up a risk-assessed hazard area and evacuate everyone, including responders, from this area
- Withdraw to a safe distance if there is any doubt about the nature or location of the explosives involved
- Consider the risk of several simultaneous explosions and/or secondary explosions
- Consider areas that provide adequate protection from an explosive blast
- Notify mobilising control of the best approach route for other responding vehicles to follow to the rendezvous point (RVP) or marshalling area
- Strictly control the use of incident ground communications that may affect explosive materials
- Take account of any local features that could exacerbate the incident (e.g. the incident has occurred at industrial premises or there is an increase in the number of persons that could be affected, such as time of day, public attractions, etc.)
- Consider the potential for flame impingement on ISO containers with fireworks or other explosives to initiate their contents. Approach with caution
- Confirm that no additional explosives remain on site (after an initial explosion and prior to fighting secondary fires)
- Position firefighting jets to prevent fire spread using branch holders and ground monitors, where it is considered safe to do so

- Confirm with the occupier/duty holder that sufficient steps have been taken to identify and remove any live explosives prior to permitting entry into an explosives storage structure

Hazard - Gases under pressure: Involved in fire (e.g. potential Boiling Liquid Expanding Vapour Explosion (BLEVE))

Hazard Knowledge

Gas is one of three states of matter. Depending on pressure, most substances can be cooled to form a solid. As heat is added to the solid it turns into a liquid at its melting point, and then changes into a gas at its boiling point.

Gases and vapours have no size or volume. They expand to fill their container or, in the open, spread out until they are equally distributed throughout the space available to them. The physical behaviour of gases is described by the gas laws (see Foundation for Hazardous Materials). Properties include:

- Gases and vapours exert an increasing pressure on their containers as they are heated
- When a gas or vapour expands, such as when it escapes its container, its pressure falls

Gases under pressure, or compressed gases, pose different hazards to chemical liquids or solids and can often be more dangerous due to:

- The potential source of high energy, particularly in high pressure cylinders
- Cylinders containing compressed gases that may fail if over-pressurised or weakened by the application of heat
- The low boiling point of some liquid contents, resulting in the potential for 'vapour flashing'
- Ease of diffusion of escaping gas
- Leakage of flammable and/or toxic gases that can cause dangerous conditions especially if they are confined
- Low flashpoint of some highly flammable liquids
- Absence of visual and/or odour detection of some leaking materials
- Unsecured heavy and bulky containers that may topple over, cause injuries, become damaged themselves and cause contents to leak.
- Cylinders that may 'rocket' if the regulator and valve assembly shears off acting like a projectile or 'torpedo'

- Liquefied gases, for example butane and propane, that respond more rapidly to heat than the permanent gases such as nitrogen or oxygen
- Low boiling point materials that can cause frostbite on contact with human tissue
- Cylinders protected by pressure relief valves, fusible plugs or bursting discs that may not work correctly in a fire situation, or if damaged
- Other physical hazards that stem from the high pressure of a cylinder's contents (for example, accidental application of a compressed gas or jet into eyes or into an open wound, whereby the gas can enter the tissue or bloodstream, is particularly dangerous).

All cylinders represent a potential hazard if directly involved in a fire. Cylinders are pressure vessels, designed to withstand high internal pressure – but if that pressure increases with heat they may fail. This is particularly important if cylinders are directly impinged with flame as, in addition to the increase in internal pressure, the cylinder shell itself starts to lose its strength because of excessive heat.

The nature of the failure and its consequences depends on the combination of cylinder design and gas type. Flammable gases clearly represent a greater risk but all failures will have significant consequences.

All flammable gas cylinders result in the release of combustion energy if they burst in a fire. Potential effects include:

- Blast pressure wave
- Fireball of up to 25 metres
- Cylinder thrown up to 150 metres
- Flying fragments may travel up to 200 metres with high looping trajectories
- Flying glass and other structural material
- Structural damage to buildings in the vicinity

To prevent the interchange of fittings between gases, cylinder valve outlets are left hand threaded on flammable gas cylinders and right hand threaded on other gases.

Acetylene

When dealing with acetylene cylinders, the following hazards should also be considered:

- Self-sustaining decomposition, producing heat and pressure
- Acetylene cylinders are normally used in conjunction with oxygen cylinders, thereby increasing the potential hazard

Acetylene is distinguished from other flammable gases by its ability to continue to 'self-heat' after the fire has been extinguished. When involved in a fire, acetylene can begin to 'decompose', that is, break down into its constituent elements of hydrogen and carbon. The decomposition reaction is exothermic – it produces heat. Acetylene cylinders are designed to contain and inhibit decomposition, but decomposition in a heated cylinder could lead to the failure of the cylinder if left unchecked

Exothermic decomposition does not produce as much heat as acetylene burning in air. Initiating decomposition requires a significant input of energy from direct flame contact on a cylinder. Mechanical shock to a cold cylinder cannot initiate decomposition.

This means that unlike other compressed gases, acetylene may continue to be a hazard after the fire has been extinguished; it requires specific operational procedures.

For further information on acetylene see Foundation for Hazardous Materials

Control measure - Substance identification: Cylinders

Control measure knowledge

The symbols that may be seen in relation to gases under pressure are:

For detailed information on classification and labelling see Foundation for Hazardous Materials.

Strategic actions

Tactical actions

Incident commanders should:

- Use signs, labels, markings, container types and detection equipment to identify pressurised gas
- Identify any physical damage to cylinders that may lead to potential failure

Control measure - Thermal imaging or scanning

Control measure knowledge

Thermal imaging cameras (TIC) and other thermal scanning equipment are devices that form an image using emitted infrared radiation as opposed to normal visible radiation. They gather information when normal observation may be inhibited due to smoke or lack of lighting. They also provide the option to search for specific points of interest such as casualties or seats of fire, which may not be obviously visible through the normal spectrum. In some situations, firespread may not be visible to the naked eye, but may be detected using TICs.

The range of thermal image cameras available is wide and they have varying specifications. However, many cameras have a numerical and colour gradient temperature scale, which may assist crews attempting to locate a fire and any causalities or for thermal scanning of a building.

The heat energy radiated from the objects in the form of infrared waves is picked up by the TIC, which is then able to identify the energy differences from the objects being scanned and convert the readings into visual images. The image displayed is therefore based on temperature differential.

Images may be displayed in black and white or in a colour range. The TIC manufacturer's information should be referred to for descriptions of how higher or hotter temperatures will be displayed on their equipment.

TICs are available in different sizes and as an integral part of a number of different resources:

- Hand-held
- Helmet-mounted
- Emergency fire vehicle-mounted
- Self-contained
- Remote-controlled
- Aircraft-mounted (helicopter, drone and aeroplane)

Thermal imaging equipment can offer considerable benefits to incident commanders during the information gathering stage of an incident, including:

- Establishing possible seats of fire
- Establishing the extent of firespread
- Establishing internal fire conditions and assessing the need for defensive or offensive action
- Searching for casualties inside a structure

- Wider search for casualties (during road traffic collisions, aircraft crashes, railway incidents, incidents in the open)
- Improved search capability during low light or low visibility
- Locating the seat of fire in large fuel supplies (for example in landfill or waste management centres)
- Locating hot spots, bullseyes, small areas of combustion or heating
- Establishing heat spread to adjacent hazards and fuel supplies
- Establishing sources of overheating in electrical or mechanical scenarios (for example lighting chokes, vehicle brakes)
- Establishing compromises or weaknesses in fire resistance
- Locating hot spots in cylinders, vessels or pipework
- Recording images and videos, which can assist subsequent investigations or debriefs
- Assisting the incident commander via video link to command and control units

Operators of thermal imaging cameras should be aware that:

- The equipment may not be intrinsically safe, limiting its use in some hazardous environments
- Some surfaces can reflect or absorb infrared radiation, causing images to be misleading to an operator. For example, the devices often depict areas of the same temperature in the same shade or colour. This can obscure some hazards such as pits, surface liquid or unsafe ground which may be dangerous for operators in that area
- Equipment using a different spectrum should not be relied on as a total replacement for normal vision. Standard service procedures for moving in smoke and darkness must be maintained and great care should be taken to ensure that personnel remain safe because battery power may be lost rapidly with little warning
- Images displayed on the devices are computerised images created from the sensor equipment. Allowances should therefore be made for alterations to the actual size and distances involved for the objects on display
- Images may be misleading as sensors may not differentiate between the heat of a fire versus the reflected heat from the sun on surfaces such as glass or polished metal. Well-insulated structures (e.g. sandwich panelled premises) do not readily allow for the passage of infrared radiation. Using a TIC may therefore indicate weaknesses in a structure but may not give any indication as to the conditions within it.

A video developed by Greater Manchester Fire and Rescue Service shows the use of thermal scanning as part of its future firefighting techniques programme.

Strategic actions

Fire and rescue services should:

- Develop tactical guidance and support arrangements for the actions to take, and hazards associated, with the use of thermal image cameras
- Consider using thermal image cameras with video link facilities
- Ensure all personnel receive information, instruction and training in the use and limitations of thermal imaging equipment

Tactical actions

Incident commanders should:

- Consider using a range of thermal imaging resources such as aerial appliances, drones and helicopters
- Consider using thermal imaging equipment for scanning when carrying out a scene survey
- Adopt a systematic approach when using thermal imaging cameras to scan and search an area

Control measure - Cordon control: Cylinders and pressurised gas

Control measure knowledge

Most industrial gases occur naturally and are extracted from the atmosphere. Transporting gases at their ordinary temperatures and pressures is not a practical or economically viable option for the chemical industry due to the size of containers that would be required. Viable storage and transport options rely either on cooling, applying pressure or dissolving gases.

The favoured option is to use pressure to liquefy a gas, but for every gas there is a critical temperature. Gases below their critical temperatures are often called vapours and can be liquefied by applying pressure so they can be transported or stored as liquids at ambient temperature. Above this critical temperature, gases cannot be liquefied by applying pressure alone. When a pressurised liquid is warmed above the critical temperature it will exert a critical pressure on its container.

Gases with a critical temperature below ambient temperature can be stored or transported as compressed gases in small quantities at ambient temperatures. When bulk quantities are required they are usually cooled to below critical temperature and transported as refrigerated or cryogenic liquids (See Hazard – Cryogenic material release).

Emergency responders may come across gases under pressure at many different locations. It is vital that they recognise them quickly when firefighting. The Carriage of Dangerous Goods Regulations set out the safe conditions for transporting gases by road.

For further information see A foundation for hazardous materials.

Initial cordon/hazard areas

Responders inside the initial cordon should use shielding and don appropriate personal protective equipment (PPE). For example, responders likely to be affected by a fireball or blast should wear breathing apparatus (BA) and full structural firefighting kit

The following key questions will assist incident commanders in assessing the immediate risk:

- Are there cylinders at the incident?
- Are the cylinders involved in fire? (i.e. is there direct flame contact, fire damage or radiated heat damage from the fire)
- Are any cylinders leaking, venting, bulging or steaming?
- What gases are involved?
- How many cylinders are there and what size are they?
- What is the temperature of the cylinder(s)?
- Is any shielding provided by any buildings or structures?
- What type of adjacent structures are there and what is their extent?
- What is the local topography (e.g. protection provided by slopes and gradients of ground levels etc?)
- What would be the effect of:
  - A potential blast pressure wave
  - A fireball (can travel up to 25 metres)
  - Projectiles (a cylinder may be thrown up to 150 metres* and cylinder fragments and other projectiles such as the valve assembly may be thrown up to 200 metres*)
  - Flying glass and other structural material?
- What structural damage could be caused to buildings in the vicinity?
- Is there a need for an exclusion zone within the hazard area?
- Are other hazards inside or close to the initial cordon?
- What is the proximity and importance of adjacent occupancies and key infrastructure, such as major roads and railways

**Possible maximum travel distances for a cylinder in the open (i.e. not within a structure or building that would provide substantial shielding and therefore reduce the distances projectiles could travel)*

If cylinders, including acetylene, have not been heated then they do not represent a hazard and should be handed over to the site operator. In a developing fire situation, consider carefully moving them if there is a risk that the fire will spread and involve them.

Where members of the public are within the identified hazard area, the incident commander may wish to consider evacuation. Where this is not possible or appropriate, attempts should be made to warn of the risks and give advice to stay away from windows and doors and stay in rooms furthest away from the risk.

For further information regarding evacuation see National Operational Guidance: Operations.

Strategic actions

Fire and rescue services should:

- Provide procedures and support arrangements for the hazards that may be encountered and actions to take when gases under pressure are identified as being involved in fire

- Be proactive in collecting information on the location and type of hazardous gases within the area of their authority

- Make significant information regarding explosive gases under pressure available to mobilising controls and operational staff

- Have liaison and contact arrangements in place to deal with emergencies involving gas cylinders with the gas cylinder supply companies. (details available via the British Compressed Gas Association (BCGA))

- Ensure that all personnel are able to identify compressed gas cylinders from their size, shape, colour and identifying markings

- Make information regarding appropriate cordon sizes for incidents involving compressed gas cylinders available to all personnel

Tactical actions

Incident commanders should:

- Establish exclusion zones, inner and outer cordons based on level of risk from cylinders and pressurised gases

- Position response vehicles outside any potential fireball and blast zone when cylinders are involved in fire

- Gather information from all relevant sources to identify cylinders involved in fire, including
    - Contents of cylinders
    - Number and size
    - Condition (including temperature)
    - Possible impact

- Assess any immediate crew and public life risks and gather information to establish an initial cordon

- Consider evacuating the potential blast zone and give evacuation or shelter-in-place guidance to those within range of projectiles

- Ensure responders inside the initial cordon make use of substantial shielding and appropriate personal protective equipment (PPE)

- Ensure that firefighters use all available substantial shielding/cover within the range of cylinders

- Consider carefully moving any cylinders that have **not** been heated to a safe location when in a developing fire situation

- Consider a minimum initial responder observation distance of 90 metres for LPG tanks/containers over 100 litres or 40kg mass

Control measure - Cool pressurised gas containers

Control measure knowledge

Responders should understand that as cylinders heat up in a fire the pressure inside them increases, direct flame contact will also weaken the cylinder wall. If heat continues to be applied then the maximum safe working pressure of the cylinder may be exceeded and eventually the cylinder will burst or fail in a violent manner, resulting in the release of a considerable amount of energy. Subsequent events will depend on the gas type. The most effective way to safely control the hazards at cylinder incidents is to stop the heat source and cool the cylinder shell. Water sprays are the most effective way of achieving this.

Any cylinder found to be physically damaged or heated by fire should be treated with caution after the fire has been extinguished as it may have been weakened, increasing the risk of cylinder failure.

Strategic actions

Fire and rescue services should:

- Have procedures and support arrangements for the hazards that may be encountered and actions to take when dealing with incidents involving cylinders

- Have procedures and support arrangements regarding the hazards that may be encountered and actions to take for a potential BLEVE

- Ensure that all personnel can recognise the situations and indicators of a potential BLEVE situation

- Provide appropriate means to enable the safe and effective delivery of firefighting media, without the requirement for physical resources

Tactical actions

Incident commanders should:

- Gather relevant information from all available sources regarding the substance involved and its potential for BLEVE

- Recognise potential BLEVE situations and exercise extreme caution when approaching them

- Extinguish the fire and apply cooling sprays directly on to any affected cylinders

- Establish ground monitors and branch holding equipment to minimise the deployment of personnel in the risk area

- Leave damaged or heated cylinders in situ and refer to specialist agencies for safe disposal

- Treat all fire affected cylinders as if they contain acetylene if their contents cannot be identified

- Approach potential BLEVE situations, where safe to do so, from an upwind direction and from the side of the tank (avoiding the 45-degree zones at each tank end)

- Approach potential BLEVE situations, where safe to do so, from an upwind direction and from the side of the tank (avoiding the 45-degree zones at each tank end)

- Consider evacuating the potential blast zone and give evacuation or shelter-in-place guidance to those within range of projectiles

- If a BLEVE is imminent, consider adopting defensive tactics where there is no risk to life. If there is a risk to life, defensive tactics may be the only option.

- Consider 'flame bending' to prevent flame contact with pressurised tanks/containers

- Consider using heavy, coarse sprays to afford protection to crews

- Consider positioning firefighting jets to prevent fire spread using branch holders and ground monitors

Control measure - Substance identification: Acetylene

Control measure knowledge

Acetylene cylinders may be encountered at domestic garages and many other commercial locations. As imported acetylene cylinders may not conform to relevant UK regulatory standards, personnel attending an incident involving cylinders must carry out a risk assessment and consider the possibility of incorrect colour markings. The incident commander should use as many sources of information as possible to verify that the contents of the cylinder match the colour coding. These may include:

- Confirmation with the owner, occupier or operative
- Any documentation available
- Site-specific risk information (SSRI)
- Visual information, for example, the shape of a cylinder or a cylinder connected to an oxygen cylinder or strapped to a welding trolley etc. N.B. although a common configuration for cutting and welding, other fuel types may also be encountered for example oxy-propane.

The following signs can indicate possible heating:

- Visible bulge in the shell – personnel should treat the cylinder with extreme caution as this indicates a greatly increased likelihood of catastrophic failure
- Burnt cylinder labels
- Melted plastic rings around the cylinder valve
- Blistered or burnt cylinder paintwork
- Surface steam when water is applied
- Pressure relief devices (if fitted) that are operating (N.B. the operation of a pressure relief disc or fusible plug with gas burning off or leaking indicates an increased likelihood of

catastrophic failure and should not be regarded as a sign of safety)

Eye witnesses may be able to confirm:

- Whether a cylinder has suffered direct flame contact and, if so, the severity and duration
- Whether a flash back has occurred (and not a backfire, which produces a single cracking or 'popping' sound)

The following cooling procedure should be followed when the acetylene cylinder has been sufficiently heated for decomposition to be initiated (i.e. above 300C – this is normally only achieved by direct flame contact)

Strategic actions

Tactical actions

Incident commanders should:

- Use signs, labels, markings and container types to identify the presence of acetylene

- Use detection equipment to identify and monitor the level of acetylene involved

- Identify if acetylene cylinders are involved in fire from all information sources

Control measure - Cool pressurised gas containers: Acetylene

Control measure knowledge

Cooling phase – Cool with water spray for one hour, using ground monitors and/or lashed jets; any firefighters carrying out essential tasks within the hazard area must have appropriate personal protective equipment (PPE) and make full use of all available substantial cover/shielding

Stop water cooling after one hour and check to see if the cylinder shell has been cooled to ambient temperature; the 'wetting test' and/or thermal imaging equipment should be used.

The ‘wetting test’:

- Get a clear view of the cylinders from a shielded location
- Briefly spray water on to the cylinder surface
- Stop spraying and looking for signs of steam rising from the surface of the cylinder
- If steam is not seen, check to see whether the wetted cylinder surface dries out quickly
- If either check is ‘failed’ (if steam is seen or the cylinder surface dries out quickly) then water cooling must be re-applied for one hour before testing again
- If both tests are ‘passed’ (if there is no steam and the cylinder surface does not dry out quickly) then the ’monitoring phase’ should start.
- Do not move the cylinder and maintain a risk assessed hazard zone

Monitoring phase – The cylinder should still not be moved for a further one hour and an appropriate, risk assessed hazard zone should be maintained. This monitoring phase is required due to the possibility of internal decomposition. During the monitoring phase, check the temperature of the cylinder at least every 15 minutes – if any increase in temperature is observed continuous water cooling should be applied for a further hour before the temperature is rechecked

When the cylinder remains effectively cooled for the whole of the ‘monitoring phase’ (i.e. the shell temperature remains at ambient temperature for one hour without being water cooled) and is not leaking, there is no risk of cylinder failure and it should be handed over to the responsible person or agency on-site.

Treat leaking acetylene cylinders with greater caution as they have a higher risk of decomposition occurring.

Multiple cylinders (or substantially concealed single cylinders) present a higher level of risk because the cooling water may not come into contact with a substantial proportion of the cylinder shell, therefore limiting the effect of cooling – if significant areas of the cylinder(s) are thought to be ‘dry’ then the cooling phase should be extended.

See Control measures – Cordon control: Cylinders and pressurised gas and Cool pressurised gas containers.

Strategic actions

Tactical actions

Incident commanders should:

- Assess the risk of decomposition within acetylene cylinders

- Leave acetylene cylinders in situ if they have been significantly heated or damaged by fire

- Leave acetylene cylinders that have been significantly heated or damaged by fire in situ

- Apply the acetylene cylinder cooling procedure as soon as possible

- Consider the need to extend the cooling phase where multiple acetylene cylinders are involved

Control measure - Identify and manage Boiling Liquid Expanding Vapour Explosion (BLEVE) situations

Control measure knowledge

Liquefied gas containers subjected to heat may fail because of a Boiling Liquid Expanding Vapour Explosion (BLEVE). This is where the boiling liquid in the container rapidly vaporises and expands explosively, bursting the container. If the gas released is flammable and it contacts a source of ignition there could also be a fireball.

BLEVEs are most commonly associated with liquefied petroleum gas (LPG) vessels, but any liquefied pressurised gas container may cause a BLEVE when heated or involved in a fire.

When LPG pressurised containers are heated, without adequate cooling or venting, a BLEVE could occur. This is usually a result of a vessel containing a liquefied pressurised gas being heated by an external fire. The contents of the vessel are heated above their boiling point and the pressure in the vessel increases.

A BLEVE can occur at any time and depends on:

- Whether the vessel is full, half full or empty
- The condition of the vessel
- The functioning of the pressure relief valve
- The duration of flame impingement above the liquid level

The main hazards from a LPG BLEVE are:

- Fire
- Thermal radiation from the fire
- Blast

- Projectiles

The danger from these hazards decreases further away from the BLEVE centre. Projectiles are the hazards with the greatest reach. The size of the BLEVE depends on the size and weight of the container, along with the amount of liquid that remains inside the container at the moment of the BLEVE. Generally speaking, the bigger the container, the bigger the BLEVE. Most flame-induced liquefied gas BLEVEs occur when half to three-quarters of the liquid remains in the container.

For further details on a BLEVE, its causes and effects, see Foundation for Hazardous Materials. Guidance on BLEVE hazard areas, evacuation distances, tank properties, critical times and cooling water flow rates for various tank sizes can be found in the Emergency Response Guide (ERG). The information provided is for guidance and should only be used where there is no specialist advice or site-specific information. Where times are given for tank failure or tank emptying through the pressure relief valve, the times provided in the ERG are typical but they can vary from situation to situation. Regarding cordons, the distances provided in ERG are very large and may not be practical in a highly populated area. However, it should also be understood that the risks increase rapidly the closer a person is to a BLEVE. Personnel should keep in mind that the furthest-reaching projectiles tend to come off in the 45-degree zones on each side of the tank ends.

Liquefied gas tanks/containers need significant heating (usually this means by direct flame) to reach BLEVE conditions but there is no 'safe period' when a pressurised container is subjected to significant direct flame contact. Therefore, if adequate cooling is not available a BLEVE should be expected at any time.

Any significant flame contact on the surface area of liquefied gas tanks or containers above the level of the liquid (i.e. the 'dry walled' areas at the top of the cylinder) is most dangerous as the internal gas will not conduct heat away as quickly as internal liquid.

The pressure relief valve operating will temporarily reduce overpressure, leading to a torching flame from the valve. This reduction in tank contents may hasten the onset of a BLEVE as the dry wall area increases as the tank is emptied.

In the event of a BLEVE a fireball can engulf exposed crews; using heavy, coarse sprays should be considered to provide a measure of protection for crews and equipment against fire effects.

See Control measure – Cordon control: Cylinders and pressurised gas and Cool pressurised gas containers.

Strategic actions

Tactical actions

Incident commanders should:

- Recognise potential BLEVE situations and exercise caution when approaching them
- Approach potential BLEVE situations from upwind and the avoiding the 45-degree zones
- Consider immediate, massive water cooling, concentrating on ‘dry wall’ areas if there is a life risk

Hazard - Combustible dust

Hazard Knowledge

The Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR) include the definition of a dangerous substance as:

‘any dust, whether in the form of solid particles or fibrous materials or otherwise, which can form an explosive mixture with air or an explosive atmosphere’

A dust explosion can occur when suspended, solid, combustible particles are ignited, potentially releasing enormous amounts of energy. Increasing the surface area of a combustible solid enhances the ease of ignition, resulting in the dust burning more rapidly than the corresponding bulk solid.

Suspended dust particles behave in a similar way to gases and a flammable dust and air mixture can form within certain limits. The most violent explosions usually result from dust and air mixtures that are fuel-rich. This means that the oxygen available in the air cannot burn all the dust and partly burnt, glowing material often remains after the explosion. This can reignite if more air becomes available. The shape and size of the dust particles, and other factors, strongly affects the force of the explosion and the explosive limits. Only weak explosions are likely where the mean particle size of the dust exceeds 200 microns or the moisture content exceeds 16%.

Secondary dust explosions may occur when the blast wave from a primary explosion entrains dust layers already present, creating a large dust and air combustible mixture that is ignited by the first explosion.

Incident commanders should be aware that dust can collect in structures and on surfaces such as rafters, roofs, suspended ceilings, ducts, crevices, dust collectors and other equipment. Fire and rescue service activities such as using jets and tactical ventilation can create or disturb fine dusts or powders that may be present in a range of situations.

Refer to the Health and Safety Executive (HSE) publication Safe handling of combustible dusts: Precautions against explosions for further information.

Control measure - Substance identification

Control measure knowledge

The information provided through legislation on hazardous materials containers is a key factor in identifying hazards to responders and the public. Other sources of information should also be considered and their value not overlooked in determining a complete picture of the incident. There are also times when marking, placarding and signs are not present, or are incorrect, damaged or obscured. Examples include during a fire, or where hazardous materials are badly controlled or used illicitly.

In addition to marking and signage, other legislative requirements for the use of substances require sites to keep records of substances held, their hazards and control measures. These requirements mean that sites should have access to Safety Data Sheets (SDS) or Control of Substances Hazardous to Health (COSHH) sheets. This information can provide information about the hazards, health effects, behaviours and control measures. Similar information can be obtained from written and/or electronic data sources such as Chemdata or the Emergency Response Guidebook.

Other sources of information that can assist may be obtained from scientific advisers such as the National Chemical Emergency Centre (NCEC) or other company or product specialists and industry mutual aid schemes, for example Bromaid. This may provide information on a substance, process or premises, or may provide assistance in interpreting information gained.

Signs, labels and other marking system

It is important for responders to recognise signs, labels and other marking systems so that they can gain information regarding the hazards associated with substance safety. These will generally be found on modes of transport or fixed sites.

Transport

The legal framework for the international transport of hazardous materials is set out in the United Nations (UN) model regulations ('Recommendations on the transport of dangerous goods', commonly known as the 'orange book'). These rules are revised every two years and form the basis of the internationally and nationally recognised legislation.

The recommendations are adopted in Europe and consequently in the UK, as ADR (Accord européen relatif au transport international des marchandises Dangereuses par Route) for road transport and RID (Reglement International concernant le transport de marchandises Dangereuses par chemin de fer) for rail transport. Additionally, the UK maintains some deviations from ADR, for

example, Hazchem placards. As both marking systems are permitted in the UK it is important for responders to be familiar with both.

The International Maritime Dangerous Goods (IMDG) code contains internationally agreed guidance on the safe transport of dangerous goods by sea, and most commonly relates to the carriage of dangerous goods in freight containers and tank containers. It is primarily used by shipping operators, but it is also relevant to those transporting dangerous goods on journeys involving a sea crossing.

Fixed sites

For static sites, warning signage is governed by the dangerous substances Notification and Marking of Sites) (NAMOS) Regulations. The aim of these regulations is to ensure that firefighters arriving at an incident are warned of the presence of hazardous materials. It is a legal requirement to notify the fire and rescue service about any site with a total quantity of 25 tonnes or more (150 tonnes for ammonium nitrate fertilisers). There is a requirement to place warning signs at access points.

See the Health and Safety Executive website for further details. Dangerous Substances (Notification and Marking of Sites) Regulations (NAMOS)

Labelling of hazardous materials for general use is governed by the Classification, Labelling and Packaging regulations (CLP). These regulations adopt the UN Globally Harmonised System (GHS) on the classification and labelling of chemicals across all European Union countries, including the UK.

Equivalent legislation in Northern Ireland is The Dangerous Substances (Notification and Marking of Sites) Regulations (Northern Ireland).

Under the Control of Asbestos Regulations (CAR), there are specific labelling requirements for asbestos in non-domestic buildings. Responders should recognise these labels.

Containment systems

Hazardous materials containers range in size from small vials and jars used in laboratories through larger packages and transport containers holding many tonnes to site storage tanks and vessels that can hold many thousands of tonnes.

It is important that during incidents, responders can:

- Recognise typical container shapes or types that would indicate the presence of hazardous materials whether in storage, in use or in transit

- Identify the basic design and construction features, including closures for storage, packaging and transportation systems

For further information on substance identification see National Operational Guidance: Health Hazards and National Operational Guidance: Physical Hazards

Strategic actions

Fire and rescue services should:

- Consider developing systems to gather pre-planning information on local risks and incident specific information

- Ensure responding personnel have the necessary instruction and training in the identification of hazardous materials containers

- Provide access to appropriate detection, identification and monitoring (DIM) equipment

- Ensure that Information on the recognition of hazardous materials is immediately available to personnel

- Ensure that responders can recognise signs, labels and other markings on hazardous materials packages

Tactical actions

Incident commanders should:

- Use signs, labels, markings, container types and detection equipment to identify substance
- Identify if containers indicating the presence of general or specific hazardous materials are involved
- Use available fire service or on-site detection equipment to identify the substance involved

Control measure - Cordon control: Combustible dust

Control measure knowledge

Combustible dusts may be present in a range of premises including industrial processing plants, food processing plants and storage vessels such as silos. In bulk solid form, these may present minimal risk to fire service operations. However, when disturbed, mixtures could form within a flammable range. It is important for incident commanders to identify potential risk as part of the information gathering process.

Any materials that can burn and that exist in a fine-powdered form may, under certain circumstances, present a risk of explosion. Example materials include:

- Sugar
- Flour or custard powder
- Instant coffee or dried milk
- Grain
- Coal
- Wood
- Certain metals
- Synthetic organic chemicals

There is no established recommended cordon distance for dust explosions. Advice should be sought from a hazardous materials advisers (HMA) or on-site specialist.

See National Operational Guidance: Hazardous materials.

Strategic actions

Tactical actions

Incident commanders should:

- Recognise the presence of combustible dust from risk information, responsible person and scene survey

- Consult on-site specialists or other advisors regarding risk of dust explosion

Control measure - Eliminate ignition sources

Control measure knowledge

From the smallest to the largest incident, the incident commander and firefighters need to be aware of, and take notice of, possible ignition sources that could create additional hazards.

Although eliminating ignition sources may not be an immediate priority in a fire situation because the fire is already burning, firefighters should be aware of the potential for additional ignition sources and their potential to start events such as fire gas ignitions in areas that may be remote from the initial seat of fire.

At incidents where there may be a release of gases or other flammable atmospheres because features such as storage vessels, tanks or pipework may fail or be damaged, incident commanders should consider this a concern and identify it in the incident dynamic or analytical risk assessments (DRA or ARA) and incident plan.

The amount of energy required to ignite a mixture of air and flammable gas or vapour (including smoke) is called the minimum ignition energy (MIE) and depends on the characteristics of the gas or vapour, concentration in air, type of oxidant, temperature and pressure.

An ignition source can be defined as a form of energy that, when added to a flammable mixture, is sufficient for the combustion process to start; an ignition source with energy greater than the minimum ignition energy (MIE) for a particular mixture is sufficient for a fire or explosion to occur. Generally, the energy required to ignite a flammable gas or vapour mixture is relatively low, though some low-energy ignition sources may not be incendiary enough for all flammable mixtures.

Ignition sources include:

- Open flames
- General firefighting operations, including cutting
- Frictional sparks and localised heating
- Impact sparks
- Sparks from electrical equipment
- Electrostatic discharge
- Vehicles
- Use of cigarettes or matches
- Hot surfaces
- Electrical equipment and lighting
- Hot processes
- Exothermic runaway reactions (water applied to reactive metals such as sodium and potassium)
- Heating equipment

It is often challenging for crews to identify and eliminate every ignition source at an operational incident. The first option for ensuring safety is therefore usually to prevent flammable gas or vapour mixtures being released or formed. All foreseeable ignition sources should also be identified and effective control measures taken.

In industrial premises, depending on the ignition sensitivity of the materials handled, the types of equipment involved and the process parameters (such as temperature and pressure), incident commanders should consult with on-site process safety professionals or the responsible person to address safety issues and provide recommendations to aid the safe resolution of the incident.

Strategic actions

Fire and rescue services should:

- Develop tactical guidance and support arrangements for the hazards and actions to be taken in eliminating ignition sources

Tactical actions

Incident commanders should:

- Extinguish the fire and eliminate all ignition sources
- Prevent escalation, contain and extinguish the fire considering all ignition sources
- Deal with any immediate fire risk and provide a means of extinguishing fires during the incident
- Identify all possible ignition sources and eliminate them as far as is possible
- Control ignition sources that cannot be eliminated as far as reasonably practicable
- Develop and communicate a firefighting plan and ventilation strategy to all personnel
- Use the appropriate extinguishing method, media, techniques and equipment
- Ensure that crews are briefed on all firefighting activities and provide regular updates on progress
- Consider removing fuel from any source of ignition

Control measure - Reduce the potential for a dust explosion

Control measure knowledge

For a dust explosion to occur, the dust and air must be within a certain range of concentrations and exposed to an ignition source. Mixtures above or below this range cannot explode. The risk of an explosion can be reduced by taking measures to eliminate all ignition sources in high-hazard areas. Wherever possible, unaffected bulk solids should not be disturbed by fire service activities. At incidents where a combustible dust cloud is unavoidable, measures such as suppression with inert gases or water sprays should be considered as part of the incident plan.

Incident commanders should be aware that increasing ventilation within a compartment that contains dust as a combustible material may affect the atmosphere. Opening access or vision panels increases the possibility of dust entering the atmosphere in explosive quantities and should not be undertaken until a risk assessment for this activity and a safe system of work aimed at preventing an explosive atmosphere being formed and mitigated is implemented, for example, by using covering sprays on openings.

Strategic actions

Fire and rescue services should:

- Ensure that all personnel are aware of the hazards that may be encountered and actions to take at incidents involving the potential for dust explosion

Tactical actions

Incident commanders should:

- Consider the risk of dust explosion as part of the incident plan

- Eliminate ignition sources in areas at risk of dust explosions

- Ensure that using firefighting jets/sprays, positive pressure ventilation (PPV) fans or other activities does not create combustible dust clouds

- Ensure that firefighting operations or positive pressure ventilation (PPV) fans do not create dust clouds

- Consider using fine water sprays or on-site systems to supress dust concentration

Control measure - Use intrinsically safe equipment

Control measure knowledge

Any equipment that is not intrinsically safe can provide an ignition source for a gas within its flammable or explosive limits. This may cause combustion or explosion. The use of intrinsically safe equipment will preclude this.

In most confined spaces, it is impossible to classify the atmosphere present. For fire and rescue service operations, intrinsically safe equipment must meet the standards for use in Zone 1 under the ATEX directives.

For further information on fireground radios see: Fireground radios guidance: ATEX-approved radios

Strategic actions

Fire and rescue services should:

- Ensure that intrinsically safe equipment is available to crews trained to work in confined spaces

Tactical actions

Incident commanders should:

- Use only intrinsically safe equipment in confined spaces where there is a risk of a flammable or explosive atmosphere

- Use only ATEX approved equipment in flammable or explosive atmospheres

- Use only ATEX approved communications equipment when crews enter any potentially explosive atmosphere

- Use only ATEX approved equipment when crews enter any potentially flammable atmosphere

Hazard -
Flammable vapours: Unignited

Hazard Knowledge

In addition to generic hazards and controls applicable to all hazardous materials, flammable vapours pose additional specific hazards when uncontained, which should be considered when encountered at incidents.

As well as posing a threat of fire, most flammable vapours also present a health hazard. This section deals only with properties that directly influence their fire hazard. For the purposes of this guidance, no distinction is made as to the way flammable vapours are produced, as the control measures for the vapour will be the same. Generally, flammable vapours will be produced following a spillage of a volatile flammable liquid or where flammable vapours under pressure have escaped their container. It should be noted that a release of a pressurised flammable liquid can produce a pool of liquid at a very low temperature (below the material's boiling point); in addition to producing a significant vapour cloud, cryogenic hazards should also be considered (See Hazard – Cryogenic material release). Control measures for minimising vapour production are covered in Hazard – Flammable liquids: Unignited).

Generally, gases and vapours, including flammable vapours, have no size or volume; they expand to fill their container or spread out in the open until they are equally distributed throughout the space available to them. Therefore, gases and vapours are the most difficult state of matter to control. When they are also flammable, they can pose significant challenges and risk to responders and the public.

Flammable gases ignite or burn producing heat and, in most cases, light (certain flammable gases have no visible flame, e.g. hydrogen and methanol). In certain conditions, they can also cause explosions. The terms used to describe flammable liquids are included in the Foundation for Hazardous Materials. These terms should be understood to assess the risk posed by this hazard.

Control measure -
Substance identification:
Flammable vapours

Control measure knowledge

This control measure should be read in conjunction with Hazardous materials – Substance identification

The symbols that may be seen in relation to flammable vapours are:

For detailed information on classification and labelling see Foundation for Hazardous Materials.

Strategic actions

Tactical actions

Incident commanders should:

- Use signs, labels, markings and container types to identify the presence of flammable vapours
- Use detection equipment to identify and monitor levels of the flammable vapours involved
- Consider the use of thermal imaging cameras to recognise leaking gas cylinders
- Identify the flammable vapour and seek specialist advice on the interpretation of its physical properties
- Gather information about risks within the vicinity of the vapour cloud

Control measure - Cordon control: Unignited flammable vapours

Control measure knowledge

An unignited vapour cloud at concentrations above its 'lower explosive limit' (LEL) creates a dangerous atmosphere and the area should be evacuated. As flammable vapours are generally invisible, their exact presence can only be determined by monitoring equipment.

The presence of flammable vapour clouds can be predicted where there is a release of flammable gases or liquids. As flammable gases are invariably stored under pressure, if gas is escaping from its container, the temperature will drop. Using a thermal imaging camera can therefore assist in identifying leaking or open cylinders.

The extent of this hazard area will depend on:

- The volume of release
- Weather conditions, such as wind speed, direction, etc.
- Local topography, proximity of storage tanks, buildings, pipelines, etc.
- The explosive limits of the gas (N.B. For practical purposes explosive and flammable limits are the same)
- Vapour density

Flammable vapour clouds can extend significant distances from the point of release. An effective cordon will need to be extended beyond the flammable vapour cloud to include the area to which radiant heat would spread if ignition occurred. Therefore, for large leaks of flammable liquids that produce significant vapour clouds, the initial cordons may be reduced or extended according to explosimeter monitoring, using a safe percentage of the lower explosive limit (LEL).

See National Operational Guidance: Hazardous materials – Contaminated members of the public

Strategic actions

Fire and rescue services should:

- Provide procedures and support arrangements for the hazards that may be encountered and actions to take in recognising unignited flammable vapours

- Provide suitable means to identify the presence of flammable vapours

- Have arrangements to make flammable vapour detection equipment available at incidents

Tactical actions

Incident commanders should:

- Establish exclusion zones, inner and outer cordons based on the level of risk from flammable vapours

- Ensure all non-essential personnel and members of the public are removed from areas where flammable vapours could ignite

- Use atmospheric monitoring equipment to identify concentrations and extent of hazard area

- Use gas monitoring to identify the extent of the hazard area

- Consider the potential for irrespirable vapours to be inhaled

- Consider the effect of buoyancy, weather and environment on the spread of the vapour cloud

- Consider the potential for the vapour cloud to move (e.g. due to wind, low-lying areas, buoyancy)

- Consider the risk of a vapour cloud explosion (See explosives and cylinder scenario)

Control measure - Eliminate ignition sources

Control measure knowledge

From the smallest to the largest incident, the incident commander and firefighters need to be aware of, and take notice of, possible ignition sources that could create additional hazards.

Although eliminating ignition sources may not be an immediate priority in a fire situation because the fire is already burning, firefighters should be aware of the potential for additional ignition sources and their potential to start events such as fire gas ignitions in areas that may be remote from the initial seat of fire.

At incidents where there may be a release of gases or other flammable atmospheres because features such as storage vessels, tanks or pipework may fail or be damaged, incident commanders should consider this a concern and identify it in the incident dynamic or analytical risk assessments (DRA or ARA) and incident plan.

The amount of energy required to ignite a mixture of air and flammable gas or vapour (including smoke) is called the minimum ignition energy (MIE) and depends on the characteristics of the gas or vapour, concentration in air, type of oxidant, temperature and pressure.

An ignition source can be defined as a form of energy that, when added to a flammable mixture, is sufficient for the combustion process to start; an ignition source with energy greater than the minimum ignition energy (MIE) for a particular mixture is sufficient for a fire or explosion to occur. Generally, the energy required to ignite a flammable gas or vapour mixture is relatively low, though some low-energy ignition sources may not be incendiary enough for all flammable mixtures.

Ignition sources include:

- Open flames
- General firefighting operations, including cutting
- Frictional sparks and localised heating
- Impact sparks
- Sparks from electrical equipment
- Electrostatic discharge
- Vehicles
- Use of cigarettes or matches
- Hot surfaces
- Electrical equipment and lighting
- Hot processes
- Exothermic runaway reactions (water applied to reactive metals such as sodium and potassium)
- Heating equipment

It is often challenging for crews to identify and eliminate every ignition source at an operational incident. The first option for ensuring safety is therefore usually to prevent flammable gas or vapour mixtures being released or formed. All foreseeable ignition sources should also be identified and effective control measures taken.

In industrial premises, depending on the ignition sensitivity of the materials handled, the types of equipment involved and the process parameters (such as temperature and pressure), incident commanders should consult with on-site process safety professionals or the responsible person to address safety issues and provide recommendations to aid the safe resolution of the incident.

Strategic actions

Fire and rescue services should:

- Develop tactical guidance and support arrangements for the hazards and actions to be taken in eliminating ignition sources

Tactical actions

Incident commanders should:

- Extinguish the fire and eliminate all ignition sources
- Prevent escalation, contain and extinguish the fire considering all ignition sources
- Deal with any immediate fire risk and provide a means of extinguishing fires during the incident
- Identify all possible ignition sources and eliminate them as far as is possible
- Control ignition sources that cannot be eliminated as far as reasonably practicable
- Develop and communicate a firefighting plan and ventilation strategy to all personnel
- Use the appropriate extinguishing method, media, techniques and equipment
- Ensure that crews are briefed on all firefighting activities and provide regular updates on progress
- Consider removing fuel from any source of ignition

Control measure - Manage the release of flammable vapours

Control measure knowledge

Of all the states of matter, a gas or vapour is by far the most challenging to control when released. The following control measures focus on actions and tactics that can be considered once a flammable material is in the vapour phase. Control measures for preventing vaporisation from an uncontained liquid will be considered under Hazard – Flammable liquids: Unignited.

Where flammable vapours are released under pressure, such as when escaping from a ruptured pressurised container, their temperature will drop rapidly. Because of this, even vapours that are lighter than air will sink to low-lying areas initially and therefore the highest concentrations of vapour will be found low to the ground and close to the release. As the temperature falls, the rate of release will reduce and in the case of some flammable vapours, ice will form at the point of release. This property may be exploited in some instances by using a spray or damp piece of material to cover the rupture (usually only on small bore, low pressure pipelines and vessels). As the water freezes a seal will be formed. (Straps may be used to hold material in place.)

Once a vapour cloud is formed there are limited tactical options to contain it. It is therefore a priority to stop any escape at source if possible, for example, by closing a valve.

Liquefied pressurised releases from pipelines may take considerable time to depressurise following an emergency shutdown.

When a vapour cloud is formed, particularly where the release is indoors, one option would be to prevent ventilation. This is not generally recommended as it will increase the concentration of flammable vapours and therefore increase likelihood of ignition. However, if the flammable vapours pose additional health effects such as being toxic (such as ammonia and hydrogen sulphide), ventilation may reduce the flammable hazard only to produce a much wider toxic hazard. In such instances, factors such as the total quantities of vapours, location of the incident, wind speed and direction will all contribute to determine the tactic that will take precedence.

Flammable vapours will only ignite when they encounter a source of ignition at concentrations within their flammable range. The precise range is specific to each substance; consequently, flammable vapours with a wide flammable range are more likely to create large ignitable vapour clouds than those with a narrow flammable range.

At operational incidents, a vapour cloud at concentrations above its upper explosive limit (UEL) should still be regarded as a dangerous environment. A key control measure for flammable vapours is to reduce the concentration in air below the lower explosive limit (LEL) and prevent ignition. Vapours in an uncontrolled state will naturally spread and in doing so, dilute.

Ventilation – Good ventilation can assist in dispersing flammable vapours to minimize the size of any ignitable plumes. This approach will need to be weighed against the generation of a larger plume and the potential to find ignition sources. This depends on the LEL of the vapour.

Water sprays – Adding water in the form of fine spray or mist will create convection currents that will assist in dispersing flammable vapours. Water mist will also act as a good absorber of heat if ignition occurs.
Most hydrocarbon fuel vapours have little or no solubility in water. Where vapours are water soluble, such as ammonia and hydrogen sulphide, water sprays may be used to dissolve the vapour cloud out of the air. This technique is called atmospheric scrubbing.

Where water sprays are beneficial, the hazards may be increased if water run-off enters any liquid pool. If the liquid spillage is significantly colder than the run-off and has a very low boiling point, this will cause a more rapid boil-off of the substance and increase the size of the vapour cloud. Even where the liquid is at an ambient temperature, with a relatively high boiling point, adding water if the liquid is immiscible will spread the spillage over a wider area, increasing the risk and increasing the surface area for vapours to be produced. Additionally, any water run-off may present a risk of pollution to the environment.

Weather – Strong winds can disperse flammable vapours and gases, rain can dissolve soluble gases (atmospheric scrubbing) and promote the mixing/dilution of any vapour plume.

Inerting gas – By replacing the air with a gas that does not support combustion, the risk of fire can be greatly reduced or eliminated. This will not only reduce the concentration of flammable vapours but also reduce the concentration of oxygen present.

Portable monitoring equipment known as LEL meters or combustible gas detectors can be used to detect the presence of flammable vapours. These meters are not substance-specific and can detect any vapour that is flammable.

Using LEL meters will enable cordons to be refined and allow monitoring for changes in the incident profile.

Once a flammable vapour cloud has formed, the options available to reduce this hazard are limited, until vapours have dissipated to a safe concentration. As a priority, responders should isolate any sources of ignition (electrical sparks, static electricity, friction sparks or naked flame) from the hazard area and manage cordons to ensure none are introduced to the area. For further information on ignition sources see National Operational Guidance: Fires and Firefighting.

Entering such a dangerous atmosphere is therefore inherently dangerous and should only be considered in circumstances where the benefits outweigh the risk, for example, to perform rescues and prevent catastrophic escalation.

Structural firefighting kit and breathing apparatus (BA) will provide the most appropriate level of personal protective equipment (PPE) for the flammable risk. This will need to be weighed against any possible health effects (such as corrosivity) from the vapour. Chemical protective clothing (CPC) is generally not suitable where heat, fire or flammable risks are present. Where the balance of risks means that personnel need to enter a vapour cloud in chemical protective clothing (CPC), additional controls should be considered such as ventilation and water sprays. Personal protective equipment (PPE) for emergency teams may need to be sufficient to protect wearers in the event of ignition of a vapour cloud that leads to a flash fire or uncontrolled vapour cloud explosion. For further information on emergency arrangements see A foundation for Breathing Apparatus. Where the risks present outweigh the benefits, defensive tactics should be implemented.

For further information see National Operational Guidance: Incident command – Ineffective safety management.

Strategic actions

Fire and rescue services should:

- Provide procedures and support arrangements regarding the hazards that may be encountered and actions to take when managing the release of unignited flammable vapours

Tactical actions

Incident commanders should:

- Isolate the flammable vapour release at source, if possible

- Consider options for stopping/reducing the escape of flammable vapours (for example, remote isolation/emergency shutdown (ESD))

- Evaluate the risks and benefits of ventilating flammable vapours

- Assess weather conditions and their impact on any flammable vapour cloud

- Use water sprays to dilute and disperse flammable vapours

- Dilute and disperse flammable vapours (e.g. using water sprays)

- Consider the impact of water run-off entering any flammable liquid pools

- Consider ventilating flammable vapour clouds – open doors and windows, consider using positive pressure ventilation (PPV)

- If crews are entering the vapour cloud ensure covering jets are positioned to minimise the risk to personnel and potential impact of vapour cloud ignition

- Identify all possible methods of isolating the release (e.g. remote isolation or emergency shutdown)

- Assess the risk from unignited flammable vapours before extinguishing and consider controlled burn

Control measure - Use intrinsically safe equipment

Control measure knowledge

Any equipment that is not intrinsically safe can provide an ignition source for a gas within its flammable or explosive limits. This may cause combustion or explosion. The use of intrinsically safe equipment will preclude this.

In most confined spaces, it is impossible to classify the atmosphere present. For fire and rescue service operations, intrinsically safe equipment must meet the standards for use in Zone 1 under the ATEX directives.

For further information on fireground radios see: Fireground radios guidance: ATEX-approved radios

Strategic actions

Fire and rescue services should:

- Ensure that intrinsically safe equipment is available to crews trained to work in confined spaces

Tactical actions

Incident commanders should:

- Use only intrinsically safe equipment in confined spaces where there is a risk of a flammable or explosive atmosphere

- Use only ATEX approved equipment in flammable or explosive atmospheres

- Use only ATEX approved communications equipment when crews enter any potentially explosive atmosphere

- Use only ATEX approved equipment when crews enter any potentially flammable atmosphere

Hazard - Flammable vapours: Ignited

Hazard Knowledge

Accidental releases of flammable liquids or gases often result in the formation of a cloud of vapour that is denser than the ambient conditions. As the cloud disperses from the source it will dilute, mixing with air. In areas, potentially some distance from the source, the cloud will be at concentrations within its flammable range. If it then encounters an ignition source a vapour cloud fire (VCF) may result; in this context, VCF is taken to mean either a flash fire or a fireball. VCFs are important because:

- They pose an intrinsic hazard, in the form of thermal radiation, so that overpressures are not important (assuming no or limited confinement/congestion)
- There is a possibility of escalation; it is highly likely that secondary fires may be started because of the flash fire/fireball and there is a high probability that following a VCF there will be a steady fire, typically either a pool fire or jet fire (or a combination of the two).

Deflagration to detonation transition – Flash fires will travel through a vapour cloud at subsonic speeds. However, where obstacles produce confinement or partial confinement and increase the speed sufficiently, an area of the vapour cloud can reach supersonic speeds, producing significant overpressure. This pressure can squash the vapour in front and cause its heat to rise. If that heat exceeds the auto-ignition temperature of vapour, the flame front can transition to detonation and explosion.

This phenomenon has been observed in a number of industrial accidents such as those at Flixborough and Buncefield.

Control measure - Substance identification: Flammable vapours

Control measure knowledge

This control measure should be read in conjunction with Hazardous materials – Substance identification

The symbols that may be seen in relation to flammable vapours are:

For detailed information on classification and labelling see Foundation for Hazardous Materials.

Strategic actions

Tactical actions

Incident commanders should:

- Use signs, labels, markings and container types to identify the presence of flammable vapours
- Use detection equipment to identify and monitor levels of the flammable vapours involved
- Consider the use of thermal imaging cameras to recognise leaking gas cylinders
- Identify the flammable vapour and seek specialist advice on the interpretation of its physical properties
- Gather information about risks within the vicinity of the vapour cloud

Control measure - Cordon control: Ignited flammable vapours

Control measure knowledge

This control measure should be read in conjunction with Cordon controls – Hazardous materials.

Once a flammable vapour cloud has ignited, responders have limited options (if any) to disrupt or intervene. Where such hazards are encountered it is essential that suitable hazard areas are implemented in all directions and all responders and members of the public are evacuated.

Strategic actions

Fire and rescue services should:

- Provide procedures and support arrangements regarding the hazards that may be encountered and actions to take when implementing hazard areas for flammable vapours

Tactical actions

Incident commanders should:

- Establish exclusion zones, inner and outer cordons based on level of risk from ignited flammable vapours

- Ensure all personnel and members of the public are evacuated from the identified hazard area

Control measure - Prevent firespread

Control measure knowledge

The unpredictable energy produced by a fireball or vapour cloud explosion can cause fire to spread rapidly to adjacent areas and develop into a large incident. Early recognition of such possible consequences will enable incident commanders to develop resources to counteract this risk of fire spread. Typically, this will involve cooling adjacent structures and/or containers.

Strategic actions

Fire and rescue services should:

- Provide procedures and support arrangements regarding the hazards that may be encountered and actions to take when protecting surrounding structures from the effects of ignited flammable vapours

Tactical actions

Incident commanders should:

- Conduct a scene survey of the surrounding area and gather relevant information to ascertain prioritised structures, areas and hazards that need protecting from the effects of ignited flammable vapours

- Cool surrounding structures, areas and hazards to minimise the effects of ignited flammable vapours

- Isolate any further fuel source, where safe to do so

- Cool surrounding structures, areas and hazards to mitigate the risk of fire spread

Control measure - Select appropriate firefighting media: Flammable vapours

Control measure knowledge

This control measure should be read in conjunction with National Operational Guidance: Fires and firefighting: Select appropriate firefighting media

Unlike most fires, extinguishing an ignited leak of flammable vapours will not necessarily reduce the hazard until the release has been isolated. Where the release is at a steady rate, from a cylinder for example, an ignited flame may pose a lower risk than extinguishing it.

Strategic actions

Tactical actions

Incident commanders should:

- Consider the risks of unignited flammable liquids before extinguishing

- Implement controls to stop or manage the release

- Balance the risks between extinguishing and allowing a controlled burn

Hazard -
Flammable liquids: Unignited

Hazard Knowledge

Uncontrolled flammable liquids pose a significant hazard to responders due to their low flash point (see flash point definition). In addition to posing a threat of fire, most of these materials also present a health hazard for the worker or emergency responder. This section deals only with those that directly influence their fire hazards.

The symbols that may be seen in relation to flammable liquids are:

For detailed information on classification and labelling see The foundation for hazardous materials.

Factors that increase fire risks from flammable liquids

Quantity and surface area – As the quantity of a flammable liquid increases, so does the risk; a large quantity can generate a spill with a greater surface area than a small quantity. Increased surface area supports the production of vapour and the potential size of the ignitable plume or fire. Additionally, any fire involving a large quantity of liquid can be deeper and thus last longer than one from a small quantity.

Heating – Hot materials are more reactive and volatile (produce more vapours) so a heated flammable liquid will generally be more ignitable than a cold one and more likely to exhibit rapid fire growth.

Containment – If materials are released in a poorly ventilated or confined situation then the hazard will be greater than in an open area where dispersion is possible. Toxic, flammable/explosion hazards are increased by confinement.

Pressure – Apart from the obvious danger of bursting its container, the fact that a material is under pressure means that it will be likely to give off far more vapour if it can escape. Increased vapour can exaggerate toxicity and flammability hazards. Additionally, pressure often increases the reactions of gaseous materials.

Incompatible materials – Some materials, especially oxidizing agents, are likely to react chemically with flammable liquids. The heat of the reaction and/or presence of oxidising agents will make the mixture liable to ignition and rapid fire growth.

Absorbers, adsorbers and wicks – These can be used to immobilise or contain a spill to restrict its surface area and prevent movement towards sensitive areas or other hazardous features such as ignition sources or incompatible materials. However, many materials can act as a wick, and increasing the surface area can increase vapour production and fire risk.

Mists – Flammable liquids that are aspirated to produce a mist can be ignited at temperatures significantly below their flashpoint. Fine sprays of heavy fuels or cleaning oils with a flashpoint above 300C can still ignite and produce severe explosions at room temperatures. See Control measures for Hazard – Combustible dust.

Location – Proximity to human, animals, property, sensitive or protected habitats.

Topography and meteorology – Slopes will spread a spill, depressions in the surface and trenches, etc. can collect/concentrate vapours that are heavier than air. Strong sunshine can heat materials and the surfaces they may contact. Rain can cause liquefied gases to boil and react with water-reactive materials.

Control measure - Substance identification

Control measure knowledge

The information provided through legislation on hazardous materials containers is a key factor in identifying hazards to responders and the public. Other sources of information should also be considered and their value not overlooked in determining a complete picture of the incident. There are also times when marking, placarding and signs are not present, or are incorrect, damaged or obscured. Examples include during a fire, or where hazardous materials are badly controlled or used illicitly.

In addition to marking and signage, other legislative requirements for the use of substances require sites to keep records of substances held, their hazards and control measures. These requirements mean that sites should have access to Safety Data Sheets (SDS) or Control of Substances Hazardous to Health (COSHH) sheets. This information can provide information about the hazards, health effects, behaviours and control measures. Similar information can be obtained from written and/or electronic data sources such as Chemdata or the Emergency Response Guidebook.

Other sources of information that can assist may be obtained from scientific advisers such as the National Chemical Emergency Centre (NCEC) or other company or product specialists and industry mutual aid schemes, for example Bromaid. This may provide information on a substance, process or premises, or may provide assistance in interpreting information gained.

Signs, labels and other marking system

It is important for responders to recognise signs, labels and other marking systems so that they can gain information regarding the hazards associated with substance safety. These will generally be found on modes of transport or fixed sites.

Transport

The legal framework for the international transport of hazardous materials is set out in the United Nations (UN) model regulations (‘Recommendations on the transport of dangerous goods‘, commonly known as the ‘orange book’). These rules are revised every two years and form the basis of the internationally and nationally recognised legislation.

The recommendations are adopted in Europe and consequently in the UK, as ADR (Accord européen relatif au transport international des marchandises Dangereuses par Route) for road transport and RID (Reglement International concernant le transport de marchandises Dangereuses par chemin de fer) for rail transport. Additionally, the UK maintains some deviations from ADR, for example, Hazchem placards. As both marking systems are permitted in the UK it is important for responders to be familiar with both.

The International Maritime Dangerous Goods (IMDG) code contains internationally agreed guidance on the safe transport of dangerous goods by sea, and most commonly relates to the carriage of dangerous goods in freight containers and tank containers. It is primarily used by shipping operators, but it is also relevant to those transporting dangerous goods on journeys involving a sea crossing.

Fixed sites

For static sites, warning signage is governed by the dangerous substances Notification and Marking of Sites) (NAMOS) Regulations. The aim of these regulations is to ensure that firefighters arriving at an incident are warned of the presence of hazardous materials. It is a legal requirement to notify the fire and rescue service about any site with a total quantity of 25 tonnes or more (150 tonnes for ammonium nitrate fertilisers). There is a requirement to place warning signs at access points.

See the Health and Safety Executive website for further details. Dangerous Substances (Notification and Marking of Sites) Regulations (NAMOS)

Labelling of hazardous materials for general use is governed by the Classification, Labelling and Packaging regulations (CLP). These regulations adopt the UN Globally Harmonised System (GHS) on the classification and labelling of chemicals across all European Union countries, including the UK.

Equivalent legislation in Northern Ireland is The Dangerous Substances (Notification and Marking of Sites) Regulations (Northern Ireland).

Under the Control of Asbestos Regulations (CAR), there are specific labelling requirements for asbestos in non-domestic buildings. Responders should recognise these labels.

Containment systems

Hazardous materials containers range in size from small vials and jars used in laboratories through larger packages and transport containers holding many tonnes to site storage tanks and vessels that can hold many thousands of tonnes.

It is important that during incidents, responders can:

- Recognise typical container shapes or types that would indicate the presence of hazardous materials whether in storage, in use or in transit

- Identify the basic design and construction features, including closures for storage, packaging and transportation systems

For further information on substance identification see National Operational Guidance: Health Hazards and National Operational Guidance: Physical Hazards

Strategic actions

Fire and rescue services should:

- Consider developing systems to gather pre-planning information on local risks and incident specific information

- Ensure responding personnel have the necessary instruction and training in the identification of hazardous materials containers

- Provide access to appropriate detection, identification and monitoring (DIM) equipment

- Ensure that Information on the recognition of hazardous materials is immediately available to personnel

- Ensure that responders can recognise signs, labels and other markings on hazardous materials packages

Tactical actions

Incident commanders should:

- Use signs, labels, markings, container types and detection equipment to identify substance

- Identify if containers indicating the presence of general or specific hazardous materials are involved
- Use available fire service or on-site detection equipment to identify the substance involved

Control measure - Manage the release of flammable vapours

Control measure knowledge

Of all the states of matter, a gas or vapour is by far the most challenging to control when released. The following control measures focus on actions and tactics that can be considered once a flammable material is in the vapour phase. Control measures for preventing vaporisation from an uncontained liquid will be considered under Hazard – Flammable liquids: Unignited.

Where flammable vapours are released under pressure, such as when escaping from a ruptured pressurised container, their temperature will drop rapidly. Because of this, even vapours that are lighter than air will sink to low-lying areas initially and therefore the highest concentrations of vapour will be found low to the ground and close to the release. As the temperature falls, the rate of release will reduce and in the case of some flammable vapours, ice will form at the point of release. This property may be exploited in some instances by using a spray or damp piece of material to cover the rupture (usually only on small bore, low pressure pipelines and vessels). As the water freezes a seal will be formed. (Straps may be used to hold material in place.)

Once a vapour cloud is formed there are limited tactical options to contain it. It is therefore a priority to stop any escape at source if possible, for example, by closing a valve.

Liquefied pressurised releases from pipelines may take considerable time to depressurise following an emergency shutdown.

When a vapour cloud is formed, particularly where the release is indoors, one option would be to prevent ventilation. This is not generally recommended as it will increase the concentration of flammable vapours and therefore increase likelihood of ignition. However, if the flammable vapours pose additional health effects such as being toxic (such as ammonia and hydrogen sulphide), ventilation may reduce the flammable hazard only to produce a much wider toxic hazard. In such instances, factors such as the total quantities of vapours, location of the incident, wind speed and direction will all contribute to determine the tactic that will take precedence.

Flammable vapours will only ignite when they encounter a source of ignition at concentrations within their flammable range. The precise range is specific to each substance; consequently, flammable vapours with a wide flammable range are more likely to create large ignitable vapour clouds than those with a narrow flammable range.

At operational incidents, a vapour cloud at concentrations above its upper explosive limit (UEL) should still be regarded as a dangerous environment. A key control measure for flammable vapours is to reduce the concentration in air below the lower explosive limit (LEL) and prevent ignition. Vapours in an uncontrolled state will naturally spread and in doing so, dilute.

Ventilation – Good ventilation can assist in dispersing flammable vapours to minimize the size of any ignitable plumes. This approach will need to be weighed against the generation of a larger plume and the potential to find ignition sources. This depends on the LEL of the vapour.

Water sprays – Adding water in the form of fine spray or mist will create convection currents that will assist in dispersing flammable vapours. Water mist will also act as a good absorber of heat if ignition occurs.
Most hydrocarbon fuel vapours have little or no solubility in water. Where vapours are water soluble, such as ammonia and hydrogen sulphide, water sprays may be used to dissolve the vapour cloud out of the air. This technique is called atmospheric scrubbing.

Where water sprays are beneficial, the hazards may be increased if water run-off enters any liquid pool. If the liquid spillage is significantly colder than the run-off and has a very low boiling point, this will cause a more rapid boil-off of the substance and increase the size of the vapour cloud. Even where the liquid is at an ambient temperature, with a relatively high boiling point, adding water if the liquid is immiscible will spread the spillage over a wider area, increasing the risk and increasing the surface area for vapours to be produced. Additionally, any water run-off may present a risk of pollution to the environment.

Weather – Strong winds can disperse flammable vapours and gases, rain can dissolve soluble gases (atmospheric scrubbing) and promote the mixing/dilution of any vapour plume.

Inerting gas – By replacing the air with a gas that does not support combustion, the risk of fire can be greatly reduced or eliminated. This will not only reduce the concentration of flammable vapours but also reduce the concentration of oxygen present.

Portable monitoring equipment known as LEL meters or combustible gas detectors can be used to detect the presence of flammable vapours. These meters are not substance-specific and can detect any vapour that is flammable.

Using LEL meters will enable cordons to be refined and allow monitoring for changes in the incident profile.

Once a flammable vapour cloud has formed, the options available to reduce this hazard are limited, until vapours have dissipated to a safe concentration. As a priority, responders should isolate any sources of ignition (electrical sparks, static electricity, friction sparks or naked flame) from the hazard area and manage cordons to ensure none are introduced to the area. For further information on ignition sources see National Operational Guidance: Fires and Firefighting.

Entering such a dangerous atmosphere is therefore inherently dangerous and should only be considered in circumstances where the benefits outweigh the risk, for example, to perform rescues and prevent catastrophic escalation.

Structural firefighting kit and breathing apparatus (BA) will provide the most appropriate level of personal protective equipment (PPE) for the flammable risk. This will need to be weighed against any possible health effects (such as corrosivity) from the vapour. Chemical protective clothing (CPC) is generally not suitable where heat, fire or flammable risks are present. Where the balance of risks means that personnel need to enter a vapour cloud in chemical protective clothing (CPC), additional controls should be considered such as ventilation and water sprays. Personal protective equipment (PPE) for emergency teams may need to be sufficient to protect wearers in the event of ignition of a vapour cloud that leads to a flash fire or uncontrolled vapour cloud explosion. For further information on emergency arrangements see A foundation for Breathing Apparatus. Where the risks present outweigh the benefits, defensive tactics should be implemented.

For further information see National Operational Guidance: Incident command – Ineffective safety management.

Strategic actions

Fire and rescue services should:

- Provide procedures and support arrangements regarding the hazards that may be encountered and actions to take when managing the release of unignited flammable vapours

Tactical actions

Incident commanders should:

- Isolate the flammable vapour release at source, if possible
- Consider options for stopping/reducing the escape of flammable vapours (for example, remote isolation/emergency shutdown (ESD))
- Evaluate the risks and benefits of ventilating flammable vapours
- Assess weather conditions and their impact on any flammable vapour cloud
- Use water sprays to dilute and disperse flammable vapours
- Dilute and disperse flammable vapours (e.g. using water sprays)

- Consider the impact of water run-off entering any flammable liquid pools

- Consider ventilating flammable vapour clouds – open doors and windows, consider using positive pressure ventilation (PPV)

- If crews are entering the vapour cloud ensure covering jets are positioned to minimise the risk to personnel and potential impact of vapour cloud ignition

- Identify all possible methods of isolating the release (e.g. remote isolation or emergency shutdown)

- Assess the risk from unignited flammable vapours before extinguishing and consider controlled burn

Control measure - Isolate sources of ignition or heat

Control measure knowledge

Due to the risk of a flammable vapour forming, as a priority, responders should isolate any sources of ignition. It should also be noted that any heat sources in the vicinity will increase vapour production and even if not hot enough to ignite the flammable liquid, will increase the level of hazard.

Strategic actions

Tactical actions

Incident commanders should:

- Remove or reduce any heat sources affecting flammable liquids to reduce vaporisation

Control measure - Containment: Flammable liquids

Control measure knowledge

Where flammable liquids are escaping from their container, stopping any leak will limit the hazard presented by the liquid pool. Various equipment may be available to manage leaks and reduce the flow, including equipment provided by the environmental agencies.

Similar to the hierarchy of control for environmental protection (See National Operational Guidance: Environmental protection), when containing or controlling a flammable liquid, the following hierarchy should be considered. The smaller the surface area the less vapour will be produced, reducing the risk of the vapour finding an ignition source whilst within its flammable range.

	Tactical Options
At source	• Close valves • Keep container upright (position leak point above the liquid level) • Use an over drum • Move container to bunded area • Use putty • Use pads and straps
Close to source	• Use a polyboom • Use sand or earth • Use spill absorbent/pads
On the surface	• Use clay mats
In the drainage system	• Use drain blockers • Close valves
In the watercourse	• Use floating booms • Use floating dams • Close barrier (for example, locks)

A number of the techniques in the chart above rely on the flammable liquid being immiscible with water and lighter than water (floating).

In addition to controlling the spread of a flammable liquid, suppressing or controlling the rate of evaporation will be necessary to prevent an ignitable vapour cloud forming. The primary method to reduce vapour production would be to cover the spill, although container cooling may be beneficial in certain situations. Providing the material used does not react with the liquid, numerous options may have a beneficial effect, such as salvage sheets, plastic sheeting or foam.

An appropriate foam can put a barrier between the flammable liquid and the supporter of combustion to inhibit the formation of an ignitable fuel/air mixture. Foam blankets can limit the size of any ignitable plume and slow the fire growth if an ignition does take place.

A key consideration when selecting foam is whether the flammable liquid is miscible with water. Alcohols are water miscible and will react with the water content of general foams, causing them to break down and be less effective. Selecting an alcohol resistant foam will counter this effect.

Although termed ‘alcohol resistant’, this type of foam will act effectively on other miscible solvents such as acetone or organic acids.

When a pressurised liquid escapes from its container, not only will large quantities of vapour be released, but also, if the leak is below the liquid level, a pool of very cold liquid at sub-zero temperatures will accumulate. This pool will vaporise rapidly. It will also pose cryogenic hazards and will boil rapidly if water or foam is introduced to the pool. This additional hazard should be considered when deciding on any tactics when dealing with leaks of flammable pressurised liquids, for example liquid petroleum gas (LPG).

For pooled spillages of liquefied pressurised gases such as propane, medium expansion foam suppression may prove effective due to its reduced water content.

Flammable liquids will produce vapours based on their vapour pressure (see definition). The higher the vapour pressure, the more volatile the liquid and the greater the volume of flammable vapours that will be produced. Temperature is another important factor in determining the quantities of vapours produced; as the temperature of a liquid increases, larger quantities of vapours will be produced.

As many flammable liquids are immiscible with water, cooling the liquids directly with water will spread the hazard. However, in situations where flammable liquids are present, removing or reducing any heat sources will reduce the potential for a flammable vapour cloud to develop. As a ‘rule of thumb’ a 10C reduction in temperature will reduce the vapour pressure by about 50 per cent.

Strategic actions

Fire and rescue services should:

- Provide appropriate means to control the spillage of flammable liquids

Tactical actions

Incident commanders should:

- Consider the effect of buoyancy, weather and the environment on the spread of the vapour cloud

- Contain flammable liquid leaks at, or as close as possible, to the source, in line with the hierarchy of control (minimise surface area)

- Consider vapour suppression

- Avoid introducing liquids to sub-zero temperature flammable liquids

- Remove or reduce any heat sources affecting flammable liquids, to reduce vaporisation

- Use signs, labels, markings and container types to identify the presence of flammable liquids

Control measure - Use intrinsically safe equipment

Control measure knowledge

Any equipment that is not intrinsically safe can provide an ignition source for a gas within its flammable or explosive limits. This may cause combustion or explosion. The use of intrinsically safe equipment will preclude this.

In most confined spaces, it is impossible to classify the atmosphere present. For fire and rescue service operations, intrinsically safe equipment must meet the standards for use in Zone 1 under [the ATEX directives](#).

For further information on fireground radios see: Fireground radios guidance: ATEX-approved radios

Strategic actions

Fire and rescue services should:

- Ensure that intrinsically safe equipment is available to crews trained to work in confined spaces

Tactical actions

Incident commanders should:

- Use only intrinsically safe equipment in confined spaces where there is a risk of a flammable or explosive atmosphere
- Use only ATEX approved equipment in flammable or explosive atmospheres
- Use only ATEX approved communications equipment when crews enter any potentially explosive atmosphere
- Use only ATEX approved equipment when crews enter any potentially flammable atmosphere

Hazard - Flammable liquids: Ignited

Hazard Knowledge

If an uncontrolled flammable liquid ignites, a large, engulfing fire will develop and will spread with the flow of the liquid. Burning liquid will follow the slope of the ground and pool in low-lying areas and drains. Under these conditions large-scale foam operations may well be required. If the liquid is still leaking from its container, the fire will continue to increase in size but the flame may also flash back to the container, introducing a risk of violent containment failure (see Hazard – Gases under pressure involved in fire). This type of fire can be most difficult to deal with, especially if it is flowing and being fed by a storage tank or pressurised pipeline. The source of the leak should be identified and isolated as soon as possible.

Control measure - Substance identification

Control measure knowledge

The information provided through legislation on hazardous materials containers is a key factor in identifying hazards to responders and the public. Other sources of information should also be considered and their value not overlooked in determining a complete picture of the incident. There are also times when marking, placarding and signs are not present, or are incorrect, damaged or obscured. Examples include during a fire, or where hazardous materials are badly controlled or used illicitly.

In addition to marking and signage, other legislative requirements for the use of substances require sites to keep records of substances held, their hazards and control measures. These requirements mean that sites should have access to Safety Data Sheets (SDS) or Control of Substances Hazardous to Health (COSHH) sheets. This information can provide information about the hazards, health effects, behaviours and control measures. Similar information can be obtained from written and/or electronic data sources such as Chemdata or the Emergency Response Guidebook.

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Signs, labels and other marking system

It is important for responders to recognise signs, labels and other marking systems so that they can gain information regarding the hazards associated with substance safety. These will generally be found on modes of transport or fixed sites.

Transport

The legal framework for the international transport of hazardous materials is set out in the United Nations (UN) model regulations ('Recommendations on the transport of dangerous goods', commonly known as the 'orange book'). These rules are revised every two years and form the basis of the internationally and nationally recognised legislation.

The recommendations are adopted in Europe and consequently in the UK, as ADR (Accord européen relatif au transport international des marchandises Dangereuses par Route) for road transport and RID (Reglement International concernant le transport de marchandises Dangereuses par chemin de fer) for rail transport. Additionally, the UK maintains some deviations from ADR, for

example, Hazchem placards. As both marking systems are permitted in the UK it is important for responders to be familiar with both.

The International Maritime Dangerous Goods (IMDG) code contains internationally agreed guidance on the safe transport of dangerous goods by sea, and most commonly relates to the carriage of dangerous goods in freight containers and tank containers. It is primarily used by shipping operators, but it is also relevant to those transporting dangerous goods on journeys involving a sea crossing.

Fixed sites

For static sites, warning signage is governed by the dangerous substances Notification and Marking of Sites) (NAMOS) Regulations. The aim of these regulations is to ensure that firefighters arriving at an incident are warned of the presence of hazardous materials. It is a legal requirement to notify the fire and rescue service about any site with a total quantity of 25 tonnes or more (150 tonnes for ammonium nitrate fertilisers). There is a requirement to place warning signs at access points.

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Under the Control of Asbestos Regulations (CAR), there are specific labelling requirements for asbestos in non-domestic buildings. Responders should recognise these labels.

Containment systems

Hazardous materials containers range in size from small vials and jars used in laboratories through larger packages and transport containers holding many tonnes to site storage tanks and vessels that can hold many thousands of tonnes.

It is important that during incidents, responders can:

- Recognise typical container shapes or types that would indicate the presence of hazardous materials whether in storage, in use or in transit
- Identify the basic design and construction features, including closures for storage, packaging and transportation systems

For further information on substance identification see National Operational Guidance: Health Hazards and National Operational Guidance: Physical Hazards

Strategic actions

Fire and rescue services should:

- Consider developing systems to gather pre-planning information on local risks and incident specific information

- Ensure responding personnel have the necessary instruction and training in the identification of hazardous materials containers

- Provide access to appropriate detection, identification and monitoring (DIM) equipment

- Ensure that Information on the recognition of hazardous materials is immediately available to personnel

- Ensure that responders can recognise signs, labels and other markings on hazardous materials packages

Tactical actions

Incident commanders should:

- Use signs, labels, markings, container types and detection equipment to identify substance
- Identify if containers indicating the presence of general or specific hazardous materials are involved
- Use available fire service or on-site detection equipment to identify the substance involved

Control measure - Manage the release of flammable vapours

Control measure knowledge

Of all the states of matter, a gas or vapour is by far the most challenging to control when released. The following control measures focus on actions and tactics that can be considered once a flammable material is in the vapour phase. Control measures for preventing vaporisation from an uncontained liquid will be considered under Hazard – Flammable liquids: Unignited.

Where flammable vapours are released under pressure, such as when escaping from a ruptured pressurised container, their temperature will drop rapidly. Because of this, even vapours that are lighter than air will sink to low-lying areas initially and therefore the highest concentrations of vapour will be found low to the ground and close to the release. As the temperature falls, the rate of release will reduce and in the case of some flammable vapours, ice will form at the point of release. This property may be exploited in some instances by using a spray or damp piece of material to cover the rupture (usually only on small bore, low pressure pipelines and vessels). As the water freezes a seal will be formed. (Straps may be used to hold material in place.)

Once a vapour cloud is formed there are limited tactical options to contain it. It is therefore a priority to stop any escape at source if possible, for example, by closing a valve.

Liquefied pressurised releases from pipelines may take considerable time to depressurise following an emergency shutdown.

When a vapour cloud is formed, particularly where the release is indoors, one option would be to prevent ventilation. This is not generally recommended as it will increase the concentration of flammable vapours and therefore increase likelihood of ignition. However, if the flammable vapours pose additional health effects such as being toxic (such as ammonia and hydrogen sulphide), ventilation may reduce the flammable hazard only to produce a much wider toxic hazard. In such instances, factors such as the total quantities of vapours, location of the incident, wind speed and direction will all contribute to determine the tactic that will take precedence.

Flammable vapours will only ignite when they encounter a source of ignition at concentrations within their flammable range. The precise range is specific to each substance; consequently, flammable vapours with a wide flammable range are more likely to create large ignitable vapour clouds than those with a narrow flammable range.

At operational incidents, a vapour cloud at concentrations above its upper explosive limit (UEL) should still be regarded as a dangerous environment. A key control measure for flammable vapours is to reduce the concentration in air below the lower explosive limit (LEL) and prevent ignition. Vapours in an uncontrolled state will naturally spread and in doing so, dilute.

Ventilation – Good ventilation can assist in dispersing flammable vapours to minimize the size of any ignitable plumes. This approach will need to be weighed against the generation of a larger plume and the potential to find ignition sources. This depends on the LEL of the vapour.

Water sprays – Adding water in the form of fine spray or mist will create convection currents that will assist in dispersing flammable vapours. Water mist will also act as a good absorber of heat if ignition occurs.
Most hydrocarbon fuel vapours have little or no solubility in water. Where vapours are water soluble, such as ammonia and hydrogen sulphide, water sprays may be used to dissolve the vapour cloud out of the air. This technique is called atmospheric scrubbing.

Where water sprays are beneficial, the hazards may be increased if water run-off enters any liquid pool. If the liquid spillage is significantly colder than the run-off and has a very low boiling point, this will cause a more rapid boil-off of the substance and increase the size of the vapour cloud. Even where the liquid is at an ambient temperature, with a relatively high boiling point, adding water if the liquid is immiscible will spread the spillage over a wider area, increasing the risk and increasing the surface area for vapours to be produced. Additionally, any water run-off may present a risk of pollution to the environment.

Weather – Strong winds can disperse flammable vapours and gases, rain can dissolve soluble gases (atmospheric scrubbing) and promote the mixing/dilution of any vapour plume.

Inerting gas – By replacing the air with a gas that does not support combustion, the risk of fire can be greatly reduced or eliminated. This will not only reduce the concentration of flammable vapours but also reduce the concentration of oxygen present.

Portable monitoring equipment known as LEL meters or combustible gas detectors can be used to detect the presence of flammable vapours. These meters are not substance-specific and can detect any vapour that is flammable.

Using LEL meters will enable cordons to be refined and allow monitoring for changes in the incident profile.

Once a flammable vapour cloud has formed, the options available to reduce this hazard are limited, until vapours have dissipated to a safe concentration. As a priority, responders should isolate any sources of ignition (electrical sparks, static electricity, friction sparks or naked flame) from the hazard area and manage cordons to ensure none are introduced to the area. For further information on ignition sources see National Operational Guidance: Fires and Firefighting.

Entering such a dangerous atmosphere is therefore inherently dangerous and should only be considered in circumstances where the benefits outweigh the risk, for example, to perform rescues and prevent catastrophic escalation.

Structural firefighting kit and breathing apparatus (BA) will provide the most appropriate level of personal protective equipment (PPE) for the flammable risk. This will need to be weighed against any possible health effects (such as corrosivity) from the vapour. Chemical protective clothing (CPC) is generally not suitable where heat, fire or flammable risks are present. Where the balance of risks means that personnel need to enter a vapour cloud in chemical protective clothing (CPC), additional controls should be considered such as ventilation and water sprays. Personal protective equipment (PPE) for emergency teams may need to be sufficient to protect wearers in the event of ignition of a vapour cloud that leads to a flash fire or uncontrolled vapour cloud explosion. For further information on emergency arrangements see A foundation for Breathing Apparatus. Where the risks present outweigh the benefits, defensive tactics should be implemented.

For further information see National Operational Guidance: Incident command – Ineffective safety management.

Strategic actions

Fire and rescue services should:

- Provide procedures and support arrangements regarding the hazards that may be encountered and actions to take when managing the release of unignited flammable vapours

Tactical actions

Incident commanders should:

- Isolate the flammable vapour release at source, if possible
- Consider options for stopping/reducing the escape of flammable vapours (for example, remote isolation/emergency shutdown (ESD))
- Evaluate the risks and benefits of ventilating flammable vapours
- Assess weather conditions and their impact on any flammable vapour cloud
- Use water sprays to dilute and disperse flammable vapours
- Dilute and disperse flammable vapours (e.g. using water sprays)
- Consider the impact of water run-off entering any flammable liquid pools
- Consider ventilating flammable vapour clouds – open doors and windows, consider using positive pressure ventilation (PPV)
- If crews are entering the vapour cloud ensure covering jets are positioned to minimise the risk to personnel and potential impact of vapour cloud ignition
- Identify all possible methods of isolating the release (e.g. remote isolation or emergency shutdown)
- Assess the risk from unignited flammable vapours before extinguishing and consider controlled burn

Control measure - Select appropriate firefighting media: Flammable liquids

Control measure knowledge

This control measure should be read in conjunction with National Operational Guidance: Fires and firefighting: Select appropriate firefighting media

Selecting the correct firefighting media is key to successfully extinguishing flammable liquid fires.

Foam is the typical media for dealing with flammable liquid fires. However, for water miscible liquids it may be possible to dilute the material to a level that is no longer flammable. This would only be possible for relatively small fires.

With a flowing spill fire, it is generally best to start at the furthest point of the fire and work towards the source of spillage. It is good practice to form a deep blanket of foam beyond the furthest point at the lowest level so that the flowing burning product will flow beneath this and be extinguished. Under certain circumstances it may be necessary to dig a trench or construct dykes made of earth to retain burning product; sandbags may also prove adequate.

Rapid deployment of containment, such as polybooms and inflatable hose, around running fuels will start to contain the spillage and allow the foam blanket to seal against the side of the polyboom.

See National Operational Guidance: Fires and firefighting – Select appropriate firefighting media

Strategic actions

Fire and rescue services should:

- Provide procedures and support arrangements regarding the hazards that may be encountered and actions to take for selecting and using appropriate firefighting media with ignited flammable liquids

Tactical actions

Incident commanders should:

- Ensure sufficient resources are in place prior to commencing any foam attack

- Consider using dry powder extinguishers to extinguish the fire at the source of the leak
- Consider using fine water spray to cool flammable liquid fire where necessary

Control measure - Controlled burning

Control measure knowledge

Controlled burning is a defensive operational tactic to prohibit or restrict the use of extinguishing media on fires to allow the combustion process to continue uninhibited. UK law does not require fire and rescue services to extinguish fires. A controlled burning strategy may warrant consideration in certain circumstances, including protecting the environment, where the benefit from offensive firefighting does not outweigh the risks, or where available resources and media are insufficient to successfully resolve the incident.

This operational strategy can be employed to limit damage to the environment when it is not possible to contain polluted fire water, as it can minimise the risk to public drinking water supplies from fire water runoff. It may also benefit air quality through improved combustion and dispersion of airborne pollutants. It can be employed in conjunction with firebreaks as a firefighting technique when responding to fires in areas such as moorlands or heathlands.

It is essential to understand that this strategy may have adverse effects, such as hazardous gaseous by-products to form or increase. The balance of potential water and airborne impacts is one of the factors that should be taken into account before implementing the strategy. See Section 3.7, Environmental Protection Handbook.

Controlled burn considered	Controlled burn likely to be inappropriate
Life or health is not at risk or a controlled burn will reduce risk to people	Life or health is at immediate risk or a controlled burn will increase risk to people
There is little chance of extinguishing the fire	There is a high chance of extinguishing the fire with minimal health or environmental impacts
Fighting the fire with other techniques could cause a significant risk to firefighters	The fire is likely to spread widely or to high-hazard areas

Property is beyond salvage	Important or valuable buildings are involved
Fire conditions, weather conditions and/or the local landscape are appropriate for minimising air quality impacts	Fire conditions, weather conditions and/or the local landscape are inappropriate
Fire water run-off could damage an area of high environmental sensitivity or value	Drainage from the site leads to an area of low environmental sensitivity or fire water is not polluting
Fire water run-off could affect drinking water sources or sewage treatment works	Fire water can be contained on-site or off-site

Incident commanders will decide whether to allow a controlled burn. Wherever possible, they should take specialist advice from hazardous materials advisers (HMA), environment agency staff, owners/occupiers and public health bodies. The decision should be communicated as appropriate, including to the public via the media if necessary.

A controlled burn strategy may be considered at any time during an incident. At incidents where it is expected that the fire will burn for some time it may be appropriate to use both controlled burn and extinguishing tactics. For example, using a controlled burn in the initial stages of an intense fire may result in lower concentrations and better dispersion of pollutants because of the high combustion temperatures as well as reduced run-off.

The technique of introducing an accelerated control burn, which may include the use of fire service positive pressure ventilation fans (PPV), can help to increase temperature and therefore decrease the combustion time.

However, with both controlled burn and an accelerated controlled burn, as the fire dies back and begins to smoulder, the pollutant levels in the smoke plume may increase, resulting in reduced dispersion of pollutants and lowering of the smoke plume and contents in the atmosphere. At this point an extinguish strategy could be used. Such a strategy would also give more time for fire water containment measures to be put in place.

Controlled burn strategies may apply to industrial or commercial premises processing or storing polluting substances but can also be useful to limit the effects of fires involving:

- Agricultural premises, for example barns or BASIS (Registration) Ltd stores
- Transport by road, rail, air or sea or hazardous and/or environmentally damaging materials in significant quantities

For sites falling under the Control of Major Accident Hazard Regulations 1999 (COMAH), The Environmental Permitting (England and Wales) Regulations 2010 and other relevant environmental legislation, fire and rescue services should liaise with site occupiers and environment agencies to establish situations where considering a controlled burn may be required as part of:

- An industry protection scheme such as the BASIS (Registration) Ltd scheme for agrochemical stores
- An incident response plan at a site regulated by environment agencies
- An environmental management system or as part of the risk management plan as an agreed environmentally best option

Certain buildings have a particularly high value, not just in rebuilding costs but also because of their architectural, cultural, historical or strategic significance. Although it is unlikely that a building of this type would be used to store significant quantities of hazardous or polluting substances, the health and environmental benefits of a controlled burn must be weighed against the value of the building when they do.

The decision to adopt a controlled burn strategy should be made following consultation with relevant agencies, for example:

- Environmental agencies
- Nature conservation bodies
- Public health organisations
- Local authority
- Highway agencies

See also: National Operational Guidance: Environmental protection

Strategic actions

Fire and rescue services should:

- Develop tactical guidance and support arrangements for the hazards that may be encountered and the actions to be taken for controlled burning
- Ensure that a controlled burn strategy takes into account both the event and post-event phase of an incident
- Make appropriate arrangements for mitigating pollution and informing the relevant environmental agency and, where necessary, the local population. Liaise with the appropriate agencies to establish air and water monitoring arrangements, both on and off site where necessary
- Identify pre-determined sites where a controlled burn strategy may be appropriate

Tactical actions

Incident commanders should:

- Consider a controlled burn strategy and communicate this to personnel and relevant authorities

Hazard -

Slop-over and boil-over

Hazard Knowledge

A 'slop-over' is where thermal expansion or surface boiling of product causes burning fuel to flow over the side of its container.

A 'boil-over' (also known as a steam explosion) can occur in prolonged tank fires containing petroleum mixtures with a wide range of boiling points, such as petroleum crude oil and certain fuel oils.

As the lighter, more volatile fractions of the mixture burn off, the heated heavier residues start to displace, moving a heat wave downwards through the tank.

Petroleum crude oil, heated to several hundred degrees centigrade, will eventually reach a water layer at the base of the tank that will suddenly boil and turn to steam. This sudden eruption ejects the whole of the tank contents and produces a dangerous shower of burning liquid, radiated over the immediate area.

these hazards are well known within the petrochemical industry, such hazards may be encountered in a variety of situations involving flammable liquids that are on fire within containers.

Control measure - Prevent heat transfer to flammable liquid

Control measure knowledge

A boil-over usually occurs when there is:

- A full surface tank fire
- The tank contains petroleum mixtures with a wide range of boiling points
- There has been a long pre-burn time
- There is a heat wave

A boil-over can occur in two different ways:

- Water being introduced to the container

- The heat wave meeting water already present at the bottom of the container

Where a heat wave is suspected to be travelling down through a flammable liquid, operational tactics should be implemented to prevent the heat wave reaching any water at the base of the container. Extinguishing the fire will prevent further heat transference, slowing and finally stopping the heat wave. Typically, foam is the most effective method for tackling a flammable liquid surface fire.

Thermal imaging may be able to identify the level between hot and cooler liquid within the container. While applying uniform cooling to the tank may slow or stop the progress of the heat wave, if the cooling is not uniform, this may risk the integrity of the tank. There is a risk that the side of the tank may split, resulting in a large spill of burning flammable liquid.

Further thermal imaging equipment monitoring will enable the incident commander to determine the success of this control measure.

Strategic actions

Tactical actions

Incident commanders should:

- Consider applying foam to a flammable liquid surface fire to limit heat transfer
- Consider boundary cooling containers of a flammable liquid to limit heat transfer
- Monitor tank contents using thermal imaging equipment

Control measure - Cordon control: Boil-over

Control measure knowledge

Where a boil-over is suspected or predicted, the incident commander should be vigilant for signs of a boil-over and ensure crews are at a suitable distance away if a boil-over is imminent. A boil-over is usually preceded by a period of quieter burning followed by a marked heightening and brightening of the flames.

See Control measure: Cordon control – Unignited flammable vapours

See Control measure Cordon control – Ignited flammable vapours

Strategic actions

Fire and rescue services should:

- Provide procedures and support arrangements regarding the hazards that may be encountered and actions to take when implementing hazard area for boil-overs

Tactical actions

Incident commanders should:

- Establish exclusion zones, inner and outer cordons based on level of risk from a boil-over or slop-over

- Assess the surrounding risks and potential impact of a boil-over

- Implement suitable cordon controls from any potential boil-over

Hazard - Flammable solids

Hazard Knowledge

Flammable solids are amongst the most common of all flammable materials, but relatively few are included in the GHS or UN hazardous substances classifications. Those that are included can exhibit special risks and this section highlights some of the more important problems associated with these hazardous materials.

A number of hazardous properties are covered within this broad hazard classification, including:

UN Class 4.1 Flammable solids, self-reactive substances and desensitised explosives

- Flammable solids – powdered, granular or paste-like substances that are readily combustible (easily ignited by brief contact with an ignition source such as a burning match) and where the flame then spreads rapidly
- Self-reactive substances and mixtures – thermally unstable liquid or solid substances or mixtures liable to undergo a strong exothermic decomposition even without the presence of oxygen.
- Desensitised explosives – explosives that, when dry, are Class 1 explosives, which are kept wetted with sufficient water or alcohol to keep them stable and safer in long term storage

These solids rarely produce sufficient vapours at ordinary temperatures to be ignitable; naphthalene and camphor being notable exceptions. However, as solids are heated, vapour production will increase as they melt and possibly boil (e.g. sulphur). Some solids, normally organic in nature, will decompose as they are heated to produce small combustible molecules that when mixed with air, may eventually ignite (e.g. wood, plastics, paper).

For naturally occurring flammable solids the water content of the material can determine its ignition temperature. For example, it is relatively easy to ignite dry grass but rather more difficult to ignite damp grass.

The shape and surface area of solids also affects the ease of ignition.

UN Class 4.2 Substances liable to spontaneous combustion

Pyrophoric liquids and solids – substances liable to ignite within five minutes of coming into contact with air

Self-heating substances and mixtures – solid or liquid substances or mixtures, other than a pyrophoric liquid or solid, that can react with air and are liable to self-heat

UN Class 4.3 Substances which in contact with water emit flammable gases

Substances and mixtures that, in contact with water, are liable to become spontaneously flammable or give off flammable gas in dangerous quantities.

Special care should be taken at incidents involving these substances to manage the risk of reactions with water. Water inside a ruptured or leaking container of water-reactive material may cause an explosion.

Control measure - Substance identification

Control measure knowledge

The information provided through legislation on hazardous materials containers is a key factor in identifying hazards to responders and the public. Other sources of information should also be considered and their value not overlooked in determining a complete picture of the incident. There are also times when marking, placarding and signs are not present, or are incorrect, damaged or obscured. Examples include during a fire, or where hazardous materials are badly controlled or used illicitly.

In addition to marking and signage, other legislative requirements for the use of substances require sites to keep records of substances held, their hazards and control measures. These requirements mean that sites should have access to Safety Data Sheets (SDS) or Control of Substances Hazardous to Health (COSHH) sheets. This information can provide information about the hazards, health effects, behaviours and control measures. Similar information can be obtained from written and/or electronic data sources such as Chemdata or the Emergency Response Guidebook.

Other sources of information that can assist may be obtained from scientific advisers such as the National Chemical Emergency Centre (NCEC) or other company or product specialists and industry mutual aid schemes, for example Bromaid. This may provide information on a substance, process or premises, or may provide assistance in interpreting information gained.

Signs, labels and other marking system

It is important for responders to recognise signs, labels and other marking systems so that they can gain information regarding the hazards associated with substance safety. These will generally be found on modes of transport or fixed sites.

Transport

The legal framework for the international transport of hazardous materials is set out in the United Nations (UN) model regulations ('Recommendations on the transport of dangerous goods', commonly known as the 'orange book'). These rules are revised every two years and form the basis of the internationally and nationally recognised legislation.

The recommendations are adopted in Europe and consequently in the UK, as ADR (Accord européen relatif au transport international des marchandises Dangereuses par Route) for road transport and RID (Reglement International concernant le transport de marchandises Dangereuses par chemin de fer) for rail transport. Additionally, the UK maintains some deviations from ADR, for example, Hazchem placards. As both marking systems are permitted in the UK it is important for responders to be familiar with both.

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- Identify the basic design and construction features, including closures for storage, packaging and transportation systems

For further information on substance identification see National Operational Guidance: Health Hazards and National Operational Guidance: Physical Hazards

Strategic actions

Fire and rescue services should:

- Consider developing systems to gather pre-planning information on local risks and incident specific information

- Ensure responding personnel have the necessary instruction and training in the identification of hazardous materials containers

- Provide access to appropriate detection, identification and monitoring (DIM) equipment

- Ensure that Information on the recognition of hazardous materials is immediately available to personnel

- Ensure that responders can recognise signs, labels and other markings on hazardous materials packages

Tactical actions

Incident commanders should:

- Use signs, labels, markings, container types and detection equipment to identify substance
- Identify if containers indicating the presence of general or specific hazardous materials are involved
- Use available fire service or on-site detection equipment to identify the substance involved

Control measure - Manage the release of flammable solids

Control measure knowledge

Control measures to manage flammable solids will either prevent ignition (and therefore fire) or will reduce the level of hazard from any fire after ignition.

All flammable solids are readily ignitable; ignition sources should therefore be isolated and heat sources should be removed. Active cooling will further reduce the likelihood of ignition. If water is used, it will have the additional benefit of increasing water content, raising the ignition temperature. However, this action needs to be balanced against the potential of generating polluting water run-off.

The use of water should also be carefully considered as some flammable solids will react with water producing heat or, in the case of water-reactive material, flammable gas or flame. Additional considerations in these cases are:

- Introducing water into a container of water-reactive material may cause an explosion
- Water may be needed to cool adjoining containers to prevent them rupturing (exploding) or the fire spreading
- Water may only be effective in controlling a water-reactive material if it can be applied at a sufficient flooding rate for an extended period
- The products from any reaction with water may be more toxic, corrosive or hazardous than the products of the fire without water applied
- When responding to an incident involving water-reactive materials, fire and rescue service personnel should take the existing conditions into account, such as precipitation, wind, location and accessibility to the incident, as well as the availability of agents to control the fire or spill

Once ignited, extinguishing media must be selected carefully as some substances within this group require specialist extinguishers (for example, metal powders).

Strategic actions

Fire and rescue services should:

- Provide procedures and support arrangements regarding the hazards that may be encountered and actions to take when managing the release of flammable solids

Tactical actions

Incident commanders should:

- Assess reactivity of material with water
- Consider undertaking a controlled burn for flammable solids
- Ensure that, for water-reactive materials, they:
  - Prevent contact with water
  - Where addition of water is necessary, consider flooding amounts
  - Absorb small spillages of water-reactive materials in earth or dry sand
- Use signs, labels, markings and container types to identify the presence of flammable solids

Control measure - Eliminate ignition sources

Control measure knowledge

From the smallest to the largest incident, the incident commander and firefighters need to be aware of, and take notice of, possible ignition sources that could create additional hazards.

Although eliminating ignition sources may not be an immediate priority in a fire situation because the fire is already burning, firefighters should be aware of the potential for additional ignition sources and their potential to start events such as fire gas ignitions in areas that may be remote from the initial seat of fire.

At incidents where there may be a release of gases or other flammable atmospheres because features such as storage vessels, tanks or pipework may fail or be damaged, incident commanders should consider this a concern and identify it in the incident dynamic or analytical risk assessments (DRA or ARA) and incident plan.

The amount of energy required to ignite a mixture of air and flammable gas or vapour (including smoke) is called the minimum ignition energy (MIE) and depends on the characteristics of the gas or vapour, concentration in air, type of oxidant, temperature and pressure.

An ignition source can be defined as a form of energy that, when added to a flammable mixture, is sufficient for the combustion process to start; an ignition source with energy greater than the minimum ignition energy (MIE) for a particular mixture is sufficient for a fire or explosion to occur. Generally, the energy required to ignite a flammable gas or vapour mixture is relatively low, though some low-energy ignition sources may not be incendiary enough for all flammable mixtures.

Ignition sources include:

- Open flames
- General firefighting operations, including cutting
- Frictional sparks and localised heating
- Impact sparks
- Sparks from electrical equipment
- Electrostatic discharge
- Vehicles
- Use of cigarettes or matches
- Hot surfaces
- Electrical equipment and lighting
- Hot processes
- Exothermic runaway reactions (water applied to reactive metals such as sodium and potassium)
- Heating equipment

It is often challenging for crews to identify and eliminate every ignition source at an operational incident. The first option for ensuring safety is therefore usually to prevent flammable gas or vapour mixtures being released or formed. All foreseeable ignition sources should also be identified and effective control measures taken.

In industrial premises, depending on the ignition sensitivity of the materials handled, the types of equipment involved and the process parameters (such as temperature and pressure), incident commanders should consult with on-site process safety professionals or the responsible person to address safety issues and provide recommendations to aid the safe resolution of the incident.

Strategic actions

Fire and rescue services should:

- Develop tactical guidance and support arrangements for the hazards and actions to be taken in eliminating ignition sources

Tactical actions

Incident commanders should:

- Extinguish the fire and eliminate all ignition sources

- Prevent escalation, contain and extinguish the fire considering all ignition sources
- Deal with any immediate fire risk and provide a means of extinguishing fires during the incident
- Identify all possible ignition sources and eliminate them as far as is possible
- Control ignition sources that cannot be eliminated as far as reasonably practicable
- Develop and communicate a firefighting plan and ventilation strategy to all personnel
- Use the appropriate extinguishing method, media, techniques and equipment
- Ensure that crews are briefed on all firefighting activities and provide regular updates on progress
- Consider removing fuel from any source of ignition

Control measure - Select appropriate firefighting media

Control measure knowledge

There are many different types of firefighting media and many different ways in which to apply them, depending on the nature of the incident encountered.

The media chosen for a given type of fire will depend on the nature of the materials involved and the size and intensity of the fire.

When applied to a fire, an extinguishing medium undergoes changes as it absorbs heat from the fire:

- Its temperature will rise
- It may evaporate
- It may chemically decompose
- It may react chemically with the burning material

To achieve maximum effect, the quantity of heat energy absorbed when these changes occur should be as large as possible.

Water

Water is the cheapest, most efficient and readily available way of extinguishing fires of a general nature. With a high latent heat of vaporisation, it takes about six times as much heat to convert a given mass of water at its boiling point into steam as that required to raise the temperature of the same amount of water to boiling point. The most efficient use of water is where as much as possible is converted into steam. The smothering effect of the steam produced at the seat of the fire is thought to play a part in assisting the extinguishing process.

Submerging the burning materials in water can be effective, particularly when considering cooling the remnants of fire. This can be achieved using a variety of container types, sizes and methods, such as buckets, large refuse skips and improvised methods. Consideration will need to be given to containing the resultant contaminated water.

There are occasions when water in any form is not effective and occasions when it is dangerous to use, particularly where there are materials that react unfavourably with water, potentially with explosive effects. Examples include magnesium, aluminium, lithium, potassium, sodium and other combinations of these substances; they are commonly used in manufacturing processes. It is important that specific sites that may store or use these materials are identified and emergency responders are made aware of the associated hazards, control measures and planning arrangements.

Foam

Firefighting foams have been developed primarily to deal with the hazards posed by liquid fuel fires. Although water is used for most incidents, it is generally ineffective against fires involving liquid fuels. This is because the density of water is greater than that of most flammable liquids so when applied it quickly sinks below their surfaces.

Finished foams consist of bubbles produced from a combination of foam concentrate and water that has been mixed with air. These air-filled bubbles form a blanket that floats on the surface of flammable liquids, knocking down and extinguishing fires by:

- Excluding air (oxygen) from the fuel surface
- Separating the flames from the fuel surface
- Restricting the release of flammable vapour from the surface of the fuel
- Forming a radiant heat barrier which can help to reduce heat feedback from flames to the fuel and hence reduce the production of flammable vapour
- Cooling the fuel surface and any metal surfaces as the foam solution drains out of the foam blanket; this process also produces steam which dilutes the oxygen around the fire

A variety of foam concentrates can be categorised into two main groups: protein or synthetic-based, depending on the chemicals used in their production. The characteristics of each concentrate and the finished foam they produce vary, making them suitable for some applications and unsuitable for others.

The main properties of firefighting foams include:

- Expansion: the amount of finished foam produced from a foam solution when it is passed through foam-making equipment

- Stability: the ability of the finished foam to retain its liquid content and to maintain the number, size and shape of its bubbles; in other words, its ability to remain intact
- Fluidity: the ability of the finished foam to be projected onto, and to flow across, the liquid to be extinguished or protected
- Contamination resistance: the ability of the finished foam to resist contamination by the liquid to which it is applied
- Sealing and resealing: the ability of the foam blanket to reseal should breaks occur, and its ability to seal against hot and irregular shaped objects
- Knockdown and extinction: the ability of the finished foam to control and extinguish fires
- Burn-back resistance: the ability of the finished foam, once formed on the fuel, to stay intact when subjected to heat and/or flame

The most common foam in use is in a compressed air foam system, which can be carried in combination with traditional water appliances. The foam attacks all three sides of the fire triangle simultaneously; the foam blankets the fuel, thereby reducing the fuel's capacity to seek out a source of oxygen and adheres to ceilings and walls, more readily aiding rapid reduction in heat. Also, the opaque surface of the foam, as it adheres to walls and ceilings, shields the fuel source from radiant energy.

Compressed air foam systems can deliver a range of useful foam consistencies, labelled from type 1 (very dry) to type 5 (wet), which are controlled by the air-to-solution ratios and, to a lesser extent, by the concentrate-to-water percentage. Types 1 and 2 foams have long drain times, meaning the bubbles do not burst and give up their water quickly. Wet foams, such as types 4 and 5, drain more quickly in the presence of heat.

Compressed air foam systems can produce a wide range of foam qualities or foam types, providing the most appropriate foam response to individual fire situations. This gives the incident commander the advantage of tailoring the best foam type to the tactical use and fire problem at hand. Generally, the environmental effects of foams are considered in terms of their toxicity and their biodegradability. It is the total volume of the foam concentrate that is released into the environment that is of concern; it does not matter by how much it has been diluted. See National Operational Guidance: Environmental protection for further information.

Fire and rescue services also use foam for other purposes in addition to firefighting. See National Operational Guidance: Hazardous materials

Dry chemical powders

The basis of most dry powder extinguishers is sodium bicarbonate. With the addition of a metallic stearate as a waterproofing agent, it is widely used as an extinguishing agent in portable extinguishers and for larger application. Dry powder is very effective at extinguishing flame (rapid knockdown), and is particularly valuable in tackling a fire involving an incident in which clothes have been soaked in flammable liquid and ignited.

Dry chemical powders are expelled from containers by gas pressure and directed at the fire in a concentrated cloud through specially designed nozzles. Dry chemical powders are also tested for their compatibility with foam because early powders tended to break down foam. The two can complement each other at fires where foam is the standard extinguishing agent.

Ternary eutectic chloride powders have been developed for some metal fires. This type of foam melts, and then flows to form a crust over the burning metal, effectively sealing it from the surrounding atmosphere and isolating the fire.

Some burning materials, such as metals that cannot be extinguished by water, may be dealt with by using dry earth, dry sand, soda ash or limestone, all of which act as smothering agents.

Carbon dioxide, vaporising liquids and inert gases

Halons (halogenated hydrocarbons) vaporise rapidly when released from their pressurised container. The vapours are heavier than air, but when drawn into the flames, they inhibit the chain reactions and suppress flaming. Halons have now been largely replaced with inert gases or fine water mists because of environmental concerns.

At normal temperatures, Carbon dioxide (CO_2) is a gas 1.5 times as dense as air. It is easily liquefied and bottled in a portable cylinder where it is contained under approximately 51 bars pressure. When discharged, cold CO_2 vapour and some solid CO_2 are expelled from the horn, which rapidly cools in the process. The solid quickly turns to gas, and some of the liquid CO_2 evaporates to maintain the pressure in the cylinder. The gas, however, extinguishes by smothering, effectively reducing the oxygen content of the air. About 20 to 30% is necessary to cause complete extinction, depending on the nature of the burning material.

Carbon dioxide is quick and clean, electrically non-conductive, non-toxic and non-corrosive. It is however an asphyxiate at the concentrations necessary to extinguish a fire. The operation of total flooding CO_2 systems requires prior evacuation of all personnel.

Another fire extinguishing method is blanketing, which deprives the fire of oxygen. This is especially useful if someone's clothes are burning. For dealing with fires such as cooking fat fryers, the best method is to smother the fire with a fire resisting blanket.

Small fires in textile materials may often be extinguished by beating them out, or by rolling and screwing up the material tightly to exclude the air. Beating is also the method normally employed to extinguish heath, crop and similar fires in rural areas when water is not readily available.

See also National Operational Guidance: Environmental Protection - Fire water run-off

Strategic actions

Fire and rescue services should:

- Develop tactical guidance and support arrangements for the hazards that may be encountered and actions to be taken when selecting appropriate firefighting media
- Identify specific firefighting media from site-specific risk information (SSRI)
- Ensure sufficient stocks and/or supplies of firefighting media are made available at incidents within the area of the fire and rescue service

- Where necessary, make contingency arrangements with neighbouring services regarding using bulk media supplies for firefighting purposes

Tactical actions

Incident commanders should:

- Select appropriate firefighting media (e.g. water, foam, dry powder, CO_2)
- Monitor the effect of the media on the fire to ensure that the anticipated outcome is achieved
- Consider the potential for running fuel fires and deploy appropriate firefighting resources
- Put in place covering and/or safety jets according to identified risks

Hazard - Oxidising materials: Involved in fire

Hazard Knowledge

Oxidising substances present an additional hazard primarily because they can initiate or support combustion of other substances. This is evident from the definition of oxidising materials given in the Classification, Labelling and Packaging (CLP) regulation:

Oxidising gas – 'Any gas or gas mixture which may, generally by providing oxygen, cause or contribute to the combustion of other material more than air does.'

Oxidising liquid or solid – 'A substance or mixture which, while in itself not necessarily combustible, may, generally by yielding oxygen, cause, or contribute to, the combustion of other material.'

In addition to the main oxidising hazard, they may have other hazardous properties such as corrosivity and toxicity and therefore, guidance should be sought regarding those hazards.

The most common way that oxidising substances support combustion is through the release of oxygen, although other chemical reactants will have the same effect, primarily chlorine, fluorine and bromine.

In terms of operational response, there are two main concerns around the loss of stability of oxidising materials, aligned to the two main classes of oxidisers:

- 5.1 Oxidising substances
- 5.2 Organic peroxides

Organic peroxides

This type of oxidising material presents a high level of hazard as it contains both a supply of chemically available oxygen to support combustion, along with organic material that can combust. Therefore, two sides of the fire triangle are present within the substance. This results in a situation where a small amount of energy, for example, from heat or friction, can complete the triangle, resulting in fire. This has the potential to be an intense fire with the risk that, under containment, an explosion can occur.

For this reason, organic peroxides are typically stored and transported under temperature-controlled conditions.

Oxidising substances other than organic peroxides

This group of oxidisers will provide oxygen, or in some cases other substances (e.g. fluorine, chlorine and bromine), that will support combustion. They are not flammable themselves and therefore need to be combined with a fuel source before combustion can be initiated. The main concern around these substances relates to losing containment or them becoming contaminated with organic materials.

Combustion due to oxidising agents and fuel mixing together may occur instantly, as the oxidising agent oxidises the fuel in an exothermic reaction and adds heat to the mixture. This increases the rate of the reaction, which will in turn add more heat to the mixture until the ignition temperature is reached and fire starts.

For detailed information on classification and labelling see Foundation for Hazardous Materials.

Control measure - Substance identification: Oxidising materials

Control measure knowledge

This control measure should be read in conjunction with Hazardous materials – Substance identification.

Organic peroxides can be identified from specific labelling under both the transportation of hazardous materials regulations and the Classification, labelling and packaging (CLP) regulations.

The symbols that may be seen in relation to organic peroxides are:

In other cases, an external ignition source would be required. Even in this type of fire, a source of oxygen is directly available to the fuel from the oxidising agent, resulting in a more intense fire.

The symbols that may be seen in relation to oxidising materials that are not organic peroxides are:

For detailed information on classification and labelling see Foundation for Hazardous Materials.

Strategic actions

Tactical actions

Incident commanders should:

- Use signs, labels, markings and container types to identify the presence of oxidising materials
- Identify the location, physical state (solid, liquid, gas), type, and quantity of any released oxidising material
- Use detection equipment to identify and monitor levels of the oxidising materials involved

Control measure - Cordon control: Oxidising materials

Control measure knowledge

An oxidising material involved in a fire indicates that the fire will be more intense than if the fuel were to combust with the atmosphere providing the only source of oxygen. Oxidising substances can behave unpredictably and react with sufficient speed and energy to create an explosion. This can be caused by a spontaneous reaction of the oxidising material itself, as can be seen with organic peroxides or because of a reaction between an oxidising material and a fuel source such as ammonium nitrate or a fuel source such as diesel, oil or petrol. Identifying the exact oxidising material involved will indicate the potential for an explosion to occur.

If it is known or suspected that an organic peroxide is involved in a fire, personnel should withdraw to a safe distance. Hazardous materials advisers (HMAs) or on-site experts should be consulted to provide advice on the substances involved, their possible impacts and an appropriate cordon distance based on the level of risk.

Organic peroxides contain a source of oxygen and fuel. Therefore, any energy supplied to the substance, either by heating or through shock/friction caused by moving the product, can initiate decomposition of an organic peroxide and lead to an explosion or initiate/intensify a fire.

See Control measure – Recognise and manage ammonium nitrate fertiliser mixtures with the potential to explode

Strategic actions

Fire and rescue services should:

- Have procedures and support arrangements to identify oxidising materials involved in fire or with the potential to explode

- Make arrangements to ensure specialist advice on oxidising materials is made available to operational crews when required

Tactical actions

Incident commanders should:

- Establish exclusion zones, inner and outer cordons based on the level of risk from oxidising materials

- Consider the risk of explosion and implement an appropriate hazard area

- Request assistance from on-site experts and/or hazardous materials advisers (HMAs) to determine the hazard level of the oxidising material

- Where Organic Peroxides are present implement appropriate levels of risk control

- Assess the potential for intensification of fire or explosion from oxidising materials

Control measure - Select appropriate firefighting media: Oxidising materials

Control measure knowledge

This control measure should be read in conjunction with National Operational Guidance: firefighting: Select appropriate firefighting media

Where firefighting or cooling is necessary, water should be applied in a way that will maximise its cooling effect (i.e. fine spray). If firefighting operations are required within the hazard area, deployment of crews and the time they are deployed within the hazard area should be kept to a minimum. Structural protection and ground monitors should be used to minimise the risk to crews.

Strategic actions

Tactical actions

Incident commanders should:

- Consider using water to either extinguish a fire or cool the oxidising material

- Ensure firefighting activities are carried out from a safe location using structural protection and/or ground monitors

Hazard - Oxidisers contaminated with combustibles

Hazard Knowledge

Contamination of an oxidising agent with a fuel (or vice versa) will result in an oxidation reaction between the two substances. This reaction may start slowly, but it will be an exothermic reaction that results in an increase in the temperature of the mixture. This in turn will increase the rate of the reaction, which will generate more heat and further increase the rate at which the reaction occurs. As this process continues it is possible that the temperature of the fuel will continue to rise to the ignition temperature for the fuel. Combustion will then occur instantly.

In other cases, the reaction between the oxidising agent and the fuel may not create sufficient heat to initiate instant combustion. However, for these mixtures, where an ignition source does lead to a fire involving the mixture, the oxidising agent will react in a way that yields oxygen. The fire is therefore no longer dependant on only oxygen from the atmosphere. This will lead to a more fierce fire that can continue even when the level of atmospheric oxygen is reduced.

Organic peroxides contain both an oxygen source and a fuel element. Therefore, the substances include two elements of the fire triangle. In this case, only energy is required to initiate a fire involving an organic peroxide. This may be provided through an increase in temperature, shock, friction or through an exothermic reaction as a result of contamination.

Control measure - Substance identification: Oxidising materials

Control measure knowledge

This control measure should be read in conjunction with Hazardous materials – Substance identification.

Organic peroxides can be identified from specific labelling under both the transportation of hazardous materials regulations and the Classification, labelling and packaging (CLP) regulations.

The symbols that may be seen in relation to organic peroxides are:

In other cases, an external ignition source would be required. Even in this type of fire, a source of oxygen is directly available to the fuel from the oxidising agent, resulting in a more intense fire.

The symbols that may be seen in relation to oxidising materials that are not organic peroxides are:

For detailed information on classification and labelling see Foundation for Hazardous Materials.

Strategic actions

Tactical actions

Incident commanders should:

- Use signs, labels, markings and container types to identify the presence of oxidising materials
- Identify the location, physical state (solid, liquid, gas), type, and quantity of any released oxidising material
- Use detection equipment to identify and monitor levels of the oxidising materials involved

Control measure - Identify heat reactions within oxidising materials

Control measure knowledge

An increase in the temperature of an oxidising material provides a strong indication that a reaction is occurring. This reaction has the potential to increase until the ignition temperature of the fuel is reached. The use of a thermal imaging camera will assist in the identification of such a reaction.

Mixtures of an oxidising substance and a fuel may react slowly at first, but the heat from the reaction will increase the rate at which the ongoing reactions occur. Therefore, even where an oxidiser and fuel mixture does not appear unstable, ongoing reactions may still lead to a fire.

The oxidising material may also intensify fire, including the potential for explosion, particularly if the fuel is stored under confinement. Therefore, at the initial stages of an incident an assessment must be made from a safe location.

Strategic actions

Fire and rescue services should:

- Develop tactical guidance and support arrangements regarding the hazards that may be encountered and actions to take to identify heat reactions within oxidising materials

- Ensure that operational crews have access to equipment/techniques that can be used to identify chemical containers with elevated temperatures

Tactical actions

Incident commanders should:

- Assess the potential for heat reactions within oxidising materials, from a safe location

- Where oxidising materials are involved in fire, assess the potential for intensification of fire or explosion

- Monitor for signs of decomposition and heat where oxidising materials are contaminated with combustibles

Control measure - Separate oxidising materials from fuel sources

Control measure knowledge

Oxidising materials can be split into two groups, organic and inorganic oxidisers. Inorganic oxidisers are not themselves combustible, but will support combustion by reacting in a way that will yield oxygen, thereby supporting combustion. Therefore, in a scenario where fuel and oxidising agents are combined and this mixture is ignited, combustion is not only dependant on the availability of atmospheric oxygen. The oxidising agent will now provide oxygen to support combustion, enabling the fuel source to burn more fiercely and in atmospheres with reduced oxygen content. Therefore, extinguishing a fire through smothering to remove oxygen is not an option, leaving cooling or removing the fuel source as the key options.

Where the fuel and oxidising materials can be physically separated, caution should be taken as the friction created by moving the oxidising material will also add energy into the product, creating a risk of rapid decomposition.

In certain circumstances, it may be appropriate to establish a physical barrier between the two materials to prevent contamination and a reaction. With advice from the on-site specialist or hazardous materials adviser (HMA), personnel should ensure that there is no potential reactivity between the barrier and the oxidising product or fuel. This option will only be available where inorganic oxidisers are present as organic oxidisers have their fuel within the same molecule as its oxygen source.

Water used in the process of extinguishing a fire or cooling containers of combustible materials can dissolve the oxidiser. This can result in the oxidiser being transported to areas where combustible materials are located, creating the potential for spontaneous combustion to occur in the future, when the water has evaporated.

For guidance regarding fire-water run-off contaminating drains and watercourses, etc. see National Operational Guidance: Environmental protection.

Strategic actions

Fire and rescue services should:

- Provide procedures, guidance and support arrangements regarding the hazards that may be encountered and actions to take to separate oxidising materials from fuel sources

Tactical actions

Incident commanders should:

- Assess the possibility of increasing the distance separating oxidising materials from fuels

- Consider separating the oxidising material from exposure to a heat source

- Predict the flow of fuels or oxidising materials that are either molten or carried by contaminated water run-off if containment is lost

- Evaluate the potential to put physical barriers in place between oxidising substances and fuels

Control measure - Apply cooling, considering the potential for reaction with water

Control measure knowledge

Applying cooling to a contaminated oxidising agent is the most effective measure to avoid a fire starting. Where a fuel source and an oxidiser have already mixed, or a spontaneously combustible oxidising material has become unstable, two sides of the fire triangle – oxygen and fuel – are already in place. Therefore, reducing heat is the main option for avoiding fire.

Where the contaminated oxidising material will react with water, take advice from the on-site specialist or hazardous materials adviser (HMA) regarding other possible tactics. Containers can be cooled where the risk of water ingress is low, but the run-off and steam created will need to be considered. See Control measure – Separate oxidising materials from fuel sources. In these cases, undertaking a controlled burn may be the most appropriate tactic. See National Operational Guidance: Environmental protection – Controlled burning.

Strategic actions

Fire and rescue services should:

- Have procedures and support arrangements to apply cooling to oxidising materials and have actions for water-reactive oxidising materials

Tactical actions

Incident commanders should:

- Identify if the oxidising material or mixture involved in an incident is water-reactive

- Assess the risk of reaction between oxidising material and cooling water

- Where appropriate, apply water to cool containers of oxidising material

- Carry out cooling operations from a safe location, using structural protection and ground monitors where appropriate

- Carry out firefighting from a safe location using structural protection and/or ground monitors

Hazard - Cryogenic materials

Hazard Knowledge

Cryogenic materials are liquefied gases that are maintained in their liquid state by a combination of cooling to very low temperatures (typically below –150C) and increased pressure. Key features of all cryogenic materials are their low temperature, including the gases that are produced through evaporation of the cooled liquid. These gases will typically be sufficiently cold to condense the water in air producing a visible fog. Also, a small volume of released liquid can produce a significant volume of gas; for example, one litre of liquefied nitrogen will result in 695 litres of nitrogen gas when warmed to a temperature of 21oC.

Cryogenics can be separated into three groups:

Inert gases – these will not typically undergo chemical reaction or support combustion. In some cases, these gases will be used to provide an inert environment to increase the safety of an industrial process (e.g. nitrogen).

Flammable gases – the gases released from these cryogenic materials will burn in air (e.g. methane as liquefied natural gas (LNG), natural gas liquids (NGLs) or hydrogen).

Oxygen – a release of liquefied oxygen creates a very high concentration of oxygen in the spillage area. This results in materials that would not typically be considered as flammable being able to support combustion. Organic materials can also react explosively when in contact with liquefied oxygen.

Specific properties of cryogenic materials must be considered during an incident where they are released:

Cold – cryogenic materials are cold enough to cause a thermal burn to the skin. This may be further characterised by a lack of initial pain, but intense pain when the affected area thaws. Unprotected skin can stick to surfaces that have been cooled by cryogenic materials, creating a problem in removing the skin without damaging it. Some materials subjected to such extremes of cold may also become brittle and break; during an operational response, this is particularly relevant to personal protective equipment (PPE) and other equipment.

Asphyxiation – the gas formed by evaporation from a cryogenic liquid is initially very cold. It will therefore typically be denser than air and accumulate close to ground level. When combined with significant volumes of gas produced from a small volume of spilt cryogenic liquid, it results in the displacement of oxygen from air. Therefore, even where the gas is not toxic, there is a danger to health due to reduced oxygen levels.

Fire hazard – flammable cryogenic material will easily form mixtures with air that are between the upper and lower explosive limits following a release, creating a fire and explosion hazard.

Oxygen-enriched air – liquid hydrogen and helium are sufficiently cold to liquefy air. Nitrogen will evaporate more rapidly from the liquefied air than oxygen. This will leave a liquid air mixture behind, which has a higher concentration of oxygen than normal air; when this evaporates, an atmosphere with a higher concentration of oxygen is created.

An increase in the temperature of a contained cryogenic liquid will lead to evaporation and an increase in pressure in the container. Cryogenic storage vessels will typically include pressure relief valves enabling gases to be released and the pressure reduced.

However, in an emergency such as a loss of thermal insulation, fire impingement on the vessel or ingress of another material (e.g. water) will lead to an immediate rise in pressure that is too significant for a pressure relief valve to reduce. In this case, the pressure rise can lead to a catastrophic failure of the container and an explosion.

Control measure - Substance identification

Control measure knowledge

The information provided through legislation on hazardous materials containers is a key factor in identifying hazards to responders and the public. Other sources of information should also be considered and their value not overlooked in determining a complete picture of the incident. There are also times when marking, placarding and signs are not present, or are incorrect, damaged or obscured. Examples include during a fire, or where hazardous materials are badly controlled or used illicitly.

In addition to marking and signage, other legislative requirements for the use of substances require sites to keep records of substances held, their hazards and control measures. These requirements mean that sites should have access to Safety Data Sheets (SDS) or Control of Substances Hazardous to Health (COSHH) sheets. This information can provide information about the hazards, health effects, behaviours and control measures. Similar information can be obtained from written and/or electronic data sources such as Chemdata or the Emergency Response Guidebook.

Other sources of information that can assist may be obtained from scientific advisers such as the National Chemical Emergency Centre (NCEC) or other company or product specialists and industry mutual aid schemes, for example Bromaid. This may provide information on a substance, process or premises, or may provide assistance in interpreting information gained.

Signs, labels and other marking system

It is important for responders to recognise signs, labels and other marking systems so that they can gain information regarding the hazards associated with substance safety. These will generally be found on modes of transport or fixed sites.

Transport

The legal framework for the international transport of hazardous materials is set out in the United Nations (UN) model regulations ('Recommendations on the transport of dangerous goods', commonly known as the 'orange book'). These rules are revised every two years and form the basis of the internationally and nationally recognised legislation.

The recommendations are adopted in Europe and consequently in the UK, as ADR (Accord européen relatif au transport international des marchandises Dangereuses par Route) for road transport and RID (Reglement International concernant le transport de marchandises Dangereuses par chemin de fer) for rail transport. Additionally, the UK maintains some deviations from ADR, for

example, Hazchem placards. As both marking systems are permitted in the UK it is important for responders to be familiar with both.

The International Maritime Dangerous Goods (IMDG) code contains internationally agreed guidance on the safe transport of dangerous goods by sea, and most commonly relates to the carriage of dangerous goods in freight containers and tank containers. It is primarily used by shipping operators, but it is also relevant to those transporting dangerous goods on journeys involving a sea crossing.

Fixed sites

For static sites, warning signage is governed by the dangerous substances Notification and Marking of Sites) (NAMOS) Regulations. The aim of these regulations is to ensure that firefighters arriving at an incident are warned of the presence of hazardous materials. It is a legal requirement to notify the fire and rescue service about any site with a total quantity of 25 tonnes or more (150 tonnes for ammonium nitrate fertilisers). There is a requirement to place warning signs at access points.

See the Health and Safety Executive website for further details. Dangerous Substances (Notification and Marking of Sites) Regulations (NAMOS)

Labelling of hazardous materials for general use is governed by the Classification, Labelling and Packaging regulations (CLP). These regulations adopt the UN Globally Harmonised System (GHS) on the classification and labelling of chemicals across all European Union countries, including the UK.

Equivalent legislation in Northern Ireland is The Dangerous Substances (Notification and Marking of Sites) Regulations (Northern Ireland).

Under the Control of Asbestos Regulations (CAR), there are specific labelling requirements for asbestos in non-domestic buildings. Responders should recognise these labels.

Containment systems

Hazardous materials containers range in size from small vials and jars used in laboratories through larger packages and transport containers holding many tonnes to site storage tanks and vessels that can hold many thousands of tonnes.

It is important that during incidents, responders can:

- Recognise typical container shapes or types that would indicate the presence of hazardous materials whether in storage, in use or in transit

- Identify the basic design and construction features, including closures for storage, packaging and transportation systems

For further information on substance identification see National Operational Guidance: Health Hazards and National Operational Guidance: Physical Hazards

Strategic actions

Fire and rescue services should:

- Consider developing systems to gather pre-planning information on local risks and incident specific information

- Ensure responding personnel have the necessary instruction and training in the identification of hazardous materials containers

- Provide access to appropriate detection, identification and monitoring (DIM) equipment

- Ensure that Information on the recognition of hazardous materials is immediately available to personnel

- Ensure that responders can recognise signs, labels and other markings on hazardous materials packages

Tactical actions

Incident commanders should:

- Use signs, labels, markings, container types and detection equipment to identify substance
- Identify if containers indicating the presence of general or specific hazardous materials are involved
- Use available fire service or on-site detection equipment to identify the substance involved

Control measure - Containment: Cryogenic materials

Control measure knowledge

Once released from containment there is no way to return cryogenic materials to their containers. The cryogenic liquid will absorb heat from its surroundings, enabling gas to form or boil. High concentrations of gas can lead to depleted or enriched oxygen atmospheres and flammable vapours at hazardous concentrations.

The only options to re-establish a safe atmosphere are to disperse or contain the gases that have already evaporated and/or prevent the release of any further cryogenic liquid.

See Hazard – Flammable vapours (unignited) for further information.

Strategic actions

Fire and rescue services should:

- Provide procedures and support arrangements regarding the hazards that may be encountered and actions to take to manage releases of cryogenic materials
- Ensure that operational crews have access to personnel with a thorough understanding of the specific hazards presented by cryogenic materials
- Consider providing access to appropriate monitoring equipment to assist with managing cryogenics materials

Tactical actions

Incident commanders should:

- Attempt to contain the spill or release of any cryogenic substances as close to the source as possible
- Consider using appropriate monitoring equipment for cryogenic materials
- Establish whether any infrastructure is in contact with the cryogenic liquid and any impact on its integrity
- Consider using water to freeze a small, slow leak if there are no water reactivity issues
- Consider dispersing cryogenic gases using water sprays
- Consider covering the cryogenic liquid pool (e.g. using a tarpaulin or foam)
- For liquid oxygen spills, determine the potential flammability of the mixture of materials

Control measure - Personal protective equipment (PPE): Cryogenic materials

Control measure knowledge

This control measure should be read in conjunction with Personal protective equipment: Hazardous materials.

Cryogenic materials will remain extremely cold after they have been released. Due to the extremely low temperatures at which they are stored it will take some time before sufficient energy is absorbed from the surroundings to increase the temperature of the released liquid and vapour to a level at which they no longer present a hazard.

The cryogenic material may have harmful or toxic properties if inhaled, and it is likely to displace oxygen to a sufficiently low level that the atmosphere presents an asphyxiation hazard for emergency responders.

Personnel entering the hazard area should wear personal protective equipment (PPE) that is appropriate for the conditions (i.e. extremes of cold and hot, reduced oxygen levels and potentially flammable environments).

Strategic actions

Fire and rescue services should:

- Provide procedures and support arrangements regarding the hazards that may be encountered and actions to take where there is a release of cryogenic materials

- Provide access to personal protective equipment (PPE) and respiratory protective equipment (RPE) suitable for use in cold conditions and in reduced oxygen environments

Tactical actions

Incident commanders should:

- Select the appropriate personal protective equipment (PPE) and respiratory protective equipment (RPE), taking advice from specialist advisors (e.g. on-site personnel, hazardous materials advisor (HMA))

- Identify the presence of on-site gloves and other PPE for protection against cryogenic materials

Control measure - Identify the potential explosive effects due to the failure of a cryogenic gas container

Control measure knowledge

Constant venting through the pressure relief valve or the container bulging are signs of an increase in temperature. By liaising with on-site personnel, any safety features of the container can be identified and it may be possible to monitor changes. Any safety features that prevent or mitigate catastrophic failure can also be identified.

Due to the extremely cold temperatures at which cryogenic materials are stored, even materials that may be viewed as cold under normal circumstances (e.g. water) are at a much higher temperature than cryogenic liquids, so would provide sufficient energy for rapid boiling of the cryogenic liquid.

Strategic actions

Fire and rescue services should:

- Ensure that operational crews have access to advice regarding the specific hazards presented by released cryogenic materials

Tactical actions

Incident commanders should:

- Identify triggers for a rapid expansion of a cryogenic liquid

- Ensure that no other substances are allowed ingress into the container

- Ensure that substances which may be reactive with cryogenic materials are kept separated

- Identify signs that the pressure inside a cryogenic container has increased

- Establish if any loss of cooling or insulation of the cryogenic container has occurred

- Liaise with on-site personnel to determine safety features of the container

- Use signs, labels, markings and container types to identify the presence of cryogenic materials

- Avoid water and other extinguishing media entering any cryogenic containment system

Control measure - Recognise consequences on processes using cryogenic materials

Control measure knowledge

Cryogenic materials are frequently used to provide an inert atmosphere or cooling in an industrial process, predominately to ensure that flammable materials do not have access to oxygen and thus preventing combustion. Cooling is typically used to control the rate at which reactions occur. Controlling the reaction rate limits the potential for thermal runaway reactions and of an explosion or fire in the reaction process. Release of the cryogenic material therefore not only creates hazards relating to the material itself, but also a loss of control of the process in which the cryogenic material was being used.

Strategic actions

Fire and rescue services should:

- Ensure that operational crews are aware of sites using cryogenic material in an industrial process

- Develop site-specific response plans for sites using cryogenic materials in industrial processes that are assessed as high risk

Tactical actions

Incident commanders should:

- Liaise with on-site personnel to ensure all processes that were supported by the cryogenic material are stopped, where it is safe to do so
- Evaluate the need for evacuation
- Determine with on-site personnel whether emergency arrangements are available for maintaining control of the process

Hazard - Oxygen-enriched atmosphere

Hazard Knowledge

Liquid hydrogen and helium are sufficiently cold to liquefy air. Nitrogen will evaporate more rapidly from the liquefied air than oxygen. This will leave behind a liquid air mixture that has a higher concentration of oxygen than normal air. When this evaporates, an atmosphere with a higher concentration of oxygen is created.

Liquid oxygen is also a frequently used cryogenic material and is transported by road and stored at premises. A release of liquid oxygen will inevitably result in elevated oxygen levels as the oxygen evaporates into the atmosphere.

Other situations where an oxygen-enriched atmosphere might occur because of certain chemical reactions include:

- Decomposition of hydrogen peroxide or another oxidising source
- Chemical oxygen generators
- Electrolysis of water

By far the most likely situation for an oxygen enrichment to be encountered is through the transport/storage of cryogenic oxygen.

Cryogenic materials can create a fire hazard through three possible routes:

- The cryogenic material is a liquefied flammable gas (e.g. methane as liquefied natural gas (LNG))
- The cryogenic material is liquefied oxygen; as this evaporates, the atmospheric oxygen concentration will be raised, increasing the potential for combustible materials to burn

- Certain cryogenic materials (liquid hydrogen and helium) are sufficiently cold to liquefy air and when this evaporates nitrogen will be released first; when oxygen subsequently evaporates this will also lead to an increase in the atmospheric concentration of oxygen

Control measure - Substance identification

Control measure knowledge

The information provided through legislation on hazardous materials containers is a key factor in identifying hazards to responders and the public. Other sources of information should also be considered and their value not overlooked in determining a complete picture of the incident. There are also times when marking, placarding and signs are not present, or are incorrect, damaged or obscured. Examples include during a fire, or where hazardous materials are badly controlled or used illicitly.

In addition to marking and signage, other legislative requirements for the use of substances require sites to keep records of substances held, their hazards and control measures. These requirements mean that sites should have access to Safety Data Sheets (SDS) or Control of Substances Hazardous to Health (COSHH) sheets. This information can provide information about the hazards, health effects, behaviours and control measures. Similar information can be obtained from written and/or electronic data sources such as Chemdata or the Emergency Response Guidebook.

Other sources of information that can assist may be obtained from scientific advisers such as the National Chemical Emergency Centre (NCEC) or other company or product specialists and industry mutual aid schemes, for example Bromaid. This may provide information on a substance, process or premises, or may provide assistance in interpreting information gained.

Signs, labels and other marking system

It is important for responders to recognise signs, labels and other marking systems so that they can gain information regarding the hazards associated with substance safety. These will generally be found on modes of transport or fixed sites.

Transport

The legal framework for the international transport of hazardous materials is set out in the United Nations (UN) model regulations ('Recommendations on the transport of dangerous goods', commonly known as the 'orange book'). These rules are revised every two years and form the basis of the internationally and nationally recognised legislation.

The recommendations are adopted in Europe and consequently in the UK, as ADR (Accord européen relatif au transport international des marchandises Dangereuses par Route) for road transport and RID (Reglement International concernant le transport de marchandises Dangereuses par chemin de fer) for rail transport. Additionally, the UK maintains some deviations from ADR, for example, Hazchem placards. As both marking systems are permitted in the UK it is important for responders to be familiar with both.

The International Maritime Dangerous Goods (IMDG) code contains internationally agreed guidance on the safe transport of dangerous goods by sea, and most commonly relates to the carriage of dangerous goods in freight containers and tank containers. It is primarily used by shipping operators, but it is also relevant to those transporting dangerous goods on journeys involving a sea crossing.

Fixed sites

For static sites, warning signage is governed by the dangerous substances Notification and Marking of Sites) (NAMOS) Regulations. The aim of these regulations is to ensure that firefighters arriving at an incident are warned of the presence of hazardous materials. It is a legal requirement to notify the fire and rescue service about any site with a total quantity of 25 tonnes or more (150 tonnes for ammonium nitrate fertilisers). There is a requirement to place warning signs at access points.

See the Health and Safety Executive website for further details. Dangerous Substances (Notification and Marking of Sites) Regulations (NAMOS)

Labelling of hazardous materials for general use is governed by the Classification, Labelling and Packaging regulations (CLP). These regulations adopt the UN Globally Harmonised System (GHS) on the classification and labelling of chemicals across all European Union countries, including the UK.

Equivalent legislation in Northern Ireland is The Dangerous Substances (Notification and Marking of Sites) Regulations (Northern Ireland).

Under the Control of Asbestos Regulations (CAR), there are specific labelling requirements for asbestos in non-domestic buildings. Responders should recognise these labels.

Containment systems

Hazardous materials containers range in size from small vials and jars used in laboratories through larger packages and transport containers holding many tonnes to site storage tanks and vessels that can hold many thousands of tonnes.

It is important that during incidents, responders can:

- Recognise typical container shapes or types that would indicate the presence of hazardous materials whether in storage, in use or in transit

- Identify the basic design and construction features, including closures for storage, packaging and transportation systems

For further information on substance identification see National Operational Guidance: Health Hazards and National Operational Guidance: Physical Hazards

Strategic actions

Fire and rescue services should:

- Consider developing systems to gather pre-planning information on local risks and incident specific information

- Ensure responding personnel have the necessary instruction and training in the identification of hazardous materials containers

- Provide access to appropriate detection, identification and monitoring (DIM) equipment

- Ensure that Information on the recognition of hazardous materials is immediately available to personnel

- Ensure that responders can recognise signs, labels and other markings on hazardous materials packages

Tactical actions

Incident commanders should:

- Use signs, labels, markings, container types and detection equipment to identify substance
- Identify if containers indicating the presence of general or specific hazardous materials are involved
- Use available fire service or on-site detection equipment to identify the substance involved

Control measure - Manage the release of cryogenic

materials

Control measure knowledge

See Hazard – Cryogenic materials

Strategic actions

Tactical actions

There are no tactical actions associated with this control measure.

Control measure - Identify potential combustible materials in oxygen-enriched atmospheres

Control measure knowledge

Elevated oxygen levels will result in the increased potential of combustible materials burning. Direct contact with liquid oxygen can also result in the ignition of materials that would not typically be considered as combustible (e.g. carbon and stainless steel, aluminium and Teflon). Organic materials may also react explosively in the presence of sufficiently high concentrations of oxygen.

Strategic actions

Fire and rescue services should:

- Provide procedures and support arrangements regarding the hazards that may be encountered and actions to take in oxygen-enriched atmospheres

Tactical actions

Incident commanders should:

- Identify areas at the incident that may have oxygen-enriched atmospheres
- Identify potentially combustible materials that will be affected by an oxygen-enriched atmosphere

Control measure - Eliminate ignition sources

Control measure knowledge

From the smallest to the largest incident, the incident commander and firefighters need to be aware of, and take notice of, possible ignition sources that could create additional hazards.

Although eliminating ignition sources may not be an immediate priority in a fire situation because the fire is already burning, firefighters should be aware of the potential for additional ignition sources and their potential to start events such as fire gas ignitions in areas that may be remote from the initial seat of fire.

At incidents where there may be a release of gases or other flammable atmospheres because features such as storage vessels, tanks or pipework may fail or be damaged, incident commanders should consider this a concern and identify it in the incident dynamic or analytical risk assessments (DRA or ARA) and incident plan.

The amount of energy required to ignite a mixture of air and flammable gas or vapour (including smoke) is called the minimum ignition energy (MIE) and depends on the characteristics of the gas or vapour, concentration in air, type of oxidant, temperature and pressure.

An ignition source can be defined as a form of energy that, when added to a flammable mixture, is sufficient for the combustion process to start; an ignition source with energy greater than the minimum ignition energy (MIE) for a particular mixture is sufficient for a fire or explosion to occur. Generally, the energy required to ignite a flammable gas or vapour mixture is relatively low, though some low-energy ignition sources may not be incendiary enough for all flammable mixtures.

Ignition sources include:

- Open flames

- General firefighting operations, including cutting
- Frictional sparks and localised heating
- Impact sparks
- Sparks from electrical equipment
- Electrostatic discharge
- Vehicles
- Use of cigarettes or matches
- Hot surfaces
- Electrical equipment and lighting
- Hot processes
- Exothermic runaway reactions (water applied to reactive metals such as sodium and potassium)
- Heating equipment

It is often challenging for crews to identify and eliminate every ignition source at an operational incident. The first option for ensuring safety is therefore usually to prevent flammable gas or vapour mixtures being released or formed. All foreseeable ignition sources should also be identified and effective control measures taken.

In industrial premises, depending on the ignition sensitivity of the materials handled, the types of equipment involved and the process parameters (such as temperature and pressure), incident commanders should consult with on-site process safety professionals or the responsible person to address safety issues and provide recommendations to aid the safe resolution of the incident.

Strategic actions

Fire and rescue services should:

- Develop tactical guidance and support arrangements for the hazards and actions to be taken in eliminating ignition sources

Tactical actions

Incident commanders should:

- Extinguish the fire and eliminate all ignition sources

- Prevent escalation, contain and extinguish the fire considering all ignition sources

- Deal with any immediate fire risk and provide a means of extinguishing fires during the incident

- Identify all possible ignition sources and eliminate them as far as is possible

- Control ignition sources that cannot be eliminated as far as reasonably practicable

- Develop and communicate a firefighting plan and ventilation strategy to all personnel
- Use the appropriate extinguishing method, media, techniques and equipment
- Ensure that crews are briefed on all firefighting activities and provide regular updates on progress
- Consider removing fuel from any source of ignition

Control measure - Carry out atmospheric monitoring

Control measure knowledge

Atmospheric monitoring should be carried out whenever operations take place in a confined space.

Before entry, the atmosphere within a confined space should be tested to check oxygen concentration and to check for the presence of hazardous gases or vapours. Atmospheric testing should be carried out by competent personnel aware of the limitations of the equipment in use.

Testing should be carried out if the atmosphere might be toxic, asphyxiating or hypoxic. Testing should also be carried out if it is known that the atmosphere was previously contaminated and subsequently ventilated.

Regular monitoring is necessary to identify any changes in the atmosphere while work is being carried out. The results of testing and monitoring should be recorded. Testing and monitoring requirements should be defined by a competent confined space supervisor, within the safe system of work.

The atmosphere in a confined space may be regularly monitored to protect personnel by using on-site or fire and rescue service monitors in a fixed location. Personal or portable monitors carried by individuals can also be used.

Strategic actions

Fire and rescue services should:

- Enable access to suitable atmospheric monitoring equipment that is can be used in a confined space

Tactical actions

Incident commanders should:

- Carry out testing and monitoring of the atmosphere and use the results to inform the incident plan

- Consider requesting specialist advice or assistance for atmospheric monitoring

Control measure - Use intrinsically safe equipment

Control measure knowledge

Any equipment that is not intrinsically safe can provide an ignition source for a gas within its flammable or explosive limits. This may cause combustion or explosion. The use of intrinsically safe equipment will preclude this.

In most confined spaces, it is impossible to classify the atmosphere present. For fire and rescue service operations, intrinsically safe equipment must meet the standards for use in Zone 1 under the ATEX directives.

For further information on fireground radios see: Fireground radios guidance: ATEX-approved radios

Strategic actions

Fire and rescue services should:

- Ensure that intrinsically safe equipment is available to crews trained to work in confined spaces

Tactical actions

Incident commanders should:

- Use only intrinsically safe equipment in confined spaces where there is a risk of a flammable or explosive atmosphere

- Use only ATEX approved equipment in flammable or explosive atmospheres
- Use only ATEX approved communications equipment when crews enter any potentially explosive atmosphere
- Use only ATEX approved equipment when crews enter any potentially flammable atmosphere